DEVELOPMENT AND APPLICATION OF A FOUR-TIER TEST TO ASSESS PRE-SERVICE PHYSICS TEACHERS' MISCONCEPTIONS ABOUT GEOMETRICAL OPTICS

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ABSTRACT

DEVELOPMENT AND APPLICATION OF A FOUR-TIER TEST TO ASSESS PRE-SERVICE PHYSICS TEACHERS' MISCONCEPTIONS ABOUT GEOMETRICAL OPTICS

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The main purpose of this study was to develop and administer a four-tier test for assessing Turkish pre-service physics teachers' misconceptions about geometrical optics. Sixteen pre-service physics teachers, who were selected by maximum variation and convenience sampling methods from three state universities in Ankara, were interviewed in the contexts of plane mirrors, spherical mirrors, and lenses. From these interviews and the studies in the literature, the Open-Ended Geometrical Optics Test was developed. It was administered to 52 pre-service physics teachers from three state universities selected by purposive and convenience sampling. The responses of each subject for each item were categorized in order to determine the alternatives of the multiple-tier multiple-choice misconception test. The initial form of the test, the Three-Tier Geometrical Optics Test (TTGOT), was administered to 53 pre-service physics teachers from three state universities selected by purposive and convenience sampling as a pilot study. The analysis of the results of the TTGOT was used to revise the test items. Finally, the Four-Tier Geometrical Optics Test (FTGOT) was developed and administered to 243 pre-service physics teachers from 12 state universities in Turkey. The validity of the FTGOT scores was established by means of some qualitative and quantitative methods. The Cronbach alpha reliability coefficients were calculated for

different test scores. Those for the total correct scores and standardized misconception scores (SUMM4) were found to be .59 and .42, respectively. Some misconceptions, which were held by more than 10 % of the pre-service teachers, were identified and considered to be significant.

Keywords: Physics Education, Misconceptions, Geometrical Optics, Diagnostic Tests, Four-Tier Tests.

ÖZ

FİZİK ÖĞRETMEN ADAYLARININ GEOMETRİK OPTİK İLE İLGİLİ KAVRAM YANILGILARINI ÖLÇMEK AMACIYLA DÖRT BASAMAKLI BİR TESTİN GELİŞTİRİLMESİ VE UYGULANMASI

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Bu çalışmanın asıl amacı Türk fizik öğretmen adaylarının geometrik optik hakkındaki kavram yanılgılarını ölçmek için dört basamaklı bir test geliştirip uygulamaktı. Ankara ilindeki üç devlet üniversitesinden maksimum çeşitlilik ve kolay ulaşılabilir durum örnekleme yöntemleri kullanılarak seçilen 16 fizik öğretmen adayı ile düzlem aynalar, küresel aynalar ve mercekler bağlamlarında görüşmeler yapıldı. Bu görüşmelere ve alanyazınındaki çalışmalara dayanarak Açık Uçlu Geometrik Optik Testi geliştirildi. Bu test, amaçlı ve kolay ulaşılabilir durum örnekleme yöntemleri kullanılarak seçilen üç devlet üniversitesinden 52 fizik öğretmen adayına uygulandı. Adayların her bir soru için verdikleri cevaplar çoktan seçmeli olarak geliştirilecek olan çok aşamalı testin çeldiricilerine karar verebilmek amacıyla kategorize edildi. Testin ilk hali olan Üç Aşamalı Geometrik Optik Testi (ÜAGOT) pilot çalışma olarak, amaçlı ve kolay ulaşılabilir durum örnekleme yöntemleri kullanılarak seçilen üç devlet üniversitesinden 52 fizik öğretmen adayına uygulandı. ÜAGOT'nin sonuçlarının analizi, testin sorularının revizasyonu için kullanıldı. Son olarak, Dört Aşamalı Geometrik Optik Testi (DAGOT) geliştirildi ve Türkiye'deki 12 devlet üniversitesinden 243 fizik öğretmen adayına uygulandı. DAGOT skorlarının geçerliği nitel ve nicel yöntemler kullanılarak sağlandı. Cronbach alpha güvenirlik katsayısı farklı test skorları için hesaplandı. Güvenirlik katsayısı, tüm test doğru skorlar ve standardize edilmiş

yanlış skorlar (SUMM4) üzerinden .59 ve .42 olarak hesaplandı. Katılımcıların % 10'undan fazlası tarafından sahip olunan kavram yanılgıları tespit edildi ve önemli olarak belirlendi.

Anahtar Kelimeler: Fizik Eğitimi, Kavram Yanılgıları, Geometrik Optik, Tanı Testleri, Dört-Basamaklı Test

To

My Parents and My Fiance

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LIST OF ABBREVIATIONS

SYMBOLS

AC	: Alternative Conceptions
CRI	: Certainty of Response Index
CGPA	: Cumulative Grade Point Average
D	: Discrimination Index
FCI	: Force Concept Inventory
FN	: False Negative
FP	: False Positive
FTGOT	: Four-Tier Geometrical Optics Test
IAI	: Interview-About-Instances
IAE	: Interview-About-Events
IDI	: Individual Demonstration Interviews
KMO	: Kaiser-Meyer-Oklin
LK	: Lack of Knowledge
MBT	: Mechanic Baseline Test
MCT	: Multiple Choice Test
MDT	: Mechanic Diagnostic Test
METU	: Middle East Technical University
MISQ	: Misconception Identification in Science Questionnaire
OCC	: Optics Course Credit
OG	: Optics Course Grade
OLC	: Optics Laboratory Credit
OLG	: Optics Laboratory Grade
p	: Item Difficulty
PCI	: Piagetian Clinical Interviews
POE	: Predict-Observe-Explain
p-prims	: Phenomenological primitives
r	: Pearson correlation
SPSS	: Statistical Package For Social Sciences
TE	: Teaching Experiment
TTGOT	: Three-Tier Geometrical Optics Test
QMVI	: Quantum Mechanics Visualization Inventory

α	: Cronbach Alpha Coefficient
ρ_{bis}	: Biserial Correlation Coefficient
ρ_{pbis}	: Point Biserial Correlation Coefficient
η	: Eta Squared

CHAPTER 1

INTRODUCTION

A complete understanding of science and the most effective way of teaching science have been two of the main concerns of researchers in science education for more than one hundred years. These concerns will probably continue to be discussed as science and technology evolves. In today's changing world and society, the necessity to prepare students for the varying demands of society have become crucial. Taking these concerns into account, starting from the 1900s, many educators became interested in developing new educational theories that offered new insights into the way students learn and retain knowledge. By the late 1950s, learning theories began to shift away from behaviorism's emphasis on stimulus-response associations and observable behaviors to cognitivism's complex cognitive and mental processes, such as thinking, problem solving, concept formation, and information processing. With the entrance of constructivism into the education literature, however, learning began to be viewed as an individual process of concept development. As a result, the roles of both learner and the teacher in the classroom have changed.

These innovations in the field of education brought new attempts to shift the focus of research attention to the learner. Starting from the 1970s, there has been an increasing thrust in science education on students' ways of conceptualizing and reasoning about the phenomena they encounter. There are several studies on students' conception and reasoning (diSessa, 1993; Driver, Guesne, & Tiberghie, 1985; Gilbert & Watts, 1983; Hammer, 1996; 2000; McDermott, 1993; Osborne, Black, & Smith, 1993; Reiner, Slotta, Chi, & Resnick, 2000; Smith, diSessa & Roschelle, 1993; Wandersee, Mintzes, & Novak, 1994). The common purpose in these studies is to depict students' understanding of several science concepts. The information gathered from these studies is particularly important, especially when designing curricular innovations, as well as in the design of a single lesson by a teacher.

Researchers from a variety of theoretical perspectives have argued that the most important attribute that students bring to their classes are their conceptions (Ausubel, 1968; Wandersee et al., 1994), most of which differ from those of scientists (Hammer, 1996; Griffiths & Preston, 1992). Student conceptions that contradict the scientific view are often

labeled “misconceptions” (Al-Rubeyea, 1996; Barke, Hazari, &Yitbarek, 2009; Gilbert & Watts, 1983; Schmidt, 1997; Smith et al., 1993). Broadly, misconceptions have the common feature of being strongly held, coherent conceptual structures which are resistant to change through traditional instruction and need special attention for students to develop a scientific understanding (Gil-Perez & Carrascosa, 1990; Hammer, 1996; Hasan, Bagayoko & Kelley, 1999; Kaltakci & Didis, 2007). Therefore, correct identification of misconceptions has become an important first step in order to gain an understanding of student learning.

The usual measures of assessment such as the ability to state correct definitions, reproduce proofs, solve standard problems cannot provide sufficiently detailed information to determine students’ scientific understanding (McDermott, 1991). Instead, in order to measure students’ conceptions on several concepts, different diagnostic tools have been developed and used by researchers. Interviews (Goldberg & McDermott, 1986 ; Osborne & Gilbert, 1979; 1980a; White & Gunstone, 1992), concept maps (Novak, 1996), open-ended or free response questionnaires (Wittman, 1998), word association (Champagne, Gunstone, & Klopfer, 1980, as cited in Wandersee et al., 1994), drawings, essays, multiple-choice tests (Beichner, 1994; Hestenes, Wells, & Swackhamer, 1992; Tamir, 1971 as cited in Chen, Lin, & Lin, 2002), and multiple-tier tests (Caleon & Subramaniam, 2010a, 2010b; Chen et al., 2002; Eryılmaz, 2010; Kutluay, 2005; Peşman, 2005; Peşman & Eryılmaz, 2010; Treagust, 1986; Tsai & Chou, 2002) are used to diagnose students’ conceptions in science education. Interviews, open-ended and multiple-choice tests are the ones commonly used in physics education research. However, each tool has some advantages as well as disadvantages over the others. Interviews have advantages such as flexibility and the possibility of obtaining in-depth information. However, they can be conducted with only a limited number of individuals and require a great deal of time. These limitations sometimes make it difficult to generalize to a broader population. Open-ended tests give responders the chance to write their answers in their own words and can be administered to larger samples compared to the interviews. However, it takes time to analyze the results and scoring may be a problem. Multiple-choice tests can be administered to a large number of individuals. They are easy to administer and analyze but cannot probe the students’ responses deeply (Fraenkel & Wallen, 2000). Also, with traditional multiple-choice tests the investigator cannot differentiate correct answers due to correct reasoning from those due to incorrect reasoning (Caleon & Subramaniam, 2010b; Peşman & Eryılmaz, 2010). In other words, correct responses may not guarantee the presence of the correct scientific conception in these tests. Similarly, a wrong answer given to a traditional multiple-choice item may not be due to the misconception held, but might be a wrong answer with correct reasoning. Hestenes et al. (1992) proposed “false

positive" and "false negative" concepts in order to emphasize the importance of accuracy of measures in a multiple-choice test. False positive is defined as a Newtonian answer chosen with non-Newtonian reasoning; whereas false negative is a non-Newtonian answer with Newtonian reasoning. False negatives are considered unproblematic and are attributed to carelessness or inattention. The minimization of false positive answers, on the other hand, is difficult. They cannot be eliminated altogether. The authors stated that the major problem in a multiple-choice test development is to minimize false positives and negatives. For this reason, researchers extended multiple-choice tests into multiple-tier tests, with two, three (or more recently four) tiers in order to overcome some of the limitations of using interviews, open-ended tests and traditional multiple-choice tests to diagnose students' conceptions.

With the two-tier diagnostic tests developed first by Treagust (1986), more valid and reliable multiple-choice diagnostic tests to identify misconceptions became possible. They made valuable contributions to the education field. The first tier of a two-tier diagnostic test is a typical multiple-choice item, but the second tier asks the reasoning for the answer in the first tier. Hence, two tier tests provide the opportunity to detect and calculate the proportion of wrong answers with correct reasoning (false negatives) and the correct answer with wrong reasoning (false positives). However, two-tier tests cannot discriminate lack of knowledge from misconceptions, as well as from scientific conceptions, false positives or false negatives. Three-tier tests eliminated this problem since, in addition to the first two tiers, the confidence level about the responses in the first two tiers is asked in the third tier. In this way, misconceptions that are eliminated from lack of knowledge and errors can be assessed. Although three-tier tests seem to eliminate many disadvantages mentioned above, they still cannot fully discriminate the confidence choices for the main answer (first tier) from confidence choices for reasoning (second tier) and therefore may overestimate students' scores and underestimate lack of knowledge. Hence, four-tier tests that ask students' confidence level for the main and for the reasoning tiers separately are proposed and discussed in the present study. In the process of developing four-tier misconception tests, other diagnostic methods such as in-depth interviews and open-ended tests were used to get the aforementioned benefits of each method and increase the validity of test scores in assessing student misconceptions.

Effective test development requires a systematic, well-organized approach to ensure sufficient validity and reliability evidence to support the proposed inferences from the test scores (Downing, 2006). Hammer (1996) makes an analogy between a researcher exploring knowledge structure of individuals and a doctor diagnosing diseases. In this analogy Hammer emphasizes the importance of studies in education that explore individuals'

conceptions. According to him a doctor who knows only one or two diseases would have only one or two options for diagnosing an ailment, regardless of the technical resources available. When the diagnosis is correct, the prescribed treatment may be effective; however, when the diagnosis is not correct, the treatment may not only be ineffective, it may be damaging. With this analogy, it is clear that studies focusing on conceptual understanding and methods to diagnose misconceptions in a valid and reliable way have great importance in physics education research.

Student misconceptions have their origins in a diverse set of personal experiences. Possible sources of student misconceptions are physical experience, direct observation, intuition, school teaching, outside of school teaching, social environment, peer culture, language, textbooks or other instructional materials, and teachers (Al-Rubayea, 1996; Andersson, 1990; Kaltakci & Eryilmaz, 2010; Renner, Abraham, Grzybowski, Marek, 1990; Wandersee et al., 1994). Teachers often subscribe to the same misconceptions as their students (Abell, 2007; Heywood, 2005; Kathryn & Jones, 1998; Wandersee et al., 1994). They are thought to be the key to improve student performance (Abell, 2007; McDermott, 2006; McDermott, Heron, Shaffer & Stetzer, 2006). There is substantial evidence that teachers are one of the main sources of student misconceptions (Abell, 2007; Heller & Finely, 1992; Kikas, 2004; Wandersee et al., 1994). Therefore, before studying student conceptions, teachers' conceptions should be determined and, if necessary, modified in order to improve students' conceptions. In this respect exploring pre-service teachers' existing misconceptions on several science concepts becomes an important concern to be investigated.

There are several studies in the literature on understanding students' conceptions in science and there has been more research in the domain of physics than in any other discipline (Duit, 2009; Duit, Niedderer, & Schecker, 2007; McDermott, 1990a; Reiner et al., 2000; Wandersee et al., 1994). These studies have focused on certain concepts in mechanics (Clement, 1982; Halloun & Hestenes, 1985; McCloskey, 1983), electricity (McDermott &Shaffer, 1992; Shipstone, 1988), and heat and temperature (Erickson, 1979, 1980; Rogan, 1988). Duit et al. (2007) documented a bibliography of the publications on students' ideas in science and reported that mechanics (especially the force concept) and electricity (especially simple electric circuits) are over-researched domains in physics. The authors mentioned the need for further attention to the other domains. Watts (1985) argued that studies for students' understanding of geometrical optics are relatively rare. In another study by Gilbert and Watts (1983), it was stated that there have been few studies in the world on the topic of light.

Kutluay (2005) emphasized the small number of studies on optics, and stated a need for studies in optics.

Student understanding in geometrical optics has attracted interest of some researchers in different countries from early childhood to university level (Andersson & Karrqvist, 1983; Bendall, Goldberg, & Galili, 1993; Colin & Viennot; 2001; Dedes & Ravanis, 2009; Eaton, Andersson, & Smith, 1984; Fetherstonhaugh & Treagust, 1987;1992; Galili,1996; Galili, Goldberg, & Bendall, 1993; Goldberg & McDermott, 1986, 1987; Heywood, 2005; Hubber, 2006; Kocakülah & Demirci, 2010; Langley, Ronen, & Eylon, 1997; Osborne et al., 1993; Rice & Feher, 1987; Ronen &Eylon,1993; Settlage, 1995; Şen, 2003; Van Zee, Hammer, Bell, Roy, & Peter, 2005; Watts, 1985; Wosilait, Heron, Shaffer, & McDermott, 1998; Yalçın, Altun, Turgut, & Aggül, 2008). All of these studies showed that students have some misconceptions in this topic regardless of their grade level and culture. However, there exist a limited number of studies on pre-service teachers, including Turkish pre-service teachers. In most of the studies in geometrical optics, interviews and open-ended tests were used as a method of investigation to determine student misconceptions with a small number of samples. However, the number of studies with multiple-tier tests with large samples was relatively few. The studies in geometrical optics can be categorized into four interrelated categories as:

1. Nature and propagation of light (properties of light, rectilinear propagation of light, illumination, shadows),
2. Vision (role of observer's eye, how we see),
3. Optical Imaging (reflection and refraction in plane mirrors, spherical mirrors, lenses, prisms),
4. Color.

Most of the previous studies in geometrical optics were conducted on the nature and propagation of light and optical imaging. However, the number of studies on topics in vision and color was relatively few. Even though the number of studies in optical imaging was comparably high among all categories, most of them dealt with plane mirrors or converging lenses as a context. Hardly any studies were found in the literature about students' conceptions in the contexts of convex mirrors, hinged plane mirrors, and diverging lenses.

In Turkey starting from the 2005-2006 academic year, the new Science and Technology teaching program has been compulsory in all elementary schools (Güneş, 2007). As a continuum of this change in the Science and Technology teaching program, the high school physics teaching program has also been developed and has started to be applied. Among the primary aims of the Science and Technology teaching program, as well as the

new Turkish high school Physics teaching program, students' understanding and conceptualization of the natural world come first (MEB Talim Terbiye Kurulu Başkanlığı, 2005a, 2005b, 2007). For this reason, studies on conceptualization have great importance. In the spiral curriculum attempt in the Science and Technology teaching program, the light and optics topic is revisited starting from fourth grade to seventh grade regularly. It is then discussed at the eleventh and twelfth grades in the four-year secondary school teaching program. It is addressed in almost all physics teacher education programs at the university level. Nevertheless the limited number of studies on this topic in Turkey requires attention.

Beichner (1994) proposed the combination of the strengths of both interviews and multiple-choice tests as an ideal course of action for testing student understanding in physics. In the present study with the combination of qualitative and quantitative designs, both the in-depth inquiry of interviewing and the broad generalization of multiple-tier tests were aimed to provide an understanding of the Turkish pre-service physics teachers' misconceptions in geometrical optics.

There is almost no in-depth study for Turkish pre-service physics teachers' conceptions in geometrical optics. This research in this respect will provide valuable information for both physics teacher education program developers and faculties at universities. The information obtained can be used to design courses that take into account student conceptions in geometrical optics. The main purpose of this study is to develop a valid and reliable four-tier diagnostic test to assess misconceptions in geometrical optics. The second purpose of the study is to diagnose the misconceptions in geometrical optics of Turkish pre-service physics teachers who have already completed optics courses in their programs.

1.1. Research Questions

The research questions investigated in this study can be classified as main questions and sub-questions. The main objectives of this study were to develop a valid and reliable four-tier multiple-choice test for assessing Turkish pre-service physics teachers' misconceptions in geometrical optics and to diagnose and categorize Turkish pre-service physics teachers' misconceptions in the topic. A two-phase study with qualitative and quantitative parts was conducted by addressing the two main questions. In addition, some sub-questions related to the two main questions were investigated. The sub-questions are related to the specified main question and were investigated within the frame of the main question, but do not comprise the whole content of the related main question.

In the first phase of the study, a valid and reliable four-tier test was developed in order to assess pre-service physics teachers' misconceptions in geometrical optics. In-depth interviews, an open-ended test, and the multiple-tier test were conducted. The purposes of the in-depth interviews were:

1. to see if the Turkish pre-service physics teachers hold the same misconceptions in geometrical optics as discussed in the literature;
2. to see if the Turkish sample has some other misconceptions which have not been mentioned in the literature before;
3. to detect the most resourceful contexts to elicit students' misconceptions in geometrical optics for the construction of an open-ended test.

The open-ended test questions were selected from the contexts revealed in the interviews with the Turkish pre-service teachers and from the contexts which had not received enough attention in previously documented studies in geometrical optics. The main purpose of administering the open-ended test was to construct the alternatives of the multiple-tier multiple-choice test from the answers and reasoning given by the pre-service teachers in their own words. With the help of the interviews and the open-ended test, as well as the literature, a misconception diagnostic test with four tiers was developed and administered to the Turkish pre-service physics teachers. Then the test scores obtained from pilot and main administrations were used to collect validity and reliability evidence for the test scores. Test validity is the degree to which the interpretation of a test score is believed to accurately represent what the test score is intended to measure.

Tests themselves cannot be valid or invalid. Instead, we validate the use of a test score in a specific context. Hence, when we say the "validity of the test", we refer to the "validity of the test scores" throughout the study. Since validity is a matter of degree, not all or none, there exists no absolute method to determine the validity of the test scores. However, qualitative and quantitative evidence from different sources were collected to ensure validity. In the present study the validity of the four tier misconception test scores was established in three ways:

1. Calculating the correlations among student scores on the first, the reasoning, and the confidence tiers. It is expected that in a valid test, students who are able to understand the question can then judge their ability to answer that particular question correctly or incorrectly (Çataloğlu, 2002).
2. Conducting the factor analysis for the correct scores and misconception scores of the students. It is expected that previously determined related items would result in some acceptable factors if a test actually measures the concepts it aims to measure.

3. Estimating the percentages of false positives, false negatives, and lack of knowledge. It is expected that these values should be minimized for establishing construct validity (Hestenes & Halloun, 1995).

The Cronbach alpha coefficient was calculated in order to establish the internal consistency of the test scores for the four-tier geometrical optics test as a measure of reliability of the test scores.

In light of the purpose of the first phase, the first main question and its sub-research questions of the present study are:

1. Are the Turkish pre-service physics teachers' scores on the Four-Tier Geometrical Optics Test (FTGOT) valid and reliable measures in assessing their misconceptions in geometrical optics?
    a. What are the misconceptions in geometrical optics of a divergent sample of pre-service physics teachers who completed optics and optics laboratory courses in all state universities in Turkey as investigated with in-depth interviews?
        i. What contexts are more resourceful in order to elicit pre-service physics teachers' misconceptions in geometrical optics?
        ii. What are the pre-service physics teachers' misconceptions that are similar to the ones from the literature?
        iii. What are the pre-service physics teachers' misconceptions that are not mentioned in the literature before?
    b. What are the misconceptions in geometrical optics of a divergent sample of pre-service physics teachers who completed optics and optics laboratory courses in all state universities in Turkey as investigated with open-ended questions?
        i. What are the pre-service physics teachers' misconceptions that are similar to the ones from the literature?
        ii. What are the pre-service physics teachers' misconceptions that are not mentioned in the literature before?
        iii. What misconceptions are more appropriate for constructing the alternatives of the multiple-tier multiple-choice test?
    c. Is there a significant correlation between the student scores;
        i. for the first and second tiers and the third tier for pilot form of the test?
        ii. for the first tier and second tier; third tier and fourth tier; first and third tiers and second and fourth tiers of the FTGOT?
    d. Does the underlying descriptive factor structure of the FTGOT support the previously determined conceptual dimension structure of the test?

e. Does the underlying descriptive factor structure of the FTGOT support the previously determined misconception structure of the test?
f. What are the percentages of false positives, false negatives, and lack of knowledge for each item and in average on the FTGOT?
g. What are the Cronbach alpha reliability coefficients of correct scores and misconception scores on the FTGOT?
h. What are the difficulty levels and the discrimination indices of each item and on average on the FTGOT?

In the second phase of the study; the constructed four-tier misconception test was used to diagnose Turkish pre-service teachers' misconceptions in geometrical optics. In this survey design, pre-service teachers' responses to the four-tier misconception test were investigated with different codings (codings for the student scores over misconceptions and over correct responses) and functions (misconception and correct scores calculated with AND, OR, SUM functions) that were suitable for the four-tier misconception tests. The results were compared with one tier, two-tier, and four-tier correspondences.

Hence, the second main research question and its sub-questions are:

2. What are the misconceptions in geometrical optics of all pre-service physics teachers who completed optics and optics laboratory courses in all state universities in Turkey as investigated with the FTGOT?
    a. How do the percentages of the pre-service physics teachers giving correct answers change when only the first tiers, first and third tiers, and all four tiers are separately taken into account with different analysis types namely AND, OR, SUM functions?
    b. How do the percentages of the pre-service physics teachers having a misconception change when only the first tier, first and third tiers, and all four tiers are separately taken into account with different analysis types namely AND, OR, SUM functions?

Table 1.1 summarizes the calculations for the FTGOT scores from the sub-research questions in the two main phases of the present study, together with the purpose of the calculations. The computable and incomputable calculations for each tier and all tiers of the test are given in the table.

Table 1.1 Calculations Performed for the Four-Tier Geometric Optics Test Scores in Order to Address the Research Questions of the Present Study

Calculations for Four Tier Testing	Only 1st tier	1st and 3rd Tiers	All Four Tiers		Purpose of Calculation
False Positive and False Negative Proportions	X	X	√	Test Development	Validity
Lack of Knowledge Proportions	X	X	√		Validity
Correlation with Confidence	X	X	√		Validity
Factor Analysis for Misconception Scores	√	√	√		Validity
Factor Analysis for Correct Scores	√	√	√		Validity
Discrimination Index	√	√	√		Validity
Difficulty index	√	√	√		Reliability
Cronbach Alpha Reliability	√	√	√		Reliability
Percentages of Correct Answers	√	√	√	Survey	Diagnostic
Percentages of Misconceptions	√	√	√		Diagnostic

Note: √ *represents the computable statistics; X represents the incomputable or not computed statistics.*

1.2. Definition of Important Terms

This section presents some important definitions related to the study. The constitutive definitions include the dictionary definitions of the terms, whereas the operational definitions specify the actions or operations necessary to measure or identify these terms.

1.2.1. Constitutive Definitions

Geometrical optics: The branch of optics dealing with the concept of light as a ray.

Conception: Conception is the formation of an image, idea, or notion in the mind with the conscious act of understanding (Webster, 1997).

Misconception: An idea which is wrong or untrue, but which people believe because they do not understand the subject properly (Longman, 2012).

Diagnostic test: Diagnostic tests are assessment tools which are concerned with the persistent or recurring learning difficulties that are left unresolved and are the causes of learning difficulties (Gronlund, 1981).

Two-tier misconception test: A two-tier misconception test is a two-level question of which the first tier requires a content response and the second tier requires a reason for the response (Treagust, 1986)

Three-tier misconception test: An additional tier that asks the confidence about the answers of the former two-tiers is included in a three-tier test (Çataloğlu, 2002).

False Negative: An incorrect answer that is chosen by individuals who have the correct, scientific reasoning for the question (Hestenes et al., 1992; Hestenes & Halloun, 1995).

False Positive: A correct response that is chosen by individuals who do not have the correct, scientific reasoning for the question (Hestenes et al., 1992; Hestenes & Halloun, 1995).

AND Function: A function used to calculate the proportion of subjects who hold a unique conception in “all” of the contexts.

OR Function: A function used to calculate the proportion of subjects who hold a unique conception in “at least one” of the contexts.

SUM Function: A function used to calculate the proportion of subjects who hold a unique conception by summing the contexts in which each subject hold that conception.

1.2.2. Operational Definitions

Four-tier misconception test: A four-level multiple-choice test that has been designed with common student misconceptions. In the first tier of the test, there is a question about concepts in geometrical optics; in the second tier the degree of confidence about the given response in the first tier is asked; in the third tier the reasoning about the answer in the first tier is given, and in the fourth tier the degree of confidence about the given reasoning in the third tier is asked.

Lack of knowledge: Lack of knowledge is decided by pre-service physics teachers' answers for the second and fourth tiers of items on the FTGOT, which ask their confidence level about their answers for the first and third tiers, respectively. The answers to those tiers may to some extent be personality sensitive. If the pre-service teacher is not sure about his/her answer in any or both of the tiers, then he/she is considered to lack the required knowledge. Table 1.2 presents the decision table for the lack of knowledge for different possibilities of confidence for the first and third tiers on the FTGOT.

Table 1.2 Decision Table for the Lack of Knowledge on the FTGOT

Confidence for the 1st tier	Confidence for the 3rd tier	Decision of researcher for lack of knowledge
Sure	Sure	No lack of knowledge
Sure	Not sure	Lack of knowledge
Not sure	Sure	Lack of knowledge
Not sure	Not sure	Lack of knowledge

Student Misconceptions about Geometrical Optics: Pre-service physics teachers' responses that contradict the scientifically accepted ideas to the conceptual questions about geometrical optics during the in-depth interviewing, open-ended testing, and the four tier testing process. On the FTGOT a student is considered to have a misconception when s/he chooses a wrong answer in the first tier, is sure about that answer in the second tier, chooses the wrong reasoning related to the answer in the first tier, and is sure about the answer in the fourth tier of an item on the FTGOT. Occasionally, when a student chooses a correct answer in the first tier, is sure about that answer in the second tier, chooses the wrong reasoning related to the

answer in the first tier, and is sure about the answer in the fourth tier of an item on the FTGOT may be considered to have a misconception, too.

*False Positiv*e: A correct answer chosen in the first tier with wrong reasoning in the third tier of the FTGOT when the responder is sure about his/her answers in both of the tiers is considered as a false positive.

False Negative: A wrong answer chosen in the first tier with correct reasoning in the third tier of the FTGOT when the responder is sure about his/her answers in both of the tiers is considered as a false negative.

Table 1.3 summarizes the decisions for the results of the first and third tier combinations on the FTGOT when a participant is sure on both the second and fourth tiers of the test (i.e., no lack of knowledge).

Table 1.3 Decision Table Based on Combinations of the Results of the First and Third-Tiers When the Participant is Sure on Both the Second and Fourth Tiers*

		RESULTS OF THE THIRD-TIER	
		Correct	*Wrong*
RESULTS OF THE FIRST-TIER	*Correct*	Scientific Knowledge	Mostly false positive Rarely misconception
	Wrong	False negative	Mostly misconception Rarely mistake

**This table is modified from Eryilmaz (2010).*

AND Function: A function used to calculate the proportion of subjects by assigning "1" to the subjects who choose the previously defined conceptual dimension or misconception choices in "all" of the related items, "0" otherwise.

OR Function: A function used to calculate the proportion of subjects by assigning "1" to the subjects who choose the previously defined conceptual dimension or misconception choices in "at least one" of the related items, "0" otherwise.

SUM Function: A function used to calculate the proportion of subjects by assigning "1" to the subjects who choose the previously defined conceptual dimension or misconception choices and summing the cases for each subject choosing the previously defined conceptual dimension or misconception choices in all of the related items.

1.3. Geometrical Optics as the Topic of Investigation

In this section, geometrical optics as the topic of investigation is presented in two sub-titles. Firstly, the scope of geometrical optics studied by pre-service teachers in Turkey is given. Secondly, the desired pre-service teacher conceptual understanding in geometrical optics is presented.

1.3.1. Scope of Geometrical Optics Studied by Pre-service Teachers

Geometrical Optics is the branch of optics that deals with the phenomena of reflection and refraction of light in optical instruments, including mirrors (single plane, hinged plane and spherical) and lenses (diverging and converging). Figure 1.1 summarizes the scope of geometrical optics in a concept map that is studied in the present investigation.

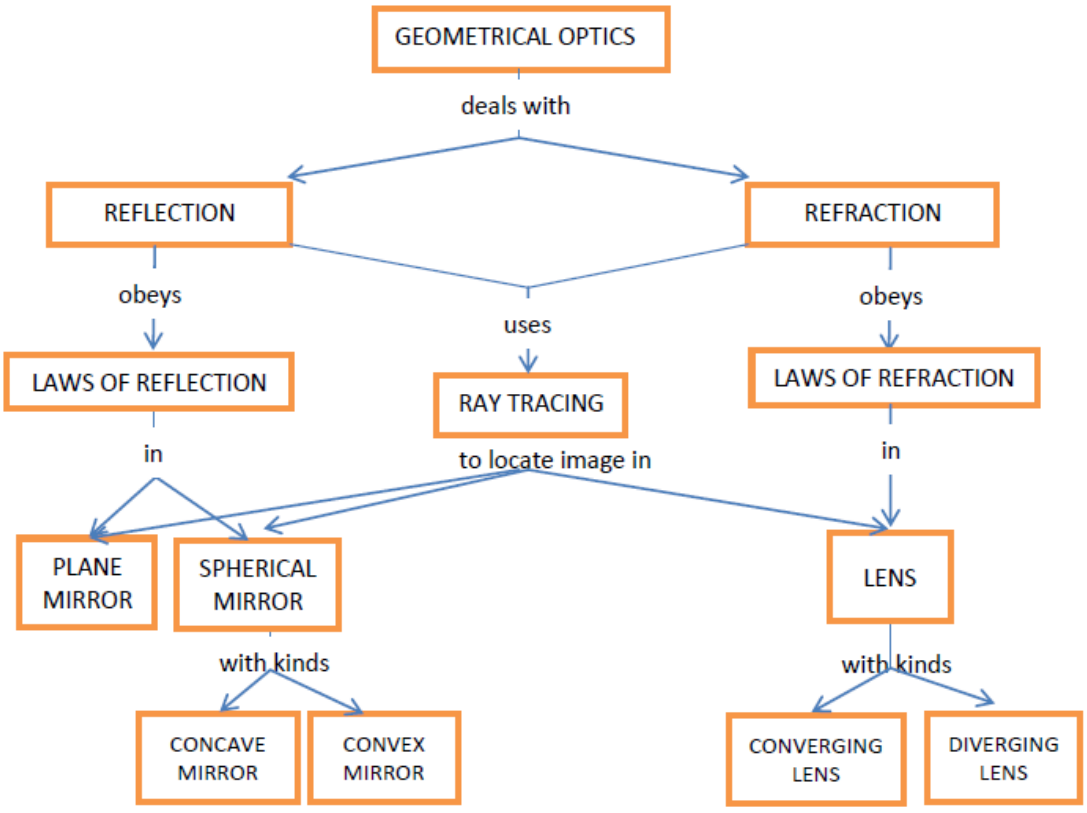


Figure 1.1 Concept Map of the Scope of Geometrical Optics that is Studied in this Investigation

1.3.2. Desired Pre-service Teacher Conceptual Understanding in Geometrical Optics

In Turkey pre-service teachers take geometrical optics courses during their elementary school, high school educations and in their teacher education programs at their universities. Although the curricula for the elementary and high schools are the same for all, the curricula for the universities may differ. In some of the universities geometrical optics is discussed in the course of Optics and Waves together with physical optics, whereas in some other universities courses dedicated to only geometrical optics and the related laboratory are offered.

Pre-service teachers who completed their geometrical optics and geometrical optics laboratory courses in their programs are expected to conceptualize some basic scientific conceptions about geometrical optics. Those scientific conceptions that are expected to be known by the pre-service physics teachers for the present study are listed below and conceptions that are incompatible with those currently accepted scientific conceptions are called “misconceptions” in the present study.

- Light propagates in a rectilinear path.
- An extended object is a collection of object points and an image is a collection of image points.
- When the light rays themselves converge to an image point it is called a real image. When the light rays do not converge to an image point, but the extensions of reflected or refracted rays converge to an image point it is called a virtual image.
- Each point on a real image emits (or reflects) an infinite number of rays in all directions. Each point on a virtual image appears to emit (or reflect) an infinite number of rays in all directions.
- When the light strikes a mirror surface, the rule of reflection holds true (the angle of reflection equals to the angle of incidence).
- When the light meets with a lens, the rule of refraction holds true (sine of the angle of refraction is directly proportional to the sine of the angle of incidence).
- Light diverging from a real image point must enter an observer’s eye for the image to be observed.
- Light diverging from a virtual image point must enter an observer’s eye for the virtual image to be simultaneously formed and observed.
- The position of an image depends only on the position of the object relative to the mirror and independent of the observer’s position.

- The number of images formed and observed in hinged plane mirrors (two mirrors case) depends on the angle between the mirrors, the position of the object located, and the position of the observer.
- A screen is a convenience for observation of real image points in space (i.e. aerial image) and there is a particular image position for an image of an object to be observed on a screen.
- The light ray is a representational tool to show the direction of light prorogation. The special rays serve as an algorithm to locate the position of an image. Any combination of two of these is sufficient to locate the position of an image. However, special rays are sufficient but not necessary in order to form an image.

1.4. Significance of the Study

As science and technology progress, many countries have begun to put more emphasis on science education. For ensuring meaningful learning, exploration of students' conceptions on certain topics has great importance. These investigations constitute the foundation or give direction to other studies that are intended to design appropriate learning contexts and materials or to determine appropriate teaching methods. There has been an acceleration in science education on investigating students' ways of conceptualization and reasoning about the physical phenomena that they encounter. Misconceptions have been one of the most prominent and widely studied research areas in physics education since they are thought to be an important factor that prevents students' learning and understanding the concepts. There are several studies in the literature for that concern students' misconceptions in science. Most of these studies are focused on concepts from mechanics, electricity, or heat and temperature in physics. However, of studies in geometrical optics is very limited and studies that focus on pre-service (or in-service teachers) are even more limited. For this reason, the main aim of this study is to explore pre-service physics teachers' misconceptions in geometrical optics.

The concept of "light" in physics is one of the concepts in which everyone may have some informal and/or formal understanding from at least daily life experiences or language used in early childhood. The literature reveals that many of the beliefs about light are not scientific, but contradict the scientifically acceptable knowledge. Revealing the misconceptions of individuals and developing appropriate instructional strategies to address them are major concerns of educational researchers. In order to determine these

misconceptions, paper-and-pencil instruments alone are not enough. Instead, to identify and categorize situations in geometrical optics requires in-depth investigations. For a given individual it is necessary to clarify, inquire and analyze every detail in his/her words, expressions, products, and activities. There is a need for a valid and reliable diagnostic tool. For these reasons, in the present study both qualitative and quantitative research methodologies are used to explore misconceptions in-depth and to portray the pre-service physics teachers' misconceptions in geometrical optics throughout Turkey.

The diagnostic tools used in assessing misconceptions have advantages as well as disadvantages. For instance, widely used interviews provide the researcher with an opportunity to investigate deeply and flexibly, but require time and effort to reach large samples and analyze the results. Multiple-choice tests overcome the aforementioned problems in interviewing, but are not good for investigating misconceptions deeply and for detecting false positives and false negatives effectively. Two-tier and three-tier diagnostic tests overcome these problems in ordinary multiple-choice tests but they are inadequate for differentiating lack of knowledge from misconceptions and overestimate the misconception scores. With the four-tier test that is developed and administered in this study, pre-service physics teachers' misconceptions free from error and lack of knowledge can be confidently assessed. Since each tool has its own strengths, the combination of these strengths with the appropriate use of different tools for diagnostic purposes is needed. Hence, the present study aims to derive benefit from three diagnostic tools, namely interview, open-ended test, and multiple-tier test with four tiers.

In the literature, there are an abundant number of studies on students' misconceptions on mechanics and electricity concepts, but little on geometrical optics and most of the studies have focused on primary or secondary school grades. The number of studies focusing on teachers' misconceptions is relatively small. Also, the studies in geometrical optics have been mainly on the nature and propagation of light and optical imaging with plane mirrors and converging lenses. There is a scarcity in other contexts in optical imaging such as hinged plane mirrors, diverging lenses, and convex mirrors. This study aims to close this gap by including these relatively untouched contexts, in addition to the others.

Evidence from research indicates that many pre-service, as well as in-service teachers, have the same difficulties as their students. Experience in teaching a physics topic (in our case geometrical optics) does not necessarily lead to the development of a conceptual understanding. Hence, the results of the present study may extend beyond pre-service

teachers in Turkey to teachers more generally and to teachers beyond Turkey. The present study focused on pre-service teachers in Turkey because of the similarity in their physics curriculum, controlled conditions of their participation and their accessibility to the researcher.

In summary, the significance of this study lies in its contribution to the literature with the development of the four-tier misconception test with the help of in-depth inquiry of qualitative research and the generalizability of quantitative research. The test helps to diagnose the misconceptions in geometrical optics, and to diagnose and present the misconceptions of the Turkish pre-service physics teachers' in geometrical optics. The findings of this study can provide curriculum developers in higher education and faculties at teacher education departments with valuable information that can guide them in designing teaching programs or other instructional practices. As a result, this study can contribute both to the literature and to practice.

CHAPTER 2

LITERATURE REVIEW

In this chapter, the literature review about student conceptions in geometrical optics is summarized within five parts. The first part presents information about student conceptions and misconceptions research. The probable sources of student misconceptions and of teacher misconceptions as a source of student misconceptions are discussed in the following part. In the third part, methods for diagnostic evaluation in misconception studies are given. Fourthly, previously documented student misconceptions in geometrical optics in the literature are presented, and finally this chapter ends with summary part.

2.1. Student Conceptions and Misconceptions

Studies on students' conceptions and reasoning in science have gained impetus over the last four decades. As students learn about the world around them formally through school education or informally through their everyday experiences, they often tend to form their own views. Because of this concern, several studies have been conducted to depict students' understanding. The different forms of student understandings have been called by a number of different terms such as preconceptions (Ausubel, 1962, as cited in Driver & Easley, 1978; Clement, 1982), anchoring conceptions (Clement, Brown, & Zietsman, 1989), alternative conceptions (Wandersee, et al, 1994; Klammer, 1998), misconceptions (Clement et al.,1989; Driver & Easley, 1978; Helm; 1980), naïve beliefs (Caramazza, McCloskey, & Green, 1980), naïve theories (McCloskey, 1983); alternative frameworks (Driver & Easley, 1978; Driver, et al., 1985), conceptual frameworks (Driver & Ericson, 1983), commonsense concepts (Halloun & Hestenes, 1985), children's science (Gilbert, Osborne, & Fensham, 1982; Gilbert & Zylbersztajn, 1985), intuitive science (Mayer, 2003), children's ideas (Osborne, et al., 1993), conceptual difficulties (McDermott, 1993), spontaneous reasoning (Viennot, 1979), phenomenological primitives (shortly p-prims) (diSessa, 1993), and some other terms as Renström, Andersson, and Marton (1990) stated: constructs, mini-theories, conceptions, ideas, notions, beliefs, schemata, scripts, frames; as Wandersee et al. (1994)

stated: naïve conceptions, erroneous ideas, conceptual disorders, prescientific conceptions, developing conceptions, everyday conceptions, and so forth.

Although the aims of all these studies are to understand students' understanding or conceptions, there exist differences on what they focus on to explain them. Smith et al. (1993) explained the difference between these terms in their article. According to these authors, the qualifiers "pre", "mis", and "alternative" each point to different presumptions about the nature and origin of conceptions. These prefix or adjectives indicate variation along a dimension. The prefix in the term "misconception" emphasizes the mistaken quality of student ideas. Terms that include the qualifier "alternative" indicate a more relativist epistemological perspective. "Preconceptions" emphasizes the existence of student ideas prior to instruction. The terms "belief" and "conception" suggest unitary cognitive structures, focus on individual ideas and do not directly implicate any larger scale structures that contain them. On the other hand, "theory" and "framework" suggest that particular student conceptions are embedded in larger scale structures that integrate and interrelate those ideas. According to Wandersee et al. (1994), the differences in the terms are not insignificant and often reflect different epistemological and theoretical commitments. For example some terms may emphasize the developmental (such as the terms with qualifiers as "naïve", "pre", "developing"), the chronological (such as the terms "first notion", intermediate understanding", children's conceptions"), or the contextual (such as the terms with qualifiers "everyday", "classroom") aspects of student understanding. Similar to the distinction made by Smith et al. (1993), Wandersee et al. (1994) differentiate alternative conceptions from alternative frameworks such that "what students say they think" indicates their alternative conceptions; whereas "what we think students think based on alternative conceptions" yields a knowledge structure called an alternative framework. The alternative framework is then a stable pattern of knowledge a larger group of learners share, whereas alternative conceptions are self-reported individual ideas.

Driver and Easley (1978) divided all these studies into two as nomothetic and ideographic approaches. In nomothetic studies, the students' understanding is assessed in terms of similarity of their responses with accepted scientific ideas. Such studies are more likely to be experimental, often using paper-pencil tests, quantification, and inferential statistics. Wandersee et al. (1994) listed terms used in these studies such as: errors, naïve conceptions, conceptual difficulties, prescientific conceptions, naïve theories, conflicting schemas, and misconceptions. In the other group called ideographic studies students' conceptualizations are explored and analyzed on their own terms without assessment against an externally defined system. The word ideographic means "self-written" and such studies

include the explication of individual cases to uncover common features. Such studies are more likely to be naturalistic, qualitative, study fewer students in depth, uses students' self-report data, and employ thick descriptions (Wandersee et al., 1994). Some terms used in ideographic studies are: children's science, alternative conceptions, alternative framework, commonsense theories, intuitive beliefs, everyday conceptions. Palacios, Cazorla and Madrid (1989) assigned the studies on students' acquisition of knowledge into two paradigms of which the first is traditional, scientific, experimental, reductionist, prescriptive, quantitative, and nomotechnical; while the second paradigm is non-traditional, artistic, naturalistic, holistic, descriptive, qualitative, and ideographic. The constructivist model of learning mostly thought it to be related to the ideographic paradigm, whereas Palacious et al. (1989) found it reasonable to look for both qualitative and quantitative studies that are brought together and merged into a single set of educational implications. Wandersee et al. (1994) suggested use of both qualitative and quantitative methods and warned about the temptation to place a particular researcher into either the nomothetic or the ideographic side on the basis of terms used.

More recently, however, there has been a shift from misconceptions research to resources research. In 1993 diSessa proposed an alternative account of intuitive physics knowledge involving phenomenological primitives (p-prims). In this model instead of considering students' conceptions inherently inconsistent with expert knowledge, they are considered as elements when appropriately organized, contribute to expert understanding. Misconception research was criticized because of its examination of restricted sets of contexts. According to resources researchers, students' conceptions failing in one context may be productive in another unidentified context. For this reason the contexts where and how conceptions are used by students have become an important concern. Smith et al. (1993) and Reiner et al. (2000) emphasized that even experts have novice knowledge in several contexts, and novice knowledge refinement might be useful in constructing expert knowledge. Considering these arguments, Smith et al. (1993) recommended research that focuses on the evolution of expert understandings in specific conceptual domains built on students' novice conceptions.

Despite these variations, all the terms stress differences between the ideas that students bring to instruction and the concepts by the current scientific theories. Whatever it is called, in almost all of these studies the main aim is the understanding of wrong and flawed conceptions that impedes learning or the identification of productive components of these flawed conceptions for other contexts. Therefore, the identification of these conceptions in a valid way becomes a prominent first step. The most frequently used terms in science and

physics education are preconceptions, alternative conceptions and misconceptions. Most of the times these terms are used synonymously for the similar aims. Even though the term "misconception" is criticized for its negative implications and thought to be in contradiction with constructivist views of knowledge, it is the most popular term used in the literature in this concern (Al-Rubayea, 1996; Hammer, 1996; Smith et al., 1993), and is easily understood by both practicing teachers and the general public (Wandersee et al., 1994). For this reason in the present study the term misconception is going to be used for those conceptions that contradict the scientifically accepted theories.

Misconception is defined by several people as "the concept of an idea at variance with current scientific thought" (Wandersee et al., 1994, p. 179); "ideas that are in conflict with the formal concepts of physics" (McDermott, 1990, p.7); "student ideas that are incompatible with currently accepted scientific knowledge" (Clement et al., 1989, p. 555); "any conceptual idea whose meaning deviates from the one commonly accepted by scientific consensus" (Cho, Kahle, & Nordland, 1985, as cited in Griffiths & Preston, 1992, p.611); "a student conception that produces a systematic pattern of errors" (Smith et al., 1993, p.119); "student conceptions that are quite different from their teachers' or those of scientists, and resistant to change even in the face of the most dogged efforts" (Sadler, 1998, p. 265); "they are not mistakes or wrong answers which result from the lack of knowledge" (Eryılmaz & Sürmeli, 2002). All definitions of the term misconception agree that students hold erroneous ideas or beliefs about scientific concepts (Al-Rubayea, 1996), and such ideas or beliefs are often strongly held, resistant to change, and hinder further learning (White & Gunstone, 1989, as cited in Fetherstonhaugh & Treagust, 1992). According to Hammer (1996) misconceptions have some characteristics in common such as:

1. They are strongly held, stable cognitive structures.
2. These conceptions differ from experts' conceptions.
3. They affect how students understand natural phenomena and scientific explanations.
4. These conceptions must be overcome, avoided, or eliminated to achieve expert understanding (p. 1318).

There is ample evidence that misconceptions are robust and consistent with respect to age, ability, gender, culture or nationality (Driver & Easley, 1978; Wandersee et al., 1994; Wang, 2004). To begin with, a large gap often exists between what is taught and what is learned in physics at all levels of instruction (McDermott et al., 2006) from primary school to upper division courses. However, only the frequency of the misconceptions may vary by domain or knowledge and by level and quality of prior instruction. The frequency of some

misconceptions remains almost constant by age (Guesne, 1985; Viennot, 1976 and Carrascosa, 1987, as cited in Gil-Perez & Carrascosa, 1990); while others change dramatically (Erickson, 1980). However, regardless of cognitive, emotional or physical maturation misconceptions are still common. Sadler (1998) stated that student misconceptions appearing to rise with age and ability before they decrease. Similarly, Shipstone (1985) found that some of the conceptual models in electricity rise with age, whereas some others decline. Moreover, results of the studies revealed that even honor students (Peters, 1982), graduate teaching assistants (McDermott et al., 2006), or professors (Reif, 1995) have similar (or the same) misconceptions on some topics that other physics students possess. Considering the gender issues, some studies proposed that males are better than females in physics (Kost, Pollock, & Finkelstein, 2009), and males have fewer misconceptions than females (Sencar & Eryilmaz, 2004); whereas, some other researchers advocated that this difference might be a subtle result of study focus and weak design (Wandersee et al, 1994). For instance; Sencar and Eryilmaz (2004) found that the difference between male and female students' misconceptions in electric circuits depends on the context of the questions. For practical questions of the misconception measurement test there was a significant difference between males and females, whereas for theoretical questions there was no significant difference in terms of gender. After controlling students' age and interest-experience related to electricity, however, this observed gender difference was mediated on the scores of practical items. Sangsupata (1993, as cited in Al-Rubayea, 1996) examined misconceptions in optics among high school students in Thailand, and found that gender had no effect on misconceptions and male and female students held the same misconceptions. However, he found that the lower grade students (10th graders) had fewer misconceptions than the students in upper grades (11th and 12th graders). Finally, studies all over the world in misconceptions on different topics of physics including optics revealed that most misconceptions are common among individuals regardless of their cultures (Driver et al., 1985; Fetherstonhaugh, Happs, & Treagust, 1987).

Wandersee et al. (1994) identified eight knowledge claims which emerged from a substantial research on misconceptions over the world. These claims were considered not as isolated assertions, but as an integrated whole, are useful for summarizing the research in this field.

Claim 1: Learners come to formal science instruction with a diverse set of "misconceptions" concerning natural objects and events.

Claim 2: The "misconceptions" that learners bring to formal science instruction cut across age, ability, gender, and cultural boundaries.

Claim 3: “Misconceptions” are tenacious and resistant to extinction by conventional teaching strategies.

Claim 4: “Misconceptions” often parallel explanations of natural phenomena offered by previous generations of scientists and philosophers.

Claim 5: “Misconceptions” have their origins in a diverse set of personal experiences including direct observation and perception, peer culture and language, as well as in teachers’ explanations and instructional materials.

Claim 6: Teachers often subscribe to the same “misconceptions” as their students.

Claim 7: Learners’ prior knowledge interacts with knowledge presented in formal instruction, resulting in a diverse set of unintended learning outcomes.

Claim 8: Instructional approaches that facilitate conceptual change can be effective classroom tools (p. 195).

The significant consequence of all these claims is that there is still potential to yield many important findings and need for further studies on this misconception research field. However, researchers should place more emphasis on some issues than on others in their future research. The need for more replication studies in different settings and cultures; the investigation of sources of misconceptions, their prevalence, and the degree to which they impede learning; and the need for more and better studies of teachers’ misconceptions are among the issues suggested for researchers to investigate.

2.2. Probable Sources of Student Misconceptions and Teachers as a Source

Wandersee et al. (1994) asserted that the origins of misconceptions, by their nature, remain speculative and the evidence for their origins are difficult to document. Different researchers proposed different probable sources of student misconceptions. According to Kikas (2004) the reasons for the rise of misconceptions are different depending on the peculiarities of concepts and the way they are taught. Smith et al. (1993) stated that misconceptions arise from students’ prior learning, either in the classroom or from their interaction with the physical and social world. Klammer (1998) argued that the answer to the question “where do the students’ alternative conceptions originate?” is not simple to answer since it deals with both cognitive features and pedagogical practice. However, he proposed experience, language and the curriculum to be the three main possible sources. According to Driver et al., (1985) children form their faulty ideas and interpretations as a result of everyday experiences in all aspects of their lives, through practical activities, talking with other people around them, and through media.

Kikas (2004) described four possible sources of misconceptions that hinder children and adults, including teachers, from gaining scientific understanding and lead the development of misconceptions. Overgeneralizations on the basis of analogy were mentioned as the first possible source of misconceptions. Although analogies are used in the classrooms to relate new information to students' prior knowledge, people may take the analogy too far. A second source of misconceptions is the nature of concepts which belong to ontologically different categories. Some concepts such as force and light were considered to be difficult to transfer to different ontological categories. Thirdly, the presentation of knowledge in school textbooks was considered to promote misconceptions both in students and teachers. The language of the textbook and the diagrams or models that it contains may lead to an incorrect interpretation by students and teachers. And as a final source of misconceptions in schools, teachers' faulty content knowledge was mentioned. Kikas (2004) conducted research on a total of 198 physics, chemistry, biology, primary, humanities, and trainee teachers to investigate misconceptions on three different phenomena: motion of objects, seasons, and changes of matter. It was concluded that very many misconceptions were found among especially trainee and primary teachers. Those teacher misconceptions act as obstacles, especially in the practice of student-centered, active teaching methods. The study also signified that there have been no studies comparing the prevalence of misconceptions on different phenomena in teachers and studies are needed in different countries.

Helm (1980) developed a multiple-choice test to identify misconceptions in physics and administered it in South Africa on individuals with a wide range of age and experience including teachers (N=65). The reported results of the study showed that out of 20 questions in the test only on one question did 80 % of the teachers select the right answer. In seven of the questions there was a strong similarity in performance between the teachers and the students (N=953); in five of the questions 51% or less of the teachers selected the right answers while an equivalent number selected the fallacious options. Relying on the results of the study, Helm (1980) interpreted that the triumvirate of teachers, textbooks and examination papers might be responsible for being the origins of common student misconceptions; "some misconceptions in physics can be linked to or reinforced by errors in textbooks, ill-conceived examination questions or carelessness in exposition by teachers" (p.97). Especially teachers were considered to be a crucial source of student misconceptions to be dealt with.

The possible sources of misconceptions in optics were grouped into four categories as: students personal experiences, textbooks, language, and teachers by Kaltakci and

Eryılmaz (2010) as a result of content analysis on previously published articles and textbooks in the topic.

The aforementioned claim by Wandersee et al. (1994) stated that misconceptions have their origins in a diverse set of personal experiences including direct observation and perception, peer culture and language, as well as in teachers' explanations and instructional materials. Among them teachers are considered as the one that has the most significance as a potential source of conceptual difficulty in students. The problem with the teachers resides in conceptual errors or misinformation held by the teachers themselves. Teachers often subscribe to the same misconceptions as their students (Abell, 2007; Heywood, 2005; Kathryn & Jones, 1998; McDermott et al., 2006; Wandersee et al., 1994). Because of their responsibility to help their students learn; however, the situation for teachers is more serious and needs more attention (McDermott et al., 2006). Improving the preparation of pre-service and in-service teachers so that they are well qualified to teach science is a crucial goal (McDermott, 2006). With these concerns the Physics Education Group at the University of Washington has been engaged in preparing both prospective and practicing elementary school and high school teachers to teach physics and physical science by inquiry since late 1960s. They have published many useful papers on improving teacher education and addressing teachers' conceptual difficulties in physics (McDermott, 1974, 1975, 1976, 1990b, 2006; McDermott et al., 2006; McDermott & Shaffer, 2000; McDermott, Shaffer, & Constantinou, 2000)

Simanek (2008) used the term "didaktikogenic" or "didaskalogenic" for student misconceptions that arise from and are reinforced during the course of instruction. Analogous to the term "iatrogenic disease" in medicine used for doctor caused ailments, misconceptions which are induced by teachers and textbooks were called didaktikogenic (in Greek "didaktikos" means "teacher" and "–genic" means "induced by"). Neither textbooks nor teachers are free of errors, and may be a possible source for students' faulty ideas. Simanek (2008) gave several examples for the sources of student misconceptions in optics many of which were thought to be caused by the representations and ray drawings of teachers and textbooks. Some of these faulty representations which may be thought as didaktikogenic are: 1) lens ray diagrams in which the light rays change their direction along the midplane of the lens may cause a problem, since in reality the change in direction occurs at the lens surfaces where there is a change in index of refraction; 2) in the representations of eye optics light rays are shown to be bent at the eye lens are problematic, since nearly 70% of the refraction occurs at the cornea of the eye.

Similarly, Ivowi (1984) conducted a study on secondary school students and teachers in Nigeria to document their misconceptions in physics, and she concluded that the main sources of the students' misconceptions were the teachers and the textbooks. Heller and Finley (1992, as cited in Al-Rubayea, 1996) studied teachers' misconceptions about electrical current, and they recommended that not only students' but also teachers' misconceptions should be considered in designing science curriculum.

Findings of studies in physics concerning teachers' subject matter knowledge showed that "…teachers' misunderstandings mirror what we know about students. This finding holds regardless of the methods used to assess teacher knowledge" (Abell, 2007, p. 1117). Ameh and Gunstone (1988, as cited in Cochran & Jones, 1998) found that the teachers' misconceptions were similar in nature and pattern to those found for students, but were couched in more scientific language. They found similar misconceptions among both pre-service and experienced secondary teachers and their students in nine science concepts, one of which was the concept of light in physics.

Teachers' subject matter knowledge has not only an effect on student subject matter knowledge, but also on their motivation in physics. Korur (2008) conducted a multi-method PhD study with qualitative and quantitative parts in order to explore the interaction between effective physics teacher characteristics from teachers' and students' shared perceptions and students' motivation. The findings of the study revealed that there were 38 effective physics teacher characteristics affecting students' motivation in physics under eight categories as perceived by teachers and students. Among these characteristics the teachers' subject matter knowledge and their personal characteristics were the two categories that mostly affected the students' motivation.

To sum up, misconceptions are strongly held, stable cognitive structures which pose obstacles to learning, are resistant to change, are difficult to remedy, and need substantial effort to overcome. There are several possible sources of student misconceptions, but they are difficult to document and eliminate. However, the first step in overcoming students' misconceptions must be to identify them correctly (Klammer, 1998).

2.3. Methods for Diagnostic Assessment

In order to study individuals' misconceptions on specific topics, several diagnostic assessment methods have been used such as interviews, concept maps, open-ended tests, word associations, multiple-choice tests, multiple-choice tests with justifications, multiple-tier tests (two-tier, three-tier, four-tier). Although, researchers have reported a variety of

methods for assessing misconceptions, they have not reached a consensus regarding a best method for this purpose (Al-Rubayea, 1996). It depends on the context of the topic to be investigated, the characteristics of the intended subjects to be investigated, and the ability and resources of the researcher. However, it is well known that a triangulation of all methods is better than a single method. In this section interviews, open-ended tests, multiple-choice tests, and multiple-tier tests are discussed in detail as the most frequently used methods for diagnosing students' misconceptions in physics.

2.3.1. Interviews and Open-Ended Tests

Among various methods of diagnosing misconceptions, interviews have the crucial role because of their in-depth inquiry and possibility of elaboration to obtain detailed descriptions of a student's cognitive structures. In fact, interviews have been found to be one of the best (Osborne & Gilbert, 1980b; West & Pines, 1985, as cited in Franklin, 1992), and the most common (Wandersee et al., 1994) approach used in uncovering students' views and possible misconceptions. Among 103 misconception studies examined by Wandersee et al. (1994), 46 % used interviews, 20 % used multiple-choice tests, 19 % used sorting tasks, 8 % used questionnaire, and 6 % used open-ended tests. The interviewing method has proven to be extremely fruitful (Beichner, 1994). Several interviewing techniques have been used in the literature such as Piagetian Clinical Interviews (PCI) (Piaget as cited in White & Gunstone, 1992), Interview-About-Instances (IAI) (Osborne & Gilbert, 1979), Interviews-About-Events (IAE) (Osborne & Gilbert, 1980a; Osborne & Freyberg, 1987), Prediction-Observation-Explanation (POE) (White & Gunstone, 1992), Individual Demonstration Interview (IDI) (Goldberg & McDermott, 1986, 1987), Teaching Experiment (TE) (Katu, Lunetta, & van den Berg as cited in Komorek & Duit, 2004).

PCI has become a model for many interview methods (Duit, Treagust, & Mansfield, 1996). In PCIs students' knowledge is in focus. It is the student who selects the language or examples to communicate and in which order to discuss things. During the interview, the student is presented with an experiment, a question, or a task to be explained. The goal is to understand students' current reasoning patterns without attempting to change them. Therefore, clinical interviews provide details of how students "currently" understand a particular physics concept. However this technique cannot reveal how best to create a change in students' thinking and follow that change (Engelhardt, Corpuz, Ozimek, & Rebello, 2003). In geometrical optics, clinical interviews were commonly used in identifying

students' conceptions by several researchers (Bendall, Goldberg & Galili, 1993; Feher & Rice, 1987).

The IAI technique (Osborne & Gilbert, 1979) is basically a conversation between an expert and a student based on questions about the concept. Questions are asked in relation to a series of line pictures, drawings or diagrams with the use of interview cards. Students' meanings for these instances are investigated in depth. Figure 2.1 illustrates two examples from the concepts of light (Watts, 1985) and force (Osborne & Gilbert, 1980b) to IAI cards.

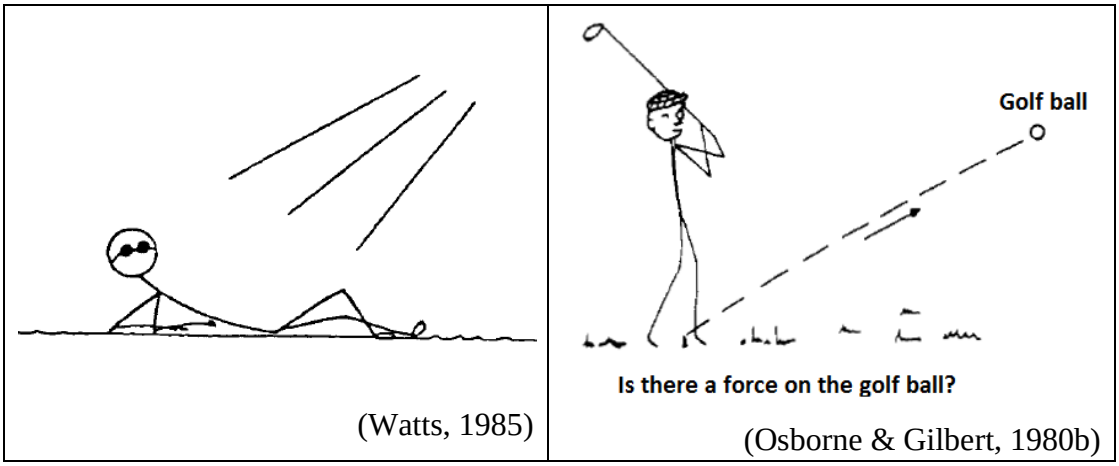


Figure 2.1 Examples of the IAI Cards for the Concepts Light (Watts, 1985) and Force (Osborne & Gilbert, 1980b)

During the interview process each card containing pictures of familiar objects or phenomena are shown, and the interviewee is asked "In your own understanding of the focus concept, is this an example or not?" (Carr, 1996). In physics education IAI method was used to examine understanding of the concepts of force (Osborne & Gilbert, 1980b), light (Watts, 1985), and energy (Kruger, 1990). Osborne and Gilbert (1980b) reported strengths and limitations of the IAI method which is summarized in Table 2.1. The IAE technique is similar to the IAI, but in this technique the stimulus shifts from pictures or drawings to activities or events carried out with the student (Carr, 1996; Kruger, 1990).

Table 2.1 Strengths and Limitations of IAI Method Mentioned by Osborne and Gilbert (1980b p. 378)

Strengths	Limitations
1. It is applicable over a wide age range. 2. It is enjoyable for interviewer and interviewee. 3. It has advantages over written answers in terms of flexibility and depth of the investigation. 4. Classifying instances is more pertinent and penetrating than asking for a definition. 5. It is concerned with the students' view rather than merely examining if the student has the correct scientific view.	1. There is the problem of choosing a limited but adequate set of instances. 2. The order of instances may influence student responses. 3. Interviews, and the transcribing and analysis of transcripts are time consuming. 4. There are difficulties associated with interviews and the analysis of the interview data, e.g. difficult to report succinctly.

TE was developed by Steffe and D'Ambrosio (1996) in the discipline of mathematics and adapted for use in science education by Katu et al. (as cited in Komorek& Duit, 2004). Various experiments and phenomena requiring explanations are discussed with the students as the researcher taking the roles of both an interviewer and a teacher. With the role of interviewer his/her job is to interpret the students' individual conceptual frameworks. With the role of teacher, he/she must have answers to students' conceptions and make the appropriate teacher intervention at just the right moment. The aim in this interview strategy is to help students become to be aware of their own concepts and their concepts' limitations. They are allowed to be stimulated to find alternative explanations and aware of the development of their conceptions and the processes for altering them (Komorek & Duit 2004). As stated by Engelhardt et al. (2003) the most important aspect of the teaching experiment is the modeling of the students' progress over an extended period. What sets the teaching interview apart from the other interviewing techniques is that it is an acceptable outcome for students to modify their thinking.

POE technique developed at the University of Pittsburgh and initially labeled as Demonstrate- Observe-Explain (DOE) (Kearney, Treagust, Yeo, & Zadnik, 2001). In the POE interviewing strategy, a physical situation is demonstrated to the student who is then required to predict the result of a specific change to this physical situation. After the prediction, the student is asked to explain his/her prediction. When the change is made, the student is allowed to describe what he sees, and finally explain any discrepancies between the prediction and observation (White & Gunstone, 1992). In other studies (Wosilait, Heron, Shaffer & McDermott, 1998; McDermott, 1991) Elicit-Confront-Resolve term was used in a similar manner with POE. IDI developed and used by Physics Education Group at the

University of Washington and is similar to POE (Goldberg & McDermott, 1983, 1986, 1987; Heron & McDermott, 1998). In this technique a simple physical system serves as the set of tasks to be performed by the student. The task provides a context for further discussions. Instead of helping the student overcome a difficulty, the main aim of the strategy is to find out how the student is thinking.

Interviews may be conducted with individuals or with groups (Eshach, 2003; Galili, Bendall, & Goldberg, 1993; La Rosa, Mayer, Paqtirxi, & Vincentini, 1984; Olivieri, Totosantucci & Vincentini, 1988; Van Zee, Hammer, Bell, Roy, & Peter, 2005). Duit et al. (1996) stated that the group interviews have the strength of studying the development of ideas in the interaction process between students. The purpose of interviewing was stated by Frankel and Wallen (2000) as finding out what is on people's mind, what they think or how they feel about something. As stated by Hestenes et al. (1992) when skillfully done, interviewing is one of the most effective means of dealing with misconceptions. Although interview strategies have the advantages such as gaining in-depth information and flexibility, a large amount of time is required to interview a large number of people in order to obtain greater generalizability. Also training in interviewing is required for the researcher. In addition, interviewer bias may taint the findings. The analysis of data is a little bit difficult and cumbersome (Adadan & Savasci, 2012; Rollnick & Mahooana, 1999; Sadler, 1998; Tongchai et al., 2009).

In order to investigate students' understanding, open-ended free-response tests were used. This method gives test takers more time to think and write about their own ideas, but it is difficult to evaluate the results (Al-Rubayea, 1996). Also because of language problems, identification of students' misconceptions becomes difficult (Bouvens as cited in Al-Rubayea, 1996) since students are generally less eager to write their answers in full sentences. Andersson and Karrqvist (1983), Colin and Viennot (2001), Langley, Ronen and Eylon (1997), Palacious, Cazorla and Cervantes (1989), Ronen and Eylon (1993) investigated conceptions in geometrical optics and used open-ended questions or tests as a diagnostic instrument.

2.3.2. Multiple-Choice Tests

In order to overcome the difficulties encountered in interviewing and open–ended testing processes, diagnostic multiple-choice tests (Treagust & Haslam as cited in Chen, Lin, & Lin, 2002), that can be immediately scored and applied to a large number of subjects have

been used to ascertain students' conceptions. These tests have been used either following in-depth interviews or alone as a broad investigative measure.

The development of multiple-choice tests on students' misconceptions makes a valuable contribution to the body of work in misconceptions research, assists in the process of helping science teachers more readily use the findings of research in their classrooms (Treagust, 1986). Results from diagnostic multiple-choice tests have been reported frequently in misconception literature. The validity evidence for this format is strong (Downing, 2006). From the point of view of teachers' usage, valid and reliable, easy-to-score, easy-to-administer, paper-and-pencil instruments enable teachers to effectively assess students' understanding of physics. A physics teacher can get information about students' knowledge and misconceptions by use of the diagnostic instruments. Once the student misconceptions are identified, teachers can work to remedy the faulty conceptions with appropriate instructional approaches. Advantages of using multiple-choice tests over other methods have been discussed by several authors (Çataloğlu, 2002; Caleon & Subramaniam, 2010a; Iona, 1986; Tamir, 1990). To sum up, some of the advantages of multiple-choice tests are:

1. They permit coverage of a wide range of topics in a relatively short time.
2. They are versatile, and can be used to measure different levels of learning and cognitive skills.
3. They are objective in terms of scoring and therefore more reliable.
4. They are easily and quickly scored.
5. They are good for students who know their subject matter but are poor writers.
6. They are suitable for item analysis by which various attributes can be determined.
7. They are the next best thing to essay questions due to students' inability to write coherent and logical expressions.
8. They provide valuable diagnostic information and are viable alternatives to interviews and other qualitative tools in gauging students' understanding and in determining the prevalence and distribution of misconceptions across a population.

The chief difficulty in these tests, however, is in interpreting students' responses if the items have not been constructed carefully (Duit et al., 1996). Researchers developed test items with distracters based on students' answers to essay questions or on other open-ended tests or interviews. Beichner (1994) suggested the combination of the strengths of

interviewing technique and multiple-choice exams as an ideal course of action in order to investigate students' understanding in physics.

In spite of the advantages of multiple-choice tests mentioned above, there are some criticisms of them. Chang, Yeh and Barufaldi (2010) and Bork (1984) stated certain limitations and drawbacks of multiple-choice questions, such as:

1. Student guessing contributes to the error variance and reduces the reliability of the test.
2. Selected choices do not provide deep insights into student ideas or conceptual understanding.
3. Students being forced to choose each answer from among a very limited list of options, which is preventing them from constructing, organizing and presenting their own answers.
4. It is extremely difficult to write good multiple-choice questions.

Another very common criticism that was described by Rollnick and Mahooana (1999) is that multiple-choice tests do not provide deep enough insight into students' ideas on the topic and students may give correct answers for wrong reasons (as cited in Kutluay, 2005). In other words, ordinary multiple-choice tests cannot differentiate correct answers due to correct reasoning from those that are due to incorrect reasoning (Caleon & Subramaniam, 2010a; Eryılmaz, 2010), so they may overestimate student scores (Peşman & Eryılmaz, 2010). Regarding this concern, Tamir (1990) conducted a study requiring students to justify their answers to the multiple-choice test. The results of the study revealed that students who chose the correct answer were not necessarily able to provide correct justifications. To overcome the limitations of multiple-choice tests, tests with multiple tiers have been developed.

There exist several examples of multiple-choice tests in the literature which are usually called conceptual tests or inventories. These tests were specifically designed as a result of thorough research in the field, and usually each distracter gives evidence about specific student misconceptions. Halloun and Hestenes (1985, 1986) were among the first to construct a physics diagnostic test (as cited in Çataloğlu, 2002), the distracters of which were constructed from students' responses that were identified as misconceptions in early studies. Since then several multiple-choice conceptual tests have been developed and used in physics education research in order to identify student conceptions. Treagust and Chandrasegaran (2007) provided a list of the studies with relevant bibliographic references that are designed to examine misconceptions in science, most of which were two-tier tests. Table 2.2 gives the references for most often used conceptual tests in physics on a variety of topics.

Table 2.2 Conceptual Tests in Physics Published in Journals

	Conceptual Test	Reference
Ordinary Multiple-Choice Tests	Force Concept Inventory (FCI)	(Hestenes, Wells & Swackhamer, 1992)
	Force& Motion Conceptual Evaluation (FMCE)	(Thornton & Sokoloff, 1998)
	Mechanic Baseline Test (MBT)	(Hestenes & Wells, 1992)
	Energy & Momentum Conceptual Survey (EMCS)	(Singh & Rosegrant, 2003)
	Test of Understanding Graphs in Kinematics (TUG-K)	(Beichner, 1994)
	Electric Circuits Conceptual Evaluation (ECCE)	(Sokoloff, 1993)
	Diagnosing and Interpreting Resistor Circuits (DIRECT)	(Engelhardt & Beichner, 2004)
	Conceptual Survey in Electricity & Magnetism (CSEM)	(Maloney, O'Kuma, Heiggelke & Van Heuvelen, 2001)
	Brief Electricity & Magnetism Assessment Tool (BEMA)	(Ding, Chabay, Sherwood & Beichner, 2006)
	Light & Optics Conceptual Evaluation (LOCE)	(Sokoloff, 1997)
	Light and Spectroscopy Concept Inventory (LSCI)	(Bardar, Prather, Brecher & Slater, 2007)
	Quantum Mechanical Visualization Inventory (QMVI)	(Cataloglu & Robinett, 2002)
	Mechanical Waves Conceptual Survey	(Tongchai, Sharma, Johnston, Arayathanitkul &Soankwan, 2009)
	The Wave Diagnostic Test (open-ended)	(Wittman, 1998)
2-Tier Tests	The Test of Image Formation by Optical Reflection (TIFOR)	(Chen, Lin & Lin, 2002)
	Student Understanding of Light and Its Properties	(Fetherstonaugh &Treagust,1992)
	Light Propagation Diagnostic Instrument (LPDI)	(Chu, Treagust & Chandrasegaran, 2009)
	Two-tier Physics Questionnaire (on mechanics, electricity and magnetism, heat, sound and wave, and optics)	(Chang, Chen, Guo, Chen, Chang, Lin, Su, Lain, Hsu, Lin, Chen, Cheng, Wang & Tseng, 2007)
3-Tier Tests	Three Tier Heat & Temperature Test	(Eryılmaz, 2010)
	Simple Electric Circuit Diagnostic Test (SECDT)	(Peşman & Eryılmaz, 2010)
	The Wave Diagnostic Instrument (WADI)	(Caleon & Subramaniam, 2010a)
	Three Tier Circular Motion Test	(Kızılcık & Güneş, 2011)
	Gravity Concept Test	(Kaltakci & Didis, 2007)
4-Tier Tests	Four Tier Wave Diagnostic Instrument (4WADI)	(Caleon & Subramaniam, 2010b)

Among these tests the Force Concept Inventory (FCI) developed by Hestenes et al. (1992) is the most popular in physics education for examining students' conceptions in mechanics.

2.3.2.1. The Force Concept Inventory (FCI)

The FCI is the improved version of the Mechanics Diagnostic Test (MDT) which was developed by Halloun and Hestenes in 1985 (Hestenes et al., 1992). MDT was first prepared in an open-ended form and administered to more than 1000 college and introductory physics students over three years. The most common misconceptions were determined and used in the final multiple-choice version of the test. It consisted of 36 multiple-choice items about kinematical and dynamical concepts. The scores on the test were thought to be a measure of qualitative understanding of mechanics. The instrument was recommended for use as a placement exam, as a means of evaluating instruction, and as a diagnostic test to identify and classify specific misconceptions. The face and content validity of the test were provided carefully. In order to establish the reliability, the researchers conducted interviews and compared the students' answers in interviews and on the test. In addition, different groups were tested at different times, and the Kuder-Richardson reliability coefficient for use as a pretest was found .86 and for use as a post-test was .89. Thus, the MDT test scores are reliable. The test was administered at Arizona State University and a nearby high school, and the average scores presented in Table 2.3 were obtained for the pretest and post-test administrations. The average normalized gain (<g>) which was used as a rough measure of the average effectiveness of a course (Hake, 1998) was found to be low for all three groups.

Table 2.3 Average of MDT Scores (in %) for Arizona State University and Nearby High School Students (revised from Halloun &Hestenes, 1985)

	Number of Students	Pretest Score	Posttest Score	<g>*
University Physics	478	51.3	64.3	0.27
College Physics	405	38.0	53.0	0.24
High school Physics	49	30.0	48.0	0.26

**<g>: Average normalized gain= ([%< posttest> - %< pretest>] / [100 - %< pretest>])*
Low-g: <g>< 0.3; Medium-g: 0.3≤ <g>< 0.7; High-g: <g> ≥ 0.7 (Hake, 1998)

In 1992 Hestenes and his colleagues developed the FCI in order to supply a more systematic and complete profile of misconceptions and administered the test to 1500 high school students and 500 university students accompanied by the MBT. The scores are given in Table 2.4. The items on the FCI were designed to be meaningful to students without formal training in mechanics and to elicit their preconceptions about the topic, in contrast to the MBT which emphasized the concepts that cannot be grasped without formal knowledge about mechanics. Therefore the best use of the MBT was suggested for post-instruction evaluation, whereas the FCI can be used both pre and post-instruction evaluations (Hestenes & Wells, 1992).

Table 2.4 Average of FCI Scores (in %) for University and High School Students in the USA (Revised from Hestenes et al., 1992)

	Number of Students	FCI Pretest %	FCI Posttest %	MBT Posttest %	FCI <g>
University	560	40.6	67.7	58.2	0.46
High School	841	37.4	62.0	43.2	0.39

The FCI is composed of 29 multiple-choice items. Each item has five distracters and each distracter measures a specific misconception. The items do not require quantitative manipulation, but a forced choice between Newtonian and non-Newtonian concepts (Cataloglu, 2002). Taxonomies or Newtonian concepts and misconceptions were provided with two separate tables. In these tables, Newtonian concepts were divided into six categories (kinematics, first law, second law, third law, superposition principle, kinds of forces), and misconceptions were divided into six categories (kinematics, impetus, active force, action/reaction pairs, concatenation of influences, other influences on motion) with a total of 30 specific misconceptions. Item distracter choices measuring each of these categories in both of the tables were provided. The researchers provided evidences to establish validity and reliability of the test scores. As a consequence of the analysis, the authors claimed that an FCI score of 60 % could be interpreted as the entry threshold to Newtonian physics. Students below this threshold were thought to have the following characteristics: undifferentiated concepts of velocity and acceleration, lack of a vectorial concept of velocity; lack of a universal force concept; fragmented and incoherent concepts about force and motion. An FCI score of 85 %, on the other hand, was interpreted as the Newtonian Mastery threshold, and anyone who gets above this score is considered as

confirmed Newtonian thinker (Hestenes & Halloun, 1995). Hestenes et al. (1992) proposed three different uses of the FCI;

1. For identifying and classifying specific misconceptions in mechanics,
2. For evaluating the effectiveness of instruction,
3. For placement purposes for colleges and universities in conjunction with the MBT.

2.3.2.2. Concerns about the FCI

Huffman and Heller (1995) inquired "what does the FCI actually measure?". The authors tried to find evidence with factor analysis from the post-test scores of a group of 145 high school and 750 university students that the FCI actually did not measure the six conceptual dimensions that were initially mentioned as comprising a force concept. For high school students, a factor analysis produced a total of ten factors, but only two of them accounted for enough variance to be considered significant. For the university students, a factor analysis produced nine factors, but only one factor accounted for enough variance to be considered significant. Based on these results, Huffman and Heller (1995) concluded that the items on the FCI are only loosely related to each other and do not necessarily measure a single force concept or the six conceptual dimensions of the force concept as originally proposed by its authors. According to the authors, one explanation for the loose relationship among the items on the FCI is that students actually have a loosely organized understanding of forces, and the students' misconceptions about the force concept are not coherent, but loosely organized, ill-defined and pieces of knowledge that are dependent upon the context of the question. The Knowledge-in-pieces and the P-prims (diSessa, 1993) were used to explain the lack of relationship between the items on the FCI. Another point discussed by Huffman and Heller was that the piece of knowledge used to answers a question could be highly dependent upon the context of the question. So, when a student answer a question, it is difficult to determine the extent to which the question is measuring students' understanding of the concept and the extent to which the question is measuring students' familiarity with the context. Therefore, the authors claimed that the inventory actually measured bits and pieces of students' knowledge that do not necessarily form a coherent force concept. Even though, from instructors' perspective, the FCI appears to measure six conceptual dimensions, the factor analysis showed that from the students' perspective the items are measuring something other than these dimensions.

As a response to Huffman and Heller's (1995) critique on what actually the FCI measures, Hestenes and Halloun (1995) reinterpreted the FCI scores. The authors stated that

in order to ensure content validity the proportions of false positives (Newtonian response with non-Newtonian reasoning) and false negatives (non-Newtonian response with Newtonian reasoning) should be estimated. The proportions of false positives and false negatives were stated to be less than 10 %. In fact, the lower the probability of false positives and false negatives, the greater the validity of a multiple-choice test. The minimization of false positives was considered to be more difficult because of the chance factor by random choices of false positives. They succeed in reducing noise from false positives in two ways: first, by assessing each category of force concepts with several questions involving different contexts, and second with powerful distractors in the FCI culled from student interviews. The data of Huffman and Heller, which did not clustering on the six dimensions, was attributed to the noise of false positives. The authors recommended Huffman and Heller to perform the factor analysis on the group of students with FCI scores between 60 % and 80 %, and above 80 % separately. They also criticized Huffman and Heller (1995) for ignoring the misconceptions table (Table II) and for interpreting the analysis of results according to only the Newtonian Concepts table (Table I). According to Hestenes and Halloun, Table I was never intended to describe students' concepts, but it described the Newtonian standard against which students' concepts could be compared. If the data were collected from a Newtonian population, such as physics professors, then they would find a single factor in which every question correlated almost perfectly with every other. Lastly, Hestenes and Halloun suggested that for best results the FCI should be administered and interpreted as a whole since separate pieces of it are less reliable and informative.

Afterwards Heller and Huffman (1995) published a new article discussing the details of factor analysis and in this respect the validity of the FCI. They stated that their results indicated that the FCI items were only weakly correlated, such that for the university sample only 17 % of the correlations were above 0.19. Similarly, for the high school sample only 12 % of the correlations were above 0.19. Since there were few strong correlations between the items, the factor analysis yielded one or two weak factors that accounted for only 16 % (university sample) to 20 % (high school sample) of the total variance in students' scores. Regarding the previous suggestion of Hestenes and Halloun (1995), they conducted a factor analysis for three separate groups of university students: one which scored below 60 %, the second which scored between 60 % and 85 %, and the third which scored above 85 %. However, they found that the correlations between the items for the three sub-samples were very similar to those of the whole sample, only somewhat lower. As a result, they concluded that students who scored between 60 % and 85 %, or above 85 % on the FCI did not have a more coherent Newtonian force concept than the students who score below 60 %. According

to Heller and Huffman, the low correlation between the FCI items might stem from two possible alternative reasons:

1. Students do not have coherent concepts, and their knowledge is in fragmented bits and pieces.
2. Students do have coherent concepts, but the test items do not measure this knowledge.

To sum up, they stated that the FCI, which has a reasonable face and content validity, is the best test available. However, a more valid test from the point of view of students' responses is needed.

Halloun and Hestenes (no date) rejected using correlation coefficients as an indication of test validity for several reasons. Reducing the items into dichotomous variables, scoring 1 for a right answer and 0 for a wrong one, were problematic in factor analysis. For these reasons, they refuted Heller and Huffman's (1995) suggestion for the need for a better test than the FCI, but emphasized the need for a better statistical analysis of the FCI results.

Steinberg and Sabella (1997) speculated that the presence of distracters in multiple-choice format of the FCI items could bias students toward the incorrect answer and inaccurately measures students' conceptual understanding. For this reason, an open-ended form of FCI concepts should be administered to understand student misconceptions better.

Rebello and Zollman (2004) studied the role of the distracters on the FCI by investigating four aspects of the FCI. These aspects were 1) whether students' performance on multiple-choice and open-ended forms of the FCI differ significantly; 2) whether student responses to open-ended questions could be categorized into the same choices provided on the current multiple-choice format of the FCI; 3) whether the presence of distracters affects students' selection of incorrect responses in the current multiple-choice format; 4) whether the student responses would change if alternative distracters that arise from the open-ended responses are added or replaced by the current FCI distracters affects. In order to check these research questions, researchers applied two forms of the FCI one is in open-ended and the other is in the multiple-choice form to a group of 238 introductory physics students. From the results of the study, it was concluded that there is no notable difference between student performances in terms of the percentage of correct responses on the two formats of the FCI, but the current multiple-choice format of the FCI is of limited value in determining the misconceptions for students who do not respond correctly.

Despite the controversial opinions about the FCI itself and the interpretation of the FCI scores, the FCI seems to be still the most common choice of teachers and researchers to

examine students' understanding and to diagnose course effectiveness in mechanics (Çataloğlu, 2002).

2.3.3. Multiple-Tier Tests

Researchers recognized the difficulty in uncovering misconceptions by traditional multiple-choice tests since the reason behind a students' selection is not evident (Griffard & Wandersee, 2001). Therefore, they extended multiple-choice tests into tests with two, three, or four tiers in order to compensate for the limitations of the ordinary multiple-choice tests used in diagnosing students' conceptions.

2.3.3.1. Two-Tier Tests

In order to gather data from more students than is possible by interviews, justifications to multiple-choice items were used (Hrepic, 2004; Tamir, 1989; Wandersee, 1983 as cited in Wang, 2004) in which students were required to justify their selection of answers in multiple-choice items in the form of short answers. These justifications were recommended to be used as raw material for the construction of two-tier tests.

Generally, the two-tier tests were described as diagnostic instruments with first tier, including multiple-choice content questions, and second tier, including multiple-choice set of reasons for the answer to the first tier (Adadan & Savasci, 2012; Chen et al., 2002; Griffard & Wandersee, 2001; Treagust, 1986). Students' answers to each item were considered correct when both the correct choice and reason are given. Distracters were derived from students' misconceptions gathered from the literature, interviews, and open-ended response tests. Two-tier tests were considered a great improvement over the previous approaches in that these tests consider students' reasoning or interpretation behind their selected response and link their choices to misconceptions of the target concept (Wang, 2004). Also as stated by Adadan and Savasci (2012), two-tier diagnostic instruments are "relatively convenient for students to respond to and more practical and valuable for teachers to use in terms of reducing guesswork, allowing for large-scale administration and easy scoring, and offering insights into students' reasoning" (p. 514).

Haslam and Treagust (1987), Treagust (1986), and Treagust and Chandrasegaran (2007) followed a three-stage process in developing a two-tier diagnostic instrument as shown in Figure 1. Later Wang (2004) added five more steps in order to make research steps more logically linked and duplicable.

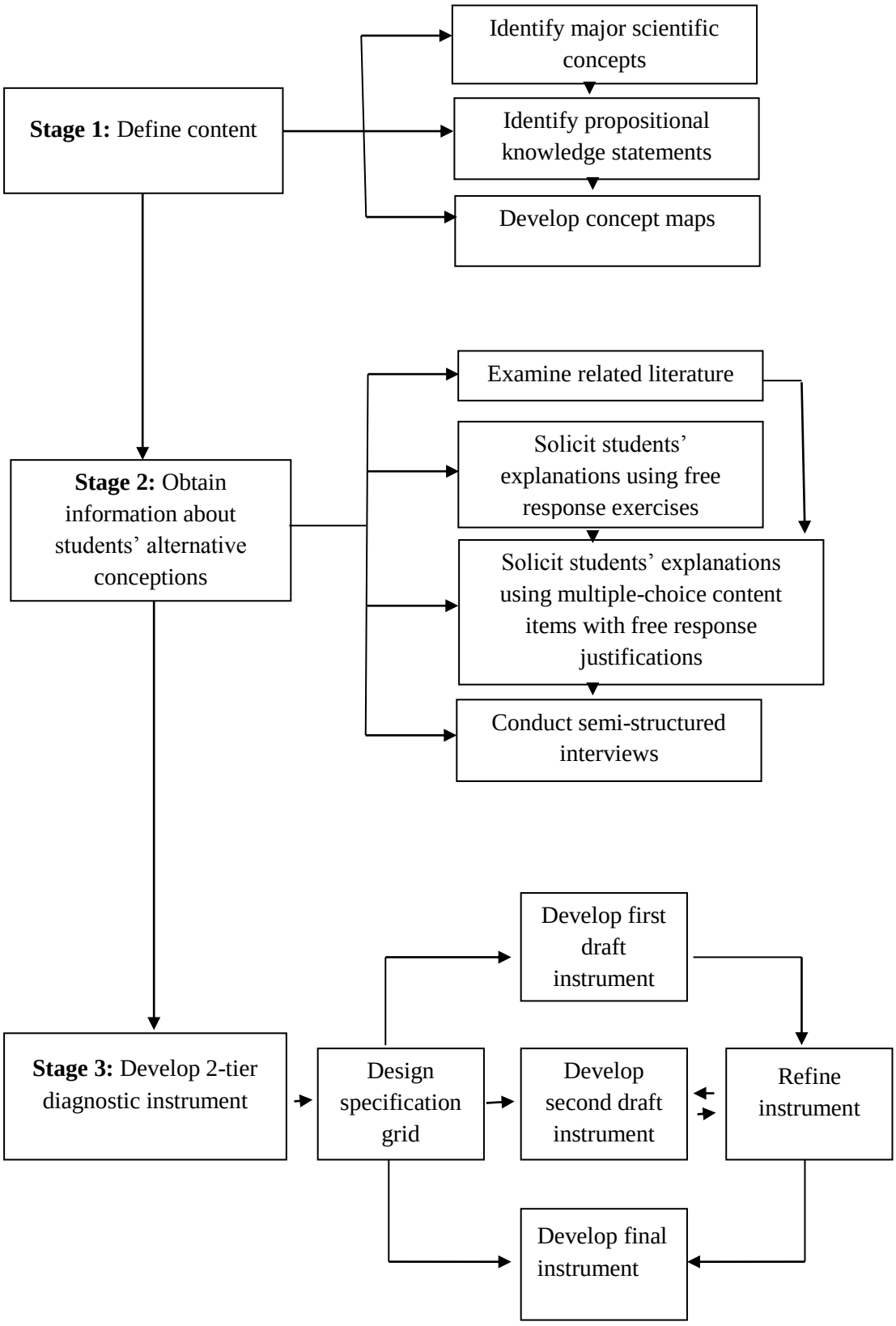


Figure 2.2 Stages in the Development of Two-Tier Multiple-Choice Diagnostic Instruments (Treagust & Chandrasegaran, 2007)

Since Treagust (1988) published his seminal work on the development of two-tier test, large number of researchers have developed and administered two-tier diagnostic tests in biology (Cheong, Treagust, Kyeleve & Oh, 2010; Griffard & Wandersee, 2001; Odom & Barrow, 1995; Tsui & Treagust, 2010), in chemistry (Adadan & Savasci, 2012; Peterson, Treagust & Garnett, 1986; Tan, Goh, Chia & Treagust, 2002), and in physics (Chang et al., 2007; Chen et al., 2002; Franklin, 1992; Rollnick & Mahooana, 1999; Tsai & Chou, 2002). Table 2.5 summarizes the two-tier tests published in science with their references.

Table 2.5 Two-Tier Tests Published in Journals

Name	Reference	Subject	Sample
• Two-tier Diagnostic Instrument in Genetics	(Tsui & Treagust, 2010)	Biology	Grade 10 & 12
• What do you know about photosynthesis and respiration in plants? Diagnostic Test	(Haslam, 1986) (Treagust, 1986) (Haslam & Treagust, 1987)	Biology	Year 8-10, 11 and 12 biology
• Two-tier Diagnostic Malaria Test	(Cheong, Treagust, Kyeleve & Oh, 2010)	Biology	Year 12 and nursing college (21 years old)
• Flowering Plant Growth and Development Diagnostic Test	(Lin, 2004)	Biology	Year 11 high school
• Two-tier Instrument on Photosynthesis	(Griffard & Wandersee, 2001)	Biology	Pre-medical students at university
• Two-tier Diagnostic Instrument in Plants and Human Circulatory System (ITP&HCS)	(Wang, 2004)	Biology	Elementary, secondary and high school
• Diffusion and Osmosis Test	(Odom & Barrow, 1995)	Biology	College, Upper high school
• Test to Identify Student Conceptualizations (TISC) (in chemical equilibrium)	(Voska & Heikkinen, 2000)	Chemistry	University general chemistry
• Qualitative Analysis Diagnostic Instrument (QADI) (inorganic chemistry)	(Tan, Goh, Chia & Treagust, 2002)	Chemistry	Grade 10 (15-17 years old)
• Covalent Bonding and Structure Diagnostic Test	(Peterson, Treagust & Garnett, 1986) (Treagust, 1986)	Chemistry	Year 11 and 12 chemistry
• Nature of Solutions and Solubility Diagnostic Instrument (NSS-DI)	(Adadan & Savasci, 2012)	Chemistry	Grade 11 (16-17 years old)
• Boiling Concept Test	(Coştu, Ayas, Niaz, Ünal & Çalık, 2007)	Chemistry	University introductory chemistry
• The Test of Image Formation by Optical Reflection (TIFOR)	(Chen, Lin & Lin, 2002)	Physics	Grades 10-12
• Two-tier Physics Questionnaire (on mechanics, electricity and magnetism, heat, sound and wave, and optics)	(Chang, Chen, Guo, Chen, Chang, Lin, Su, Lain, Hsu, Lin, Chen, Cheng, Wang & Tseng, 2007)	Physics	Elementary school to high school
• Student Understanding of Light and Its Properties	(Fetherstonaugh & Treagust,1992)	Physics	Grade 8-12 (13-17 years old)
• Light Propagation Diagnostic Instrument (LPDI)	(Chu, Treagust & Chandrasegaran, 2009)	Physics	Grades 7-10

Franklin's (1992) 40-item diagnostic two-tier instrument called Misconception Identification in Science Questionnaire (MISQ) was developed in order to detect misconceptions in the areas of force, heat, light and electricity and administered to 509 high school and university students in the USA. The overall test reliability was found to be .81. The discrimination indexes for 11 of the 40 items were found to be below .20. In order to ensure validity, 27 students who took the written test were then interviewed with the same items and an agreement rate (AR) was calculated for the degree to which responses supplied by students in both forms were similar for the first and second tiers separately. The AR among all first tiers ranged from .37 to .96; among all second tiers the range was .22 to .78. In addition to the two tiers asking topic-specific questions and their reasons, in the MISQ each student was asked to rate how sure they were that their answers were correct. This step is very similar to those used as a third tier in three-tier tests which will be discussed in the next section. Additionally, each student was asked to indicate how sensible or logical their responses were for each item. These two scales were rated for each item separately in the MISQ, and were used to determine if any relationship exist between students' confidence in their responses, the sensibleness of their responses and their MISQ score. They found a slight positive correlation ($r = .26$, $p < .001$) between MISQ score and the students' confidence rating of their responses, and a similar correlation ($r = .31$, $p < .001$) for the sensibleness rating of their answers. It was also found that in general male students scored higher than their female peers and viewed their responses as more sensible and with more confidence. As age decreased the confidence and the sensibleness rating were found to be tended to decrease.

Al-Rubayea (1996) modified the MISQ developed by Franklin (1992) by selecting four items from each of the four concept areas, and by adding one more step to each item by asking students about the source of their answer and reason in the first two tiers. The test was administered to 1080 Saudi Arabian high school students. A positive correlation was found between students' responses, confidence in answers, and sensibleness similar to the findings of Franklin (1992). Guessing was found to be the most dominant source of misconceptions for this study. The analysis for the first two-tiers about the four concepts revealed that considerable percentages of Saudi high school students had misconceptions: electricity and magnetism (62.5 %), force and motion (66.4 %), light and color (74.8 %), and heat and temperature (85.3 %).

Chen et al. (2002) developed a two-tier test called as TIFOR in order to identify Taiwanese high school students' understanding in geometrical optics. In this study researchers followed a four step procedure for the development of two-tier tests. Firstly, the

scope of the target conceptions in terms of propositional statements and concept maps were defined. Secondly, an open-ended questionnaire was prepared and administered to high school students. Thirdly, students' responses were analyzed and commonly held misconceptions identified. Further information was gathered from interviews. Finally, a two-tier multiple-choice test was constructed based on the answers given to an open-ended questionnaire and interviews. The second tier also included a blank into which the students could write any other reason beyond the givens. The constructed test was administered to 317 high school students in Taiwan. The internal consistency reliability was found as .74. The results of the study showed that a high percentage of students do not comprehend the nature and mechanism of image formation through mirror reflection.

Tsai and Chu (2002) developed a three networked two-tier test items in science (on the concepts weight, sound, and heat and light) and administered to 555 14 years old, 599 16 years old students in Taiwan. The distinction of this study was that the test was administered on the web. Only one item per screen was presented, and for every item there were two steps. After the students made a choice in the first tier, then the system showed the second tier with the first tier remaining on the screen. Students' responses on each of the three items were categorized as incorrect (incorrect in both tiers), partially correct (correct in one tier and incorrect in the other) or correct (correct in both tiers). The results of the single two-tier item related to light and heat propagation showed that 16 % of the 8th graders and 19 % of the 10th graders chose the correct answer, whereas an almost equal proportion of students (14 % of 8th graders and 12 % of 10th graders) held an almost opposite misconception that heat can be propagated in a vacuum condition but that light could not. The data analysis also showed that the responses of the 10th graders were not significantly different from those of the 8th graders for this light and heat related item ($\chi^2 = 14.93$, d.f. = 19, $p > .05$).

Fetherstonhaugh and Treagust (1992) conducted research to obtain data on student understanding of light and its properties, develop materials, and evaluate the effectiveness of a teaching strategy using these materials to elicit conceptual change in the topic. They developed a 16-item diagnostic test in four areas: How does light travel?; How do we see?; How is light reflected?; How do lenses work?. Twelve of the items in the test were in two-tier form with multiple-choice questions accompanied by an open response for the student to provide a reason for choosing the distractor. The remaining four items had only an open response. The test was administered in a city high school as a pretest (n=27) and the Kuder Richardson reliability of the test was found to be .67. Also the test was administered as a pretest (n=20), posttest (n=16), and delayed posttest (n=10) in a country high school. The diagnostic test identified nine misconceptions and indicated that a large proportion of

students in both groups had misconceptions prior to formal instruction. Some of these misconceptions were still prevalent in the post-test following a conceptual change teaching strategy and in the delayed post-test three years after the administration of the post-test. Misconceptions related to how lenses work especially seemed to be strongly held and resistant to change. These nine misconceptions identified in this study together with their percentages are summarized in Table 2.6. Another important result deduced from the study was that student ideas were applied differently depending upon the context.

Table 2.6 Percentages of Students' Misconceptions about Light Identified with Two-Tier Diagnostic Test in Fetherstonhaugh and Treagust's (1992) Study

	City School	Country School		
Misconception	Pretest (n=27)	Pretest (n=20)	Posttest (n=16)	Delayed Posttest (n=10)
1. Light travels a different distance depending upon whether it is day or night.	41	35	13	0
2. Light does not travel during the day.	19	20	6	0
3. Light does not travel at all during the night.	4	15	6	0
4. We see by looking, not by light being reflected to our eyes.	77	75	25	0
5. People can just see in the dark.	22	10	0	10
6. Cats can see in the dark.	70	60	12	20
7. Light stays on mirrors.	22	25	6	0
8. Lenses are not necessary to form images.	56	83	31	40
9. A whole lens is necessary to form an image.	100	94	25	9

The study which criticized two-tier tests was done by Griffard and Wandersee (2001) in the discipline of biology. In order to examine the effectiveness of two-tier tests they used an instrument developed by Haslam and Treagust on photosynthesis. The study was conducted on six college students by paper and pencil instrument designed to detect alternative conceptions, and the participants responded to the two-tier instrument in a think-aloud task. The findings of the study raised concerns about the validity of using two tier tests for diagnosing alternative conceptions, since they claimed that the two-tier tests may diagnose alternative conceptions invalidly. It is not certain whether the students' mistakes were due to misconceptions or unnecessary wording of the test. Another concern about two-tier tests that was expressed by Tamir (1989) was that the forced-choice items in two-tier tests provide clues to correct answers that participants would not have had in an open-ended survey or interview. For instance a student can choose an answer in the second tier on the

basis of whether it logically followed from their responses to the first tier (Griffard & Wandersee, 2001; Chang et al., 2007), or the content of each choice of the second tier seems partially correct to a responder, but this partially correct response may attract the responder (Chang, et al., 2007). Caleon and Subramaniam (2010a) and Hasan et al. (1999) called the attention to significant limitations of two-tier tests in that, those tests cannot differentiate mistakes due to lack of knowledge from mistakes due to existence of alternative conceptions; and they cannot differentiate correct responses due to scientific knowledge and those due to guessing. Thus, two-tier tests might overestimate or underestimate students' scientific conceptions (Chang et al., 2001) or overestimate the proportions of the misconceptions since the gap in knowledge could not be determined by two tier tests (Aydın, 2007; Caleon & Subramaniam, 2010a, 2010b; Kutluay, 2005; Peşman, 2005; Peşman & Eryılmaz, 2010; Türker, 2005). Chang et al. (2007) also mentioned that since the choices in the second tier constructed from the results of interviews, open-ended questionnaires and, the literature review students are likely to construct their own conceptions out of these and may tend to choose any item of the second tier arbitrarily. In order to eliminate this problem a blank alternative was included with the multiple-choice items so that responders could write an answer that is not provided (Aydın, 2007; Eryılmaz, 2010; Peşman & Eryılmaz, 2010; Türker, 2005).

To sum up, two-tier tests have advantages over ordinary multiple-choice tests. The most important of them is that those tests provide students' reasoning or interpretation behind their selected response. However, these tests have some limitations in discriminating lack of knowledge from misconceptions, mistakes, or scientific knowledge. For this reason three-tier tests become crucial in order to determine whether the answers given to the first two tiers are due to a misconception or a mistake due to lack of knowledge.

2.3.3.2. Three-Tier Tests

The limitations mentioned for the two-tier tests were intended to be compensated by incorporating a third tier to each item of the test asking for the confidence in the answers given in the first two tiers (Aydın, 2007; Caleon & Subramaniam, 2010a; Eryılmaz & Sürmeli, 2002; Eryılmaz, 2010; Kutluay, 2005; Peşman, 2005; Peşman & Eryılmaz, 2010; Türker, 2005).

Confidence rating has been one of the main means of investigation in calibration research in the field of psychology since 1970s in which individuals were asked to indicate their belief about the accuracy of their answers to the test items (Echternacht, 1972; Stankov

& Crawford, 1997). Generally, confidence ratings are valuable for minimizing the guessing effects and improving the reliability of the test by its special scoring system. In the methods of scoring in confidence testing a right answer given with high confidence was given more credit than a wrong answer given with low confidence (Echternacht, 1972). For example, Dressel and Schmid (1953 as cited in Echternacht, 1972) used the scoring system below in Table 2.7 in a degree of certainty test in which examinees indicated on a four-point scale their certainty in a single answer selected.

Table 2.7 Scoring System Used by Dressel and Schmid (1953) in Confidence Testing

		If the correct answer was marked	If the correct answer was *not* marked
The certainty value marked was;	Positive	4	-4
	Fairly sure	3	-3
	Rational guess	2	-2
	No defensible choice	1	-1

It is considered as a *good calibration* in the confidence rating when an individual has a higher confidence when his answers were correct than confidence when the answers were wrong; whereas, considered as *mis-calibrated* if there was a mismatch between accuracy and confidence (Baker & Fogarty, 2004; Baker, 2010; Lundeberg, 1992; Lundeberg, Brown & Elbedour, 2000; Caleon & Subramaniam, 2010b). Bias score indicated the size and direction of this mismatch and was calculated as the average of confidence ratings across all items in a task minus the proportion correct score for that task. (Baker & Fogarty, 2004; Stankov & Crawford, 1997). If a bias score is positive in sign *overconfidence* is present; if it is negative then *underconfidence* exists; *perfect calibration* is demonstrated however when the bias score is exactly zero. Research in this field revealed that individual differences in academic performance, gender, age, personality, ability, or even the nature of the testing instrument influence confidence and bias scores (Baker, 2010; Lundeberg, 1992; Stankov & Crawford, 1997). For instance; women were found to be less confident than men in their abilities in mathematics and science, and this gender difference increases with age (Hyde, Fennema, & Lamon, 1990; Lundeberg & Moch, 1985 as cited in Lundeberg, Fox & Puncohar, 1994; Lundeberg et al., 2000). Koehler (1994 as cited in Pallier et al., 2002) found confidence level is sensitive to question format, such that open-ended format tests elicit less

confidence bias than the multiple-choice format tests. Even though the confidence paradigm has been widely investigated in psychology, science education research involving the use of confidence rating in assessment is scant (Caleon & Subramaniam, 2010b) and relatively new. Al-Rubeyea (1996), Caleon and Subramaniam (2010a); Clement et al. (1992), Cataloglu (2002), Franklin, 1992), Hasan et al. (1999) and Woehl (2010) made a good attempt by including confidence tiers in their studies. However, these studies still could not improve typical multiple choice tests' limitations in discriminating lack of knowledge from misconceptions, mistakes, or scientific knowledge.

Clement et al. (1989) used confidence rating in the determination of anchoring conception of students. Anchoring conceptions are defined as an intuitive knowledge structure that is in rough agreement with accepted theory. In their case, a problem situation was considered as an anchoring example for a student if he or she makes a correct response to the problem and indicates substantial confidence in the answer. The authors developed a 14 item diagnostic multiple choice test to identify anchoring examples in mechanics. For each question in the test, students were asked to indicate their confidence on a scale ranging from 0 (just a blind guess) to 3 (I'm sure I'm right). The confidence ratings in this study were used to determine confident anchors for confidence level ratings of 2 or higher.

Perez and Carrascosa (1990) mentioned that in mechanics pupils have the most coherent and rooted alternative framework. In a study asking students to express their confidence in the answers, the results showed that most of the wrong answers on mechanics were given with high confidence.

Hasan, Bagayoko and Kelley (1999) described a simple and novel method for identifying misconceptions. They introduced the Certainty of Response Index (CRI) which is used commonly in social sciences, where a respondent is requested to provide the degree of his certainty. Irrespective of whether the answer was correct or wrong, a low degree of confidence indicates guessing which implies a lack of knowledge. On the other hand, if the respondent has a high degree of confidence in his choice and arrived at the correct answer, it would indicate that the high degree of certainty was justified. However, if the answer was wrong, the high certainty would indicate a misplaced confidence in his knowledge of the subject matter which is an indicator of the existence of a misconception. Hence, CRI enables someone to differentiate between lack of knowledge and a misconception. With this aim Hasan et al. (1999) modified Mechanics Diagnostic Test (Halloun & Hestenes, 1985) by adding a CRI scale from 0 to 5 (0: totally guessed answer,1: almost a guess, 2: not sure, 3: sure, 4: almost certain, 5: certain) to the ordinary multiple-choice test. The test was administered to a total of 106 college freshmen students. In the analysis process, they used

the decision matrix given in Table 2.8. According to the analysis of students' responses in 50 % of the items students had high average CRI values for wrong answers, which might be an indicator of student misconceptions in these questions. In the remaining 50 % of the questions, on the other hand, students had low average CRI values for wrong answers which indicated a lack of knowledge. Differentiation of misconceptions from lack of knowledge was seen to be important since the presence of misconceptions or lack of knowledge requires different instructional practices.

Table 2.8 Decision Matrix for an Individual Student and for a Given Question (Hasan et al., 1999)

	Low CRI (<2.5)	High CRI (>2.5)
Correct answer	Lack of knowledge (lucky guess)	Knowledge of correct concepts
Wrong answer	Lack of knowledge	Misconception

Çataloğlu (2002) constructed a three tier Quantum Mechanics Visualization Inventory (QMVI); the first tier of which included an ordinary multiple-choice test, the second tier of which was an open-ended question asking for the reasoning, and the third tier of which was a 4 level Likert type scale asking for the students' confidence level for each item. He explained the usage of the third confidence level as:

> Although not a very crucial tier and an uncommon practice in test construction, the third tier added another data dimension which was utilized in the QMVI construction. The third was a self-assessment by the student about how well they perceived they did on a particular question. Therefore, a moderate correlation coefficient should exist between the students score on tier one and on tier three (p. 38).

In his study, the degree of correlation between QMVI scores and confidence levels was used as validity evidence with the assumption that students who were able to understand the question, could then judge their ability to answer that particular question correctly or incorrectly. Hence, when a positive correlation between students' test scores and their confidence levels exists, it can be concluded that the students' believed they understood what they were reading. Çataloğlu performed the reliability analysis for different subgroups that took the test and found positive correlations between their QMVI scores and confidence levels with Pearson coefficients ranging from .393 to .501 for groups, and .490 for overall groups.

Woehl (2010) use the term "certitude" for the subjective estimate of the likelihood of responding correctly and measured it by asking participants to rate their confidence in the accuracy of an answer they have given a question. Discrepancy between student's confidence and the actual outcome was used as the indicator of a poor metacognition, whereas an agreement between them was interpreted as high metacognition. Table 2.9 shows how certitude scores were determined in this study. A higher total certitude score was used an indication of the higher certitude accuracy and, thus, greater metacognitive ability.

Table 2.9 Determination of Certitude Scores for Interpreting Student Metacognition

	I'm very confident	I'm somewhat confident	I'm unsure
Correct answer	1	0	-1
Wrong answer	-1	0	1

Caleon and Subramaniam (2010a, 2010b) developed three- and four-tier multiple-choice tests as an enhanced version of the two-tier multiple-choice tests on the properties and propagation of mechanical waves in physics. The 14-item three-tier test comprised the content tier which measures content knowledge; the reason tier which measures explanatory knowledge; and the confidence tier which measures the strength of conceptual understanding of the respondents and the test was administered to 243 grade 10 students after formal instruction on the topic. Two scores were calculated for each question (1) content score ("1" was given for each correct content choice, and "0" otherwise), (2) both tiers score ("1" was given when both responses in content and reason tiers were correct, "0" otherwise). In addition to these two conceptual scores some variables were calculated from the confidence rating ("1" for Just Guessing to "6" for Absolutely Confident) given for each question. These variables calculated from the confidence ratings were:

Variable and its description

CF Mean confidence of students when giving a correct or incorrect response.

CFC Mean confidence of students when giving a correct response.

CFW Mean confidence of students when giving a wrong response.

CAQ Mean confidence accuracy quotient. ($\mathrm{CAQ} = \frac{\mathrm{CFC}-\mathrm{CFW}}{\mathrm{SD}}$)

CB Confidence bias which gives the standardized value of confidence discrimination. (CB = Confidence rating in a scale of 0 to 1 - Proportion of students who gave correct responses)

Also the alternative conceptions were identified and labeled as in Table 2.10. The genuine alternative conceptions were thought to be due to lack of understanding of concepts and application of wrong reasoning; whereas, spurious alternative conceptions were attributed to the lack of knowledge or guessing. With three-tier form (2010a) they identified 21 significant alternative conceptions, of which 11 were genuine ACs and 10 were spurious ACs. Among them, four were identified as strong significant alternative conceptions.

Table 2.10 Categorization of Alternative Conceptions by Caleon and Subramaniam (2010a; 2010b)

Alternative conception (AC)	Description
Significant ACs	Incorrect content-reason options that are selected by at least 10% of the sample
Genuine ACs	Significant ACs expressed with confidence (i.e. CF > 3.5)
Spurious ACs	Significant ACs expressed with low confidence (i.e. CF < 3.5)
Moderate ACs	Genuine ACs expressed with medium level (i.e. 3.5 < CF < 4.0)
Strong ACs	Genuine ACs expressed with high level (i.e. CF > 4.0)

Aydın (2007), Eryılmaz and Sürmeli (2002), Eryılmaz (2010), Kaltakci and Didis (2007), Kızılcık and Güneş (2011), Kutluay (2005), Peşman (2005), Peşman and Eryılmaz (2010), Türker (2005) assessed students' misconceptions similar to those mentioned before in the three-tier tests. However, they used the three tier test results to identify and analyze misconceptions in a slightly different manner.

In almost all of the above three-tier test development processes, the researchers benefited from diverse methods of diagnosis of misconceptions. The diversity in the data collection methods enabled the researchers to gain valuable information about the students' misconceptions as well as providing a good foundation for developing a valid and reliable diagnostic assessment tool. Figure 2.3 illustrates the order and names of these diagnostic methods used in the three-tier test development process.

Figure 2.3 General Three Tier Test Development Process

For statistically establishing the validity of the developed three tier test three quantitative techniques were used: (1) finding correlation between student scores on the first two tiers and confidence levels on the third tier, with the logic that in a properly working test students with higher scores are expected to be more confident about the correctness of their answers if they correctly understand what is asked on a test (Çataloğlu, 2002), (2) conducting explanatory factor analysis to determine whether related items would load into the same factors or not, (3) calculating proportions of false positives and false negatives, with the logic that for content validity the proportions of false positives and false negatives should be minimum (Hestenes & Halloun, 1995). In addition to validity, reliability analysis was conducted to examine the consistency of results across items within a test. Finally, the mean percentages of each misconception were reported for the first tier, first two tiers, and all three tiers and the difference between these percentages was interpreted.

Eryılmaz and Sürmeli (2002) developed a three-tier test on heat and temperature to assess ninth-grade students' misconceptions in Turkey. In this test, the students were asked a content question in the first tier; the reasoning for the content question was asked in the second tier; and in the third tier students' confidence about the first two tiers was asked. According to the authors, if a student selected an incorrect choice in the first tier, explained the answers with reasons was and confident about those two choices, then that student was considered to have a predefined specific misconception. The 19-item test was developed from a test on the topic which was translated by Başer (1996) into Turkish. The researchers added second tiers for students' reasoning based on the literature search and third tiers for their confidence of each item. Also they provided students with a blank choice for the first two tiers to write their own answers or reasons not existing among the available choices. A table of specification for the misconception choices and of the descriptions of those 15 misconceptions were prepared and then the table together with the three tier test was examined by five experts in the field. Additionally, three students with different cognitive states were interviewed with the test items in a think aloud process to see if the items of the test worked properly. Afterwards, the three-tier test was administered to 77 ninth-grade

students in Ankara, Turkey. In the data analysis the researchers calculated the percentages of students who held each of the predefined misconceptions as well as the mean percentages according to only the first tiers, the first two tiers, and all three tiers of the test. They found the mean percentages as 46 %, 27 %, and 18 % respectively. The difference between the mean percentages of the only first tier and first two tier tests was 19 %, which was attributed to the existence of students' errors. The 9 % difference between the mean percentages of the first two tiers and all three tiers was attributed to the lack of knowledge of the students in the heat and temperature topic. The researchers concluded that three-tier tests could confidently assess misconceptions that are free of errors and lack of knowledge in a more valid way.

Kutluay (2005) developed a three-tier test to diagnose eleventh grade students' misconceptions about geometrical optics in İstanbul, Turkey. In the first step of the test development the researcher prepared an interview guide and 15 students were interviewed with 16 questions in the guide. Afterwards, an open-ended test was developed based on the interview results and a literature review and administered to 114 eleventh grade science students. The responses of the students for each item were then categorized with their frequencies. These categories together with the interview results and the literature research were used in the development of the Three-tier Geometric Optics Misconception Test (TTGOMT). The final form of the test was administered to 141 eleventh grade high school students. In order to check content validity of the test, a factor analysis was conducted and five categories were found. Also, the proportions of false positives and false negatives were found to be 28.2 % and 3.4 % respectively. The construct validity was established by estimating the correlation between the scores of the students for the first two tiers and confidence levels in the third tier. The reliability of the test was found to be .55 considering the correct answers, and .28 considering the misconceptions for all three-tier scores. The mean percentages of misconceptions were found to be 19 %, 13 %, 10 % for only first tier analysis, first two tiers, and all three tiers, respectively. A 6 % difference was calculated between only the first tier and first two tiers analysis, and 3.4 % of it were considered as the proportions of false negatives, whereas the remaining 2.6 % was considered as the result of inconsistent answers. Similarly, the 3 % difference between the first two tiers and all three tiers analyses were considered to stem from lack of knowledge. In a second analysis conducted over the correct scores for only first, first two tiers, and all three tiers, percentages of the correct answers given to each item in the test and the mean percentages were calculated. As a result, the average values of 45 %, 17 %, and 13 % were calculated for only the first, first two tiers, and all three tiers analysis, respectively. The 28 % difference between only first and first two tiers were attributed to the false positives, whereas the 4 %

difference between the first two tiers and all three tiers analysis was considered due to lack of knowledge. According to the results of the three tier test, the most prevalent misconceptions which existed in more than 10 % of the sample are listed in Table 2.11. These results were in agreement with the findings of the previous studies (Galili, 1996; Guesne, 1985; Fetherstonhaugh & Treagust, 1992; Goldberg & McDermott, 1986).

Table 2.11 The Misconceptions in Geometric Optics Identified in the More than 10 % of the Sample in the Study of Kutluay (2005)

	Misconception	%
M3	Eyes can get used to seeing in total darkness.	11
M5	Light is emanating in only one direction from each source, like flash light beams.	18
M6	Shadows of the objects are clearer when the bigger bulb is used as a light source.	18
M10	Shadow is black color and light is white color. When they overlap, they mix and form the grey color. In a similar way, when the shadow and light overlap, the shadow reduce the brightness of the light.	13
M12	An image in a plane mirror lies behind the mirror along the line of sight between a viewer and the object.	14
M13	An observer sees the object because the observer directs sight lines toward it, with light possibly emitted from the eyes.	14
M16	Image of a black object on the mirror was due to black rays bouncing off the black object.	22
M18	While watching an object its position also shifted as they viewed it from different perspectives.	20

In other similar studies, Peşman (2005), Türker (2005), Aydın (2007), and Kızılcık and Güneş (2011) developed three-tier tests in physics and calculated statistics in a similar manner. Table 2.12 summarizes some of the descriptive statistics for three-tier tests and Table 2.13 gives the mean percentages calculated for these studies based on the number of tiers. Among these tests, Türker (2005) developed the three tier version of some of the selected FCI items and Aydın (2007) developed the three tier version of the TUG-K items.

However, Eryılmaz (2010) performed some further analysis in dealing with misconception scores. The study selected and concentrated on the common heat and temperature misconceptions and developed a three tier test with five items (4 of them are in three tiers, one is two tiers (second tier of which is a confidence tier)) to assess five misconceptions. These are: (1) Heat and temperature are the same (MisHeatTemp). (2) Temperature of an object depends on its size (Mistemp1). (3) Temperature of an object depends on the material (MisTemp2). (4) Heat of an object depends on its size (MisHeat1). (5) Heat of an object depends on the material (MisHeat2). As can be understood for each

context there are two three-tier items for heat and temperature separately. The test was administered to a total of 1898 bachelor, master, and PhD students as an online test, and used a new coding style as well as the old one to calculate misconception scores, and compared the results that emerged from this new coding to the previously used ones. In the old coding style, percentages of each of five misconceptions mentioned above according to the first, first two and all tiers were calculated. The reliability and factor analysis for these misconception scores were calculated. In the new coding style, however, the first tiers of the temperature and heat questions for each context were coded as a question, the second tiers of the temperature and heat questions were coded as another question, and the third tiers of the temperature and heat questions were coded as still another question. The coding checks whether the participants chose the same alternative for heat and temperature of the desk in the first, second, and third tiers of the questions. They presented the percentages of misconceptions in this new coding in two forms: whether participants manifested the misconception in every situation (AllAND) or at least in one situation (AllOR). In calculating AllAND a student was given a misconception score of "1" if he/she chose the corresponding misconception selection in all tiers of the 1st question and all tiers of the 2nd question and all tiers of the 3rd question. While calculating AllOR percentages however, the student was given a misconception score of "1" if he/she chose the corresponding misconception selection in all tiers of the 1st question or all tiers of the 2nd question or all tiers of the 3rd question. Acceptable factors and high reliability coefficients were found. Participants' misconceptions were so high that the reliability coefficients for misconceptions scores in this new coding were .77 for bachelors, .76 for master, and .86 for PhD students. A unique factor was formed for PhD students, which can be interpreted as indicating that participants' responses about the relationship between heat and temperature did not change according to the context.

Table 2.12 Some Descriptive Statistics for Three-Tier Tests

Topic (Reference)	Item Number (Misc. Number)	Administered Group	Sample Size	Reliability Coefficient Over		% of False Positives	% of False Negatives	Difficulty Index	Discrimination Index
				correct scores	misconception scores				
Heat and Temperature *(Eryılmaz & Sürmeli, 2002)*	19 (15)	9th grade	77	-	-	-	-	-	-
Force and Motion *(Türker, 2005)*	16 (16)	11th grade	207	.48	.62	8.0	6.0	.05 - .20	-
Simple Electric Circuits *(Peşman, 2005; Peşman & Eryılmaz, 2010)*	12 (11)	9th grade	124	.69	.33	17.5 10.3*	10.8 4.1*	.24	.46
Geometric Optics *(Kutluay, 2005)*	16 (20)	11th grade	141	.55	.28	28.2	3.4	.13	.34
Kinematics Graphs *(Aydın, 2007)*	21 (8)	10th grade	495	.84	.69	3.0	7.0	-	-
Heat and Temperature *(Eryılmaz , 2010)*	5 (5)	Bachelor Master PhD	1619 219 60	.43 .53 .63	.48 (.77)** .59 (.76)** .57 (.86)**	5.8 6.8 6.5	2.0 3.0 6.8	.19	.70
Mechanical Waves *(Caleon & Subramaniam, 2010a)*	14 (19)	10th grade	243	.64**	-	-	-	.12 - .42***	.42***
Circular Motion Test *(Kızılcık & Güneş, 2011)*	7 (10)	Preservice teachers	286	.68****	-	-	-	-	-

**Statistics obtained from the article is different from thesis. ** Values in parenthesis calculated for the new coding. ***Statistics was computed for the first two tiers. ****Statistics was computed for the first tier only.*

Table 2.13 The Mean Percentages of Misconceptions Based on Number of Tiers

	Eryılmaz & Sürmeli (2002)	Kutluay (2005)	Peşman (2005)	Türker (2005)	Aydın (2007)
Only First Tier	46 %	19 %	24 %	41 %	16 %
First Two Tiers	27 %	13 %	14 %	27 %	10 %
All Three Tiers	18 %	10 %	9 %	21 %	8 %
Difference between First Two Tiers and Only First Tier	19 %	6 %	10 %	14 %	6 %
Difference between All Three Tiers and First Two Tiers	9 %	3 %	5 %	6 %	2 %

In general, reliability coefficients for misconception tests are lower than achievement tests (Eryılmaz, 2010). There are various factors that affect reliability coefficients such as group homogeneity, time limit of the completion of the test, test length, spread of scores, difficulty of the test, objectivity (Crocker & Algina, 1986; Grounlund & Linn, 1990 as cited in Peşman 2005). Some factors are related to the test, some others are related to the group to which the test is administered, and some others are related to the environment (Gay, 1985). The reason for the lower reliability values for the misconception tests compared to the achievement tests might be due to the low discrimination and the high difficulty indexes. The reliability of the tests with very easy or very difficult items would be low since the variability of the scores would be low (Traub, 1994). Even though all above three-tier tests were developed as misconception tests, there are some variations among their reliability values. These differences might stem from the factors mentioned above. For instance, since the reliability measure of coefficient alpha is a method for estimating internal consistency of the test scores, relatively high reliability value in Eryılmaz's (2010) study might be due to the unidimensional nature of the test, i.e. test items' measuring a single common factor (misconception). Another difference between the reliability coefficients might be due to the type of scores used to calculate reliability. Even though all used three tier test to assess misconceptions, some of the studies calculated reliability over only first tier scores (Kızılcık

& Güneş, 2011) and some others calculated over the first two-tier scores (Caleon & Subramaniam, 2010a). The reliability coefficients calculated for the correct scores are usually larger than the reliability coefficient for the misconception scores except for Türker (2005). This situation was reported as a "questionable value" by the author since she expected the case to be reversed.

Difficulty indexes were found to be quite low, which shows the three-tier tests are rather difficult. The item discrimination indexes, which show how effectively the item discriminates between the high achiever and low achiever examinees, were calculated in a few of the three-tier studies and most of those reported values were quite satisfactory (i.e. $D \geq .40$ as defined by Crocker & Algina (1986)) which shows items in the test functioning well in discriminating those examinees. The proportions of false positives and false negatives were found to be less that 10 % in all, except the false positive proportion of Kutluay (2005) which could be an evidence for high content validity of the test results (Hestenes & Halloun, 1995).

Consequently, three tier tests had the advantage of discriminating the students' lack of knowledge from their misconceptions. Hence, they were considered to assess student misconceptions in a more valid and reliable way compared to ordinary multiple-choice tests and two-tier tests (Aydın, 2007; Eryılmaz, 2010; Kutluay, 2005; Peşman, 2005; Peşman & Eryılmaz, 2010; Türker, 2005). However, since in three-tier tests, students were asked for their confidence for the choices in the first two tiers covertly, this might underestimate proportions of lack of knowledge and overestimate student scores. For this reason, four-tier tests in which confidence ratings were asked for the content and reasoning tiers separately should be used.

2.3.3.3. Four-Tier Tests

Even though three-tier tests were thought to be measuring misconceptions free from errors and lack of knowledge in a valid way, they still have some limitations due to the covert rating of the confidence for the first and second tiers in those tests. This situation may result in two problems: one is the underestimation of the lack of knowledge proportions, and the other one is the overestimation of the students' misconception scores and the correct scores. To explain these problems in three-tier tests, one can look at Table 2.14 and Table 2.15 below. Table 2.14 provides the comparison of decisions for four-tier and three-tier tests in determining the lack of knowledge based on the possible student rating of confidence in four-tier tests. For example, if a student is "sure" about his answer in the main question tier

and “not sure” about his answer in the reasoning tier in a four-tier test, the researcher can decide “lack of knowledge” for that item. However, in the corresponding three-tier form of the same item the student may indicate his confidence for the main and reasoning tiers either as “sure” or “not sure”. As a result, depending on the rating of confidence, the researcher may have a decision of “lack of knowledge” if he is “not sure”; or “no lack of knowledge” if he is “sure”. Hence, proportion of lack of knowledge may be underestimated in three-tier tests.

Table 2.14 Comparison of Four-Tier Tests and Three-Tier Tests in Terms of Determining Lack of Knowledge (LK)

Four-tier Test			Three-tier test	
Confidence for the 1st tier	Confidence for the 3rd tier	Decision of researcher for LK in four-tier test	Corresponding possible student selection in three-tier test	Decision of researcher for LK in three-tier test
Sure	Sure	No LK	Sure	No LK
Sure	Not sure	LK	Sure Not sure	No LK if “sure” LK if “not sure”
Not sure	Sure	LK	Sure Not sure	No LK if “sure” LK if “not sure”
Not sure	Not sure	LK	Not Sure	LK

LK: Lack of Knowledge

Similarly, in the decision of misconception scores and correct scores, three-tier tests overestimate the proportions of those scores compared to the four-tier tests. Table 2.15 compares the decisions for three and four-tier tests. For instance, in a four tier test, if a student gives a correct answer to the main question in the first tier and is sure about his answer for this tier, then gives a correct answer to the reasoning question in the third tier but is not sure about his answer for this tier, then the researcher’s decision about the student’s answer for this item is “lack of knowledge” because there is doubt about at least one tier of the student’s answer. However in a parallel three-tier test in which the confidence rating is asked for two tiers together, the same student may select “sure” or “not sure” since he is not sure for at least one of the tiers. If he chooses “not sure” the researcher’s decision would be that student has a “lack of knowledge”, but if the student chooses “sure” then the reseracher’s decison for that student’s answer for this item would be he has a “scientific knowledge” on this item. Hence his correct score would be overestimated.

Table 2.15 Comparison of Decisions in Four-Tier Tests and Three-Tier Tests

1st tier	2nd tier	3rd tier	4th tier	Decision for four-tier test	Decision for three-tier test
Correct	Sure	Correct	Sure	SC	SC
Correct	Sure	Correct	Not sure	LK	SC if "sure" LK if "not sure"
Correct	Not sure	Correct	Sure	LK	SC if "sure" LK if "not sure"
Correct	Not sure	Correct	Not sure	LK	LK
Correct	Sure	Wrong	Sure	FP Rarely MSC	FP Rarely MSC
Correct	Sure	Wrong	Not sure	LK	FP if "sure" Rarely MSC if "sure" LK if "not sure"
Correct	Not sure	Wrong	Sure	LK	FP if "sure" Rarely MSC if "sure" LK if "not sure"
Correct	Not sure	Wrong	Not sure	LK	LK
Wrong	Sure	Correct	Sure	FN	FN
Wrong	Sure	Correct	Not sure	LK	FN if "sure" LK if "not sure"
Wrong	Not sure	Correct	Sure	LK	FN if "sure" LK if "not sure"
Wrong	Not sure	Correct	Not sure	LK	LK
Wrong	Sure	Wrong	Sure	MSC Rarely MTK	MSC Rarely MTK
Wrong	Sure	Wrong	Not sure	LK	MSC if "sure" Rarely MTK if "sure" LK if "not sure"
Wrong	Not sure	Wrong	Sure	LK	MSC if "sure" Rarely MTK if "sure" LK if "not sure"
Wrong	Not sure	Wrong	Not sure	LK	LK

SC: Scientific Conception; LK: Lack of Knowledge; FP: False Positive; FN: False Negative; MSC: Misconception; MTK: Mistake

In the science education literature, there exists no study assessing students' misconceptions with an analysis of a four-tier diagnostic test. To date, the only four-tier diagnostic test in science education has been the modification of the three-tier form of Caleon and Subramaniam (2010b) into four-tier format. The 12-item four-tier test was on mechanical waves in physics and 70 % of the content of the test featured familiar concepts on waves, whereas the rest deliberately featured some less familiar concepts about waves. The test was administered to 598 grade 9 and 10 students. In this study, the confidence tiers were again used for the calculation of some confidence related variables as mentioned before. They calculated two other scores; a content score ("1" was given for each correct content choice, and "0" when otherwise), and a both tiers score ("1" was given when both responses in the content and reason tiers were correct, and "0" otherwise). In determining the alternative conceptions scores however, they only considered the students' answers to those content and reasoning tiers, i.e. first and third tiers. Those who chose incorrect content-reason options were considered to have the predefined alternative conception. The test was thought to assess 19 alternative conceptions. As mentioned before, the authors categorized these alternative conceptions as significant, geniune, spurious, moderate, or strong alternative conceptions depending on the prevelance of them among the group and the confidence rating for their choice. The Croanbach alpha reliability for the test was found to be .40 for the first content tier, .88 for the second confidence tier, .19 for the third reasoning tier, .91 for the fourth confidence tier, .50 for both content and reasoning tiers together, and .92 for the confidence tiers together. As a result, they found that of 19 alternative conceptions identified, nine were found to be geniune, in that they are due to lack of understanding or wrong reasoning. Those geniune misconceptions were of moderate strength, which were interpreted likely to be altered by precise instruction.

To conclude, there are several ways to diagnose students' misconceptions in science, but all diagnostic asssessment methods have their own strengths and limitations. Researchers or teachers who aim to use them should be cautious about these concerns and use the more appropriate method or a method serving best for their purposes. Table 2.16 summarizes these methods with their strenghts and weaknessess.

Table 2.16 Comparison of Strengths and Weaknesses of Diagnostic Methods

	Methods to Diagnose Misconceptions					
	Interview	**Open-ended Test**	**Ordinary MCT**	**Two-tier MCT**	**Three-tier MCT**	**Four-tier MCT**
Strengths	Provides in-depth information. Flexibility of questioning.	Gives responders the chance to write their answers in their own words. Responders may give new and valuable answers which are not thought by the researcher before.	Time efficient in administering. Immediately scored. Objectively scored. Validity evidence is strong. Applied to a large number of subjects.	Holds all the strengths provided with Ordinary MCT. Gives an opportunity to decide the proportions of false positives and false negatives.	Holds all the strengths provided with Two-tier MCT. Determines the answers given to the first two tiers are due to misconception or a mistake due to lack of knowledge.	Holds all the strengths provided with Three-tier MCT. Truly assesses misconceptions which are free of errors and lack of knowledge.
Weaknesses	Requires a large amount of time to obtain and analyze the data. Requires a large number of people to obtain a greater generalizability. Requires training in interviewing. Analysis of data is difficult and subjective. Responders not respond freely if not built trust to the interviewer.	Takes time to analyze responses. Scoring is a problem. Response-rate is relatively small (students are resistant to write their response and reasoning clearly).	Less usable for the measurement of psychomotor skills. Do not provide deep enough investigation into the students' ideas. Students may give correct answers for wrong reasons (False Positive) or wrong answer with correct reasons. (False Negative) Wrongly interpreting students' responses if the items have not been constructed carefully. Guessing. Difficult to develop a well-constructed item.	Overestimates the proportions of the misconceptions since the lack of knowledge cannot be determined.	Underestimates the proportions of lack of knowledge since cannot decide whether the responder is sure for his/her answer in the first tier, in the second tier or in both tiers. Overestimates students' scores.	Requires a longer testing time. Usefulness may be limited to diagnostic purposes.

MCT: Multiple Choice Test

2.4. Previously Documented Misconceptions in Geometrical Optics

Although the number of misconception studies in physics is high compared to the other science fields, such as chemistry and biology (Duit, 2009; Duit et al., 2007; Wandersee et al., 1994), these studies have been conducted mostly in mechanics or electricity. There have been relatively few investigations of students' misconceptions in geometrical optics (Kutluay, 2005). Even though vision is one of our most important senses and our experience with light starts with birth, previously conducted studies showed that individuals have serious problems in understanding the nature of light, light propagation, vision, and optical imaging, regardless of their background, age, ability, or other characteristics.

The scope and definition of geometrical optics described by Langley, Ronen, and Eylon (1997) as:

> Geometrical optics deals with optical phenomena involving light propagation through an optical system and the creation of an illumination pattern. In the presence of an observer this can create a visual pattern, by which we mean an interpreted illumination pattern. Formal knowledge in geometric optics can be said to consist of four interrelated components: optical system (configurations of light sources, mirrors, prisms, and lenses); light propagation (rectilinear propagation, absorption, reflection, and refraction); illumination patterns (shadows and images); and finally, a systematic manner for linking the former components using verbal, graphical, and algebraic representations (pp. 399-400).

In his study Hubber (2006) listed seven key concepts of geometrical optics that should be used as criteria in the exploration of students' understanding. Those specified key scientific concepts of geometrical optics are:

1. Light from the object must enter the eye before vision of that object is possible.
2. Each point on a luminous object emits light in all directions.
3. Light travels in straight lines until it hits something.
4. (a) When light is reflected from a mirrored surface, the rule of reflection holds true.
   (b) Lights reflected in all directions from a non-mirrored surface.
5. (a) In general, light will change direction when passing from one transparent material into another.
   (b) Light will not change direction when passing from one transparent material into another if it hits the second material at right angles to its surface.
6. The color of an object is the color of the light that is reflected by the object.
7. (a) All the light from each point on an object that passes through a lens, or reflects off a mirror, contributes to the formation of a corresponding image point.

(b) The divergent light from each point on the object that passes through a lens, or is reflected from a mirror, either converges to the corresponding point on the real image or appears to diverge from the corresponding point on the virtual image.

The main aim of physics instruction should be the comprehension of those scientific concepts and application of those concepts to an understanding of the real world phenomena. However, there is ample evidence that people construct their own conception of light, which usually contradicts scientific instruction.

Galili and Hazan (2000) listed seven factors as possible obstacles for the construction of scientific knowledge in optics. The factors that impede the learning of optics and that are possible sources of misconceptions are:

1. The characteristic parameters of light (its speed, wavelength, etc.) are beyond the perception of human senses.
2. Many optical phenomena (light scattering, halos) observed in everyday life cannot be treated without taking into account the role of the media (air, water) through which light travels.
3. The observer is an inherent part of the optical system and nothing shows the observer his/her true physical role as a part of the optical system.
4. Language causes problems of a psychological nature, like the words “shining eyes”, “mirrors reflect images” or “red book”.
5. Common-sense explanations based on everyday experiences, straightforward interpretations, and superficial reasoning commonly used to explain phenomena interfere with the development of a proper ray model.
6. Interdisciplinary nature of optics in three disciplines-physics, physiology and psychology-adds to the confusion.
7. Heavy emphasis on graphical symbolism in optics instruction leads students to misinterpretations.

Table 2.17 lists 59 references to research articles, the topics in geometrical optics studied, the diagnostic instruments used, and the size and age of the population studied. Following Table 2.17 are Figures 2.4, 2.5, and 2.6, which summarize the frequency distribution of geometrical optics topics, diagnostic methods, and educational levels of the population studied.

Table 2.17 Summary of Studies about Students' Conceptions in Geometrical Optics

	Reference	Topic	Diagnosis Instruments	Sample	
				Size	Age
1. 2.	Piaget, 1963; 1969	Vision, Light propagation	Clinical Interviews	5	5-10
3.	Stead & Osborne,1980	Light propagation, Vision	Interview-about-instances Multiple choice test	36 379	10-15
4. 5.	Andersson & Karrqvist, 1982; 1983	Light propagation, Refraction, Vision, Color	Open ended test	558	12-15
6.	Guesne, Sere & Tiberghien, 1983	Light propagation, Nature of light, Mirrors	Individual interviews Questionnaires	13	10-14
7.	Goldberg & McDermott, 1983	Mirrors, Lenses	Individual-demonstration-interviews	90	University students
8.	La Rosa, Mayer, Patrizi, Vincentini-Missoni,1984	Reflection, Refraction, Dispersion	Group and individual interviews Open answer questions	63	16-17
9.	Eaton, Anderson & Smith, 1984	Vision, propagation of light, lenses, mirrors, color	Short answer questions Multiple choice questions	54	5th grade
10.	Guesne, 1985	Shadow formation, Mirrors	Interviews	30	10-15
11.	Watts, 1985	Light nature, Optic systems	Interview-about-instances	1	4th grade
12.	Goldberg & McDermott, 1986	Plane mirror	Individual demonstration interview Group demonstration Questionnaires	>200	University students
13.	Goldberg & McDermott 1987	Plane mirrors, Converging Lenses, Concave Mirrors	Individual demonstration interviews Group demonstrations questionnaires Multiple choice questions	80-200	University students
14.	Rice & Feher, 1987	Light propagation (pinhole)	Individual clinical interviews	110	9-13
15.	Feher & Rice, 1988	Propagation of light, shadows	Interviews	40	8-14

Table 2.17 Summary of Studies about Students' Conceptions in Geometrical Optics (Cont'd)

	Reference	Topic	Diagnosis Instruments	Sample	
				Size	Age
16.	Olivieri, Totosantucci & Vincentini, 1988	Color (colored shadows)	Individual and group interviews	37	Physicist, chemist, pedagogist
17.	Shapiro, 1989	Nature of light, vision, color, refraction,	Interview, survey, video recall data, student drawings, stories, assignments	1	10
18.	Palacious, Cazorla & Madrid, 1989	Nature of light, propagation of light, mirror, lens, prism	Open ended questions	44	Trainee teachers
19.	Fetherstonhaugh, Happs & Treagust, 1987	Light propagation, Vision, Mirrors, Lenses	2-tier diagnostic test (open response in the second tier)	>43	13-15
20.	Fetherstonhaugh & Treagust, 1992		Open ended test Semi-structured interviews		
21.	Feher & Rice-Meyer, 1992	Color (colored objects and colored shadows)	Individual interviews	32+35	8-13
22.	Franklin, 1992	Vision, propagation of light, color	Interviews Two-tier test	509	9-12th grades
23.	Osborne, Black, & Smith, 1993	Sources of light, Representations of light, Nature of vision	Writing and drawings	64	7-11
24.	Bendall, Goldberg & Galili, 1993	Vision, shadows, mirror images	Clinical interviews	30	Prospective elementary teachers
25.	Galili, Bendall, & Goldberg, 1993	Plane mirrors, Curved mirrors, Converging lens, Prism	Individual interview	27	Prospective elementary teachers
26.	Ronen & Eylon, 1993	Plane mirror, converging lens	Open ended question	29-92	10th grade
27.	Grayson, 1995	Converging lens	Multiple choice question with justification	35	University students
28.	Seattlage, 1995	Behavior of light	Observations	23	3rd grade
29.	Selley, 1996	Nature of light, Vision	Small group interviews Drawings and written responses	28	9-11
30.	Al-Rubayea, 1996	Vision, Nature of light, Color	Two-tier test	1080	10-12th Grades
31.	Langley, Ronen, & Eylon, 1997	Light propagation, Vision, Mirrors	Open ended questionnaire	139	14-15

Table 2.17 Summary of Studies about Students' Conceptions in Geometrical Optics (Cont'd)

	Reference	Topic	Diagnosis Instruments	Sample	
				Size	Age
32.	Wosilait, Heron, Shaffer & McDermott, 1998	Propagation of light (aperture)	Open ended questions	>1000	University students Graduate students
33.	Heron & McDermott, 1998	Converging lens, Illumination	Individual demonstration interviews	20	University students
			Multiple choice test questions with explanations required	200	Graduate students
34.	Hirn & Viennot, 2000	Propagation of light, vision, color, lenses	Interviews, logbooks, class observations	-	8th grade
35.	Galili & Hazan, 2000a	Vision, properties of light, shadow, color, reflection and refraction	Open ended questionnaire	166	10th grade and teacher training college students
36. 37.	Galili & Hazan, 2000b; 2001	Vision, properties of light, reflection and refraction	Open ended questionnaire Interview	234	10th grade
38.	Colin & Viennot, 2001	Converging lens	Open ended questions	120-250	University students
39.	Büyükkasap, Düzgün & Ertuğrul, 2001*	Nature of light, propagation of light	Open ended questions Multiple choice questions	214	10-11th grades
40.	Colin, Chauvet, & Viennot, 2002	Nature of light,	Questionnaire	139	Upper secondary school students
41.	Croucher, Bertamini, & Hetch, 2002	Plane mirror	Paper pencil tasks	184	19
42.	Chen, Lin, & Lin, 2002	Plane mirror	Two-tier test	317	15-18
43.	Eshach, 2003	Shadows	Small group interview	6	10th grade
44.	Şen, 2003*	Nature of light, vision, plane mirrors	Open ended questions True-false questions Multiple choice questions	304	9-13

Table 2.17 Summary of Studies about Students' Conceptions in Geometrical Optics (Cont'd)

	Reference	Topic	Diagnosis Instruments	Sample	
				Size	Age
45.	Kara, Kanlı & Yağbasan, 2003*	Nature of light, light propagation, lenses, mirrors, prisms	Multiple choice test	100	11th grade
46.	Heywood, 2005	Vision, Image formation and observation in a plane mirror	Individual interviews Interpretation of drawings	55	Primary trainee teachers
48.	Hecht, Bertamini & Gamer, 2005	Plane mirror	Dynamic displays	7	19-30
49.	Kutluay, 2005	Shadows, Plane mirrors, propagation of light	Interview Open ended test Three tier test	141	11th grade
50.	Parker, 2006	Shadows	Interviews Discourses Reflective journals Summative assignment writings	13	Primary trainee teachers
51.	Hubber, 2006	Nature of light	Semi-structured interviews Questionnaires Classroom observations	6	10-12th grades
52.	Yalcin, Altun, Turgut & Aggül, 2008*	Nature of light, propagation of light	Open-ended questions Interviews	100	16-18
53.	Isik, 2008	Pinholes, plane mirrors, convex lenses, refraction	Multiple Choice Test	39	15-18
54.	Dedes & Ravanis, 2009	Illumination (propagation of light)	Individual interview Open ended test	48	12-16
55.	Chen, 2009	Shadows	Multiple method interview instrument	32	4-5
56.	Chu, Treagust, Chandrasegaran, 2009	Light propagation	Two-tier multiple choice questions	1786	7-10th grades
57.	Kaewkhong, Mazzolini, Emarat, & Arayathanitkul, 2010	Refraction through planar surface	Multiple choice questions Semi-open ended questions	220	11th grade
58.	Kocakülah & Demirci, 2010	Plane mirror	Open-ended questions Semi-structured interviews	147	Secondary school students
59.	Anıl & Küçüközer, 2010*	Plane mirror	Open-ended questions	310	9th grade

**Represents the geometrical optics studies conducted on Turkish sample*

From those documented 59 studies in geometrical optics in Table 2.17, the number of studies with respect to the geometrical optics topics investigated, method of diagnosis for identification of the conceptions, and grade levels of the samples of the studies are illustrated in Figures 2.4, 2.5, and 2.6, respectively.

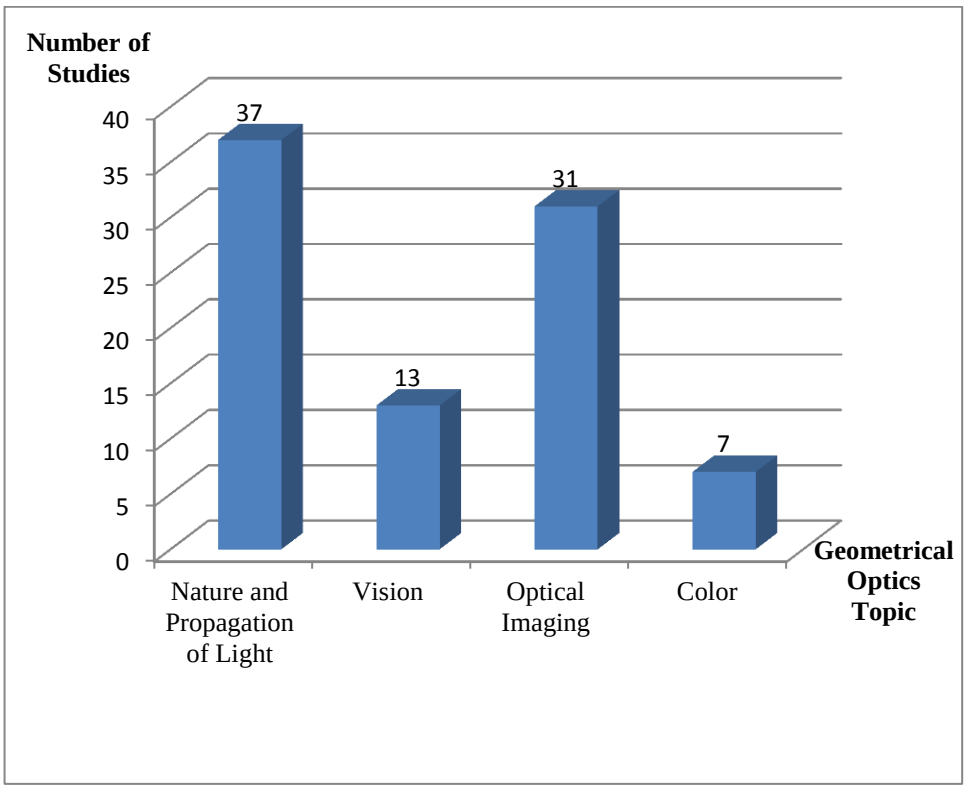


Figure 2.4 Frequency Distribution of Geometrical Optics Topics Investigated in the Studies

The studies in geometrical optics can be categorized into four interrelated groups according to their topics. These are nature and propagation of light (properties of light, rectilinear propagation of light, illumination, shadows); vision (role of observer's eye, how we see); optical imaging (plane mirrors, spherical mirrors, lenses, prisms); and color. As seen from Figure 2.4 most of the studies were conducted on the nature and propagation of light and optical imaging topics. The number of studies in vision and color topics was relatively few. Additionally, of the 31 studies in optical imaging, most were on plane mirrors or converging lenses. The number of studies of students' conceptions in the contexts of spherical mirrors, hinged plane mirrors, and diverging lenses were fewer.

Student conceptions in the tabulated geometrical optics studies in Table 2.17 were mainly identified by the use of interviews and open-ended questions (see Figure 2.5). The

number of studies with multiple-tier tests was relatively few in number. Even though in most of the studies researchers used more than one method to diagnose students' conceptions, because of the method selection sample sizes were small. Therefore, the results might have generalization problems.

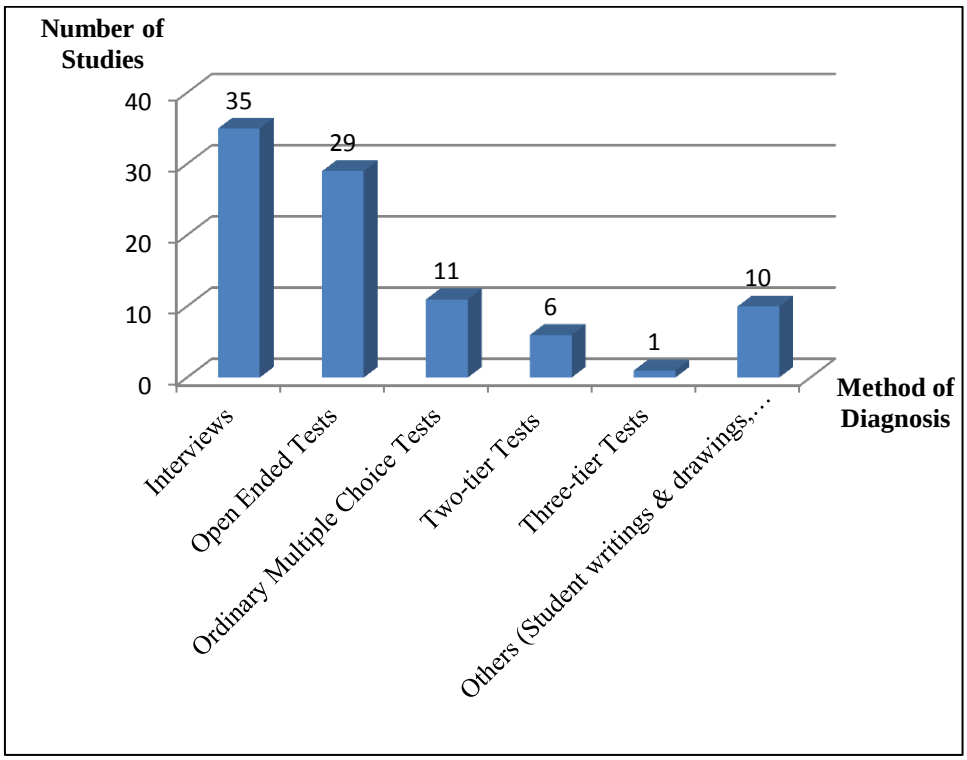


Figure 2.5 Frequency Distribution of Diagnosis Methods Used in Geometrical Optics Studies

Figure 2.6 provides the frequencies for the sample grade levels for the geometrical optics conceptions studies.

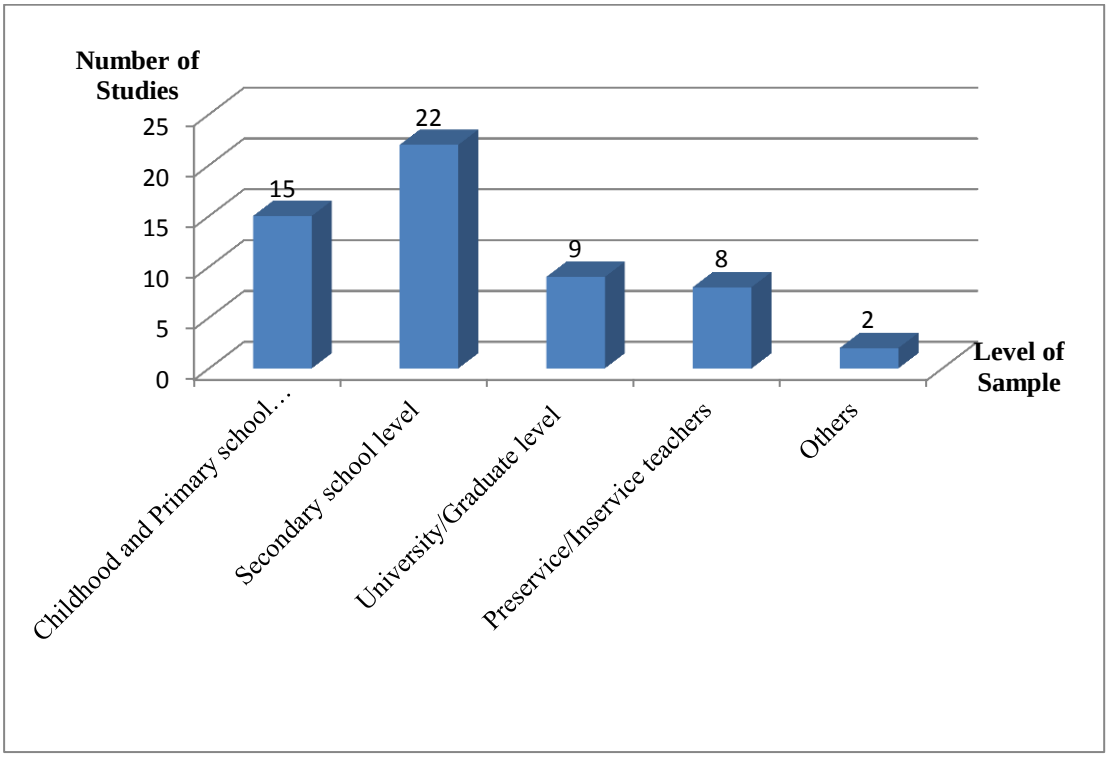


Figure 2.6 Frequency Distribution of Sample Grade Levels in Geometrical Optics Studies

The studies were mostly conducted in secondary school and at childhood and primary school levels. There were comparable numbers of studies conducted on university/graduate students and teachers. The number of studies on secondary school pre-service teachers was relatively small compared to the studies on elementary school pre-service teachers in geometrical optics, which was also the case for other subjects as reported by Abell (2007) in misconceptions studies.

As Langley, Ronen and Eylon (1997) claimed, students' ideas in geometrical optics are not simply attributable to the age of the subjects. Although maturation may change some of the ideas (Guesne, 1985; Osborne, Black &Smith, 1993), these differences among ages might be due to everyday experiences and their effect on development (Osborne et al., 1993). Studies of college or university students according to age, or prospective teachers' knowledge (Bendall, Goldberg, & Galili, 1993; Galili, Bendall, & Goldberg, 1993; Galili & Hazan, 2000; Goldberg & McDermott, 1983, 1986, 1987; Heywood, 2005; Wosilait, Heron, Shaffer, & McDermott, 1998;) about light, seeing, shadows, mirror, and lens images revealed very similar results to those found for younger subjects (Andersson & Karrqvist, 1983; Eaton, Anderson, & Smith, 1984; Feher, 1990; Fetherstonhaugh, Happs, & Treagust, 1987; Guesne, 1985; Langley et al., 1997; Osborne et al., 1993; Rice & Feher, 1987). The

results of the studies also showed that the conceptions of individuals about geometrical optics vary only little, or not at all, from one culture to another (Fetherstanhaugh et al., 1987; Langley et al., 1997; Osborne et al., 1993).

Research described in the documented literature shows that some misconceptions of students in geometrical optics are context dependent (Andersson & Karrqvist, 1983; Chu et al., 2009; Fetherstanhaugh & Treagust, 1987, 1992; Galili, 1996; Guesne, 1985; Heywood, 2005; Langley et al., 1997; Osborne et al., 1993). Reasoning activated in one context to explain a phenomena may not be used in another context that requires the same or similar knowledge. In other words, people do not use concepts systematically in optics and that the particular situation determines the conception that is prevalent (Guesne, Sere & Tiberghien 1983 as cited in Fetherstanhaugh & Treagust, 1987). For instance, the study of Langley et al. (1997) dealt with the conceptions of high school students about vision and seeing prior to formal instruction for luminous (seeing a candle) and non-luminous (seeing a flower) objects with explicit observer and observer-free situations. Different explanations were given by the students for those two contexts in terms of the process of seeing. In the case of seeing a lighted candle, students believed that the candle was visible because light leaving the flame enters the eye; whereas, in seeing the flower, students believed that the light that was present around the flower made it visible. Chu et al. (2009) conducted a large-scale study with 7-10 Korean students ($N > 1786$) using a two-tier multiple-choice test with four pairs of items. The pairs of items in the test were designed such that each pair evaluates the same concept in two different contexts. The concepts investigated and the two different contexts are presented in Table 2.18, together with the percentages of students giving correct answers for the contexts separately and together. Additionally, Table 2.19 presents the context-dependent alternative conceptions that emerged from the analysis of the study and the corresponding percentages of students having these conceptions with regard to the grade levels. From this analysis of the study, the researchers identified several context dependent alternative conceptions that were held by about 25% of the subjects.

Table 2.18 Description of the Contexts and the Percentages of Students with Correct Answers to the Questions in Each Context in the Study of Chu et al. (2009)

Concept	Context 1	Context 2	Contexts 1 & 2
"Light travels in straight lines in all directions until it strikes an object"	Light propagation during the day (46%)	Light propagation at night (49%)	41%
"Light travels in straight lines to our eyes from both non-luminous and luminous objects and is then focused on the retina.	Visibility of a non-luminous objects (23%)	Visibility of luminous objects (26%)	13%
"Light travels in straight lines past an obstruction"	Visibility of a lighted lamp above an obstruction (23%)	Illumination by a lighted lamp above an obstruction (21%)	13%
"An object is visible because light is reflected rom the object to the eyes"	Vision of cats in the dark (22%)	Vision of human in the dark (55%)	20%

Table 2.19 Description and the Percentages of Students' Context Dependent Alternative Conceptions Identified from the Study of Chu et al. (2009)

Contexts	Context-Dependent Alternative Conceptions	Grade level			
		7	8	9	10
Day and light	Light does not travel at all during the day. It stays on the light bulb.	-	46	35	-
Luminous and non-luminous objects	There are merely bundles of rays from the illuminated objects without considering our eye focusing the light to the retina.	23	24	21	16
Cats and human eyesight in the dark	Cats can clearly see objects in the dark.	33	35	26	32

As has been mentioned before, misconceptions in geometrical optics found in the literature can be categorized under four categories. These are conceptions about vision, conceptions about nature and propagation of light, conceptions about optical imaging, and

conceptions about color. It is hard to separate these categories from one another with sharp lines since they are interwoven. The lack of a correct conception for vision, for example, is most probably one of the reasons for the difficulty in comprehending the notion of a virtual image. Nonetheless, for convenience, in the next sections some related studies are summarized within those four headings.

2.4.1. Vision

In order to perceive the surroundings, vision is probably the most important of the senses. However, since the mechanism underlying vision seems effortless and spontaneous most individuals, regardless of grade level, do not think about how we see objects; more specifically, they do not think about the role of light and the observer's eye in the process of seeing.

Galili and Hazan (2000a, 2000b) defined the Scheme of Spontaneous Vision as a facet of knowledge in which vision is perceived as an activity performed naturally by the eye, or light is considered as a supportive background that improves vision. Students with this belief seemed to think that aiming or focusing the eyes on the object is sufficient for vision. In these studies the researchers identified the abundance of the students' pre- and post-instruction schemes of knowledge and interpreted the gain in each scheme by a scheme gain coefficient (which is the difference in the abundance of each scheme before and after instruction). Among eight mentioned schemes, Spontaneous Vision had the most negative gain coefficient (-18 per cent), meaning that the students in this study changed their conception in "how we see objects" after instruction with more scientific conception schemes as analyzed by Galili and Hazan (2000a). In this study 166 high school and teacher training college students' knowledge of light, vision and related topics were explored before and after commonly practiced instruction. In their other study (Galili & Hazan, 2000b), 141 tenth grade students were instructed with historically oriented course and 93 tenth grade students were instructed by conventional instruction on light. Again the abundance of the scheme of Spontaneous Vision was calculated, and again the post-test showed a decrease in the unscientific scheme (-24 per cent).

In the case study by Eaton, Anderson and Smith (1984) with two teachers and six of their fifth-grade students, it was found that subjects had the incomplete conception that "we see objects because light shines on and brightens them", but not realizing the necessity of the reflection of light from the object to the observer's eye. Also it was stated that reflected light only related to mirrors. Most students had difficulty in understanding that opaque objects

reflect light to our eyes. Shapiro (1989) in a case study with a pupil asked about vision in an interview and obtained an answer that light is necessary for seeing the building since it illuminates it.

Guesne (1985) stated that many students think light is required in order to see an object. However light does not necessarily reach the observer's eye. In some other situations, students might think of the eye as a receptor of light in the cases of incandescent objects, but with ordinary objects, they thought of the eye as an active agent. Although its frequency was small compared with the other unscientific conceptions, some children thought that the light rays originate in the eye and travel to the object to enable vision (Guesne, 1985) which is parallel to the Pythagorean conception of vision (Galili & Hazan, 2001) in the sixth century BC.

Fetherstonhaugh and Treagust said that about 75 percent of their sample used a Visual Ray idea: the conception that we see not by light reflected to our eyes, but by just looking. Jung (as cited in Driver, Squires, Rushworth, & Wood-Robinson, 1999) reported that 12-14 years old students had problems in interpreting vision, such that no connection was made between seeing and receiving light from an object.

Osborne, Black, Smith and Meadows (1993) suggested that children had three unscientific representation of the vision process. These were "vision as an active process," in which children made no connection with a light source and indicated a link between the eye toward the object; "vision as an active process involving light" which reconciled the active eye idea with light being necessary by drawing the line from light source to the eye and then to the object; "vision as light and active eye directed towards object" in which students thought that light source illuminates the object and we see the object by looking at it.

2.4.2. Nature and Propagation of Light

Studies showed that only a minority of students hold the scientific view that light propagates in a rectilinear path and is not identified with a particular source (Guesne, 1985; Fetherstanhaugh & Treagust, 1987; Osborne et al., 1993).

When children with age range 10-11 were asked about light, different conceptions appear. They identify light with its source (light is the bulb on the ceiling), with its effect (light is luminous patches on the ground by the sunlight), or as a state (light is brightness) instead of as a distinct entity in space. Even a same child may use one or the other conception according to the situation, or s/he may shift from one conception to the other while explaining the same phenomenon (Guesne, 1985). The notion of the straight path of

light is also conceptualized differently from the scientific view by children. Light is envisioned as moving along linear rays (Guesne, 1985).

Galili and Hazan (2000a, 2000b) defined students' conception of "light as an object in space" with a Corporeal Light Scheme. In this conception students defined vision and light in a circular manner. Light was explained as an entity that fills space and remains in it. In this scheme, the light rays (which are actually a model or tool for representation of the path of light) were conceived as concrete entities by students.

Watts (1985) conducted a case study on a single subject in order to examine student conception of light. During the interview-about-instances process in this study, it was revealed that the subject moved between two descriptions about the nature of light. He was unsure about whether light is a single composite entity, or it is a collection of these entities, more specifically undistinguished between ray and beam concepts.

Watts and Gilbert (as cited in Driver et al., 1999) proposed seven frameworks about students' conceptions about nature of light: Ambient Light (a distinction is drawn between direct light and normal daylight); Composite Light (light is thought to be composed of parts or as a single entity); De-coupled Light (light being completely separate from seeing); Illuminative Light (light is thought to be intentionally designed to allow us to see); Modal Light (many different kinds of light are identified); Obvious Light (light is thought to be a property only of large luminous bodies); Projected Light (light as a substance that is projected).

Reiner, Slotta, Chi, and Resnick (2000) synthesized the literature in terms of the substance schema, and they stated that a materialistic conception of light is common among people. Instead of perceiving light as a process of electromagnetic energy propagation, it was perceived as a material substance which can flow and remain at rest, can be mixed as if a liquid, can create friction upon contact, something inherent of an object.

In terms of the transmission of light, several studies exist in the literature. Fetherstonhaugh and Treagust (1992) claimed that students of ages 13-15 had the conception that light travels different distances depending on whether it is day or night. Even some of the students had the idea that light does not travel at night.

Children's ideas about shadows contradict the scientific conception that shadow is conceived as the presence of something that light allows us to see, rather than the absence of light (Feher & Rice, 1988). In this study 40 children of ages 8 to 14 interviewed about the shadow when a large ball is placed in front of a crossed light. The results showed that students had the idea that shadows always look like the object. They did not consider the role of a light source in the formation of shadows.

Wosilait, Heron, Shaffer, and McDermott (1998) investigated how physics students at the introductory university level and beyond think about simple phenomena involving illumination and shadow. Before the discussion of a tutorial, entitled “Light and Shadow,” students were asked to describe the pattern on the screen when a mask with different shaped apertures is placed between a light source of different shapes and a screen. Although the correct response required the recognition that light travel in straight line and an extended source can be treated as a series of point sources, the students thought that light could only pass through the hole, so it did not matter what the light source was. The results of this study showed that even though many students had the knowledge that light travels in a straight line, they were not able to apply this knowledge.

2.4.3. Optical Imaging

Goldberg, Bendall, and Galili (1991) asserted that students have difficulty in understanding certain basic aspects of image formation by optical systems such as the role of the eye in observing images or the role of the screen and the criteria for real or virtual image formation. In order to identify the conceptions of students the researchers used simple demonstrations with converging lens and a pinhole. The terms “screen reproduction” and “aerial reproduction” were discussed and illustrated throughout the study in the situations of the presence or absence of the screen at the image point in the image formation by a converging lens system. Also the role of the observer in both real and virtual image formation and observation was considered.

Goldberg and McDermott (1986) did individual demonstration interviews with 65 college students (both algebra-based and calculus-based) both before and after the instruction in geometrical optics. Through this study some unscientific conceptions about properties of a plane mirror emerged. Some of the students thought that the image of an object in a plane mirror lies on the surface of the mirror. Other students had the “line-of-sight” reasoning in which they tried to locate images along the line of sight. Also the study showed that many students had the conception that when they move away from the mirror, the amount of image they could see of his/her own image would increase. The researchers concluded that the way in which reflection by a plane mirror is taught in introductory college physics did not usually result in a functional understanding.

Galili, Goldberg, and Bendall (1991) discussed three incorrect concepts in the formation of images by plane mirrors. These were: how a mirror image is formed, why a piece of paper does not behave like a mirror, and left-right or front-back reversion in a plane

mirror. It was emphasized that both the mirror and the observer are necessary for the formation of virtual image, which is often ignored by textbooks, teachers, and therefore to the students. Secondly it was stated in the study that it is common for pre-secondary students to think that a mirror reflects light, but a piece of paper does not. This conception is very common among all grade levels as discussed in the vision part of the study. Similarly, Anderson, and Smith (as cited in Driver et al., 1999) found that about 60 % of the students described light as bouncing off mirrors but not of other surfaces. In the study of Galili et al. (1991) it was also mentioned that students had the conception that reflection is left-right orientation in a plane mirror. In this study it was suggested that students should be encouraged to think about what causes the observed properties of images in plane mirrors. In order to develop an understanding of both the behavior of light and the role of the observer in image formation.

Goldberg and McDermott (1987) investigated students' understanding of the real image produced by converging lenses and concave mirrors before and after instruction in geometrical optics. They used individual demonstration interviews (with 80 students) as a primary method of investigation, and a group demonstration questionnaire and multiple choice tests (with 200 students) as a supplementary method of investigation. The results of the study showed that even the students who had just completed geometrical optics instruction did not seem to understand the function of a lens, mirror, or screen. The difficulties in drawing and interpreting ray diagrams showed inadequate understanding of the light ray concept and its representation.

In the other study of Galili, Bendall, and Goldberg (1993) in image formation with 27 prospective elementary teachers, students' answers to the questions about how we see was investigated. It was found that the subjects of the study lacked the knowledge of the link between the eye and the observed object or image. Students' conceptions were categorized into three classifications as pre-instruction students' knowledge, hybridization of pre-instruction knowledge, and formal physics knowledge. It was claimed that the post-instruction students had hybrid knowledge, which is an intermediate state of knowledge. Students with pre-instruction knowledge (also called Image Holistic Scheme in Galili et al., 1993; Galili, 1996; Galili & Hazan, 2000a) thought that the image goes directly to the mirror and stays there in the plane mirror. Students with hybrid knowledge (also called Image Projection Conceptualization) thought that a single ray drawn from the object to the mirror and reflected into the eye forms the image. However, this knowledge is still not formal physics knowledge, but in an intermediate state between pre-instruction and formal knowledge.

In a comparative study conducted by Fetherstonhaugh, Happs, and Treagust (1987) on 13-16 years old students, a large number of Western Australian students like France, New Zealand, Sweden and the United States, had the conception that an image exists in mirror. Many of them could not provide a correct explanation about the location of images in mirrors. To questions with lenses 42 % of the students answered with an unscientific response, stating that when the lens was removed from the system, an image would be formed on the screen.

Heywood (2005) investigated 55 primary trainee teachers' conceptions in how an object is seen and how an image is formed in a plane mirror. They described the vision process in general by interviewing the subjects and interpreting their diagrammatic representations related to the questions. The researchers examined the subjects' knowledge of images and vision within optically complex situations requiring careful consideration of the positions of observer, object, and image. The results of the study showed that trainee teachers experienced significant difficulties in articulating coherent explanations regarding basic ideas about light and optical instruments. In a task with a moving observer in a plane mirror context, ~60 % of the participants had the notion that the image of stationary objects in front of a plane mirror appears to move, depending on the position of the moving observer. This conception was labeled previously by Goldberg and McDermott (1986) as "line of sight reasoning" such that the image is wrongly located along the line of sight. Parallax type of explanations depending on the experience of watching an object shift its position as viewed from different perspectives may be thought to be its probable source. Students with this reasoning usually failed to realize that the absolute position of the object remains the same when the observer moves, but only the apparent position relative to the background changes.

2.4.4. Color

Students' conceptions also vary about the color of light. Eaton et al. (1984) stated that most students believe color to be a property of objects and not of light. For this reason students with unscientific conceptions mentioned that "the book is red" rather than "the book is reflecting red light". In this respect, students seem to have an incomplete understanding of the vision process as well. Also five of the six students in the study had the misconception about color as "white light does not contain all colors of light, but it is pure or colorless".

The same misconceptions were detected in the study by Anderson and Smith (as cited in Driver et al., 1999) such that 72 % of the sample did not think that white light was a

mixture of colors, and 61 % thought that color was an innate property of an object and that our eyes see the color of the object rather than the color of the reflected light.

Galili and Hazan (2000a) asserted a Color Pigment Scheme in which light and color were considered as independent physical entities. In some of the facets constructing this scheme, color was thought as paint colors so they gave the properties of color of paint to light color of light. The appearance of these conceptions was attached to insufficient considerations about color in relation to vision and the emphasis on the observer's eye.

The article of Olivieri, Torosantucci and Vincentini (1988) reported two different conceptions regarding the color conception in shadows in the context of geometrical optics for the participants of the study (8 physicists, 4 mathematicians, 2 pedagogists, 1 pedagogue, 20 in-service teachers, a mathematician, and a chemist). The task asked the participants who had different expertise about the experimental observation of a red and a green shadow on a yellow background and their prediction of what would happen with three beams of light at the position at which they intersect. The two conceptions that emerged from the study were identified as an object-shadow network and color-mixing. The object-shadow network was related to the notion that the source of light was thought to be either an integral part of the theory (the red light produces red shadow) or peripheral in importance (the shadow is always black in color, no matter the color of light source). The color-mixing notion however related to the mixing of paints (mixing colors generally produces a darkening in color). The results revealed that knowledge of geometrical optics facilitates the pinpointing of the color problem, whereas the experience with the mixing of paints acted as a barrier to understanding the mixing of light beams.

Feher and Meyer-Rice (1992) examined 8-13 years old children's ideas about colored objects and colored shadows. In the colored objects task, children were asked to predict the color of colored objects under colored lights. In their predictions, the participants in the study had the following notions: colored light has no effect on the color of an object (6%), colored light is always dark (19 %), colored light mixes with the color of an object (47 %), colored light gives its color to the object (12 %). In the another task related to colored shadows, the children were asked the color of the shadows produced by colored light and colored objects. The following notions were identified: the shadow is dark or black always (59 %), the shadow is the color of the light (35 %), and the shadow is the color of the object (6 %).

2.5. Researcher's Personal Experience in the Present Study

Even the limited number of studies in optics reveals that students' at nearly all grade levels have difficulty in understanding optical phenomena from primary school to university level. The personal experience and observation of the researcher with pre-service physics teachers support these findings as well. Personal experiences show that most pre-service physics teachers, who complete physics courses for their content knowledge, still have the same misconceptions presented in the literature. This researcher has had the experience of investigating pre- and in-service teachers' conceptions in several topics including geometrical optics for five years. As a Teaching Assistant in the inquiry-oriented laboratory course specially designed for prospective physics teachers in Middle East Technical University, the researchers have had an invaluable opportunity to investigate pre-service physics teachers' conceptions in plane mirrors and converging lens contexts. During the one year-long academic visit to the University of Washington Physics Education Group, the researcher had examined the Light and Optics module in Physics by Inquiry. The investigator had participated as an instructor during the NSF-funded Summer Institute for in-service teachers in the USA. These experiences in teaching geometrical optics helped the researcher understand the difficulties encountered by students studying this topic.

