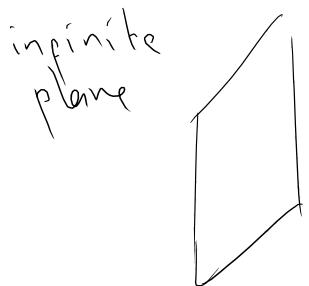
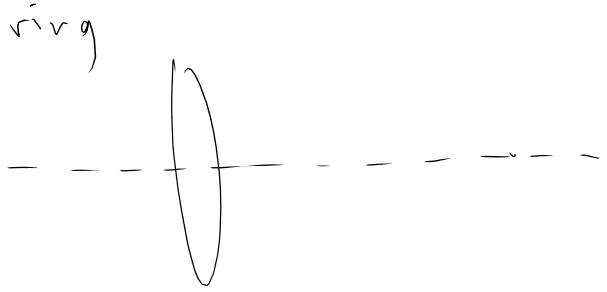
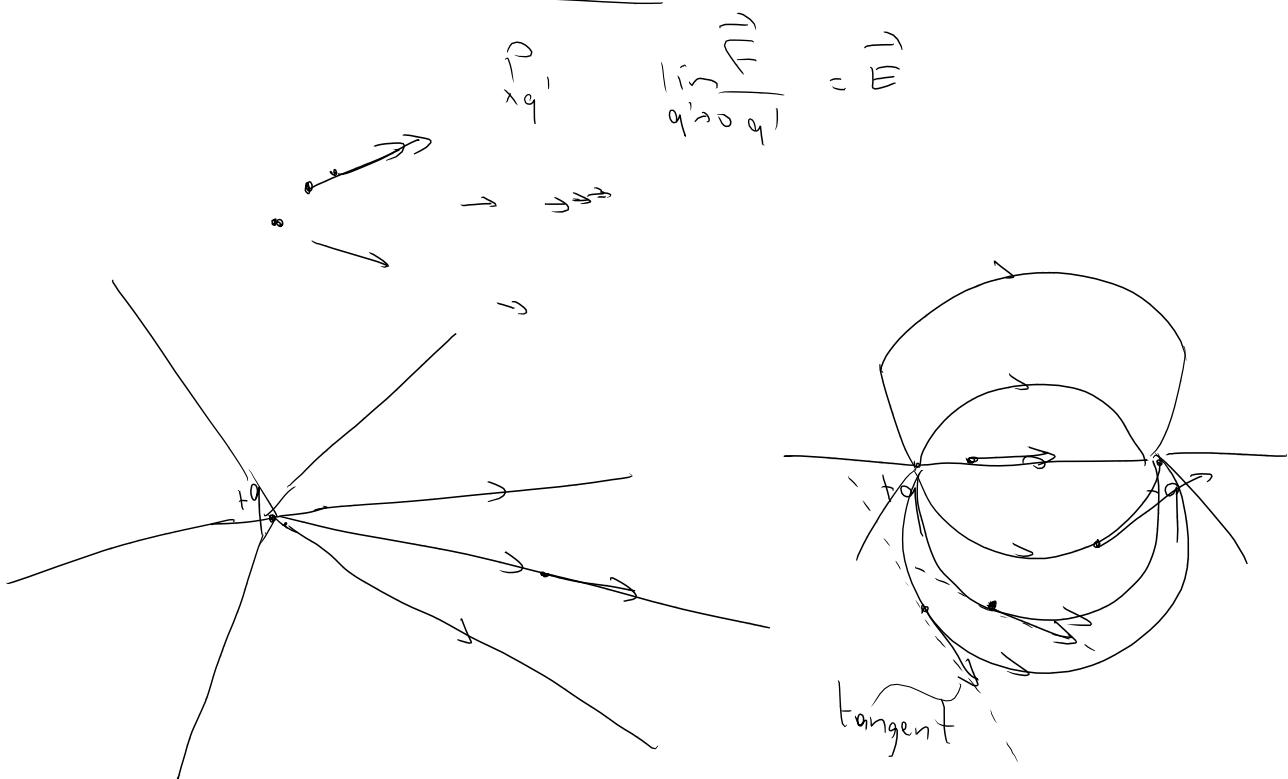


March 3, 2016

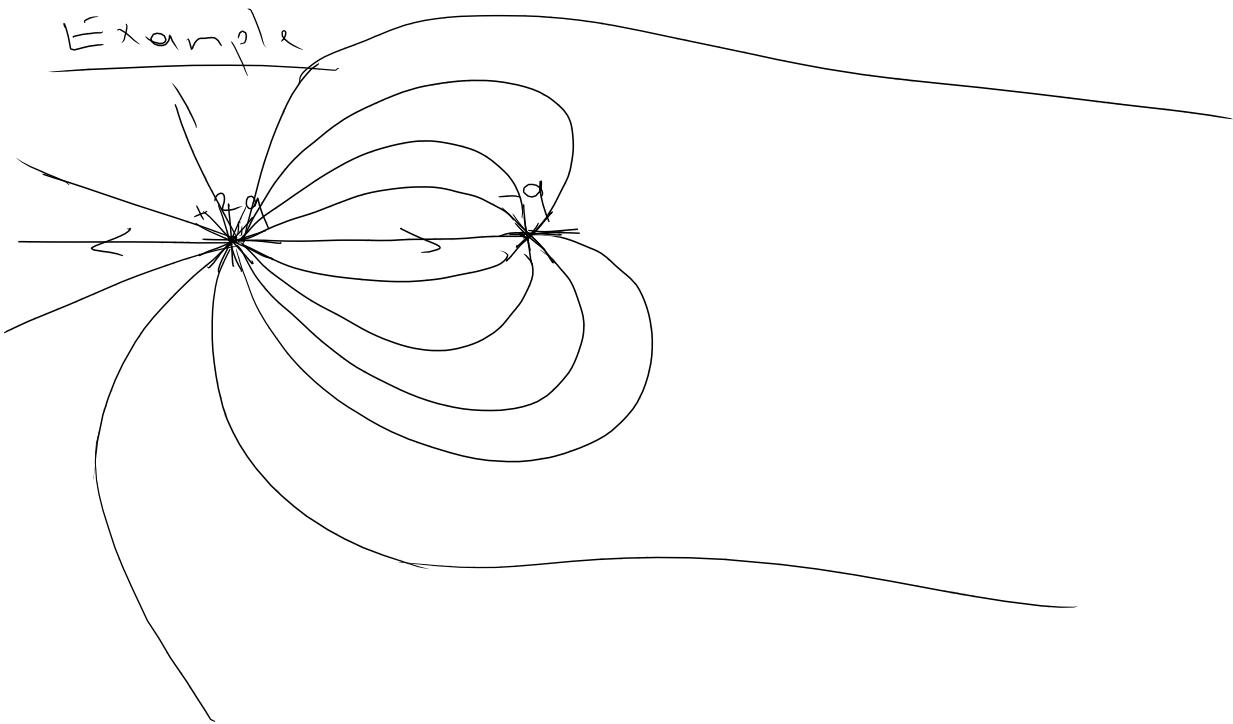


$$E = \frac{\sigma}{2\epsilon_0}$$