2.6. Summary of Related Literature

In science education, students' ways of conceptualization and reasoning about the physical phenomena are an important research area. The studies in this area have been called by several terms: preconceptions, anchoring conceptions, alternative conceptions, misconceptions, naïve beliefs, commonsense concepts, children's science, conceptual difficulties, spontaneous reasoning, phenomenological primitives (shortly p-prims). The studies of misconceptions research, which are concerned with student knowledge that contradicts scientific knowledge, have aroused an extensive amount of interest. According to Hammer (1996), most misconceptions research is based on certain assumptions, including scientifically incorrect conceptions that are strongly held and stable, that differ from experts' conceptions, and that affect how students understand natural phenomena. For this reason must be avoided, and eliminated. The misconceptions differed from the other terms mentioned above in that they were different from scientific concepts. Research in education has demonstrated that students come to a physics course with their own views about the world. These views are often different from the scientifically accepted ones, and to be

strongly held, robust, resistant to change through instruction. They hinder further learning and knowledge development (White & Gunstone, 1989; Fetherstonhaugh & Treagust, 1992; Hammer, 1996). Other research has documented that even after physics instruction, students may have a weak understanding of fundamental concepts (McDermott, 1990, 1991; Hestenes et al., 1992). Detailed studies have revealed several possible sources of student misconceptions. Among them are personal experiences, language and analogies used, textbooks, and teachers (Helm, 1980; Kaltakci & Eryilmaz, 2010; Kikas, 2004; Wandersee et al., 1994). Teachers often subscribe to the same misconceptions as their students (Abell, 2007; Heywood, 2005; Kathryn & Jones, 1998; McDermott et al., 2006; Wandersee et al., 1994). Because of their responsibility to help their students learn; studies on teachers' misconception is particularly important. Although it is said to be difficult to document and eliminate these possible source of misconceptions, the first step in overcoming students' misconceptions must be to identify them correctly (Klammer, 1998).

For the purpose of studying individuals' conceptions on specific topics, various diagnostic evaluation methods have been used. Examples are interviews, open ended tests, multiple choice tests, and multiple-tier tests. All of these diagnostic methods have some advantages, as well as some limitations. For this reason, obtaining the benefits of these several methods increases the value of the study. Interviews were among the most common and the best diagnostic methods in misconception studies (Osborne & Gilbert, 1980, Wandersee et al., 1994). Even though interviews provide in-depth information and have the flexibility of further questioning, a large amount of time is required to obtain and analyze the data. Also it is necessary to conduct the interviews with a large number of individuals to obtain a greater generalizability (Beichner, 1994; Çataloğlu, 2002; Franklin, 1992). Although it is possible to overcome the generalizability problem with open-ended tests, it still takes time to analyze the responses and information obtained is not as deep as from the interviews (Beichner, 1994). Multiple-choice tests have advantages over interviews and open-ended tests in that they can be administered to large samples in an efficient time. The results can be scored quickly and objectively, and the validity evidences are strong (Çataloğlu, 2002; Tamir, 1990; Iona, 1986). However, the most prominent limitation of multiple choice tests is their inadequacy in identifying wrong answers with correct reasons and correct answers with wrong reasons (Caleon & Subramaniam, 2010a, 2010b; Eryılmaz, 2010). In order to compensate for this limitation of ordinary multiple-choice tests, researchers have developed two-tier tests by asking students' justifications for their answers (Al-Rubayea, 1996; Chang et al., 2007; Chen, Lin & Lin, 2002; Chu, Treagust & Chandrasegaran, 2009; Çataloğlu, 2002; Fetherstanhaugh & Treagust, 1992; Franklin, 1992). On the other hand, two-tier tests

overestimate the proportions of misconceptions since they are inadequate in discriminating misconceptions from lack of knowledge (Eryılmaz, 2010; Peşman & Eryılmaz, 2010). Hence, a third tier asking for confidence about the answer and including reasoning tiers were asked on three-tier tests in order to obtain a more valid and reliable diagnostic tool (Aydın, 2007; Caleon & Subramaniam, 2010a; Eryılmaz & Sürmeli, 2002; Eryılmaz, 2010; Kutluay, 2005; Peşman, 2005; Peşman, 2010; Türker, 2005). In three-tier tests, students were asked for their confidence in main and reasoning tiers together. However, individuals might indicate their confidence differently when they are sure in one tier but not in the other tier. This situation, therefore, might underestimate the proportion of lack of knowledge and overestimate student scores. As a result, it has been recommended that four-tier tests to be used. These ask for confidence in the main answer and reasoning tiers separately (Caleon & Subramaniam, 2010b). Four-tier tests have been rarely used to identify misconceptions.

Misconceptions in geometrical optics have been detected through interviews, open-ended tests, and ordinary multiple-choice tests. Some student conceptions in geometrical optics found in the literature can be categorized under four inter-related titles. These are student conceptions about vision (Andersson & Karrqvist, 1982; Eaton et al., 1984; Galili & Hazan, 2000a, 2000b; Guesne, 1985; Osborne et al., 1993), conceptions about nature and propagation of light (Feher & Rice, 1988; Fetherstanhaugh & Treagust, 1992; Guesne, 1985; Watts, 1985; Wosilait et al., 1998), conceptions about optical imaging (Galili et al., 1991; Goldberg & McDermott, 1986, 1987; Goldberg et al., 1991; Heywood, 2005) , and conceptions about color (Eaton et al., 1984; Feher & Meyer-Rice, 1992; Galili & Hazan, 2000a; Olivieri et al., 1988). Misconceptions about vision can be listed as the following:

- Vision is an activity performed naturally by the eye and light is a supportive background that improves vision.
- Aiming or focusing the eyes on an object is sufficient for vision.
- Opaque objects do not reflect light to our eyes.
- We see objects because light shines on and brightens them.
- To see an object, light does not necessarily reach the observer's eye.
- Light rays originate from the eye to the object to enable the vision (eye is sending out rays).
- People can just see in the dark (eyes getting used to the dark).

Most common student misconceptions about the nature and propagation of light are as the following:

- Identifying light with its source (light is the bulb on the ceiling), identifying light with its effect (light is luminous patches on the ground by the sunlight), identifying light with its state (light is brightness).
- Light is located in space between source and effect and does not propagate through space.
- Light is a material substance which can flow and remain at rest, can be mixed as if a liquid can create friction upon contact, something inherent of an object.
- Light moves along linear light rays.
- Brightness of light determines how many rays are being produced. The more rays the brighter the light.
- Light rays carry a travelling image in mirrors and lenses.
- A ray is a physical entity rather than a graphical representation of light.
- Light is a property only of large luminous bodies.
- Light travels different distances depending on it is day or night.
- Shadow is conceived as the presence of something that light allows us to see.
- Shadows are seen as being "reflections" of objects.
- Shape of the aperture/object determines the shape of illumination /shadow.
- Shape of the light source determines the shape of illumination /shadow.

Student misconceptions in optical imaging found in the literature can be summarized as:

- Images in a plane mirror are located along the line of sight.
- Image is resident on the mirror or possibly just behind it.
- Moving away from the mirror, the amount of seeing image would increase.
- Moving away from the mirror, a person or image gets smaller.
- Images in a mirror could be in a number of places at the same time.
- Mirror reflects light, but a piece of paper does not.
- The reflection is left-right orientation in a plane mirror.
- Observer is not important in virtual or real image formation.
- Lenses are not necessary to form images on the screen.
- A whole lens is necessary to form an image.
- Lenses are making things bigger.

Some misconceptions about color are:

- Color is a property of objects.
- White light is pure or colorless.
- Light colors are the same as paint colors.

Student conceptions on several concepts such as on mechanics, electricity, heat and temperature have been discussed widely. The results from previously documented studies on geometrical optics revealed that some of the misconceptions on this topic are abundant, regardless of the age and academic background of the individuals, and they are context dependent. They require greater attention during instruction than they have often received.

CHAPTER 3

METHODOLOGY

The methodology and the overall design of the present study are described in this chapter. It includes a description of the population, the features of the sample, the research design, the instruments used in the study, the variables, the procedure followed, the statistical techniques used in the analysis of the results, and the assumptions made.

3.1. Research Type and Design

The first phase of the study was the development of a four-tier test. This process does not match any common research design. In the second phase of this study, a cross-sectional survey design was used. This design was chosen since the aim was to collect descriptive information about students' conceptions in geometrical optics from a sample at just one point in time.

3.2. Population and Sample

The target population of the study consists of all Turkish pre-service physics teachers who completed the geometrical optics and geometrical optics laboratory courses in their five-year physics teacher education programs. There are a total of 13 state universities in Turkey, which have five-year undergraduate physics teacher education programs. Appendix A lists the five-year physics teacher education programs of all of the 13 state universities. Pre-service physics teachers are selected and placed into those universities according to their score in a national university entrance exam in Turkey. Table 3.1 gives some general information about each of the 13 state universities with physics teacher education programs in Turkey that constitute the target population of the present study. This table provides information about student placement in each university (The term, "Capacity", represents the maximum number of students accepted for the program in the specified university by the university entrance exam. "Min Placement Score" represents the minimum university exam score for an individual to be accepted for the program. "Rank Among All"

represents the ranking of the universities with respect to their minimum university placement score) and the semesters in which geometrical optics and geometrical optics laboratory courses are in their five year undergraduate physics teacher education programs with their corresponding course credits. For instance, Middle East Technical University (METU) is an English-medium university, and its physics teacher education program has a capacity of a maximum of 36 students with a minimum university placement score of 403.375. METU is ranked as second among all of the 13 universities according to its university placement score for pre-service physics teachers. In their five-year physics teacher education program, geometrical optics course is in the third semester with a course credit of 4, whereas the geometrical optics laboratory course is in the fourth semester with a course credit of 3. For this reason, 36 pre-service physics teachers who just took and passed optics and optics laboratory courses and were on their fifth semester contribute to the target population of the present study.

The accessible population for the study was all Turkish pre-service physics teachers who had just completed the geometrical optics and geometrical optics laboratory courses in their program and had registered in one of the corresponding semester courses that are convenient for the researcher's access. The corresponding semesters from which the pre-service teachers were selected was determined for each university. For each university, it was one or two semesters after the pre-service teachers had taken the geometrical optics and/or geometrical optics laboratory course. The selection of the courses was based on convenience for accessibility. The researcher contacted faculties in each university and determined the most fully enrolled and available courses for selecting the sample. For interviews the courses were selected from the three universities in Ankara on the basis of the ease of access to the individuals for prolonged interviews. For open-ended test and three tier test administrations, the 13 universities were divided into three groups according to their rankings on the university placement scores. One course from each of these groups was selected. In this way, it was possible to get a divergent range of courses from different universities. In the FTGOT administration, however, accessible courses from all 13 universities were determined and used for test administration. Unfortunately, before the administration of the FTGOT, a big earthquake occurred in Van. Therefore, Yüzüncü Yıl University could not be included in the sample during this process.

Table 3.1 Information about the Universities with Physics Teacher Education Programs in Turkey that Constitutes the Target Population of the Study*

University	Capacity	Min Placement Score	Rank Among All	Semester of Optics (Credit)	Semester of Optics Lab (Credit)
Atatürk University Kazım Karabekir Education Faculty	41	265.522	11	3 (4)	3 (1)
Balıkesir University Necatibey Education Faculty	41	290.600	8	3 (4)	3 (1)
Boğaziçi University Education Faculty (English)	36	451.270	1	4 (4)**	-
Dicle University Ziya Gökalp Education Faculty	41	262.831	12	6 (6)	6 (1)
Dokuz Eylül University Buca Education Faculty	41	321.963	5	5 (5)	5 (1)
Gazi University Gazi Education Faculty	41	326.151	4	3 (4)	3 (1)
Hacettepe University Education Faculty (German)	41	312.801	6	6 (3)	6 (1)
Karadeniz Teknik University Education Faculty	41	286.652	9	6 (4)***	6 (1)***
Marmara University Atatürk Education Faculty	41	347.293	3	7 (3)	-
Middle East Technical University Education Faculty (English)	36	403.375	2	3 (4)	4 (3)
Ondokuz Mayıs University Education Faculty	41	281.181	10	4 (4)	4 (1)
Selçuk University Ahmet Keleşoğlu Education Faculty	41	295.482	7	4 (4)	4 (1)
Yüzüncü Yıl University Education Faculty	41	247.124	13	4 (4)	4 (1)

**Data is obtained from Turkish Higher Education Council. **Optics laboratory applications are included in the optics course. ***Elective Course*

3.2.1. Sample and Sampling Procedure for Interviews

The sample of the qualitative part of this study was comprised of a divergent sample of 16 Turkish pre-service physics teachers from three state universities in Ankara. In the selection of individuals for the interviews, a combination of Convenience Sampling and Maximum Variation Sampling methods were used. Three state universities with five-year undergraduate physics teacher education programs in Ankara were selected through Convenience Sampling for their ease of accessibility for conducting prolonged interviews. This was the procedure for the Convenience Sampling part. Then a total of sixteen participants were selected through Maximum Variation sampling from these conveniently selected universities. The interviews were conducted in the spring semester of the 2011-2012 academic year. Therefore pre-service physics teachers in their sixth semester at METU and Gazi Universities, and in their eighth semester at Hacettepe University were listed. The maximum variation was done according to GRADE score of these listed students in each university as an average of weighted averages of optics and optics laboratory course grades, and cumulative grade point average (CGPA) of students. Students in each university were ranked according to their GRADE score. The equation used is given below:

$$\text{GRADE}=\frac{1}{2}\left[\text{CGPA}+\frac{(\text{OCGxOCC})+(\text{OLGxOLC})}{\text{OCC+OLC}}\right] \quad (1)$$

where CGPA is Cumulative Grade Point Average; OG is Optics Course Grade; OCC is Optics Course Credit; OLG is Optics Laboratory Grade; and OLC is Optics Laboratory Credit.

Table 3.2 summarizes some descriptive information about the pre-service physics teachers from which the interview participants were selected. For instance, at METU a total of 20 students were registered in their sixth semester of the program: 9 of them were female and 11 of them were male. The average GRADE score calculated by the equation given above for all of the 20 students was 2.57 with a standard deviation of 0.66. Appendix B gives all of the information about the pre-service teachers from which the 16 interview participants in the present study were selected.

Table 3.2 Information about Interview Universities

University	# of Students Registered*	Semester of Students	Average of GRADE	StDv of GRADE
METU	20 (F:9 M:11)	6	2.57	0.66
GAZI U.	40 (F: 29 M:11)	6	2.62	0.48
HACETTEPE U.	14 (F:10 M:4)	8	2.28	0.41

**F: Female, M: Male*

According to the ranking of GRADE scores, high-medium-low achieving categories were determined and an effort was made to select the participants for the interviews equally from those three categories. Pre-service physics teachers were assigned as high, medium, or low achieving according to their GRADE score as:

High Achieving -------Above one standard deviation above the average of GRADE scores.

Medium Achieving ---Between one standard deviation above and below the average of GRADE scores.

Low Achieving-------- Below one standard deviation below the average of GRADE scores.

The researcher talked to random students from each of these categories. The students who volunteered to participate in the study were selected. As a result, 16 participants were selected with the criteria mentioned above for the interviews part. Some demographic information about the participants selected for the interviews is given in Table 3.3.

Table 3.3 Demographic Information about the Sixteen Participants Selected for Interviews

Code	University	Semester	Gender	CGPA	Optics Grade	Optics Lab Grade	GRADE
M1	METU	6	Male	3.51	4.00	4.00	3.76
M2	METU	6	Female	3.30	3.50	4.00	3.51
M3	METU	6	Male	2.75	3.00	1.50	2.55
M4	METU	6	Female	2.47	2.00	1.50	2.13
M5	METU	6	Male	1.98	1.00	2.50	1.81
M6	METU	6	Male	1.95	1.00	1.50	1.58
G1	GAZI U.	6	Female	2.84	3.50	4.00	3.22
G2	GAZI U.	6	Female	2.90	3.50	3.00	3.15
G3	GAZI U.	6	Female	2.72	3.50	3.50	3.11
G4	GAZI U.	6	Female	2.67	3.00	3.00	2.84
G5	GAZI U.	6	Female	2.19	3.00	3.50	2.65
G6	GAZI U.	6	Female	2.02	2.00	3.00	2.11
H1	HACETTEPE U.	8	Female	2.56	3.00	2.50	2.74
H2	HACETTEPE U.	8	Female	3.47	1.50	3.00	2.61
H3	HACETTEPE U.	8	Male	2.06	2.00	3.50	2.16
H4	HACETTEPE U.	8	Male	2.42	1.50	3.00	2.09

3.2.2. Sample and Sampling Procedure for the Open-Ended Test

The open-ended test was administered to the purposefully and conveniently selected divergent sample of 52 pre-service physics teachers at three universities in Turkey. First of all, the selection of universities for the open-ended test administration was done by purposeful sampling. To do so, the universities were grouped into three categories according to their ranking or the university placement exam. One of the universities from each category was selected. This previous information about the ranking of universities led the researcher to believe that the sample selected would be representative of the population. The selection of the universities from each category and the selection of the courses were done by Convenience Sampling (by considering the ease of accessibility). As a result, the open-ended tests were sent to four universities: Marmara University, Dokuz Eylül University, Balıkesir

University, and Yüzüncü Yıl University. However, the test could not be administered at Marmara University due to some problems related to the administration time management. The instructor would not spare a class hour during the semester for the open-ended test administration. Since Dokuz Eylül University was already in the same category with Marmara University, missing Marmara University did not hurt the sampling much. Table 3.4 gives information about the universities in which open-ended tests were administered.

Table 3.4 Information about Open Ended Test Universities

University	Rank	Semester of Students	Sample Size		
			Female	Male	Total
Balıkesir University	8	6	10	6	16
Dokuz Eylül University	5	8	9	10	19
Yüzüncü Yıl University	13	6	8	9	17

3.2.3. Sample and Sampling Procedure for Three-Tier Test in Pilot Study

For the pilot testing of the Three-Tier Geometrical Optics Test (TTGOT), a combination of purposeful and convenient sampling methods was used. Since the administrations of the open-ended test and the pilot test were conducted during the same spring semester of 2010-2011 academic year, different universities were purposefully selected from each of the aforementioned three categories. Then the appropriate courses were selected from each university by convenience in terms of accessibility. Consequently, a sample of 53 pre-service physics teachers from the three universities namely Atatürk University, Hacettepe University, and METU constituted the sample for the pilot testing of the TTGOT. Table 3.5 provides the information about the universities where the pilot study was conducted.

Table 3.5 Information about Pilot Test of Three Tier Geometrical Optics Test Universities

University	Rank	Semester of Students	Sample Size		
			Female	Male	Total
Atatürk University	11	6	13	11	24
Hacettepe University	6	8	9	5	14
METU	2	6	7	8	15

3.2.4. Sample and Sampling Procedure for Four-Tier Geometrical Optics Test

A total of 523 pre-service physics teachers were placed by university placement exams in all 13 state universities in each year. The FTGOT was administered to a total of 243 pre-service teachers, which constituted the 46 % of the target population in all of these universities, except Yüzüncü Yıl University (There occurred a big earthquake in Van; hence the classes in Yüzüncü Yıl University were cancelled throughout the semester). In each university the appropriate semesters for administration were determined by considering the optics and optics laboratory courses in their educational programs. The administration of the FTGOT was performed in the 2011-2012 fall semester, hence courses that were taken one or two semesters after taking the optics and optics laboratory courses were listed for each university. The researcher contacted the instructors of the corresponding semester courses in the universities, and tried to select the most crowded and accessible courses for the administration of the FTGOT. In selecting the courses, the courses of the instructors that had a background and interest in physics education research were preferred. Therefore, the accessible population was also the sample group to which the FTGOT was administered. At the day of administrations 243 of 270 pre-service teachers were reached (which corresponds to 90 % of the accessible population).

Through missing item analysis, 30 subjects were removed from the analysis of the study, since these subjects had blank/omitted responses in more than 25 % of all the misconception categories. The details about the missing item analysis and the determination of the subjects removed from the study will be discussed in Chapter 4. In Table 3.6 the information about the universities that the FTGOT was administered is given in detail.

To sum up, Table 3.7 summarizes the whole sample and sampling process for the development of the FTGOT and the survey part.

Table 3.6 Information about FTGOT Universities

University	Rank	Semester of Students	Target Population	Accessible Population	Sample Size		
					Female	Male	Total
Atatürk University	11	5	41	23	17	6	23
Balıkesir University	8	5	41	38	22	13	35
Boğaziçi University	1	5	36	11	0	4	4
Dicle University	12	7	41	13	8	5	13
Dokuz Eylül University	5	7	41	26	9	13	22
Gazi University	4	5	41	40	25	9	34
Hacettepe University	6	7	41	11	8	3	11
Karadeniz Teknik University	9	7	41	25	8	6	14
Marmara University	3	9	41	25	9	4	13
Middle East Technical University	2	5	36	23	15	17	32
Ondokuz Mayıs University	10	5	41	28	9	9	18
Selçuk University	7	5	41	30	17	7	24
Yüzüncü Yıl University	13	5	41	-	-	-	-
		TOTAL	523	270	147	96	243

Table 3.7 Summary of the Samples and Sampling Methods of the Whole Study*

University	Rank	Interviews	Open Ended Test	Pilot TTGOT	Main FTGOT
Boğaziçi University	1				√
Middle East Technical University	2	√		√	√
Marmara University	3		X		√
Gazi University	4	√			√
Dokuz Eylül University	5		√		√
Hacettepe University	6	√		√	√
Selçuk University	7				√
Balıkesir University	8		√		√
Karadeniz Teknik University	9				√
Ondokuz Mayıs University	10				√
Atatürk University	11			√	√
Dicle University	12				√
Yüzüncü Yıl University	13		√		X
Sample Size		16	52	53	243
Sampling Type		Convenience & Maximum Variation	Convenience & Purposive	Convenience & Purposive	No sampling , accessible population

*√ *shows the administered group, X shows could not administered group due to problems.*

3.3. Instruments

In order to develop multiple-tier diagnostic tests to assess misconceptions, the researchers were mostly inspired by the method that was used by Treagust (1986), which

was discussed in Chapter 2. This method generally includes the use of previous literature, concept map analysis, interview results, and open ended test results to construct the multiple-tier, multiple-choice tests. In the current study, a similar method used by Treagust and the previous researchers (Kutluay, 2005; Peşman, 2005; Peşman & Eryılmaz, 2010; Türker, 2005) was used. Four different instruments were developed and used for different purposes in this study. These instruments were the Interview Guide, the Open-Ended Geometrical Optics Test, the Three Tier Geometrical Optics Test (TTGOT), and the Four Tier Geometrical Optics Test (FTGOT). In this section, the development and administration procedures of these instruments are described in detail.

3.3.1. The Interview Guide

The Interview-About-Instances technique (Osborne, & Gilbert, 1980) was used in the interviewing part of the study. During this process, the participants were provided with some diagrams related to the questions in the Interview Guide that was designed for this study. The interviewer asked the related questions in order to elicit the ideas held by the pre-service physics teachers. The Semi-Structured Interview Guide (see Appendix C) was prepared by considering the misconceptions about geometrical optics reported in the literature review and the personal experiences of the researcher about student conceptions on this topic.

In order to prepare the Interview Guide, the researcher reviewed the literature that speaks on the most common misconceptions in geometrical optics at all grade levels. The most resourceful contexts in terms of the prevalence of misconceptions among upper grades and the contexts which have not received enough attention to be studied were determined. Together with the personal experience of the researcher while teaching in a course specially designed for inquiry-based laboratory teaching for pre-service physics teachers at METU, and in a Summer Institute program at the University of Washington specially designed for preparing in-service science teachers to teach physics concepts by inquiry. The researcher has chosen the contexts of the investigation for the present study. In the literature review, the most resourceful contexts were found to be related to optical imaging for the upper grade students. Also, some of the contexts in optical imaging such as hinged plane mirrors, diverging lenses, and convex mirrors have not been studied by many researchers. Only a few theoretical studies were found about these contexts. Furthermore, equal importance was attached to questions in the optical imaging in “seeing/forming an image of oneself” and “seeing/forming an image of others”. Hence, the researcher prepared the preliminary version

of the Interview Guide according to the Table of Specification for the interview questions. The Table of Specification for the Interview Questions (see Appendix D) is a two dimensional table with contexts in optical imaging (plane mirrors, spherical mirrors, lenses) in one dimension, and the cases in optical imaging ("seeing/forming an image of oneself" and "seeing/forming an image of others") in the other dimension. Some of the questions in the Interview Guide were modified or inspired from by the questions from the literature, while some others were constructed by the researcher. Appendix E gives the sources of the interview questions in the Interview Guide together with their references if they were modified from the literature.

To establish the content validity, the Interview Guide that involves the interview questions in geometrical optics within different contexts and cases was given to three instructors from the Department of Secondary Science and Mathematics Education with physics education majors at METU together with an Expert Opinion Form (see Appendix F). They investigated the test and made some suggestions to modify the test items on the test for better understanding, as well as some suggestions to the administration of the test. In the light of these suggestions, necessary corrections were made on some items, especially with their figures and grammatical structures. Also, the experts suggested that the interviews should be conducted in more than two sessions, each session including one of the contexts.

As a result, the 35-item Semi-Structured Interview Guide was prepared (see Appendix C). Most of the questions in the guide required students to draw diagrams in the explanation and description of their answers to the questions. Therefore for each items in the interview guide, interviewees were provided with a paper with multiple figures on it for them to work on (see Appendix G). The questions were open-ended in nature with some additional follow-up questions and probes.

The interviews were conducted individually within five sessions for sixteen participants selected by convenience and maximum variation sampling methods from the three universities in Ankara. The content of the five sessions for the interviews and the average time for completion of each session are given in Table 3.8. The researcher made a schedule for each session according to the availability of each of the participants, and made one interview in a week with a single participant. Hence, the completion of all of the interviews with all participants took five weeks, with an average of 35-75-minute interviews with each participant.

Table 3.8 Information about the Interview Sessions of the Study

Sessions	Content	Average Time for Completion (min)
Session 1	Warm up, general questions about the topic, determination of the resourceful contexts in geometrical optics.	60
Session 2	Plane mirror related items.	75
Session 3	Spherical mirror related items.	65
Session 4	Hinged mirrors related items.	35
Session 5	Lens related items, closing, and reflections.	35

The first session of the interviews were dedicated to building rapport between the interviewee and the participants, informing participants about the aim of the study and the contexts to be discussed, asking general questions about the geometrical optics in order to determine the contexts in which the participants had difficulty. The researcher video-recorded each interview session with the permissions of the participants. The drawings of each participant on his or her working papers were collected as a secondary data. The analyses of the interview data took three weeks. The results of the analysis were primarily used to develop the open-ended test for this study and also to construct the alternatives of the multiple-tier, multiple-choice test. The results of the interviews are discussed in detail in Chapter 4.

3.3.2. The Open-Ended Geometrical Optics Test

After conducting the interviews, the researcher developed an open ended test (see Appendix H) by considering the results of previously conducted interviews for determining the resourceful contexts for detecting pre-service teachers' misconceptions in geometrical optics, and by checking the literature review. The main aim of administering the open-ended test was to get a greater generalizability and to construct the alternatives of the multiple-choice, multiple-tier test in geometrical optics. Almost all of the questions in the Open-Ended Test were selected from the Interview Guide. However, some small modifications were made in order to enhance the quality of some of the questions. For instance, in Items 1, 2, 9, and 10 on the Open-Ended Geometrical Optics Test, the cats numbered with 3 and 4 were moved to left one unit square. The reason for making this change was to reduce the interference of different misconceptions, since in its previous form in the Interview Guide

pre-service teachers had problems with Cats 2 and 4 that were on the same line to the left boarder of the plane mirror. Also in deciding the items on the open-ended test, the number of items in each context and case were balanced with the help of the Table of Specification (see Appendix I).

As a result, there were 24 items in the Open-Ended Geometrical Optics Test. In the first tier of each item is a question related to geometrical optics; while in the second tier of the item, reasoning about a given answer was asked. The test was given to the same three instructors for evaluation in order to establish content validity.

The open-ended test was administered to 52 pre-service teachers from the selected three universities from different regions of Turkey (see Table 3.4). The open-ended tests together with the Open-Ended Test Administration Guide (see Appendix J) were mailed to the instructors who were volunteers in the administration of the test in their courses, and the tests were administered by these instructors in approximately 90 minutes. In the analysis of this part, the researcher documented and grouped the responses of pre-service physics teachers to each question (see Appendix K) and then categorized the meaningful responses with their frequencies (see Table 4.1 in Chapter 4). Administration of the open-ended test and the analysis of the test results took a total of 5 weeks.

3.3.3. The Three-Tier Geometrical Optics Test for the Pilot Study

In the light of the analysis of the Open-ended Geometrical Optics Test results, interview results, and the common misconceptions mentioned in the previous literature, the Three-Tier Geometrical Optics Test (TTGOT) was developed. TTGOT is a three tier multiple choice test (see Appendix L) designed to assess the misconceptions of pre-service physics teachers about geometrical optics. The first tiers of the TTGOT items are ordinary multiple-choice questions. Second tiers, which are in multiple-choice format, ask for the reasoning for the answer in the first tiers. And finally, third tiers ask for the rating of their confidence for their answers in the first two tiers. Moreover, blank alternatives to write any answers different from the available alternatives were added at the end of both first and second tiers of each item on the TTGOT. The items of the TTGOT were mostly taken from the Open-Ended Geometrical Optics Test. Two of the items (Item 3 and Item 4) on the open-ended test were removed totally from the TTGOT, since they were found to be less resourceful contexts for the pre-service teachers as a result of the analysis of the open-ended test. Also, some sub-questions on the open-ended form of the test (1B, 2A, 7A, 9A, 10A, 11A, 19B) were removed from the TTGOT, since they did not yield considerable answers in

the open-ended form. In removing the items the researcher considered the content validity of the test, so that the proportion of the contexts and cases in the Table of Specification for the TTGOT were still acceptable. For the content validity, the Table of Specification (see Appendix M) and the Table for Item Choices for the Misconceptions (see Appendix N) were prepared for the TTGOT. The TTGOT together with the Expert Opinion Form (see Appendix O) were given to three experts who had previously reviewed the interview and open-ended test. After making the necessary revisions, the TTGOT was administered to seven fourth grade pre-service physics teachers at METU in one hour. Subjects were told to ask if anything on the test were not clear during the administration. After the subjects all completed the TTGOT, two instructors (one of them was the researcher and the other one was the expert who reviewed the interview guide, open-ended test, and the TTGOT) initiated a discussion about the TTGOT items' clarity, the difficulties they encountered in the wording, figures, etc., and asked for their suggestions for better understanding the test items. The difficulties and suggestions expressed by the subjects were all noted and the necessary modifications, such as the minor typing errors or the logical ordering of the alternatives in some of the items, were done. At the end, the final version of the TTGOT with 22 items, all items of which had three tiers, was developed. The answer key of the TTGOT is given in Appendix P.

The TTGOT was administered to 53 pre-service physics teachers from three different universities in Turkey selected by convenient and purposive sampling methods (see Table 3.5). The researcher was available during the administration of the test in two of the universities in Ankara together with the instructors of the course, whereas the test was sent to the third university to be administered by the instructor. In order to standardize the conditions for the administration process, the researcher informed the instructor about the administration by phone and also sent a Test Administration Guide to the instructor (see Appendix Q). The administration of the test lasted for 60 minutes. Based on the previous applications of the test, this time was enough for the completion of the TTGOT by almost all of the students. The answers of the subjects on the TTGOT were analyzed and the results were used to develop and improve the FTGOT. The Cronbach alpha coefficient for the TTGOT scores was found to be .72 over the correct scores for all three tiers. Descriptive analysis for the choice of each main answer and reasoning options, calculations of the proportions of false positives (11 %) and false negatives (4 %) were done for the TTGOT scores. Also, an item analysis for the TTGOT scores was conducted and the problematic alternatives of the test were detected to be improved or removed from the test. The details of the analysis of the TTGOT scores are discussed in Chapter 4.

3.3.4. The Four-Tier Geometrical Optics Test

By analyzing the results of the TTGOT data, the researcher made the necessary modifications or revisions, and developed the FTGOT. Two of the items (Items 7 and 15) on the TTGOT were removed from the FTGOT, since the item analysis for the TTGOT for all three tiers scores produced negative point-biserial for these items. The researcher removed Item 7, but not Item 12 by considering the content validity of the test. Since, if Item 12 had been removed from the test, according to the Table of Specification there wouldn't be enough items for assessing the case of "observing oneself" category. Item 15 was also removed from the test, since proportion of the false positive for this item was relatively high (55 %) and there was another item (Item 17) assessing the same context-case. Some of the alternatives in the test were shortened in order to enhance the readability and comprehension (1.2.b, 1.2.c, 1.2.d, 2.2.c, 2.2.d, 2.2.e, 3.2.a, 3.2.b, 3.2.c, 4.2.c, 5.2.c, 5.2.d, 5.2.e, 8.2.f, 10.2.a, 10.2.b, 10.2.c, 10.2.d, 11.2.b, 11.2.c, 11.2.g, 12.2.b, 12.2.c, 12.2.d, 13.2.b, 13.2.d, 16.2.a, 16.2.b, 16.2.c, 16.2.d, 16.2.f, 17.2.a, 17.2.b, 17.2.c, 17.2.d, 17.2.e, 18.2.a, 18.2.b, 20.2.c, 21.2.b, 21.2.c, 21.2.d, 21.2.e, 22.2.b, 22.2.c, 22.2.d), some alternatives were divided and added as a new alternative (6.2.d, 8.2.c, 9.2.a). Some alternatives were combined into one alternative (19.2.c-d), some alternatives removed altogether (8.2.d, 9.2.b, 12.2.e). The other major difference between the TTGOT and the FTGOT was in the confidence tier. In the FTGOT one more tier asking the confidence rating for the answers for the first tier and the reasoning tier separately was added. As a result the test became a four-tier test. The confidence ratings were scaled into four as "Totally Sure", "Sure", "Not Sure", "Totally Not Sure", since some of the subjects who took the TTGOT complained about their difficulty to rate confidence in its previous form as "Sure" and "Not Sure". As a result, the 20-item FTGOT with four-tiers was developed (see Appendix R). In the first tier of the test are questions about the concepts in geometrical optics; in the second tier the degree of confidence about the given response in the first tier is asked; in the third tier the reasoning about the answer in the first tier is given, and in the fourth tier the degree of confidence about the given reasoning in the third tier is asked. The Table of Specification for the FTGOT was prepared (see Appendix S). For establishing the face and the content validity, the FTGOT was given to six experts. Five of the experts were instructors at the Department of Secondary Science and Mathematics Education with physics education majors at METU and Gazi University. One of the experts was a PhD student in physics education at METU and a physics teacher in a high school. All of the experts were provided with an Expert Opinion Form (see Appendix T) for the FTGOT and the final form of the test itself.

According to their suggestions, some corrections on the stems and the alternatives of the test were made. For checking the grammatical rules and language, the test was given to a Turkish teacher from a high school and necessary corrections were made. At the end, the final version of the FTGOT had 20 items. The answer key of the FTGOT (see Appendix U) and the misconception choices (see Appendix V) for the four tier form of the test were also revised and brought into final form.

The FTGOT was administered to 243 pre-service physics teachers from 12 different universities in Turkey. The courses in which the test was administered were selected through Convenience Sampling by contacting the instructors. The administrations of the three universities in Ankara were done under supervision of the researcher. However the tests were sent to the other universities through mail. In order to equate the conditions for the administration process, the researcher informed the instructors about the administration by phone and also sent a Test Administration Guide to the instructors (see Appendix W). The administrations of the FTGOT lasted 50 minutes, one lecture hour at the universities, during four weeks of 2011-2012 Fall semester.

3.4. Variables

In the present study, several variables were obtained for each subject by using the answer key of the FTGOT (see Appendix U), the table for the misconception choices for the FTGOT (see Appendix V), and the raw data (see Appendix X). The Microsoft (MS) Excel program was used to enter the raw data (items in columns and subjects in rows), and the data were changed to nominal level (dummy- coded) for further analysis. By using the logical functions (IF, AND, OR functions) of the MS Excel program, students' answers on the raw data were recoded as 0 (incorrect answer / non-existing misconception) or 1 (correct answer / existing misconception). With this way three kinds of variables emerged namely correct scores, misconception scores, and confidence scores. Correct scores were calculated with the subjects' correct answers to the each item on the FTGOT by using the answer key in Appendix U. Misconception scores were calculated with subjects' incorrect answers on the FTGOT that indicated the misconception choices given in Appendix V. The confidence scores were calculated based on the confidence rating in the second and fourth tiers on the FTGOT. For both Correct scores and Misconception scores, AND, OR, and SUM scores were calculated by using AND, OR, SUM functions of the MS Excel program. Consequently, the variables of the present study and their descriptions are as the following:

3.4.1. Correct Scores

Correct Only First: This score was obtained by using each subject's responses for only the first tier of items on the FTGOT. Each subject's correct answers for the first tiers of each item were coded as 1, and others were coded as 0. Summing the columns gave each subject's score based on only the first tier of the test, whereas summing the rows gave the sum of correct responses given to only the first tier by all subjects. Dividing the latter by the total number of students gave the proportion of correct responses for the first tiers of the each item (difficulty level of first tier).

Correct Only Third: This score was obtained by using each subject's responses for only the third tier of items on the FTGOT. Each subject's correct answers for the third tiers of each item were coded as 1, and others were coded as 0. Summing the columns gave each subject's score based on only the third tier of the test, whereas summing the rows gave the sum of correct responses given to only the third tier by all subjects. Dividing the latter by the total number of students gave the proportion of correct responses for the third tiers of the each item (difficulty level of third tier).

Correct First and Third: This score was obtained by using each subject's responses for the first and third tiers of each item on the FTGOT. When a subject's responses to the first and third tiers were both correct, it was coded as 1; otherwise it was coded as 0. Summing the columns gave each subject's score based on correctness of responses to the first and third (reasoning) tiers of the test, whereas summing the rows gave the sum of correct responses given to the first and third tiers by all subjects. Dividing the latter by the total number of students gave the proportion of correct responses for the first and third tiers of each item (difficulty level of two-tier test).

Correct All Four: This score was obtained by using each subject's responses to all four tiers of items on the FTGOT. When a subject's responses to the first and third tiers were correct, and both responses to the second and fourth tiers were either "Totally Sure" or "Sure", then it was coded as 1; otherwise, it was coded as 0. Summing the columns gave each subject's scores based on all four tiers of the test, whereas summing the rows gave the sum of correct responses according to all four tiers. Dividing the latter by the total number of students gave the proportion of correct responses for each item (difficulty level of four-tier test).

3.4.2. Misconception Scores

Misconception Only First: This score was obtained by using each subject's choice selections indicating misconceptions according to the only first tiers in the table for the misconception selections in Appendix V and student responses to only the first tiers on the FTGOT. Each subject's choice selections indicating misconceptions were coded as 1, and otherwise it was coded as 0. Summing the columns gave each subject's total misconception score based on only the first tier of the test, whereas summing the rows gave the sum of misconception responses given to only the first tier by all subjects. Dividing the latter by the total number of students gave the proportion of misconception responses for the first tier of each item (difficulty level of first tier).

Misconception Only Third: This score was obtained by using subjects' choice selections indicating misconceptions according to the only third tiers in the Table for the misconception selections in Appendix V and student responses to only the third tiers on the FTGOT. Each subject's choice selections indicating misconceptions were coded as 1, and otherwise they were coded as 0. Summing the columns gave each subject's misconception score based on only the third tier of the test, whereas summing the rows gave the sum of misconception responses given to only the third tier by all subjects. Dividing the latter by the total number of students gave the proportion of misconception responses for the third tier of each item (difficulty level of third tier).

Misconception First and Third: This score was obtained by using subjects' choice selections indicating misconceptions according to the first and third tiers in the Table for the misconception selections in Appendix V and student responses to the first and third tiers on the FTGOT. Each subject's choice selections indicating misconceptions were coded as 1, and otherwise they were coded as 0. Summing the columns gave each subject's misconception score based on the first and third tiers of the test, whereas summing the rows gave the sum of misconception responses given to the first and third tiers by all subjects. Dividing the latter by the total number of students gave the proportion of misconception responses for the first and third tiers of each item (difficulty level of two-tier test).

Misconception All Four: This score was obtained by using subjects' choice selections indicating misconceptions according to the all four tiers in the table for the misconception selections in Appendix V and subject responses to the all four tiers on the FTGOT. Each subject's choice selections indicating misconceptions were coded as 1, and otherwise it was coded as 0. Summing the columns gave each subject's misconception score based on the all four tiers of the test, whereas summing the rows gave the sum of

misconception responses to the all four tiers by all subjects. Dividing the latter by the total number of students gave the proportion of misconception responses for each item (difficulty level of four-tier test).

AND, OR and SUM Scores are calculated for both correct and misconception scores of students and for considering only first tiers, first and third tiers, and all four tiers separately. Table 3.9 represents these calculated scores and their abbreviations used for simplicity. The general definitions of the AND, OR, and SUM scores are as follows:

AND Score: This score was obtained by using subjects' choice selections indicating conceptual dimensions (see Appendix S) or misconceptions (see Appendix V), and subject responses to the FTGOT items. Each subject's choice selections indicating correct answer or misconception were coded as 1 if the subject chose the previously defined conceptual dimension or misconception choices in "all" of the related items, 0 otherwise.

OR Score: This score was obtained by using subjects' choice selections indicating conceptual dimensions (see Appendix S) or misconceptions (see Appendix V), and subject's responses to the FTGOT items. Each subject's choice selections indicating correct answer or misconception were coded as 1 if the subject chose the previously defined conceptual dimension or misconception choices in "at least one" of the related items, 0 otherwise.

SUM Score: This score was obtained by using subjects' choice selections indicating conceptual dimensions (see Appendix S) or misconceptions (see Appendix V), and subject responses to the FTGOT items. Each subject's choice selections indicating correct answer or misconception were coded as 1 if the subject chose the previously defined conceptual dimension or misconception choices and summing the cases for each subject choosing the previously defined conceptual dimension or misconception choices in all of the related items.

Table 3.9 Calculated AND, OR and SUM Scores for the Correct and Misconception Scores

		AND	*OR*	*SUM*
Correct Scores	*Correct Only First*	*ANDC1*	*ORC1*	*SUMC1*
	Correct First and Third	*ANDC2*	*ORC2*	*SUMC2*
	Correct All Four	*ANDC4*	*ORC4*	*SUMC4*
Misconception Scores	*Misconception Only First*	*ANDM1*	*ORM1*	*SUMM1*
	Misconception First and Third	*ANDM2*	*ORM2*	*SUMM2*
	Misconception All Four	*ANDM4*	*ORM4*	*SUMM4*

As an example, the production of the Misconception Only First AND (ANDM1), Misconception Only First OR (ORM1), and Misconception Only First SUM (SUMM1) scores are illustrated in Figure 3.1 and Figure 3.2. The illustrations show only the first and last three subjects in rows among 213 subjects, and only first three and last two misconceptions (M1, M2, M3, M20, M21) in columns. For example, the twentieth misconception (M20) was assessed by two items (Item 14 and Item 15) as shown in Figure 3.1. According to the figure, if a subject's response to the first tier of Item 14 was d, it was coded as 1, otherwise coded as 0 for this tier of the item. Similarly, if a subject's response to the first tier of Item 15 was b, it was coded as 1, otherwise coded as 0. As shown in the figure, the other misconceptions M1, M2, M3, and M21 were assessed with 7, 4, 3, and 2 items, respectively.

In Figure 3.2, an illustration of the calculations of ANDM1, ORM1 and SUMM1 scores are given. For example, in calculating ANDM1 score for M20, it was coded as "1" for a subject whose responses to the first tier of Item 14 was "d" and Item 15 was "b", otherwise it was coded as "0". ANDM1 score shows the misconception selection in all of the related items for a misconception. So, summing the columns for all 21 misconceptions gave each subject's ANDM1 score out of 21. Summing the rows gave the sum of ANDM1 scores for the corresponding misconception.

For calculating ORM1score for M20, it was coded as "1" for a subject either whose response to the first tier of Item 14 was "d" or Item 15 was "b", otherwise coded as "0". ORM1 score shows the misconception selection in at least one of the related items for a misconception. Summing the columns for all 21 misconceptions gave each subject's ORM1 score out of 21. Summing the rows gave the sum of ORM1 scores for the corresponding misconception.

For calculating SUMM1 score for M20, it was coded as "1" for a subject whose responses to the first tier of Item 14 was "d" and Item 15 was "b"; coded as "0.5" for a subject either whose response to the first tier of Item 14 was "d" or Item 15 was "b"; "0" for a subject whose response neither to the first tiers of Item 14 was "d" nor Item 15 was "b". Summing the columns for all 21 misconceptions gave each subject's SUMM1 score out of 21. Summing the rows gave the sum of SUMM1 scores for the corresponding misconception. Since not all misconceptions were assessed by an equal number of items (for instance M1 was assessed by 7 items, whereas M20 was assessed by 2 items), the scores were equated by dividing the total number of misconception choices by the total number of items measuring the corresponding misconception category.

3.4.3. Confidence Scores

First Confidence: This score was obtained by using each subject's response to only the second tier, which questioned if respondents were confident about their responses to the first tier. It was coded as 1 for students who chose either "Totally Sure" or "Sure" as a response, and 0 otherwise. Summing the columns gave students' first confidence scores.

Second Confidence: This score was obtained by using each subject's response to the only fourth tier, which questioned if respondents were confident about their responses to the third (reasoning) tier. It was coded as 1 for students who chose either "Totally Sure" or "Sure" as a response, and 0 otherwise. Summing the columns gave students' second confidence scores.

Both Confidences: This score was obtained by using each subject's response to the second and fourth tiers. It was coded as 1 for students who chose either "Totally Sure" or "Sure" as a response for both second and fourth tiers, and 0 otherwise. Summing the columns gave students' both confidences scores.

To conclude with, there are two basic types of variables-quantitative and categorical. Each uses a different type of analysis and measurement, requiring different type of measurement scales: nominal, ordinal, interval, and ratio (Fraenkel & Wallen, 2000). In terms of scale of measurement, the variables described throughout the variables section are interval scales and the variables are quantitative.

Misconception Selection Choices Indicating a Misconception According to Only First Tiers.

M1 (7 items)	M2 (4 items)	M3 (3 items)	M20 (2 items)	M21 (2 items)
1.1. a or b	1.1. c	1.1. d	14.1. d	14.1. b, c, d, or e
2.1. a	2.1. b	14.1. a	15.1. b	15.1. a
3.1. d	4.1. b	15.1. a or b		
7.1. e	13.1. a or b			
8.1. c or d				
15.1. b				
18.1. c				

Students' Raw Data for the First Tiers of the Corresponding Items

	M1							M2				M3			M20		M21	
St #	1.1	2.1	3.1	7.1	8.1	15.1	18.1	1.1	2.1	4.1	13.1	1.1	14.1	15.1	14.1	15.1	14.1	15.1
1	d	b	c	b	b	a	a	d	b	c	a	d	c	a	c	a	c	a
2	d	c	c	c	c	a	d	d	c	b	a	d	d	a	d	a	d	a
3	d	c	c	c	e	a	c	d	c	a	a	d	d	a	d	a	d	a
211	d	c	c	e	b	b	c	d	c	c	d	d	d	b	d	b	d	b
212	d	c	c	d	e	b	c	d	c	a	a	d	d	b	d	b	d	b
213	d	c	c	d	e	b	c	d	c	a	d	d	a	b	a	b	a	b

Converted Students' Raw Data to Nominal Level.

	M1							M2				M3			M20		M21	
St #	1.1	2.1	3.1	7.1	8.1	15.1	18.1	1.1	2.1	4.1	13.1	1.1	14.1	15.1	14.1	15.1	14.1	15.1
1	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	1	1
2	0	0	0	0	1	0	0	0	0	1	1	1	0	0	1	0	1	1
3	0	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	1	1
211	0	0	0	1	0	1	1	0	0	0	0	1	0	1	1	1	1	0
212	0	0	0	0	0	1	1	0	0	0	1	1	0	1	1	1	1	0
213	0	0	0	0	0	1	1	0	0	0	0	1	1	1	0	1	0	0

Figure 3.1 An Example Illustration of How Subjects' Raw Data Coded into Nominal Level by using Misconception Selection Choices

Misconception Only First AND Scores (ANDM1)

St #	M1	M2	M3		M20	M21	Total (/21)
1	0	0	0		0	1	3
2	0	0	0		0	1	3
3	0	0	0		0	1	2
211	0	0	0		1	0	2
212	0	0	0		1	0	2
213	0	0	1		0	0	1
Total	0	4	8		34	110	
%	0	2	4		16	52	

Misconception Only First OR Scores (ORM1)

St #	M1	M2	M3		M20	M21	Total (/21)
1	0	1	1		0	1	12
2	1	1	1		1	1	12
3	1	1	1		1	1	14
211	1	0	1		1	1	9
212	1	1	1		1	1	11
213	1	0	1		1	0	10
Total	166	164	164		122	198	
%	78	77	77		57	93	

Misconception Only First SUM Scores (SUMM1)

St #	M1	M2	M3		M20	M21	Total (/21)
1	0	0.5	0.3		0	1	4.5
2	0.1	0.5	0.3		0.5	1	4.9
3	0.1	0.3	0.3		0.5	1	6.4
211	0.4	0	0.7		1	0.5	4.9
212	0.3	0.3	0.7		1	0.5	5.4
213	0.3	0	1		0.5	0	4.2
Total	46	67	79		78	154	
%	22	31	37		37	73	

Figure 3.2 An Example Illustration of How ANDM1, ORM1, and SUMM1 Scores were Produced

3.5. Procedure

In this section, the procedure followed in the study is explained in detail. In this study, in order to develop a four-tier diagnostic test to assess pre-service physics teachers' misconceptions in geometrical optics, the related literature was carefully reviewed and the Interview Guide was developed based on the literature review and the researcher's own experience in the field. Interviews were conducted with 16 pre-service physics teachers in Ankara. The results from the interviews, together with the findings from the literature, were used to determine the most resourceful contexts for eliciting the misconceptions about geometrical optics and for constructing the Open-Ended Geometrical Optics Test.

The 24-item Open-Ended Geometrical Optics Test was developed and administered to 52 pre-service physics teachers from three different universities in Turkey. The responses

given to the Open-Ended Test were categorized, and the results were used to develop the alternatives on the multiple-choice TTGOT (Three-Tier Geometrical Optics Test). The TTGOT, which was in three-tier format, was administered to 53 pre-service physics teachers from three different universities in Turkey and the results were used to revise the test. Finally, the FTGOT (Four-Tier Geometrical Optics Test) was developed and administered to 243 pre-service physics teachers from 12 different universities in Turkey and the results were analyzed.

At the beginning of the study, a detailed literature review was carried out by the researcher. The key words such as physics education, misconceptions, misconception assessment, diagnostic tests, two-tier tests, three-tier tests, four-tier tests, interview-about-instances, geometrical optics were identified and searched through national and international primary and secondary sources. Dissertation Abstract International (DAI), Educational Researches Information Center (ERIC), Social Science Citation Index (SSCI), Science Direct, EbscoHost and the Internet were searched in detail. The Master and Ph.D. Theses completed at METU, the Council of Higher Education (YÖK) database for other theses beyond METU, Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, Milli Eğitim Dergisi, Eğitim ve Bilim, Çağdaş Eğitim Dergisi, Eğitim Araştırmaları Dergisi were also searched as the sources for Turkish studies.

After the literature review, the researcher prepared a misconceptions list for geometrical optics and determined the steps to be followed to develop the FTGOT. It was decided that the interviews would be the first step. The Interview Guide (see Appendix C) was designed to assess some common misconceptions mentioned in the literature, as well as to identify the contexts that had not received enough attention in the literature. Some of the items in the Interview Guide were revised from the questions in the literature, while the rest were developed by the researcher (see Appendix E). Before starting the interviews and the administrations of the tests, official permissions were obtained from the Human Subjects Ethics Committee of each university for conducting the study (see Appendix Y). The Interview Guide was given to three experts from the Department of Secondary Science and Mathematics Education at METU. These experts examined the items and the figures in terms of their conceptual accuracy, clarity for understanding, the appropriateness for the intended group's level, grammatical structure, and language. These experts also checked and made comments about the distribution of items in the different contexts (plane mirrors, spherical mirrors, and lenses) and cases (observing oneself, observing objects/others). After establishing the face and content validity and making the necessary corrections, the interviews were divided into five sessions according to their contexts and conducted with 16

pre-service physics teachers selected conveniently and purposefully in Ankara. The first session was devoted to building rapport between the interviewee and the researcher and identifying the contexts in which the interviewees had problems. The interview results revealed which would be the most useful contexts to include on the open-ended test, what and how widespread the misconceptions were, and if there were any new misconceptions that had not been mentioned in the literature. The researcher conducted one interview session each week with each participant. Hence, it took five weeks to complete all five sessions.

From the results of the interviews for determining the resourceful contexts for detecting pre-service teachers' misconceptions in geometrical optics and the literature review, the researcher developed the Open-ended Geometric Optic Test (see Appendix H). The test was given to the same three METU instructors to get their opinions and make necessary revisions in order to establish the content validity. The Open-ended Geometrical Optics Test was administered to 52 pre-service teachers in three universities in Turkey in 90 minutes. The subjects' answers to the open-ended test were analyzed in detail. Similar responses given to each item formed a category. Each category of an item included the correct conception or misconceptions, but sometimes there were some deficient or meaningless responses. The most prevalent categories that emerged were selected to guide the design of the alternatives on the multiple-choice, multiple-tier test, in addition to the literature review and interview results.

After the interviews and the open-ended testing, the three-tier multiple-choice test was designed. It includes common misconceptions in geometrical optics in its distracters. The TTGOT includes 22 items which was supposed to assess three contexts and two cases according to Appendix M and 25 different misconceptions according to Appendix N. Special attention was paid in the construction of the test for assessing each misconception and each context-case combination with two or more items. Then, the TTGOT together with the Expert Opinion Form (see Appendix O) were given to the three experts who had reviewed the interview and open-ended questions with the aim of establishing content validity. The suggestions that came from each of the experts in terms of the item-content (cases and contexts) agreement, item-misconception agreement, appropriateness of the test to the intended group, understandability of the wordings on the test items were taken into consideration and the necessary revisions were made on the TTGOT based on the feedback. Before administering the TTGOT to a large sample, the test was administered to seven fourth grade pre-service physics teachers at METU in one hour. The purpose of this pre-administration was to see if the items were clear in terms of figures and wordings, to determine if the time allocated for the test administration was appropriate, and to ask for

suggestions to make the test more understandable. The difficulties and suggestions expressed by the subjects were all noted, and the necessary modifications, such as minor typing errors or the logical ordering of the alternatives in some of the items were done. The final version of the TTGOT with 22 items was administered to 53 pre-service physics teachers from three different universities in Turkey in 60 minutes. The researcher was available during the administration of the test in two of the universities in Ankara, together with the instructors of the course. The test was sent to the third university to be administered by the instructor. The TTGOT was considered as a pilot study for the improvement of the items on the test before administering the test to the large sample in all thirteen universities. Therefore item analysis was performed to see if the alternatives on the test work properly and to determine if the false positive and false negative proportions were below the minimum acceptable value for ensuring the validity. A factor analysis could not be conducted because of the small number of the sample size for the TTGOT administration. According to the results obtained, the test items were revised and the FTGOT was developed.

The major modification made from the TTGOT to the FTGOT was the addition of a separate confidence tier for the reasoning that was used to obtain the answer. This fourth tier was in addition to the confidence tier for the main answer. Additionally, the degree of confidence was increased to four levels and the length of the alternatives on the test was shortened. Two of the items were totally removed from the test on the basis of the previous item analysis in the pilot study. Afterwards, the 20-item FTGOT with four-tiers and the Expert Opinion Form (see Appendix T) was given to eight experts from the Department of Secondary Science and Mathematics Education at METU and Gazi University for establishing the face and the content validity. According to their suggestions, some corrections on the items of the test were made. It was also given to a Turkish teacher from a high school for checking of the grammatical rules and language. Finally, the final version of the FTGOT (see Appendix R) with 20 items was developed and administered to 243 pre-service physics teachers from 12 different universities in Turkey. One of the universities in the population was removed from the study because an earthquake in the city had led to the cancellation of all classes for the semester during which the test was administered. The FTGOT was administered in 50 minutes. The data obtained were analyzed (discussed in Chapter 4) and the final version of the FTGOT was developed. Figure 3.3 summarizes the procedure followed in the study that was explained in detail in this section.

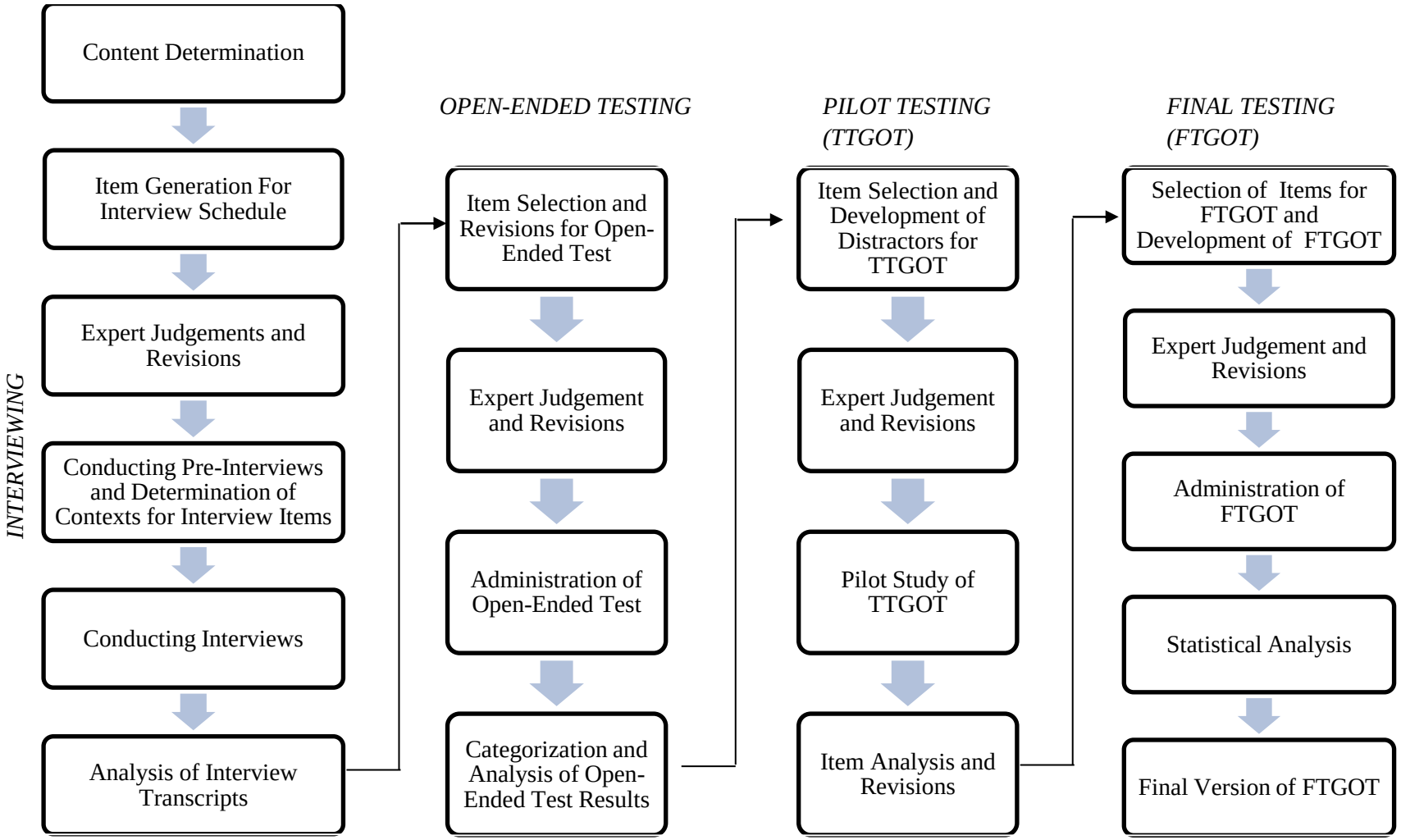


Figure 3.3 The Development Process of the FTGOT in the Present Study

3.6. Analysis of Data

Microsoft (MS) Excel, Statistical Package for Social Sciences (SPSS) program, and Item and Test Analysis Program (ITEMAN) were used for the statistical analysis of the data in this study. Firstly, the data were screened out for outliers and influential data points. Also a missing data analysis was done for the preparation of the data for further analysis. Then, the validity and reliability analysis of the test scores were continued. Finally, the item analysis for the test scores was performed.

3.6.1. Validity Analysis

Fraenkel and Wallen (2000) defined validity as "the appropriateness, meaningfulness, and usefulness of the specific inferences researchers make based on the data they collect" (p.169). Briefly, validity is all about the drawing of correct conclusions based on the data obtained from an assessment. Validation, therefore, is the process of collecting evidence to support such inferences (Crocker & Algina, 1986; Frankel & Wallen, 2000; Kane, 2006). Three major types of evidences for validity are described by Fraenkel and Wallen (2000) as:

Content-related evidence of validity: It refers to the content and the format of the instrument. The content and the format of the test must be consistent with the definition of the variable and the sample of the subjects to be measured. Therefore, content validation is partly a matter of determining if the content of the instrument is an adequate sample of the domain of content it is supposed to represents. The other aspect of the content validation is, on the other hand, the format of the instrument, i.e. clarity of printing, appropriateness of language, clarity of directions, size of type, etc.

Criterion-related evidence of validity: It refers to the relationship between scores obtained using the instrument and scores obtained using one or more other instruments or measures. The strength of the relationship between test scores and the criterion performance provides a criterion related evidence for validity.

Construct-related evidence of validity: It refers to the nature of the psychological construct or characteristic being measured by the instrument. Usually, there are three steps for obtaining construct-related evidence of validity: clear definition of the variable being measured; forming of hypotheses based on a theory underlying the variable; testing of the hypothesis both logically and empirically.

Validity of the FTGOT was established by some qualitative and quantitative techniques. First of all, the test items were examined and judged in terms of the content and format by the experts in each step of the test development (interviewing, open-ended testing, TTGOT testing, FTGOT testing) for getting content-related evidence of validity. The table of specifications prepared for the contexts and cases measured by the test, and the table for the misconceptions choices were examined by the experts for their adequacy and compatibility with the test items. Also, the format, test directions, figures and language were judged by the experts.

Secondly, the correlation between the students' scores on the first, the reasoning, and the confidence tiers were investigated separately and in combination to establish construct validity. According to Çataloğlu (2002) in a valid test, students who were able to understand the question could then judge their ability to answer that particular question correctly or incorrectly. Hence, it is expected that students with higher scores would be more confident about the correctness of their answers if they understand what they read on the test. With this aim, the correlation between the student scores from the first tiers and the second tiers, third tiers and the fourth tiers, the first & third tiers, and second & fourth tiers were estimated by using the SPSS program. The calculated Pearson correlations (r) were interpreted according to the guideline suggested by Cohen (1988, as cited in Pallant, 2005):

r = .10 to r = .29 or r = -.10 to r = -.29 Small

r = .30 to r = .49 or r = -.30 to r = -.49 Medium

r = .50 to r = 1.0 or r = -.50 to r = -1.0 Large

Thirdly, proportions of false positives, false negatives and lack of knowledge were estimated for the content-related evidences. The proportions of false negatives and false positives should be less than 10 % in order to obtain good evidence for the validity (Hestenes & Halloun, 1995). Since validity mainly deals with whether the test does or does not measure what it actually intends to measure, the proportions of lack of knowledge should also be estimated and sorted out from the students' scores in addition to the false positives and the false negatives.

Lastly, explanatory factor analysis was used for the evidences of construct validity of the test scores. The factor analysis is a statistical technique based on the correlations between test items. It is widely used in the process of constructing and validating tests. It is ideally used early in the test development process to provide empirical evidence that can be used along with theoretical criteria to guide the selection of test items that appear to measure a particular theoretical construct (Heller & Huffman, 1995). In factor analysis, the correlations between all items are analyzed in order to select groups of items (called as

factors) that all appear to measure the same idea. By examining the items that are grouped together, the researcher can determine if the test actually measures the concepts it appears to measure (Huffman & Heller, 1995). In order to conduct the factor analysis the data reduction technique in the SPSS program was used. However before conducting the factor analysis some requirements should be met. Pallant (2005) summarized these assumptions as follows:

- *Sample size:* Ideally the overall sample size should be over 150 and there should be a ratio of at least five cases for each of the variables.
- *Factorability of the correlation matrix*: For factor analysis, the correlation matrix should have at least some correlations of r = .30 or greater. The Barlett's test of sphericity, which tests whether the correlation matrix is an identity matrix or not, should be statistically significant at the specified alpha level ($p < .05$). The Kaiser-Meyer-Oklin (KMO) value, which is a measure of sampling adequacy, should exceed the recommended value of .60 supporting the factorability to the correlation matrix. A KMO value of .50 or above can also be accepted for factorability (Child, 2006; Schwab, 2002 as cited in Kutluay, 2005)
- *Linearity*: Since factor analysis is based on correlation, it is assumed that the relationship between the variables is linear. However, it is certainly not practical to check scatterplots of all variables with all other variables.
- *Outliers among cases*: Factor analysis can be sensitive to outliers; therefore, initial data screening and checking the outliers for either removing or recoding to a less extreme value is important.

In the present study, a principal component factor analysis (with varimax factor rotation for the correct scores and the misconceptions scores) was performed by using the SPSS program.

Item discrimination index, D, which is a measure of how a test item discriminates between high scorers and low scorers might also be considered as an indicator of test validity. This issue will be discussed in detail in the next sub-sections.

3.6.2. Reliability Analysis

Reliability refers to the consistency of the test scores and the extent to which the measures are free from errors. We can measure error by estimating how consistently a trait is assessed (McMillan & Schumacher, 2001; Linn, 2006). The objective in selecting or evaluating instruments is to look for evidence that error has been controlled as much as possible. Also, as Buckendahl and Plake (2006) stated "without adequate reliability

evidence, other validity evidence may not be meaningful" (p.733). There are different types of reliability estimates, but in the present study the internal consistency of the test scores were estimated by calculating the Cronbach Alpha coefficient. This coefficient is an index of both item homogeneity and item quality (Crocker & Algina, 1986). According to Fraenkel and Wallen (2000) there are some benchmarks to evaluate reliability coefficients. For many commercially available achievement tests, the reliability coefficients are typically .90 or higher; whilst for many classroom achievement tests the reliability coefficients are .70 or above. For research purposes, a rule of thumb is that reliability should be .70 or higher. However, in misconception tests, as different from the achievement tests, the reliability coefficients are lower (Eryılmaz, 2010). For researcher developed misconception tests the reliability coefficient of .60 or higher usually can be consider as good.

There are some factors that affect the reliability coefficients. These factors are: group homogeneity, time limit, test length (Crocker & Algina, 1986), number of the alternatives in an item, the subjectivity of a score, and item difficulty (Marx, 1998). Their effects on the reliability coefficient can be summarized as:

- *Group Homogeneity*: The magnitude of reliability coefficient depends on the variation among individuals on both their true scores and error scores. So, if a sample of examinees is highly homogeneous on the trait being measured, the reliability coefficient will be lower than if the sample were more heterogeneous. In short, the more diverse the group, the more reliable the test scores.
- *Time limit*: When a test has a rigid time limit such that some examinees finish the test, but others do not (i.e., speed test), the reliability coefficient may be artificially inflated because of consistencies in performance caused by the test's time limit. It is inappropriate to use methods of internal consistency for the speed tests, whereas appropriate for the power tests in which all examinees finish the test (Gregory, 1992 as cited in Marx, 1998).
- *Test length*: Longer tests are more reliable than shorter tests composed of similar items. In general, the longer the test, the closer the observed score is to the true score.
- *Number of alternatives in an item*: The optimal number of alternatives is determined by the test developer. Any extra, non-plausible distracters included in an item's alternatives may lead to ambiguity of the item, and decreases its reliability.
- *Subjectivity of a score*: The subjectivity of a score lowers the reliability. The scoring of multiple choice exams is objective, which increases reliability.

- *Item difficulty*: Maximizing the true score variance by appropriate choice of item difficulty can affect the reliability. To maximize variance, the item difficulties should be nearly equal and of medium value. However, in general the items are rather difficult in misconception tests compared to achievement tests (Peşman & Eryılmaz, 2010).

In order to increase the reliability of the test scores, the factors mentioned above were taken into consideration during this study. The sample of the study was heterogeneous, such that universities from all over Turkey were included in the study; and the subjects included all academic grade point averages and genders. There was a recommended time limit for the test's completion, but the test administers were informed to give the necessary additional time for the completion of the test, so that the test is not a speed test. The test was in multiple-choice format which reduces the score subjectivity. Student responses written into the blank alternatives were either recoded into the existing alternatives, or investigated systematically for whether they build up a new alternative or not. The number of alternatives was determined by the researcher from the frequently mentioned misconceptions in the interviews, open-ended test responses, and the literature. The alternatives that cause any ambiguity were removed from the test. The item difficulties were also considered for the test items, which will be discussed in detail in the next sub-sections. The ITEMAN program and SPSS program were used to calculate the reliability coefficient.

3.6.3. Item Analysis

According to Crocker and Algina (1986) a general goal in test construction is to obtain a test of minimum length that will yield scores with the necessary degree of reliability and validity for the intended uses. In constructing a new test or shortening an existing one, the final set of items is usually identified through a process called item analysis. The term item analysis is used to define the computation and examination of any statistical property of the subjects' responses to an individual test item. There are some calculations and indices performed for item analysis in this study by using ITEMAN and SPSS programs, and these are explained in the following sub-sections.

3.6.3.1. Descriptive Statistics

In order to interpret the data obtained in this study three types of statistics were considered in the descriptive statistics part. These are a measure of central tendency, shape of distribution, and measure of variability. For the shape of distribution, the histograms were drawn and the skewness and kurtosis values were obtained. These measures were used to determine whether the distributions of scores are normal or not. Central tendency was determined through mean, median, and mode. In order to determine how spread the scores were, standard deviation was calculated.

The most important descriptive statistic in the survey part of the study was the frequency distributions. The number of students having each misconception was calculated in frequencies and in percentages and presented through tables.

3.6.3.2. Item Difficulty

Item difficulty (p) is basically the proportion of examinees who answer an item correctly. Nearly all test score parameters are affected by item difficulty (Crocker & Algina, 1986). It is measured by an index called difficulty index, and this index indicates how hard the item is (Haladayna, 1997). For the norm-referenced score interpretation, item difficulties typically fall in the range of .60 to .80. The total test score variance is maximized when the item difficulty is .50. For the criterion referenced test developers, however, it is more reasonable to determine the average or median difficulty level for each cluster of items that measures a common objective. However, at the same time a single item that is too easy or difficult compared to others based on the same objective should be examined for technical flaws, unintentional clues, miskeying, or ambiguities in wording that may affect the difficulty regardless of subject content (Crocker & Algina, 1986).

3.6.3.3. Item Discrimination

The item discrimination is an index of how effectively the item discriminates between the examinees who are relatively high on the criterion of interest and those who are relatively low. The goal is to identify the items for which high-scoring examinees have a high probability of answering correctly and low-scoring examinees have a low probability of answering correctly (Crocker & Algina, 1986). A parameter called discrimination index (D)

can be used for dichotomously scored items. Ebel (1965 as cited in Crocker & Algina, 1986) offered a guideline for interpretation of the D-values as:

If $D \geq .40$, the item is functioning quite satisfactorily.

If $.30 \leq D \leq .39$, little or no revision is required.

If $.20 \leq D \leq .29$, the item is marginal and needs revision.

If $D \leq .19$, the item should be eliminated or completely revised.

Point Biserial Correlation (ρ_{pbis}), which indicates how closely performance on a test item scored 0 to 1 is related to performance on the total test score, is another discrimination index for items. Biserial Correlation Coefficient (ρ_{bis}), on the other hand, has an assumption that the latent variable underlying item performance is normally distributed (Crocker & Algina, 1986). Most item analysis work uses point-biserial correlation as the preferred method and it should probably be selected if one does not understand the distinction between the two types of correlation (ITEMAN, 2006, p.6). It is important to note that selection of items based on the item analysis data may be less appropriate for the criterion referenced tests than for the norm referenced tests, since the representativeness of the domain of interest may be reduced by such item selection on statistical criteria (Crocker & Algina, 1986).

3.7. Assumptions

It was assumed that the pre-service physics teachers answered the items in the instruments sincerely. Throughout the investigation, there was no indication that this assumption was not valid.

CHAPTER 4

RESULTS

In this chapter, the results of the interviews, the open-ended test, the TTGOT, and the FTGOT are given in four different sections. In the analysis of the interviews part, the misconceptions in geometrical optics as investigated with in-depth interviews are analyzed in detail. In the analysis of the open-ended test results part, the answer and reasoning categories emerged on the open-ended test and its detailed analysis are given. The analysis of the TTGOT part includes the analysis of the TTGOT test results for the improvement of the multiple-tier multiple-choice test items. In the analysis of the FTGOT part, the validity and reliability analysis of the FTGOT test scores and the descriptive survey results are given.

4.1. Analysis of the Interviews

The interview results revealed that pre-service teachers had some of the same common misconceptions about geometrical optics discussed in the literature, as well as some that had not been mentioned before. The interview results were used to identify the most resourceful contexts in geometrical optics to elicit pre-service teachers' misconceptions for the construction of open-ended test (in order to answer Research Question 1.a.).

The analysis revealed that pre-service teachers may use some key terms in the topic arbitrarily or mistakenly. When they say "image" they may only refer to the reflection of light rays from an optical instrument such as mirrors, or they may refer to anything that is seen by the eye. Additionally, their definitions of real and virtual images are often differ from one individual to another. Some participants made the distinction between real and virtual images as follows:

> "Image is anything around us that we see with our eyes. Real images do not require any optical instrument. For instance, when I directly look at this pencil, I do not need any instrument, this is a real image. However, virtual images are the ones formed by optical instruments such as mirrors." (Participants H1, G5, and M6)

> "My real images are the ones that are directly the same with me in orientation and size. In plane mirrors, the images are real since they are directly the same with the object. When I say virtual, however, the upside-down images are coming to my mind." (Participant M4)

> "For instance lenses make the object bigger or smaller, they do not show you the real images of the objects." (Participant H3)
>
> "Real images are formed at the same side of the mirror or lens with the object. Virtual images, however, are formed at the opposite side." (Participants H2 and M5)
>
> "Real images are the ones that can only be seen on a screen, without a screen those images cannot be seen. However, the virtual images do not require a screen." (Participants G2 and G4)
>
> "Virtual images are the erect; real images are the upside-down images of the objects." (Participants G2 and M3)
>
> "Real image is the one the light rays themselves converge to an image point. The virtual image, is the one in which the light rays do not converge to an image point, but the extensions of reflected or refracted rays converge to that point or appear to emanate from that point."(Participants M2 and H4)

This diversity in their conceptions of real and virtual images made the pre-service teachers' reasoning about different contexts in geometrical optics even more difficult to interpret. However, this diversity also signifies that, even after instruction, conceptions in geometrical optics may not be totally scientific, and needs to be investigated. The participants also used some other key terms, such as "field of view", arbitrarily. They used this term especially in their explanations related to the observation of images in phrases such as "field of view of the mirror", "field of view of image", "point of view of observer", "angle of view of observer" or "field of view of observer" interchangeably.

The participants also had also some other difficulties in determining the image location, image type (real or virtual), or image orientation for a particular object located at a certain position relative to an optical instrument, such as a mirror or lens. However, those difficulties seem to be highly related to the context of the problems at hand. Therefore, the aim of the first session of the interviews was to build trust between the participants and the researcher, inform the participants about the study, learn more about the participants (about their academic background, interest toward, or experience with geometrical optics), and decide the most resourceful contexts for eliciting misconceptions about the topic in order to revise the interview sessions. In the following section, findings from this first session of the interviews are presented.

4.1.1. Determination of Common Misconceptions and Identification of Resourceful Contexts for Eliciting Common Misconceptions

In the first session of the interviews, the participants were asked some general questions related to image formation and the observation process for a single plane mirror, hinged plane mirrors, spherical mirrors (concave and convex), and lenses (converging and diverging) (See Appendix C). The questions are mainly about the properties of the images formed in a certain optical instrument, the role of the observer in image formation process, the role of observer in the image observation process, the effect of a moving observer on the image formation, the effect of a moving object on image formation, the difference between observing oneself and observing other objects, and the effect of covering some parts of the optical instrument.

As a result of the analysis of the interview transcripts, the following contexts and topics were found to be fruitful for eliciting misconceptions in the rest of the study:

- Formation of a virtual image is often thought to be independent of the observer's presence, such that a virtual image is formed whether an observer sees it or not. Hence, image formation and observation are thought as separate events and that a moving observer or moving object only makes a difference in the image observation process, while, image formation is not affected by them. Therefore, the items in which either the object or the observer is moving are resourceful contexts for inclusion in the study.
- Participants often thought that image size in a plane mirror depends on mirror size, distance between the object and the mirror, and distance of the observer to the mirror. Hence, in appropriate items, these situations should be investigated.
- For the hinged plane mirrors, most of the participants thought that only the angle between the mirrors affects the number of images formed or observed in the plane mirrors, not the location of the object or the observer.
- Covering some parts of an optical instrument may or may not make a difference in image formation and in the observation of an object depending on which part of the instrument is covered. Participants stated that, when the outer parts of an instrument are covered, it does not make any difference for image formation. However, when the inner sides of a spherical mirror or lens is covered, or the parts of the plane mirrors where the object is in the front is covered, it causes the image to disappear. Extracts from the interview with one of the participants is given as an example:

Participant M3: If we cover some parts of the plane mirror, it does not affect the image formation. It is like decreasing the mirror size. Does it make any difference when a small object is in front of a 10 m^2 or 1 m^2 plane mirror? But, if the size of the object is bigger than the mirror, some part of the image is not formed.
….
Participant M3: In a hinged plane mirror… Hmm… Let's say I cover the portion where two plane mirrors intersect with 90^0 originally. They will no longer intersect with 90^0; the angle would become smaller in that case.
….
Participant M3: While covering the spherical mirror, if I am just decreasing the size of the mirror it is not a problem. But, if I am covering the mirror from the middle, it does.
Interviewer: What do you mean? Could you explain more?
Participant M3: Covering the contour of the mirror, it is just like cutting the sides. It makes the mirror smaller in size. Look at this (Participant sketched the drawing shown in Figure 4.1.a on a paper). However, if the middle of the mirror is covered like this (Participant sketched the drawing shown in Figure 4.1.b on a paper), the cardboard absorbs the light, and does not allow the light coming from the focal point to reflect. No image is formed in this case. Therefore, where you are covering a spherical mirror is important.
….
Participant M3: Similarly, if I cover the lens from its contour it does not make any difference, but covering one side does. For instance, if I cover right side of a lens, it is no more a converging lens (Participant sketched the drawing shown in Figure 4.1.c on a paper). One side behaves as if converging lens, the other side behaves as if a plane mirror. Therefore, the refraction of the light lessens and the image if formed farther from the lens.

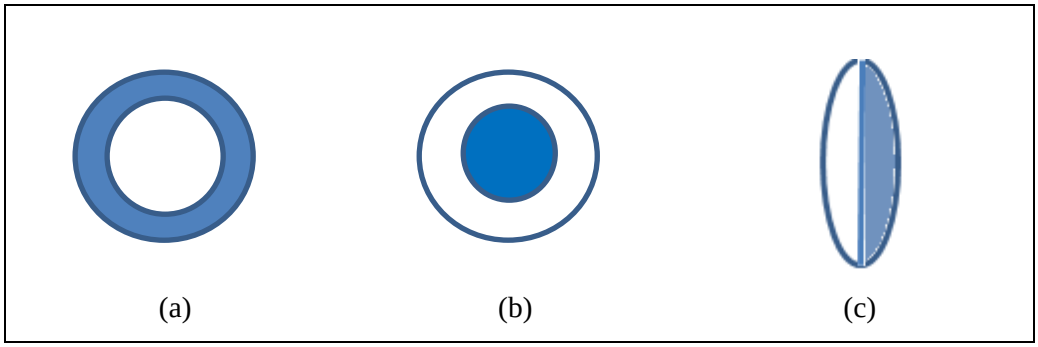
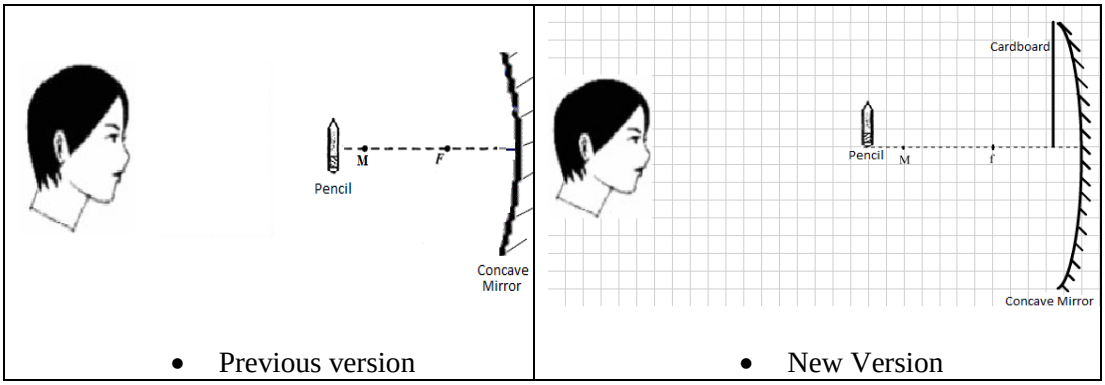


Figure 4.1 Drawings of Participant M3 for Explaining the Effect of Covering Some Parts of a Spherical Mirror (a), (b) and Converging Lens (c)

As the result of some of the student responses in the first interview session, the items related to covering some part of a concave mirror or a converging lens were revised. For example, in the first version of the related interview question (Item 28) half of the object (pencil) was not in line with the covered part of the mirror. In the revised form of the item (Item 23), however, the whole pencil is located above the principal axis, so that all parts of

the object are aligned with the covered part of the mirror. Previous and new versions of the related items were given in Figure 4.2. In the previous version, there was a sub-question related to the placement of a cardboard with multiple holes on it. This item was removed but the cardboard with a single hole in the middle was kept.



- Previous version
- New Version

Figure 4.2 An Example of a Revision in the Interview Items with Previous (a) and New Version (b) as a Result of the Analysis of the First Interview Session

- Some participants often thought that a real image can only be seen on a screen and without a screen real images cannot be observed. Other participants thought, however, that without a screen the observer should place his/her eye at the image location to see it. Moving the screen to a different location makes the image size bigger or smaller was another common belief.
- The inability to discriminate between observing oneself and observing others with an optical instrument was also pervasive among participants. Some of the participants claimed that it is possible to see oneself from a lens depending on one's position. Others claimed that it is only possible to see the virtual images of oneself if it is formed on the same side of the optical instrument as the observer.

While explaining their reasoning, participants used several of their daily life experiences with spoons, security mirrors, mirrors at the hair dresser, mirrors in the car or bus, mirrors at the shopping malls, eye-glasses, magnifying glasses, etc. Some of the interview items were already in those contexts (Item 8 is at a hair dresser, Item 26 in a bus, Item 29 in a shop). Even though a spoon was mentioned by many of the participants for explaining their conceptions about the convex and concave mirrors, this context was intentionally not used in items such as Items 24 and 25. The reason was the focal length of a

tablespoon is less than 2 cm and for an individual to look at a spoon at a distance less than the focal length is usually uncommon or even impossible.

As a result of the analysis of the first interview session, the items were revised and the final version of the interview schedule was obtained and the interviews were conducted. In the following sections the analysis of the interview results for each of the contexts (plane mirrors, spherical mirrors, and lenses) are going to be presented with considering the misconceptions detected on the topic.

4.1.2. Misconceptions Related to Plane Mirrors

In the Interview Guide, there are 17 items related to plane mirrors. Fourteen of them are in the context of single plane mirrors, while three of them in the context of hinged plane mirrors. In this section, the results of interview for plane mirrors (single plane mirrors and hinged plane mirrors) are presented together with some extracts from the interviews as examples. Analysis of the interviews in the context of plane mirrors revealed that participants had certain misconceptions. Some of those have already been discussed in the previous studies on this topic, but some of them are new. These detected common misconceptions are presented below:

i. Image formation has no relation to the observer's presence or activity and image formation is a separate event from image observation (Galili, 1996; Galili, Goldberg, & Bendall, 1991; Ronen & Eylon, 1993):

Items 1, 2, 3, and 5 in the Interview Guide (see Appendix C) include a moving observer and stationary objects in a single plane mirror context. Item 4, however, includes moving objects and a stationary observer. When the participants were asked about whether the observer's seeing the objects affects the image formation in a plane mirror or not, most of the participants claimed that image formation has no relation to the observer's presence. They thought image formation and observation as separate events. Participants usually claimed that there is an order: image is formed first and depending on the position of the observer this formed image may or may not be seen by the observer. As one of the participants remarked:

> "The images of the cats are formed in the plane mirror, but depending on the position of Hasan, he may not see those formed images." (Participant H2)

Participants with those ideas usually lacked the scientific idea that in the case of a virtual image, the image is formed only within the observer's eye and the observer constitutes an integral part of the optical system.

In the context of Item 6, however, the observer intentionally is not included. Here participants were asked about whether the image of the battery is or is not formed in the plane mirror in the presence of an opaque obstacle between the object and the mirror. Some participants thought that image of the battery would be formed from the uncovered part of the mirror no matter if an observer sees it or not.

For Items 27, 28, and 29 in the hinged plane mirror context, similar claims were presented by the participants. In this context, they thought that multiple images of an object are formed in the plane mirrors by multiple reflections, but the observer could see some or all of the images depending on his/her location. In other words, they thought that images are first formed and then observed, instead of simultaneously formed and observed.

Among all 16 participants of the present study, only one of them correctly explained the simultaneity of virtual image formation and observation, as well as the observer's eye acting as an integral part of the process. Participants' ideas about the observer's passive role in virtual image formation but the active role in virtual image observation process were found to be independent of item context. In all related items in plane mirrors, participants advocated their faulty conception.

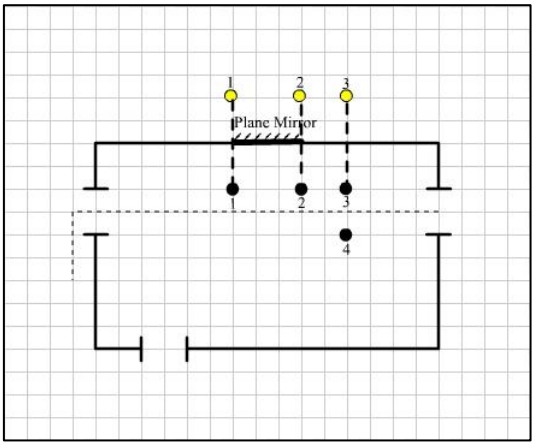
ii. Any obstacle between an object and a plane mirror hinders the image formation and/or observation process.

For Items 1, 2, 3, 6, and 13 with obstacles or some other objects between the object and the plane mirror, participants claimed that the image of the object is not formed or observed in the plane mirror. As an illustration an excerpt of a participant's response is provided below:

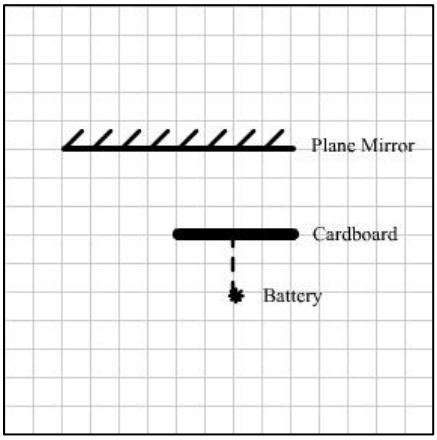
> "(Referring to the figures in Items 1, 2, and 3) The image of Cat 4 is not formed in the plane mirror since Cat 3 acts as an obstacle between Cat 4 and the plane mirror. For this reason only the images of Cat 1, 2 and 3 are formed." (Participant G2)

Similarly, in Item 6 participants who hold this faulty idea claimed that no image of the battery would be formed in the mirror because of the cardboard. There are two types of reasoning related to it: the parallel rays from the battery would not reach to the mirror due to the cardboard or the image of the cardboard hinders the image of the battery. In Item 13, participants proposed that the observer looking at her face in a plane mirror would only see

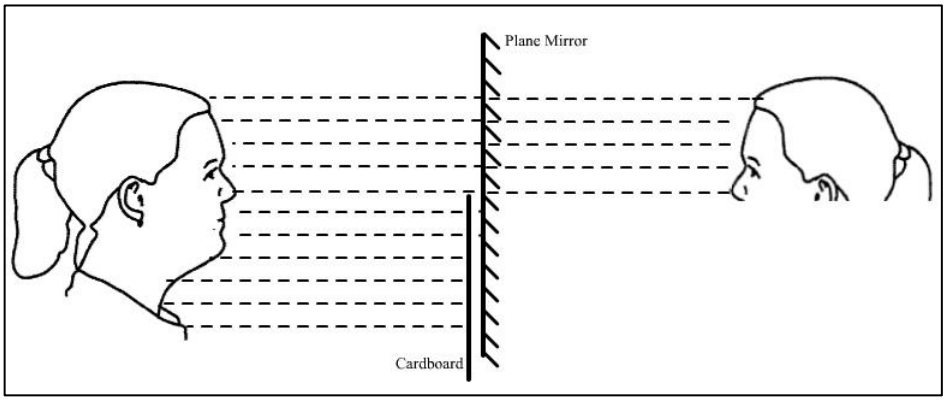
the portion of her face which corresponds to the uncovered part of the plane mirror. Their reasoning with the presence of an obstacle for those items usually came along with some common type of ray diagrams. Participants who used this reasoning usually drew perpendicular rays from each object point to the mirror surface. If the drawn rays would meet the mirror surface, the image of that object point was thought to be formed or seen. Figure 4.3 illustrates the common ray diagrams used by the participants related to the misconception.



(a) Item 1



(b) Item 6



(c) Item 13

Figure 4.3 Drawings by Participants Who Claimed that Any Obstacle between an Object and a Plane Mirror Hinders the Image Formation and/or Observation Process

iii. An image of an object lying outside the borders of a mirror is not formed and/or observed.

In explaining their reasoning with image formation and observation in plane mirrors, some of the participants claimed that the object should be in line with the mirror for the image of it to be formed or seen. Participants arguing this idea stated that:

> "(Referring to the figures in Items 1, 2, and 3) Only the images of Cats 1 and 2 are formed/seen in the plane mirror, because only those cats are within the borders of the mirror." (Participant H1)

> "(Referring to the figure in Item 4) The images of Cat 1 and 2 are formed when the cats are in line with the mirror borders. Therefore, the observer can see both of the cats at the same time." (Participant H2)

In Item 5, participants were asked to assign the place where the climbing girl would see her whole body along her way for the first time. Participants falling in the present category claimed that the whole body of the girl should be in line with the borders of the mirror for her to see her whole body. Similar reasoning was held for Items 8, 9, 10, 11 or 12. The perpendicular rays were used in order to explain their reasoning like in the previous misconception category. Those participants usually thought that the image size equals to the mirror size when the plane mirror is smaller in size than the object. The present and the previous misconception category have something in common. One of the participant excerpt given below supports this:

> "(Referring to the figure in Item 13) Covering some part of a mirror is like decreasing the mirror size, so I could not see bottom part of my face from this small mirror." (Participant M5)

iv. Moving closer to/farther from a plane mirror affects the extent of the image seen in the plane mirror (Goldberg & McDermott, 1986).

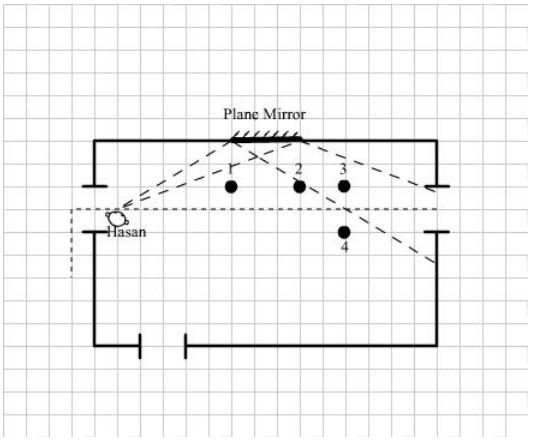
In Items 9, 10, 12, and 13, the participants were asked about the ways to see more of their body in the plane mirror. Many of the participants said that they would see more of themselves by moving back. Those participants believed that when they move farther away from the plane mirror, the image size becomes smaller and more of their body parts fit into the mirror. Some other students, however, thought that they would see more of themselves by moving toward the mirror. According to them, by moving closer to the plane mirror, their field of view would increase and they would see more of their body. These participants did not realize that the size or the orientation of the mirror on the wall, not distance from it determines how much of themselves they can see.

In Item 11, however, the participants were asked about the ways in which they see more of another person's body who is standing next to them. In this case, moving toward the mirror would enabled the person to see more of his twin's body. However, moving away from the mirror, as some of the participants claimed, would not enable him to see more of his twin's body.

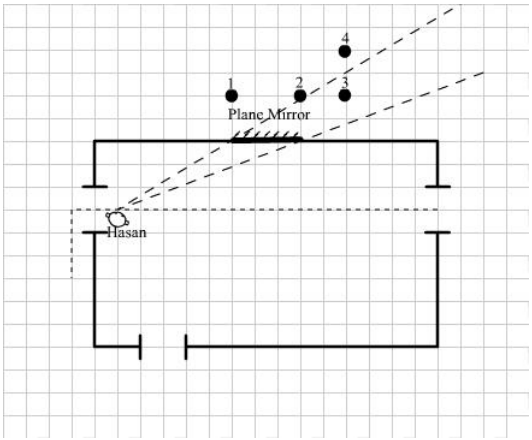
v. The closeness of an object to the observer determines the seeing order in plane mirrors.

Most of the participants' answers were correct for Items 1, 2, 3, 4, and 5 in terms of stating the order of seeing objects in a plane, but the ray diagrams they used to explain their reasoning differed a lot. To illustrate the difference, Figure 4.4 can be examined. In the figure, different ray diagrams drawn by the participants were shown. These diagrams were drawn by the participants to explain their reasoning for the order of seeing the objects in Item 1, but similar drawings were also used in the other items as well. Participants who used the drawings that are shown managed to state the order correctly (Cats 3, 2, 4, 1). However the drawings gave some clues that the participants may or may not have understood the seeing process scientifically. In drawing (a) the observer has an active role, whereas the cats have passive roles. Two rays are drawn from the observer's eye to the edges of the mirror and reflect. The cats present in the space between these two reflected rays would be seen by the observer. Although this drawing helped the participants to order the cats correctly, it does not include the simultaneous image formation and observation process. The rays directed from the observer's eye to the mirror edges may be due to the participants' mistaken belief that light originates from the eye. In drawing (b), the observer's eye has also an active role. However, in that drawing the reflection of the light rays is neglected. The rays drawn from the observer's eye to the mirror edges are extended to the back of the mirror and the images of cats located between these two extended rays were thought to be seen. Similarly, in the third drawing (c) the reflection of light rays is not represented in the drawing. In that case, the light rays originate from the image of the observer to the edges of the mirror. The rays are extended front of the mirror and the cats located in the region between these two rays were thought to be visible. In the drawings (d) and (e), the objects (i.e., cats) have an active role while the observer has a passive one. In the drawing (d), the images of the objects are already formed in the absence of the observer. In the drawing (e), however, the observer's seeing and the formation of the image were not mentioned simultaneously. The last drawing

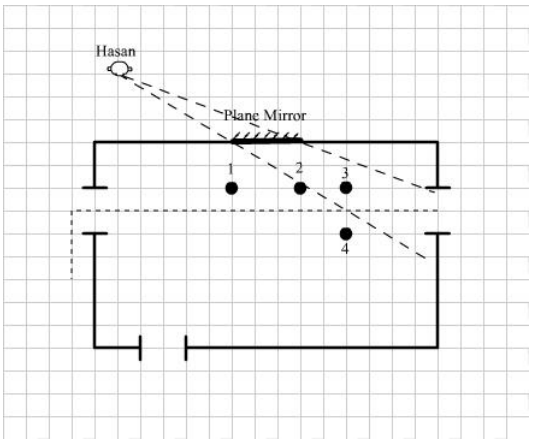
(f) in which the image formation and observation for one of the objects is depicted correctly was drawn by only a limited number of participants.



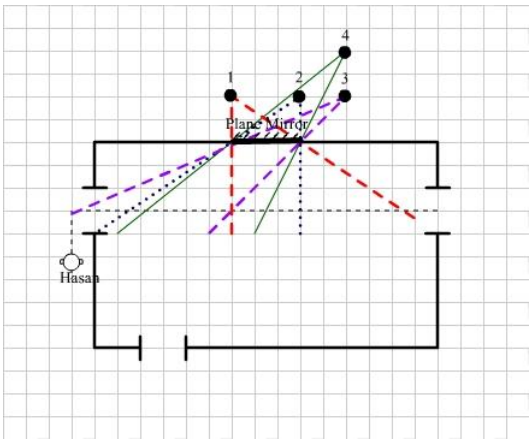
(a) Active real observer-Passive real object



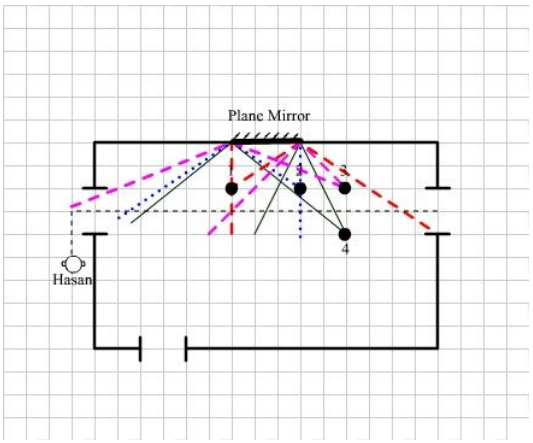
(b) Active real observer-Passive image object



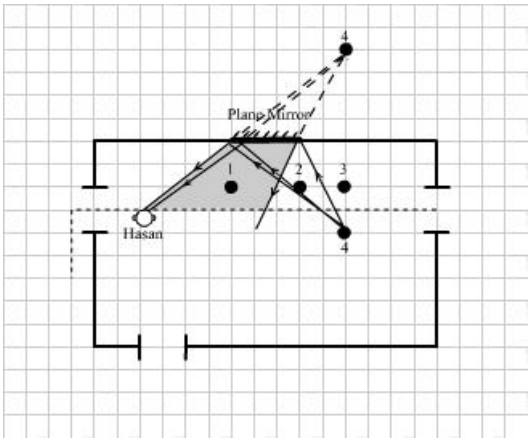
(c) Active image observer-Passive real Object



(d) Active image object–Passive real Observer



(e) Active real object- Passive real observer



(f) Active real object –Active real observer & Flux of light

Figure 4.4 Variation in Participants' Drawings for Item 1

Some of the participants, however, presumed that an object that is close to the observer can be seen earlier compared to the other objects. With this reasoning they claimed the seeing order to be Cats 1, 2, 3 and 4 for Item 1. In Item 3, the observer moves along an axis which is perpendicular to the mirror surface and beyond the mirror edges. For this reason, that item produces more varied answers and reasoning.

vi. Only the angle between the mirrors determines the number of images formed/seen in hinged plane mirrors (Kulkarni, 1960).

Many participants believed that the number of images formed/seen in hinged plane mirrors depends only on the angle between the mirrors. They thought the number being independent of the position of the object or the position of the observer. In fact, that is only true for the angles which are submultiples of 180^0. Kulkarni (1960) and Iona (1982) discussed the physics about it in their articles. The participants of the present study were interviewed with three items (Items 27, 28 and 29) in order to investigate their answers and related reasoning. Most of the participants held that misconception. They did not consider the simultaneity of the formation and observation of virtual images by multiple reflections.

In Item 28, the participants were provided with hinged plane mirrors with a 105^0 angle. In addition to the above mentioned difficulty related to the position of object and observer, some other interesting answers were given. Many participants claimed that, for angles other than 90^0, 60^0, 45^0, etc. (which do not result in a whole number from the equation $(360^0 / \alpha) - 1$) in addition to the full images, some other partial images would be formed and seen. Some of the other participants, however, claimed that it is not possible to see partial images, so the number obtained from the equation should be rounded to the whole number. Two student statements related to this mistaken idea are provided below:

> "Hmm…From the equation, I obtained 2.46 which is not a whole number. I think it is not possible to see a partial image in the mirrors. Therefore the boy would probably see only 2 images of the ball in the mirrors." (Participant G3)

> "I used the equation $(360^0 / \alpha)$ -1 and it results about 2.46. So, the boy would see a half image of the ball in addition to two complete images of it. No matter where the object or the observer is located as long as between the two mirrors, the number would not change." (Participant H1)

One of the participants said that for angles other than 90^0, 60^0, 45^0, etc., no images would be formed. Participants who used the ray tracing method instead of the equation,

however, came out with a different answer. Figure 4.5 shows a drawing of a participant who claimed that four images of the ball would be formed and seen in the plane mirrors.

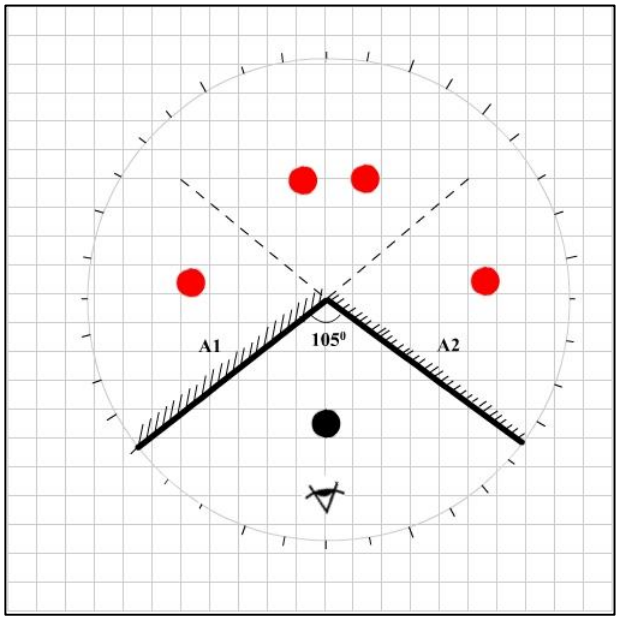
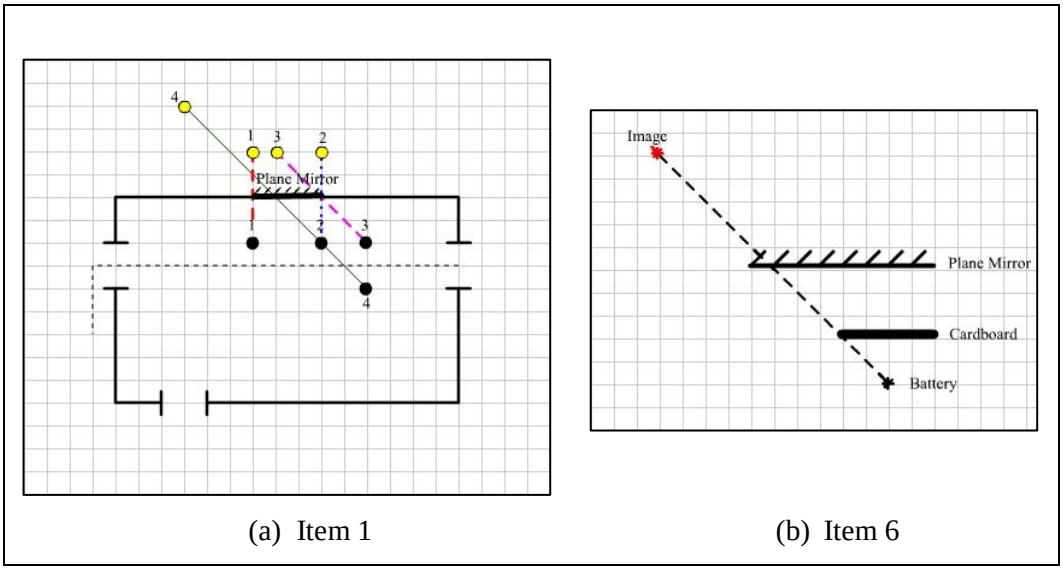


Figure 4.5 A Sample Drawing of a Participant for Item 28

During the interviews, some other misconceptions were also detected. However, those misconceptions were not considered to be very common among the participants. For instance, few participants located the image of an object on the plane mirror surface (especially in the back silvered part) or along the incoming light ray. A participant who thought the image is located along the incoming light ray used the drawings shown in Figure 4.6 for answering Items 1 and 6. In Item 8, few participants stated that if the barber moved to the right, the location of the image of the boy would shift to the left. In Item 14, two of the participants claimed that when the mirror is broken into nine pieces and placed on the wall as shown in the figure, they would see nine images of the boy in each of the mirror pieces. In Items 27, 28, and 29, one of the participants stated that only the number of mirrors determines the number of images formed in hinged plane mirrors.



(a) Item 1 (b) Item 6

Figure 4.6 A Participant's Drawings for Locating an Image along Incoming Light Ray

Another interesting, but not common, misconception is that any small part of a mirror is enough to form / see the image of an object. This is true only when light from the object could reach to the mirror. This misconception was expressed by one of the participants in the context of Item 6. The following excerpt from the interview is illustrative.

> Interviewer: (Referring to the figure in Item 6) Do you think the image of that battery would be formed in the plane mirror?
> Participant M5: Yes, it would. Suppose the part of the mirror behind the cardboard does not exist. The image of the battery would still be formed.
> Interviewer: Let's think the cardboard was one unit square longer. Would it affect the image formation?
> Participant M5: No I don't think so. Still image would be formed. Only a small part of a mirror is enough for the image to be formed.
> Interviewer: What about when the length of cardboard is equal to the length of the mirror?
> Participant M5: Hmm… No change, the image would be formed… There is some distance between the cardboard and the mirror, isn't there?
> Interviewer: Yes.
> Participant M5: Yes, the image would be formed…But...Hmm...It seems stupid what I said, but…I changed my mind. The image is not formed.
> Interviewer: Why? What is your reasoning for it?
> Participant M5: The image of the cardboard would block the image of the battery, and nobody would see the image of the battery. If nobody can see the image of the battery, we cannot say the image of the battery exists.

Light rays moves in straight lines. If the cardboard were one unit longer as the interviewer suggested during the interview, it would not be possible for the rays to reach the mirror and reflect to any of the observers. Hence, no image would be formed in that situation. However,

as the participant stated, some may believe that only a small part of a mirror is enough to form an image.

In the Interview Guide, there were many items that were intended to elicit the participants' ideas about similar concepts. However, including all of them in the open-ended and multiple-tier tests is not possible in terms of feasibility (considering time constraints, length of the test, etc.). Therefore, a critical analysis was done by the researcher to determine which items would be included in the paper-and-pencil tests and which ones would not be. Some of the less resourceful items to elicit misconceptions were not included in the open-ended test (Items 7, 8, and 14). Some other items (Items 2, 9, 12, and 13), however, were found to be answered in the same way as some other items in the instrument. Therefore, those items were not included in the open-ended test in order to shorten the length of the test.

4.1.3. Misconceptions Related to Spherical Mirrors and Lenses

In the Interview Guide, there are 12 items related to spherical mirrors (6 of them in the context of concave spherical mirrors and 6 of them in the context of convex spherical mirrors) and 6 items related to lenses (4 of them in the context of converging lens and 2 of them in the context of diverging lens). Analysis of the interviews revealed that participants have certain misconceptions about spherical mirrors and lenses, and those misconceptions share some similarities. For this reason, the misconceptions identified for these two contexts are given together in Section 4.1.3. Some of the common misconceptions are presented below:

i. (All) Special rays are necessary to form/see an image (Goldberg & McDermott, 1986).

A great many of the participants seemed to believe that the special rays are necessary to form an image in spherical mirrors or lenses. In fact, the special rays (at least two of them) are sufficient but not necessary in order to locate the position of the image. Since the special rays are convenient because of their simple rules for tracing the path of light rays; they are usually used in geometrical optics. It is apparent that the instruction itself may be a possible source of the misconception mentioned in this category. In Items 15 to 20, participants were asked about image formation and observation in spherical mirrors. Participants, who believed that the special rays are necessary, answered those items by stating that if the special rays from the object to the mirror surface would reach that surface, the image of that

object would be formed or seen in the mirror. If not, no image would be formed. Participants who used this reasoning mostly used two of the special rays: the ray parallel to the principal axis and the ray from the focal point. The following excerpt shows a typical answer given by the participants for Item 15.

> "The parallel rays drawn from Cats 3 and 4 would not reach to the surface of the mirror. The other ray (referring to the special ray passing from the focal point and reflecting parallel to the principal axis) is not enough to form the image. There should be at least two rays intersecting at a point. Therefore only the images of Cat 1 and Cat 2 would be formed and seen." (Participant G5)

In Items 21, 22, 23, 30, and 31E, in which some part of the spherical mirror or lens is covered with an opaque cardboard, the same misconception with special rays was activated. Some of the participants thought that if one or more of the special rays are blocked because of the cardboard, the image of the object would not be formed or seen at all or only partially. In Item 30, participants were asked with a set of questions about image formation in a lens when different parts of the lens are covered with a cardboard. Participants who thought that special rays are necessary could not understand that any portion of the lens would be sufficient to form a complete image and that covering some part of the lens only results in a dimmer image. Yet, their answers changed depending on which portion of the lens is blocked or on the size of the object. Figure 4.7 illustrates a typical answer given by Participant M3 to the related questions. Answers of the other participants were very similar to that one.

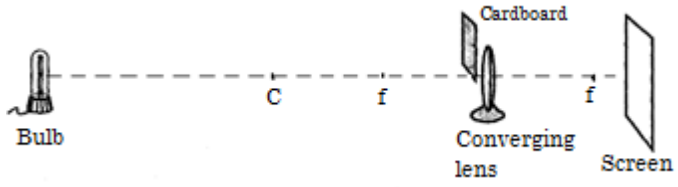
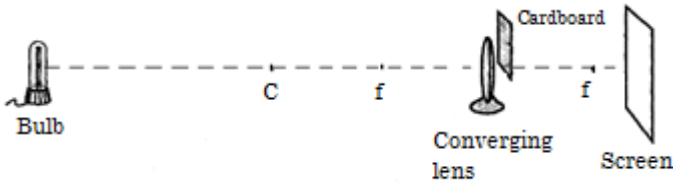
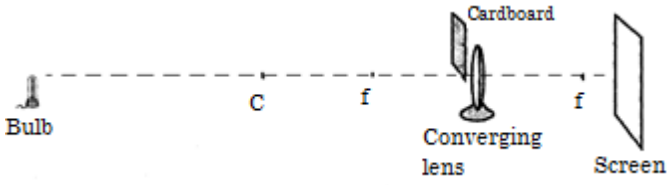
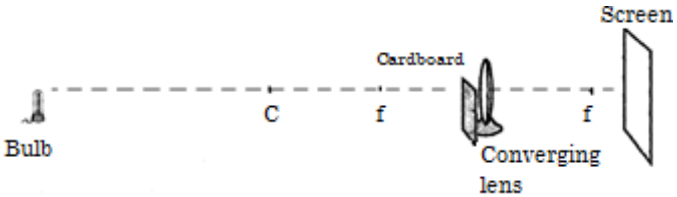
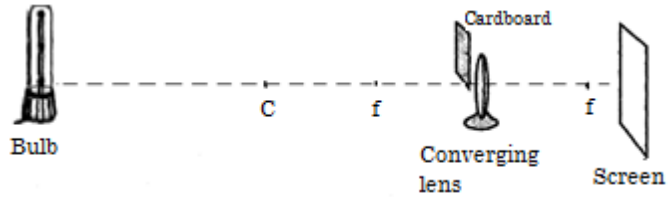
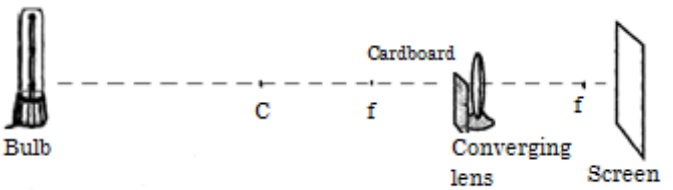
Question	Typical Answer
 (a)	• Only image of the lower part of the lamp would be formed on the screen.
 (b)	• Only image of the lower part of the lamp would be formed on the screen.
 (c)	• Image of the whole lamp would be formed on the screen.
 (d)	• No image of the lamp would be formed on the screen.
 (e)	• Only image of the bottom part of the lamp would be formed.
 (f)	• Only image of the middle part of the lamp would be formed.

Figure 4.7 A Typical Participant Answer to Item 30

ii. No image is formed / seen of an object at the focal point in a convex mirror / diverging lens.

Many of the participants failed to answer the questions related to convex mirror or diverging lens because of their faulty transfers from the concave mirror and converging lens. As a striking example, participants' thought about an object located at the focal point can be given. Some of participants claimed that no image of an object would be formed or seen which is located at the focal point. In fact, when the object is located at the focal point of a convex mirror or a diverging lens, a virtual image of the object would be formed between the focal point and the mirror or the lens. Some other participants claimed that the image of the objects in front of a convex mirror or diverging lens would be formed in the same regions as their counterparts in concave mirror or converging lens, but on the other side of the mirror or the lens. One of the student explanations below exemplifies this idea:

> "(Referring to the figure in Item 25) In a convex mirror, the image is always formed on the other side of the mirror. When Selin is standing beyond the center length; her image would be formed between the focal point and the center of the convex mirror on the other side. When she is at the center; her image would be at the center on the other side of the mirror. When she is between the focal point and the center; then her image would be beyond the center length on the other side. At the focal point, her image would be at the infinity and she would not see her image."(Participant H1)

That participant had fragmented knowledge about the convex mirrors such that she knows that an object's image in a convex mirror would be formed on the other side of the mirror. However, that participant transferred her knowledge about image positions in a concave mirror to the convex mirror context in a faulty way. In fact, in a convex mirror regardless of where the object is located, the image would be formed on the other side of the mirror and between the focal point and the mirror itself.

iii. Real images can only be formed / seen on a screen.

In the items related to concave mirrors and converging lens, some of the participants stated that the real images would only be formed or seen on a screen. Unfortunately, those participants could not conceive of a real image as existing in space, independent of a surface as an aerial image. In fact, the function of a screen is to reflect the light rays to the observer's eye so that the image may be seen from different places. In the absence of the screen, however, the observer's eye should be placed in a proper position such that the light rays diverging from the real image point can enter the eye. In the present study, however,

participants may or may not activate that misconception depending on the context of the question. Their experience with similar situations mentioned in the items may affect their answers and reasoning. Those students, who recognized that the screen was not necessary, may have a difficulty to determine where the observer should be placed to see the image. Most of them suggested placing the observer's eye to the point where the real image would be formed.

iv. An observer can see himself/herself outside of the region enclosed by the normal lines to the mirror borders.

In the concave and convex mirror contexts, some of the participants thought it to be possible to see one's eye outside of the region enclosed by the normal lines to the mirror borders. In fact, for an observer to see his/her own eye from a mirror, the light rays from the eye must reflect back to the eye. So, it is only possible when the eye is along the normal line to the mirror surface. Because, only when the eye is along the normal line, can the light rays reflect back to the eye (assuming the size of the eyes and the distance between the eyes are small). The normal line at any point on a spherical mirror can be obtained by connecting that point with the center of the mirror with a straight line. Items 19 and 20 asked to the participants for the position on the rope where the girl first sees her eye on the concave and convex mirrors, respectively. Figure 4.8 illustrates those positions for the concave and convex mirrors for the girl to see her eye.

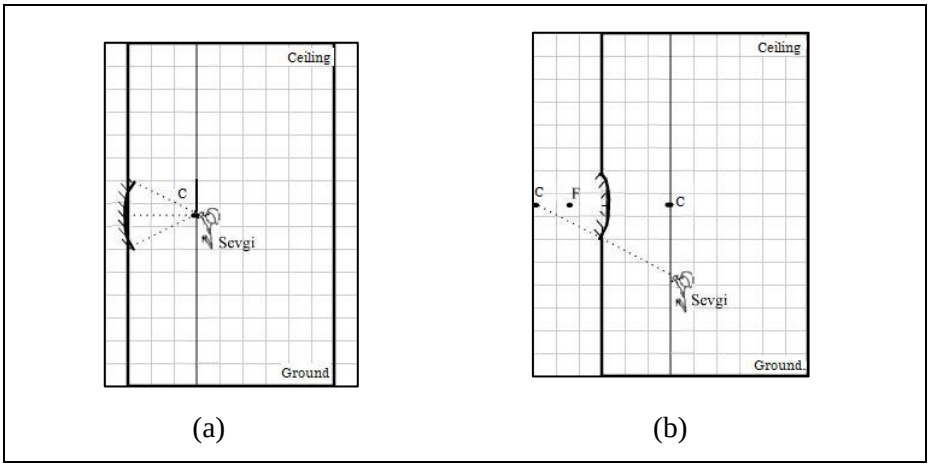


Figure 4.8 Positions Where the Girl First Sees Her Eye from the Concave (a) and Convex (b) Mirrors

Some of the participants, however, claimed that the girl would see her eye out of the region enclosed by the normal lines to the mirror borders. One of the participant's statement was:

> "The rope that she climbs passes through the center of the mirror. So anywhere along the rope she would see her eye from the mirror." (Participant G5)

Some others who thought the special rays are necessary to form or see an image claimed also that she would see her eye from some other positions. They thought that when her eyes along the first possible line drawn from the eye to the concave mirror that is passing from the focal point (Figure 4.9.a and b) or when her eye is along the bottom border of the mirror (Figure 4.9.c), she would see her eye.

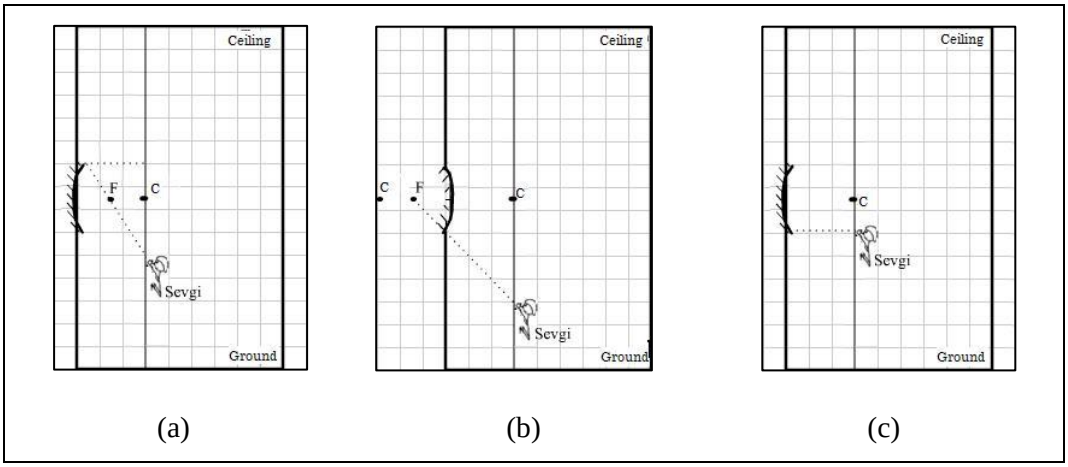


Figure 4.9 Participants' Drawings Showing an Observer can See herself out of the Region Enclosed by the Normal Lines to the Mirror Borders

v. A real image can be seen with a different size / orientation if a screen is placed at a different location than the image point (Goldberg & McDermott, 1986).

Some participants believed that when the screen is moved back along the principal axis from the real image position, the size or orientation of the image would change. Those participants did not have an understanding that unless the screen is placed at a particular image position, no image would be seen on the screen. Because for other positions of the screen, the image becomes blurred and disappears altogether. Most of the participants, who thought the image size would change, claimed that the image gets bigger. According to their reasoning, when the screen moved back the light rays diverging from the image point produces a bigger image on the screen. Some others claimed that the orientation of the image

would also change (i.e. become erect), since the rays diverging from the image point would invert. Participant M3 claimed that "the image on the screen would be bigger, erect and virtual, because beyond the image point the light rays diverges and do not intersect at a point anymore". Those reasoning of the participants were very similar to the reasoning mentioned in the study of Goldberg and McDermott (1986). A small number of participants who claimed that the image gets smaller, however, used a proportional reasoning which is different from the justifications mentioned in the previous studies. According to the participants in the present study, the converging lens which produces an image in smaller size would produce a much smaller image when the screen is moved back. That is, the farther away the screen is the smaller the image would be on the screen. The failure of the participants to recognize that there is a single position for an image to be seen on a screen would result this misconception.

There are also some other misconceptions detected from the interview with the participants. Those are listed and briefly explained below.

vi. Only the images formed on the same side as an observer can be seen.

Those participants who have this misconception believed that an observer can only see the images formed on the same side with the observer (i.e. for the spherical mirrors only real images, and for the lenses only virtual images of an object would be seen). Mostly for Items 24, 25, 32, 33, 34, and 35 this reasoning used by some of the participants.

vii. Unlike real images, virtual images cannot be seen in spherical mirrors / lenses.

As discussed before, some of the participants have difficulty in conceptualizing the real and virtual images. Those who thought virtual images cannot be seen, but only real images can, are included in this category. Depending on the context of the item, those participants were found to activate their faulty conception.

viii. Someone can directly see oneself from a lens.

In a lens the light rays from an object refracts and passes to the other side of the lens. Therefore, there is no way for someone directly to see oneself from a lens (ignoring the reflections), because the light rays cannot reach back to the observer's eye. In Items 32 and 33, participants were asked about the properties of their own image they would see from the

lens. Some of the participants of the present study claimed that someone would see oneself in different positions depending on the distance from the lens.

In general, participants' knowledge in spherical mirrors and lenses was fragmented in nature. They had certain pieces of knowledge which mainly comes from their formal instruction, but in the present study participants were unable to relate this knowledge to simple and different contexts. During the interviews, it was realized that participants' experience with spherical mirrors and lenses, both in and out of school, was less compared to the plane mirrors. Therefore, their answers mostly depending on their formal instruction. Also, it was realized that their answers and reasoning much more dependent on the context of the question asked compared to the plane mirror.

As a result of the analysis of the interviews, some of the items in the interview guide were found to be less resourceful in terms of eliciting participants' misconceptions in geometrical optics than the others. For some cases and context, there were more than needed items. Hence, considering the content validity and the feasibility of the test, some of the items (Items 17, 18, 21, 22, 26, 30, 35) were decided to be removed from the open-ended form.

4.2. Analysis of the Open-Ended Geometrical Optics Test Results

The Open-Ended Geometrical Optics Test (see Appendix H) was administered to the aforementioned sample of 52 pre-service physics teachers from three state universities. The main purpose of administering the open-ended test was to identify the misconceptions to construct the alternatives of the multiple-tier multiple-choice test from the answers and reasoning given by the pre-service teachers. For this reason in this section pre-service teachers' answers to the open-ended test were categorized and analyzed for constructing the alternatives on the test (in order to answer Research Question 1.b.).

4.2.1. Reasoning Categories on the Open-Ended Test

Subjects' responses to the items on the Open-Ended Geometrical Optics Test were grouped together according to their answer types in the first tiers and their reasoning in the second tiers (see Appendix K). The subjects' responses and reasoning for the items on the test were carefully investigated and each subject's response was assigned to an appropriate category. In determining the categories, the meaningfully similar responses given by the subjects to an item were identified, and the frequency of answers for each category was

counted by careful analysis of subjects' responses. In assigning subjects' responses to a category, in addition to their written answers to the corresponding item, their diagrammatic drawings to explain their responses were also taken into account. Table 4.1 shows the categories that emerged from the subjects' responses and their frequencies for each item on the open-ended test. The categories which show the correct answer for the corresponding item were shown as bold and with an asterisk (*) in the table. The total frequency for each item may not result the sample size (i.e., 52), since some of the subjects gave no answer to the items or used more than one type of reasoning for their explanations.

Table 4.1 Categories of the Subjects' Responses for Each Item on the Open-Ended Test

Item No	**Category No**	**Reasoning Category Description**	**Frequency**
Item 1A	1	Images of all cats are formed in the plane mirror whether Hasan sees them or not as he walks on the path.	13
	2	Images of cats that have no obstacles between them and the plane mirror are formed.	7
	3	**Image formation and observation of the cats occur simultaneously, so images of all cats are formed as Hasan walks and sees the cats. ***	6
	4	Images of cats just within the front borders of the plane mirror are formed.	5
	5	Images of cats are formed behind the plane mirror along any incoming ray from the cat to the mirror.	4
	6	Images of cats are formed in front of the plane mirror.	4
	7	Deficient or not meaningful.	9
Item 1B	1	**Drawing the regions for each cat to be seen by ray tracing method, the order of rays intersecting Hasan's walking path determines the seeing order.***	20
	2	Closeness of the images of the cats to Hasan/mirror determines the seeing order of the images in the plane mirror.	7
	3	Closeness of Hasan to the cats determines the seeing order of the images in the plane mirror.	4
	4	Images of cats that have no obstacles between them and the plane mirror can be seen.	2
	5	Images of cats just within the front borders of the plane mirror can be seen.	2
	6	Images of cats that are lying behind Hasan as he walks on the path cannot be seen.	1
	7	Deficient or not meaningful.	19

Table 4.1 Categories of the Subjects' Responses for Each Item on the Open-Ended Test (Cont'd)

Item 2A	1	Images of all cats are formed in the plane mirror whether Hasan sees them or not as he walks on the path.	11
	2	**Image formation and observation of the cats occur simultaneously, so images of all cats are formed as Hasan walks and sees the cats. ***	6
	3	Images of cats that have no obstacles between them and the plane mirror are formed.	4
	4	Images of cats are formed in front of the plane mirror.	3
	5	Images of cats just within the front borders of the plane mirror are formed.	2
	6	Images of cats are formed behind the plane mirror along the incoming light from the cat to the mirror.	2
	7	Deficient or not meaningful.	19
Item 2B	1	Drawing the regions for each cat to be seen by ray tracing method, the order of rays intersecting Hasan's walking path determines the seeing order.	9
	2	**Drawing the regions for each cat to be seen by ray tracing method, when Hasan enters this region he can see the corresponding cat at the same instant the image of the cat is formed.***	8
	3	Closeness of Hasan to the cats determines the seeing order of the images in the plane mirror.	6
	4	Images of cats that have no obstacles between them and the plane mirror can be seen.	5
	5	Closeness of the images of the cats to Hasan determines the seeing order of the images in the plane mirror.	2
	6	Images of cats just within the front borders of the plane mirror can be seen.	2
	7	Deficient or not meaningful.	17
Item 3A	1	**Image formation and observation of the cats occur simultaneously, so images of both cats are formed as they enter Hasan's field of vision. ***	18
	2	Images of both cats are formed in the plane mirror whether Hasan sees them or not.	12
	3	Images of cats just within the front borders of the plane mirror can be formed.	6
	4	Deficient or not meaningful.	14
Item 3B	1	**Drawing the field of vision for Hasan, the order of the cats entering the field of vision determines the seeing order.***	26
	2	Closeness of the cats to Hasan determines the seeing order of the images in the plane mirror.	8
	3	Images of cats just within the front borders of the plane mirror can be formed and it takes the same time for the cats to be within the borders of the mirror.	2
	4	Deficient or not meaningful.	8

Table 4.1 Categories of the Subjects' Responses for Each Item on the Open-Ended Test (Cont'd)

Item 4A	1	**Image formation and observation of the bulbs occur simultaneously, so images of all bulbs are formed as Sevgi climbs and sees the bulbs ***	12
	2	Images of all bulbs are formed in the plane mirror whether Sevgi sees them or not.	4
	3	Images of bulbs just within the front borders of the plane mirror can be formed.	4
	4	Images of bulbs are formed behind the plane mirror along the incoming light from the bulb to the mirror.	2
	5	Images of bulbs are formed in front of the plane mirror.	2
	6	Deficient or not meaningful.	20
Item 4B	1	**Drawing the regions for each bulb to be seen by ray tracing method, the order of rays intersecting Sevgi's climbing path determines the seeing order.***	23
	2	Closeness of the images of the bulbs/ object bulbs to Sevgi determines the seeing order of the images in the plane mirror.	12
	3	Deficient or not meaningful.	13
Item 5	1	In order to see her whole body, eyes of Sevgi should be aligned with the bottom of the mirror.	16
	2	**In order to see her whole body, rays from every point of her body should reflect from the mirror and reach to her eyes.***	14
	3	In order to see her whole body, her whole body should be totally in front of the mirror.	9
	4	In order to see her whole body, eyes of Sevgi should be aligned with the top of the mirror.	2
	5	Plane mirrors can be thought as to be in infinite length, so she can see her whole body anywhere.	1
	6	Deficient or not meaningful.	5
Item 6	1	Because of the opaque cardboard between the battery and the mirror (no perpendicular ray can reach to the mirror), image of the battery is not formed.	13
	2	A small portion of the mirror is enough for image formation. / Any single ray from the battery reaching to the mirror is enough for image formation.	7
	3	The image of the battery is formed from a small portion of the mirror, but an observer can or cannot see it depending on his/her position.	5
	4	**Image formation and observation occur simultaneously, so the image of the battery is formed as the rays from the battery reflected from the mirror and reach to an observer's eye. ***	4
	5	Image of the battery is not formed because image of the cardboard in the mirror obstacles the formation of the image of the battery.	3

Table 4.1 Categories of the Subjects' Responses for Each Item on the Open-Ended Test (Cont'd)

	6	The image of the battery is not formed because only a single (limited number of) ray can reach to the mirror.	1
	7	Some parts of the image of the battery are formed, since some rays can reach to the mirror whereas some other rays cannot because of the cardboard.	1
	8	Deficient or not meaningful.	8
Item 7A	1	**Rays from Murat's knees reflect from the bottom of the mirror and reaches to his eyes.***	26
	2	Only the portion of Murat's body just in front of the mirror can be seen.	8
	3	Mirror size that is half of Murat's body length is enough to see his whole body.	2
	4	Mirror size that is half of Murat's body length enables Murat to see half of his body.	1
	5	Deficient or not meaningful.	9
Item 7B	1	Field of vision increases by moving away/moving toward the mirror/moving mirror down on the wall, so that Murat can see his whole body.	17
	2	**Moving mirror down on the wall moves the field of vision without changing its size, so that all of Murat's body enters that field.***	8
	3	Mirror size determines image size that can be seen from the mirror.	4
	4	Mirror size that is half of Murat's body length is enough to see his whole body.	1
	5	Deficient or not meaningful.	37
Item 8	1	Field of vision increases by moving away from the mirror/moving mirror down on the wall, so that Suat can see more of Fırat's body.	15
	2	**Field of vision increases by moving toward the mirror, so that Suat can see more of Fırat's body.***	8
	3	**Moving mirror down on the wall / Jumping up moves the field of vision without changing its size, so that Suat can see more of Fırat's body.***	5
	4	Mirror size determines image size that can be seen from the mirror.	3
	5	Moving mirror down on the wall/Jumping up increases the body length in front of the mirror, so that Suat can see more of Fırat's body.	2
	6	Deficient or not meaningful.	32

Table 4.1 Categories of the Subjects' Responses for Each Item on the Open-Ended Test (Cont'd)

Item 9A	1	An image can be formed only if it is not on the focal point of a concave mirror.	10
	2	Images of cats just within the front borders /curvature of the concave mirror are formed.	4
	3	If a special ray (parallel to the axis or passing from the focal point) that is drawn from a cat to the mirror could reach the concave mirror, then the image of that cat can be formed.	3
	4	**Image formation and observation of the cats occur simultaneously, so images of cats that are formed behind Hasan's path cannot be formed since they cannot be observed. ***	2
	5	Deficient or not meaningful.	19
Item 9B	1	Closeness of the images of the cats to Hasan determines the seeing order of the images in the concave mirror.	10
	2	Images of cats just within the front borders /curvature of the concave mirror are formed and be seen.	6
	3	Closeness of Hasan to the cats determines the seeing order of the images in the concave mirror.	4
	4	**In order to see a real image of the cat without a screen, Hasan should stand behind the point that the image is formed and look through the region that the diverging light rays from that image point can reach to his eyes. ***	1
	5	Deficient or not meaningful.	15
Item 10A	1	An image can be formed only if it is not on the focal point of a convex mirror.	9
	2	Only real images can be seen. However, in convex mirror no real images of the cats can be formed.	4
	3	Images of cats just within the front borders /curvature of the convex mirror are formed.	3
	4	Images of cats that have no obstacles between them and the convex mirror are formed.	1
	5	If a special ray (parallel to the axis or passing from the focal point) that is drawn from a cat to the mirror could reach the concave mirror, then the image of that cat can be formed.	1
	6	**Image formation and observation of the cats occur simultaneously, so images of all cats are formed as Hasan walks and sees the cats. ***	1
	7	Deficient or not meaningful.	12
Item 11A	1	If a special ray (parallel to the axis or passing from the focal point) that is drawn from a lamp to the mirror could reach the concave mirror, then the image of that lamp can be formed.	7
	2	Images of lamps just within the front borders /curvature of the concave mirror are formed.	5

Table 4.1 Categories of the Subjects' Responses for Each Item on the Open-Ended Test (Cont'd)

	3	**Image formation and observation of the lamps occur simultaneously, so images of all lamps are formed as Sevgi climbs and sees the lamps. ***	3
	4	Deficient or not meaningful.	16
Item 11B	1	Closeness of the images of the lamps to Sevgi determines the seeing order of the images in the concave mirror.	5
	2	Closeness of Sevgi to the lamps determines the seeing order of the images in the concave mirror.	3
	3	**In order to see a real image of the cat without a screen, Hasan should stand behind the point that the image is formed and look through the region that the diverging light rays from that image point can reach to his eyes. ***	2
	4	Images of cats just within the front borders /curvature of the concave mirror are formed and be seen.	1
	5	Deficient or not meaningful.	11
Item 12	1	**In order to see her eyes, rays from her eyes should reflect from the concave mirror and reach back to her eyes.***	8
	2	Since the climbing rope is along the center of the concave mirror, all the rays from Sevgi to the mirror reflects back to her eye in anywhere along the rope.	2
	3	If a special ray (parallel to the axis or passing from the focal point) that is drawn from Sevgi to the mirror could reach the concave mirror, then she can see her image.	2
	4	In order to see her eyes, eyes of Sevgi should be aligned with the bottom of the concave mirror.	1
	5	Deficient or not meaningful.	13
Item 13	1	In the convex mirror only at the point M on the rope, the light rays can reflect back to her eyes.	4
	2	**In order to see her eyes, rays from her eyes should reflect from the convex mirror and reach back to her eyes.***	3
	3	Since convex mirror diverges all the rays, all the rays from Sevgi to the mirror reflects back to her in anywhere along the rope.	2
	4	If a special ray (parallel to the axis or passing from the focal point) that is drawn from Sevgi to the mirror could reach the convex mirror, then she can see her image.	1
	5	Image of Sevgi's eye is virtual and the light rays from her eyes cannot intersect anywhere, so it is impossible for her to see her eyes in a convex mirror.	1
	6	Deficient or not meaningful.	5

Table 4.1 Categories of the Subjects' Responses for Each Item on the Open-Ended Test (Cont'd)

Item 14	1	Selin could manage to see her image on the concave mirror anywhere except the focal point. Because, when she is at the focal point, her image will be formed in the infinity.	11
	2	$1/f = 1/d_O + 1/d_I$	8
	3	Selin can see her image on the concave mirror only when she is at the center of the mirror. Because only when she is there her image is at the same size with her.	4
	4	When Selin is between the concave mirror itself and the focal point of the mirror, her image would be formed in the infinity and could not be seen.	4
	5	Unlike real images, virtual images cannot be seen in the concave mirrors.	1
	6	**In order to see her face, rays reflecting from each point of Selin's face should reflect back from the concave mirror and reach to her eyes. Also she should be in a region behind where her image is formed.***	0
	7	Deficient or not meaningful.	6
Item 15	1	Selin could manage to see her image on the convex mirror anywhere except the focal point. Because, when she is at the focal point, her image will be formed in the infinity.	7
	2	**In order to see her face, rays reflecting from each point of Selin's face should reflect back from the convex mirror and reach to her eyes. In this way in all positions of her face her image is simultaneously be formed and seen.***	4
	3	$1/f = 1/d_O + 1/d_I$	4
	4	When Selin is beyond the center in front of the convex mirror, her image will be formed between F-M in the back of the mirror; when she is at the center, her image will be formed at M in the back of the mirror; when she is at between F-M, her image will be formed beyond M in the back of the mirror.	3
	5	Selin can see her image on the convex mirror only when she is at the center of the mirror. Because only when she is there her image is at the same size with her.	3
	6	Deficient or not meaningful.	7
Item 16	1	**The image of the pencil will not be changed in terms of its place and shape, only it gets dimmer.***	9
	2	Image of the pencil will not be formed, since the parallel rays from the pencil to the mirror is blocked by the cardboard.	6
	3	Since half of the mirror is covered by the cardboard, half of the image of the pencil can be seen / formed.	6
	4	Image of the pencil will not be formed, since parallel rays from the pencil to the mirror is blocked by the cardboard and the other one special ray is not enough to form the image.	5

Table 4.1 Categories of the Subjects' Responses for Each Item on the Open-Ended Test (Cont'd)

	5	Because of the cardboard, only the image of the pencil's bottom point is formed.	2
	6	Deficient or not meaningful.	5
Item 17	1	$n = (360/\alpha) - 1$	31
	2	**The light rays coming from the object to the mirrors reflect and reach to the observer's eyes. With the rays reaching to his eyes the image of the object is both formed and seen.***	0
	3	Deficient or not meaningful.	5
Item 18	1	At certain angles for which we cannot obtain a whole number from the equation $(360 / \alpha) - 1$; in addition to his whole images the observer can also see his partial images.	13
	2	**The light rays coming from the observer to the mirrors reflect and reach to the observer's eyes. With the rays reaching to his eyes the image of the observer is both formed and seen.***	4
	3	At certain angles for which we cannot obtain a whole number from the equation $(360 / \alpha) - 1$; the number of images that could be seen rounded to the closest whole number.	3
	4	Determining the location of the image of the observer in the two plane mirrors separately, and then taking the image of these formed images, the observer can see all of those 4 images.	3
	5	Deficient or not meaningful.	7
Item 19A	1	$n = (360 / \alpha) - 1$	24
	2	The image of the ball in one mirror will form another image in the other mirror, and in turn there will be infinite number of images of the ball.	2
	3	**The light rays coming from the ball to the mirrors reflect and reach to the observer's eyes. With the rays reaching to observer's eyes the image of the ball is both formed and seen.***	1
	4	Deficient or not meaningful.	3
Item 19B	1	The number of images that can be seen from the hinged mirrors only depends on the angle between the mirrors.	18
	2	**With the rays reaching to observer's eyes the image of the ball is simultaneously formed and seen, so depending on the position of the observer the number of images of the ball would change.***	3
	3	The number of images formed in the mirrors does not change, but the number of images that can be seen by the observer will be changed.	2
	4	Deficient or not meaningful.	4

Table 4.1 Categories of the Subjects' Responses for Each Item on the Open-Ended Test (Cont'd)

	1	**Since the location of the image of the nail is the same with the previous case, no image will be formed on the screen when the screen moved back.***	12
Item 20	2	Since the location of the image of the nail is the same with the previous case, when the screen moved back a larger image of the nail is formed.	10
	3	The image of the nail formed in the converging lens is smaller than the object nail itself. As the screen moved back, the image gets smaller.	2
	4	Since the image of the nail converges to the same image location, the rays diverge from that point and the image inverts onto the screen.	1
	5	Deficient or not meaningful.	4
Item 21	1	Only the image of the middle of the nail will be formed on the screen, since the parallel rays from the other parts of the nail to the lens is blocked by the cardboard.	12
	2	**Since from each point of the nail light can reach to the uncovered part of the lens, the size and shape of the image does not change. Only the image gets dimmer.***	6
	3	Since the hole is in the shape of a circle, on the screen there will be an image in the shape of a circle.	3
	4	Parallel rays drawn from the different points on the nail to the lens are obstructed by the cardboard. The other one special ray that can be drawn is not enough to form the image.	1
	5	Deficient or not meaningful.	1
Item 22	1	In order to see the whole image of the pencil, the observer should look from the same side of the image formed.	11
	2	**For an observer to see the whole image of the pencil, the rays coming to the lens from each point of the pencil refracted and reach to the observer's eye. ***	4
	3	For an observer to see the whole image of the pencil, one should look within the region enclosed by the three rays shown in the figure.	3
	4	The whole image can only be seen when look at the image from the other side and within the borders of the lens.	2
	5	Deficient or not meaningful.	3
Item 23	1	Selin could manage to see her image on the converging lens anywhere except the focal point. Because, when she is at the focal point, her image will be formed in the infinity.	7
	2	**Selin cannot see her image, since in none of the situations the rays from Selin's face refracted by the lens can reach to her eyes.***	4
	3	Unlike real images, virtual images cannot be seen.	3
	4	The real images can only be seen on a screen.	1
	5	Deficient or not meaningful.	12

Table 4.1 Categories of the Subjects' Responses for Each Item on the Open-Ended Test (Cont'd)

Item 24	1	Selin can see her image in all of the locations, since the rays from her face refracted by the lens and intersect in the same side and in front of her.	6
	2	Selin could manage to see her image on the diverging lens anywhere except the focal point. Because, when she is at the focal point, her image will be formed in the infinity.	4
	3	Unlike real images, virtual images cannot be seen.	3
	4	Selin can see her image with diverging lens only when she is at the center of the lens. Because only when she is there her image is at the same size with her.	2
	5	The real images can only be seen on a screen.	1
	6	**Selin cannot see her image, since in none of the situations the rays from Selin's face refracted by the lens can reach to her eyes.***	1
	7	Deficient or not meaningful.	7

4.2.2. Analysis of the Reasoning Categories in the Open-Ended Test Results

In this section the analysis of the reasoning categories that emerged from the open-ended test results is discussed in relation to the reports on misconceptions in the literature. The pre-service teachers' misconceptions that are similar to the ones in the literature and the ones that are not mentioned in previous literature were identified in order to construct the alternatives on the multiple-tier multiple-choice test in geometrical optics.

The first item on the open-ended test has two parts: one is related to the image formation and the other is related to the image observation. There are seven categories for the first part of the first item on the open-ended test. The first category, which was the most common among the subjects was one of the misconceptions previously mentioned in the literature in several studies (Galili, 1996; Galili, Goldberg & Bendall, 1991; Galili & Hazan, 2000a; Heywood, 2005; Ronen & Eylon, 1993). Subjects in this category considered image formation and observation processes as separate events. They seemed to think that image formation has no relation to an observer's presence. Subjects in the second reasoning category mostly claimed that the image of Cat 4 is not formed because of Cat 3 or Cat 2. These subjects generally have a single ray from Cat 4 to the mirror. When it was blocked by one of the other cats, they thought that cat obscured all of the light that would reach the mirror. Similar misconceptions were also found among students in different contexts of plane mirrors in the literature (Anıl & Küçüközer, 2010; Ronen & Eylon, 1993). The

misconceptions related to this type of reasoning are mainly due to thinking that light rays propagate in only one direction. The fifth reasoning category is similar to the "line-of-sight" reasoning which was mentioned by Goldberg and McDermott (1986). The subjects using this type of reasoning tried to locate the image along the line of sight of the observer. On this particular item in the open-ended test, the subjects tried to locate the image of the cats along any line from the cat to the mirror. The fourth and sixth reasoning categories are not explicitly mentioned in the previous literature and were identified in the present study. Subjects whose reasoning fits the fourth category thought that for an object's image to be formed in the plane mirror, the object must lie in the borders of the plane mirror. Therefore, subjects who claimed that only the images of Cats 1 and 2 are formed in the plane mirror, usually proposed this reasoning. Subjects who belong to reasoning category six claimed that the images of the cats were formed somewhere in front of the plane mirror on the same side as the cats. In their representations the subjects who reasoned in this way located the images of the cats along the reflected light rays from the mirrors. The second part of the first item yielded same reasoning categories as the first part of the first item for the fourth and fifth reasoning categories. The other reasoning categories (Category 2, 3, 6) that emerged, however, were unique to the present study.

The second item on the open-ended test has a context similar to the first item, but the observer moves along a perpendicular line off-axis to the plane mirror and observes the stationary objects (cats). The subjects' responses for the first and second part of this item revealed the same reasoning categories as the first item with similar frequencies.

In the context of the third item, the observer is stationary while the two objects (cats) are moving. The first and second parts of the item did not elicit misconceptions as effectively as the previous two items. Therefore this item has removed from the test. Item removal did not hurt the content validity, since according to the Table of Specification (see Appendix I), there were more items than needed for the plane mirrors context of observing others case.

Analysis of the responses to the fourth item produced six reasoning categories for the first part, and only three categories for the second part. All of the categories that emerged from the subjects' responses were the same as the first two items. Nothing new in terms of reasoning has identified. Therefore, this item was removed from the study altogether.

The fifth item produced six reasoning categories. This item context is new, so some of the reasoning categories were also new and unique to the present study. With the reasoning in the first category, most of the subjects believed that eyes aligned with the mirror are enough to see the whole body. This kind of reasoning neglected the necessity of reflections from the all points on the body to the eyes of the observer. The third reasoning

category, on the other hand, is very similar to the reasoning in the previous items on which the cats were thought to be within the borders of the plane mirror to be seen. The fifth reasoning category, even though not frequent among the subjects, seemed as a plausible misconception reasoning and therefore was included in the multiple choice alternatives.

For the sixth item, there are eight reasoning categories. Discussion of the results with similar items in the studies of Ronen and Eylon (1993) and Anıl and Küçüközer (2010) was not detailed enough to document all of the reasoning had by students. The findings of the latter study revealed that 17.1 % of the sample thought that, because of the obstacle, the perpendicular rays from the object could not reach the mirror. Therefore, the image of the object could not be formed in the plane mirror. This finding is very similar to the first reasoning category found in the present study. Reasoning similar to the third category was discussed in the study of Ronen and Eylon (1993) and other related studies in which image formation and observation are seen as separate events that happen in an order (image formation occurs first and is then observed by an observer). The other reasoning categories that emerged in the analysis of the subjects' responses are new and unique to the present study. All of these were used in construction of the alternatives on the multiple-choice test.

There were two related parts for the seventh item. Both produced five reasoning categories. The question in the second part of the item was also asked by Goldberg and McDermott (1986) in their studies, and the most common answer of their subjects for seeing more of their own bodies was moving back from the mirror. The subjects seemed to be unable to understand that the size of one's own image that is visible to an observer does not depend on the distance from the mirror, but only on the size of the mirror relative to the observer. The results of the present study also propose that the same reasoning category as the most frequent one. In addition to the misconceptions found in the previous items, a new misconception category was found that was not mentioned in the previous studies. That is, some of the subjects had a fragmented knowledge from their physics courses that a mirror the size of half of the observer's height is enough to see his whole body in the mirror. However, in this kind of reasoning, subjects who ignore the relative height of the mirror on the wall, are still erroneous.

Item eight is very similar to the previous item. In Item eight, instead of observing oneself, the observer observes someone else. In this specific situation, however, moving toward the mirror helps the observer to see more of the other person's body. In this item, the responses of the subjects to the open-ended item yielded two correct reasoning categories. Therefore, the format of the multiple-choice test was arranged to include both of these correct answers within the alternatives.

Item nine revealed five reasoning categories for the image formation and observation process in the concave mirror context. Most of the subjects seemed to think that an object which is not located at the focal point of a concave mirror can be seen from anywhere. These subjects usually lacked the understanding of an aerial image observation for the real image formed by a concave mirror. In the absence of the screen, in order to see an aerial image the observer should be positioned in a place where the light from that aerial image point can enter the observer's eye. Subjects who expressed the reasoning in the first category lacked this conceptual understanding. The second reasoning category for the image formation part is very similar to the reasoning in the plane mirrors. In the concave mirror context, some of the subjects thought that the image of objects that is within the borders, or the curve of a concave mirror, is formed and observed. This extension of this misconception to the spherical mirror context is new for the present study.

As listed in the third reasoning category, subjects may have overgeneralized the use of the special rays in the concave mirror context too, and thought these special rays as necessary to form an image of object. Similar findings were previously discussed for the other contexts in previous studies (Goldberg & McDermott, 1987; Grayson, 1995). In their reasoning for the image observation in concave mirrors, the subjects again used the "closeness of the images to the observer" or "closeness of the objects to the observer" to answer the corresponding question. One of the striking points that was realized for this item -and the following items in the not familiar contexts such as concave and convex mirrors- is that the frequency of deficient or not meaningful answers for the reasoning are abundant compared with the other categories. This may be due to the fragmented knowledge, or not coherent explanations of the subjects.

Three of the reasoning categories for the image formation part for the tenth item (categories 1, 3 and 5) are the same as for the ninth item. Also the fourth category was previously encountered in the plane mirror context. Category two is a new type of reasoning that emerged for the convex mirror context. Subjects who proposed this reasoning thought that only real images of the objects can be seen, but the convex mirror never forms a real image of the cats. About this kind of reasoning, the fact that in a convex mirror the type of image is always virtual is correct, but this type of reasoning that presumes real images is wrong.

For Item eleven, the responders used the same reasoning that has been discussed in the previous items.

Items twelve and thirteen refer to observing oneself in concave and convex mirrors, respectively. Only one category (category 3 in Item 12 and category 4 in Item 13) is common

to the two items. This category refers to overuse of the special rays in the image formation and observation processes. In the item related to the concave mirror, category two was the most remarkable. According to some subjects, since the climbing rope passes by the center of the mirror, they thought that along this axis all the rays would reflect back to the observer. In the item related to the convex mirror related, however, subjects who gave the same answer that along this axis all the rays would reflect back to the observer used a different reasoning (see category 3 for Item 13). For the item related to the convex mirror, subjects who gave the reasoning in Category 1 probably understood that the light rays from Sevgi's eyes should reflect back to her eyes in order for her to see own eyes. However, they could not realize that when Sevgi is along any line passing through the center of the back of the convex mirror the rays would reflect back to her.

None of the subjects were able to give a correct explanation for Item fourteen. This item, which is similar to Item nine, requires subjects' understanding of aerial real image formation and observation. According to the most frequent response in the first category, subjects thought that an observer could see his/her image in the concave mirror anywhere except the focal point. The reasoning in the second category includes the lens maker's formula. Subjects who used the formula as their reasoning were unable to conceptualize the image observation. They only tried to find the location of the image. The reasoning acquired in the fifth category is similar to the reasoning category two in item ten.

Item fifteen is the convex mirror context version of the previous item. All of the reasoning categories except the fourth are common. What is new and worth to mentioning the reasoning for this item is that some of the subjects had a tendency to generalize some of their knowledge for the concave mirrors to the context of convex mirrors. For instance, some subjects thought that in a convex mirror, if the object is beyond the center in front of the convex mirror, the image is formed between the focal point and the center in the back of the mirror. If it is at the center, the image is formed at the center in the back of the mirror. If it is between the focal point and the center, the image is formed beyond the center in the back of the mirror. If it is at the focal point, the image is formed at infinity.

Item sixteen is adapted from a previous study (Goldberg & McDermott, 1987). The reasoning mentioned in category two was also common among the students of this previous study, too. The other types of reasoning in the other categories were all either the same as the previous studies or the reasoning categories as mentioned in the previous items.

Investigations of student understanding of images in the hinged plane mirrors context are relatively scarce. Therefore, student misconceptions in this context have not been studied much. Many students seem to think that the number of images depends only on the

angle (α) between the hinged mirrors and is independent of the position of the object (Kulkarni, 1960) and the position of the observer's eye (Iona, 1982). Item 17 was deliberately included to reveal the status of this understanding about the context, but the results of the subjects' response to the item do not yield a good category. The only, and the most common, reasoning is related to the equation used to find the number of images that are formed for a specified angle.

Item eighteen generated five reasoning categories for its specifically selected hinged plane mirror context with a special angle between them. In contrast to the common applications of the well-known equation $n = (360 / \alpha) - 1$, an angle (α) which produces a fraction for n yielded more variety in the reasonings about this context. As mentioned by Kulkarni (1958) students have a misunderstanding that for angles other than 90^0, 60^0, etc. a whole number of images is not obtained. The subjects of the present study had different explanations for the same context that are unique to the present study. These explanations are given in Categories 1, 3, and 4 for this item.

The second part of item nineteen asks explicitly whether the number of images formed in a hinged plane mirror context depends on the observer's position. The first category reveals the dominant angle explanation mentioned previously. The third category, however, presents a very similar type of reasoning that is discussed for the items in the plane mirror context, namely, that image formation and observation are thought of as separate and independent events.

The categories that emerged for the twentieth item are almost the same as the ones mentioned by Goldberg and McDermott (1987). In a similar question, Goldberg and McDermott asked what would happen to the image if the screen was moved toward the lens. In the present case, however, the question asked involved moving the screen away from the lens. In the second category, the reasoning of subjects for why they think the image gets smaller is somewhat different from the one in the literature. The subjects of the present study reasoned that the converging lens produces an image smaller than the object size, so they thought the farther from the screen, the smaller the image size.

Item twenty-one was also adapted from the study of Goldberg and McDermott (1987). However in the present study, the hole on the cardboard is intentionally chosen to be smaller than that of the image size. Goldberg and McDermott (1987) reported that about half of their sample responded that the image would vanish. In our specifically designed but similar item, however, some other different reasoning categories emerged. The most common response was that the image of the center of the object would be formed. Most of the subjects who proposed this reasoning used parallel rays in their ray diagrams and

reasoned that parallel rays from the top and bottom parts of the nail were blocked by the cardboard. The responders who gave the reasoning in the third category associated the image shape on the screen with the shape of the hole on the cardboard. This kind of reasoning was found to be prevalent for light propagation through masks and for shadow formation (Chen, 2009; Dedes & Ravanis, 2009; Feher & Rice, 1988; Wosilait et al., 1998), but new for the optical imaging by a lens.

The analysis of the subjects' responses to Item twenty-two results in five categories. Reasoning in the first category which states that the observer should be on the same side as the image to see it was the most widespread response for this item. In the third category, subjects associated the special rays with the image observation process, and as discussed previously in the other contexts, they thought that special rays are necessary to see an image.

Items twenty-three and twenty-four are very similar in their format. Only the contexts differ. The main idea necessary to answer the items correctly is to reason that there is no way for an observer to see herself, because the refracted light rays from her face cannot reach her eyes. However, the categories that emerged for these two items showed that these two items are resourceful contexts for understanding the subjects' conceptions of the image observation process. The categories identified for these two questions are very much similar to the ones in the contexts of concave and convex mirrors.

In general, the subjects' response rate for familiar contexts, such as plane mirrors, is higher than for less familiar contexts, such as spherical mirrors. It seems to be because of lack of knowledge on these contexts. Another point that should be noted is that in almost all of the items, there exist some categories labeled as deficient or not meaningful. Especially for some of the items, the frequency of answers that are in this category is relatively high. The subjects' responses belonging to those categories usually included facets of knowledge, which were activated in the corresponding item context. They were sometimes correct or sometimes wrong, but generally they were not relevant to the answer. These kinds of responses might also be an indicator of inconsistent conceptions or lack of knowledge.

Items three and four were removed from the test since they were thought not to be resourceful enough. Existence of more than a sufficient number of items that measure the case of observing someone else in the plane mirror context enabled us to confidently exclude these two items from the following multiple-choice test. There were some other items which were found to be not sufficiently resourceful (such as Item seventeen) but in consideration of the content validity of the test, these items were kept. Some of the items in the open-ended test consist of two parts (Items 1, 2, 3, 4, 7, 9, 10, 11, and 19) and the categories that resulted for these two parts of the same item sometimes overlapped. Therefore, in constructing the

alternatives on the multiple-choice test, categories from both parts of the same item were used if applicable. In the multiple-choice test, only one part of each item was included. Either the most resourceful part was selected or the one that helped more to vary the questions on the test.

4.3. Analysis of the Results of the Three Tier Geometrical Optics Test (TTGOT)

From the analysis of the Open-Ended Geometrical Optics Test results, interview results, and the common misconceptions mentioned in the previous literature, the Three-Tier Geometric Optic Test (TTGOT) was developed and administered as a pilot study. The pilot-testing data were entered into MS-Excel file and some pre-analysis was conducted for the test scores. The sample of the pilot study was 53 pre-service physics teachers from three universities in Turkey. Some preliminary analyses were conducted with these data. The sample of the pilot study was not adequate in consideration of the factor analysis. Pallant (2007) suggests that ideally the overall sample size should be more than 150 and there should be a ratio of at least five cases for each of the variables for a factor analysis. The relatively small sample size (n=53) of the present pilot study hinders that analysis. For a correlational study, the minimum acceptable sample size suggested is 30 (Fraenkel & Wallen, 2000 p.368), which shows the sample size was adequate for estimating the correlation coefficient between the first two tiers score and the confidence score of the test as construct related evidence (Çataloğlu, 2002) and for estimating the internal reliability coefficient. The analyses that were performed to obtain some information about the TTGOT items were;

1. Analysis of the percentage of subjects choosing each first tier and reasoning tier alternative for each item of the TTGOT.
2. ITEMAN analysis for the TTGOT scores.
3. Descriptive analysis of the TTGOT scores with percentages of correct answers for only the first tiers, first two tiers and all three tiers; percentages of false positives, false negatives, and lack of knowledge.
4. Correlation between the subjects' scores for the first two tiers and the third tier.

Firstly, in order to determine if there existed any not working alternatives on the TTGOT, the percentages of subjects choosing each of the alternative pairs in the first and reasoning tiers were determined. Table 4.2 shows the percentage of subjects that selected a particular first tier and reasoning tier alternative in each of the TTGOT items. None of the subjects chose the correct answer alternative pair for the first and second tiers in Item 7.

Therefore, this item was removed from the study. For all of the other items, the correct alternative pairs were selected by at least some of the subjects. Also, the percentages were investigated according to the table provided in Appendix N showing the misconception selections. The pairs of first and reasoning tier alternatives that show a specific misconception and that were selected by less than 5 % were detected and considered as weak distracters (Caleon, 2010). Weak distracters were then investigated and were revised or removed from the test

Table 4.2 Percentage of Subjects Choosing Each First Tier and Reasoning Tier Alternative for Each Item on the TTGOT (N=53)

I[a]	First Tier Alternatives	Reasoning Tier Alternatives								
		a	b	c	d	e	f	g	OA[b]	Total
1	a	0	0	0	0				0	0
	b	8	2	4	0				0	14
	c	2	13	4	2				0	21
	d	0	0	32	28*				4	60
	OA	0	0	0	0				0	0
	Total	10	15	40	30				0	95
2	a	2	0	0	0	4			2	6
	b	0	0	2	2	4			2	8
	c	2	2	0	6	28*			6	38
	d	0	0	0	11	4			0	15
	e	0	2	0	0	0			0	2
	OA	0	0	0	0	9			0	9
	Total	4	4	2	19	49			10	88
3	a	2	2	0	0				0	4
	b	0	6	2	0				0	8
	c	0	6	2	43*				4	51
	d	0	0	8	15				2	23
	OA	0	0	2	0				0	2
	Total	2	14	14	58				6	94
4	a	0	2	9	9	0			2	22
	b	13	8	0	6	13			4	44
	c	0	0	2	28*	0			0	30
	OA	0	0	0	0	0			0	0
	Total	13	10	11	43	13			6	96
5	a	0	8	0	2	0			0	10
	b	8	15	2	4	2			2	33
	c	0	4	0	2	26*			2	34
	d	0	0	4	8	4			0	16
	OA	0	2	0	0	2			0	4
	Total	8	29	6	16	34			4	93
6	a	15	0	2	0	2			0	19
	b	11	0	0	2	2			2	17
	c	4	0	2	2	0			0	8
	d	17	2	19*	8	0			0	46
	e	0	0	0	2	0			2	4
	OA	2	0	4	0	0			0	6
	Total	49	2	27	14	4			4	100

Table 4.2 Percentage of Subjects Choosing Each First Tier and Reasoning Tier Alternative for Each Item on the TTGOT (N=53) (Cont'd)

7	a	2	0	4	2	0	0	0	0	8
	b	0	6	0	6	2	0	8	0	22
	c	0	0	0	4	2	0	6	0	12
	d	0	0	0	0	6	2	2	2	12
	e	0	0	0	2	0	2	4	0	8
	f	0	0	0	0*	0	2	0	0	2
	OA	0	0	15	0	0	2	4	2	23
	Total	2	6	19	14	10	8	24	4	87
8	a	4	0	6	9	6	0		0	25
	b	4	0	2	2	4	0		0	12
	c	2	0	0	8	2	0		0	12
	d	0	2	0	15	6*	0		2	25
	e	0	2	0	0	0	0		0	2
	f	0	0	0	0	2	11		0	13
	OA	0	0	0	0	0	0		4	4
	Total	10	4	8	34	20	11		6	93
9	a	0	4	2	4	0	4		0	14
	b	4	9	8	13*	2	11		0	47
	c	0	0	4	0	0	0		0	4
	d	0	0	0	0	6	0		0	6
	e	0	0	13	2	0	2		0	17
	OA	0	0	0	0	0	2		2	4
	Total	4	13	27	19	8	19		2	92
10	a	4	0	2	0	0			0	6
	b	0	0	2	9	0			2	13
	c	0	2	6	0	11			0	19
	d	0	9	0	4	2			0	15
	e	2	0	32*	2	2			0	38
	OA	0	0	0	0	0			0	0
	Total	6	11	42	15	15			2	91
11	a	0	0	0	2	0	0	0	0	2
	b	0	2	0	0	0	0	8	0	10
	c	2	0	2	0	8	0	0	0	12
	d	4	0	9	2	2	26*	0	2	45
	e	0	0	0	0	8	0	0	0	8
	f	0	0	11	0	0	4	0	0	15
	OA	0	0	0	0	0	0	0	0	0
	Total	6	2	22	4	18	30	8	2	92
12	a	0	0	0	2	2			0	4
	b	8	0	2	4	6			0	20
	c	0	4	17	8	9			0	38
	d	0	0	0	2*	2			0	4
	e	0	11	2	2	2			0	17
	OA	0	2	2	4	0			2	8
	Total	8	17	23	22	19			2	91
13	a	0	2	6*	4	2			4	18
	b	6	4	9	4	0			0	23
	c	0	4	8	6	9			0	27
	d	0	0	2	4	0			0	6
	e	0	8	2	8	0			0	18
	OA	0	0	0	0	0			2	2
	Total	6	18	27	26	11			6	94

Table 4.2 Percentage of Subjects Choosing Each First Tier and Reasoning Tier Alternative for Each Item on the TTGOT (N=53) (Cont'd)

14	a	13	0	8	0	0		0	21
	b	2	0	8	0	2		0	12
	c	4	4	0	0	0		0	8
	d	0	2	2	38*	0		0	42
	OA	0	0	2	4	0		6	12
	Total	19	6	20	42	2		6	95
15	a	2	55	8	4*			0	69
	b	0	4	6	2			0	12
	c	0	4	6	2			0	12
	d	2	2	0	0			0	4
	OA	0	0	0	2			2	4
	Total	4	65	20	10			2	100
16	a	0	0	0	0	2	2	0	4
	b	0	2	2	8	2	4	0	18
	c	0	4	13	2	0	2	0	21
	d	2	4	2	21	0	2*	4	35
	e	0	6	2	2	2	0	0	12
	OA	0	0	0	0	0	2	0	2
	Total	2	16	19	33	6	12	4	92
17	a	0	0	9	42	4		0	55
	b	6	11	4*	2	4		0	27
	c	0	0	2	0	0		0	2
	d	0	0	2	0	0		0	2
	OA	0	0	2	0	2		0	4
	Total	6	11	19	44	10		0	90
18	a	25	4	2	2			0	33
	b	2	0	15	0			0	17
	c	0	4	0	2			0	6
	d	0	0	4	21*			0	25
	OA	0	2	0	6			0	8
	Total	27	10	21	31			0	89
19	a	2	0	11	0			2	13
	b	0	26	0	6			0	32
	c	15*	4	4	2			0	25
	d	4	0	0	9			0	13
	OA	0	0	0	0			0	0
	Total	21	30	15	17			2	83
20	a	8	0	0	4	0		0	12
	b	8	6	6	0	4		0	24
	c	2	2	4	11	4		0	23
	d	2	6	2	0	8*		0	18
	e	0	0	4	6	0		0	10
	OA	0	0	0	0	2		0	2
	Total	20	14	16	21	18		0	89
21	a	0	2	2	2	2		0	8
	b	11	0	6	13	2		0	32
	c	2	0	11	8	0		0	21
	d	0	11	2	2	0		0	15
	e	0	0	0	0	9*		4	13
	OA	0	0	0	0	2		0	2
	Total	13	13	21	25	15		4	91

Table 4.2 Percentage of Subjects Choosing Each First Tier and Reasoning Tier Alternative for Each Item on the TTGOT (N=53) (Cont'd)

22	a	0	6	0	6	0	0	12
	b	9	0	8	6	0	0	23
	c	0	4	6	13	2	0	25
	d	0	0	2	0	0	0	2
	e	0	2	8	2	15*	0	27
	OA	0	0	0	0	0	0	0
	Total	9	12	24	27	17	0	89

*Note: * Correct answers. [a]I-Item number in the Pilot GOT. [b]OA-Percentage of students with their own answers or a combination of answers.*

Secondly, an ITEMAN analysis was conducted in order to analyze test item response data to determine the extent to which items were contributing to the reliability of the test and which response alternatives were functioning well for each item. In addition to item-level statistics the ITEMAN program also provides statistical indicators on the performance of the test as a whole such as mean, standard deviation, difficulty and discrimination indexes. The ITEMAN program was conducted for the all three tier scores of the TTGOT and the results are summarized in Table 4.3. Three of the subjects who had omitted responses for more than half of the test items were not included in the analysis.

The mean score of the TTGOT was found to be 2.72 with a standard deviation of 2.58. The test was rather difficult with a mean difficulty index of .12, also quite discriminating with a discrimination index of .38. The Cronbach alpha reliability coefficient was found to be .72 for all three tiers score, which showed the internal consistency of the scores.

Table 4.3 ITEMAN Analysis Results for the TTGOT for All Three Tiers Scores

Descriptive Statistics	TTGOT Misconception All Three Tier Scores				
Number of students	50				
Number of items	22				
Mean	2.72				
Median	2				
Min. Score	0				
Max. Score	10				
Standard deviation	2.58				
Std. Error of Mean	1.38				
Reliability (Cronbach Alpha Coefficient)	.72				
Skewness	1.03				
Kurtosis	.18				
Point-biserial coefficients	.38				
	1) .36 2) .47 3) .63 4) .13 5) .65	6) .37 7) -9.0 8) .24 9) .16 10) .58	11) .27 12) -9.0 13) .25 14) .48 15) .18	16) .40 17) .01 18) .63 19) .61 20) .18	21) .57 22) .35
Difficulty level	.12				
	1) .16 2) .22 3) .44 4) .18 5) .26	6) .08 7) .00 8) .02 9) .06 10) .28	11) .14 12) .00 13) .06 14) .24 15) .02	16) .02 17) .02 18) .18 19) .12 20) .02	21) .08 22) .12

By using the Ms-Excel, the false positive, false negative, and lack of knowledge percentages for all of the 22 items on the TTGOT and the mean percentages of all items were calculated for the content related evidence for the validity of the TTGOT scores. Also, in Table 4.4 the percentages of correct answers given by the subjects to the items on the TTGOT were presented for only first tier, first two tiers, and all three tiers taken into account. The false positive percentages were in average 11 %, and false negatives were 4 %. False positive proportion was quite above the 10 % recommended by Hestenes and Halloun (1995) for content related evidence for validity of the test scores. When the false positive percentages were investigated for each item, Item 15 seemed to be problematic with 55 %. Therefore this item was removed from the test.

For the evidence of construct validity, the correlation between subjects' first two tiers scores and third tier scores were investigated. The correlation coefficient was found to be .38, which showed moderate correlation.

Table 4.4 Percentages of False Positives, False Negatives, Lack of Knowledge, Correct Answers for Only First Tier, Correct Answers for First Two Tiers and Correct Answers for All Three Tiers for the TTGOT Scores

	I1 %	I2 %	I3 %	I4 %	I5 %	I6 %	I7 %	I8 %	I9 %	I10 %	I11 %	I12 %	I13 %	I14 %	I15 %	I16 %	I17 %	I18 %	I19 %	I20 %	I21 %	I22 %	Mean %
False Positives	30	11	9	2	9	21	2	6	17	6	9	2	8	0	55	25	19	0	0	4	4	6	11
False Negatives	0	0	13	9	6	6	8	2	4	6	2	8	6	2	6	4	4	8	2	2	2	0	4
Lack of Knowledge	11	3	1	9	0	11	0	4	7	6	11	2	0	13	2	0	2	4	4	6	1	4	4.5
Only First Tiers	64	43	57	32	36	45	6	26	49	40	47	4	19	42	70	38	32	25	25	19	13	26	34.4
First Two Tiers	28	28	43	28	26	19	0	6	13	32	26	2	6	38	4	2	4	21	15	8	9	15	16.9
All Three Tiers	17	25	42	19	26	8	0	2	6	26	15	0	6	25	2	2	2	17	11	2	8	11	12.4

Note: I# represents the item number in the TTGOT.

4.4. Analysis of the Results of the Four-Tier Geometrical Optics Test (FTGOT)

Results of the TTGOT were used to revise the test items and the Four-Tier Geometrical Optics Test (FTGOT) was developed and administered to 243 pre-service physics teachers in Turkey. Firstly, the prior analysis to prepare the data for further analysis is discussed in this section. Secondly, in order to investigate the first research question of the present study, the analysis of the data for getting quantitative evidence for validity and reliability of the FTGOT scores are discussed. Finally, the descriptive analysis results of the FTGOT scores for the survey part of the study are presented to investigate the second main research question of the study.

4.4.1. Prior Analysis

Before starting to any statistical analysis, the FTGOT responses of the subjects were prepared for the further analysis. These prior analyses of the raw data were: (1) data cleaning for any abnormal data, (2) dealing with the blank alternative responses of the subjects on the multiple-choice test items, and (3) dealing with the omitted responses of the subjects.

4.4.1.1. Data Cleaning

Data cleaning is basically the detection and correction of errors in a data set. The probable errors were checked by looking at descriptive statistics and outliers from the SPSS outputs. No errors or outliers were found among the data.

4.4.1.2. Dealing with the Blank Alternatives

Blank alternatives for writing any answer and reasoning different from the given choices were added to both first and third tiers of each item on the FTGOT. Subjects who chose the blank alternatives for each item on the FTGOT were identified from the raw data file, and the statements written by each of them were analyzed in detail (see Appendix Z). Table 4.5 shows the coding categories that emerged from the analyzed blank alternative statements with their examples to describe each category and their frequencies. All statements written by the subjects were coded into one of these six categories.

Table 4.6 gives the number of subjects who filled the blank alternatives for each item in detail for each of the coding categories. According to Table 4.6, in average of only 3.1 % of the subjects filled the blank alternative for each item.

The detailed analysis showed that 23.2 % of the subjects who filled the blank alternatives wrote statements that have the same meaning as one of the present alternatives on the FTGOT items (*Directly Recoded Blanks-DRB*) and that 9.9 % of the subjects wrote statements that contain the combination of both the correct and wrong alternatives together or the combination of two wrong alternatives together *(Binary Recoded Blanks-BRB).* Consequently, a total of 33.1 % of the blank alternatives were re-coded into one or more of the existing alternatives in the FTGOT. Subject statements for the blank alternatives falling into both of these categories were recoded into the existing alternatives, and the raw data file was revised for further analysis.

Table 4.5 Description of Coding Categories and Their Frequencies

Code Name	Code	Code Description	Example(s)	f (%)
Directly Recoded Blank	DRB	Blank statements that can be recoded into the existing distracters of the test.	*"When she is at F image is at infinity and cannot see herself, at other places she can see herself."* (P76 at Item 11.3) Decision: Recoded into the existing alternative "a"	70 (23.2)
Binary Recoded Blank	BRB	Statement with two options (either both wrong or one wrong-one correct option) selected together from the existing distracters of the test.	*"Both distracters b and c (Walking away from the mirror or moving the mirror down on the wall"* (P14, P21, P58, P111 at Item 5.1) Decision: Recoded into the existing alternatives "b-c"	30 (9.9)
Irrelevant or Erroneous Blank	IEB	Statements with erroneous or irrelevant answers for the corresponding item.	*"When he first enters the room he sees cats 2,3,4, before leaving the room he sees cat 1"* (P7 at Item 1.3)	111 (36.7)
New Option	New	Totally new and plausible (wrong or right) statements different from the distracters of the test.	*"When object is at 1,5F its image is at 3F; so when it is at F its image is at 2F=M"* (P219 at Item 11.3)	33 (10.9)
Empty Blank	EB	Selected blank options without any explanation.	(P48, P196, P231 at Item 11.1)	47 (15.6)
Not Know	NK	"Not know/sure" statements written in blank option.	*"I do not know"* (P15 at Item 19.3)	11 (3.6)
			Total	302 (100)

P#: Subject number

Table 4.6 Number of Subjects Who Filled the Blank Alternative for Each Item Tier

Item	DRB	BRB	IEB	New	NK	EB	Total
1.1	-	-	8	-	-	1	9
1.3	2	-	11	-	-	5	18
2.1	2	-	18	-	-	1	21
2.3	4	-	2	1	-	-	7
3.1	-	-	1	-	-	-	1
3.3	5	-	-	-	-	1	6
4.1	3	-	-	1	-	-	4
4.3	-	-	-	1	-	1	2
5.1	1	5	-	3	-	-	9
5.3	3	3	2	1	-	1	10
6.1	2	16	-	-	-	1	19
6.3	2	1	2	-	-	1	6
7.1	1	-	9	-	-	-	10
7.3	1	-	-	-	1	-	2
8.1	-	-	1	-	1	-	2
8.3	3	1	2	-	1	1	8
9.1	-	-	-	-	1	-	1
9.3	1	-	-	-	3	-	4
10.1	-	-	-	-	-	-	0
10.3	2	-	-	-	1	-	3
11.1	-	-	12	3	-	3	18
11.3	5	-	4	2	1	4	16
12.1	-	-	3	3	-	-	6
12.3	2	-	3	1	1	1	8
13.1	4	-	-	-	-	-	4
13.3	5	-	-	-	-	1	6
14.1	6	-	3	1	-	-	10
14.3	2	-	-	-	-	-	2
15.1	1	-	-	1	-	1	3
15.3	-	-	1	-	-	3	4
16.1	5	-	-	1	-	-	6
16.3	5	-	-	1	-	2	8
17.1	2	1	-	2	-	1	6
17.3	-	1	2	-	-	4	7
18.1	-	-	1	2	-	1	4
18.3	-	-	-	1	-	2	3
19.1	1	-	6	4	-	1	12
19.3	-	1	1	4	1	5	12
20.1	-	-	16	-	-	1	17
20.3	-	1	3	-	-	4	8
Total	70	30	111	33	11	47	302
%	23.2	9.9	36.7	10.9	15.6	3.6	100
Average %*	0.7	0.3	1.1	0.3	0.1	0.5	3.1

DRB-Directly Recoded Blanks, BRB- Binary Recoded Blanks, IEB- Irrelevant or Erroneous Blanks, New- New Alternatives, EB-Empty Blanks, NK-Not Know

**Average % is the percentage of blank alternatives filled by the subjects to the possible blanks in the main and reasoning tiers of the test, and calculated as:*

$$\textit{Average \%} = \frac{Total\ number\ of blank\ alternatives\ filled\ X\ 100}{Number\ of\ participants\ X\ Total\ number\ of\ possible\ blank\ alternatives\ in\ \ main\ and\ reasoning\ tiers}$$

Some of the statements written in the blank alternatives were new and plausible wrong or right options *(New Option-New)* for the items which need to be taken into account in case of any revision of the FTGOT alternatives. Most frequently written blank statements were checked whether they were suitable for adding as a new alternative to the corresponding item or not. For the current study, however, none was stated by more than 10 % of the total sample. Therefore, none of them were worth including in the revised version of the FTGOT.

15.6 % of the subjects chose the blank alternative as an option but wrote nothing to explain their answers or reasoning (*Empty Blanks-EB*) and 3.6 % who chose the blank alternative stated that s/he did not know or was not sure about the answer (*Not Know-NK*). Subjects in both of these categories are considered as having read the item but were not able to answer it, which were omitted responses.

The other statements filled by the subjects for the blank alternatives were either erroneous due to some fragmented or deficient knowledge in the topic or totally irrelevant answers *(Erroneous or Irrelevant Blanks-EIB).* Statements that were categorized as EIB remained the same as in the raw data. The relatively large percentage of responses in the EIB category in the blank alternatives might be due to the fragmented and non-consistent conceptions of the subjects on the topic of geometric optics.

4.4.1.3. Dealing with the Omitted Responses

Among all 243 subjects who took the test, 163 subjects had no omitted responses at all throughout the test. The remaining 80 subjects omitted responses on a total of 80 tiers (20 items with four tiers in each) on the FTGOT. The frequency of the omitted responses ranges from a minimum of one to a maximum of 72 for the subjects of the present study. The mean of the frequency of all omitted responses for the 243 subjects yield a value of 4.08 with a standard deviation of 9.76. The subjects who are lying one standard deviation above the mean (which corresponds to 14 or more omitted response frequency) were identified. There were 27 subjects (Subjects 2, 12, 33, 34, 39, 41, 42, 44, 64, 65, 86, 92, 94, 98, 102, 111, 136, 151, 154, 168, 174, 181,184, 187, 197, 213, and 215) in the sample lying above one standard deviation, which corresponds to 11.1 percent of the total sample. This means that, those 27 subjects with 14 or more omitted responses completed less than 80 percent of the test.

Secondly, the frequencies of each subject's omitted responses in each of the 21 misconception categories were calculated. Those who had more than 25 percent of omitted responses in any of the misconception categories for each tier of the test were identified.

Subjects who had omitted responses on more than 25 percent of all 21 misconception categories were listed. There were 30 subjects (Subjects 2, 12, 33, 34, 39, 41, 42, 44, 64, 65, 67, 86, 92, 94, 98, 102, 111, 136, 151, 154, 168, 169, 174, 181,184, 187, 197, 213, 215, and 223) with omitted responses in five or more misconception categories (which corresponds to 25 percent or more) among 21 which corresponds to 12.3 % of the total sample. It was decided to remove these 30 subjects from further analysis of the study. For the remaining subjects, the omitted responses in each misconception category could be determined from their remaining filled responses in the same category for that misconception. The remaining sample size (N=213) was enough for factor analysis and other descriptive analysis. Therefore, all statistical analyses were performed these 213 subjects.

4.4.2. Validity and Reliability of the FTGOT Scores

The FTGOT was administered to 243 pre-service physics teachers in Turkey, and the data from the 213 sample were analyzed for obtaining validity and reliability evidences. As Downing (2006) stated, an effective test development requires a systematic, well-organized approach to ensure sufficient validity and reliability evidence to support the proposed inferences from the test scores. In this section, the analysis of the results of the FTGOT is presented in terms of validity and reliability of the scores.

Validity of a test score can be established by some qualitative and quantitative techniques. As a qualitative technique, expert judgments were used for the content validation procedure which was explained in detail in Chapter 3. Briefly in content validation, independent experts in the content domain judge whether the items on the FTGOT adequately sample the domain of interest, i.e. misconceptions in geometrical optics, or not. Depending on the feedback from the experts in each step, necessary revisions were made to the test to enhance the content validity of the test scores. For statistically establishing the validity of the test scores, however, three quantitative techniques mainly were used: (1) investigating the correlations among the students' scores on the first, the reasoning, and the confidence tiers; (2) conducting the factor analysis for the correct scores and misconception scores; and (3) estimating the percentages of false positives, false negatives, and lack of knowledge.

4.4.2.1. Correlations among the Students' Correct Scores and Confidence Scores

According to Çataloğlu (2002) in a valid test, students who are able to understand the question can then judge their ability to answer that particular question correctly or incorrectly. So, students with higher scores are expected to be more confident about their answers on the test. Since the confidence ratings were asked for the first tier and reasoning tier separately, the calculations of these correlations were modified for the four-tier test format. In three-tier tests, the correlation between the scores on the first two tiers and confidence level on the third tier was calculated as construct-related validity evidence (Aydin, 2007; Çataloğlu, 2002; Kutluay, 2005; Peşman, 2005; Peşman & Eryılmaz, 2010). In the present study, however, three different correlations were calculated for the same purpose of obtaining construct validity evidence (in order to answer Research Question 1.c.). These are:

1. Correlation between first tiers (correct only first score) and second tiers (first confidence score);
2. Correlation between third tiers (correct only third score) and fourth tiers (second confidence score);
3. Correlation between first and third tiers (correct first and third score) and second and fourth tiers (both confidences score).

Table 4.7 shows these correlations for all these three combinations.

Table 4.7 Correlations between Correct Only First Score and First Confidence Score; Correct Only Third Score and Second Confidence Score; Correct First and Third Score and Both Confidences Score

		First Confidence Score
Correct Only First Score	Pearson Correlation	.194*
	Sig. (2-tailed)	.005
	N	213
		Second Confidence Score
Correct Only Third Score	Pearson Correlation	.127
	Sig. (2-tailed)	.065
	N	213
		Both Confidences Score
Correct First and Third Score	Pearson Correlation	.218*
	Sig. (2-tailed)	.001
	N	213

*Correlation is significant at the 0.01 level (2-tailed)

There are small positive and significant correlations between correct only first score and first confidence score (r = .194), and between correct first and third score and both confidences score (r = .218). It means that students with high scores have higher confidence than students with low scores for these two cases. However, there is no significant correlation between correct only third score and second confidence score.

The reasons for small and no correlations can be investigated by using scatter plots. The sign and degree of relationship between variables is what a scatter plot illustrates (Frankel & Wallen, 2000). Figure 4.10 shows the scatter plots of correct only first score and first confidence score; correct only third score and second confidence score; correct first and third score and both confidences score.

From the three scatterplots it is obvious that there are no indications of curvilinear relationships between the variables. Therefore, it would be appropriate to calculate Pearson product-moment correlations for those variable pairs (Pallant, 2005). Although the correlation coefficients are significant between Only First Score and First Confidence Score, and Correct First and Third Score and Both Confidences Score, it is small in magnitude. For a strong positive relationship, students with higher scores are expected to be more confident about their answers on the test, whereas students with lower scores are likely to be less confident. However, at the right-bottom side of the scatter plots there are some students with high confidence levels with low scores. Those students are confident about their wrong answers, some of which might be misconceptions, or they might select wrong answers by chance. The other reason for no or small correlation between the variables might be related to the difficulty of the test. In the scatter plots, it can be seen that the proportion of students with high scores is very few. So the slopes of the lines are small which indicates that students' confidence scores are generally more than their correct scores.

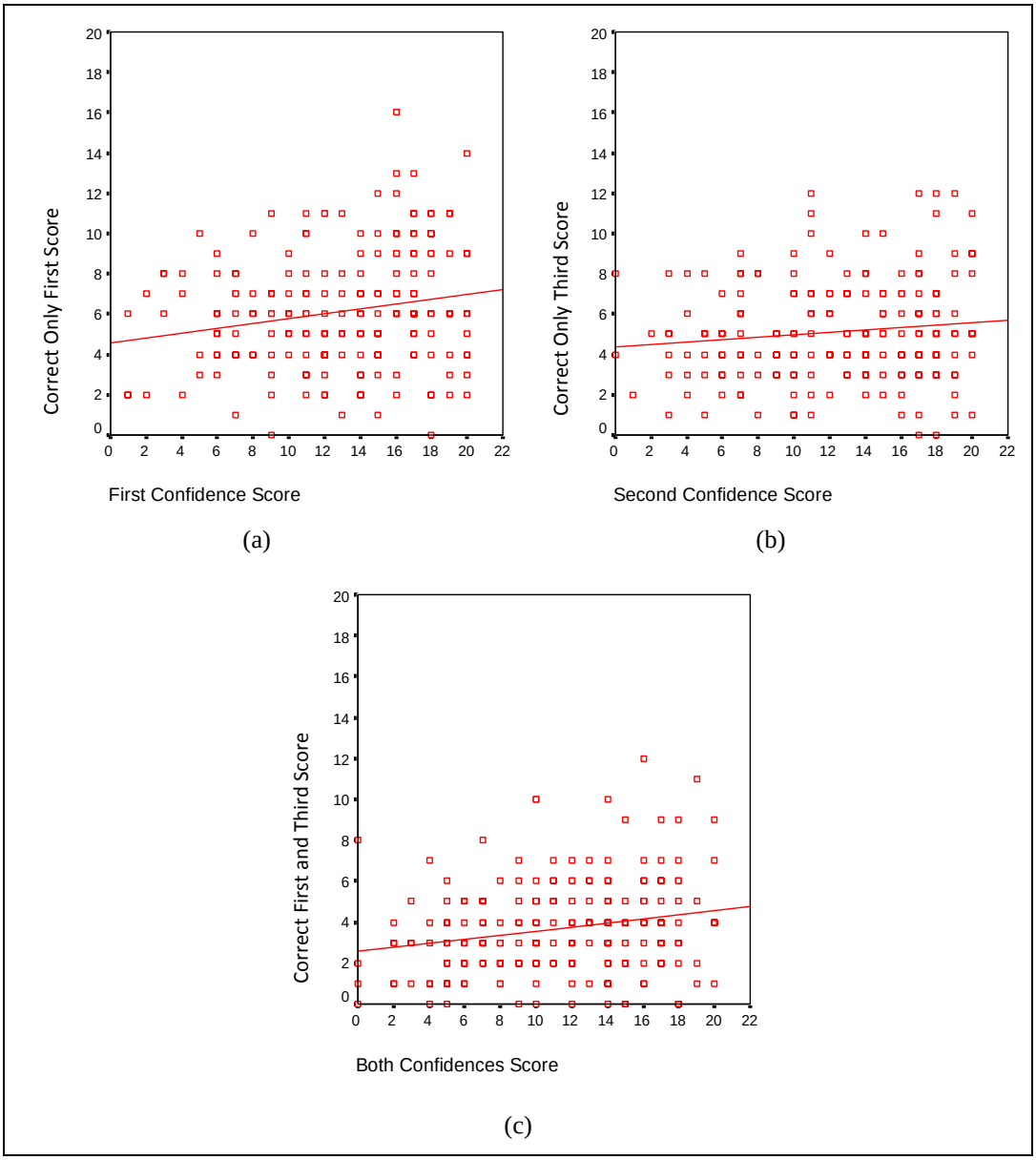


Figure 4.10 Scatter Plots of (a) Correct Only First Score vs. First Confidence Score; (b) Correct Only Third Score vs. Second Confidence Score; (c) Correct First and Third Score vs. Both Confidences Score

As mentioned in Chapter 2, women were found to be less confident than men in science, and this gender difference increases with age (Hyde, Fennema, & Lamon, 1990; Lundeberg & Moch, 1985 as cited in Lundeberg, Fox & Puncohar, 1994; Lundeberg et al., 2000). In order to investigate if gender is a possible factor for the low correlation between the scores mentioned above, some further analysis was performed beyond the research questions. First of all, an independent samples t-test was conducted to compare the mean

scores of two groups (i.e., males and females). The results were examined to determine whether there was a significant difference in the mean confidence scores (first confidence, second confidence, both confidences) for males and females.

- There is a significant mean difference between males (M = 14.36, SD = 3.84) and females (M = 12.14, SD = 4.98; t (208) = -3.66, p = .00 for) in their first confidence scores. The magnitude of the difference in the means is moderate (eta squared = .06).
- There is a significant mean difference between males (M = 14.22, SD = 4.38) and females (M = 11.55, SD = 5.13; t (201) = -4.06, p = .00) in their second confidence scores. The magnitude of the difference in the means is moderate (eta squared = .07).
- There is a significant mean difference between males (M = 12.86, SD = 4.44) and females (M = 10.42, SD = 5.12; t (211) = -3.61, p = .00) in both of their confidence scores. The magnitude of the difference in the means is moderate (eta squared = .06).

The eta squared statistics shows the effect size, which indicates the relative magnitude of the difference between means (Pallant, 2005). It can be calculated by the formula below:

$$\text{Eta squared} = \frac{t2}{t2+df} \qquad (2)$$

Cohen (1988, as cited in Pallant 2005) proposed a guideline in order to interpret the strength of eta squared (η) values:

η = .01 small effect

η = .06 moderate effect

η = .14 large effect

According to this guideline, the magnitude of the differences between the means of males and females are moderate for all the three confidence scores. So, similar to the previous studies mentioned in the literature, males are more confident in their responses than females for the FTGOT items. Since this is the case, the correlations between the subjects' correct scores and confidence scores were recalculated for the male and female subjects separately by splitting files in terms of gender. The results of the Pearson correlation analysis are given in Table 4.8 for male and female subjects separately.

Table 4.8 Correlations between Correct Only First Score and First Confidence Score; Correct Only Third Score and Second Confidence Score; Correct First and Third Score and Both Confidences Score for Male and Female Subjects Separately

		MALE	FEMALE
		First Confidence Score	**First Confidence Score**
Correct Only First Score	Pearson Correlation	.346*	.023
	Sig. (2-tailed)	.001	.798
	N	87	126
		Second Confidence Score	**Second Confidence Score**
Correct Only Third Score	Pearson Correlation	.318*	-.079
	Sig. (2-tailed)	.003	.376
	N	87	126
		Both Confidences Score	**Both Confidences Score**
Correct First and Third Score	Pearson Correlation	.364*	.061
	Sig. (2-tailed)	.001	.501
	N	87	126

*Correlation is significant at the 0.01 level (2-tailed)

The results showed that there are positive significant correlations for the male subjects, whereas no significant correlations exist for the female subjects between the all three correct scores and confidence scores. Therefore, the mis-calibration (i.e., the mismatch between the accuracy of the answers and the confidence) of female subjects might be one of the reasons for the small or no significant correlation between the correct scores and confidence scores for all subjects presented in Table 4.7.

Figure 4.11 illustrates the scatter plots of correct only first score and first confidence score; correct only third score and second confidence score; correct first and third score and both confidences score for the male and female subjects separately. As seen from the scatter plots male subjects with high scores on the FTGOT items are confident about their answers, whereas male subjects with low scores are not confident about their answers. This is an evidence for the construct validity of the FTGOT scores for males. As a personality trait, female subjects are generally less confident about their answers, which also holds true for the present sample of female students. As can be seen from the scatter plots, female subjects are confident when they have low scores, which might be due to their robust misconceptions. Also, they are not confident even when their score on the test is high, which might be due to their lack of knowledge. Another point that can be seen from the scatter plots is that for both

male and female subjects the number of subjects with high test scores are a low number, which is an indication that the test is rather difficult. As stated by Crocker and Algina (1986) “nearly all total test score parameters are affected by item difficulty” (p. 312). This might be another reason for the low Pearson correlation coefficients between the correct scores and confidence scores in the present study.

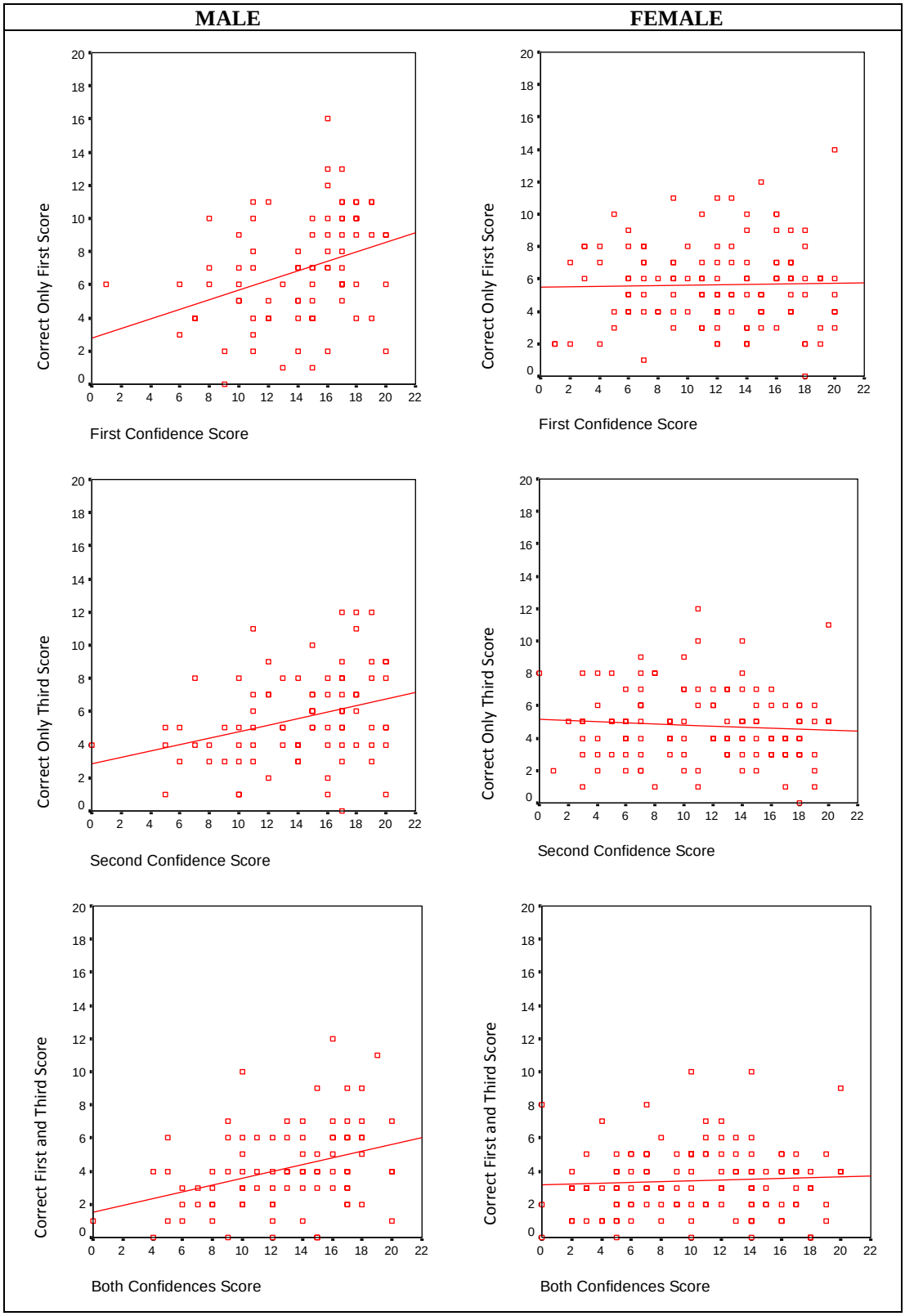


Figure 4.11 Scatter Plots of Only First Score vs. First Confidence Score; Correct Only Third Score vs. Second Confidence Score; Correct First and Third Score vs. Both Confidences Score for Male and Female Subjects Separately

4.4.2.2. Factor Analysis Results for the Correct Scores and Misconception Scores

One of the common uses of factor analysis is construct validation, that is obtaining evidence of convergent and discriminant validity by demonstrating that indicators of selected constructs load onto separate factors in the expected manner (Brown, 2006). Explanatory factor analysis is typically used earlier in the process of test development and for construct validation. In the present study, two explanatory factor analyses were conducted: one for the correct scores (in order to answer Research Question 1.d) and the other for the misconceptions scores (in order to answer Research Question 1.e). The first factor analysis for the correct scores was conducted because related items in the test would be expected to result in some acceptable factors. For the correct scores of total test items, correct scores of items according to the contexts (plane mirror, spherical mirror, lens), correct scores of items according to the cases (observing oneself, observing others), correct scores of ANDC1, ANDC2, ANDC4, ORC1, ORC2, ORC4, SUMC1, SUMC2, SUMC4 principal component factor analysis with varimax factor rotation were performed by using the SPSS program. The second factor analysis was conducted for the misconception scores to check whether possible related misconceptions result in some acceptable factors. This factor analysis was run over the misconception scores of ANDM1, ANDM2, ANDM4, ORM1, ORM2, ORM4, SUMM1, SUMM2, and SUMM4 by using principal component factor analysis with varimax factor rotation in the SPSS program. The details of the SPSS settings to conduct the factor analysis are given in Table 4.9.

Table 4.9 The SPSS Settings for Conducting Factor Analysis

Descriptives	Statistics	Univariate descriptives
		Initial solution
	Correlation Matrix	Coefficients
		Anti-image
		KMO and Bartlett's test of sphericity
Extraction	Method	Principal components
	Analyze	Correlation matrix
	Display	Unrotated factor solution
		Scree plot
	Extract	Eigenvalues over 1
Rotation	Method	Varimax
	Display	Rotated solution
Options	Exclude cases listwise	
	Coefficient display format	Sorted by size
		Suppress values less than .30

4.4.2.2.1. Factor Analysis Results for the Correct Scores

Over the correct scores 27 different factor analyses were conducted. The reason for conducting the factor analysis was to find evidence for the construct validity. It was expected that previously determined related items would result in some acceptable factors if the developed test actually measures the concepts it aims to measure. The factor analysis was conducted over the correct scores for the whole test items, as well as for each sub-context (plane mirror, spherical mirror, lens) and sub-cases (observing oneself, observing others), and for the tiers (only first tier, first and third tiers, all four tiers) separately. Also, correct scores coded with AND, OR, SUM functions were factor analyzed for each tier. The results were grouped and presented in Table 4.14 for ease of comparison.

It is cumbersome to write the whole factor analysis process for all of these 27 scores. Therefore, one of them is explained in detail here and the results of the rest of the correct scores have been summarized in Table 4.14.

To exemplify the factor analysis process, Total Test-Only First Tier Scores were chosen. In order to conduct the factor analysis on the Total Test-Only First Tier Scores, some assumptions were checked first. Pallant (2005) stated that the overall sample should be over 150 and there should be a ratio of at least five cases for each of the variables for conducting factor analysis. In the present study the sample size is 213, and there are 20 items inserted into the factor analysis for the correct scores analysis on the Total Test-Only First Tier Scores. Hence, the sample size of the study is suitable for conducting the factor analysis. Tabachnick and Fidell (2001, as cited in Pallant 2005) recommended an inspection of the correlation matrix for evidence of coefficients greater than .30. When the correlation matrix of the factor analysis conducted by using Total Test-Only First Tier Scores was examined, two of the 190 correlation coefficients were found to be over .30. According to Pallant (2005), if few correlations above this level are found, then factor analysis is appropriate.

The SPSS program also assesses the factorability of the data by two statistical measures: Bartlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) measures of sampling adequacy. Table 4.10 shows the KMO measures of sampling adequacy and Bartlett's test of sphericity for the subjects' scores. The KMO which is .61 is above the suggested value of .60 for a good factor analysis, and the probability ($p = .00$) associated with the Bartlett's test of sphericity is significant (i.e. $p < .05$). Therefore, it is rejected that the correlation matrix is an identity matrix. This result means that test items are generally not independent from each other (Peşman, 2005).

Table 4.10 The SPSS Output Showing KMO and Bartlett's Test for Correct Only First Tier Scores

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.613
Bartlett's Test of Sphericity	Approx. Chi-Square	407.731
	df	190
	Sig.	.000

When the measures of sampling adequacy (MSA) values and the anti-image correlation matrix diagonals were investigated, all were found to be greater than .50, which is the least acceptable value.

Items with communality values less than .50 were checked, and Items 3, 7, 8, 12, 14, 16, 18 were removed from the analysis. In order to conduct factor analysis, each item's communality value must be equal to or above .50. When the factor analysis was conducted with the remaining items, 6 factors yielded with only one item in the last factor. Therefore, Item 11 was also removed. Also, Item 4 was removed, since it had a negative factor loading value and an anti-image correlation matrix diagonal less than .50. The cumulative percent of variance was 54 % and by changing the eigenvalue from 1 to .9 the cumulative percent was increased. The factor analysis was run again, and yielded five factors.

As a result, the cumulative percent of variance was 63 %, which means these five factors explain a total of 63 % of the variance. The communalities of the last factor analysis were shown in Table 4.11. Also, Table 4.12 shows five factors obtained as a result of factor analysis. Factor loadings less than .30 are not shown in the table. It can be seen from the table that most of the items load quite strongly (above .40).

Table 4.11 The SPSS Output Showing Communalities for Correct Only First Tier Scores

Communalities		
	Initial	Extraction
Item 1	1.000	.762
Item 2	1.000	.655
Item 5	1.000	.631
Item 6	1.000	.636
Item 9	1.000	.604
Item 10	1.000	.506
Item 13	1.000	.571
Item 15	1.000	.521
Item 17	1.000	.583
Item 19	1.000	.725
Item 20	1.000	.707
Extraction Method: Principal Component Analysis.		

Table 4.12 The SPSS Output Showing the Rotated Component Matrix for Correct Only First Tier Scores

	Component				
	1	2	3	4	5
Item 20	.833				
Item 19	.813				
Item 15	.475			-.366	
Item 6		.785			
Item 5		.720			
Item 1			.844		
Item 2		.352	.716		
Item 9				.763	
Item 10			.308	.578	
Item 13					.694
Item 17					.681

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

a Rotation converged in 8 iterations.

The Scree plot provided by the SPSS in Figure 4.12, also supports five factors. As seen from the Scree plot, the last substantial decline in the magnitude of the eigenvalues happens after the fifth point.

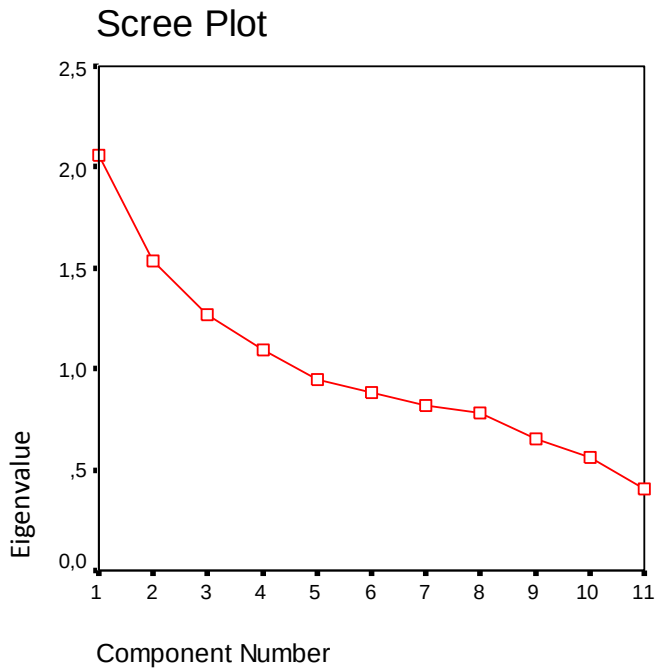


Figure 4.12 The SPSS Output Showing the Scree Plot

According to the result of the factor analysis Items 15, 19, 20; Items 5 and 6; Items 1 and 2; Items 9 and 10; Items 13 and 17 formed five factors. From these results, Table 4.13 was constructed in order to present the interpretations about each factor.

Table 4.13 Interpretation of the Factors Obtained from the Analysis of Correct Scores of Total Test-Only First Tier Scores

Factors	Items	Factor Name (Interpretation)
1	15, 19, 20	Items 19 and 20 require the subjects' understanding of observing oneself in the context of lenses. The formats of the items are very similar, but the optical instruments used vary in those two items. For a correct answer, subjects should realize that it is not possible to see oneself from a lens, because no light from own face can reach back to the eyes of the observer. Hence it is reasonable that these two items loaded into the same factor. However, it is not reasonable that Item 15 enters this factor. Cronbach alpha reliability for Items 19, 20, and 15 is .51, whereas for Items 19 and 20 is .70.
2	5, 6	Items 5 and 6 are both measuring the subjects' understanding of image observation in a plane mirror context. Item 5 is related to observing oneself, but Item 6 is related to observing someone else in a plane mirror. Both items were constructed in a similar format in which small mirror sizes are selected intentionally so that seeing the whole image of oneself or someone else is not possible. The subjects' reasoning for the ways to see the more of the body parts were asked and the ways to increase the observed part of the bodies from the plane mirror were expected. Cronbach alpha reliability for Items 5 and 6 is .43.
3	1, 2	Items 1 and 2 are related to the case of observing others in the context of plane mirror. Both items are measuring the image formation and observation processes in the plane mirror context when the observed objects are stationary whereas the observer is moving. The formats of the items are similar, but only the observers' moving path differs. In item 1 the observer moves parallel to the mirror. In Item 2, however, the observer moves perpendicular to the plane mirror. Cronbach alpha reliability for Items 1 and 2 is .51.
4	9, 10	Items 9 and 10 are both related to the case of observing oneself in the context of the spherical mirror. The formats of the both items are the same, only the mirrors where the observer who climbs a rope is trying to observe her image is changing (one is convex, the other is concave mirror). Cronbach alpha reliability for Items 9 and 10 is .51.
5	13, 17	Items 13 and 17 are in different contexts (Item 13 is in concave mirror and Item 17 is in converging lens contexts) but related to observing an object from an optical device which is partially covered with an opaque cardboard. Both of the items requires subjects to understand that the remaining uncovered parts of the optical instruments are enough for the image formation and observation, and as a result the entire images of the objects remain intact, but only their brightness decrease. Cronbach alpha reliability for Items 13 and 17 is .22.

The same procedures explained for the factor analysis of Correct Only First Tier Scores were performed for the other correct scores for different tiers. The results of the factor analyses were summarized in Table 4.14. The second column of the table shows the cumulative percentage of variance explained by the factors yielded as a result of the analysis. The third column represents the Cronbach alpha reliability of the all items in all of the yielded factors, whereas the sixth column represents that of the factors separately. In the fourth column the number of factors obtained as a result of the analysis, and in the fifth column the items loaded into each of the yielded factors are represented. The seventh column shows the total number of items that were entered into the factor analysis since some of the items had to be removed during the process according to the assumptions made in the factor analysis. Finally, the last column denotes the factor loadings of each item to the corresponding factor.

Table 4.14 Results of the Reliability and Factor Analysis of the Correct Scores

Correct Scores	% of Variance Explained	Reliability (croanbach alpha)	Number of Factors	Factors and their Items	Reliability of Factors	Total Number of Items	Factor Loadings of Each Item
Total Test-Only First Tier	63	.52	5	1. I20+I19+I15 2. I5+I6 3. I1+I2 4. I9+I10 5. I13+I17	1. .51 2. .43 3. .51 4. .30 5. .22	11	1. .833 + .813 + .475 2. .785 + .720 3. .844 + .716 4. .763 + .578 5. .694 + . 681
Total Test-First & Third Tiers	61	.50	5	1. I20+I19 2. I17+I13+I16 3. I1+I3 4. I8+I2 5. I4+I5	1. .65 2. .37 3. .19 4. .34 5. .33	11	1. .836 + .805 2. .749 + .585 + .538 3. .705 + .642 4. .815 + .563 5. .843 + .668
Total Test-All Four Tiers	53	.56	5	1. I5+I4+I6+I3 2. I17+I7+I12 3. I18+I11 4. I10+I13 5. I14+I8	1. .44 2. .27 3. .40 4. .39 5. .16	13	1. .774 + .563 + .512 + .508 2. .713 + .541 + .489 3. .756 + .675 4. .847 + .490 5. .777 + .562
Plane Mirror-Only First Tier	58	.57	2	1. I1+I2+I3 2. I6+I5	1. .52 2. .43	5	1. .814 + .632 + .627 2. .852 + .675

Table 4.14 Results of the Reliability and Factor Analysis of the Correct Scores (Cont'd)

Plane Mirror-First & Third Tiers	64	.29	3	1. I2+I3 2. I15+I14 3. I4+I5	1. .45 2. .37 3. .33	6	1. .834 + .718 2. .788 + .769 3. .838 + .685
Plane Mirror -All Four Tiers	52	.47	3	1. I3+I5+I2+I6 2. I14+I15 3. I1+I4	1. .47 2. .52 3. -.04	8	1. .675 + .634 + .611 + .439 2. 818 + .812 3. .798 + -.534
Spherical Mirror-Only First Tier	81	.36	3	1. I8+I9 2. I10 3. I13	1. .34 2. - 3. -	4	1. .877 + .631 2. .941 3. .997
Spherical Mirror-First & Third Tiers	-	-	-	No factors obtained. Communalities are below .50	-	-	-
Spherical Mirror-All Four Tiers	-	-	-	No factors obtained. Communalities are below .50	-	-	-
Lens-Only First Tier	75	.48	3	1. I20+I19+I16 2. I18 3. I17	1. .59 2. - 3. -	5	1. .857 + .851+ .503 2. .951 3. .929
Lens-First & Third Tiers	75	.65	1	1. I19+I20	1. .65	2	1. .864 + .864
Lens-All Four Tiers	-	-	-	Not factorable. KMO <.50	-	-	-
Observing Oneself-Only First Tier	66	.40	4	1. I20+I19 2. I9+I14+I10 3. I5+I3 4. I11	1. .70 2. .38 3. .41 4. -	8	1. .879 + .857 2. .724 + .648 + .571 3. .779 + .766 4. .901
Observing Oneself-First & Third Tiers	78	.38	4	1. I20+I19 2. I5+I10 3. I9 4. I14	1. .65 2. .23 3. - 4. -	6	1. .871 + .840 2. .880 + .557 3. .894 4. 983
Observing Oneself-All Four Tiers	74	.38	3	1. I20+I19 2. I5 3. I12+I14	1. .73 2. - 3. -.06	5	1. .887 + .875 2. .921 3. .786 + -.645
Observing Others-Only First Tier	68	.37	4	1. I2+I1 2. I16+I18+I13 3. I8 4. I4	1. .51 2. .30 3. - 4. -	7	1. .788 + .748 2. .812 + .576 + .431 3. .903 4. .911
Observing Others-First & Third Tiers	81	.26	3	1. I16+I13 2. I2 3. I6	1. .31 2. - 3. -	4	1. .886 + .590 2. .886 3. .974

Table 4.14 Results of the Reliability and Factor Analysis of the Correct Scores (Cont'd)

Observing Others- All Four Tiers	76	.34	4	1. I13 + I18 2. I6+I1 3. I4 4. I17	1. .32 2. .15 3. - 4. -	6	1. .748 + .533 2. .709 + .624 3. .720 4. -.628
ANDC1	There are fewer than two cases, at least one of the variables has zero variance, there is only one variable in the analysis, or correlation coefficients could not be computed for all pairs of variables. No further statistics will be computed.						
ANDC2	There are fewer than two cases, at least one of the variables has zero variance, there is only one variable in the analysis, or correlation coefficients could not be computed for all pairs of variables. No further statistics will be computed.						
ANDC4	There are fewer than two cases, at least one of the variables has zero variance, there is only one variable in the analysis, or correlation coefficients could not be computed for all pairs of variables. No further statistics will be computed.						
ORC1	83	.37	3	1. LOwn+LOth 2. POwn 3. Poth	1. .45 2. - 3. -	4	1. .832 + .771 2. .976 3. .982
ORC2	63	.41	3	1. LOth+LOwn 2. SOwn+SOth 3. Pown+POth	1. .37 2. .38 3. .29	6	1. .805 + .692 2. .836 + .574 3. .860 + .612
ORC4	66	.51	3	1. SOwn+Soth 2. Lown+LOth 3. Pown+POth	1. .50 2. .26 3. .39	6	1. .829 + .689 2. .779 + .615 3. .797 + .768
SUMC1	65	.45	2	1. POth+Pown 2. Loth+LOwn	1. .47 2. .40	4	1. .829 + .776 2. .835 + .740
SUMC2	63	.49	3	1. POth+ Pown 2. LOth+LOwn 3. SOwn+SOth	1. .48 2. .25 3. .36	6	1. .784 + .777 2. .782 + .652 3. .899 + .452
SUMC4	69	.58	2	1. POwn+Poth 2. SOwn+SOth	1. .54 2. .52	4	1. .842 + .772 2. .896 + .701

I#: Item number; POwn: plane mirror-observing oneself; POth: plane mirror-observing others; SOwn: spherical mirror-observing oneself; SOth: spherical mirror-observing others; LOwn: lens-observing oneself; LOth: lens-observing others

The correct scores for the total test items considering the only first tier, first and third tiers, and all four tiers produced meaningful factors with items loaded to the factors quite strongly (above .40). The reliability of the items constituting the factors increases for the all four tiers score, whereas the total variance explained decreases to 53 %. The interpretations of the factors for the total test scores for only the first tier were given previously in Table 4.13. The interpretations for the total test scores for the first and third tiers and all four tiers are given in Table 4.15.

Table 4.15 Interpretations of the Factors Obtained from the Analysis of Correct Scores of Total Test- First and Third Tiers, and All Four Tiers Scores

	Factors	Items	Factor Name (Interpretation)
Total Test-First and Third Tiers Score	1	19, 20	Items 19 and 20 require the subjects' understanding of observing oneself in the context of lenses. The formats of the items are very similar, but the optical instruments used vary in those two items. For a correct answer, subjects should realize that it is not possible to see oneself from a lens, because no light from own face can reach back to the eyes of the observer. Hence it is reasonable that these two items loaded into the same factor. Cronbach alpha reliability for Items 19 and 20 is .65.
	2	13, 16, 17	Items 13 and 17 are in different contexts (Item 13 is in concave mirror and Item 17 is in converging lens contexts) but related to observing an object from an optical device which is partially covered with an opaque cardboard. Both of the items requires subjects to understand that the remaining uncovered parts of the optical instruments are enough for the image formation and observation, and as a result the entire images of the objects remain intact, but only their brightness decrease. Items 16 and 17, however, are both related to observing others case in the converging lens context. Cronbach alpha reliability for all three items is .50.
	3	1, 3	Items 1 and 3 are both in the context of plane mirror. Item 1 is related to observing others, but Item 3 is related to observing oneself. Cronbach alpha reliability for Items 1 and 3 is .19.
	4	2, 8	Items 2 and 8 loaded to the same factor, but there is not a good interpretation exist to explain that relationship. Cronbach alpha reliability for Items 2 and 8 is .34.
	5	4, 5	Items 4 and 5 are both in the context of plane mirror. Item 4 is related to image formation and observation of others when there is an obstacle between the object and the mirror. Item 5, however, is related to observing oneself in the plane mirror context. Cronbach alpha reliability for Items 4 and 5 is .33.
	1	3, 4, 5, 6	All of the four items are in the context of plane mirror. Cronbach alpha reliability for Items 3, 4, 5, and 6 is .44.
	2	7, 12, 17	Items 7, 12, and 17 are loaded to the same factor, but there is not a good interpretation to explain that relationship. Cronbach alpha reliability for Items 7, 12, and 17 is .27.

Table 4.15 Interpretations of the Factors Obtained from the Analysis of Correct Scores of Total Test- First and Third Tiers, and All Four Tiers Scores (Cont'd)

	Factors	Items	Factor Name (Interpretation)
Total Test-All Four Tiers Score	3	11, 18	Items 11 and 18 are loaded to the same factor, but there is not a good interpretation exist to explain that relationship. Cronbach alpha reliability for Items 11 and 18 is .40.
	4	10, 13	Items 10 and 13 are both in the spherical mirror context. Item 10 is related to observing oneself in the convex mirror context, whereas Item 13 is related to observing another object in the concave mirror some part of which is covered with an opaque cardboard. Cronbach alpha reliability for Items 10 and 13 is .39.
	5	8, 14	Items 8 and 14 are loaded to the same factor, but there is not a good interpretation exist to explain that relationship. Cronbach alpha reliability for Items 8 and 14 is .16.

The factor analysis results for the correct scores for the three contexts separately according to its tiers are also given in Table 4.14. Two of the scores for the spherical mirror context (spherical mirror-first and third tiers; spherical mirror-all four tiers) did not yield factors since the communalities, which represent the proportion of the variance for each of the variables included in the analysis that is explained by the components in the factors, are not higher than .50. Also, Lens-All Four Tier scores do not form any factors, since the KMO value was found to be less than .50 which shows that the scores are not factorable. Item 4 loaded negatively into the last factor of Plane mirror-All Four Tiers Score. Factor loadings are the weights and correlations between each variable and the factor. A negative value indicates an inverse impact on the factor. For instance; in calculating the factor scores, the score coming from this negatively loaded item should be subtracted rather than added in the computations. The factors obtained for the rest of the scores are interpreted and presented in Table 4.16.

Table 4.16 Interpretation of the Factors Obtained from the Analysis of Correct Scores According to Their Contexts

	Factors	Items	Factor Name (Interpretation)
Plane Mirror-Only First Tier Score	1	1, 2, 3	The formats of the Items 1, 2, and 3 are in common. The Items 1 and 2 are related to observing others, whereas Item 3 is related to observing oneself in the context of plane mirror. The observer is moving in all of the items while observing the image from the mirror. Cronbach alpha reliability for Items 1, 2, and 3 is .52.
	2	5, 6	The Item 5 is related with observing oneself, but Item 6 is related to observing someone else in a plane mirror. Both items were constructed in a similar format in which small mirror sizes are selected intentionally so that seeing the whole image of oneself or someone else is not possible. The subjects' reasoning for the ways to see the more of the body parts were asked and the ways to increase the observed part of the bodies from the plane mirror were expected. Cronbach alpha reliability for Items 5 and 6 is .43.
Plane Mirror-First and Third Tiers Score	1	2, 3	The formats of the Items 2 and 3 are in common. The Item 2 is related to observing others, but Item 3 is related to observing oneself. Cronbach alpha reliability for Items 1 and 3 is .45.
	2	14, 15	Both Items 14 and 15 are related to the image formation and observation in the hinged plane mirrors. The correct understanding of the items requires the simultaneity of image formation and observation for plane mirrors, the dependence of number of images formed and observed to the location of the object and observer as well as the angle between the plane mirrors. Cronbach alpha reliability for Items 14 and 15 is .37.
	3	4, 5	Items 4 and 5 loaded to the same factor, but there is not a good interpretation exist to explain that relationship. Cronbach alpha reliability for Items 14 and 15 is .33.
Plane Mirror-All Four Tiers Score	1	2, 3, 5, 6	All Items 2, 3, 5, and 6 loaded to the same factor, but there is not a good interpretation exist to explain that relationship. Cronbach alpha reliability for Items 14 and 15 is .47.
	2	14, 15	Both Items 14 and 15 are related to the image formation and observation in the hinged plane mirrors. The correct understanding of the items requires the simultaneity of image formation and observation for plane mirrors, the dependence of number of images formed and observed to the location of the object and observer as well as the angle between the plane mirrors. Cronbach alpha reliability for Items 14 and 15 is .52.

Table 4.16 Interpretation of the Factors Obtained from the Analysis of Correct Scores According to Their Contexts (Cont'd)

	Factors	Items	Factor Name (Interpretation)
	3	1, 4	Items 1 and 4 are both related to observing others in plane mirrors, and no other interpretation to explain that relationship can be found. The loading of Item 4 is negative. Cronbach alpha reliability for Items 1 and 4 is -.04.
Spherical Mirror-Only First Tier Score	1	8 ,9	Items 8 and 9 are in the same format, but differ in their cases. Item 8 asks for observing other objects as an observer climbs a rope in the context of concave mirror, and Item 9 asks for observing oneself for exactly the same situation. Cronbach alpha reliability for Items 8 and 9 is .34.
	2	10	A single item.
	3	13	A single item.
Lens-Only First Tier Score	1	16, 19, 20	Items 19 and 20 require the subjects' understanding of observing oneself in the context of lenses. The formats of the items are very similar, but the optical instruments used vary in those two items. However, it is not reasonable that Item 16 enters this factor. Cronbach alpha reliability for Items 16, 19, and 20 is.59.
	2	18	A single item.
	3	17	A single item.
Lens-First and Third Tiers Score	1	19, 20	Items 19 and 20 require the subjects' understanding of observing oneself in the context of lenses. The formats of the items are very similar, but the optical instruments used vary in those two items. For a correct answer, subjects should realize that it is not possible to see oneself from a lens, because no light from own face can reach back to the eyes of the observer. Cronbach alpha reliability for Items 19 and 20 is .65.

The factor analysis results for the correct scores of the two cases (observing oneself, observing others) on the tiers of interest are also given in Table 4.14. In each of the factor analyses at least one factor contains only one item and the reliabilities of the factors are low compared to the previous correct scores (correct scores for the total test or for the contexts). The factors obtained for the correct scores according to the cases are interpreted and presented in Table 4.17.

Table 4.17 Interpretation of the Factors Obtained from the Analysis of Correct Scores According to Their Cases

	Factors	Items	Factor Name (Interpretation)
Observing Oneself-Only First Tier Score	1	19, 20	Both Item 19 and 20 are in the lens context. The formats of the items are the same. Cronbach alpha reliability for Items 19 and 20 is .70.
	2	9, 10, 14	The Items 9 and 10 are the same in their format, and also in their contexts. Both are in the spherical mirror context in which an observer tries to observe her own image as she climbs the rope. In Item 9 the mirror is a concave mirror, whereas in Item 10 it is a convex mirror. The Item 14, however, is in the hinged mirror context and no relation with the other two items is detected. Cronbach alpha reliability for Items 9, 10, and 14 is .38.
	3	3, 5	Both items are in the plane mirror context. Cronbach alpha reliability for Items 3 and 5 is .41.
	4	11	A single item.
Observing Oneself -First and Third Tiers Score	1	19, 20	Both Item 19 and 20 are in the lens context. The formats of the items are the same. Cronbach alpha reliability for Items 19 and 20 is .65.
	2	5, 10	Both Items 5 and 10 loaded to the same factor, but there is not a good interpretation to explain that relationship. Cronbach alpha reliability for Items 5 and 10 is .23.
	3	9	A single item.
	4	14	A single item.
Observing Oneself - All Four Tiers Score	1	19, 20	Both Item 19 and 20 are in the lens context. The formats of the items are the same. Cronbach alpha reliability for Items 19 and 20 is .73.
	2	5	A single item.
	3	12, 14	Both Items 12 and 14 loaded to the same factor, but there is not a good interpretation to explain that relationship. Cronbach alpha reliability for Items 12 and 14 is -.06.
Observing Others -Only First Tier Score	1	1, 2	The formats of the Items 1 and 2 are in common. They are both in the context of plane mirror. The observer is moving in both of the items while observing the image of objects from the mirror. Cronbach alpha reliability for Items 1 and 2 is .51.
	2	13, 16, 18	Items 16 and 18 are in the lens context, but Item 13 is in spherical mirrors. Not a good interpretation to explain the relationship between the items can be made. Cronbach alpha reliability for Items 13, 16, and 18 is .30.
	3	8	A single item.
	4	4	A single item.

Table 4.17 Interpretation of the Factors Obtained from the Analysis of Correct Scores According to Their Cases (Cont'd)

	Factors	Items	Factor Name (Interpretation)
Observing Others – First and Third Tiers Score	1	13, 16	Not a good interpretation exists to explain the relationship between the items can be made. Cronbach alpha reliability for Items 13 and 16 is .31.
	2	2	A single item.
	3	6	A single item.
Observing Others- All Four Tiers Score	1	13, 18	Not a good interpretation exists to explain the relationship between the items can be made. Cronbach alpha reliability for Items 13, 16, and 18 is .32.
	2	1, 6	Both Item 1 and Item 6 are in the plane mirror context, but the formats of the items are quite different. Cronbach alpha reliability for Items 1 and 6 is .15.
	3	4	A single item.
	4	17	A single item.

A new coding was used, which we call AND, OR, SUM functions. There are six variables produced for each of the functions for the correct scores as: plane mirrors-observing oneself, plane mirrors-observing others, spherical mirrors-observing oneself, spherical mirrors-observing others, lenses-observing oneself, lenses-observing others. AND scores were for whether a subject has a correct answer for every item in a specific variable. OR scores were for whether a subject has a correct answer at least in one situation. SUM scores were for summing the cases of correct answers for the items in a specified variable. The factor analysis results for those newly coded scores were also shown in Table 4.14. Since the spread of scores is very low for the AND scores, the factor analysis statistics could not be computed by the SPSS for each of the tier analyses. OR and SUM functions of the correct scores for different tiers (only first, first and third, and all four tiers) yielded some factors that are discussed in Table 4.18. In all of the yielded factors, the same contexts were grouped together, which is a good indicator of the construct validity.

Table 4.18 Interpretation of the Factors Obtained from the Analysis of Correct Scores Coded with AND, OR, SUM Functions

	Factors	Items	Factor Name (Interpretation)
OR-Only First Tier Score (ORC1)	1	LOwn, LOth	Both are in the same context which is lenses. Cronbach alpha reliability for the variables is .45.
	2	POwn	A single item.
	3	POth	A single item.
OR -First and Third Tiers Score (ORC2)	1	LOth, LOwn	Both are in the same context which is lenses. Cronbach alpha reliability for the variables is .37.
	2	SOwn, SOth	Both are in the same context which is spherical mirrors. Cronbach alpha reliability for the variables is .38.
	3	POwn, POth	Both are in the same context which is plane mirrors. Cronbach alpha reliability for the variables is .29.
OR -All Four Tiers Score (ORC4)	1	SOwn, SOth	Both are in the same context which is spherical mirrors. Cronbach alpha reliability for the variables is .50.
	2	LOwn, Loth	Both are in the same context which is lenses. Cronbach alpha reliability for the variables is .26.
	3	Pown, POth	Both are in the same context which is plane mirrors. Cronbach alpha reliability for the variables is .39.
SUM-Only First Tier Score (SUMC1)	1	POth, POwn	Both are in the same context which is plane mirrors. Cronbach alpha reliability for the variables is .47.
	2	LOth, LOwn	Both are in the same context which is lenses. Cronbach alpha reliability for the variables is .40.
SUM– First and Third Tiers Score (SUMC2)	1	POth, Pown	Both are in the same context which is plane mirrors. Cronbach alpha reliability for the variables is .48.
	2	LOth, LOwn	Both are in the same context which is lenses. Cronbach alpha reliability for the variables is .25.
	3	SOwn, SOth	Both are in the same context which is spherical mirrors. Cronbach alpha reliability for the variables is .36.
SUM- All Four Tiers Score (SUMC4)	1	POwn, POth	Both are in the same context which is plane mirrors. Cronbach alpha reliability for the variables is .54.
	2	Sown, SOth	Both are in the same context which is spherical mirrors. Cronbach alpha reliability for the variables is .52.

4.4.2.2.2. Factor Analysis Results for the Misconception Scores

For the misconception scores nine different factor analyses were conducted. The misconception scores were coded with AND (in all items), OR (in at least one of the items), SUM (the number of cases) functions, and factor analyses were conducted over those scores. The results of the factor analysis are presented in Table 4.19. The spread of the misconception scores for the AND function is very low, which therefore did not allow the factor analysis program to conduct statistics.

Compared to the correct scores discussed previously, Cronbach alpha reliabilities for the misconception scores are quite low or even negative. Since Cronbach alpha is a measure of internal consistency, that is, how closely related a set of misconceptions are as a group, the low values show the low relation between the misconceptions and also is a measure of multidimensionality of the test. The interpretation of the factors that are obtained for the misconception scores are given in Table 4.20. In the only first-tier factor analysis results, most of the misconceptions that loaded to the same factor have some common item choices according to the first tier. This is the main reason why they are grouped together. For the first and third tiers, and all four tiers, however, some interesting factors were found for ORM2 and SUMM4. The factor with M1 and M2 of ORM2 score and the factor with M7 and M12 of SUMM4 scores are both related to the presence of no obstacle between the object and the optical instrument or to the object being in front of the optical instrument.

Table 4.19 Results of the Reliability and Factor Analysis of the Misconception Scores

	% of Variance Explained	Reliability (croanbach alpha)	Number of Factors	Factors and their Misconceptions	Reliability of Factors (pearson correlation)	Total Number of Misconceptions	Factor Loadings of Each Misconception
ANDM1	There are fewer than two cases, at least one of the variables has zero variance, there is only one variable in the analysis, or correlation coefficients could not be computed for all pairs of variables. No further statistics will be computed.						
ANDM2	There are fewer than two cases, at least one of the variables has zero variance, there is only one variable in the analysis, or correlation coefficients could not be computed for all pairs of variables. No further statistics will be computed.						
ANDM4	There are fewer than two cases, at least one of the variables has zero variance, there is only one variable in the analysis, or correlation coefficients could not be computed for all pairs of variables. No further statistics will be computed.						
ORM1	72	.10	8	1. M14+M13+M15 2. M11+M5+M6 3. M20+M3+M21 4. M10+M8 5. M7+M2 6. M18 7. M9 8. M4	1. -.17 2. .70 3. .14 4. -.62 5. .29 6. - 7. - 8. -	16	1. .884 + .881 + -.707 2. .931 + .930 + .436 3. .777 + .654 + -.487 4. -.777 + .742 5. .766 + .766 6. .882 7. .891 8. .922
ORM2	65	-.002	4	1. M18 + M7 2. M20+M6 3. M12 4. M1+M2	1. -.40 2. .20 3. - 4. .15	7	1. .789 + -.657 2. .836 + .598 3. .841 4. .733 + .712
ORM4	72	.45	6	1. M4+M7+M1 2. M2 3. M21+M14 4. M5+M10 5. M9 6. M12	1. .41 2. - 3. .33 4. .31 5. - 6. -	10	1. .758 + .722 + .512 2. .819 3. .809 + .603 4. .835 + .671 5. .903 6. .932
SUMM1	66	.16	2	1. M11+M5+M6 2. M20+M21+M1	1. .76 2. -.80	6	1. .942 + .932 + .630 2. .777 + -.775 + .766
SUMM2	There are fewer than two cases, at least one of the variables has zero variance, there is only one variable in the analysis, or correlation coefficients could not be computed for all pairs of variables. No further statistics will be computed.						
SUMM4	76	.35	4	1. M11+M5 2. M14+M18 3. M7+M12 4. M19	1. .91 2. .27 3. .18 4. -	7	1. .948 + .936 2. .822 + .683 3. .832 + .646 4. .875

Table 4.20 Interpretation of the Factors Obtained from the Analysis of Misconception Scores Coded with AND, OR, SUM Functions

	Factors	Misconceptions	Factor Name (Interpretation)
OR-Only First Tier Score (ORM1)	1	13, 14, 15	All three misconceptions are related to the same items which are asking for the ways to increase the size of the observed image from the plane mirror.
	2	5, 6, 11	All three misconceptions include the reasoning for the thought that an observer can see an object or herself all along her way.
	3	3, 20, 21	All three misconceptions are related to the plane mirrors, mostly with hinged plane mirrors. All of them are for the subjects' explanations for the number of images formed or observed in a hinged plane mirror.
	4	8, 10	Not a good interpretation to explain the relationship between the misconceptions can be made.
	5	2, 7	Misconception 2 and Misconception 7 have common reasoning that when there is an obstacle between the object and optical device the image is not formed.
	6	18	A single item.
	7	9	A single item.
	8	4	A single item.
OR -First and Third Tiers Score (ORM2)	1	7, 18	Not a good interpretation exists to explain the relationship between the misconceptions can be made.
	2	6, 20	Not a good interpretation exists to explain the relationship between the misconceptions can be made.
	3	12	A single item.
	4	1, 2	Misconception 1 signifies that in order to see/form an image object should be within the borders of the optical instrument. Misconception 2 signifies, however, there should not be an obstacle between the object and the optical instrument to see/form image of it. These two misconceptions share something common, such that the object should be directly in front of the mirror to be seen/formed image.

Table 4.20 Interpretation of the Factors Obtained from the Analysis of Misconception Scores Coded with AND, OR, SUM Functions (Cont'd)

	Factors	Misconceptions	Factor Name (Interpretation)
OR -All Four Tiers Score (ORM4)	1	1, 4, 7	Not a good interpretation exists to explain the relationship between the misconceptions can be made.
	2	2	A single item.
	3	14, 21	Not a good interpretation exists to explain the relationship between the misconceptions can be made.
	4	5, 10	Not a good interpretation exists to explain the relationship between the misconceptions can be made.
	5	9	A single item.
	6	12	A single item.
SUM-Only First Tier Score (SUMM1)	1	5, 6, 11	All three misconceptions include the reasoning for the thought that an observer can see an object or herself all along her way.
	2	1, 20, 21	Misconceptions 20 and 21 are both related to the image formation and observation in hinged plane mirrors, but not a good interpretation found to explain the relationship between the Misconception 1 and the other two.
SUM- All Four Tiers Score (SUMM4)	1	5, 11	Both misconceptions include the reasoning for the thought that an observer can see an object or herself all along her way.
	2	14, 18	Not a good interpretation exists to explain the relationship between the misconceptions can be made.
	3	7, 12	All item choices in Misconception 12 and some item choices in Misconception 7 are related to the image formation/observation in the presence of some obstacles.
	4	19	A single item.

4.4.2.3. Proportion of False Positives, False Negatives, and Lack of Knowledge

Fraenkel and Wallen (2000) proposed that "the drawing of correct conclusions based on the data obtained from an assessment is what validity is all about" (p.169). Therefore, the main question to answer is "how accurate is this measure for our intended purpose?". Hestenes and Halloun (1995) suggested that estimation of the probability of false positives and false negatives in order to get evidence for the content validity of a test score. According to them, in order to establish content validity, the proportions of false positives and false negatives should be minimized. They conducted follow-up interviews for determining the proportions of wrong answer with correct reasoning (false negative) and correct answer with wrong reasoning (false positive). However, interviewing all the students who took the test requires time and effort. On the other hand, the multiple tier tests provide a great advantage for estimating those proportions from the students' own responses to the test.

Additionally, as Hasan et al. (1999) emphasized, the differentiation of lack of knowledge from misconceptions is crucial, since they require different instructional practices. As the aim of the FTGOT was to assess the misconceptions of the subjects, not the lack of knowledge, estimating the proportion of lack of knowledge becomes important for obtaining evidence for the content validity of the test scores.

The proportions of false positives, false negatives, and the lack of knowledge on the FTGOT were estimated by using the MS Excel program (in order to answer Research Question 1f). In order to compute the proportion of lack of knowledge, students' responses to the first and third tiers and all four tiers were used. In order to find the proportions for the lack of knowledge for each item, the proportions of correct responses of all four tiers were subtracted from the proportions of correct responses of first and third tiers for each item. In order to compute the lack of knowledge proportion, the proportions for first and third tiers and all four tiers for correct scores in Figure 4.6 was used.

For computing the proportions of false negatives and false positives, only answers without lack of knowledge were considered, i.e., they were computed over the students' scores who were "Totally sure" or "Sure" about their answers in the first and third tiers of the test (see Table 1.3 for details). A student who chose the correct answer for the first tier and the wrong answer for the third tier when he is "Totally sure" or "Sure" about on both of the tiers was coded as "1" indicating false positive. However, in eight of the items (Items 1, 5, 6, 7, 8, 14, 15, 20), choice of some correct-wrong selections in the first and third tiers corresponds to misconceptions, instead of false positives. Therefore, these selections were excluded from the false positive calculations. To illustrate this for Item 14, if a student

selects the choice “d” for the first tier and selects “a” for the third tier and is sure about both answers, he would then be given a misconception point (see M20 from Appendix V). Even though the answer “d” for the first tier of this item is a correct response, the student’s correct-wrong selection for this particular case is not labeled as a false positive, but as a misconception. For the false negatives, a student who chooses wrong answer for the first tier and correct answer for the third tier, when “Totally sure” or “Sure” on both of the tiers was coded as “1”. Summing these false positive and false negative values for all subjects gives the total number of false positives and false negatives for each item and on average. By considering the sample size (213), the proportions of false positives and false negatives for each item and on average were calculated.

The results of the analysis for the percentages of false positives, false negatives and lack of knowledge are given in Table 4.21. The mean proportion of the false positives was estimated as 3.5 % and of the false negatives as 3.3 %. The mean proportions of both false positive and false negatives are below 10 %, which was recommended by Hestenes and Halloun (1995). When the percentages of the false positives are checked for each item, none of them are found to be so high. In checking false negatives for each item, however, Items 2 and 4 are identified as being above 10 %, but much above. Hestenes and Halloun (1995) attributed the false negatives to carelessness or inattention and claimed that the minimization of them is less difficult compared to false positives. Therefore, low percentages of false positives and false negatives would be good evidence for the content validity of the FTGOT test scores.

Additionally, the mean proportion of lack of knowledge is found to be 5.1 %. The proportions of lack of knowledge were calculated from the difference between subjects’ percentages of correct responses for the first and third tiers scores and all four tier scores from Figure 4.15. Although, as stated by Peşman and Eryılmaz (2010), the high proportion of lack of knowledge is reasonable owing to the nature of misconception tests and the deficiencies in the instructions given. The proportion of lack of knowledge is not so high for the present study. Only Items 9, 10, 13, and 18 are the ones with the lack of knowledge percentages about 10 %. The high proportion of lack of knowledge for these items might stem from the contexts of the items, since they are all not familiar types of questions for the subjects. During the interviews, most of the participants struggled with those questions, too. For instance in Items 9 and 10, the interview participants were not able to draw a normal line to the border of the spherical mirror and said it was the first time they were thinking about that kind of question. Another reason for the high lack of knowledge for those items might be due to their difficulty, which will be discussed in the following sub-sections.

Table 4.21 The Percentages of False Positives, False Negatives, and Lack of Knowledge on the FTGOT for Correct Scores

	Items (%)																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	**M**	**SD**
False Positives	7	3	4	0	8	2	0	5	1	8	0	2	0	8	6	1	2	3	5	5	3.5	2.8
False Negatives	2	12	4	13	6	6	3	1	3	0	4	4	0	0	0	2	1	1	2	1	3.3	3.7
Lack of Knowledge	4	6	5	4	3	4	5	5	12	8	3	2	9	1	5	5	5	8	3	5	5.1	2.6

4.4.2.4. Reliability of the Scores

Cronbach alpha coefficient (α) was calculated as a measure of the internal consistency of the test scores. A reliability coefficient α generally has values $0 \leq \alpha \leq 1$. The larger the value of α, the larger the reliability of the test scores. For the FTGOT scores, the reliability coefficients were calculated separately for both correct and misconception scores of only first tier, first and third tiers, and for all four tiers for AND, OR, SUM functions in order to provide a comparison (in order to answer Research Question 1.g). The SPSS program was used to calculate the reliability coefficients, but the results were double checked with the outputs of the ITEMAN program used for the item analysis.

The results of the reliability analysis for the correct scores are presented in Table 4.22. The reliability of the correct scores was calculated for the only first tier scores, first and third tiers scores, and all four tier scores separately, and .55, .49, .59 coefficient alpha reliabilities obtained, respectively. Thus, at least 59 % of the total score variance of all four tiers correct score is due to the true score variance (Crocker & Algina, 1986). The spread of the scores, as does the standard deviation, reduces from the one tier to four tiers score analysis, which causes the reliability to decrease. However, at the same time from one tier to four tiers scoring, the test scores' validity increases (i.e., they truly measure what they intended to measure) and so does the reliability. Also there are some other factors, such as the multidimensionality of the test, the difficulty indices of the items that might be responsible for the non-systematic change in the reliability coefficients when different tiers are taken into consideration.

Crocker and Algina (1986) stated that it would be more reasonable for criterion-referenced tests to determine statistics for each cluster of items that measures a common objective. For this reason, the correct scores were clustered according to the Table of Specification prepared by the researcher (see Appendix S): first according to their contexts (plane mirror, spherical mirror, lens) and second according to the cases (observing oneself, observing others). The Cronbach alpha coefficients for each of the clusters were calculated. Considering the only first tier scores, the reliability coefficients were estimated to be higher when the scores were grouped according to their contexts and cases. For instance, the coefficients indicate that the use of the items related to the plane mirror context for assessing subjects' qualitative understanding in geometrical optics yielded reliable results with reliability coefficient of .72. Whereas including all test items for the only first tier reliability calculation yields a lower reliability, .55. On the contrary, the same is not true for the all four

tiers scores. Using all test items yields more reliable results compared to the ones grouped according to the contexts and cases for all four tiers scores.

Table 4.22 Cronbach Alpha Reliabilities for Correct Scores

	Reliability (Coefficient Alpha)								
	Total	Context			Case		AND-OR-SUM		
Correct Scores	Total Test	Plane Mirror	Spherical Mirror	Lens	Observing Oneself	Observing Others	AND	OR	SUM
Only First Tier	.55	.72	.77	.77	.77	.78	.14	.39	.53
First and Third Tiers	.49	.35	.28	.37	.28	.33	-.03	.41	.49
All Four Tiers	.59	.47	.40	.31	.31	.47	-.02	.51	.58

The results of the reliability analysis for the misconception scores are shown in Table 4.23. Similarly, the reliability of the misconception AND, OR, SUM scores were calculated for the only first tier, first and third tiers, and all four tiers separately. The reliability coefficients are higher for all four tier scores than either the only first tier or the first and third tiers scores. This might be related to the increase in the validity of the test scores. Interestingly, some of the reliability coefficients are found to be negative. According to Nichols (1999) α is negative whenever the sum of the individual item variances is greater than the scale variance, or in other words, whenever the average covariance among the items is negative. This might stem from several possibilities such as; the wrongly coding of some items that are worded in opposite directions; small sample size, small number of items, or the case that the items do not truly have positive covariances, and therefore do not form a useful single scale because they are not measuring the same thing.

Table 4.23 Cronbach Alpha Reliabilities for Misconceptions Scores

Misconception Scores	Reliability (Coefficient Alpha)		
	AND	OR	SUM
Only First Tier	-.20	.13	-.29
First and Third Tiers	.02	.20	.06
All Four Tiers	.08	.46	.42

The reliability coefficients calculated over the misconceptions scores are generally low compared to the ones over correct scores. Haladayna (1997) stated that:

> "Reliability strongly rests on a foundation of highly discriminating items. If items are highly discriminating and test scores vary, you can bet that the reliability coefficient will be high" (p. 248).

Hence, a discrimination index analysis was done to investigate whether the test items were able to discriminate high scorer and low scorer subjects on the misconceptions defined. The discrimination indexes were generally found low, which means the subjects are homogeneous with respect to pre-defined misconceptions in geometrical optics. No matter whether high scorer or low scorer, misconceptions are quite common among subjects. Item discrimination indices will be discussed in the next sub-section.

4.4.3. Item Analysis

Item difficulty levels and item discrimination indexes on the FTGOT were produced by using the ITEMAN program (in order to answer Research Question 1.h). Table 4.24 shows average item difficulty levels for the correct and misconception scores. For the FTGOT scores, the item difficulty levels were calculated separately for misconception scores of only first tier, first and third tiers, and all four tiers for AND, OR, SUM functions in order to provide a comparison. For correct scores the indexes were calculated for the whole scores, as well as for the context (plane mirror, spherical mirror, lens) and case (observing oneself, observing others) subcategories separately for only first tier, first and second tiers, and all four tiers. The difficulty levels were found to decrease from only first tiers to all four tiers, which was quite reasonable. Since the proportions of correct answers are decreasing from a one-tier to four-tiers scoring. This decrease is related to the inclusion of the false positives and lack of knowledge proportions in the correct answers proportions in the only first tier scores, which overestimates the proportions of correct answers. In the FTGOT wrong

answers are more important than correct answers, and the test has very strong distracters. This is the primary reason that most of the items are very difficult.

Table 4.24 Difficulty Levels of Correct and Misconception Scores

	Correct Scores									Misconception Scores		
	Total	Context			Case		AND-OR-SUM			AND-OR-SUM		
Tiers	Total Test	Plane Mirror	Spherical Mirror	Lens	Observing Oneself	Observing Others	AND	OR	SUM	AND	OR	SUM
Only First Tier	.31	.79	.55	.50	.64	.63	.04	.61	.29	.09	.60	.29
First and Third Tiers	.18	.23	.19	.12	.18	.19	.01	.46	.17	.03	.35	.15
All Four Tiers	.13	.18	.12	.06	.13	.13	.0	.34	.12	.02	.23	.09

The average discrimination indexes for the correct scores and misconceptions scores can be seen from Table 4.25. This index was estimated by point-biserial coefficients for the individual items and mean item-total coefficient for the average by using the ITEMAN program. However, the discrimination index for misconception SUM scores was calculated by using MS Excel since the ITEMAN program only calculates a discrimination index for dichotomously scored items. Discrimination indices over correct scores are quite larger than the ones for the misconception scores, which indicate that misconceptions are quite pervasive among high scorers as well as low scorers. As mentioned before, this might be one of the reasons for the low reliability coefficients obtained for the misconceptions scores. The average item discrimination indexes for all four tiers scores range from .13 to .52, and that means an average item on the test is quite discriminatory.

Table 4.25 Discrimination Indexes of Correct and Misconception Scores

Tiers	Correct Scores									Misconception Scores		
	Total	Context			Case		AND-OR-SUM			AND-OR-SUM		
	Total Test	Plane Mirror	Spherical Mirror	Lens	Observing Oneself	Observing Others	AND	OR	SUM	AND	OR	SUM
Only First Tier	.32	.58	.65	.72	.59	.55	.43	.50	.36	.21	.23	.12
First and Third Tiers	.29	.40	.42	.54	.37	.35	.50	.50	.27	.24	.24	.11
All Four Tiers	.32	.42	.45	.52	.38	.38	.66	.53	.25	.28	.28	.13

4.4.4. Descriptive Statistics Results of the FTGOT

The overall descriptive statistics for the correct and misconception scores were analyzed by SPSS and ITEMAN programs. Table 4.26 summarizes the descriptive statistics for correct and misconception scores for all four tiers scores. The means of the scores for different scoring types differ, but they are all quite low (mean of correct scores is 2.65 out of 20; mean of correct-AND, OR, SUM scores are .03, 2.04, .73 out of 6; mean of misconception-AND, OR, SUM scores are .38, 4.84, 1.98 out of 21, respectively). The standard deviations are 2.17 for correct scores; .17, 1.42, .64 for correct-AND, OR, SUM scores; .60, 2.40, 1.09 for misconception-AND, OR, SUM scores, respectively. The standard deviation shows how spread out the scores are throughout the distribution. Such small values obtained for the standard deviations in the present study show that the scores are not spread sufficiently. This might be one of the reasons for the small reliability coefficients discussed earlier. Actually, all these results can be associated with the nature of diagnostic tests since the alternatives were carefully constructed according to the most pervasive misconceptions of the subjects.

Table 4.26 Overall Descriptive Statistics for All Four Tiers Scores on the FTGOT

Descriptive Statistics		Correct Scores									Misconception Scores		
		Total	Context			Case		AND-OR-SUM			AND-OR-SUM		
		Total Test	Plane Mirror	Spherical Mirror	Lens	Observing Oneself	Observing Others	AND	OR	SUM	AND	OR	SUM
Number of students		213	213	213	213	213	213	213	213	213	213	213	213
Number of items		20	8	7	5	9	11	6	6	6	21	21	21
Mean		2.65	1.47	.85	.32	1.20	1.45	.03	2.04	.73	.38	4.84	1.98
Median		2	1	1	0	1	1	0	2	.06	0	4	1.8
Min. score		0	0	0	0	0	0	0	0	0	0	0	0
Max. score		11	6	5	3	5	8	1	6	3.3	2	13	5
Standard deviation		2.17	1.34	1.03	0.63	1.11	1.42	.17	1.42	.64	.60	2.40	1.09
Std. Error of Mean		.15	.98	.80	.52	.92	1.03	.01	.09	.04	.57	1.77	.07
Skewness		1.10	.96	1.22	1.86	.94	1.37	5.74	.42	1.20	1.35	.42	.36
Kurtosis		1.50	.81	1.42	2.54	.78	2.42	31.3	-.39	1.64	.75	-.03	-.30
Point-biserial coefficients		.32	.42	.45	.52	.38	.38	.66	.53	.25	.28	.28	.13
N	< .20	3	2	1	0	2	1	4	0	1	17	6	17
	.20 - .29	6	0	1	0	0	2	0	0	3	2	5	1
	.30 - .39	4	1	1	0	3	4	0	1	2	0	6	1
	.40 - .49	5	1	0	3	2	2	1	0	0	0	4	0
	.50 - .59	2	2	3	1	2	1	0	4	0	1	0	1
	.60 - .69	0	2	1	1	0	1	0	1	0	0	0	0
	>.70	0	0	0	0	0	0	1	0	0	1	0	0
Difficulty level		.13	.18	.12	.06	.13	.13	.00	.34	.12	.02	.23	.09
N	.00 - .09	11	3	4	4	5	6	6	1	2	20	4	15
	.10 - .19	3	1	1	1	2	1	0	0	4	0	7	4
	.20 - .29	5	3	2	0	1	4	0	2	0	1	3	1
	.30 - .39	0	0	0	0	0	0	0	0	0	0	4	1
	.40 - .49	1	1	0	0	1	0	0	2	0	0	2	0
	.50 - .59	0	0	0	0	0	0	0	1	0	0	1	0

Figure 4.13 illustrates the histograms of the correct all four tier scores of all items, correct all four tier scores of items according to the contexts (plane mirror, spherical mirror, lens), cases (observing oneself and observing others), and functions (AND, OR, SUM). The scores are skewed positively which indicates that the subjects' scores clustered to the left at the low values, as can be seen from the figure. Positive values of kurtosis shows that the distribution is rather peaked, i.e. clustered in the center.

Figure 4.14 shows the histograms of the misconception for all four tiers scores with respect to AND, OR, SUM functions. It is obvious from the figure that the distribution of the SUM scores is closer to the normal distribution than the OR and AND scores. AND scores are the least dispersed and are clustered around some values. This fact is related to the nature of the AND function, since it only gives a score of 1 if a subject selects the appropriate alternatives in each of the four tiers and in all of the contexts related to the corresponding misconception. For instance, M1 was assessed by 7 items, and a subject who selects the choices showing the misconception M1 in all of these 7 items can get a score of 1, otherwise the score is 0. This is the reason for the abundance of 0 scores, and the small dispersion of the scores.

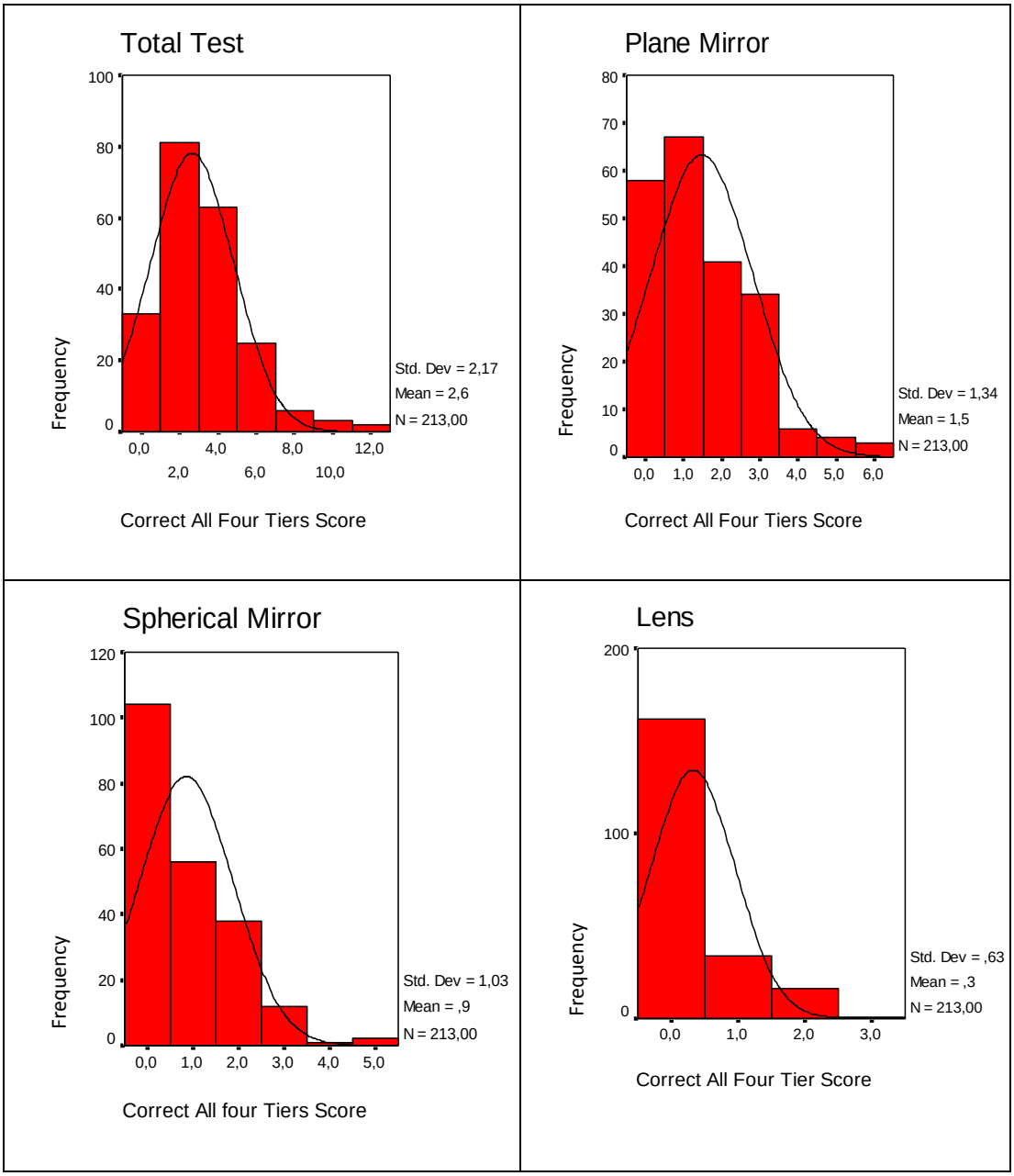


Figure 4.13 Histograms of Correct Scores

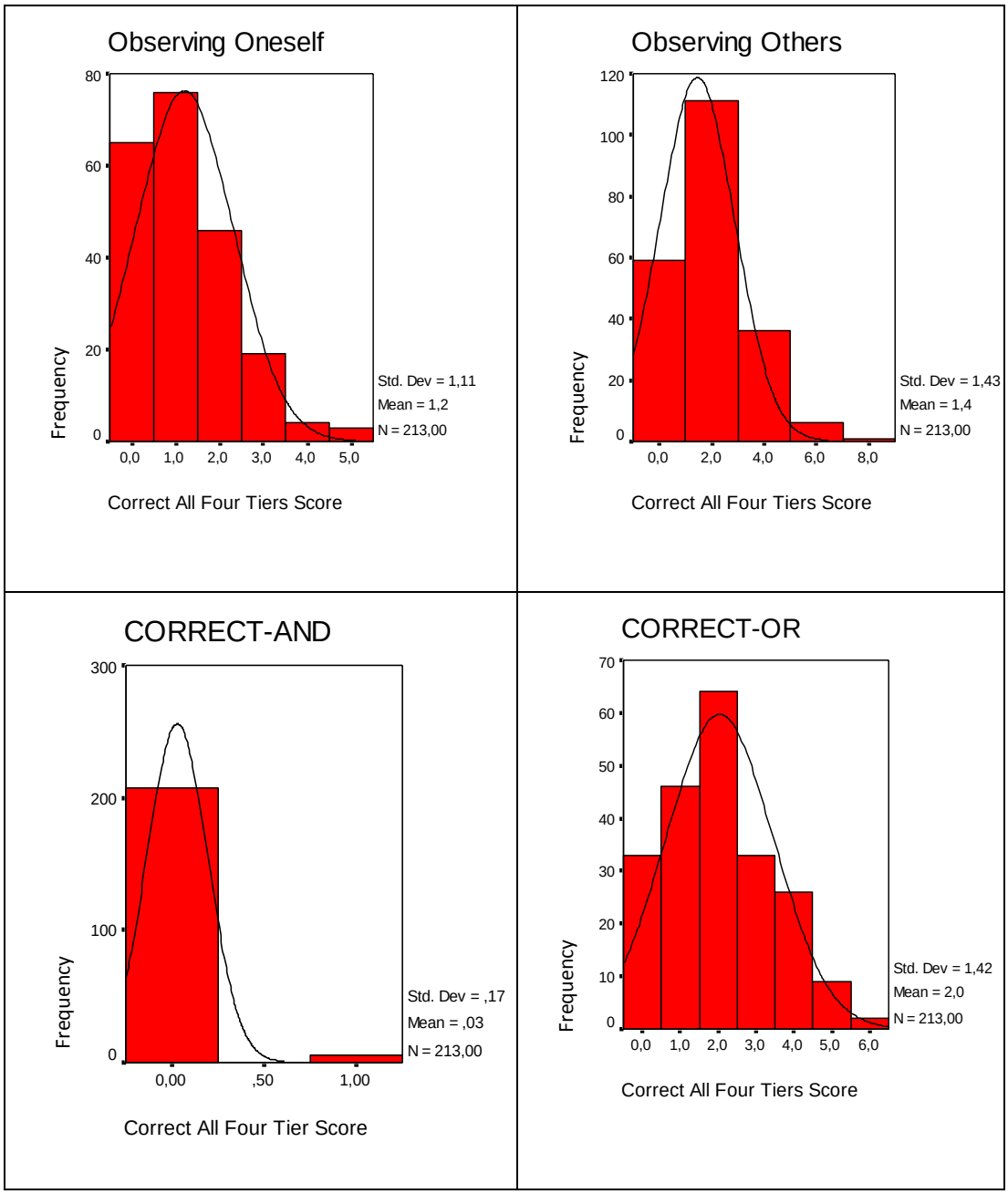


Figure 4.13 Histograms of Correct Scores (Cont'd)

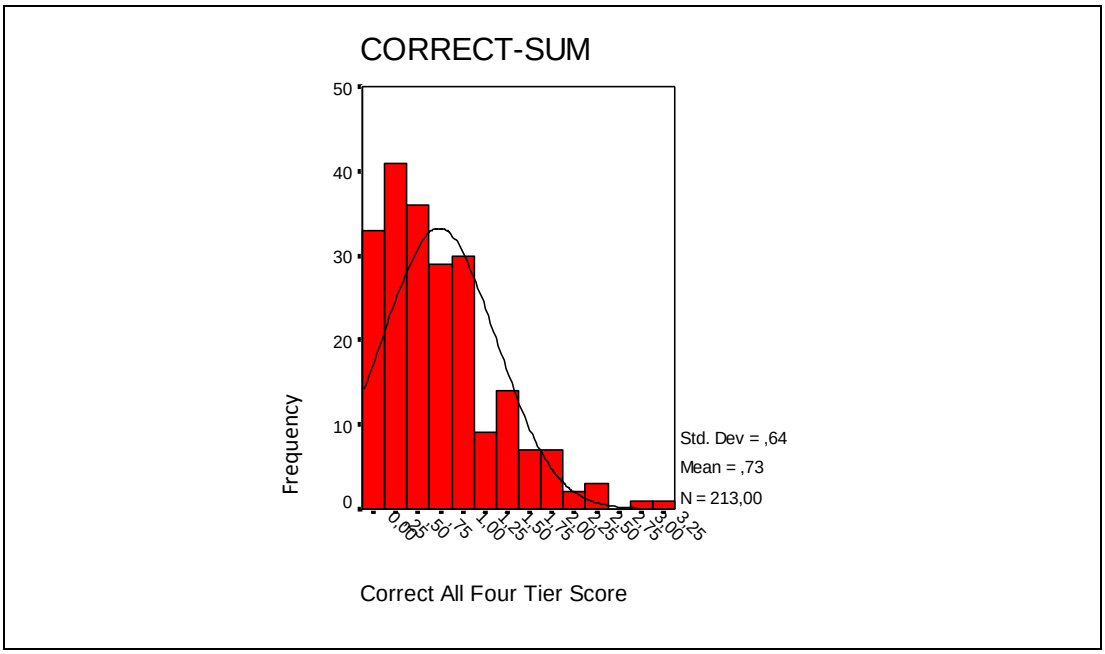


Figure 4.13 Histograms of Correct Scores (Cont'd)

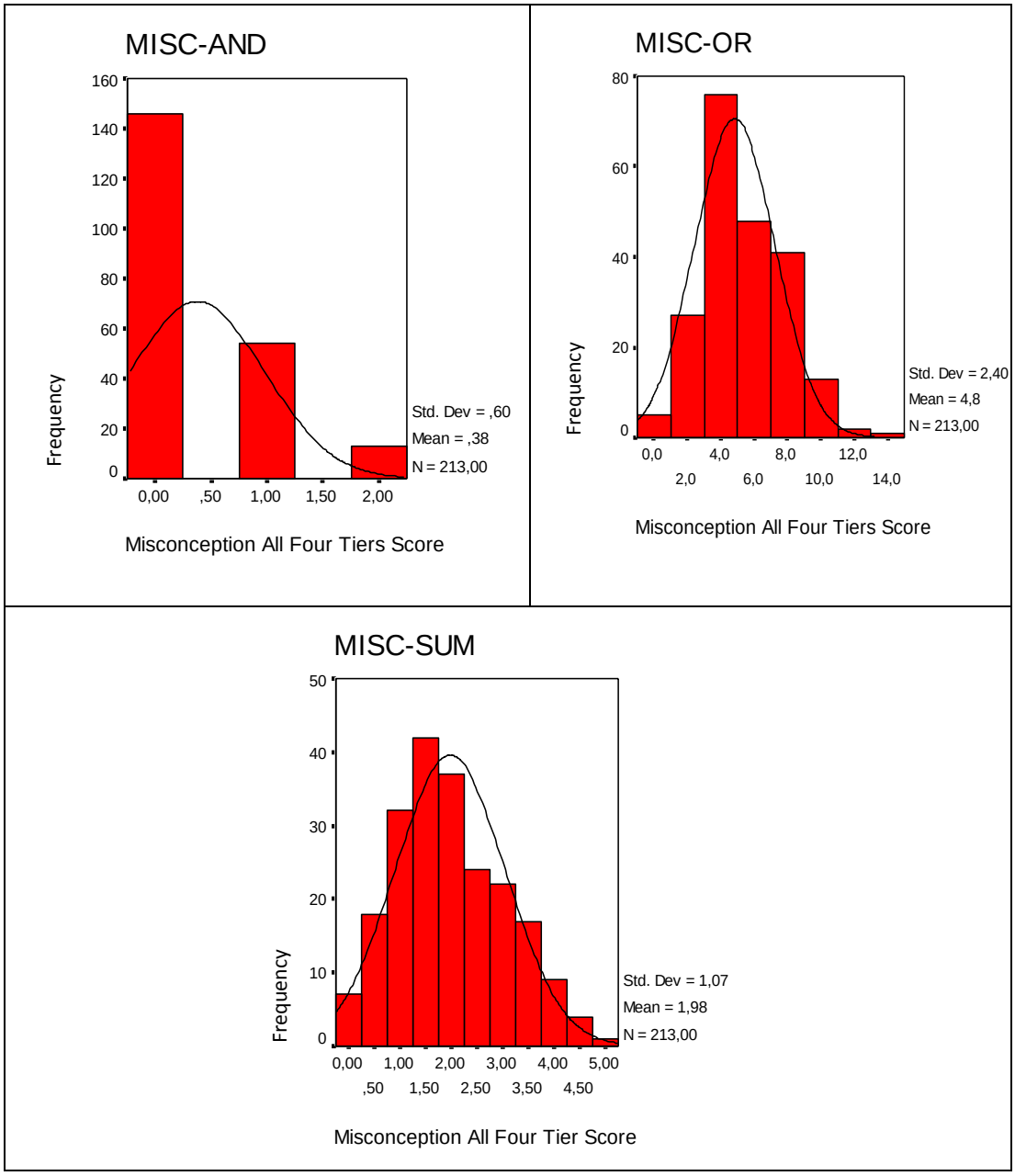


Figure 4.14 Histograms of Misconceptions Scores

4.4.5. Survey Results of the FTGOT

In the second phase of the present study, the FTGOT was used to diagnose Turkish pre-service physics teachers' misconceptions in geometrical optics. In this survey design, the FTGOT results were analyzed with different functions (AND, OR, SUM) for correct scores (in order to answer Research Question 2.a) and misconception scores (in order to answer Research Question 2.b). Figure 4.15 illustrates the percentages of correct responses of the

subjects on the FTGOT in terms of the number of tiers. In analyzing the survey results, the ones for the only first tiers are assumed to represent a conventional multiple-choice test, the ones for the first and third tiers are assumed to represent two-tier tests. A comparison of the mean percentages in Figure 4.15 showed that conventional multiple-choice tests and two-tier tests overestimate the percentages of students who have the correct qualitative understanding of geometrical optics. If the FTGOT had been a conventional multiple-choice test with only its first tiers, on average 30.8 % of the subjects would have answered the test correctly. When the FTGOT was considered as a two-tier test, however, the average percentage of correct responses decreased to 18.4 %. The 12.4 % difference between the mean percentages of the one- and two-tier tests mean 12.4 % of the participants did not correctly explain the reasons for their answers to the first tier. About 2.8 % of this difference is due to false positives, i.e. correct answers with wrong reasoning. The remaining 9.6 % of the difference is due to the subjects' correct answers to the first tier with wrong reasoning in the third tier and not sure in either or both of the second and fourth tiers. The difference between the mean percentages of the two-tier test and the four-tier test was 5.1 %. This difference is due to the subjects who gave correct responses in the first and third tiers of the FTGOT, but not sure in either or both of their answers for these two tiers. This difference corresponds to the proportion of subjects with lack of knowledge even though their answers for the first tier and reasoning tiers were correct.

The percentages of correct AND, OR, SUM scores of the subjects were compared in terms of the number of tiers in Figures 4.16, 4.17, and 4.18, respectively. According to the correct-AND score, the average percentage of the correct answers for the test items grouped according to their contexts and cases is 3.8 % for the only first tier, 0.7 % for two-tiers, and 0.3 % for all four tiers. The lack of knowledge percentage is about 0.4 % for this scoring type on average. The lack of knowledge percentage for individual variables are all 0 except in the lens context in the observing oneself case. Referring to Figure 4.17, however, the percentages of correct-OR scores reveal an average of 34 % of correct answer according to all four tiers and 11.8 % of lack of knowledge. For the correct-OR scores, the biggest difference between the two-tier and all four tiers (i.e. lack of knowledge percentage) exists in the spherical mirror context in the observing oneself and others cases. For the correct-SUM scores, however, the average percentage of correct scores is found to be 12.2 % for all four tiers. The difference in percentages between two-tier test and four-tier test which corresponds to the lack of knowledge percentages is 5.1 % which is the same difference as the one for the correct responses on the total test in Figure 4.15.

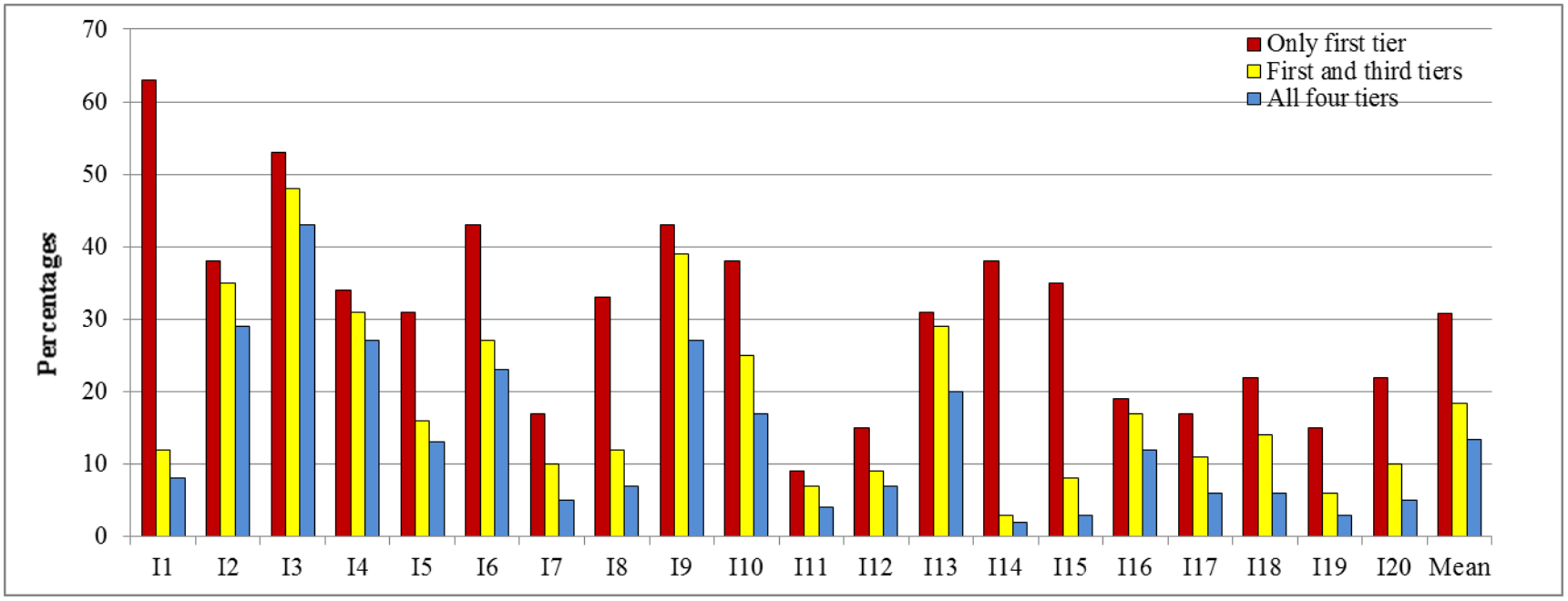
Similarly, the misconception AND, OR, SUM scores of the subjects were compared in terms of the number of tiers for only first tier (conventional multiple-choice test), first and third tiers (two-tier test), and all four tiers. Figure 4.19 represents the percentages of each of 21 misconceptions and the mean misconception percentage in terms of the number of tiers. In this figure the misconception-AND scores were taken into consideration, i.e. percentages of the subjects' who have selected the choices in all of the four tiers for all of the related items showing that specific misconception according to the misconception selection table in Appendix V. Since misconceptions are thought to be strongly held, coherent conceptual structures, we decided that Misconception-AND scores can be used for calculating the percentages of strongly held, context independent misconception percentages. On average, only 1.8 % of the subjects had the misconceptions in geometrical optics in a coherent way. A comparison of the mean percentages revealed that the one- and two-tier tests overestimated the percentages of misconceptions. On the contrary, the four-tier test was the most precise in calculating the percentages of misconceptions held. Some students might have given wrong answers for the first tier although they might not have had any misconception. That might be because of the false negatives or lack of knowledge. Furthermore, when the misconceptions for the tiers were checked carefully, it was seen that the percentages of misconceptions were very small or even zero for most of them. This might be related to the number of items that are measuring those specific misconceptions. For instance, referring to the table in Appendix V, M1 was measured with 7 items, whereas M21 was measured with only 2 items. Hence selecting a wrong answer in two items was more probable than selecting a wrong answer in all 7 items. This might be the main reason for the zero percentages in M1, M7, M10, M17, and M18. Hence, there should be some standardization. This might be possible with either misconception-SUM scores, or by constructing a test measuring each misconception with an equal number of items. Misconceptions are considered significant when they exist in at least 10 % of the sample (Caleon & Subramaniam, 2010a, 2010b; Tan et al., 2002). The results show that only the misconception M21 (20 %) was quite common, coherent misconception among the subjects according to ANDM4 scores.

Misconception-OR scores' percentages in terms of the type of the test are illustrated in Figure 4.20. As described earlier, misconception-OR score percentages give the proportions of the subjects who have selected the misconception choices in all of the four tiers for at least one of the related items showing that specific misconception. In most of the previous studies in three-tier tests this scoring (i.e., OR scores) was used for determining the proportions of each misconceptions. However, this type of scoring has the similar problems as AND scores, but, in this case overestimating the proportions for the misconceptions with

larger number of items that measure it. According to the misconception-OR score percentages for different types of the test, the misconception percentage is about 23 when all four tiers were taken into account, and all misconceptions except four of them (M9, M11, M16, M20) are above 10 % and quite common. The remaining 17 of the misconceptions were quite common with more than 10 %.

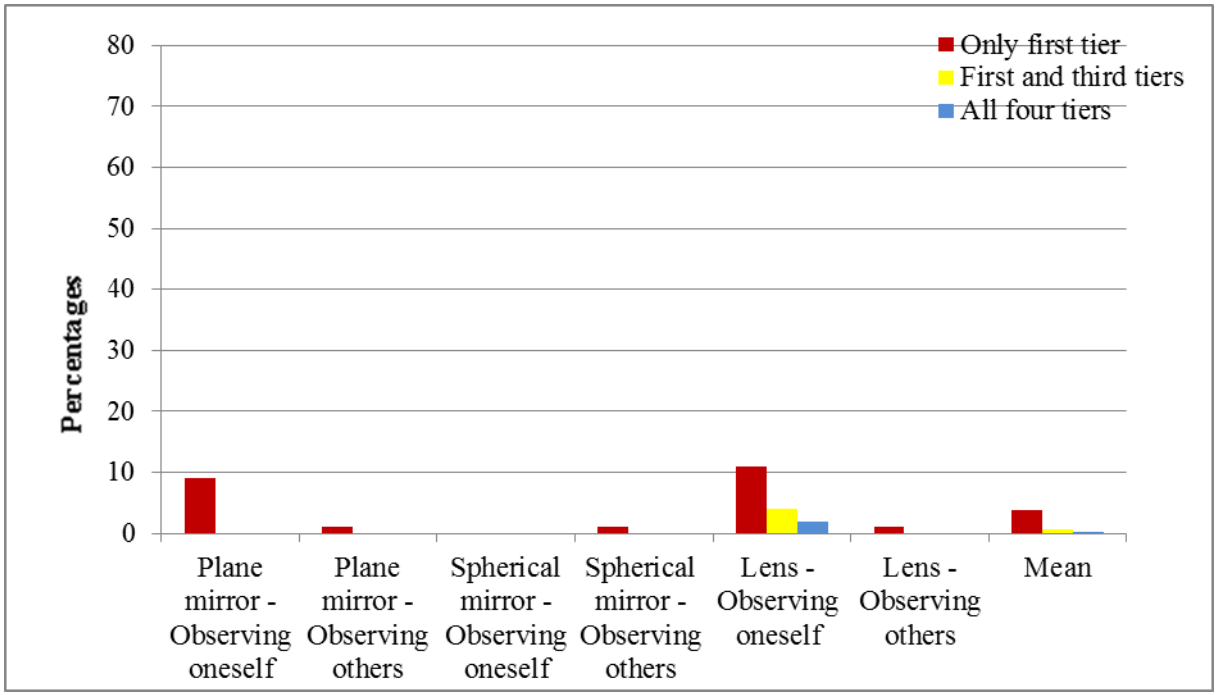
A new scoring for misconceptions, that is misconceptions-SUM scores, was offered in this study which reduces the overestimation of misconception percentages of OR scores and the underestimation of misconception percentages of AND scores by eliminating the negative effect of unequal numbers of items measuring a specific misconception. In this scoring, the number of selections of the misconception choices in all of the four tiers for all of the related items showing that specific misconception were counted, and the obtained number were divided into the total number of items measuring this specific misconception. In this way, more dispersed scores were obtained, as well as the limitations caused by the unequal number of items measuring misconceptions were reduced. Figure 4.21. shows the misconception percentages for different types of tests in terms of the misconception-SUM scores. The difference between the mean percentages of the one and two-tier tests was 14 %. Part of this difference might be due to the false positives, whereas some other part might be due to the lack of knowledge. The difference between the mean percentages of the two-tier test and four-tier test was 5.5 % and this was due to lack of knowledge. According to the careful analysis of the percentages of each misconception for four-tier test results of misconceptions-SUM scores, in 6 of the misconceptions (M2, M3, M12, M14, M19, M21), subjects have misconception percentages of 10 % or above, most of which are misconceptions in the plane mirror context.

The single misconception identified with misconceptions-AND score percentages of 10 % or above (M21), was considered as strongly held, context-independent, coherent, significant misconception for the pre-service physics teachers in the present study. Sixteen misconceptions identified with misconceptions-OR score percentages of 10 % or above (M1, M2, M3, M4, M5, M6, M7, M8, M10, M12, M13, M14, M15, M17, M18, M19), were considered as context-dependent, loosely held, significant misconceptions. According to misconceptions-OR score percentages, the percentage of M21 was also above 10 %, but it was previously identified as context-independent in the misconceptions-AND score analysis. Therefore, M21 is not included among the context-dependent misconceptions.



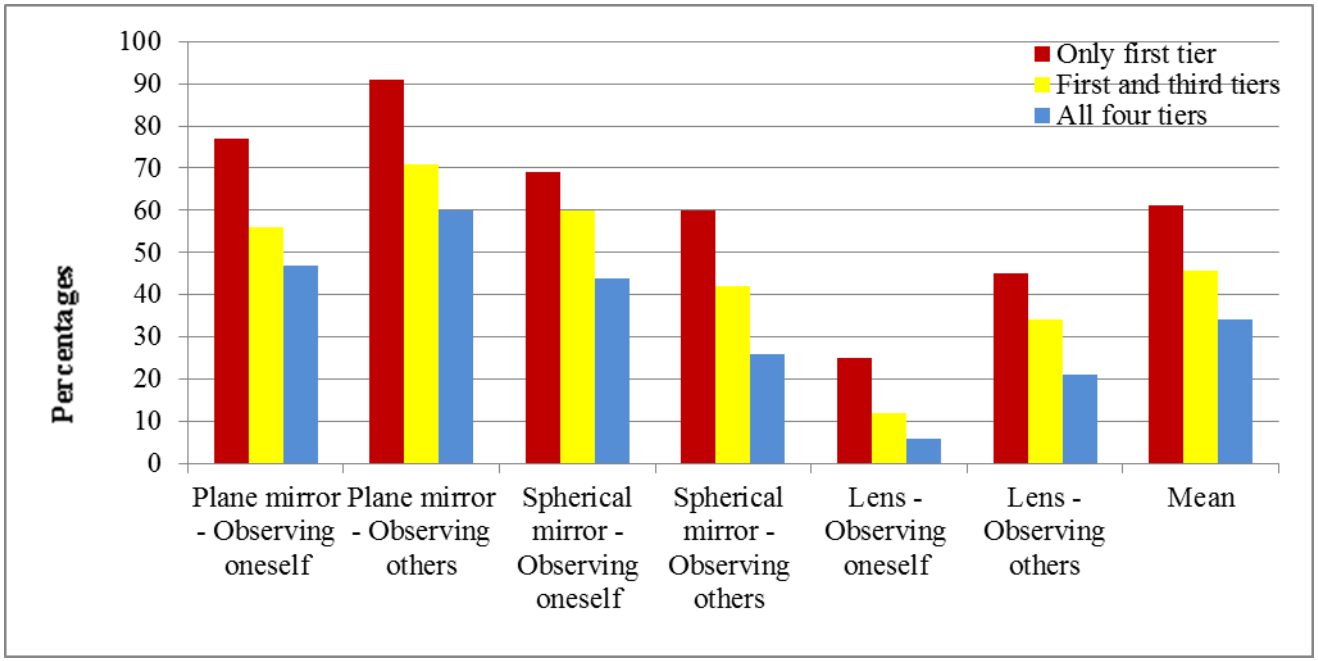
Correct	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15	I16	I17	I18	I19	I20	Mean
Only first tier	63	38	53	34	31	43	17	33	43	38	9	15	31	38	35	19	17	22	15	22	30.8
First and third tiers	12	35	48	31	16	27	10	12	39	25	7	9	29	3	8	17	11	14	6	10	18.4
All four tiers	8	29	43	27	13	23	5	7	27	17	4	7	20	2	3	12	6	6	3	5	13.3

Figure 4.15 Percentages of Correct Answers in Terms of Type of the Test



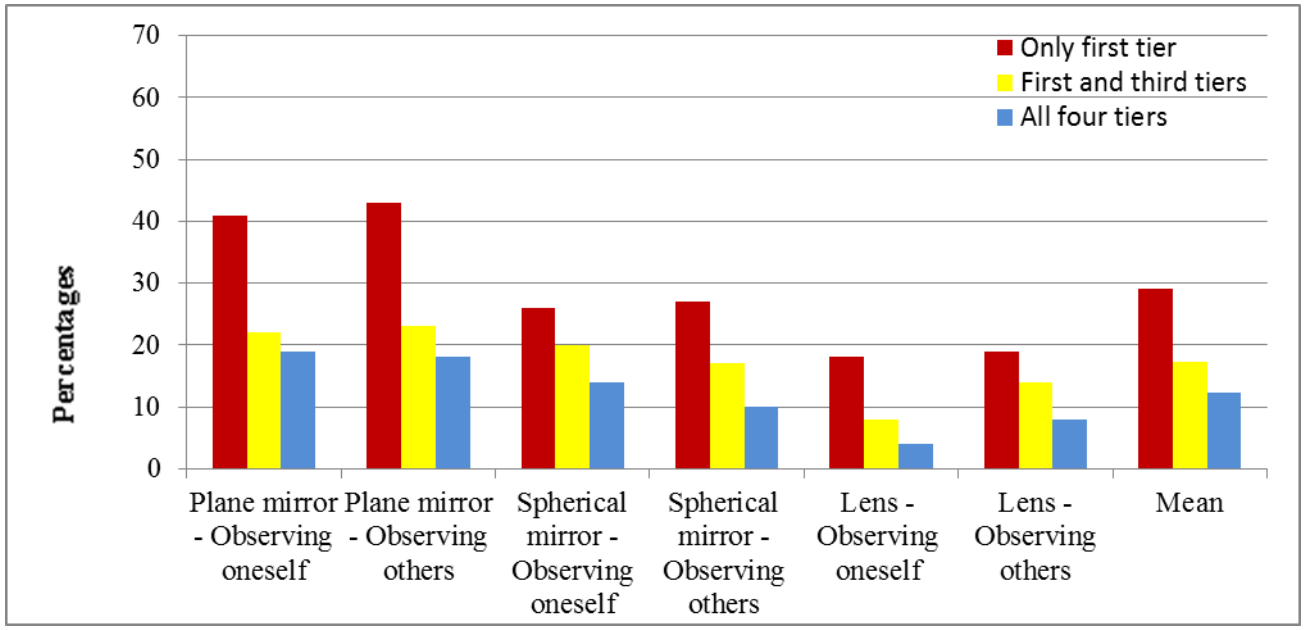
Correct-AND	Plane mirror - Observing oneself	Plane mirror – Observing others	Spherical mirror- Observing oneself	Spherical mirror- Observing others	Lens – Observing oneself	Lens – Observing others	Mean
Only first tier	9	1	0	1	11	1	3.8
First and third tiers	0	0	0	0	4	0	0.7
All four tiers	0	0	0	0	2	0	0.3

Figure 4.16 Percentages of Correct Scores with AND Function in Terms of Type of the Test



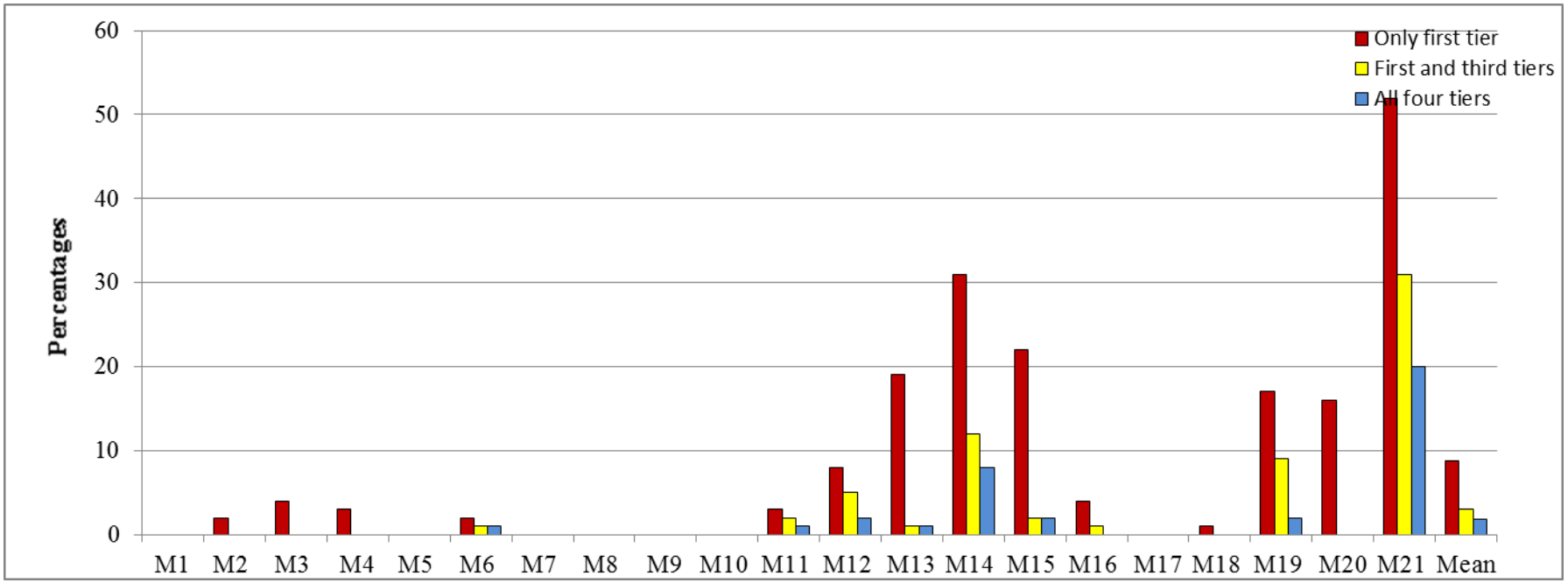
Correct-OR	Plane mirror - Observing oneself	Plane mirror – Observing others	Spherical mirror- Observing oneself	Spherical mirror- Observing others	Lens – Observing oneself	Lens – Observing others	Mean
Only first tier	77	91	69	60	25	45	61.2
First and third tiers	56	71	60	42	12	34	45.8
All four tiers	47	60	44	26	6	21	34.0

Figure 4.17 Percentages of Correct Scores with OR Function in Terms of Type of the Test



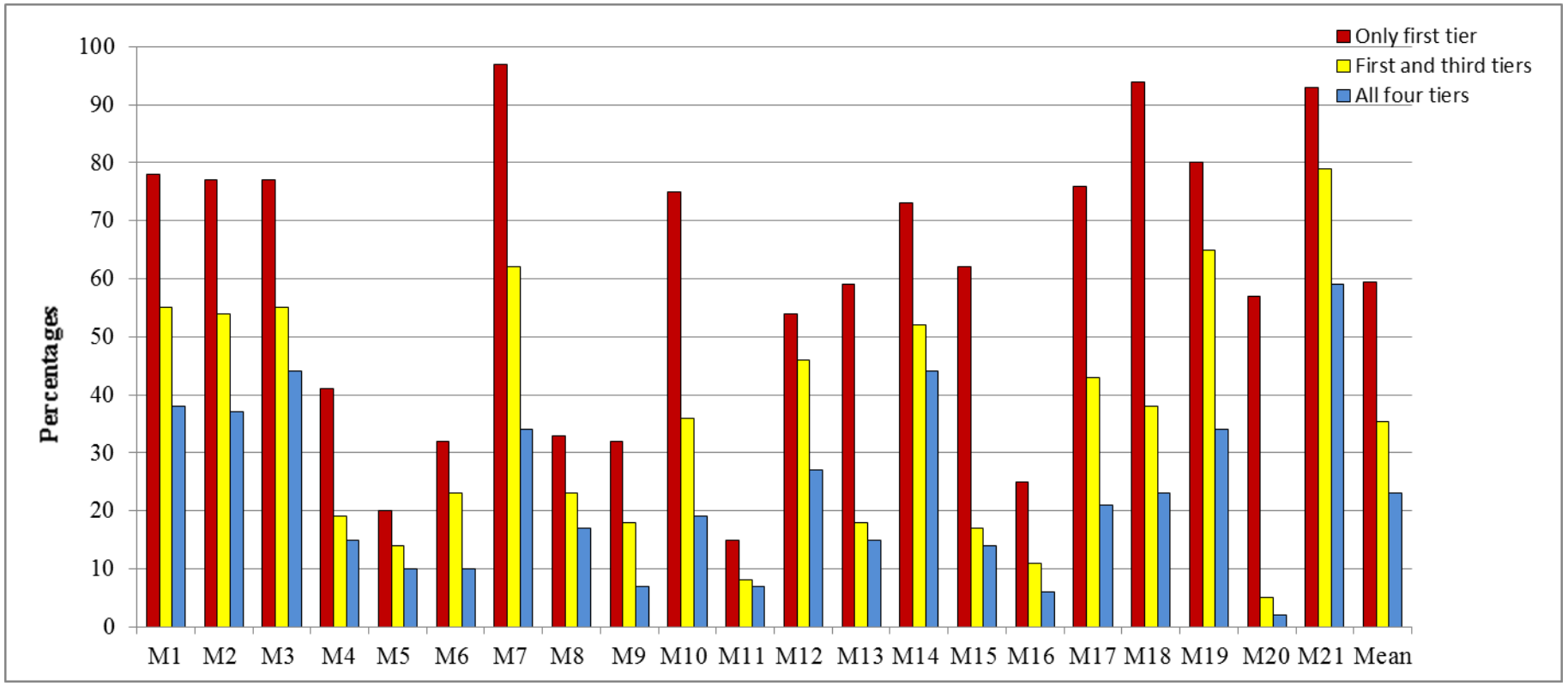
Correct-SUM	Plane mirror - Observing oneself	Plane mirror – Observing others	Spherical mirror- Observing oneself	Spherical mirror- Observing others	Lens – Observing oneself	Lens – Observing others	Mean
Only first tier	41	43	26	27	18	19	29.0
First and third tiers	22	23	20	17	8	14	17.3
All four tiers	19	18	14	10	4	8	12.2

Figure 4.18 Percentages of Correct Scores with SUM Function in Terms of Type of the Test



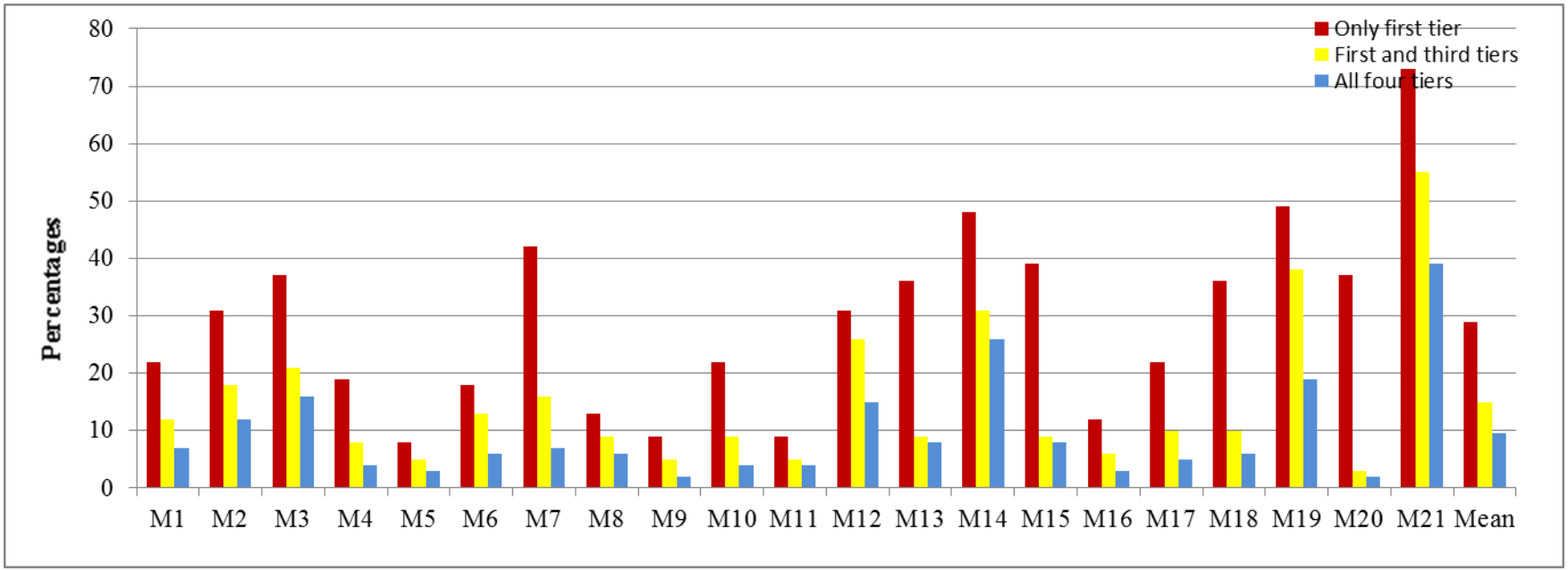
AND-Misc	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	Mean
Only first tier	0	2	4	3	0	2	0	0	0	0	3	8	19	31	22	4	0	1	17	16	52	8.8
First and third tiers	0	0	0	0	0	1	0	0	0	0	2	5	1	12	2	1	0	0	9	0	31	3.0
All four tiers	0	0	0	0	0	1	0	0	0	0	1	2	1	8	2	0	0	0	2	0	20	1.8

Figure 4.19 Percentages of Misconceptions Scores with AND Function in Terms of Type of the Test



OR-Misc	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	Mean
Only first tier	78	77	77	41	20	32	97	33	32	75	15	54	59	73	62	25	76	94	80	57	93	59.5
First and third tiers	55	54	55	19	14	23	62	23	18	36	8	46	18	52	17	11	43	38	65	5	79	35.3
All four tiers	38	37	44	15	10	10	34	17	7	19	7	27	15	44	14	6	21	23	34	2	59	23.0

Figure 4.20 Percentages of Misconceptions Scores with OR Function in Terms of Type of the Test



SUM-Misc	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	Mean
Only first tier	22	31	37	19	8	18	42	13	9	22	9	31	36	48	39	12	22	36	49	37	73	29
First and third tiers	12	18	21	8	5	13	16	9	5	9	5	26	9	31	9	6	10	10	38	3	55	15
All four tiers	7	12	16	4	3	6	7	6	2	4	4	15	8	26	8	3	5	6	19	2	39	9.5

Figure 4.21 Percentages of Misconceptions Scores with SUM Function in Terms of Type of the Test

As mentioned earlier, in comparing the percentages of the individual misconceptions, the number of items measuring each misconception might cause several problems. Therefore, it was desirable to equalize the number of items measuring each misconception. In order to do this, the percentages of misconceptions according to all four tiers measured by each item in the test were determined. Table 4.27 shows the distribution of these misconception percentages detected by each of the items in the test. Since in a researcher developed test up to a 10 % of the standard error of measurement is acceptable. Misconceptions with less than 10 % (M4, M5, M9, M11, M16, M20) were found to be less important for consideration and removed from the analysis of the results. Then from the remaining 15 misconceptions, the items with the largest three misconception percentages were identified as measuring the corresponding misconception. These selected percentages are highlighted for each of the items in Table 4.27. As a result of this selection, 3 of the items (Items 2, 19, 20) in the test were not selected because the percentages of misconceptions were so small for measuring any of the misconceptions. Therefore, these items were removed from the analysis. Consequently, a new test was constructed that measures 15 misconceptions with 17 items. Each of the misconceptions were measured with either two (M6, M12, M13, M14, M15, M19, M21) or three (M1, M2, M3, M7, M8, M10, M17, M18) items in the test.

Table 4.28 shows the descriptive statistics for this new 17-item test that measures 15 misconceptions. The mean and standard deviations did not change much for the misconception AND, OR, SUM scores for the 21 misconceptions or 15 misconceptions cases. Figure 4.22 shows the histograms for the misconception AND, OR, SUM scores for the 15-misconceptions measuring test. Cronbach alpha reliabilities are decreased a little bit for the 15-misconception measuring test for all four tiers, but this decrease is not so significant. There is a small increase in the difficulty index and discrimination index for all four tiers for this new test, but the increase is not significant as summarized in Table 4.29.

Table 4.27 Distribution of Percentages of Misconceptions to the Items (According to Misconception All Four Tiers Scores)

Item	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	M25	M26	M27	Total
1	7	13	38																									58
2	3	1		4																		10						18
3	17				3			10																				30
4		17					9																10					36
5													14	30	5	2								4				55
6													2	23	11	4												40
7	2			2		9				4								6										23
8	8			4			7		2									2										23
9					5		10	5	2		5																	27
10					2	2	6	1		4	3														8			26
11									3	8							6	13										30
12										4							5	6								5		20
13		18					8					4																30
14			4																	1	42							47
15	8		5																	2	36							51
16																			33									33
17							3					25							3								3	34
18	5						7										10											22
19									2	4							0	3										9
20									0	1							1	4										6
Total	50	49	47	10	10	11	50	16	9	25	8	29	16	53	16	6	22	34	36	3	78	10	10	4	8	5	3	

Table 4.28 Descriptive Statistics for All four Tiers Score of 15 Misconceptions Measuring Test

Descriptive Statistics		Misconception Scores for Selected 15 Misconceptions		
		AND	OR	SUM
Number of students		213	213	213
Number of items		15	15	15
Mean		.37	4.1	2.0
Median		0	4	1.8
Min. score		0	0	0
Max. score		2	9	4.8
Standard deviation		.59	2.05	1.1
Std. Error of Mean		.04	.14	.07
Skewness		1.3	.33	.32
Kurtosis		.81	-.27	-.41
Point-biserial coefficients		.29	.32	.18
N	< .20	8	3	10
	.20 - .29	1	4	2
	.30 - .39	3	3	1
	.40 - .49	1	5	1
	.50 - .59	2	0	1
	.60 - .69	0	0	0
	>.70	0	0	0
Difficulty level		.02	.27	.13
N	.00 - .09	9	0	8
	.10 - .19	3	5	5
	.20 - .29	1	5	1
	.30 - .39	1	2	1
	.40 - .49	0	2	0
	.50 - .59	1	1	0

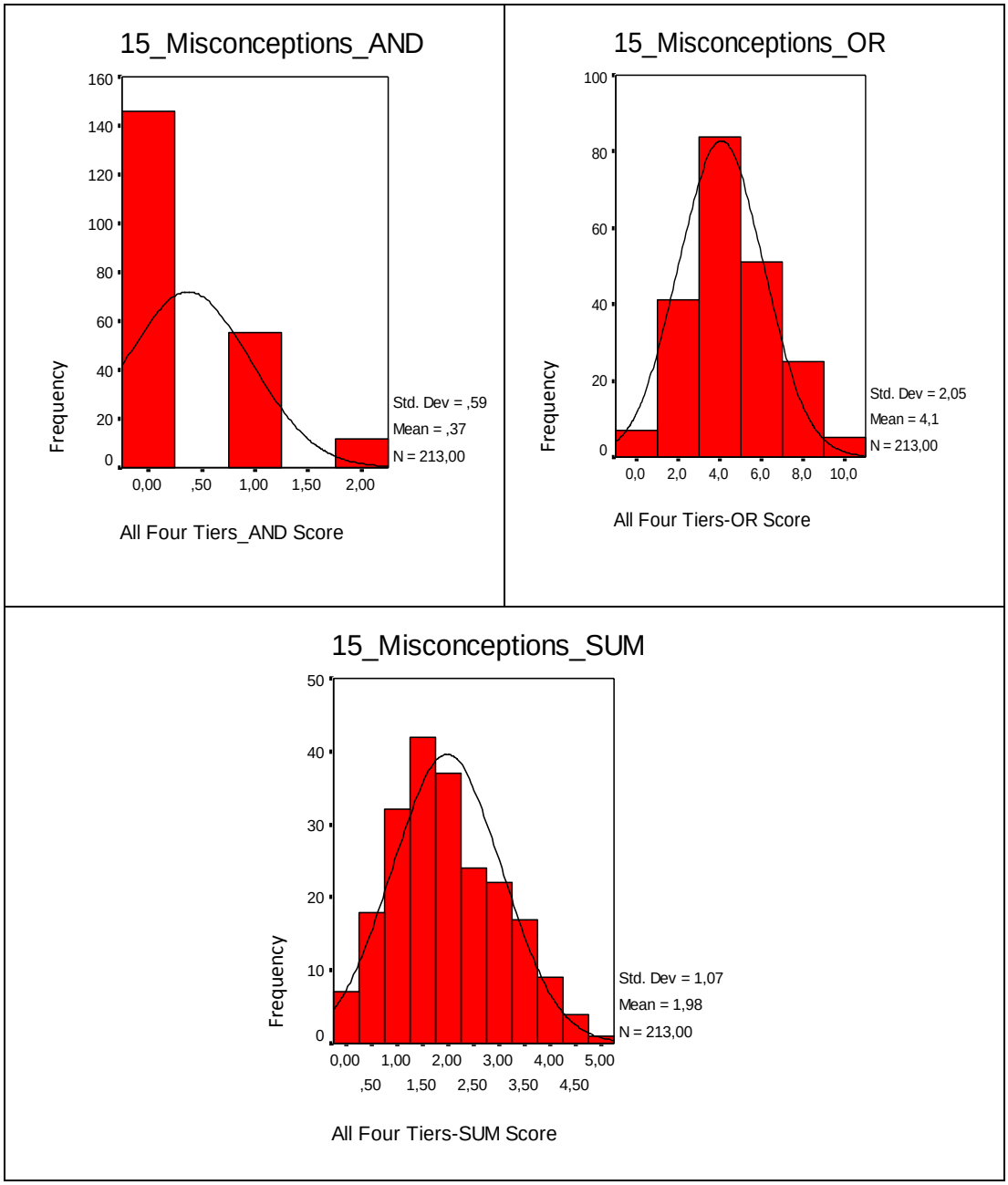


Figure 4.22 Histograms for the Test with Selected 15 Misconceptions

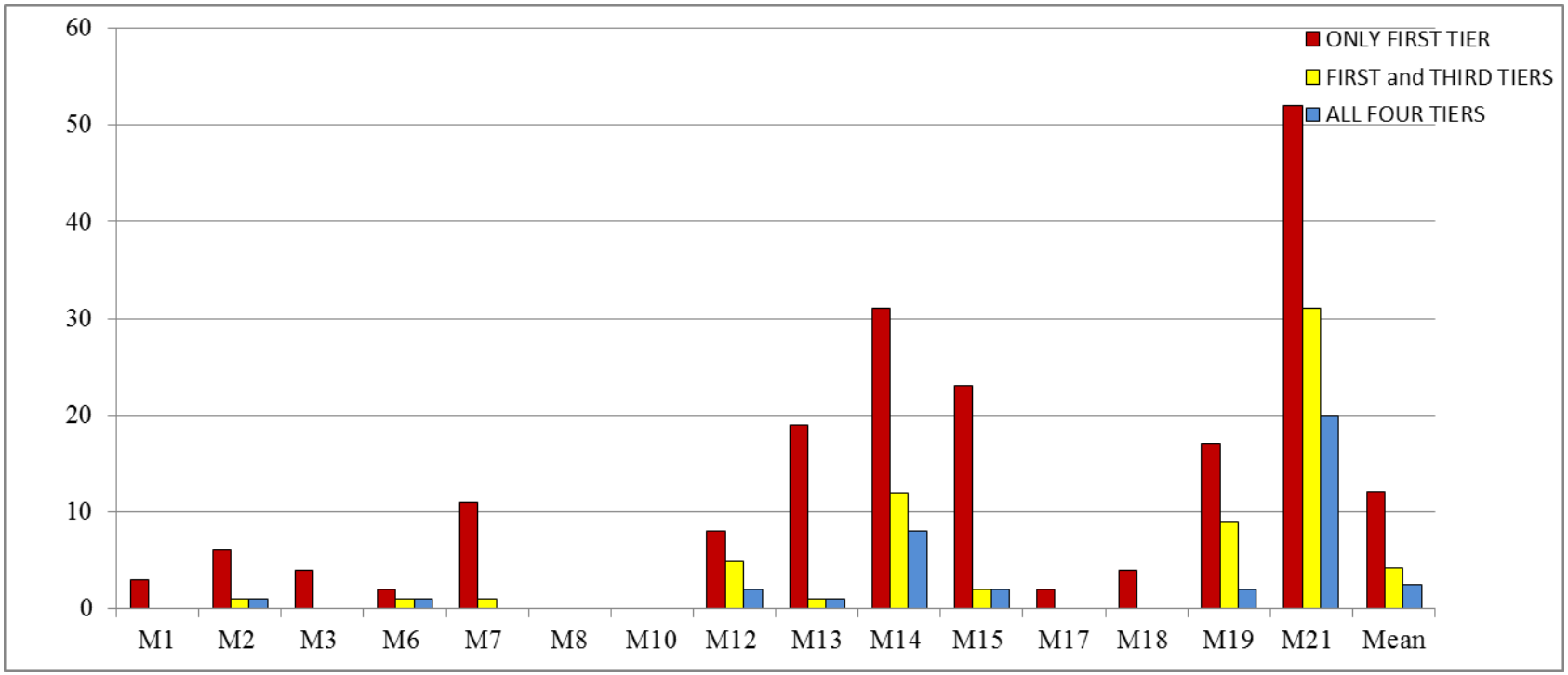
Table 4.29 Reliability Indexes, Difficulty levels, and Discrimination Indexes of 15 Misconceptions Measuring Test

Indexes for the Test with Selected 15 Misconceptions									
	Cronbach Alpha			Difficulty Levels			Discrimination Index		
Tiers	AND	OR	SUM	AND	OR	SUM	AND	OR	SUM
Only First Tier	.01	.14	-.18	.12	.66	.37	.24	.27	.45
First and Third Tiers	-.08	.12	-.08	.04	.40	.21	.21	.27	.36
All Four Tiers	.07	.38	.39	.02	.27	.13	.29	.32	.40

Figures 4.23, 4.24, and 4.25 show the percentages of each of the 15 misconceptions and the mean of misconceptions measured by misconceptions AND, OR, SUM scores respectively for the three types of tests. Similar to the previous 21 misconception measuring test analysis, in the present test the AND score percentages illustrate the context independent, robust misconceptions. According to them, M14 and M21 were the most robust ones.

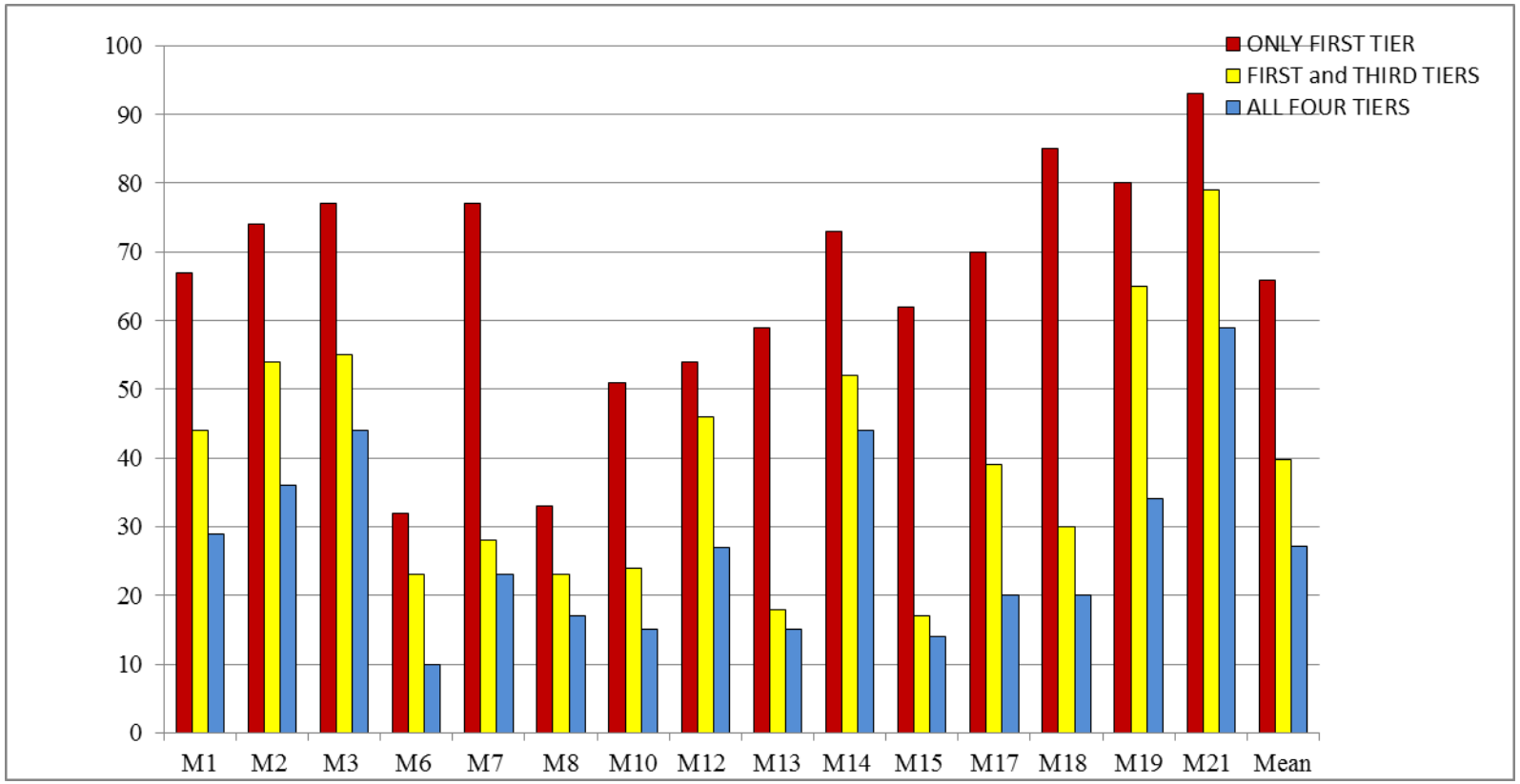
In misconception OR score analysis, M3, in addition to the previous two misconceptions found significant in AND score analysis. This shows that M3 was also a pervasive misconception among the subjects, whereas it depends on the context of the items measuring this specific misconception. None of the subjects selected misconception alternative choices in all of the 3 items measuring it. However, 44 % of the subjects selected misconception alternative choices in at least one of the three items. According to Table 4.27, most probably in Item 1 most of the subjects selected the corresponding misconception.

Misconception SUM score analysis for the three types of test shows that considering all four tiers an average of 13.1 % of the subjects had the 15 misconceptions. Whereas, if it were a conventional one-tier multiple-choice test or a two-tier multiple-choice test, an average of 37.5% or 20.8% of the subjects would have had those 15 subjects, respectively. The difference of 16.7 % between one-tier and two-tier tests was due to false positives and lack of knowledge, whereas a 7.7 % difference between two-tier and four-tier tests was due to lack of knowledge. Individual analysis of the misconceptions-SUM scores percentages for all four tiers revealed that M1, M2, M3, M12, M14, M19, M21 were the most common significant misconceptions with percentages of more than 10 %.



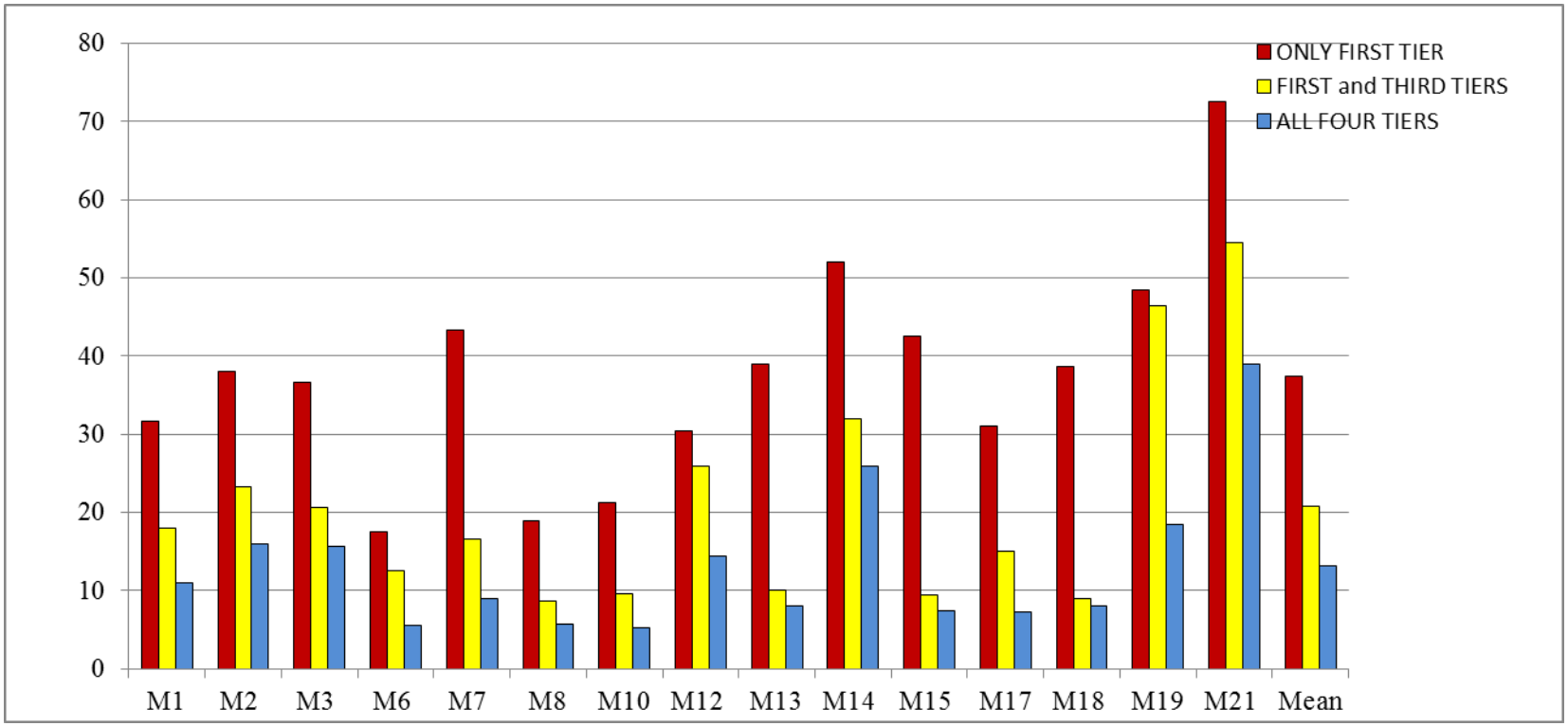
AND-Misc-15	M1	M2	M3	M6	M7	M8	M10	M12	M13	M14	M15	M17	M18	M19	M21	Mean
Only first tier	3	6	4	2	11	0	0	8	19	31	23	2	4	17	52	12.1
First and third tiers	0	1	0	1	1	0	0	5	1	12	2	0	0	9	31	4.2
All four tiers	0	1	0	1	0	0	0	2	1	8	2	0	0	2	20	2.5

Figure 4.23 Percentages of 15 Misconceptions Scores with AND Function in Terms of Type of the Test



OR-Misc-15	M1	M2	M3	M6	M7	M8	M10	M12	M13	M14	M15	M17	M18	M19	M21	Mean
Only first tier	67	74	77	32	77	33	51	54	59	73	62	70	85	80	93	65.8
First and third tiers	44	54	55	23	28	23	24	46	18	52	17	39	30	65	79	39.8
All four tiers	29	36	44	10	23	17	15	27	15	44	14	20	20	34	59	27.1

Figure 4.24 Percentages of 15 Misconceptions Scores with OR Function in Terms of Type of the Test



SUM-Misc-15	M1	M2	M3	M6	M7	M8	M10	M12	M13	M14	M15	M17	M18	M19	M21	Mean
Only first tier	32	38	37	18	43	19	21	31	39	52	43	31	39	49	73	37.5
First and third tiers	18	23	21	13	17	9	10	26	10	32	10	15	9	47	55	20.8
All four tiers	11	16	16	6	9	6	5	15	8	26	8	7	8	19	39	13.1

Figure 4.25 Percentages of 15 Misconceptions Scores with SUM Function in Terms of Type of the Test

The factor analysis was also conducted for this new 15-misconceptions measuring test for the misconception scores of AND, OR, SUM functions and the results are tabulated in Table 4.30.

Table 4.30 Results of the Reliability and Factor Analysis of the New Misconception-15 Scores

	% of Variance Explained	Reliability (croanbach alpha)	Number of Factors	Factors and their Misconceptions	Reliability of Factors (pearson correlation)	Total Number of Misconceptions	Factor Loadings of Each Misconception
ANDM1-15	There are fewer than two cases, at least one of the variables has zero variance, there is only one variable in the analysis, or correlation coefficients could not be computed for all pairs of variables. No further statistics will be computed.						
ANDM2-15	There are fewer than two cases, at least one of the variables has zero variance, there is only one variable in the analysis, or correlation coefficients could not be computed for all pairs of variables. No further statistics will be computed.						
ANDM4-15	There are fewer than two cases, at least one of the variables has zero variance, there is only one variable in the analysis, or correlation coefficients could not be computed for all pairs of variables. No further statistics will be computed.						
ORM1-15	69	.15	6	1. M13+M14+M15 2. M10+M17 3. M7+M2 4. M21+M3 5. M8+M18 6. M19+M12	1. -.16 2. .76 3. .79 4. -.21 5. -.16 6. -.12	13	1. .838 + .811 + -.623 2. .743 + .726 3. .757 + .594 4. -.560 + .461 5. .648 + -.546 6. -.597 + .535
ORM2-15	64	.13	5	1. M2+M14 2. M15+M13 3. M18+M10 4. M1 5. M8+M17	1. .32 2. -.36 3. -.36 4. - 5. .15	9	1. .829 + .614 2. .724 + -.654 3. .775 + -.668 4. .773 5. .890 + .472
ORM4-15	61	.47	5	1. M17+M21+M19 2. M6+M1 3. M2+M14 4. M8+M12 5. M10	1. .36 2. .20 3. .31 4. .19 5. -	10	1. .728 + .583 + .490 2. .704 + .670 3. .798 + .576 4. .792 + .614 5. .920

Table 4.30 Results of the Reliability and Factor Analysis of the New Misconception-15 Scores (Cont'd)

SUMM1-15	83	-.27	4	1. M14+M13+M15 2. M17+M10 3. M18+M8 4. M21	1. -1.2 2. .82 3. .62 4. -	8	1. .937 + .885 + -.880 2. .930 + .876 3. .842 + .821 4. .993
SUMM2-15	-	-	-	Not factorable. KMO < .50	-	-	-
SUMM4-15	67	.42	5	1. M14+M21 2. M12+M17 3. M10+M2 4. M1 5. M3+M19	1. .36 2. .22 3. .29 4. - 5. .07	9	1. .758 + .728 2. .790 + .497 3. .749 + .747 4. .864 5. .775 + .621

Factor analysis for the misconception scores for the AND function could not be performed, because the spread of scores obtained with this function is very low. Similar to the previous 21 misconception case, the SUMM2 score was found to be not factorable because the KMO value is below .50. The interpretation of the factors that are obtained for the new misconception scores are given in Table 4.31.

Table 4.31 Interpretation of the Factors Obtained from the Analysis of Misconception Scores Coded with AND, OR, SUM Functions

	Factors	Misconceptions	Factor Name (Interpretation)
OR-Only First Tier Score (ORM1)	1	13, 14, 15	All three misconceptions are related to the same items which are asking for the ways to increase the size of the observed image from the plane mirror.
	2	10, 17	Not a good interpretation exists to explain the relationship between the misconceptions can be made.
	3	2, 7	Misconception 2 and Misconception 7 have common reasoning that when there is an obstacle between the object and optical device the image is not formed.
	4	3, 21	Both misconceptions are related to the image formation and observation in the plane mirrors.
	5	8, 18	Not a good interpretation exists to explain the relationship between the misconceptions can be made.
	6	12, 19	Not a good interpretation exists to explain the relationship between the misconceptions can be made.

Table 4.31 Interpretation of the Factors Obtained from the Analysis of Misconception Scores Coded with AND, OR, SUM Functions (Cont'd)

	Factors	Misconceptions	Factor Name (Interpretation)
OR -First and Third Tiers Score (ORM2)	1	2, 14	Not a good interpretation exists to explain the relationship between the misconceptions can be made.
	2	13, 15	Both misconceptions are related to the same items which are asking for the ways to increase the size of the observed image from the plane mirror
	3	10, 18	Not a good interpretation exists to explain the relationship between the misconceptions can be made.
	4	1	A single item.
	5	8, 17	Not a good interpretation exists to explain the relationship between the misconceptions can be made.
OR -All Four Tiers Score (ORM4)	1	17, 19, 21	Not a good interpretation exists to explain the relationship between the misconceptions can be made.
	2	1, 6	Not a good interpretation exists to explain the relationship between the misconceptions can be made.
	3	2, 14	Not a good interpretation exists to explain the relationship between the misconceptions can be made.
	4	8, 12	Not a good interpretation exists to explain the relationship between the misconceptions can be made.
	5	10	A single item.
SUM-Only First Tier Score (SUMM1)	1	13, 14, 15	All three misconceptions are related to the same items which are asking for the ways to increase the size of the observed image from the plane mirror.
	2	10, 17	Not a good interpretation exists to explain the relationship between the misconceptions can be made.
	3	8, 18	Not a good interpretation exists to explain the relationship between the misconceptions can be made.
	4	21	A single item.

Table 4.31 Interpretation of the Factors Obtained from the Analysis of Misconception Scores Coded with AND, OR, SUM Functions (Cont'd)

	Factors	Misconceptions	Factor Name (Interpretation)
SUM- All Four Tiers Score (SUMM4)	1	14, 21	Both misconceptions are in the context of plane mirrors.
	2	12, 17	Not a good interpretation exists to explain the relationship between the misconceptions can be made.
	3	2, 10	Not a good interpretation exists to explain the relationship between the misconceptions can be made.
	4	1	A single item.
	5	3, 19	Not a good interpretation exists to explain the relationship between the misconceptions can be made.

CHAPTER 5

DISCUSSION, CONCLUSIONS AND IMPLICATIONS

The goal of this study was the development of a four-tier test in order to assess pre-service physics teachers' misconceptions about geometrical optics. In this chapter, the results obtained from the present study are summarized and discussed in relation with the previous studies in the literature. Afterwards, the conclusions drawn from the study are presented. The internal and external validity of the study, the implications of the results and the recommendations for further research offered by this study are included at the end of this chapter.

5.1. Discussion of the Results

The development of the FTGOT followed a certain procedure. The results from each of the steps in the procedure were critically analyzed and presented in the preceding chapters. In this section, the results are discussed in greater detail.

Analysis of the interviews demonstrated that participants had serious difficulties even in the very basic concepts of geometrical optics. They used some of the key terms (such as "image", "reflection", "refraction", "field of vision" etc.) to explain their reasoning arbitrarily or mistakenly. They might either have had difficulty in using the correct terminology for their explanations or had serious conceptual problems in geometrical optics. Participants' experience with optical instruments, discussed in the context of the item, was found to influence their answers and reasoning either in a constructive or destructive way. From the interviews, it appeared that most of their experiences in geometrical optics were from either their daily usage of the optical instruments or from their laboratory experiences at their universities. The experience of the participants with spherical mirrors or lenses was less than their experience with plane mirrors both in school and out of school. Experience as a possible source of student conceptions has been discussed in several studies (Driver et al., 1985; Goldberg & McDermott, 1986; Klammer, 1998; Smith et al., 1993; Wandersee et al., 1994). In the study of Goldberg and McDermott (1986), for example, the influence of experience with a plane mirror on student reasoning was discussed in detail. The authors

suggested that the participants' strong conviction that by moving back they could see more of themselves in a plane mirror might have been due to invalid inferences drawn from their experience. People usually stand farther back to see their entire body with a minimum amount of eye movement. This common experience might have been a possible reason for the faulty reasoning that one can see more of oneself by standing farther away from a mirror.

Another important result that was deduced from analysis of both the interview and the open-ended test was that the pre-service teachers' knowledge in geometrical optics, especially about spherical mirrors and lenses, was fragmented in nature. An important outcome of studying geometrical optics is expected to be in the ability to relate general physical principles to everyday experience. However, the results of this study have shown that, even after formal instruction in schools from the elementary school to university, the subjects were unable to connect their formal knowledge to the specific contexts in geometrical optics which were presented through the items. Even though, they seemed to answer easily the standard textbook questions in geometrical optics by rote or by comprehension at a surface level, they failed to relate their knowledge to simple but different contexts that require a deep level of comprehension. The comparatively high level of deficient or not meaningful proportions of answers to the open-ended test items might be an indicator of their loosely organized, ill-defined and fragmented knowledge in this topic.

Both the oral and written discussions during the interviews and the written responses on the open-ended test items indicated that pre-service teachers had a loosely organized understanding of concepts in geometrical optics. Their misconceptions, if any, were mostly not coherent but context dependent. Some of the reasoning activated in one context to explain phenomena was found not to be used in another context that requires the same or similar knowledge. For example, the reasoning that "any obstacle between an object and a mirror hinders the image formation and /or observation process" was activated by Item 1, in which the observer was moving parallel to the plane mirror surface, whereas most of the same participants did not use the same reasoning for Item 16 in which the observer was moving parallel to a convex mirror surface. These findings show similarity with the findings of previous studies (Andersson & Karrqvist, 1983; Chu et al., 2009; Galili, 1996; Langley et al., 1997) that expressed the context dependence of misconceptions in geometrical optics.

In terms of conceptual understanding in geometrical optics, some concepts were considered to be more problematic and might be considered as probable misconceptions to be assessed in the FTGOT. In dealing with plane mirrors (including a single plane mirror and hinged plane mirrors), more than half of the participants based at least one of their explanations on the belief that the image formation and observation are separate events. As

discussed by Galili (1996), Galili, Goldberg and Bendall, (1991), Ronen and Eylon (1993) for their post-instructional students, the participants of the present study also seemed to think that the image is formed in a plane mirror by rays from the object to the mirror and that after the image is formed, light rays transfer the image to the observer's eye. Whether or not the mirror image is observed, it always stays in the mirror. There is usually a lack scientific understanding that image formation and observation are simultaneous events in plane mirrors and that the image is formed only on the retina in the observer's eye. The pre-service teachers in the present study had already completed their courses in geometrical optics and geometrical optics laboratory. In these courses, they are taught about virtual image formation in plane mirrors. However, many of the current optics textbooks and traditional class teaching do not include the function of the eye in the formation of a virtual image. Therefore, faulty inferences by pre-service teachers' seem nearly unavoidable.

Participants who hold the misconceptions "any obstacle between an object and a plane mirror hinders the image formation / observation of an object" and "only the images of the objects within the borders of the plane mirror are formed /seen" were found to use the same diagrams in explaining their answers for the items. They usually drew a single light ray from each object point preferentially in the direction of the optical instrument, in our case in the direction of the plane mirror (see Figure 4.3). Their inability to conceptualize the idea that all object points emit light equally in all directions isotropically, led them to faulty conceptions. Similar findings were discussed by Rice and Feher (1987) in the context of the formation of images through pinholes by the use of extended light sources. Galili (1996) labeled that kind of representation as the "flashlight model" and found those representations as a serious barrier to the genuine understanding of optical phenomena.

For the items that asked for ways to increase the body size which is observable from a plane mirror, students' experience with plane mirrors was found to influence their reasoning. Instead of using any ray drawings to justify their answers, most of the participants answered the items intuitively depending on their everyday life experiences. Those findings were very similar to the findings of Goldberg and McDermott (1986). Bendall et al. (1993) and Galili (1996) proposed that extensive experience with a plane mirror in everyday life naturally produces rich and rather well structured naïve knowledge to account for images that are observed in mirrors.

Misconceptions about hinged plane mirrors are a less often studied context in geometrical optics and is given little emphasis in classroom practices. Classroom discussion about hinged plane mirrors is mostly about the formula: $N = (360^0 / \alpha) - 1$, which gives the number of images obtained by multiple reflections in two hinged plane mirrors. Participants,

however, could not conceptualize that number as not independent of object position and observer position. Also, the same participants had the misconception that the full number of images for angles other than 90^0, 60^0, 45^0, etc., possibly are not obtained because the formula would give a fraction. It is nearly impossible to find in a textbook the derivation of the aforementioned formula or the inequalities which enable one to calculate the number of images for any value of α, for the specific object positions (Kulkarni, 1960) and observer positions (Iona, 1982).

Participants' reasoning for their answers on questions involving in the spherical mirrors and lenses were found to be similar. Mostly their reasoning for concave mirrors shared something in common with their reasoning for converging lenses, as did their reasoning for convex mirrors and diverging lenses. Therefore, the findings for those contexts were presented together. The most prominent difficulty in those contexts was found to be related to the use of light rays. Representations are powerful tools, especially in geometrical optics. However, the light ray was found to be a not fully developed concept for most of the participants. Similar to the discussions in the previous studies (Bendall et al., 1993; Galili & Hazan, 2000a; Goldberg & McDermott, 1987; Osborne et al., 1993), participants in the present study thought of light rays as physical entities that form an image rather than a geometrical representation of how light behaves under certain situations. Especially in the usage of special rays in the contexts of spherical mirrors and lenses, they had difficulty in understanding the idea that special rays are sufficient but not necessary for image formation.

Participants' knowledge of spherical mirrors and lenses was mostly fragmented. The situation for convex mirrors and the diverging lens was even worse. From their formal instruction, participants had acquired certain pieces of knowledge related to the topic but those fragments do not comprise full conceptual understanding of the topic. In some of the cases, the participants were found to transfer their knowledge in one context incorrectly to another context. For instance, although most of the participants expressed that in a convex mirror the image would be formed in the back of the mirror regardless of where the object is located, they thought that an image of an object located at the focal point would not be formed in a convex mirror. Those kinds of transfers which led to incorrect answers to the items were quite common among the participants of the present study were not mentioned in the literature before.

Another common misconception in the context of concave mirror and converging lens was related to the usage of the screen in the observation of a real image. Participants had difficulty in understanding the scientific conception that a screen is only a convenience for observation of real image points in space (i.e., aerial image) and there is a particular image

position for an image of an object to be observed on a screen. Some participants defined real images in relation to the presence of a screen, and therefore thought that real images could not be present in space in the absence of a screen. Some others however, thought that if a screen moved farther or closer to the optical instrument, the image of the object would be still seen on the screen with a different size or orientation. Those findings show similarities with those of Goldberg and McDermott (1987) and Galili (1996). The representations and ray diagrams are usually responsible for that type of reasoning.

The analysis of the Open-Ended Geometrical Optics Test results was also interesting. The proportions of deficient and not meaningful reasoning for the items on the test were relatively high for more than half of the items. This is another indication that the pre-service teachers' knowledge was fragmented. Their correct response rate for the items in familiar contexts from their daily life (such as plane mirrors) and from their instruction is higher than the less familiar contexts (such as spherical mirrors). This small rate of correct responses might be due to the lack of knowledge in those contexts. In the analysis of the open-ended test responses, it was found that in addition to some totally new reasoning, there was reasoning similar to that expressed during the interviews. The open-ended test was beneficial in that more subjects than the participants in the interviews were tested in the topic of interest. Their written responses guided the researcher to construct the alternatives on the multiple-choice test from the common subject responses.

As stated by Downing (2006) effective test development requires a systematic approach to ensure sufficient validity and reliability evidence to support the proposed inferences from the test scores. In this study, the validity of the FTGOT was established in three ways. The first of these was to determine whether a positive correlation exists between the student scores and students' confidence. According to Çataloğlu (2002), a positive correlation between the student scores and students' confidence would be an evidence for construct validity. He expected that students who are able to understand a question can then judge their ability to answer that question correctly or incorrectly. In the previous studies on the development of three-tier tests, a correlation coefficient was calculated between the subjects' first two tiers scores and their confidence scores. The correlations found in those studies range between .11 and .51. Türker (2005) developed a three-tier test in order to assess high school students' misconceptions on force and motion and found a positive, but not significant correlation of .11 between the scores of the first two tiers and the confidence tier. Kutluay (2005) on his three-tier test on geometrical optics found a positive significant coefficient of .33. In their three-tier tests, Aydın (2007) found a correlation of .41 (on kinematics graphs), Çataloğlu (2002) found a correlation of .49 (quantum mechanics), and

Peşman (2005) found a correlation of .51 (on simple electric circuits). Four-tier tests, however, require a different procedure since confidence about the main answer and about the reasoning are asked separately. In the present study, three correlations were calculated with a similar purpose as in three-tier tests: to establish the construct validity of the test scores. These variables and the correlation coefficients between them are: (1) Correlation between first tiers (correct only first score) and second tiers (first confidence score) (r = .194); (2) Correlation between third tiers (correct only third score) and fourth tiers (second confidence score) (r = .127); (3) Correlation between first and third tiers (correct first and third score) and second and fourth tiers (both confidences score) (r = .218). The first and third correlations were found to be significant, but small in strength. However, when the correlations were re-calculated for the male and female subjects separately, the correlations were found to be positive and significant for males, but not significant for the females in all three correlations. As a personality trait, female subjects appeared less confident about their answers than males. This gender difference appears to increases with age (Hyde, Fennema, & Lamon, 1990; Lundeberg & Moch, 1985 as cited in Lundeberg, Fox & Puncohar, 1994; Lundeberg et al., 2000). With the gender and the age factors taken into account, the low or no correlations for the whole group, a positive moderate correlation for the males is obvious in this study. That means male subjects with high scores on the FTGOT items are confident about their answers, whereas male subjects with low scores are not confident about their answers. This result is evidence for the construct validity of the FTGOT scores for the males.

Secondly, factor analyses for establishing construct validity were performed. Factor analyses were conducted over correct scores and misconception scores for different contexts, cases, and for AND, OR, SUM functions for ordinary multiple-choice test (only first tier), two-tier test (first and third tiers) and four-tier test (all four tiers) separately. When the subjects' scores for the total test items were factor-analyzed for only first tier, first and third tiers, and all four tiers, all produced five factors. In some of the factors some plausible items came together with quite moderate or high reliabilities, while in some other factors the items loaded into the same factor and could not be interpreted by the researcher. It was found that the items were loaded to the factors mainly according to either their contexts or according to the similarity of their item format. For the total test correct scores, the reliability of the items loaded into the factors was found to increase from only the first tier to all four tiers, while the percentage of the total variance explained decreased. The reason for the increase in the reliability might be due to the increase in the validity and the number of items that enter into the factor analysis. As a result of factor analysis, all four-tier scores for the total test items produced two meaningful factors. The first factor includes Items 3, 4, 5, and 6 all of which

are in the plane mirror context with quite high factor loadings (>.50) and a factor reliability of .44. The second factor for the total test all four tiers score includes Items 10 and 13, which are both in the spherical mirror context. When the factor analysis was conducted for the items according to their contexts or cases separately, the items were found to be loaded to some interpretable factors according to the format of the items. The correct scores were coded for their context and cases with AND, OR, SUM functions such that the AND score shows that the answer is correct in all of the six coded variables, the OR score shows that the answer is correct in at least one of the six coded variables, the SUM score shows the sum of times that the item is correct in all of the six variables. Over Correct AND scores (i.e., ANDC1, ANDC2, ANDC4), no factor analysis could be run because of the small variance of the scores. Most of the scores of the subjects are 0 for this coding. Therefore, the correlation coefficients could not be computed. However, the OR and SUM scores all produced 2 or 3 factors according to the contexts of the items. The factor reliabilities for all four tier scores were found to be higher than the one or two-tier scores, and the factor loadings are quite high. This could be a good evidence for the construct validity of the FTGOT test scores.

The factor analysis could not be conducted over the misconception AND scores (ANDM1, ANDM2, ANDM4) because of the low variance in the scores. The factor reliabilities for the other misconception scores were found to be low or even negative. Since the reliability is a measure of the internal consistency, the misconceptions comprising the factors were thought to be independent of each other. According to Marx (1988), reliability is influenced by the item difficulties. Since the FTGOT is a misconception test with powerful distracters, it is a rather difficult test. As a result of the factor analysis on SUMM4 scores, misconceptions M7 (“all special rays are necessary to form / see image”) and M12 (“covering some part of a mirror/lens causes the disappearance of some part of the image”) were found to be loaded into a single factors. This result shows an agreement with the interview results. However, the correlation between these two misconceptions is low (.18). Factor analysis has been severely criticized in the literature, especially for the case of dichotomous variables (Halloun & Hestenes, no date), so SUM scores may overcome this limitation with their continuous scoring. Also, one of the factors of ORM2 scores which includes misconceptions M1 (“the images of objects can be formed/seen only when the object is within the borders of the mirror/lens”) and M2 (“if there is an obstacle in front of an object, its image cannot be formed / seen in the mirror”) show an agreement with the interview results. Hence, the low reliabilities might be the consequence of the difficulty of the test. Heller and Huffman (1995) proposed two possible alternative reasons for the low correlation between the FCI items they found as a result of the factor analysis:

1. Students do not have coherent concepts, and their knowledge consists of fragmented bits and pieces.
2. Students do have coherent concepts, but the test items do not measure this knowledge.

In the present study, the subjects' knowledge in geometrical optics was found to be fragmented in nature and even context dependent. This might be one of the reasons for being able to get only a small number of plausible factors as validity evidences.

Thirdly, the percentages of false positives, false negatives, and lack of knowledge were estimated as evidence of validity of the FTGOT scores. Hestenes and Halloun (1995) stated that the proportions of false positives and false negatives should be less than 10 %. In fact, the lower the probability of false positives and false negatives, the greater the validity of a multiple-choice test. In the present study, the proportions of false positives was estimated to be 3.5 % and false negatives to be 3.3 % over the total test correct scores. Both are below the threshold percentage defined by Hestenes and Halloun (1995). The proportion of lack of knowledge was 5.1 %. All three proportions, which are below 10 %, are evidence for the content validity of the FTGOT scores. As a qualitative method to ensure the content validity of the FTGOT, the test was examined by the experts. Validity is about drawing correct conclusions based on the data obtained from an assessment. Validation, therefore, is the process of collecting evidence to support such inferences (Crocker & Algina, 1986, Frankel & Wallen, 2000; Kane, 2006). In conclusion, in this study validity evidence for the test scores was collected through some qualitative and quantitative techniques and the FTGOT was found to be a valid test.

The Cronbach alpha reliability coefficient of the correct scores of the total test items was found to be .59 for the present study. Aydın (2007), Kutluay (2005), Peşman (2005) and Türker (2005) estimated the reliability coefficients for their correct scores as .84, .55, .69, .48, respectively. All, except Türker (2005), calculated the reliability coefficients over misconception scores to be lower than the correct scores (.69, .28, .33, .62, respectively). In the present study, however, there is no single reliability coefficient for the misconception scores. However, for comparison with the previous studies, the All Four Tiers OR score over misconception scores (ORM4), which is .46, can be used. In Table 4.26, it can be seen that the standard deviations of correct scores were bigger than the standard deviations of misconception scores (considering the number of items measuring each and the mean scores of each). In other words, the spread of scores for correct scores is larger than the spread of misconception scores. Also, discrimination indexes for the misconception scores were found to be close to 0. Thus, there were no differences between students with high scores and

students with low scores with respect to their misconceptions. This result is the indicator of the homogeneity of the sample in terms of possessing misconceptions and might be the reason for the low reliability coefficients of the misconception scores. In the present study, for both the correct and misconception scores, reliability coefficients were calculated for AND, OR, SUM scores. Reliability coefficients for the AND scores were found to be very low or even negative compared to the others. This result might be related to the non-spreading scores for the AND scoring because most of the scores for the participants in this coding is zero. In a similar way, for correct scores the reliability coefficients were calculated for each context and case separately. Compared to the total test correct scores, the reliability coefficients were found to be lower for the contexts and cases, because the number of items is smaller for them. As Marx (1998) stated, the longer tests are more reliable than shorter tests. The spread of scores, so does the standard deviation, reduce from one tier to four tiers score analysis, which results the reliability to decrease. On the other hand, as the validity of the test scores increases, so does the reliability. For this reason, there is not a trend in increase or decrease in the reliability coefficients from one-tier analysis to four-tier analysis. Since the FTGOT is specially designed to assess misconceptions about geometrical optics, it has very strong distracters. As a result, the items are very difficult with small difficulty levels. As Crocker and Algina (1986) stated nearly all test score parameters are affected by item difficulty. This might be another reason for low reliability coefficients.

Before the present study, researchers had investigated the mean percentages of correct items and misconceptions in terms of only first tier, first two tiers and all three tiers. Table 2.13 summarizes these average percentages for the misconceptions examined in previous studies. The difference between the percentages of the first two tiers and only first tier gives the proportion of inconsistent student answers, while the difference between all three tiers and the first two tiers gives the proportion of lack of knowledge. In the present study, over the total test correct scores the mean percentages of correct items was found to be 30.8 %, 18.4 %, and 13.3 % for the only first tier, first and third tiers and all four tiers, respectively. The 12.4 % difference between the only first tier and first and third tiers is due to inconsistent reasoning. The 5.1 % difference between the first and third tiers and all four tiers gives the proportion of lack of knowledge. The correct score percentages for different tiers were calculated for the other correct scores in terms of contexts, cases, and functions. These are interpreted in the same way as above. The correct SUM scores yield a similar difference in correct proportions to those of the total test correct scores, i.e. 11.7 % for the difference between the only first tier and first and third tiers; 5.1 % for the first and third tiers and all four tiers. This result might be an indicator of how SUM scores better estimate the

percentages compared to AND or OR scores. However, in certain situations AND and OR scores might be useful depending on the objective of the user of the test. For instance, if one wants to identify context independent, strongly held, coherent conceptions AND scores are useful, whereas if the objective is to identify context-dependent, loosely held conceptions, OR scores are useful. The problem with AND scores is their underestimation of the misconception proportions and dependence on the number of items that measure it; whereas OR scores is the overestimation of the misconception proportions and the number of items that measure it. Therefore, either the number of items measuring each misconception should be equal, or there is a need of standardization if one is going to compare misconceptions with one other. In the present study, standardization was accomplished by means of the SUM scores. However, if the test user's aim is to compare the groups in terms of total test scores, this standardization may not be needed.

Misconceptions are considered significant when they exist in at least 10 % of the sample (Caleon & Subramaniam, 2010a, 2010b; Tan et al., 2002). Investigating all misconceptions, only M21 ("only the angle between mirrors determines the number of images seen in hinged plane mirrors" with 20 %) was the misconception with a percentage of above 10 %, according to all four tiers of Misconception AND scores (ANDM4). This result shows context independence for pre-service teachers on this single misconception in the context of hinged plane mirrors. According to Misconception OR scores (ORM4), however, all but four misconceptions were found to be present in 10 % or more of the participants. Those misconceptions that were below 10 % were M9 ("real images can only be seen on a screen" with 7 %), M11 ("an observer moving along the line passing the center of a spherical mirror can see himself any point along this line" with 7 %), M16 ("image size always equals to the mirror size" with 6 %), and M20 ("only the number of mirrors determines the number of images seen in hinged plane mirrors" with 2 %). However, both AND and OR scores are very much dependent on the number of misconception choices given for measuring it. According to the standardized misconception SUM score (SUMM4) percentages, the misconception percentages which are independent of the number of misconception choices measuring it were obtained. The results show that M2 ("if there is an obstacle in front of an object, its image would not be formed" with 12 %), M3 ("image formation and observation process are separate events and happening in an order in plane mirrors" with 16 %), M12 ("covering some part of a mirror/lens causes the disappearance of some part of image" with 15 %), M14 ("moving closer to/farther from a plane mirror, someone can see more of himself" with 26 %), M19 ("a real image can be seen with a different size/orientation if a screen is placed to another location from the image point" with 19 %) and M21 ("only the

angle between the mirrors determines the number of images seen in hinged plane mirrors") were the misconceptions which were held by more than 10 % of the pre-service teachers and regarded as significant misconceptions.

As Crocker and Algina (1986) stated, a general goal in test construction is to obtain a test of minimum length that yields scores with the necessary degree of reliability and validity for the intended use. With this purpose, the researcher picked the most significant misconceptions and the items that contribute to those significant misconceptions. This reduced form of the FTGOT included 17 items for assessing 15 misconceptions. The Cronbach alpha reliability coefficients are decreased a little bit, but this decrease is not so significant. There is a small increase in the difficulty index and discrimination index for all four tiers in this new form of the test, but the increase is not so significant. The percentages of each misconception and the average are also similar for the new form which measures 15 misconceptions. The alternative form of this test may be used depending on the purpose of the investigator.

5.2. Conclusions

The results from the present investigation demonstrate that the four-tier test developed in this study (i.e., FTGOT) is a valid and reliable instrument in assessing conceptual understanding in geometrical optics. Together with the other diagnostic methods, such as interviews, four-tier tests can provide useful information about the conceptual understanding of the population under investigation. Some specific conclusions that can be drawn from the present study are listed below.

1. Pre-service physics teachers, even after they have completed their courses in the domain of physics, have certain misconceptions about geometrical optics. The interview results revealed that the misconceptions in the context of plane mirrors were found to be usually context-independent, while the ones in the contexts of spherical mirrors and lenses are usually fragmented and context-dependent. This situation might be related to the subjects' having more experience with plane mirrors compared to spherical mirrors and lenses.
2. Four-tier tests have an advantage over two or three-tier tests in that subjects' lack of knowledge can be discriminated from their misconceptions by the means of the confidence tiers. Three-tier tests also claimed that they discriminate the lack of knowledge, but they underestimate the proportion of lack of knowledge and

overestimate misconceptions scores. On the contrary, four-tier tests assess misconceptions that are free from errors and lack of knowledge.

3. As a first method to find validity evidence for the FTGOT scores, the correlations between the scores on the first tiers (correct only first score) and the second tiers (first confidence score); between third tiers (correct only third score) and fourth tiers (second confidence score); between first and third tiers (correct first and third score) and second and fourth tiers (both confidences score) was investigated and Pearson correlation coefficients of .194, .127, and .218 were found, respectively. These results mean that subjects with high scores on the first tier of the FTGOT were slightly more confident than the subjects with low scores. Also, subjects with high scores both on the first and third tiers of the FTGOT were slightly more confident on both tiers than the subjects with low scores. When the correlations were re-calculated for the male and female subjects separately, the correlations were found to be positive and significant for males (with medium Pearson correlation coefficients of .346, .318, .364, respectively), but not significant for the females in all three correlations. In other words, the test worked properly for the all subjects, but better for the male subjects.
4. As a second method to find validity evidence for the FTGOT scores, factor analyses were conducted over the correct scores and misconception scores. It is expected that all items and misconceptions formed acceptable factors. However, in order to meet the assumptions of the factor analysis, some items or misconceptions were removed from the analysis. Although not all items formed interpretable factors over the correct scores, it was found that the items were loaded to the factors mainly according to either their contexts or according to the similarity of their item format. For the factor analysis conducted over misconception scores, on the other hand, the interpretation of the formed factors was even more difficult. The factor reliabilities for the misconception scores were found to be low or even negative. Since the reliability is a measure of the internal consistency, the misconceptions comprising the factors were thought to be independent from one other. This might be the consequence of subjects' not having coherent concepts and their having knowledge in a fragmented bits and pieces.
5. Thirdly, the percentages of false positives, false negatives, and lack of knowledge were calculated as validity evidence. The lower the probabilities of false positives, false negatives and lack of knowledge, the greater the validity of a multiple-choice test. In the present study the proportions of false positives was estimated to be 3.5 %,

false negatives to be 3.3 %, and lack of knowledge to be 5.1 % over the total test correct scores. All of them were below 10 % which was an evidence for the content validity.

6. Reliability of the FTGOT was calculated for the correct scores and misconception scores for different scores and functions. The Cronbach alpha reliability coefficient of the correct scores of the total test items for all four tiers was found to be .59. The reliability coefficients for the misconception tests are generally lower than the achievement tests (Eryılmaz, 2010). For a researcher-based misconception test, the reliability coefficients of about .60 or higher can be considered as good. For the reliability coefficients over misconception scores, the one calculated for the misconception SUM score was thought to be crucial and found to be .42. Because SUM scores standardize the misconceptions in terms of the number of misconception choices measuring the specific misconceptions. It can be concluded from the reliability coefficients that the FTGOT assess subjects' achievement more reliably than student misconceptions about geometrical optics.
7. In the present study, as different from the previous studies, three separate functions were used to calculate the proportions of the misconceptions. AND function was used to calculate the proportions of misconceptions that are present in all of the related contexts (i.e., consistent, coherent, context-independent misconceptions). That means in this scoring, someone who had the related misconception choices in all of the items in the test was considered to have this specific misconception. OR function was used to calculate the proportions of misconceptions that are present in at least one of the related contexts (i.e., inconsistent, loosely held, context-dependent misconceptions). In this scoring, someone who had the related misconception choices in one of the items was considered to have this specific misconception. Both AND and OR functions might be useful in certain circumstances for specific uses but AND scores underestimate the percentages of misconceptions while OR scores overestimate it. Both scores, very much dependent on the misconception choices measuring a specific misconception. Thus, a comparison between the misconceptions becomes impossible. Standardization was achieved with the SUM function, which is independent of the number of misconception choices measuring specific misconceptions.
8. Misconceptions which were hold by more than 10 % of the subjects were considered as significant misconceptions. According to the all four tiers of Misconception AND scores (ANDM4) only M21 ("only the angle between mirrors determines the number

of images seen in hinged plane mirrors") with 20 % was found to be a significant misconception. According to all four tiers of Misconception OR scores (ORM4), however, all but four misconceptions were found to be above 10 %. Those misconceptions that were below 10 % were M9 ("real images can only be seen on a screen") with 7 %, M11 ("an observer moving along the line passing from the center of a spherical mirror can see himself any point along this line") with 7 %, M16 ("image size always equals to the mirror size" with) 6 %, and M20 ("only the number of mirrors determines the number of images seen in hinged plane mirrors") with 2 %. According to the all four tiers Misconception SUM scores (SUMM4), M2 ("if there is an obstacle in front of an object, its image would not be formed") with 12 %, M3 ("image formation and observation process are separate events and happening in an order in plane mirrors") with 16 %, M12 ("covering some part of a mirror/lens causes the disappearance of some part of image") with 15 %, M14 ("moving closer to/farther from a plane mirror, someone can see more of himself") with 26 %, M19 ("a real image can be seen with a different size/orientation if a screen is placed to another location from the image point") with 19 % and M21 ("only the angle between the mirrors determines the number of images seen in hinged plane mirrors") with 39 % were the significant misconceptions.

9. SUM scores have some advantages over the other scores because they eliminate the problems due to the unequal number of items or misconception choices assessing a single conceptual dimension or misconception. Factor analysis is criticized for the case of dichotomous variables. The continuity of the SUM scores may eliminate this problem, too.
10. Although AND or OR scores seem to be underestimating or overestimating the percentages, they are useful in determining the context-independent, coherent conceptions (AND scores) or context-dependent, loosely held conceptions (OR scores). However, one should be careful that statistical analysis over the AND scores yields no validity and reliability evidence because of non-dispersing nature of the AND scores for this standards.
11. Investigating the percentages of correct answers or misconceptions for one tier, two tiers and four tiers of the FTGOT can lead to interpretations for the difference between the percentages. For example, the difference between the percentages of the first and third tiers and only first tier gives the proportion of inconsistent student answers. Some of those percentages are the percentages of false positives, while the

difference between all four tiers and the first and third tiers gives the proportion of lack of knowledge.

12. Blank alternatives used in the present study provided the subjects with an opportunity to write any answer or reasoning that they thought not included in the available alternatives of the test items. In the FTGOT, an average of 3.1 % of the subjects filled the blank alternatives in all of the main and reasoning tiers. Some of the subjects restated the available alternatives in their own words (23.2 %); some of them thought that two of the available alternatives were correct for the item of interest (9.9 %); while some others wrote totally new plausible answers or reasoning (10.9 %). In the study, a total of 33.1 % of the all answers written in the blank alternatives were recoded into one of the existing alternatives. In this respect, the inclusion of the blank alternatives might be a good practice for overcoming the forced-choice limitations of the multiple-choice tests. With the inclusion of that option, the subjects are free to write their answers in their own words like in the open-ended tests. Moreover, new plausible correct or incorrect responses written by the subjects to those alternatives would give the test developers information for revising the test distracters after a critical analysis. The proportion of the new plausible answers given to the blank alternatives for the FTGOT was not high enough to be included among the alternatives of the test items.

5.3. Internal Validity of the Study

Internal validity means that any observed outcome is actually due to the independent variable instead of an unexpected independent variable. McMillan and Schumacher (2001) defined it as the extent to which extraneous variables have been controlled or accounted for. In this section of the study, the possible threats to the internal validity and their control are discussed. The design of the study included some control for the threats of subject characteristics, testing, maturation, attitude of subjects and regression. According to Fraenkel and Wallen (2000) there are four threats to internal validity in a survey research; mortality, location, instrumentation and instrument decay.

Location might be considered as a threat in this study in administrating the test. For this reason, the data were collected in similar places in all of the universities. The open-ended test, the TTGOT and the FTGOT were all administered in the classrooms instead of laboratories or other places in all of the universities. Therefore, differences in the places in which administration of the test took place did not affect the responses of subjects. The

physical conditions of the classrooms, such as seats, desks, and heating were about the same. Furthermore, the interviews took place under standard conditions at the laboratories of each university.

Instrumentation threat to the internal validity includes the way in which instruments are used in a study (Fraenkel & Wallen, 2000). It includes instrument decay, data collector characteristics, and data collector bias. Instrument decay was not a problem for this part of the study since the developed test is in the multiple-choice format. So the instrument itself or the scoring of the instrument did not change over time. Data collector characteristic may be a possible threat to the internal validity since the traits of data collectors may influence the outcome. It was not possible to use a single data collector. The instructors who administered the test were all informed by the researcher through administration guides (see Appendices J, Q, and W). The researcher also informed the data collectors by telephone before administrations and got detailed information about the administration processes afterwards. In order to eliminate the data collector bias, *i.e.*, the distortion of data by data collectors, the researcher observed some of the administration processes to insure the procedures were applied in standard conditions in all of the classrooms.

Loss of subjects (*i.e.*, mortality) might be a threat to internal validity since some subjects in the sample were not present on the day of the test administration. The tests were administered by the instructors without announcing the administration before. In the present study, 90 % of the accessible population took the test, which is quite satisfactory. The subjects who were absent on the day of administration did not have a common reason.

History might be a possible threat for internal validity, but as Fraenkel and Walllen (2000) stated, any researcher can be certain that one group has not had experiences that differ from those of other groups. For this reason, any unexpected event happened during the administration of the test, it was documented in the study. For instance, just before the administrations of the FTGOT, a large earthquake occurred in the eastern part of Turkey. Therefore, Yüzüncü Yıl University was excluded from the present study.

5.4. External Validity of the Study

External validity refers to the generalizability of the results. There are two general categories of external validity that need to be considered: population external validity and ecological external validity. Population validity is related with the extent to which the results of the present study can be generalized to other people. Ecological validity, on the other

hand, is related with the extent to which generalizing the results is limited to similar conditions (McMillan & Schumacher, 2001).

The number of pre-service physics teachers who registered to the corresponding courses of the semester of interest was around 270 and the FTGOT was administered to 243 pre-service physics teachers. This corresponds to approximately 90 % of the accessible population. Therefore, we are quite confident in generalizing the outcomes of the present study to the accessible population, which includes all universities in Turkey with physics teacher education programs.

There are many variables that can affect intellectual characteristics such as region, educational facilities, socio-economic status, experience with the topic, or interest in the topic. All these variables may affect the results of the study. In the present case those variables have not been taken into account. Although for this reason, it might not be possible to generalize the results to all populations, there has been sufficient research on conceptual understanding in geometrical optics to indicate that the findings are widely applicable.

5.5. Implications of the Study

The results of this study have several important implications. Some of those implications are discussed in this section based on the findings of the current study.

One of the implications of this study is that there is a need of conceptual teaching of the physics topics. Complex problem solving or even advance courses taken do not necessarily mean to scientific understanding, but there is a need for conceptual model development. Many student conceptions are not scientifically acceptable regardless of whether or not they receive instruction, and that these conceptions are difficult to change through regular instruction (Fetherstonhaugh and Treagust, 1992). Even though the misconceptions in geometrical optics discussed in this study for pre-service teachers are in common with many high school or university students, the situation for pre-service or in-service teachers is more serious and needs more attention. Since teachers are the key to improve student performance (McDermott, Heron, Shaffer & Stetzer, 2006; McDermott, 2006), the results of this study signifies the need for deepening the conceptual understanding of pre-service and in-service teachers in the topics they are expected to teach, more specifically for this study in the topic of geometrical optics. In order to make physics meaningful to their students, teachers should have a higher content knowledge in specific physics topics, as well as have a strong pedagogical content knowledge about how to teach a specific topic more effectively. Including certain advanced physics courses in teacher

education programs would be desirable but not sufficient. A more crucial attempt would be bringing mostly conceptual content teaching courses to the pre-service teacher education programs. Within those courses teacher candidates not only develop more coherent models on the specific physics concepts, but also be aware of probable student difficulties in those concepts for their future teaching career.

The interview, open-ended test and four-tier test results all showed that the pre-service teachers have mainly difficulties about the ray model, the function of the observer, and the function of the screen in image formation and observation process. Although, ray model is a powerful tool to explain most of the optical phenomena, the mis-usage of the model may cause the surface understanding and wrong interpretations of the phenomena. Therefore, the ray model should be discussed in detail during the geometrical optics instruction. Especially for the usage of the special rays, the emphasis should be given for their simplification, and not necessity. It is also necessary to emphasize the importance of the observer's eye in image formation and observation process, and intentionally use and emphasize the observer's eye in any optical phenomena. The screens, especially in real image observation process should be used, but at the same time students should be provided with an experience to see an aerial image in the absence of the screen. The inability to relate the theoretical knowledge to the practical context to be one of the main weaknesses of many students as revealed from the interviews. Therefore, they should be provided with more inquiry oriented laboratory experiences during their geometrical optics instruction.

The results of this study have some implications also for classroom practice such that the development of a diagnostic instrument to assess the common student misconceptions in geometrical optics helps teachers to design and improve their teaching on the topic. For one thing, the existence of a valid and reliable, easy to administer, easy to score instrument would enable the teachers to confidently assess students' understanding of science concepts. For another thing, once misconceptions or the lack of knowledge are identified by the four-tier tests, the teachers would be more directed about what to do in the classroom. Depending on the test results, the teacher either tries to remedy the problem by addressing the students' misconceptions or improves the quality of the instruction to compensate the lack of knowledge. Similarly, researchers in the science education need to measure the conceptions in a valid and reliable way in order to make correct conclusions about their findings. Therefore, four-tier tests might be useful in assessing conceptual understanding or misconceptions in a specific topic in order to gather data from large groups for research purposes.

Textbooks play a vital role in the teaching and learning of physics topics. Teachers as well as their students seem to use textbooks most of the time during the teaching and learning process (Good, 1993) and textbooks have a very important influence on both teachers and their students. However, sometimes the textbooks become a source of student misconceptions with the information they provide. Teachers often have the same alternative conceptions as their students and the poorly written textbooks may be responsible for the persistence of their alternative conceptions (Wandersee et al., 1994). Therefore, readers of the books and especially the teachers should be aware of the explanations and representations in the textbooks and discuss them with their students to prevent construction of misconceptions in the minds. Also, textbook writers and textbook analyzers should be watchful for possible sources of student misconceptions. For instance, in many of the textbooks the role of the observer's eye is ignored or not specifically emphasized in the image formation and observation process. Similarly, the special rays are discussed as if they are the only rays that form an image. Hence, the teachers and students should be alert about the information presented with the textbooks since they do not always contain the scientifically accepted knowledge, but may be incorrect or incomplete, vague or misleading.

Palmer (1999) claimed that students may have both a misconception and a scientifically acceptable conception and those different conceptions can be brought into play in different problem contexts. This is one of the consequences of the context dependence of the misconceptions or scientific conceptions, and the not coherent but fragmented nature of the knowledge. The coherent, context independent misconceptions require different remedies than the context dependent and inconsistent misconceptions. The analyses provided with AND, OR, SUM functions would provide people with the identification of context dependent or independent misconceptions depending on their purpose.

Many pre-service teachers clearly need more preparation in geometrical optics than is usually provided. The implications for in-service teachers are obvious. In-service teachers of physics have completed the same kinds of courses as the pre-service teachers who participated in this study and it is unlikely that teaching geometrical optics as they themselves taught this material has greatly increased their own understanding. All teachers of physics should have the opportunity to participate in an inquiry-oriented, laboratory-based course in geometrical optics in which they are guided in constructing a ray model for light from their own observations. By extension, this recommendation applies other topics in physics, as well as to other sciences.

5.6. Recommendations for Further Research

The recommendations offered for further research studies are as follows:

1. The results of the present study signifies that four-tier diagnostic tests assess subjects' misconceptions about geometrical optics in a more valid way compared to one-tier, two-tier, or three-tier tests. Therefore, there is a need for investigation of misconceptions with four-tier tests in other physics topics.
2. The independent variables such as university, gender, socio-economic status, experience with geometrical optics, interest toward geometrical optics was not taken into account in the present study. However, studies that investigate the effect of those variables to the pre-service teachers' misconceptions about geometrical optics can be done.
3. The FTGOT was administered to pre-service teachers to identify their misconceptions in geometrical optics. One reason for focusing on pre-service teachers is that collecting data from pre-service teachers is more efficient than collecting it from in-service teachers since they are already available in the faculties. The other reason is that it is easier to do something about the misconceptions and the lack of knowledge of pre-service teachers because they are still university students. However, this does not mean that we would expect in-service teachers to be very different in their conceptual understanding of geometrical optics. Therefore, it can be suggested that the FTGOT would be administered to the in-service teachers in the future studies and their misconception in the topic should be investigated.
4. There are no studies on the development of four-tier tests in other fields of science such as chemistry or biology. Researchers should develop four-tier tests for assessing students' misconceptions in those science fields in order to assess it in a more valid way.
5. In the diagnostic test development studies, concentrating on a few misconceptions and measuring each misconception with more than three items would help to increase the reliability of misconceptions scores. Also, measuring each misconception with an equal number of items would equate the AND and OR scores of subjects for each misconceptions. In this way those scores for each misconception would be compared with each other.
6. The relationships between the misconceptions listed in the present study can be investigated by using a causal modeling which uses a cause and effect logic to describe the behavior of the system.

7. Future studies that concentrates on the development of curricula with appropriate teaching strategies or methods to address the misconceptions identified in this study would be worth to study. The results of the present study signified the need for a more conceptual curriculum like Physics by Inquiry (McDermott, 1996) for the pre-service teachers. The experimental studies that investigate the effectiveness of those curricula that address common misconceptions in geometrical optics are needed.

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APPENDIX A

FIVE-YEAR PHYSICS TEACHER EDUCATION PROGRAMS OF FACULTIES IN TURKEY

Table A.1 Atatürk University Kazım Karabekir Education Faculty Physics Teacher Education Program

1. Yarıyıl Ders Planı						**2. Yarıyıl Ders Planı**					
KODU	**DERS**	**Z / S**	**T+U**	**K**	**AKTS**	**KODU**	**DERS**	**Z / S**	**T+U**	**K**	**AKTS**
103AL	Fizik Laboratuvarı - 1	Zorunlu	0+2	1	4	104AL	Fizik Laboratuvarı II	Zorunlu	0+2	1	4
109AL	Genel Kimya Laboratuvarı I	Zorunlu	0+2	1	3	110AL	Genel Kimya Laboratuvarı II	Zorunlu	0+2	1	3
GK101	Türk Dili I	Zorunlu	2+0	2	2	GK102	Turk Dili II	Zorunlu	2+0	2	2
KKEF13	Eğitim Bilimine Giriş	Zorunlu	3+0		4	KKEF16	Gelişim Psikolojisi	Zorunlu	+0	3	5
105 L	Genel Matematik I	Zorunlu	4+0	4	7	108AL	Genel Kimya II	Zorunlu	4+0	4	8
107AL	Genel Kimya I	Zorunlu	4+0	4	8	106AL	Genel Matematik II	Zorunlu	4+0	4	7
101AL	Fizik -1 (mekanik)	Zorunlu	6+0	6	7	102AL	Genel Fizik II	Zorunlu	6+0	6	7
3. Yarıyıl Ders Planı						**4. Yarıyıl Ders Planı**					
KODU	**DERS**	**Z / S**	**T+U**	**K**	**AKTS**	**KODU**	**DERS**	**Z / S**	**T+U**	**K**	**AKTS**
203AL	Geometrik Optik Laboratuvarı	Zorunlu	0+2	1	5	204AL	Fizik Optik Laboratuvarı	Zorunl	0+2	1	
207AL	Geometri Bilgisi	Zorunlu	2+0	2	0	208AL	Genel Biyoloji	Zorunlu	2+0	2	4
GK206	Yabancı Dil (ingilizce) II	Zorunlu	2+0	2	2	KKEF25	Program Geliştirme ve Öğretim	Zorunlu	2+0		3
KKEF20	Öğrenme, Öğretim Kuram ve Yaklaşımları	Zorunlu	3+0	3	5	KKEF11	Bilim Tarihi	Zorunlu	2+0	2	3
205AL	Diferansiyel Denklemler I	Zorunlu	4+0	4	5	GK206	Yabancı Dil (ingilizce) II	Zorunlu	2+0	2	
201AL	Geometrik Optik	Zorunlu	4+0	4	6	206AL	Diferansiyel Denklemler II	Zorunlu	4+0	4	5
						202AL	Fizik Optik	Zorunlu	4+0	4	0
5. Yarıyıl Ders Planı						**6. Yarıyıl Ders Planı**					
KODU	**DERS**	**Z / S**	**T+U**	**K**	**AKTS**	**KODU**	**DERS**	**Z / S**	**T+U**	**K**	**AKTS**
305AL	Elektronik Laboratuvarı	Zorunlu	0+2	1	4	KKEF29	Türk Eğitim Sistemi ve Okul Yönetimi	Zorunlu	+	2	3
309GK	Laboratuar Güv. ve İlkyardım Bilgisi	Zorunlu	2+0	2	5	114GK	Atatürk İlkeleri ve İnkılap Tarihi II	Zorunlu	2+0	2	2
115GK	Atatürk İlkeleri ve İnkılap Tarihi I	Zorunlu	2+0	2	2	306AL	Modern Fizik	Zor nlu	3+0	3	5
301AL	Bilgisayara Giriş	Zorunlu	2+2	3	7	302AL	Fizikte Matematik Metotlar	Zorunlu	4+0	4	9
KKEF23	Ölçme ve Değerlendirme	Zorunlu	3+0	3	4	304AL	Termodinamik	Zorunlu	4+0	4	9
303AL	Elektronik	Zorunlu	4+0	4	8						
7. Yarıyıl Ders Planı						**8. Yarıyıl Ders Planı**					
KODU	**DERS**	**Z / S**	**T+U**	**K**	**AKTS**	**KODU**	**DERS**	**Z / S**	**T+U**	**K**	**AKTS**
401AL	Akışkanlar Mekaniği	Zorunlu	2+0	2	3	412GK	Bilim ve İnsan -2	Zorunlu	2+0	2	3
KKEF27	Sınıf Yönetimi	Zorunlu	2+0	2	3	410GK	Kavram Yanılgıları -2	Zorunlu	2+0	2	4
411GK	Bilim ve İnsan -1	Zorunlu	2+0	2	3	408MB	Alan Eğitiminde Araştırma Projesi	Zorunlu	2+2	3	6
409GK	Kavram Yanılgıları -1	Zorunlu	2+0	2	4	406MB	Özel Öğretim Yöntemleri -1	Zorunlu	2+2	4	2
KKEF17	Okul Deneyimi	Zorunlu	1+4	3	6	402AL	Elektromagnetik Teori	Zorunlu	4+0	4	9
403AL	Kuantum Fiziği	Zorunlu	4+0	4	6	404AL	Katıhal Fiziği	Zorunlu	4+0	4	9
9. Yarıyıl Ders Planı						**10. Yarıyıl Ders Planı**					
KODU	**DERS**	**Z / S**	**T+U**	**KR**	**AKTS**	**KODU**	**DERS**	**Z / S**	**T+U**	**K**	**AKTS**
509GK	Bilim Felsefesi	Zorunlu	2+0	2	5	502AL	Atom ve Çekirdek Fiziği Laboratuarı	Zorunlu	0+2	1	3
507AL	Seçmeli -1	Zorunlu	3+0	3	4	512GK	Fen ve Teknoloji	Zorunlu	2+0	2	6
KKEF19	Öğretim Teknolojileri ve Materyal Geliştirme	Zorunlu	2+2	3	4	508AL	Seçmeli II	Zorunlu	3+0	3	4
503MB	Özel Öğretim Yöntemleri - 2	Zorunlu	2+2	4	3	KKEF26	Rehberlik	Zorunlu	3+0	3	4
501AL	Atom ve Molekül Fiziği	Zorunlu	4+0	4	6	502AL	Çekirdek Fiziği	Zorunlu	4+0	4	10
						KKEF21	Öğretmenlik Uygulaması	Zorunlu	2+6	5	6

** Öğrenciler, zorunlu dersleri öncelikli almak üzere her yarıyıl alacağı dersleri 30 AKTS'ye tamamlar.*

Table A.2 Balıkesir University Necatibey Education Faculty Physics Teacher Education Program

1. YARIYIL

Kodu	Dersin Adı	S	U	T	EST
FZE1101	Fizik Öğretmenliğine Giriş	2	0	2	2
EBB 1101	Eğitim Bilimine Giriş	3	0	3	3
FIZ 1130	Mekanik	7	2	5	6
MAT1122	Genel Matematik I	4	0	4	0
FIZ 1131	Mekanik Lab.	2	0	0	1
TDI 1101	Türk Dili I	2	0	2	0
YDI 1101	Yabancı D I	2	0	2	0
AIT 1101	Atatürk Ilkeleri ve Inkılap Tarihi I	2	0	2	0
	TOPLAM	24	2	20	12

2. YARIYIL

Kodu	Dersin Adı	S	U	T	EST
FIZ 1220	Elektrik ve Manyetizma	7	2	5	6
ENF 1201	Bilgisayar(Uygulama Yazılımları)	4	2	2	
EBB 1201	Gelişim Psikolojisi	3	0	3	3
MAT1230	Genel Matematik II	4	0		
FIZ 1221	Elektrik ve Manyetizma Lab.	2	0	0	1
TDI 1201	Türk Dili II	2	0	2	2
AIT 1201	Atatürk Ilkeleri ve Inkılap Tarihi II	2	0	2	2
YDI 1001	Yabancı Dil - II	2	0	2	0
	Gelişim_öğrenme	3	0	3	5
	TOPLAM	29	4	23	23

3. YARIYIL

Kodu	Dersin Adı	S	U	T	EST
KIM2120	Genel Kimya-I	0	0	4	4
KIM2121	Genel Kimya Lab.- I	0	2	0	1
MAT2120	Diferansiyel Denklemler	4	2	2	3
BIY2110	Genel Biyoloji-1	2	0	2	2
FIZ 2120	Elektrik	6	2	4	5
FIZ 2121	Elektrik Lab.	2	2	0	1
FIZ 2112	Optik	4	0	4	4
FIZ 2113	Optik Lab.	2	2	0	1
FIZ 2115	Bilgisayar Programlama	4	0	4	4
	TOPLAM	24	10	20	25

4. YARIYIL

Kodu	Dersin Adı	S	U	T	EST
BIY 2220	Genel Biyoloji- II		0	2	2
KIM 2221	Genel Kimya Lab.- II	2	2	0	1
KIM 2220	Genel Kimya-II	4	0	4	6
FIZ 2213	Fizikte Matematiksel Metotlar	4	0	4	4
FIZ 2214	Elektronik	4	0	4	4
FIZ 2215	Elektronik Laboratuvarı	2	2	0	1
EBB 2201	Öğretme Öğrenme Kuram ve Yaklaşımları	3	0	3	3
	TOPLAM	21	4	17	21

5. YARIYIL

Kodu	Dersin Adı	S	U	T	EST
EBB3101	Program Geliştirme ve Öğretim	3	0	3	3
FİZ 3110	Kuantum Fiziği I	4	0	4	4
FIZ 3112	Isı ve ermodinamik	3	0	3	3
FIZ 3111	Atom ve Molekül Fiziği	4	0	4	4
FIZ 3113	Astronominin Temel Kavramları	3	0	3	3
FZE3101	Bilg. Dest. Fizik Eğitimi	3	0	3	0
	TOPLAM	20	0	20	17

6. YARIYIL

Kodu	Dersin Adı	S	U	T	ES
FIZ3210	Kuantum Fiziği II	4	0	4	4
EBB 3201	Ölçme ve Değerlendirme	3	0	3	5
FİZ 3211	Çekirdek Fiziği	4	0	4	4
FIZ 3212	Atom ve Çekirdek Fiziği Lab.	2	0		1
FZG 3201	Bilim Tarihi	2	0	2	2
FZE 3201	Güncel ve Kavramsal Fizik	3	0	3	3
FZG 3203	İnsan Hakları ve Avrupa Birliği(seçmeli I)	3	0	3	3
	TOPLAM	21	0	19	22

7. YARIYIL

Kodu	Dersin Adı	S	U	T	ES
FIZ 4110	Katıhal Fiziği- I	0	0	4	5
EBB 4105	Ölçme ve Değerlendirme	0	0	3	4
EBB 4101	Sınıf Yönetimi	0	0	2	2
FIZ 4113	Dijital Elektronik ve Uygulamaları	0	0	3	5
FIZ 4111	Titreşim ve Dalgalar	0	0	3	4
FIZ 4101	Fizik Özel Öğretim Yöntemleri I	0	2	2	5
EBB 4102	Türk Eğitim Sistemi ve Okul Yönetimi	0	0	2	4
FZE4101	Fizik Özel Öğretim Yöntemleri I	0	2	0	0
	TOPLAM	0	4	19	29

8. YARIYIL

Kodu	Dersin Adı	S	U	T	ES
EBB 4201	Rehberlik	3	0	3	3
FZG 4211	İlkyardım ve Sağlık Bilgisi	3	0	3	3
FIZ 4210	İstatistik Fizik	4	0	4	4
FIZ 4211	Katıhal Fiziği - II	4	0	4	4
FZE4202	Öğretim Tek. ve Mat. Tasarımı	4	2	2	3
FZE4201	Fizik Özel Öğretim Yöntemleri - II	4	2	2	3
	TOPLAM	2	4	18	20

9. YARIYIL

Kodu	Dersin Adı	S	U	T	ES
FZE5101	Öğr. tek. materyal geliştirme	4	2	2	3
FZE5202	Fizik özel öğretim yöntemleri II	4	2	2	3
EBB5201	Sınıf yönetimi	4	0	4	4
FZE5105	Kavram Öğrt. ve Prob. Çözme	0	0	3	0
FZE5103	Fizik özel öğretim yöntemleri II	4	2	2	0
EGT5102	Sınıf Yönetimi	4	2	2	0
FZE5105	Fen Bil.Bil.Mat.Haz.I (SEÇMELİ)	3	0	3	0
FZE5104	Okul Deneyimi II	1	4	1	0
FZE5106	Fen Bil.Ölçme ve Değ. (SEÇMELİ)	3	0	3	0
FZE 5103	Özel Öğretim Yön. II	0	2	2	8

10. YARIYIL

Kodu	Dersin Adı	S	U	T	ES
FZE5201	Konu alanı ders kitabı incelemesi	3	2	2	3
FZE5203	Öğretmenlik Uygulaması	2	6	2	0
FZE5203	Fen Bil.Bil.Mat.Haz.II (SEÇMELİ)	3	0	3	0
FZE 5204	Bilg. dest. fizik eğit. ve projesi (SEÇMELİ)	3	0	3	3
FZE4205	Okul Deneyimi I	0	0	0	0
FZE6205	Uzmanlık Alan Dersi	0	0	5	0
EGT5202	Rehberlik	3	0	3	3
EGT4203	Öğretimi planlama ve değerlendirme	5	2	3	0
EGT4201	Öğretmenlik Mesleğine Giriş	3	0	3	0
EGT4202	Gelişim ve öğrenme	3	0	3	0

Table A.3 Boğaziçi University Education Faculty Physics Teacher Education Program

Dönem 1

Ders Kodu	Ders Adı	Kredi
PHYS 101	Fizik I	4
MATH 101	Analiz I	4
CHEM 103	Genel Kimya I	3
SCED 103	Oryantasyon	1
AE 111/	İleri Düzeyde İngilizce I/	3
----	Sosyal Bilimler Seçmelisi	
	Toplam Kredi : 15	

Dönem 2

Ders Kodu	Ders Adı	Kredi
PHYS 102	Fizik II	4
MATH 102	Analiz II	4
CHEM 104	Genel Kimya II	3
CHEM 09	General Chem stry Laboratory	1
AE 112/	İleri Düzeyde İngilizce II/	3
---	Sosyal Bilimler Seçmelisi	
Toplam Kredi : 15		

Dönem 3

Ders Kodu	Ders Adı	Kredi
ED 101	Eği ime Giriş	3
PHYS 201	Fizik III	4
PHYS 221	Maddenin Isıl Özellikleri	3
MATH 201	Matris Kuramı	4
ENG 101	Bilgisayar Kullanımına Giriş	3
TK 221	Türkçe I	2
	Toplam Kredi : 19	

Dönem 4

Ders Kodu	Ders Adı	Kredi
PHYS 202	Fizik IV	4
MAT 202	Diferansiyel Denklemler	4
EE 210	Elektrik Mühendisliğine Giriş	3
---	Sosyal Bilimler Seçmelisi	3
---	Sınırsız Seçmeli	3
TK 222	Türkç II	2
	Toplam Kredi : 19	

Dönem 5

Ders Kodu	Ders Adı	Kredi
ED 213	Gelişim ve Öğrenme	3
E 221	Rehberlik ve Psikolojik Danışmanlığın Temel İlkeleri	3
PHYS 301	Klasik Mekanik I	3
PHYS 407	İleri Kuantum Fiziği I	3
---	Sosyal Bilimler Seçmelisi	3
HTR 311	Atatürk İlkeleri ve İnkılap Tarihi I	2
	Toplam Kredi : 17	

Dönem 6

Ders Kodu	Ders Adı	Kredi
ED 262	Öğret mde Planlama ve Değerle dirme	4
PHYS 302	Klasik Mekanik II	3
PHYS 408	İleri Kuantum Fiziği II	3
---	Alan seçmelisi	3
---	Matematik Seçmelisi	3
HTR 312	Atatürk İlkeleri e İnkılap Tarihi II	2
	Toplam Kredi : 18	

Dönem 7

Ders Kodu	Ders Adı	Kredi
CET 360	Öğretim Teknolojileri ve Materyal Geliştirme	3
SCED 420	Teaching Methods in Science and Mathematics	3
---	SCED, ED, PRED veya CET seçmelisi	3
- -	Fizik Seçmel i	3
---	Çevre bilimleri seçmelisi (CE 222 veya ESC 301)	3
	Toplam Kredi : 15	

Dönem 8

Ders Kodu	Ders Adı	Kredi
SCED 340	B lim, Teknoloji ve Toplum	3
SCED 450	Matematik ve Fen Alanları Öğretiminde Okul Deneyimi I	3
ED 382	Sınıf Yönetimi	3
---	Fizik Seçmelisi	3
PHYS 380	Elektromagnetizm ve Radyasyon	3
	Toplam Kredi : 15	

Dönem 9

Ders Kodu	Ders Adı	Kredi
SCED 404	Fen Eğitiminde Araştırma Uygulaması	4
SCED 441	Fen Eğitiminde Öğretim Yöntemleri	3
SCED 451	Matematik ve Fen Alanları Öğretiminde Okul Deneyimi II	3
---	Alan Seçmelisi	3
---	Felsefe veya Bilim Tarihi Seçmeli	3
	Toplam Kredi : 16	

Dönem 10

Ders Kodu	Ders Adı	Kredi
SCED 408	Fen ve Matematik Öğretiminde Ders Kitabı İncelemesi	3
SCED 418	Fizik Öğretmenliği Uygulama Semineri	4
SCED 442	Fizik Öğretmenliği Uygulaması	4
---	Fizik Seçmelisi	3
---	Sınırsı Seçmeli	3
	Toplam Kredi : 17	

Tüm Dönemlerin Kredi Toplamı : 166

Table A.4 Dokuz Eylül University Education Faculty Physics Teacher Education Program

BİRİNCİ YARIYIL

Kod	Ders Adı	T	U
EGİ 1001	EĞİTİM BİLİMİNE GİRİŞ	3	0
FİZ 1001	FİZİK I	4	0
FİZ 1003	FİZİK LAB I	0	2
KİM 1021	KİMYA I	4	0
KİM 1023	KİMYA LAB I	0	2
MAT 1013	ANALİZ I	4	0
ATA 1001	ATATÜRK İLK.VE İNK.TAR. I	2	0
TDL 1001	TÜRK DİLİ I	2	0

İKİNCİ YARIYIL

Kod	Ders Adı	T	U
EGİ 1002	GELİŞİM PSİKOLOJİSİ	3	0
FİZ 1002	FİZİK II	4	0
FİZ 1004	FİZİK LAB. II	0	2
KİM 1022	KİMYA II	4	0
KİM 1024	KİMYA LAB. II	0	2
MAT 1014	ANALİZ II	4	0
ATA 1002	ATATÜRK İLK. VE İNK. TAR. II	2	0
TDL 1002	TÜRK DİLİ II	2	0
BDE 1002	SEÇMELİ (BEDEN)	2	0
GSM 1002	SEÇMELİ (MÜZİK)	2	0
GSR 1002	SEÇMELİ (RESİM)	2	0

ÜÇÜNCÜ YARIYIL

Kod	Ders Adı	T	U
BİL 2011	BİLGİSAYAR PROG.I	2	2
EGİ 2001	ÖĞRENME ÖĞRETME KURAM VE YAKLAŞIMLARI	3	0
FIZ 2001	FİZİK III	4	0
FIZ 2003	FİZİK LAB. III	0	2
FİZ 2015	FİZİKTE MAT.YÖN.I	3	0
MAT 2007	DİFERANSİYEL DENKLEMLER	3	0
YDA 2003	SEÇ. YABANCI DİL I (ALMANCA)	4	0
YDF 2003	SEÇ.YABANCI DİL I(FRANSIZCA)	4	0
YDİ 2003	SEÇ.YABANCI DİL I(İNGİLİZCE)	4	0

DÖRDÜNCÜ YARIYIL

Kod	Ders Adı	T	U
BİL 2012	BİLGİSAYAR PROG.II	2	2
EGİ 2002	ÖLÇME VE DEĞERLENDİRME	3	0
FIZ 2002	FİZİK IV	4	0
FIZ 2004	FİZİK LAB. IV	0	2
FİZ 2024	FİZİKTE MATEMATİK YÖNT.II	3	0
FİZ 2108	TİTREŞİM VE DALGALAR	3	0
FİZ 2110	TİTREŞİM VE DALGALAR LAB.	0	2
YDA 2004	SEÇ.YABANCI DİL II(ALMANCA)	4	0
YDF 2004	SEÇ.YABANCI DİL II(FRANSIZCA)	4	0
YDİ 2004	SEÇ.YABANCI DİL II(İNGİLİZCE)	4	0

BEŞİNCİ YARIYIL

Kod	Ders Adı	T	U
EGİ 3001	PROGRAM GELİŞTİRME VE ÖĞRETİM	3	0
FİZ 3001	KUVANTUM FİZİĞİ	4	0
FİZ 3009	OPTİK LAB.	0	2
FİZ 3019	OPTİK	5	0
FİZ 3107	MODERN FİZİK I	3	0

FİZ 3109	ALAN SEÇ.I (UYGULAMALI FİZİK I)	2	0
FİZ 3111	ALAN SEÇ.I (LAZERLER VE FİBER OPTİK)	2	0
FİZ 3113	ALAN SEÇ.I (MESLEKİ YABANCI DİL I)	2	0
GNK 3001	GK SEÇ.I (TÜRKİYE'NİN DOĞAL ZENGİNLİKLERİ)	2	0
GNK 3003	GK SEÇ. I (BİLİM TARİHİ)	2	0
GNK 3005	GK SEÇ. I (FEN, TEKNOLOJİ VE TOPLUM)	2	0
GNK 3007	GK SEÇ.I (ÇAĞDAŞ TÜRK EDEB.)	2	0

ALTINCI YARIYIL

Kod	Ders Adı	T	U
FİZ 3102	ÖĞRETİM TEKNOLOJİLERİ VE MATERYAL TAS.	2	2
FİZ 3104	ELEKTROMANYETİK KURAM	4	0
FİZ 3106	MODERN FİZİK II	3	0
FİZ 3108	MODERN FİZİK LAB.	0	2
FİZ 3110	ELEKTRONİK	4	0
FİZ 3112	ELEKTRONİK LAB.	0	2

Seçmeli Dersler

FİZ 3114	ALAN SEÇ.II (UYGULAMALI FİZİK II)	2	0
FİZ 3116	ALAN SEÇ.II (OPTİK UYGULAMALARI)	2	0
FİZ 3118	ALAN SEÇ.II (MESLEKİ YABANCI DİL II)	2	0
GNK 3002	GK.SEÇ.II (ERGEN RUH SAĞLIĞI)	2	0
GNK 3004	GK SEÇ.II (İNSAN İLİŞ.VE İLETİŞİM)	2	0
GNK 3008	GK SEÇ.II (MESLEK ETİĞİ)	2	0
GNK 3010	GK SEÇ.II (SAĞLIKLI YAŞAM BİLGİSİ)	2	0

YEDİNCİ YARIYIL

Kod	Ders Adı	T	U
EGİ 4001	TÜRK EĞİTİM SİSTEMİ VE OKUL YÖNETİMİ	2	0
FİZ 4101	ÖZEL ÖĞRETİM YÖNTEMLERİ - I	2	2
FİZ 4103	ÇEKİRDEK FİZİĞİ I	4	0
FİZ 4105	ÇEKİRDEK FİZİĞİ LAB. I	0	2
FİZ 4107	FİZİK EĞİTİMİNDE ÖLÇME VE DEĞERLENDİRME	2	0
FİZ 4109	ORTAÖĞRETİMDE DENEY TASARIMI -I	2	0
FİZ 4111	İSTATİSTİK FİZİK	3	0

Seçmeli Dersler

FİZ 4019	ALAN SEÇ III (FİZİĞİN TARİHSEL GELİŞİMİ)	2	0
FİZ 4021	ALAN SEÇ III (ASTROFİZİK)	2	0
FİZ 4023	ALAN SEÇ III (FİZİKTE BİLGİSAYAR DESTEKLİ EĞİTİM)	2	0

SEKİZİNCİ YARIYIL

Kod	Ders Adı	T	U
EGİ 4002	SINIF YÖNETİMİ	2	0
FİZ 4002	TERMODİNAMİK	4	0
FİZ 4004	ÖZEL ÖĞRETİM YÖNTEMLERİ - II	2	2
FİZ 4006	ÇEKİRDEK FİZİĞİ II	4	0
FİZ 4008	ÇEKİRDEK FİZİĞİ LAB.II	0	2
FİZ 4010	FİZİK EĞİTİMİNDE BİLİMSEL ARAŞTIRMA YÖNT.	2	0
FİZ 4012	ORTAÖĞRETİMDE DENEY TASARIMI II	2	0

Seçmeli Dersler

FİZ 4014	ALAN SEÇ.IV (NANOTEKNOLOJİ VE UYGULAMALARI)	2	0
FİZ 4016	ALAN SEÇ.IV (FİZİK EĞİTİ.MODELLEME VE BİLİM.SÜREÇ BECERİ.)	2	0
FİZ 4018	ALAN SEÇ.IV (FİZİKTE PROBLEM ÇÖZME)	2	0

DOKUZUNCU YARIYIL

Kod	Ders Adı	T	U
EGİ 5001	REHBERLİK	3	0
FİZ 5001	ATOM FİZİĞİ	4	0
FİZ 5003	KATIHAL FİZİĞİ I	4	0
FİZ 5005	ORTAÖĞRETİM FİZİK KİTAPLARININ İNCELENMESİ	2	0
FİZ 5007	OKUL DENEYİMİ	1	4

Seçmeli Dersler

FİZ 5009	MESLEK SEÇ.I (ORTAÖĞR.FİZİK EĞİT.TEMEL KAV.ÖĞR.I)	2	0
FİZ 5011	MESLEK SEÇ.I(FİZİK EĞİT.AKTİF ÖĞRENME TEKNİKLERİ)	2	0
FİZ 5013	MESLEK SEÇ.I (FİZİK EĞİTİMİNDE İSTATİSTİK)	2	0

Kod	Ders Adı	T	U
FİZ 5002	MOLEKÜL FİZİĞİ	4	0
FİZ 5004	KATIHAL FİZİĞİ II	4	0
FİZ 5006	ÖĞRETMENLİK UYGULAMASI	2	6
FİZ 5008	FİZİK EĞİTİMİNDE ARAŞTIRMA PROJESİ	2	2
FİZ 5010	FİZİK EĞİTİMİNDE ALANYAZIN İNCELEMESİ	2	0

Seçmeli Dersler

FİZ 5012	MESLEK SEÇ.II (ORTAÖĞR.FİZİK EĞİT.TEMEL KAV.ÖĞR.II)	2	0
FİZ 5014	MESLEK SEÇ.II (FİZİKTE ÖĞRENME VE ÇALIŞMA BECERİLERİ)	2	0
FİZ 5016	MESLEK SEÇ.II (FİZİK ÖĞRETMENİNİN MESLEKİ GELİŞİMİ)	2	0

Table A.5 Dicle University Ziya Gökalp Education Faculty Physics Teacher Education Program

1. YARIYIL

	KODU	DERSİN ADI	T	U	K
A	FZÖ101	TEMEL FİZİK-I	6	0	6
A	FZÖ103	TEMEL FİZİK LAB-I	0	2	1
A	FZÖ105	TEMEL KİMYA-I	4	0	4
A	FZÖ107	TEMEL KİMYA LAB-I	0	2	1
A	FZÖ109	GENEL MATEMATİK-I	4	0	4
MB	FZÖ151	EĞİTİM BİLİMİNE GİRİŞ	3	0	3
GK	FZÖ161	TÜRK DİLİ-I	2	0	2
GK	FZÖ171	ATA. İLKE. VE İNK.TAR.-I	2	0	2
GK	FZÖ181	YABANCI DİL-I	2	0	2
		Toplam	**23**	**4**	**25**

2. YARIYIL

	KODU	DERSİN ADI	T	U	K
A	FZÖ102	TEMEL FİZİK-II	6	0	6
A	FZÖ104	TEMEL FİZİK LAB-II	0	2	1
A	FZÖ106	TEMEL KİMYA-II	4	0	4
A	FZÖ108	TEMEL KİMYA LAB-II	0	2	1
A	FZÖ110	GENEL MATEMATİK-II	4	0	4
MB	FZÖ152	GELİŞİM PSİKOLOJİSİ	3	0	3
GK	FZÖ162	TÜRK DİLİ-II	2	0	2
GK	FZÖ172	ATA. İLKE. VE İNK.TAR.-II	2	0	2
GK	FZÖ182	YABANCI DİL-II	2	0	2
		Toplam	**23**	**4**	**25**

3. YARIYIL

	KODU	DERSİN ADI	T	U	K
A	FZÖ201	MEKANİK	6	0	6
A	FZÖ203	MEKANİK LAB	0	2	1
A	FZÖ205	LİNEER CEBİR	4	2	5
A	FZÖ207	GENEL BİYOLOJİ-I	2	0	2
A	FZÖ209	GENEL BİYOLOJİ LABI	0	2	1
MB	FZÖ251	ÖĞREN-ÖĞR.KURAM VE YAKLAŞ.	3	0	3
		Toplam	**15**	**6**	**18**

4. YARIYIL

	KODU	DERSİN ADI	T	U	K
A	FZÖ202	ELEKTRİK	6	0	6
A	FZÖ204	ELEKTRİK LAB	0	2	1
A	FZÖ206	ANALİTİK GEOMETRİ	4	0	4
A	FZÖ208	GENEL BİYOLOJİ-II	2	0	2
A	FZÖ210	GENEL BİYOLOJİ LAB-II	0	2	1
MB	FZÖ252	PROG. GELİŞ. VE ÖĞRETİM	3	0	3
MB	FZÖ254	ÖZEL ÖĞRETİM YÖNT.-I	2	2	3
		Toplam	**17**	**6**	**20**

5. YARIYIL

	KODU	DERSİN ADI	T	U	K
A	FZÖ301	DİF DENKLEMLER-I	4	0	4
A	FZÖ303	FİZİĞİN MAT. METODLARI	4	0	4
GK	FZÖ305	BİLGİSAYARA GİRİŞ	2	0	2
GK	FZÖ307	BİLGİSAYAR LAB	0	4	2
A	FZÖ309	KUANTUM FİZİĞİ-I	4	0	4
MB	FZÖ311	ÖZEL ÖĞRETİM YÖNTEMLERİ-II	2	2	3
MB	FZÖ351	TÜRK EĞİT.SİST. VE OKUL YÖNET.	2	0	2
		Toplam	**18**	**6**	**21**

6. YARIYIL

	KODU	DERSİN ADI	T	U	K
A	FZÖ302	DİF DENKLEMLER-II	4	0	4
A	FZÖ304	OPTİK VE DALGALAR	6	0	6
A	FZÖ306	OPTİK VE DAL. LAB	0	2	1
A	FZÖ308	TERMODİNAMİK	4	0	4
A	FZÖ310	KUANTUM FİZİĞİ-II	4	0	4
MB	FZÖ352	ÖĞRET.TEK. VE MAT. GELİŞ.	2	2	3
		Toplam	**20**	**4**	**22**

7. YARIYIL

	KODU	DERSİN ADI	T	U	K
A	FZÖ401	ELEKTRONİK	4	0	4
A	FZÖ403	ELEKTRONİK LAB	0	4	2
A	FZÖ405	AKIŞKANLAR MEKANİĞİ-I	2	0	2
A	FZÖ407	İSTATİSTİK FİZİK	4	0	4
MB	FZÖ409	BİLİM TARİHİ	2	0	2
MB	FZÖ451	SINIF YÖNETİMİ	2	0	2
		Toplam	**14**	**4**	**16**

8. YARIYIL

	KODU	DERSİN ADI	T	U	K
A	FZÖ402	ELEKTROMANYETİK TEORİ	4	0	4
A	FZÖ404	ATOM VE MOL FİZİĞİ	6	2	7
A	FZÖ406	AKIŞKANLAR MEKANİĞİ-II	2	0	2
MB	FZÖ408	ALAN EĞİT. ARAŞ. PROJESİ	2	2	3
MB	FZÖ452	ÖLÇME VE DEĞERLENDİRME	3	0	3
		Toplam	**17**	**4**	**19**

9. YARIYIL

	KODU	DERSİN ADI	T	U	K
A	FZÖ501	ÇEKİRDEK FİZİĞİ	6	0	6
A	FZÖ503	ÇEKİRDEK FİZİĞİ LAB	0	2	1
A	FZÖ505	KATIHAL FİZİĞİ-I	4	0	4
MB	FZÖ507	OKUL DENEYİMİ	1	4	3
MB	FZÖ551	REHBERLİK	3	0	3
		Toplam	**14**	**6**	**17**

10. YARIYIL

	KODU	DERSİN ADI	T	U	K
A	FZÖ502	FİZ. EĞİT. ÖZEL KONULAR	2	0	2
A	FZÖ504	SEÇMELİ	2	0	2
A	FZÖ506	KATIHAL FİZİĞİ-II	4	0	4
MB	FZÖ508	ÖĞRETMENLİK UYG.	2	6	5
		Toplam	**10**	**6**	**13**

GENEL TOPLAM	TEORİK	UYGULAMA	KREDİ	SAAT
	171	50	196	221

Table A.6 Gazi University Education Faculty Physics Teacher Education Program

BİRİNCİ YIL

I. YARIYIL

Kodu	Dersin Adı	T	U	K
FİZ101G	Atatürk İlkeleri ve İnkılap Tarihi I	2	0	2
FİZ103G	Türk Dili I	2	0	2
FİZ105A	Fizik I (Mekanik I)	4	2	5
FİZ107A	Fizik Laboratuvarı I(Mekanik I)	0	2	1
FİZ109A	Temel Matematik I	4	0	4
FİZ111G	Temel Kimya I	4	0	4
FİZ115G	Genel Biyoloji	2	0	2
FİZ117G	Genel Biyoloji Laboratuvarı	0	2	1
FİZ119M	Eğitim Bilimime Giriş	3	0	3
Toplam Kredi		23		

II. YARIYIL

Kodu	Dersin Adı	T	U	K
FİZ102G	Atatürk İlkeleri ve İnkılap Tarihi II	2	0	2
FİZ104G	Türk Dili II	2	0	2
FİZ106A	Fizik II (Mekanik II)	4	2	5
FİZ108A	Fizik Laboratuvarı II(Mekanik II)	0	2	1
FİZ110A	Temel Matematik II	4	0	4
FİZ112G	Temel Kimya II	4	0	4
FİZ114G	Temel Kimya Laboratuvarı	0	2	1
FİZ116G	Gelişim Psikolojisi	3	0	3
Toplam Kredi		21		

İKİNCİ YIL

III. YARIYIL

Kodu	Dersin Adı	T	U	K
FİZ201A	Fizik III (Elektrik)	4	2	5
FİZ203G	Temel Bilgisayar Kullanımı	4	0	4
FİZ205A	Fizik Laboratuvarı III(Elektrik)	0	2	1
FİZ207A	Optik	4	0	4
FİZ209A	Optik Laboratuvarı	0	2	1
FİZ211A	Diferansiyel Denklemler	2	2	3
FİZ213M	Türk Eğitim Sistemi ve Okul Yönetimi	2	0	2
		20		

IV. YARIYIL

Kodu	Dersin Adı	T	U	K
FİZ202A	Fizik IV (Elektromagnetizma)	4	2	5
FİZ204A	Fizik Laboratuvarı IV (Manyetizma)	0	2	1
FİZ206G	Bilgisayar Programlama	4	0	4
FİZ208A	İstatistik Fizik	3	0	3
FİZ210A	Fizikte Matematiksel Metodlar I	4	0	4
FİZ212M	Sınıf Yönetimi	2	0	2
Toplam Kredi		19		

ÜÇÜNCÜ YIL

V. YARIYIL

Kodu	Dersin Adı	T	U	K
FİZ301M	Bilgisayar Destekli Fizik Eğitimi	3	0	3
FİZ303A	Termodinamik	3	0	3
FİZ305A	Fizikte Matematiksel Metodlar II	4	0	4
FİZ307A	Elektronik	4	0	4
FİZ309A	Elektronik Laboratuvarı	0	2	1
FİZ311G	Yabancı Dil I (İngilizce)	2	0	2
FİZ311G	Yabancı Dil I (Almanca)	2	0	2
FİZ311G	Yabancı Dil I (Fransızca)	2	0	2
FİZ313M	Rehberlik	3	0	3
Toplam Kredi		20		

VI. YARIYIL

Kodu	Dersin Adı	T	U	K
FİZ302A	Kuantum Fiziği	4	0	4
FİZ304A	Fizikte Özel Konular I	3	0	3
FİZ306A	Titreşimler ve Dalgalar	4	0	4
FİZ308A	Titreşimler ve Dalgalar Lab.	0	2	1
FİZ310G	Yabancı Dil II (İngilizce)	2	0	2
FİZ310G	Yabancı Dil II (Almanca)	2	0	2
FİZ310G	Yabancı Dil II (Fransızca)	2	0	2
FİZ312M	Öğrt. Öğrenme Kuram ve Yaklaşımları	3	0	3
FİZ314G	Seçmeli: Bilim Felsefesi	2	0	2
FİZ316G	Seçmeli: Etkin İletişim Becerileri	2	0	2
FİZ318G	Seçmeli: Hava ve İklim Bilgisi	2	0	2
Toplam Kredi		19		

DÖRDÜNCÜ YIL

VII. YARIYIL

Kodu	Dersin Adı	T	U	K
FİZ401A	Elektromagnetik Teori	4	0	4
FİZ403A	Atom Fiziği	4	0	4
FİZ405A	Fizikte Özel Konular II	3	0	3
FİZ407M	Program Geliştirme ve Öğretim	3	0	3
FİZ409M	Özel Öğretim Yöntemleri I	2	2	3
FİZ411A	Seçmeli: Astronomi	2	0	2
FİZ413A	Seçmeli: X-Işınları ve Uygulamaları	2	0	2
FİZ415A	Seçmeli: Mesleki İngilizce I	2	0	2
FİZ417A	Seçmeli: Fiziksel Elektronik	2	0	2
FİZ419G	Seçmeli: Toplumu Hizmet Uygulamaları	1	2	2
FİZ421G	Seçmeli: Diger Anabilim Dallarının Alan derslerinden Bir Ders	2	0	2
Toplam Kredi		**21**		

VIII. YARIYIL

Kodu	Dersin Adı	T	U	K
FİZ402A	Çekirdek Fiziği	4	0	4
FİZ404A	Katıhal Fiziği	4	0	4
FİZ406A	Atom Fiziği Laboratuvarı	0	2	1
FİZ408M	Özel Öğretim Yöntemleri II	2	2	3
FİZ410M	Ölçme ve Değerlendirme	3	0	3
FİZ412A	Seçmeli:İleri Elektronik	2	0	2
FİZ414A	Seçmeli: Süperiletkenlik ve Uyg.	2	0	2
FİZ416A	Seçmeli: Atom ve Çek.Fiz.Uyg.	2	0	2
FİZ418M	Seçmeli: Konu Alanı Ders Kit. İnc.	2	0	2
FİZ420M	Seçmeli: Fzik Eğt. Problem Çözme	2	0	2
Toplam Kredi		**19**		

BEŞİNCİ YIL

IX. YARIYIL

Kodu	Dersin Adı	T	U	K
FİZ501A	Teknik Elektrik Laboratuvarı	0	2	1
FİZ503M	Okul Deneyimi	1	4	3
FİZ505A	Ortaöğretim Fizik Deneyleri I	0	2	1
FİZ507M	Öğrt. Teknoloj. ve Mat. Tasarımı	2	2	3
FİZ509G	Bilim Tarihi	2	0	2
FİZ511A	Seçmeli: Fizik Eğitiminde Literatür	2	0	2
FİZ513A	Seçmeli: Fen Teknoloji Toplum	2	0	2
FİZ515M	Seçmeli: Fizik Eğitiminde Modelleme	2	0	2
FİZ517M	Seçmeli: Fiz.Eğt.Tem.Kav. Öğretimi	2	0	2
Toplam Kredi		**14**		

X. YARIYIL

Kodu	Dersin Adı	T	U	K
FİZ502A	Ortaöğretim Fizik Deneyleri II	0	2	1
FİZ504M	Öğretmenlik Uygulaması	2	6	5
FİZ506M	Alan Eğitimi Araştırma Projesi	2	2	3
FİZ508M	Seçmeli: Fizik Eğitiminde İst. Yönt.	2	0	2
FİZ510M	Seçmeli: Fizikte Kavram Yanılgıları	2	0	2
FİZ512A	Seçmeli: Mesleki İngilizce-II	2	0	2
FİZ514A	Seçmeli: Nano Teknoloji ve Uyg.	2	0	2
Toplam Kredi		**13**		

GENEL TOPLAM **TEORİK: 160** **UYGULAMA: 60** **KREDİ: 189** **SAAT: 220**

A: Alan Dersleri, **M**: Öğretmenlik Meslek Bilgisi Dersleri, **G**: Genel Kültür Dersleri

NOT: 10 yarıyılda bir öğrencinin alması gereken seçmeli ders sayısı; **4 Alan Bilgisi, 3 Meslek Bilgisi** ve **1 Genel kültür** olmak üzere toplam 8'dir. Öğrencilerin bu seçmeli dersleri hangi yarıyılda aldığına bakılmaksızın tamamlaması esas alınacaktır.

Table A.7 Hacettepe University Education Faculty Physics Teacher Education Program

I. Yarı Yıl

Kodu	Dersin Adı	Kredi
O M 103	Eğitim Bilimlerine Giriş	3
FİÖ 111	Mekanik I	5
KİÖ 107	Temel Kimya I	3
MTÖ 113	Genel Matematik I	4
FİÖ 113	Meslek Almancası I	3
TKD 103	Türk Dili I	2
	Toplam	20

II. Yarı Yıl

Kodu	Dersin Adı	Kredi
OFM 104	Gelişim Psikolojisi	3
FİÖ 112	Mekanik II	5
KİÖ 108	Te el Kimya II	3
KİÖ 110	Temel Kimya Lab. II	1
MTÖ 114	Genel Matematik II	4
FİÖ 114	Meslek Almancası II	3
TKD 104	Türk Dili II	2
	Toplam	21

III. Yarı Yıl

Kodu	Dersin Adı	Kredi
AIT 203	Atatürk İlk. Ve İnk. Tarih I	2
FİÖ 211	lektrik ve Magnetizma I	
MTÖ 215	Analitik Geometri	3
FİÖ 215	Bilgisayar	3
OGK	Seçmali GK	2
OFM 203-02	Öğrenme Öğretme Kuram ve Yak.	3
FİÖ 213-01/02	Fizik laboratuarı I	1
	Toplam	18

IV. Yarı Yıl

Kodu	Dersin Adı	Kredi
AIT 204	Atatürk İlk. Ve İnk. Tarih II	2
FİÖ 212	Elekt ik ve Magnetizma II	4
FİÖ 214-01/02	Fizik laboratuarı II	1
MTÖ 216	Diferansiyel Denklemler	3
OGK	Seçmeli GK	2
OGK	Seçmeli GK	2
OFM 204-02	Program Geliştirme ve Öğretim	3
	Toplam	17

V. Yarı Yıl

Kodu	Dersin Adı	Kredi
FİÖ 311	Titreşim ve Dalgalar	4
FİÖ 313	Fizikte Matematiksel Yön. I	3
FİÖ 315	Elektronik	3
FİÖ 307-01/01	Elektronik Laboratuarı	1
OGK	Seçmeli GK	2
OFM 303-02	Ölçme ve Değerlendirme	3
	Toplam	16

VI. Yarı Yıl

Kodu	Dersin Adı	Kredi
FİÖ 312	Optik	3
FİÖ 3 4	Fizikte Matematiks l Yöntemler II	3
FİÖ 316	Modern Fizik	3
FİÖ 318-01/02	Fizik Laboratuarı III	1
OGK	Seçmeli GK	2
OFM 304-02	Türk Eğitim Sistemi ve Okul Yön.	2
	Toplam	14

VII. Yarı Yıl

Kodu	Dersin Adı	Kredi
FİÖ 411	Kuantum Fiziği I	4
FİÖ 413	Termodinamik	3
FİÖ 415-0 /02	Fizik Laboratuarı IV	1
OFM 403-03/04	Özel Öğretim I	3
OFM 405-03/04	Öğretim Teknolojileri ve Materyal T.	3
OGK	Seçmeli GK	2
	Toplam	6

VIII. Yarı Yıl

Kodu	Dersin Adı	Kredi
FİÖ 412	Kuantum Fiziği II	4
FİÖ 416	Katıhal Fiziği	5
FİÖ 418-01/02	Fizik Laboratuarı V	1
OFM 420-03/04	Özel Öğretim Yöntemleri II	3
OFM 406-02	Rehberlik	3
OGK	Seçmeli GK	2
	Toplam	18

IX. Yarı Yıl

Kodu	Dersin Adı	Kredi
FİÖ 517	Modern Fizik Öğretimi	4
FİÖ 519	İstatistik Fizik	4
OFM 03-02	Sınıf Yönetimi	2
FM 505-4/5/6	Okul Deneyimi	3
OGK	Seçmeli GK	2
OGK	Seçmeli GK	2
	Toplam	17

X. Yarı Yıl

Kodu	Dersin Adı	Kredi
OFM 504-4/5/6	Alan Eğitiminde Araştırma Pro esi	3
OFM 506-4/5/6	Öğretmenlik Uygulaması	5
OGK	Seçmeli GK	2
OGK	Seçmeli GK	2
FİÖ	Seçm li Alan Dersi*	3
	Toplam	15

5. Yıl Bahar Dönemi Seçimli Alan Dersleri

Dersin Kodu ve Adı	Kredi
FİÖ520 001 441520 TEORİK MEKANİK	3
FİÖ522 001 441522 GÖRELİLİK KURAMI ÖĞRT.	3
FİÖ524 001 441524 FİZİĞİN TEKNOLOJİDEKİ UYGU.	3

Table A.8 Karadeniz Teknik University Fatih Education Faculty Physics Teacher Education Program

	Kodu	Ders Adı	ECTS	+U+L	Z/S	Kodu	Ders Adı	ECTS	D+U+L	Z/S
1. Yıl	**Güz Dönemi**					**Bahar Dönemi**				
	AITB191	Atatürk İlk. Ve İnk. Tar - I	2	2+0+0	Z	AITB192	Atatürk İlk. Ve İnk. Tar - II	2	2+0+0	Z
	TDB 101	Türk Dil - I	2	2+0+0	Z	TDB 102	Tür Dili - II	2	2+0+0	Z
	MATO121	Matematik - I	6	4+0+0	Z	FIZO114	Elektromanyetizma Lab.	2	0+0+2	Z
	FIZO113	Fizik Laboratuarı - I	2	0+0+2	Z	FIZO116	Elektromanyetizma	7	6+0+0	Z
	KIMO119	Kimya - I	4	4+0+0	Z	KIMO118	Kimya - II	5	4+0+0	Z
	FIZO115	Fizik - I	6	4+2+0	Z	MATO122	Matematik - II	5	4+0+0	Z
	MATO113	Lineer Cebir	4	4+0+0	Z	MATO120	Analitik Geometri	5	4+0+0	Z
	YDB 171	İngilizce I	3	3+0+0	Z	YDB 172	İngilizce II	2	2+0+0	Z
	ENF 100	Temel Bilgi Teknolojileri Kul.	3	2+1+0	Z		Bahar Dönemi Toplamı:	30	24+0+2	
		Güz Dönemi Toplamı:	32	25+3+2						
2. Yıl	**Güz Dönemi**					**Bahar Dönemi**				
	ENF 245	Temel Bilgisayar - I	4	3+1+0	Z	ENF 246	Bilgisayar - II	4	3+1+0	Z
	OMES213	Eğitim Bilimine Giriş	4	3+0+0	Z	OMES202	Gelişim Psikolojisi	4	3+0+0	Z
	FIZO201	Isı Ve Termodinamik	7	4+0+0	Z	FIZO214	Elektrik Ve Magnetizma	8	4+0+0	Z
	FIZO203	Mekanik	8	4+0+0	Z	FIZO216	Elektrik Ve Magnetizma Lab.	3	0+0+2	Z
	FIZO205	Mekanik Labaratuarı	3	0+0+2	Z	FIZO218	Modern Fizik	6	4+0+0	Z
	MATO267	Diferansiyel Denklemler	4	4+0+0	Z	FIZO222	Fizikte Matematik Yöntemler	5	4+0+0	Z
		Güz Dönemi Toplamı:	30	18+1+2			Bahar Dönemi Top amı:	30	18+1+2	
3. Yıl	**Güz Dönemi**					**Bahar Dönemi**				
	OFMF321	Program Geliştirme Ve Öğretim	4	3+0+0	Z	OMES302	Türk Eğitim Sis. Ve Okul Yön.	3	2+0+0	Z
	FIZO307	Kuantum Mekaniği - I	8	4+0+0	Z	FIZO314	Çevre Fiziği	7	4+0+0	Z
	FIZO309	Elektronik - I	6	4+0+0	Z	FIZO312	Elektromagnetik Teori	8	4+0+0	Z
	FIZO313	Elektrik Devreler Laboratuarı	4	0+0+2	Z		Seçmeli-1	6	4+0+0	S
	FIZO311	Titreşimler Ve Dalgalar		4+0+0	Z	S Dersle				
		Güz Dönemi Toplamı:	30	5+0+2		SECA302	Optik Laboratuarı	6	0+0+2	S
						SECA308	Fizik O tik	6	4+0+0	S
						SECA310	Kuantum Mekaniği - II	6	4+0+0	S
						SECA312	X Işınları Kırınımı	6	3+0+0	S
						SECA314	Geometrik Optik	6	4+0+0	S
							Bahar Dönemi Toplamı:	30	18+0+0	
4. Yıl	**Güz Dönemi**					**Bahar Dönemi**				
	Sınıf Yönetimi		3	2+0+0	Z	OFMF402	Ölçme Ve Değerlendirme	6	3+0+0	Z
	Özel Öğretim Yöntemleri – I		8	2+2+0	Z	OFMF404	Öğretim Tek. Ve Mater. Tas.	8	2+2+0	Z
	Bilim Tari i		3	2+0+0	Z	OFMF406	Özel Öğretim Yöntemleri - II	8	2+2+0	Z
	Katıhal Fiziği		7	4+0+0	Z	FIZO428	Çekirdek Fiziği	5	4+0+0	Z
	Atom Ve Molekül Fiziği		6	4+0+0	Z		S-1	3	3+0+0	S
	S-1		3	3+0+0	S	S Dersler				
	S Dersler					SECA410	Teknoloji Des. Fizik Öğretimi	3	3+0+0	S
	Fizik Öğr. Temel Kavram. Öğr.		3	3+0+0	S	SECA412	Fizik Öğr. Prob. Çöz. Yön. Uyg	3	3+0+0	S
	Fizikte Benzetim Ve Modelleme		3	3+0+0	S	SECA414	Fizik Eğt. S Konular	3	3+0+0	S
	Fizik Ve Felsefe		3	3+0+	S	SECA416	Öğrenme Kuramları	3	3+0+0	S
	Okul Gelişimi		3	3+0+0	S	SECA418	Konu Alanı Ders Kitabı İncele.	3	3+0+0	S
	Fiziğin Güncel Uyg. Alanları		3	3+0+0	S	SECA450	Fizikte Kavram Yanılgıları	3	3+0+0	S
		Güz Dönemi Toplamı:	30	17+2+0			Bahar Dönemi Toplamı:	30	14+4+0	
5. Yıl	**Güz Dönemi**					**Bahar Dönemi**				
	OFMF501	Öğrenme Öğretme Kuram Ve Yak.	6	3+0+0		OFMF500	Alan Eğitim. Araştırma Projesi	7	2+2+0	Z
	OFMF503	Okul Deneyimi	6	1+4+0	Z	OMES502	Rehberlik	6	3+0+0	Z
	OFMF505	Bilimsel Araştırma Yöntemleri	8	3+0+0	Z	OFMF504	Öğretmenlik Uygulaması	12	2+6+0	Z
		S-1	5	3+0+0	S		S-1	5	3+0+0	S
		S-2	5	3+0+0	S	S Dersler				
	S Dersler					SECA510	Güzel Konuşma Ve Yazma	5	3+0+0	S
	SECA511	Fizik Ve Diğer Bilim Dalları	5	3+0+0	S		Bahar Dönemi Toplamı:	30	10+8+0	
	SECA515	Ortaöğr. Fizik eney. Tas.	5	3+0+0	S					
	SECG501	İnsan İlişkileri Ve İletişim	5	2+0+0	S					
	SECG507	Çevre Eğitimi	5	2+0+0	S					
	SECG517	Mesleki İngilizce	5	2+0+0	S					
		Güz Dönemi Toplamı:	30	13+4+0						

Table A.9 Marmara University Atatürk Education Faculty Physics Teacher Education Program

Atatürk Eğitim Fakültesi Fizik Öğretmenliği Anabilim Dalı Lisans Programı
(2007 Yılı Girişli Öğrenciler İçin)

1. YARIYIL					
	Ders Kodu	Ders Adı	T	U	KR
GK	ATA121	Atatürk İlkeleri ve İnkılap Tarihi I	2	0	2
A	FZK101	Fizik I	5	0	5
A	FZK103	Fizik Laboratuarı I	0	4	2
A	FZK107	Genel Kimya I	4	0	4
A	FZK109	Genel Kimya Laboratuarı I	0	2	1
A	FZK105	Matematik I	4	0	4
GK	TRD101	Türk Dili I	2	0	2
GK	YDZI101	Yabancı Dil I (İngilizce)	2	0	2
	YDZA101	Yabancı Dil I (Almanca)			
	YDZF101	Yabancı Dil I (Fransızca)			
		TOPLAM	19	6	22

2. YARIYIL					
	Ders Kodu	Ders Adı	T	U	KR
GK	ATA121	Atatürk İlkeleri ve İnkılap Tarihi II	2	0	2
A	FZK102	Fizik II	5	0	5
A	FZK104	Fizik Laboratuarı II	0	4	2
A	FZK108	Genel Kimya II	4	0	4
A	FZK110	Genel Kimya Laboratuarı II	0	2	1
A	FZK106	Matematik II	4	0	4
GK	TRD102	Türk Dili II	2	0	2
GK	YDZI102	Yabancı Dil II (İngilizce)	2	0	2
	YDZA102	Yabancı Dil II (Almanca)			
	YDZF102	Yabancı Dil II (Fransızca)			
		TOPLAM	19	6	22

3. YARIYIL					
	Ders Kodu	Ders Adı	T	U	KR
MB	EGT101	Eğitim Bilimine Giriş	3	0	3
A	FZK205	Fizikte Matematik Yöntemler I	4	0	4
A	FZK201	Fizik III	5	0	5
A	FZK203	Fizik Laboratuarı III	0	4	2
A	FZK207	Elektronik I	4	0	4
A	FZK209	Elektronik Lab I	0	4	2
GK	FZK211	Toplumsal Afet Bilinci	2	0	2
		TOPLAM	18	8	22

4. YARIYIL					
	Ders Kodu	Ders Adı	T	U	KR
MB	EGT208	Gelişim Psikolojisi	3	0	3
A	FZK202	Modern Fizik	4	0	4
A	FZK204	Modern Fizik Laboratuarı	0	4	2
GK	FZKS202	Seçmeli I(Sivil Korunma Ve Vatandaşlık)	2	0	2
A	FZK208	Elektronik II	4	0	4
A	FZK210	Elektronik Lab II	0	4	2
A	FZK206	Diferansiyel Denklemler	4	0	4
		TOPLAM	17	8	21

5. YARIYIL					
	Ders Kodu	Ders Adı	T	U	KR
GK	FZK307	Bilgisayar Uygulamaları I	2	0	2
MB	EGT402	Türk Eğitim Sistemi ve Okul Yönetimi	2	0	2
A	FZK303	Elektrik ve Manyetizma	3	0	3
A	FZK305	Kuantum Mekaniği	3	0	3
A	FZK301	Mekanik	4	0	4
GK	FZKS301	Seçmeli II (Mesleki İngilizce)	2	0	2
		TOPLAM	16	0	16

6. YARIYIL					
	Ders Kodu	Ders Adı	T	U	KR
GK	FZK304	Bilgisayar Uygulamaları II	2	0	2
MB	EGT403	Rehberlik	3	0	3
A	FZK302	İstatistik Fizik ve Termodinamik	5	0	5
GK	FZKS302	Seçmeli III (Bilim Felsefesi)	2	0	2
		TOPLAM	12	0	12

7. YARIYIL					
	Ders Kodu	Ders Adı	T	U	KR
A	FZK403	Optik ve Dalgalar	3	0	3
A	FZK401	Katıhal Fiziği	3	0	3
MB	EGT301	Sınıf Yönetimi	2	0	2
MB	EGT414	Program Geliştirme ve Öğretim	3	0	3
GK	FZKS401	Seçmeli IV(Popüler Fizik)	2	0	2
		TOPLAM	13	0	13

8. YARIYIL					
	Ders Kodu	Ders Adı	T	U	KR
MB	EGT412	Öğrenme-Öğretme Kuram ve Yaklaşımları	3	0	3
MB	EGT303	Özel Öğretim Yöntemleri I	2	2	3
A	FZK402	Nükleer Fizik	3	0	3
A	FZK404	Atom Fiziği	3	0	3
GK	FZKS402	Seçmeli V (Yan Dallar)	2	0	2
		TOPLAM	13	2	14

9. YARIYIL					
	Ders Kodu	Ders Adı	T	U	KR
MB	EGT202	Öğretim Teknolojileri ve Materyal Tasarımı	2	2	3
MB	EGT302	Ölçme ve Değerlendirme	3	0	3
MB	EGT405	Okul Deneyimi	1	4	3
A	FZK501	Özel Öğretim Yöntemleri II	2	2	3
		TOPLAM	8	8	12

10. YARIYIL					
	Ders Kodu	Ders Adı	T	U	KR
GK	BIT301	Bilim Tarihi	2	0	2
MB	EGT406	Öğretmenlik Uygulaması	2	6	5
MB	EGT502	Alan Eğitiminde Araştırma Projesi	2	2	3
GK	FZKS502	Seçmeli VI (Doğada Fizik:Gezi ve Kamp Uygulamaları)	2	0	2
		TOPLAM	8	8	12

GENEL TOPLAM	T	U	KR
	143	46	166

A: Alan ve Alan Eğitimi Dersleri
MB: Öğretmenlik Meslek Bilgisi Dersleri
GK: Genel Kültür Dersleri

Table A.10 Ondokuz Mayıs University Education Faculty Physics Teacher Education Program

	I.YARIYIL						II.YARIYIL				
KODU	DERSİN ADI	T	U	K	ECTS	KODU	DERSİN ADI	T	U	K	ECTS
FİZ 101	Fizik I	4	2	5	9	FİZ 102	Fizik II	4	2	5	9
FİZ 103	Fizik I Lab. (Mek.)	0	2	1	3	FİZ 104	Fizik II Lab. (Elk.)	0	2	1	3
MAT 107	Matematik I	4	0	4	6	MAT 108	Matematik II	4	0	4	6
YDE 101	Yabancı Dil	3	0	3	5	YDE 102	Yabancı Dil	3	0	3	5
TİT 101	Atatürk İlk. Ve Ink. Tarihi	2	0	2	3	TİT 102	Atatürk İlk. Ve Ink. Tarihi	2	0	2	3
TDE 101	Türk Dili	2	0	2	3	TDE 102	Türk Dili	2	0	2	3
EGT 101	Eğitim Bilimine Giriş	3	0	3	5	EGT 102	Gelişim Psikolojisi	3	0	3	5
TOPLAM		18	4	20	34	TOPLAM		18	4	20	34
	III. YARIYIL						IV. YARIYIL				
KODU	DERSİN ADI	T	U	K	ECTS	KODU	DERSİN ADI	T	U	K	ECTS
FİZ 201	Modern Fizik	4	0	4	6	KİM 202	Kimya II	4	2	5	9
FİZ 203	Modern Fizik Lab.	0	2	1	3	FİZ 204	Akışkanlar Mekaniği	4	0	4	6
KİM 205	Kimya I	4	2	5	9	FİZ 206	Optik ve Dalgalar	4	0	4	6
FİZ 207	Termodinamik	2	0	2	3	FİZ 208	Optik ve Dalgalar Lab.	0	2	1	3
FİZ 209	Bilgisayar Kullanımı	2	2	3	6	FİZ 210	Astronomi	2	0	2	3
EGT 201	Program Geliş. Ve Öğrt.	3	0	3	5	EGT 202	Türk Eğt. Sist. Ve Okul Yönk.	2	0	2	3
TOPLAM		15	6	18	32	TOPLAM		16	4	18	30
	V.YARIYIL						VI.YARIYIL				
KODU	DERSİN ADI	T	U	K	ECTS	KODU	DERSİN ADI	T	U	K	ECTS
MAT 301	Dif. Denklemler	4	0	4	6	MAT 302	Analitik Geometri	4	0	4	6
MAT 303	Lineer Cebir	4	0	4	6	FİZ 304	Bilgisayar Programlama	2	2	3	6
FİZ 305	Elektronik I	4	0	4	6	FİZ 306	Elektronik II	4	0	4	6
FİZ 307	Elektronik I Lab.	0	2	1	3	FİZ 308	Elektronik II Lab.	0	2	1	3
FİZ 309	Fizikte Mat. Yönt. I	4	0	4	6	FİZ 310	Elektromagnetizma	3	0	3	5
EGT 301	Ölçme ve Değerlendirme	3	0	3	5	EGT 302	Sınıf Yönetimi	2	0	2	3
						EGT 304	GK Seçmeli (Bilim Tarihi)	2	0	2	3
TOPLAM		19	2	20	32	TOPLAM		17	4	19	32
	VII.YARIYIL						VIII.YARIYIL				
KODU	DERSİN ADI	T	U	K	ECTS	KODU	DERSİN ADI	T	U	K	ECTS
FİZ 401	Kuantum Mekanigi I	4	0	4	6	FİZ 402	Kuantum Mekaniği II	4	0	4	6
FİZ 403	İstatistik Fizik	4	0	4	6	FİZ 404	Klasik Mekanik	4	0	4	6
EGT 401	Özel Öğretim Yöntemleri I	2	2	3	6	EGT 402	Özel Öğretim Yöntemleri II	2	2	3	6
EGT 403	Öğrenme ve Öğrt. Kuram.	3	0	3	5	EGT 404	Rehberlik	3	0	3	5
TOPLAM		13	2	14	23	TOPLAM		13	2	14	23
	IX.YARIYIL						X.YARIYIL				
KODU	DERSİN ADI	T	U	K	ECTS	KODU	DERSİN ADI	T	U	K	ECTS
FİZ 501	Katıhal Fiziği I	4	0	4	6	FİZ 502	Atom ve Mol. Fiz. I	4	0	4	6
FİZ 503	Elektromagnetik Teo.	3	0	3	5	FİZ 504	Nükleer Fiziğe Giriş	4	0	4	6
EGT 501	Okul Deneyimi	1	4	3	8	EGT 502	Öğretmenliuk Uygulaması	2	6	5	12
EGT 503	Öğretim Tek. Ve Mat. Tas.	2	2	3	6	EGT 504	Alan Eğt. Arş. Projesi	2	2	3	6
EGT 505	Seçmeli (Topluma Hiz. Uyg.)	1	2	2	5						
TOPLAM		11	8	15	30	TOPLAM		12	8	16	30

GENEL TOPLAM	TEORİK	UYGULAMA	KREDİ	SAAT	ECTS
	152	44	174	196	300

Table A.11 Middle East Technical University Education Faculty Physics Teacher Education Program

I. Semester			T	U	K
PHYS 109	Mechanics	A	5	2	6
CHEM 101	General Chemistry I	A	4	2	5
MATH 119	Calculus with Analytic Geometry	A	4	2	5
ENG 101	Development of Reading and Writing Skills I	GK	4	0	4
IS 100	Int. to Inf. Tech. and App.	GK	0	0	0
TOTAL			**17**	**6**	**20**

II. Semester			T	U	K
PHYS 110	Electromagnetism	A	5	2	6
CHEM 102	General Chemistry II	A	4	2	5
MATH 120	Calculus	A	4	2	5
ENG 102	Development of Read. and Writ. Skills II	GK	4	0	4
TOTAL			**17**	**6**	**20**

III. Semester			T	U	K
PHYS 203	Introductory Electronics	A	3	2	4
PHYS 209	Math. Methods in Phys. I	A	4	0	4
PHYS 221	Optics and Waves	A	4	0	4
MATH 260	Linear Algebra	A	3	0	3
HIST 2201	Principles of Kemal Atatürk I	GK	2	0	0
EDS 200	Introduction to Education	MB	3	0	3
TOTAL			**19**	**2**	**18**

IV. Semester			T	U	K
PHYS 202	Modern Physics	A	4	0	4
PHYS 210	Math. Methods in Phys. II	A	4	0	4
PHYS 222	Optics and Waves Lab.	A	1	4	3
ENG 211	Academic Oral Presentation Sk.	GK	3	0	3
HIST 2202	Principles of Kemal Atatürk II	GK	2	0	0
EDS 221	Development & Learning	MB	3	0	3
TOTAL			**17**	**4**	**17**

V. Semester			T	U	K
PHYS 311	Classical Mechanics	A	4	2	5
PHYS 307	Applied Modern Physics Lab.	A	1	4	3
TURK 305	Turkish I	GK	2	0	2
SSME 301	Curriculum Development & Instruction in Science /Mathematics Education	MB	3	0	3
SSME 309	Theories & Approaches in Teaching & Learning of Science /Mathematics	MB	3	0	3
Elective	Restricted Elective* I	A	3	0	3
TOTAL			**16**	**6**	**19**

VI. Semester			T	U	K
PHYS 300	Quantum Physics	A	3	0	3
PHYS 334	Electromagnetic Theory	A	4	2	5
TURK 306	Turkish II	GK	2	0	2
ENG 311	Advanced Communication Skills	GK	3	0	3
SSME 302	Measurement & Evaluation in Science/Mathematics Education	MB	3	0	3
SSME 400	Computer Applications in Science/Mathematics Education	GK	2	2	3
TOTAL			**17**	**4**	**19**

VII. Semester			T	U	K
PHYS 431	Quantum Mechanics I	A	4	0	4
SSME 511	Methods of Science/Mathematics Teaching I	MB	2	2	3
SSME 518	Instructional Technology and Material Development	MB	2	2	3
SSME 443	High School Physics Curriculum Review I	MB	3	0	3
Elective	Restricted Elective* II	A	3	0	3
TOTAL			**14**	**4**	**16**

VIII. Semester			T	U	K
SSME 512	Methods of Science/Mathematics Teaching II	MB	2	2	3
SSME 403	Lab Experiments in Science Education	MB	3	0	3
Elective	Restricted Elective* III	A	3	0	3
Elective	Elective I	MB	3	0	3
Elective	Elective II	GK	3	0	3
TOTAL			**14**	**2**	**15**

IX. Semester			T	U	K
SSME 534	School Experience in Science/Mathematics Education	MB	1	4	3
EDS 551	Turkish Educational System and School Management	MB	3	0	3
Elective	Elective III	GK	3	0	3
Elective	Elective IV	GK	3	0	3
TOTAL			**10**	**4**	**12**

X. Semester			T	U	K
SSME 544	Practice Teaching in Science/Mathematics Education	MB	2	6	5
SSME 555	Research Projects in Science/Mathematics Education	MB	2	2	3
EDS 510	Classroom Management	MB	2	2	3
EDS 522	Guidance	MB	3	0	3
TOTAL			**9**	**10**	**14**

T: Teorik U: Uygulama K: Kredi S:Saat

Table A.12 Selçuk University Ahmet Keleşoğlu Education Faculty Physics Teacher Education Program

1. SINIF

I. YARIYIL

KODU	DERSİN ADI	T	U	K
0207101	Genel Fizik I	6	0	6
0207102	Genel Matematik I	4	0	4
0207103	Genel Kimya I	4	0	4
0207104	Genel Fizik Laboratuarı I	0	2	1
0207105	Genel Kimya Laboratuarı I	0	2	1
0207106	Eğitim Bilimine Giriş	3	0	3
0207111	Genel Biyoloji I	4	0	4
0207140	Atatürk İlkeleri ve İnkılâp Tarihi I	2	0	2
0207150	Türk Dili I	2	0	2
0207161	Yabancı Dil- I (İng.)	2	0	2
0207162	Yabancı Dil- I (Alm.)	2	0	2
0207163	Yabancı Dil I (Frn.)	2	0	2
	Kredi	**29**		

II. YARIYIL

KODU	DERSİN ADI	T	U	K
0207201	Genel Fizik II	6	0	6
0207202	Genel Matematik II	4	0	4
0207203	Genel Kimya II	4	0	4
0207204	Genel Fizik Laboratuarı II	0	2	1
0207205	Genel Kimya Laboratuarı II	0	2	1
0207210	Gelişim Psikolojisi	3	0	3
0207211	Genel Biyoloji II	4	0	4
0207240	Atatürk İlkeleri ve İnkılâp Tarihi II	2	0	2
0207250	Türk Dili II	2	0	2
0207261	Yabancı Dil-II (İng.)	2	0	2
0207262	Yabancı Dil- II (Alm.)	2	0	2
0207263	Yabancı Dil- II (Frn.)	2	0	2
	Kredi	**29**		

2. SINIF

III. YARIYIL

KODU	DERSİN ADI	T	U	K
0207301	Genel Fizik III	4	0	4
0207302	Fizikte Matematik Metotlar I	4	0	4
0207303	Lineer Cebir	3	0	3
0207306	Genel Fizik Laboratuarı III	0	2	1
0207308	Temel Bilgisayar Teknolojileri ve Kullanımı	2	2	0
0207311	Mekanik	4	0	4
0207316	Türk Eğitim Sistemi ve Okul Yönetimi	2	0	2
	Kredi	**18**		

IV. YARIYIL

KODU	DERSİN ADI	T	U	K
0207401	Genel Fizik IV	4	0	4
0207402	Fizikte Matematik Metodlar II	4	0	4
0207406	Genel Fizik Laboratuarı IV	0	2	1
0207409	Temel Bilgisayar Bilimleri	2	2	3
0207410	Diferansiyel Denklemler	4	0	4
0207414	Sınıf Yönetimi	2	0	2
0207415	Elektro Manyetizma	4	0	4
0207416	Elektrik ve Magnetizma Laboratuarı	0	2	1
	Kredi	**23**		

3. SINIF

V. YARIYIL

KODU	DERSİN ADI	T	U	K
0207501	Kuantum Fiziği I	4	0	4
0207503	Dalgalar ve Titreşimler	4	0	4
0207505	Dalgalar ve Titreşimler Laboratuarı	0	2	1
0207510	Fiziksel Optik	3	0	3
0207513	Rehberlik	3	0	3
	Kredi	**15**		

VI. YARIYIL

KODU	DERSİN ADI	T	U	K
0207601	Kuantum Fiziği II	4	0	4
0207602	Elektronik	4	0	4
0207604	Elektronik Laboratuarı	0	2	1
0207611	Atom Fiziği	4	0	4
0207615	Öğrenme-Öğretme Kuram ve Yaklaşımları	3	0	3
	Kredi	**16**		

4. SINIF

VII. YARIYIL

KODU	DERSİN ADI	T	U	K
0207704	Modern Fizik Laboratuarı	0	2	1
0207710	Nükleer Fizik	4	0	4
0207712	Elektromagnetik Teori	4	0	4
0207717	Katıhal Fiziği	4	0	4
0207722	Program Geliştirme ve Öğretim	3	0	3
0207723	Seç I: Spektroskopi	2	0	2
0207724	Seç I: Özel Relativite Teorisi	2	0	2
0207725	Seç I: Analitik Mekanik	2	0	2
0207726	Seç I:	2	0	2
	Kredi	**18**		

VIII. YARIYIL

KODU	DERSİN ADI	T	U	K
0207824	Özel Öğretim Yöntemleri I	2	2	3
0207827	İstatistik Fizik	4	0	4
0207828	Molekül Fiziği	2	0	2
0207829	Ölçme ve Değerlendirme	3	0	3
0207830	Fizikte Özel Konular	3	0	3
0207831	Seç II: Fizik Ders Kitabı İnceleme	2	0	2
0207832	Seç II: Fizikte Problem Çözme	2	0	2
0207833	Seç II: Fizikte Bilgisayar Destekli Eğitim	2	0	2
0207834	Seç II: Fizik Eğitiminde İstatistiki Analiz	2	0	2
0207835	Seç II:	2	0	2
	Kredi	**17**		

5. SINIF

IX. YARIYIL

KODU	DERSİN ADI	T	U	K
0207921	Öğretim Teknolojileri ve Materyal Geliştirme	2	2	3
0207922	Sınıf Yönetimi	2	2	3
0207923	Özel Öğretim Yöntemleri II	2	2	3
0207924	Okul Deneyimi II	1	4	3
0207930	Seç III: Fizik Eğitiminde Araştırma Teknikleri	3	0	3
0207931	Seç III: Bilgisayar Destekli Fizik Eğitimi	3	0	3
0207932	Seç III: Yarı İletkenler ve Uygulamaları	3	0	3
0207933	Seç III:	3	0	3
	Kredi	**15**		

X. YARIYIL

KODU	DERSİN ADI	T	U	K
0207021	Konu Alanı Ders Kitabı İncelemesi	2	2	3
0207022	Rehberlik	3	0	3
0207023	Öğretmenlik Uygulaması	2	6	5
0207029	Seç IV: Işınımlar ve Elementer Parçacıklar	3	0	3
0207030	Seç IV: Bilim Tarihi	3	0	3
0207031	Seç IV: Fizik Eğitiminde Özel Konular	3	0	3
0207032	Seç IV:	3	0	3
	Kredi	**14**		

TOPLAM KREDİ: 194

Table A.13 Yüzüncü Yıl University Education Faculty Physics Teacher Education Program

Dersin Kodu	Dersin Adı	T	U	K	AKTS	Dersin Kodu	Dersin Adı	T	U	K	AKTS
1.sınıf I. Yarıyıl						**1.sınıf II. Yarıyıl**					
Fiz101	Mekanik	3	2	4	6	Fiz102	Isı ve Molekül Fiziği	4	0	4	6
Fiz103	Mekanik Lab. A Grubu	0	2	1		Fiz104	Bilgisayara Giriş II	2	0	2	2
Fiz103	Mekanik Lab. B Grubu	0	2	1	2	Kim102	Genel Kimya II	4	0	4	6
Kim101	Genel Kimya I	4	0	4	6	Mat102	Analiz II	4	0	4	6
Mat101	Analiz I	6	0	6	6	TDE102	Türk Dili II	2	0	2	2
Mat111	Bilgisayara Giriş-I	2	0	2	2	AİT102	Atatürk İlkeleri ve İnkılap Tarihi I	2	0	2	2
TDE101	Türk Dili I	2	0	2	2	YB102	Yabancı Dil II	2	0	2	2
AİT101	Atatürk İlkeleri ve İnkılap TarihiI	2	0	2	2	MB102	Gelişim Psikolojisi	3	0	3	2
YB101	Yabancı Dil I	2	0	2	2						
MB101	Eğitim Bilimine Giriş	3	0	3	2						
2.sınıf I. Yarıyıl						**2.sınıf II. Yarıyıl**					
Fiz201	Elektrik ve Magnetizma	3	2	4	6	Fiz202	Optik	4	0	4	6
Fiz203	Elektrik ve Magnetizma Lab. A Grubu	0	2	1	2	Fiz204	Klasik Mekanik I	4	0	4	6
Fiz203	Elektrik ve Magnetizma Lab. B Grubu	0	2	1		Fiz206	Bilgisayar Programlama II	2	2	3	4
Fiz205	Bilgisayar Programlama I	2	2	3	4	Fiz208	Optik Lab. A Grubu	0	2	1	2
Fiz209	Modern Fizik	4	0	4	6	Fiz208	Optik Lab. B Grubu	0	2	1	
Mat205	Diferansiyel Denklemler I	4	0	4	6	Mat206	Diferansiyel Denklemler II	4	0	4	6
Mat211	Analitik Geometri	4	0	4	6	Mat232	Lineer Cebir	4	0	4	6
MB201	Program Geliştirme ve Öğretim	4	0	4	2	MB202	Öğretim Teknolojileri ve Materyal Tasarımı	2	2	3	2
3.sınıf I. Yarıyıl						**3.sınıf II. Yarıyıl**					
Fiz303	Elektromagnetik Teori I	4	0	4	6	Fiz304	Elektromagnetik Teori II	4	0	4	6
Fiz305	Elektronik I	4	0	4	6	Fiz306	Elektronik II	4	0	4	6
Fiz309	Atom Fiziği	4	0	4	6	Fiz312	Fizikte Matematiksel Yöntemler	4	0	4	6
Fiz311	Klasik Mekanik II	4	0	4	6	Fiz314	Elektronik Lab. A Grubu	0	2	1	2
Fiz312	Katıların Optik Özellikleri	2	0	2	2	Fiz314	Elektronik Lab. B Grubu	0	2	1	
Fiz322	Grup Teorisine Giriş	2	0	2	2	Fiz310	Nükleer Fizik I	4	0	4	6
MB301	Bilim Tarihi	2	0	2	2	Fiz324	Enerji kaynakları ve Sistemleri	2	0	2	2
						Mb302	Sınıf Yönetimi	2	0	2	2
4.sınıf I. Yarıyıl						**4.sınıf II. Yarıyıl**					
Fiz 401	Kuantum Mekaniği I	4	0	4	6	Fiz 402	Kuantum Mekaniği II	4	0	4	6
Fiz 403	Yoğun Madde Fiziği I	4	0	4	6	Fiz 404	Yoğun Madde Fiziği II	4	0	4	6
Fiz 407	Mezuniyet Çalışması-I	2	0	2	2	Fiz 423	Aşırı İletkenlik II	0	4	2	2
Fiz 409	Termodinamik ve İstatistik Fizik I	4	0	4	6	Fiz 410	Termodinamik ve İstatistik Fizik II	4	0	4	6
Fiz 420	Mesleki İngilizce	2	0	2	2	Fiz 424	Yarı iletken Fiziğine Geçiş Seçmeli	2	0	2	2
Fiz 422	Aşırı İletkenlik I	2	0	2	2		Yarı İletken Aygıtlar Seçmeli	2	0	2	2
Fiz 425	Nükleer Fizik II	2	0	2	2		Rehberlik	3	0	3	2
	Ölçme ve Değerlendirme	3	0	3	2		Öğrenme Öğretme Kuram ve Yaklaşımları	3	0	3	2
	Seçmeli Ders (Genel Kültür)	2	0	2	2		Mezuniyet Çalışması -II	0	4	2	2
5.sınıf I. Yarıyıl						**5.sınıf II. Yarıyıl**					
MB 501	Türk Eğitim Sistemi ve Okul Yönetimi	2	0	2	2	AB 501	Alan Eğitiminde Araştırma Projesi				6
MB 503	Okul Deneyimi I	1	4	3	4	MB 504	Öğretmenlik Uygulaması	6	2	5	6
MB 505	Özel Öğretim Yöntemleri I	2	2	3	6	MB 506	Özel Öğretim Yöntemleri II	2	2	3	6
	Seçmeli I(Ortaöğretim Fizik Öğretim Programının İncelenmesi I)				4		Seçmeli II (Elektrik Öğrenimini ve Öğretiminde Kapasitör Destekli Sistemler)				4
	Seçmeli I (Alan eğitiminde Araştırma Teknikleri)				4		Seçmeli II (Enerji Eğitimi)				4
							Seçmeli II (Egzotik Atomlar)				4

APPENDIX B

INFORMATION ABOUT THE PRE-SERVICE PHYSICS TEACHERS FROM WHICH THE INTERVIEW PARTICIPANTS WERE SELECTED

Table B.1 Pre-service Physics Teachers Registered to the 3rd Grade in the 2010-2011 Spring Semester at Middle East Technical University (METU)

#	CGPA	OPTICS GRADE (OG) (Letter)	OPTICS GRADE (OG) (Numeric)	OPTICS LAB GRADE (OLG) (Letter)	OPTICS LAB GRADE (OLG) (Numeric)	WEIGHTED AVRAGE OF OPTIC GRADE & OPTIC LAB GRADE (WAOG)	AVERAGE of CGPA & WAOG	Selected participants
1	3.51	AA	4	AA	4	4.00	3.76	*
2	3.30	BA	3.5	AA	4	3.71	3.51	*
3	3.04	BA	3.5	AA	4	3.71	3.38	
4	2.75	BA	3.5	AA	4	3.71	3.23	
5	2.79	BA	3.5	BA	3.5	3.50	3.15	
6	2.72	BB	3	AA	4	3.43	3.07	
7	2.43	AA	4	BB	3	3.57	3.00	
8	2.59	CB	2.5	AA	4	3.14	2.87	
9	2.52	BB	3	BB	3	3.00	2.76	
10	2.55	CB	2.5	BB	3	2.71	2.63	
11	2.75	BB	3	DC	1.5	2.36	2.55	*
12	2.20	CC	2	BA	3.5	2.64	2.42	
13	2.47	CC	2	DC	1.5	1.79	2.13	*
14	2.22	CC	2	CC	2	2.00	2.11	
15	2.19	DD	1	BB	3	1.86	2.02	
16	1.69	CC	2	CC	2	2.00	1.85	
17	1.98	DD	1	CB	2.5	1.64	1.81	*
18	1.98	DD	1	CB	2.5	1.64	1.81	
19	1.91	DD	1	CB	2.5	1.64	1.78	
20	1.95	DD	1	DC	1.5	1.21	1.58	*
21	2.71	BB	3	-		1.71	2.21	NI
22	2.26	CC	2	-		1.14	1.70	NI
23	2.03	DC	1.5	-		0.86	1.44	NI
24	1.91	DC	1.5	-		0.86	1.38	NI
Average							**2.57**	
StDv							**0.66**	

Table B.2 Pre-service Physics Teachers Registered to the 3rd Grade in the 2010-2011 Spring Semester at Gazi University

#	CGPA	OPTICS GRADE (OG) (Letter)	OPTICS GRADE (OG) (Numeric)	OPTICS LAB GRADE (OLG) (Letter)	OPTICS LAB GRADE (OLG) (Numeric)	WEIGHTED AVRAGE OF OPTIC GRADE & OPTIC LAB GRADE (WAOG)	AVERAGE of CGPA & WAOG	Selected participants
1	2.97	AA	4	AA	4	4	3.49	
2	3.50	BA	3.5	BB	3	3.4	3.45	
3	2.84	BA	3.5	AA	4	3.6	3.22	*
4	2.90	BA	3.5	BB	3	3.4	3.15	*
5	3.30	BB	3	BB	3	3	3.15	
6	2.78	BA	3.5	BA	3.5	3.5	3.14	
7	2.72	BA	3.5	BA	3.5	3.5	3.11	*
8	2.62	BA	3.5	BA	3.5	3.5	3.06	
9	3.12	BB	3	BB	3	3	3.06	
10	2.88	BB	3	BA	3.5	3.1	2.99	
11	2.82	BB	3	BA	3.5	3.1	2.96	
12	3.40	CB	2.5	CB	2.5	2.5	2.95	
13	2.86	BB	3	BB	3	3	2.93	
14	2.82	BB	3	CB	2.5	2.9	2.86	
15	2.67	BB	3	BB	3	3	2.84	*
16	2.49	BB	3	BA	3.5	3.1	2.8	
17	2.56	BB	3	BB	3	3	2.78	
18	2.41	BB	3	BA	3.5	3.1	2.76	
19	2.86	CB	2.5	BB	3	2.6	2.73	
20	2.50	BB	3	CB	2.5	2.9	2.7	
21	2.27	BB	3	BA	3.5	3.1	2.69	
22	2.42	BB	3	CB	2.5	2.9	2.66	
23	2.19	BB	3	BA	3.5	3.1	2.65	*
24	1.90	BB	3	AA	4	3.2	2.55	
25	2.28	CB	2.5	CB	3.5	2.7	2.49	
26	2.17	BB	3	CC	2	2.8	2.49	
27	2.86	CC	2	CB	2.5	2.1	2.48	
28	2.16	CB	2.5	BA	3.5	2.7	2.43	
29	2.10	BB	3	DC	1.5	2.7	2.4	
30	1.85	BB	3	CB	2.5	2.9	2.38	
31	1.82	BB	3	CB	2.5	2.9	2.36	
32	2.51	CC	2	BB	3	2.2	2.36	
33	2.09	CB	2.5	CB	2.5	2.5	2.3	
34	2.57	DC	1.5	CB	2.5	1.7	2.14	
35	2.02	CC	2	BB	3	2.2	2.11	
36	1.82	CB	2.5	CC	2	2.4	2.11	*
37	2.25	DC	1.5	CB	2.5	1.7	1.98	
38	1.67	CC	2	CB	2.5	2.1	1.89	
39	1.52	CC	2	CB	2.5	2.1	1.81	
40	1.97	DC	1.5	DD	1	1.4	1.69	
41	1.41	DD	1	CB	2.5	1.3	1.36	
42	1.15	FF	0				0.58	NI
Average							**2.62**	
StDv							**0.48**	
StDv							**0.48**	

Table B.3 Pre-service Physics Teachers Registered to the 4th Grade in the 2010-2011Spring Semester at Hacettepe University

#	CGPA	OPTICS GRADE (OG) (Letter)	OPTICS GRADE (OG) (Numeric)	OPTICS LAB GRADE (OLG) (Letter)	OPTICS LAB GRADE (OLG) (Numeric)	WEIGHTED AVRAGE OF OPTIC GRADE & OPTIC LAB GRADE (WAOG)	AVERAGE of CGPA & WAOG	Selected participants
1	2.61	A2	3.5	B1	3	3.42	3.01	
2	2.56	B1	3	B2	2.5	2.92	2.74	*
3	3.47	C2	1.5	B1	3	1.75	2.61	*
4	2.40	B2	2.5	B1	3	2.58	2.49	
5	3.17	C2	1.5	B1	3	1.75	2.46	
6	3.24	C2	1.5	C1	2	1.58	2.41	
7	2.03	B2	2.5	B1	3	2.58	2.31	
8	2.91	C2	1.5	B2	2.5	1.67	2.29	
9	2.06	C1	2	B2	3.5	2.25	2.16	*
10	2.42	C2	1.5	B1	3	1.75	2.09	*
11	2.49	D1	1	C1	2	1.17	1.83	
12	2.83	D2	0.5	C2	1.5	0.67	1.75	
13	1.93	D1	1	C1	2	1.17	1.55	
14	1.40	F1	0	F1	0	0.00	0.70	
Average							**2.28**	
StDv							**0.41**	

Note: NI represents not included participants in the study because of not completed optic course(s).

APPENDIX C

THE INTERVIEW GUIDE

Gönüllü Katılım Formu

Bu çalışma, ODTÜ Eğitim Fakültesi araştırma görevlilerinden Derya Kaltakçı tarafından yürütülen fizik öğretmen adaylarının geometrik optik konularındaki kavramlamaları ve bu kavramlamaların tespiti üzerine bir çalışmadır. Bu çalışmanın amacı, öğretmen adaylarının bu konudaki görüşlerini ortaya çıkarmak ve zihinlerindeki modelleri tespit edip kategorize etmektir. Bu araştırmada ortaya çıkacak sonuçların eğitim fakültesindeki derslerin içeriğine ve öğretmen eğitimi sürecine katkıda bulunacağı düşünülmektedir.

Çalışmaya katılım tamamıyla gönüllülük temelinde olmalıdır. Cevaplarınız tamamıyla gizli tutulacak ve sadece araştırmacılar tarafından değerlendirilecektir; elde edilecek bilgiler bilimsel yayımlarda kullanılacaktır.

Anket ve testler, genel olarak kişisel rahatsızlık verecek soruları içermemektedir. Ancak, katılım sırasında sorulardan ya da herhangi başka bir nedenden ötürü kendinizi rahatsız hissederseniz çalışmayı yarıda bırakabilirsiniz. Çalışma süresince bu çalışmayla ilgili tüm sorularınız cevaplanacaktır.

Sizin için bir sakıncası yoksa görüşmeler kaydedilecektir. Görüşmelerimiz toplam beş oturumdan oluşacak ve her görüşme yaklaşık olarak bir saat sürecektir.

Bu çalışmaya katıldığınız için şimdiden teşekkür ederiz. Çalışma hakkında daha fazla bilgi almak için Eğitim Fakültesi araştırma görevlilerinden Derya Kaltakçı (Oda: EF-205; Tel: 210 6489; E-posta: kaderya@metu.edu.tr) ile iletişim kurabilirsiniz.

Bu çalışmaya tamamen gönüllü olarak katılıyorum ve istediğim zaman yarıda kesip çıkabileceğimi biliyorum. Verdiğim bilgilerin bilimsel amaçlı yayımlarda kullanılmasını kabul ediyorum. (Formu doldurup imzaladıktan sonra uygulayıcıya geri veriniz).

İsim Soyad Tarih İmza

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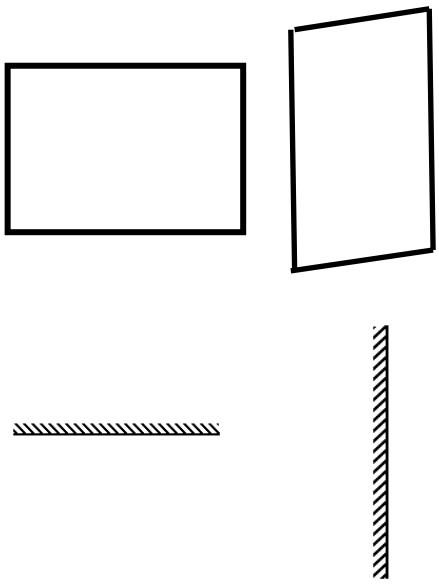
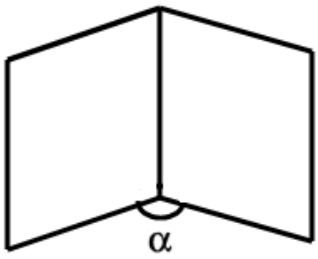
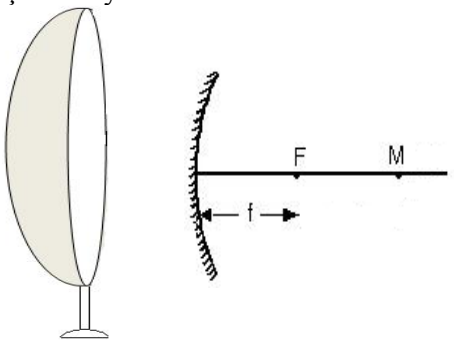
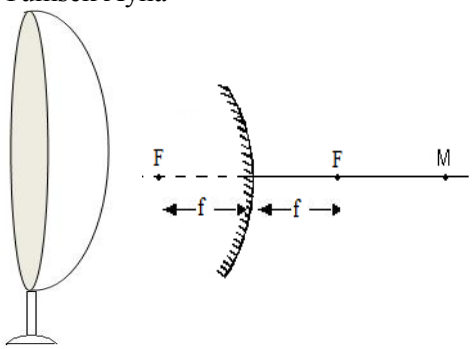
AÇIKLAYICI RESİMLER, ÇİZİMLER ve FORMÜLLER

Aşağıdaki tabloda Geometrik Optik Testi'nde yer alan sorularda bahsi geçen optik araçlara örnek olabilecek fotoğraflar, bu optik araçlara ait perspektif (yandan) veya üstten çizimler ile bu konularda ihtiyaç duyabileceğiniz bazı formüller size verilmiştir.

OPTİK ARACIN FOTOĞRAFI	OPTİK ARACIN PERSPEKTİF veya ÜSTTEN GÖRÜNÜŞÜNÜN ÇİZİMLERİ	OPTİK ARAÇ İLE İLGİLİ FORMÜLLER
Düzlem Ayna 		
Kesişen Aynalar 		**n:** Aynalarda oluşan toplam görüntü sayısı **α :** Aynalar arasındaki açı olmak üzere $n=\frac{360}{\alpha}-1$

<table>
<tr>
<td>Çukur ve Tümsek Aynalar

 </td>
<td>Çukur Ayna
 

Tümsek Ayna
 
</td>
<td>F: Aynanın odağı

M: Aynanın merkezi

f: Aynanın odak uzaklığı

d_c: Cismin aynaya olan uzaklığı

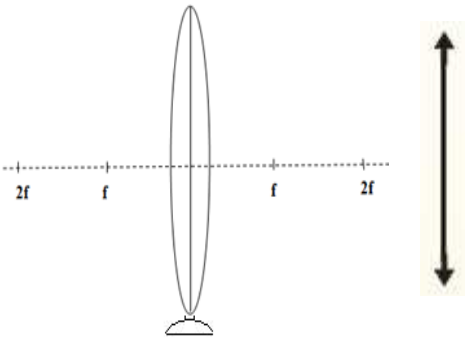
d_g: Görüntünün aynaya olan uzaklığı

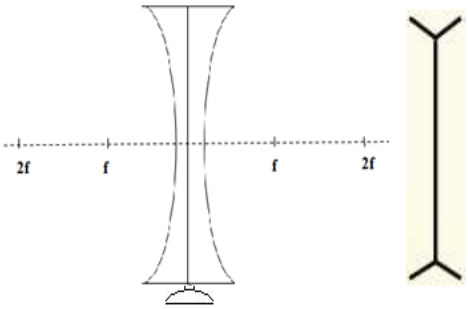
h_o: Cismin boyu

h_g: Görüntünün boyu olmak üzere

$\frac{1}{f} = \frac{1}{d_c} + \frac{1}{d_g}$

$\frac{h_o}{h_g} = \frac{d_c}{d_g}$</td>
</tr>
<tr>
<td>İnce ve Kalın Kenarlı Mercekler

 </td>
<td>İnce Kenarlı Mercek
 

Kalın Kenarlı Mercek
 
</td>
<td>f: Merceğin odak uzaklığı

d_c: Cismin merceğe olan uzaklığı

d_g Görüntünün merceğe olan uzaklığı

h_o: Cismin boyu

h_g: Görüntünün boyu olmak üzere

$\frac{1}{f} = \frac{1}{d_c} + \frac{1}{d_g}$

$\frac{h_o}{h_g} = \frac{d_c}{d_g}$</td>
</tr>
</table>

GÖRÜŞME FORMU #1

Katılımcı:		
Tarih:	**Saat:** ***Başlama:*** ***Bitiş:***	**Yer:**
Doğum tarihi: / /	**GNO:**	**Üniversite:**
A.Ö.D:	**B.Ö.D:**	**Lise Türü:**

ISINMA SORULARI

1) Fizik öğretmenliği bölümde şu an kaçıncı döneminizdesiniz?

2) Fizik dersleri ile aranız nasıl? Kendinizi başarılı buluyor musunuz? Açıklayınız.

3) Bölümünüzü kaçıncı tercih olarak kazandınız?

4) Fizikte geometrik optik konusu ile aranız nasıl? Kendinizi bu konuda başarılı buluyor musunuz? Açıklayınız.

5) Lisede geometrik optik konusu ile aranız nasıldı? Bu konuda başarılı mıydınız? Açıklayınız. ÖSS'de optik ile ilgili soruları yapabildiniz mi?

6) Üniversitede optik dersini hangi döneminizde aldınız ve geçtiniz? Bu dersten (Optik) aldığınız not veya harf nedir?

7) Üniversitede optik laboratuarı dersini hangi döneminizde aldınız ve geçtiniz? (Ayrı dönemlerde ise) Bu dersten(Optik laboratuarı) aldığınız not veya harf nedir?

8) Üniversitede bu zorunlu derslerin dışında içinde geometrik optik veya uygulamalarını tamamen veya kısmen konu alan seçmeli bir ders aldınız mı? Aldıysanız belirtiniz.

9) Geometrik optik ile ilgili bildikleriniz sizce temel olarak nereden gelmektedir?

- Tecrübelerinizin geometrik optik bilginiz üzerindeki etkisi sizce nedir?
- İlköğretim-Lise-Üniversitede aldığınız derslerin (Ders kitapları, öğretmenler, laboratuar deneyleri, ödev-proje vb.) geometrik optik bilginiz üzerindeki etkisi sizce nedir?
- Yazılı veya görsel medyanın (gazete, dergi, TV, radyo, film, belgesel vb.) geometrik optik bilginiz üzerindeki etkisi sizce nedir?

10) Bir konuyu **tecrübe etmek** bu konuda deneyim sahibi olmak ve bu konu ile ilgili faaliyetlerde bulunmuş olmak anlamına gelmektedir. Buna göre Geometrik optik ile ilgili tecrübeleriniz nelerdir? *Örnek: Teleskop kullanmak.*

11) Bir konuya karşı **ilgili olmak**, bu konuda yeni bilgiler edinmeye istekli olmak ve bu konu ile ilgili faaliyetlere istekli olarak katılmak anlamına gelmektedir. Buna göre Geometrik optik konularına hangi şekilde ilgi duyarsınız? *Örnek: Boş zamanlarında geometrik ile ilgili dergi, kitap vs. okumak.*

GENEL SORULAR

1) Geometrik optik nedir?

2) Işık nedir? Nasıl yayılır? Işık modelleri hakkında ne biliyorsunuz?

3) Işık farklı bir ortamla karşılaştığı zaman nasıl davranır? Bu ortamlar neler olabilir? Ve her birinde nasıl davranmasını beklersiniz?

- Aynalar (düzlem, küresel, kesişen)
- Mercekler (ince ve kalın kenarlı)

4) Görüntü nedir?

5) Gerçek görüntü nedir? Hangi görüntülere gerçek görüntü deriz? Nasıl oluşur? Nasıl gözlemlenebilir? Bu duruma bir örnek verebilir misiniz?

- Ekran kullanılmaz ise gerçek görüntü oluşur mu? (Oluşursa nasıl oluşur? Oluşmazsa neden?) Nasıl görülebilir? Bu duruma bir örnek verebilir misiniz?
- Gerçek görüntünün oluşumu ve gözlemlenmesinde gözlemcinin önemi sizce nedir? Bu duruma bir örnek verebilir misiniz?

6) Sanal (zahiri) görüntü nedir? Hangi görüntülere sanal görüntü deriz? Nasıl oluşur? Nasıl gözlemlenebilir? Bu duruma bir örnek verebilir misiniz?

- Sanal görüntünün oluşumu ve gözlemlenmesinde gözlemcinin önemi sizce nedir? Bu duruma bir örnek verebilir misiniz?

7) Düzlem aynada oluşan görüntü ne tür bir görüntüdür? Neden? Bu görüntü nasıl oluşur?

- Görüntü oluşumunda gözlemcinin yerinin önemi sizce nedir? Görüntünün gözlemlenmesinde gözlemcinin yerinin önemi sizce nedir?
- Cismin aynaya göre pozisyonunun görüntünün oluşumuna etkisi nedir? (Ayna sınırları dışındaki bir cismin görüntüsü oluşur mu? Gözlemlenebilir mi?)
- Gözlemcinin belli yerlerde cismi görüp belli yerlerde görmemesi cismin görüntüsünün oluşup oluşmamasını etkiler mi? Bu duruma bir örnek verebilir misiniz?
- Gözlemcinin hareketli olup olmaması cismin görüntüsünün oluşup oluşmamasını, görüntünün yerini ve büyüklüğünü etkiler mi? Bu duruma bir örnek verebilir misiniz?
- Cismin hareketli olup olmaması görüntüsünün oluşup oluşmamasını, yerini ve büyüklüğünü etkiler mi? Bu duruma bir örnek verebilir misiniz?
- Düzlem aynada oluşan görüntünün boyu nelere bağlı? Görüntünün boyunu artırmak ya da azaltmak mümkün mü? Nasıl? Bu duruma bir örnek verebilir misiniz?
- Düzlem aynada kendimizi gözlemlemek ve başka bir kişi ya da nesneyi gözlemlemek arasındaki fark sizce nedir? Bu duruma bir örnek verebilir misiniz?
- Aynanın belli kısımlarını kapatmak cismin görüntüsünün oluşumunu engeller mi? Bu duruma bir örnek verebilir misiniz?

8) Kesişen iki ayna arasında oluşan görüntü ne tür görüntüdür? Neden? Bu görüntüler nasıl oluşur? Aynalar arasındaki açı görüntüleri nasıl etkiler? Aynalar arasındaki açı dışında görüntü sayısını etkileyen başka faktörler var mıdır?

- Gözlemcinin yerinin görüntü oluşumuna ve görüntü sayısına etkisi sizce nedir? Bu duruma bir örnek verebilir misiniz?
- Cismin pozisyonunun görüntünün oluşumuna ve görüntü sayısına etkisi nedir? Bu duruma bir örnek verebilir misiniz?
- Gözlemcinin belli yerlerde cismi görüp belli yerlerde görmemesi cismin görüntüsünün oluşup oluşmamasını etkiler mi? Bu duruma bir örnek verebilir misiniz?
- Kesişen aynalarda kendimizi gözlemlemek ve başka bir kişi ya da nesneyi gözlemlemek arasındaki fark sizce nedir? Bu duruma bir örnek verebilir misiniz?
- Aynaların belli kısımlarını kapatmak cismin görüntüsünün oluşumunu engeller mi? Bu duruma bir örnek verebilir misiniz?

9) Çukur ve tümsek aynalarda oluşan görüntüler ne tür görüntüdür? Neden? Bu görüntüler nasıl oluşur?

- Görüntü oluşumunda gözlemcinin yerinin önemi sizce nedir? Görüntünün gözlemlenmesinde gözlemcinin yerinin önemi sizce nedir? Bu duruma bir örnek verebilir misiniz?
- Cismin pozisyonunun görüntünün oluşumuna etkisi nedir? Bu duruma bir örnek verebilir misiniz?
- Gözlemcinin belli yerlerde cismi görüp belli yerlerde görmemesi cismin görüntüsünün oluşup oluşmamasını etkiler mi? Bu duruma bir örnek verebilir misiniz?
- Çukur aynada kendimizi gözlemlemek ve başka bir kişi ya da nesneyi gözlemlemek arasındaki fark sizce nedir? Bu duruma bir örnek verebilir misiniz? Bu durumda ne gibi farklılıklar işin içerisine girer?
- Tümsek aynada kendimizi gözlemlemek ve başka bir kişi ya da nesneyi gözlemlemek arasındaki fark sizce nedir? Bu duruma bir örnek verebilir misiniz? Bu durumda ne gibi farklılıklar işin içerisine girer?
- Çukur veya Tümsek aynalarda aynanın bir kısmını kapatmak cismin görüntüsünün oluşumunu etkiler mi? Bu duruma bir örnek verebilir misiniz?

10) İnce ve kalın kenarlı merceklerde oluşan görüntüler ne tür görüntüdür? Neden? Bu görüntüler nasıl oluşur?

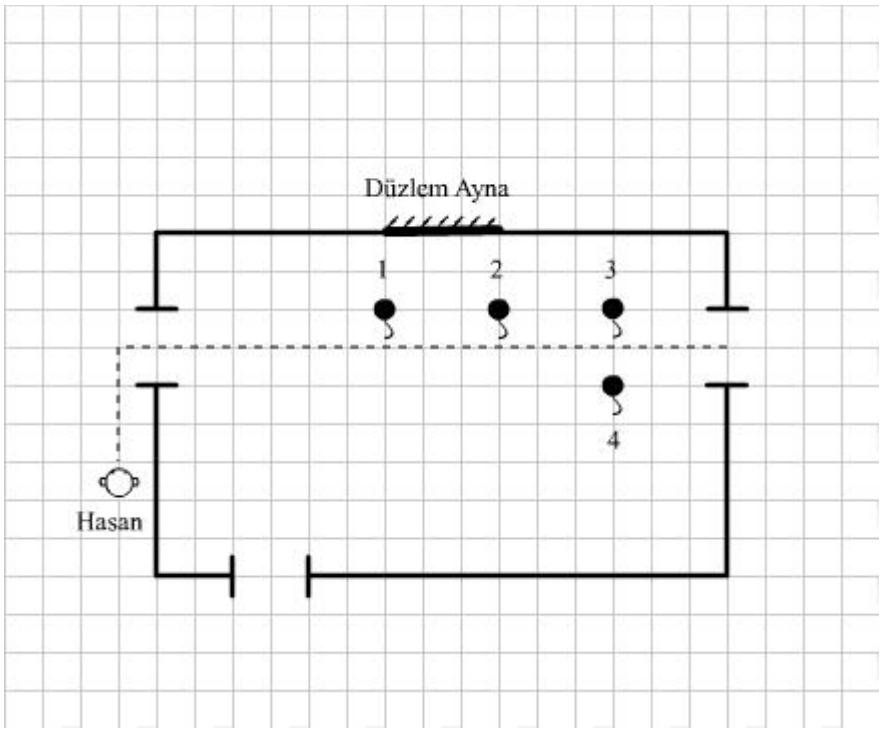
- Görüntü oluşumunda gözlemcinin yerinin önemi sizce nedir? Görüntünün gözlemlenmesinde gözlemcinin yerinin önemi sizce nedir? Bu duruma bir örnek verebilir misiniz?
- Cismin pozisyonunun görüntünün oluşumuna etkisi nedir? Gözlemcinin belli yerlerde cismi görüp belli yerlerde görmemesi cismin görüntüsünün oluşup oluşmamasını etkiler mi? Bu duruma bir örnek verebilir misiniz?
- İnce kenarlı mercekte kendimizi gözlemlemek ve başka bir kişi ya da nesneyi gözlemlemek arasındaki fark sizce nedir? Bu duruma bir örnek verebilir misiniz?
- Kalın kenarlı mercekte kendimizi gözlemlemek ve başka bir kişi ya da nesneyi gözlemlemek arasındaki fark sizce nedir? Bu duruma bir örnek verebilir misiniz?
- İnce veya Kalın kenarlı merceğin bir kısmının kapatmak cismin görüntüsünün oluşumunu etkiler mi? Bu duruma bir örnek verebilir misiniz?

GÖRÜŞME FORMU #2

DÜZLEM AYNA

1-4 numaralı sorulardaki şekillerde ışık kaynağı ile homojen bir şekilde aydınlatılmış bir odanın üstten görünüşü verilmiştir.

1)



Hasan kapıdan içeri girip oda boyunca kesikli çizgi ile gösterilen yolda ilerlerken kendisinin ve 1-4 ile numaralandırılmış kedilerin görüntüsünü duvardaki düzlem aynada gözlemlemeye çalışmaktadır. Buna göre;

A. Numaralandırılmış kedilerin hangilerinin düzlem aynada görüntüsü oluşur? Nerede oluşur? Neden?

B. Hasan ilk olarak hangi kedinin görüntüsünü düzlem aynada görür? Görüntü nerededir? Bu durumda Hasan nerededir? Nedenlerini açıklayınız.

C. Hasan'ın çizgi üzerinde ilerlerken kedileri hangi sıra ile göreceğini nedenleriyle açıklayınız.

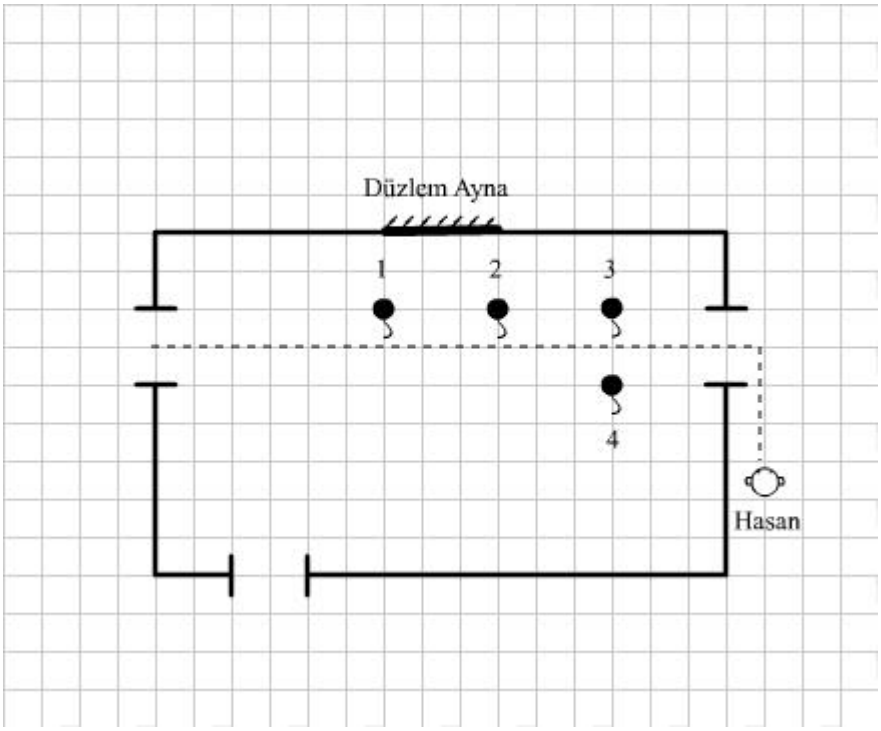
D. Hasan hareket ederken kedilerin görüntüsünün boyu, yeri değişir mi? Neden?

E. Hasan çizgi üzerinde ilerlerken ilk hangi noktada kendisinin görüntüsünü görebilir? Şekil üzerinde Hasan'ın ve görüntüsünün yerlerini işaretleyiniz. Nedenlerini açıklayınız.

F. Hasan çizgi üzerinde ilerlerken kendi görüntüsünün boyu ve yeri değişir mi? Neden?

G. Hasan çizgi üzerinde ilerlerken kedilerin görüntüsünü belli yerlerde görüp belli yerlerde görememesi o kedinin düzlem aynada görüntüsünün oluşup oluşmamasını etkiler mi?

2)



Hasan odaya sağ kapıdan girip oda boyunca kesikli çizgi ile gösterilen yolda ilerlerken kendisinin ve 1-4 ile numaralandırılmış kedilerin görüntüsünü düzlem aynada gözlemlemeye çalışmaktadır. Buna göre;

A. Numaralandırılmış kedilerin hangilerinin düzlem aynada görüntüsü oluşur? Nerede oluşur? Neden?

B. Hasan ilk olarak hangi kedinin görüntüsünü düzlem aynada görür? Görüntü nerededir? Bu durumda Hasan nerededir? Nedenlerini açıklayınız.

C. Hasan'ın çizgi üzerinde ilerlerken kedileri hangi sıra ile göreceğini nedenleriyle açıklayınız.

D. Hasan hareket ederken kedilerin görüntüsünün boyu, yeri değişir mi? Neden?

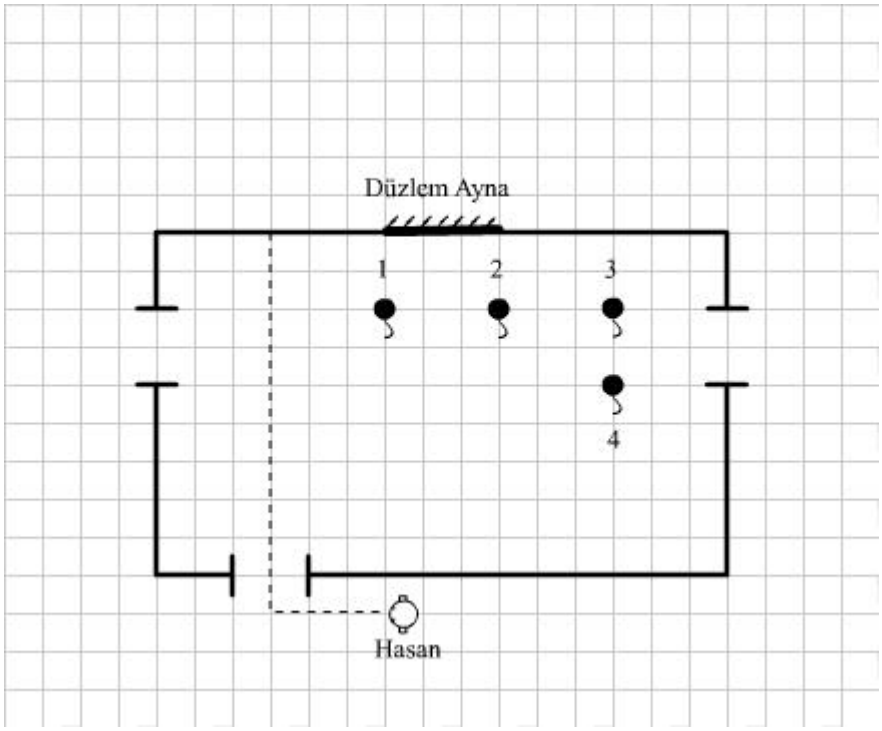
E. 3 ve 4 numaralı kedilerin görüntülerinin boylarını ve yerlerini karşılaştırınız. Nedenleriyle açıklayınız.

F. Hasan çizgi üzerinde ilerlerken ilk hangi noktada kendisinin görüntüsünü görebilir? Şekil üzerinde Hasan'ın ve görüntüsünün yerlerini işaretleyiniz. Nedenlerini açıklayınız.

G. Hasan çizgi üzerinde ilerlerken kendi görüntüsünün boyu ve yeri değişir mi? Neden?

H. Hasan çizgi üzerinde ilerlerken kedilerin görüntüsünü belli yerlerde görüp belli yerlerde görememesi o kedinin düzlem aynada görüntüsünün oluşup oluşmamasını etkiler mi?

3)



Hasan odaya arka kapıdan girip oda boyunca kesikli çizgi ile gösterilen yolda ilerlerken kendisinin ve 1-4 ile numaralandırılmış kedilerin görüntüsünü düzlem aynada gözlemlemeye çalışmaktadır. Buna göre;

A. Numaralandırılmış kedilerin hangilerinin düzlem aynada görüntüsü oluşur? Nerede oluşur? Neden?

B. Hasan ilk olarak hangi kedinin görüntüsünü düzlem aynada görür? Görüntü nerededir? Bu durumda Hasan nerededir? Nedenlerini açıklayınız.

C. Hasan'ın çizgi üzerinde ilerlerken kedileri hangi sıra ile göreceğini nedenleriyle açıklayınız.

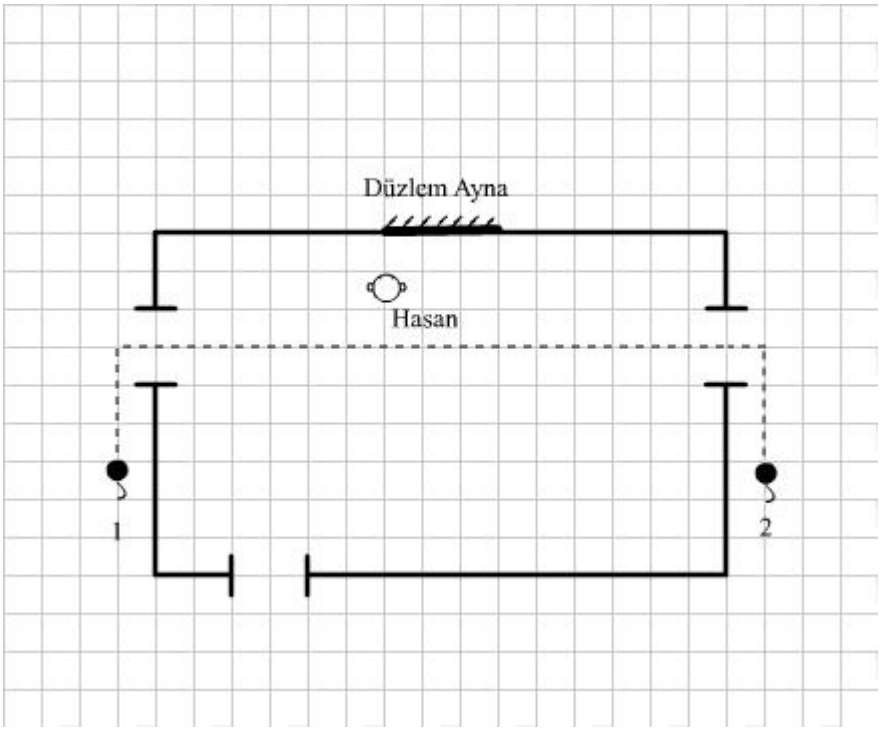
D. Hasan hareket ederken kedilerin görüntüsünün boyu, yeri değişir mi? Neden?

E. Hasan çizgi üzerinde ilerlerken ilk hangi noktada kendisinin görüntüsünü görebilir? Şekil üzerinde Hasan'ın ve görüntüsünün yerlerini işaretleyiniz. Nedenlerini açıklayınız.

F. Hasan çizgi üzerinde ilerlerken kendi görüntüsünün boyu ve yeri değişir mi? Neden?

G. Hasan çizgi üzerinde ilerlerken kedilerin görüntüsünü belli yerlerde görüp belli yerlerde görememesi o kedinin düzlem aynada görüntüsünün oluşup oluşmamasını etkiler mi?

4)



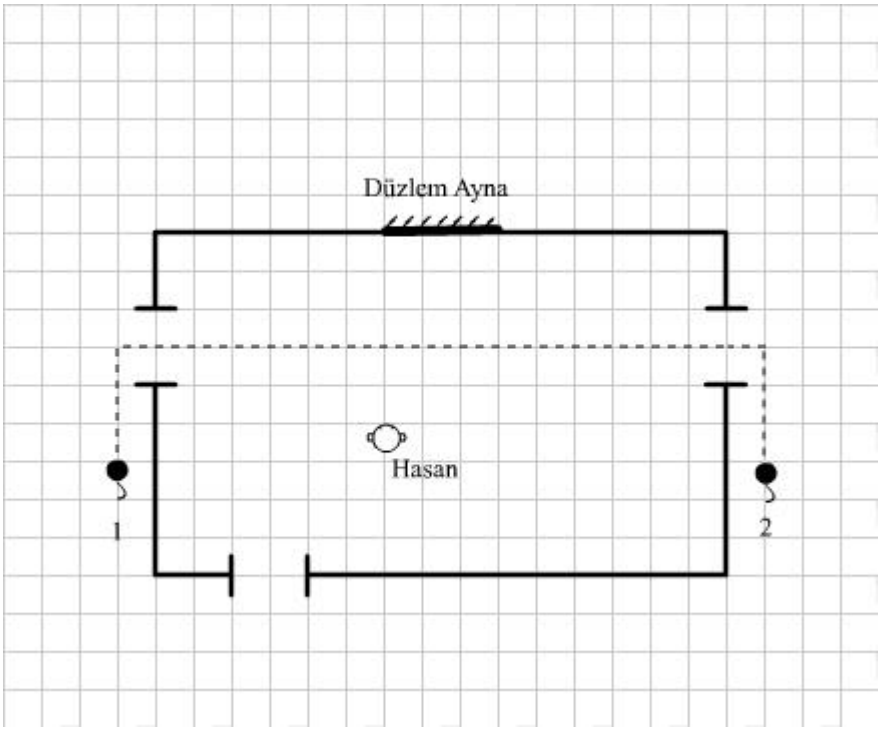
Hasan düzlem aynanın ön cephe sınırı içinde düzlem aynaya bakmakta iken odanın sağ ve sol kapılarından 1 ve 2 numaralı kediler aynı anda içeri girip oda boyunca kesikli çizgi ile gösterilen yolda eşit süratle ilerlemektedirler. Buna göre;

A. Numaralandırılmış kedilerin hangilerinin düzlem aynada görüntüsü oluşur? Nerede oluşur? Neden?

B. Hasan ilk olarak hangi kedinin görüntüsünü düzlem aynada görür? Bu durumda görülen kedi nerededir? Görüntüsü nerededir? Nedenlerini açıklayınız.

C. Kedilerin her biri hareket ederken görüntülerinin boyu, yeri değişir mi? Neden?

D. Hasan düzlem aynadan kedilerin izlediği yol önünde kalacak şekilde aşağıdaki şekildeki gibi uzaklaşırsa;



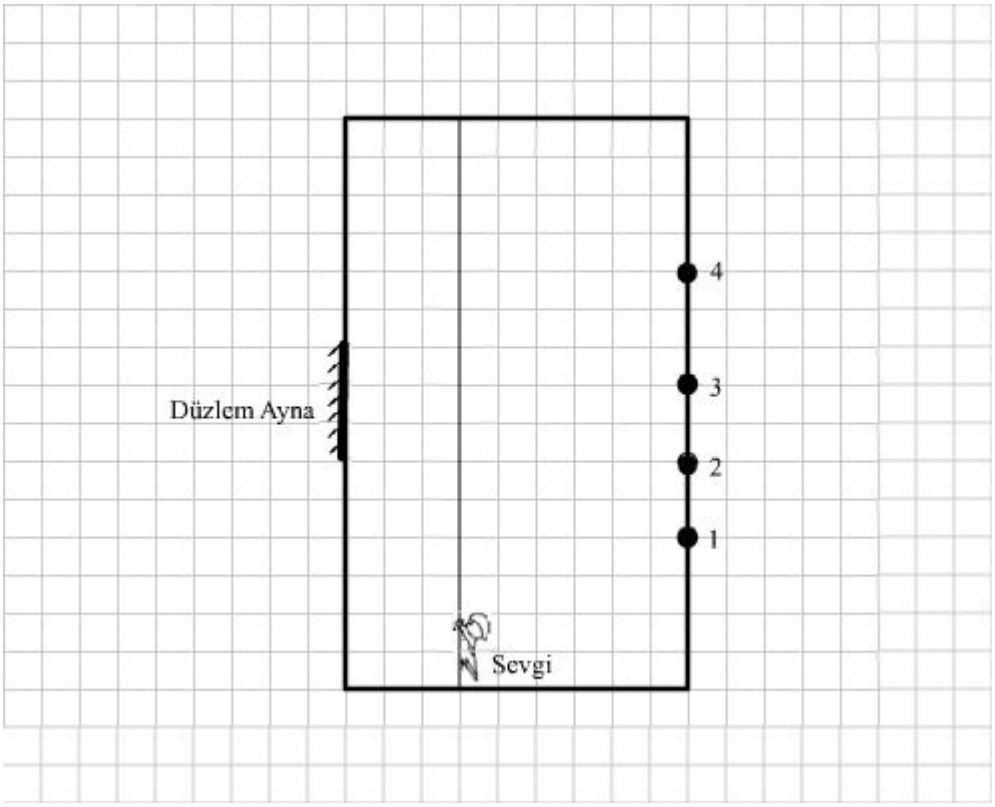
i. Hasan'ın düzlem aynada gözlemlediği kendi görüntüsünün boyu ve yeri bir önceki duruma göre nasıl değişir? Nedenlerini açıklayınız.

ii. Hasan'ın düzlem aynada gözlemlediği kedilerin görüntüsünün boyu ve yeri bir önceki duruma göre nasıl değişir? Nedenlerini açıklayınız.

iii. Hasan ilk olarak hangi kedinin görüntüsünü düzlem aynada görür? Bu durumda görülen kedi nerededir? Görüntüsü nerededir? Nedenlerini açıklayınız.

5 numaralı sorudaki şekilde bir ışık kaynağı ile homojen bir şekilde aydınlatılmış bir odanın yandan görünüşü verilmiştir. Şekildeki düzlem ayna bulunduğu duvarın eni genişliğinde duvarı kaplamaktadır. İp ve 1-4 ile numaralandırılmış lambalar ise oda ve duvarın ortası hizasındadır.

5)



Sevgi tavanda asılı ip ile yukarı tırmanırken kendisinin ve arkasındaki duvara yerleştirilmiş 1-4 ile numaralandırılmış lambaların görüntüsünü düzlem aynadan gözlemlemeye çalışmaktadır. Buna göre;

A. Numaralandırılmış lambaların hangilerinin düzlem aynada görüntüsü oluşur? Nerede oluşur? Neden?

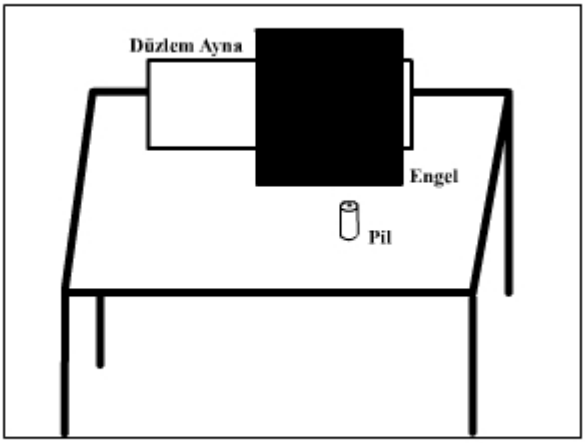
B. Sevgi tırmanırken ilk olarak hangi lambanın görüntüsünü düzlem aynada görür? Görüntü nerededir? Bu durumda Sevgi nerededir?

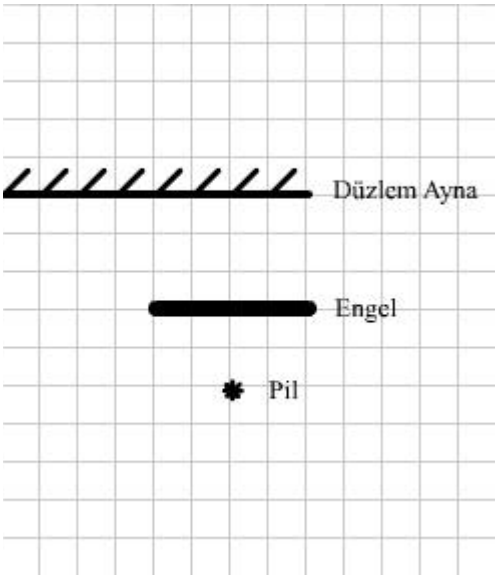
C. Sevgi kendisinin görüntüsünü düzlem aynada ilk olarak nerede iken görür? Şekil üzerinde Sevgi'nin ve görüntüsünün yerlerini işaretleyiniz. Nedenlerini açıklayınız.

D. Sevgi'nin ip ile yukarı tırmanırken lambaların görüntüsünü belli yerlerde görüp belli yerlerde görememesi o lambanın düzlem aynada görüntüsünün oluşup oluşmamasını etkiler mi?

6)

Homojen bir şekilde aydınlatılmış bir odada masanın üzerinde bulunan düzlem aynanın önüne aşağıdaki şekilde gösterildiği gibi saydam olmayan bir engel yerleştirilmiştir. Engelin arkasına ise şekildeki gibi bir pil yerleştirilmiştir. Sağdaki çizimde bu şeklin üstten gösterimi yer almaktadır. Buna göre;

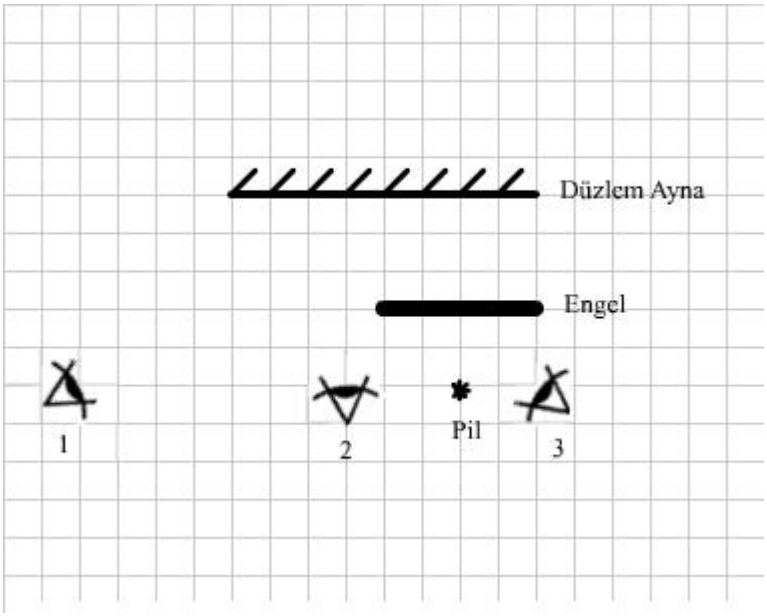




A. Pilin aynada görüntüsü oluşur mu? Neden?

B. Pilin görüntüsü görülebilir mi? Nasıl?

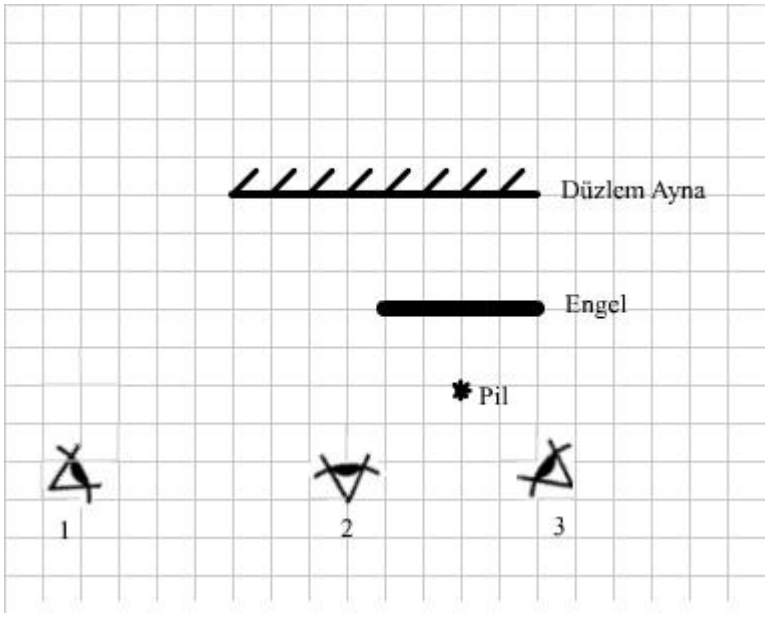
C.



i. 1-3 ile numaralandırılmış hangi gözlemci ya da gözlemciler pilin görüntüsünü görebilirler? Nasıl ve nerede görür(ler)?

ii. Hangi numaralı gözlemci ya da gözlemciler kendi görüntüsünü görebilir? Nasıl ve nerede görür(ler)?

D. Gözlemciler şekilde gösterildiği gibi geriye doğru giderlerse;

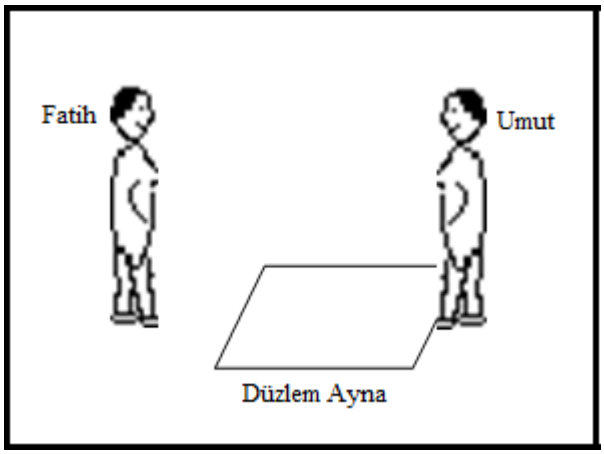


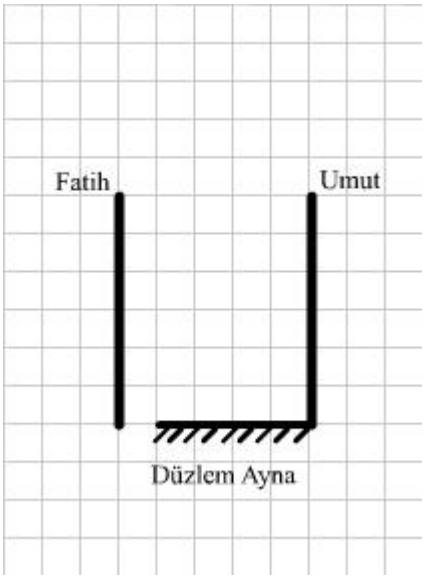
i. Hangi gözlemci ya da gözlemciler pilin görüntüsünü görebilir? Nasıl ve nerede görür(ler)?

ii. Hangi numaralı gözlemci ya da gözlemciler kendi görüntüsünü görebilir? Nasıl ve nerede görür(ler)?

7)

150 cm boyundaki Umut ve Fatih bir alışveriş merkezinde yerde yatay olarak duran 100X100 cm boyutlarındaki bir aynanın yanında şekilde gösterildiği gibi durmaktadırlar. Umut aynanın hemen yanında aynanın üzerine basmadan ayakta dururken, Fatih Umut'un karşısında ve aynadan 25 cm uzaklıkta durup her ikisi de aynaya bakmaktadır. Sağdaki çizimde bu şeklin yandan gösterimi yer almaktadır. Buna göre;





A. Umut kendi vücudunun görüntüsünü aynaya baktığında görebilir mi? Neden?

i. Görürse vücudunun ne kadarının görüntüsünü aynada görebilir?

B. Fatih kendi vücudunun görüntüsünü aynaya baktığında görebilir mi? Neden?

i. Görürse vücudunun ne kadarının görüntüsünü aynada görebilir?

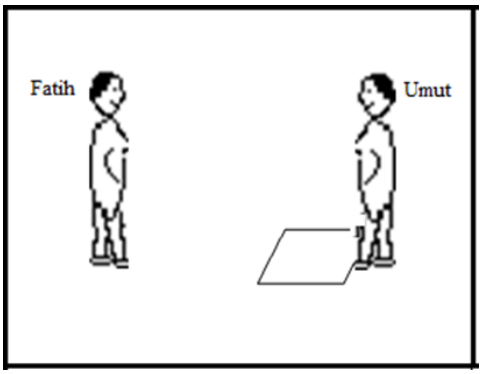
C. Fatih, Umut'un vücudunun görüntüsünü aynada görebilir mi? Neden?

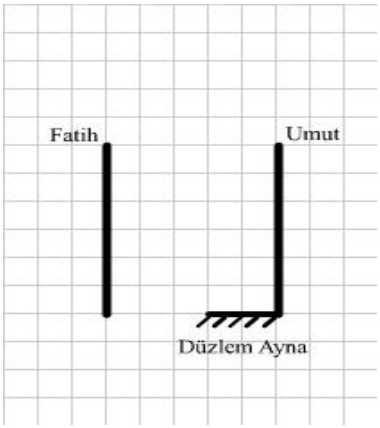
i. Görürse vücudunun ne kadarının görüntüsünü aynada görebilir?

D. Umut, Fatih'in vücudunun görüntüsünü aynada görebilir mi? Neden?

i. Görürse vücudunun ne kadarının görüntüsünü aynada görebilir?

E. Aynanın boyutları 50X50 cm olacak şekilde yarıya indirilirse;



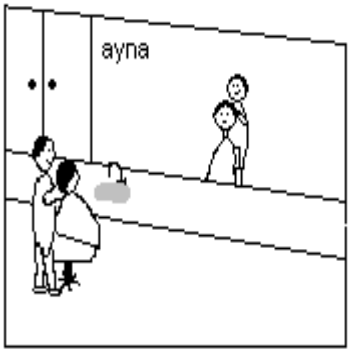


i. Umut'un aynada gördüğü görüntüsünün boyu, şekli ve yeri nasıl değişir? Neden?
ii. Fatih'in aynada gördüğü görüntüsünün boyu, şekli ve yeri nasıl değişir? Neden?
iii. Umut'un aynada gördüğü Fatih'in görüntüsünün boyu, şekli ve yeri nasıl değişir?Neden?

8)

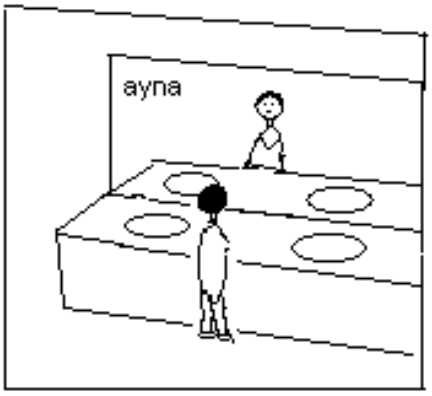
Kuaför salonunda, kuaför müşterisinin arkasında iken aynaya baktığında müşterinin görüntüsünü şekildeki gibi görüyor. Kuaför, müşterinin sağ tarafındaki saçları kesmek için bir miktar sağ tarafa kaydığında ve bu durumda iken aynaya baktığında müşterinin görüntüsünün yeri, şekli ve büyüklüğü nasıl değişir?

(Koltuk ve müşteri yerinde sabit durmaktadır).



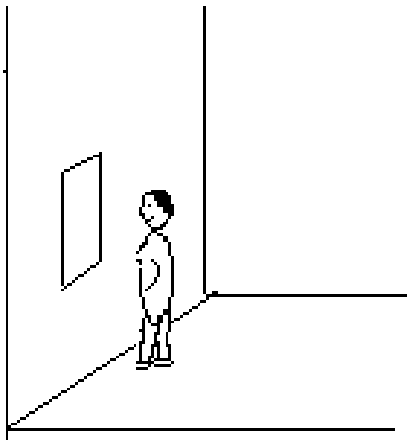
9)

Hasan teneffüste okulundaki lavaboyu kullanırken lavabonun hemen arkasına monte edilmiş aynada kendi görüntüsüne bakmaktadır. Yeni aldığı pantolonun üzerinde nasıl göründüğünü merak eden Hasan pantolonunu görebilmek istemektedir. Aynadan geriye doğru uzaklaşırsa pantolonunu görmeyi başarabilir mi?



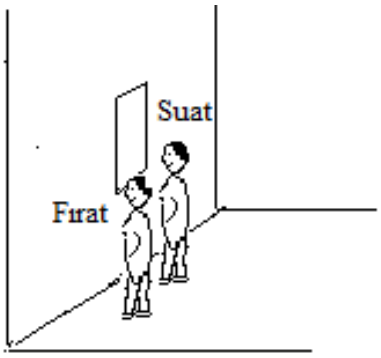
10)

Yerden yüksekliği göğüs hizasında olan ve duvarda asılı olan düzlem aynada görüntüsüne bakan Murat, bir defada vücudunun daha fazlasını görmek istemektedir. Bunun için ne yapmalıdır?



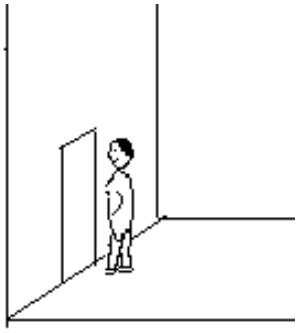
11)

Suat ve ikizi Fırat duvara monte edilmiş düzlem aynanın karşısında görüntülerine bakmaktadırlar. Suat bir defada Fırat'ın vücudunun daha fazlasını görmek istemektedir. Bunun için ne yapmalıdır?

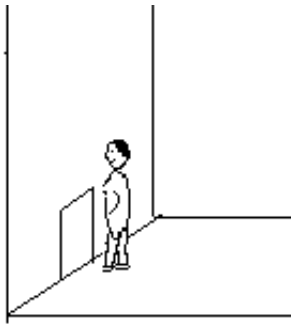


12)

Özkan odasındaki yüksekliği kendi boyuna eşit ve Şekil 1'de gösterildiği gibi duvara monte edilmiş düzlem aynada kendi görüntüsünü gözlemlemektedir.



Şekil 1



Şekil 2

A. Düzlem aynanın boyu önceki boyunun (ve Özkan'ın boyunun) yarısı olacak şekilde başka bir düzlem ayna ile Şekil 2'deki gibi değiştirilirse Özkan'ın aynada gördüğü kendi görüntüsü(nün boyu, şekli ve yeri) nasıl değişir?

B. Şekil 2'deki durumda Özkan tüm vücudunun görüntüsünü aynada görebilir mi? (ayaklarını ve saçlarını görebilir mi?)

i. Önceki soruya verdiğiniz cevap göremez ise, Özkan tüm vücudunu aynada görebilmek için ne yapmalıdır?

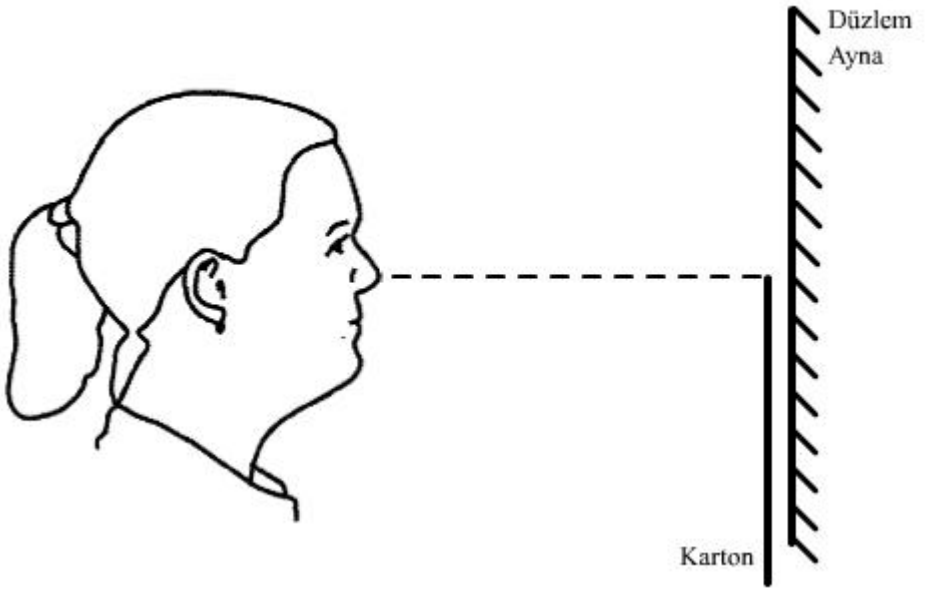
a. Aynadan uzaklaşırsa görebilir mi? Neden?

b. Aynanın yerden yüksekliği değiştirilirse görebilir mi? Neden?

c. Aynanın duvardaki hangi konumu tüm vücudunu görebilmesi için en uygundur?

13)

Duvara monte edilmiş düzlem aynaya bakan öğrencinin bir arkadaşı düzlem aynanın alt yarısını öğrencinin burun hizasına kadar bir kartla şekilde gösterildiği gibi kapatırsa,

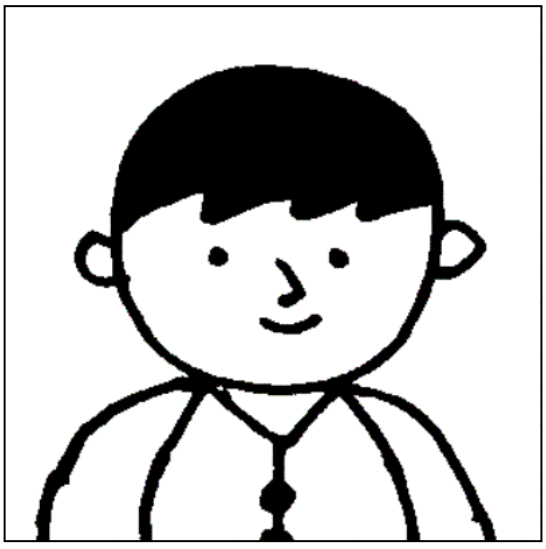


A. Öğrenci yüzünün hangi kısımlarını aynada görebilir? Neden?

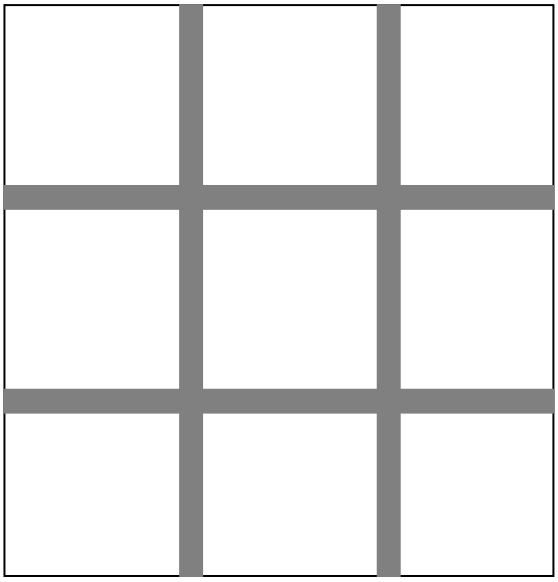
B. Öğrenci aynada yüzünün daha fazlasını görebilmek için ne(ler) yapabilir?

14)

Murat duvarda asılı düzlem aynanın karşısında iken Murat'ın annesi aynada oğlunun görüntüsünü Şekil 1'deki gibi görmektedir. Ayna 9 eşit parçaya ayrılıp, aralarında eşit açıklık bulunacak şekilde Şekil 2'deki gibi duvara yeniden monte edilirse, Murat'ın annesi Şekil 2'deki aynada ne görür? (Murat ve annesinin yerleri sabittir)



Şekil 1



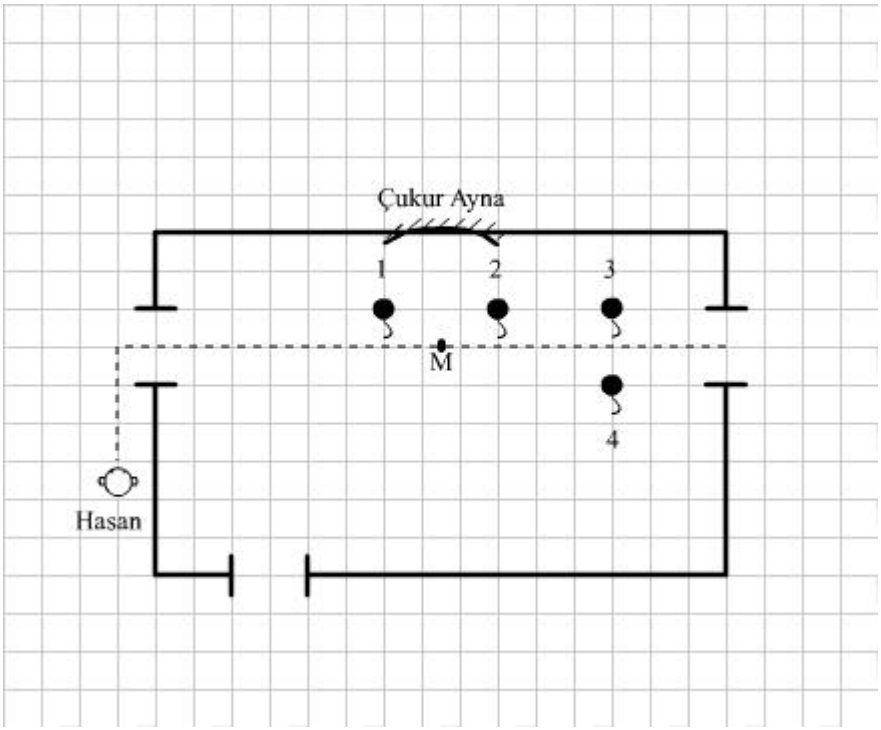
Şekil 2

GÖRÜŞME FORMU #3

KÜRESEL AYNALAR

15-18 numaralı sorulardaki şekillerde ışık kaynağı ile homojen bir şekilde aydınlatılmış bir odanın üstten görünüşü verilmiştir.

15)



Hasan kapıdan içeri girip oda boyunca kesikli çizgi ile gösterilen yolda ilerlerken kendisinin ve 1-4 ile numaralandırılmış kedilerin görüntüsünü duvardaki çukur aynada gözlemlemeye çalışmaktadır. Çukur aynanın merkez uzaklığı M ile gösterilmiştir. Buna göre;

A. Numaralandırılmış kedilerin hangilerinin çukur aynada görüntüsü oluşur? Nerede oluşur? Neden?

B. Hasan ilk olarak hangi kedinin görüntüsünü çukur aynada görür? Görüntü nerededir? Bu durumda Hasan nerededir? Nedenlerini açıklayınız.

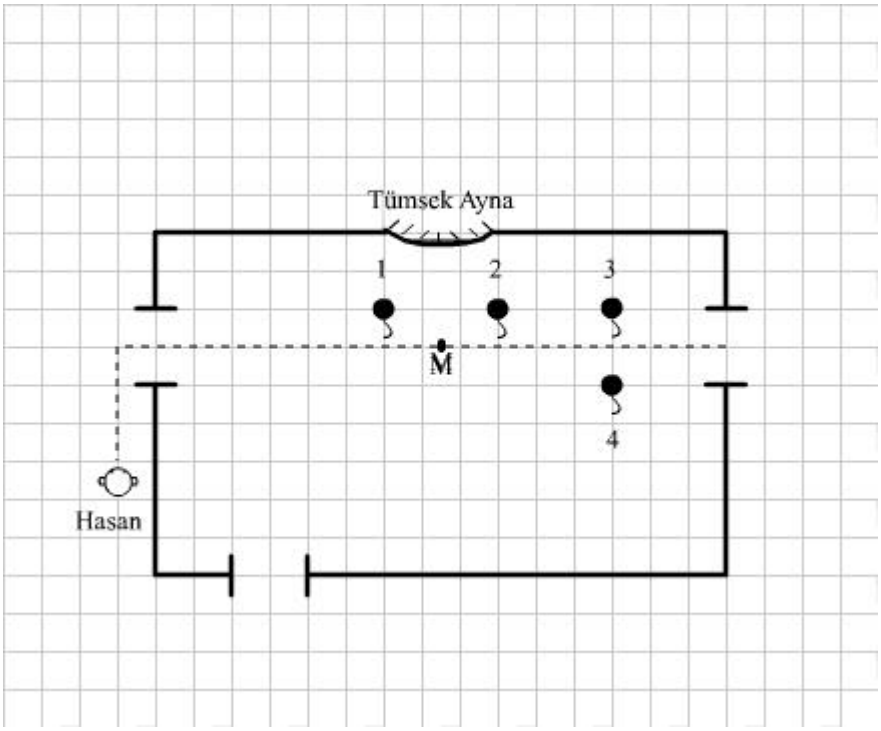
C. Hasan'ın çizgi üzerinde ilerlerken kedileri hangi sıra ile göreceğini nedenleriyle açıklayınız.

D. Hasan hareket ederken kedilerin görüntüsünün boyu, yeri değişir mi? Neden?

E. Hasan çizgi üzerinde ilerlerken ilk hangi noktada kendisinin görüntüsünü çukur aynada görebilir? Şekil üzerinde Hasan'ın ve görüntüsünün yerlerini işaretleyiniz. Nedenlerini açıklayınız.

F. Hasan çizgi üzerinde ilerlerken kendi görüntüsünün boyu ve yeri değişir mi? Neden?

16)



Hasan kapıdan içeri girip oda boyunca kesikli çizgi ile gösterilen yolda ilerlerken kendisinin ve 1-4 ile numaralandırılmış kedilerin görüntüsünü duvardaki tümsek aynada gözlemlemeye çalışmaktadır. Tümsek aynanın merkez uzaklığı M ile gösterilmiştir. Buna göre;

A. Numaralandırılmış kedilerin hangilerinin tümsek aynada görüntüsü oluşur? Nerede oluşur? Neden?

B. Hasan ilk olarak hangi kedinin görüntüsünü tümsek aynada görür? Görüntü nerededir? Bu durumda Hasan nerededir? Nedenlerini açıklayınız.

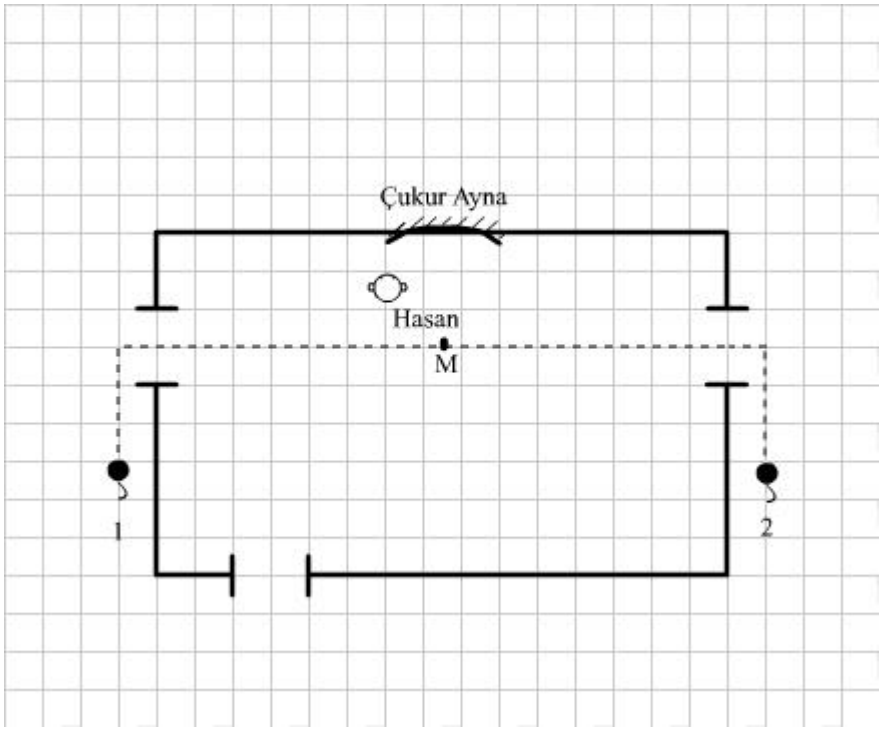
C. Hasan'ın çizgi üzerinde ilerlerken kedileri hangi sıra ile göreceğini nedenleriyle açıklayınız.

D. Hasan hareket ederken kedilerin görüntüsünün boyu, yeri değişir mi? Neden?

E. Hasan çizgi üzerinde ilerlerken ilk hangi noktada kendisinin görüntüsünü tümsek aynada görebilir? Şekil üzerinde Hasan'ın ve görüntüsünün yerlerini işaretleyiniz. Nedenlerini açıklayınız.

F. Hasan çizgi üzerinde ilerlerken kendi görüntüsünün boyu ve yeri değişir mi? Neden?

17)



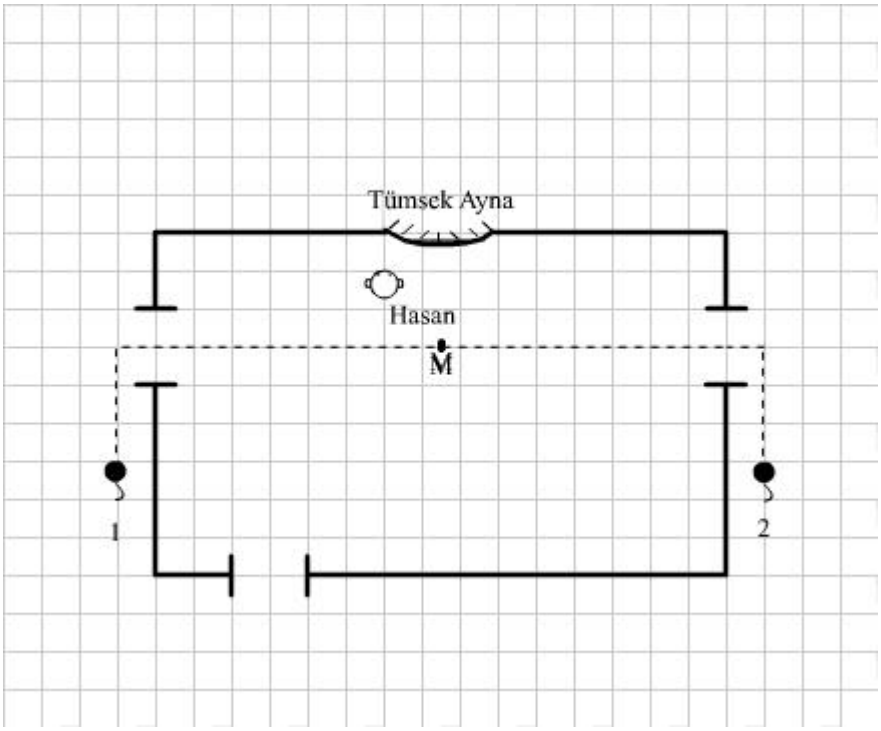
Hasan çukur aynanın ön cephe sınırı içinde çukur aynaya bakmakta iken odanın sağ ve sol kapılarından 1 ve 2 numaralı kediler aynı anda içeri girip oda boyunca kesikli çizgi ile gösterilen yolda eşit süratle ilerlemektedirler. Buna göre;

A. Numaralandırılmış kedilerin hangilerinin çukur aynada görüntüsü oluşur? Nerede oluşur? Neden?

B. Hasan ilk olarak hangi kedinin görüntüsünü çukur aynada görür? Görüntü nerededir? Bu durumda görülen kedi nerededir? Nedenlerini açıklayınız.

C. Kedilerin her biri hareket ederken görüntülerinin boyu, yeri değişir mi? Neden?

18)



Hasan tümsek aynanın ön cephe sınırı içinde tümsek aynaya bakmakta iken odanın sağ ve sol kapılarından 1 ve 2 numaralı kediler içeri girip oda boyunca kesikli çizgi ile gösterilen yolda eşit süratle ilerlemektedirler. Buna göre;

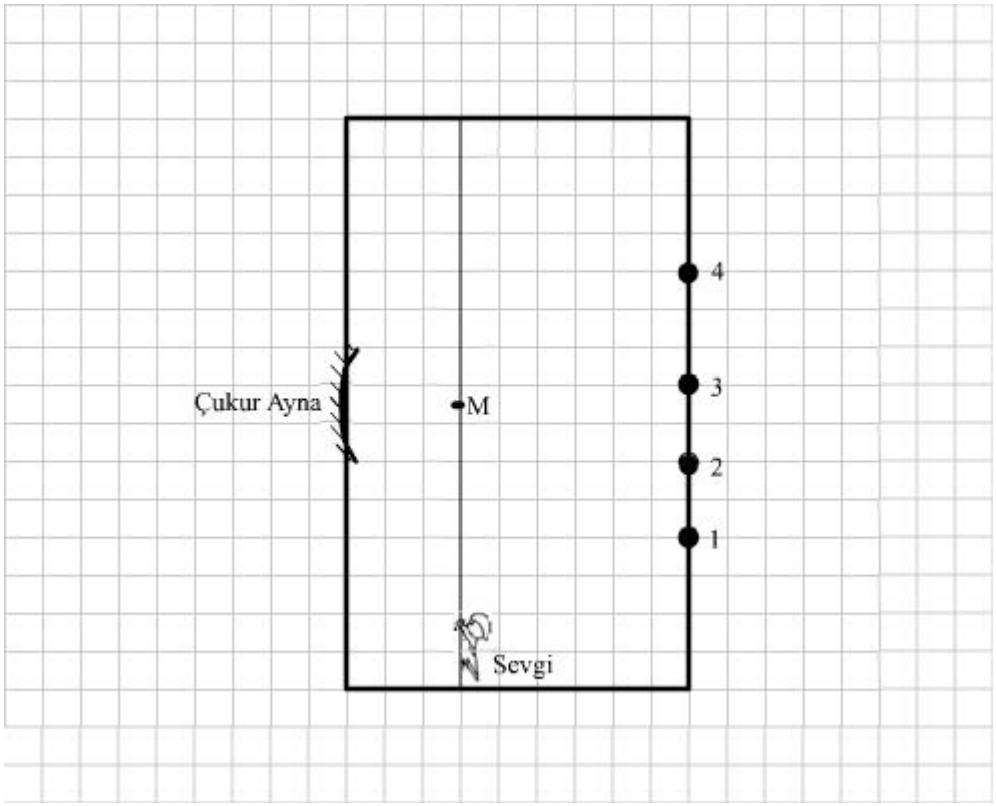
A. Numaralandırılmış kedilerin hangilerinin tümsek aynada görüntüsü oluşur? Nerede oluşur? Neden?

B. Hasan ilk olarak hangi kedinin görüntüsünü tümsek aynada görür? Görüntü nerededir? Bu durumda görülen kedi nerededir? Nedenlerini açıklayınız.

C. Kedilerin her biri hareket ederken görüntülerinin boyu, yeri değişir mi? Neden?

19-20 numaralı sorudaki şekilde bir ışık kaynağı ile homojen bir şekilde aydınlatılmış bir odanın yandan görünüşü verilmiştir. İp ve 1-4 ile numaralandırılmış, lambalar küresel ayna ve duvarın ortası hizasındadır. Sevgi'nin tırmandığı ipin aynaya olan uzaklığı aynanın merkez uzaklığı kadardır ve M ile gösterilmiştir.

19)



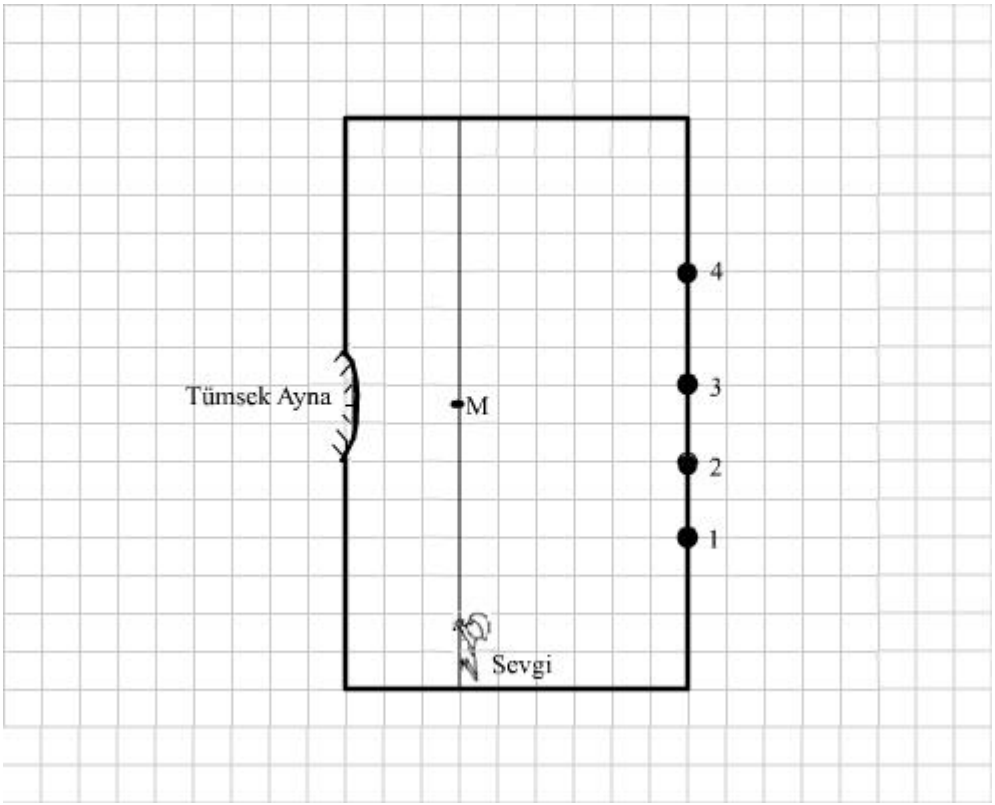
Sevgi tavanda asılı ip ile yukarı tırmanırken kendisinin ve arkasındaki duvara yerleştirilmiş 1-4 ile numaralandırılmış lambaların görüntüsünü çukur aynadan gözlemlemeye çalışmaktadır. Buna göre;

A. Numaralandırılmış lambaların hangilerinin çukur aynada görüntüsü oluşur? Nerede oluşur? Neden?

B. Sevgi tırmanırken ilk olarak hangi lambanın görüntüsünü çukur aynada görür? Görüntü nerededir? Bu durumda Sevgi nerededir?

C. Sevgi kendisinin görüntüsünü çukur aynada ilk olarak nerede iken görür? Şekil üzerinde Sevgi'nin ve görüntüsünün yerlerini işaretleyiniz. Nedenlerini açıklayınız.

20)



Sevgi tavanda asılı ip ile yukarı tırmanırken kendisinin ve arkasındaki duvara yerleştirilmiş 1-4 ile numaralandırılmış lambaların görüntüsünü tümsek aynadan gözlemlemeye çalışmaktadır. Buna göre;

A. Numaralandırılmış lambaların hangilerinin tümsek aynada görüntüsü oluşur? Nerede oluşur? Neden?

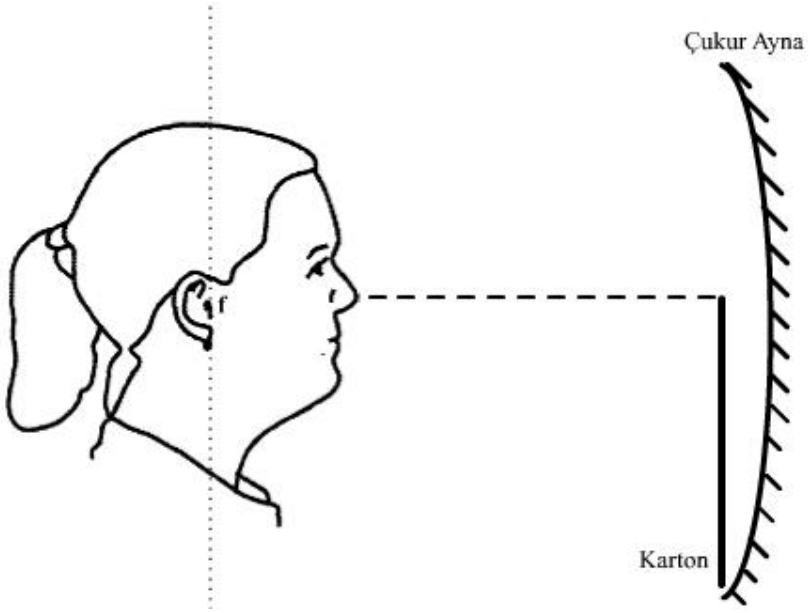
B. Sevgi tırmanırken ilk olarak hangi lambanın görüntüsünü tümsek aynada görür? Görüntü nerededir? Bu durumda Sevgi nerededir?

C. Sevgi kendisinin görüntüsünü tümsek aynada ilk olarak nerede iken görür? Şekil üzerinde Sevgi'nin ve görüntüsünün yerlerini işaretleyiniz. Nedenlerini açıklayınız.

21-22 numaralı sorulardaki şekillerde ayna ve öğrencinin yandan görünüşü verilmiştir. Aynaya bakan öğrencinin yüzü ayna ile odak uzaklığı arasındadır ve aynanın odak uzaklığı f ile gösterilmiştir.

21)

Duvara monte edilmiş çukur aynaya şekildeki gibi bakan öğrencinin bir arkadaşı çukur aynanın alt yarısını öğrencinin burun hizasına kadar bir kartla şekilde gösterildiği gibi kapatırsa;

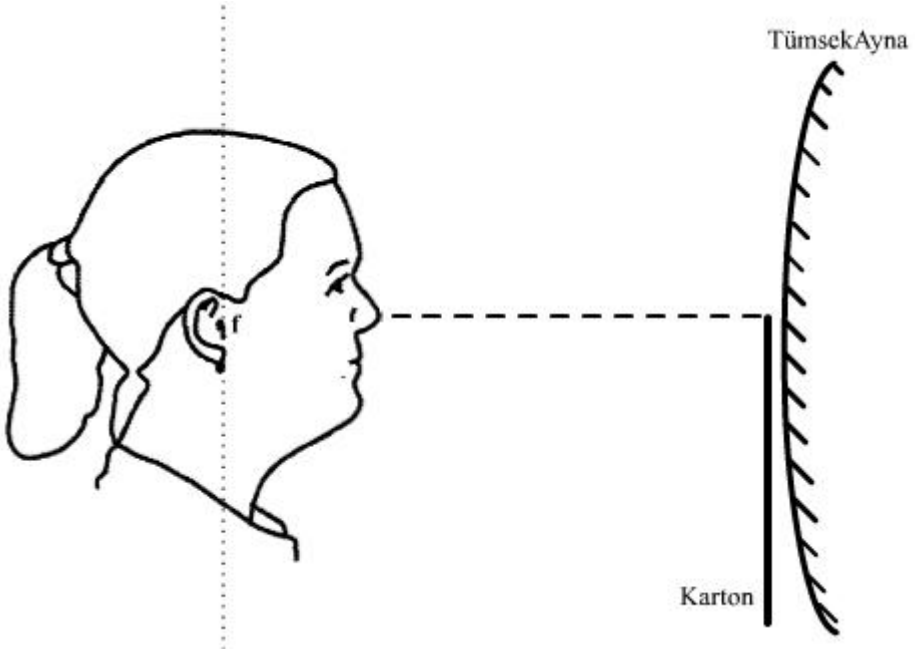


A. Öğrenci yüzünün hangi kısımlarını aynada görebilir? Neden?

B. Öğrenci aynada yüzünün daha fazlasını görebilmek için ne(ler) yapabilir?

22)

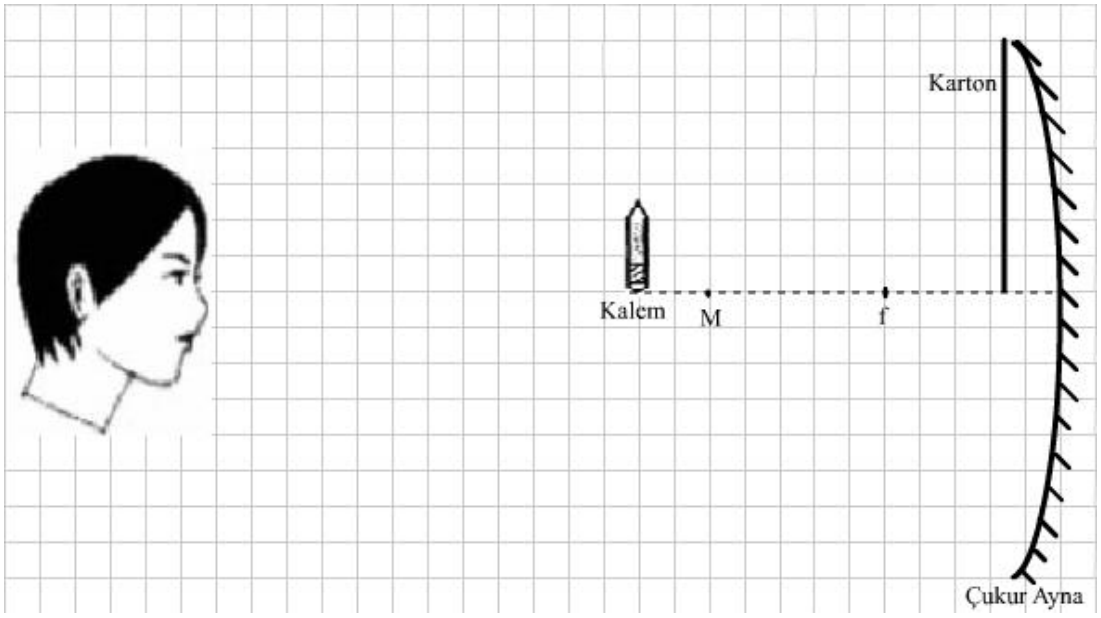
Duvara monte edilmiş tümsek aynaya şekildeki gibi bakan öğrencinin bir arkadaşı çukur aynanın alt yarısını öğrencinin burun hizasına kadar bir kartla şekilde gösterildiği gibi kapatırsa;



A. Öğrenci yüzünün hangi kısımlarını aynada görebilir? Neden?

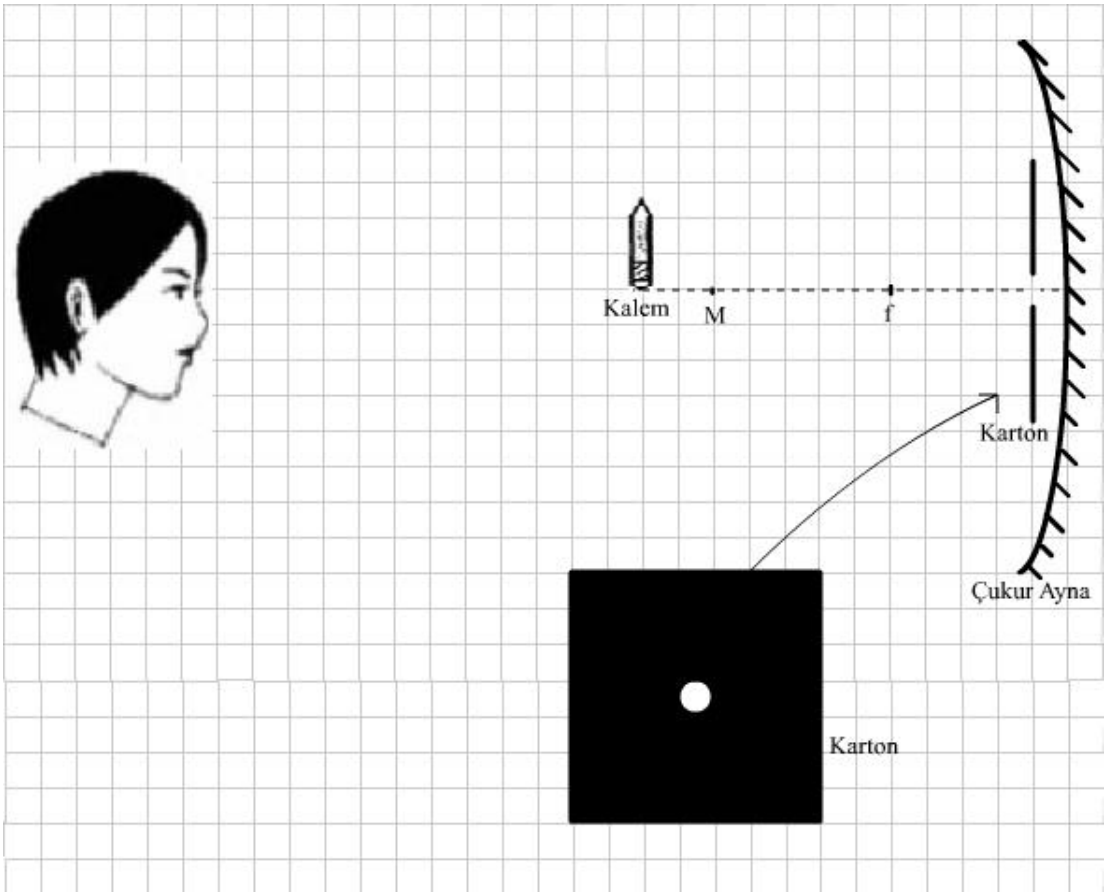
B. Öğrenci aynada yüzünün daha fazlasını görebilmek için ne(ler) yapabilir?

23)
Aşağıdaki şekillerde gözlemci, kalem, çukur ayna ve kartonun yandan görünüşü verilmiştir. M çukur aynanın merkezini, f ise aynanın odağını göstermektedir.



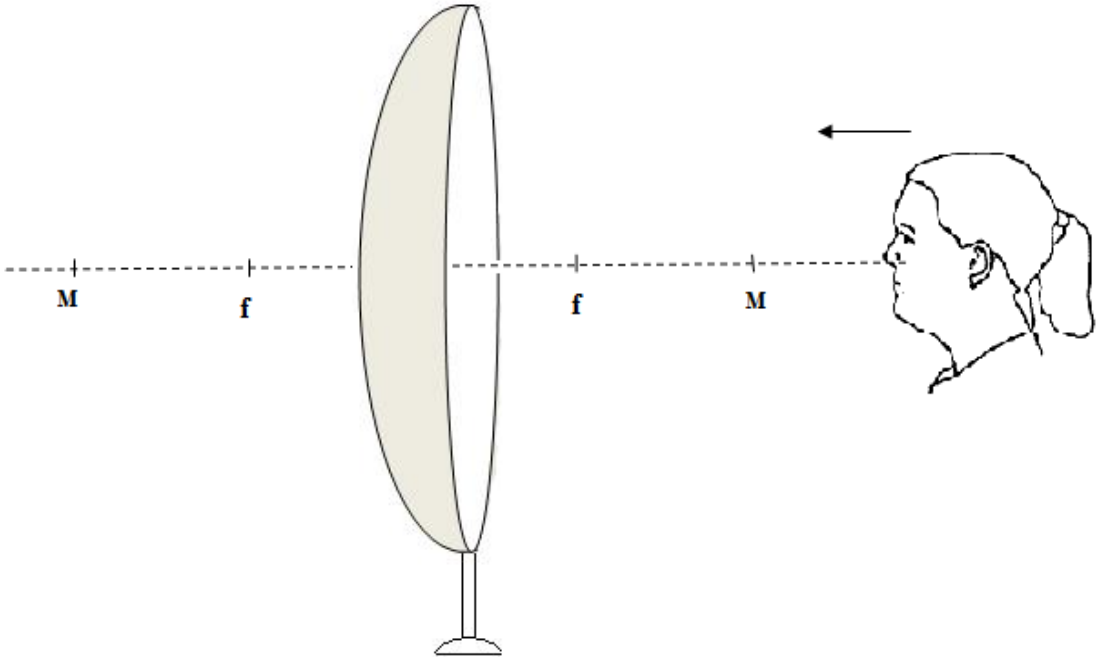
A. Çukur aynanın merkez uzaklığından öteye yerleştirilen bir kalemin görüntüsü şekildeki gözlemci tarafından gözlemlenmeye çalışılmaktadır. Çukur aynanın üst yarısı bir kartonla tamamen kapatılırsa kalemin görüntüsünde bir değişiklik olur mu? Olursa nasıl? Olmazsa neden? Nedenleriyle açıklayınız.

B. Çukur aynanın ön yüzüne tam ortasında 5 cm çapında daire şeklinde açıklık olan bir karton şekildeki gibi yerleştirildiğinde kalemin görüntüsünde bir değişiklik olur mu? Olursa nasıl? Olmazsa neden? Nedenleriyle açıklayınız.



24 ve 25 numaralı sorulardaki şekillerde gözlemci ve küresel aynanın yandan görünüşü verilmiştir. M küresel aynanın merkez, f ise odak uzaklığını göstermektedir.

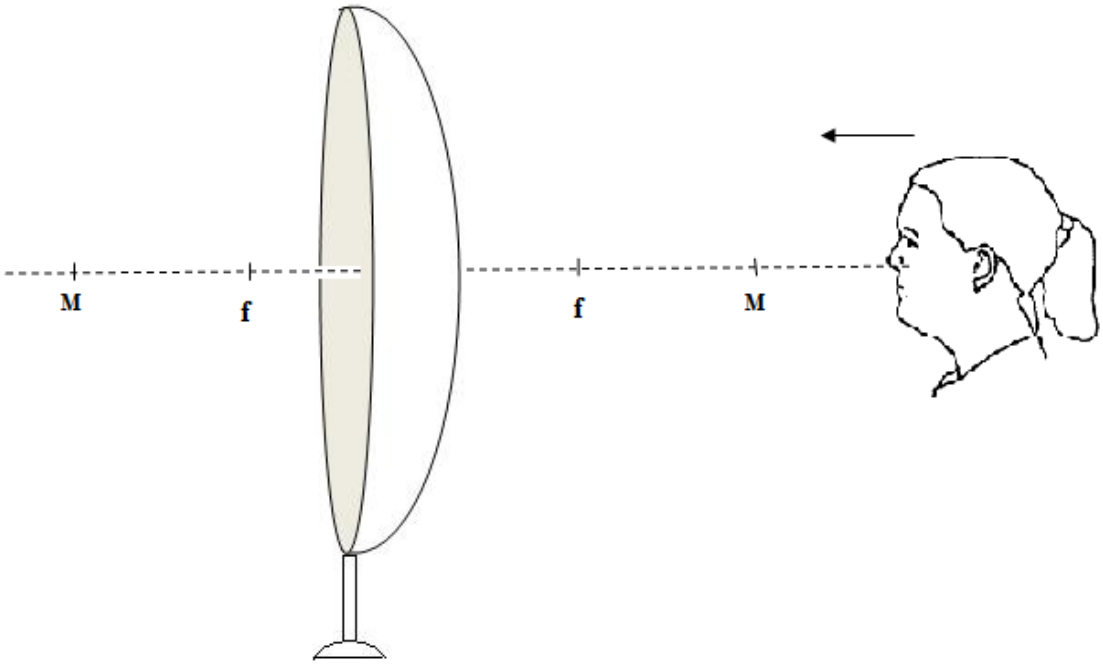
24)



A. Selin şekilde gösterilen mesafeden çukur aynaya bakarak aynada başının görüntüsünü görmek istemektedir. Selin'in çukur aynada kendi görüntüsünü bu konumdan görebilmesi mümkün mü? Görürse görüntünün yeri ve özelliklerini yazınız.

B. Selin ok işareti yönünde hareket ederek çukur aynaya yaklaşırken başının hangi pozisyonunda/pozisyonlarında kendi görüntüsünü görebilir? Bu durumda görüntünün yeri ve özelliklerini yazınız.

25)

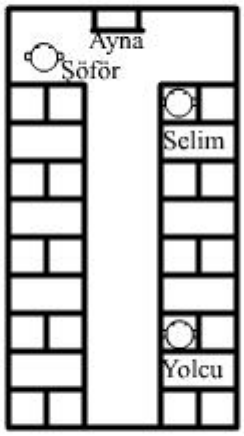


A. Selin şekilde gösterilen mesafeden tümsek aynaya bakarak aynada başının görüntüsünü görmek istemektedir. Selin'in tümsek aynada kendi görüntüsünü bu konumdan görebilmesi mümkün mü? Görürse görüntünün yeri ve özelliklerini yazınız.

B. Selin ok işareti yönünde hareket ederek tümsek aynaya yaklaşırken başının hangi pozisyonunda/pozisyonlarında kendi görüntüsünü görebilir? Bu durumda görüntünün yeri ve özelliklerini yazınız.

26)

A. Aşağıdaki şekilde bir otobüsün <u>üstten görünüşü</u> verilmiştir. Şekilde gösterildiği gibi otobüsün sağ ön koltuğunda oturan Selim şoförün dikiz aynasına bakmaktadır. Selim otobüse yeni binen bir yolcunun koridorda ilerleyerek arka sıralarda kendisiyle aynı hizada boş bir koltuğa oturduğunu dikiz aynasından görebilmektedir. Buna göre, otobüste kullanılan bu dikiz ayna hangi tür ayna olabilir? Nedenleriyle açıklayınız.



B. Selim bulunduğu konumdan kendi görüntüsünü bu dikiz aynada görebilir mi? Nedenleriyle açıklayınız.

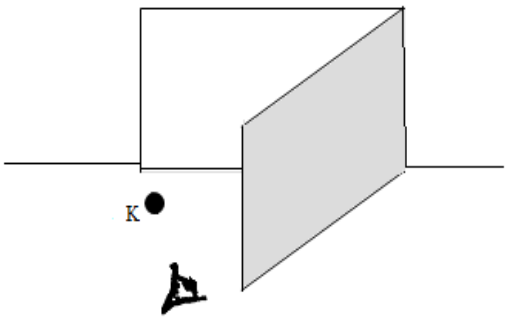
GÖRÜŞME FORMU #4

KESİŞEN AYNALAR

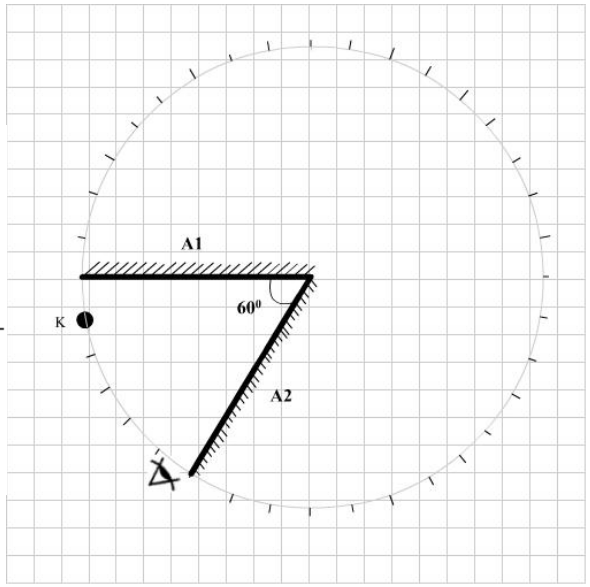
27-29numaralı sorulardaki şekillerde aralarında belli bir açı ile kesişen düzlem aynaların yandan ve üstten görünüşleri verilmiştir. Ayrıca konumları şekil üzerinde belirtilen gözlemcilerin bulunduğu yerden başını çevirerek görüntüleri gözlemlediği düşünülmelidir.

27)

A. Aralarındaki açı 60^0 olacak şekilde yerleştirilen iki düzlem ayna arasına konulan K cisminin görüntüsü şekildeki konumdan bakan bir gözlemci tarafından gözlemlenmektedir. Bu gözlemci K cisminin kaç görüntüsünü görür? Bu görüntü ya da görüntülerin yer(ler)ini şekil üzerinde belirtiniz. Nedenleriyle açıklayınız.

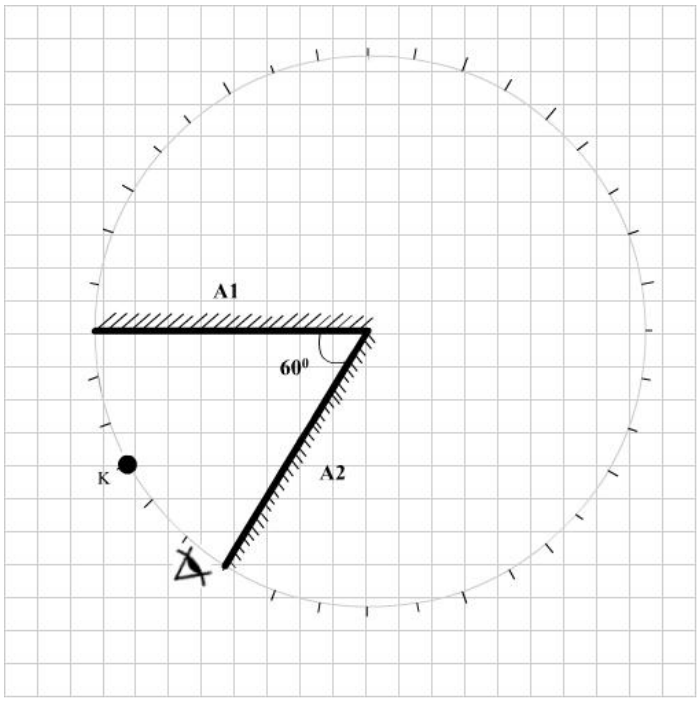


Yandan Görünüş

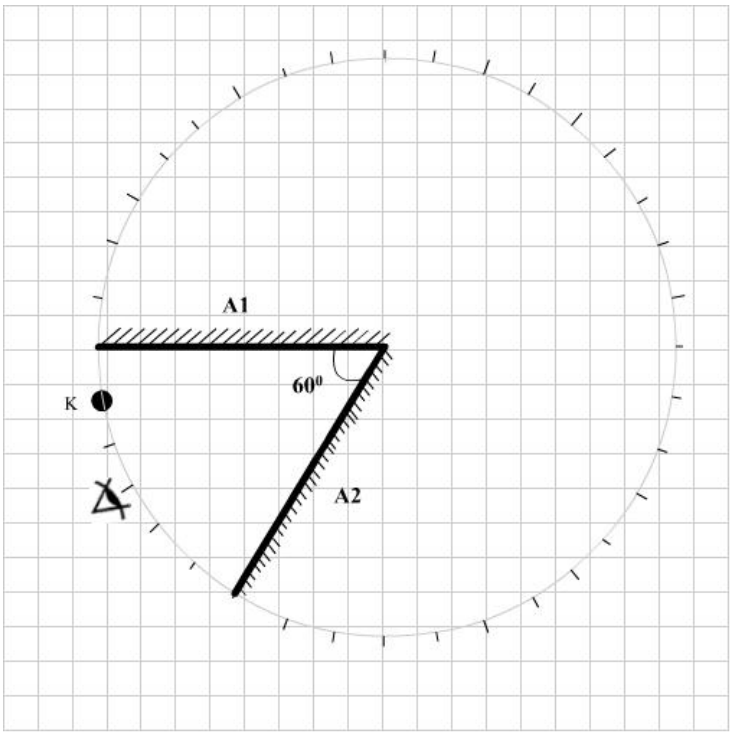


Üstten Görünüş

B. K cisimi gözlemciye şekildeki gibi yaklaştırılıp aynaların kesişim doğrultusuna getirilirse gözlemcinin bulunduğu yerden görebileceği K cisminin görüntü sayısı, görüntünün büyüklüğü ve yerinde bir önceki duruma göre bir değişiklik olur mu? Neden?

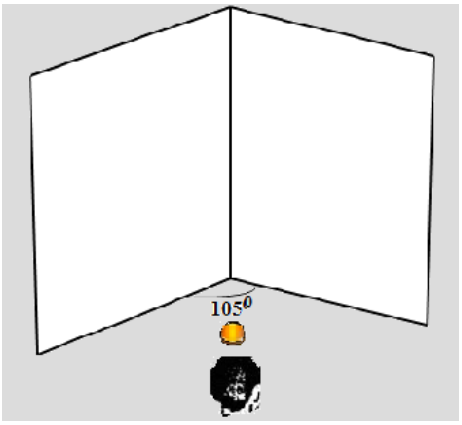


C. Gözlemci cisme doğru şekildeki gibi yaklaşıp aynaların kesişim doğrultusuna gelirse gözlemcinin bu yeni konumundan görebileceği cismin görüntü sayısı, görüntünün büyüklüğü ve yerinde ilk duruma göre bir değişiklik olur mu? Neden?

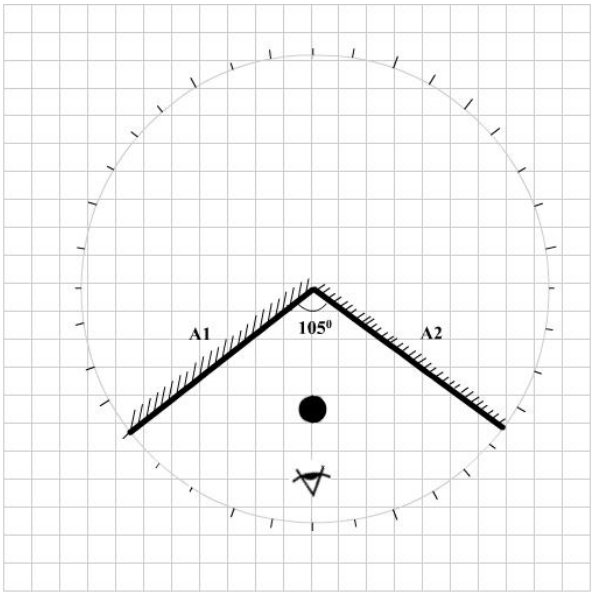


28)

A. Aralarında 105^0 açı olacak şekilde yerleştirilen kesişen iki düzlem ayna arasına aynaların kesişim doğrusu üzerinde olacak şekilde bir madeni para koyuluyor. Şekilde gösterildiği gibi kesişim doğrusu üzerinden bakan bir gözlemci cismin kaç görüntüsünü görebilir? Görebildiği görüntü ya da görüntülerin yerini şekil üzerinde belirtiniz? Nedenleriyle açıklayınız.

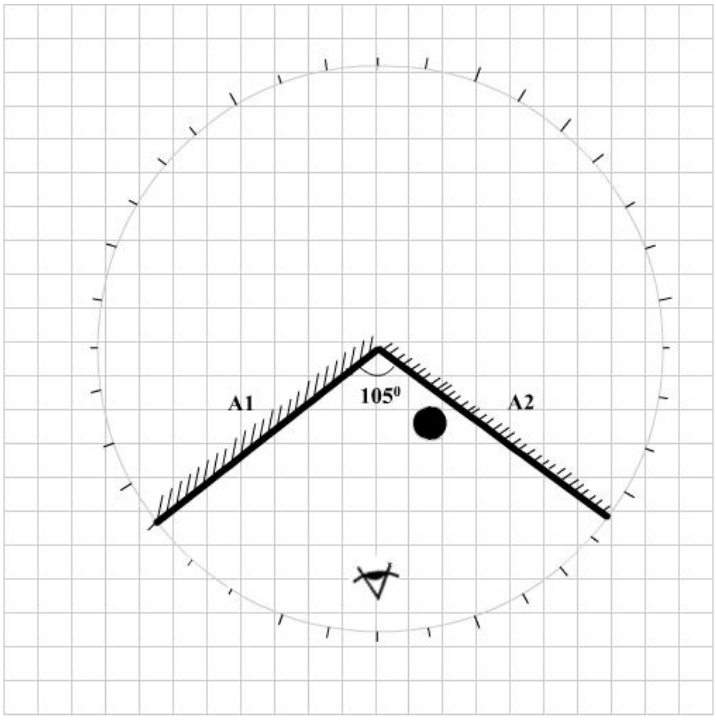


Yandan Görünüş

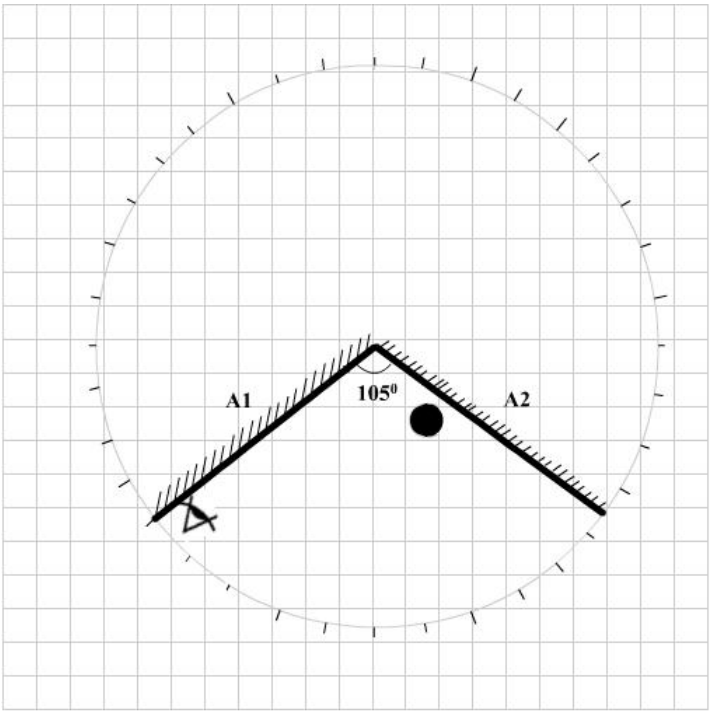


Üstten Görünüş

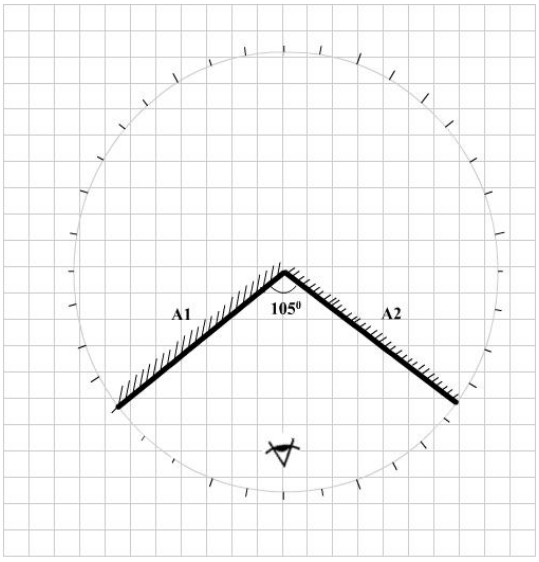
B. Madeni para şekildeki gibi aynaya yaklaştırılırsa gözlemci bulunduğu yerden cismin kaç görüntüsünü görebilir?



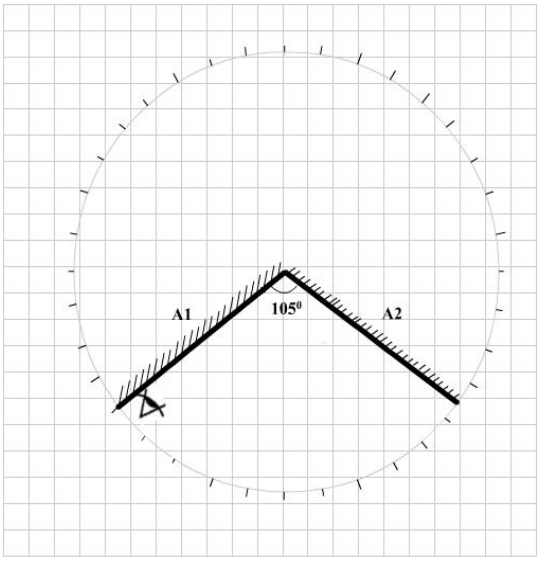
C. Gözlemci şekildeki gibi aynaya yaklaşırsa cismin kaç görüntüsünü görebilir?



D. Gözlemci Şekil 1 ve Şekil 2'deki konumlarda iken kendisinin kaç görüntüsünü görebilir? Ayrı ayrı nedenleriyle açıklayarak anlatınız.

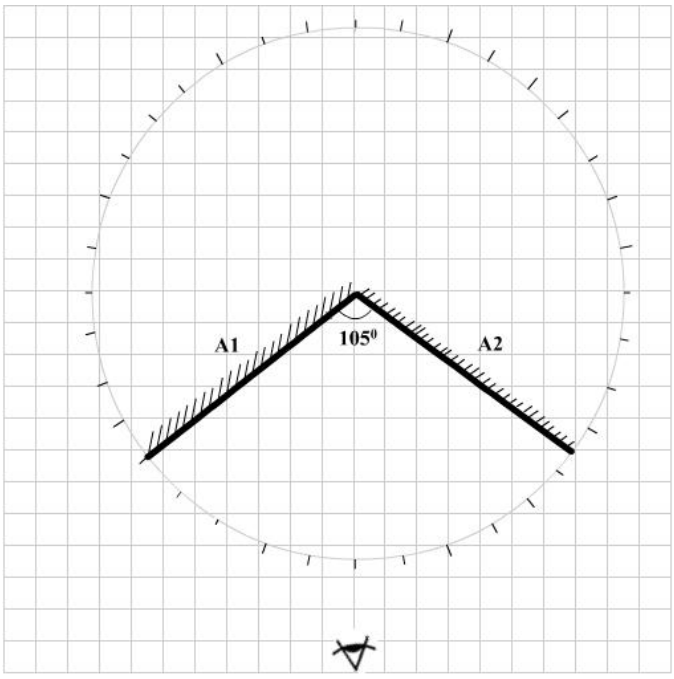


Şekil 1



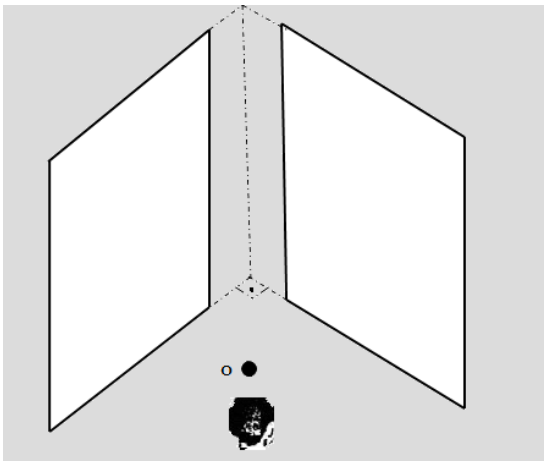
Şekil 2

E. Gözlemci aynadan uzaklaşırsa kaç görüntüsünü görebilir?

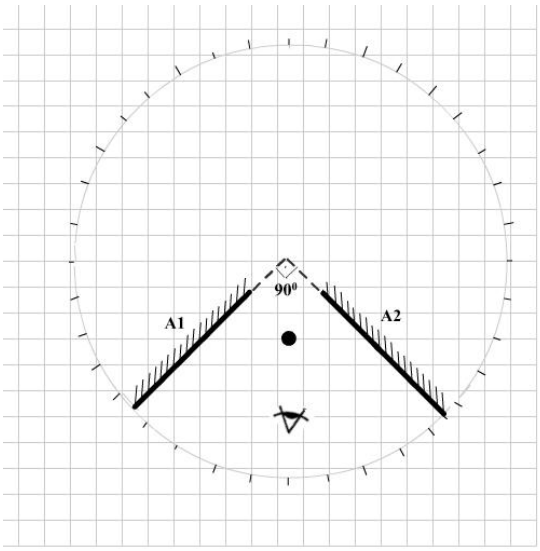


29)

A. Bir alışveriş mağazasının birbirine dik duvarlarına iki düzlem ayna aralarında 90^0 açı ile ve biraz mesafe bırakılarak şekildeki gibi monte edilmiştir. Buna göre şekildeki gözlemci yerdeki topun kaç görüntüsünü görebilir? Görebildiği görüntü ya da görüntülerin yerini şekil üzerinde belirtiniz. Nedenleriyle açıklayınız.

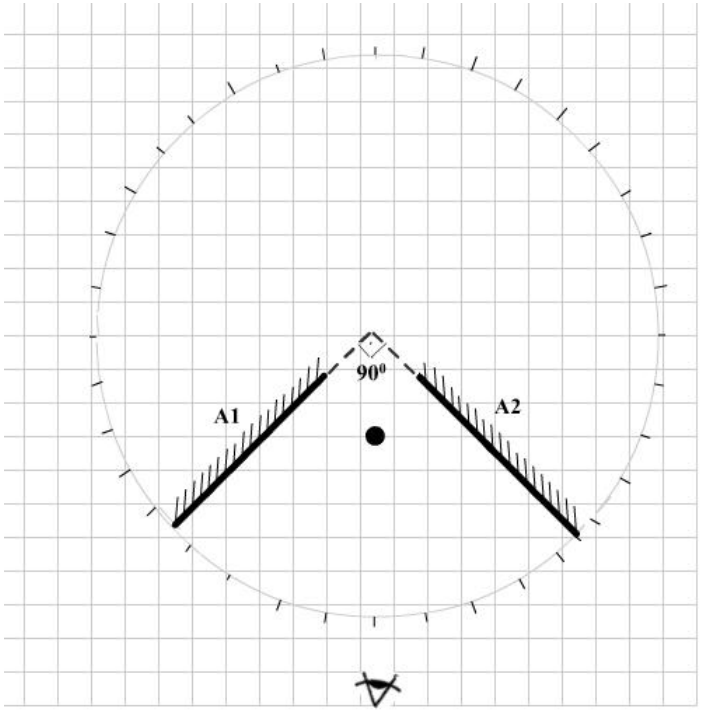


Yandan Görünüş

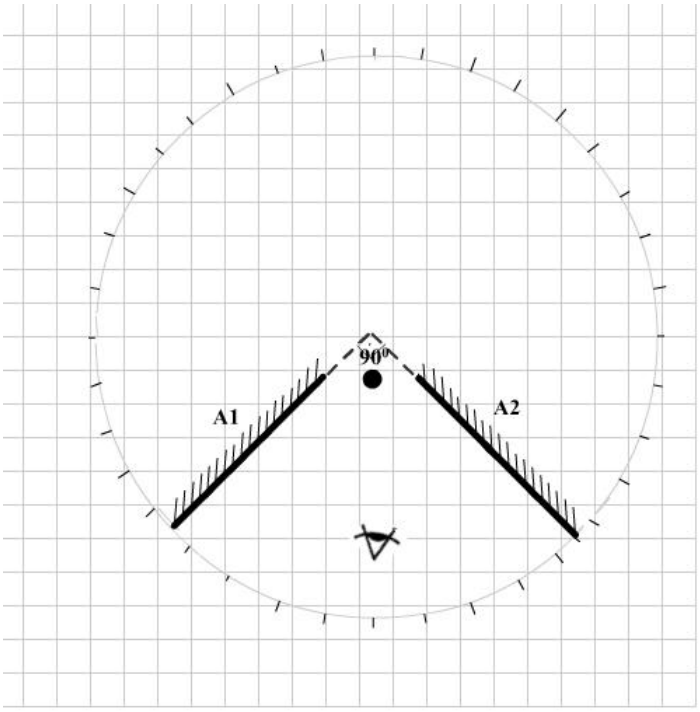


Üstten Görünüş

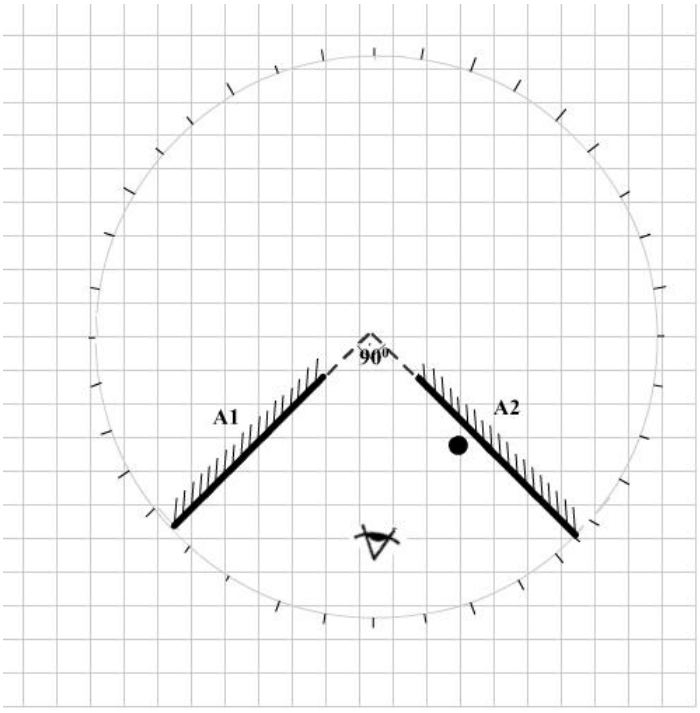
B. Cismin ve aynaların yerleri sabit kalırken gözlemci aynalardan uzaklaşacak şekilde geriye doğru gittiği takdirde gözlemleyebildiği görüntü sayısında, görüntünün yerinde ve büyüklüğünde bir değişiklik olur mu? Neden?



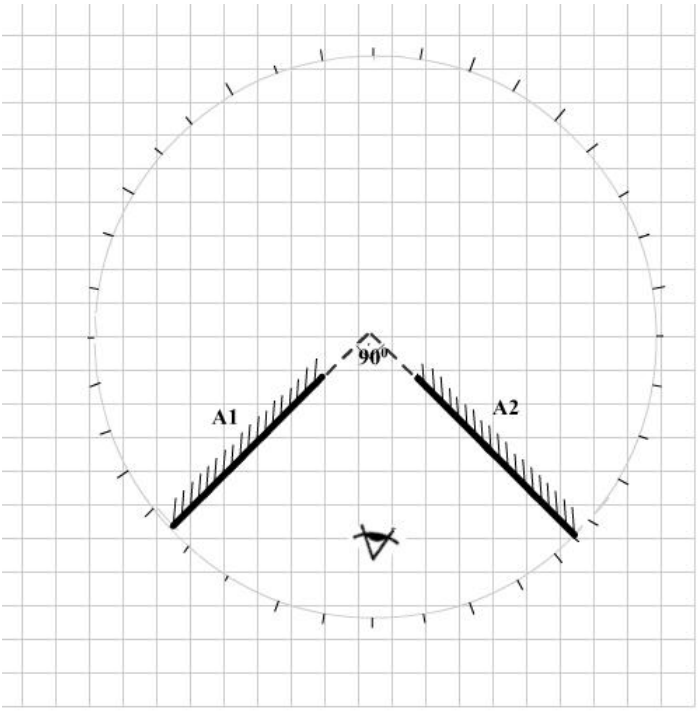
C. Cisim gözlemciden uzaklaşacak şekilde aynaların kesişim eksenine doğru bir miktar hareket ettiği takdirde gözlemcinin gözlemleyebildiği görüntü sayısında, görüntünün yerinde ve büyüklüğünde bir değişiklik olur mu? Neden?



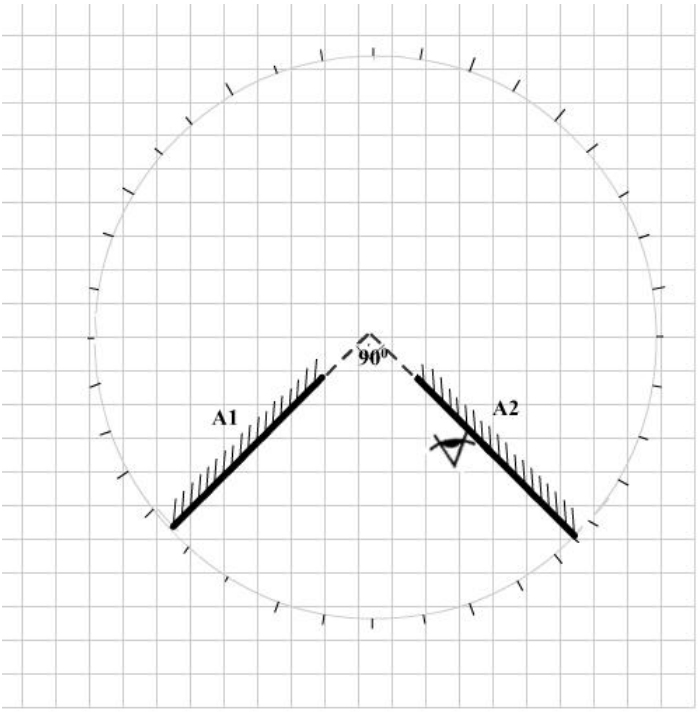
D. Cisim aynaya yaklaşacak şekilde bir miktar hareket ettiği takdirde gözlemcinin gözlemleyebildiği görüntü sayısında, görüntünün yerinde ve büyüklüğünde bir değişiklik olur mu? Neden?



E. Gözlemci şekildeki konumunda kendisinin kaç görüntüsünü görebilir? Görebildiği görüntü ya da görüntülerin yerini şekil üzerinde belirtiniz? Nedenleriyle açıklayınız.



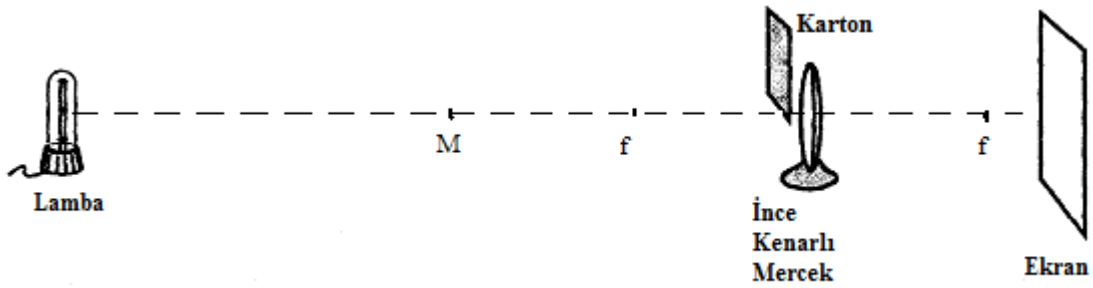
F. Gözlemci şekildeki gibi aynaya yaklaşırsa gözlemleyebildiği kendi görüntüsünün sayısında, görüntünün yerinde ve büyüklüğünde nasıl bir değişiklik olur? Neden?



GÖRÜŞME FORMU #5

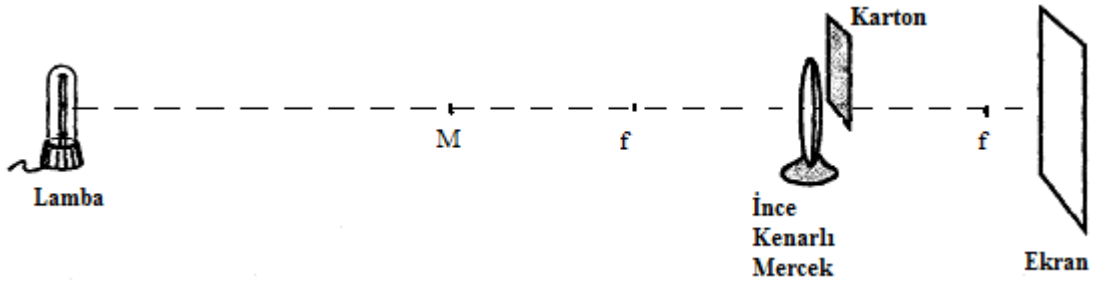
MERCEKLER

30)



A. Şekilde gösterildiği gibi bir lamba ince kenarlı merceğin merkez uzaklığından öteye yerleştirilmiştir. f ince kenarlı merceğin odak uzaklığını, M ise merkez uzaklığını göstermektedir. Merceğin üst yarısı ışığı geçirmeyen bir karton ile şekildeki gibi kapatılırsa ekranda görülen lambanın görüntüsünde nasıl bir değişiklik olur? Nedenleriyle açıklayınız.

B.

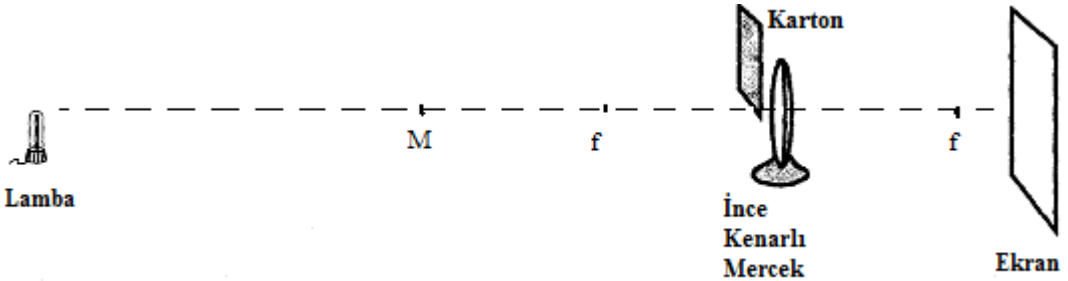


Karton merceğin diğer yüzüne şekildeki gibi kapatılırsa ekranda görülen lambanın görüntüsünde nasıl bir değişiklik olur? Nedenleriyle açıklayınız.

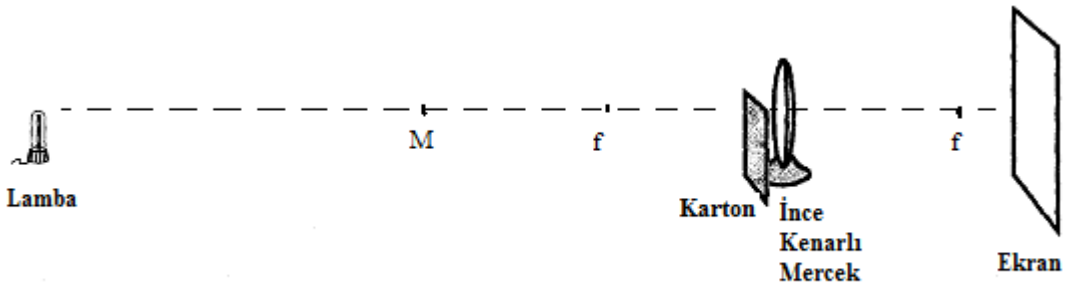
C.

Lamba boyu merceğin boyunun yarısı kadar olan başka bir lamba ile değiştirildiğinde;

i. Merceğin üst yarısı şekildeki gibi bir karton ile kapatılırsa ekranda görülen lambanın görüntüsünde nasıl bir değişiklik olur? Nedenleriyle açıklayınız.

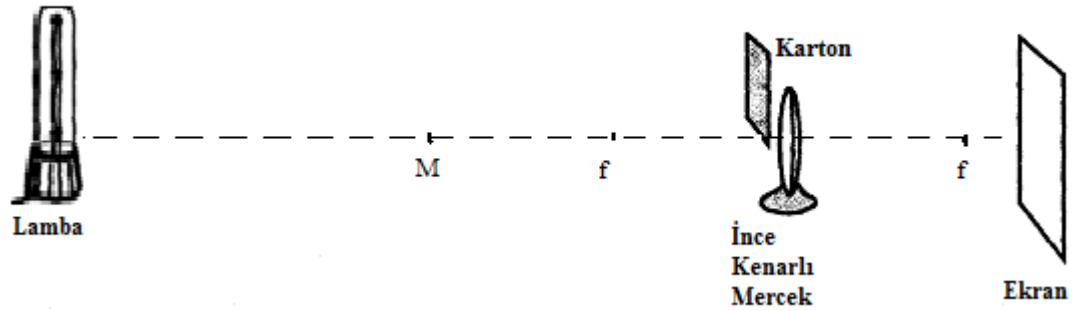


ii. Merceğin alt yarısı şekildeki gibi bir karton ile kapatılırsa ekranda görülen lambanın görüntüsünde nasıl bir değişiklik olur? Nedenleriyle açıklayınız.

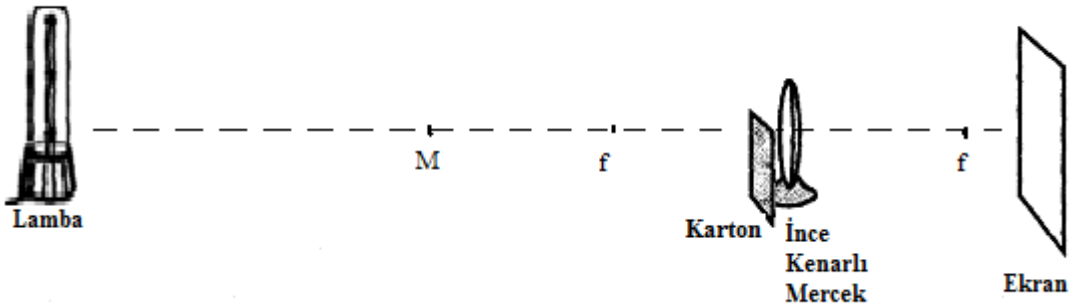


D. Lamba boyu merceğin boyunun iki katı kadar olan başka bir lamba ile değiştirildiğinde;

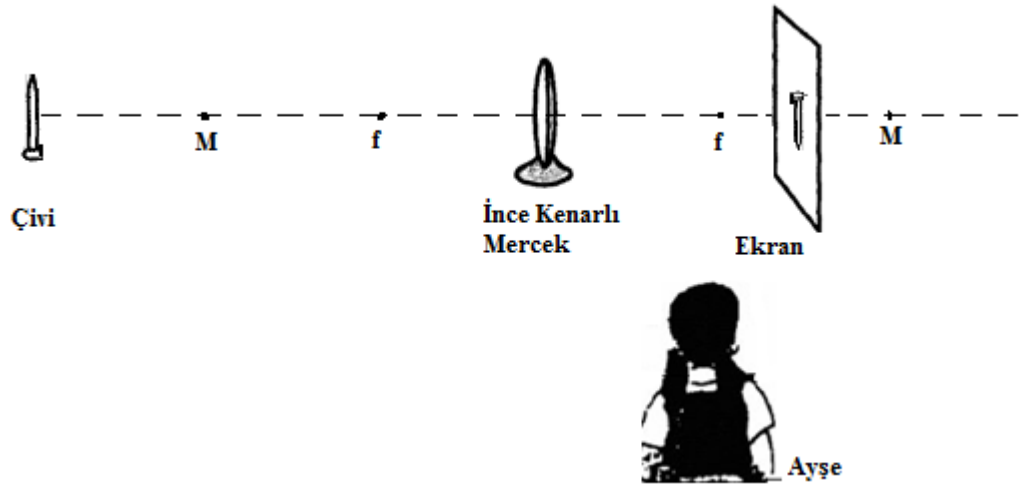
i. Merceğin üst yarısı şekildeki gibi bir karton ile kapatılırsa ekranda görülen lambanın görüntüsünde nasıl bir değişiklik olur? Nedenleriyle açıklayınız.



ii. Merceğin alt yarısı şekildeki gibi bir karton ile kapatılırsa ekranda görülen lambanın görüntüsünde nasıl bir değişiklik olur? Nedenleriyle açıklayınız.

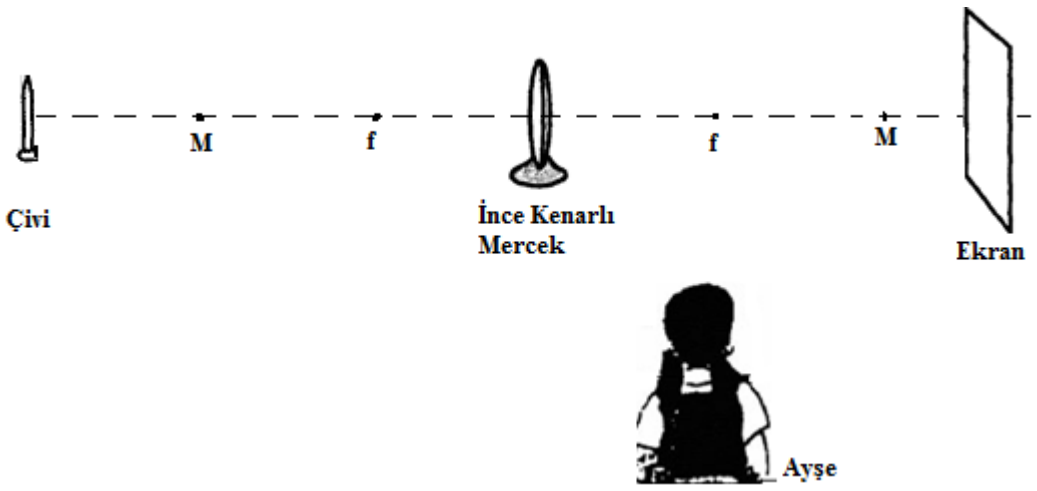


31)



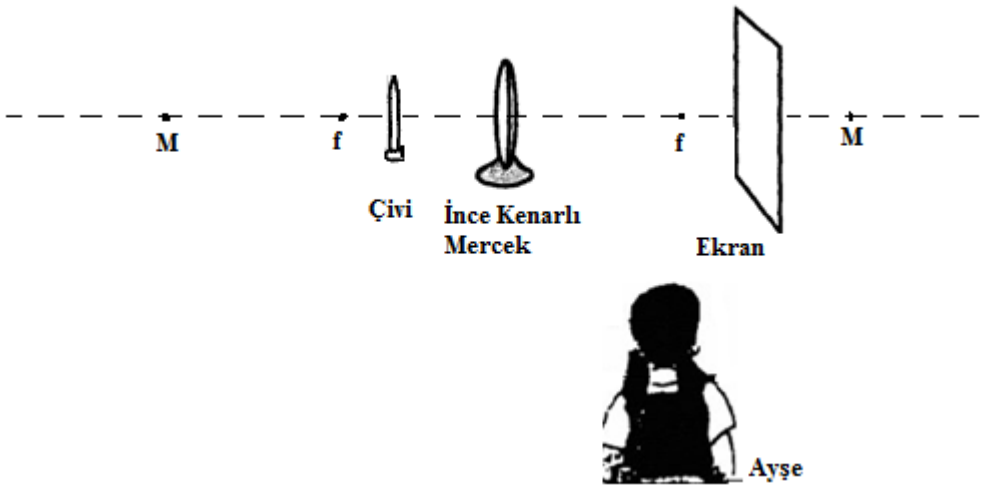
Ayşe ince kenarlı mercek önüne yerleştirilen bir çivinin net görüntüsünü şekildeki gibi merceğin diğer tarafında, küçük ve ters olarak ekran üzerine gözlemlemektedir. f ince kenarlı merceğin odak uzaklığını, M ise merkez uzaklığını göstermektedir. Buna göre;

A.



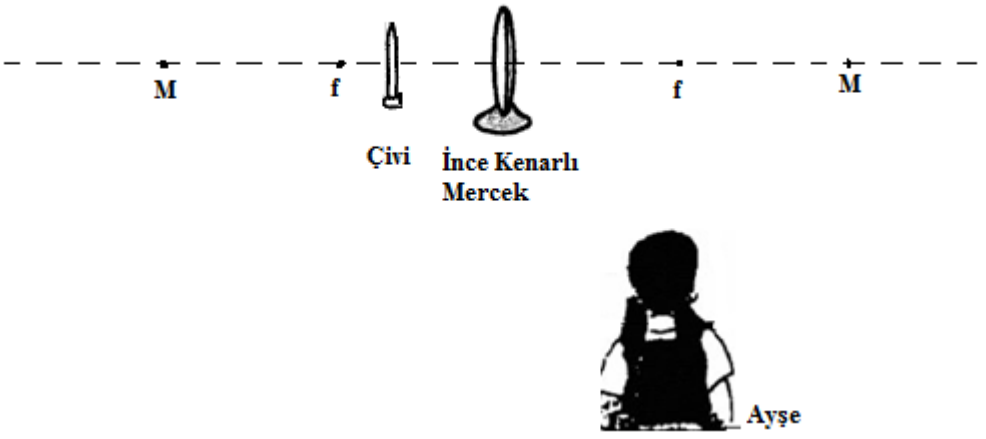
Diğer nesnelerin yerleri sabit kalmak koşuluyla ekran mercekten uzaklaşacak şekilde geriye doğru çekilirse çivinin ekran üzerindeki görüntüsünde nasıl bir değişiklik olur? Nedenleriyle açıklayınız.

B.



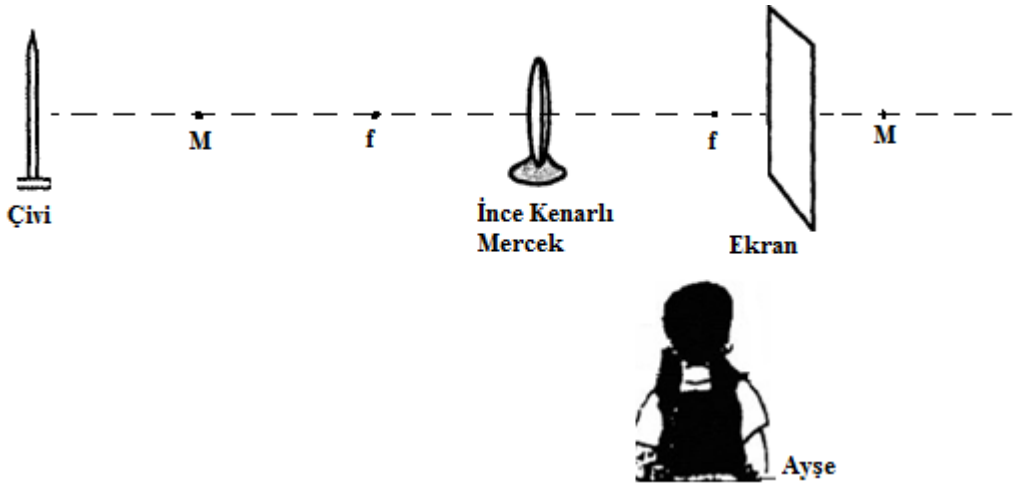
Diğer nesnelerin yerleri sabit kalmak koşuluyla çivi merceğe yaklaştırılırsa çivinin ekran üzerindeki görüntüsünde nasıl bir değişiklik olur ? Nedenleriyle açıklayınız.

C.



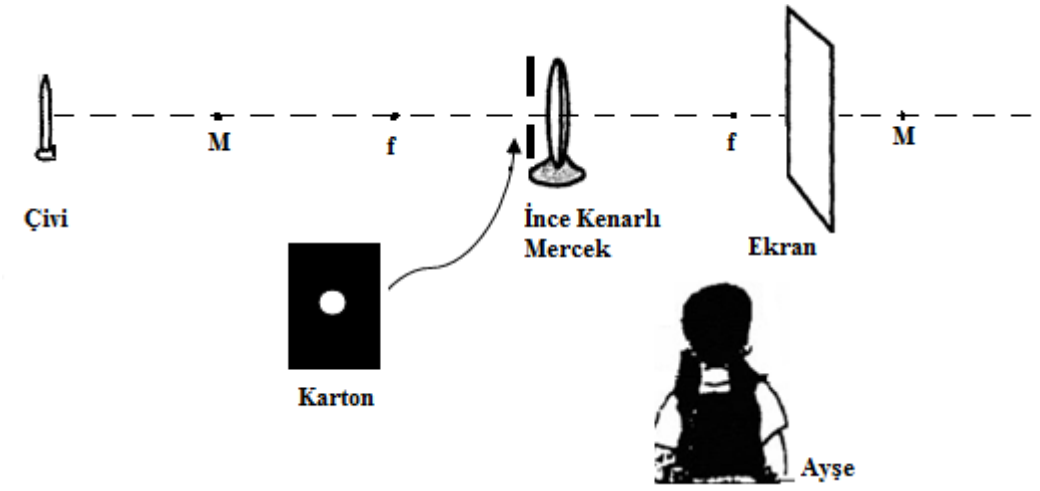
Ekran tamamen kaldırılırsa çivinin görüntüsü oluşur mu? Oluşursa nerede oluşur? Ayşe bulunduğu konumdan çivinin görüntüsünü görebilir mi? Nedenleriyle açıklayınız. Göremez ise görebileceği yeni bir konum önerebilir misiniz?

D.



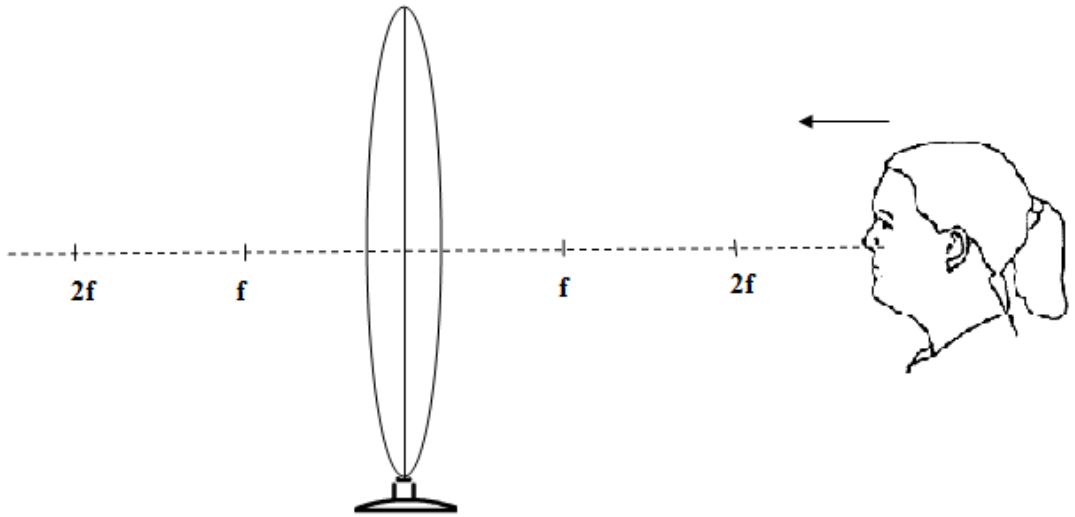
Boyu merceğin boyundan büyük başka bir çivi merceğin karşısına yerleştirilirse Ayşe'nin ekranda gözlemlediği görüntü nasıl değişir? Nedenleriyle açıklayınız.

E.



Merceğin ön yüzüne tam ortasında daire şeklinde açıklık olan bir karton şekildeki gibi yerleştirildiğinde çivinin ekran üzerindeki görüntüsünde nasıl bir değişiklik olur? Nedenleriyle açıklayınız.

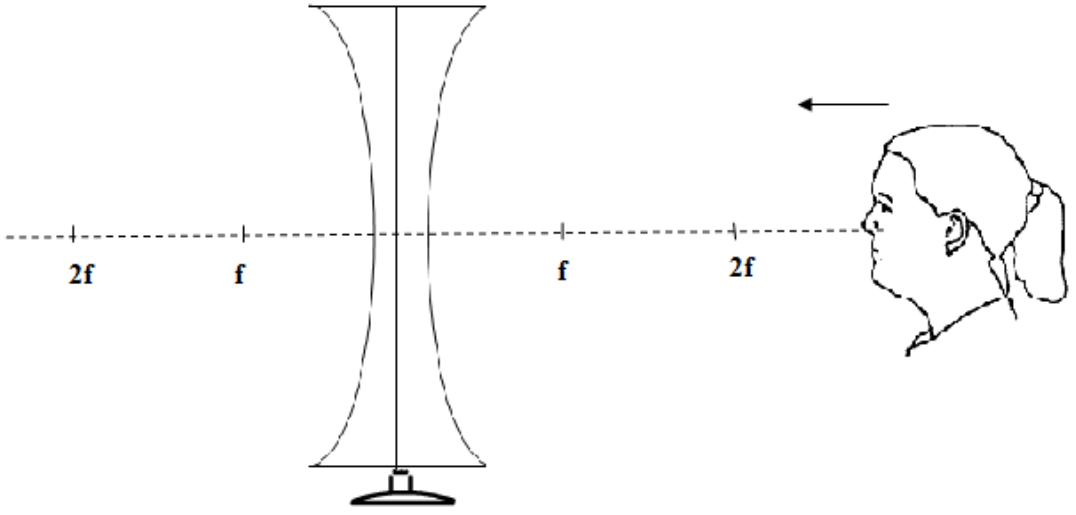
32)



A. Selin şekilde gösterilen mesafeden ince kenarlı bir merceğe bakarak mercekte başının görüntüsünü görmek istemektedir. Selin'in mercekte kendi görüntüsünü bu konumdan görebilmesi mümkün mü? Görürse görüntünün yeri ve özelliklerini yazınız.

B. Selin ok işareti yönünde hareket ederek merceğe yaklaşırken başının hangi pozisyonunda/pozisyonlarında mercekte kendi görüntüsünü görebilir? Bu durumda görüntünün yeri ve özelliklerini yazınız.

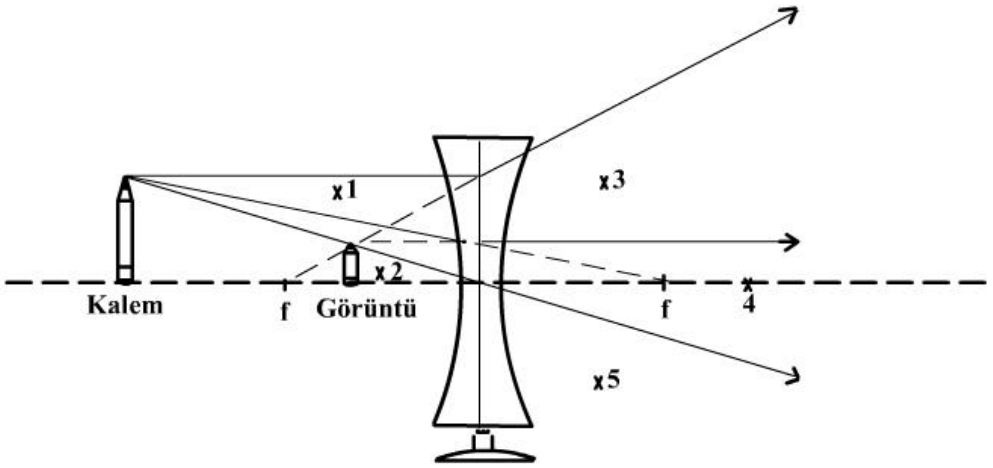
33)



A. Selin şekilde gösterilen mesafeden kalın kenarlı bir merceğe bakarak mercekte başının görüntüsünü görmek istemektedir. Selin'in mercekte kendi görüntüsünü bu konumdan görebilmesi mümkün mü? Görürse görüntünün yeri ve özelliklerini yazınız.

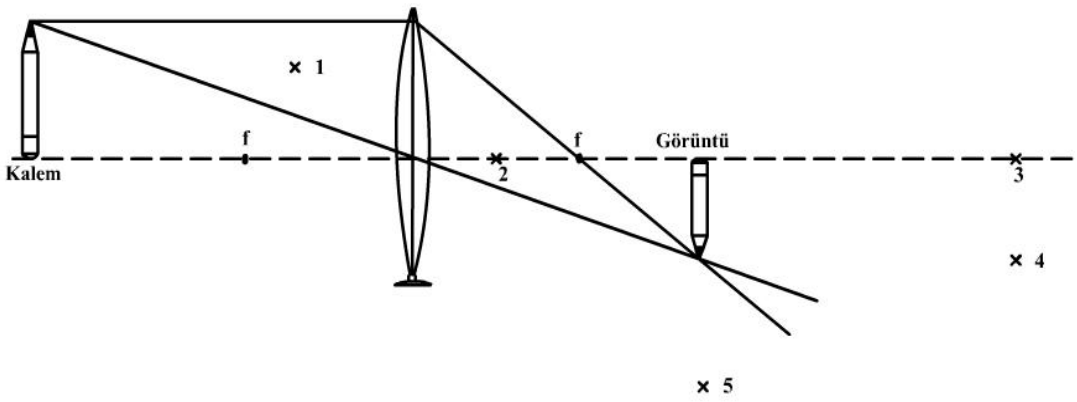
B. Selin ok işareti yönünde hareket ederek merceğe yaklaşırken başının hangi pozisyonunda/pozisyonlarında mercekte kendi görüntüsünü görebilir? Bu durumda görüntünün yeri ve özelliklerini yazınız.

34)



Şekildeki ışın diyagramında kalın kenarlı merceğin önüne yerleştirilmiş bir kalem ve bu kalemin görüntüsü verilmiştir. Kalemin ucundan çizilen üç ışının mercekten geçtikten sonra izlediği yollar şekilde çizilmiştir. Buna göre 1-5 numaraları ile numaralanmış beş noktadan hangisi ya da hangilerinden bakan gözlemciler kalemin görüntüsünün tamamını görebilir? Nedenleriyle açıklayınız.

35)



Şekildeki ışın diyagramında ince kenarlı merceğin önüne yerleştirilmiş bir kalem ve bu kalemin görüntüsü verilmiştir. Kalemin ucundan çizilen iki ışının mercekten geçtikten sonra izlediği yollar şekilde çizilmiştir. Buna göre 1-5 numaraları ile numaralanmış beş noktadan hangisi ya da hangilerinden bakan gözlemciler kalemin görüntüsünün tamamını görebilir? Nedenleriyle açıklayınız.

TABLE OF SPECIFICATION FOR THE INTERVIEW GUIDE

Table D.1 Table of Specification for the Interview Guide

CASE / CONTEXT		OBSERVING ONESELF	Subtotal	OBSERVING OTHERS	Subtotal	TOTAL
Plane Mirrors	**Plane Mirror**	1, 2, 3, 4, 5, 6, 7, 9, 10, 12, 13	11	1, 2, 3, 4, 5, 6, 7, 8, 11, 14	10	14
	Hinged Mirrors	28, 29	2	27, 28, 29	3	3
Spherical Mirrors	**Concave Mirror**	15, 19, 21, 24	4	15, 17, 19, 23	4	6
	Convex Mirror	16, 20, 22, 25	4	16, 18, 20, 26	4	6
Lenses	**Converging Lens**	32	1	30, 31, 35	3	4
	Diverging Lens	33	1	34	1	2
TOTAL		23		25		35

APPENDIX E

REFERENCES OF THE ITEMS IN THE INTERVIEW GUIDE

INTERVIEW #	ITEM #	REFERENCE
1	1-10	Original
	1	Revised from Croucher, Bertamini & Hecht, 2002
	2	Revised from Croucher, Bertamini & Hecht, 2002
	3	Revised from Croucher, Bertamini & Hecht, 2002
	4	Revised from Croucher, Bertamini & Hecht, 2002
	5	Revised from Croucher, Bertamini & Hecht, 2002
	6	Revised from Ronen & Eylon, 1993
2	7	Original
	8	Original
	9	Original
	10	Revised from Goldberg & McDermott, 1986
	11	Original
	12	Original
	13	Revised from McDermott, 1996
	14	Revised from Yurumezoglu & Oguz-Unver, 2010
	15	Original
	16	Original
	17	Original
	18	Original
	19	Original
3	20	Original
	21	Original
	22	Original
	23	Revised from Goldberg & McDermott, 1987
	24	Original
	25	Original
	26	Original
	27	Original
4	28	Original
	29	Original
	30	Revised from Goldberg & McDermott, 1987
	31	Revised from Goldberg & McDermott, 1987
5	32	Original
	33	Original
	34	Original
	35	Revised from McDermott &Shaffer, 2009

REFERENCES OF ITEMS (NOT INCLUDED IN THE REFERENCES SECTION)

McDermott, L. C. & Shaffer, P.S. (2009). *Tutorials in Introductory Physics*. Preliminary 2nd Ed. Custom Pub: USA.

Yurumezoglu, K. & Oguz-Unver, A. (2010). Experiments on the nature of how multiple images form in a plane mirror. *Lat. Am. J. Phys. Educ.*, *4*(3), 515-519.

APPENDIX F

EXPERT OPINION FORM FOR THE INTERVIEW GUIDE

UZMAN GÖRÜŞ FORMU

Sayın Uzman,

Bu yarı yapılandırılmış görüşme protokolü fizik öğretmen adaylarının geometrik optik konularında sahip oldukları kavramlamaların tespit edilip ortaya çıkarılması için geliştirilmiştir.

Bu çalışmaya konu olan geometrik optik bağlamları:

- Düzlem aynalar
- Kesişen aynalar
- Çukur aynalar
- Tümsek aynalar
- İnce kenarlı mercekler
- Kalın kenarlı merceklerdir.

Görüşme protokolündeki sorularda her bir bağlam içerisinde gözlemcinin kendi görüntüsünü gözlemlemesi ve başka bir cismi ya da kişiyi gözlemlemesi olaylarına yer verilmiştir.

Görüşme soruları ile araştırılması planlanan temel olaylar:

- Zahiri görüntünün oluşumunda gözlemcinin önemi.
- Gerçek görüntünün oluşumunda ekranın etkisi.
- Gerçek görüntünün ekransız gözlemlenmesinde gözlemcinin yerinin önemi.
- Ayna, mercek gibi optik araçlarla görüntü oluşumu ve gözlemlenmesinde optik aracın büyüklüğünün, yerinin ve oryantasyonunun önemi.
- Ayna, mercek gibi optik araçlarla görüntü oluşumu ve gözlemlenmesinde optik aracın engelle kapatılmasının görüntü oluşumu ve gözlemlenmesine etkileri.
- Gözlemci ya da gözlenenin hareketlerinin görüntü oluşumu ve gözlemlenmesine etkileri.

Görüşme protokolündeki soruları ve size verilen tabloyu dikkatlice inceleyip bununla ilgili aşağıdaki soruları lütfen yanıtlayınız.

İlginize teşekkür ederim.

1. Sorular içinde sizce fizik öğretmen adaylarının seviyesine uygun olmadığını düşündüklerinizi nedenleriyle belirtiniz. Mümkünse çözüm öneriniz.

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2. Sorular içinde sizce fizik öğretmen adaylarının geometrik optik bağlamlarındaki kavramlamalarını ortaya çıkarmak için uygun olmayanları nedenleriyle belirtiniz. Mümkünse çözüm öneriniz.

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3. Dağılım tablosu içinde verilen bağlam ve olay ile eşleşmeyen soruları belirtiniz.

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4. Sorular içinde sizce dili uygun olmayanları belirtiniz. Mümkünse çözüm öneriniz.

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5. Soruların çizimleri içinde sizce anlaşılabilir olmayanları belirtiniz. Mümkünse çözüm öneriniz.

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6. Sorular iki oturumda uygulanacak olursa, konu bütünlüğü ve uygulama süresi bakımından oturumların 1-20 ve 21-33 numaralı sorular şeklinde yapılması sizce uygun mu?

□ Evet □ Hayır

Cevabınız "Hayır" ise nedenini açıklayınız. Mümkünse çözüm öneriniz.

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7. Sorular içinde kavramsal hata içerenler varsa nedenleriyle belirtiniz. Mümkünse çözüm öneriniz.

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GÖRÜŞME SORULARININ DAĞILIM TABLOSU

BAĞLAM \ OLAY		KENDİSİNİ GÖZLEMLEME	Ara Toplam	NESNEYİ / BAŞKASINI GÖZLEMLEME	Ara Toplam	TOPLAM
Düzlem Aynalar	Düzlem Ayna	1 (2,3) 16 5 18 12 19 13 20 15	9	1 (2,3) 13 4 14 5 17 12	7	16
	Kesişen Aynalar	29 30	2	27 29 30	3	5
Küresel Aynalar	Çukur Ayna	6 8 19 31	4	6 8 10 28	4	8
	Tümsek Ayna	7 9 19 32	4	7 9 11 33	4	8
Mercekler	İnce Kenarlı Mercek	23	1	21 (26) 22	2	3
	Kalın Kenarlı Mercek	24	1	25	1	2
TOPLAM		21		21		42

*Tablodaki rakamlar görüşme formundaki soru numaralarını göstermektedir.

**Parantez içerisindeki rakamlar birbirine alternatif olarak düşünülen soru numaralarını göstermektedir.

APPENDIX G

A SAMPLE OF STUDENT COPY OF AN INTERVIEW QUESTION

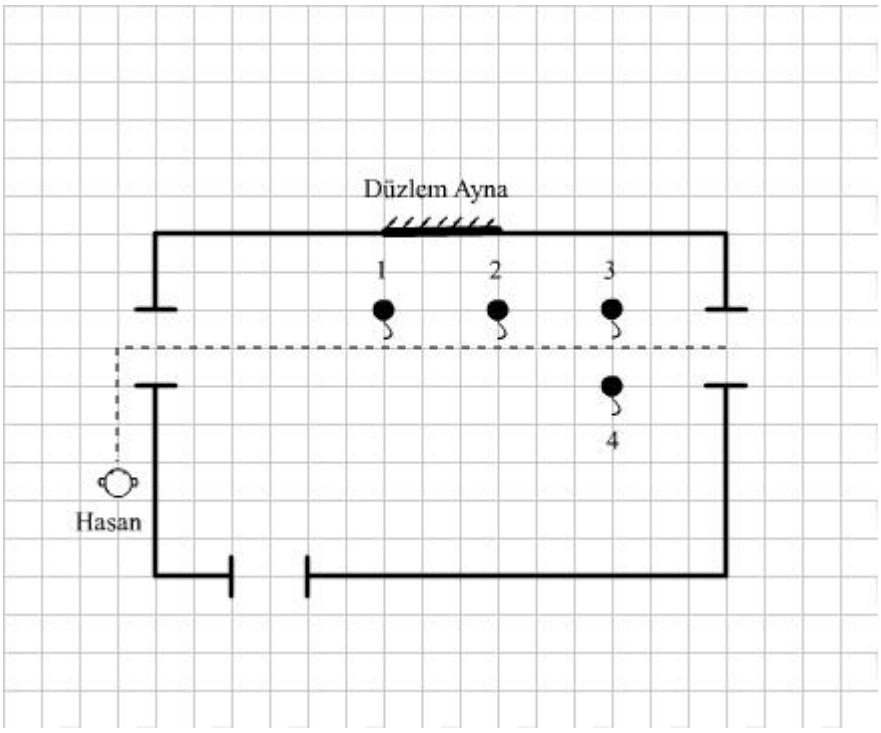
GÖRÜŞME FORMU #2

Katılımcı:		
Tarih:	**Saat:** ***Başlama:*** ***Bitiş:***	**Yer:**

DÜZLEM AYNA

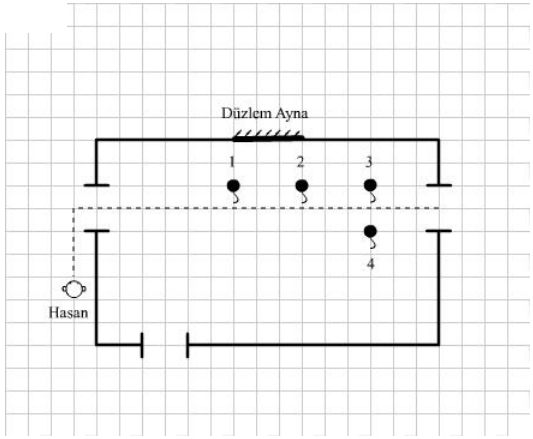
1-4 numaralı sorulardaki şekillerde ışık kaynağı ile homojen bir şekilde aydınlatılmış bir odanın üstten görünüşü verilmiştir.

1)

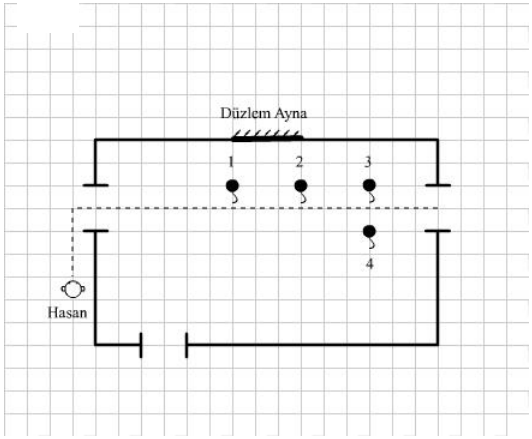


Hasan kapıdan içeri girip oda boyunca kesikli çizgi ile gösterilen yolda ilerlerken kendisinin ve 1-4 ile numaralandırılmış kedilerin görüntüsünü duvardaki düzlem aynada gözlemlemeye çalışmaktadır. Buna göre;

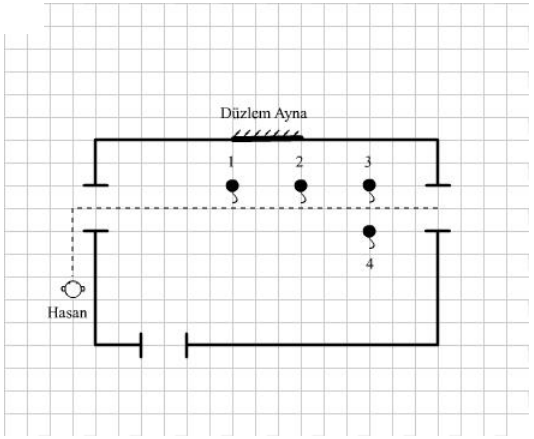
B


Düzlem Ayna
1
2
3
4
Hasan

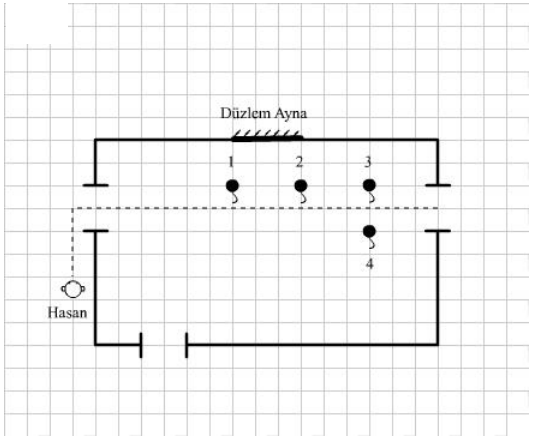
C


Düzlem Ayna
1
2
3
4
Hasan

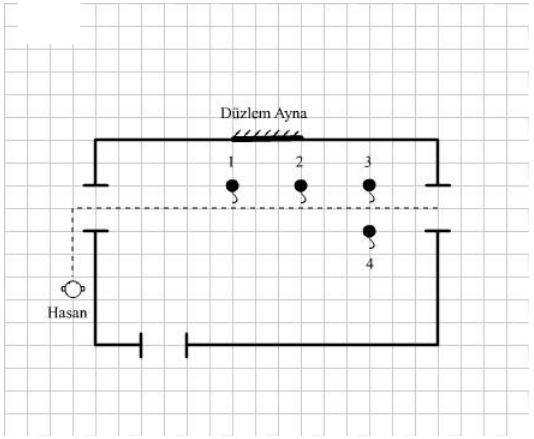
D


Düzlem Ayna
1
2
3
4
Hasan

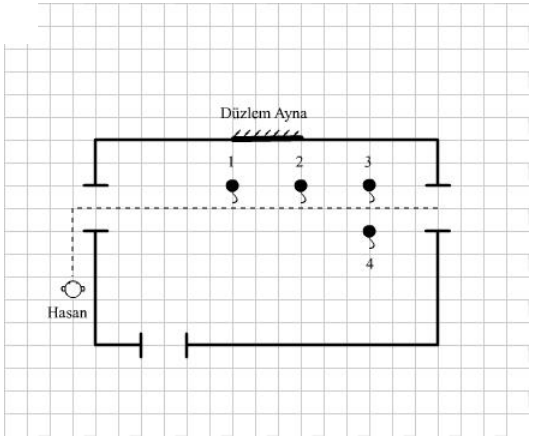
E


Düzlem Ayna
1
2
3
4
Hasan

F


Düzlem Ayna
1
2
3
4
Hasan

G


Düzlem Ayna
1
2
3
4
Hasan

APPENDIX H

THE OPEN-ENDED GEOMETRICAL OPTICS TEST

GEOMETRİK OPTİK TESTİ

Cinsiyetiniz: □ Kız □ Erkek

Doğum tarihiniz (Gün/Ay/Yıl): ____/___/_____

Üniversitenizin adı:_____

Bölümünüzün adı: □ Fizik □ Fizik Öğretmenliği □ Diğer (_____)

Sınıfınız: □1 □ 2 □ 3 □ 4 □ 5 □ Diğer (_____)

Üniversitedeki genel not ortalamanız: _____

Üniversitede optik dersinden aldığınız not veya harf: _____

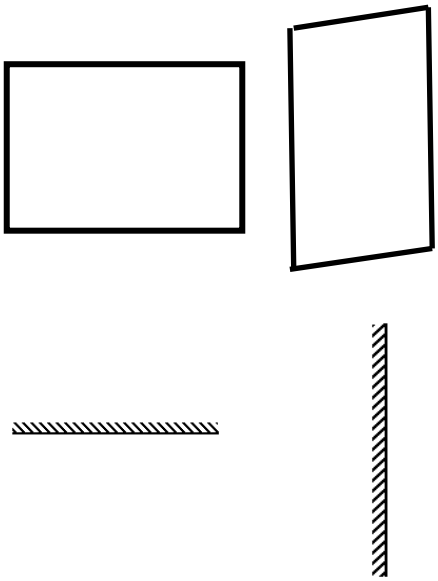
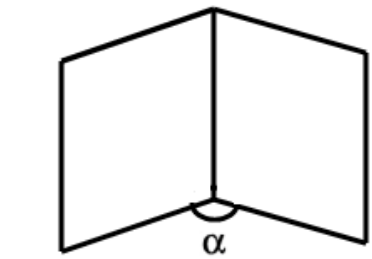
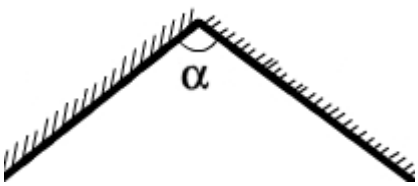
Üniversitede optik laboratuar dersinden aldığınız not veya harf: _____

Yönergeler

1. Sınava başlamadan önce yukarıda verilen kısmı **eksiksiz** doldurunuz.
2. Testte **24** soru yer almaktadır. Lütfen bütün sorulara cevap vermek için gayret gösteriniz ve verdiğiniz cevabın **nedenini** açıkça yazınız.
3. Sınavı tamamlamak için önerilen süre yaklaşık **90** dakikadır.
4. Sınavda gerekli olabilecek formüller ve şekiller arka sayfada mevcuttur.
5. Bu testin sonuçları Ortadoğu Teknik Üniversitesi'nde Ortaöğretim Fen ve Matematik Alanları Eğitimi Bölümü'nde doktora yapan araştırmacının tezinde veri olarak kullanılacaktır.
6. Bu bir bilimsel çalışmadır. Siz de şu an bilimsel bir çalışmanın parçasısınız. Gerekli ilgiyi gösterdiğiniz için teşekkür ederiz.

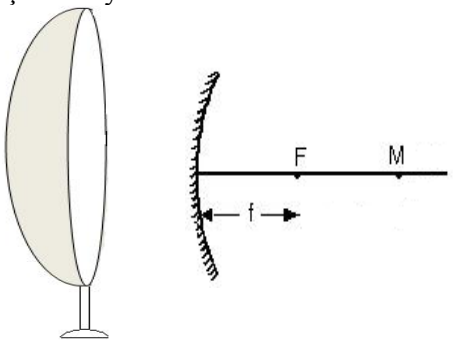
AÇIKLAYICI RESİMLER, ÇİZİMLER ve FORMÜLLER

Aşağıdaki tabloda Geometrik Optik Testi'nde yer alan sorularda bahsi geçen optik araçlara örnek olabilecek fotoğraflar, bu optik araçlara ait perspektif (yandan) veya üstten çizimler ile bu konularda ihtiyaç duyabileceğiniz bazı formüller size verilmiştir.

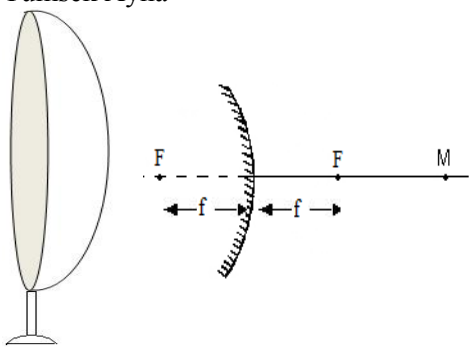
OPTİK ARACIN FOTOĞRAFI	OPTİK ARACIN PERSPEKTİF veya ÜSTTEN GÖRÜNÜŞÜNÜN ÇİZİMLERİ	OPTİK ARAÇ İLE İLGİLİ FORMÜLLER
Düzlem Ayna 		
Kesişen Aynalar 	 	**n:** Aynalarda oluşan toplam görüntü sayısı **α :** Aynalar arasındaki açı olmak üzere $n=\frac{360}{\alpha}-1$

Çukur ve Tümsek Aynalar

Çukur Ayna



Tümsek Ayna



F: Aynanın odağı

M: Aynanın merkezi

f: Aynanın odak uzaklığı

d_c: Cismin aynaya olan uzaklığı

d_g: Görüntünün aynaya olan uzaklığı

h_o: Cismin boyu

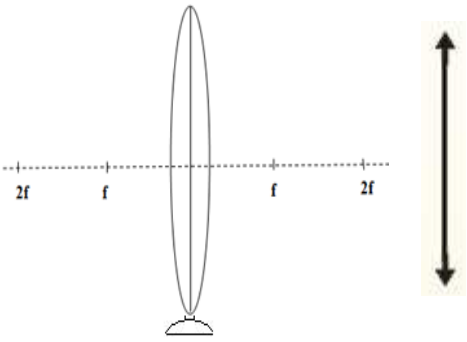
h_g: Görüntünün boyu olmak üzere

$$\frac{1}{f} = \frac{1}{d_c} + \frac{1}{d_g}$$

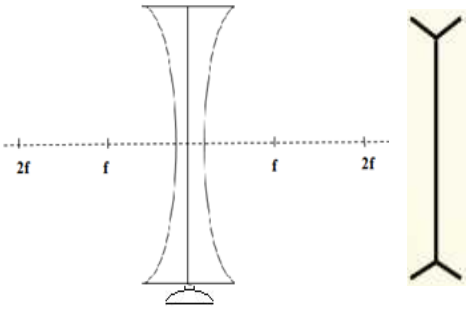
$$\frac{h_o}{h_g} = \frac{d_c}{d_g}$$

İnce ve Kalın Kenarlı Mercekler

İnce Kenarlı Mercek



Kalın Kenarlı Mercek



f: Merceğin odak uzaklığı

d_c: Cismin merceğe olan uzaklığı

d_g Görüntünün merceğe olan uzaklığı

h_o: Cismin boyu

h_g: Görüntünün boyu olmak üzere

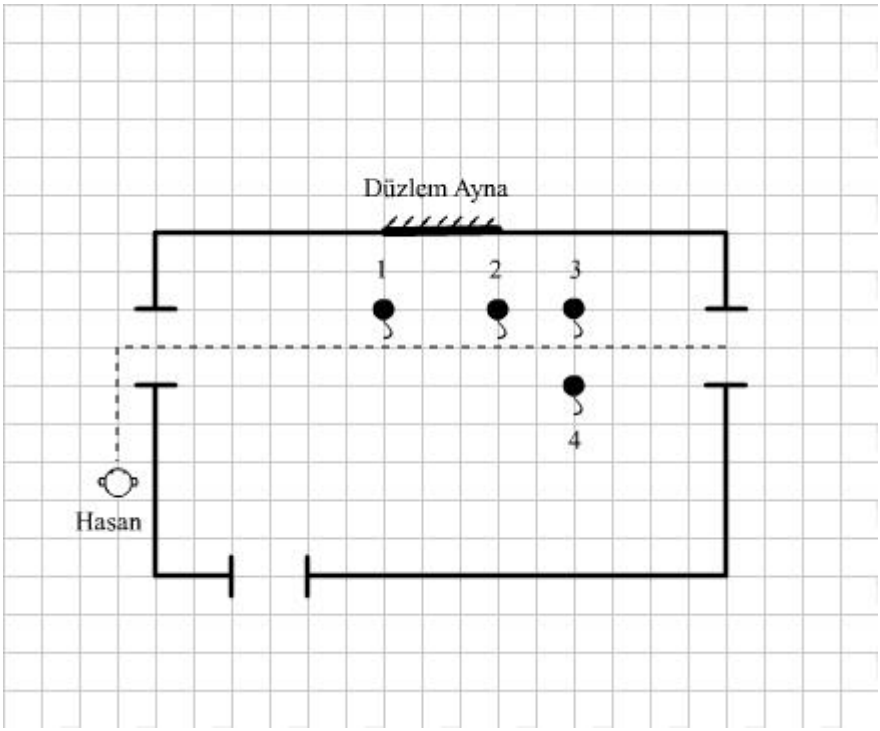
$$\frac{1}{f} = \frac{1}{d_c} + \frac{1}{d_g}$$

$$\frac{h_o}{h_g} = \frac{d_c}{d_g}$$

DÜZLEM AYNALAR

1-2 numaralı sorulardaki şekillerde ışık kaynağı ile homojen bir şekilde aydınlatılmış bir odanın üstten görünüşü verilmiştir. Hasan kapıdan içeri girip oda boyunca kesikli çizgi ile gösterilen yolda ilerlerken kendisinin ve 1-4 ile numaralandırılmış kedilerin görüntüsünü duvardaki düzlem aynada gözlemlemeye çalışmaktadır. Buna göre;

1)



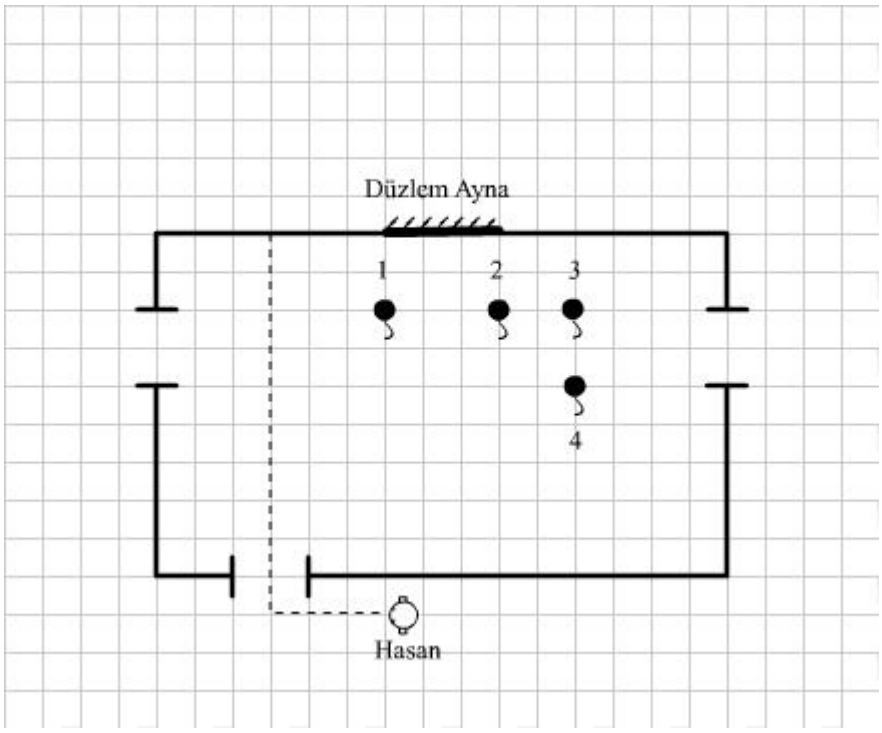
A1. Numaralandırılmış kedilerin hangilerinin görüntüsü oluşur? Görüntülerin yerlerini şekil üzerinde çiziniz.

A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

B1. Hasan kesikli çizgi üzerinde ilerlerken kedileri hangi sıra ile görür?

B2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

2)



A1. Numaralandırılmış kedilerin hangilerinin görüntüsü oluşur? Görüntülerin yerlerini şekil üzerinde çiziniz.

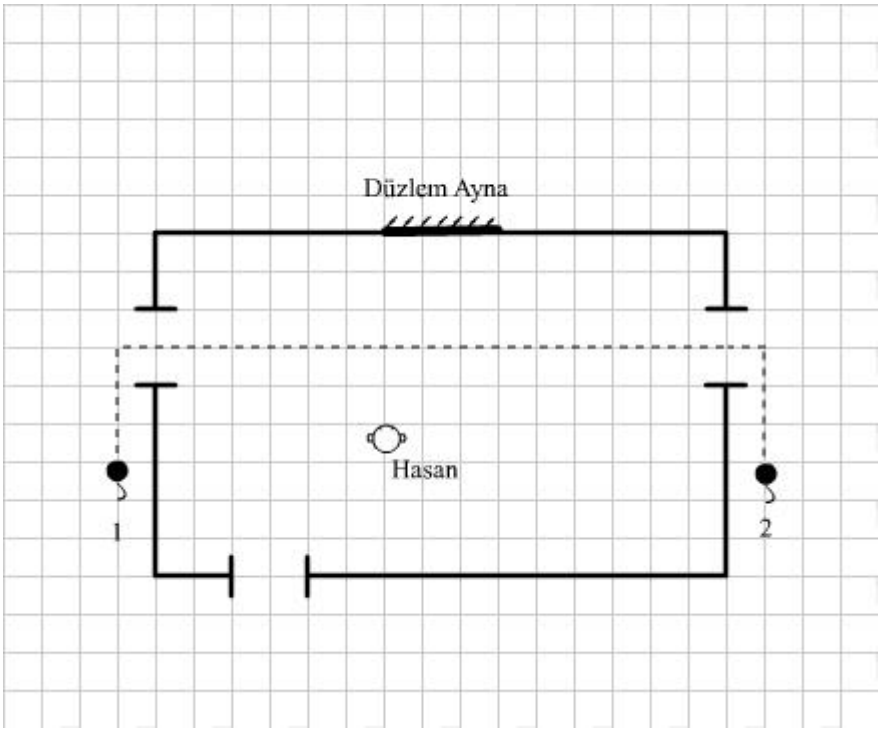
A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

B1. Hasan kesikli çizgi üzerinde ilerlerken kedileri hangi sıra ile görür?

B2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

3 numaralı sorudaki şekilde ışık kaynağı ile homojen bir şekilde aydınlatılmış bir odanın üstten görünüşü verilmiştir. Hasan düzlem aynanın ön cephe sınırı içinde düzlem aynaya bakmakta iken odanın sağ ve sol kapılarından 1 ve 2 numaralı kediler aynı anda içeri girip oda boyunca kesikli çizgi ile gösterilen yolda eşit süratle ilerlemektedirler. Buna göre;

3)



A1. Numaralandırılmış kedilerin hangilerinin görüntüsü oluşur? Görüntülerin yerlerini şekil üzerinde çiziniz.

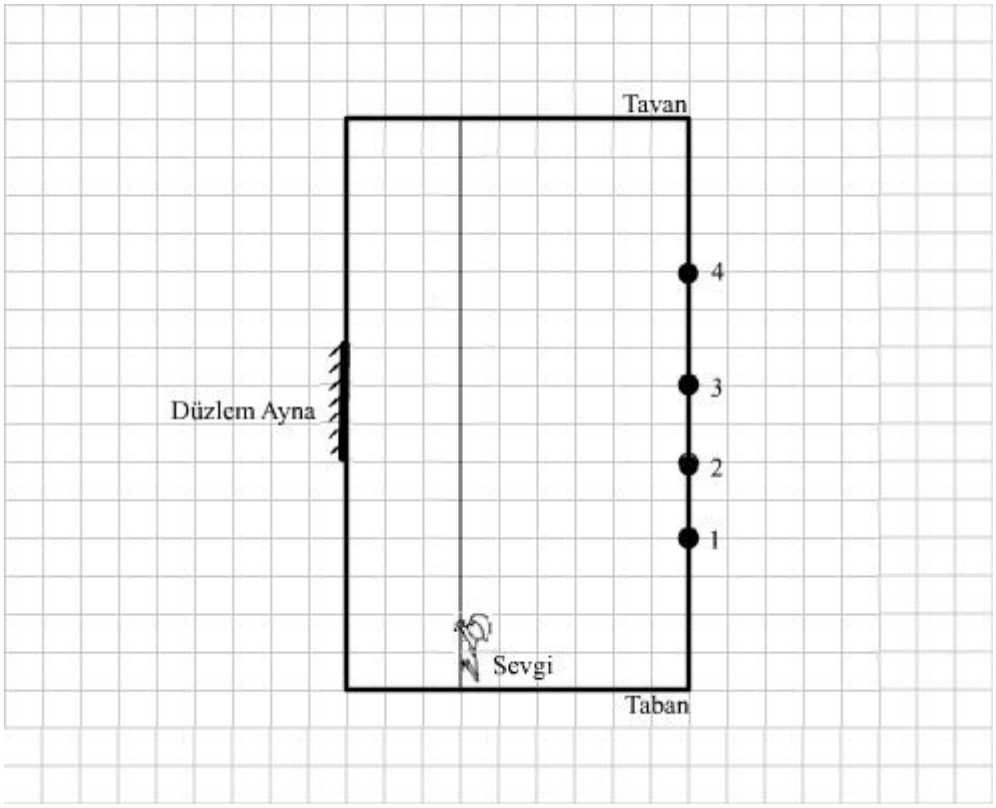
A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

B1. Hasan kesikli çizgi üzerinde ilerlerleyen kedileri hangi sıra ile görür?

B2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

4-5 numaralı sorulardaki şekillerde bir ışık kaynağı ile homojen bir şekilde aydınlatılmış bir odanın yandan görünüşü verilmiştir. Sevgi tavanda asılı ip ile yukarı tırmanırken kendisinin ve arkasındaki duvara yerleştirilmiş 1-4 ile numaralandırılmış lambaların görüntüsünü düzlem aynadan gözlemlemeye çalışmaktadır. Buna göre;

4)



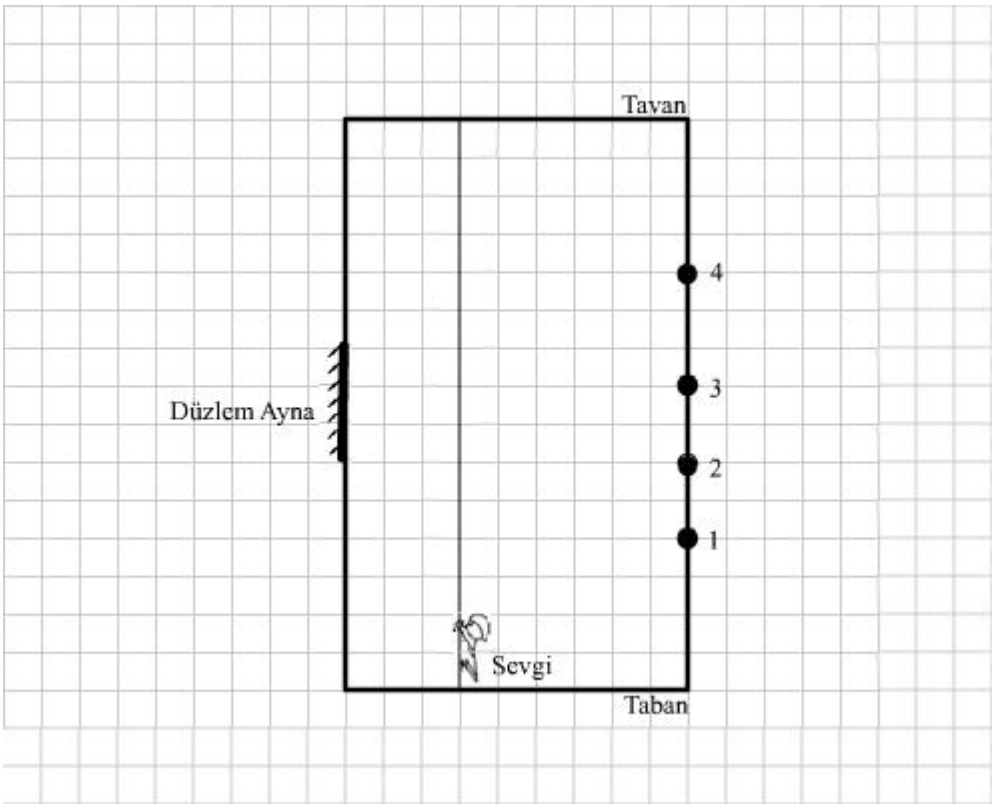
A1. Numaralandırılmış lambaların hangilerinin görüntüsü oluşur? Görüntülerin yerlerini şekil üzerinde çiziniz.

A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

B1. Sevgi tırmanırken lambaları hangi sıra ile görür?

B2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

5)

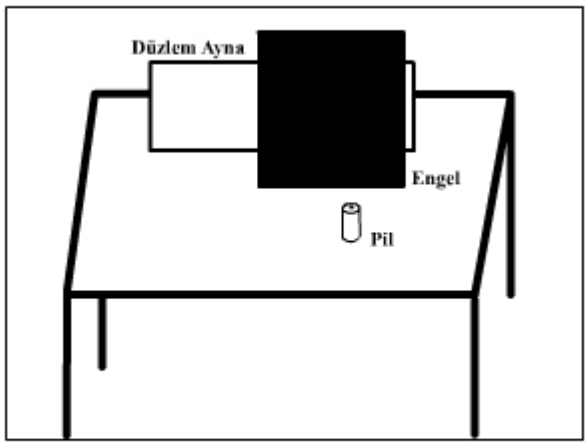


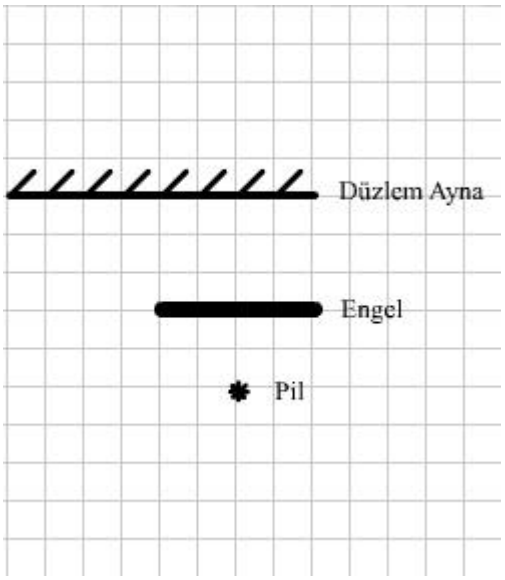
A1. Sevgi tırmanırken ilk olarak nerede iken kendisinin görüntüsünün tamamını görebilir? Bu durumda iken şekil üzerinde Sevgi'nin ve görüntüsünün yerlerini işaretleyiniz.

A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

6)

Homojen bir şekilde aydınlatılmış bir odada masanın üzerinde bulunan düzlem aynanın önüne aşağıdaki şekilde gösterildiği gibi saydam olmayan bir engel yerleştirilmiştir. Engelin önüne ise şekildeki gibi bir pil yerleştirilmiştir. Sağdaki çizimde aynı şeklin üstten gösterimi yer almaktadır. Buna göre;





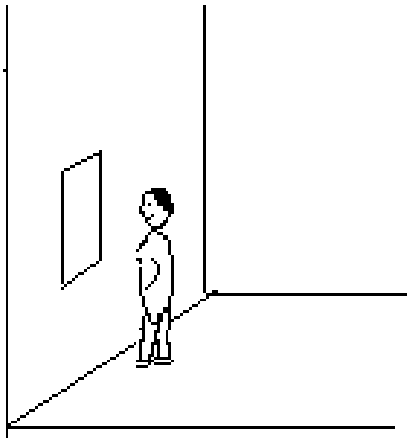
Üstten Görünüş

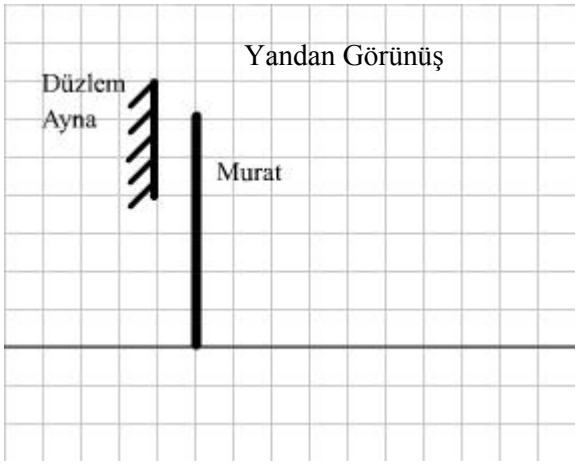
A1. Pilin aynada görüntüsü oluşur mu? Oluşursa şekil üzerinde görüntünün yerini işaretleyiniz.

A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

7)

Murat, kendisinin boyunun yarısı büyüklüğünde ve yerden yüksekliği göğüs hizasında olan duvarda asılı düzlem aynada görüntüsüne şekildeki gibi bakmaktadır. Sağdaki çizimde aynı şeklin yandan gösterimi yer almaktadır. Buna göre;





A1. Murat vücudunun ne kadarını düzlem aynada görebilir? Şekil üzerinde işaretleyiniz.

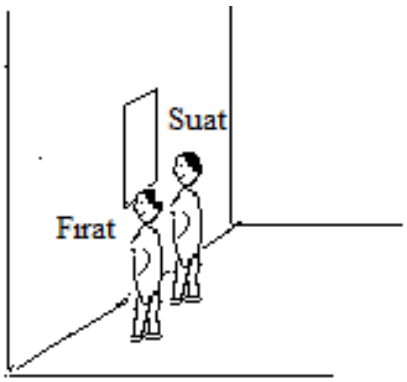
A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

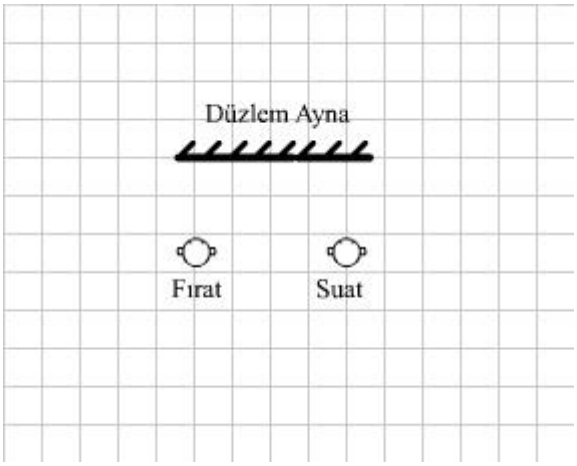
B1. Murat bir defada vücudunun daha fazlasını görebilmek için ne(ler) yapabilir?

B2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

8)

Suat ve ikizi Fırat duvara monte edilmiş düzlem aynanın karşısında görüntülerine bakmaktadırlar. Sağdaki çizimde aynı şeklin üstten gösterimi yer almaktadır. Buna göre;





Üstten Görünüş

A1. Suat bir defada Fırat'ın vücudunun daha fazlasını görmek istemektedir. Bunun için Suat ne(ler) yapabilir?

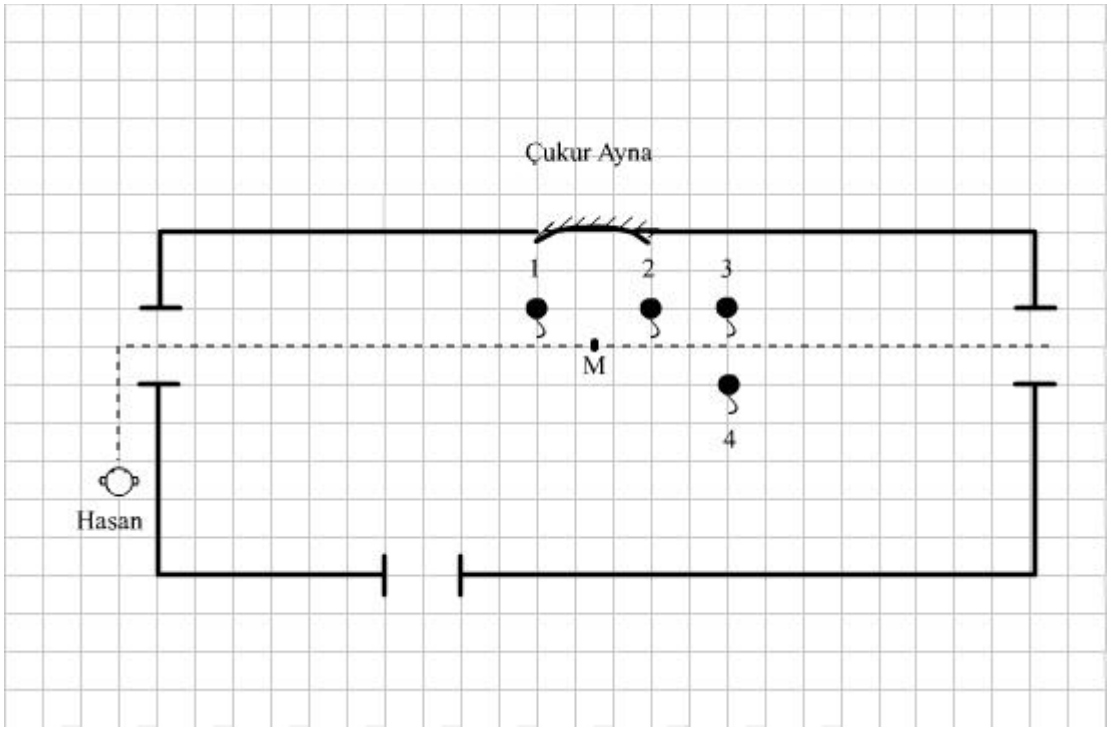
A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

KÜRESEL AYNALAR

9-10 numaralı sorulardaki şekillerde ışık kaynağı ile homojen bir şekilde aydınlatılmış bir odanın üstten görünüşü verilmiştir.

9)

Hasan kapıdan içeri girip oda boyunca kesikli çizgi ile gösterilen yolda ilerlerken kendisinin ve 1-4 ile numaralandırılmış kedilerin görüntüsünü duvardaki çukur aynada gözlemlemeye çalışmaktadır. Çukur aynanın merkez uzaklığı M ile gösterilmiştir. Buna göre;



A1. Numaralandırılmış kedilerin hangilerinin görüntüsü oluşur? Görüntülerin yerlerini şekil üzerinde çiziniz.

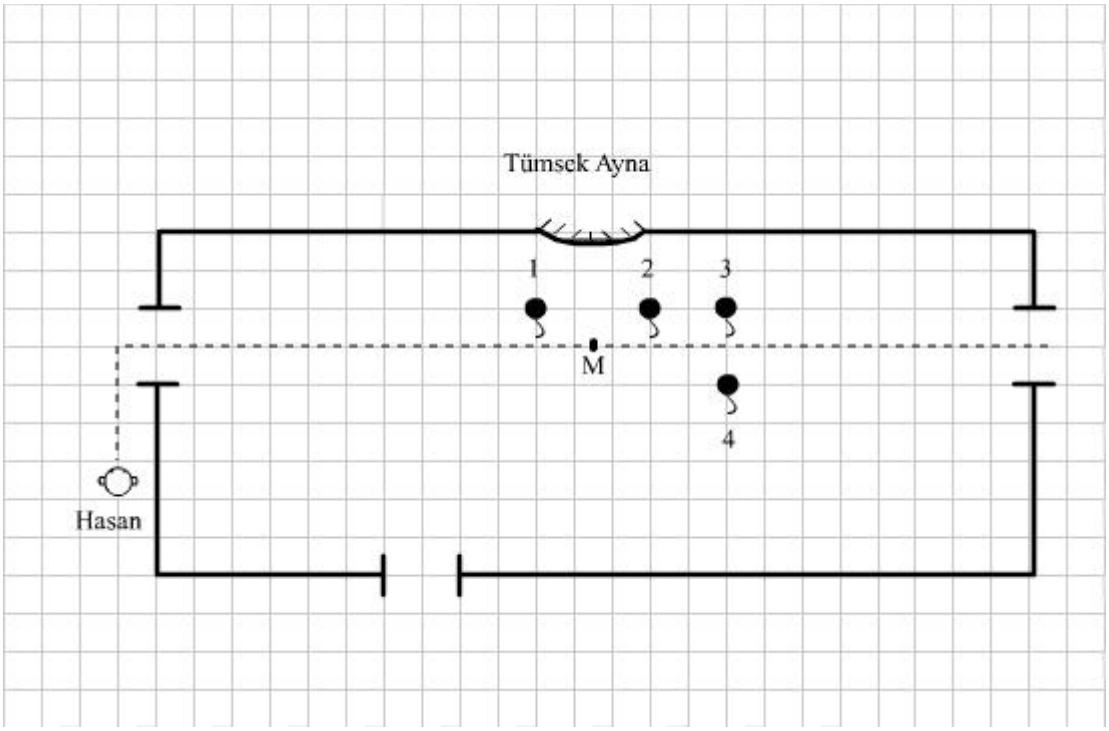
A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

B1. Hasan kesikli çizgi üzerinde ilerlerken kedileri hangi sıra ile görür?

B2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

10)

Hasan kapıdan içeri girip oda boyunca kesikli çizgi ile gösterilen yolda ilerlerken kendisinin ve 1-4 ile numaralandırılmış kedilerin görüntüsünü duvardaki tümsek aynada gözlemlemeye çalışmaktadır. Tümsek aynanın merkez uzaklığı M ile gösterilmiştir. Buna göre;



A1. Numaralandırılmış kedilerin hangilerinin görüntüsü oluşur? Görüntülerin yerlerini şekil üzerinde çiziniz.

A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

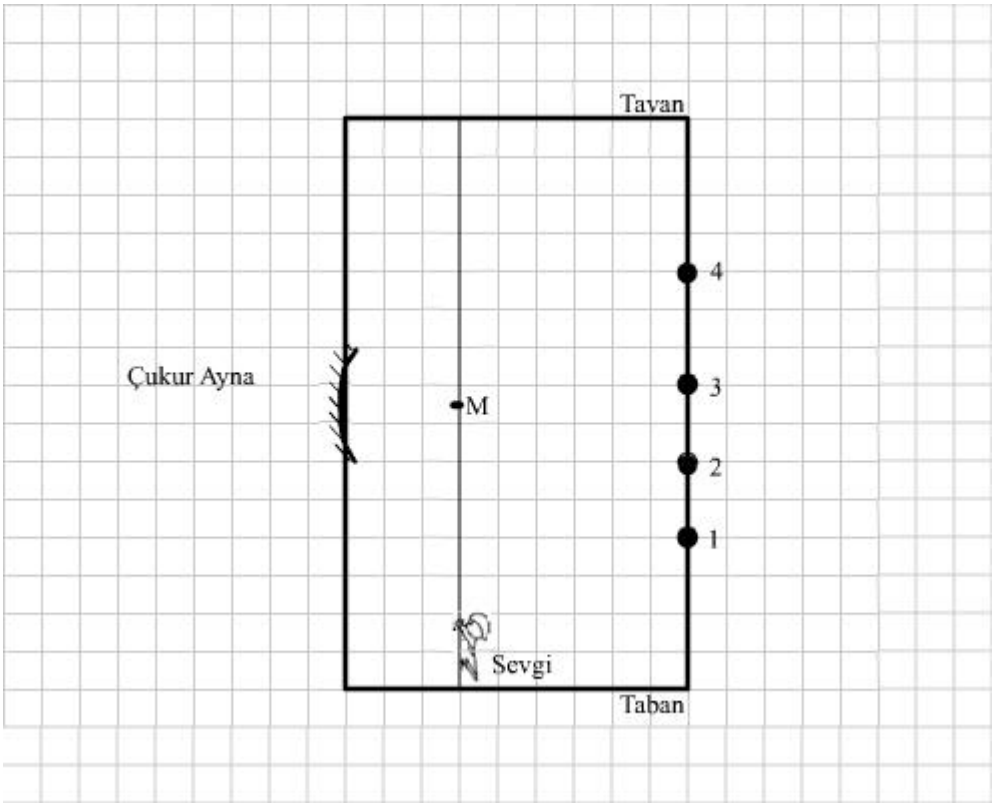
B1. Hasan kesikli çizgi üzerinde ilerlerken kedileri hangi sıra ile görür?

B2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

11-13 numaralı sorudaki şekilde bir ışık kaynağı ile homojen bir şekilde aydınlatılmış bir odanın yandan görünüşü verilmiştir. Sevgi'nin tırmandığı ipin aynaya olan uzaklığı aynanın merkez uzaklığı kadardır ve M ile gösterilmiştir.

11)

Sevgi tavanda asılı ip ile yukarı tırmanırken kendisinin ve arkasındaki duvara yerleştirilmiş 1-4 ile numaralandırılmış lambaların görüntüsünü duvardaki çukur aynadan gözlemlemeye çalışmaktadır. Buna göre;



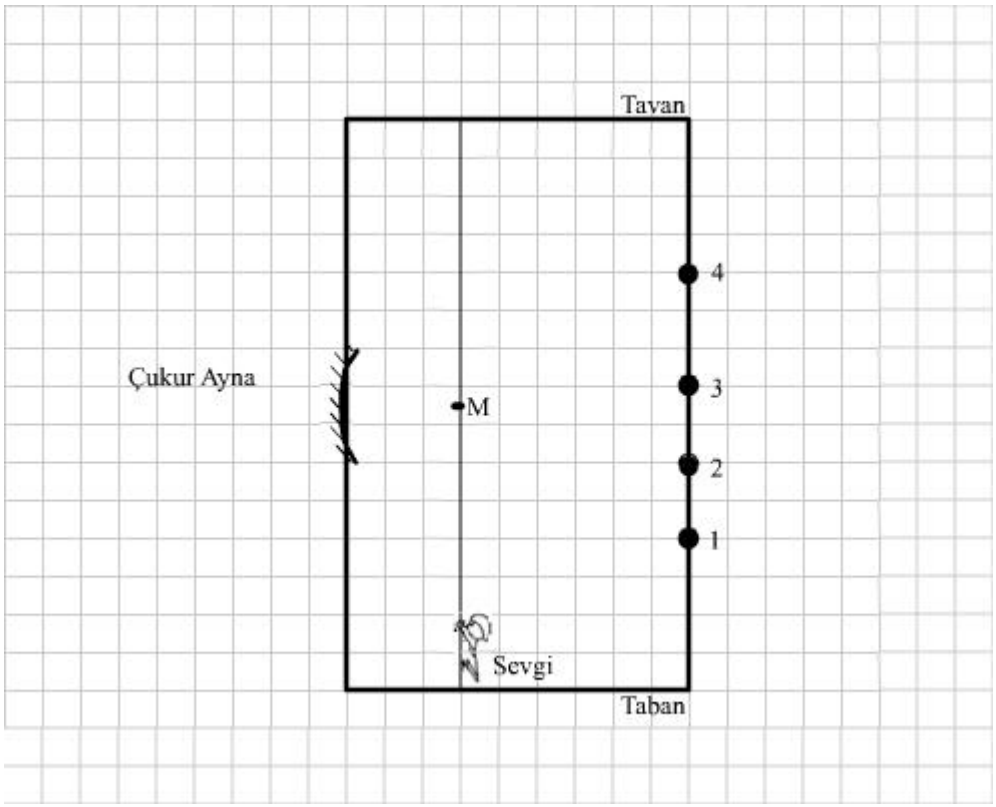
A1. Numaralandırılmış lambaların hangilerinin görüntüsü oluşur? Görüntülerin yerlerini şekil üzerinde çiziniz.

A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

B1. Sevgi tırmanırken lambaları hangi sıra ile görür?

B2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

12)

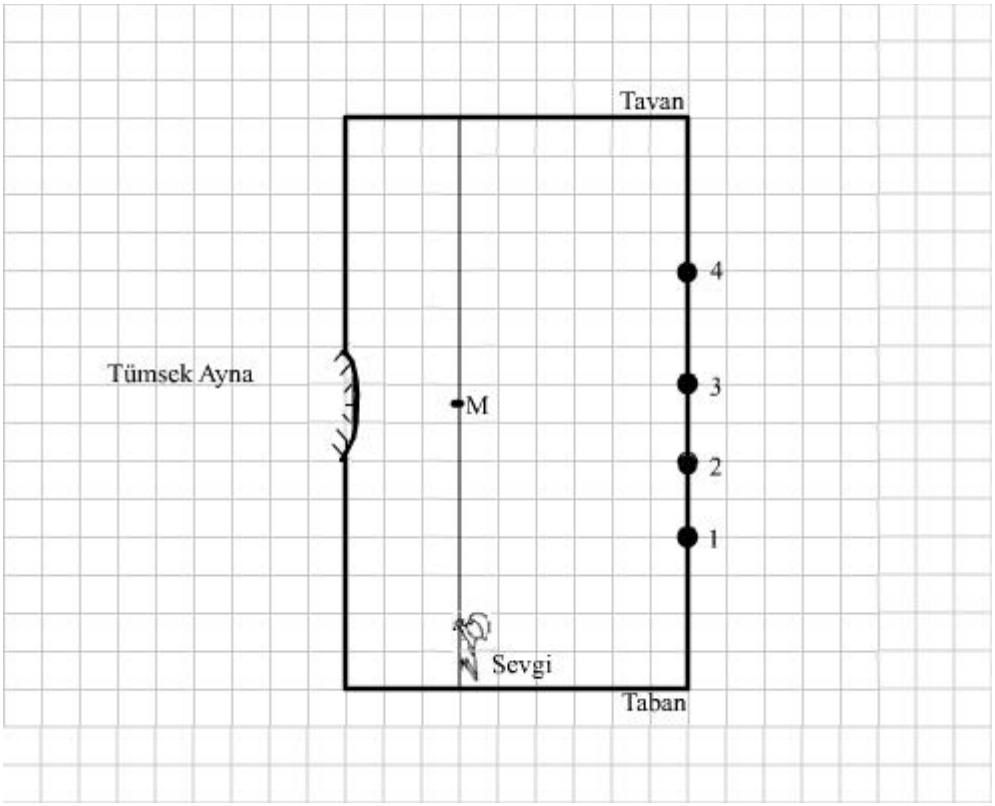


A1. Sevgi tırmanırken ilk olarak nerede iken kendi gözlerinin görüntüsünü görebilir? Bu durumda iken şekil üzerinde Sevgi'nin ve görüntüsünün yerlerini işaretleyiniz.

A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

13)

Sevgi tavanda asılı ip ile yukarı tırmanırken kendisinin ve arkasındaki duvara yerleştirilmiş 1-4 ile numaralandırılmış lambaların görüntüsünü duvardaki tümsek aynadan gözlemlemeye çalışmaktadır. Buna göre;

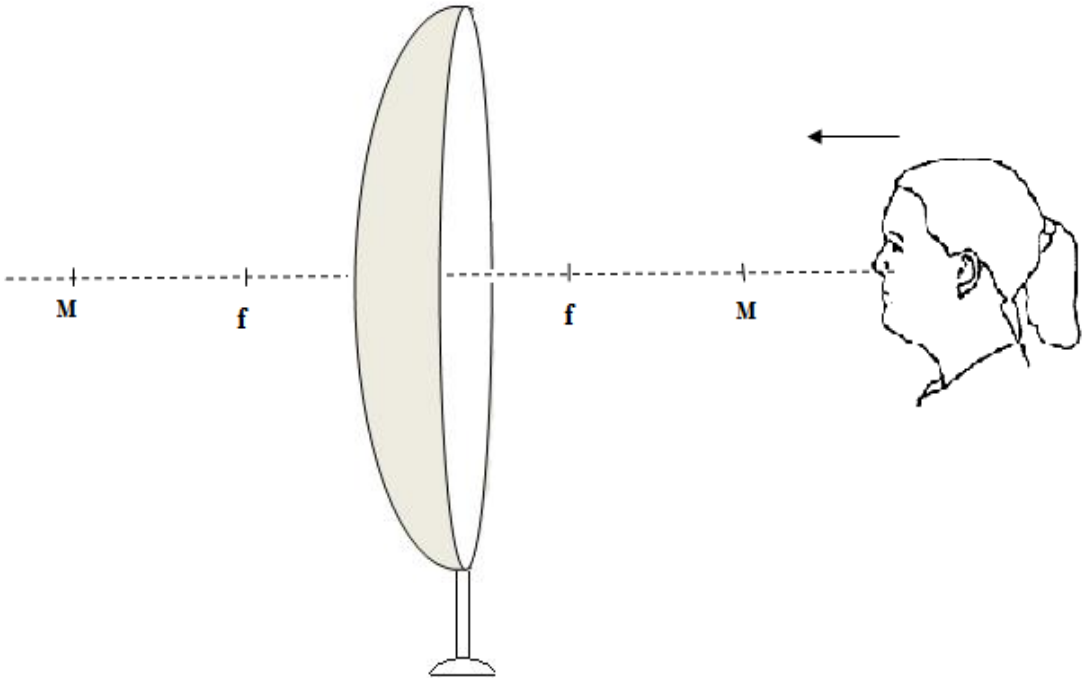


A1. Sevgi tırmanırken ilk olarak nerede iken kendi gözlerinin görüntüsünü görebilir? Bu durumda iken şekil üzerinde Sevgi'nin ve görüntüsünün yerlerini işaretleyiniz.

A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

14 ve 15 numaralı sorulardaki şekillerde gözlemci ve küresel aynanın yandan görünüşü verilmiştir. M küresel aynanın merkez, f ise odak uzaklığını göstermektedir.

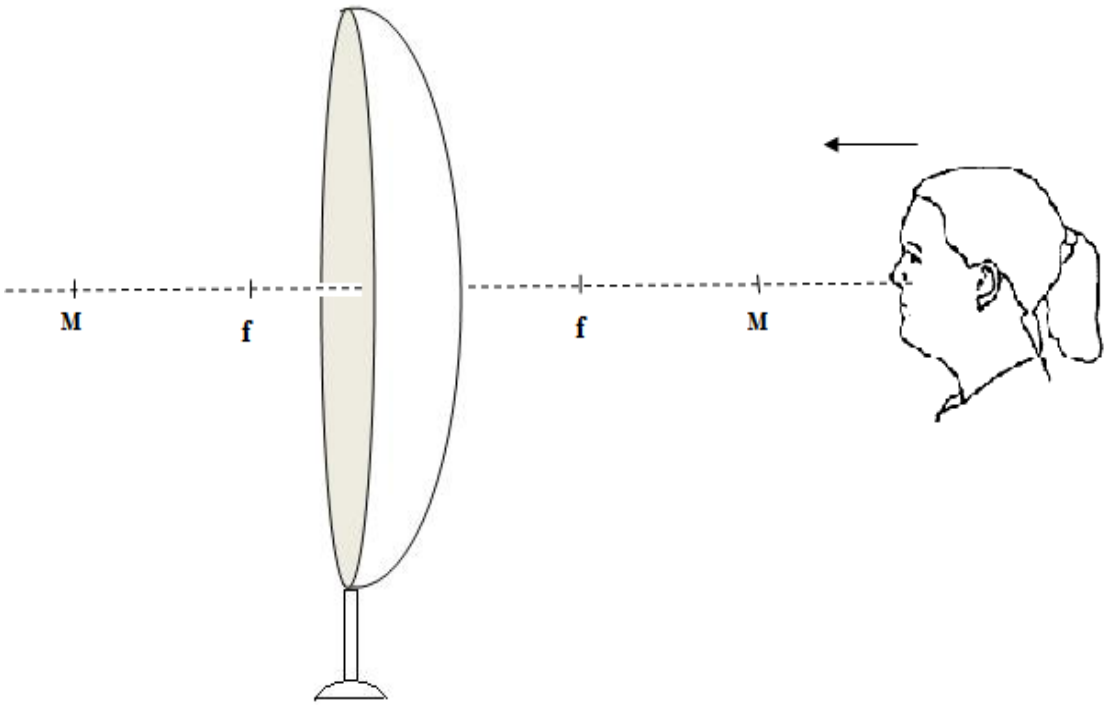
14)



A1. Selin şekilde gösterilen mesafelerden çukur aynaya bakarak yüzünün görüntüsünü görmek istemektedir. Selin ok işareti yönünde çukur aynaya yaklaşırken başının hangi pozisyon ya da pozisyonlarında kendi görüntüsünü görebilir? Bu durum(lar) için ayrı ayrı görüntünün yeri ve özelliklerini yazınız.

A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

15)

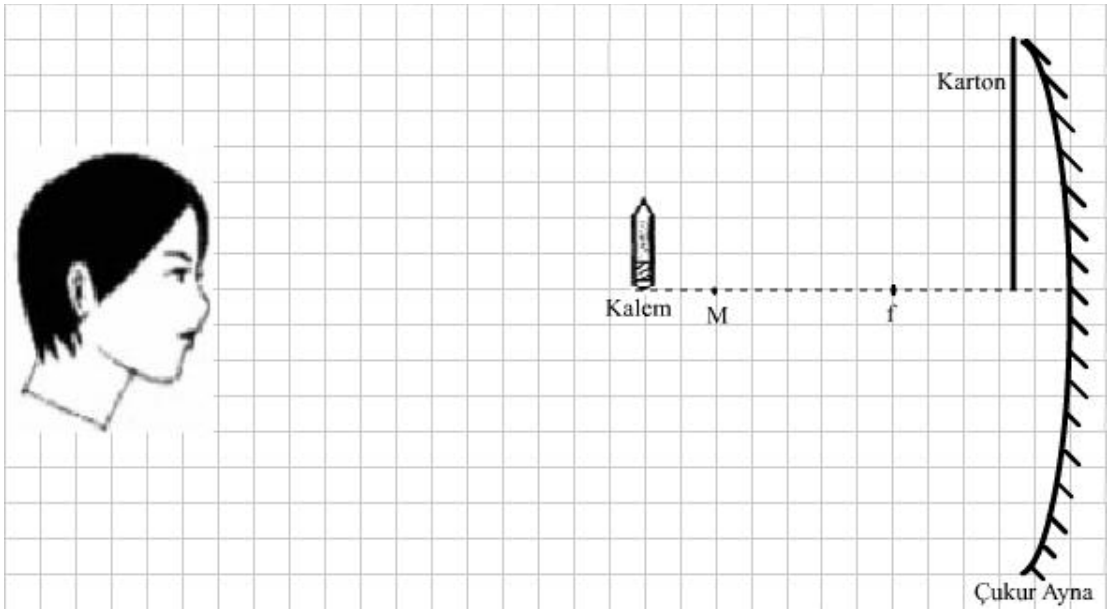


A1. Selin şekilde gösterilen mesafelerden tümsek aynaya bakarak yüzünün görüntüsünü görmek istemektedir. Selin ok işareti yönünde tümsek aynaya yaklaşırken başının hangi pozisyon ya da pozisyonlarında kendi görüntüsünü görebilir? Bu durum(lar) için ayrı ayrı görüntünün yeri ve özelliklerini yazınız.

A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

16)

Aşağıdaki şekilde gözlemci, kalem, çukur ayna ve kartonun yandan görünüşü verilmiştir. M çukur aynanın merkezini, f ise aynanın odağını göstermektedir.



A1. Çukur aynanın merkez uzaklığından öteye yerleştirilen bir kalemin görüntüsü şekildeki gözlemci tarafından gözlemlenmektedir. Çukur aynanın üst yarısı bir kartonla tamamen kapatılırsa kalemin görüntüsünde nasıl bir değişiklik olur?

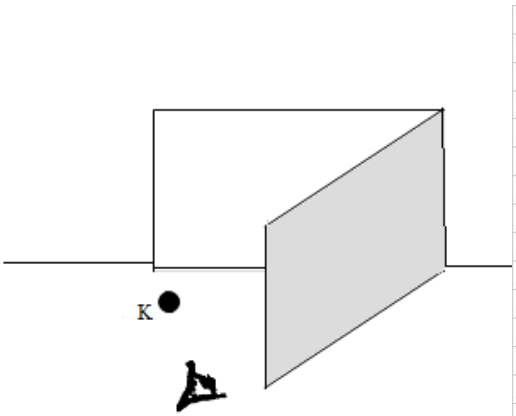
A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

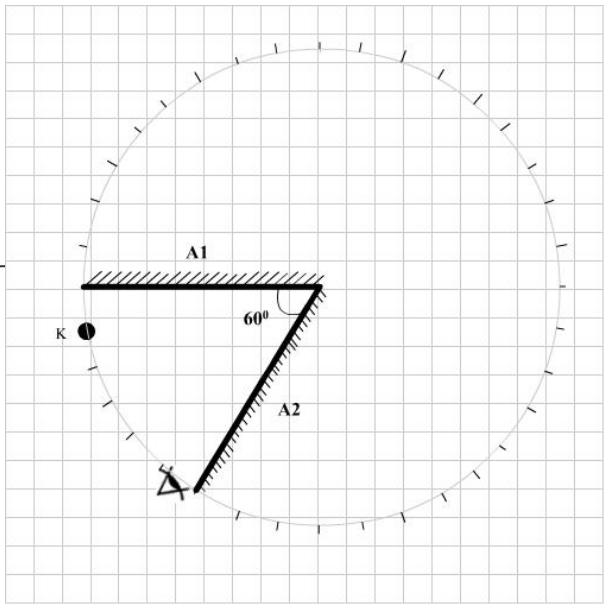
KESİŞEN AYNALAR

17-19numaralı sorulardaki şekillerde aralarında belli bir açı ile kesişen düzlem aynaların yandan ve üstten görünüşleri verilmiştir. Ayrıca konumları şekil üzerinde belirtilen gözlemcilerin bulunduğu yerden başını çevirerek görüntüleri gözlemlediği düşünülmelidir.

17)

Aralarındaki açı 60^0 olacak şekilde yerleştirilen iki düzlem ayna arasına konulan K cisminin görüntüsü şekildeki konumdan bakan bir gözlemci tarafından gözlemlenmektedir.Buna göre;





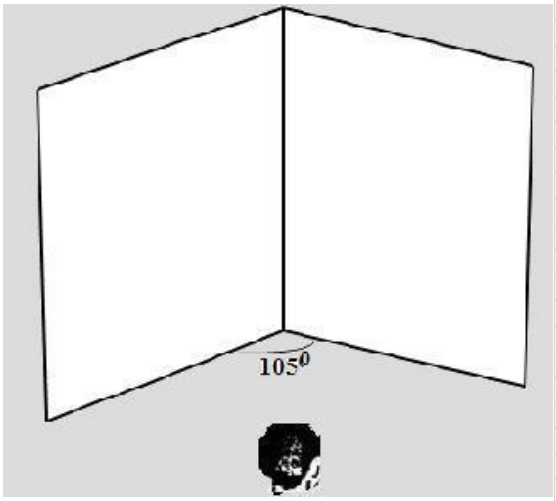
Yandan Görünüş Üstten Görünüş

A1. Bu gözlemci K cisminin kaç görüntüsünü görür? Bu görüntü ya da görüntülerin yer(ler)ini şekil üzerinde belirtiniz.

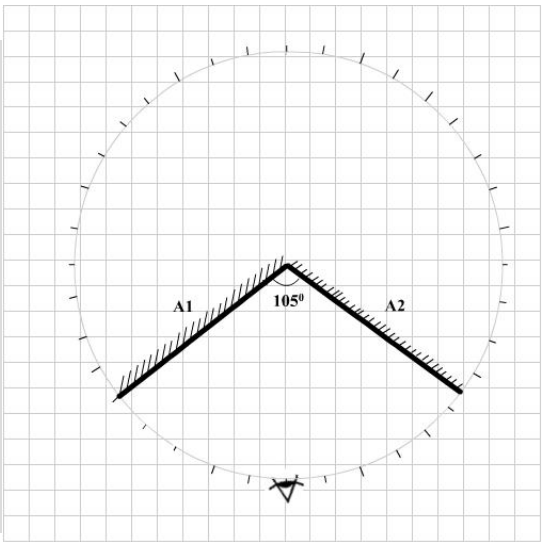
A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

18)

Aralarındaki açı 105^0 olacak şekilde kesişen iki düzlem ayna arasından şekildeki konumdan bakan bir gözlemci kendisini gözlemlemektedir. Buna göre;



Yandan Görünüş



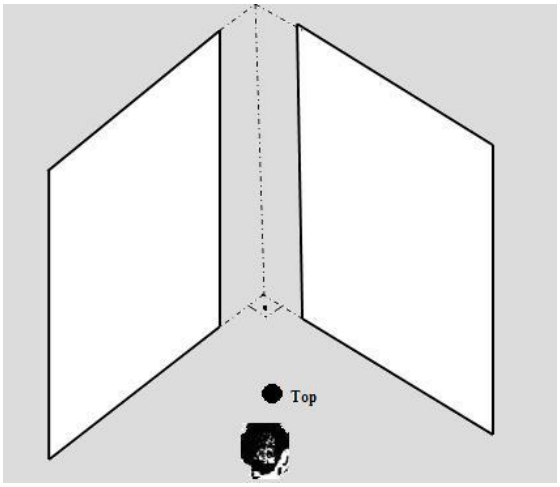
Üstten Görünüş

A1. Bu gözlemci <u>kendisinin</u> kaç görüntüsünü görür? Bu görüntü ya da görüntülerin yer(ler)ini şekil üzerinde belirtiniz.

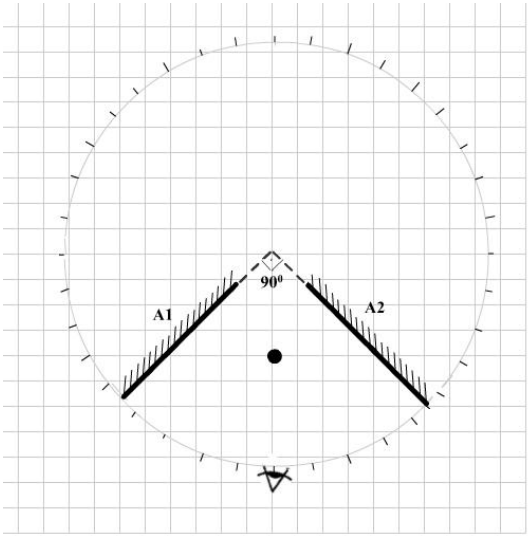
A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

19)

Bir alışveriş mağazasının birbirine dik duvarlarına iki düzlem ayna aralarında 90^0 açı ile ve biraz mesafe bırakılarak şekildeki gibi monte edilmiştir. Buna göre;



Yandan Görünüş



Üstten Görünüş

A1. Şekildeki konumdan bakan gözlemci yerdeki topun kaç görüntüsünü görür? Bu görüntü ya da görüntülerin yer(ler)ini şekil üzerinde belirtiniz.

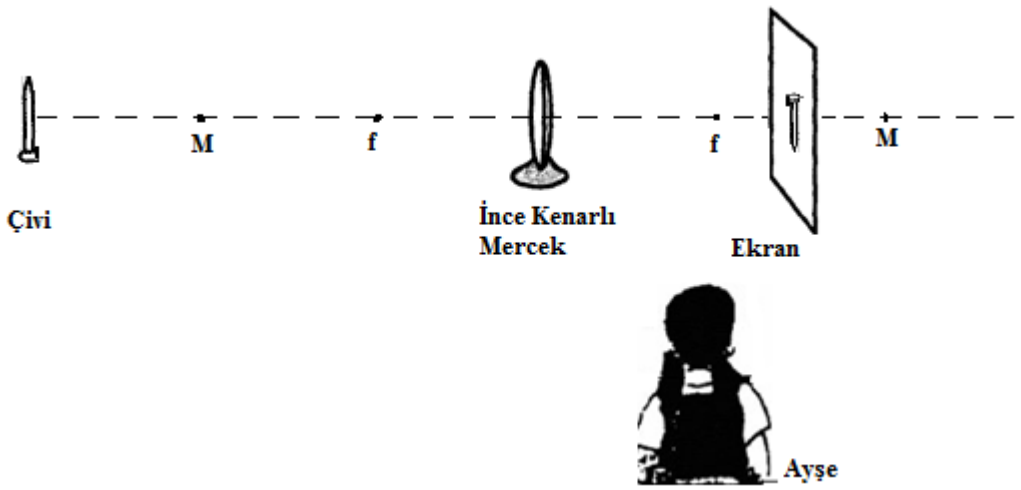
A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

B1. Diğer nesnelerin yerleri sabit kalmak koşulu ile gözlemci farklı bir konumdan baktığında gördüğü görüntü sayısı değişir mi?

B2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

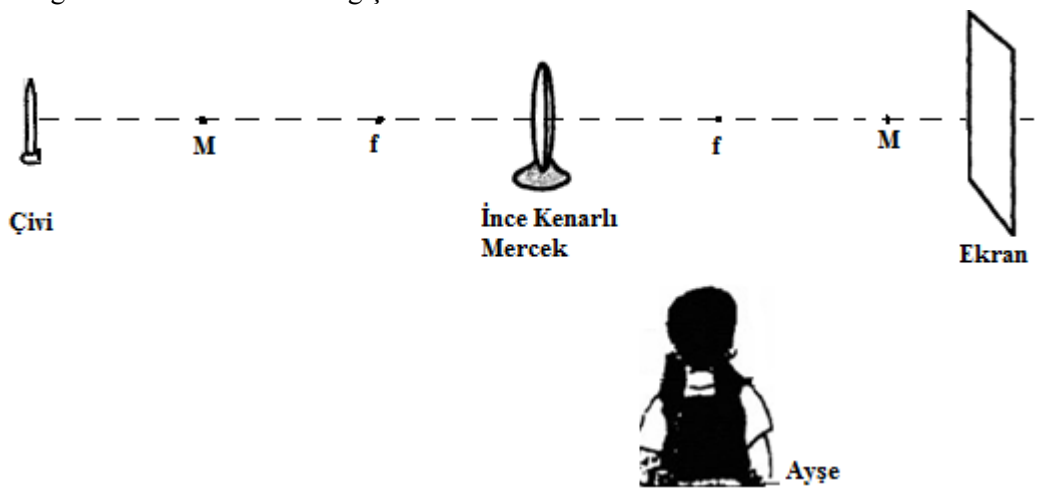
MERCEKLER

20-21 numaralı sorularda Ayşe ince kenarlı mercek önüne yerleştirilen bir çivinin net görüntüsünü şekildeki gibi merceğin diğer tarafında, küçük ve ters olarak ekran üzerine gözlemlemektedir. f ince kenarlı merceğin odak uzaklığını, M ise merkez uzaklığını göstermektedir. Buna göre;



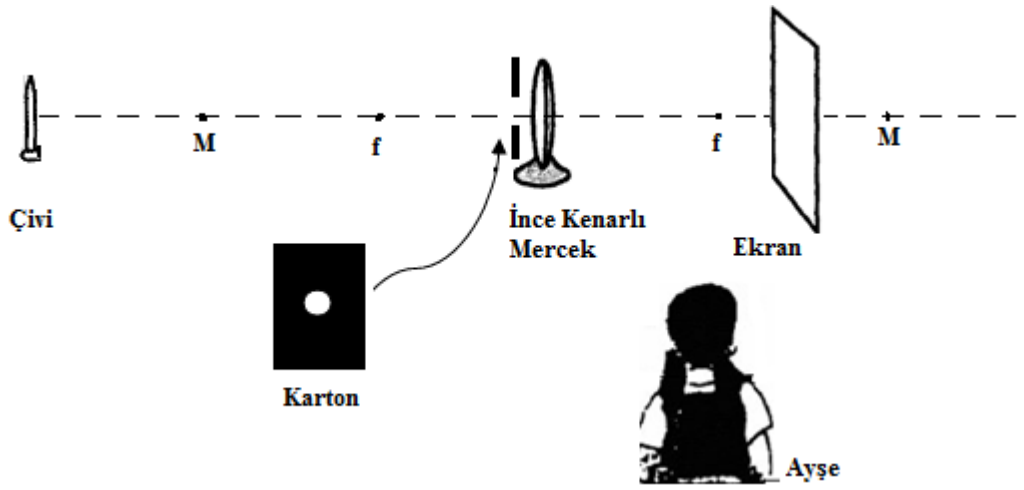
20)

A1. Diğer nesnelerin yerleri sabit kalmak koşuluyla ekran aşağıdaki şekildeki gibi mercekten uzaklaşacak şekilde geriye doğru çekilirse çivinin ekran üzerindeki görüntüsünde nasıl bir değişiklik olur?



A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

21)

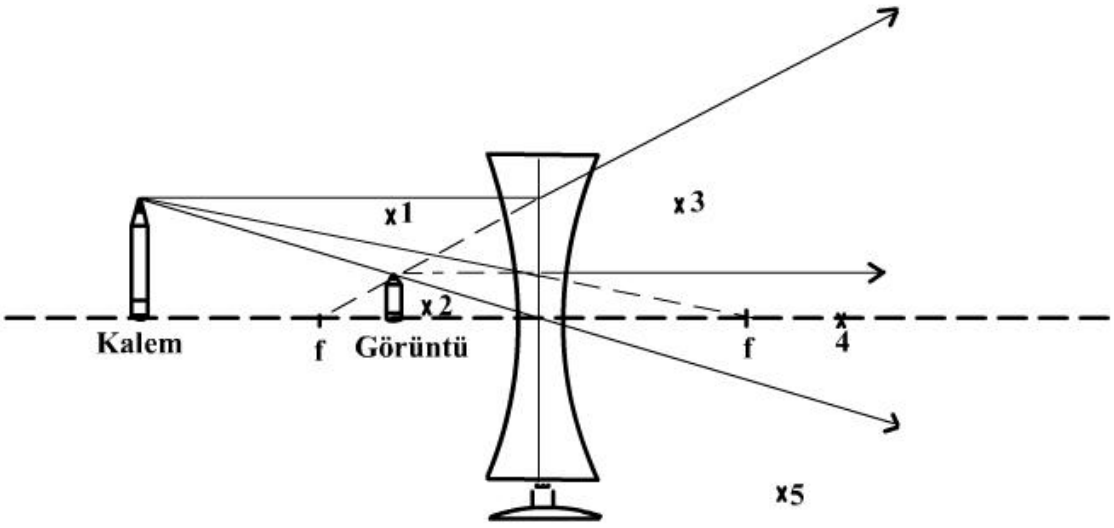


A1. Merceğin ön yüzüne tam ortasında daire şeklinde açıklık olan bir karton şekildeki gibi yerleştirildiğinde Ayşe ekranda ne görür?

A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

22)

Şekildeki ışın diyagramında kalın kenarlı merceğin önüne yerleştirilmiş bir kalem ve bu kalemin görüntüsü verilmiştir. Kalemin ucundan çizilen üç ışının mercekten geçtikten sonra izlediği yollar şekilde çizilmiştir. Buna göre;

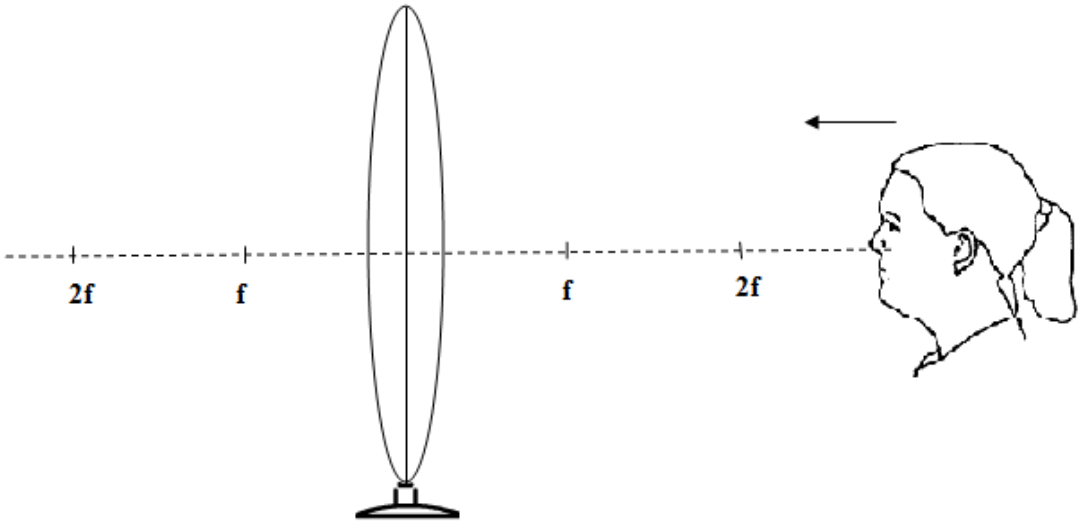


A1. 1-5 numaraları ile numaralanmış beş noktadan hangisi ya da hangilerinden bakan gözlemci(ler) kalemin görüntüsünün tamamını görebilir?

A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

23 ve 24 numaralı sorulardaki şekillerde gözlemci ve merceklerin yandan görünüşü verilmiştir. 2f merceğin merkez, f ise odak uzaklığını göstermektedir.

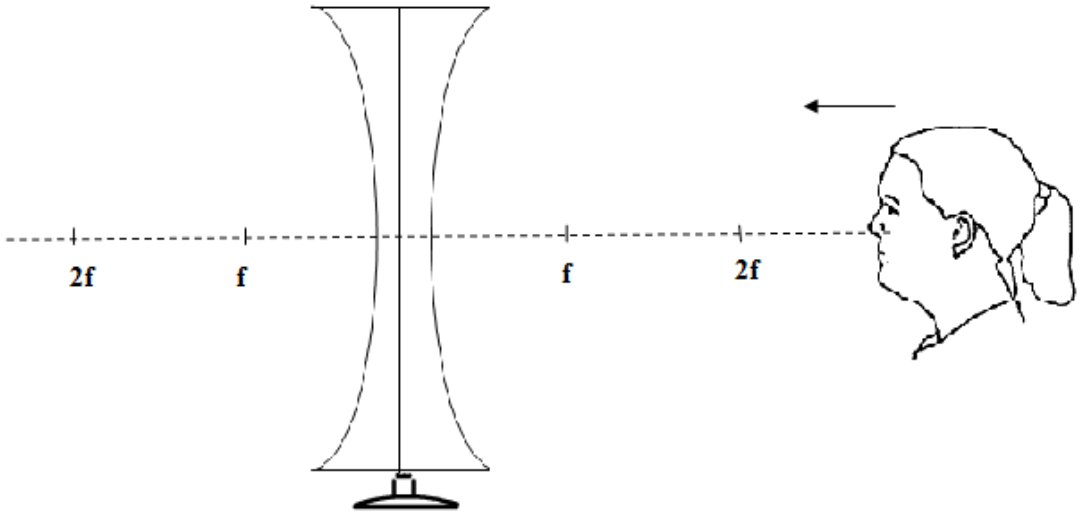
23)



A1. Selin şekilde gösterilen mesafelerden ince kenarlı bir merceğe bakarak mercekte yüzünün görüntüsünü görmek istemektedir. Selin ok işareti yönünde merceğe yaklaşırken başının hangi pozisyon ya da pozisyonlarında kendi görüntüsünü görebilir? Bu durum(lar) için ayrı ayrı görüntünün yeri ve özelliklerini yazınız.

A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

24)



A1. Selin şekilde gösterilen mesafelerden kalın kenarlı bir merceğe bakarak mercekte yüzünün görüntüsünü görmek istemektedir. Selin ok işareti yönünde merceğe yaklaşırken başının hangi pozisyon ya da pozisyonlarında kendi görüntüsünü görebilir? Bu durum(lar) için ayrı ayrı görüntünün yeri ve özelliklerini yazınız.

A2. Yukarıdaki soruya verdiğiniz cevabın nedenini açıklayınız.

Table I.1 Table of Specification for the Open-Ended Test

CASE / CONTEXT		OBSERVING ONESELF	Subtotal	OBSERVING OTHERS	Subtotal	TOTAL
Plane Mirrors	**Plane Mirror**	5 7	2	1 2 3 4 6 8	6	8
	Hinged Mirrors	18	1	17 19	2	3
Spherical Mirrors	**Concave Mirror**	12 14	2	9 16 11	3	5
	Convex Mirror	13 15	2	10	1	3
Lenses	**Converging Lens**	23	1	20 21	2	3
	Diverging Lens	24	1	22	1	2
TOTAL		9		15		24

APPENDIX J

OPEN-ENDED TEST ADMINISTRATION GUIDE

TESTİN UYGULANIŞINA İLİŞKİN YÖNERGE

1) Öğrencilerin testin giriş sayfasındaki açıklamaları okumasını ve ilk sayfayı **eksiksiz** doldurmasını sağlayınız.

2) Sınav süresi **90 dakika** (1,5 saat) olarak önerilmektedir. Daha fazla süreye ihtiyaç duyan öğrencilere imkanlar el verdiği ölçüde izin verilebilir.

3) Sınavda ihtiyaç duyulabilecek **formüllerin** testin kapak sayfasının arka yüzünde olduğu hatırlatılmalıdır.

4) Sınav sırasında mutlaka öğrencilerin başında bir gözetmen bulunması ve bilgi alışverişine izin verilmemesini sağlayınız.

5) Sınavda öğrencilerin cevapları kadar bu cevabı vermelerindeki **nedenleri** de tam ve eksiksiz doldurmaları gerektiğini hatırlatınız.

6) Sınav bitiminde testleri toplayıp (boş testlerle birlikte) aşağıdaki adrese kargo ile **karşıdan ödemeli (ücreti alıcıdan tahsilli)** olarak en kısa zamanda postalayınız.

Adres:

Derya KALTAKÇI

Eğitim Fakültesi, OFMAE Bölümü, Oda no: 205

ODTÜ, 06800, Ankara

Telefon(iş): 0312 210 6489

7) Sınav sırasında karşılaşılan herhangi bir sorun ya da önerilerinizi bu kağıdın arka sayfasına yazabilirsiniz.

8) Sınavın uygulanmasında emeği geçen herkese çok teşekkür ederiz. Saygılarımızla.

Araştırmacı: Arş. Gör. Derya KALTAKÇI

Tez Danışmanı: Yrd. Doç. Dr. Ali ERYILMAZ

Sınava giren öğrenci sayısı:

Sınavı uygulayan kişininin:

Adı-Soyadı:

E-posta adresi:

Kurumu:

APPENDIX K

SUBJECTS' ANSWERS AND REASONINGS TO THE OPEN-ENDED TEST ITEMS

DÜZLEM AYNALAR

Item 1.A.

- **ANSWER TYPE 1:** 1,2,3 ve 4

1. Aynanın görüntüsü arkada oluşmaz (1)
2. İlerlerken tüm noktalardan geçeceği için hepsinin görüntüsünü görür *(kedilerin görüntüsünden aynanın sol sınırına tek bir ışın çizip, kesikli çizgiyi kestirmiş)* (4)
3. Çünkü dört kedi de aynanın önündedir. Dolayısıyla hepsinin farklı bakış açılarından görüntüsü görülebilir (5)
4. H_1'deyken 3'ü görür; H_2'deyken 2'yi ve 3'ü görür; H_3'teyken hepsini görür; H_4'teyken 1,2 ve 4'ü görür; H_5'teyken 1 ve 2'yi görür; H_6'dayken 1'i görür. Görüş açısından dolayıdır. (11)
5. Hepsini görür. Nedeni görüş açısıdır. Bütün kediler aynanın görüş alanındadır.(12)
6. Çizgide ilerledikçe kedilerin görüntülerini görmeye başlayacaktır. (14)
7. Hasan çizgi boyunca yürüdüğü için aynadan çok geniş aralıkları görebilir. (15)
8. Bir kediden aynanın kenarlarına çizgiler çekerim ve aynanın normaliyle eşit açı yapacak şekilde bir daha çizgi çizerim. En son çizdiğim bu çizgilerin arasındaki alanda olan biri bu kediyi görür. Aynı işlemi bütün kediler için yaparım ve hepsini görebileceğini görürüm. Görüntüsü ise bu alan içinde nerden bakarsam bakayım aynaya eşit uzaklıkta ve diktir. (16)
9. Düzlem aynada görüntü ile cisim aynaya göre simetriktir ve cismin aynaya olan uzaklığı ile görüntünün aynaya olan uzaklığı birbirine eşittir. (18)
10. 1,2,3,4 görüntüsü oluşur ve Hasan girerken 1,2,3; çıkarken de 4'ü görür. Görüntülerin görüş alanı Hasan'ın görüş alanında bulunur. (19) (28)
11. Yansıma yöntemi ile çizildiği için.(20)
12. Bakılan açıya göre hepsinin görüntüsü oluşur.(23)
13. Her cismin aynada görüntüsü vardır. (24)
14. Farklı açılardan bakıldığında hepsinin görüntüsü oluşur.(25)
15. Yansıma kuralına göre hepsinin görüntüsü oluşur. Ancak gözlemcinin bulunduğu yere göre sanal görüntüleri görme durumu değişir.(30)
16. İlgili şekiller çizildiğinde görüntülerin oluştuğu ortaya çıkıyor. (31)
17. Hepsinin görüntüsü oluşur ve biri hariç hepsini görür. (32) *(4 numaralı kedi hariç)* (33) *(1 numaralı kedi hariç)*
18. Bakış açısıyla ilgili. Hasan ilk girdiğinde biri hariç hepsini görür. 1. nin görüntüsü oluşur ama Hasan görmez, en son onu görür.(34)
19. Cismin görüntüsü aynaya göre simetriktir. (35)
20. Kedilerin aynadaki yansımalarına göre yol üzerinde farklı noktalarda kediler görünür. (36)
21. Düz aynada simetrisi alınır. (42)
22. Hepsini görür çünkü aynanın iki ucuna ışınlar çizersek diğer tarafta görüntüler bu kollar arasında kalır. (43)
23. Hasan'ın bulunduğu noktaya bağlı. (46)
24. Düzlem aynanın iki ucuna dikmeler gönderdiğimizde. (Görüntüler aynanın ön yüzünde Hasan'ın yürüdüğü yola simetrik) (50)
25. 2 ve 3. kedilerin görüntüsü aynı yerde. *(Kedilerden aynanın herhangi bir yerine ışın çizip normalle eşit açı yapacak şekilde yansıtılmış. Görüntüler yansıyan bu ışınlar üzerine, görüntüler aynanın önünde oalacak şekilde yerleştirilmiş)* (52)

- **ANSWER TYPE 2:** 1, 2 ve 3

1. Düzlem aynaya paralel, kediye eşit uzaklıkta bir ayna koyduğumuzda hangi kedilerin görüntülerinin oluştuğuna bakarız. *(Hayali bir ayna çizip, bu aynada kedilerin görüntüsünü belirlemiş)*(10)
2. 4 numaralı kediyi göremeyiz önünde 3 numaralı kedi olduğundan. (13)
3. 3, 4'ün önünde engeldir.(21)
4. Aynaya her bir kediden ışın yolladığımızda 1,2,3 numaralı kedilerin görüntülerinin oluştuğu, 4 numaralı kedinin ise ya aynaya ışının ulaşamadığı ya da 2 numaralı kedi tarafından engellendiği görülür.(22)
5. Aynaya kedilerden ışın yolladığımızda 1,2 ve 3'ten çıkanlar ulaşırken 4' ten çıkanlar ulaşamaz.(29)
6. Yansıma olayından dolayı kedilerin görüntüsü aynanın arkasında oluşur. (38)
7. İlk önce odaya girdiğinde aynaya ışık gönderdiğimizde 1,2 ve 3 numaralı kedilere ışık gider fakat 4 numaralı kedi ışık görmediği için (3. kedi engeller) görünmez. (40)
8. 4 numaralı kedinin yansıması Hasan'ın görüş açısına girmediği için göremez. (44)
9. 1,2,3 numaralı kedilerin görüntüsü düzlem aynada yansır. Ancak 4. kedi 3. kedinin arkasında olduğu için görüntüsü yansımaz. (45)

- **ANSWER TYPE 3:** 1 ve 2

1. Düzlem aynada görüntü direk simetriğinde oluşur. Bu nedenle 1 ve 2 nin görüntüsü oluşur, 3 ve 4'ün oluşmaz. (3)
2. 1 ve 2 numaralı kediler kendilerini görürler ve görüş alanı içinde kalırlar.(6)
3. Düzlem aynada görüş açısı içinde kalan kedilerin görüntüsü aynanın arkasında eşit birim uzaklıkta oluşur. (17)
4. Aynanın karşısındalar. (27)
5. Ayna sınırları içindeki kedilerin görüntüsü oluşur.

- **ANSWER TYPE 4:** 1, 2 ve 4

1. Düzlem aynada cismin görüntüsü aynanın arkasında ve cismin aynaya olan uzaklığı ile aynıdır (kedilerden aynanın herhangi bir yerine ışın çizilip arkaya doğru uzatılmış ve o çizgi üzerinde işaretlenmiş.) (2) (48)

- **ANSWER TYPE 5:** 2 ve 3

1. 2. ve 3. kediler görüntü alanına girdiği için görüntüleri Hasan'da gözükür. (39)
2. Işığın aynadaki yansımaları çizilerek gösterilebilir.(*Görüntü ayna ile aynı tarafta bulunmuş)* (49)

- **ANSWER TYPE 6:** 1 ve 4

1. Düzlem dalgalar aynanın arka tarafında zahiri ve simetrik bir görüntü oluşturur. *(1 ve 4 nolu kedilerden aynanın sol kenarına çizgi çizip aynaya eşit mesafeye görüntü yerleştirilmiş)* (51)

- **ANSWER TYPE 7:** 2 ve 4

1. İki yansıyan ışın arasında 2 ve 4 nolu kediler vardır *(Hasan herhangi bir yerde iken aynanın iki ucuna ışın çizip arada kalan kedileri değerlendirmiş)* (7)

- **ANSWER TYPE 8:** 3 ve 4

1. 1. ve 2. kedilerin düzlem aynada oluşan görüntülerinden aynanın uçlarına iki ışın çizersek göründükleri bölge aynanın dış tarafında kalır. Bu yüzden Hasan 1 ve 2. kediyi göremez. Ama 3. ve 4. kedilerin görüntülerinden aynaya çizilen ışınlar ayna boyunca 3. ve 4. kedilerin görüntü alanlarını içine alır. Bu yüzden 3. ve 4. kedileri görür. *(Kedilerden aynanın sağ yada sol sınırına ışın çizip bu çizgi uzerinde aynaya eşit mesafede görüntünün yerini belirttikten sonra bu görüntü pozisyonlarından aynanın sağ ve sol sınırına ışın çizip oluşan bölgede ilgili kedinin kendinin bulunup bulunmamasına bakmış)* (9)

Item 1.B.

- **ANSWER TYPE 1:** 3,2,4,1

1. Hasan odaya girerken bakış alanı olarak ilk 3 numaralı kedinin görüntüsü girer, daha sonra görüş alanı yürüdükçe değişeceğinden diğer görüntüleri görmüş olacaktır.(5)
2. Nedeni görüntünün aynaya göre görüntüsünün alınmasıdır. Yani görüntünün görüntüsü. (12)
3. Görüntülerin aynada görülebileciği için görüntülerin ayna üzerinden Hasan'ın en erken görebileceği şekilde yollar çizerek Hasan'ın yolunun en başına gelen görüntüler daha erken görüleceğinden bu şekilde yaptım. (15)
4. A2 de açıkladığım çizgiler arasındaki alanın sol kapıdan taraftaki sınırı 3,2,4,1, diye sırayla başlar. Gözlemci de sol kapıdan girip sağ kapıya doğru ilerleyeceği için bu sıraya göre görür. (16)
5. Odanın kapısına geldiğinde görüş alanında sadece 3 numaralı kedi vardır. Odaya girip ilerledikçe görüş alanı değişir ve 2., 4. ve sonra 1. kediyi görür. (18)
6. Görüş alanı kesikli çizginin en solundan başlamasına göre sıralama yapılır. (23)
7. Cisim-Gözlemci terslemesi kullanılarak, görüş alanı kesikli yolun en solundan başlamasına göre sıralama yapılır.(*Aynanın arkasına kedilerin görüntüsü bulunmuş, görüntüden aynanın sınırlarına ışın çizip kedilerden bu alanda kalanları görür*) (25)
8. Gerekli çizim yapıldığında cevap bulunur. (27)
9. Görüş alanları çizildiğinde ortaya çıkıyor. (31)
10. Hasan'ın görüş alanı çizildiğinde ilk olarak 3 nolu kediyi görebilir. İlerlemeye başladıkça sırasıyla 2,4,1 nolu kedileri görebilir. (35)
11. Kedilerin görüntü sıralamasını istediği için. (37)
12. İlerleme doğrultusunda yine iki ucuna dikmeler gönderdiğimizde önce 3 sonra 2,4,1 görülür. (50)
13. Sebep yok. (26)

- **ANSWER TYPE 2:** 1,2,3

1. 1,2,3 şeklinde görür. 4'ü göremez çünkü 4. kedi gözlemcinin arka tarafındadır. (8)
2. 4 ün görüntüsü 3 önünde engel olduğu için oluşmaz. Aynada baktığında sırasıyla 1,2,3 ü görür.(21)
3. Aynaya en yakın 1'in görüntüsü en uzak 3'ün. (32)
4. Sebep yok (13)

- **ANSWER TYPE 3:** 3,2,1

1. Odaya ilk girdiğinde ayna üzerine ışın gönderirsek tam yansımadan dolayı önce 3 sonra 2 en sonda da 1 görünür. (40)
2. Sebep yok. (22) (29) (44)

- **ANSWER TYPE 4:** 1,2,3,4

1. Çünkü düzlem aynada sırasıyla 1,2,3 ve 4'ün görüntüsü vardır. (1)
2. Aynanın iki ucuna ışınlar çizersek diğer tarafta görüntüler bu kollar arasında kalır. (43)
3. Hasan çizgi üzerinde ilerlerken görüş açısı sırasıyla olur. (46)

- **ANSWER TYPE 5:** 3,4,1,2

1. Görüntülerin görüş alanı 3,4,2,1, sırasıyla girişten çıkışa doğrudur.(19)
2. Hasan'ın çizgili yolda ilerlerken her adımda ondan aynaya ışın çizdim ve yansımalarına baktım. Hangi numaraları kapsıyorsa onları görüyordur. (20)
3. Çünkü cisimlerin görüntülerinin görüş alanları bu sırayla girişten çıkışa doğrudur.(28)

- **ANSWER TYPE 6:** 1,2,4,3

1. Hasan cisimleri aynada görür. (*Hasan çizgi üzerinde ilerlerken aynanın herhangi bir yerine ışın çizip yansıtmış*) (24)
2. Hasan'ın ilerlediği yola göre görüş alanı içerisine sırayla bu kediler girer. (30)
3. Sebep yok. (45)

- **ANSWER TYPE 7:** 1,2,3=4

1. Yol üzerinde ilerlerken aynadan 1 i ve 2 yi sonrasında 3 ve 4'ü (*kedilerin kendisini*) aynı anda görür. (3)
2. Önce 1, sonra 2, daha sonra 3 ve 4 aynı anda. Çünkü görüntülerin yerleri Hasan'a yakın. (6)

- **ANSWER TYPE 8:** 3,4,2,1

1. Hasan ilk göründüğünde aynanın ön kısmının ucundan diğer ucunu gözlemlediğinde 3,4,2,1 sırası ile görür. (39)
2. Hasan çizgili yolda ilerlerken her adımda ondan aynaya ışın çizdim ve yansımalara baktım. Hangi numaraları kapsıyorsa onları görüyor.

- **ANSWER TYPE 9:** 4,2=3,1

1. Kedilerin aynadaki görüntülerinin uzantılarını çizdim. 4' noktasına vardığında 4. kediyi görür. Sonra işaretli yerlere geldikçe sırasıyla diğer kedileri de görür. (Kedilerin görüntüsünden aynanın sol sınırına tek bir ışın çizip, kesikli çizgiyi kestirmiş)
2. Sebep yok. (52)

- **ANSWER TYPE 10:** 2,3,4,1

1. Aynaya en yakın 2 nin görüntüsü en uzak 4 ayrıca bakış açısıyla ilgili.(34)
2. Düzlem aynada gelen ışınlar gelme açısıyla yansırlar. Bundan dolayı Hasan yansımaları bu sıra ile görür. (36)

- **ANSWER TYPE 11:** 2,4,3,1

1. Şekilde çizdiğim gibi oluşan görüntülere baktığı zaman kapsadığı alandır. (14)

- **ANSWER TYPE 12:** 4,1,2,3

1. Çünkü önce aynada 4 numaralı kedinin görüntüsü oluşur. Daha sonra ötekilerin. (47)

- **ANSWER TYPE 13:** 4,3,2,1

1. Düzlem aynadaki görüntüyü incelemek için. (41)

- **ANSWER TYPE 14:** 3,2=4,1

1. Kedilerin aynadaki görüntülerinin uzantılarını çizdim. 3' noktasına vardığında 3. kediyi görür. Sonra işaretli yerlere geldikçe sırasıyla diğer kedileri görür.(*Kedilerin aynanın arkasındaki görüntülerinden aynanın sol sınırına ışın çizip, kesikli çizgiyi kesme sıraları karşılaştırılmış*) (4)

- **ANSWER TYPE 15:** 1,3,2,4

1. Taradığı alandan ilk hangisi görünürse onu görür. (42)

- **ANSWER TYPE 16:** 1,2,4

1. Sebep yok. (2)

- **ANSWER TYPE 17:** 1,3,2

1. Görüntü çizgilerine baktığımıda sıralama bu şekilde oluyor. *(Hayali bir ayna çizip, bu aynada kedilerin görüntüsünü belirlemiş)* (10)

- **ANSWER TYPE 18:** 2,1,4

1. Hasan'ın bakış açısından dolayı önce 2 sonra 1 ve daha sonra 4'ü görür. (48)

- **ANSWER TYPE 19:** 2,3,4

1. Aynaya en yakın 2 nin görüntüsü en uzak 4 (*Hasan odaya girdiğinde aynanın sol kenarına ışın çizip yansıtmış*) (33)

- **ANSWER TYPE 20:** 2,3

1. Sebep yok. (49)

- **ANSWER TYPE 21:** 3,4

1. 3. kedinin görüntüsünden çizilen ışınların oluşturduğu alan 4. kedinin oluşturduğu alandan önce geliyor. Yani Hasan ilerledikçe önce 3. kedinin görüntüsünün alanını görüyor (*Kedilerden aynanın sağ yada sol sınırına ışın çizip bu çizgi uzerinde aynaya eşit mesafede görüntünün yerini belirttikten sonra bu görüntü pozisyonlarından aynanın sağ ve sol sınırına ışın çizip oluşan bölgede ilgili kedinin kendinin bulunup bulunmamasına bakmış*) (9)

- **ANSWER TYPE 22:** 2,4

1. Gelen ve yansıyan ışınları çizdiğimizde iki yansıyan ışın arasında önce 2 nolu kediyi, daha sonra Hasan ilerlediğinde 4 nolu kediyi görür. *(Hasan herhangi bir yerde iken aynanın iki ucuna ışın çizip arada kalan kedileri değerlendirmiş)*(7)

- **ANSWER TYPE 23:** 1,2

1. Birinci kedi daha öndedir. (17)

- **ANSWER TYPE 24:** 1,4

1. Hasan çizgi üzerinde ilerlerken görüş açılarına göre ışınlar gönderdim. Aynanın normali ile aynı açıyı yapan ışınların devamını arkasında ilerlettim arada kalan alan görüş alanıdır. Böylece yorumlarımı yaptım. (51)

Item 2.A.

- **ANSWER TYPE 1:**1, 2, 3 ve 4

1. Çünkü dört cisimde görüş alanı içindedir. (1)
2. Çünkü dört cisimde görüş alanındadır. (2)
3. Hepsinin görüntüsü oluşur. Ancak farklı yerlerde oluşur. Aynı yerden bakan birisi tüm görüntüleri göremez. Ancak farklı yerlerden uygun açılarla bakılırsa hepsinin görüntüsünü aynada görebiliriz. (4)
4. Hepsinin görüntüsü oluşur ancak görebilmek için farklı görüş alanları oluşturmak gerekir. Ayrıca tüm kediler aynanın önündedir. (5)
5. Görüntülerin aynaya olan uzaklığı, cismin aynaya olan uzaklığının iki katıdır. (8)
6. Kedilerin aynadaki görüntülerinden aynanın uçlarından çizilen ışınlar doğrultusunda hepsinin içeride görüntüsü oluşur. (9)
7. Düzlem aynada görüntü ile cismin aynaya göre simetrik olması gerektiği göz önüne alınırsa hepsinin görüntüsü oluşur. (18)
8. Yansıma kanunu. (20)
9. Farklı noktalarda tüm görüntüleri görür. (23)
10. Düzlem aynaya bakan birinin arkada görüntüsü oluşur. (24)
11. Hareket halindeki gözlemci farklı noktalardan tüm görüntüleri algılar. (25)
12. Yansıma kuralına göre hepsinin görüntüsü oluşur. Ancak baktığımız yere göre görüntüsünü gördüğümüz cisim değişir. (30)
13. Simetri. Düzlem aynada görüntü aynı uzaklıkta. (32) (33)
14. 1. kediyi göremez çünkü hiç görüş açısına girmiyor. (46)
15. Görüş alanı. (48)
16. Çünkü ayna simetrik olarak bütün görüntüleri yansıtır. (51)
17. Sebep yok. (6) (26) (41) (43) (52)

- **ANSWER TYPE 2:** 2, 3 ve 4

1. Görüş açısından dolayıdır. (*Çizgi üzerinde ilerlerken Hasan'ın görebildiği kediler belirlenmiş*) (11)
2. Nedeni görüş açısıdır. (12)
3. Görüş alanı. (14)
4. Hasan yürürken ayna üzerinden görebileceği alan içinde sadece 2,3, ve 4 vardır. (15)
5. Çünkü 1. kedinin aynada görebileceği alan Hasan'ın yoluyla çakışmaz. Diğer kedilerinki çakışır. (16)
6. Görüş alanları Hasan'ın geçtiği yere dahildir. (31)
7. Düzlem aynada görüntü aynı uzaklıkta. (34)

8. Aynadaki kedilerin yansımasından dolayı Hasan'ın aynadaki görüş açısı bunlardır. (36)
9. Görüntü yerleri ve görüntü oluşumunu istediği için. (37)
10. Ayna düzlemine simetrik olarak arka tarafta görüntülerini çizdik ve ayna yüzeyine gönderilen ışınlar kedileri görürse görüntü oluşur. (40)
11. Sebep yok. (50)

- **ANSWER TYPE 3:** 1, 2 ve 3

1. 4'ün önünde engel var. (21)
2. 1. soru A2 ile cevabım aynı. (*Aynaya her bir kediden ışın yolladığımızda 1,2,3 numaralı kedilerin görüntülerinin oluştuğu, 4 numaralı kedinin ise ya aynaya ışının ulaşamadığı ya da 2 numaralı kedi tarafından engellendiği görülür*.) (22)
3. Önceki soruyla aynı. (*Aynaya kedilerden ışın yolladığımızda 1,2 ve 3 'ten çıkanlar ulaşırken 4 ten çıkanlar ulaşamaz*.) (29)
4. Yansıma olaylarından dolayı kedilerin ayna arkasında görüntüleri oluşur. Fakat 4. kedinin görüntüsü oluşmaz. Sebebi ise 4'ten çıkan ışın 3'e çarpıp aynaya ulaşmadan geri yansır. (38)
5. 4. kedinin görüntüsü oluşmaz.(45)

- **ANSWER TYPE 4:**1 ve 2

1. Düzlem aynada görüntü direk aynanın arkasındaki simetriğinde olur. 1 ve 2 numaranın direk düzlem aynanın arkasında olduğundan (simetriği) görüntüsü oluşur. (3)
2. Aynanın görüş alanındaki noktalar olduğu için. (17)
3. Sebep yok. (27)

- **ANSWER TYPE 5:** 3 ve 4

1. Görüntü alanına girdiği için, görüntülerini görür. (39)
2. 3 ve 4 numaralı kedilerin görüntüsü düzlem aynada görülür. Ancak 1 ve 2'nin görüntüsü yoktur. (47)

- **ANSWER TYPE 6:** 2 ve 3

1. İki yansıyan ışın arasında 2 ve 3 nolu kediler vardır. (7)
2. Işığın yansımaları kullanılarak bulunur. (49)

- **ANSWER TYPE 7:** Yalnız 3

1. Hasan yolunu değiştirdiği için Hasan'ın tek görebildiği kedi 3 numaralı kedi olacaktır. (*Aynanın aynı tarafta görüntüsünü çizmiş ve kedilerin buna göre simetriğini almış*) (10)

- **ANSWER TYPE 8:** Yalnız 1

1. İkisinin ortak kesiştiği taralı alanda yalnız 1 var.(*2, 3 ve 4 nolu kedilerden aynanın iki sınırına ışın gönderip eşit açı ile yansıttığında oluşan üç bölgenin kesiştiği bölgede 1. kedinin olduğunu göstermiş*) (42)

- **ANSWER TYPE 9:** Yalnız 4

1. Diğerlerinin yansıması Hasan'ın görüş açısına girmediği için göremez. (44)

Item 2.B.

- **ANSWER TYPE 1:** 2, 4, 3

1. Hasan yolda yürüdükçe görüş alanı değişeceğinden sadece 2,4,3 'ü görür. Görüş alanına girmeyen 1 numaralı kediyi ise göremez. (5)
2. Görüş alanı en son 3'ün görüntüsüne doğru kayar. (14)
3. Yansıma ile ışın yollayıp. Hasan'ın her adımda görebileceği alan değişir. (20)
4. Görüş alanı çizildiğinde ilk görünen 2, daha sonra 4, sonra 3 görünüyor. (31)
5. Kedilerin görüntü sırasını istediği için. (37)
6. Bu belirttiğimiz kedilerden çıkacak ışınlar, kesikli çizgi üzerinde ilerleyen Hasan'a ulaşacağından bu kedilerin görüntülerini görür. (38)
7. Burada ışınları gönderdiğimiz zaman ilk durumda 4,3,ve 1 numaralı kediler görünmez. Fakat Hasan ilerledikçe 2,4 ve 3 sırasıyla görünür olur. Ancak 1 numaralı kedi yol boyunca görünmezdir. (40)

8. İlerleme doğrultusunda aynanın her iki ucuna dikmeler çizdiğimde önce 2-4-3 görmüştür. (50)

- **ANSWER TYPE 2:** 2,3,4

1. 1 nolu kedi Hasan'ın görüş alanına girmez. (23)
2. 1 nolu kedi Hasan'ın görüş alanına girmiyor. Diğer kedileri de kendisine olan yakınlığı ile orantılı şekilde görür. (25)
3. 1'i görmez kapıdan bakınca. (34)
4. Sebep yok. (32) (33) (46)

- **ANSWER TYPE 3:** 2=4, 3

1. Görüş açısına giren kedilerin görüntüsünü görür, sonra kedilerin görüntüsü görüş açısından çıkar. (11)
2. Aslında 2'yi daha önce görmesi gerekir fakat duvardan göremez. Duvar bittiği yani aynayı gördüğü anda 2 ve 4 ayna üzerinden görme alanı içerisinde olur ve ikisini aynı anda görür. (15)
3. 4 ile 2'yi kapıdan girdiği anda görmeye başlar; 3. kediyi üç kare ötede görmeye başlar. 4. ve 2. kedilerin aynada görülebildikleri alan kapıyı da içine alırken, 3. kedinin aynada görülebileceği alan sınırı üç kare öteden başlar. (16)
4. İlerleme doğrultusu boyunca, görüş alanını çizdiğimizde ilk olarak 2 ve 4'ü, ardından 3'ü görebileceğini buluruz. Fakat 1 numaralı kediyi göremez. Çünkü yol boyunca hiçbir noktada görüş alanının içinde bulunmaz. (18)
5. Sebep yok. (26)

- **ANSWER TYPE 4:** 1,2,3,4

1. Hasan odaya girdiğinde görüntülerden Hasan'a en yakın olanı 1'in görüntüsüdür. 2-3-4 sırasıyla devam ediyor. (35)
2. Sebep yok. (1) (2) (28)

- **ANSWER TYPE5:** 3,4,2,1

1. Çünkü Hasan'dan düzlem aynaya iki ışın gönderirsek o ışınlar arasında kalan yerleri görür. (43)
2. Cevap yok. (41) (44)

- **ANSWER TYPE 6:** 2,3

1. Hasan ilerlediğinde gelen ve yasıyan ışını çizeriz, önce 2 nolu kediyi görürüz. Biraz daha ileri gittiğinde gelen ve yansıyan ışını çizeriz ve 3 nolu kediyi görürüz. (7)
2. Doğrusal yolda ilerleyen Hasan'ın gözünden çıkan ışıkla aynada ilk görüntü veren kedi 2 numaralı sonra 3 numaralı kedidir.(49)

- **ANSWER TYPE 7:** 4, 1=2=3

1. Hasan kesikli çizgi üzerinde ilerlerken önce 4 numarayı, sonra 1,2,3 'ü görecektir. Çünkü yolda ilerlerken görüş alanına bu sırada girecekler. (3)
2. Yerleri. (6)

- **ANSWER TYPE 8:** 1=2=3

1. Çünkü Hasan aynaya dik yönde ilerliyor. (8)
2. Hasan'ın birim kare ilerlediğini ve çapraz görmediğini düşünerek bu cevabı verdim. (21)

- **ANSWER TYPE 9:** 2,4,3,1

1. Aynanın iki ucuna ışınlar gönderilir ve iki alanda kalanlar görülür. (24)
2. Birim kare yol aldırarak ışınlar yolladık. (29)

- **ANSWER TYPE 10:** 2,3,1

1. Birer birim kare yol aldırarak ışın yolladım. (22)
2. Gerekli çizim yapıldığında sonuca ulaşılır. (27)

- **ANSWER TYPE 11:** 3,2=4

1. Görüntülerin doğrultularını çizdiğimizde 1'in yolu Hasan'ın yoluyla kesişmez. 3'ü ilk görür. Sonra ise 2 ve 4'ü görür. (4)

- **ANSWER TYPE 12:** 3,2,4

1. Görüntünün görüntüsü. (12)

- **ANSWER TYPE 13:** 2,1

1. Çünkü bu defa Hasan düşeyde yürümektedir. (17)

- **ANSWER TYPE 14:** 3,2

1. Çünkü Hasan'ın gittiği yolda 3. kedinin görüntüsünden yollanan ışın 2. kedininkinden daha önde. (*3 ve 4 nolu kedilerin görüntüsü kedilerden aynaya yollanan çizgi üzerinde bulunmuş. Görüntülerden ayna sınırlarına çizilen ışınlardan yalnızca 2 ve 3'ten gelenler Hasan'ın yolunu kesmiş*) (9)

- **ANSWER TYPE 15:** Yalnız 3

1. A2'nin aynısı. (*Hasan yolunu değiştirdiği için Hasan'ın tek görebileceği kedi 3 numaralı kedi olacaktır*.) (10)

- **ANSWER TYPE 16:** 3,4,2

1. Hasan'ın yoluyla kedilerin yansımalarının kesiştiği nokta sıralamasına göre belirlenir. (36)

- **ANSWER TYPE 17**: 4,3,2

1. İlk önce aynadan görüntü alınan 4-3-2. (47)

- **ANSWER TYPE 18**: 2,4

1. Hasan'ın görüş alanına girdiği için 2 ve 4. kedileri görür. (39)

- **ANSWER TYPE 19**: Yalnız 1

1. İkisinin ortak kesiştiği ortak alan yalnız 1. (42)

- **ANSWER TYPE 20**: Yalnız 2

1. Görüş alanı. (48)

- **ANSWER TYPE 21**: 1,4

1. Yolun başında Hasan 4. kediyi göremez sadece 1. yi görür, ilerledikçe de 1. yi göremez 4.'yü görür. Görüş alanı çizgilerini Hasan'ın yerine göre çizdiğimizde gördükleri belli olur. (51)

- **ANSWER TYPE 22:** 2,1,3,4

1. Sebep yok. (13)

- **ANSWER TYPE 23:** 3,2,1

1. Sebep yok. (30)

- **ANSWER TYPE 24**: 1,2,3

1. Sebep yok. (45)

- **ANSWER TYPE 25**: 4,2=3,1

1. Sebep yok. (52)

Item 3.A.

- **ANSWER TYPE 1**: 1 ve 2

1. 2 numaralı 5 birim kare yol aldıktan sonra hasan'ın görüş alanına girer. Ancak 1 numaralı kedi 5 birim kare yol aldığı zaman halen görüş alanının dışındadır. (5)
2. Görüş alanı. (6)

3. 2. kedi Hasan'ın görüş alanına daha önce girer. (8)
4. Sırasıyla ikisinin de görüntüsü oluşur. (1)
5. Odaya girdikleri andan itibaren iki kedinin de görüntüsü düzlem aynada oluşur. (2)
6. Her iki kedinin de görüntüsü nokta ile gösterilen yerlerde olur. Düzlem aynada görüntü tam simetriğinde oluştuğundan görüntüler bu şekildedir. (3)
7. Kediler işaretli alandan geçerken Hasan'ın görüntüsü bu aralıkları görebildiği için her iki kediyi de görür. (4)
8. Her ikisinin de oluşur, çünkü düzlem aynanın önündeler. (5)
9. Hareket ettikleri için A-B arasında sürekli görüntüleri değişir. (6)
10. Aynaya çizilen ışınlar içeri giriyor. (9)
11. 1 ve 2 numaralı kediler 1' ve 2' numaralı ışınların (Hasan'dan aynanın uçlarına çizilip yansıyan ışınların) arasında olduklarında görüntü oluşur. Kediler belli bir yerde sabit durmuyor, hareket halinde oldukları için belli bir nokta belirtemeyiz. Dolayısıyla Hasan'dan düzlem aynaya ışınlar göndeririz ve görüntülerin bu ışınlar arasında oluşabileceğini söyleyebiliriz. (10)
12. Hasan'ın görüş açısı şekildeki gibidir (*Hasan'dan aynanın iki ucuna ışın çizip aynanın arkasına uzatmış*). Bu yüzden onun görüş açısına giren kedileri (*kedilerin görüntülerini*) şekildeki gibi görür. (11)
13. İkisini de görür. Sabit yerleri yoktur. Yukarıdaki çizilen aralıkta(*Hasan'ın görüntüsünden aynanın uçlarına ışın çizip uzatmış*) görüntüleri oluşur.Nedeni görüntünün oluşması, yansıma vs. (12)
14. Çizikli şekle göre *(Hasan'ın görüntüsünden aynanın uçlarına ışın çizip uzatmış* 1,2. (14)
15. 1 ve 2 numaralı kedilerin görüntüleri bir yerde oluşmaz. Hasan'ın ayna üzerindeki görme alanında ilerler ve Hasan'ın görme ekseni boyunca görüntü oluşur. (15)
16. Çünkü iki kedi de farklı zamanlarda Hasan'ın aynadaki görüş alanına girer ve farklı zamanlarda çıkar. Hasan kendi hizasındayken kedileri aynada görür, çünkü Hasan'ın göz hizası kedinin boyundan büyüktür. (16)
17. Önce 2'nin görntüsü oluşur. Aynı sürede 2 nolu kedi aynanın görüş alanına girmiş olur. (17)
18. Kediler şekildeki konumda iken aynada görüntüleri oluşmaz. Kediler odadan içeri girdiği anda birer görüntü oluşur, kediler yol boyunca ilerlerken görüntüleri de aynı hızla ilerler. (18)
19. İkisinin de görüntüsü oluşur. 1,2 de görüntü oluşur. Kediler ilerledikçe görüntü yer değiştirir. (19)
20. Girişten itibaren çıkışa dek kedilerin görüntüsü oluşur. Işın çizerek, yansıma kanunları. (20)
21. İkisinin de oluşur. İlerledikçe yer değiştirir. (21)
22. Kediler hareket halinde olduğu için birden fazla noktada görüntüleri oluşur. (23)
23. Kediler sürekli hareket halinde oldukları için birden fazla noktada görüntüleri oluşur. (25)
24. İkisinin de görüntüsü oluşur. Ancak bunu çizemeyeceğim çünkü, hareket ettiklerinden görüntülerinin yerleri sürekli değişir. (26)
25. Kediler ilerledikçe görüntünün yeri değişir. (28)
26. Hasan'ın görüş alanını çizdiğimizde. (29)
27. İkisinin de ilk başta oluşmaz (*oda dışında iken*) (30)
28. İkisinin de oluşur, çünkü ikisi de aynaya doğru gelmektedir. (31)
29. İki kedinin de görüntüsü Hasan'ın aynadaki görüş alanına göre olur. Bu aralıkta önce 2 sonra ikisi birlikte sonra 1 görünür. Hasan'ın aynadan görebileceği alan doğrusal çizgilerle çevrelenen alandır da ondan. (36)
30. Görüntü yerleri istediği için. (37)
31. Yansıma. (38)
32. Aynadan gözüktüğü an kediler kendilerini görür. (39)
33. İlk önce aynada görebileceğimiz alanı aynanın her iki ucuna ışık göndererek belirledik, bu alana giren kediler görünmeye başlar. (40)
34. Eğer taralı alan (*Hasan'ın görüş alanı çizilmiş*) içerisine girerlerse görüntüleri oluşur ya da odaya ilk girdiklerinde görüntü oluşmaya başlar. (42)
35. Düzlem aynaya cisim ne kadar uzakta ise görüntü de aynanın arkasında o kadar uzağında oluşur. (43)
36. Hasan'ın görüş alanı. (46)
37. Çünkü kediler görüş alanına girdikleri için. (47)

38. Odaya girer girmez iki kedinin de görüntüsü aynada oluşur. Çünkü düzlem ayna arka tarafında zhiri ve simetrik bir görüntü oluşturur. (51)
39. İki kedi de aynı eşit hızda ilerler. (52)
40. Sebep yok. (32) (33) (34) (35) (48) (50)

- **ANSWER TYPE 2:** Yalnız 2

1. Hasan'ın görüş alanı çizilip kedileri eşit mesafede yürütttüğümde 2 nolu kedinin alana girdiğinde yalnız 2 oluşur. 1 henüz alana girmediği için oluşmaz. Ancak 10 ve daha fazla birim yürütürsem her ikiside oluşur.(22)
2. Görüş alanına sadece 2 numaralı kedi giriyor. (44)
3. Işık yol boyunca 2 ile görüntü oluşturur. (49)

- **ANSWER TYPE 3:** Görüntüleri oluşmaz

1. Çünkü aynayı görmezler. (8)
2. Ayna görmüyor. (24)

- **ANSWER TYPE 4:** Yalnız 1

1. 1'i görür. Hasan'ın görüş alanında 1 vardır. (13)

Item 3.B.

- **ANSWER TYPE 1**: 2,1

1. 2. kedinin Hasan'a uzaklığı daha fazladır. (1)
2. Hasan 2. Kediye daha uzak olduğundan düzlem aynadan görüş mesafesi daha fazladır. Bu nedenle Hasan önce 2. kediyi görür. (2)
3. Işınlar 2 numaralı kediye daha yakın. (10)
4. Önce 2 görüş açısına girer. (11)
5. Görüntü oluşabilecek alan önce 2 girer. (12)
6. Hasan'ın görüş alanına önce 2 numaralı girer. (14)
7. Hasan'ın ayna üzerinden görme alanına ilk 2 girer. (15)
8. Kedilerin hareket yolu ile Hasan'ın aynadaki görüş alanının çakıştığı yol 2. kediye daha yakındır. (16)
9. 2 nolu kedi odada ilerlerken görüntüsü de aynı hızla ilerler ve daha önce görüş alanına girer. (18)
10. Hasan'ın görüş alanına ilk 2 nolu kedinin görüntüsü düşer. (19)
11. Görüş alanına ilk 2 girer daha sonra 1. (21)
12. Eşit mesafede yürütüldüğünde ilk 2 bu alana girer. (22)
13. Görüş alanına önce 2 sonra 1 girer. (23)
14. Hasan'ın görüş alanına giren ilk kedi 2'dir. (25)
15. Gerekli çizim yapıldığında çözüm bulunur. (27)
16. Çünkü Hasan'ın görüş alanına ilk olarak 2 nolu kedinin görüntüsü düşer. (28)
17. Hasan'ın görüş alanına girebilmesi için 2'nin 9 birim; 1'in 10 birim ilerlemesi gerekir. (29)
18. Görüş alanına önce 2 nolu kedi girecektir. (30)
19. Görüş alanı 2. Kedinin geldiği yere daha yakın. (31)
20. Şekilde belli. (34)
21. Alanın şeklinden ve 2. kediye yakın olmasından dolayı böyledir. (36)
22. Sıralama istediği için. (37)
23. Aynada görünebilecek alana ilk giren kedi 2 numaralı kedi olduğu için ilk önce 2. Kedi görünür. Sonra da 1. görünür. (40)
24. Eşit sürede yol alırken ilk 2 numaralı taralı alana girer sonra 1 numaralı. (42)
25. Görüş alanı. (46)
26. Önce 2 görüş alanına girer. (47)
27. Hasan'ın bulunduğu konum. (48)
28. Düzlem aynanın görüş alanı içerisine 2 önce girdi. (50)
29. Önce 2 nolu kedi, ilerlerken yolu daha yakındır Hasan'a. (52)
30. Sebep yok. (26) (32) (33) (41) (45)

- **ANSWER TYPE 2:** 1,2

1. Çünkü Hasan'ın gözlem alanına önce o girecektir. (3)
2. Işın çizeriz görünen alanı belirleriz. Böylelikle hangisinin önce göreceğini saptarız. (20)
3. İkincinin yolu daha uzun. (24)
4. 1 numaralı kedinin görünüsü Hasan'a daha çabuk ulaşacağı için önce 1 nolu kediyi görür. (35)
5. Önce 1 numaralı kedinin görüntüsü görünür, sonra ikisinin görüntüsünü aynı anda ve aynı yerde görür. 1. kedi 2. den önce Hasan'ın görüş alanına giriyor. (38)

- **ANSWER TYPE 3:** İkisi aynı anda görünür.

1. Nedeni A2 deki ile aynı (*Düzlem aynaya cisim ne kadar uzakta ise görüntü de aynanın arkasında o kadar uzağında oluşur*) (43)
2. İkisi de aynı anda girdiğine göre aynı anda görünür. Hasan'ın görüş alanı belli, kedilerin giriş yerleri ve konumları belli olduğu için aynı anda görünür. (51)

- **ANSWER TYPE 4:** Yalnız 2

1. 2 daha önce görüş alanına girmiştir. (17)
2. 2. kedi Hasan'ın görüş alanına giriyor. (39)
3. Görüntü alanına ilk girdiği için. (49)

- **ANSWER TYPE 5:** Yalnız 1

1. Çizilen ışın 1. kedi üzerinde. (9)

Item 4.A.

- **ANSWER TYPE 1:** 1,2,3,4

1. Sevgi tırmanırken aynaya her türlü açı ile bakacağı için tüm lambaları görür. (4)
2. Düzlem aynanın önünde oldukları için görüntüleri oluşur. (5)
3. Aynaya göre simetrilerini aldım.(6)
4. Görüntünün uzaklığı cismin uzaklığının iki katıdır. (8)
5. Işınların hepsi içeriye giriyor. (9)
6. Sevgi hareket halinde olduğu için ışınların arasına girdiğinde mutlaka hepsini görecektir. (10)
7. Görüş açısından dolayı. (11)
8. Nedeni görüş alanı içindedirler. (12)
9. Sevgi yukarı doğru hareket ettiği için bütün lambalar görme alanı içine girer. (15)
10. Çünkü bütün lambalar Sevgi'nin görüş alanına zaman içinde girerler ve düzlem aynada görüntü eşit uzaklıkta ve dik olur. (16)
11. Sevgi yukarı çıktıkça görüş alanı daha da artar. (17)
12. Düzlem bir aynada cisimlerin aynaya göre simetrik bir görütüsü oluşur. (18)
13. Yansıma. (20)
14. Farklı açılardan görülemeyen görüntüler görülebilir. (23) (25)
15. Yansıma kuralına göre. (30)
16. Aynanın uçlarına gönderilen ışınlarla lambaların görüntü aralığı belirlenir. (36)
17. Görüntü yerlerini istediği için. (37)
18. Yukarı doğru tırmanınca aynada görünebilecek alana girdikleri için görüntüleri oluşur. (40)
19. Simetrisi alındığında hepside görünür. (42)
20. Düzlem aynaya cisim ne kadar uzakta ise görüntüsü de o kadar uzağında arka tarafta oluşur. (43)
21. Görüş alanına ilk nerede girdiğini gözünden çıkan ışınların lambaları nerede gördüğünü yansıma ile bulduk. (49)
22. Çünkü düzlem ayna simetrik ve zahiri görüntü oluşturur. (51)
23. Sebep yok. (14) (21) (22) (26) (29)(32)(33) (34) (41) (45) (46) (48) (50)

- **ANSWER TYPE 2:** 2 ve 3

1. 1 ve 4'ün oluşmaz, 2'nin sadece yarısının görüntüsü oluşur. 3'ün görüntüsü oluşur. 1 ve 4'ün simetriği düzlem aynanın arkasına düşmemektedir. 2'nin ise yarısı düşmektedir. 3'ün tamamı düşmektedir. (3)

2. Aynaya göre simetriklerinin ayna arkasında oluşması. (38)
3. Görüş alanına girdiği için. (39)
4. Sebep yok. (27)

- **ANSWER TYPE 3:** 2,3 ve 4

1. Sevgi yukarı asıldıkça aynanın uçlarına ışınlar yolluyoruz. 4,3 ve 2 numarayı görebiliyoruz, 1 numaralı lamba görünmüyor. (7)
2. Şekil üzerinde belirttim (*Sevgi'nin pozisyonlarına göre aynanın alt sınırına ışın çizip aynanın arkasına uzatmış, aynanın arkasındaki 2',3',4' noktalarına denk gelen yerleri belirlemiş*) (13)
3. Görüş alanı çizildiğinde Sevgi'nin 1'i göremediği ortaya çıkıyor. (31)

- **ANSWER TYPE 4:** Hiçbirinin oluşmaz.

1. Hiçbiri görüntü alanına girmez. (47)

- **ANSWER TYPE 5:** 1 ve 4

1. 3 aynada dik, 2'de oluşmaz. (52)

- **ANSWER TYPE 6:** 1,2 ve 3

1. Sebep yok. (44)

Item 4.B.

- **ANSWER TYPE 1**: 4,3,2,1

1. Lambaların görüntüsünün uzantısını aldım. Sevgi tırmanırken sıralama bu şekilde oluyor. (4)
2. Çünkü Sevgi ip tırmanıyorken lambalar 4-3-2-1 sırasıyla görüş alanına girer. (5)
3. Görüş alanı. (6)
4. Görüntülerin sırası. (12)
5. 4'ün görüntüsü daha yukarıdadır, Sevgi ise yola aşağıdan başlar. Bu sebeple ayna üzerinden ilk 4 görülür daha sonra sırasıyla 1'e kadar gider. (15)
6. Lambaların aynadaki görülebileceği alanın bir sınırı aşağıdan yukarıya doğru böyledir. Sevgi'de aşağıdan yukarıya doğru gittiği için sıra böyle olur. (16)
7. 4 en önce görüş alanındadır. (17)
8. Şekildeki gibi Sevgi ilerledikçe görüş alanını çizdiğimizde önce 4 ardından 3,2, ve 1 numaralı lambayı görebileceğini buluruz. (18)
9. Çizdiğimiz ışınların kapsadığı alanlara bakarak. Sevgi ilerledikçe değişecektir. (20)
10. Sevgi'yi ilerlettikçe görüş alanını çizerek buldum. (22)
11. Gözlemci yukarı doğru ilerlerken görüş alanı aşağı doğru hareket eder. (23) (25)
12. Yine Sevgi görüntülerin görüş alanını bu sırayla görür. (28)
13. Sırasıyla sevgi'yi 1 birim kare ilerletip görüş alanını çizip buldum (29)
14. En uzakta olanı önce görecektir. (30)
15. Görüş alanı hareket ettikçe değiştiği için bu sırada görür. (35)
16. Sıralama istediği için. (37)
17. Sevgi'nin görüş alanına sırasıyla bu kedilerin görüntüleri girer. (38)
18. Tam yansımadan dolayı sırasıyla 4,3,2,1 şeklinde görür. (40)
19. Taralı alana ilk girenler. (42)
20. Çünkü tırmandıkça lambalar görüş alanına girecektir. (43)
21. Sırasıyla görüş alanına giriyor. (46)
22. Yansıma kanunlarıyla ilgili. (49)
23. Sevgi ilerlerken aynanın görüş alanına göre önce 4,3,2,1 sıralaması girdi. (50)
24. Sebep yok. (14) (19) (32) (33) (34) (41) (45)

- **ANSWER TYPE 2**: 1,2,3,4

1. Çünkü Sevgi lambaları kendisine paralel olarak görür. (3)
2. Sevgi'nin görüş alanına giren lambaların sırası 1,2,3,4 olduğu için. (8)
3. Işınların açılarından (10)
4. Çünkü 1,2,3,4 lambaları sırası ile Sevgi'nin görüş alanına giriyor. (39)

5. Sevgi'nin bulunduğu konumdan dolayı. (48)
6. Sevgi'nin görüş açısı ona göre gösterir. (51)
7. Sebep yok. (9)

- **ANSWER TYPE 3**: 4,2=3,1

1. Görüş alanından dolayı 5 kare yukarda sadece 4 'ü görür ilerledikçe 2,3 sonra 1 (21)
2. Gerekli çizim yapıldığında sonuç bulunur. (27)
3. Sebep yok. (26)

- **ANSWER TYPE 4**: 4,1,3,2

1. Işıkların görüntü alanları rastladığı sınır çizgilerinin sırasına göre belirlenir. (36)

- **ANSWER TYPE 5**: 4,2,3,1

1. Sevgi'nin görüş açısına sırasıyla bu şekilde girerler. (11)

- **ANSWER TYPE 6**: 4,3,2

1. Görüş alanı çizildiğinde önce 4'ün görüldüğü ortaya çıkıyor. (31)

- **ANSWER TYPE 7**: 2,3,4

1. İlerlemesine göre 2,3,4 görür. (13)

- **ANSWER TYPE 8**: 4,2,3

1. Işınları aynanın uçlarına çizdiğimizde önce 4 nolu lambayı görür. (7)

- **ANSWER TYPE 9**: 4,1

1. 4 nolu lamba 1 nolu lambadan daha aşağıda ve Sevgi'ye daha yakın. (52)

- **ANSWER TYPE 10**: Hiçbirini göremez.

1. Hiçbiri görüntü alanına girmez. (47)

- **ANSWER TYPE 11**: 3,2,1

1. Sebep yok (44)

Item 5.

- **ANSWER TYPE 1**: Sevgi'nin başı/gözü aynanın alt sınırı hizasında iken.

1. Yansıma kanunlarından dolayı. (4)
2. Sevgi kendi görüş alanına girdiğinde kendini görür. (6)
3. Işınları çizdiğimde 2 doğrultusunda dik olduğundan kendisini görür. (7)
4. Kendisinin ilk görüş alanı ilk olarak 2'de çakışır. Sevgi yukarıya tırmandıkça görüş alanı genişliyor ve ilk 2'de kendini görür. (19)
5. Aynanın uçlarına belirttiğim noktalardan ışın göndererek buldum. (22)
6. Kendisi ile görüş alanı ilk olarak 2'de çakışır. Sevgi yukarıys tırmsndıkçs görüş slsnı genişliyor ve ilk olarak 2'de kendini görüyor. (28)
7. Görüş alanı çizerek tespit ettim. (29)
8. Görüntüsünü görebilmesi için ayna hizasında olması gerekir. (31) (32) (33)
9. Sevgi'nin görebileceği alan ayna uçlarına çizilen çizgilerle belirlenir. Sevgi ilk defa 2 üzerindeyken bu çizgilerde görünür. (36)
10. Nedeni düzlem aynaya ilk gelen 2 nolu lamba hizasında görüntüsü tam oluşur. (42)
11. Tamamen aynanın sınır çizgisine girdiğinde ve aynanın iç alanındaki yerlerde Sevgi kendisini görür. Aynanın dışında Sevgi görüş alanında kendisini göremez. (46)
12. Düzlem aynada görüntü. (48)
13. Görüş alanı. (51)
14. Sebep yok. (13)

- **ANSWER TYPE 2:** Sevgi'nin başı/gözü 2 ve 3 numaralı lambalar arasındaki doğrultuda; ayakları 1 ve 2 numaralı lambalar arasındaki doğrultuda iken.

1. Yansıma ve görüntü oluşumu. (12)

2. Sevgi'nin kendisini tamamen görebilmesi için boyunun yarısına kadar aynanın en alt noktasından yukarı çıkmalıdır. Boylece gözleri en yukarıda yani kafasında olduğu için kendisini tam olarak şekildeki yerde görebilir. (15)
3. Bir kişinin düzlem aynada kendi görüntüsünün tamamını görebilmesi için aynanın yerden yüksekliğinin, kişinin boyunun yarısı olması gerekir. Sevgi tabandan 5 birim yukarıdayken aynanın o noktadan uzaklığı 1 birim, yani Sevgi'nin boyunun yarısıdır. (18)
4. Görüş alanı hesabı. (21)
5. Göz seviyesi boyun en üst kısmı olarak alınırsa, aynanın en alt kısmına boyun yarısı denk geldiği ilk anda Sevgi kendini tamamen görür. (25)
6. Tamamını görebilmesi için gözüne gelen ışınların yansımasını dikkate alırız. (30)
7. Çünkü ancak o bölgede kendisi ayndaki görüş alanına girebiliyor. (38)
8. Sevgi'nin boyu iki birim olarak verilmiştir. Tamamını görmek için 1 birim hizasını geçince öteki yarısını da görür. (40)
9. Sebep yok. (26) (27) (34) (35) (37) (49)

- **ANSWER TYPE 3**: Sevgi'nin tüm bedeni 2 ve 3 numaralı lambalar doğrultusunda, aynanın karşısında iken.

1. Sevgi'nin başı 3 numaralı lambanın hizasına tam olarak geldiğinde şekildeki gibi görüntüsünü tam olarak görecektir. Çünkü Sevgi 3 numaralı lambaya ulaştığında tamamı düzlem aynanın önünde olacaktır. Bu durumda kendi görüntüsünün tamamını aynada görür. (3)
2. İlk olarak kendisi tamamen aynanın önüne gelince görebilir. Ancak görüş alanına girerse görüntüsünün tamamını görmüş olacağından o belirttiğim noktada görür. (5)
3. Görüş alanına bakıldığı zaman bu şekilde olur. (11)
4. Eşit boy ve mesafeyi yakaladığı an olduğu için. (14)
5. Kendi görüntüsünü kendi göreceği için aynanın iki ucunun normalleri arasında olması gerekir. Kendini tamamen görebilmek için tamamen aynanın iki ucunun normalleri arasında olması gerekir. (16)
6. Sebep yok. (9) (41) (45) (52)

- **ANSWER TYPE 4:** Sevgi'nin başı/gözü aynanın üst sınırı hizasında iken

1. Tam görüş alanına girdiği için. (43)
2. Sebep yok. (44)

- **ANSWER TYPE 5:** 3 numaralı lamba doğrultusunda iken.

1. Görüntü arkada oluştuğu için. (50)
2. Sebep yok. (47)

- **ANSWER TYPE 6:** Olduğu yerde iken.

1. Olduğu yerde zaten görüntüsünün tamamını görür. Çünkü düzlem aynalar sonsuz uzunlukta kabul edilir. (24)

- **ANSWER TYPE 7**: Odanın tabanından aynanın alt sınırına çizilen çizginin ipi kestiği noktaya geldiğinde.

1. Işınların geçtiği alanda olduğu için Sevgi kendini ilk orda görür. (10)

- **ANSWER TYPE 8:** 4 numaralı lamba doğrultusunda iken.

1. Önce 4 numarada görür. Işın ve oluşan alanlar. (20)

- **ANSWER TYPE 9:** 4 numaralı lambanın göründüğü bölgede iken.

1. 4. görüntüde tamamıyla görüş alanına girdiği için. (39)

Item 6.

- **ANSWER TYPE 1:** Oluşmaz.

1. Saydam olmayan cisim olduğundan görüntüsü oluşmaz. Pilin görüntüsü engeli aşamaz. (1)

2. Pilin tam önünde engel olduğundan ve düzlem aynada görüntü tam simetriğinde oluştuğundan burada görüntü oluşmaz. (3)
3. Engelden dolayı oluşmaz. Önünde engel var ve cisimden çıkan ışınlar engelin kenarlarından geçerek aynaya çarparlar. Cismin görüntüsü oluşur ama ayna üzerinde oluşmaz. (6)
4. Önündeki engel pilin görüntüsünün oluşmasını engeller. (7)
5. Engel olduğundan görüntüsünü gözlemleyemeyiz. (13)
6. Engel görüntü oluşumunu engeller. (17)
7. Önünde bir engel varsa engelin görüntüsü oluşur. (21)
8. Önünde saydam olmayan bir engel bulunduğu için. (31) (32) (33)
9. Bir cismin görüntüsünün oluşabilmesi için aynaya bakış açısına göre nerde oluştuğu öğrenilebilir. Fakat üstten yani karşıdan baktığımızda aynanın önünde engel olduğu için oluşmaz. (40)
10. Çünkü engel cismin görüntüsünün üzerinde olduğu için. (43)
11. Saydam olmayan engel pilin görüntüsünü kapattığı için görüntü oluşmaz. (44)
12. Çünkü engel var. (45)
13. Önündeki engel pilin görünmesini engeller. (46)
14. Çünkü pilden aynaya ancak bir taraftan ışık gönderilebiliyor. (47)
15. Engelden dolayı oluşmaz. (48)
16. Işık yansıma yaparken engel pil ile görüş alanının dışına çıkar ve görüntü oluşmaz. (49)
17. Görüş alanında değil. (50)
18. Cisimden çıkan dik ışınlar aynaya ulaşamaz. (51)
19. Çünkü önünde cisimden daha büyük bir engel var. (52)
20. Sebep yok (26)

- **ANSWER TYPE 2:** Oluşur.

1. Engelin yüzeyini yalayarak geçer ve böylece pilin düzlem aynada görüntüsü oluşur. (tek ışın) (2)
2. Yansıma kanunları (Tek bir ışın aynayı görüyor). (4)
3. Aynanın küçük bir bölümünden de olsa pilin görüntüsü oluşur diyorum (2 ışın). (5)
4. Pilin önünde engel olduğu için tek bir taraftan görüntü alınacaktır. (10)
5. Görüntü oluşur fakat gözükmez, engel kapatır. (11)
6. Yansıma ve görüntü oluşumu. (12)
7. Şekilden belli (Pilden aynanın açıkta kalan kısmına ışın yollayıp aynanın arkasında bu çizgi üzerinde görüntünün yerini tespit etmiş) (14)
8. Pil aynayı görmese de soldaki bir insan pili aynada görebilir. (15)şekilde çizdiğim taralı alanda (pilden aynaya 2 adet ışın gönderip yansıtmış, yansıyan ışınlar arasında kalan bölgeyi taramış) olan biri pilin aynadaki görüntüsünü görebilir. (16)
9. Önünde engel olduğu için görüntünün oluşmayacağı düşünülebilir. Fakat engel olması bir anlam ifade etmez. Bunu şu şekilde destekleyebiliriz: örneğin, şekildeki A noktasından aynaya bakan bir gözlemci pilin görüntüsünü görebilecektir. Bu da demektir ki, pilin görüntüsü önünde engel olsa da olmasa da oluşur. (18)
10. Pilden çıkan ışın aynaya ulaşabilir bu nedenle görüntü oluşur. (tek ışın) (23)
11. Pil düzlem aynanın bir kısmını görmektedir. (24)
12. Pilden çıkan bir ışın aynaya ulaşabilmektedir. Bu nedenle görüntü oluşur. (25)
13. Görüntünün oluşmasına engel, engel teşkil etmez. Ancak baktığımız görüş alanına göre görülüp görülmemesi değişir. (30)
14. Oluşur fakat görünmez, işaretli yerden bakmak lazım. (34)
15. Ayna kenarlarından engelin kenarları üzerine çizilecek doğrularla aynanın göremediği alan belirlenir ve bu alanın dışarısındakiler görür. (36)
16. Oluşur. (Pilden aynanın açıkta kalan kısmına ışın yollayıp aynanın arkasında bu çizgi üzerinde görüntünün yerini tespit etmiş) (37)
17. Çünkü pilin ayna arkasında yansıması var. (Pilden aynanın açıkta kalan kısmına ışın yollayıp aynanın arkasında bu çizgi üzerinde görüntünün yerini tespit etmiş) (38)
18. 1. bölgede aynada görüntüsü oluşur, 1. bölge de görüş alanına girdiği için kendisini görür. (Görüntü ayna üzerinde) (39)
19. Oluşur. (Pilden aynanın açıkta kalan kısmına ışın yollamış, devamı çizilmemiş) (41)
20. Çizimler arasında kalan taralı alan (2 ışın yollanmış) (42)

- **ANSWER TYPE 3:** Bir kısmı oluşur.

1. Işınlardan biri ulaşırken, diğeri engel yüzünden ulaşamaz. (20)

Item 7.A.

- **ANSWER TYPE 1:** Bacaklarından yukarısını (üstten 4 birim karelik kısmını) görür.

1. Çünkü Murat'ın görüş alanı sadece vücudunun 2/3'ünü görebilecek kadardır. (5)
2. Görüş alanından dolayı. (6)
3. Murat'ın en üst noktasının aynadaki görüntüsü belirlenir ve görüş açısı buna göre çizilir. (7)
4. Murat'ın boyundan düzlem aynanın en alt ucuna ışın yollayıp bunu yansıttığımızda en fazla görebileceği alanı buluruz. (10)
5. Görüş alanı. (12)
6. Murat'ın görme alanı en fazla 2/3 kadardır. (15)
7. Murat'ın gözünün aynadaki görüş alanı Murat'ın o kadarı kadar olduğu için. (16)
8. Murat'ın gözünden aynada görebileceği bölgeyi çizersek vücudunun 2/3'ünü göreceğini bulabiliriz. (18)
9. Murat'ın gözünden ışın çıkartırsak 4 birimde keser. (19)
10. Görüş alanını çizersek şekildeki gibi 6 birimden 4 birimi gözükür. (23)
11. Göz seviyesinin görüntüsünü alıp ışınların ulaştığı noktalar görülür. (25)
12. Yansıma kanunları. (27)
13. Murat'ın gözünden ışın çıkartırsak 4 birimde keser. (28)
14. Aynanın görüş alanına ışın gönderirsek yansıma şekildeki gibi olur. (30)
15. Çizimle bu sonuca ulaşılır. (31)
16. Murat'ın aynadaki görüş alanı işaretlenen yer kadardır. (35)
17. Murat'ın görüş açısı aynanın kenarlarına çizilen doğrularla belirlenir. (36)
18. Murat'ın aynada gördüğü kısım görüş alanına giren kısım olduğundan bedeninin 4/6'sını görür. (38)
19. Vücudunun diğer kısmını görür, bir kısmını da görmez. (39)
20. Aynanın en alt köşes,ne ışın gönderirsek maksimum göreceği alanı buluruz. (40)
21. Çizimde nedeni görülüyor. (42)
22. Bacak kısmını göremez. (46)
23. Gözden çıkan ışık Murat'ın 2/3'ünü kapsar. (49)
24. Aynanın görüş alanına o bölgesi giriyor. (50)
25. Sebep yok (21) (26) (32) (33) (34) (37) (41) (45)

- **ANSWER TYPE 2:** Göğüs hizasına kadar olan (üstten 2 birim karelik) kısmını görür.

1. Çünkü bu kadarlık kısmı aynanın önündedir. Düzlem aynada görüntü cismin tam simetriğinde oluştuğundan diğer kısımların aynada simetriği yoktur. (3)
2. Aynanın altta kalan kısmı aynayı görmediği için görüntüsü orada oluşmaz. (4)
3. Işınlar ve kapladığı alan. (20)
4. Sebep yok. (22) (29) (47) (48) (52)

- **ANSWER TYPE 3:** Tamamını görür.

1. Aynanın boyu h/2. (11)
2. Aynı boyda görünür. Gelen ve yansıyan doğrultuları alırsak aynı boyda çıkar. (13)
3. Şekilde gösterildi. (14)
4. Sebep yok. (24)

- **ANSWER TYPE 4:** Vücudunun yarısını görür.

1. Vücudunun yarısını aynada görebilir. Çünkü ayna boyunun yarısıdır. (44)
2. Görüş alanı. (51)

- **ANSWER TYPE 5:** Kendisini göremez.

1. Görüş alanında değil. (17)

Item 7.B.

- **ANSWER TYPE 1:** Aynayı aşağıya indirmelidir.

1. Aynayı 1 birim aşağıya indirirse kendini görebilir. Görüş alanına girdiği için. (6)
2. Formül böyle söyler. (..12)
3. Çünkü ancak o zaman görüş alanına girebilir. (17)
4. Murat eğer aynayı 1 birim aşağı indirirse vücudunun tamamını görebilir. Buna karşın aynaya (eğilmeden) yaklaşıp uzaklaşarak bunu başaramaz. Bir tabure, sandalye vs. üzerine çıkabilir. (..18)
5. Aynayı 1 birim aşağıya indirirse kendini de 1 birim fazla görür. (29)
6. Çizimden. (27)
7. Aşağı doğru 1 birim indirsin. Kendi hareketi etki etmez hep aynı olur. (34)
8. Görüş açılarını artıtabilmesi için aynanın merkezine yaklaşması lazım. (...36)
9. Bedeninin tamamının görüş alanına girmesi için. (38)
10. Yukarıda çizildiği gibi Murat ile ayna mesafesi görüntünün boyunu değiştirmez. Fakat aynayı aşağı çekmek alanı artırır. (40)
11. Böylece görüş alanını artırarak kendini tümden seyredebilir. (..51)
12. Sebep yok. (10) (..22) (..26) (...30) (32) (33) (39) (41) (42) (44) (46)

- **ANSWER TYPE 2**: Yukarı zıplamalıdır / Birşeyin üzerine çıkmalıdır.

1. Çünkü zıpladığında vücudunun daha büyük kısmı aynanın görüş alanına girecektir. (3)
2. Tam olarak 1 birim kare zıplaması yeterlidir. Zıplayarak görüş alanını artırabilir. (5)
3. Bir birim yükseğe çıktığında Murat'ın en üst noktasının görüntüsü işaretlendiğinde Murat tamamen görüş alanı içerisinde olur. (8)
4. Bir birim zıpladığında görme alanının içinde olur. (..15)
5. Murat'ın gözünün aynada görebileceği görüş alanına girebilmek için. (..16)
6. Murat eğer 1 birim yukarı zıplarsa vücudunun tamamını görebilir. Buna karşın aynaya (eğilmeden) yaklaşıp uzaklaşarak bunu başaramaz. (18)
7. Yukarıya doğru hareket ederse daha fazla görüş alanı elde eder. (30)
8. Görüş açılarını artırabilmesi için aynanın merkezine yaklaşması lazım. (36)
9. Böylece görüş alanını artırarak kendini tümden seyredebilir. (51)
10. Sebep yok. (10) (37) (..44)

- **ANSWER TYPE 3:** Aynanın boyunu büyütmelidir.

1. Aynayı büyüttüğümüzde vücudunun her tarafında yansıma kanunları gereği görüntüsü oluşacaktır. (4)
2. Aynayı bir birim uzattığında Murat'ın en üst noktasının görüntüsü işaretlendiğinde Murat tamamen görüş alanı içrisinde olur. (..8)
3. Aynanın boyu artırılmalı.Görüş alanını artırmak için ayna boyunu değiştirerek sağlayabiliriz. Murat'ın yer değiştirmesi işe yaramaz.(21)
4. Görüş alanını çizersek ileri veya geri giderek değişmediğini görürüz. Aynanın boyu büyürse görüş alanı artar. (23)
5. Murat'ın boyu çok uzun ayna kısa, ayna uzatılırsa Murat kendisini görebilir.(..39)
6. Ayna kendisinin boyu kadar olmalı. (45)
7. Sebep yok. (22) (26) (29) (..30) (35) (47)

- **ANSWER TYPE 4**: Aynadan uzaklaşmalıdır.

1. Aynı şekilde geriye doğru gittiğinde aynanın görüş alanına girecektir. (..3)
2. Formül böyle söyler. (12)
3. Murat'ın gözünün aynada görebileceği görüş alanına girebilmek için. (16)
4. Aynaya uzak bir yerden bakmalıdır. (24)
5. Düzlem aynada görüntü oluşumu. (48)
6. Ayna ile Murat arasındaki mesafe arttıkça ışığın kapsadığı alan artar. Dolayısıyla görüntü Murat'ın tamamını kapsar. (49)
7. Görüş açısı büyüyeceği için. (50)
8. Böylece görüş alanını artırarak kendini tümden seyredebilir. (...51)
9. Sebep yok. (..4) (..47)

- **ANSWER TYPE 5:** Hiçbirşey yapmasına gerek yok.

1. Zaten hepsini görüyor. (14)
2. Murat'ın aynadan uzaklaşması hiçbir işe yaramaz. (19)
3. İleri geri gitse de göreceği alan değişmez, çünkü alınan noktalar ve çıkan alan aynı. (20)
4. Görüntü alanı ileri ya da geri veya aşağı yukarı değişmez. (25)
5. Murat'ın aynadan uzaklaşması, aynayı yukarı-aşağı hareket ettirmek işe yaramaz. (28)

- **ANSWER TYPE 6:** Aynayı uzaklaştırmalıdır.

1. Ayna uzaklaşınca görüş alanı artar. (31)
2. Görüş açısı büyüyeceği için. (..50)
3. Sebep yok. (..41) (52)

- **ANSWER TYPE 7:** Aynaya yaklaşmalıdır.

1. Aynaya yaklaşarak görüş alanını artırabilir. (..5)
2. Yaklaşırsa doğrultuları daha uzakta ve dolayısıyla büyük çıkar. (13)
3. Yaklaştığında görme alanının içinde olur. (15)

- **ANSWER TYPE 8:** Aynanın açısı değiştirilebilir.

1. Sebep yok. (...26)

- **ANSWER TYPE 9:** Aynanın şeklini değiştirmelidir.

1. Sebep yok. (35)

- **ANSWER TYPE 10:** Aynaya doğru eğilebilir.

1. Görüş açılarını artıtabilmesi için aynanın merkezine yaklaşması lazım. (..36)

Note: Student number without any dot (.) before the number means students' first option for that item; number with two dots(..) means that student's second option; number with three dots (...) means that student's third option for the same item.

Item 8.

- **ANSWER TYPE 1:** Suat yukarı zıplamalıdır / Birşeyin üzerine çıkmalıdır.

1. Bu durumda vücudunun daha büyük bir kısmı aynanın görüş alanına girecek, böylece daha büyük bir kısmın simetriğinde görüntü oluşacaktır. (3)
2. Görüş alanını artırmak gerektiği için. (..5)
3. Suat'ın görüş alanını artırmak istediğim için. (6)
4. Yükseğe çıktığında Suat tamamen Fırat'ın görüş açısı içinde olur. (..8)
5. Zıpladığında Fırat görme alanına girebilir. (..15)
6. Aynada görebileceği bölge artacaktır. Öne eğilmediği sürece yaklaşıp uzaklaşması göreceği bölgeyi değiştirmez. (18)
7. Görme alanının tamamına Fırat'ı sokmak için. (20)
8. Suat'ın Fırat'tan daha yukarıda olması lazım. (37)
9. Görüş alanı. (...51)
10. Sebep yok. (14) (..26)

- **ANSWER TYPE 2**: Suat aynadan uzaklaşmalıdır.

1. Bu durumda vücudunun daha büyük bir kısmı aynanın görüş alanına girecek, böylece daha büyük bir kısmın simetriğinde görüntü oluşacaktır. (..3)
2. Nedeni görüş alanıdır. (12)
3. Aynadan çapraz şekilde uzaklaşmalıdır, uzaklaştıkça görüntü büyür. (24)
4. Görüntü oluşumu. (48)
5. Mesafe arttıkça görüntü oluşumu artar. (49)
6. Aynadan Fırat'a bakış açısını büyütmek için. (..50)
7. Görüş alanı. (..51)
8. Aynadan uzaklaşarak aradaki mesafeyi artırır. (52)
9. Sebep yok. (10) (45) (47)

- **ANSWER TYPE 3:** Suat aynaya yaklaşmalıdır.

1. Görüş alanını artırmak gerektiği için. (5)
2. Aynaya yaklaştığında görme alanı artar. (15)
3. Suat aynaya yaklaşırsa görüntü alanı artar. (23)
4. Aynaya yaklaştıkça görüntü daha yakında ve büyük görünür. (36)
5. Görüş alanında kardeşinin vücudunun daha fazlasını görmesi için. (..38)
6. Suat aynaya yaklaşırsa Suat'a göre aynada görülecek alan artar. (40)
7. Sebep yok. (..19) (..28) (41) (..44)

- **ANSWER TYPE 4:** Aynayı aşağı indirmelidir.

1. Suat'ın görüş alanını artırmak istediğim için. (..6)
2. Aynada görebileceği bölge artacaktır. Öne eğilmediği sürece yaklaşıp uzaklaşması göreceği bölgeyi değiştirmez. (..18)
3. Şekilden. (27)
4. Görüş alanını değiştirmek için bu yöntemlerden yararlanabiliriz. (30)
5. Görüş alanında kardeşinin vücudunun daha fazlasını görmesi için. (38)
6. Ayna yukarıda olduğundan dolayı Suat Fırat'ı tam göremiyor. (..39)
7. Görüş alanı. (51)
8. Sebep yok. (34) (..41)

- **ANSWER TYPE 5:** Suat Fırat'tan sağa doğru uzaklaşabilir.

1. Görüş alanını değiştirmek için bu yöntemlerden yararlanabiliriz. (30)
2. Aynadan Fırat'a bakış açısını büyütmek için. (50)
3. Sebep yok. (..14) (44) (46) (..47)

- **ANSWER TYPE 6:** Fırat aynadan biraz uzaklaşmalıdır.

1. Suat'ın gözünün aynadaki görüş alanının içine Fırat'ın alan olarak daha fazla görüntüsü gireceği için. (16)
2. Fırat aynadan uzaklaşırsa görüntü alanı artar. (..23)
3. Fırat'ın uzaklaşması Suat'ın yaklaşmasıyla benzer olduğu için aynı etkiyi yaratır. (*görüntü alanı artar*). (..25)
4. Fırat uzaklaşınca görüntü alanı değişmez fakat Fırat daha daha çok girer. (..40)
5. Sebep yok. (...41)

- **ANSWER TYPE 7:** Aynanın boyunu büyütmelidir.

1. Yansına kanunları. (4)
2. Aynayı yere doğru uzattığında Suat tamamen Fırat'ın görüş açısı içinde olur. (8)
3. Ayna yukarıda olduğundan dolayı Suat Fırat'ı tam göremiyor. (..39)
4. Sebep yok. (26)

- **ANSWER TYPE 8:** Suat Fırat'a doğru yaklaşabilir.

1. Sebep yok. (..10) (19) (28) (42)

- **ANSWER TYPE 9:** Aynayı uzaklaştırabilir.

1. Görüş alanını artrır. (31) (32) (33)
2. Sebep yok. (..45)

- **ANSWER TYPE 10:** Suat aynaya doğru eğilebilir.

1. Aynada görebileceği bölge artacaktır. Öne eğilmediği sürece yaklaşıp uzaklaşması göreceği bölgeyi değiştirmez. (...18)

- **ANSWER TYPE 11:** Fırat aşağı doğru çömelmelidir.

1. Görüş alanını artırmak gerektiği için. (...5)

Note: Student number without any dot (.) before the number means students' first option for that item; number with two dots(..) means that student's second option; number with three dots (...) means that student's third option for the same item.

KÜRESEL AYNALAR

Item 9.A.

- **ANSWER TYPE 1:** 1,2,3 ve 4

1. Şekilden öyle bir netice çıkardım. (5)
2. Yerlerinden dolayı. (6)
3. 1/f = 1/c + 1/g. Formülden g degerini buluyoruz. Tepe noktasına göre bulduğumuz değerin neresi olduğunu belirliyoruz. (16)
4. Çukur aynada sadece odak noktasındaki cismin görüntüsünü göremez. (17) (25)
5. Özel ışınlardan yararlanarak hepsinin görüntüsünü şekildeki gibi buluruz. (18)
6. Çukur aynada sadece odak noktasındaki cismin görüntüsü görülemez. (23)
7. 1,2,3, nolu kedilerin görüntüleri sonsuzla merkez arasında oluşur, 4 nolu kedinin görüntüsü odakla merkez arasında oluşur. (35)
8. Yine aynanın uçlarından yansıyan ışınların kesiştiği noktalarca belirlenir. (36)
9. Hepsinin de görüntüleri aynada oluştuğu için. (39)
10. Çukur aynada görüntüyü göstermek için. (41)
11. Sebep yok. (2) (9) (15) (45) (52)

- **ANSWER TYPE 2:** 1 ve 2

1. 1 ve 2 numaralı kedilerin görüntüsü odakta oluşacaktır. Çünkü asal eksene paralel gelen düzlemde görüntü odaktadır. (3)
2. 3 ve 4 çukur aynanın görüş açısı içinde değildir. (8)
3. 3 ve 4'ün oluşmamasının nedeni eğrilik yarıçapından dışarıda kalmasları. (30)
4. Ayna küresel. (34)
5. Çukur aynada aynaya paralel gelen odaktan geçecek şekilde yansır. Tepe noktasından geçecek şekilde gelen ışın aynı açıyla yansır. (38)
6. Çukur ayna daha dar alanı gösterir. (46)
7. 1 ve 2 numaradan çıkan ışınlar merkezde toplanır. Ancak 3 ve 4 numaradan çıkan ışınlar merkezin dışına dağılırlar. (47)
8. Cevap yok. (10) (14) (31) (32) (33) (37) (42)

- **ANSWER TYPE 3:**1, 2 ve 4

1. Merkezden gelen merkezden geçer. (12)
2. Aynanın iki yanına ışınlar çizilir. (24)
3. Çukur aynada görüntü oluşumu. (48)

- **ANSWER TYPE 4**: Yalnız 4

1. 1,2, ve 3'ün görüntüsü merkezin dışında olur. Onun için göremez. 4'ü görür. (4)
2. Çünkü odak hizasında olan cisimden aynaya iki ışın gönderip yansıyan ışınları kesişmiyor. Bu yüzden görüntü oluşmaz. 4'de ise merkezin dışındaki cismin görüntüsü odak ile ayna arasında oluşur. (43)

- **ANSWER TYPE 5:** Yalnız 3

1. 2,4 ve 1'i göremez. Çünkü gönderilen ışınlar kendilerini görmez. (40)

- **ANSWER TYPE 6:**1, 2 ve 3

1. 1/f = 1/c + 1/g (21)

- **ANSWER TYPE 7:** 1 ve 4

1. Sebep yok. (1)

- **ANSWER TYPE 8:** 2,3 ve 4

1. Sebep yok. (7)

Item 9.B.

- **ANSWER TYPE 1:** 2,1

1. 2'nin görüntüsünü önce görür. (30)
2. 2'nin görüntüsü daha önde oluşur. (31) (33)
3. 2'nin görüntüsü daha yakın oluşur. (32)
4. Aynada görüntü aldığımızda önce 2 sonra 1 görülür. (47)
5. Sebep yok. (42)

- **ANSWER TYPE 2:** 1,2

1. Önce 1'in görüntüsü sonra 2'nin görüntüsü oluşur. (*3 ve 4 çukur aynanın görüş açısı içinde değildir ilk aşamada verilen cevap*tır.) (8)
2. Sebep yok. (10) (37)

- **ANSWER TYPE 3:** 1=2

1. 1 ve 2 'yi aynı anda görür. Çünkü aynı hizada bulunmaktadır. (46)
2. Cevap yok. (34)

- **ANSWER TYPE 4:** 3,2,4,1

1. Görüş alanı. (6)
2. Şekle göre görüntüleri 3,2,4,1 şeklinde bir sıra ile görecektir. (18)
3. Sebep yok. (23)

- **ANSWER TYPE 5:** 3,4,2,1

1. Görüntülerin görüş alanına giriş sıraları öyle olduğu için. (5)
2. Sebep yok. (15) (41)

- **ANSWER TYPE 6:** 4,3,2,1

1. Görüş alanına girdiği için. (39)
2. Sebep yok. (45) (52)

- **ANSWER TYPE 7:** 1,2,3,4

1. Hasan merkez doğrultusunda ilerlediği için kedilerin görüntülerini görme sırası kedilerin kendine yakınlığı ile orantılıdır. (25)
2. Sebep yok. (17)

- **ANSWER TYPE 8:** 1=2, 4,3

1. 1 ve 2 'nin görüntüleri aynı odakta olduğundan aynı anda görünür. +'ün görüntüsü Hasan'a 3'ten daha önce ulaşacaktır. (3)

- **ANSWER TYPE 9:** 4,1,2,3

1. Hasan 4 nolu görüntüye daha yakın olduğu için önce görür. Bu sıra 1,2,3 ile devam eder. (35)

- **ANSWER TYPE 10:** 2,3,4,1

1. Görüntüler kedilerin aynada yansımalarına göre belirlenir. O yüzden. (36)

- **ANSWER TYPE 11:** 1,4

1. Çünkü 1. Cisim Hasan'a daha yakındır. (1)

- **ANSWER TYPE 12:** Yalnız 4

1. 1,2 ve 3 'ün görüntüsü merkezin dışında olur. Onun için göremez. Sadece 4'ü görür. (4)

- **ANSWER TYPE 13:** Yalnız 3

1. 2,4 ve 1'i göremez. Çünkü gönderilen ışınlar kendilerini görmez. (40)

- **ANSWER TYPE 14:** 1,2,4

1. Çukur ayna olduğu için Hasan ilerleme yönüne göre bu sırayı görür. (12)

- **ANSWER TYPE 15:** 1,3,2,4

1. Sebep yok. (24)

- **ANSWER TYPE 16:** 1,2,4,3

1. Sebep yok. (27)

- **ANSWER TYPE 17:** 4, 1=2=3

1. Sebep yok. (9)

- **ANSWER TYPE 18:** 4,2,1

1. Sebep yok. (48)

Item 10.A.

- **ANSWER TYPE 1:** 1,2,3 ve 4

1. Tümsek aynada bu kedilerin hepsinin görüntüsü aynanın görüş alanına girdiğinden sanal olarak görüntü oluşur. (3)
2. Hepsinin görüntüsü odakla tepe noktası arasında oluşur. (4)
3. Şekilde öyle buldum. (5)
4. Işınlar. (10)
5. Kedilerden çıkan ışınlar sanaldır ve odak ile ayna arasında kesişir. (17)
6. Özel ışınları kullanarak kedilerin görüntülerinin yerlerini bulabiliriz. (18)
7. Özel ışınlarla bulunabilir. (23)
8. Kedilerden çıkan tüm ışınlar sanal odak ile ayna arasında bir yerde kesişir. (25)
9. 1,2,4 odakla ayna arasında aynanın arkasındadır. 3 sonsuza gider odağı hedeflediğinde. Tümsek aynanın merkezi ve odağı aynanın arkasında olur. Odağı hedeflemedikçe odakla ayna arasında, yoksa sonsuzda olur. (36)
10. Tümsek aynanın görüntü kurallarından şekildeki gibi olur. (40)
11. Tümsek aynada görüntü cisim nerede olursa olsun ayna ile odak arasında oluşur. (43)
12. Tümsek aynada görüntü. (48)

13. Sebep yok. (9) (15) (30) (41) (42)

- **ANSWER TYPE 2:** 1, 2 ve 4

1. 3. kedi bükeyin dışında kalıyor. (12)
2. Görüş alanına girdiği için. (39)
3. Sebep yok. (24)

- **ANSWER TYPE 3:** 1 ve 2

1. Tümsek ayanya paralel gelen ışın uzantısı odaktan geçecek şekilde yansır. Tümsek aynanın merkezine gelen ışın uzantısı merkezden geçecek şekilde kendi üzerinden yansır. (38)
2. Sebep yok. (1) (46)

- **ANSWER TYPE 4:** Hiçbirinin gerçek görüntüsü oluşmaz.

1. Tümsek aynada gerçek görüntü yoktur. (31) (32) (33) (34)

- **ANSWER TYPE 5:** 1, 2 ve 3

1. 2. kedi 4'ü engeller. (21)

- **ANSWER TYPE 6:** 2, 3 ve 4

1. Sebep yok. (7)

- **ANSWER TYPE 7:** Yalnız 1

1. Sebep yok. (44)

Item 11.A.

- **ANSWER TYPE 1:** 1, 2, 3 ve 4

1. Çukur aynanın görüş alanına hepsi girer. (3)
2. Görüntüler gerçek, ters ve yarısı kadardır çukur aynadaki yansıma kanunlarından. (4)
3. Çukur aynadan dolayı. (6)
4. Aynanın eğrilik yarıçapının içinde kalıyorlar. (12)
5. Bütün cisimlerin görüntüleri şekildeki gibi bulunabilir. Cisimlerden çıkan ışınların kesiştikleri noktalar belirlenir. (18)
6. Lambalardan çıkan ışınlar farklı yansımalar sonucu belirli noktalarda kesişirler. (25)
7. Gönderilen ışınlar doğrultusunda 4 cisminde görüntüsü oluşur. (28)
8. İlgili şekiller çizildiğinde görülüyor. (31) (33) (34)
9. $1/f = 1/D_c + 1/D_g$ (35)
10. Hepsinin odakla merkez arasında oluşur. Çünkü odağın görüntü alanı içindedirler. (36)
11. Görüş alanına girdiği için. (39)
12. Merkeze gönderilen ışınlar tam yansıma yapar ve tüm lambalar görünür. (40)
13. Çukur aynada görüntü. (48)
14. Sebep yok. (5) (9) (15) (21) (24) (32) (42) (47) (52)

- **ANSWER TYPE 2:** 2 ve 3

1. Eğrilik yarıçapına göre. (30)
2. Çukur aynadaki görüntüyü göstermek. (41)
3. 2 ve 3'ün görüntüsü odak noktasında oluşur. (46)

- **ANSWER TYPE 3:**1, 3 ve 4

1. 3'ten merkez üzerine çizgiler gönderdiğimizde 1 ve 4'ten de gönderdiğimizde görüntü oluşur. Ama 2'den gönderdiğimizde ayna üzerinden geçmez. (1)
4. Sebep yok. (10) (27) (45)

- **ANSWER TYPE 4:** 3 ve 4

1. Sevgi yukarı doğru tırmanıyor. Paralel ışın birde asal ekseni kesen ışın yolladık. 3 ve 4. Lambaları göremeyeceğini bulduk. (13)

- **ANSWER TYPE 5:** 1 ve 4

1. Sebep yok. (44)

Item 11.B.

- **ANSWER TYPE 1:** 4,3,2,1

1. Görüntülerin oluşma sırası böyledir. (3)
2. Yukarı tırmanırken karşısına ilk çıkma sırası o şekildedir. (4)
3. Görüş alanına giriş sırası. (5)
4. Görüntülerin yerleri. (6)
5. Görüntüleri şekildeki gibi bulduğumuza göre, önce 4'ü, sonra 3'ü, 2'yi ve en son da 1'i görür. (18)
6. Bunlar odakla merkez arasında ters şekilde şekildeki gibi dizilirler. (36)
7. Görüş alanına girdiği için. (39)
8. Yine tam yansımadan sırasıyla 4,3,2,1 şeklinde görür. (40)
9. Sebep yok. (42) (44) (52)

- **ANSWER TYPE 2:** 1,2,3,4

1. Yukarıya tırmandığı için aynanın öncelikle üst tarafından görüntü alır. Bu görüntü 1'in görüntüsüdür. (12)
2. Sevgi merkez doğrultusunda ilerlerken oluşturduğu görüntü alanı kendisiyle birlikte yukarı ilerler. (25)
3. Sebep yok. (17) (24) (35) (45)

- **ANSWER TYPE 3:** 4,3

1. Yukarı doğru tırmanıyor. Önce 4 'ü görür. (13)

- **ANSWER TYPE 4:** 2,1,3,4

1. Çukur aynada görüntü. (48)

- **ANSWER TYPE 5:** 2,3

1. Sebep yok. (10) (27) (41)

- **ANSWER TYPE 6:** 3, 1=4, 2

1. Sebep yok. (9)

- **ANSWER TYPE 7:** 1,3,4

1. Sebep yok. (1)

Item 12.

- **ANSWER TYPE 1:** Merkezde iken.

1. Tam merkeze geldiğinde görüntüsü gerçek ve terstir. O anda görebilir. (4)
2. Çünkü diğer noktalarda gözünden çıkan ışınlar tam merkezdeyken ışınlar tekrar gözüne gelir. (5)
3. Merkeze geldiğinde görür. (6)
4. Çukur aynada M dışında olan cisimlerin görüntüleri f ile M arasındadır. (11)
5. Görüntüyü görebilmek için aynaya dik bakmak gerekir ve sadece dik olarak M noktası vardır. (15)
6. M noktasına gelinceye kadar görüntüsü daha yukarıda oluşur. İlk olarak M noktasına geldiğinde görüntüsü de M'de oluşur. (18)
7. Sadece merkezde gelen ışınlar kendi üzerinden geri yansır. (36)
8. Sevgi'nin kendini nasıl görebileceğine dayalı olarak bu cevap verilmiştir. (39)
9. Tam merkezde kendini görür. Çünkü diğer yerlerde görüntüfarklı yerlerde olur. Ama merkezde tam yansıma olur. (40)
10. Merkezde oluşan görüntüyü gözlemlediğimden. (41)
11. Merkeze gelen ışın kendi üzerinden geri yansır. (52)
12. Sebep yok. (8) (9) (27) (33) (44) (45)

- **ANSWER TYPE 2:** 1. lamba hizasında iken.

1. 1'e geldiğinde ilk çukur aynada Sevgi'nin görüntüsü oluşur. (3)
2. Çukur aynada görüntü oluşumu. (48)
3. Sebep yok. (10) (13) (28)

- **ANSWER TYPE 3:**Olduğu yerde görür.

1. Sevgi merkezde olduğundan, kendinden çıkan tüm ışınlar geri yansır. (17)
2. Sevgi merkez doğrultusunda, kendinden çıkan tüm ışınlar geri yansır. (25)

- **ANSWER TYPE 4:** 1. ve 2. lambaların arası hizasında iken.

1. Merkezden gelen merkezden geçer. (12)

- **ANSWER TYPE 5:** 2. lamba hizasında (çukur aynanın alt sınırında) iken.

1. Sebep yok. (42)

Item 13.

- **ANSWER TYPE 1:** Aynanın önünde merkez uzaklığında iken.

1. Gelen ışın merkezde tekrar geri yansır. (36)
2. Tümsek aynada görüntü oluşumunu gözlemlemek. (41)
3. Görüntüsü aynanın arkasındaki merkezde oluşur. (44)
4. Tümsek aynada görüntü oluşumu. (48)
5. Sebep yok. (6) (27)

- **ANSWER TYPE 2:** Aynanın arkasındaki merkez ile aynanın alt sınırı doğrultusunda iken.

1. Aynı şekilde gözlerini görebilmesi için aynaya dik olması gerekir ve ilk aynaya dik olduğu yer işaretlenmiş yerdir. (15)
2. Çünkü tümsek aynaya gönderilen dik ışınlar kendi üzerinden geri yansır. Dolayısıyla ilk olarak dik ışın oluyorsa orada olur. (40)

- **ANSWER TYPE 3:** Olduğu yerde görür.

1. Görüntü aynanın arkasında olur. Tırmanmaya başlarken görür. Tümsek aynalarda görüntü odak ile ayna arasında oluşur. (17)
2. Tırmanmaya başlarken görüntüsünü görmeye başlar. Tümsek aynalarda görüntü odak ile ayna arasında oluşur. (25)

- **ANSWER TYPE 4:** 1. lamba hizasında iken.

1. Aynı şekilde 1 numaraya geldiğinde tümsek aynanın görüş alanına girer. (3)
2. Sebep yok. (42)

- **ANSWER TYPE 5:** 1. ve 2. lambaların arası hizasında iken.

1. Merkezden gelen yine merkezden geçer. (12)
2. Sebep yok. (45)

- **ANSWER TYPE:** Kendisini göremez.

1. İki ışın sonsuzda birleşir. (10)

- **ANSWER TYPE:** Aynanın arkasındaki odak ile aynanın alt sınırı doğrultusunda iken.

1. Sebep yok. (24)

Item 14.

- **ANSWER TYPE 1:** Merkezin dışında, merkezde, odakla merkez arasında, odakla ayna arasında iken.

1. Çünkü çukur aynada bu noktalarda görüntü elde edilir.(3)
2. Merkezin dışındayken görüntüsü odakla merkez arasındadır. Merkeze yaklaştıkça görüntü de merkeze yaklaşır. Odakla merkez arasına geldiğinde merkezin dışına çıkar. Aynaya yaklaşırken görüntü de ters yönde merkezin dışına doğru uzaklaşır. Sonra bir anda sanal görüntü odakla tepe noktası arasına gelir. Çukur aynada yansıma kanunları ile açıkladım. (4)
3. Ayna ile odak arasında ise görüntüsü sonsuzda olur. Odakla merkez arasında ,se görüntümerkezden ötede olur. Merkezde ise görüntü merkezde olur. Merkezden ötede ise görüntü odak ile merkezde olur. (9)
4. Merkezde görür. Asal eksen ile f arasında görüntüsünü 2 kat büyüklüğünde, M-f arasında, M dışında da gözlemlenir. (13)
5. Odak noktası dışında tüm noktalarda yüzünü görür. (17)
6. M noktasına gelmeden önce, görüntüsü ters ve küçüktür. Odakla merkez arasında ve aynanın ön kısmındadır, görüntü gerçektir. M noktasına geldiğinde, görüntüsü ters aynı boyda, M noktasında ve gerçektir. M ve f arasında, görüntüsü ters, gerçek, aynanın önünde, M noktasından dışarıda ve daha büyüktür. F ile tepe noktası arasında ise, görüntü sanal, düz, aynanın arkasında ve büyüktür. Yukarıda belirttiğim noktalar için görüntünün yeri ve özellikleri cisimden çıkan ışınların aynadan yansımalarının kesişim noktası belirlenerek kolaylıkla bulunabilir. Sadece f noktasına geldiğinde görüntüsünü göremez, çünkü bu durumda görüntüsü sonsuzdadır. (18)
7. Odak noktası dışında tüm noktalarda yüzünü görür. Görüntüler terstir. Aynaya yaklaştıkça görüntüler küçülür. Sadece odak noktasında olduğu an görüntü sonsuzda olduğu için algılanamaz. (25)
8. Merkezden odağa kadar kendi görüntüsünü görür. Odaktayken göremez görüntü sonsuzda oluşur. Odakla ayna arasındayken de göebilir. Merkezden dışardayken görüntü odakla

merkez arasında ter ve küçüktür, merkezdeyken görüntü cisimle aynı boy ters ve merkezdedir. Odakla merkez arasındayken görüntü merkezin dışındadır, ters ve büyüktür. Odaktayken görüntü sonsuzdadır. Odakla ayna arasındayken görüntü düz ve büyüktür. Çukur aynanın kurallarında aynaya yaklaştıkça görüntü büyür. $1/f = 1/D_c+1/D_g$ kuralına göre yapılır. (30)

9. Merkez noktasına gelene kadar görüntüsünü ters ve daha küçük görür. Merkez noktasında eşit ve ters; odak ile merkez arasında ters ve olduğundan büyük; odak ile ayna arasında ise düz ve sanal görünür. Çukur aynanın görüntü yasalarından. (40)

- **ANSWER TYPE 2:** Merkezin dışında, merkezde, odakla merkez arasında iken

1. Görüntüsü merkeze doğru büyür. Kendine göre görüntüsü yavaştır. Merkezden sonra büyümeye devam eder. Kendine göre hızı daha da hızlanır. Görüntü de terstir ta ki odağa kadar. Odaktan sonra düzelir ama sanal olur ve görülmez. Çukur aynanın özelliğinden açıkladım. (6)
2. Odakta iken görüntü sonsuzda. (11)
3. Merkezde, merkezle odak arasında ve merkezin dışında görüntüsünü görür. Odak ile ayna arasında görüntü sonsuzda oluşabileceği için göremez. $1/f = 1/f + 1/x'$ x'=sonsuz oluşmaz. (19)
4. f-2f, 2f dışında ve 2f'de görüntüsü oluşur, O-f arasında görüntü sonsuzda oluşur. Çukur aynada cisim bu noktalarda görüntü verir. (20)
5. Merkezde, merkezle odak arasında ve merkez dışında görüntüsünü görür. Odak ile ayna arasında görüntü sonsuzda oluşacağı için göremez. Görüntü cisim ile ters yandadır. Çukur aynada görüntü oluşumundaki kurallar geçerli. $1/f= 1/x + 1/x'$ $1/f= 1/f + 1/ x'$ x'= sonsuz ise oluşmaz.(28)
6. Merkezdeki cismin görüntüsü merkezde ve ters olur. Merkezin dışındaki cismin görüntüsü odak ile ayna arasında olur. Odak ile ayna arasındaki cismin görüntüsü merkezin dışında olur. Çünkü aynaya yaklaştıkça görüntüsü de aynadan uzaklaşmakta ve ters oluşmaktadır. Ters görür. (43)

- **ANSWER TYPE 3:** Merkezde iken.

1. Merkezde iken görünüsünü görebilir, odakta iken görüntüsünü göremez. (1)
2. Merkezde tam tersini görür. (27)
3. Sadece merkezde çünkü ancak burada görüntü değişmez. Görüntü diğer yerlerde büyük yada küçük olabilir, yalnız merkezde değişmez. (36)
4. M noktasında kendini görür, ya da çukur ayna yaklaştırıldığında. (39)

- **ANSWER TYPE 4:** Merkezin dışında iken.

1. Görüntüsü düz ve cisimden küçüktür. Sanaldır. (10)
2. Kendisini ters görür. (42)
3. Görüntüsünü merkez ile odak arasında, gerçek büyüklüğünden daha küçük görür. Çünkü cisim merkezin dışındadır. (46)
4. Selin merkeze yaklaşırsa görüntü de merkeze yaklaşır, ters ve gerçek şekilde oluşur. (49)

- **ANSWER TYPE 5:** Merkezin dışında, merkezde, odak ve merkez arasında, odakta, odak ve ayna arasında iken.

1. Merkez dışındayken görüntü F-M arası, küçük, ters. Merkezde; merkezde görüntü, aynı boy, ters. F-M arası; merkez dışı, ters, büyük. F; sonsuzda. T-F arası; sanal, düz, F-T arası ayna arkası. (21)

2. Selim yüzünün görüntüsünü ters odak ile tepe noktası arasında görür. Görüntü daha küçüktür. Selim merkez noktasına gelinceye kadar görüntü kendisine yaklaşır ve boyu artar. Merkezden sonra tersi olur. Görüntü gerçektir. Bu özelliklerin hepsi $1/f = 1/d_c + 1/d_g$ formülünden çıkar. (38)
3. Çukur aynaya yaklaşarak görüntüsünü merkez, odak ve tepe noktasına kadar görmeye başlar. Tepe noktasında görüntü sıfır olur. Görüntüyü merkezde çizdiğimde merkezde, odakta çizdiğimde odakta çıktığı için. (45)

- **ANSWER TYPE 6:** Merkezin dışında, odak ile merkez arasında, odak ve ayna arasında iken.

1. Cisim M'nin dışında ise görüntü f-M arasında oluşur. Cisim f-M arasında ise görüntü M'nin dışında olur. Cisim O-f arasında ise görüntü f^{-1}-O arasında olur. (12)
2. Merkeze gelene kadar odak ile merkez arasında ters olarak kendisini görür. Merkezden odağa kadar ise görüntüsünü merkezden ileride ters görür. Odak ile tepe arasında ise aynanın arkasında düz ve zahiri görür. Görüntüyü çizdiğimizde veya formüllerle baktığımızda bu şekilde olur. (15)

- **ANSWER TYPE 7:** Merkezin dışında, merkezde, odakla merkez arasında, odakta iken

1. İlk durum 3f'de iken 1,5f'de düz görür. 2f'de aynı boyda yine 2f'de görür. 1,5f'de 3f'te düz daha büyük görür. f'de ise kendini sonsuzda görür. (24)
2. M-sonsuz arasında iken görüntü f-M arasında; M'deyken M ve ters görüntü oluşur. F-M arasındayken görüntü M-sonsuz arasında; f'de iken görüntü sonsuzda oluşur. (35)

- **ANSWER TYPE 8:** Merkezin dışında, merkezde, odakta, odak ve ayna arasında iken.

1. Merkezin dışındaysa, görüntü merkezle odak arasındadır. Merkezdeyse, görüntü merkezdedir. F'de ise, görüntü sonsuzdadır. T-F arasında ise, görüntü zahiridir, aynanın arkasındadır. (7)

- **ANSWER TYPE 9:** Merkezin dışında, merkezde, odakta iken.

1. M; M düz aynı - 3f; 1,5f - f; sonsuz. $1/f = 1/d_c + 1/d_g$ (37)

- **ANSWER TYPE 10:** Odakla merkez arasında iken.

1. f ile merkez arasındayken görebilir. Görüntü ters ve gerçektir. f'te görmez çünkü görüntü sonsuzda oluşur. (41)

Item 15.

- **ANSWER TYPE 1:** Merkezin dışında, merkezde, odak ve merkez arasında, odak ve ayna arasında iken.

1. Selin merkezin dışındaysa, görüntü F-M arasında. Merkezdeyse, görüntü merkezdedir. F-M arasında ise, görüntü merkezin dışında. F-T arasında ise, görüntü aynanın arkasındadır. (7)
2. Odak noktası dışında tüm görüntülerini görür. Görüntüler ayna arkasında, sanal ve düzdür. Sadece odak noktasındaki görüntü algılanamaz. (17)
3. Selin hangi noktada olursa olsun, görüntüsü aynanın arkasında yani sanal, düz ve kendisinden küçüktür. F noktası hariç, oradayken kendisini göremez. Çünkü odak noktasına geldiğinde görüntüsü sonsuzda olacaktır. (18)
4. Odak noktası dışında tüm görüntülerini görür. Sadece odak noktasındaki görüntü algılanamaz. (25)

5. Görüntüsünü merkezin dışındayken görebilir. Çünkü görüntü hep ayna ile odak arasındadır. Odaktayken görüntü sonsuzdadır. Görüntü düz ve küçüktür. Ama aynaya yaklaşırken görüntü hep büyür. Sonsuzdayken de nokta halinde odakta oluşur. Tümsek aynanın özellikleridir. $-1/f = \pm 1/D_c \pm 1/D_g$

- **ANSWER TYPE 2:** Merkezin dışında, merkezde, odak ve merkez arasında, odakta, odak ve ayna arasında iken.

1. Tümsek aynada görüntü hep f/2'de (aynanın arkasında) ve sanaldır.(11)
2. f-T arasında görür. Nedeni tümsek aynada sadece bu kesimde oluşur. (12)
3. Selin yüzünün görüntüsünü her zaman daha küçük görür. Görüntü aynanın arkasında düz ve zahiridir. Tümsek aynasa cismin görüntüsü her zaman düz ve aynanın arkasındadır. $-1/f=1/d_c-1/d_g$ (38)
4. Cisim nerede olursa olsun görüntü odak ile ayna arasında olur. Hiçbir zaman gerçek görüntü oluşmaz. (43)

- **ANSWER TYPE 3:** Merkezin dışında, merkezde, odak ve merkez arasında, odakta, odak ve ayna arasında iken.

1. Görüntü sanal ve düzdür. Odakla tepe noktası arasında oluşur. Tümsek aynada yansıma kanunlarından. (4)
2. Her noktada görüntü düz, aynanın arkasında ve f-T arasındadır. (21)
3. Aynaya yaklaştıkça boyu ters ama daha büyük olur. $-1/f=1/D_g+1/D_c$
4. Sebep yok. (28)

- **ANSWER TYPE 4:** Merkezde iken.

1. Merkezde iken kendi görüntüsünü görebilir. (1)
2. Yine merkezde, yine aynı sebepten görüntü arkada ve odakla ayna arasında daha küçük görür. Merkezde değişmez. (36)
3. Sebep yok. (39)

- **ANSWER TYPE 5:** Merkezin dışında, merkezde, odak ve merkez arasında iken.

1. Buradaki (Selin merkezin dışında iken) görüntü aynanın öbür tarafında F-M arasında oluşur, zahiridir. Buradaki (Selin merkezde iken) görüntü aynanın öbür tarafında M'de oluşur, zahiridir. Buradaki (Selin odak ve merkez arasında iken) görüntü aynanın öbür tarafında oluşur, zahiridir. (9)
2. Görüntüler zahiri. (20)

- **ANSWER TYPE 6:** Merkezin dışında iken.

1. Görüntüsü cisimle aynı boyda, sanal ve terstir. (10)
2. Selin kendisini aynanın arkasında odak ile aynanın arasında; büyüklüğünü ise daha büyük bir şekilde görür. (46)

- **ANSWER TYPE 7:** Merkezin dışında, merkezde, odakta iken.

1. M'de iken M'de düz aynı boyda; f'de iken sonsuzda; M dışında ise f-mercek arasında. (37)
2. M-M'de; 3f-1,5f'de; f-f/2'dedir. (50)

- **ANSWER TYPE 8:** Merkezin dışında, odak ve merkez arasında, odakta, odak ve ayna arasında iken

1. Tümsek aynada görüntüler buralarda oluştuğundan Selin bu noktalarda görüntüsünü görür. (3)

- **ANSWER TYPE 9:** Merkezin dışında, odak ve merkez arasında iken.

1. Sebep yok. (13)

- **ANSWER TYPE 10:**

1. Bilmiyorum cisim sonsuzda iken görüntü odakta zahiri şekilde oluşur. (49)

Item 16.

- **ANSWER TYPE 1:** Kalemin görüntüsü oluşmaz/görülmez.

1. Oluşmaz, çünkü kalem aynada görülemez. (3)
2. Oluşmaz. (*kalemin ucundan asal eksene paralel bir ışın çizilmiş*) (2)
3. Görüntü oluşmaz (*kalemin ucundan asal eksene paralel ve aynanın tepe noktasına iki ışın çizilmiş*) (6)
4. Görüntü oluşmaz, çünkü odaktan geçen ışığın kesişeceği başka bir ışık oluşmaz. (*kalemin ucundan asal eksene paralel ve odaktan geçecek şekilde iki ışın çizilmiş*) (8)
5. Normalde F-M arasında görüntü olmalıdır. Karton bunu engellemektedir. (13)
6. Gözlenemez çünkü ışınlar aynaya ulaşmaz. (21)
7. Karton konulmadan önce görüntü M-f arasında ve terstir. Ancak karton konulduğunda görüntü oluşmaz. (*kalemin ucundan asal eksene paralel ve aynanın tepe noktasına iki ışın çizilmiş*) (37)
8. Görüntü oluşmaz. (*kalemin ucundan asal eksene paralel bir ışın çizilmiş*) (39)
9. Görüntü oluşmaz. (*kalemin ucundan asal eksene paralel ve odaktan geçen iki ışın çizilmiş*) (42)
10. Kalemin görüntüsü oluşmaz. Çünkü eksen üzerinde hem cisim hem de karton aynı taraftadır. (46)
11. Görüntü oluşmaz. Engelden dolayı. (48)
12. Aynaya ışın gitmediği için görüntü oluşmaz. Işınlar ulaşmadığı için. (*kalemin ucundan asal eksene paralel ve merkeze iki ışın çizilmiş*) (51)
13. Görünmez. (52)

- **ANSWER TYPE 2:** Kalemin görüntüsü değişmez.

1. Cisim merkezin dışındaysa, görüntü merkez ile odak arasındadır, terstir. (*kalemin ucundan aynanın tepe noktasına ve odaktan geçecek şekilde iki ışın çizilmiş*) (7)
2. Kalem merkezle odak arasında, ters ve cisimden daha büyüktür. (*kalemin ucundan merkezden geçen ve odaktan geçen iki ışın çizilmiş*) (10)
3. Değişiklik olmaz, çünkü küresel aynalarda görüntü bulmak için gönderilen ışınlar için büyük bir kesit alanı gerekmez. (*kalemin ucundan f ile M arasından geçecek şekilde herhangi bir ışın aynaya çizilip merkez ile eşit açı yaptırılarak yansıtılmış)* (17)
4. Şekildeki gibi cisimden ışınlar gönderilirse, görütünün yeri bulunabilir. Karton, görüntünün yerini veya şeklini etkilemez. Sonuçta aynanın alt kısmı hala açıktır ve cisimden çıkan ışınlar tek bir doğrultuda değil, her doğrultuda yayılır. Biz bunlardan bazı özel olanları kullanarak görüntünün yerini kolaylıkla bulabiliriz. (*kalemin ucundan merkezden geçen ve odaktan geçen iki ışın çizilmiş*) (18)
5. Aynı. (*kalemin ucundan merkezden geçen ve odaktan geçen iki ışın çizilmiş*) (23)
6. Küresel aynalarda görüntü bulmak için gönderilen ışınlar için büyük kesit alanına ihtiyaç yoktur. (*kalemin ucundan f ile M arasından geçecek şekilde herhangi bir ışın aynaya çizilip merkez ile eşit açı yaptırılarak yansıtılmış)* (25)
7. Görüntü yine oluşur. (28)

8. Değişiklik olmaz odaktan gelecek şekilde çizilirse ışın görüntünün boyu değişmez. (*kalemin ucundan odaktan geçen ve aynanın tepe noktasına iki ışın çizilmiş*) (30)
9. Görüntüsünü görür ama tam aydınlık göremez, gölgeli görür. Çünkü karton ışınları tam olarak geçirmez. (*kalemin ucundan asal eksene paralel ve aynanın tepe noktasına iki ışın çizilmiş*) (43)
10. Kalemin görüntüsü değişmez. (44)
11. 3f-1,5f mantığı. (50)

- **ANSWER TYPE 3:** Görüntü küçülür/Görüntünün yarısı kaybolur.

1. Görüntünün alta doğru olması lazımken yine üstte olur ve yarısı kadar olur. Karton olmasaydı görüntü yine f-M arasında oluşurdu. Ama aşağı yönde olurdu. Ama üst kısımda engel olduğu için kalem alttan görüntü alır ve görüntü üst kısımda oluşur. (12)
2. Küçülür çünkü yarısı kapatılıyor. (24)
3. Kalemin görüntüsünün yarısı görülebilir. Engel aynanın yarısına yerleştirildiği için. (31) (33)
4. Yarısı görünür. (34)
5. Kısalma olur. Çünkü görüntü yansımaları ve gelen açılar değişir. (36)

- **ANSWER TYPE 4:** Kalemin görüntüsü nokta şeklinde oluşur.

1. Kalemin bir kısmının görüntüsü oluşur. Bu nokta şeklindedir. Işık gönderip gördüm. (*kalemin ucundan asal eksene paralel ve odaktan geçecek şekilde iki ışın çizilmiş*) (49)

- **ANSWER TYPE 5:** Kalemin görüntüsünün uç kısmı oluşmaz.

1. Sebep yok. (27)

KESİŞEN AYNALAR

Item 17.

- **ANSWER TYPE 1**: 5

1. (360/α)-1 formülünden dolayı 5 görüntüsü oluşur. (1)
2. 360^0, kesişen aynalarda aynalar arasındaki açıya bölünüp 1 çıkarılırsa görüntü sayısı bulunur. (2)
3. n = (360/α)-1 = 5 (3) (7) (11) (13) (15) (18) (21) (23) (24) (26) (31) (33) (34) (37) (41) (42) (47) (48) (49) (50)
4. (360/α)-1 = 5 görüntüsü olur. Aslında 6'dır. Ancak 2 tanesi üst üste çakışır. Bu yüzden 5 olur. (4)
5. Formülden öyle çıkıyor. (6) (46)
6. (360/α)-1 = 5. 5. Görüntü A2 aynasının arkasında kaldığından başka görüntü oluşmaz. (8)
7. (360/α)-1 = 5. Aynanın görüntü alabildiği görüş alanları içinde görüntü görülebilir. (12)
8. Görüntüler bir başka görüntüler için oluşma seebidir. (25)
9. Her aynada görüntüler çakışıncaya kadar yansımalar alınır. n =(360/α)-1
10. (360/60)-1 = 5. İki ayna arasındaki açı ne kadar küçülürse görüntü o kadar çok olur.(43)
11. (360/60)-1 = 5. Yansımalardan dolayı. (51)

- **ANSWER TYPE 2:** 6

1. 360/60 = 6 (19) (20) (28)

- **ANSWER TYPE 3:** 4

1. 4 görüntüsü oluşur. (10)

- **ANSWER TYPE 4:** 3

1. Düzlem aynadaki görüntü kuralından. (40)

Item 18.

- **ANSWER TYPE 1:** 2,43

1. (360/105)-1 kadar görüntü oluşur. Formülden kaynaklanıyor. (1)
2. (360/105)-1 kadar görüntü oluşur. (2) (11) (37) (42) (50) (51)
3. n= (360/ α)-1= 2,4 (7) (33) (47) (49)
4. n=(360/105)-1= 2 tane tamamen görüntüsü oluşur. 1 tane de bir kısmını görür. Aradaki açının tam bölünememesinden kaynaklanıyor. (46)
5. n=(360/105)-1 Düzlem aynada görüntü oluşumu. (48)

- **ANSWER TYPE 2:** 2

1. (360/105)-1=2 görüntüsünü görür. Yansıma kanunlarından. (4)
2. (360/105)-1=2 tane görür. 2. görüntü her iki aynanın da arkasında kalır. (8)
3. (360/105)-1=2 tane görüntü. Ayna çok açık. Bu yüzden az oluşur. (12)
4. (360/105)-1=2,45. 2 görüntüsünü tam görür. (18)
5. (360/105)-1≈ 2. Aynalar arası açı arttıkça görüntülerin tekrar görüntü oluşturabilmesi için ayna önüne düşme durumu azalır. (25)
6. 2 net görüntüsü oluşur. n= (360/ α)-1=2. (30)

- **ANSWER TYPE 3:** 4

1. Aynaları uzatırsak gözün bir görüntüsü A1 aynasında sonra görüntüsünün görüntüsüde A2 aynasında oluşur oldu iki görüntü. Aynı şekilde gözün A2 aynasında görüntüsü de bu şekilde oluşacak. Toplam 4 görüntü oluşur. (43)
2. Sebep yok. (6) (21)

- **ANSWER TYPE 4:**Sonsuz sayıda görüntü olur.

1. Geniş açılı bir düzlem olduğundan. (10)

- **ANSWER TYPE 5:** 3,43

1. 360/105=24/7 (19) (20) (28) (31)

- **ANSWER TYPE 6:** 3

1. (360/105)-1=2,4 tane. 3 görüntü görür. (34)

- **ANSWER TYPE 7:**1

1. Sebep yok. (44)

- **ANSWER TYPE 8:**

1. (360-105) / n (9)

Item 19.A.

- **ANSWER TYPE 1:** 3

1. (360/90)-1=3 Formulde yerine yerleştirdiğimizde bunlar oluşur. (3)
2. (360/90)-1=3 Yansıma kanunları. (4)
3. 4 tane görüntü oluşur. 2 tane görüntü üst üste gelir ve 3 görüntü gibi olur. (6)

4. (360/90)-1=3 (7) (13) (18) (21) (30) (31) (32) (34) (35) (37) (42) (46) (47) (49) (50) (51)
5. 3 görüntüsünü görür. 1. ve 4. görüntüler üst üste oluşur. (8)
6. (360/90)-1=3 Aynaları uzatırsak ve bunların uzantıları da çakışırsa yine yukarıdaki işlem yapılır. (12)
7. Tek bir düzlem aynada bir görüntü oluşur. Oluşan görüntü diğer aynada başka görüntü oluşturabilir. (25)
8. 4 görüntüsü oluşur. Ama ikisi üst üste geldiği için 3 görüntüsünü görür. Aynaya eşit uzaklıkta ışınlar gönderdiğimizde eşit uzaklıkta bir yerde görüntü oluşur. (43)
9. (360/90)-1=3 Düzlem aynada görüntü oluşumu. (48)

- **ANSWER TYPE 2:**Sonsuz görüntü oluşur.

1. Topun her iki aynada da görüntüsü oluşur. (1)
2. Topun her iki aynada da görüntüsü oluşur sırasıyla. (2)

- **ANSWER TYPE 3:** 4

1. Sebep yok. (10) (44)

- **ANSWER TYPE 4:** 2

1. Sebep yok. (24)

- **ANSWER TYPE:**

1. (360-90) / n (9)

Item 19.B.

- **ANSWER TYPE 1:** Değişmez.

1. Gözlemci konumunu değiştikçe görüntü sayısı değişmez. (1) (2)
2. Aynalar arasındaki açı aynıdır. Bu nedenle görüntü sayısı değişmez. (3)
3. Herhangi bir görüş alanındaysa sayı değişmez. (12)
4. Aynalar arasındaki açı ve nesnenin konumu sabit kaldığı sürece görüntü sayısı sabittir. (18)
5. Aynalar değişmiyor. (24)
6. Sebep yok. (4) (13) (21) (31) (32) (34) (35) (37) (48) (49) (50) (52)

- **ANSWER TYPE 2:** Değişir.

1. Cevap yok. (6) (42)
2. Görüş açısı değişeceğinden. (8)
3. Herhangi bir aynanın arka tarafına düşecek şekilde konumlanırsa oluşan görüntü sayısı azalır. (25)
4. İki aynadan birinin ilk görüntüsü görülemeyebilir. (30)
5. Aynalarda oluşan görüntü sayısı değişmez. Fakat gözlemcinin gördüğü değişebilir. (46)
6. Açı değiştiği için değişir. (47)

MERCEKLER

Item 20.

- **ANSWER TYPE 1:** Ekranda görüntüsü oluşmaz.

1. Ekran uzaklaştırılırsa, geriye doğru çekilirse görüntü netliğini kaybeder. (1)
2. Çivinin ekran üzerindeki görüntüsünün netliği azalır. Ekranı yaklaştırırsak netliği artar. (7)

3. Çivi M'nin dışında olduğu için görüntü f ile M arasında olacaktır. Ekranda çivi gözükmez. (11)
4. Çivinin görüntüsü f ile M arasında oluşur. Bu durumda görüntü ekran üzerine düşmez. (18)
5. Görüntünün yeri değişmez çünkü yine f-2f arasındadır. (20)
6. Görüntü ekran üzerinde oluşmaz. Mercek ve merceğin çiviye olan uzaklığı sabit kaldığı için görüntünün yeri değişmez. (25)
7. Görüntü f-M arasında oluştuğu için ekran uzaklaştırılınca görüntü ekrana düşmez. (35)
8. Ekran uzaklaşınca görüntünün yeri değişmez. Çünkü görüntü hep f ile M arasında olur. (40)
9. İnce kenarlı mercekte mercekten gelen ışın odakla-merkez arasına geldiğinde görüntü ters ve gerçekten daha küçük olur. Ancak görüntü merkezin dışına düşerse ters ve sonsuz olur. (47)
10. Sebep yok. (6) (21) (37) (42) (50)

- **ANSWER TYPE 2:** Ekranda görüntü büyür.

1. Görüntü merkez dışında daha büyük olur. (3)
2. İnce kenarlı mercekte yansıma kanunları. (4)
3. Ters ve cisimle aynı boyda olur. (10)
4. Görüntü ilk f-M arasında oluşur. Ekran geri çekilirse görüntü büyür. (12)
5. Uzaklaştığından boyu büyür. (24)
6. Görüntü büyür. Çünkü ince kenarlı mercekten kırılan ışınların kesiştikleri noktalar daha uzakta kesişir. (28)
7. Ters döner. (32) (33) (34)
8. Odak ile merkez arasında görüntü küçük, M'nin dışında büyür. (48)
9. İnce kenarlı mercek çividen sebep görüntüsü tümsek ayna gibi davranır. (49)
10. Kırılmadan dolayı. (51)
11. Sebep yok. (23)

- **ANSWER TYPE 3:** Ekranda görüntü küçülür.

1. Görüntüsü netliğini kaybedebilir ve küçülür. Cismin yeri değişmeyeceğinden görüntünün yeri değişmez ancak ekrana izdüşümü değişir. (30)
2. Oluşan şekil biraz daha küçülür ve tamamı görünmeyebilir. (46)
3. Sebep yok. (45)

Item 21.

- **ANSWER TYPE 1:** Çivinin orta kısmını görür.

1. Çünkü karton çivinin diğer kısımlarının görünmesini engelleyecektir. (3)
2. Çivinin sadece görünen kısmından çıkan ışınlar mercekten geçerek kırılır. (4)
3. Aynada çivinin bir bölümünü görür. Çünkü ayna çivinin tam görüntüsünü alamaz. Yani ekranda çivinin sivri yeri ve topuzu görünmez. (12)
4. Aralıktan geçen ışınlar çivinin görüntüsünü oluşturur, aralık kadar çivinin görüntüsü oluşur. (20)
5. Çivinin ortasını görür. Açık kısımdan geçen ışınlar görüntüyü oluşturacağından. (21)
6. Ters, küçük görür. Kartondan dolayı. (24)
7. Aralıktan kırılan ışınların kesiştiği noktalar arasındaki görüntüyü görür. (28)
8. Çivinin bir kısmının görüntüsü ekran üzerine düşer. Engel olacağından çividen gelen bir kısım görüntünün ışını kırılacaktır. (30)
9. Kalemin sadece bir kısmını görür ve gerçek boyundan küçük görür. Merkezden sonraki cisimlerin görüntüsü merkez ile odak arasında olur. Fakat karton boyunun tamamını engellediği için bir kısmı tek görünür. (40)

10. Çemberin büyüklüğü ile orantılı olarak görüntü oluşur. (46)
11. Çivinin bir kısmı ekranda görünür. Engelden dolayı. (48)
12. Çivinin bir kesiti görünür. Kırılmadan. (51)

- **ANSWER TYPE 2:** Ekranda çivinin tamamının ters görüntüsü oluşur.

1. Çivinin görüntüsünü ters, cisimden küçük bir şekilde görür. Kartonu göremez. Kartonun görüntüsü şekildekine benzer bir yerde (cisimle aynı tarafta) yani sanaldır. Bu durumda görüntüsü zaten ekran üzerine düşmez. Çivinin görüntüsü tam da ekranın bulunduğu noktada oluşur. Dolayısıyla ekranda sadece çivinin görüntüsü oluşur. (18)
2. Oluşan görüntü odak uzaklığı değişmediği sürece değişmez, merceğin gerçek boyutu sabittir. Eğrilik yarıçapında bir değişiklik yoktur. (25)
3. Görüntü uzaklıklarla orantılı olarak ekrana yansır. (35)
4. Görüntüden daha kısa ve ters bir görüntü görür. Çünkü ekran f-m arasında olduğu için burada oluşan görüntünün özellikleri de budur. (47)
5. Sebep yok. (7) (37)

- **ANSWER TYPE 3:** Ekranda daire şekli görür.

1. Kartondaki açıklık daire olduğu için. (11)
2. Büyük bir açıklık ve ortası karanlık . (44)
3. Sebep yok. (52)

- **ANSWER TYPE 4:** Görüntüsü oluşmaz.

1. Tepe noktasına gelen ışığın görüntüsünü görebilir. Tek başına görüntüye yetmez. (1)

- **ANSWER TYPE 5:** Çivinin görüntsü küçülür.

1. Sebep yok. (10)

Item 22.

- **ANSWER TYPE 1:** 1 ve 2

1. Görüntü sol tarafta oluşur. Sağ tarafta cisimden çıkan ışınlar kesişmez be nedenle 3,4 ve 5 görüntüyü göremez. (25)
2. Görüntü ön tarafta olduğu için. (51)
3. Sebep yok. (1) (13)

- **ANSWER TYPE 2:** 1

1. Işınlar o eksende kesişiyor. (24)
2. Kalemin görüntüsünün kesişme noktalarının tamamını görür. (49)
3. Sebep yok. (20) (28) (37) (46) (50)

- **ANSWER TYPE 3:** 1,3 ve 4

1. Işınların arasında oldukları için. (10)
2. 2 ve 5 noktalarından bakan gözlemciler cisimden çıkan ışınların tamamını göremediklerinden, 1,3 ve 4 numaralara ışınlar tam onlara gelir. (30)

- **ANSWER TYPE 4:** 3 ve 4

1. Buralardan baktığında cismin tamamı gözlem alanına girer. (3)

- **ANSWER TYPE 5:** 3

1. Nedeni odaktan cisme doğru çekilen ışınlardan sadece o ışınlardan faydalanabilir. (12)

- **ANSWER TYPE 6:** 1, 2,3 ve 4

1. 5 numaralı gözlemci haricinde tam tüm noktalar görüş alanında olduğundan dolayı görünür. (40)

- **ANSWER TYPE 7:** 2,3 ve 4

1. Çünkü ışınların hepsinin tamamını kapsıyor. (4)

- **ANSWER TYPE 8:** 3, 4 ve 5

1. Sebep yok. (21) (32) (33) (34)

- **ANSWER TYPE 9:** 4

1. Sebep yok. (9) (41)

- **ANSWER TYPE 10:** 2 ve3

1. Sebep yok. (7)

- **ANSWER TYPE 11:** 1, 2,3, 4 ve 5

1. Sebep yok. (42)

- **ANSWER TYPE 12:** 2 ve 4

1. Sebep yok. (47)

- **ANSWER TYPE 13:** 1,2 ve 3

1. Sebep yok. (52)

Item 23.

- **ANSWER TYPE 1:** Merkezin dışında, merkezde, odak ve merkez arasında, odak ve mercek arasında iken.

1. 2f'nin dışındayken görüntü f-2f arasındadır. 2f'deyken görüntü yine 2f dedir. F-2f arasındayken görüntü 2f'nin dışındadır. T-f arasındayken görüntü merceğin arkasında oluşur. (7)
2. 2f noktasına gelinceye kadar görüntüsü merceğin diğer tarafında, ters ve gerçektir. 2f'e geldiğinde görüntüsü merceğin diğer tarafında ters, gerçek ve aynı boydadır. f noktasındayken görüntüsünü göremez. f ile mercek arasına geldiğinde ise görüntüsü düz, daha büyük ve kendisiyle aynı tarafta yani sanaldır. Şekildeki gibi özel ışınlar yardımıyla görüntünün yeri ve özelliklerini bulabiliriz. Selin odak noktası hariç her noktada görüntüsünü görebilir. Odak noktasındayken görüntüsü sonsuzda oluşacaktır. (18)
3. Merkez dışı; mercek arkası f-2f arası, küçük, ters, gerçek. Merkez; mercek arkası merkezde, aynı boyda, ters, gerçek. f-2f; 2f dışı, büyük, ters, gerçek. f ve öncesinde; düz, küçük, sanal mercek önü. (21)
4. F noktası dışında tüm noktalarda görüntüsünü görebilir. Selin merceğe yaklaştıkça görüntü boyu artar. Görüntüsü terstir. Odak noktasındayken görüntüsü sonsuzda oluşur. (25)

5. 2f'e varmadan önceki durumlarda ters ve kendi boyundan küçük. Merkezde ters ve kendi boyunda. Merkez ile odak arasında ters ve daha büyük. Odak ve mercek arasında ise düz ve kendi boyundan büyük ve sanal. Yine ince kenarlı merceğin görüntü yasalarından. (40)
6. 3f'de ise 1,5f'de görür, terstir. 2f'de 2f'de görür, aynı boydadır, terstir. 1,5f'de ise 3f'de görür, büyüktür. f'de ise sonsuzdadır. f ile mercek arasındaysa aynanın arkasında, büyük sanaldır. (50)
7. f hariç heryerde görüntüsünü görebilir. Çünkü f'de görüntü sonsuzda öncesinde arkada f'den sonrasında önde oluşur. (51)

- **ANSWER TYPE 2:** Merkezin dışında, merkezde, odak ve merkez arasında iken.

1. 2f dışında kendinden küçük görüntü görür. 2f'de aynısını görür. f-2f 'de kendinden büyük görüntü görür. (19)
2. Çünkü f-2f, 2f dışı, 2f'de gerçek görüntü veriyr. Ters görüntü. (20)
3. 2f dışında görür, kendinden küçük görür. 2f'de aynısını görür. f-2f'de kendinden büyük görüntü görür. (28)

- **ANSWER TYPE 3:** Hiçbir yerde göremez.

1. Çünkü görüntüyü görebilmek için bir ekrana düşürülmesi gerekir. (12)
2. Sebep yok. (32) (33) (34)

- **ANSWER TYPE 4:** Merkezin dışında iken.

1. Görüntüsü de hareket eder, sanal M'ye doğru. (6)
2. Düz, gerçek, odakta ve cisimle aynı boyutta.(10)
3. Görüntü terstir. (48)

- **ANSWER TYPE 5:** Merkezin dışında, merkezde, odak ve merkez arasında, odakta, odak ve mercek arasında iken.

1. Önce baş kısmını ve aynaya yaklaştıkça yüzünün tamamını görebilir. (13)
2. 2f'e kadar görüntüsü olduğundan daha küçük. 2f'de aynı boyda. 2f'den sonra daha büyük görür. (46)

- **ANSWER TYPE 6:** Merkezde, odak ve merkez arasında, odak ve mercek arasında iken.

1. 2f'teyken 2f'te; f-2f arasındayken 2f'in dışında; f ve ince kenarlı mercek arasında oluşur. Çünkü ice kenarlı mercekte görüntüler bu noktalarda oluşur. (3)

- **ANSWER TYPE 7:** Merkezin dışında**,** odak ve merkez arasında, odak ve mercek arasında iken.

1. Sadece odak ve tepe noktası arasındayken düz, sanal ve cisimden küçüktür. Merkezin dışındayken odakla merkez arasında ters gerçek cismin boyunun yarısı kadar. Odakla merkez arasındayken ters gerçek cismin boyundan iki kat büyük. Çukur aynada yansıma kanunlarıyla aynı. (4)

- **ANSWER TYPE 8:** Odakta

1. Odağa geldiğinde görüntüsünü net görür. (42)

- **ANSWER TYPE 9:** Merkezin dışında, merkezde

1. (*2f dışında iken*) yoluna düşeceğinden görebilir. Çukur aynayla aynıdır yalnız merkezden sonra kendisi engel olduğundan göremez. f'de görüntü sonsuzda oluşur. 2f'de eşit olur. Çukur ayna kurallarıyla hemen hemen aynıdır. (30)

- **ANSWER TYPE 10:** Merkezin dışında, merkezde, odakta, odak ve mercek arasında iken.

1. Selin 3f, görüntü 1,5f, düz. Selin 2f, görüntü 2f, aynı, düz. Selin f, görüntü sonsuz, düz. Selin f-mercek arası, görüntü merceğin arkası, düz. (37)

- **ANSWER TYPE 11:** Merkezde iken.

1. Sebep yok. (9) (11) (35)

Item 24.

- **ANSWER TYPE 1:** Merkezin dışında, merkezde, odak ve merkez arasında, odakta, odak ve mercek arasında iken.

1. Görüntüsü hep odakla tepe noktası arasında olur. Kalın kenarlı mercekte yansıma kanunları. (4)
2. Her noktada mercek önü, düz, sanal, küçük, f ile T arasında görüntü oluşur. Kalın kenarlı merceklerde görüntü oluşumu. (21)
3. Merkez noktasında görüntü f'de oluşur. Diğer tüm noktalarda odak ile mercek arasında oluşur. Kalın kenarlı merceğin görüntü yasalarından dolayı öyle olur. (40)
4. f ile ayna arasında görüntü aynaya yaklaştıkça büyür ve görüntü gerçektir. (46)
5. Her yerde görüntü vardır, yaklaştıkça görüntü küçülür. (48)
6. Her pozisyonda görüntü vardır. Yaklaştıkça görüntü küçülür. Görüş alanı ve kırılmalardan dolayı. (51)

- **ANSWER TYPE 2:** Merkezin dışında, merkezde, odak ve merkez arasında, odak ve mercek arasında iken.

1. f noktasına gelinceye kadar görüntüsü kendisinden küçük, düz sanal kendisiyle aynı taraftadır. f noktasında göremez. f ile mercek arasındayken de aynı şekilde kendisiyle aynı tarafta, sanal, düz ve daha küçüktür. Kalın kenarlı mercekte cisim nerede olursa olsun görüntüsü düz, cisimle aynı tarafta yani sanal, cisimden daha küçüktür. Cisim odak noktasındayken görüntü sonsuzda oluşacağından göremez. Bunları özel ışınları kullanarak da şekildeki gibi gösterebiliriz. (18)
2. Odak noktası dışında görüntüsünü algılayabilir. Görüntüler düz ve odak ile mercek arasındadır, sanaldır. Odak noktasında iken Selin'in gözünden çıkan ışınlar kesişmez, bu nedenle görüntü oluşmaz. (25)
3. f-2f arasına görüntü düşer. Odağa geldiğinde göremez. (30)
4. 3f'de iken görüntü 1,5f'dedir, ters, küçük. 2f'de ise görüntü 2f'dedir, aynı boydadır. 1,5f'de ,se görüntü 3f'dedir, büyüktür, terstir. Odakta ise sonsuzdadır. Odakla mercek arasındaysa aynanın arkasında, sanaldır, büyüktür. (50)

- **ANSWER TYPE 3:** Hiçbir yerde göremez.

1. Hiçbirinde göremez. Yine burada da ekran yok. Ekrana düşürülmeyen görüntü görülemez. (12)
2. Göremez, zahiri. Mercekte gerçek görüntü görür. (32) (33) (34)
3. Sebep yok. (14)

- **ANSWER TYPE 4:** Merkezde iken.

1. 2f noktasında kendi başını tam olarak görebilir. (39)

2. 2f'de iken görüntü 2f'de oluşur, ters ve gerçek. f'de iken görüntü oluşmaz, sonsuzda oluşur. (41)

- **ANSWER TYPE 5:** Merkezin dışında iken.

1. Kalın kenarlı merceğin öbür tarafında ve cisim boyundan küçük olur, zahiridir. Kalın kenarlı mercekte görüntü dağıtıcıdır ve merceğin diğer tarafında oluşur görüntü ve zahiridir. (9)
2. Görüntü sanal, odakta, düz, cisimden daha büyük. (10)

- **ANSWER TYPE 6:** Odakta iken.

1. Odağa geldiğinde görüntüsünü net görür. (42)

- **ANSWER TYPE 7:** Merkezde, odakta, odak ve mercek arasında iken.

1. Selin merkezde ise görüntü merkezde, Selin odakta ise görüntü sonduzda, Selin odakla mercek arasında ise görüntü merkezin dışında oluşur, görüntü zahiridir.Nedeni Selin'in gözünden çıkan ışık ışınlarının merkez ve odağa gönderiminden oluşur. (49)

- **ANSWER TYPE 8:** Merkezin dışında, merkezde, odakta, odak ve mercek arasında iken.

1. Selin 2f, görüntü 2f, aynı, düz. Selin f; görüntü sonsuz, düz. Selin 3f, görüntü 1,5f, küçük, düz. Selin f-mercek arası, görüntü merceğin arkasında, daha küçük, düz. (37)

- **ANSWER TYPE 9:** Merkezin dışında, merkezde, odak ve merkez arasında iken.

1. f-2f, 2f dışı, 2f'de oluşur. Zahiri görüntü oluşur, yani ışınların uzantısı kesişir. (20)

- **ANSWER TYPE 10:** Merkezin dışında, odak ve merkez arasında, odak ve mercek arasında iken.

1. 2f'nin dışında, f-2f arasında, f ve mercek arasında görebilir. Çünkü kalın kenarlı mercekte görüntüler bu noktalarda oluştuğundan Selin'de kendini bu noktalarda görecektir. (3)

APPENDIX L

THE THREE-TIER GEOMETRICAL OPTICS TEST

GEOMETRİK OPTİK TESTİ

Cinsiyetiniz: □ Kız □ Erkek

Doğum tarihiniz (Gün/Ay/Yıl): ____/___/_____

Üniversitenizin adı:_____

Bölümünüzün adı: □ Fizik □ Fizik Öğretmenliği □ Diğer (_____)

Sınıfınız: □1 □ 2 □ 3 □ 4 □ 5 □ Diğer (_____)

Üniversitedeki genel not ortalamanız: _____

Üniversitede optik dersinden aldığınız not veya harf: _____

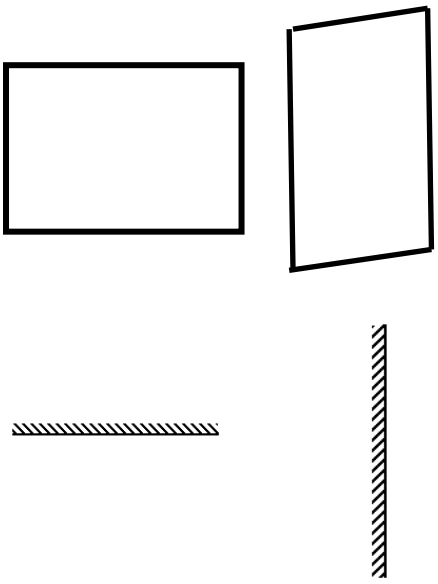
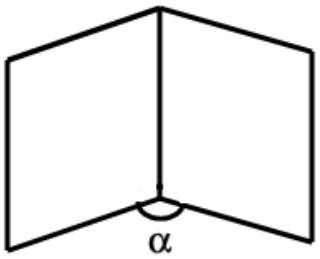
Üniversitede optik laboratuar dersinden aldığınız not veya harf:_____

Yönergeler

1. Sınava başlamadan önce yukarıda verilen kısmı **eksiksiz** doldurunuz.
2. Testte **22** soru yer almaktadır. Lütfen bütün sorulara cevap vermek için gayret gösteriniz ve verdiğiniz cevabın **nedenini** açıkça yazınız.
3. Sınavı tamamlamak için önerilen süre yaklaşık **60** dakikadır.
4. Sınavda gerekli olabilecek formüller ve şekiller arka sayfada mevcuttur.
5. Bu testin sonuçları Ortadoğu Teknik Üniversitesi'nde Ortaöğretim Fen ve Matematik Alanları Eğitimi Bölümü'nde doktora yapan araştırmacının tezinde veri olarak kullanılacaktır.
6. Bu bir bilimsel çalışmadır. Siz de şu an bilimsel bir çalışmanın parçasısınız. Gerekli ilgiyi gösterdiğiniz için teşekkür ederiz.

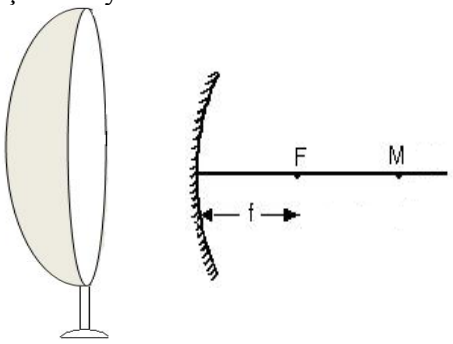
AÇIKLAYICI RESİMLER, ÇİZİMLER ve FORMÜLLER

Aşağıdaki tabloda Geometrik Optik Testi'nde yer alan sorularda bahsi geçen optik araçlara örnek olabilecek fotoğraflar, bu optik araçlara ait perspektif (yandan) veya üstten çizimler ile bu konularda ihtiyaç duyabileceğiniz bazı formüller size verilmiştir.

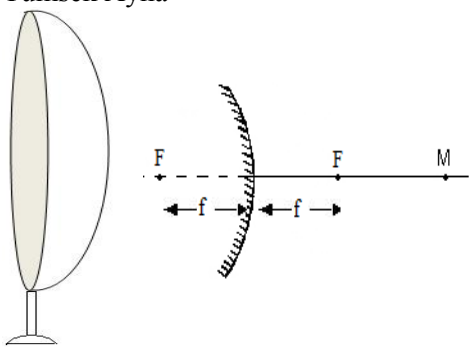
OPTİK ARACIN FOTOĞRAFI	OPTİK ARACIN PERSPEKTİF veya ÜSTTEN GÖRÜNÜŞÜNÜN ÇİZİMLERİ	OPTİK ARAÇ İLE İLGİLİ FORMÜLLER
Düzlem Ayna 		
Kesişen Aynalar 		**n:** Aynalarda oluşan toplam görüntü sayısı **α :** Aynalar arasındaki açı olmak üzere $n=\frac{360}{\alpha}-1$

Çukur ve Tümsek Aynalar

Çukur Ayna



Tümsek Ayna



F: Aynanın odağı

M: Aynanın merkezi

f: Aynanın odak uzaklığı

d_c: Cismin aynaya olan uzaklığı

d_g: Görüntünün aynaya olan uzaklığı

h_o: Cismin boyu

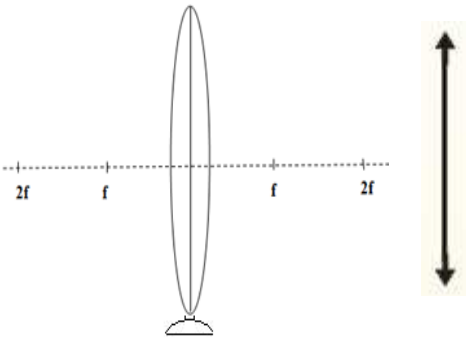
h_g: Görüntünün boyu olmak üzere

$$\frac{1}{f} = \frac{1}{d_c} + \frac{1}{d_g}$$

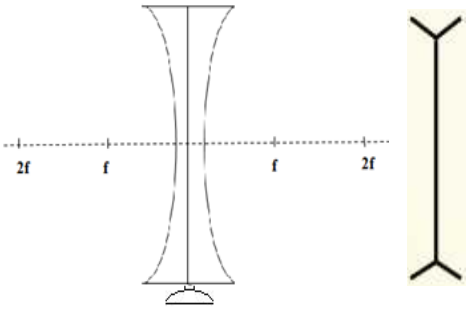
$$\frac{h_o}{h_g} = \frac{d_c}{d_g}$$

İnce ve Kalın Kenarlı Mercekler

İnce Kenarlı Mercek



Kalın Kenarlı Mercek



f: Merceğin odak uzaklığı

d_c: Cismin merceğe olan uzaklığı

d_g Görüntünün merceğe olan uzaklığı

h_o: Cismin boyu

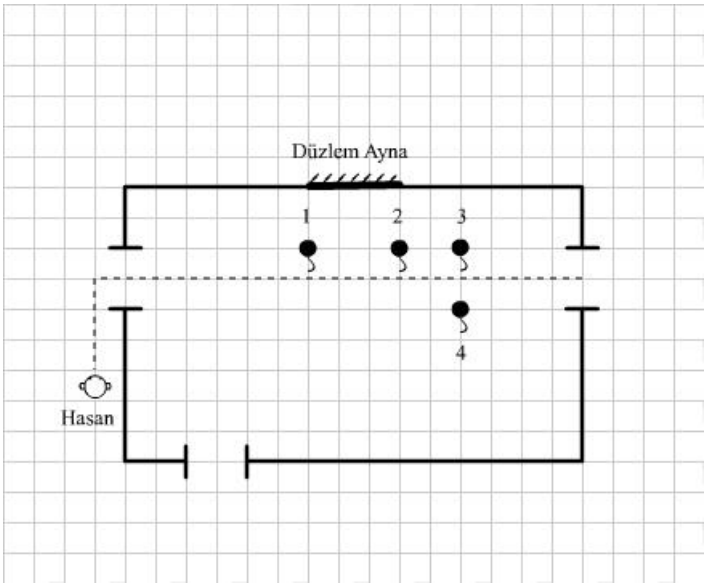
h_g: Görüntünün boyu olmak üzere

$$\frac{1}{f} = \frac{1}{d_c} + \frac{1}{d_g}$$

$$\frac{h_o}{h_g} = \frac{d_c}{d_g}$$

DÜZLEM AYNALAR

1.1. Işık kaynağı ile homojen bir şekilde aydınlatılmış bir odanın üstten görünüşü aşağıda verilmiştir. Hasan kapıdan içeri girip oda boyunca kesikli çizgi ile gösterilen yolda ilerlerken 1-4 ile numaralandırılmış kedilerin görüntüsünü duvardaki düzlem aynada gözlemlemeye çalışmaktadır. Buna göre; **numaralandırılmış kedilerin hangilerinin görüntüsü oluşur?**



a) Yalnız 1 **b)** 1 ve 2 **c)** 1, 2 ve 3 **d)** 1, 2, 3 ve 4 **e)** Diğer:.....

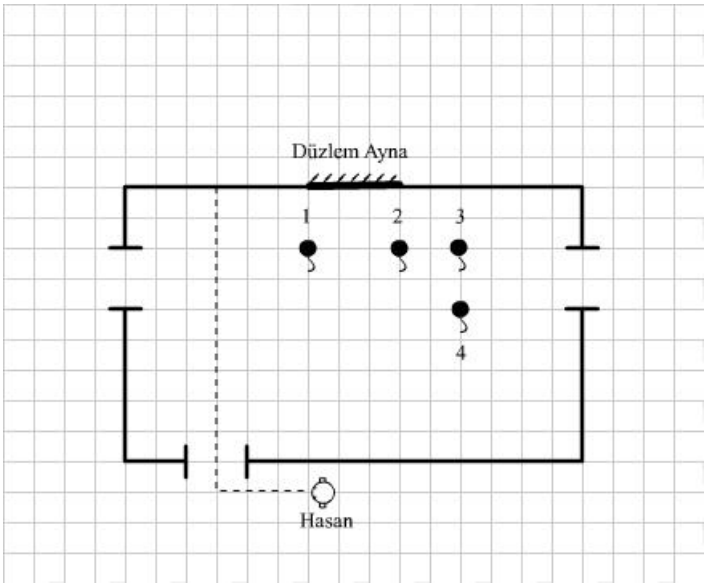
1.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Yalnızca düzlem ayna sınırları içinde kalan kedilerin görüntüsü aynada oluşabilir.
b) Oda içerisindeki kedilerden yalnızca önünde başka bir kedi olmayanların görüntüsü aynada oluşabilir. Çünkü öndeki kedi arkasındaki kediden aynaya ışık ulaşmasını engeller.
c) Oda içerisindeki kedilerin tamamının görüntüsü oluşur. Hasan oda içerisinde ilerlerken belli yerlerde bazı kedileri göremiyor olsa bile, o kedinin düzlem aynada görüntüsü oluşur.
d) Oda içerisindeki kedilerin tamamının görüntüsü oluşabilir. Ancak, görüntü oluşumu ve gözlemlenmesi aynı anda gerçekleşen olaylardır. Hasan oda içerisinde ilerlerken belli yerlerde belli kedileri göremiyorsa o kedinin o anda düzlem aynada görüntüsü oluşmamıştır.
e) Diğer:.....

1.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. **b)** Emin değilim.

2.1. Işık kaynağı ile homojen bir şekilde aydınlatılmış bir odanın üstten görünüşü aşağıda verilmiştir. Hasan arka kapıdan içeri girip oda boyunca kesikli çizgi ile gösterilen yolda ilerlerken 1-4 ile numaralandırılmış kedilerin görüntüsünü duvardaki düzlem aynada gözlemlemeye çalışmaktadır. Buna göre; **Hasan kesikli çizgi üzerinde ilerlerken kedilerin görüntüsünü hangi sıra ile görür?**



a) 1, 2 **b)** 2, 3 **c)** 2 = 4, 3 **d)** 3, 4, 2 **e)** 1, 2, 4, 3 **f)** 4, 1, 2, 3 **g)** Diğer:.....

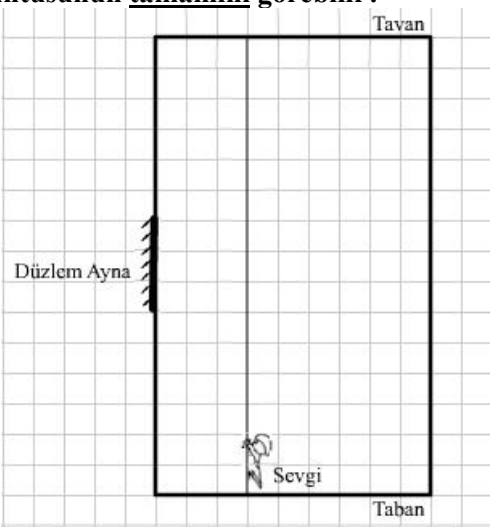
2.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Hasan yalnızca düzlem ayna sınırları içinde kalan kedilerin görüntüsünü görebilir.
b) Hasan ilerlerken kendisine yakın olan kedinin görüntüsünü daha önce görebilir.
c) Oda içerisindeki kedilerden yalnızca önünde başka bir kedi olmayanların görüntüsü görülebilir. Çünkü öndeki kedi arkasındaki kediden aynaya ışık ulaşmasını engeller.
d) Kedilerin her birinden aynanın sağ ve sol sınırlarına ışınlar çizilerek aynanın görüş alanı belirlendiğinde; Hasan aynadan yansıyıp kesikli çizgiyi kesen ışınların sırasına göre ilk olarak 3 numaralı kediyi görebilir.1 numaralı kediyi ışınlar çizgiyi kesmeyeceği için göremez.
e) Hasan çizgi üzerinde ilerlerken görüş alanına giren kedileri sırasıyla görebilir. Kedilerin her birinden aynanın sağ ve sol sınırına ışınlar çizildiğinde yansıyan ışınlar arasında kalan bölgede iken o kedinin görüntüsünü görebilir.
f) Diğer:.....

2.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

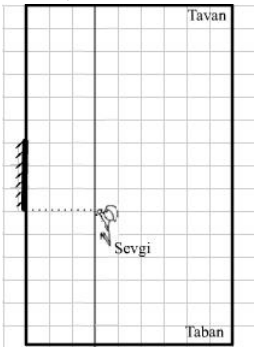
a) Eminim. **b)** Emin değilim.

3.1. Işık kaynağı ile homojen bir şekilde aydınlatılmış bir odanın yandan görünüşü verilmiştir. Sevgi tavanda asılı ip ile yukarı tırmanırken kendisinin görüntüsünü düzlem aynadan gözlemlemeye çalışmaktadır. Buna göre; Sevgi tırmanırken**ilk olarak nerede iken kendisinin görüntüsünün tamamını görebilir?**

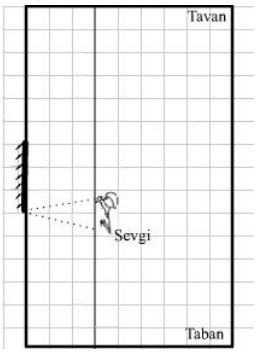


a) Tırmanmaya başlamadan bulunduğu yerde görebilir.

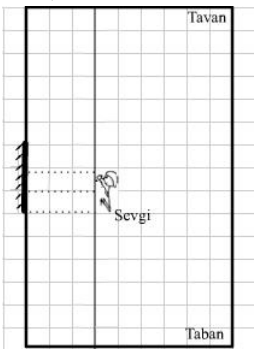
b)



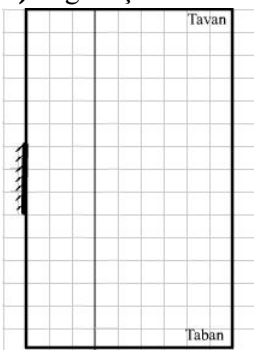
c)



d)



e) Diğer: Çiziniz.



3.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Sevgi tırmanmaya başlamadan, odanın tabanında iken kendi görüntüsünü görebilir. Çünkü düzlem aynalar sonsuz uzunlukta kabul edilebilir.

b) Sevgi'nin gözleri aynanın alt sınırı hizasına geldiği zaman ve direk karşıya baktığında gözlerini, tam bu noktada aynanın içinden aşağı doğru baktığında ise tüm vücudunu görebilir.

c) Sevgi'nin tüm vücudunun düzlem aynadaki görüntüsünün aynaya dik simetrisinde ve aynanın arkasında oluşabilmesi için, tüm vücudunun aynanın tam karşısında olması gerekir.

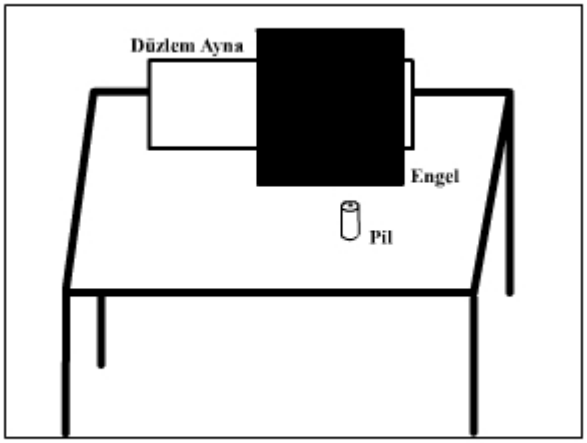
d) Sevgi'nin tüm vücudunu görebilmesi için vücudunun en alt noktasından aynaya gelen ışının aynada yansıyarak gözlerine ulaşabilmesi gerekir.

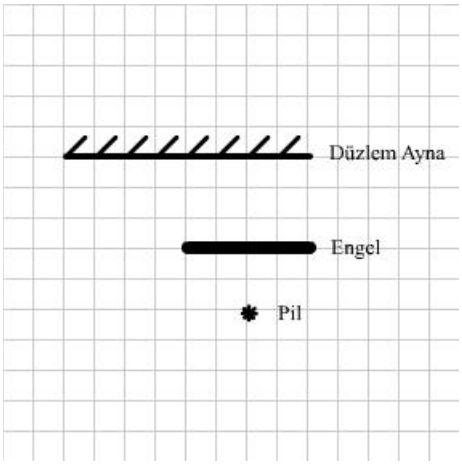
e) Diğer:.....**.....**

3.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. **b)** Emin değilim.

4.1. Homojen bir şekilde aydınlatılmış bir odada masanın üzerinde bulunan düzlem aynanın önüne aşağıdaki şekilde gösterildiği gibi saydam olmayan bir engel yerleştirilmiştir. Engelin önüne ise şekildeki gibi bir pil yerleştirilmiştir. Sağdaki çizimde aynı şeklin üstten gösterimi yer almaktadır. Buna göre; **pilin aynada görüntüsü oluşur mu?**





Üstten Görünüş

a) Oluşur. **b)** Oluşmaz. **c)** Bakan kişiye göre değişir. **d)** Diğer:.....

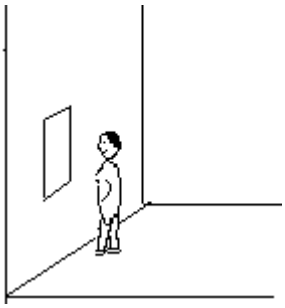
4.2. Yukarıdaki seçeneği seçmemin sebebi;

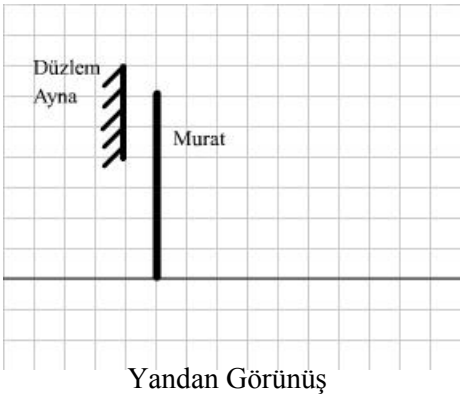
a) Ayna ile pil arasındaki engel sebebiyle pilden aynaya dik ışın ulaşamaz.
b) Engelin de aynada bir görüntüsü oluşur ve bu görüntü pilin görüntüsünün oluşumunu engeller.
c) Ayna ile pil arasında şekildeki engelin olması, bu aynanın yarısı uzunluğundaki bir aynanın sınırları dışına konulan bir pilin görüntüsünün oluşmasına benzer. Aynanın tamamını kaplamadıkça, engelin aynanın ne kadarını kapladığı görüntünün oluşumunu etkilemez.
d) Sadece pilden aynaya ulaşıp yansıyan ışınların o bölgeden bakan bir gözlemcinin gözüne ulaşması halinde pilin görüntüsü oluşur, diğer durumlarda pilin görüntüsü oluşmaz.
e) Pilden çıkıp engelin sol sınırından aynaya sadece bir tek ışın çizilebilir, tek bir ışın görüntüsünün oluşması için yeterli değildir.
f) Diğer:.....

4.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. **b)** Emin değilim.

5.1. Murat, kendisinin boyunun yarısı büyüklüğünde ve yerden yüksekliği göğüs hizasında olan duvarda asılı düzlem aynada görüntüsüne şekildeki gibi bakmaktadır. Sağdaki çizimde aynı şeklin yandan gösterimi yer almaktadır. Buna göre; **Murat bir defada vücudunun <u>tamamını</u> görebilmek için ne yapmalıdır?**





Yandan Görünüş

a) Aynaya yaklaşmalı.
b) Aynadan uzaklaşmalı.
c) Aynayı aşağı kaydırmalı.
d) Hiçbirisi
e) Diğer:.....

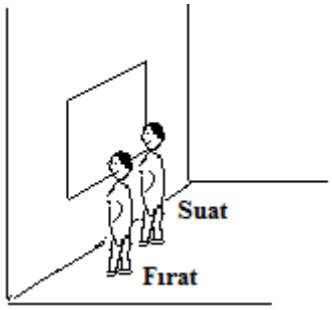
5.2. Yukarıdaki seçeneği seçmemin sebebi;

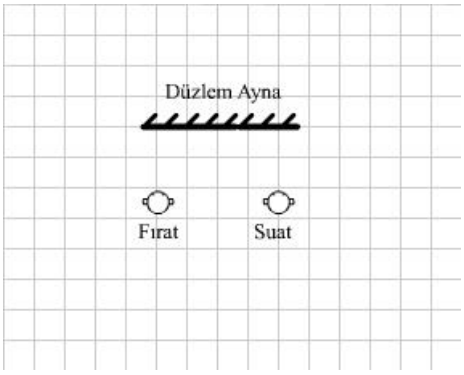
a) Murat'ın görüntüsünün boyu küçülür ve böylece aynaya görüntüsünün tamamı sığabilir.
b) Murat'ın görüş alanı artacağı için vücudunun tamamını görebilir.
c) Murat'ın aynada görebileceği görüntüsünün boyu en fazla aynanın boyu kadar olabilir. Aynanın boyu Murat'ın boyunun yarısı kadar olduğu için en fazla vücudunun yarısı kadarını görebilir.
d) Aynanın boyunun Murat'ın boyunun en az yarısı kadar olması Murat'ın boyunun tamamını görebilmesi için yeterlidir. Bu sebeple Murat aynayı duvarın en alt kısmına alsa bile aynaya baktığında vücudunun tamamını görebilir.
e) Aynanın boyunun Murat'ın boyunun en az yarısı büyüklüğünde olması kadar aynanın duvardaki pozisyonu da Murat'ın vücudunun tamamını görmesi için önemlidir. Aynanın üst sınırı Murat'ın alın hizasında olduğunda tamamını görebilir.
f) Diğer:.....

5.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. **b)** Emin değilim.

6.1. Suat ve ikizi Fırat duvara monte edilmiş düzlem aynanın karşısında görüntülerine bakmaktadırlar. Sağdaki çizimde aynı şeklin üstten gösterimi yer almaktadır. **Suat bir defada Fırat'ın boyunun daha fazlasını görmek istemektedir, bunun için <u>Suat</u> ne yapmalıdır?**





Üstten Görünüş

I. Aynaya yaklaşmalı.
II. Aynadan uzaklaşmalı.
III. Aynayı aşağı almalı.

a) Yalnız I **b)** Yalnız II **c)** Yalnız III **d)** I veya III **e)** Hiçbirisi **f)** Diğer:…

6.2. Yukarıdaki seçeneği seçmemin sebebi;

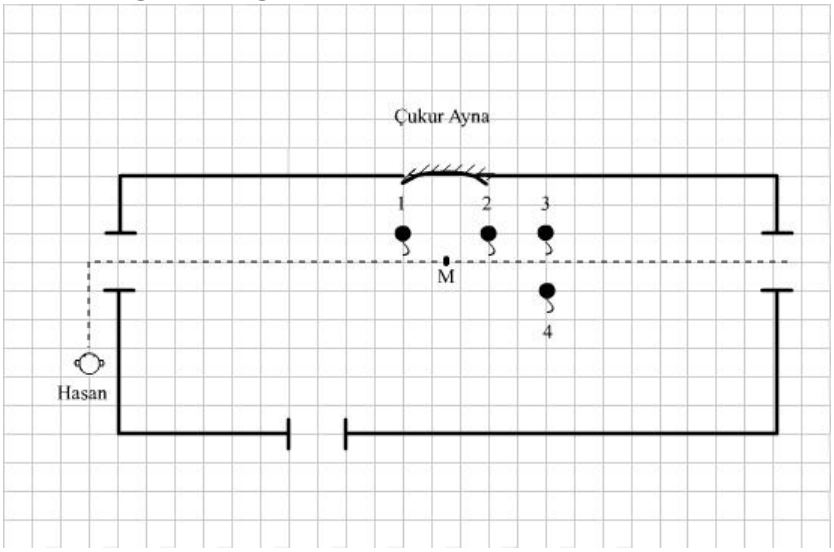
a) Suat'ın görüş alanı artacağı için Fırat'ın vücudunun daha fazlasını görebilir.
b) Fırat'ın aynanın tam karşısındaki vücudunun kısımları artacağı için aynada oluşan görüntüsünün boyu artacaktır.
c) Fırat'ın görüntüsünün daha fazlasını görebilmesi Suat'ın görüş alanı arttığında ya da görüş alanının büyüklüğü değişmeden bu alan aşağı kaydığında mümkündür.
d) Fırat'ın aynada oluşan görüntüsünün boyu aynanın boyu kadardır. Aynaya yaklaşıp uzaklaşmak, aynayı hareket ettirmek yalnızca Fırat'ın vücudunun görülebilen bölgesini değiştirir, vücudunun görülebilen bölgesinin boyu her zaman sabittir.
e) Hem Suat'ın hem de Fırat'ın görüntüsünün boyu küçülür ve aynaya görüntülerinin daha fazlası sığabilir.
f) Diğer:.....

6.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. **b)** Emin değilim.

KÜRESEL AYNALAR

7.1. Işık kaynağı ile homojen bir şekilde aydınlatılmış bir odanın üstten görünüşü aşağıda verilmiştir. Hasan kapıdan içeri girip oda boyunca kesikli çizgi ile gösterilen yolda ilerlerken kendisinin ve 1-4 ile numaralandırılmış kedilerin görüntüsünü duvardaki çukur aynada gözlemlemeye çalışmaktadır. Çukur aynanın merkez uzaklığı M ile gösterilmiştir. Buna göre; **Hasan kesikli çizgi üzerinde ilerlerken kedilerin görüntüsünü hangi sıra ile görür?**



a) 1, 2, 3, 4 **b)** 3, 2, 4, 1 **c)** 4, 2, 1 **d)** 3, 2, 1 **e)** 1, 2 **f)** Yalnız 4 **g)** Hiçbirisi **h)** Diğer:.....

7.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Çukur aynada yalnızca odak noktasındaki cismin görüntüsü görülemez. Hasan odak noktasında bulunmayan tüm bu kedileri, kedilerin kendisine yakınlığına göre sırasıyla görür.

b) Çukur aynada yalnızca odak noktasındaki cismin görüntüsü görülemez. Hasan odak noktasında bulunmayan tüm bu kedileri, görüntülerinin kendisine yakınlığına göre sırasıyla görür.

c) Tüm kedilerin görüntüsü gerçek görüntüdür ve gerçek görüntü ancak bir ekran üzerinde görülebilir.

d) Tüm kedilerin görüntüsü gerçek görüntüdür ve ekran kullanılmadığı zaman gerçek görüntünün oluştuğu noktanın gerisinden, oradan dağılan ışınların arasında kalan bölgeden bakılırsa görüntü görülebilir.

e) Oda içerisindeki kedilerden yalnızca önünde başka bir kedi olmayanların görüntüsü aynada oluşur ve görülebilir. Çünkü öndeki kedi arkasındaki kediden aynaya ışık ulaşmasını engeller.

f) Yalnızca çukur ayna sınırları içinde ve aynanın eğrilik yarıçapı içinde kalan kedilerin görüntüsü aynada oluşur ve görülebilir.

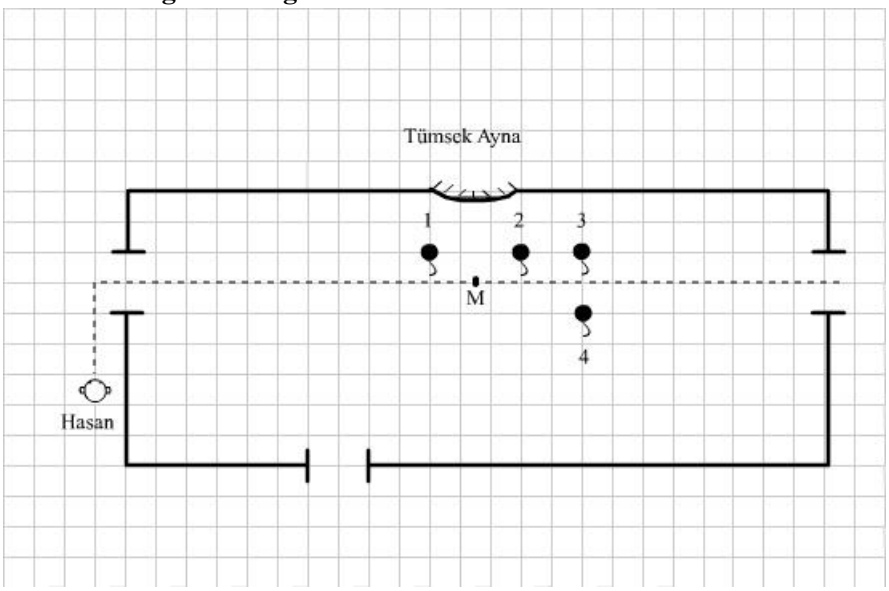
g) Aynanın odak noktasından geçecek şekilde kedilerden ışın çizildiğinde, aynaya ışın ulaşabilenlerin görüntüsü oluşur ve görülebilir.

h) Diğer:.....

7.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. **b)** Emin değilim.

8.1. Işık kaynağı ile homojen bir şekilde aydınlatılmış bir odanın üstten görünüşü aşağıda verilmiştir.Hasan kapıdan içeri girip oda boyunca kesikli çizgi ile gösterilen yolda ilerlerken kendisinin ve 1-4 ile numaralandırılmış kedilerin görüntüsünü duvardaki tümsek aynada gözlemlemeye çalışmaktadır. Tümsek aynanın merkez uzaklığı M ile gösterilmiştir. Buna göre; **Hasan kesikli çizgi üzerinde ilerlerken kedilerin görüntüsünü hangi sıra ile görür?**



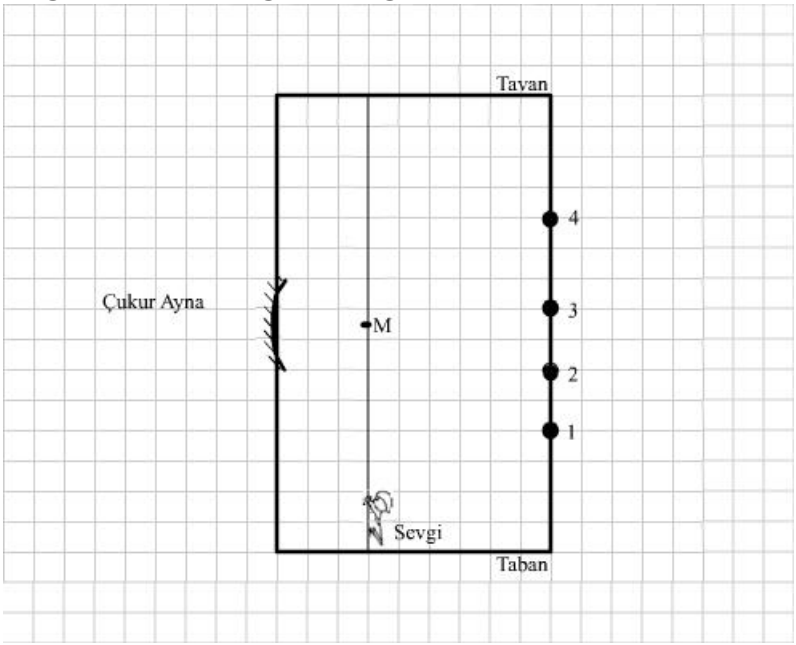
a) 1, 2, 3, 4 **b)** 4, 3, 2, 1 **c)** 1 = 2 = 3 = 4 **d)** 3, 2, 4, 1 **e)** 1, 2 **f)** Hiçbirisi
g) Diğer:.....

8.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Tümsek ayna ışığı dağıttığı için odaya girdiği anda hepsini görebilir.
b) Yalnızca tümsek ayna sınırları içindeki kedilerin görüntüsü oluşur ve görülebilir.
c) Tümsek aynada yalnızca odak uzaklığındaki cismin görüntüsü görülemez. Hasan odak uzaklığında bulunmayan tüm bu kedileri, kedilerin kendisine yakınlığına göre sırasıyla görür.
d) Tümsek aynada yalnızca odak uzaklığındaki cismin görüntüsü görülemez. Hasan odak uzaklığında bulunmayan tüm bu kedileri, görüntülerinin kendisine yakınlığına göre sırasıyla görür.
e) Tümsek aynada odak noktasındaki cisimler de dahil tüm görüntüler görülebilir. Hasan ilerlerken kedileri kendi görüş alanına girme sırasına göre görebilir.
f) Sanal görüntüler görülemez, yalnızca gerçek olan görüntüler görülebilir. Tüm kedilerin görüntüsü sanal olduğu için görülemez.
g) Diğer:.....

8.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?
a) Eminim. **b)** Emin değilim.

9.1. Işık kaynağı ile homojen bir şekilde aydınlatılmış bir odanın yandan görünüşü aşağıda verilmiştir. Sevgi'nin tırmandığı ipin aynaya olan uzaklığı aynanın merkez uzaklığı kadardır ve M ile gösterilmiştir.Sevgi tavanda asılı ip ile yukarı tırmanırken kendisinin ve arkasındaki duvara yerleştirilmiş 1-4 ile numaralandırılmış lambaların görüntüsünü duvardaki çukur aynadan gözlemlemeye çalışmaktadır. Buna göre; **Sevgi tırmanırken lambaların görüntüsünü hangi sıra ile görür?**



a) 1, 2, 3, 4 **b)** 4, 3, 2, 1 **c)** 2, 3 **d)** 3, 2 **e)** Hiçbirisi **f)** Diğer:.....

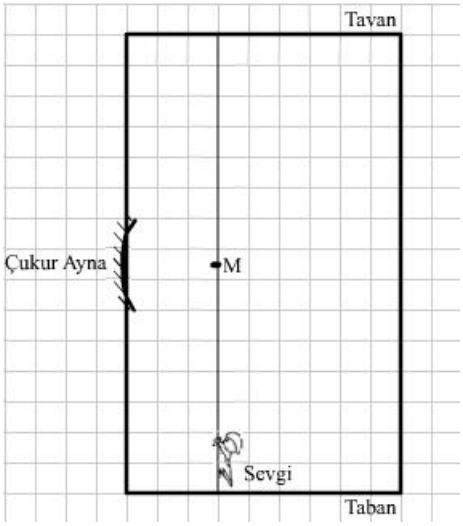
9.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Çukur aynada yalnızca odak noktasındaki cismin görüntüsü görülemez. Sevgi odak noktasında bulunmayan tüm bu lambaları, lambaların kendisine yakınlığına göre sırasıyla görür.
b) Çukur aynada yalnızca odak noktasındaki cismin görüntüsü görülemez. Sevgi odak noktasında bulunmayan tüm bu lambaları, görüntülerinin kendisine yakınlığına göre sırasıyla görür.
c) Tüm lambaların görüntüsü gerçek görüntüdür ve gerçek görüntü ancak bir ekran üzerinde görülebilir.
d) Tüm lambaların görüntüsü gerçek görüntüdür ve ekran kullanılmadığı zaman gerçek görüntünün oluştuğu noktanın gerisinden, oradan dağılan ışınların arasında kalan bölgeden bakılırsa görüntü görülebilir.
e) Yalnızca çukur ayna sınırları içinde ve aynanın eğrilik yarıçapı içinde kalan lambaların görüntüsü aynada oluşur ve görülebilir.
f) Aynanın odak noktasından geçecek şekilde lambalardan ışın çizildiğinde, aynaya ışın ulaşabilenlerin görüntüsü oluşur ve görülebilir.
g) Diğer:.....

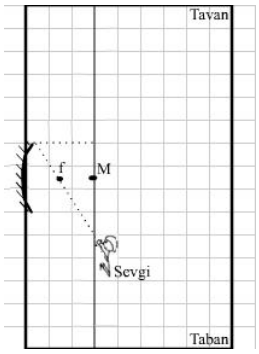
9.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

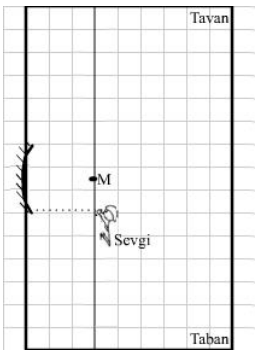
a) Eminim. **b)** Emin değilim.

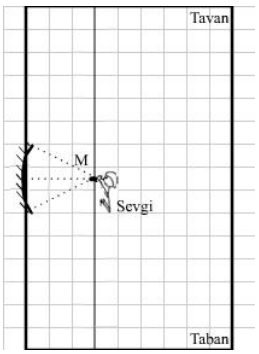
10.1. Önceki soruda, **Sevgi tırmanırken <u>ilk</u> olarak nerede iken <u>kendi gözlerinin</u> görüntüsünü görebilir?**

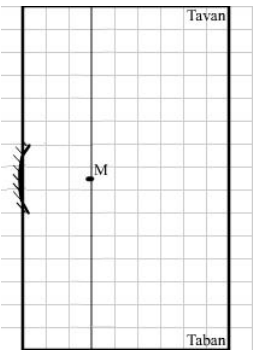


a) Tırmanmaya başlamadan bulunduğu yerde görebilir.
b) Hiçbir yerde göremez.
c) **d)** **e)** **f)** Diğer:









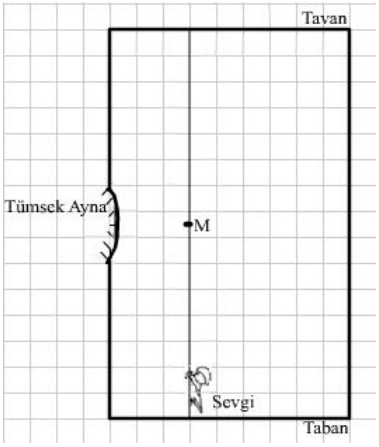
10.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Sevgi'nin tırmandığı ip çukur aynanın merkezinden geçtiği için ışınlar kendi üzerinden geri yansır. Sevgi tırmanırken nerede olursa olsun kendi gözlerini görebilir.
b) Sevgi kendi gözlerini sadece gözleri ayna sınırları içinde iken görebilir. Dolayısıyla ilk olarak gözleri çukur aynanın alt sınırı hizasina geldiğinde görebilir.
c) Sevgi kendi gözlerini ilk ve yalnızca gözleri çukur aynanın merkezine geldiğinde görebilir. Çünkü yalnızca M noktasında iken gözlerinden yansıyan ışınlar tekrar gözlerine ulaşır.
d) Sevgi'nin tırmandığı ip çukur aynanın merkezinden geçtiği için Sevgi'nin gözlerinin görüntüsü gerçek görüntüdür ve gerçek görüntü ancak bir ekran üzerinde görülebilir.
e) Sevgi'nin gözlerinden çukur aynanın sınırına çizilebilecek ve odaktan geçen ilk ışın doğrultusunda iken Sevgi ilk olarak gözlerinin oluşan görüntüsünü görebilir.
f) Diğer:.....

10.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

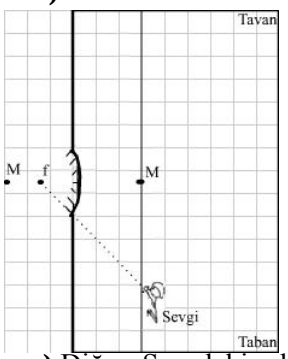
a) Eminim. **b)** Emin değilim.

11.1. Sevgi tavanda asılı ip ile yukarı tırmanırken kendisinin görüntüsünü duvardaki tümsek aynadan gözlemlemeye çalışmaktadır. Buna göre; **Sevgi tırmanırken ilk olarak nerede iken kendi gözlerinin görüntüsünü görebilir?**

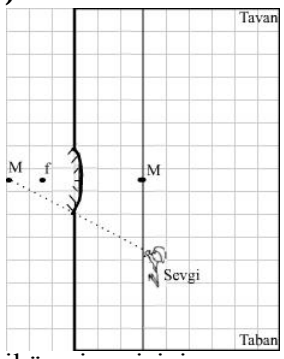


a) Tırmanmaya başlamadan bulunduğu yerde görebilir. **b)** Hiçbir yerde göremez.

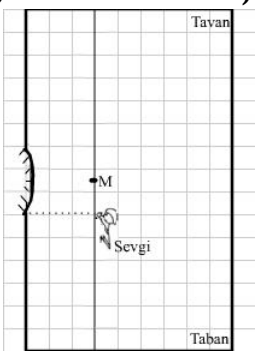
c)



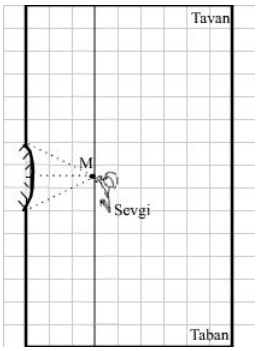
d)



e)



f)



g) Diğer: Sorudaki şekil üzerine çiziniz.

11.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Sevgi'nin tırmandığı ip tümsek aynanın merkez uzaklığından geçtiği için, Sevgi tırmanırken nerede olursa olsun kendi gözlerini görebilir.

b) Sevgi kendi gözlerini sadece gözleri ayna sınırları içinde iken görebilir, dolayısıyla ilk olarak gözleri tümsek aynanın alt sınırı hizasina geldiğinde görebilir.

c) Sevgi kendi gözlerini ilk olarak gözleri tümsek aynanın merkezine geldiğinde görebilir, çünkü yalnızca M noktasında iken gözlerinden yansıyan ışınlar tekrar gözlerine ulaşır.

d) Tümsek ayna ışığı dağıttığı için, Sevgi tırmanırken nerede olursa olsun kendi gözlerini görebilir.

e) Sevgi'nin gözlerinden tümsek aynanın sınırına çizilebilecek ve odaktan geçen ilk ışın doğrultusunda iken Sevgi ilk olarak gözlerinin görüntüsünü görebilir.

f) Sevgi'nin gözlerinden tümsek aynaya, aynanın arkasındaki merkezi doğrultusunda gelen ışınlar yansıyarak tekrar gözlerine ulaşabilir.

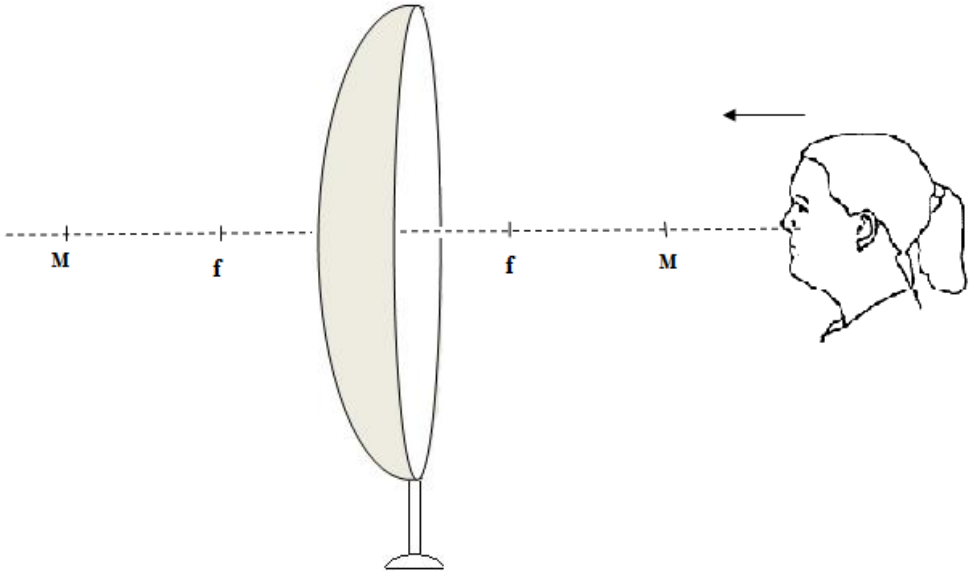
g) Sanal görüntüler görülemez, yalnızca gerçek olan görüntüler görülebilir. Sevgi'nin gözlerinin tümsek aynadaki görüntüsü sanal olduğu için hiçbir yerde göremez.

h) Diğer:.....

11.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. **b)** Emin değilim.

12.1. Selin aşağıdaki şekilde gösterilen mesafeden çukur aynaya bakarak yüzünün görüntüsünü görmek istemektedir. M çukur aynanın merkez, f ise odak uzaklığını göstermektedir. **Selin ok işareti yönünde çukur aynaya yaklaşırken başının hangi pozisyon ya da pozisyonlarında kendi görüntüsünü görebilir?**



I. Merkezin dışında (M'nin dışında)
II. Merkezde (M'de)
III. Odak ve merkez arasında (f-M arasında)
IV. Odakta (f'de)
V. Odak ve çukur ayna arasında (f-ayna arasında)

a) I, II, III, IV, V **b)** I, II, III, V **c)** I, II, III **d)** I, V **e)** Yalnız V **f)** Diğer:...

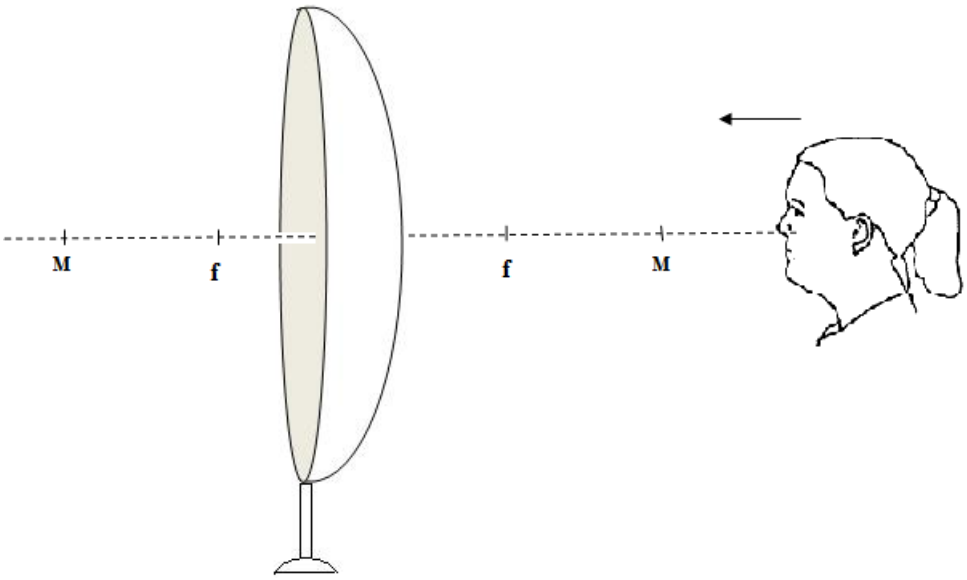
12.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Selin odakta iken yüzünün görüntüsü sonsuzda oluştuğu için.
b) Gerçek görüntü sadece ekran üzerine düşürülürse görülebilir. Bu nedenle Selin yalnızca yüzünün sanal görüntüsünün oluştuğu yerlerde kendisini görebilir.
c) Sanal görüntüler görülemez, yalnızca gerçek olan görüntüler görülebilir. Bu nedenle Selin yalnızca yüzünün gerçek görüntüsünün oluştuğu yerlerde kendisini görebilir.
d) Selin'in yüzünün her bir noktasından aynaya ulaşan ışınların yansıyarak Selin'in gözüne ulaşması durumunda Selin kendisini görebilir. Ancak gerçek görüntülerini görebilmesi için görüntüsünün oluştuğu yerin gerisinden bakıyor olması gerekir.
e) Selin'in yüzünün her bir noktasından aynaya ulaşan ışınların yansıyarak Selin'in gözüne ulaşması durumunda Selin kendisini görebilir. Kendisinin arkasında oluşacak gerçek görüntüsünün birkısmını aynadan görebilir.
f) Diğer:.....

12.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. **b)** Emin değilim.

13.1. Selin aşağıdaki şekilde gösterilen mesafeden tümsek aynaya bakarak yüzünün görüntüsünü görmek istemektedir. M tümsek aynanın merkez, f ise odak uzaklığını göstermektedir. **Selin ok işareti yönünde tümsek aynaya yaklaşırken başının hangi pozisyon ya da pozisyonlarında kendi görüntüsünü görebilir?**



I. Merkezin dışında (M'nin dışında)
II. Merkezde (M'de)
III. Odak ve merkez arasında (f-M arasında)
IV. Odakta (f)
V. Odak ve tümsek ayna arasında (f-ayna arasında)

a) I, II, III, IV, V **b)** I, II, III, V **c)** I, II, III **d)** Yalnız V **e)** Hiçbirisi **f)** Diğer:...

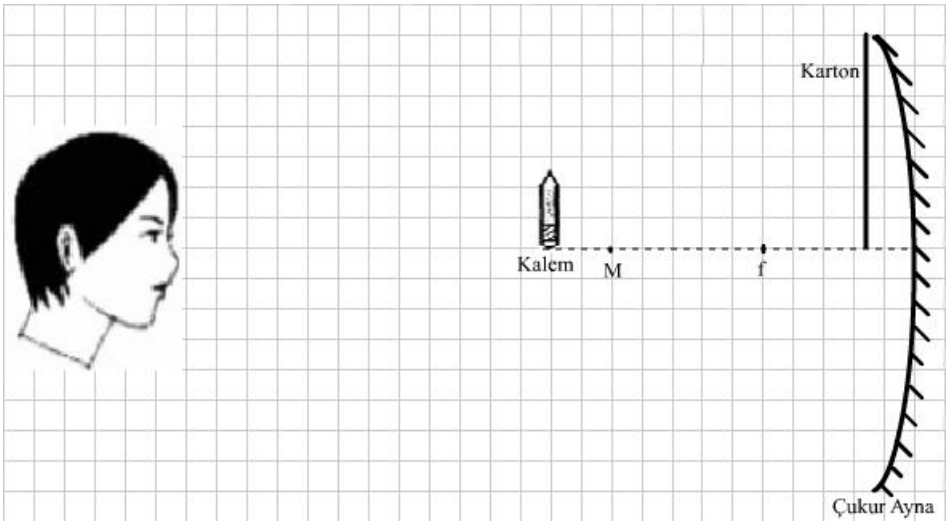
13.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Selin odakta iken yüzünün görüntüsü sonsuzda oluşacağı için.
b) Sanal görüntüler görülemez, yalnızca gerçek olan görüntüler görülebilir. Tümsek aynada Selin'in görüntüsü odak noktası da dahil her pozisyonda sanaldır.
c) Selin'in yüzünün her bir noktasından aynaya ulaşan ışınların yansıyarak Selin'in gözüne ulaşması durumunda kendisini görebilir.
d) Selin'in yüzünden aynaya ulaşan ışınların yansıyarak Selin'in gözüne ulaşması durumunda kendisini görebilir. Ancak tümsek aynada ışınlar her durumda aynanın arkasında kesişir ve Selin'in gözüne ulaşamaz.
e) Selin'in görüntüsü I. durumda aynanın arkasında f-M arasında; II. durumda aynanın arkasında M'de; III. durumda aynanın arkasında M'nin dışında oluşur ve Selin bu görüntülerini görebilir.
f) Diğer:.....

13.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. **b)** Emin değilim.

14.1. Aşağıdaki şekilde gözlemci, kalem, çukur ayna ve kartonun yandan görünüşü verilmiştir. M çukur aynanın merkezini, f ise aynanın odağını göstermektedir. Çukur aynanın merkez uzaklığından öteye yerleştirilen bir kalemin görüntüsü şekildeki gözlemci tarafından gözlemlenmektedir. **Çukur aynanın üst yarısı bir kartonla tamamen kapatılırsa kalemin görüntüsünde nasıl bir değişiklik olur?**



a) Kalemin görüntüsü tamamen kaybolur.
b) Kalemin yalnızca silgisinin nokta şeklinde görüntüsü olur.
c) Kalemin yarısının görüntüsü olur.
d) Kalemin görüntüsü karton kapatılmadan önce oluştuğu yerde ve önceki ile aynı boyutta olur.
e) Diğer:.....

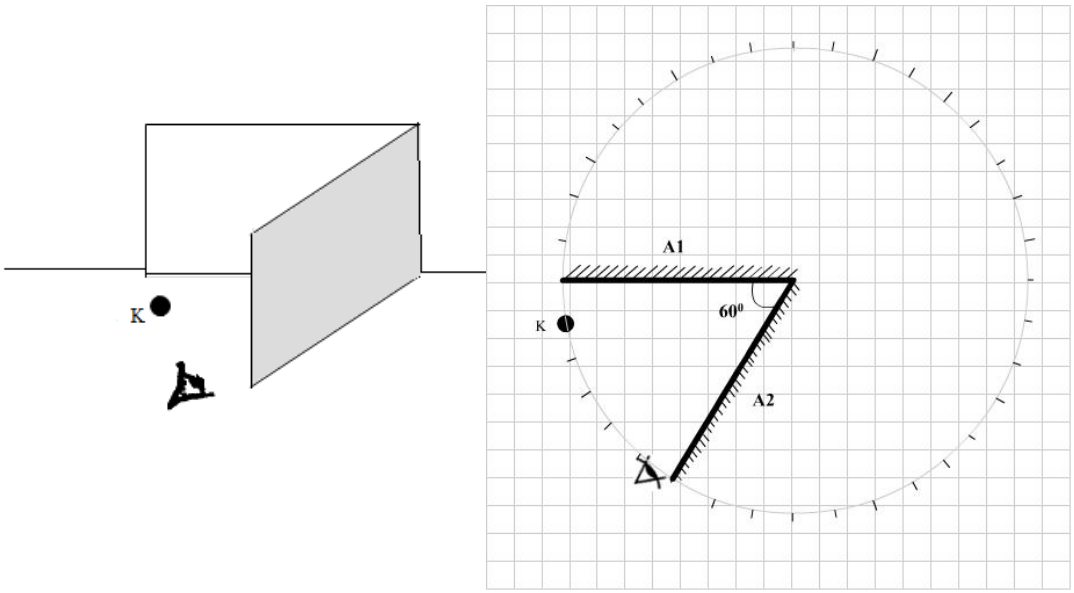
14.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Kalemden çıkan ışınlar kartondan dolayı aynaya ulaşamaz.
b) Aynanın yarısı kapatıldığı için, kalemin görüntüsünün de yarısı kaybolur.
c) Kalemin farklı noktalarından asal eksene paralel çizilen ışınlar karton tarafından engellenir. Çizilebilen diğer tek bir özel ışın görüntü oluşturmak için yeterli değildir, en az iki ışın çizmek gerekir.
d) Kalemin üzerindeki her bir noktadan aynanın açıkta kalan bölümüne ışık gelebileceği için kalemin görüntüsünün boyu, yeri ve şeklinde bir değişiklik olmaz.
e) Kartonun da çukur aynada bir görüntüsü oluşur ve bu görüntü kalemin görüntüsünün oluşumunu engeller.
f) Diğer:.....

14.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?
a) Eminim. **b)** Emin değilim.

KESİŞEN AYNALAR

15.1. Aşağıda aralarındaki açı 60^0 olacak şekilde yerleştirilen iki düzlem aynanın yandan ve üstten görünüşleri verilmiştir. Aynalar arasına konulan K cisminin görüntüsü şekildeki konumdan bakan bir gözlemci tarafından gözlemlenmektedir. Konumu şekil üzerinde belirtilen gözlemcinin bulunduğu yerden başını çevirerek görüntüleri gözlemlediği düşünülmelidir. Buna göre; **bu gözlemci K cisminin kaç görüntüsünü görür?**



Yandan Görünüş Üstten Görünüş

a) 5 **b)** 4 **c)** 3 **d)** 2 **e)** Diğer:.....

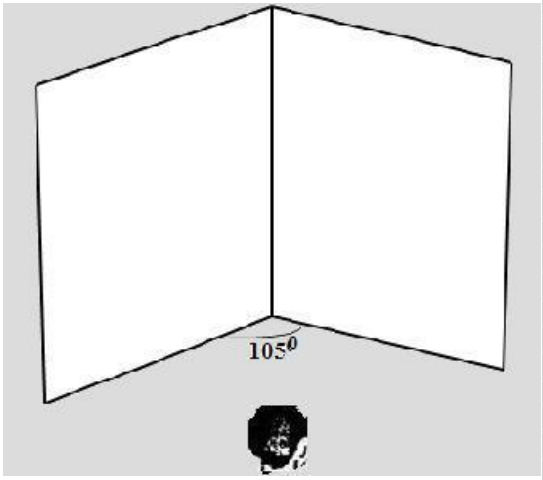
15.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Gözlemcinin görebileceği görüntü sayısını ayna sayısı belirler. Şekilde iki ayna olduğu için gözlemci, aradaki açıdan bağımsız olarak, cismin her bir aynada ayrı ayrı birer görüntüsünü görebilir.
b) Gözlemcinin görebileceği görüntü sayısı aynalar arasındaki açıya(α) bağlıdır ve cisim ya da gözlemci nerede olursa olsun $(360^0 / \alpha) - 1$ tane görüntüsünü görebilir.
c) Gözlemcinin görebileceği görüntü sayısı aynalar arasındaki açıya(α) ve gözlemcinin yerine bağlıdır. Cismin görüntülerinden gözlemcinin görüş alanı içinde olanlarını görebilir.
d) Gözlemcinin görebileceği görüntü sayısı aynalar arasındaki açıya(α), cismin yerine ve gözlemcinin yerine bağlıdır.
e) Diğer:.....

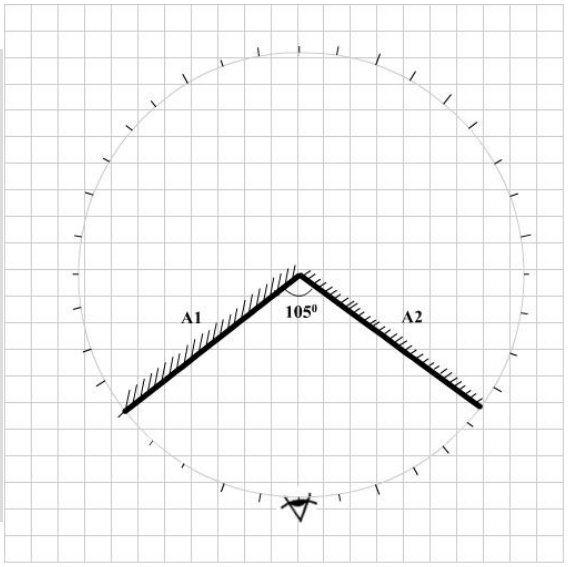
15.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. **b)** Emin değilim.

16.1. Aşağıda aralarındaki açı 105^0 olacak şekilde yerleştirilen iki düzlem aynanın <u>önden</u> ve <u>üstten görünüşleri</u> verilmiştir. Konumu şekil üzerinde belirtilen bir gözlemci 105^0 açı ile kesişen aynalarda kendisini gözlemlemektedir. Buna göre; **bu gözlemci <u>kendisinin</u> kaç görüntüsünü görür?**



Önden Görünüş



Üstten Görünüş

a) 4 **b)** 3 **c)** 2.43 **d)** 2 **e)** Hiçbir görüntüsünü göremez. **f)** Diğer:.....

16.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Gözlemcinin görebileceği görüntü sayısını ayna sayısı belirler. Şekilde iki ayna olduğu için gözlemci, aradaki açıdan bağımsız olarak, kendisinin her bir aynada ayrı ayrı birer görüntüsünü görebilir.

b) Gözlemcinin görebileceği görüntü sayısısadece aynalar arasındaki açıya(α) bağlıdır veyalnızca (360^0 / α) - 1 sonucu tam sayı elde edebileceğimiz açılar olduğunda gözlemci kendi görüntüsünü görebilir.

c) Gözlemcinin görebileceği görüntü sayısısadece aynalar arasındaki açıya(α) bağlıdır ve (360^0 / α) - 1 sonucu tam sayı elde edemediğimiz açılarda gözlemci kendisinin tam görüntülerinin yanı sıra çakışık ve tam olmayan görüntülerini de görebilir.

d) Gözlemcinin görebileceği görüntü sayısısadece aynalar arasındaki açıya bağlıdır ve (360^0 / α) - 1 sonucu tam sayı elde edemediğimiz açılarda formülden elde ettiğimiz sayıyı tam sayıya yuvarlarız, çünkü yarım görüntü olamaz.

e) Gözlemcinin iki aynada ayrı ayrı oluşan görüntülerini ve bu görüntülerin diğer aynadaki görüntüsünün yerini belirlediğimizde, gözlemci bu belirlenen tüm görüntüleri görebilir.

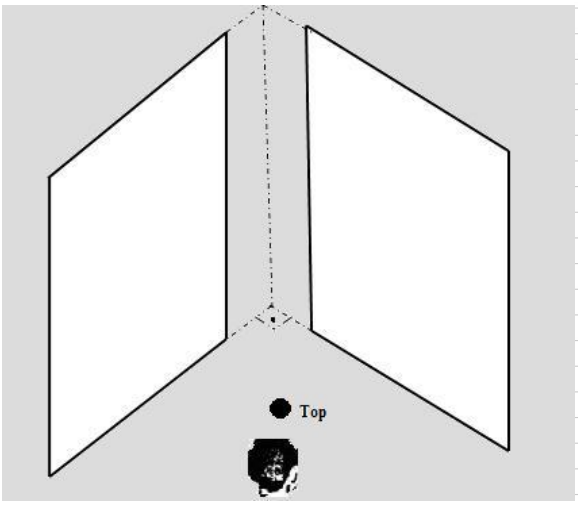
f) Gözlemcinin görebileceği görüntü sayısı aynalar arasındaki açı(α) kadar, gözlemcinin pozisyonuna da bağlıdır. Gözlemcinin kendisinden aynalara ulaşan ışınların yansımaları sonucu gözlemcinin gözüne ulaşabilen ışınlarla görüntüsü oluşur ve bu görüntülerini görebilir.

g) Diğer:.....

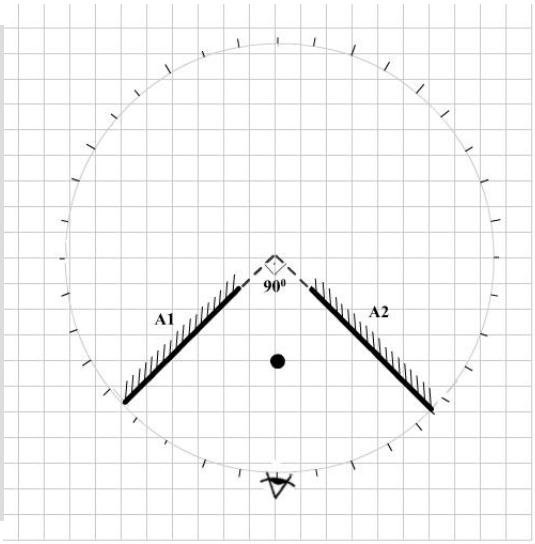
16.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. **b)** Emin değilim.

17.1. Bir alışveriş mağazasının birbirine dik duvarlarına iki düzlem ayna aralarında 90^0 açı ile ve biraz mesafe bırakılarak aşağıdaki şekildeki gibi monte edilmiştir. Buna göre; **şekildeki konumdan bakan gözlemci yerdeki <u>topun</u> kaç görüntüsünü görür?**



Önden Görünüş



Üstten Görünüş

a) 3 **b)** 2 **c)** 1 **d)** Topun hiçbir görüntüsünü göremez. **e)** Diğer:.....

17.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Gözlemcinin görebileceği görüntü sayısını ayna sayısı belirler. Şekilde iki ayna olduğu için gözlemci, cismin her bir aynada birer görüntüsünü görebilir.

b) Aynalar arasında mesafe olduğu için topun A1 aynasında oluşan görüntüsünün A2 aynasında tekrar bir görüntüsü oluşamaz. Aynı şekilde topun A2 aynasında oluşan görüntüsünün A1 aynasında görüntüsü oluşamaz. Bu sebeple gözlemci nereden bakarsa baksın sadece iki görüntü görebilir.

c) Gözlemcinin görebileceği görüntü sayısı aynalar arasındaki açıya(α), cismin yerine ve gözlemcinin yerine bağlıdır. Görüntü oluşumu ve gözlemlenmesi aynı anda gerçekleşen olaylar olduğu için yansımalar sonucu gözlemcinin gözüne ulaşan ışınlarla topun görüntüsü oluşur ve bu görüntüleri görebilir.

d) Gözlemcinin görebileceği görüntü sayısı aynalar arasındaki açıya(α) bağlıdır. Aynalar arasında mesafe olsa bile, topun yansımalar sonucu $(360^0 / \alpha) - 1$ tane görüntüsü oluşur ve gözlemci oluşan tüm görüntüleri aynalar arasından baktığı için görebilir.

e) Gözlemcinin görebileceği görüntü sayısı aynalar arasındaki açıya(α) bağlıdır. Aynalar arasında mesafe olsa bile, topun yansımalar sonucu $(360^0 / \alpha) - 1$ tane görüntüsü oluşur, fakat gözlemci sadece görüş alanı içine giren görüntüleri görebilir.

f) Diğer:.....

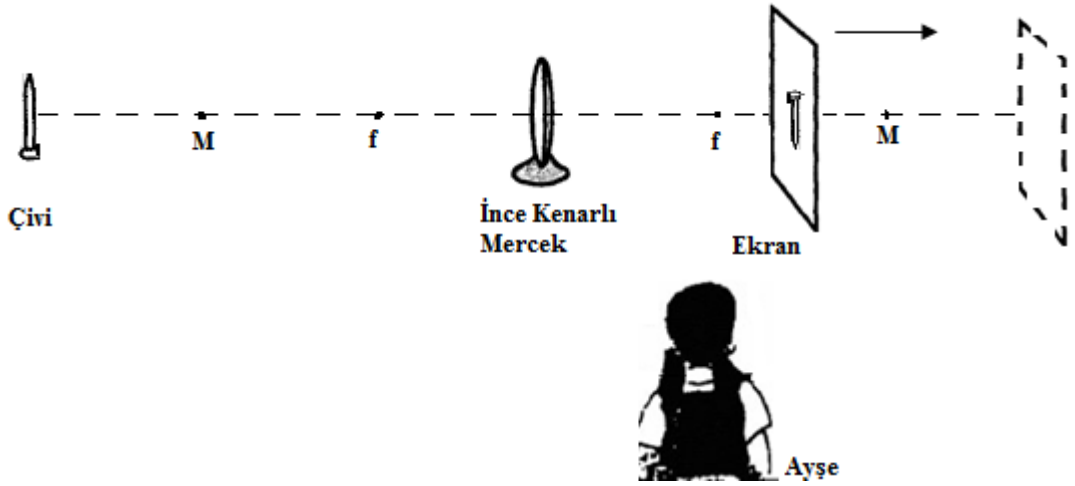
17.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. **b)** Emin değilim.

MERCEKLER

18.1. Ayşe ince kenarlı mercek önüne yerleştirilen bir çivinin net görüntüsünü aşağıdaki şekildeki gibi merceğin diğer tarafında, küçük ve ters olarak ekran üzerine gözlemlemektedir. f ince kenarlı merceğin odak uzaklığını, M ise merkez uzaklığını göstermektedir.

Diğer nesnelerin yerleri sabit kalmak koşuluyla **ekran aşağıdaki şekildeki gibi mercekten uzaklaşacak şekilde geriye doğru kesikli çizgiler ile gösterilen yere çekilirse, çivinin ekran üzerindeki görüntüsünde nasıl bir değişiklik olur?**



a) Görüntü büyür.
b) Görüntü küçülür.
c) Çivi ile aynı yönlü düz bir görüntü oluşur.
d) Görüntü oluşmaz**.**
e) Diğer:.....

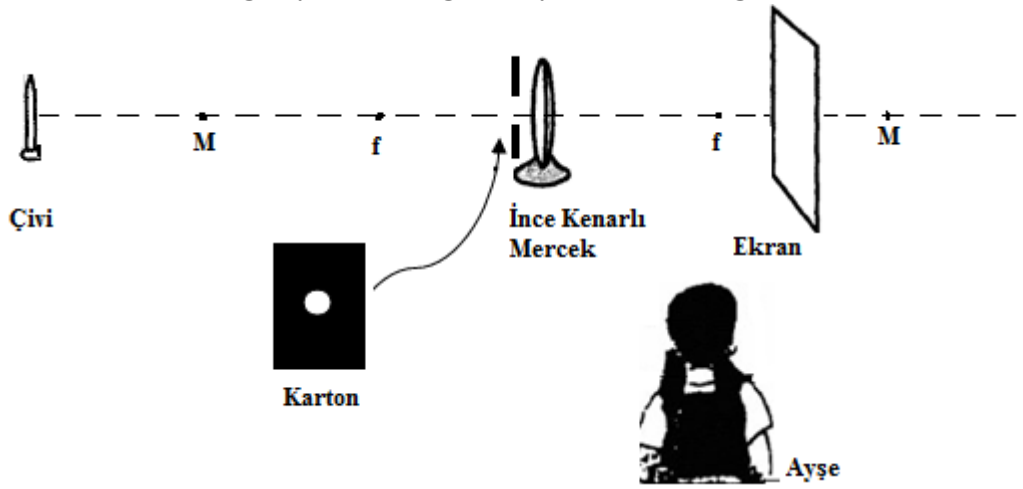
18.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Çivinin merceğe olan uzaklığı değişmediği için görüntünün yeri değişmez. f-M arasında oluşan görüntüden dağılan ışınlar geriye çekilen ekran üzerinde daha büyük, ters bir görüntü oluşturur.
b) Çivinin merceğe olan uzaklığı değişmediği için görüntünün yeri değişmez. f-M arasında kesişen ışınlar dağılarak ters dönerler. Böylece çivinin düz bir görüntüsü oluşur.
c) İnce kenarlı mercekte ekran üzerinde oluşan görüntü ters ve cisimden küçüktür. Ekran mercekten uzağa giderse üzerine düşen görüntü de o kadar küçülür.
d) Çivinin merceğe olan uzaklığı değişmediği için görüntünün yeri değişmez ve ekran uzaklaştırıldığında ekrana bir görüntü düşmez.
e) Diğer:.....

18.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. **b)** Emin değilim.

19.1. Önceki soruda **merceğin ön yüzüne tam ortasında daire şeklinde açıklık olan bir <u>karton</u> şekildeki gibi yerleştirildiğinde Ayşe ekranda ne görür?**



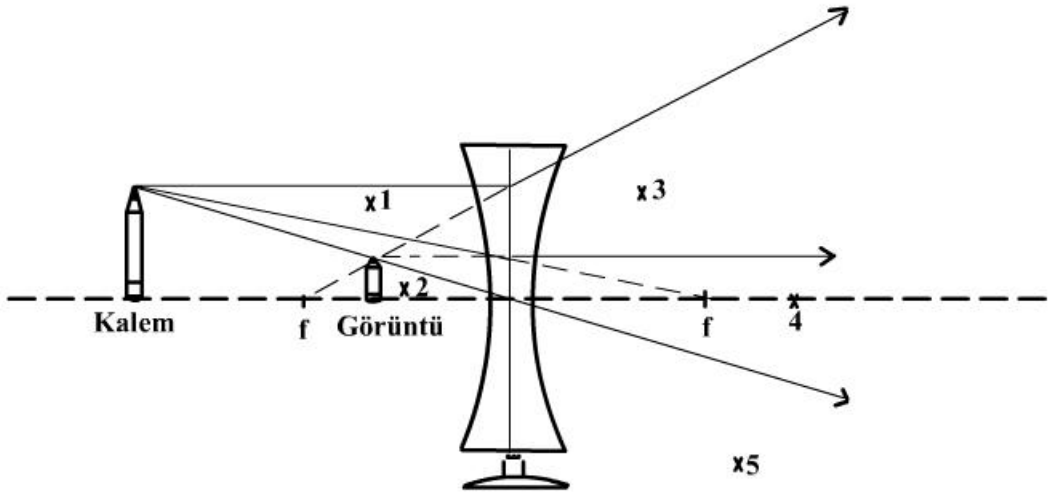
a) Hiçbir şey göremez.
b) Sadece çivinin orta kısmının görüntüsünü görebilir.
c) Çivinin tamamının ters görüntüsünü görebilir.
d) Çivinin daha büyük ve net olmayan ters görüntüsünü görebilir.
e) Diğer:.....

19.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Çivinin üzerindeki her bir noktadan merceğin açıkta kalan bölümüne ışık gelebileceği için çivinin görüntüsünün boyu ve şeklinde bir değişiklik olmaz.
b) Karton, çivinin uç kısımlarından merceğe ışık gelmesine engel olacağı için çivinin sadece ortasının görüntüsü ekranda görülebilir.
c) Merceğin açıkta kalan bölümü küçük bir mercek gibi davranır. Ancak odak ve merkez uzaklıkları küçüleceği için çivinin görüntüsü merceğe daha yakın oluşur ve ekran üzerine görüntü düşmez.
d) Merceğin açıkta kalan bölümü küçük bir mercek gibi davranır. Ancak odak ve merkez uzaklıkları küçüleceği için çivinin görüntüsü merceğe daha yakın oluşur ve ekran üzerinde daha büyük ve net olmayan bir görüntü görülür.
e) Diğer:.....

19.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?
a) Eminim. **b)** Emin değilim.

20.1. Şekildeki ışın diyagramında kalın kenarlı merceğin önüne yerleştirilmiş bir kalem ve bu kalemin görüntüsü verilmiştir. Kalemin ucundan çizilen üç ışının mercekten geçtikten sonra izlediği yollar şekilde çizilmiştir. Buna göre; **1-5 numaraları ile numaralanmış beş noktadan hangisi ya da hangilerinden bakan gözlemci(ler) kalemin görüntüsünün tamamını görebilir?**



a) Yalnız 1 **b)** 1 ve 2 **c)** 3 ve 4 **d)** 3, 4 ve 5 **e)** 1, 3 ve 4 **f)** Diğer:.....

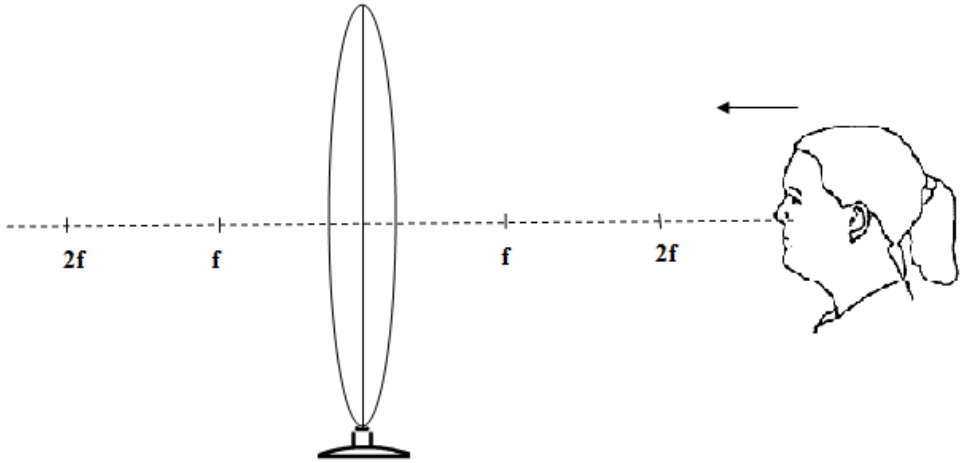
20.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Görüntü ile aynı taraftan ve görüntünün hizasından bakıldığı zaman görülebilir.
b) Görüntüye merceğin karşı tarafından ve mercek sınırları içinden baktığı zaman görülebilir.
c) Kalemin görüntüsünü oluşturan ışınlar merceğin sol tarafında (kalemle aynı tarafta) kesişir. Merceğin sağ tarafında ışınlar kesişmediği için o taraftan bakan gözlemciler görüntüyü göremezler.
d) Gözlemcilerin görüntünün tamamını görebilmesi için şekilde çizilen üç ışının sınırladığı alan içinden bakması gerekir.
e) Gözlemcilerin görüntünün tamamını görebilmesi için kalemin her bir noktasından merceğe ulaşan ışınların kırıldıktan sonra gözlemcinin gözüne ulaşabildiği bir alandan bakılması gerekir.
f) Diğer:.....

20.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. **b)** Emin değilim.

21.1. Selin aşağıdaki şekilde gösterilen mesafelerden ince kenarlı bir merceğe bakarak mercekte yüzünün görüntüsünü görmek istemektedir. Şekilde Selin ve merceğin yandan görünüşü verilmiştir. 2f merceğin merkez, f ise odak uzaklığını göstermektedir. Buna göre; **Selin ok işareti yönünde ince kenarlı merceğe yaklaşırken başının hangi pozisyon ya da pozisyonlarında kendi görüntüsünü görebilir?**



I. Merkezin dışında (2f'nin dışında)
II. Merkezde (2f'de)
III. Odak ve merkez arasında (f-2f arasında)
IV. Odakta (f'de)
V. Odak ve mercek arasında (f-mercek arasında)

a) I, II, III, IV, V **b)** I, II, III, V **c)** I, II, III **d)** V **e)** Hiçbiri **f)** Diğer:.....

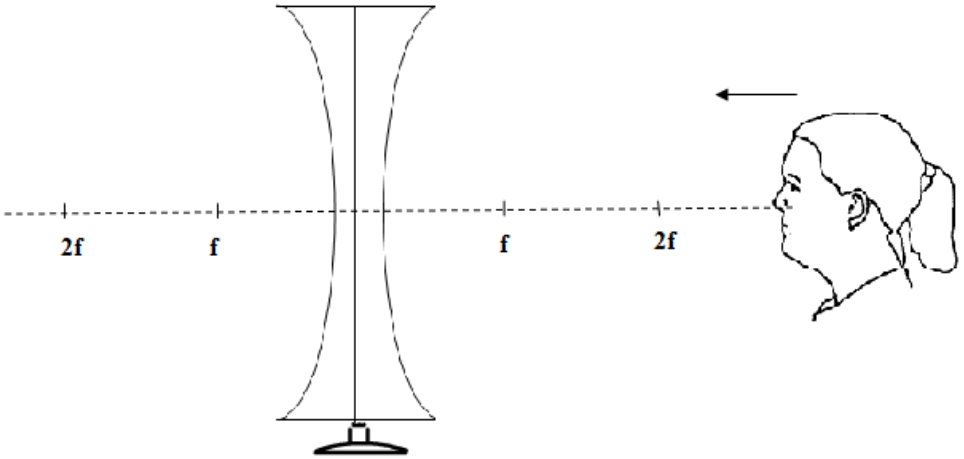
21.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Selin odakta iken yüzünün görüntüsü sonsuzda oluştuğu için.
b) Gerçek görüntü sadece ekran üzerine düşürülürse görülebilir. Bu nedenle Selin yalnızca yüzünün sanal görüntüsünün oluştuğu yerlerde kendisini görebilir.
c) Sanal görüntüler görülemez, yalnızca gerçek olan görüntüler görülebilir. Bu nedenle Selin yalnızca yüzünün gerçek görüntüsünün oluştuğu yerlerde kendisini görebilir.
d) Selin'in yüzünden yansıyıp mercekte kırılan ışınların Selin'in gözüne ulaşması durumunda kendisini görebilir. Dolayısıyla kendisini görebilmesi, ışınların kendisi ile aynı tarafta ve önünde kesiştiği durumlar için mümkündür.
e) Selin'in yüzünden yansıyıp mercekte kırılan ışınlar hiçbir pozisyonda Selin'in gözüne ulaşamayacağı için kendi görüntüsünü görebilmesi mümkün değildir.
f) Diğer:.....

21.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. **b)** Emin değilim.

22.1. Selin aşağıdaki şekilde gösterilen mesafelerden kalın kenarlı bir merceğe bakarak mercekte yüzünün görüntüsünü görmek istemektedir. Şekilde Selin ve merceğin yandan görünüşü verilmiştir. 2f merceğin merkez, f ise odak uzaklığını göstermektedir. Buna göre; **Selin ok işareti yönünde kalın kenarlı merceğe yaklaşırken başının hangi pozisyon ya da pozisyonlarında kendi görüntüsünü görebilir?**



I. Merkezin dışında (2f'nin dışında)
II. Merkezde (2f'de)
III. Odak ve merkez arasında (f-2f arasında)
IV. Odakta (f'de)
V. Odak ve mercek arasında (f-mercek arasında)

a) I, II, III, IV, V **b)** I, II, III, **c)** I, II, III **d)** I ve II **e)** Hiçbiri **f)** Diğer:.....

22.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Selin odakta iken yüzünün görüntüsü sonsuzda oluştuğu için.
b) Gerçek görüntü sadece ekran üzerine düşürülürse görülebilir. Bu nedenle Selin yalnızca yüzünün sanal görüntüsünün oluştuğu yerlerde kendisini görebilir.
c) Sanal görüntüler görülemez, yalnızca gerçek olan görüntüler görülebilir. Bu nedenle Selin yalnızca yüzünün gerçek görüntüsünün oluştuğu yerlerde kendisini görebilir.
d) Selin'in yüzünden yansıyıp mercekte kırılan ışınların Selin'in gözüne ulaşması durumunda kendisini görebilir. Dolayısıyla kendisini görebilmesi, ışınların kendisi ile aynı tarafta ve önünde kesiştiği durumlar için mümkündür.
e) Selin'in yüzünden yansıyıp mercekte kırılan ışınlar hiçbir pozisyonda Selin'in gözüne ulaşamayacağı için kendi görüntüsünü görebilmesi mümkün değildir.
f) Diğer:.....

22.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. **b)** Emin değilim.

TEST BİTTİ.

Table M.1. Table of Specification for the TTGOT

CASE / CONTEXT		OBSERVING ONESELF	Subtotal	OBSERVING OTHERS	Subtotal	TOTAL
Plane Mirrors	**Plane Mirror**	3 5	2	1 4 2 6	4	6
	Hinged Mirrors	16	1	15 17	2	3
Spherical Mirrors	**Concave Mirror**	10 12	2	7 9 14	3	5
	Convex Mirror	11 13	2	8	1	3
Lenses	**Converging Lens**	21	1	18 19	2	3
	Diverging Lens	22	1	20	1	2
TOTAL		9		13		22

APPENDIX N

TABLE OF ITEM CHOICES INDICATING MISCONCEPTIONS FOR THE TTGOT

M #	MISCONCEPTION DESCRIPTION	ITEMS		
M1.	Only the images of objects within the boarders of the mirror/lens can be formed / observed.	1.1.a 1.1.b 2.1.a 3.1.d 5.1.d 7.1.e 8.1.e 9.1.c 9.1.d 17.1.b 20.1.c	1.2.a 1.2.a 2.2.a 3.2.c 5.2.c 7.2.f 8.2.b 9.2.e 9.2.e 17.2.b 20.2.b	1.3 a 1.3.a 2.3.a 3.3.a 5.3.a 7.3.a 8.3.a 9.3.a 9.3.a 17.3.a 20.3.a
M2.	If there is an obstacle or another object in front of an object its image cannot be formed / observed in the mirror.	1.1.c 2.1.b 4.1.b 4.1.b 7.1.d 14.1.a 14.1.a	1.2.b 2.2.c 4.2.a 4.2.b 7.2.e 14.2.a 14.2.e	1.3.a 2.3.a 4.3.a 4.3.a 7.3.a 14.3.a 14.3.a
M3.	No matter real or virtual, image formation and observation processes are happening in an order. Firstly image is formed and then observed. A virtual image may be formed whether any observer observes it or not.	1.1.d 15.1.b 16.1.a 17.1.b	1.2.c 15.2.c 16.2.e 17.2.e	1.3.a 15.3.a 16.3.a 17.3.a
M4.	Closeness of image to the observer determines the observation order in mirrors.	7.1.b 8.1.a 8.1.b	7.2.b 8.2.d 8.2.d	7.3.a 8.3.a 8.3.a
M5.	Closeness of object to the observer determines the observation order in mirrors.	2.1.e 2.1.f 7.1.a 8.1.a 9.1.a	2.2.b 2.2.b 7.2.a 8.2.c 9.2.a	2.3.a 2.3.a 7.3.a 8.3.a 9.3.a
M6.	Field of vision attributed to the mirror instead of the observer, and it is thought as discreate instead of a continues region.	2.1.d	2.2.d	2.3.a
M7.	An observer can see himself/object out of the region enclosed by normal lines to the mirror boarders.	3.1.a 8.1.c 10.1.a	3.2.a 8.2.a 10.2.a	3.3.a 8.3.a 10.3.a

		11.1.a 11.1.a	11.2.a 11.2.d	11.3.a 11.3.a
M8.	Special rays are necessary to form/observe an image.	4.1.b 7.1.c 9.1.b 9.1.c 9.1.d 11.1.c 14.1.a 14.1.b 20.1.c 20.1.d	4.2.e 7.2.g 9.2.f 9.2.f 9.2.f 11.2.e 14.2.c 14.2.c 20.2.d 20.2.d	4.3.a 7.3.a 9.3.a 9.3.a 9.3.a 11.3.a 14.3.a 14.3.a 20.3.a 20.3.a
M9.	An observer can see himself totally when his eyes are aligned with the mirror.	3.1.b 10.1.d 11.1.e	3.2.b 10.2.b 11.2.b	3.3.a 10.3.a 11.3.a
M10.	Real images can only be observed on a screen.	7.1.g 9.1.e 12.1.e 21.1.d 22.1.a	7.2.c 9.2.c 12.2.a 21.2.b 22.2.b	7.3.a 9.3.a 12.3.a 21.3.a 22.3.a
M11.	Virtual images cannot be observed, only real images can be.	8.1.f 11.1.b 12.1.c 21.1.c 22.1.e	8.2.f 11.2.g 12.2.c 21.2.c 22.2.c	8.3.a 11.3.a 12.3.a 21.3.a 22.3.a
M12.	An observer moving along the line passing from the center of a spherical mirror can observe himself in any point along this line.	10.1.a 11.1.a	10.2.a 11.2.a	10.3.a 11.3.a
M13.	Covering some part of a mirror/lens causes dissepperaing of some part of image	14.1.c 19.1.b	14.2.b 19.2.b	14.3.a 19.3.a
M14.	A small part of mirror is enough to form and observe image of an object without considering the light can reach it or not.	4.1.a	4.2.c	4.3.a
M15.	Moving back from a plane mirror image becomes smaller and more of it can fit inside the mirror.	5.1.b 6.1.b	5.2.a 6.2.e	5.3.a 6.3.a
M16.	Moving closer/farher to the plane mirror someone can see more of himself because of the increase in the field of view.	5.1.a 5.1.b	5.2.b 5.2.b	5.3.a 5.3.a
M17.	In order to see whole body length in a plane mirror, you need only a mirror sized as half of your body length regardless of where this mirror is located on the wall.	5.1.c	5.2.d	5.3.a
M18.	Moving mirror down on the wall increases the field of view.	6.1.c 6.1.d	6.2.a 6.2.a	6.3.a 6.3.a

M19.	Image size equals to the mirror size.	6.1.c 6.1.e	6.2.b 6.2.d	6.3.a 6.3.a
M20.	At focal lenght no image formed/observed in convex mirrors/lens.	8.1.a 8.1.b 13.1.b 22.1.b	8.2.c 8.2.d 13.2.a 22.2.a	8.3.a 8.3.a 13.3.a 22.3.a
M21.	An image formed in the same side with an observer can be seen.	12.1.c 13.1.a 20.1.a 20.1.b 21.1.d 22.1.a	12.2.e 13.2.e 20.2.a 20.1.c 21.2.d 22.2.d	12.3.a 13.3.a 20.3.a 20.3.a 21.3.a 22.3.a
M22.	An image can be seen if it is not on the focal point.	7.1.a 7.1.b 9.1.a 9.1.b 9.1.a 9.1.b 12.1.b 13.1.b 21.1.b 22.1.b	7.2.a 7.2.b 9.2.a 9.2.a 9.2.b 9.2.b 12.2.a 13.2.a 21.2.a 22.2.a	7.3.a 7.3.a 9.3.a 9.3.a 9.3.a 9.3.a 12.3.a 13.3.a 21.3.a 22.3.a
M23.	Moving screen to another place changes image size/orientation.	18.1.a 18.1.b 18.1.c 19.1.a 19.1.d	18.2.a 18.2.c 18.2.b 19.2.c 19.2.d	18.3.a 18.3.a 18.3.a 19.3.a 19.3.a
M24.	Only number of mirrors determine the observed image number .	15.1.d 16.1.d 17.1.b	15.2.a 16.2.a 17.2.a	15.3.a 16.3.a 17.3.a
M25.	Number of image observed only depends on the angle between mirrors.	15.1.a 16.1.b 16.1.c 16.1.d 17.1.a	15.2.b 16.2.d 16.2.c 16.2.d 17.2.d	15.3.a 16.3.a 16.3.a 16.3.a 17.3.a

APPENDIX O

EXPERT OPINION FORM FOR THE TTGOT

Geometrik Optik Testi Uzman Değerlendirme Formu

Sayın Uzman,

Bu test fizik öğretmen adaylarının geometrik optik konularında sahip oldukları kavram yanılgılarının tespit edilip ortaya çıkarılması için geliştirilmiştir.

Bu çalışmaya konu olan geometrik optik bağlamları:

- Düzlem aynalar
- Kesişen aynalar
- Çukur aynalar
- Tümsek aynalar
- İnce kenarlı mercekler
- Kalın kenarlı merceklerdir.

Testteki sorularda her bir bağlam içerisinde gözlemcinin kendi görüntüsünü gözlemlemesi ve başka bir cismi ya da kişiyi gözlemlemesi olaylarına yer verilmiştir.

Testteki soruları ve size verilen Kavram Yanılgısı ve Belirtge tablolarını dikkatlice inceleyip bununla ilgili aşağıdaki soruları lütfen yanıtlayınız.

İlginize teşekkür ederim.

- Üç aşamalı soruların dağılım tablosunda verilen bağlam ve olayların her biri için verilen soru numarası doğru mu?
- Üç aşamalı soruların dağılım tablosunda verilen bağlam ve olaylar sizce testte uygun sayıda soru ile temsil edilmiş mi?
- Kavram yanılgıları tablosunda belirtilen seçenekler, ilgili kavram yanılgılarını temsil ediyor mu?
- Kavram yanılgıları tablosunda belirtilen kavram yanılgıları sizce testte uygun sayıda soru ile temsil edilmiş mi?
- Kabul edilen cevaplar tablosunda belirtilen doğru cevaplarda sizce sorunlu olanlar var mı?

APPENDIX P

CORRECT ANSWER CHOICES FOR THE TTGOT

I#	**ITEMS**		
I1.	1.1. d	1.2. d	1.3. a
I2.	2.1. c	2.2. e	2.3. a
I3.	3.1. c	3.2. d	3.3. a
I4.	4.1. c	4.2. d	4.3. a
I5.	5.1. c	5.2. e	5.3. a
I6.	6.1. d	6.2. c	6.3. a
I7.	7.1. f	7.2. d	7.3. a
I8.	8.1. d	8.2. e	8.3. a
I9.	9.1. b	9.2. d	9.3. a
I10.	10.1. e	10.2. c	10.3. a
I11.	11.1. d	11.2. f	10.3. a
I12.	12.1. d	12.2. d	11.3. a
I13.	13.1. a	13.2. c	12.3. a
I14.	14.1. d	13.2. d	13.3. a
I15.	15.1.a	15.2. d	15.3. a
I16.	16.1. d	16.2. f	16.3. a
I17.	17.1. b	17.2. c	17.3. a
I18.	18.1. d	18.2. d	18.3. a
I19.	19.1. c	19.2. a	19.3. a
I20.	20.1. d	20.2. e	20.3. a
I21.	21.1. e	21.2. e	21.3. a
I22.	22.1. e	22.2. e	22.3. a

APPENDIX Q

THE TTGOT ADMINISTRATION GUIDE

TESTİN UYGULANIŞINA DAİR ÖNERİLER

1) Öğrencilerin testin giriş sayfasındaki açıklamaları okumasını ve ilk sayfayı **eksiksiz** doldurmasını sağlayınız.
2) Sınav süresi **60 dakika** (1 saat) olarak önerilmektedir. Daha fazla süreye ihtiyaç duyan öğrencilere imkanlar el verdiği ölçüde izin verilebilir.
3) Sınavda ihtiyaç duyulabilecek **formüllerin** testin kapak sayfasının arka yüzünde olduğu hatırlatılmalıdır.
4) Sınav sırasında mutlaka öğrencilerin başında bir gözetmen bulunması ve bilgi alışverişine izin verilmemesini sağlayınız.
5) Öğrencilerinizin testin her bir sorusunun tüm aşamalarını eksiksiz olarak doldurmaları gerektiğini hatırlatınız.
6) Testin sonunda yer alan **İlgi ve Tecrübe Anketini** mutlaka doldurmalarını sağlayınız.
7) Sınav bitiminde testleri toplayıp (boş testlerle birlikte) aşağıdaki adrese kargo ile **karşıdan ödemeli (ücreti alıcıdan tahsilli)** olarak en kısa zamanda postalayınız.

Gönderim Adresi:

Derya KALTAKÇI
Eğitim Fakültesi, OFMAE Bölümü, Oda no: 205
ODTÜ, 06800, Ankara
Telefon(iş): 0312 210 6489
E-posta: kaderya@metu.edu.tr

8) Sınav sırasında karşılaşılan herhangi bir sorun ya da önerilerinizi bu kağıdın arka sayfasına yazabilirsiniz.
9) Sınavın uygulanmasında emeği geçen herkese çok teşekkür ederiz. Saygılarımızla.

Araştırmacı: Arş. Gör. Derya KALTAKÇI

Tez Danışmanı: Yrd. Doç. Dr. Ali ERYILMAZ

Sınava giren öğrenci sayısı:

Sınavı uygulayan kişininin:

Adı-Soyadı:
E-mail adresi:
Kurumu:

APPENDIX R

THE FOUR-TIER GEOMETRICAL OPTICS TEST (FTGOT)

GEOMETRİK OPTİK TESTİ

Cinsiyetiniz: □ Kız □ Erkek

Doğum tarihiniz (Gün/Ay/Yıl): ____/___/_____

Üniversitenizin adı:_____

Bölümünüzün adı: □ Fizik □ Fizik Öğretmenliği □ Diğer (_____)

Sınıfınız: □1 □ 2 □ 3 □ 4 □ 5 □ Diğer (_____)

Üniversitedeki genel not ortalamanız: _____

Üniversitede optik dersinden aldığınız not veya harf: _____

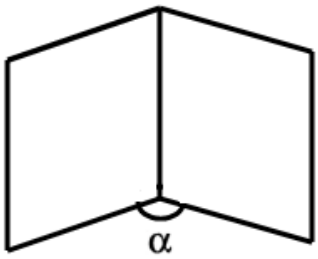
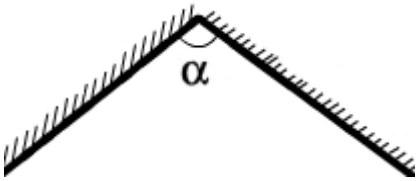
Üniversitede optik laboratuar dersinden aldığınız not veya harf:_____

Yönergeler

1. Sınava başlamadan önce yukarıda verilen kısmı **eksiksiz** doldurunuz.
2. Testte herbiri dört aşamadan oluşan **20** soru yer almaktadır. Lütfen bütün sorulara cevap vermek için gayret gösteriniz.
3. Soruların 1. aşamasında soru ile ilgili cevabınızı; 2. aşamasında bu cevaptan ne kadar emin olduğunuzu; 3. aşamasında 1. aşamada verdiğiniz cevabı seçme sebebinizi; 4. aşamada ise seçtiğiniz bu sebepten ne kadar emin olduğunuzu işaretleyiniz.
4. Soruları cevaplarken aynalarda kırılmaları, merceklerde yansımaları ihmal ediniz.
5. Sınavı tamamlamak için önerilen süre yaklaşık **50** dakikadır.
6. Sınavda gerekli olabilecek formüller ve şekiller bu sayfanın arkasında mevcuttur.
7. Bu testin sonuçları Ortadoğu Teknik Üniversitesi'nde Ortaöğretim Fen ve Matematik Alanları Eğitimi Bölümü'nde doktora yapan araştırmacının tezinde veri olarak kullanılacaktır. Bu bir bilimsel çalışmadır. Siz de şu an bilimsel bir çalışmanın parçasısınız. Gerekli ilgiyi gösterdiğiniz için teşekkür ederiz.

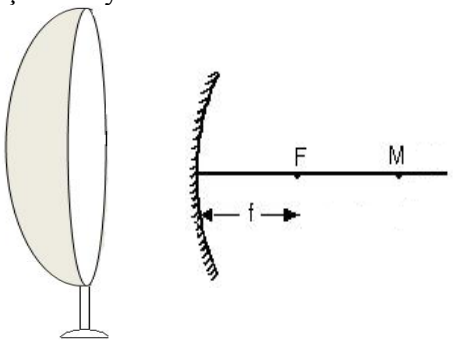
AÇIKLAYICI RESİMLER, ÇİZİMLER ve FORMÜLLER

Aşağıdaki tabloda Geometrik Optik Testi'nde yer alan sorularda bahsi geçen optik araçlara örnek olabilecek fotoğraflar, bu optik araçlara ait perspektif (yandan) veya üstten çizimler ile bu konularda ihtiyaç duyabileceğiniz bazı formüller verilmiştir.

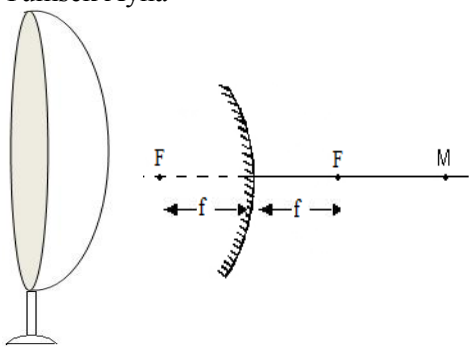
OPTİK ARACIN FOTOĞRAFI	OPTİK ARACIN PERSPEKTİF veya ÜSTTEN GÖRÜNÜŞÜNÜN ÇİZİMLERİ	OPTİK ARAÇ İLE İLGİLİ FORMÜLLER
Düzlem Ayna 	 	
Kesişen Aynalar 	 	**n:** Aynalarda oluşan toplam görüntü sayısı **α :** Aynalar arasındaki açı olmak üzere $n=\frac{360}{\alpha}-1$

Çukur ve Tümsek Aynalar

Çukur Ayna



Tümsek Ayna



F: Aynanın odağı

M: Aynanın merkezi

f: Aynanın odak uzaklığı

d_c: Cismin aynaya olan uzaklığı

d_g: Görüntünün aynaya olan uzaklığı

h_o: Cismin boyu

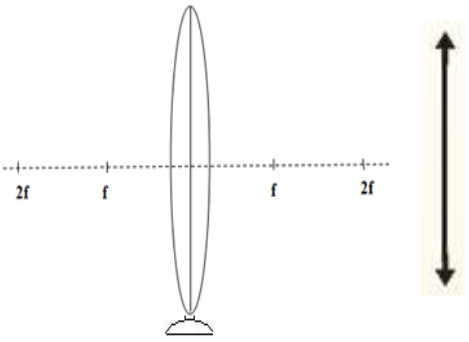
h_g: Görüntünün boyu olmak üzere

$$\frac{1}{f} = \frac{1}{d_c} + \frac{1}{d_g}$$

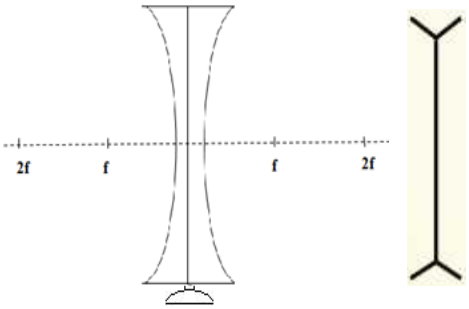
$$\frac{h_o}{h_g} = \frac{d_c}{d_g}$$

İnce ve Kalın Kenarlı Mercekler

İnce Kenarlı Mercek



Kalın Kenarlı Mercek



f: Merceğin odak uzaklığı

d_c: Cismin merceğe olan uzaklığı

d_g Görüntünün merceğe olan uzaklığı

h_o: Cismin boyu

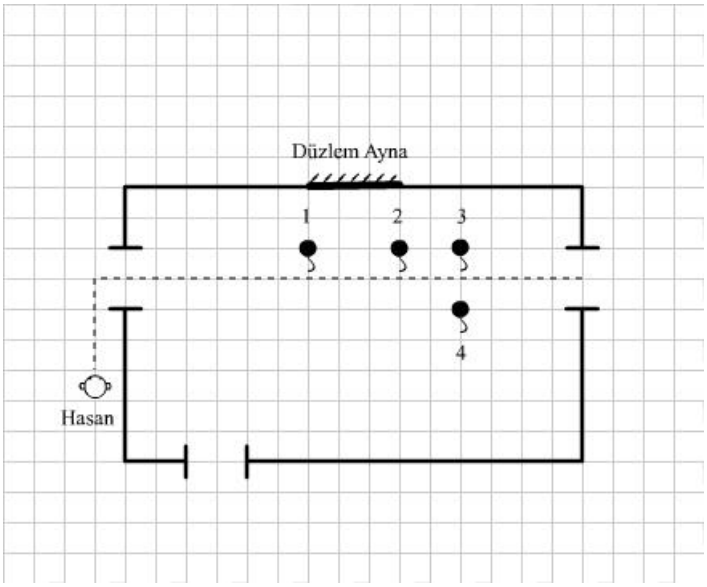
h_g: Görüntünün boyu olmak üzere

$$\frac{1}{f} = \frac{1}{d_c} + \frac{1}{d_g}$$

$$\frac{h_o}{h_g} = \frac{d_c}{d_g}$$

DÜZLEM AYNALAR

1.1. Homojen bir şekilde aydınlatılmış bir odanın üstten görünüşü aşağıda verilmiştir. Hasan kapıdan içeri girip oda boyunca kesikli çizgi ile gösterilen yolda ilerlerken 1, 2, 3 ve 4 ile numaralandırılmış kedilerin görüntüsünü duvardaki düzlem aynada gözlemlemeye çalışmaktadır. Buna göre; **numaralandırılmış kedilerin hangilerinin görüntüsü oluşur?**



a) Yalnız 1 **b)** 1 ve 2 **c)** 1, 2 ve 3 **d)** 1, 2, 3 ve 4 **e)** Diğer:.....

1.2. Yukarıdaki soruya verdiğiniz cevaptan ne kadar eminsiniz?

a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

1.3. Soruya verdiğim cevap seçeneğini seçmemin sebebi;

a) Yalnızca düzlem ayna sınırları içinde kalan kedilerin görüntüsü aynada oluşabilir.

b) Oda içerisindeki kedilerden yalnızca önünde başka bir kedi olmayanların görüntüsü aynada oluşabilir.

c) Hasan oda içerisinde ilerlerken belli yerlerde bazı kedileri göremiyor olsa bile, o kedinin düzlem aynada görüntüsü oluşur.

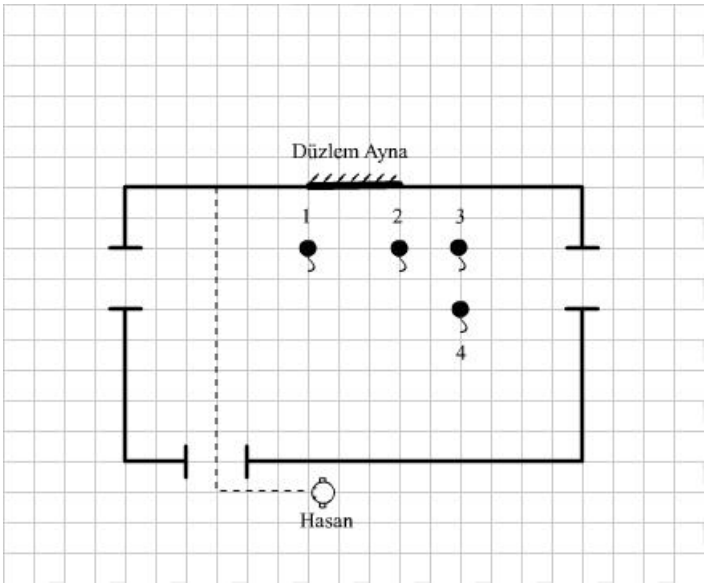
d) Görüntü oluşumu ve gözlemlenmesi aynı anda gerçekleşen olaylar olduğu için, Hasan belli yerlerde belli kedileri göremiyorsa o kedinin o anda düzlem aynada görüntüsü oluşmamıştır.

e) Diğer:.....

1.4. Yukarıda belirttiğiniz sebepten ne kadar eminsiniz?

a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

2.1. Homojen bir şekilde aydınlatılmış bir odanın üstten görünüşü aşağıda verilmiştir. Hasan arka kapıdan içeri girip oda boyunca kesikli çizgi ile gösterilen yolda ilerlerken 1, 2, 3 ve 4 ile numaralandırılmış kedilerin görüntüsünü duvardaki düzlem aynada gözlemlemeye çalışmaktadır. Buna göre; **Hasan kesikli çizgi üzerinde ilerlerken kedilerin görüntüsünü hangi sıra ile görür?**



a) 1, 2 **b)** 2, 3 **c)** 2 = 4, 3 **d)** 3, 4, 2 **e)** 1, 2, 4, 3 **f)** 4, 1, 2, 3 **g)** Diğer:.....

2.2. Yukarıdaki soruya verdiğiniz cevaptan ne kadar eminsiniz?

a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

2.3. Soruya verdiğim cevap seçeneğini seçmemin sebebi;

a) Hasan yalnızca düzlem ayna sınırları içinde kalan kedilerin görüntüsünü görebilir.

b) Hasan ilerlerken kendisine yakın olan kedinin görüntüsünü daha önce görebilir.

c) Oda içerisindeki kedilerden yalnızca önünde başka bir kedi olmayanların görüntüsü görülebilir.

d) Kedilerin her birinden aynanın sağ ve sol sınırlarına ışınlar çizilerek Hasan'ın görüş alanı belirlendiğinde; Hasan aynadan yansıyıp kesikli çizgiyi kesen ışınların sırasına göre ilk olarak 3 numaralı kediyi görebilir.

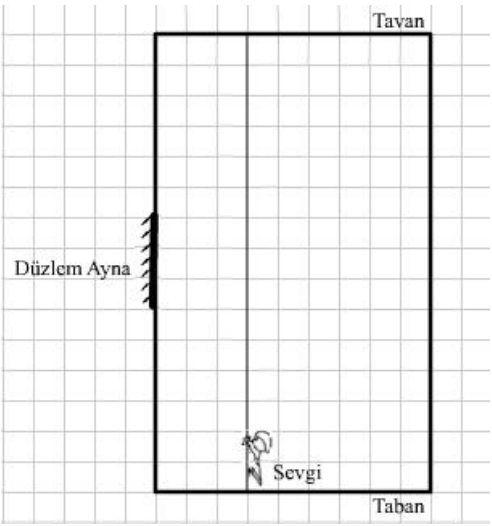
e) Kedilerin her birinden aynanın sağ ve sol sınırına ışınlar çizilerek Hasan'ın görüş alanı belirlendiğinde; Hasan aynadan yansıyan ışınlar arasında kalan bölgede iken o kedinin görüntüsünü görebilir.

f) Diğer:.....

2.4. Yukarıda belirttiğiniz sebepten ne kadar eminsiniz?

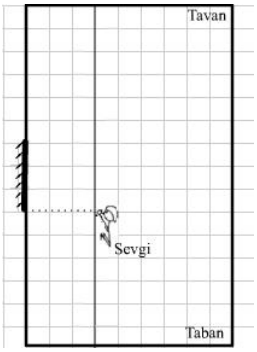
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

3.1. Homojen bir şekilde aydınlatılmış bir odanın yandan görünüşü aşağıda verilmiştir. Sevgi tavanda asılı ip ile yukarı tırmanırken kendisinin görüntüsünü düzlem aynadan gözlemlemeye çalışmaktadır. Buna göre; Sevgi tırmanırken**ilk olarak nerede iken kendisinin görüntüsünün tamamını görebilir?**

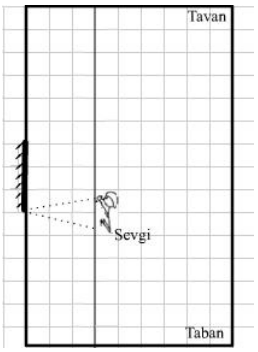


a) Tırmanmaya başlamadan bulunduğu yerde görebilir.

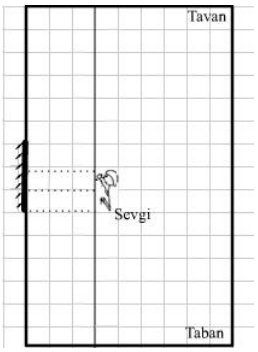
b)



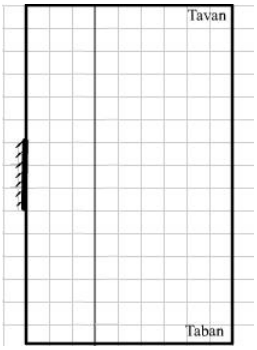
c)



d)



e)Diğer: Çiziniz.



3.2. Yukarıdaki soruya verdiğiniz cevaptan ne kadar eminsiniz?

a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

3.3. Soruya verdiğim cevap seçeneğini seçmemin sebebi;

a) Düzlem aynalar sonsuz uzunlukta kabul edilebildiği için, Sevgi tırmanmaya başlamadan kendi görüntüsünün tamamını görebilir.

b) Gözleri aynanın alt sınırı hizasına geldiği anda, Sevgi aynanın içinden aşağı doğru baktığında kendi görüntüsünün tamamını görebilir.

c) Sevgi'nin görüntüsünün tamamını görebilmesi için tüm vücudunun aynanın karşısında olması gerekir.

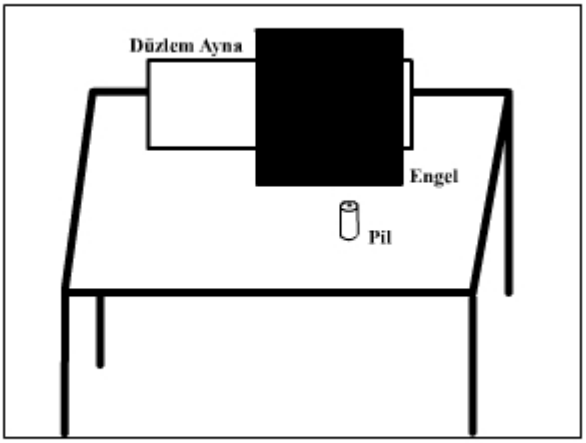
d) Sevgi'nin tüm vücudunu görebilmesi için vücudunun en alt noktasından aynaya gelen ışının aynada yansıyarak gözlerine ulaşabilmesi gerekir.

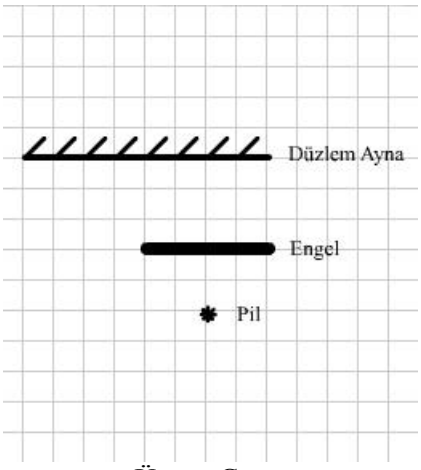
e) Diğer:.....**.....**

3.4. Yukarıda belirttiğiniz sebepten ne kadar eminsiniz?

a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

4.1. Homojen bir şekilde aydınlatılmış bir odada masanın üzerinde bulunan düzlem aynanın önüne aşağıdaki şekilde gösterildiği gibi saydam olmayan bir engel yerleştirilmiştir. Engelin önüne ise şekildeki gibi bir pil yerleştirilmiştir. Sağdaki çizimde aynı şeklin üstten gösterimi yer almaktadır. Buna göre; **pilin aynada görüntüsü oluşur mu?**





Üstten Görünüş

a) Oluşur. **b)** Oluşmaz. **c)** Bakan kişiye göre değişir. **d)** Diğer:.....

4.2. Yukarıdaki soruya verdiğiniz cevaptan ne kadar eminsiniz?

a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

4.3. Soruya verdiğim cevap seçeneğini seçmemin sebebi;

a) Ayna ile pil arasındaki engel sebebiyle pilden aynaya dik ışın ulaşamaz.

b) Engelin de aynada bir görüntüsü oluşur ve bu görüntü pilin görüntüsünün oluşumunu engeller.

c) Aynanın tamamını kaplamadıkça, engelin aynanın ne kadarını kapladığı görüntünün oluşumunu etkilemez.

d) Sadece pilden aynaya ulaşıp yansıyan ışınların o bölgeden bakan bir gözlemcinin gözüne ulaşması halinde pilin görüntüsü oluşur, diğer durumlarda pilin görüntüsü oluşmaz.

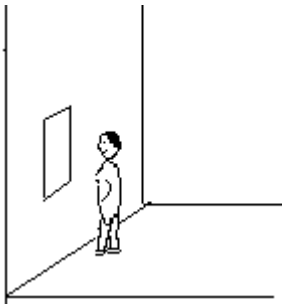
e) Pilden çıkıp engelin sol sınırından aynaya sadece bir tek ışın çizilebilir, tek bir ışın pilin görüntüsünün oluşması için yeterli değildir.

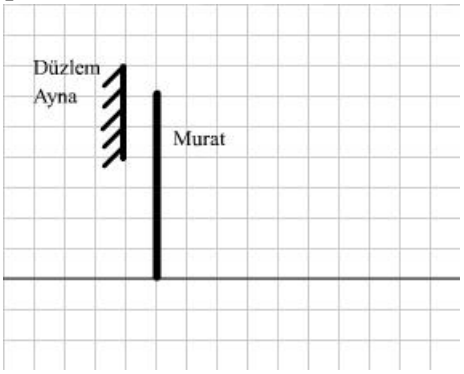
f) Diğer:.....

4.4. Yukarıda belirttiğiniz sebepten ne kadar eminsiniz?

a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

5.1. Murat, kendisinin boyunun yarısı büyüklüğünde ve yerden yüksekliği göğüs hizasında olan duvarda asılı düzlem aynada görüntüsüne şekildeki gibi bakmaktadır. Sağdaki çizimde aynı şeklin yandan gösterimi yer almaktadır. Buna göre; **Murat bir defada vücudunun <u>tamamını</u> görebilmek için ne yapmalıdır?**





Yandan Görünüş

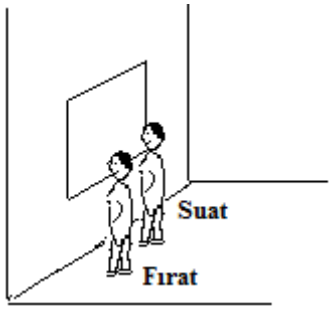
a) Aynaya yaklaşmalı.
b) Aynadan uzaklaşmalı.
c) Aynayı aşağı kaydırmalı.
d) Hiçbirisi.
e) Diğer:.....

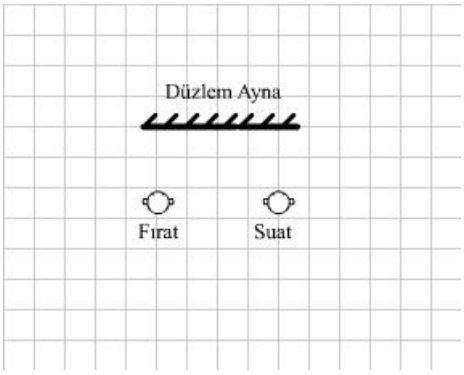
5.2. Yukarıdaki soruya verdiğiniz cevaptan ne kadar eminsiniz?
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

5.3. Soruya verdiğim cevap seçeneğini seçmemin sebebi;
a) Murat'ın görüntüsünün boyu küçülür ve böylece aynaya görüntüsünün tamamı sığabilir.
b) Murat'ın görüş alanı artacağı için vücudunun tamamını görebilir.
c) Murat'ın aynada görebileceği görüntüsünün boyu en fazla aynanın boyu kadar olabilir.
d) Aynanın boyunun Murat'ın boyunun en az yarısı kadar olması Murat'ın boyunun tamamını görebilmesi için yeterlidir.
e) Aynanın boyunun Murat'ın boyunun en az yarısı büyüklüğünde olması kadar aynanın duvardaki pozisyonu da Murat'ın vücudunun tamamını görmesi için önemlidir.
f) Diğer:.....

5.4. Yukarıda belirttiğiniz sebepten ne kadar eminsiniz?
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

6.1. Suat ve ikizi Fırat duvara monte edilmiş düzlem aynanın karşısında görüntülerine bakmaktadırlar. Sağdaki çizimde aynı şeklin üstten gösterimi yer almaktadır. **Suat bir defada Fırat'ın boyunun daha fazlasını görmek istemektedir, bunun için <u>Suat</u> ne yapmalıdır?**





Üstten Görünüş

I. Aynaya yaklaşmalı.
II. Aynadan uzaklaşmalı.
III. Aynayı aşağı kaydırmalı.

a) Yalnız I **b)** Yalnız II **c)** Yalnız III **d)** I veya III **e)** Hiçbirisi **f)** Diğer:……

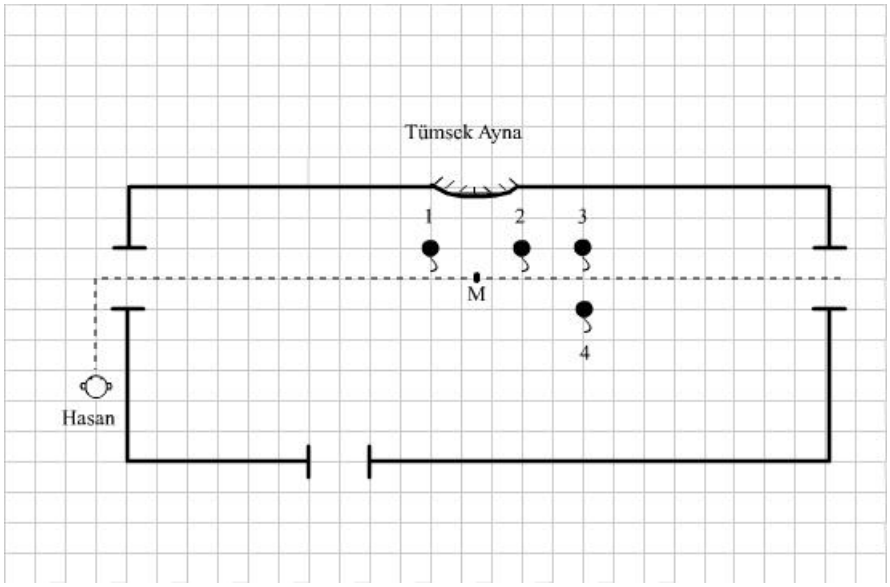
6.2. Yukarıdaki soruya verdiğiniz cevaptan ne kadar eminsiniz?
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

6.3. Soruya verdiğim cevap seçeneğini seçmemin sebebi;
a) Suat'ın görüş alanı artacağı için Fırat'ın vücudunun daha fazlasını görebilir.
b) Fırat'ın aynanın tam karşısındaki vücudunun kısımları artacağı için aynada oluşan görüntüsünün boyu artacaktır.
c) Fırat'ın görüntüsünün daha fazlasını görebilmesi Suat'ın görüş alanı arttığında ya da görüş alanının büyüklüğü değişmeden bu alan aşağı kaydığında mümkündür.
d) Fırat'ın aynada oluşan görüntüsünün boyu aynanın boyu kadardır.
e) Aynaya yaklaşıp uzaklaşmak, aynayı hareket ettirmek yalnızca Fırat'ın vücudunun görülebilen bölgesini değiştirir, vücudunun görülebilen bölgesinin büyüklüğü sabittir.
f) Hem Suat'ın hem de Fırat'ın görüntüsünün boyu küçülür ve aynaya görüntülerinin daha fazlası sığabilir.
g) Diğer:.....

6.4. Yukarıda belirttiğiniz sebepten ne kadar eminsiniz?
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

KÜRESEL AYNALAR

7.1. Homojen bir şekilde aydınlatılmış bir odanın üstten görünüşü aşağıda verilmiştir.Hasan kapıdan içeri girip oda boyunca kesikli çizgi ile gösterilen yolda ilerlerken kendisinin ve 1, 2, 3 ve 4 ile numaralandırılmış kedilerin görüntüsünü duvardaki tümsek aynada gözlemlemeye çalışmaktadır. Tümsek aynanın merkez uzaklığı M ile gösterilmiştir. Buna göre; **Hasan kesikli çizgi üzerinde ilerlerken kedilerin görüntüsünü hangi sıra ile görür?**



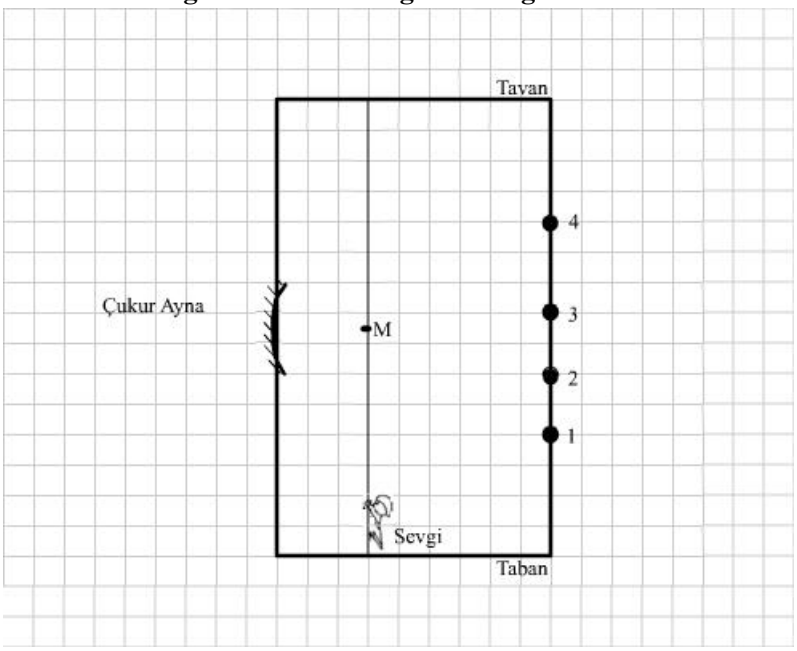
a) 1, 2, 3, 4 **b)** 4, 3, 2, 1 **c)** 1 = 2 = 3 = 4 **d)** 3, 2, 4, 1 **e)** 1, 2 **f)** Hiçbirini göremez.
g) Diğer:.....

7.2. Yukarıdaki soruya verdiğiniz cevaptan ne kadar eminsiniz?
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

7.3. Soruya verdiğim cevap seçeneğini seçmemin sebebi;
a) Tümsek ayna ışığı dağıttığı için odaya girdiği anda hepsini görebilir.
b) Yalnızca tümsek ayna sınırları içindeki kedilerin görüntüsü oluşur ve görülebilir.
c) Tümsek aynada yalnızca odak uzaklığındaki cismin görüntüsü görülemez.
d) Hasan ilerlerken kendisine yakın olan kedinin görüntüsünü daha önce görebilir.
e) Tümsek aynada odak uzaklığındaki cisimlerin görüntüleri de dahil tüm görüntüler Hasan'ın görüş alanına girme sırasına göre görülebilir.
f) Sanal görüntüler görülemez, yalnızca gerçek olan görüntüler görülebilir.
g) Diğer:.....

7.4. Yukarıda belirttiğiniz sebepten ne kadar eminsiniz?
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

8.1. Homojen bir şekilde aydınlatılmış bir odanın yandan görünüşü aşağıda verilmiştir. Sevgi'nin tırmandığı ipin aynaya olan uzaklığı aynanın merkez uzaklığı kadardır ve M ile gösterilmiştir.Sevgi tavanda asılı ip ile yukarı tırmanırken kendisinin ve arkasındaki duvara yerleştirilmiş 1, 2, 3 ve 4 ile numaralandırılmış lambaların görüntüsünü duvardaki çukur aynadan gözlemlemeye çalışmaktadır. Buna göre; **Sevgi tırmanırken duvardaki lambaların görüntüsünü hangi sıra ile görür?**



a) 1, 2, 3, 4 **b)** 4, 3, 2, 1 **c)** 2, 3 **d)** 3, 2 **e)** Hiçbirini göremez. **f)** Diğer:.....

8.2. Yukarıdaki soruya verdiğiniz cevaptan ne kadar eminsiniz?

a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

8.3. Soruya verdiğim cevap seçeneğini seçmemin sebebi;

a) Çukur aynada yalnızca odak uzaklığındaki cismin görüntüsü görülemez.

b) Sevgi tırmanırken kendisine yakın olan lambanın görüntüsünü daha önce görebilir.

c) Tüm lambaların görüntüsü gerçek görüntüdür ve gerçek görüntü ancak bir ekran üzerinde görülebilir.

d) Tüm lambaların görüntüsü gerçek görüntüdür ve ekran kullanılmadığı zaman gerçek görüntünün oluştuğu noktanın gerisinden ve oradan dağılan ışınların arasında kalan bölgeden bakılırsa görüntü görülebilir.

e) Yalnızca çukur ayna sınırları ve aynanın eğrilik yarıçapı içinde kalan lambaların görüntüsü aynada oluşur ve görülebilir.

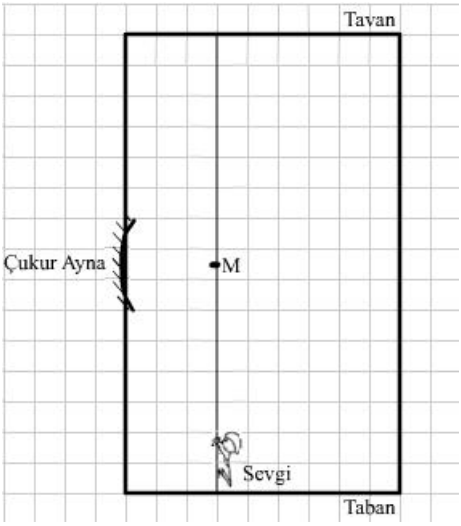
f) Aynanın odak noktasından geçecek şekilde lambalardan ışın çizildiğinde, sadece aynaya ışınları ulaşabilenlerin görüntüsü oluşur ve görülebilir.

g) Diğer:.....

8.4. Yukarıda belirttiğiniz sebepten ne kadar eminsiniz?

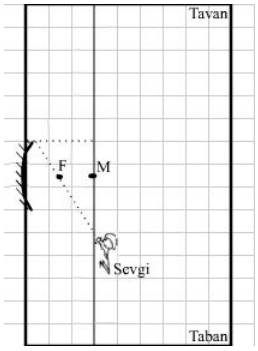
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

9.1. Önceki soruda, **Sevgi tırmanırken <u>ilk</u> olarak nerede iken <u>kendi gözlerinin</u> görüntüsünü görebilir?**

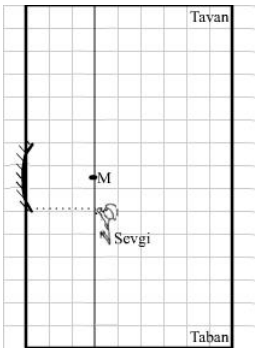


a) Tırmanmaya başlamadan bulunduğu yerde görebilir.
b) Hiçbir yerde göremez.

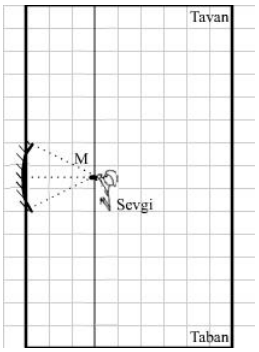
c)



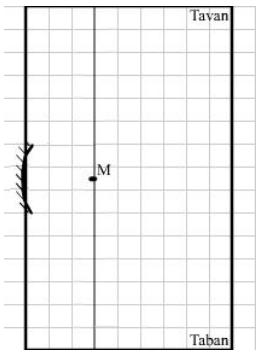
d)



e)



f) Diğer: Çiziniz



9.2. Yukarıdaki soruya verdiğiniz cevaptan ne kadar eminsiniz?

a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

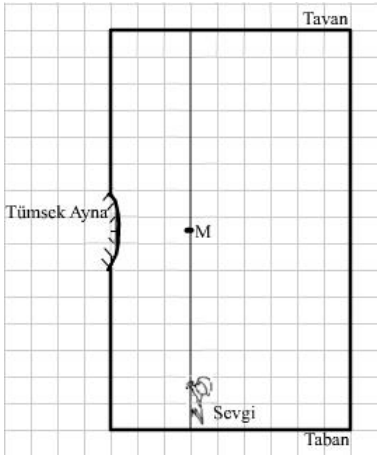
9.3. Soruya verdiğim cevap seçeneğini seçmemin sebebi;

a) Sevgi'nin tırmandığı ip çukur aynanın merkezinden geçtiği için, Sevgi nerede olursa olsun ışınlar gözüne geri yansır ve kendi gözlerini görebilir.
b) Sevgi kendi gözlerini sadece gözleri ayna sınırları içinde iken görebilir.
c) Sevgi yalnızca M noktasında iken gözlerinden aynaya ulaşan ışınlar yansıyarak tekrar gözlerine ulaşır.
d) Sevgi'nin gözlerinin görüntüsü gerçek görüntüdür ve gerçek görüntü ancak bir ekran üzerinde görülebilir.
e) Sevgi'nin gözlerinden çukur aynanın sınırına çizilebilecek ve odaktan geçen ilk ışın doğrultusunda iken Sevgi ilk olarak gözlerinin görüntüsünü görebilir.
f) Diğer:.....

9.4. Yukarıda belirttiğiniz sebepten ne kadar eminsiniz?

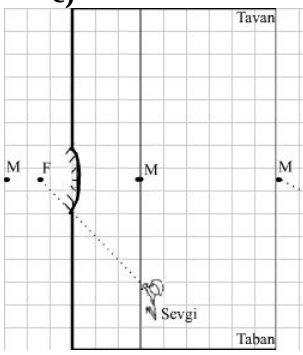
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

10.1. Sevgi tavanda asılı ip ile yukarı tırmanırken kendisinin görüntüsünü duvardaki tümsek aynadan gözlemlemeye çalışmaktadır. Buna göre; **Sevgi tırmanırken ilk olarak nerede iken kendi gözlerinin görüntüsünü görebilir?**

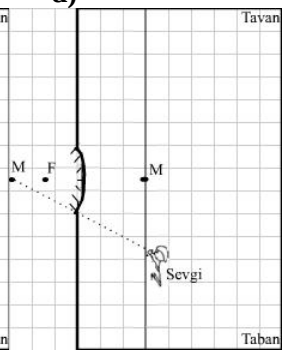


a) Tırmanmaya başlamadan bulunduğu yerde görebilir. **b)** Hiçbir yerde göremez.

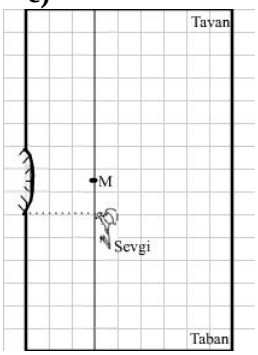
c)



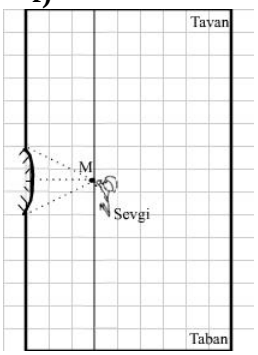
d)



e)



f)



g) Diğer: Sorudaki şekil üzerine çiziniz.

10.2. Yukarıdaki soruya verdiğiniz cevaptan ne kadar eminsiniz?

a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

10.3. Soruya verdiğim cevap seçeneğini seçmemin sebebi;

a) Sevgi'nin tırmandığı ip tümsek aynanın merkez uzaklığından geçtiği için, Sevgi nerede olursa olsun ışınlar gözüne geri yansır ve kendi gözlerini görebilir.

b) Sevgi kendi gözlerini sadece gözleri ayna sınırları içinde iken görebilir.

c) Sevgi yalnızca M noktasında iken gözlerinden aynaya ulaşan ışınlar yansıyarak tekrar gözlerine ulaşır.

d) Tümsek ayna ışığı dağıttığı için, Sevgi tırmanırken nerede olursa olsun kendi gözlerini görebilir.

e) Sevgi'nin gözlerinden tümsek aynanın sınırına çizilebilecek ve odaktan geçen ilk ışın doğrultusunda iken Sevgi ilk olarak gözlerinin görüntüsünü görebilir.

f) Sevgi'nin gözlerinden tümsek aynaya, aynanın arkasındaki merkezi doğrultusunda gelen ışınlar yansıyarak ilk olarak tekrar gözlerine ulaşabilir.

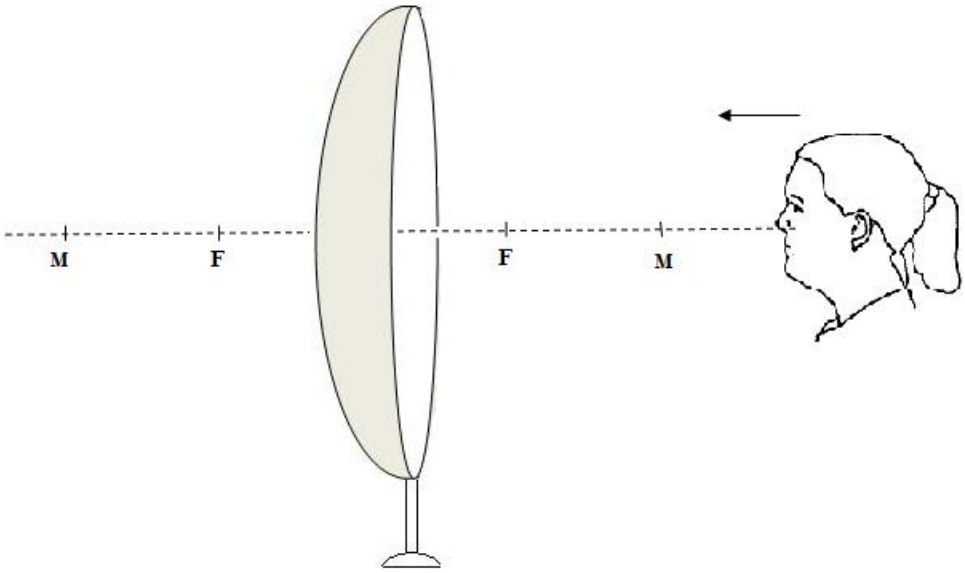
g) Sanal görüntüler görülemez, yalnızca gerçek görüntüler görülebilir.

h) Diğer:.....

10.4. Yukarıda belirttiğiniz sebepten ne kadar eminsiniz?

a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

11.1. Selin aşağıdaki şekilde gösterilen mesafeden çukur aynaya bakarak yüzünün görüntüsünü görmek istemektedir. M çukur aynanın merkezini, F ise odağını göstermektedir. **Selin ok işareti yönünde çukur aynaya yaklaşırken başının hangi pozisyon ya da pozisyonlarında kendi görüntüsünü görebilir?**



I. Merkezin dışında (M'nin dışında)
II. Merkezde (M'de)
III. Odak ve merkez arasında (F-M arasında)
IV. Odakta (F'de)
V. Odak ve çukur ayna arasında (F-ayna arasında)

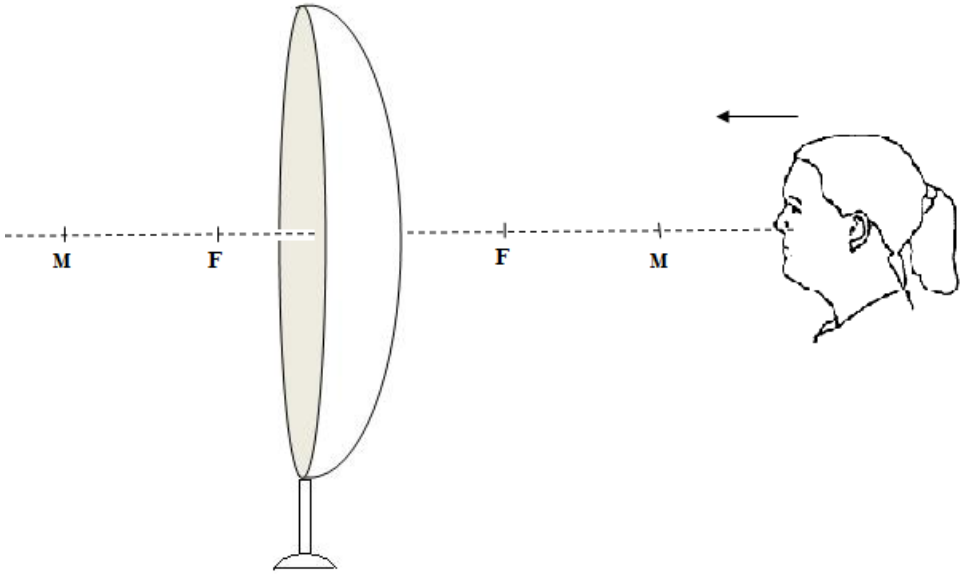
a) I, II, III, IV, V **b)** I, II, III, V **c)** I, II, III **d)** I, V **e)** Yalnız V **f)** Diğer:....

11.2. Yukarıdaki soruya verdiğiniz cevaptan ne kadar eminsiniz?
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

11.3. Soruya verdiğim cevap seçeneğini seçmemin sebebi;
a) Selin odakta iken yüzünün görüntüsü sonsuzda oluştuğu için.
b) Gerçek görüntüler sadece ekran üzerinde görülebilir.
c) Sanal görüntüler görülemez, yalnızca gerçek olan görüntüler görülebilir.
d) Selin'in yüzünün her bir noktasından aynaya ulaşan ışınların yansıyarak Selin'in gözüne ulaşması ve görüntüsünün oluştuğu yerin gerisinden bakıyor olması gerekir.
e) Selin, aynanın ön yüzünde kendisi ile aynı tarafta oluşacak tüm görüntülerini görebilir.
f) Diğer:.....

11.4. Yukarıda belirttiğiniz sebepten ne kadar eminsiniz?
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

12.1. Selin aşağıdaki şekilde gösterilen mesafeden tümsek aynaya bakarak yüzünün görüntüsünü görmek istemektedir. M tümsek aynanın merkezini, F ise odağını göstermektedir. **Selin ok işareti yönünde tümsek aynaya yaklaşırken başının hangi pozisyon ya da pozisyonlarında kendi görüntüsünü görebilir?**



I. Merkezin dışında (M'nin dışında)
II. Merkezde (M'de)
III. Odak ve merkez arasında (F-M arasında)
IV. Odakta (F)
V. Odak ve tümsek ayna arasında (F-ayna arasında)

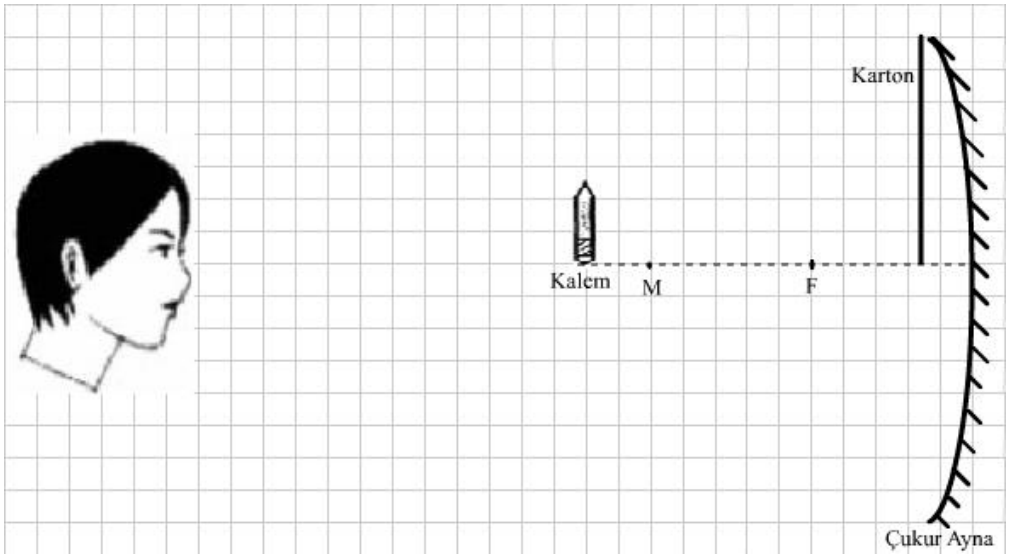
a) I, II, III, IV, V **b)** I, II, III, V **c)** I, II, III **d)** Yalnız V **e)** Hiçbirisi **f)** Diğer:.....

12.2. Yukarıdaki soruya verdiğiniz cevaptan ne kadar eminsiniz?
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

12.3. Soruya verdiğim cevap seçeneğini seçmemin sebebi;
a) Selin odakta iken yüzünün görüntüsü sonsuzda oluşacağı için.
b) Sanal görüntüler görülemez, yalnızca gerçek olan görüntüler görülebilir.
c) Selin'in yüzünün her bir noktasından aynaya ulaşan ışınların yansıyarak Selin'in gözüne ulaşması durumunda kendisini görebilir.
d) Selin'in yüzünden aynaya ulaşan ışınlar tümsek aynanın arkasında kesişir ve Selin'in gözüne ulaşamaz.
e) Selin'in görüntüsü I. durumda aynanın arkasında F-M arasında; II. durumda aynanın arkasında M'de; III. durumda aynanın arkasında M'nin dışında oluşur ve Selin bu görüntülerini görebilir.
f) Diğer:.....

12.4. Yukarıda belirttiğiniz sebepten ne kadar eminsiniz?
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

13.1. Aşağıdaki şekilde gözlemci, kalem, çukur ayna ve kartonun yandan görünüşü verilmiştir. M çukur aynanın merkezini, F ise aynanın odağını göstermektedir. Çukur aynanın merkez uzaklığından öteye yerleştirilen bir kalemin görüntüsü şekildeki gözlemci tarafından gözlemlenmektedir. **Çukur aynanın üst yarısı bir kartonla tamamen kapatılırsa kalemin görüntüsünde nasıl bir değişiklik olur?**



a) Kalemin görüntüsü tamamen kaybolur.
b) Kalemin yalnızca silgisinin nokta şeklinde görüntüsü olur.
c) Kalemin yarısının görüntüsü olur.
d) Kalemin görüntüsü karton kapatılmadan önce oluştuğu yerde ve önceki ile aynı boyutta olur.
e) Diğer:.....

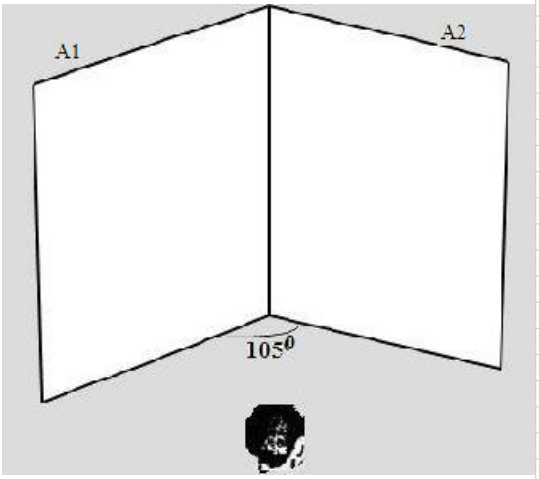
13.2. Yukarıdaki soruya verdiğiniz cevaptan ne kadar eminsiniz?
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

13.3. Soruya verdiğim cevap seçeneğini seçmemin sebebi;
a) Kalemden çıkan ışınlar kartondan dolayı aynaya ulaşamaz.
b) Aynanın yarısı kapatıldığı için, kalemin görüntüsünün de yarısı kaybolur.
c) Kalemin farklı noktalarından asal eksene paralel çizilen ışınlar karton tarafından engellenir. Çizilebilen diğer tek bir özel ışın görüntü oluşturmak için yeterli değildir.
d) Kalemin üzerindeki her bir noktadan aynanın açıkta kalan bölümüne ışık gelebileceği için kalemin görüntüsünün boyu, yeri ve şeklinde bir değişiklik olmaz.
e) Kartonun da çukur aynada bir görüntüsü oluşur ve bu görüntü kalemin görüntüsünün oluşumunu engeller.
f) Diğer:.....

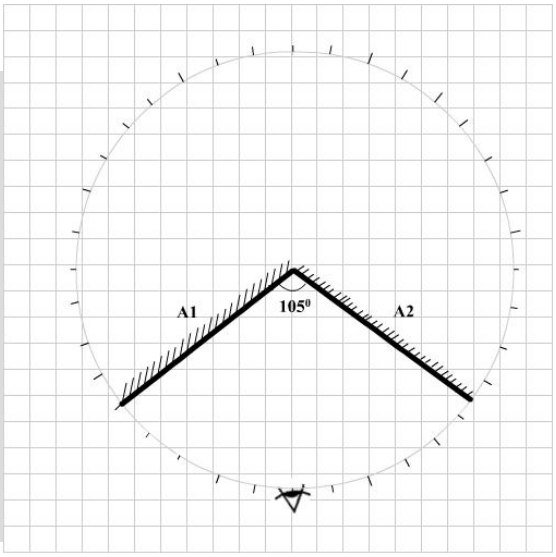
13.4. Yukarıda belirttiğiniz sebepten ne kadar eminsiniz?
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

KESİŞEN AYNALAR

14.1. Aşağıda aralarındaki açı (α) 105^0 olacak şekilde yerleştirilen iki düzlem aynanın <u>önden</u> ve <u>üstten görünüşleri</u> verilmiştir. Konumu şekil üzerinde belirtilen bir gözlemci 105^0 açı ile kesişen aynalarda kendisini gözlemlemektedir. Buna göre; **bu gözlemci <u>kendisinin</u> kaç görüntüsünü görür?**



Önden Görünüş



Üstten Görünüş

a) 4 **b)** 3 **c)** 2.43 **d)** 2 **e)** Hiçbir görüntüsünü göremez. **f)** Diğer:.....

14.2. Yukarıdaki soruya verdiğiniz cevaptan ne kadar eminsiniz?

a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

14.3. Soruya verdiğim cevap seçeneğini seçmemin sebebi;

a) Gözlemcinin görebileceği görüntü sayısını yalnızca ayna sayısı belirler.

b) Yalnızca (360^0 / α) - 1 sonucu tam sayı elde edebileceğimiz belli açılarda gözlemci kendi görüntüsünü görebilir.

c) (360^0 / α) - 1 sonucu tam sayı elde edemediğimiz için gözlemci kendisinin tam görüntülerinin yanı sıra çakışık ve tam olmayan görüntülerini de görebilir.

d) (360^0 / α) - 1 sonucu tam sayı elde edemediğimiz açılarda formülden elde ettiğimiz sayıyı tam sayıya yuvarlarız, çünkü yarım görüntü olamaz.

e) Gözlemcinin iki aynada ayrı ayrı oluşan görüntülerini ve bu görüntülerin diğer aynadaki görüntüsünün yerini belirlediğimizde, gözlemci bu belirlenen tüm görüntülerini görebilir.

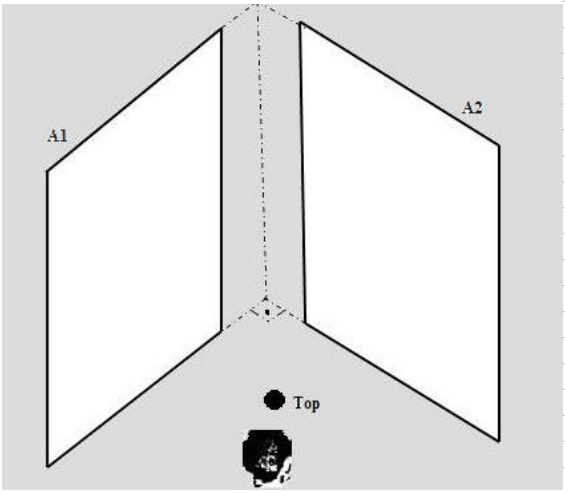
f) Gözlemcinin kendisinden aynalara ulaşan ışınların yansımaları sonucu gözlemcinin gözüne ulaşabilen ışınlarla görüntüsü oluşur ve bu görüntülerini görebilir.

g) Diğer:.....

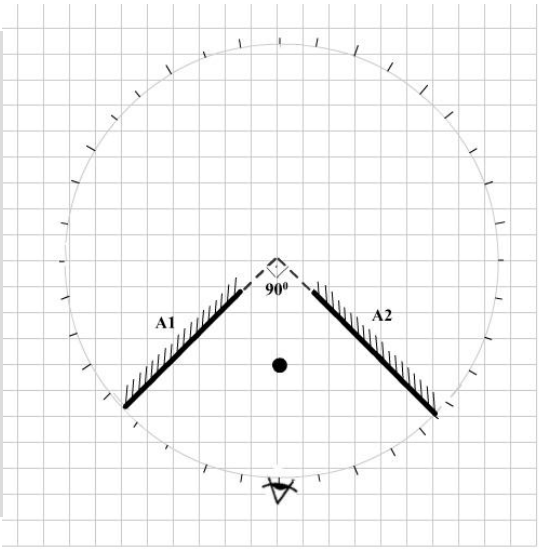
14.4. Yukarıda belirttiğiniz sebepten ne kadar eminsiniz?

a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

15.1. Bir alışveriş mağazasının birbirine dik duvarlarına iki düzlem ayna aralarında 90^0 açı (α) ile ve biraz mesafe bırakılarak aşağıdaki şekildeki gibi monte edilmiştir. Aynalar arasına konulan bir top şekildeki konumdan bakan bir gözlemci tarafından gözlemlenmektedir. Buna göre; **bu gözlemci yerdeki <u>topun</u> kaç görüntüsünü görür?**



Önden Görünüş



Üstten Görünüş

a) 3 **b)** 2 **c)** 1 **d)** Topun hiçbir görüntüsünü göremez. **e)** Diğer:.....

15.2. Yukarıdaki soruya verdiğiniz cevaptan ne kadar eminsiniz?

a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

15.3. Soruya verdiğim cevap seçeneğini seçmemin sebebi;

a) Gözlemcinin görebileceği görüntü sayısını yalnızca ayna sayısı belirler.

b) Aynalar arasında mesafe olduğu için topun A1 aynasında oluşan görüntüsünün A2 aynasında tekrar bir görüntüsü oluşamaz.

c) Görüntü oluşumu ve gözlemlenmesi aynı anda gerçekleşen olaylar olduğu için yansımalar sonucu gözlemcinin gözüne ulaşan ışınlarla topun görüntüsü oluşur ve bu görüntüleri görebilir.

d) Aynalar arasında mesafe olsa bile, topun yansımalar sonucu (360^0 / α) – 1 tane görüntüsü oluşur ve gözlemci oluşan tüm görüntüleri aynalar arasından baktığı için görebilir.

e) Aynalar arasında mesafe olsa bile, topun yansımalar sonucu (360^0 / α) – 1 tane görüntüsü oluşur, fakat gözlemci sadece görüş alanı içine giren görüntüleri görebilir.

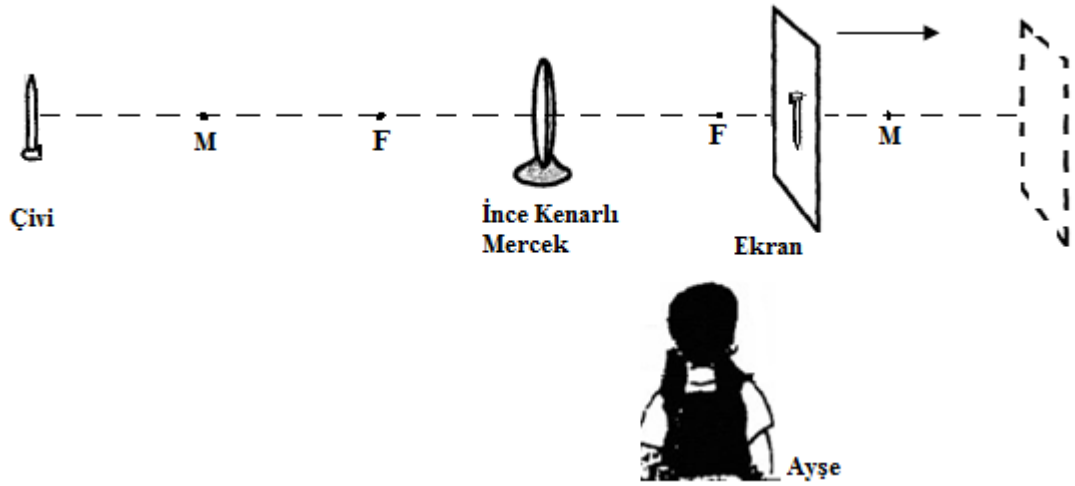
f) Diğer:.....

15.4. Yukarıda belirttiğiniz sebepten ne kadar eminsiniz?

a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

MERCEKLER

16.1. Ayşe ince kenarlı mercek önüne yerleştirilen bir çivinin net görüntüsünü aşağıdaki şekildeki gibi merceğin diğer tarafında, küçük ve ters olarak ekran üzerine gözlemlemektedir. F ince kenarlı merceğin odağını, M ise merkezini göstermektedir. Diğer nesnelerin yerleri sabit kalmak koşuluyla **ekran aşağıdaki şekildeki gibi mercekten uzaklaşacak şekilde geriye doğru kesikli çizgiler ile gösterilen yere çekilirse, çivinin ekran üzerindeki görüntüsünde nasıl bir değişiklik olur?**



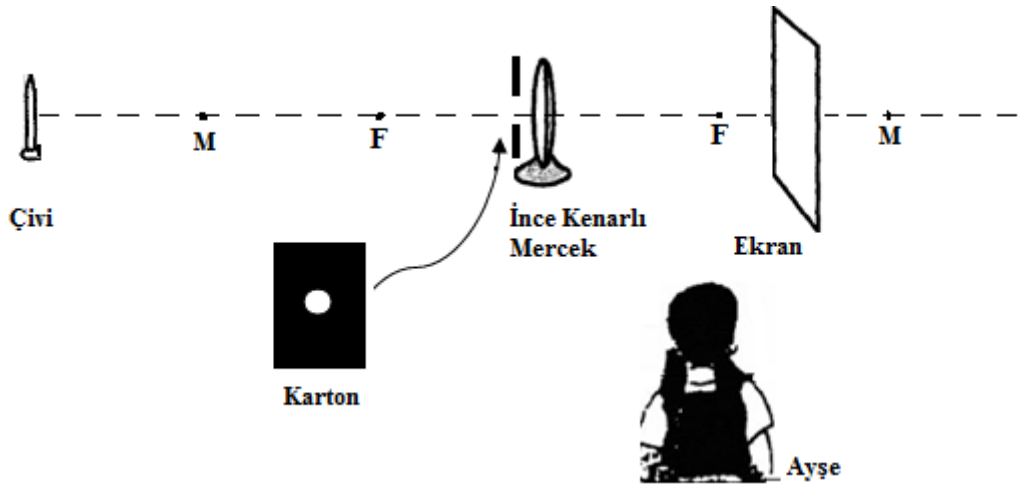
a) Görüntü büyür.
b) Görüntü küçülür.
c) Çivi ile aynı yönlü düz bir görüntü oluşur.
d) Görüntü oluşmaz**.**
e) Diğer:.....

16.2. Yukarıdaki soruya verdiğiniz cevaptan ne kadar eminsiniz?
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

16.3. Soruya verdiğim cevap seçeneğini seçmemin sebebi;
a) Çivinin merceğe olan uzaklığı değişmediği için görüntünün yeri değişmez ve oluşan görüntüden dağılan ışınlar geriye çekilen ekran üzerinde daha büyük, ters bir görüntü oluşturur.
b) Çivinin merceğe olan uzaklığı değişmediği için görüntünün yeri değişmez ve burada kesişen ışınlar dağılarak ters dönerken ekran üzerinde çivinin düz bir görüntüsü oluşur.
c) İnce kenarlı mercekte ekran üzerinde oluşan görüntü ters ve cisimden küçüktür. Ekran mercekten uzaklaştıkça üzerine düşen görüntü de o kadar küçülür.
d) Çivinin merceğe olan uzaklığı değişmediği için görüntünün yeri değişmez ve ekran uzaklaştırıldığında ekrana bir görüntü düşmez.
e) Diğer:.....

16.4. Yukarıda belirttiğiniz sebepten ne kadar eminsiniz?
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

17.1. Önceki soruda ekran üzerinde çivinin net görüntüsü görülebilirken **merceğin ön yüzüne tam ortasında daire şeklinde açıklık olan bir <u>karton</u> şekildeki gibi yerleştirilirse Ayşe <u>ekranda</u> ne görür?**



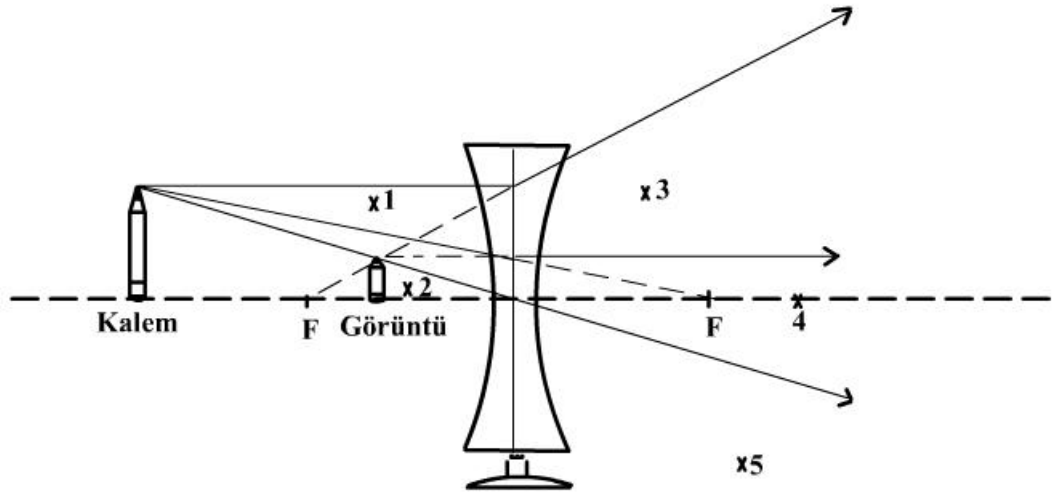
a) Hiçbir şey göremez.
b) Sadece çivinin orta kısmının görüntüsünü görebilir.
c) Çivinin tamamının ters görüntüsünü görebilir.
d) Çivinin daha büyük ve net olmayan ters görüntüsünü görebilir.
e) Diğer:.....

17.2. Yukarıdaki soruya verdiğiniz cevaptan ne kadar eminsiniz?
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

17.3. Soruya verdiğim cevap seçeneğini seçmemin sebebi;
a) Çivinin üzerindeki her bir noktadan merceğin açıkta kalan bölümüne ışık gelebileceği için çivinin görüntüsünün boyu ve şeklinde bir değişiklik olmaz.
b) Karton, çivinin uç kısımlarından merceğe ışık gelmesine engel olacağı için çivinin sadece ortasının görüntüsü ekranda görülebilir.
c) Merceğin açıkta kalan bölümü odak ve merkez uzaklıkları daha küçük bir mercek gibi davranacağı için çivinin görüntüsü merceğe daha yakın oluşur.
d) Çivinin farklı noktalarından çizilen ışınlar karton tarafından engellenir. Çizilebilen diğer tek bir özel ışın görüntü oluşturmak için yeterli değildir.
e) Diğer:.....

17.4. Yukarıda belirttiğiniz sebepten ne kadar eminsiniz?
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

18.1. Şekildeki ışın diyagramında kalın kenarlı merceğin önüne yerleştirilmiş bir kalem ve bu kalemin görüntüsü verilmiştir. Kalemin ucundan çizilen üç ışının mercekten geçtikten sonra izlediği yollar şekilde çizilmiştir. Buna göre; **1, 2, 3, 4 ve 5 ile numaralandırılmış beş noktadan hangisi ya da hangilerinden bakan gözlemci(ler) kalemin görüntüsünün tamamını görebilir?**



a) Yalnız 1 **b)** 1 ve 2 **c)** 3 ve 4 **d)** 3, 4 ve 5 **e)** 1, 3 ve 4 **f)** Diğer:.....

18.2. Yukarıdaki soruya verdiğiniz cevaptan ne kadar eminsiniz?

a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

18.3. Soruya verdiğim cevap seçeneğini seçmemin sebebi;

a) Görüntü ile aynı taraftan ve görüntünün hizasından bakıldığı zaman görülebilir.

b) Görüntüye merceğin karşı tarafından ve yalnızca mercek sınırları içinden bakıldığı zaman görülebilir.

c) Kalemin görüntüsünü oluşturan ışınlar merceğin karşı tarafında kesişmediği için o taraftan bakan gözlemciler görüntüyü göremezler.

d) Gözlemcilerin görüntünün tamamını görebilmesi için şekilde çizilen üç ışının sınırladığı alan içinden bakması gerekir.

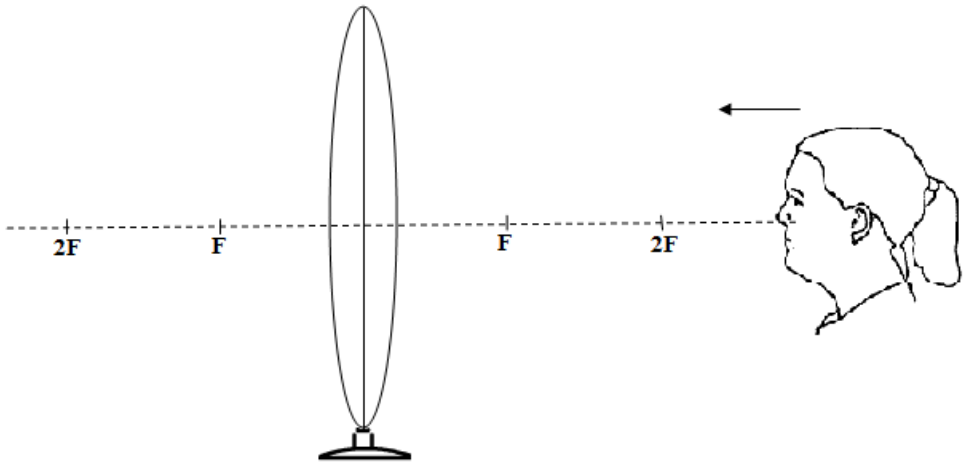
e) Gözlemcilerin görüntünün tamamını görebilmesi için kalemin her bir noktasından merceğe ulaşan ışınların kırıldıktan sonra gözlemcinin gözüne ulaşabildiği bir alandan bakılması gerekir.

f) Diğer:.....

18.4. Yukarıda belirttiğiniz sebepten ne kadar eminsiniz?

a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

19.1. Selin aşağıdaki şekilde gösterilen mesafelerden ince kenarlı bir merceğe bakarak mercekte yüzünün görüntüsünü görmek istemektedir. Şekilde Selin ve merceğin yandan görünüşü verilmiştir. 2F merceğin merkez, F ise odağını göstermektedir. Buna göre; **Selin ok işareti yönünde ince kenarlı merceğe yaklaşırken başının hangi pozisyon ya da pozisyonlarında kendi görüntüsünü görebilir?**



I. Merkezin dışında (2F'nin dışında)
II. Merkezde (2F'de)
III. Odak ve merkez arasında (F-2F arasında)
IV. Odakta (F'de)
V. Odak ve mercek arasında (F-mercek arasında)

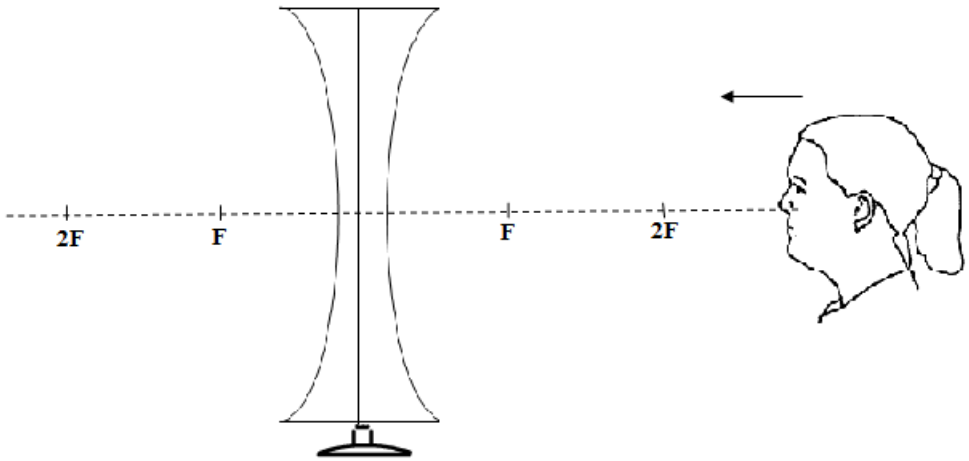
a) I, II, III, IV, V **b)** I, II, III, V **c)** I, II, III **d)** V **e)** Hiçbiri **f)** Diğer:.....

19.2. Yukarıdaki soruya verdiğiniz cevaptan ne kadar eminsiniz?
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

19.3. Soruya verdiğim cevap seçeneğini seçmemin sebebi;
a) Selin odakta iken yüzünün görüntüsü sonsuzda oluşur.
b) Gerçek görüntü sadece ekran üzerine düşürülürse görülebilir.
c) Sanal görüntüler görülemez, yalnızca gerçek olan görüntüler görülebilir.
d) Selin, yüzünden yansıyıp mercekte kırılan ışınların kendisi ile aynı tarafta ve önünde kesiştiği durumlarda görebilir.
e) Selin'in yüzünden yansıyıp mercekte kırılan ışınlar hiçbir pozisyonda Selin'in gözüne ulaşamaz.
f) Diğer:.....

19.4. Yukarıda belirttiğiniz sebepten ne kadar eminsiniz?
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

20.1. Selin aşağıdaki şekilde gösterilen mesafelerden kalın kenarlı bir merceğe bakarak mercekte yüzünün görüntüsünü görmek istemektedir. Şekilde Selin ve merceğin yandan görünüşü verilmiştir. 2F merceğin merkez, F ise odağını göstermektedir. Buna göre; **Selin ok işareti yönünde kalın kenarlı merceğe yaklaşırken başının hangi pozisyon ya da pozisyonlarında kendi görüntüsünü görebilir?**



I. Merkezin dışında (2F'nin dışında)
II. Merkezde (2F'de)
III. Odak ve merkez arasında (F-2F arasında)
IV. Odakta (F'de)
V. Odak ve mercek arasında (F-mercek arasında)

a) I, II, III, IV, V **b)** I, II, III, V **c)** I, II, III **d)** I ve II **e)** Hiçbiri **f)** Diğer:.....

20.2. Yukarıdaki soruya verdiğiniz cevaptan ne kadar eminsiniz?
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

20.3. Soruya verdiğim cevap seçeneğini seçmemin sebebi;
a) Selin odakta iken yüzünün görüntüsü sonsuzda oluşur.
b) Gerçek görüntü sadece ekran üzerine düşürülürse görülebilir.
c) Sanal görüntüler görülemez, yalnızca gerçek olan görüntüler görülebilir.
d) Selin, yüzünden yansıyıp mercekte kırılan ışınların kendisi ile aynı tarafta ve önünde kesiştiği durumlarda görebilir.
e) Selin'in yüzünden yansıyıp mercekte kırılan ışınlar hiçbir pozisyonda Selin'in gözüne ulaşamaz.
f) Diğer:.....

20.4. Yukarıda belirttiğiniz sebepten ne kadar eminsiniz?
a) Kesinlikle eminim. **b)** Eminim. **c)** Emin değilim. **d)** Kesinlikle emin değilim.

TEST BİTTİ.

ROUGH ENGLISH TRANSLATION OF THE FTGOT

GEOMETRICAL OPTICS TEST

Gender: □ Female □ Male

Date of Birth (Day/Month/Year): ___/___/_____

University: _____

Department: □ Physics □ Physics Teacher □ Other (_____)

Grade Level: □1 □ 2 □ 3 □ 4 □ 5 □ Other (_____)

CGPA: _____

Optics Course Grade: _____

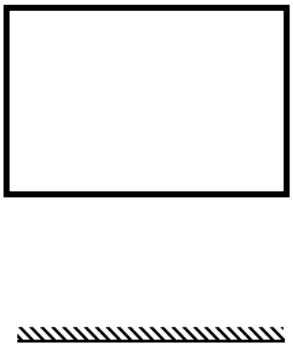
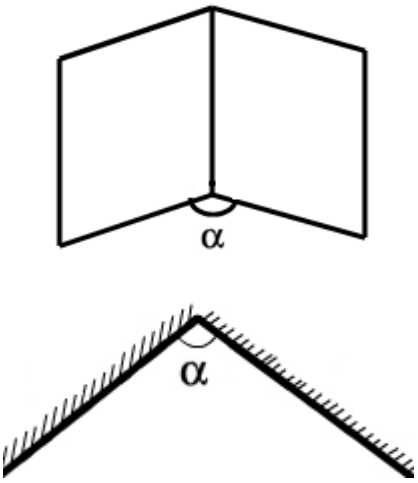
Optics Laboratory Course Grade: _____

Directions

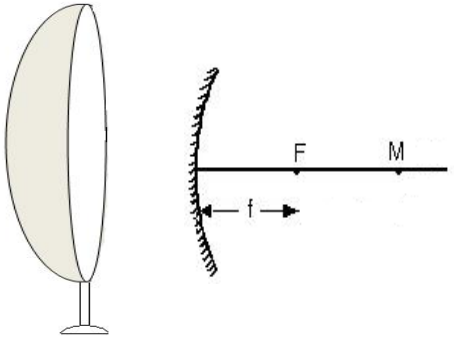
1. Fill in the parts above without leaving any of them unanswered before starting the test.
2. In the test there are 20 questions that each consists of four tiers. Please try to answer each tier of the questions.
3. In the first tier of each question select your answer for the question; in the second tier rate your confidence in the first tier; in the third tier select your reasoning about the answer for the question; and in the fourth tier rate your confidence in the third tier.
4. While answering the questions ignore reflection takes place on the lenses and refraction in the mirrors.
5. Duration of the test is recommended approximately 50 minutes.
6. The formulas and the ray diagrams that might be useful in answering the questions are given in the next page.
7. The results of the test will be used as a data by a researcher who is doing PhD at the Department of Secondary Science and Mathematics Education at Middle East Technical University. This is a research study and you are a part of this research. Thanks for your attention and interest.

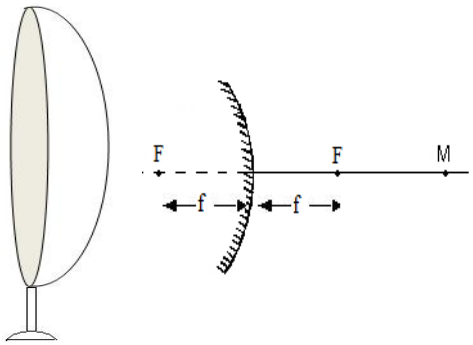
USEFUL PICTURES, RAY DIAGRAMS and FORMULAS

In the table below some useful pictures, drawings, ray diagrams and formulas related to the optical instruments mentioned in Geometrical Optics Test are provided.

PICTURE OF OPTICAL INSTRUMENT	TOP-VIEW or SIDE-VIEW DRAWING OF OPTICAL INSTRUMENT	FORMULAS RELATED TO OPTICAL INSTRUMENT
Single Plane Mirror		
Hinged Plane Mirrors		**n:** Total number of the formed images **α :** Angle between the mirrors $n=\frac{360}{\alpha}-1$

<table>
<tr>
<td>Concave and Convex Mirrors

 </td>
<td>Concave Mirror
 

Convex Mirror
 
</td>
<td>F: Focal point of the mirror

M: Center of the mirror

f: Focal length of the mirror

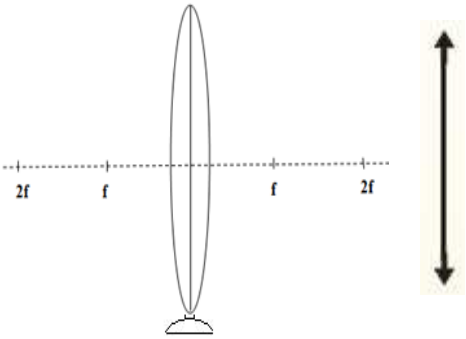
d_c: Distance of object from the mirror

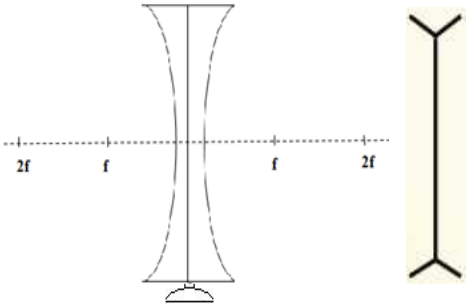
d_g Distance of image from the mirror

h_o: Height of object

h_g: Height of image
$\frac{1}{f} = \frac{1}{d_c} + \frac{1}{d_g}$

$\frac{h_o}{h_g} = \frac{d_c}{d_g}$</td>
</tr>
<tr>
<td>Converging and Diverging Lenses

 </td>
<td>Converging Lens
 

Diverging Lens
 
</td>
<td>f: Focal length of the lens

d_c: Distance of object from the lens

d_g Distance of image from the lens

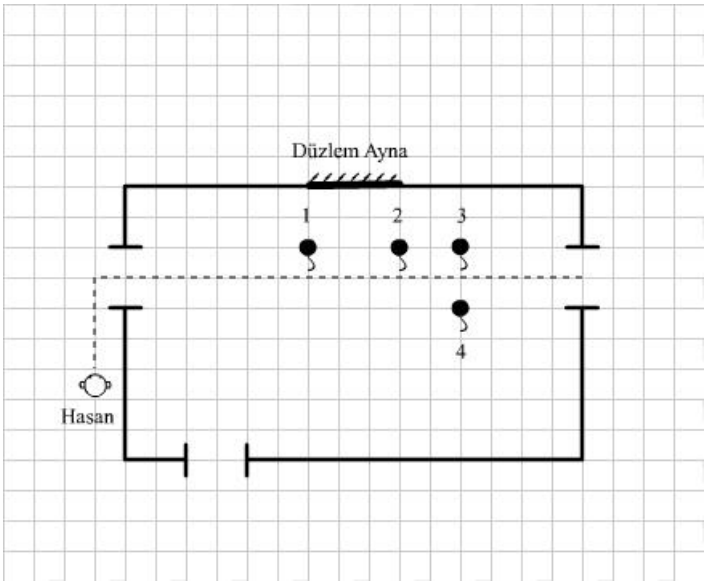
h_o: Height of object

h_g: Height of image
$\frac{1}{f} = \frac{1}{d_c} + \frac{1}{d_g}$

$\frac{h_o}{h_g} = \frac{d_c}{d_g}$</td>
</tr>
</table>

PLANE MIRRORS

1.1. Below you can see the top-view of a homogenously illuminated room. Hasan enters the room from the left door and as he walks along the path shown with dashed line, he tries to observe images of the cats numbered by 1, 2, 3 and 4 in the plane mirror on the wall. So; **which of the cats' images will be formed in the plane mirror?**



a) Only 1 **b)** 1 and 2 **c)** 1, 2 and 3 **d)** 1, 2, 3 and 4 **e)** Other:.....

1.2. How confident are you in your answer for the above question?

a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

1.3. The reason for my answer to the question is;

a) Only the images of the cats that are directly in front of the plane mirror are formed.

b) Only the images of the cats with no other cats stand in front of them are formed.

c) Even if Hasan cannot see the cats at certain places in the room as he walks along, image of those cats are formed in the plane mirror.

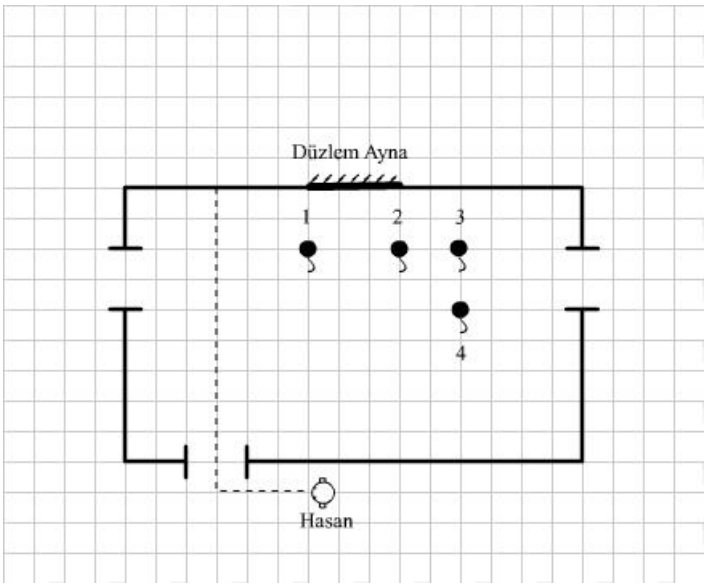
d) Since image formation and observation occurs simultaneously, even if Hasan cannot see cats' at certain places as he walks along the room, images of those cats are not formed in the plane mirror at that time.

e) Other:.....

1.4. How confident are you in your answer for the above question?

a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

2.1. Below you can see the top-view of a homogenously illuminated room. Hasan enters the room from the back door and as he walks along the path shown with dashed line, he tries to observe images of cats numbered by 1, 2, 3 and 4 in the plane mirror on the wall. So; **in which order does Hasan see images of cats in the plane mirror as he walks along the path?**



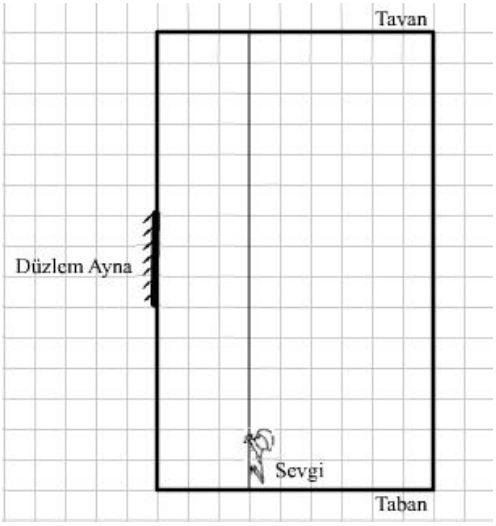
a) 1, 2 **b)** 2, 3 **c)** 2 = 4, 3 **d)** 3, 4, 2 **e)** 1, 2, 4, 3 **f)** 4, 1, 2, 3 **g)** Other:.....

2.2. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

2.3. The reason for my answer to the question is;
a) Hasan can see only images of the cats stand within the borders of the plane mirror.
b) Hasan can see the image of the cat which is closest to him as he walks along the path.
c) Only the images of cats can be seen if there is no cat in front of them.
d) When Hasan's field of view is determined by drawing rays from each of the cats to the right and left edges of the plane mirror; firstly he can see Cat 3 depending on the order of rays reflected from the mirror and intersect the dashed line.
e) When Hasan's field of view is determined by drawing rays from each of the cats to the right and left edges of the plane mirror; he can see that cat's image when he is within the region of the reflected rays from the mirror.
f) Other:.....

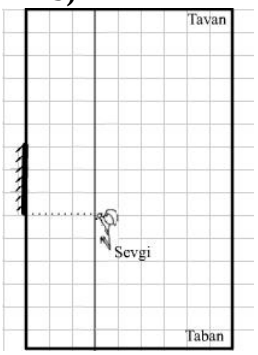
2.4. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

3.1. Below you can see the side-view of a homogenously illuminated room. As Sevgi climbs the rope from the bottom to the ceiling of the room, she tries to observe her image in the plane mirror on the wall. So; **where can she see her whole body in the plane mirror for the first time?**

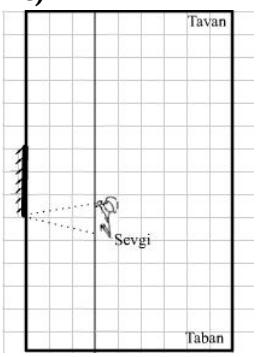


a) She can see when she is on the room floor before starting to climb.

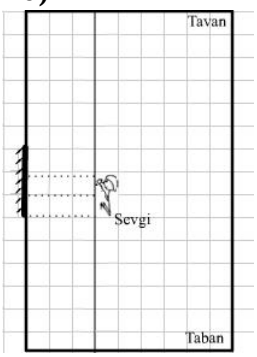
b)



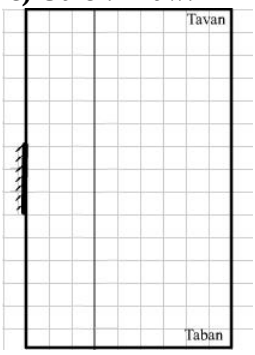
c)



d)



e) Other: Draw.



3.2. How confident are you in your answer for the above question?

a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

3.3. The reason for my answer to the question is;

a) Since plane mirrors are considered as in infinite length, Sevgi can see her whole body before climbing the rope.

b) When her eyes' positions align with the bottom edge of the mirror, Sevgi can see her whole body if she looks down through the mirror.

c) Sevgi's whole body should be in front of the mirror in order to see her whole body.

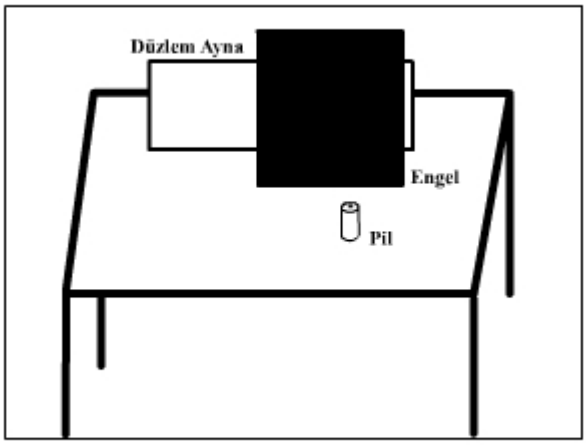
d) To see her whole body, rays coming from the bottom of Sevgi's body should reflect from the mirror and reach to her eyes.

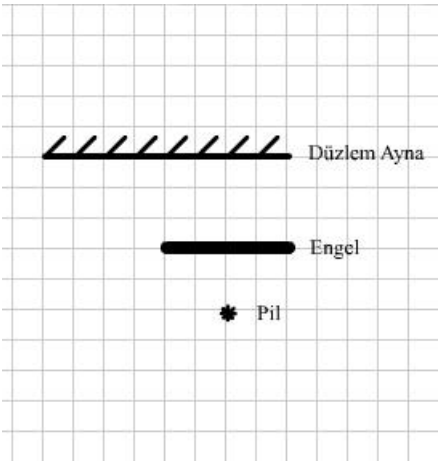
e) Other:.....

3.4. How confident are you in your answer for the above question?

a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

4.1. In a homogenously illuminated room, an opaque cardboard is placed in front of a plane mirror. A battery is placed in front of the cardboard as shown in the below picture on the left. On the right, you can see the top-view drawing of the same picture. So; **is the image of the battery formed in the plane mirror?**





Top-view

a) Image is formed. **b)** Image is not formed. **c)** It depends on the observer. **d)** Other:...

4.2. How confident are you in your answer for the above question?

a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

4.3. The reason for my answer to the question is;

a) Because of the cardboard, no perpendicular ray can reach from the battery to the mirror.

b) Image of the cardboard is also formed in the mirror and it prevents the image formation of the battery.

c) Unless the cardboard cover the whole mirror, it does not matter how much of the mirror is covered by the cardboard in the image formation of the battery,

d) Only if the rays from the battery reflected by the mirror reach to an observer's eye which looks in that region, image of the battery is formed; otherwise no image of the battery can be formed.

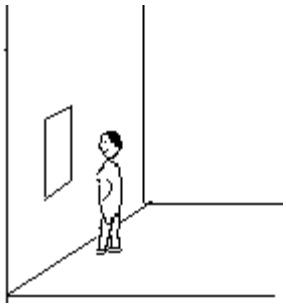
e) Only one ray can be drawn from the battery by passing through the cardboard's left edge to the mirror, but one ray is not enough to form image of the battery.

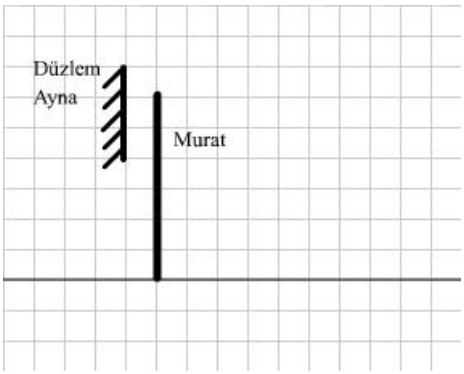
f) Other:.....

4.4. How confident are you in your answer for the above question?

a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

5.1. Murat is looking at his image in a plane mirror which is half of his body length and hanged on the wall that the bottom of the mirror is aligned with his breast as shown in the below figure on the left. On the right, you can see the side-view drawing of the same figure. So; **what would Murat do in order to see his <u>whole body</u> at once?**





Side-view

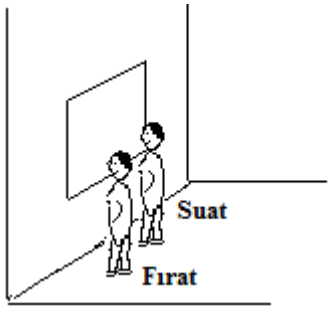
a) Come closer to the mirror.
b) Go farther away from the mirror.
c) Slides the plane mirror downward direction.
d) Nothing.
e) Other:.....

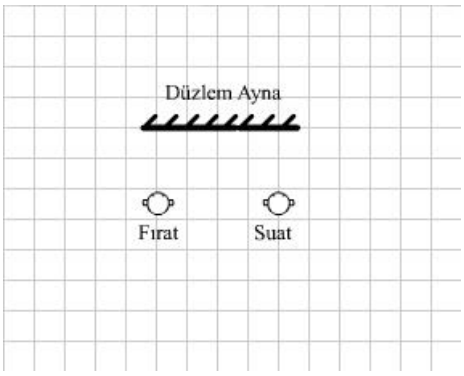
5.2. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

5.3. The reason for my answer to the question is;
a) Height of Murat's image becomes smaller and whole image fits into the mirror.
b) Since Murat's field of view will get wider, he can see his whole body.
c) Maximum height of his image that Murat can see in the mirror equals to the height of the mirror.
d) It is enough to have a mirror sized as half of Murat's body height to see his whole body.
e) The position of the mirror on the wall is important as well as the size of the mirror which should be at least half of Murat's body height to see his whole body.
f) Other:.....

5.4. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

6.1. Suat and his twin Fırat are looking at their images in front of a plane mirror placed on the wall as shown in the figure on the left below. On the right, you can see the top-view drawing of the same figure. So, **what should Suat do in order to see more of Fırat's body in the mirror at once?**





Top view

I. Come closer to the mirror.
II. Go farther away from the mirror.
III. Slides the mirror in the downward direction.

a) Only I **b)** Only II **c)** Only III **d)** I or III **e)** None of them. **f)** Other:……

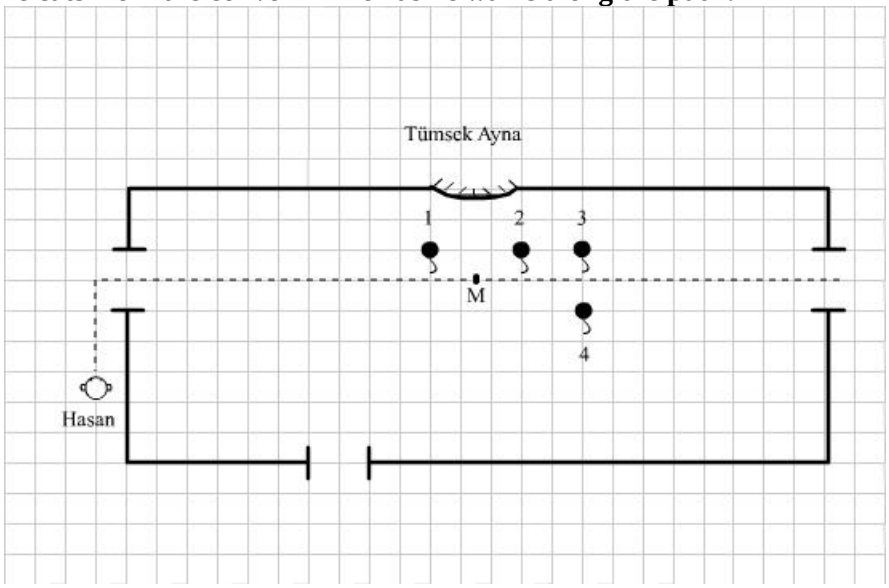
6.2. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

6.3. The reason for my answer to the question is;
a) Since Suat's field of view becomes wider, he can see more of Fırat's body.
b) Since Fırat's body parts just in front of the mirror gets larger, the height of his image in the mirror gets longer.
c) When Suat's field of view becomes wider or the field of view slides downward without changing the size of that field, it is possible for Suat to see more of Fırat's image.
d) Height of Fırat's image in the mirror is equal to the size of the mirror.
e) Coming closer to or going farther away from the mirror or moving the mirror on the wall only changes the visible parts of Fırat's body, the height of the visible part of his body is constant.
f) Both Suat's and Fırat's images get smaller, and more of their images fit to the mirror.
g) Other:.....

6.4. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

SPHERICAL MIRRORS

7.1. Below you can see the top-view of a homogenously illuminated room. Hasan enters the room from the left door and as he walks along the path shown with dashed line, he tries to observe the cats numbered by 1, 2, 3 and 4 from the convex mirror on the wall. The center distance of the convex mirror is shown with M. **So; in which order does Hasan see the cats from the convex mirror as he walks along the path?**



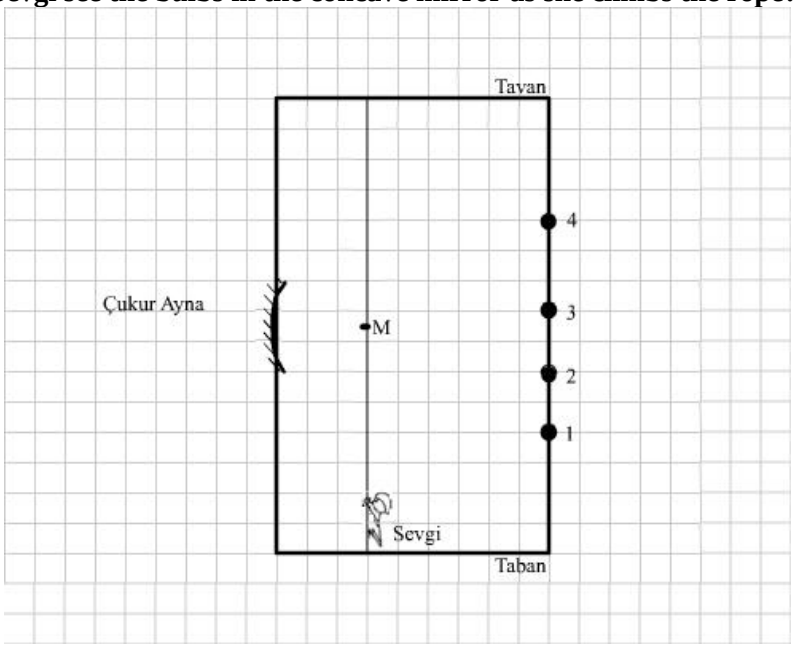
a) 1, 2, 3, 4 **b)** 4, 3, 2, 1 **c)** 1 = 2 = 3 = 4 **d)** 3, 2, 4, 1 **e)** 1, 2
f) None of them. **g)** Other:……..

7.2. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

7.3. The reason for my answer to the question is;
a) Hasan can see all the cats when he enters the room as incident light rays diverge from convex mirror to everywhere.
b) Only the images of the cats which stand within the borders of the convex mirror can be formed and seen.
c) Only image of the object cannot be seen if the objectis located at the focal length of a convex mirror.
d) As Hasan walks along the path, firstly he can see the image of the closest cat to him.
e) All the images including the images of the objects located at the focal length of the convex mirror can be seen according to their order in entering Hasan's field of view.
f) Unlike real images, virtual images cannot be seen.
g) Other:.....

7.4. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

8.1. Below you can see the side-view of a homogenously illuminated room. As Sevgi climbs the rope from the floor to the ceiling of the room, she tries to observe the images of the bulbs numbered with 1, 2, 3, and 4 in the concave mirror on the wall. The rope which Sevgi climbs passes through the center of curvature of the concave mirror. **So; in which order does Sevgi see the bulbs in the concave mirror as she climbs the rope?**



a) 1, 2, 3, 4 **b)** 4, 3, 2, 1 **c)** 2, 3 **d)** 3, 2 **e)** None of them. **f)** Other:.....

8.2. How confident are you in your answer for the above question?

a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

8.3. Reason for my answer to the question is;

a) In a concave mirror, only the images of objects where objects are located at the focal point cannot be seen.

b) While Sevgi climbs the rope, firstly she can see the closest bulb to her.

c) The images of the all bulbs are real, and real images can only be seen on a screen.

d) Images of the all bulbs are real and, if no screen is used, the image can be seen in the region between the points behind where the image is formed and the rays diverge from that point.

e) Only images of bulbs can be formed and seen if they are located within the borders of the concave mirror and its radius of curvature.

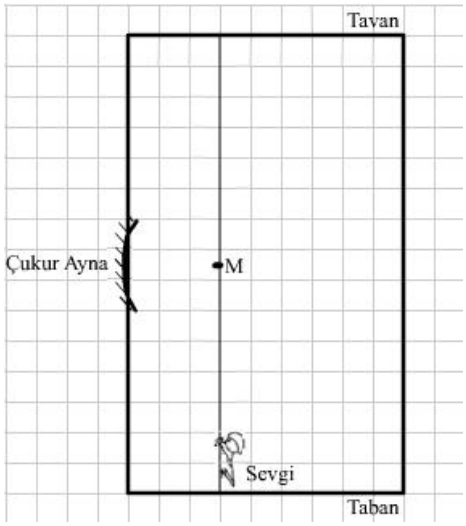
f) When the rays are drawn from the bulbs that pass through the focal point of the concave mirror, only the images of the bulbs can be formed and seen if rays coming from the bulbs can reach the concave mirror.

g) Other:.....

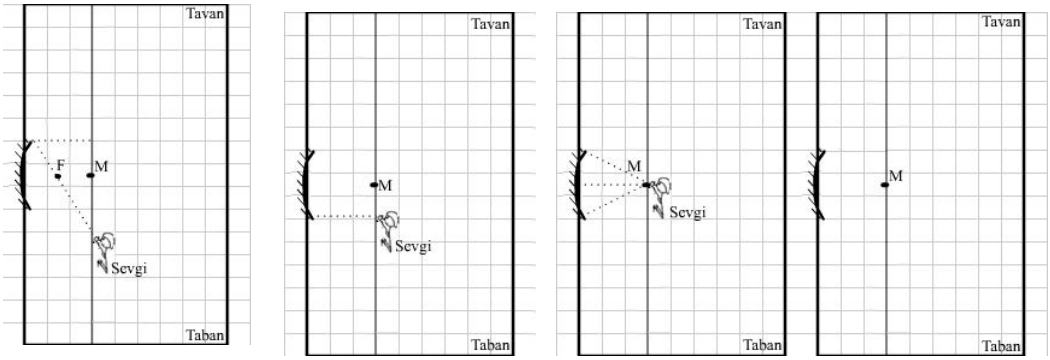
8.4. How confident are you in your answer for the above question?

a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

9.1. In the previous question, **where can Sevgi see image of her eyes in the <u>concave mirror</u> for the <u>first time</u>?**



a) She can see when she is on the floor before starting to climb.
b) She cannot see at anywhere.
c) **d)** **e)** **f)** Other: Draw

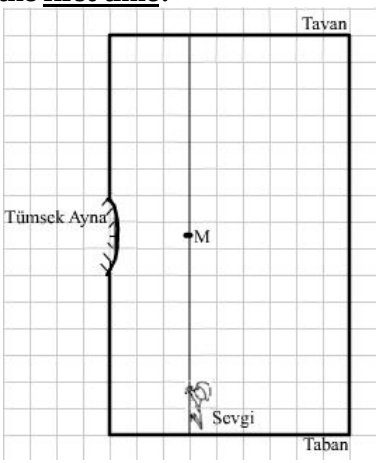


9.2. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

9.3. Reason for my answer to the question is;
a) Since the rope that Sevgi climbs is passing from the center of the concave mirror, rays reflects back to her eyes and she can see her eyes anywhere along the rope.
b) Sevgi can see her eyes only when her eyes are in the borders of the concave mirror.
c) Only when Sevgi's eyes are at the point M, the rays reaching to mirror from her eyes would reflect back to her eyes again.
d) The images of Sevgi's eyes are real, and real images can only be seen on a screen.
e) When Sevgi's eyes are along the first possible line drawn from her eyes to the concave mirror that is passing from the focal point, she can see her eyes.
f) Other:.....

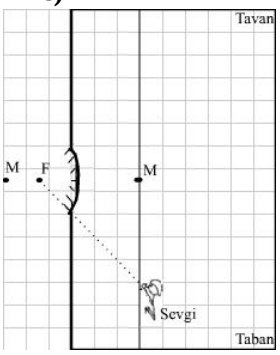
9.4. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

10.1. As Sevgi climbs the rope from bottom to the ceiling of the room, she tries to observe herself in the convex mirror on the wall. The rope which Sevgi climbs passes through the center length of the concave mirror. **So, where can Sevgi see image of her eyes in the concave mirror for the <u>first time</u>?**

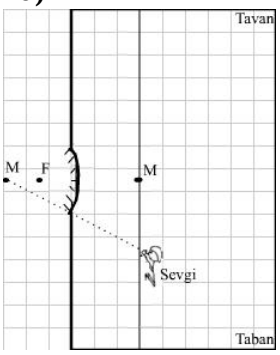


a) She can see when she is on the floor before starting to climb. **b)** Nowhere at all.

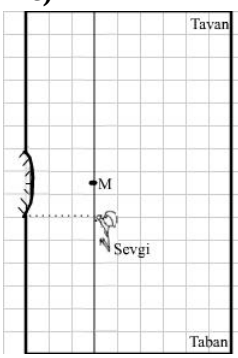
c)



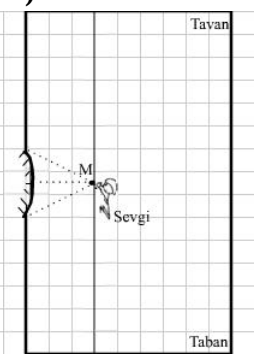
d)



e)



f)



g) Other: Draw on the figure of the question.

10.2. How confident are you in your answer for the above question?

a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

10.3. Reason for my answer to the question is;

a) Since the rope that Sevgi climbs is passing from the center length of the convex mirror, rays reflect back to her eyes and she can see her eyes anywhere along rope.

b) Sevgi can see image of her eyes if only her eyes are in the region of convex mirror's borders.

c) Only when Sevgi is at point M, the rays reach to mirror from her eyes can reflect back to her eyes again.

d) As rays diverge from the convex mirror, while climbing the rope Sevgi see her eyes at anywhere.

e) When Sevgi's eyes are along the first possible line drawn from her eyes to the convex mirror that is passing from the focal point, she can see her eyes.

f) When Sevgi's eyes are along the first possible line drawn from her eyes to the convex mirror that is passing from the center of the mirror, she can see her eyes.

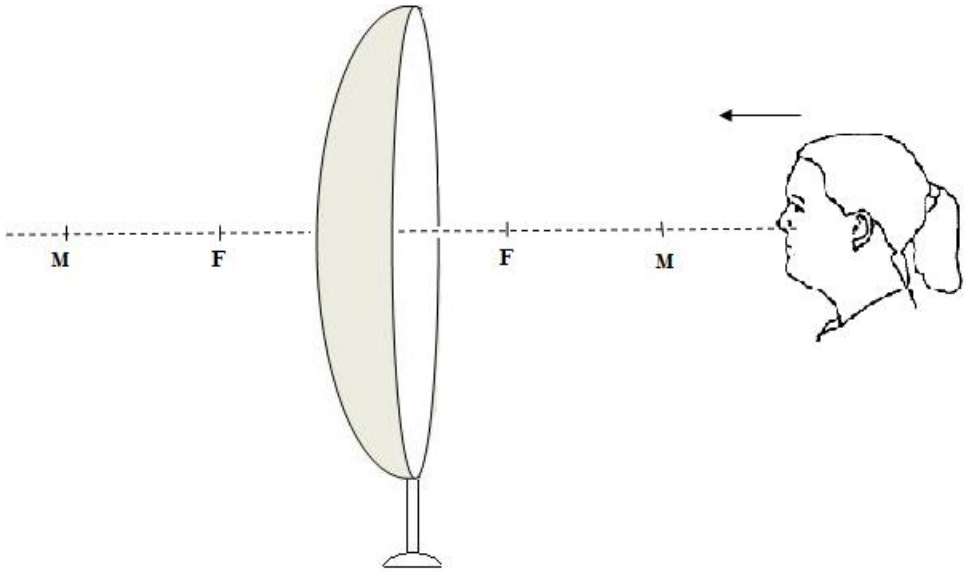
g) Unlike real images, virtual images cannot be seen.

h) Other:.....

10.4. How confident are you in your answer for the above question?

a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

11.1. Selin tries to see her face in the concave mirror from a distance as shown in the figure below. M represents the center of the concave mirror, and F represents the focal point of it. **So, while approaching to the concave mirror in which position(s) does Selin manage to see image of her face in the concave mirror?**



I. Beyond the center (Beyond M)
II. At the center (at M)
III. Between focal point and center (Between F and M)
IV. At the focal point (at F)
V. Between focal point and the mirror (Between F and mirror)

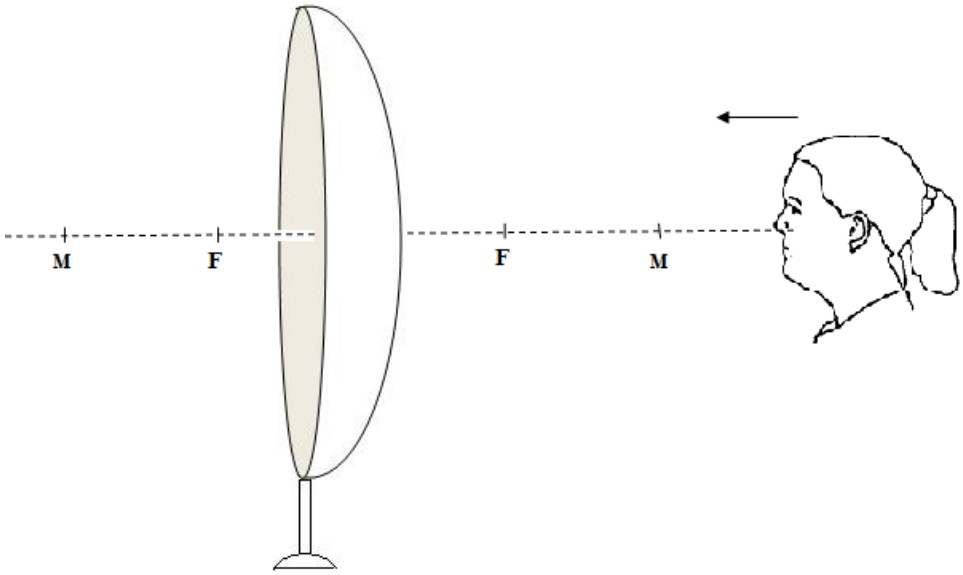
a) I, II, III, IV, V **b)** I, II, III, V **c)** I, II, III **d)** I, V **e)** Only V **f)** Other:….

11.2. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

11.3. Reason for my answer to the question is;
a) When Selin is at the focal point, the image of her face formed at the infinity.
b) Real images can only be seen on a screen.
c) Unlike real images, virtual images cannot be seen.
d) The rays from each point of Selin's face should reflect from the mirror to her eyes, and she needs to look behind the point where image is formed.
e) Selin can see her image(s) that is/are formed in front of the concave mirror which are at the same side with herself.
f) Other:.....

11.4. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

12.1. Selin tries to see her face from the convex mirror from a distance as shown in the figure below. M represents the center of the convex mirror, and F represents the focal point of it. **So, while approaching to the convex mirror in which position(s) does Selin manage to see image of her face in the convex mirror?**



I. Beyond the center (Beyond M)
II. At the center (at M)
III. Between focal point and center (Between F and M)
IV. At the focal point (at F)
V. Between focal point and the mirror (Between F and mirror)

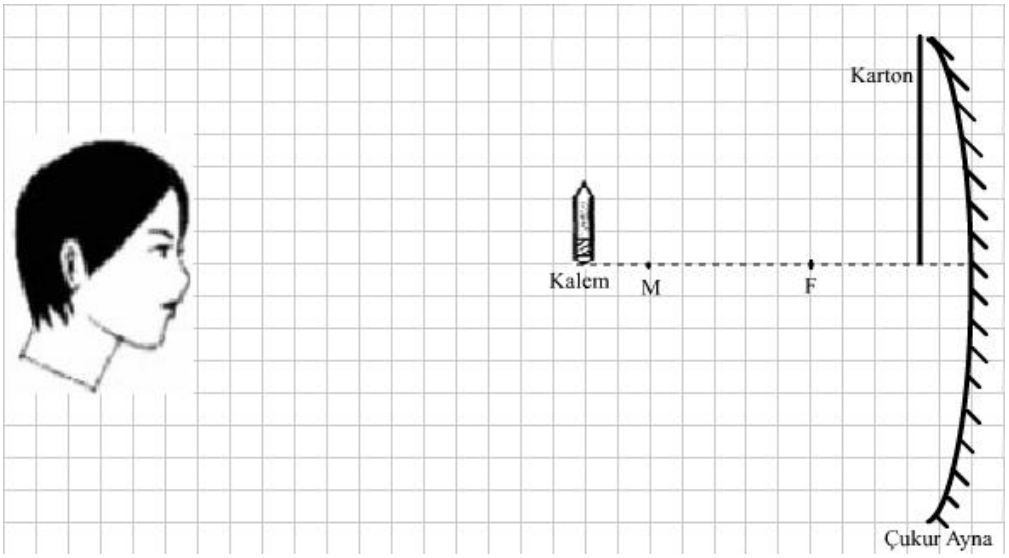
a) I, II, III, IV, V **b)** I, II, III, V **c)** I, II, III **d)** Only V **e)** None of them **f)** Other:..

12.2. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

12.3. Reason for my answer to the question is;
a) When Selin is at the focal point, the image of her face is formed at the infinity.
b) Unlike real images, virtual images cannot be seen.
c) Selin can see her eyes if the rays from each point of her face reflect from the mirror to her eyes again.
d) The rays from each point of Selin's face intersects at the back of the convex mirror and cannot reach to her eyes.
e) In situation I Selin's image is formed between F and M at the back of the convex mirror; in situation II her image is formed at M at the back of the mirror; in situation III her image is formed at the back of the mirror beyond M, and Selin can see all these images.
f) Other:.....

12.4. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

13.1. In the figure shown below, the side-view of an observer, a pencil, an opaque obstacle and a concave mirror is shown. M represents the center of the concave mirror, and F represents the focal point of it. The image of the pencil that is located beyond the M of the mirror is tried to be observed by the observer. **What happens to the image of the pencil if the top half of the concave mirror is covered by an opaque obstacle as shown in the figure?**



a) Image of the pencil disappears totally.
b) Only the image of the bottom of the pencil is formed like a dot.
c) Only half of the pencil's image is formed.
d) Pencil's image is formed at the same place and in the same size as the half of the mirror is not covered.
e) Other:.....

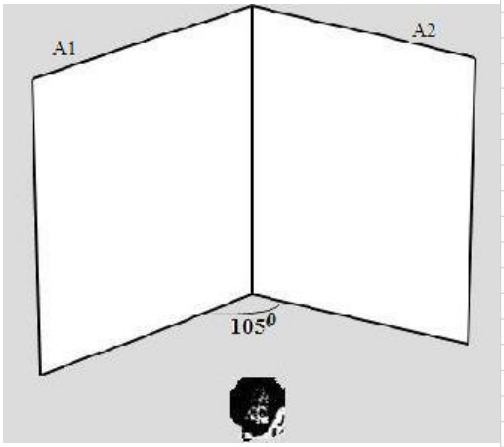
13.2. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

13.3. Reason for my answer to the question is;
a) The rays that are emanating from the pencil cannot reach to the mirror because of the opaque obstacle.
b) Since half of the mirror is covered, half of the image disappears.
c) Parallel rays drawn from the different points on the pencil to the mirror are obstructed by the obstacle. The other special ray that can be drawn is not enough to form the image.
d) Since from each point on the pencil light can reach to the uncovered part of the mirror, the size of the pencil's image, its location, and the shape does not change.
e) The image of the obstacle also formed in the mirror and that image hinders the formation of the pencil's image.
f) Other:.....

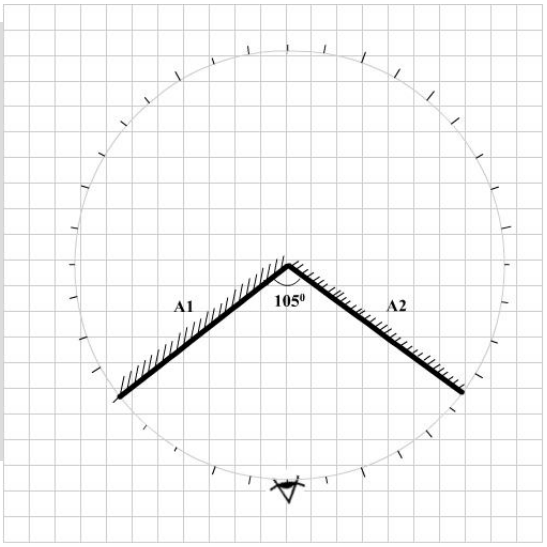
13.4. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

HINGED PLANE MIRRORS

14.1. Below you can see the <u>front</u> and <u>top views</u> of hinged plane mirrors with a 105^0 angle (α) between them. An observer the location of which is shown on the figures tries to observe his image(s) in the hinged plane mirrors with an angle of 105^0. **So; how many images of himself would he see in the hinged plane mirrors?**



Front view



Top view

a) 4 **b)** 3 **c)** 2.43 **d)** 2 **e)** No image can be seen. **f)** Other:.....

14.2. How confident are you in your answer for the above question?

a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

14.3. Reason for my answer to the question is;

a) Only the number of hinged plane mirrors determines the number of the images that an observer would see.

b) Only for certain angles (α) by which a whole number is obtained from the equation $(360^0 / \alpha) - 1$, an observer would see his images.

c) At certain angles for which we cannot obtain a whole number from the equation $(360^0 / \alpha) - 1$, observer would see partial images in addition to his whole images.

d) At certain angles for which we cannot obtain a whole number from the equation $(360^0 / \alpha) - 1$, we would round the number we obtained to a whole number, since half formation of images are not possible.

e) When we determine observer's images formed in each mirror separately and images of these formed images in other mirror, observer can see all these determined images of him.

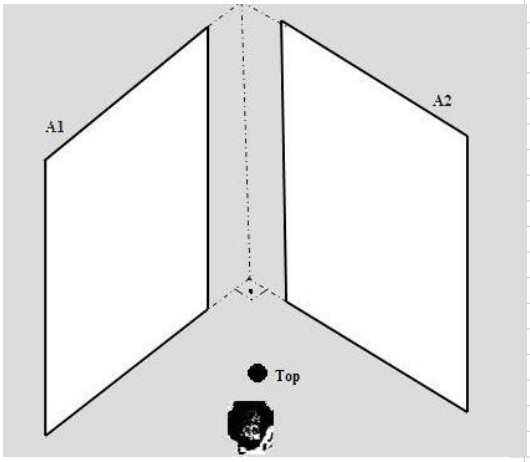
f) Observer's images are formed by reflections of rays from the observer that reach to mirrors and then the observer's eye, and these images can be seen.

g) Other:.....

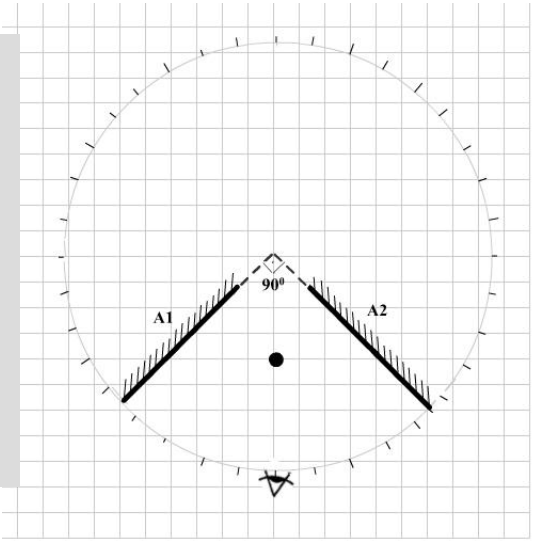
14.4. How confident are you in your answer for the above question?

a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

15.1. Below you can see the front and top views of two plane mirrors in a store's perpendicular walls. The plane mirrors are located on the walls with a 90^0 angle (α) between them and with some space is left as shown in the figures. The image(s) of the ball placed between the mirrors is tried to be observed by the observer as shown in the figures. **So; how many image(s) of the ball would the observer see in the plane mirrors on the wall?**



Front view



Top view

a) 3 **b)** 2 **c)** 1 **d)** No image can be seen. **e)** Other:.....

15.2. How confident are you in your answer for the above question?

a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

15.3. Reason for my answer to the question is;

a) Only the number of plane mirrors determines the number of the images that the observer would see.

b) Since there is a gap between the plane mirrors, the image of the ball formed in the mirror A1 would not produce a second image in the mirror A2.

c) Since image formation and observation occur simultaneously, the images of the ball is formed through the reflections from the plane mirrors that reach to the observer's eye, and observer can see these images.

d) Although there is a gap between the plane mirrors, a number of ball's images that can be obtained from the equation $(360^0 / \alpha) - 1$ is formed after reflections. Since the observer is looking between the mirrors, he would see all of those images.

e) Although there is a gap between the plane mirrors, a number of ball's images that can be obtained from the equation $(3600 / \alpha) - 1$ is formed. However, observer can see only those remains in his field of view.

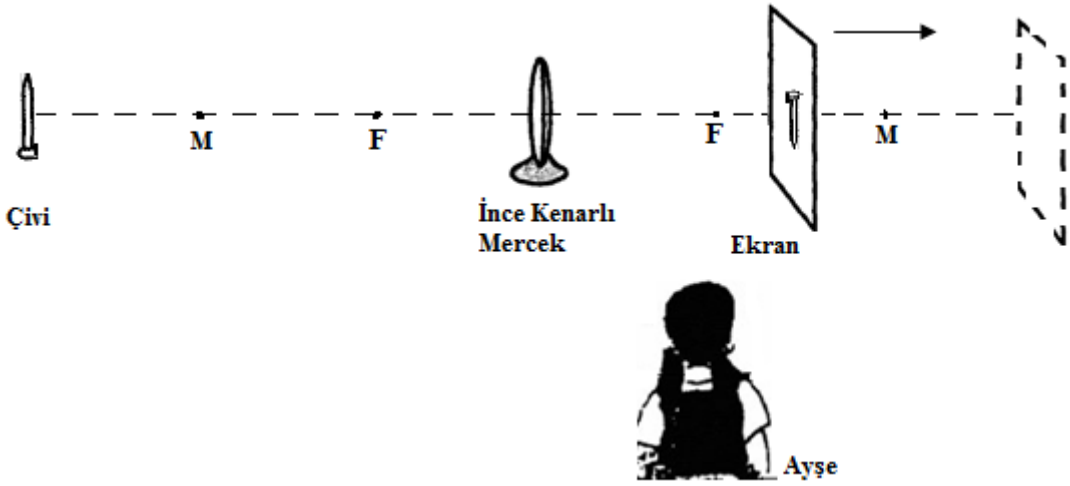
f) Other:.....

15.4. How confident are you in your answer for the above question?

a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

LENSES

16.1. As shown in the below figure, Ayşe observes a clear image on the screen of a nail which is placed in front of a converging lens. The image observed on the screen is upside down and smaller in size compared to the nail itself. F represents the focal point of the converging lens, and M represents the center of it. **What does happen to the image of the nail on the screen if the screen is moved away from the lens in the direction of the shown arrow to its new position without changing the positions of the other objects?**



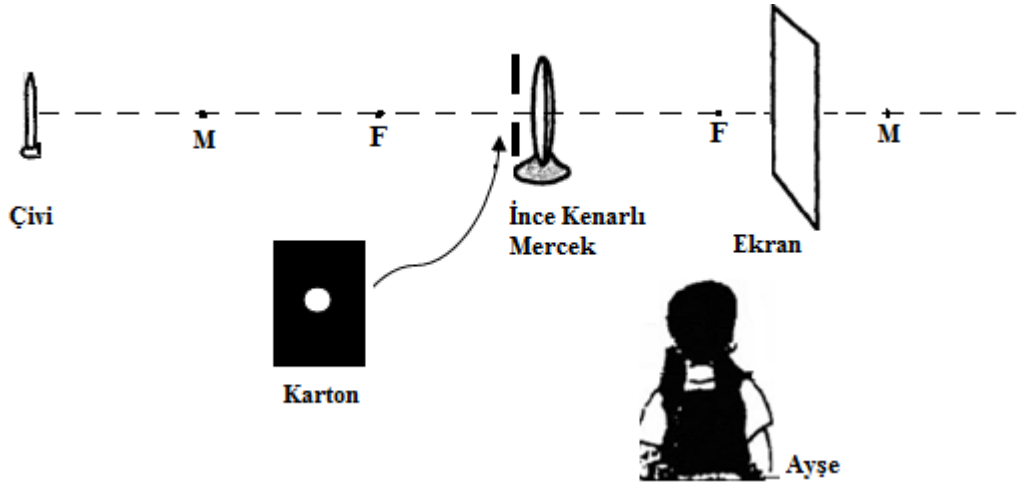
a) Image gets larger.
b) Image gets smaller.
c) An erect image is formed in the same direction with the object nail.
d) No image is formed**.**
e) Other:.....

16.2. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

16.3. Reason for my answer to the question is;
a) Since the distance between the nail and the lens does not change, the location of image does not change and diverging rays from the formed image will form enlarged and upside down image on the moved screen.
b) Since the distance between the nail and the lens does not change, the location of image does not change and intersecting rays at that point diverge again and form an erect image on the moved screen.
c) Images formed on a screen by a converging lens are always upside down and smaller in size. As the screen moves farther from the lens, the image gets smaller in the same proportion.
d) Since the distance between the nail and the lens does not change, the location of the image does not change and no image is formed on the screen.
e) Other:.....

16.4. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

17.1. In the previous question, when Ayşe can see a clear image of the nail on the screen a cardboard with a hole in the middle of it placed in front of the converging lens as shown in the below figure. **What would Ayşe see on the screen if the cardboard with a hole is placed in front of the converging lens?**



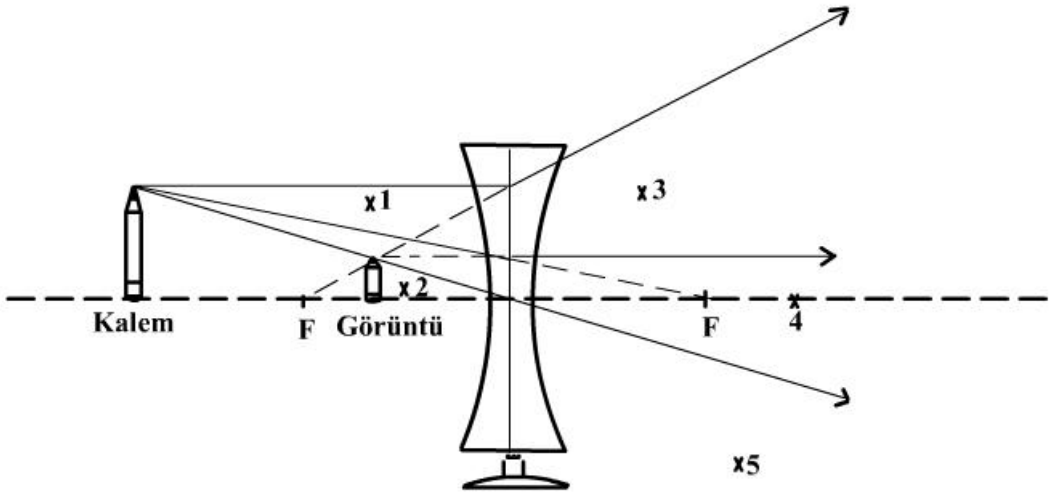
a) She cannot see anything.
b) She can only see the middle part of the nail.
c) She can see whole image of the nail in upside down position.
d) She can see enlarged, upside down but blur image of the nail.
e) Other:.....

17.2. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

17.3. Reason for my answer to the question is;
a) Since light would reach to the uncovered part of the lens from each point on the nail, the size and shape of the image does not change.
b) Cardboard hinders light coming from the top and bottom of the nail to the lens. Therefore, only the image of middle part of the nail will be seen on the screen.
c) Uncovered part of the lens will behave as a smaller lens with smaller focal length. Therefore, image of the nail will be formed closer to the lens.
d) Parallel rays drawn from different points on the nail will be obstructed by the cardboard. To form an image, drawing one special ray left is not enough.
e) Other:.....

17.4. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

18.1. Below you can see the ray diagram drawn to locate the image of a pencil placed in front of a diverging lens. In the figure the path of the three rays from the tip of the pencil is shown after they reach the diverging lens. **Which of the observers located in the positions numbered by 1, 2, 3, 4, and 5 would see the whole image of the pencil?**



a) Only 1 **b)** 1 and 2 **c)** 3 and 4 **d)** 3, 4 and 5 **e)** 1, 3 and 4 **f)** Other:.....

18.2. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

18.3. Reason for my answer to the question is;

a) The whole image of the pencil would only be seen from the same side of and along with the image.

b) The whole image would only be seen when someone looks at the image from the other side and within the borders of the lens.

c) Since the rays forming the image of the pencil are not intersecting on the other side of the lens, observers looking from that side would not see the image.

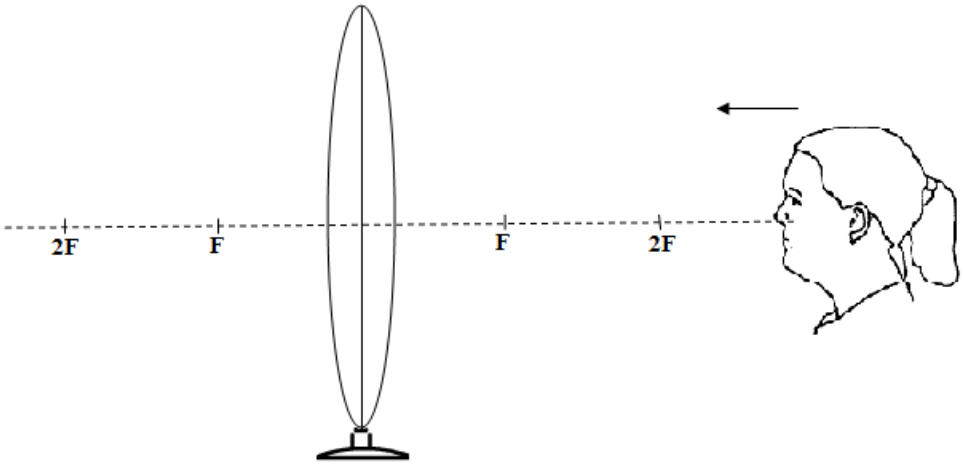
d) For an observer to see the whole image of the pencil, one should look within the region enclosed by the three rays shown in the figure.

e) For an observer to see the whole image of the pencil, one should look from the region where the rays can reach to the observer's eye after the rays coming from the each point of the pencil are refracted by the lens.

f) Other:.....

18.4. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

19.1. In the figure below the side view of Selin and a converging lens are shown. Selin tries to see her face from the converging lens from a distance as shown in the figure below. 2F represents the center of the converging lens, and F represents the focal point of it. **So, as approaching to the converging lens in which position(s) does Selin manage to see the image of her face in the converging lens?**



I. Beyond the center (Beyond 2F)
II. At the center (at 2F)
III. Between focal point and center (Between F and 2F)
IV. At the focal point (at F)
V. Between focal point and the lens (Between F and lens)

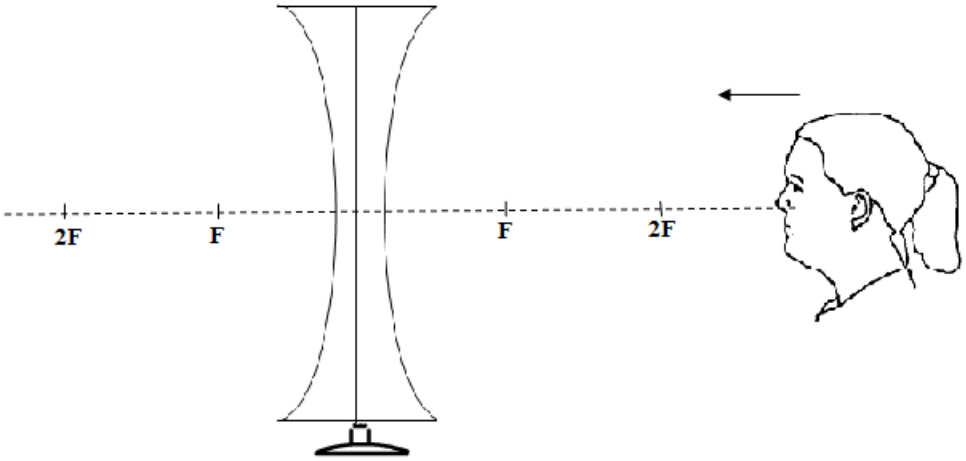
a) I, II, III, IV, V **b)** I, II, III, V **c)** I, II, III **d)** V **e)** None of them. **f)** Other:.....

19.2. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

19.3. Reason for my answer to the question is;
a) When Selin is at the focal point of the lens, her image is formed at the infinity.
b) Real images can only be seen on a screen.
c) Unlike real images, virtual images cannot be seen.
d) Selin can see her face when the rays reflecting from her face are refracted by the lens and then intersect at the same side and in front of her.
e) The rays reflecting from Selin's face that are refracted by the lens cannot reach to Selin's eyes in any positions.
f) Other:.....

19.4. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure**.**

20.1. In the figure below the side view of Selin and a diverging lens are shown. Selin tries to see her face from the diverging lens from a distance as shown in the figure below. 2F represents the center of the diverging lens, and F represents the focal point of it. **So, as approaching the diverging lens in which position(s) does Selin manage to see the image of her face in the diverging lens?**



I. Beyond the center (Beyond 2F)
II. At the center (at 2F)
III. Between focal point and center (Between F and 2F)
IV. At the focal point (at F)
V. Between focal point and the lens (Between F and lens)

a) I, II, III, IV, V **b)** I, II, III, V **c)** I, II, III **d)** I and II **e)** None of them **f)** Other:...

20.2. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

20.3. Reason for my answer to the question is;
a) When Selin is at the focal point of the lens, her image is formed at the infinity.
b) Real images can only be seen on a screen.
c) Unlike real images, virtual images cannot be seen.
d) Selin can see her face when the rays reflecting from her face are refracted by the lens and then intersect at the same side and in front of her.
e) The rays reflecting from Selin's face that are refracted by the lens cannot reach to Selin's eyes in any positions.
f) Other:.....

20.4. How confident are you in your answer for the above question?
a) Absolutely sure. **b)** Sure. **c)** Not sure. **d)** Absolutely not sure.

THE END OF THE TEST.

Table S.1. Table of Specification for the FTGOT

CONTEXT \ CASE		OBSERVING ONESELF	Subtotal (%)	OBSERVING OTHERS	Subtotal (%)	TOTAL (%)
Plane Mirrors	**Single Plane Mirror**	**I**3 **I**5 **M**1-**M**5-**M**8-**M**13-**M**14-**M**15-**M**16	2 (10%)	**I**1 **I**4 **I**2 **I**6 **M**1-**M**2-**M**3-**M**4-**M**7-**M**13-**M**14-**M**15-**M**16	4 (20%)	6 (30%)
	Hinged Plane Mirrors	**I**14 **M**3-**M**20-**M**21	1 (5%)	**I**15 **M**1- **M**3-**M**20-**M**21	1 (5%)	2 (10%)
Spherical Mirrors	**Concave Mirror**	**I**9 **I**11 **M**5-**M**7-**M**8-**M**9-**M**10-**M**17-**M**18	2 (10%)	**I**8 **I**13 **M**1-**M**2-**M**4-**M**7-**M**9-**M**12-**M**18	2 (10%)	4 (20%)
	Convex Mirror	**I**10 **I**12 **M**5-**M**6-**M**7-**M**8-**M**10-**M**11-**M**17-**M**18	2 (10%)	**I**7 **M**1-**M**4-**M**6-**M**10-**M**18	1 (5%)	3 (15%)
Lenses	**Converging Lens**	**I**19 **M**9-**M**10-**M**17-**M**18	1 (5%)	**I**16 **I**17 **M**7-**M**12-**M**19	2 (10%)	3 (15%)
	Diverging Lens	**I**20 **M**9-**M**10-**M**17-**M**18	1 (5%)	**I**18 **M**1-**M**7-**M**17	1 (5%)	2 (10%)
TOTAL (%)		9 (45%)		11 (55%)		20 (100%)

I#: *Represents Item number in the Four Tier Geometrical Optics Test***.**
M#: *Represents Misconception number in the Table of Misconception Choices.*

APPENDIX T

EXPERT OPINION FORM FOR THE FTGOT

Geometrik Optik Testi Uzman Değerlendirme Formu

Sayın Uzman,

Lütfen Geometrik Optik Testi ile ilgili aşağıdaki ifadeleri okuyup bununla ilgili düşüncelerinizi en iyi açıklayan seçeneği işaretleyiniz. Eklemek istediğiniz önerilerinizi ifadelerin yanında yer alan boşluğa yazabilirsiniz.

İlginize teşekkür ederim.

Genel Bilgiler:

Amaç: Bu test fizik öğretmen adaylarının "Geometrik Optik" konusundaki sahip oldukları kavramlamaların tespit edilip ortaya çıkarılması için geliştirilmiştir.

Soru Sayısı: Her biri dört aşamadan oluşan 20 çoktan seçmeli sorudan oluşmaktadır.

Öngörülen Cevaplama Süresi: 50 dakika (1 ders saati)

İFADELER		**Az ← → Çok**					**ÖNERİLERİNİZ**
		1	**2**	**3**	**4**	**5**	
1.	Testin maddeleri hedef öğrencilerin bilişsel seviyelerine uygun mu?						
2.	Testin tamamlanması için ayrılan süre sizce uygun mu?						
3.	Testin yönergeleri sizce açık ve takip edilebilir mi?						
4.	Testin dili hedef öğrenciler için sizce uygun mu?						
5.	Testte kullanılan yazı boyutunun okunabilirliği sizce uygun mu?						
6.	Testin maddelerinde kullanılan şekiller sizce anlaşılabilir mi?						
7.	Test maddeleri (soru kökü veya çeldiriciler) doğru cevap ya da diğer maddeler için ipucu içeriyor mu?						
8.	Formüllerin yanı sıra ışın diyagramlarının da testin kapak sayfasında verilmesi, soruların cevaplanması sırasında istenmeyen bir ipucu verir mi?						

İFADELER		Az ⟷ Çok					ÖNERİLERİNİZ
		1	2	3	4	5	
9.	Testteki soruların sıralanışı (bağlamlara göre düzenlenmiş bu haliyle) sizce uygun mu?						
10.	Testteki soruların olaylara göre 1-2-7-3-8-9-10-4-5-6-14-15-11-12-19-20-13-16-17-18 numaralı sorular şeklinde sıralanışı testin takibini sizce kolaylaştırır mı?						
11.	Dört aşamalı soruların dağılım tablosunda (Tablo 1) verilen bağlam ve olayların her biri için verilen soru numarası ve kavram yanılgısı numarası doğru mu?						
12.	Dört aşamalı soruların dağılım tablosunda (Tablo 1) verilen bağlam ve olaylar sizce testte uygun sayıda soru ile temsil edilmiş mi?						
13.	Dört aşamalı soruların dağılım tablosunda (Tablo 1) verilen bağlam ve olaylar sizce testte uygun sayıda kavram yanılgısı ile temsil edilmiş mi?						
14.	Kavram yanılgıları tablosunda (Tablo 2) belirtilen seçenekler, ilgili kavram yanılgılarını temsil ediyor mu?						
15.	Kavram yanılgıları tablosunda (Tablo 2) belirtilen kavram yanılgıları sizce testte uygun sayıda soru ile temsil edilmiş mi?						
16.	Kabul edilen cevaplar tablosunda (Tablo 3) belirtilen doğru cevaplarda sizce sorunlu olanlar var mı?						

TABLO 1.*DÖRT AŞAMALI SORULARIN DAĞILIM TABLOSU*

BAĞLAM \ OLAY		KENDİSİNİ GÖZLEMLEME	Soruların Ara Toplamı (%)	NESNEYİ / BAŞKASINI GÖZLEMLEME	Soruların Ara Toplam (%)	TOPLAM (%)
Düzlem Aynalar	Düzlem Ayna	I3 I5 M1-M5-M8-M13-M14-M15-M16	2 (10%)	I1 I4 I2 I6 M1-M2-M3-M4-M7-M13-M14-M15-M16	4 (20%)	6 (30%)
	Kesişen Aynalar	I14 M3-M20-M21	1 (5%)	I15 M1- M3-M20-M21	1 (5%)	2 (10%)
Küresel Aynalar	Çukur Ayna	I9 I11 M5-M7-M8-M9-M10-M17-M18	2 (10%)	I8 I13 M1-M2-M4-M7-M9-M12-M18	2 (10%)	4 (20%)
	Tümsek Ayna	I10 I12 M5-M6-M7-M8-M10-M11-M17-M18	2 (10%)	I7 M1-M4-M6-M10-M18	1 (5%)	3 (15%)
Mercekler	İnce Kenarlı Mercek	I19 M9-M10-M17-M18	1 (5%)	I16 I17 M7-M12-M19	2 (10%)	3 (15%)
	Kalın Kenarlı Mercek	I20 M9-M10-M17-M18	1 (5%)	I18 M1-M7-M17	1 (5%)	2 (10%)
TOPLAM (%)		9 (45%)		11 (55%)		20 (100%)

I#: *Geometrik Optik Testindeki soru numaralarını temsil etmektedir.*

M#: *Kavram Yanılgıları Tablosundaki kavram yanılgısı numaralarını temsil etmektedir.*

TABLO 2.*KAVRAM YANILGILARI TABLOSU*

M #	**MISCONCEPTION DESCRIPTION**	**ITEMS**			
M1.	The images of objects can be formed /seen only when the object is within the borders of the mirror/lens.	1.1.a,b 2.1.a 3.1.d 7.1.e 8.1.c,d 15.1.b 18.1.c	1.2.a,b 2.2.a,b 3.2.a,b 7.2.a,b 8.2.a,b 15.2.a,b 18.2.a,b	1.3 a 2.3.a 3.3.c 7.3.b 8.3.e 15.3.b 18.3.b	1.4.a,b 2.4.a,b 3.4.a,b 7.4.a,b 8.4.a,b 15.4.a,b 18.4.a,b
M2.	If there is an obstacle or another object in front of an object, its image cannot be formed /seen in the mirror.	1.1.c 2.1.b 4.1.b 13.1.a,b	1.2.a,b 2.2.a,b 4.2.a,b 13.2.a,b	1.3.b 2.3.c 4.3.a,b 13.2.a,e	1.4.a,b 2.4.a,b 4.4.a,b 13.4.a,b
M3.	Image formation and observation processes are separate events and happen in an order. An image is formed first and then observed. An image is formed whether any observer sees it or not.	1.1.d 14.1.a 15.1.b,d	1.2.a,b 14.2.a,b 15.2.a,b	1.3.c 14.3.e 15.3.e	1.4.a,b 14.4.a,b 15.4.a,b
M4.	Closeness of object to the observer determines the observation/seeing order in mirrors.	2.1.e,f 7.1.a 8.1.a	2.2.a,b 7.2.a,b 8.2.a,b	2.3.b 7.3.d 8.3.b	2.4.a,b 7.4.a,b 8.4.a,b
M5.	An observer can see himself outside of the region enclosed by the normal lines to the mirror borders.	3.1.a 9.1.a 10.1.a	3.2.a,b 9.2.a,b 10.2.a,b	3.3.a 9.3.a 10.3.a	3.4.a,b 9.4.a,b 10.4.a,b
M6.	An observer can see anything in a convex mirror, since it diverges all of the light reaching it.	7.1.c 10.1.a	7.2.a,b 10.2.a,b	7.3.a 10.3.a	7.4.a,b 10.4.a,b
M7.	(All) special rays are necessary to form / see an image.	4.1.b 8.1.b,c,d 9.1.c 10.1.c 13.1.a,b 17.1.a 18.1.a,c,d	4.2.a,b 8.2. a,b 9.2.a,b 10.2.a,b 13.2.a,b 17.2.a,b 18.2.a,b	4.3.e 8.3.f 9.3.e 10.3.e 13.3.c 17.3.d 18.3.d	4.4.a,b 8.4. a,b 9.4.a,b 10.4.a,b 13.4.a,b 17.4.a,b 18.4.a,b
M8.	An observer can see his whole body only when his eyes are aligned with the mirror.	3.1.b 9.1.d 10.1.e	3.2.a,b 9.2. a,b 10.2.a,b	3.3.b 9.3.b 10.3.b	3.4.a,b 9.4. a,b 10.4.a,b
M9.	Real images can only be seen on a screen.	8.1.e 9.1.b 11.1.e 19.1.d 20.1.a	8.2.a,b 9.2.a,b 11.2.a,b 19.2.a,b 20.2.a,b	8.3.c 9.3.d 11.3.b 19.3.b 20.3.b	8.4.a,b 9.4.a,b 11.4.a,b 19.4.a,b 20.4.a,b
M10.	Unlike real images, virtual images cannot be seen in mirrors/ lenses.	7.1.f 10.1.b 11.1.c 12.1.b,c 19.1.c 20.1.e	7.2.a,b 10.2.a,b 11.2.a,b 12.2.a,b 19.2.a,b 20.2.a,b	7.3.f 10.3.g 11.3.c 12.3.b 19.3.c 20.3.c	7.4.a,b 10.4.a,b 11.4.a,b 12.4.a,b 19.4.a,b 20.4.a,b

M11.	An observer moving along the line passing through the center of a spherical mirror can see himself in any point along this line.	9.1.a 10.1.a	9.2.a,b 10.2.a,b	9.3.a 10.3.a	9.4.a,b 10.4.a,b
M12.	Covering some part of a mirror / lens causes the disappearance of some part of the image.	13.1.c 17.1.b	13.2.a,b 17.2.a,b	13.3.b 17.3.b	13.4.a,b 17.4.a,b
M13.	As one moves back from a plane mirror, the image becomes smaller and more of it can fit inside the mirror.	5.1.b 6.1.b	5.2.a,b 6.2.a,b	5.3.a 6.3.f	5.4.a,b 6.4.a,b
M14.	As one moves closer to/farther from a plane mirror, someone can see more of himself because of the increase in the field of view.	5.1.a,b 6.1.a,b	5.2.a,b 6.2.a,b	5.3.b 6.3.a	5.4.a,b 6.4.a,b
M15.	Moving a plane mirror down on a wall increases the field of view of an observer.	5.1.c 6.1.c,d	5.2.a,b 6.2.a,b	5.3.b 6.3.a	5.4.a,b 6.4.a,b
M16.	Image size always equals the mirror size.	5.1.d 6.1.c 6.1.e	5.2.a,b 6.2.a,b	5.3.c 6.3.b 6.3.d,e	5.4.a,b 6.4.a,b
M17.	Only an image formed on the same side as an observer can be seen.	11.1.c 12.1.e 18.1.a,b 19.1.d 20.1.a	11.2.a,b 12.2.a,b 18.2.a,b 19.2.a,b 20.2.a,b	11.3.e 12.3.d 18.3.a,c 19.3.d 20.3.d	11.4.a,b 12.4.a,b 18.4.a,b 19.4.a,b 20.4.a,b
M18.	An image can be seen if it is not at the focal point. No image is formed /seen of an object at the focal length in a convex mirror/lens.	7.1.a,b,c 8.1.a,b 11.1.b 12.1.b 19.1.b 20.1.b	7.2.a,b 8.2.a,b 11.2.a,b 12.2.a,b 19.2.a,b 20.2.a,b	7.3.c 8.3.a 11.3.a 12.3.a 19.3.a 20.3.a	7.4.a,b 8.4.a,b 11.4.a,b 12.4.a,b 19.4.a,b 20.4.a,b
M19.	A real image can be seen of a different size/orientation if a screen is placed at another location from the image point.	16.1.a 16.1.b 16.1.c 17.1.a, d	16.2.a,b 17.2.a,b	16.3.a 16.3.c 16.3.b 17.3.c	16.4.a,b 17.4.a,b
M20.	Only the number of mirrors determines the number of images seen in a hinged mirror.	14.1.d 15.1.b	14.2.a,b 15.2.a,b	14.3.a 15.3.a	14.4.a,b 15.4.a,b
M21.	Only the angle between mirrors determines the number of images seen in a hinged mirror.	14.1.b,d 14.1.c 14.1.e 15.1.a	14.2.a,b 15.2.a,b	14.3.d 14.3.c 14.3.b 15.3.d	14.4.a,b 15.4.a,b
	OTHER MISCONCEPTIONS				
M22.	Field of vision is considered as a discrete instead of a continues region.	2.1.d	2.2.a,b	2.3.d	2.4.a,b
M23.	A small part of a mirror is enough to form /see the image of an object without considering whether light from the object can reach it or not.	4.1.a	4.2.a,b	4.3.c	4.4.a,b

M24.	In order to see a whole body in a plane mirror, a mirror sized as half of the body length is enough, regardless of where the mirror is located on the wall.	5.1.d	5.2.a,b	5.3.d	5.4.a,b
M25.	Only if an observer is at the center of a convex mirror, light rays reflect and reach to his eye.	10.1.f	10.2.a,b	10.3.c	10.4.a,b
M26.	Image in a convex mirror/lens may be formed out of the region between F and the mirror/lens.	12.1.a	12.2.a,b	12.3.e	12.4.a,b
M27.	Covering some part of a mirror/lens reduces its focal length (F) and radius and results in the formation of the image at a place that is different from its original position.	17.1.a,d	17.2.a,b	17.3.c	17.4.a,b

TABLO 3.*KABUL EDİLEN CEVAPLAR TABLOSU*

I#	**ITEMS**			
I1.	1.1. d	1.2. a,b	1.3.d	1.4. a,b
I2.	2.1. c	2.2. a,b	2.3. e	2.4. a,b
I3.	3.1. c	3.2. a,b	3.3. d	3.4. a,b
I4.	4.1. c	4.2. a,b	4.3. d	4.4. a,b
I5.	5.1. c	5.2. a,b	5.3. e	5.4. a,b
I6.	6.1. d	6.2. a,b	6.3. c	6.4. a,b
I7.	7.1. d	7.2. a,b	7.3. e	7.4. a,b
I8.	8.1. b	8.2. a,b	8.3. d	8.4. a,b
I9.	9.1. e	9.2. a,b	9.3. c	9.4. a,b
I10.	10.1. d	10.2. a,b	10.3. f	10.4. a,b
I11.	11.1. d	11.2. a,b	11.3. d	11.4. a,b
I12.	12.1. a	12.2. a,b	12.3. c	12.4. a,b
I13.	13.1. d	13.2. a,b	13.3. d	13.4. a,b
I14.	14.1. d	14.2. a,b	14.3. f	14.4. a,b
I15.	15.1. b	15.2. a,b	15.3. c	15.4. a,b
I16.	16.1. d	16.2. a,b	16.3. d	16.4. a,b
I17.	17.1. c	17.2. a,b	17.3. a	17.4. a,b
I18.	18.1. d	18.2. a,b	18.3. e	18.4. a,b
I19.	19.1. e	19.2. a,b	19.3. e	19.4. a,b
I20.	20.1. e	20.2. a,b	20.3. e	20.4. a,b

APPENDIX U

CORRECT ANSWER CHOICES FOR THE FTGOT

I#	**ITEMS**			
I1.	1.1. d	1.2. a,b	1.3.d	1.4. a,b
I2.	2.1. c	2.2. a,b	2.3. e	2.4. a,b
I3.	3.1. c	3.2. a,b	3.3. d	3.4. a,b
I4.	4.1. c	4.2. a,b	4.3. d	4.4. a,b
I5.	5.1. c	5.2. a,b	5.3. e	5.4. a,b
I6.	6.1. d	6.2. a,b	6.3. c	6.4. a,b
I7.	7.1. d	7.2. a,b	7.3. e	7.4. a,b
I8.	8.1. b	8.2. a,b	8.3. d	8.4. a,b
I9.	9.1. e	9.2. a,b	9.3. c	9.4. a,b
I10.	10.1. d	10.2. a,b	10.3. f	10.4. a,b
I11.	11.1. d	11.2. a,b	11.3. d	11.4. a,b
I12.	12.1. a	12.2. a,b	12.3. c	12.4. a,b
I13.	13.1. d	13.2. a,b	13.3. d	13.4. a,b
I14.	14.1. d	14.2. a,b	14.3. f	14.4. a,b
I15.	15.1. b	15.2. a,b	15.3. c	15.4. a,b
I16.	16.1. d	16.2. a,b	16.3. d	16.4. a,b
I17.	17.1. c	17.2. a,b	17.3. a	17.4. a,b
I18.	18.1. d	18.2. a,b	18.3. e	18.4. a,b
I19.	19.1. e	19.2. a,b	19.3. e	19.4. a,b
I20.	20.1. e	20.2. a,b	20.3. e	20.4. a,b

APPENDIX V

TABLE OF ITEM CHOICES INDICATING MISCONCEPTIONS FOR THE FTGOT

M #	MISCONCEPTION DESCRIPTION	ITEMS			
M1.	The images of objects can be formed /seen only when the object is within the borders of the mirror/lens.	1.1.a,b 2.1.a 3.1.d 7.1.e 8.1.c,d 15.1.b 18.1.c	1.2.a,b 2.2.a,b 3.2.a,b 7.2.a,b 8.2.a,b 15.2.a,b 18.2.a,b	1.3 a 2.3.a 3.3.c 7.3.b 8.3.e 15.3.b 18.3.b	1.4.a,b 2.4.a,b 3.4.a,b 7.4.a,b 8.4.a,b 15.4.a,b 18.4.a,b
M2.	If there is an obstacle or another object in front of an object, its image cannot be formed /seen in the mirror.	1.1.c 2.1.b 4.1.b 13.1.a,b	1.2.a,b 2.2.a,b 4.2.a,b 13.2.a,b	1.3.b 2.3.c 4.3.a,b 13.2.a,e	1.4.a,b 2.4.a,b 4.4.a,b 13.4.a,b
M3.	Image formation and observation processes are separate events and happen in an order. An image is formed first and then observed. An image is formed whether any observer sees it or not.	1.1.d 14.1.a 15.1.b,d	1.2.a,b 14.2.a,b 15.2.a,b	1.3.c 14.3.e 15.3.e	1.4.a,b 14.4.a,b 15.4.a,b
M4.	Closeness of object to the observer determines the observation/seeing order in mirrors.	2.1.e,f 7.1.a 8.1.a	2.2.a,b 7.2.a,b 8.2.a,b	2.3.b 7.3.d 8.3.b	2.4.a,b 7.4.a,b 8.4.a,b
M5.	An observer can see himself outside of the region enclosed by the normal lines to the mirror borders.	3.1.a 9.1.a 10.1.a	3.2.a,b 9.2.a,b 10.2.a,b	3.3.a 9.3.a 10.3.a	3.4.a,b 9.4.a,b 10.4.a,b
M6.	An observer can see anything in a convex mirror, since it diverges all of the light reaching it.	7.1.c 10.1.a	7.2.a,b 10.2.a,b	7.3.a 10.3.a	7.4.a,b 10.4.a,b
M7.	(All) special rays are necessary to form / see an image.	4.1.b 8.1.b,c,d 9.1.c 10.1.c 13.1.a,b 17.1.a 18.1.a,c,d	4.2.a,b 8.2. a,b 9.2.a,b 10.2.a,b 13.2.a,b 17.2.a,b 18.2.a,b	4.3.e 8.3.f 9.3.e 10.3.e 13.3.c 17.3.d 18.3.d	4.4.a,b 8.4. a,b 9.4.a,b 10.4.a,b 13.4.a,b 17.4.a,b 18.4.a,b

M8.	An observer can see his whole body only when his eyes are aligned with the mirror.	3.1.b 9.1.d 10.1.e	3.2.a,b 9.2. a,b 10.2.a,b	3.3.b 9.3.b 10.3.b	3.4.a,b 9.4. a,b 10.4.a,b
M9.	Real images can only be seen on a screen.	8.1.e 9.1.b 11.1.e 19.1.d 20.1.a	8.2.a,b 9.2.a,b 11.2.a,b 19.2.a,b 20.2.a,b	8.3.c 9.3.d 11.3.b 19.3.b 20.3.b	8.4.a,b 9.4.a,b 11.4.a,b 19.4.a,b 20.4.a,b
M10.	Unlike real images, virtual images cannot be seen in mirrors/ lenses.	7.1.f 10.1.b 11.1.c 12.1.b,c 19.1.c 20.1.e	7.2.a,b 10.2.a,b 11.2.a,b 12.2.a,b 19.2.a,b 20.2.a,b	7.3.f 10.3.g 11.3.c 12.3.b 19.3.c 20.3.c	7.4.a,b 10.4.a,b 11.4.a,b 12.4.a,b 19.4.a,b 20.4.a,b
M11.	An observer moving along the line passing through the center of a spherical mirror can see himself in any point along this line.	9.1.a 10.1.a	9.2.a,b 10.2.a,b	9.3.a 10.3.a	9.4.a,b 10.4.a,b
M12.	Covering some part of a mirror / lens causes the disappearance of some part of the image.	13.1.c 17.1.b	13.2.a,b 17.2.a,b	13.3.b 17.3.b	13.4.a,b 17.4.a,b
M13.	As one moves back from a plane mirror, the image becomes smaller and more of it can fit inside the mirror.	5.1.b 6.1.b	5.2.a,b 6.2.a,b	5.3.a 6.3.f	5.4.a,b 6.4.a,b
M14.	As one moves closer to/farther from a plane mirror, someone can see more of himself because of the increase in the field of view.	5.1.a,b 6.1.a,b	5.2.a,b 6.2.a,b	5.3.b 6.3.a	5.4.a,b 6.4.a,b
M15.	Moving a plane mirror down on a wall increases the field of view of an observer.	5.1.c 6.1.c,d	5.2.a,b 6.2.a,b	5.3.b 6.3.a	5.4.a,b 6.4.a,b
M16.	Image size always equals the mirror size.	5.1.d 6.1.c 6.1.e	5.2.a,b 6.2.a,b	5.3.c 6.3.b 6.3.d,e	5.4.a,b 6.4.a,b
M17.	Only an image formed on the same side as an observer can be seen.	11.1.c 12.1.e 18.1.a,b 19.1.d 20.1.a	11.2.a,b 12.2.a,b 18.2.a,b 19.2.a,b 20.2.a,b	11.3.e 12.3.d 18.3.a,c 19.3.d 20.3.d	11.4.a,b 12.4.a,b 18.4.a,b 19.4.a,b 20.4.a,b
M18.	An image can be seen if it is not at the focal point. No image is formed /seen of an object at the focal length in a	7.1.a,b,c 8.1.a,b 11.1.b	7.2.a,b 8.2.a,b 11.2.a,b	7.3.c 8.3.a 11.3.a	7.4.a,b 8.4.a,b 11.4.a,b

	convex mirror/lens.	12.1.b 19.1.b 20.1.b	12.2.a,b 19.2.a,b 20.2.a,b	12.3.a 19.3.a 20.3.a	12.4.a,b 19.4.a,b 20.4.a,b
M19.	A real image can be seen of a different size/orientation if a screen is placed at another location from the image point.	16.1.a 16.1.b 16.1.c 17.1.a, d	16.2.a,b 17.2.a,b	16.3.a 16.3.c 16.3.b 17.3.c	16.4.a,b 17.4.a,b
M20.	Only the number of mirrors determines the number of images seen in a hinged mirror.	14.1.d 15.1.b	14.2.a,b 15.2.a,b	14.3.a 15.3.a	14.4.a,b 15.4.a,b
M21.	Only the angle between mirrors determines the number of images seen in a hinged mirror.	14.1.b,d 14.1.c 14.1.e 15.1.a	14.2.a,b 15.2.a,b	14.3.d 14.3.c 14.3.b 15.3.d	14.4.a,b 15.4.a,b
	OTHER MISCONCEPTIONS				
M22.	Field of vision is considered as a discrete instead of a continues region.	2.1.d	2.2.a,b	2.3.d	2.4.a,b
M23.	A small part of a mirror is enough to form /see the image of an object without considering whether light from the object can reach it or not.	4.1.a	4.2.a,b	4.3.c	4.4.a,b
M24.	In order to see a whole body in a plane mirror, a mirror sized as half of the body length is enough, regardless of where the mirror is located on the wall.	5.1.d	5.2.a,b	5.3.d	5.4.a,b
M25.	Only if an observer is at the center of a convex mirror, light rays can reflect and reach to his eye.	10.1.f	10.2.a,b	10.3.c	10.4.a,b
M26.	Image in a convex mirror/lens may be formed out of the region between F and the mirror/lens.	12.1.a	12.2.a,b	12.3.e	12.4.a,b
M27.	Covering some part of a mirror/lens reduces its focal length (F) and radius, and results in the formation of the image at a place that is different from its original position.	17.1.a,d	17.2.a,b	17.3.c	17.4.a,b

APPENDIX W

THE FTGOT ADMINISTRATION GUIDE

TESTİN UYGULANIŞINA İLİŞKİN YÖNERGE

1. Öğrencilerin testin giriş sayfasındaki açıklamaları okumasını ve ilk sayfayı **eksiksiz** doldurmasını sağlayınız.
2. Sınav süresi **50 dakika** (1 ders saati) olarak önerilmektedir. Daha fazla süreye ihtiyaç duyan öğrencilere imkanlar el verdiği ölçüde izin verilebilir.
3. Sınavda ihtiyaç duyulabilecek **formüllerin** testin kapak sayfasının arka yüzünde olduğu hatırlatılmalıdır.
4. Sınav sırasında mutlaka öğrencilerin başında bir gözetmen bulunması ve bilgi alışverişine izin verilmemesini sağlayınız.
5. Öğrencilerinizin testin her bir sorusunun tüm aşamalarını eksiksiz olarak doldurmaları gerektiğini hatırlatınız.
6. Sınav bitiminde testleri toplayıp (boş testlerle birlikte) aşağıdaki adrese kargo ile **karşıdan ödemeli (ücreti alıcıdan tahsilli)** olarak en kısa zamanda postalayınız.

Gönderim Adresi:

Derya KALTAKÇI
Eğitim Fakültesi, OFMAE Bölümü, Oda no: 205
ODTÜ, 06800, Ankara
Telefon(iş): 0312 210 6489
E-posta: kaderya@metu.edu.tr

Herhangi bir kargo şirketini arayıp gönderiniz olduğunu bildirdiğinizde, kargo şirketi bulunduğunuz yerden gönderiyi alacaktır. Bazı kargo şirketleri ve telefon numaraları şu şekildedir: **Yurtiçi Kargo** (444 99 99), **Aras Kargo** (444 25 52), **MNG Kargo** (444 06 06), **Sürat Kargo** (444 01 27), **PTT Kargo** (169)

7. Sınav sırasında karşılaşılan herhangi bir sorun ya da önerilerinizi bu kağıdın arka sayfasına yazabilirsiniz.
8. Sınavın uygulanmasında emeği geçen herkese çok teşekkür ederiz. Saygılarımızla.

Araştırmacı: Arş. Gör. Derya KALTAKÇI

Tez Danışmanı: Yrd. Doç. Dr. Ali ERYILMAZ

Sınava giren öğrenci sayısı: ……

Sınavı uygulayan kişininin:
Adı-Soyadı: …….....
E-mail adresi: …….
Kurumu: ……

APPENDIX X

RAW DATA OF THE FTGOT

Students	Gender	1.1.	1.2.	1.3.	1.4.	2.1.	2.2.	2.3.	2.4.	3.1.	3.2.	3.3.	3.4.	4.1.	4.2.	4.3.	4.4.	5.1.	5.2.	5.3.	5.4.	6.1.	6.2.	6.3.	6.4.	7.1.	7.2.	7.3.	7.4.	8.1.	8.2.	8.3.	8.4.	9.1.	9.2.	9.3.	9.4.	10.1.	10.2.	10.3.	10.4.
1	1	D	B	C	B	B	C	E	B	C	B	B	B	C	B	D	B	B	B	E	B	F	B	C	B	B	C	E	C	B	C	F	B	C	C	D	C	D	C	E	B
2	1	E	C	C	C	G	B	E	C	C	B	D	C	B	B	A	B	B	B	A	B	B	B	F	B	A	C	E	C	B	C	D	C	C	B	E	B				
3	1	D	B	C	B	C	C	E	B	C	B	D	B	B	B	E	B	A	B	B	B	D	B	A	B	C	C	A	B	C	C	F	B	E	B	C	C	D	B	F	B
4	1	D	A	D	B	C	A	E	A	C	A	D	A	A	A	D	A	D	B	E	C	C	B	A	B	C	B	E	C	E	B	A	C	E	B	C	C	D	B	E	C
5	2	D	B	D	C	C	A	E	B	C	A	D	A	A	A	D	B	C	B	F	B	D	B	F	C	C	C	C	B	B	B	G	C	D	C	B	C	D	C	F	C
6	2	D	A	C	A	C	A	E	A	C	A	D	A	A	A	C	B	C	B	E	B	C	B	A	B	G	C	E	C	B	B	D	B	E	C	C	C	F	C	C	C
7	2	D	A	E	A	C	B	E	B	D	A	D	A	D	A	E	B	D	A	E	A	D	A	F	B	A	B	E	A	B	A	D	A	E	B	C	B	D	A	F	A
8	1	D	A	D	B	C	A	E	A	C	A	D	A	A	A	D	B	C	A	D	A	F	B	F	B	A	C	C	B	A	C	B	C	C	C	E	C	D	C	E	C
9	1	D	A	C	B	C	A	E	B	C	A	D	A	C	A	D	B	A	A	B	A	F	C	C	B	D	C	F	B	A	B			D	D	B	C	D	C	F	B
10	2	D	A	C	A	E	B	A	B	C	A	D	A	A	A	C	A	B	A	B	A	B	A	A	A	A	C	E	C	A	C	F	C	E	C	C	C	F	C	C	C
11	2	D	A	E	B	D	A	D	A	C	A	D	A	A	A	C	A	B	A	B	B	C	A	C	A	C	B	A	B	B	A	F	C	E	B	C	B	F	B	C	B
12	1	D	B	C	B	E	B	E	B	D	B	E	B	B	B	A	B	A	B	E	B	C	A	C	B									C	C	C	C	B	C	G	C
13	1	E	B	D	C	E	B	E	C	E	B	D	B	C	B	D	C	B	B	E	B	D	B	C	C	F	C	F	C	B	C	F	C	C	B	E	B	B	B	G	C
14	2	D	B	C	B	C	B	E	B	D	B	D	B	A	B	C	B	E	B	C	B	D	B	E	B	C	B	A	B	D	C	E	C	D	C	E	C	D	B	C	B
15	2	D	B	C	B	D	B	D	B	C	B	C	B	B	A	E	C	B	A	B	B	D	B	C	B	A	C	D	C	E	D	C	D	B	D	D	D	D	B	F	B
16	2	D	A	C	B	D	B	D	A	D	A	D	B	A	A	D	A	B	A	B	A	A	A	A	A	D	A	E	A	B	B	F	C	E	A	C	B	D	C	E	C
17	1	D	B	C	A	D	B	D	B	D	B	C	B	B	A	B	A	D	B	C	C	A	C	A	C	E	C	F	D	D	C	E	D	B	D	D	C	F	C	C	C
18	1	D	B	C	B	C	B	E	B	C	B	D	B	B	B	D	B	A	A	B	B	D	C	C	C		C		C	D	C	E	C	D	B	D	C	D	C	F	C
19	2	D	B	C	B	D	B	D	B	C	B	D	B	C	B	D	B	C	B	F	B	D	B	E	B	C	C	E	C	C	C	F	C	D	C	E	C	D	B	F	B
20	2	D	A	C	B	C	A	E	A	C	A	D	A	A	A	D	A	D	B	C	B	C	B	C	B	C	B	A	B	A	B	G	A	E	B	C	A	F	C	C	C
21	2	D	A	C	A	C	A	E	A	D	B	C	A	B	B	E	A	E	B	F	A	E	C	D	B	C	B	A	B	B	B	E	B	E	B	D	B	F	B	G	B
22	2	D	A	C	B	C	A	E	A	C	A	D	A	A	A	D	A	C	A	D	A	D	A	C	A	D	B	E	B	B	A	D	A	E	A	C	B	D	A	C	B
23	2	D	A	E	A	C	A	E	A	C	A	D	A	C	A	D	A	C	A	F	A	D	A	A	A	C	B	E	A	F	A	F	A	E	A	C	A	D	A	F	A
24	2	D	B	C	C	B	A	D	B	D	A	C	A	A	B	C	B	A	B	B	B	A	B	A	B	C	C	A	B	E	B	D	C	E	A	C	A	A	B	D	B
25	2	D	A	C	C	C	A	E	A	C	A	D	A	A	C	F	C	C	B	B	C	D	B	C	B	D	C	E	C	C	B	E	B	C	A	E	A	C	B	E	C
26	1	E	B	B	B	B	B	E	B	C	B	D	B	C	A	D	A	A	B	B	B	D	A	C	A	G	C	B	C	D	D	E	C	D	C	B	C	E	C	B	C
27	2	D	A	C	B	D	C	D	C	C	A	D	A	C	B	D	A	D	B	D	A	E	C	E	B	C	B	A	B	B	C	F	C	E	B	C	B	D	B	C	B
28	1	D	B	E	B	G	C	E	C	C	B	D	A	C	B	D	B	C	A	E	A	F	C	G	C	A	D	E	D	A	D	G	C	C	B	E	B	C	C	E	C
29	1	D	A	C	B	G	A	B	B	C	A	D	A	C	A	D	A	C	A	E	A	A	B	A	B	G	C	B	C	B	B	E	C	E	B	E	C	F	C	C	C
30	1	D	B	C	B	D	B	D	B	C	B	D	B	B	B	A	C	C	C	E	B	D	C	E	C	B	C	E	B	C	C	F	C	C	B	E	B	B	D	G	C
31	2	B	B	A	B	A	B	A	B	A	C	A	C	B	A	A	B	B	B	B	B	B	D	B	C	B	E	D	D	C	A	C	A	C	D	C	B	C	D	C	F	C
32	1	D	B	C	B	E	B	E	B	C	B	D	B	B	B	B	B	B	B	B	E	B	A	B	A	B	G	C	F	C	B	B	F	C	C	B	B	B	C	B	B	B
33	1	C	B	A	B	E	A	B	B	D	B	C	C	C	A	D	B	B	B	A	B	E	B	E	B	E	C	C	C	C	C	A	C	E	C	A	C	D	B	F	B
34	1	D	B	C	B	G	C	E	C	B	B	B	C	C	B	D	B	B	B	A	B	A	B	A	B					B	B	C	C	A	B	A	B	C	B	E	B
35	2	D	A	D	B	C	A	F	A	D	A	E	A	A	B	D	B	B	A	B	A	D	B	A	B	A	B	G	B	B	A	G	B	B	B	A	B	E	B	E	B
36	2	D	A	C	A	G	A	D	A	B	B	B	A	A	A	C	A	B	A	B	A	A	A	A	B	E	B	D	B	A	A	B	A	D	B	C	B	C	C	E	B
37	2	D	B	A	B	E	A	B	A	C	A	D	A	C	A	D	B	C	A	B	A	C	B	B	A	A	B	C	A	B	A	F	A	E	A	C	A	D	A	F	A
38	2	D	A	E	A	C	A	E	A	C	A	D	A	A	A	F	A	B	A	A	A	D	A	C	A	D	C	C	E	C	C	C	C	B	E	B	C	C	E	C	
39	1	C	B	C	C	D	B	D	B	D	B	C	B	C	C	D	B	B	B	B	B	F	C	A	C	E	D	B	B	C	D	E	B	D	B	B	C	B	E	B	
40	1	C	A	B	A	G	A	C	A	B	A	B	A	B	B	E		D	B	D	B	E	B	E	B	F	C	F	C	D	B	E	B	C	C	E	B	D	B	F	B
41	1	D	B	D	C					C	B	D	B	C	B			B	A	B	B	D	B	A	B																
42	1	D	B	C	B	C	B	E	B	D	B	C	B	A	B	D	C	B	A	A	A	A	B	B	B																
43	2	D	B	E	B	E	B	B	B	D	B	C	B	A	B	D	B	B	B	B		B	B	A	B	A	D	E	C	B	B	E	C	E	B	C	C	E	C	B	C
44	2	D	A	C						D	C	D	B	C		E	B	B	C	A	C	C	B	B	A	D	C	D	C									E	B	F	B
45	2	C	B	B	B	G	C	D	B	D	B	C	B	B	A	B	B	B	C	B	D	B	C	B	G	B	B	B	B	E	B	D	B	B	B	B	D		D	B	
46	2	C	A	A	A	E	B	E	B	B	C	D	B	B	B	A	B	C	B	E	B	D	B	A	B	G	C	E	B	D	C	F	B	C	C	E	B	C	C	E	B
47	1	D	B	C	B	D	B	D	B	C	B	B	B	A	C	C	C	A	B	B	B	F	C	A	C	D	D	F	D	B	D	D	D	E	C	C	C	F	C	C	C
48	1	D	B	B	B	E	C	E	C	C	B	D	B	B	A	B	A	B	A	A	B	A	C	A	C	A	C	A	C	B	D	C	B	D	C	C	C	E	C	E	C
49	1	D	B	C	B	F	C	E	C	C	C	B	C	C	B	D	B	B	B	B	B	B	C	B	C	A	D	D	D	A	D		D	E	B	C	C	D	C	E	D
50	2	C	A	B	A	A	A	A	A	C	A	D	A	A	A	C	A	B	A	B	A	B	A	C	A	E	A	B	A	C	A	E	A	D	A	D	A	D	A	C	A
51	1	C	B	C	B	E	A	C	C	A	A	A	A	A	A	D	A	B	A	B	A	D	A	C	A	F	D	F	D	C	A	E	A	E	A	C	A	C	C	D	A
52	1	D	B	E	B	G	B	D	B	B	B	B	B	B	B	E	C	B	B	A	B	B	B	A	B	B	C	F	C	C	B	E	A	C	A	E	C	C	B	E	B
53	1	D	B	E	B	G	C	D	C	C	B	B	A	B	B	E	C	B	B	A	B	B	B	A	B	B	C	F	C	B	B	E	C	c	B	E	D	C	B	E	B
54	1	C	A	B	B	D	B	D	B	B	B	B	B	C	C	E	C	C	B	E	B	D	B	A	B	C	D	A	C	D	B	E	C	E	B	C	B	D	B	F	C
55	1	C	A	B	A	B	B	D	B	C	A	B	A	B	B	E	B	C	A	E	A	D	B	C	B	C	C	E	C	A	C	B	C	E	C	C	C	F	C	C	C
56	1	B	A	A	B	D	A	D	B	C	B	D	B	B	B	E	B	A	B	B	B	D	B	C	B	D	B	E	B	B	B	F	B	C	B	E	B	C	B	E	B
57	2	C	B	B	B	E	B	B	B	D	B	C	C	C	C	D	C	B	B	B	B	D	B	C	B	A	C	D	C	A	B	C	B	A	C	B	C	C	B	E	B
58	2	B	B	A	B	B	B	E	B	C	A	D	A	C	A	D	A	E	A	F	B	D	B	C	B	B	C	B	C	B	B	C	B	F	A	F	A	C	B	E	B
59	1	A	C	B	C	A	D	A	D	C	B	D	C	B	B	E	B	C	C	C	B	D	B	C	C	C	D	A	D	B	D			E	D	C	D	F	D	C	D
60	1	C	B	B	B	C		E	C	C	B	D	A	B	A	E	A	B	A	B	B	D	B	E	B	B	C	E	D	A	D	B	C	B	C	D	C	F	C	C	C

Students	Gender	1.1.	1.2.	1.3.	1.4.	2.1.	2.2.	2.3.	2.4.	3.1.	3.2.	3.3.	3.4.	4.1.	4.2.	4.3.	4.4.	5.1.	5.2.	5.3.	5.4.	6.1.	6.2.	6.3.	6.4.	7.1.	7.2.	7.3.	7.4.	8.1.	8.2.	8.3.	8.4.	9.1.	9.2.	9.3.	9.4.	10.1.	10.2.	10.3.	10.4.
61	1	D	B	C	C	C	A	E	B	C	A	D	B	B	A	A	A	C	A	B	A	D	A	A	A	F	A	F	A	C	A	F	C	C	B	C	B	B	A	G	A
62	1	D	B	D	B	D	C	D	B	C	B	D	B	A	B	C	C	D	B	D	B	B	B	A	B	B	C	E	B	B	B	E	B	D	B	B	B	A	B	A	B
63	1	C	B	B	C	E	B	E	C	D	C	C	B	C	C	D	B	B	A	B	B	A	B	G	A	A	C	A	C	A	B	F	D	E	B	C	A			G	C
64	2	C	A	B	B	G	B	D		C	A	D	A	B	A	A	C	C	A	E	A	D	A	C	A	A	C	C	A	C	E	A	C	A	B	A	D	A	A	C	A	C
65	1	C	B	B	B	B	B	F	B	C	A	E	A	B	B	E	B	C	A	F	B	E	B	E	B	E	B	B	C					E	B	C	B	D	B	F	B
66	1	C	B	B	A	C	C	E	B	A	B	A	B	C	A	D	B	B	A	B	B	C	C	B	B	C	C	A	C	D	C	E	B	E	C	C	C	D	B	F	B
67	1	E	C	C	B	A	B	A	B	D	B	C	B	B	C	B	C	B	B	A	B	B	B	A	B					E	B	C	B	C	C	C	B	F	B	C	B
68	2	D	A	C	A	C	B	E	B	C	A	D	B	C	A	D	B	C	A	E	A	A	A	A	A	A	B	D	B	B	C	F	B	E	B	E	C	D	A	F	A
69	2	C	A	B	A	D	C	D	B	D	A	C	A	B	A	B	A	C	A	C	A	B	A	A	B	C	B	F	C	C	B	E	B	D	A	B	A	F	A	D	A
70	1	D	B	C	B	D	B	D	B	C	C	D	B	B	C	B	B	B	B	B	B	B	B	A	C	C	B	A	B			D	C	E	B	C	B	F	B	C	B
71	1	D	B	C	B	D	C	C	C	C	A	D	B	B	A	A	A	D	A	C	B	D	B	C	B	B	B	C	B	C	C	A	C	E	B	C	B	B	C	G	C
72	1	B	A	A	A	A	A	A	A	B	A	B	A	B	A	A	A	B	A	D	A	D	A	C	A	C	A	A	A	A	A	B	A	E	A	C	A	F	A	C	A
73	2	D	B	C	C	B	B	D	B	D	B	C	B	B	B	E	B	D	C	C	C	B	C	F	C	F	C	F	C	B	C	D	C	E	B	C	B	F	B	C	B
74	1	C	B	B	B	C	B	C	B	D	A	C	A	C	A	D	A	B	A	B	A	B	A	A	A	E	C	C	C	D	B	E	C	E	C	C	C	F	B	C	B
75	1	C	C	B	C	C	B	E	C	B	B	B	C	A	B	D	B	B	B	B	B	D	B	A	B	B	B	C	B	B	C	D	C	E	B	C	B	F	C	C	C
76	1	D	B	C	B	C	B	E	A	B	B	B	B	A	B	B	E	A	E	A	B	C	A	C	A	B	D	B	B	C	F	C	C	B	E	B					
77	1	B	B	A	B	F	B	B	B	C	C	D	C	B	C	E	C	B	B	A	C	B	C	A	C	C	C	A	C	D	C	E	C	D	B	E	C	B	C	G	C
78	2	C	B	B	B	B	B	E	B	D	B	C	B	B	B	B	B	B	A	A	B	B	B	A	B	C	B	A	C	A	C	E	C	D	B	B	B	F	C	C	C
79	2	D	B	D	B	B	B	E	B	C	B	D	B	C	B	D	B	A	B	B	B	D	B	C	B	C	C	A	C	A	B	B	B	A	B	A	B	A	B	A	B
80	1	C	B	B	B	D	B	D	B	D	B	C	B	B	A	A	B	B	A	B	A	B	A	A	B	F	B	F	B	A	B	A	B	A	B	D	B	B	B	G	B
81	1	B	A	A	A	E	A	E	B	C	B	D	B	B	B	B	B	B	B	A	B	A	B	B	A	C	F	B	F	B	A	B	B	B	E	A	C	A	F	A	C	A
82	1	C	B	C	B	E	B	B	B	D	B	C	B	B	B	E	B	B	B	E	B	D	B	C	B	E	C	B	C	D	C	E	C	C	C	E	C	D	B	F	B
83	2	E	B		B	E	B	E	B	D	B	C	B	C	B	D	B	B	B	A	B	B	B	F	B	E	D	B	D	A	C	F	B	E	A	C	B	F	B	C	B
84	1	A	B	D	B	D	C	D	C	B	B	B	C				B	A	B	A	D	A	C	A			C	A	D	C	F	C	E	A	C	A	F	A	F	A
85	2	B	B	A	B	C	B	D	B	E	B	D	B	B	A	B	B	B	B	F		G	B	C	B	A	B		B	B		D	B	B	C	E	C	B	C	E	B
86	2	D	A	D	A	C	A	E	A	C	A	D	A	C	A	D	A	C	A	E	A	F	A	G	A									D	B	E	B	C	B	E	B
87	1	D	B	C	A	F	A	E	A	B	A	B	A	D	A	C	A	B	A	E	B	D	A	C	A	F	B	G	A	C	A	F	A	C	A	E	A	B	A	G	C
88	1	C	B	B	A	G	B	E	B	C	B	D	B	B	B	E	B	C	A	E	A	A	A	A	A					B	A	F	B	D	C	E	B	B	A	G	A
89	2	D	B	C	A	C	B	E	B	C	A	D	B	A	A	F	A	E	A	F	A	D	A	C	B	A	C	B	C	E	C	C	B	B	C	D	B	D	B	F	B
90	1	D	B	C	B	C	C	E	C	C	B	D	B	B	B	E	B	C	B	E	B	C	B	C	C	C	C	E	C	D	C	F	C	E	C	C	C	D	C	F	C
91	1	D	A	C	A	C	A	E	A	C	B	D	B	B	B	A	B	C	A	B	A	D	B	A	B	C	C	A	C	E	C	C	C	A	C	A	C	D	B	F	B
92	2	B	A	A	A	B	A	C	A	D	A	C	A	C	A	D	A	D	A	D	A	B	A	A	A					B	C	D	C	E	B	C	B	C	C	E	C
93	1	D	B	C	C					D	B	C	B	B	B	D	B	B	B	B	B	B	B	A	C			E	B	B	B	D	B	E	B	C	B	D	B	F	B
94	1	C	C	D	C	E	C	D	B	A	B	E	C	B	A	B	B	D	B	C	B	A	C	D	C	B	C	F	C	C	C	E	C	C	C	E	C				
95	1	D	B	C	B	C	B			C	B	D	B	B	A	B	D	B	D	B	F	B	A	B	E	B	B	B	E	B	C	B	B	B	F	B	B	B	H	B
96	1	B	B	C	B	B	B	E	B	C	B	D	B	A	B	D	B	C	B	E	B	D	B	C	C	A	C	D	C	A	C	B	C	C	C	C	C	C	C	E	B
97	2	D	B	C	B	E	B	E	B	B	B	B	B	A	B	D	B	B	B	F	B	D	B	A	B	A	B	D	B	A	B	B	B	C	C	F	C	D	B	C	B
98	2	D	B	C	A	G	B	F	B	C	B	D	B	B	B	B	C	B	B	B	B	D	B	A	B	E	C	G	A	F		G	A	D	C	F	A	D	C	H	A
99	1	C	B	D	B	C	B	E	A	B	B	B	B	B	B	A	B	B	A	A	A	C	B	C	B	E	C	B	C	E	C	E	C	A	C	A	B	D	B	C	B
100	2	D	A	C	B	C	A	E	A	C	A	D	A	C	B	D	B	C	A	B	B	E	A	E	B	D	B	E	B	B	B	G	B	B	C	D	B	D	B	F	B
101	2	D	A	D	B	D	B	D	A	C	A	D	A	C	A	D	A	B	A	B	A	F	A	C	A	E	C	F	B	D	C	D	C	C	C	E	C	A	B	D	C
102	2	C	B	B	B	B	A	E	B	C	C	D	C	A	B	D	B	B	A	A	A	D	A	C	A	E	A	D	C	B	C	D	C	E	B	C	B	D	C	F	C
103	2	D	C	B	B	F	C	B	B	D	B	C	B	B	A	A	A	B	A	A	A	B	B	A	A	C	D	A	D	A	C	B	C	E	B	C	B	F	A	C	A
104	1	C	C	B	C	D	C	D	C	D	C	C	B	A	B	D	B	A	C	B	C	D	C	C	C	F	C	F	C	B	C			E	C	C	C	D	C	C	C
105	1	D	B	C	A	C	A	E	B	D	B	C	B	B	A	A	B	B	B	A	B	B	B	A	D	B	C	C	A	D	C	E	C	E	B	A	B	F	C	C	C
106	1	D	B	C	B	D	B	D	B	D	B	C	B	C	B	D	B	B	B	B	B	B	D	B	B	B	C	C	A	C	C	C	E	C	E	B	C	B	F	C	C	C
107	1	D	B	C	C	C	B	E	B	D	B	C	B	C	A	D	A	C	B	E	C	D	B	C	B	A	C	C	C	D	B	E	B	E	A	C	B	F	C	F	C
108	2	D	A	C	A	C	A	E	A	C	A	D	A	C	A	D	A	C	A	D	A	F	C	F	B	C	B	C	B	B	A	D	A	C	A	C	A	D	A	F	A
109	1	C	A	B	A	G	A		A	C	A	D	A	B	A	F	A	B	A	A	A	A	A	A	A	A	A	A		A	A	A	A	B	A	D	A	D	A	F	A
110	1	B	C	A	C	F	C	E	B	D	B	C	B	B	B	B	B	A	C	C	D	A	C	E	C	B	D	E	D	D	D	E	C	C	C	C	B	F	C	C	C
111	1	E	B	E	C	D	B	D	B	B	A	B	B	C	B	D	B	E	B	F	B	F	D	G	D					B	C	E	C								
112	1	D	B	C	C	C	B	E	B	D	B	C	B	B	C	B	C	B	C	B	B	F	C	A	C	D	C	E	C	B	C	E	C	E	C	C	C	E	D	E	C
113	2	D	A	D	B	C	B	E	B	C	A	D	A	A	B	C	B	A	A	B	A	D	A	A	B	A	B	A	B	C	B	E	C					A	B	D	C
114	2	D	C	D	C	D	D	E	D	D	B	C	B	C	C	C	C	A	C	B	B	D	C	C	D	C	B	E	B	B	B	A	B	E	C	C	C	E	A	B	B
115	1	D	D	D	D	F	D	B	D	D	B	C	D	C	D	D	D	C	C	E	D	F	C	A	C	E	C	D	D	D	B	E	C	E	C	C	C	D	B	F	C
116	1	D	B	D	B	C	B	E	B	D	A	D	A	B	A	A	A	A	B	B	B	D	B	C	B	B	B	E	B	B	A	F	A	E	A	C	A	F	A	C	A
117	1	D	A	C	A	C	B	E	B	C	A	D	A	C	B	D	B	C	A	E	A	D	A	C	A	D	C	C	B	E	C	D	B	E	B	D	C	E	B	E	C
118	1	D	B	C	B	E	C	E	C	D	B	C	B	B	B	B	B	B	B	B	B	E	C	E	B	C	C	A	C	E	D	C	D	E	C	C	C	D	C	F	C
119	1	B	C	A	C	E	C	B	C	D	B	C	B	B	B	B	B	B	B	B	B	E	C	E	C	C	D	A	D	E	D	C	D	C	C	C	C	D	C	F	C
120	1	D	B	C	B	F	C	E	C	D	B	C	B	B	B	D	B	A	B	B	B	A	B	A	B	A	B	C	B	E	B	C	B	A	B	D	B	A	B	D	B
121	1	B	B	A	B	A	B	A	B	A	C	D	C	B	B	E	B	B	B	B	B	E	B	E	B	A	B	C	B	A	C	C	B	B	C	B	C	B	A	B	B
122	1	D	A	C	A	D	C	D	C	D	B	C	B	B	B	E	A	B	A	A	B	B	B	C	B	D	B	E	B	C	C	E	C	E	C	C	C	D	D	F	C
123	1	C	B	B	B	A	B	A	B	D	A	C	A	A	A	D	A	B	A	A	A	A	B	A	A	F	B	F	C	A	B	B	B	C	B	C	B	D	B	C	B
124	1	C	B	B	B	B	C	E	C	E	B	D	C	A	B	C	A	B	B	B	B	B	B	F	B	B	B	E	C	B	B	F	B	E	C	D	C	C	C	E	C
125	2	D	A	C	A	C	A	E	A	C	A	D	A	A	A	C	A	C	A	B	A	D	A	C	C	A	C	E	C	E	B	C	A	A	B	A	B	D	A	F	A
126	1	D	B	C	B	C	B	E	A	C	B	D	B	A	B	C	B	B	B	A	B	A	B	B	B	D	B	C	B	E	B	F	C	D	C	B	C	E	C	B	C
127	1	B	B	A	B	C	C	E	C	C	C	D	B	A	B	C	B	D	B	D	B	D	B	C	C	E	B	B	C	C	B	D	C	E	C	C	C	D	C	F	C
128	1	D	B	C	B	C	B	E	B	C	C	B	C	A	B	C	B	C	B	E	B	D	B	C	C	A	C	D	C	C	C	E	C	E	C	C	C	D	C	F	C
129	2	D	B	D	C	E	C	E	C	C	B	D	B	A	C	E	C	B	B	A	B	A	B	B	B	D	B	C	B	E	B	C	D	D	B	B	C	E	B	B	B
130	1	D	A	C	A	C	A	E	A	B	A	B	A	B	A	B	A	A	B	A	A	A	B	A	A	B	D	E	D	B	C	D	C	E	B	C	D	A	D	F	A
131	2	D	A	C	A	C	A	F	A	C	A	D	A	C	A	D	A	C	A	D	A	D	A	C	B	G	A	E	A	A		E	A	C	A	E	A	D	A	F	A
132	2	D	B	C	B	C	B	E	B	D	B	C	C	C	B	D	B	B	C	A	C	B	B	A	B	C	C	A	C	C	C	E	C	E	C	C	C	D	C	E	C
133	1	D	A	C	B	F	C	E	C	B	B	B	C	B	D	B	B	B	B	C	E	B	C	D	E	D	E	D	C	D	B	B	D	C	F	D	C	F	D	F	D
134	1	C	B	B	B	B	B	E	C	D	C	C	C	C	B	D	B	D	C	D	B	D	C	A	B	F	C	F	C	A	C	A	C	A	C	A	C	C	C	E	C
135	2	D	B	C	B	C	B	E	B	A	B	A	B	C	B	D	B	B	A	B	A	A	B	A	B	C	B	A	C	E	B	D	B	D	B	E	B	D	B	F	B
136	1	D	B	C	B	G	B	D	B	C	A	D	A	C	B	D	B	D	B	C	B	A	B	A	B																
137	1	C	B	D	C	E	B	E	B	A	B	A	B	C	B	D	B	B	A	B	A	D	B	C	B	C	B	A	B	D	B	E	B	E	B	C	B	D	B	F	B
138	1	C	B	B	B	F	C	E	C	A	B	A	B	C	B	D	B	B	B	B	B	D	B	C	B	C	B	A	B	A	B	F	B	E	B	C	B	B	B	E	B
139	1	C	B	B	B	B	B	E	B	C	B	D	B	A	B	E	B	B	A	A	B	B	B	F	B	D	B	C	B	C	B	D	C	B	B	D	C	B	B	G	B
140	2	D	B	C	B	A	C	A	C	C	B	D	B	B	B	A	B	D	B	C	B	B	B	F	C	D	C	B	C	D	C	B	C	B	D	D	C	B	B	G	C

Students	Gender	1.1.	1.2.	1.3.	1.4.	2.1.	2.2.	2.3.	2.4.	3.1.	3.2.	3.3.	3.4.	4.1.	4.2.	4.3.	4.4.	5.1.	5.2.	5.3.	5.4.	6.1.	6.2.	6.3.	6.4.	7.1.	7.2.	7.3.	7.4.	8.1.	8.2.	8.3.	8.4.	9.1.	9.2.	9.3.	9.4.	10.1.	10.2.	10.3.	10.4.
141	1	C	B	E	B	F	B	B	B	C	B	E	B	B	B	A	B	A	B	B	C	A	B	A	C	A	C	D	C	A	C	B	C	C	B	E	B	C	B	E	B
142	2	D	B	E	A	G	B	E	A	C	A	D	A	C	A	D	A	C	A	E	A	D	B	A	A	C	C	A	B	E	C	E	C	E	B	C	B	F	B	C	B
143	1	D	B	E	A	C	A	E	A	C	B	D	A	C	A	D	A	B	A	B	A	F	A	C	A	C	C	A	C	E	C	C	C	C	C	D	C	E	C		
144	1	D	A	C	A	C	A	E	A	B	A	B	A	A	A	C	A	B	A	B	A	B	A	A	A	C	A	A	A	B	A	A	A	E	A	C	A	D	A	C	A
145	1	D	A	C	A	D	B	D	B	D	A	C	A	B	A	B	A	A	A	B	A	A	B	A	B	A	C	E	A	A	C	E	C	D	B	C	B	F	B	C	B
146	1	E	A	A	A	G	A	E	B	D	A	C	A	C	A	D	A	D	A	C	C	C	B	B	B					B	B			E	B	C	B	A	C	D	B
147	1	C	A	A	B	D	A	D	B	D	B	C	B	C	C	D	C	B	A	B	A	B	B	A	B					B	B	D	C	E	C	C	C	D	C	C	C
148	2	B	B	A	B	E	C	B	C	B	C	B	C	C	C	D	C	B	B	B	B	D	B	C	B	C	B	A	B	D	B	E	B	A	B	A	B	D	B	F	B
149	2	C	A	B	A	B	A	E	A	C	A	D	A	B	A	A	A	C	A	E	A	C	A	C	A	C	C	A	C	A	C	F	A	E	A	C	A	F	C	A	C
150	1	D	B	C	B	D	B	E	B	C	B	D	B	C	B	D	B	D	B	D	B	F	B	C	B	D	B	C	C	B	B	C	B	D	B	B	B	D	B	C	A
151	1	D	B			C	A	E	A	C	A	D	B	C	B	D	B	B	A	D	A	A	A	A	A	B	C	C	B	B	B	A	B	D	B	B	B	C	B	B	B
152	1	D	A	C	A	D	B	E	A	C	B	D	B	B	C	A	C	B	B	A	A	D	B	C	B	C	A	A	A	B	B	C	B	D	B	B	B	D	B	C	A
153	1	D	A	C	A	C	B	E	B	C	C	D	C	B	C	A	C	B	B	B	B	D	B	C	B	D	B	E	C	B	B	C	B	D	B	B	B	F	B	C	A
154	1	C	B	C	B					A	B	A	B	C	A	D	A	C	B	E	B	D	B	C	B					A	C	C	C	C	C	E	C	C	C	E	C
155	1	C	B	B	A	C	B	E	B	B	B	B	B	A	B	C	B	B	B	A	B	A	B	A	B	A	D	D	D	C	B	E	B	E	B	C	D	D	B	F	C
156	2	D	A	D	C	D	B	D	B	C	C	D	C	B	B	E	A	B	B	E	B	B	B	A	B	B	E	C	D	C	E	C	D	B	B	B	D	C	F	B	
157	1	A	A	E	A	G	B	A	B	C	B	D	B	C	B	D	B	B	B	B	B	C	C	C	C	E	B	B	B	C	B	E	B	C	B	E	B	C	B	E	B
158	1	B	B	A	C	A	C	A	C	B	B	B	C	A	B	C	C	B	B	D	B	B	C	C	C	C	B	A	B	B	B	D	C	A	B	A	B	A	B	D	B
159	1	D	B	D	D	B	A	D	C	A	B	A	C	B	B	E	B	B	B	B	B	A	B	A	B	F	B	F	B	C	B	E	B	D	B	B	B	F	D	C	C
160	1	D	B	D	B	E	B	E	B	B	B	B	B	A	B	C	B	B	B	A	B	A	B	A	B	A	D	A	D	C	B	E	B	E	B	C	B	D	B	F	C
161	1	B	B	A	B	A	B	A	B	D	B	C	C	A	B	E	B	B	B	C	B	E	B	E	A	C	B	A	B	B	B	A	B	C	B	E	B	A	B	D	B
162	2	D	B	C	C	C	C	E	C	D	B	C	B	B	B	A	B	A	A	B	A	D	A	A	A	C	B	A	B	B	D	A	E	B	C	A	D	A	C	A	
163	2	D	B	C	B	C	B	F	B	C	B	D	B	C	B	D	B	C	B	E	B	D	B	C	B	C	B	A	B	A	B	D	B	C	B	E	B	D	B	F	B
164	2	D	B	D	B	D	A	D	A	C	A	D	B	A	A	D	A	B	A	A	A	D	B	A	B	B	B	B	B	E	C	G	C	E	B	C	B	D	B	C	B
165	1	D	B	C	B	D	A	D	A	C	B	B	A	B	C	B	D	C	D	B	B	B	E	B	B	C	B	B	B	F	B	E	B	C	B	D	B	C	B	F	B
166	2	D	B	A	B	C	B	E	A	D	A	C	A	B	A	D	A	B	A	B	A	B	B	A	B	B	B	B	C	A	A	B	B	E	B	C	B	D	A	A	A
167	2	D	B	D	B	C	B	E	B	C	B	D	B	B	B	E	B	C	B	B	B	D	B	A	B	E	C	B	C	D	C	E	B	D	B	E	B	E	B	B	B
168	1	D	A	E	A	D	C	D	C	C	A	D	A					C	A	E	A	B	A	G	A	D	A	E	A												
169	1	B	C	A	B	D	C	D	C	C	C	D	B	B	A	B	B	B	B	C	A	C								B	B	C	B	C	B	B	C	F	C	C	C
170	2	D	B	C	A	B	A	E	B	D	A	C	A	C	A	D	B	C	A	B	B	A	B	A	A	E	D	B	C	A	C	F	C	C	B	E	B	C	B	E	B
171	1	B	B	C	B	A	B	C	B	A	C	A	C	A	B	C	C	B	A	B	C	B	A	A	C	D	D	E	B	B	B	F	B	B	B	D	C	F	B	C	B
172	1	A	C	B	B	A	B	C	B	B	B	B	B	A	B	D	B	D	B	D	B	B	B	A	C	E	C	F	B	B	B	F	B	E	B	C	B	F	B	C	A
173	1	D	B	C	B	D	C	D	C	D	B	C	A	A	B	C	B	B	B	D	B	A	B	E	B	C	B	A	C	D	B	F	C	C	C	B	D	C	C	E	D
174	1	D	B	E	B	B	B	E	B	C	B	D	B	A	C	D	C	B	B	B	B	D	B	C	B	B	C	E	C	D	C	E	C	C	C	E	C	D	B	F	B
175	1	D	B	C	B	G	B	E	B	C	B	D	B	C	C	E	B	B	B	B	B	C	B	C	B	B	C	D	C	D	C	E	C	D	C	C	C	C	C	G	C
176	1	D	B	C	B	C	A	E	B	C	B	D	B	B	C	E	B	C	B	C	B	B	B	A	B	G	C	F	C	B	B	F	C	E	B	C	B	D	B	F	B
177	2	D	A	C	A	C	A	E	B	C	B	D	B	B	C	D	B	C	B	B	C	B	B	A	B	G	C	F	B	B	B	F	C	E	B	C	B	D	B	F	B
178	2	C	B	B	A	C	B	D	A	B	A	B	A	C	B	D	B	C	A	C	A	D	A	C	A	A	B	D	B	C	A	E	B	E	A	C	B	D	B	F	B
179	2	C	A	A	B	D	B	D	B	B	B	B	B	C	C	D	B	C	A	C	A	D	B	C	B	D	B			B	A	C	B	E	B	C	A	D	A	F	B
180	2	D	B	D	B	C	B	E	B	C	B	D	B	C	B	D	B	C	B	E	B	D	B	C	B	C	B	A	B	B	B	D	B	C	B	C	B	F	B	C	B
181	1	C	B	C	B	C	B	D	B	C	D	D	A	B	B	D	B	C	A	E	A	C	B	C	B	E	B	F	B	D	B	E	B	D	B	E	B	C	C	E	C
182	1	C	B	B	B	C	D	E	C	C	C	D	C	A	C	D	C	B	A	A	B	D	B	C	B	C	D	A	C	B	D	D	C	A	A	A	A	F	D	C	C
183	2	D	B	C	B	C	A	E	A	C	A	D	A	A	A	C	A	C	A	E	A	D	A	C	A	C	A	A	A	B	A	D	B	E	A	C	A	D	A	F	A
184	1	D	B	D	B	C	A	E	B	C	A	D	B	B	A	B	A	B	A	C	B	C	B							E	C	C	C								
185	2	D	A	E	A	C	B	D	B	C	A	D	A	B	A	F	A	C	A	B	A	B	A	A	B	D	C	E	C	E	B	E	B	E	B	C	B	B	C	G	B
186	1	D	A	C	A	E	A	E	A	C	A	D	A	C	A	D	A	B	A	B	A	B	A	A	A	D	B	E	B	E	A	E	B	E	A	C	A	D	A	F	A
187	1	C	B	B	B	D	D	E	C	C	C	D	C	B	C	E	C	C	D	E	D	B	D	C	D	D	D	E	D					E	D	B	D				
188	1	B	B	D	B	B	B	E	B	C	B	C	B	C	B	D	B	C	B	E	B	A	B	B	B	B	E	B	B	B	B	E	B	E	B	C	B	D	B	C	B
189	2	D	A	D	B	F	B	B	B	B	A	B	A	A	A	C	A	C	A	E	A	D	A	C	A	D	A	E	C	A	A	F	B	E	B	C	B	D	A	C	B
190	2	C	C	B	B	A	B	A	B	B	B	B	B	B	B	E	B	B	B	B	A	C	B	C	B	A	B	C	B	A	B	B	B	A	B	A	A	B	B	G	A
191	1	C	B	B	B	G	B	A	B	C	A	D	A	C	B	D	B	B	B	D	B	D	A	C	A	D	A	E	C	A	A	B	A	B	B	D	B	D	B	B	B
192	1	D	D	D	D	B	D	E	D	C	D	D	D	C	B	D	B	C	D	E	D	D	B	A	B	A	D	D	D	B	B	E	B	C	D	E	C	D	C	F	C
193	1	C	A	C	A	C	A	E	B	C	A	D	A	B	B	B	C	C	A	D	A	F	C	A	D	F	B	F	B	C		E	A	D	B	E	B	B	A	G	A
194	2	D	A	C	A	C	A	E	B	C	A	E	A	C	A	D	A	B	A	A	A	B	A	A	A	F	A	F	A	A	C	E	B	B	B	D	B	E	B	E	C
195	2	E	A	C	A	B	A	C	A	B	A	B	B	A	C	D	B	C	A	D	B	E	C	E	B	D	B	E	B	C	C	D	C	D	C	E	C	E	C	E	C
196	2	D	A	C	A	C	A	E	B	C	A	E	A	C	A	D	A	B	A	A	A	B	A	A	A	F	A	F	A	C	B	C	B	A	A	A	A	F	A	C	A
197	2	C	B	B	B	D	C	D	B	C	B	D	B					B	B	A	B	D	B	A	B	C	B	A	B					E	B	C	B	D	B	F	B
198	2	D	B	C	B	D	B	D	B	C	B	D	B	C	B	D	B	B	B	B	A	B	D	B	A	B	C	B	A	B					A	B	A	B	D	B	F	B
199	2	D	A	E	A	C	A	E	A	C	A	D	A	A	A	D	A	E	A	F	A	D	A	A	A	D	A	G	A	D	B	C	B	B	D	F	D	F	A	E	A
200	2	D	A	C	A	C	A	E	B	C	A	D	A	A	D	A	C	A	D	B	D	A	A	A	D	A	C	B	D	C	D	A	A	B	C	C	E	B	A	A	
201	2	D	A	B	C	D	C	B	C	A	B	D	C	C	C	C	D	C	C	E	C	C	B	A	B	B	D	D	B	B	B	E	C	A	A	E	A	B	B	G	B
202	2	C	C	C	C	D	C	E	C	D	C	D	C	C	C	B	C	D	C	A	C	D	C	B	C	D	C	E	C	C	C	C	F	C	A	C	D	D	A	C	C	D
203	1	D	A	C	A	D	B	D	B	B	C	B	B	A	C	C	B	A	B	B	B	D	B	C	B	B	C	E	C	B	C	D	C	D	B	B	B	C	C	E	C
204	1	D	C	C	C	D	C	D	C	B	C	D	C	C	C	D	C	C	C	E	C	B	B	F	B	C	C	C	C	B	C	A	C	E	B	C	B	F	B	C	B
205	1	D	B	D	B	C	A	E	B	C	A	D	A	C	A	D	B	C	A	E	A	D	A	C	A	C	B	A	C	B	A	D	B	E	B	C	C	C	D	E	D
206	1	D	A	D	C	C	B	E	B	D	B	C	B	C	B	D	B	B	B	B	A	C	D	B	C	B	C	C	A	C	D	B	E	B	E	B	C	B	C	B	E	B
207	1	D	A	C	A	C	B	E	B	B	A	B	A	E	A	C	A	B	A	D	A	A	A	A	A	C	D	C	C	B	F	B	E	B	C	B	E	B	C	B	E	B
208	1	D	A	D	B	C	B	E	B	B	A	B	B	B	A	E	B	C	A	B	B	D	A	C	B	A	C	B	C	D	B	E	B	E	B	C	B	A	B	D	B
209	2	C	C	D	C	D	C	D	C	D	C	C	C	A	C	C	C	D	C	C	C	E	C	D	C	A	C	D	C	A	C	B	C	A	C	A	C	A	B	A	B
210	2	D	B	C	B	D	B	D	B	C	B	D	B	C	D	C	A	B	A	B	D	B	C	B	E	C	B	A	D	B	E	A	A	A	A	A	E	D	G	D	
211	1	D	B	C	B	C	C	E	C	D	B	D	B	B	C	E	C	B	B	E	B	D	C	F	C	D	C	E	C	C	B	E	C	A	C	A	C	A	C	A	C
212	2	B	A	A	B	C	A	E	B	C	A	D	A	C	A	D	B	C	A	E	A	D	A	C	A	C	C	A	C	B	A	F	B	C	B	E	C	C	D	E	D
213	2	C	B	B	B	G	B	F	B	C	B	B	B	A	B	B	B	B	B	E	B	E	B	E	B	E	C	B	C	C	C	E	C	E	B	C	B	F	B	C	B
214	1	D	C	A	C	F	C	B	C	A	C	A	C	B	C	E	C	B	B	B	C	E	C	D	C	D	C	D	C	A	C	B	C	D	C	B	C	E	C	B	C
215	1	C	B	C	B	A	B	A	B																																
216	1	C	B	C	B	B	B	B	B	C	A	D	A	B	B	B	B	B	B	B	B	B	B	A	B	A	C	D	C	B	C	A	B	A	B	A	B	A	B	A	B
217	1	C	B	B	B	B		C	B	A	B	A	B	A	B	D	B	B	B	A	B	B	B	A	B	E	C	B	C	C	B	E	B	D	C	E	C	C	C	A	C
218	2	B	B	B	B	A	C	C	C	B	B	B	B	C	B	D	B	B	A	B	A	F	C	F	B	D	C	D	C	D	B	F	C	D	C	B	C	C	B	E	C
219	2	B	A	A	A	E	C	E	C	C	B	D	B	B	A	A	A	B	B	A	B	D	A	E	A	D	A	F	A	E	A	C	A	B	B	G	B				
220	1	C	B	B	B	E	C	B	B	D	C	C	C	C	B	D	B	C	A	E	B	B	A	A	A	E	C	F	C	E	C	E	C	C	B	E	B	C	C	E	C

Students	Gender	1.1.	1.2.	1.3.	1.4.	2.1.	2.2.	2.3.	2.4.	3.1.	3.2.	3.3.	3.4.	4.1.	4.2.	4.3.	4.4.	5.1.	5.2.	5.3.	5.4.	6.1.	6.2.	6.3.	6.4.	7.1.	7.2.	7.3.	7.4.	8.1.	8.2.	8.3.	8.4.	9.1.	9.2.	9.3.	9.4.	10.1.	10.2.	10.3.	10.4.
220	1	C	B	B	B	E	C	B	B	D	C	C	C	C	B	D	B	C	A	E	B	B	A	A	A	E	C	F	C	E	C	E	C	C	B	E	B	C	C	E	C
221	1	D	B	C	B	C	A	E	A	A	C	A	B	C	A	D	A	B	A	E	A	B	C	A	B	D	C	D	C	E	C	E	C	D	C	E	C	C	C	G	B
222	1	D	B	C	B	C	B	E	C	C	B	D	B	B	B	B	B	B	B	B	C	C	C	C	C	C	C	E	B	D	D	D	C	C	C	E	C	C	E	C	C
223	1	D	A	E	A	B	B	F	B	C	B	D	B	B	B	B	B	A	B	B	B	A	B	A	B	C	C	A	C		D		D	C	C	E	C		D		D
224	2	C	B	D	C	C	B	E	A	C	A	D	A	C	A	D	A	B	A	B	B	A	A	A	B	G	C	E	C	B	B	D	B	D	B	E	B	C	B	E	B
225	1	D	A	C	A	B	A	F	A	C	B	D	B	B	A	E	A	E	A	E	A	B	B	A	B	D	C	E	C	B	C	D	C	E	C	C	C	D	B	H	B
226	1	D	B	D	B	A	C	E	C	C	C	D	C	B	B	A	B	B	B	B	B	E	B	E	B	A	D	D	C	D	C	E	C	E	B	C	B	C	C	E	B
227	1	C	C	B	B	D	C	D	C	D	B	C	B	C	A	D	B	B	A	D	B	B	C	A	C	B	C	B	C	C	C	D	C	C	C	E	B	C	B	E	C
228	1	B	C	A	C	B	C	E	B	C	D	D	C	B	D	D	B	A	C	A	C	E	B	E	C	A	C	E	C	E	D	C	C	A	D	E	C	C	C	E	D
229	1	D	B	D	B	C	C	E	A	C	B	D	C	B	A	A	A	B	B	A	B	A	B	A	B	A	D	C	C	A	B	E	C	C	B	E	B	C	B	E	C
230	1	C	C	D	C	A	C	E	C	C	C	D	B	D	B	D	C	E	B	D	B	F	C	C	C	F	D	F	C	E	C	C	B	E	C	C	C	B	C	G	D
231	2	D	B	C	B	G	C	C	B	D	B	C	B	B	A	B	B	B	A	E	A	E	C	E	D	C	C	A	C	C	C	F	B	E	C	D	C	D	B	F	B
232	2	C	A	D	A	B	B	E	A	C	B	D	B	B	B	B	B	A	B	B	A	E	B	E	B	C	C	A	C	B	B	D	B	E	B	C	B	D	B	F	B
233	1	C	B	B	B	A	C	C	D	C	B	D	B	B	C	E	C	B	B	B	B	B	B	A	B	A	D	E	D	C	D	E	D	C	B	E	B	C	C	E	C
234	2	D	B	C	B	C	C	E	C	C	A	D	A	A	A	C	B	B	A	D	A	A	B	A	A	F	B	F	B	B	A	D	A	E	A	C	A	F	B	C	A
235	1	B	B	A	B	B	C	E	C	D	C	C	C	B	C	E	C	C	C	C	C	D	C	A	C	A	C	C	C	A	C	F	C	E	C	C	C	A	C	D	C
236	1	D	B	C	B	C	C	E	B	C	B	D	B	C	B	D	A	C	A	D	B	B	C	E	B	A	C	B	C	C	C	E	C	D	B	A	B	D	B	F	B
237	1	D	C	C	C	E	B	E	B	B	B	B	B	B	C	A	C	D	B	D	B	B	C	B	C	C	C	C	C	C	C	B	F	C	C	C	E	C	A	B	A	B
238	2	D	B	C	A	C		E	A	C	A	D	A	A	A	D	A	C	A	E	A	D	B	C	B	D	C	E	B	B	B	E	C	E	B	C	A	F	C	C	C
239	1	D	B	C	B	C	B	E	B	C	B	D	B	C	B	D	B	C	B	E	B	D	B	C	B	D	B	E	C	B	C	D	C	C	C	E	C	D	B	F	C
240	2	D	A	C	A	D	A	D	A	D	A	C	A	A	B	D	A	D	A	C	A	D	B	C	A	A	B	D	B	B	C	E	C	C	B	E	B	C	B	E	B
241	2	D	A	E	A	C	A	E	A	C	A	D	A	C	A	D	A	C	A	E	A	D	A	C	A	E	B	B	B	B	A	G	A	E	A	C	A	D	A	F	A
242	2	D	A	C	A	C	A	E	A	C	A	D	A	D	A	D	A	C	A	E	A	D	B	C	A	D	A	E	A	E	B	C	B	B	C	D	B	D	B	F	B
243	2	D	C	C	A	C	A	E	A	C	A	D	A	A	A	D	A	B	A	B	A	D	B	C	A	D	B	E	B	E	B	C	B	B	D	D	B	C	B	E	A

Students	Gender	11.1.	11.2.	11.3.	11.4.	12.1.	12.2.	12.3.	12.4.	13.1.	13.2.	13.3.	13.4.	14.1.	14.2.	14.3.	14.4.	15.1.	15.2.	15.3.	15.4.	16.1.	16.2.	16.3.	16.4.	17.1.	17.2.	17.3.	17.4.	18.1.	18.2.	18.3.	18.4.	19.1.	19.2.	19.3.	19.4.	20.1.	20.2.	20.3.	20.4.
1	1	C	B	E	B	C	B	E	B	A	B	A	B	F	C	C	C	A	B	D	C	A	C	A	C	C	C	C	A	C	A	C	C	C	A	B	C	C	A	B
2	1	C	C	D	C	C	C	E	B	D	B	D	B	D	C	E	B	B	B	C	B	D	B	D	B	B	C	D	C	D											
3	1	E	B	B	B	A	C	C	C	A	C	A	C	D	B	D	C	A	B	D	B	D	B	D	B	C	C	A	C	D	B	B	B	C	B	A	B	C	C	B	B
4	1	E	B	D	B	D	B	C	B	A	C	E	C	D	C	E	B	A	B	E	C	A	A	B	C	B	B	B	B	C	B	D	B	C	B	B	A	E	C	E	D
5	2	B	B	A	B	B	B	A	B	D	A	D	A	D	B	C	B	B	B	B	B	A	B			A	C	C	C	D	B	E	B	E	B	E	C	E	B	E	C
6	2	B	C	A	C	B	C	A	C	A	D	E	D	D	A	D	A	B	C	E	C	B	B	C	B	C	B	A	B	C	C	D	C	E	A	B	A	E	A	B	A
7	2	C	B	E	A	A	A	E	A	C	B	B	B	D	A	F	A	B	A	C	A	A	A	D	A	C	A	B	A	B	C	E	C	C	C	F	C	C	A	E	A
8	1	C	C	A	B	C	C	B	C	D	B	D	C	D	C	D	C	A	C	D	C	C	C	B	C	B	C	B	C	B	C	A	C	C	C	A	B	C	C	D	C
9	1	C	B	E	B	D	C	B	B	B	B	A	C	D	B	B	B	A	A	D	B	A	B	A	B	C	B	A	C	D	B	E	B	E	A	B	A	E	B	B	A
10	2	B	B	A	B	B	B	A	B	D	B	D	B	D	B	D	B	A	B	D	B	A	B	A	B	B	B	B	C	A	B	B	B	E	B	E	B	E	B	E	B
11	2	C	B	E	C	C	C	E	B	D	B	D	B	D	A	E	B	A	A	D	A	D	B	D	B	C	B	A	B	D	A	B	B	C	B	B	B	C	C	B	B
12	1	B	C	D	C	E	C	B	C					D	B	B	C	B	B	B	B	B	B	C	B	C	B	A	B					E	B	E	B	E	B	E	B
13	1	C	B	D	C	E	C	B	C	C	C	B	C	D	B	B	B	A	B	D	C	A	C	A	B	D	C	D	C	D	C	B	C	B	C	A	C	E	D	E	C
14	2	B	B	D	C	D	B	C	C	B	C	A	C	D	B	D	B	A	B	D	B	A	B	C	B	B	B	B	B	D	C	B	C	B	C	D	C	E	C	B	B
15	2	C	D	D	A	D	D	E	D	A	B	A	B	D	A	D	D	A	A	D	B	A	C	D	C	E	D	E	D	B	D	A	D	E	D	F		B	D	B	D
16	2	B	B	A	A	B	B	A	A	D	D	B	C	D	B	C	B	A	B	D	B	D	B	D	A	B	C	B	C	D	C	B	C	B	B	A	A	B	B	A	A
17	1	C	C	B	C	C	C	D	D	A	C	A	B	D	B	B	B	D	C	C	C	D	C	B	C	D	D	C	D	D	D	E	C	D	D	B	C	D	C	B	C
18	1	B	B	C	A	B	B	E	A	A	B	C	B	D	A	B	B	B	C	E	C	B	C	C	C	D	C	C	C	D	C	D	C	B	C	D	C	B	C	D	C
19	2	D	C	D	C	C	C	C	C	D	C	D	C	D	B	D	B	A	B	D	B	C	C	D	C	D	C	D	C	C	B	D	B	D	C	D	C	D	C	D	C
20	2	C	A	C	B	C	C	B	C	A	B	C	B	D	B	D	B	B	A	B	A	D	B	D	B	B	B	B	B	C	B	D	B	C	A	C	A	C	C	C	B
21	2	C	B	C	B	C	B	D	B	D	B	D	B	C	C	C	B	A	B	C	B	A	A	A	B	B	B	B	B	C	C	D	C	C	B	C	A	C	A	C	A
22	2	E	A	B	A	A	C	D	B	A	A	C	A	D	A	D	A	B	B	D	B	B	C	B	B	C	B	B	C	B	C	C	C	E	B	B	B	C	B	D	A
23	2	A	A	D	A	D	A	F	A	A	A	A	C	A	A	A	E	A	E	A	F	B	A	A	A	A	D	A	E	B	D	A	E	A	A	A	D	A	A	A	F	A
24	2	B	B	A	B	C	C	E	C	D	C	D	B	D	B	D	B	B	B	D	A	C	A	A	A	A	B	B	B	B	D	B	C	B	E	A	E	A	E	A	E	A
25	2	C	B	D	C	A	A	C	B	D	A	D	A	C	B	C	B	A	A	D	B	A	A	A	B	C	B	A	B	C	C	B	C	E	B	B	E	B	B	B	B
26	1	B	B	A	B	A	C	C	C	D	C	D	C	D	B	B	B	A	B	D	B	A	B	E	B	B	C	B	C	B	B	C	B	B	B	A	B	A	C	C	C
27	2	C	B	A	A	C	C	E	C	D	C	D	B	D	C	D	C	A	C	D	C	A	B	A	B	C	B	A	C	E	B	D	C	E	C	E	C	E	C	E	C
28	1	F	B	F	B	F	C	D	C	D	C	D	C	C	C	C	C	B	D	E	B	A	B	A	B	C	C	A	C	C	D	B	C	B	C	A	C	B	C	A	C
29	1	F	B	D	C	E	B	B	B	D	B	D	B	F	A	C	B	D	C	B	C	A	C	A	C	C	B	A	B	B	A	B	F	B	D	B	E	B	E	B	A
30	1	C	B	A	B	C	B	A	B	B	C	A	C	C	B	B	B	A	B	D	B	D	B	D	B	A	B	D	B	B	C	C	C	B	D	A	C	B	D	C	C
31	2	D	C	A	C	D	C	C	C	C	B	B	C	A	B	E	C	B	C	D	C	A	B	B	C	B	B	B	B	A	C	A	B	C	B	B	B	C	B	C	B
32	1	C	B	C	B	C	B	B	B	A	B	A	B	D	B	C	B	A	B	D	B	A	B	A	B	B	B	B	B	B	C	A	C	C	B	C	B	D	C	A	B
33	1	E	D			E	C	D	C	D	C	D	C	D	B	D	C	A	B	D	B	A	C	A	B																
34	1	D	C	D	C					A	C	A	C	D	B	B	B	B	B	E	B	A	C	A	C	D	C	C	C	B	C	C	C								
35	2	F	A	D	B	A	B	C	B	D	A	D	A	C	B	C	B	A	B	D	B	A	B	E	B	B	B	A	B	B	B	C	B	F	B	F	B	A	B	C	B
36	2	F	E	F	C					A	C	A	B	E	C	B	C	B	C	C	B	A	C	A	B	B	B	B	C	D	B	E	B					F	C	B	C
37	2	A	A	E	A	E	B	B	A	B	B	C	B	B	B	D	B	B	A	B	B	C	A	B	A	B	A	B	A	C	B	B	A	A	A	E	A	E	B	C	B
38	2	C	C	A	C	D	D	C	D	A	B	C	B	A	C	E	C	B	B	C	C	A	C	A	C	B	C	C	C	C	C	C	B	C	B	C	C	C	C	C	B
39	1	C	C	C	C																																				
40	1	A	C	E	C	E	C	D	C	D	B	F	D	B	D	D	C	A	B	E	D	B	C	E	D	A	B	C	C	D	A	E	B	B	C	D	B	E	D	C	C
41	1																													E	B	D	C					F	C	D	C
42	1	C	B	A	B					D	C	D	C	E	C	B	C	A	C	D	C																				
43	2	C	C	C	C	C	C	E	C	E	B	F	C	D	C	F	C	A	C	E	C	A	B	A	B	D	C	C	C	A	C	C	C	B	C	A	C	C	C	D	C
44	2	E	C	C	C	D	D	E	D	A	D	A	C	F	C	F	B					C	C	C	C									B	D	E	C	B	D	D	D
45	2	A	B	E	B	D	B	D	B	B		C	B	C		C	B	B	B	E	B	B		C	B	D	B	D	B	B	B	B	B	A	B	D	B	F			B
46	2	F	C	D	B	C	C	E	B	C	C	F	C	C	A	B	A	B	C	E	C	D	C	D	B	B	C	B	B	B	C	A	C	D	C	D	C	C	B	D	C
47	1	B	C	D	C	D	C	D	C	D	C	D	C	D	B	E	C	A	B	D	B	A	C	D	D	B	C	C	D	C	C	D	C	B	C	D	C	F	D	D	C
48	1	F	C	B	B	D	B	E	D	E	C	A	C	B	D	C	D	E	D	F	D	A	B	E	D	E	D	E	D	F	C	D	C	E	B	F	C	F	C	B	C
49	1	C	C	C	D	C	D	D	D	D	C	D	C	D	A	D	B	A	B	D	C	A	C	A	D	C	B	A	B	B	D	A	D	F	D	F	D	B	C	D	C
50	2	B	A	B	A	B	A	C	A	A	A	A	A	B	A	D	A	D	A	B	A	A	A	A	A	B	A	B	A	B	A	C	A	B	A	D	A	C	A	E	A
51	1	C	A	A	A	E	A	D	A	D	A	D	A	D	A	D	A	D	A	B	A	C	C	B	C	C	A	A	A									C	A	D	A
52	1	A	C	E	C	C	B	B	C	D	B	D	B	C	B	C	B	B	B	B	C	B	D	B	D	B	B	C	D	C	D	B	E	B	F	C	D	C	B	C	D	D
53	1	A	C	E	C	C	C	B	C	D	B	D	B	C	B	C	B	A	B	D	B	D	B	D	B	B	B	D	D	C	B	E	D	E	D	F	D	B	C	D	D
54	1	C	B	C	C	D	C	B	D	A	B	A	B	C	C	D	D	A	B	D	C	C	C	B	D	D	D	C	C	C	C	B	C	C	B	D	C	C	C	D	C
55	1	C	C	D	C	D	C	D	C	D	C	D	C	C	C	D	C	A	C	D	C	C	C	B	C	C	C	A	C	B	C	B	C	C	B	D	C	C	C	D	C
56	1	C	B	A	B	D	B	C	B	A	B	E	B	C	B	C	B	A	B	D	B	D	B	D	B	B	B	B	B	B	B	B	C	B	C	B	D	B	C	B	D	B
57	2	B	B	B	B	C	B	A	C	A	C	C	C	E	B	B	B	A	B	D	B	A	B	A	B	B	B	B	B	A	C	C	D	C	B	D	B	C	C	C	C
58	2	D	B	D	B	C	C	E	B	A	C	D	C	D	B	B	B	A	B	D	B	A	C	A	A	D	C	C	C	E	B	D	B	C	B	A	D	D	D	B	D
59	1	C	C	A	C	C	D	A	D	A	D	A	C	D	B	D	B	B		B	C	B	D	C	D	C	D	C	D	B	C	C	D	C	D	A	D	C	D	A	D
60	1	B	C	A	C	E	C	B	C	A	C	C	C	E	C	B	C	B	C	E	C	B	B	C	B	D	C	C	C	B	C	A	C	B	C	D	C	E	C	C	C
61	1	C	A	C	A	D	A	A	B	A	A	A	A	C	C	B	B	A	A	D	B	B	A	C	B	C	B	A	B	B	B	A	B	D	B	B	B	C	B	B	B
62	1	C	B	E	B	E	B	B	B	A	C	A	C	E	C	B	B	B	B	B	B	A	B	A	B	B	B	B	B	C	C	B	C	C	B	C	B	E	B	E	B
63	1	C	B	A	A	D	D	B	C	A	C	A	C	A	C	B	B	A	C	B	A	C	A	A	D	D	C	B	C	B	B	B	B	A	B	D	C	C	C		
64	2	E	A	F	B	A	A	F	A	A	C	A	C	C	B	C	C	B	B	C	B	B	A	C	A																
65	1	F	B							A	B	A	B	A	B	E	B	A	B	D	B	D	B	D	B	B	B	B	B	B	C	C	C								
66	1	C	C	B	C	E	B	D	B	D	B	D	B	B	C	C	B	A	B	D	B	B	C	C	C	B	C	B	C	B	C	A	C	E	C	E	C	C	C	B	C
67	1	B	C	B	B					C	C	E	C	C	B	C	B	A	B	D	B	B	B	B	C	B	C	B	C	F	C	C	C	B	C	F	C	C	C	B	C
68	2	B	A	D	B	C	B	C	C	D	B	D	B	C	A	C	A	A	B	D	A	A	A	B	A	B	B	C	B	B	A	C	A	B	A	D	B	C	B	D	C
69	2	C	A	C	B	C	C	E	B	A	A	A	A	B	C	C	B	A	B	D	B	C	B	A	C	B	B	C	B	B	A	C	C	D	C	D	B	C	C	D	B
70	1	C	B	C	B	D	B	D	B	C	C	B	C	D	C	B	C	E	C	C	C	B	B	C	B	E	B	E	B	B	C	E	D	B	C	A	B	C	B	A	B
71	1	D	D	D	D	A	D	C	D	B	D	C	D	D	C	A	C	A	C	C	C									D	D	D	D	D	D	B	D	A	D	B	D
72	1	F	A	B	A	F	A	C	A	A	A	A	A	D	A	F	A	B	A	C	A	A	A	A	A	D	A	E	A	E	A	D	A	C	A	A	A	D	A	A	A
73	2	D	B	D	B	E	C	B	B	A	C	A	C	C	B	D	B	B	B	B	B	B	C	C	C	D	B	C	B	D	B	E	B	C	C	B	C	B	C	D	C
74	1	C	B	D	C	C	B	B	B	B	C	C	C	C	A	C	A	A	A	D	A	B	B	B	B	B	B	B	B	E	C	C	B								
75	1	C	B	C	B	D	B	B	C	C	B	B	C	C	B	C	C					A	C	A	C	B	B	B	B	C	C	D	C	C	B	A	C	C	C	A	C
76	1	B	C	F	C	B	C	C	C	A	C	C	C	B	B	D	B	A	B	D	B	A	C	A	C	E	C	A	C	A	C	A	C	B	B	B	C	B	C	D	C
77	1	D	B	A	B	E	D	D	D	A	D	C	D				D	D	B	D	B	D	C	D	A	D	D	D	E	D	D	D	D	C	D	C	E	C	C	D
78	2	B	B	A	A	C	B	B	B	A	B	E	B	D	A	D	B	B	B	E	B	A	B	A	B	B	C	B	B	C	C	B	C	C	B	A	B	F	B	C	B
79	2	B	B	A	B	D	B	C	C	D	B	D	C	B	B	B	E	B	D	C	D	C	B	B	B	E	D	C	C	C	B	B	B	D	C	B	C	B	C	D	C
80	1	B	B	A	A	E	B	B	B	B	C	C	C	C	B	C	B	A	B	D	B	A	B	A	B	A	B	D	B	A	B	C	B	B	B	D	B	B	C	C	C

Students	Gender	11.1.	11.2.	11.3.	11.4.	12.1.	12.2.	12.3.	12.4.	13.1.	13.2.	13.3.	13.4.	14.1.	14.2.	14.3.	14.4.	15.1.	15.2.	15.3.	15.4.	16.1.	16.2.	16.3.	16.4.	17.1.	17.2.	17.3.	17.4.	18.1.	18.2.	18.3.	18.4.	19.1.	19.2.	19.3.	19.4.	20.1.	20.2.	20.3.	20.4.
80	1	B	B	A	A	E	B	B	B	B	C	C	C	C	B	C	B	A	B	D	B	A	B	A	B	A	B	D	B	A	B	C	B	B	B	D	B	B	C	C	C
81	1	B	A	A	A	B	A	A	A	C	C	B	B	C	B	C	B	A	B	D	B	A	B	A	B	A	B	D	B	A	B	A	B	B	B	A	B	B	C	A	C
82	1	E	C	E	C	C	B	E	B	A	B	C	B	E	B	B	B	A	B	E	B	A	B	A	B	D	B	C	B	B	B	C	B	C	C	C	C	D	C	C	C
83	2	C		D	B	C	C	E	B	D	A	D	B	C	B	C	B	A	B	D	B	D	B	D	B	B	C	C	C	C	B	B	B	C	B	D	B	C	B	D	C
84	1	B	B	A	A	B	A	A	A	A	C	A	B	D	A	D	A	A	A	E	A	C	A	B	A	D	B	C	B				B	C	A	C	B	C	A	C
85	2	A	C	E	C	C	C	D	C	A	B	A	C	B	B	D	B	A	A	D	B	C	B	B	B	A	B	D	C	A	C	C	C	B	C	A	C	D	C	C	C
86	2	E	C	D	C	A	B	C	A				F	A	C	A	B	B	E	B	B	B	E	B	A	C	A	C	B	C	B	C	D	C	E	C					
87	1	A	E	A	D	A	F	A	B	A	C	A	A	A	E	A	B	A	B	B	A	C	A	B	B	C	A	C	A	C	A	D	A	C	A	D	A	C	C	D	C
88	1	C	A	E	A	E	A	B	A	A	A	C	A	D	A	F	A	B	B	E	B	D	C	D	A	A	B	D	A	B	C	C	C	C	A	C	A	E	B	B	B
89	2	B	B	A	B	A	B	C	B	D	B	D	B	D	B	D	C	B	A	E	B	E	B	C	B	B	B	B	B	B	C	C	C	C	C	C	C	C	C	C	C
90	1	C	B	E	B	A	B	F	B	D	B	D	B	F	B	C	C	A	B	D	B	E	C	D	B					C	C	D	C	E	B	E	B	E	B	E	B
91	1	C	B	E	B	B	B	E	B	D	B	D	B	D	B	A	B	A	B	D	B	E	B	E	B					B	B	C	B	C	B			E	B	D	C
92	2	C	C	C	C					A	A	A	A	F	B	D	B	B	A	B	A	A	A	A	A	B	A	B	A												
93	1	B	C	D	B	B	C	A	C	D	B	C	B	C	B	C	B	B	B	B	B	B	A	B	A	B	C	B	A	C	B	B	C	C	E	C	D	B	E	C	E	B
94	1									D	C	D	C	D	D	C	C	B	B	E	C	A	B	A	B	D	B	C	B												
95	1	E	B	B	B	E	B	D	B	A	B	A	B	C	B	C	B	A	B	E	B	A	B	A	B	B	B	B	B	F	B	F	B	B	B	A	B	B	B	A	B
96	1	C	B	C	B	D	C	B	C	D	C	D	C	F	B	B	C	A	C	D	C	D	C	D	C	E	C	D	C	D	C	F	C	C	B	F	C	F	C	C	B
97	2	B	B	A	B	E	B	B	B	A	C	A	C	D	A	D	A	A	A	D	A	B	C	C	C	A	C	D	B	E	B	D	B	B	B	C	B	B	C	A	C
98	2	A	C	F	A																																				
99	1	B	B	A	A	B	B	A	B	A	C	E	B	B	B	D	B	B	B	B	B	A	B	A	C	B	B	B	B	B	C	A	C	B	C	A	B	B	B	A	B
100	2	B	B	D	B	A	B	E	B	D	B	D	B	C	B	C	B	A	B	F	B	C	B	B	B	C	B	C	B	E	C	D	B	B	B	D	C	A	B	D	C
101	2	B	B	A	A	C	B	E	B	B	A	D	B	A	A	E	A	A	B	D	B	D	B	D	C	A	C	D	B	E	B	D	B	C	B	A	B	D	C	D	C
102	2	A	B	D	B					D	A	D	A	B	C	D	C	D	C	B	D									B	C	C	C								
103	2	C	C	A	C	D	C	A	C	C	C	B	C	E	C	B	C	A	C	D	C	B	A	C	C	B	D	B	D	C	C	B	D	B	B	A	B	B	B	A	B
104	1	D	B	D	B					B	C	A	C	D	C	D	C	B	C	E	C	A	C	A	C	B	C	B	C	C	C	B	C	B	D	A	D	B	D	A	D
105	1	B	C	A	B	C	C	A	C	D	C	D	C	C	B	C	B	A	B	D	C	D	B	D	C	C	A	C	E	D	B	D	C	C	C	B	C	C	A	C	C
106	1	C	B	D	C	B	C	A	C	A	B	A	B	E	B	B	B	B	C	A	C	B	C	C	C	D	C	B	C	B	C	D	C	C	B	D	B	B	C	C	C
107	1	C	C	D	C	B	C	A	C	A	A	C	A	C	B	B	B	B	C	A	C	C	C	C	C	D	C	B	C	B	B	D	B	C	B	D	B	D	C	D	D
108	2	C	A	D	A	A	A	C	A	A	A	A	A	A	A	E	B	B	A	A	A	A	A	A	A	B	B	B	B	C	B	B	B	C	B	E	B	E	E		D	B
109	1	B	A	A	A	C	A	A	A	D	A	D	A	E	A	B	A	B	A	B	A	E	A	D	A	A	A	D	A	A	A	A	A	D	A			B	A	D	A
110	1	D	D	E	D	C	D	E	D	B	C	C	D	B	C	D	C	A	C	E	C	B	D	C	D	A	D	D	D	D	D	E	C	C	D	D	D	B	D	D	D
111	1									B	D	A	D	D	A	A	A	B	D	A	D	B	D	C	D	B	A	B	A	A	B	A	B	F	C	A	B	F	C
112	1	B	C	A	C	B	C	C	C	B	C	C	C	C	C	C	C	B	C	E	C	D	C	D	C	A	C	D	C	C	C	D	C	B	C	A	C	E	D	C	C
113	2	C	B	A	B	C	B	A	B	A	B	A	B	A	C	E	C	B	C	A	C	A	C	A	C	A	C	B	C	B	C	C	C	B	C	C	C	A	C	C	C
114	2	B	B	A	C	A	D	B	C	C	C	E	C	E	C	B	B	D	A	B	D	D	D	D	B	B	B	B	D	B	E	D	E	C	C	C	E	D	E	C	C
115	1	C	B	E	D	A	D	F	D	A	C	E	D					B	C	C	D	A	D	A	D	B	C	B	D	D	D	E	D	E	B	B	D	E	D	E	D
116	1	F	A	F	A	F	C	F	C	A	B	A	B	D	B	C	B	A	A	D	A	E	B	E	B	B	B	B	B	B	C	D	C	F	C	F	C	B	C	F	C
117	1	E	A	B	B	B	B	E	B	B	C	A	C	A	B	E	C	A	A	D	A	A	C	A	C	D	C	C	C	E	C	E	C	B	B	B	B	C	B	A	C
118	1	C	C	E	C	C	C	B	C	A	C	C	D	D	C	D	C	B	B	C	C	A	B	A	B	B	C	B	C	C	C	B	C	C	C	C	C	C	C	D	C
119	1	C	C	E	C	C	C	B	C	A	D	C	D	D	C	D	C	A	C	C	C	A	B	A	B	B	C	B	C	C	C	B	C	C	C	C	C	C	C	D	C
120	1	C	B	D	B	E	B	D	B	A	C	A	C	D	B	D	B	A	B	D	B	B	B	C	B	B	C	B	C	A	C	E	C	C	C	D	C	C	C	D	C
121	1	C	B	B	B	A	B	C	B	A	B	A	B	D	C	D	C	B	B	D	B	D	B	C	C	B	B	B	B	B	C	C	C	C	B	D	B	A	C	D	B
122	1	C	C	E	C	C	C	B	C	B	C	C	C	C	B	C	C	A	B	E	C	B	C	C	C	D	C	C	C									A	C	D	C
123	1	C	A	E	A	E	A	B	A	A	A	A	A	E	A	B	A	B	A	A	A	A	A	A	A	A	B	A	B	A	E	C	B	B	C	A	C	A	C	B	C
124	1	B	C	C	C	C	B	E	A	B	B	E	B	E	B	B	B	A	B	D	B	B	C	C	B	D	D	C	C	A	B	D	B	B	D	A	B	C	C	A	B
125	2	E	A	B	A	A	A	E	B	D	A	D	A	A	A	E	B	B	A	B	B	A	A	A	A	C	A	A	A	B	C	C	C	D	A	B	A	A	A	B	A
126	1	B	B	A	C	E	B	D	B	A	C	C	C	C	B	B	B	A	B	D	B	B	B	C	B	B	B	B	B	B	B	A	B	B	B	B	B	B	B	B	B
127	1	B	B	A	B	D	C	D	C	A	B	A		A	B	E	B	A	B	D	C	A	B	B	C	B	C	D	C	B	C	B	C	C	C	D	C	C	B	A	C
128	1	B	B	A	B	D	C	D	C	A	B	A	B	A	B	D	B	A	B	D	C	B	C	C	C	D	C	C	C	B	C	B	C	C	C	D	C	B	C	A	C
129	2	B	B	E	C	D	B	C	B	A	C	A	C	C	B	B	C	A	B	D	C	B	B	C	C	C	C	B	C	C	C	B	C	B	B	B	C	B	B	B	B
130	1	A	B	C	A	B	A	A	A	A	A	A	C	A	D	A	D	A	A	A	E	A	D	A	B	A	B	A	B	A	D	B	C	B	A	A	F	A	A	A	A
131	2	C	A	C	A	A	C	E	C	D	B	F	B	C		G	A	A	A	E	A	E	A	E	A	B	A	B	A	B	A	A	A	D	A	D	A	E	A	E	A
132	2	C	C	D	C	A	C	C	C	A	C	A	C	D	B	D	C	A	B	D	B	B	C	A	C	B	C	B	C	C	C	C	C	C	B	D	C	C	C	D	C
133	1	E	C	B	C	A	B	C	B	A	B	A	B	B	C	D	C	B	D	B	D	B	D	C	D	A	D	D	D	A	D	A	D	A	D	D	D	A	D	E	D
134	1	C	B	E	B	A	D	B	C	C	C	B	C	E	B	B	B	A	B	D	B	A	C	A	C	A	C	D	C	B	D	C	C	C	C	D	C	E	D	B	C
135	2	B	B	F	B	D	B	B	B	B	B	E	B	C	B	C	B	A	B	D	B	C	B	B	B	D	C	D	C	A	B	C	B	B	B	A	B	B	C	D	C
136	1													C	C	F	C	B	C	E	C	A	C	A	C	B	C	B	C												
137	1	C	B	C	B	C	B	E	B	A	B	A	B	D	B	D	B	A	B	D	B	C	C	C	C	B	B	B	B	C	C	D	B	B	B	D	B	C	B	D	B
138	1	C	B	C	B	C	B	E	B	A	B	A	B	D	B	D	B	B	B	B	B	B	A	C	A	C	A	C	D	C	C	C	D	C	B	C	D	C	B	C	D	C
139	1	A	B	E	B	D	B	B	B	A	B	A	B	D	B	B	B	B	C	B	C	B	C	B	C	B	D	B	D	B	D	B	D	B	B	D	B	C	C	D	B
140	2	B	B	A	B	E	B	D	B	A	B	A	A	C	B	B	B	B	C	D	B	B	B	C	B	C	B	A	A	E	B	E	B	D	B	E	B	D	C	E	C
141	1	C	B	F	B	D	B	B	B	E	B	F	B	D	C	D	C	A	B	D	B	D	B	D	B	B	B	B	B	E	B	E	B	C	B	C	B	F	C	C	C
142	2	C	B	A	B	A	B	C	A	C	B	B	C	C	B	B	B	A	A	A	B	C	C	C	B	A	A	B	C	D	B	E	B	A	B	C	A	C	C	A	C
143	1	C	C	D	C	C	C	E	C	B	C	A	C	D	B	D	B	A	B	D	B	D	C	D	C	C	C	A	C	C	B	E	C	E	B	B	B	E	B	B	B
144	1	C	A	B	A	C	A	E	A	D	A	D	A	C	A	C	A	A	A	E	A	B	A	C	D	D	D	C	D	B	A	A	A	C	A	A	A	C	A	A	A
145	1	B	C	A	B	B	B	A	B	A	B	A	B	D	B	F	B	B	B	B	B	D	B	D	A	B	B	B	B	B	A	C	B	E	B	E	A	E	B	E	A
146	1	B	B	E	B	D	B	D	C	D	B	D	B	D	B	D	B	A	D	A	D	A	D	B	B	B	B	B	B	B	A	D	C	B	B	C	B	C	B	E	C
147	1	B	B	D	A	D	C	D	C	D	C	D	C	D	B	D	A	A	A	D	A	D	B	D	B	B	B	B	A	D	C	E	C	C	A	B	A				
148	2	A	B	E	C	E	B	D	B	C	B	B	B	B	C	F	C	B	C	E	C	B	B	C	B	A	B	D	B	C	B	B	B	A	B	D	B	D	B	D	B
149	2	C	C	E	C	C	C	E	C	A	C	E	A	E	A	B	A	A	A	E	A	B	A	C	A	B	C	B	A	D	C	E	A	C	A	E	A	C	A	A	A
150	1	A	C	C	B	D	C	B	B	A	B	A	B	C	A	B	A	A	B	D	B	A	B	A	B	B	B	B	B	B	B	C	D					F	B	C	B
151	1	B	B	A	B																									E	B	D	B	B	B	A	B	B	B	A	B
152	1	A	C	E	B	D	C	B	B	A	B	A	B	C	A	C	A	A	A	D	B	A	B	A	B	B	B	B	B	B	B	D	C	F	B	B	B	F	B	C	B
153	1	A	C	C	B	C	C	B	B	A	A	A	A	C	A	C	A	A	A	D	B	A	B	A	B	B	B	B	B	A	B	A	D	F	B	B	B	F	B	C	B
154	1	D	B	D	B					B	D	A	A	C	B	C	B	A	B	D	C					B	C	B	C	D	B	E	B	B	B	A	B				
155	1	D	C	D	C	F	B	B	B	C	C	B	C	C	C	C	A	A	D	A	B	B	C	B	B	B	B	E	B	D	B	B	D	B	F	C	C	C
156	2	C	B	E	B	C	C	E	C	A	C	C	B	A	D	E	D	B	D	B	D	B	B	C	B	B	B	B	B	A	C	A	B	C	B	D	B	C	B	D	B
157	1	B	A	A	A	C	B	B	B	E	B	B	B	D	B	G	B	A	B	D	B	A	B	A	B	B	B	B	B	C	B	B	B	D	B	B	B	C	B	C	B
158	1	D	B	D	B	C	B	E	B	D	B	D	B	D	B	D	B	B	B	C	C	C	C	B	A	B	C	B	B	D	A	E	B	B	B	A	B	E	B	E	B
159	1	B	B	A	B	A	C	C	D	E	B	C	B	A	B	E	B	B	C	C	B	A	C	B	C	D	C	C	D	A	C	C	C	E	B	E	C	E	D	E	C
160	1	B	C	D	C	F	B	B	B	C	C	B	C	C	C	C	C	A	A	D	A	B	B	C	B	B	B	B	B	C	B	B	B	B	B	B	B	F	C	C	C

Students	Gender	11.1.	11.2.	11.3.	11.4.	12.1.	12.2.	12.3.	12.4.	13.1.	13.2.	13.3.	13.4.	14.1.	14.2.	14.3.	14.4.	15.1.	15.2.	15.3.	15.4.	16.1.	16.2.	16.3.	16.4.	17.1.	17.2.	17.3.	17.4.	18.1.	18.2.	18.3.	18.4.	19.1.	19.2.	19.3.	19.4.	20.1.	20.2.	20.3.	20.4.
161	1	B	B	C	D	C	B	E	B	D	B	D	B	D	B	D	B	B	C	C	C	C	B	A	B	D	C	C	B	D	A	E	B	B	A	D	C	E	B	E	B
162	2	C	C	C	B	C	C	E	B	B	B	A	C	D	B	B	C	A	B	D	B	A	C	A	C	B	C	B	B	C	A	D	C	B	B	D	B	A	B	D	B
163	2	F	B	D	B					D	B	D	B	C	B	C	B	B	B	B	B	D	B	D	B					D	B	E	B	F	B	D	B	A	B	D	B
164	2	C	C	B	C	C	C	B	C	D	B	D	B	C	B	C	B	A	B	D	B	B	B	B	B	B	B	B	B	E	C	C	C	F	C	A	C	D	B	C	B
165	1	C	C	D	B	C	C	B	C	C	C	B	C	C	B	C	B	A	B	D	B	D	B	D	B	B	C	D	C	D	C	E	C	E	C	E	C	C	B	D	B
166	2	C	A	C	B	D	A	D	A	A	A	A	A	C	A	C	A	A	A	D	A	B	A	C	B	B	B	A	B	B	C	A	B	C	B	B	B	D	B	D	B
167	2	C	B	E	B	C	B	E	B	D	B	D	B	E	B	B	B	B	B	E	B	D	B	D	B	B	B	B	C	B	D	B	E	B	B	B	B	E	B	B	B
168	1																					A	B	A	C					C	C	B	C	E	C	E	C	E	C	E	C
169	1	C	C	A	C	C	C			A	C	A	C	C	B	C	B	B	C	B	C	A	C	A	C	B	C	B	C	A	C	E	C	C	C	A	C	C	C		
170	2	B	B	A	A	B	B	A	B	C	B	B	B	D	C	F	C	B	C	C	D	C	B	B	C	E	C	C	B	A	D	A	C	B	B	A	B	B	A	B	B
171	1	C	A	C	C	D	B	B	C	C	B	B	B	D	A	D	B	A	B	E	C	A	B	A	C	C	C	C	D	D	C	B	B	E	D	A	D	B	D	D	C
172	1	C	A	F	A	D	B	B	B	C	B	B	C	D	A	D	B	B	A	E	B	A	B	A	B	C	C	C	D	D	C	E	B	E	D	E	D	B	D	D	C
173	1	D	C	D	C	B	C	A	D	B	B	C	B	D	B	D	B	B	C	B	C	B	C	C	C	D	B	C	B	A	B	A	B	C	B	C	B	B	C	A	B
174	1	C	B	F	B	D	B	B	B	D	B	F	B	D	C	D	C					A	C	A	C	C	C	D	C												
175	1	A	C	B	C	A	C	B	C	A	C	A	C	C	B	C	C	B	C	B	C	B	C	C	C	A	C	D	C	B	C	C	C	B	C	A	C	E	C	E	C
176	1	B	B	C	B	C	B	B	B	D	B	D	B	D	A	D	A	A	A	E	A	A	B	A	B	D	B	C	B	A	C	A	B	C	B	D	B	F	B	D	B
177	2	B	B	C	B	C	B	B	C	D	B	D	B	D	A	D	A	A	A	E	A	A	B	A	B	D	B	C	B	A	C	A	B	C	B	D	B	F	B	D	B
178	2	C	B	A	B	D	C	B	B	C	B	B	B	D	A	D	B	B	A	B	A	C	A	D	A	B	A	B	B	B	C	C	B	C	C	A	B	D	B	C	B
179	2	C	C	B	C	B	C	A	C	B	B	E	C	D	B	D	B	B	B	B	A	A	A	A	A	B	C	B	B	E	C	D	B	C	C	B	B	B	C		
180	2	D	B	D	B	B	B	A	B	D	B	D	B	A	B	E	B	A	C	D	C	A	B	A	B	C	B	A	B	D	B	E	B	B	B	A	B	B	B	A	B
181	1																																								
182	1	C	B	A	B	D	A	C	C	C	C	B	D	C	B	C	B	A	B	D	B	A	A	E	C	A	D	D	D	A	D	E	D	D	C	D	D	B	D	D	D
183	2	A	A	E	A	A	A	C	A	D	A	D	A	C	C	C	C	A	A	D	B	B	B	C	B	B	B	D	B	C	C	D	B	B	C	D	B	B	A	D	A
184	1	E	A	C	A	C	A	E	A	D	B	D	B	E	C	B	C	B	B	B	B	B	B	C	B	B	B	C	B					D	B	B	B	E	B	E	B
185	2	F	B	B	B	A	B	F	B	D	A	D	B	C	B	C	B	A	B	D	C	D	B	B	B	B	B	B	B	B	B	C	B	F	B	F	B	D	B	D	B
186	1	C	A	C	A	A	A	C	B	D	A	D	A	D	A	D	B	B	A	E	B	D	A	D	A	C	B	A	B	B	A	E	B	E	A	B	A	E	A	B	A
187	1	C	D	E	D					B	D	C	D													B	D	B	D	C	D	D	D								
188	1	C	B	E	B	B	B	C	B	B	C	C	C	D	B	B	C	A	C	D	D	A	C	C	C	B	C	B	C	C	C	D	C	B	C	D	C	C	C	D	D
189	2	C	B	C	C	C	B	C	B	A	A	A	C	B	D	B	A	C	B	C	C	B	B	C	B	A	D	D	D	D	B	E	C	E	B	E	B	E	B	E	B
190	2	C	D	C	D	E	D	B	D	D	C	D	D	E	B	B	C	A	A	D	A	B	C	C	C	A	D	D	D	D	C	E	C	B	C	D	C	C	C	C	C
191	1	C	B	C	B	A	B	C	B	A	A	A	A	E	A	B	A	D	B	B	B	A	A	B	A	A	A	A	A	C	B	B	B	C	A	C	C	B	B	A	C
192	1	C	B	C	D	C	C	B	C	D	C	D	C	E	B	B	C	A	A	D	A	C	D	B	D	A	D	D	D	D	D	E	C	B	D	D	D	C	D	B	D
193	1	F	C	D	C	E	B	B	B	C	B	B	B	C	A	C	B	A	A	D	A	A	A	A	A	B	B	B	A	F	C	C	B	E	B	E	B	E	B	C	B
194	2	C	B	E	C	E	C	D	D	D	C	E	D	C	C	D	B	B	B	C	B	C	C	B	C	A	B	D	C	B	C	E	C	C	B	D	D	A	C	B	C
195	2	C	B	C	B	B	C	E	C	C	C	B	C	A	C	E	C	A	C	D	C	C	C	C	C	C	C	C	C	C	B	C	C	C	D	C	D	C	D	C	C
196	2	F	B	F	B	B	A	A	A	B	C	D	C	E	C	B	C	C	C	A	C	A	A	B	A	B	B	B	B	D	B	C	B	A	B	B	C	A	A	A	A
197	2	B	B	A	B					C	C	B	C	A	B	D	B									B	B	B	B					B	B	A	B	B	A	A	A
198	2	B	B	A	B	B	B	A	B	C	C	B	C	D	B	B	B	A	B	D	B					B	B	B	B	B	B	C	B	D	B	B	B	B	A	B	
199	2	C	B	F	A	B	B	D	A	C	B	E	A	C	A	C	B	B	A	F	B	C	B	D	A	B	B	B	B	C	A	C	B	B	B	E	C	D	D	F	D
200	2	A	B	C	B	C	B	C	A	B	C	A	A	B	D	B	A	B	C	C	A	A	A	D	D	A	B	C	C	E	C	C	A	D	A	C	B	C	A	D	A
201	2	C	C	B	C	D	B	D	C	A	C	E	C	B	D	A	C	A	A	D	A	A	C	B	C	C	A	D	B	C	B	D	C	B	D	C	C	C	C	C	E
202	2	C	C	A	D	C	C	D	D	D	C	E	D	D	C	E	D	A	B	D	D	B	C	A	D	C	C	B	D	C	D	D	C	B	D	D	D	C	D	E	C
203	1	C	C	D	C	B	C	C	C	A	B	A	C	C	C	F	C	C	B	B	E	C	B	C	C	C	B	C	B	C	C	C	D	C	B	C	D	C	B	C	B
204	1	D	C	E	C	C	C	D	C	D	C	C	C	B	C	D	C	C	C	C	C	C	B	C	B	C	D	C	D	C	C	C	B	C	D	C	D	C	C	C	C
205	1	D	C	D	C	C	C	B	C	D	B	D	B	C	A	C	A	A	A	D	B	A	B	A	B	B	B	B	B	C	B	B	B	C	B	C	B				
206	1	C	B	D	C					D	B	D	B	C	B	C	B	A	B	D	B	A	B	A	B	B	B	B	B	C	B	B	B	C	B	D	B				
207	1	D	B	D	B	E	B	D	B	D	A	D	A	C	A	C	A	A	A	D	B	A	A	A	B	B	B	B	B	C	B	D	B	C	B	D	B	C	C	C	C
208	1	C	B	E	B	E	B	D	B	D	B	D	B	C	B	C	B	A	B	D	B	A	A	A	B	B	B	B	B	C	B	D	B	C	B	D	B	C	B	D	B
209	2	B	B	A	B	B	B	A	C	A	B	E	B	A	B	E	C	D	B	B	B	B	B	C	D	B	C	C	B	B	B	C	C	D	D	B	C	B	B	A	C
210	2	C	D	C	D	B	D	C	D	C	D	B	D	C	D	C	D	C	D	D	D	B	D	A	D	A	D	D	C	D	B	D	B	D	A	D	D	D	C	D	
211	1	C	C	D	C	C	C	E	C	D	C	D	C	A	C	E	C	B	C	C	C	B	C	C	C	D	C	B	C	D	C	E	C	C	C	D	C	C	C	C	C
212	2	E	D	C	C	C	C	E	B	C	C	B	C	D	B	E	B	B	A	C	B	B	C	C	D	B	D	B	D	C	A	D	B	C	D	D	D	C	D	D	D
213	2	E	B	B	B	A	C	C	C	A	B	A	B																												
214	1	C	C	C	C	B	C	C	C	C	C	C	E	C	E	C	B	B	C	C	C	C	B	C	C	C	B	C	B	C	C	C	B	C	B	C	B	C	B	C	C
215	1																																								
216	1	B	B	A	A	B	B	A	B	A	B	A	B	B	B	D	B	A	B	D	C	B	B	C	B	B	B	B	C	B	B	A	B	B	B	A	B	B	B	A	B
217	1	D	B	D	B	A	B	C	B	A	B	A	B	E	B	A	B	B	B	B	B	B	C	B	B	B	B	F	B	B	B										
218	2	D	C	D	C	C	C	E	C	D	C	D	C	A	C	E	C	B	C	B	C	B	C	C	C	B	C	B	C	D	C	E	C	C	C	C	C	B	C	C	C
219	2	F	C	F	B	E	A	D	A	B	A	C	A	E	A	B	B	A	A	D	A	D	A	D	A	B	A	B	A	B	A	A	B	C	A	C	A	E	C	E	C
220	1	C	B	C	B	D	C	E	B	A	B	C	B	F	A	C	C	A	A	D	A	B	B	C	B	A	C	D	C	B	C	C	C	A	B	D	C	B	C	D	
221	1	F	D	E	D	A	B	C	B	A	B	A	A	E	A	B	B	A	B	D	B	B	B	C	C	B	C	B	B	A	C	F	D	C	C	D	D	F	D	F	D
222	1	B	D	A	C	C	D	E	C	D	D	D	D	A	C	B	D	A	C	D	C	C	C	B	C	D	D	C	D	E	D	B	D	B	D	D	D	B	D	D	D
223	1	C	B	C	C	C	B	E	C	A	C	A	C	F	A	D	B	A	A	D	B		D		D	C	C	A	C	B	C	C	C	B	C	D	C	C	C		C
224	2	F	C	D	B	D	B	D	C	D	A	D	A	D	A	D	C	A	B	D	B	B	D	C	D	B	C	C	C	D	B	E	B								
225	1	F	A	F	A	D	B	B	B	A	B	C	B	B	B	C	B	D	C	B	C	B	C	C	C	B	D	C	D												
226	1	D	C	D	B	A	C	C	B	A	B	A	B	D	B	D	C	B	C	E	C	B	B	C	B	B	B	B	C	B	C	E	D	C	C	D	C	C	C	D	C
227	1	C	C	D	C	E	C	B	C	D	B	D	B	D	B	A	B	B	A	B	A	C	B	C	A	C	D	C	B	B	B	B	B	C	B	C	C	B	B	C	C
228	1	A	C	E	C	C	C	E	C	A	D	C	D	C	C	C	C	A	C	D	C	A	C	A	D	D	D	C	D	D	D	E	C	A	D	D	C	B	D	C	D
229	1	A	C	E	C	C	D	E	B	A	A	A	A	C	A	C	A	A	A	E	A	D	A	D	B	A	B	D	B	D	C	E	A	A	C	D	A	C	D	D	B
230	1		D		D	E	C	B	C	A	D	C	C	C	B	E	B	A	B	E	B	D	B	D	B	B	B	B	C	D	E	C	E	D	B	D	E	C	E	D	B	C
231	2	F	D	F	D					D	A	D	A	C	A	C	A	A	A	D	A	E	D	C	C	B	C	B	C	A	D	E	D	E	D	C	D	E	D	B	D
232	2	A	C	D	C	E	B	B	B	A	B	A	B	D	B	D	B	A	A	D	A	B	A	C	A	D	C	D	C	C	C	B	C	D	C	D	C	B	B	D	B
233	1	D	B	D	B	C	C	E	C	A	D	A	B	C	B	C	B	A	B	D	B	B	D	C	D	D	B	E	C	D	C	E	C	C	B	C	C	A	B	F	B
234	2	B	C	D	C	B	B	E	B	A	A	A	B	C	A	B	A	A	A	D	A	B	A	C	A	D	B	C	B	D	C	D	B	C	A	D	C	A	A	C	A
235	1	C	B	E	C	E	B	D	B	B	C	E	C	F	C	D	C	B	C	E	C	B	C	A	C	D	C	C	C	D	C	D	C	C	C	C	B	E	C	C	B
236	1	B	B	A	B	C	C	E	C	A	C	A	C	D	B	D	B	A	B	D	B	B	B	C	C	D	C	C	C	B	D	B	B	C	A	C	C	C	C	C	C
237	1	B	C	A	B	F	D	F	D	B	C	D	D	C	D	B	B	A	B	D	B	B	C	C	C	D	C	D	C	B	D	C	C	B	B	D	C	C	C	D	C
238	2	D	B	C	C	C	C	E	C	A	D	A	D	D	A	D	A	C	D	E	D	E	C	B	C	D	C	C	B	B	C	C	C	C	B	D	B	C	B	D	B
239	1	A	C	E	C	A	C	E	C	A	C	A	C	D	C	A	A	D	B	B	C	C	C	C	D	C	E	D	E	C	D	C	C	D	C	D	A	C	D	C	C
240	2	A	B	E	C	A	B	C	B	A	B	C	B	C	B	C	B	B	B	B	B	D	B	D	B	C	C	A	C	D	C	E	B	E	B	B	B	E	B	B	B
241	2	B	A	A	B	A	A	F	A	D	A	D	A	D	A	E	A	B	C	B	C	D	A	D	B	B	C	B	C	C	C	D	C	E	B	F	A	E	C	F	A
242	2	E	B	B	B	D	C	C	C	A	A	A	A	D	C	B	C	B	A	E	A	D	B	D	A	B	B	B	A	C	C	D	C	F	A	B	A	C	C	D	C
243	2	E	A	C	A	C	A	E	A	D	A	D	A	A	A	E	A	B	A	E	A	D	A	D	A	C	A	A	A	C	B	B	B	C	A	C	A	E	A	C	A

APPENDIX Y

PERMISSIONS OF THE UNIVERSITIES FOR THE ADMINISTARTIONS

O.DT.Ü
FEN BİLİMLERİ ENSTİTÜSÜ
YÖNETİM KURULU KARARI

Tarih: 06.01.2011
Sayı: FBE: 2011/19

GÖREVLENDİRME VE İZİN

Ortaöğretim Fen ve Matematik Alanları Eğitimi EABD doktora programı öğrencisi Derya Kaltakçı'nın 01 Ocak 2011-31 Aralık 2011 tarihleri arasında "*Fizik öğretmen adaylarının geometrik optik konusundaki kavramlamalarının tespit edilmesi* " başlıklı araştırmasına ilişkin hazırlanan anketi ekli etik komite başvuru formunda belirtilen okullarda uygulama yapmak için görevlendirilme başvurusu incelenmiş; ilgili danışman görüşüne dayanarak adı geçen öğrencinin isteği doğrultusunda görevlendirilmesine oybirliği ile karar verilmiştir.

Prof. Dr. Canan Özgen *FBE Müdürü*	**Prof. Dr. Gürsevil Turan** *FBE Müd. Yard.*	**Doç. Dr. Nil Uzun** *FBE Müd. Yard.*
Prof. Dr. Vedat Toprak *Üye*	KATILAMADI **Prof.Dr. Haluk Sucuoğlu** *Üye*	**Doç. Dr. Ayşe Berkman** *Üye*

T.C.
BALIKESİR ÜNİVERSİTESİ REKTÖRLÜĞÜ
Öğrenci İşleri Daire Başkanlığı

ÖĞRENCİ DAİRESİ BŞ. K-Q TSE-ISO-EN 9000

Sayı : B.30.2.BAÜ.0.72.00.00.300-321/2179 28./2./2011
Konu : Anket izni

ORTA DOĞU TEKNİK ÜNİVERSİTESİ REKTÖRLÜĞÜNE

İLGİ : 19.01.2011 tarih ve B.30.2.ODT.72.00.00/420-416-000981 sayılı yazınız.

Üniversitemiz Necatibey Eğitim Fakültesi Dekanlığınca ilgi yazınızda adı geçen Derya KALTAKÇI' nın araştırma veri toplamak amacıyla anket uygulama isteği, bizzat kendisinin yapması kaydıyla uygun görülmüştür.

Bilgilerinize arz ederim.

Prof.Dr.Mahir ALKAN
Rektör

04.03.11* 4134

Çağış Kampusu (10145) BALIKESİR Tel: (0 266) 612 14 00(8 Hat) Faks: (0 266) 612 14 28 e-posta: ogris@balikesir.edu.tr Elektronik Ağ: www.balikesir.edu.tr

T.C
DİCLE ÜNİVERSİTESİ REKTÖRLÜĞÜ
Öğrenci İşleri Daire Başkanlığı

ÖĞRENCİ İŞLERİ DAİRE BAŞKANLIĞI Ev. Arş. Mü[illegible]

EFQM
Committed to excellence

Sayı : B.30.2.DİC.0.72.00.00/ 150 – 2495
Konu : Uygulama İzni

01../03/2011
DİYARBAKIR

ORTA DOĞU TEKNİK ÜNİVERSİTESİ REKTÖRLÜĞÜNE
ANKARA

İlgi: 19.01.2011 tarih ve 1420/413 sayılı yazınız.

Üniversiteniz Ortaöğretim Fen ve Matematik Alanları Eğitimi EABD doktora programı öğrencisi Derya KALTAKÇI'nın, "Fizik Öğretmen Adaylarının Geometrik Optik Konusundaki Kavramlamalarının Tespit Edilmesi" konusunda Üniversitemiz Eğitim Fakültesinde uygulama yapma isteği Üniversitemizce uygun görülmüştür.

Bilgilerinize arz ederim.

Prof. Dr. Mustafa ARICA
Rektör a.
Rektör Yardımcısı

T.C
DOKUZ EYLÜL ÜNİVERSİTESİ
BUCA EĞİTİM FAKÜLTESİ
ORTAÖĞRETİM FEN VE MATEMATİK
ALANLAR EĞİTİMİ BÖLÜMÜ BAŞKANLIĞI

Sayı : B.30.2.DEÜ.0.16.00/162 **16 Mayıs 2011**
Konu:

DEKANLIK MAKAMINA

İLGİ: 15.04.2011 tarih ve 72.00/500/1948 sayılı yazınız.

Orta Doğu Teknik Üniversitesi Ortaöğretim Fen ve Matematik Alanlar Eğitimi EABD Doktora Programı öğrencisi Derya KALTAKÇI'nın "Fizik Öğretmen Adaylarının Geometrik Optik Konusund Kavramlamalarının Tespit Edilmesi" başlıklı araştırması kapsamında Bölümümüz Fizik Eğitimi Anabilim Dalı öğrencilerine uygulama yapması; uygulamayı kendisinin yapması şartıyla uygun görülmektedir.

Gereği için bilgilerinize arz ederim.

Prof.Dr.Mehmet KARTAL
Bölüm Başkanı

16.05.2011

Uğur Mumcu Caddesi 135 Sokak No:5 35150 Buca / İZMİR Tel.: 0- 232 - 4204882-4204883-4204884-4204885-4204886-4204887 – 4204598 – 4207602 – 4400808 – 4409609 – 4409611 – 4409612 - 4409613 – 4409615 – 4201472 Fax.: 0-232-4204895 – 0-232-4409610 web: www.deu.edu.tr/egitim e-mail: egitim@deu.edu.tr

T.C.
GAZİ ÜNİVERSİTESİ
GAZİ EĞİTİM FAKÜLTESİ
ORTAÖĞRETİM FEN VE MATEMATİK ALANLARI
EĞİTİMİ BÖLÜMÜ

SAYI : B.30.2.GÜN.0.12.15.00/ 950 16.02.2011
KONU : İzin

GAZİ EĞİTİM FAKÜLTESİ DEKANLIĞINA

İLGİ: 11.02.2011 tarih ve B.30.2.GÜN.0.12.72.02/772 sayılı yazınız.

Orta Doğu Teknik Üniversitesi Ortaöğretim Fen ve Matematik Alanları Eğitimi ABD Doktora Programı Öğrencisi Derya KALTAKÇI'nın "Fizik Öğretmen Adaylarının Geometrik Optik Konusundaki Kavramlamaların Tespit Edilmesi" konulu tezi ile ilgili anketi uygulama isteği Fizik Eğitimi Anabilim Dalımızca değerlendirilmiş olup, Anabilim Dalımızın görüşü ekte sunulmuştur.

Bilgilerinize arz ederim.

Doç.Dr.Tahir ATICI
Bölüm Başkanı V.

EK: 1

Gazi Eğitim Fakültesi Ortaöğretim Fen ve Matematik Alanlar Eğitimi Bölümü K Blok 06500 Beşevler-ANKARATelefon: (312) 202 82 73
Faks: + 90 (312) 222 84 83 e-posta: gef@gazi.edu.tr

T.C.
GAZİ ÜNİVERSİTESİ
GAZİ EĞİTİM FAKÜLTESİ
ORTAÖĞRETİM FEN VE MATEMATİK ALANLARI EĞİTİMİ BÖLÜM BAŞKANLIĞINA

Orta Doğu Teknik Üniversitesi Ortaöğretim Fen ve Matematik Alanları Eğitimi EABD doktora programı öğrencisi Derya KALTAKÇI tarafından yürütülen, "Fizik Öğretmen Adaylarının Geometrik Optik Konusundaki Kavramlamalarının Tespit Edilmesi" konulu teze ilişkin olarak sunulan başvuru metni, çalışma ile ilgili veri toplama sürecinin, anket, mülakat, gözlem ve ses kaydı gibi süreçleri kapsadığını ifade etmektedir. Hazırlanan anket otuz sayfadan oluşan ve optik konusunda kapsamlı yorum ve değerlendirme gerektiren bir metindir. Başvuru belgelerinde de belirtildiği üzere öğrencinin söz konusu anketi cevaplaması en az bir saatini alacaktır. Bu bağlamda söz konusu çalışmaya katılımın gönüllülük esasına dayanması gerektiği kanaatindeyiz. Tez yürütücüsünün öğrencilerle bizzat görüşmesi, katılımları konusunda motivasyonlarını sağlaması va ayrıca anket ve planlanan diğer veri toplama proseslerinin, öğrencinin ders saatleri dışında ayıracağı bir vakitte ve Derya KALTAKÇI nezaretinde gerçekleşmesi kaydıyla uygulanmasının uygun olduğunu görüş ve bilgilerinize arzederiz.

Prof. Dr. Selma Moğol
Fizik Eğitimi Anabilim Dalı Başk.
S. Moğol

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Dr. A... Saat :

Sayı: B.30.2.HAC.0.70.01.00/ 240-743

04.03.11

Orta Doğu Teknik Üniversitesi Rektörlüğüne,

İlgi: 19.01.2011 tarih ve ODT.72.00.00/420-407/972 sayılı yazınız.

Üniversiteniz Eğitim Fakültesi Ortaöğretim Fen ve Matematik Eğitimi Anabilim Dalı Doktora Programı öğrencisi **Derya KALTAKÇI**'nın **Yrd.Doç.Dr. Ali ERYILMAZ** danışmanlığında hazırladığı 01 Ocak 2011-31 Aralık 2011 tarihleri arasında; **"Fizik Öğretmen Adaylarının Geometrik Optik Konusundaki Kavramlamalarının Tespit Edilmesi"** başlıklı ve 410.01-357 başvuru nolu çalışması gereği ekte yer alan anketleri başvuru formunda belirtilen okullarda uygulama isteğine ilişkin alınan yazı ve ekleri, Üniversitemiz Senatosu Etik Komisyonunun 25 Şubat 2011 tarihinde yapmış olduğu toplantıda incelenmiş olup, etik açıdan uygun bulunmuştur.

Gereğini bilgilerinize saygılarımla arz ederim.

Prof.Dr. Sevil GÜRGAN
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Rektör Yardımcısı

08.03.11* 4490

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ÖĞRENCİ İŞLER DAİRESİ B[illegible]
Ev. Arş. Md. Saad[illegible] 24 / 02 / 2011

Sayı/Ref : B.30.2.KTÜ.0.70.72.00/ 595/ 317
Konu/Subj. : Anket Çalışması

T.C.
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Öğrenci İşleri Daire Başkanlığı

İLGİ :19.01.2011 gün ve B.30.2.ODT.72.00.00/420-411 Sayılı yazınız;

Üniversiteniz Ortaöğretim Fen ve Matematik Alanları Eğitimi EABD Doktora Programı öğrencilerinden Derya KALTAKÇI' nın; **"Fizik Öğretmen Adaylarının Geometrik Optik Konusundaki Kavramlamalarının tespit edilmesi "** Başlıklı araştırmasını Üniversitemizde uygulama isteği, uygulamanın bizzat kendisi tarafından yapılması şartıyla uygun görülmüştür.

Bilgilerinizi rica ederim.

Prof.Dr.Selahattin KÖSE
Rektör a.
Rektör Yardımcısı

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Öğrenci İşleri Daire Başkanlığı

ÖĞRENCİ
DAİRESİ BAŞKANLIĞI
Ev. Arş. Md. Saat :
15 MART 2011

Sayı : B.30.2.MAR.0.72.00.00-4593
Konu : Derya KALTAKÇI hk.

İstanbul, ../../2011

ORTA DOĞU TEKNİK ÜNİVERSİTESİ REKTÖRLÜĞÜNE

İlgi : 19/01/2011 tarih ve 1420-410 sayılı yazınız.

Üniversiteniz Ortaöğretim Fen ve Matematik Alanları Eğitimi EABD doktora programı öğrencisi Derya KALTAKÇI'nın "Fizik Öğretmen Adaylarının Geometrik Optik Konusundaki Kavramlarının Tespit Edilmesi" konulu araştırmasını, Atatürk Eğitim Fakültesi Ortaöğretim Fen ve Matematik Alanları Eğitimi Bölümü Fizik Eğitimi Anabilim Dalında yapması uygun görülmüş olup bilgilerinize arz ederim.

Prof. Dr. Hamza KANDUR
Rektör a.
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22.03.11* 5524

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01597

Sayı : B.30.2.ODM.0.70.00.00/605.01-[117]-
Konu :

25/02/2011

ORTA DOĞU TEKNİK ÜNİVERSİTESİ REKTÖRLÜĞÜNE

İLGİ: 19.01.2011 tarihli ve B.30.2.ODT.72.00.00/420-409-000974 sayılı yazınız.

İlgide kayıtlı yazınızda belirtilen Üniversiteniz Ortaöğretim Fen ve Matematik Alanları Eğitimi EABD doktora programı öğrencisi Derya KALTAKÇI'nın 01 Ocak-31 Aralık 2011 tarihleri arasında "Fizik Öğretmen Adaylarının Geometrik Optik Konusundaki Kavramlamalarının Tespit Edilmesi" başlıklı araştırmasına ilişkin Üniversitemiz Eğitim Fakültesinde uygulama yapma isteği Rektörlüğümüzce uygun görülmüştür.

Bilgilerinizi ve gereğini arz ederim.

Prof. Dr. Hüseyin AKAN
Rektör

28/02/11* 3661

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ÖĞ... DAİRESİ B...LIĞI
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T.C.
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Öğrenci İşleri Daire Başkanlığı

Sayı : B.30.2.SEL.0.72.00.00/200- 261 01.03.2011* 32563
Konu : Araştırma İzni

ORTA DOĞU TEKNİK ÜNİVERSİTESİ REKTÖRLÜĞÜNE
ANKARA

İlgi: 19/01/2011 tarih ve B.30.2.ODT.72.00.00/420-408/973 sayılı yazınız.

Üniversiteniz Fen ve Matematik Alanları Eğitimi Ana Bilim Dalı doktora programı öğrencisi Derya Kaltakçı'nın 01 Ocak 2011-31 Aralık 2011 tarihleri arasında "Fizik Öğretmen Adaylarının Geometrik Optik Konusundaki Kavramalarının Tespit Edilmesi" konulu anket çalışmasını Üniversitemiz Ahmet Keleşoğlu Eğitim Fakültesi'nde yapmasına ilişkin Üniversitemiz Ahmet Keleşoğlu Eğitim Fakültesi Dekanlığı'nın 25.02.2011 tarih ve B.30.2.SEL.0.12.72.00/313 sayılı yazısı ekte gönderilmektedir.

Bilgilerinize arz ederim.

Prof.Dr.Şefik BİLİR
Rektör a.
Rektör Yardımcısı

EKLER:
1-Yazı(1 sayfa)

04.03.11* 4132

T.C.
SELÇUK ÜNİVERSİTESİ
AHMET KELEŞOĞLU EĞİTİM FAKÜLTESİ DEKANLIĞI

25.02.2011

Bölüm : Öğrenci İşleri
Sayı : B.30.2.SEL.0.12.72.00/ 0313 **Konya. .../.../ 2011**
Konu : Anket Uygulama

SELÇUK ÜNİVERSİTESİ REKTÖRLÜĞÜNE
(Öğrenci İşleri Daire Başkanlığı)

İLGİ: 04.01.2011 tarih ve 200-141/01401 sayılı yazınız.

Orta Doğu Üniversitesi Fen ve Matematik Alanları Eğitimi Ana Bilim Dalı doktora programı öğrencisi Derya KALTAKÇI'nın 01 Ocak 2011 – 31 Aralık 2011 tarihleri arasında **"Fizik Öğretmen Adaylarının Geometrik Optik Konusundaki Kavramlamalarının Tespit Edilmesi"** konulu araştırmasına veri toplamak amacıyla Fakültemiz Ortaöğretim Fen ve Matematik Alanlar Eğitimi Bölümü Fizik Eğitimi Anabilim Dalı öğrencilerine anket uygulama isteği "bilimsel çalışmaların bu şekilde toplanması" ilgili Anabilim Dalı Başkanlığı tarafından uygun görülmemiştir.

Bilgilerinizi arz ederim.

Prof. Dr. Musa GÜRSEL
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APPENDIX Z

STATEMENTS OF PARTICIPANTS FOR THE BLANK ALTERNATIVES AND THEIR CODING

Item	Written Blank Answer *(participant #)*	Decision*	Recoded into	Frequency
1.1	1,2,4 *(2) (13) (26) (146)*	IEB		4
	BOŞ *(67)*	EB		1
	2,3,4 *(83) (111)*	IEB		2
	Yalnız 3 *(195)*	IEB		1
1.3	İlk girdiğinde 2,3,4'ü görecek, çıkmadan önce 1'i görecek. *(7)*	IEB		1
	Hasan ilerlerken sırasıyla hepsini görecektir. *(11)*	IEB		1
	Hepsini görebilir düzlem aynadaki yansımalarından dolayı. *(23)*	IEB		1
	O düzlemde ilerlediği için hepsini bir şekilde görür. *(28)*	IEB		1
	Kedi görüntüleri farklı birim karelerde oluşmaktadır. Hasan yolculuk boyunca her birini farklı sürelerde görebilir. *(38)*	DRB	c	1
	Hasan odada ilerledikçe kedilerin hepsini mutlaka görecektir. *(43)*	IEB		1
	BOŞ *(52) (53) (111) (141) (199)*	EB		5
	Hasan etrafına bakıyorsa hepsini görür. *(142)*	IEB		1
	Hasan hareket ettiği için aynaya bakış açısı sürekli değişmiştir ve hepsini aynı anda göremese de tüm kedileri görür. *(143)*	IEB		1
	Görüş alanına giren çizilen bölgede görüntü oluşur, o da o görüntüyü görür. *(157)*	DRB	c	1
	Hasan oda içerisinde hareket ettiği için bütün kedilerin görüntüsünü görebilir. *(168)*	IEB		1
	Hasan sürekli ilerleme halinde olduğu için yandaki görüntüler değişmektedir. Konuma göre görüntüler değişir. *(174)*	IEB		1
	Hasan ilerlerken görüş açısı değiştiği için tüm kedileri aynı anda görememektedir. Ama yol güzergahı üzerinde hepsini görür. *(185)*	IEB		1
	Hasan devamlı yer değiştirdiği için bir noktada göremediği kedi varsa bile diğer noktada görür. *(223)*	IEB		1
	Hasan ilerlerken görüş alanı değişiyor ve bütün kediler herhangi bir zamanda görüş alanına giriyorlar. *(241)*	IEB		1
2.1	4,2,1 *(2)*	IEB		1
	4, 2=3 *(28)*	IEB		1
	1, 2=4, 3 *(29)*	DRB	e	1
	3, 2=4 *(34) (36)*	IEB		2
	BOŞ *(40)*	EB		1
	3, 2, 1 *(45)*	IEB		1
	1,3 *(52) (53)*	IEB		2
	3,2,4 *(64)*	DRB	d	1
	2,3,1*(88)*	IEB		1
	2,4,3 *(142) (146)*	IEB		2
	1*(98) (157)*	IEB		2

	1,3,2 *(109)*	IEB		1
	3,4,2,3 *(136)*	IEB		1
	2=4,3,1 *(175)*	IEB		1
	2,4 *(191)*	IEB		1
	1,2,3 *(213) (231)*	IEB		2
2.3	Hasan'ın sanal hareketine göre görüş açısı çizilerek kedilerin görülmesi belirlenir. *(35)*	New		1
	Hasan'ın gözünden aynanın sağ ve sol sınırına ışınlar çizilerek gözün görüş alanı belirlenir. Aynadan yansıyan ışınlar arasında kalan bölgede iken o kedinin görüntüsü görülür. 4 numaralı kedinin görüntüsünü 2 numaralı kedi engeller. *(65)*	DRB	c	1
	Her bir kedinin görüntüsü çizilip sonra Hasan'ın görüş alanı belirlendiğinde Hasan 1 nolu kediyi görebilmektedir. *(98)*	IEB		1
	Hasan içeri girdiği anda 2 ve 4 daha sonra 3 ü görür görüş alanı çizildiğinde. *(163)*	DRB	e	1
	3 nolu kedi de görüş alanı içerisinde. *(213)*	IEB		1
	Hasan'dan düzlem aynanın iki ucuna ışın gönderilir. Görüş alanı içinde kalan kediler, başka bir kedi görüş alanını değiştirmiyorsa görülür. *(223)*	DRB	c	1
	Kedilerin her birinden aynanın sağ ve sol sınırına ışınlar çizerek Hasan'ın görüş alanı belirlendiğinde önce 3, sonra 2 numaralı kediyi görür. 4'ün görüntüsü oluşur fakat 2 numaralı kedi önüne geçtiği için Hasan 4 numaralı kediyi göremez. *(225)*	DRB	c	1
3.1	*Şekil üzerinde çizilmiş.(13)*	IEB		1
3.3	Gözlerinden aynanın uçlarına doğrular çizdiğimizde (görme alanı) vücudunun bu alan içerisinde olması gerekiyor. Eğer c şıkkında aynı konumda daha uzun boylu olsaydı da kendini görebilirdi. *(12)*	DRB	d	1
	Sevgi'nin görüş bölgesi çizilir. Vücudu içinde kalınca tamamen kendini görmüş olur. *(35)*	DRB	d	1
	Sevgi'nin tüm vücudunu görebilmesi için aynanın uç kısmından itibaren Sevgi'nin boyunun yarısının görünmesi gerekiyor. *(65)*	DRB	d	1
	BOŞ *(141)*	EB		1
	Sevgi'nin gözlerinden ışın çizerek görüş alanını bularak yapılacak. *(194)*	DRB	d	1
	Gözlerden ışın çizerek görüş açısından bulduk. *(196)*	DRB	d	1
4.1	Yarısı oluşur. *(7)*	New		1
	Oluşur ancak bakan kişi engelin ardındaysa göremez ama bu oluşmadığı anlamına gelmez. *(87)*	DRB	a	1
	Gözlemcinin görüş alanına göre değişir. *(230)*	DRB	c	1
	Görüntü oluşur ama görmek için uygun yerden bakmak gerekir. *(242)*	DRB	a	1
4.3	BOŞ *(25)*	EB		1
	Aynanın sol son birim karesini pilden çıkan ışın görür, görüntü oluşur. *(38)*	New		1
5.1	b ve c şıkları *(14) (21) (58) (111)*	BRB	b-c	4
	Aynanın üst kenarını biraz aşağıya bakacak şekilde oynatmalıyız. *(76)*	New		1
	a ve c de doğrudur. *(89)*	BRB	a-c	1
	Aynanın tepe noktasına zıplasa yeter. *(199)*	New		1
	Aynanın boyutuna bağlı. *(225)*	New		1
	Zaten ayna Murat'ın boyunun yarısı büyüklüğündeyse vücudunun tamamını görebilir. *(230)*	DRB	d	1
5.3	Ayağından gelen ışının gözüne ulaşması için aşağı kaydırılmalı. *(5)*	DRB	e	1
	Ayna aşağı kaydırılmalı. *(19)*	IEB		1
	BOŞ *(21)*	EB		1
	Aynadan yansıyan ışınlara göre aynayı aşağıya kaydırmak Murat'ın tamamını görmesine neden olur. *(23)*	DRB	e	1
	a ve d şıkları *(58)*	BRB	a-d	1

	Murat'ın aynada vücudunun tamamını görebilmesi için aynanın yerden yüksekliğinin gözün yerden yüksekliğinin yarısı kadar olmalıdır. *(65)*	DRB	e	1
	a'da aynaya yaklaşarak görüş alanını büyütür ve görür tüm bedenini. c'de ise aynayı aşağıya indirirsek tüm vücudu sabit olan görüş alanına girer. *(89)*	BRB	a-c	1
	Cisim merkez dışında olmalıdır ki görüntüsünü görsün. *(97)*	IEB		1
	Hem aynanın boyu aşağı kaydırılmalı ve Murat geriye doğru 4 birim gitmeli. *(111)*	BRB	b-c	1
	Aynanın alt ucuna baktığında ayaklarını görecek kadar zıplamalı. *(199)*	New		1
6.1	II ve III *(1) (8) (28) (39) (95) (101) (108) (111) (112) (115) (143) (150) (230)*	BRB	b-c	13
	I, II ve III *(9)(47) (193)*	BRB	a-d	3
	BOŞ *(85)*	EB		1
	Şayet aynanın boyu Fırat'ın boyunun en az yarısından fazla ise ve ayna aşağı kaydırılmak suretiyle Suat Fırat'ın boyunun tamamından fazlasını görebilir. *(86)*	DRB	c	1
	İkisi de uzaklaşmalı. *(218)*	DRB	b	1
6.3	c (III için) ve f (II için) şıkkı. *(28)*	BRB	c-f	1
	Suat aynaya yaklaşırsa Fırat ondan uzak kalacak ve görecek. *(63)*	DRB	a	1
	Zaten Fırat'ın boyunun tamamını görmektedir. *(85)*	IEB		1
	Şayet aynanın boyu Fırat'ın boyunun en az yarısından fazla ise ve ayna aşağı kaydırılmak suretiyle Suat Fırat'ın boyunun tamamından fazlasını görebilir. *(86)*	IEB		1
	BOŞ *(111)*	EB		1
	Suat'ın görüş alanı artmıştır ve uzakta olduğundan dolayı Suat'ın boyu kısa. Fırat aynaya yakın olduğu için Suat Fırat'ı kendisinden büyük görür. *(168)*	DRB	a	1
7.1	4,3,1,2 *(6)*	IEB		1
	2,1*(26)*	DRB	e	1
	1,2,3*(29)*	IEB		1
	4 *(32)*	IEB		1
	3,2,1*(45)*	IEB		1
	1,2,4 *(46)*	IEB		1
	3,4,2,1 *(131)*	IEB		1
	1=2=3*(176) (177)*	IEB		2
	1,2=3=4 *(224)*	IEB		1
7.3	Hareket boyunca tümsek aynaya göre değişen görüş bölgesi değiştirilerek sonuç bulunur. *(35)*	DRB	e	1
	Geometrik optik almadığım için bu konuyu bilmiyorum. *(98)*	NK		1
8.1	3=2, 4=1*(23)*	IEB		1
	Bilmiyorum. (98)	NK		1
8.3	İlk 4 numaradan ışık gelir gözümüze ve öyle devam eder. *(5)*	DRB	d	1
	Hepsinin görüntüsü aynı yerde olur ama uzunlukları farklı ve yönleri de farklı. 1 daha uzun, 2 daha küçük sonra 3 en sonda 4. *(20)*	IEB		1
	a ve e şıkkı *(28)*	BRB	a-e	1
	Sevgi'nin görüş bölgesi çizilir. *(35)*	DRB	d	1
	Geometrik optik almadığım için bu konuyu bilmiyorum. *(98)*	NK		1
	BOŞ *(100)*	EB		1
	Görüntüler çakışır. *(164)*	IEB		1
	Sevgi'den aynaya ışın gönderip görüş alanını belirleriz. Görüş alanı da Sevgi hareketli olduğu için değişiyor, içinde kalanları görebilir. *(241)*	DRB	d	1
9.1	Bilmiyorum. *(58)*	NK		1
9.3	Bilmiyorum. *(58)*	NK		1
	Görüntü ekrana düşürülmelidir. *(95)*	DRB	d	1

	Emin değilim. *(97)*	NK		1
	Geometrik optik almadığım için bu konuyu bilmiyorum. *(98)*	NK		1
10.1	-			1
10.3	Tümsek aynada görüntü sanaldır, gözlenemez. *(95)*	DRB	g	1
	Geometrik optik almadığım için bu konuyu bilmiyorum. *(98)*	NK		1
	Işınlar M'den geçtiği ilk an gözlerini görebilir. *(225)*	DRB	f	1
11.1	III *(28)*	IEB		1
	I ve III *(29)*	IEB		1
	I, III, V *(35)*	IEB		1
	II, IV *(36)*	IEB		1
	IV, V *(46)*	IEB		1
	BOŞ *(48) (196) (231)*	EB		3
	I ve II *(65)* (163)	IEB		2
	II *(72) (116) (185)*	New		3
	II, III, IV *(193) (224) (225)*	IEB		3
	III, IV *(219)*	IEB		1
	I,II,III,IV *(221)*	IEB		1
11.3	Uzaktan geliyormuş gibi düşündüm ve odaktan geçirdim. Birde aynayla ekseni aynı açı yaptırıp yansıttım. *(28)*	IEB		1
	BOŞ *(36) (196) (199) (231)*	EB		4
	Sadece zahiri görüntüler görülebilir. *(64)*	New		1
	F'de görüntü sonsuzda olduğu için göremez diğer konumlarda görür. *(76)*	DRB	a	1
	Geometrik optik almadığım için bu konuyu bilmiyorum. *(98)*	NK		1
	Merkezde iken görüntü aynı büyüklükte ve düz oluşur. *(116)*	IEB		1
	Odak noktasında iken görüntü sonsuzda oluşur. Bu durumda diğer her yerde görüntü oluşur. *(135)*	DRB	a	1
	Odaktayken sonsuzda oluşur göremez. Aynayla odak arasındayken de sanal görüntü oluşur göremez. Diğerlerinde görür. *(141)*	DRB	c	1
	Odakta görüntü sonsuzda, F-ayna arasında görüntü sanaldır. *(172)*	DRB	c	1
	Selin merkezde iken kendisinin aynısını ama tersini merkezde görür. Odağa yaklaştıkça görüntü büyür. Odakta olduğunda görüntü sonsuzda olur. *(174)*	IEB		1
	Görüntü odak ile tepe noktası arasında oluşur. *(185)*	IEB		1
	F-M arasında örneğin 1,5 F'de görüntü 3F'de oluşur. F'deki görüntü 2F=M'de olur. *(219)*	New		1
	Merkezin dışında görüntü oluşur fakat sonsuzdadır. F ile tepe noktası arasında görüntü aynanın arkasında oluşacağından göremez. *(225)*	DRB	e	1
12.1	Ekran olmadan göremez. *(28)*	New		1
	II *(72) (116)*	New		2
	IV ve V *(155)*	IEB		1
	III ve V *(160)*	IEB		1
	I,II,III,IV*(237)*	IEB		1
12.3	Aynaya yakınken kendisini görebilir. *(23)*	IEB		1
	Tüm görüntüler sanaldır ve görülür. *(64)*	DRB	c	1
	Her durum için Selin kendini görebilir. *(90)*	DRB	c	1
	BOŞ *(115)*	EB		1
	Görüntü merkezde iken oluşur. *(116)*	New		1
	Görüntü odak ile tepe noktası arasında oluşur. *(185)*	IEB		1
	Bilmiyorum. *(237)*	NK		1
	Tümsek aynalarda nesne nerede olursa olsun görüntü ayna ile odak arasında oluşur. *(241)*	IEB		1
13.1	Kalemin görüntüsü ters oluşur. *(43)*	DRB	d	1
	Yarısı kadar görüntü kapatmadan öncedir. Kartonla kapatıldıktan sonra yarısından daha azı görünür. *(141)*	DRB	c	1
	Kalemin uç kısmını göremez silgi tarafı görülebilir. Boyu 2 birim ise 4 birim olacağı yerde 2 birim olarak görebilir. *(157)*	DRB	c	1

	Göremez. *(159)*	DRB	a	1
13.3	BOŞ *(40)*	EB		1
	Kalemin uçlarından odak noktasına iki ışın gönderirsek görüntü oluşur. *(43)*	DRB	d	1
	Kalemden aynaya gönderilen ışınlar kartonla engellenir, diğer taraftan görüntü elde edilir ama kırılan engele takılarak görülemez. *(46)*	DRB	c	1
	Karton, sanal görüntü ile gözlemci arasında oluşmaz ve bu yüzden engel olmaz. *(131)*	DRB	d	1
	Yarısından daha azı görünür. *(141)*	DRB	b	1
	Kalem 3f de olduğu için görüntü 1,5f de ters biçimde olur. *(174)*	DRB	d	1
14.1	3.43 *(1) (220)*	DRB	c	2
	2 ve parçalı *(29)*	DRB	c	1
	∞ *(44)*	New		1
	2 den fazla *(86)*	DRB	c	1
	105^0 360^0'ye tam bölünseydi tam bir sayı değeri verebilirdik.*(90)*	DRB	c	1
	1*(92) (235)*	IEB		2
	1 aynada 2, diğer aynada 3*(96)*	IEB		1
	(73/21)-1 *(223)*	DRB	c	1
14.3	Formüle göre kendisini 2,43 kez görebilir. Kendini 2 kez net olarak görür, 3. görüntüsünü tam göremez. *(131)*	DRB	c	1
	(360/α)-1 formülüne göre 2,...küsürlü cevap elde ederiz. Bu 2 tam görüntüdür. *(157)*	DRB	d	1
15.1	4 *(23)*	IEB		1
	BOŞ *(48)*	EB		1
	∞ *(70)*	New		1
15.3	Yansımalardan ve oluşan görüntülerden tekrar görür. *(23)*	IEB		1
	BOŞ *(48) (100) (199)*	EB		3
16.1	Görüntü F-M arasında oluştuğu için ekranı M'nin dışına doğru kaydırdığımızda görüntü flulaşır, küçülür sonrada belirsiz bir ışık şekline benzer. *(89)*	DRB	b	1
	Düzgün bir görüntü oluşmaz. *(90)*	DRB	d	1
	Görüntünün netliği azalır ya da belirgin bir görüntü oluşmaz. *(91)*	DRB	d	1
	Görüntü değişmez. *(116)*	New		1
	Görüntü büyür ve net görünmez. *(131)*	DRB	d	1
	Ters ve küçük oluşur. *(231)*	DRB	b	1
16.3	Gelen ışınların açısı büyür (ekranda) daha çok alan kaplar. *(26)*	DRB	a	1
	Görüntü merkez dışında olacağı için büyür. *(35)*	DRB	a	1
	BOŞ *(40) (48)*	EB		2
	Görüntü ekrana düşer ama bu görüntü ışık topu halinde de olabilir, net olmayabilir de. *(91)*	DRB	d	1
	Ekranın yeri önemli değildir. Aynı görüntü oluşur. *(116)*	New		1
	Görüntüsü birçok yerde vardır fakat net değildir. Biz en net halini konuştuğumuz için görüntü olmadığını da söyleyebiliriz. *(131)*	DRB	d	1
	Görüntü büyür çizimlerden de anlaşıldığı gibi. *(182)*	DRB	a	1
17.1	b ve c şıklarının ortası. *(15)*	BRB	b-c	1
	BOŞ *(48)*	EB		1
	Aynanın arkasında düz ve net bir görüntü. *(70)*	New		1
	Çiviyi olduğu gibi görür. *(76)*	DRB	c	1
	Net olmayan nokta gibi bir görüntü. *(96)*	DRB	a	1
	Daha küçük bir görüntü oluşur. *(170)*	New		1
17.3	a ve b şıklarının arası. *(15)*	BRB	a-b	1
	Işınlar çizilirse büyük ve ters olduğu görülür. *(23)*	IEB		1
	BOŞ *(48) (70) (233) (239)*	EB		4
	Büyük ters. *(72)*	IEB		1
18.1	BOŞ *(48)*	EB		1
	Hiçbiri. *(95) (193)*	New		2
	1,2,3,4 *(217)*	IEB		1

18.3	Görüntünün ekrana düşürülmesi gerek. *(95)*	New		1
	BOŞ *(96) (221)*	EB		2
19.1	I *(29) (52)*	IEB		2
	I, III, V *(35)*	IEB		1
	II *(49)* (152) (153) (185)	New		4
	BOŞ *(67)*	EB		1
	II, III, IV *(116)*	IEB		1
	I ve II *(163) (164)*	IEB		2
	Perde olmadan göremez. *(242)*	DRB	e	1
19.3	BOŞ *(7) (48) (53) (96) (111)*	EB		5
	Bilmiyorum. *(15)*	NK		1
	Görüntü oluşan alanda görebilir. *(35)*	New		1
	Formülden *(49)*	IEB		1
	Sonsuzdaki cisim sonsuzda oluşur ve gözükmez. *(116)*	New		1
	Selin sonsuzda iken (2F dışı) görüntü odakta oluşur. *(130)*	New		1
	Selin'in kendi görüntüsünü gözü ekran olarak düşündüğümüzde mercekteki kırılan ışınların uzantıları Selin'in gözüne gelmesi gerekir. *(185)*	New		1
	b ve e şıklarının ikisi de doğru. *(241)*	BRB	b-e	1
20.1	I, III, IV *(36)*	IEB		1
	II,III,IV *(41) (221)*	IEB		2
	III *(45) (150) (152) (153)*	IEB		4
	V *(47) (78) (96) (176) (141) (177)*	IEB		6
	BOŞ *(48)*	EB		1
	IV *(49)*	IEB		1
	II, IV *(155) (160)*	IEB		2
20.3	Işınlar çizilirse görebilir. *(23)*	IEB		1
	BOŞ *(111) (199) (221)(233)*	EB		4
	Odakla mercek arasında gözükmez. *(116)*	IEB		1
	b ve e şıklarının ikisi de var. *(241)*	BRB	b-e	1
	Her durumda ayna ile mercek arasında görür. *(242)*	IEB		1

Note: Numbers in parenthesis show the participant number who wrote the corresponding statement for the blank alternative in the item.

**Codes in the Decision column are the same with Table 4.5*

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Kaltakçı, Derya
Nationality: Turkish (TC)
Date and Place of Birth: 15 January 1982, İzmit
Marital Status: Single
email: deryakaltakci@gmail.com

EDUCATION

Degree	Institution	Year of Graduation
MS	METU Physics Education, Ankara	2005
BS	METU Physics Education, Ankara	2005
High School	2000 Evler High School, Nevşehir	2000

WORK EXPERIENCE

Year	Place	Enrollment
2005- Present	METU	Research Assistant
2009 – 2010	University of Washington	Visiting Scientist

HONORS

Year	Event
June, 2005	Graduation With the First Rank Among 281 Graduates of the Bachelor's Degree Programs in the Education Faculty, METU, Ankara.
June, 2005	Graduation With the First Rank Among 50 Graduates of the Department of Secondary Science and Mathematics Education, METU, Ankara.
2001-2005	First Ranks in the Department of Secondary Science and Mathematics Education, METU, Ankara.
June, 2000	Graduation With the First Rank in 2000 Evler High School, Nevşehir.
1997- 1999	First Ranks in İhsaniye High School, Kocaeli.

FOREIGN LANGUAGES

Advanced English, Beginning German

PUBLICATIONS

International

1. Kaltakci, D. & Eryilmaz, E. (2011). Context based questions: optics in animal eyes. *Physics Education, 46* (3), 323-327.

2. Kaltakci, D. & Oktay, O. (2011). A guided-Inquiry laboratory experiment to reveal students' comprehension of friction concept: a qualitative study. *Balkan Physics Letters (BPL), 19, 191020,*180-190.

3. Kaltakci, D. (2011). Integrating teaching and learning in pre-service physics teacher education. *Balkan Physics Letters (BPL), 19, 191010*, 95-98.

4. Kaltakci, D. & Eryilmaz, A. (2010). Sources of Optics Misconceptions. In G. Çakmakçı & M. F. Taşar (Eds.), *Contemporary Science Education Research: Learning and Assessment,* (pp.13-16). Ankara, Turkey: Pegem Akademi. (ISBN 9786053640332)

5. Kaltakci, D. & Didis, D. (2007). Identification of pre-service physics teachers' misconceptions on gravity concept: A study with a 3-tier misconception test. In S. A. Çetin, & İ. Hikmet (Eds.), *Proceedings of the American Institute of Physics (AIP), USA, 899*, 499-500.

National

1. Kaltakci, D. (2010). Fen ve Fizik Öğretmenlerinin Hizmet İçi Eğitimine Washington Üniversitesi'nden Bir Örnek Uygulama. In M. Ş. Bulbul (Ed.), *Türkiye'de Fizik Eğitimi Alanındaki Tecrübeler, Sorunlar, Çözümler ve Öneriler* (pp. 13-17). (ISBN: 978-605-88420-0-7)

CONFERENCES

International

1. Kaltakci, D. & Eryilmaz, A. (2012). Variation in the Representations of Pre-service Physics Teachers in Image Formation and Observation. *The World Conference on Physics Education (WCPE)*, Istanbul, Turkey, July 2012.

2. Kaltakci, D. & Eryilmaz, A. (2010). Identifying Pre-service Physics Teachers' Misconceptions With Three-Tier Tests. *GIREP-ICPE-MPTL Conference 2010*, Reims, France, August 2010.

3. Kaltakci, D. (2010). Integrating Teaching and Learning in Pre-Servive Physics Teacher Education. *Turkish Physical Society 27th International Physics Congress*, Istanbul, Turkey, September, 2010.

4. Oktay, O. & **Kaltakci, D.** (2010). How Pre-Service Physics Teachers Interpret static and Kinetic Friction: A Laboratory Experiment. *GIREP-ICPE-MPTL Conference 2010*, Reims, France, August 2010.

5. Kaltakci, D. & Oktay, O. (2010). A Guided-Inquiry Laboratory Experiment to reveal students' Comprehension of Friction Concept: A Qualitative Study. *Turkish Physical Society 27th International Physics Congress*, Istanbul, Turkey, September, 2010.

6. Kaltakci, D. & Eryilmaz, A. (2009). Sources of Optics Misconceptions. *European Science Education Research Association (ESERA) Conference*, Istanbul, Turkey, August, 2009.

7. Kaltakci, D. & Eryilmaz, A. (2008). Does Ray Model Make It Easy? Or Difficult? *GIREP2008 International Conference on Physics Curriculum Design, Development and Validation*, Cyprus, August 2008.

8. Kaltakci, D. & Eryilmaz, A. (2008). New Context To Optics Teaching. *GIREP2008 International Conference on Physics Curriculum Design, Development and Validation*, Cyprus, August 2008.

9. Didis, N. & **Kaltakci, D.** (2008). A Proposal For The Analysis Of Three-Tier Misconception Tests, *25. International Physics Congress*, Bodrum, August 2008.

10. Kaltakci, D. (2008). From Learning to Teaching: An Example of Methods of Science Teaching Course. *10th International Conference on Further Education in the Balkan Countries*, Konya, October 2008. (Poster presentation)

11. Kaltakci, D. (2008). Misconceptions and Their Diagnosis with Multiple-Tier Tests. *10th International Conference on Further Education in the Balkan Countries,* Konya, *Turkey, October 2008. (Poster presentation)*

12. Kaltakci, D.& Eryilmaz, A. (2007). Importance of Observer's Eye in Optics: Textbook Analysis, *GIREP-EPEC Conference Frontiers of Physics Education*, Opatija, Croatia, August 2007.

13. Kaltakci, D. & Didis, N. (2007). Near or Far Transfer and Pre-Service Teachers' Conceptions in Gravity, *GIREP-EPEC Conference Frontiers of Physics Education*, Opatija, Croatia, August 2007.

14. Didis, N. & **Kaltakci, D.** (2007). Using Mathematical Models of Gravity Concept, *GIREP-EPEC Conference Frontiers of Physics Education*, Opatija, Croatia, August 2007. (Poster presentation)

15. Kaltakci, D. & Didis, D. (2006). Identification of pre-service physics teachers' misconceptions on gravity concept: A study with a 3-tier misconception test, *Sixth International Conference of the Balkan Physical Union*, Istanbul, Turkey, August, 2006.

National

1. Kaltakci, D., Eryilmaz, A. & McDermott, L. C. (2012). Fizik Öğretmen Adaylarının Düzlem Aynada Görüntü Oluşumu ve Gözlemlenmesine İlişkin Muhakemelerindeki Farklılıkların İncelenmesi, *X. National Science and Mathematics Education Congress,* Niğde, June 2012.

2. Kaltakci, D. & Eryilmaz, A. (2010). Işın Modeli Kullanımının Öğretmen Adaylarının Kavramlamalarına Etkileri, *IX. National Science and Mathematics Education Congress,*

Izmir, September 2010.

3. Kaltakci, D. & Eryilmaz, A. (2008). Öğrencilerin Optik Konusundaki Yanlış Kavramlamalarının Kaynakları, *VIII. National Science and Mathematics Education Congress*, Bolu, August 2008. (Poster presentation)

4. Kaltakci, D. & Didis, N. (2006). Fizik Öğretmenliği Son Sınıf Öğrencilerinin Farklı Ortamlar İçin Yerçekimi Kavramını Yorumlayabilmeleri, *VII. National Science and Mathematics Education Congress*, Ankara, September 2006. (Poster presentation)

5. Didis, N. & **Kaltakci, D.** (2006). Fizik Öğretmenliği Öğrencilerinin Yerçekimi Kavramına İlişkin Durumları Açıklarken Matematiksel Modelleri Yorumlayabilmeleri, *VII. National Science and Mathematics Education Congress*, Ankara, September 2006. (Poster presentation)

ATTENDED WORKSHOPS / SEMINARS

Date	**Event**
June, 2011	Alternative Teaching Methods Seminar for Inservice Teachers, Çanakkale, Turkey (As an instructor).
July, 2009	NSF Summer Institute in Physics and Physical Science for Inservice Teachers By Lillian C. McDermott and Physics Education Group, Department of Physics, University of Washington (As an instructor).
August 2007	GIREP-EPEC Opatija - Frontiers of Physics Education **Learning Physics By Guided Inquiry**. Workshop presented by Lillian C. McDermott & Paula R. L. Heron, University of Washington, USA.
August 2007	GIREP-EPEC Opatija -Frontiers of Physics Education **Physics Research in the Classroom**. Workshop presented by Karwasz Grzegorz,University Nicolaus Copernicus, Torun, Poland.

MEMBERSHIPS

European Science Education Research Association (ESERA) membership

Editorial Review Board of Science Education Review membership

Turkish Science Education and Research Association (SERA) membership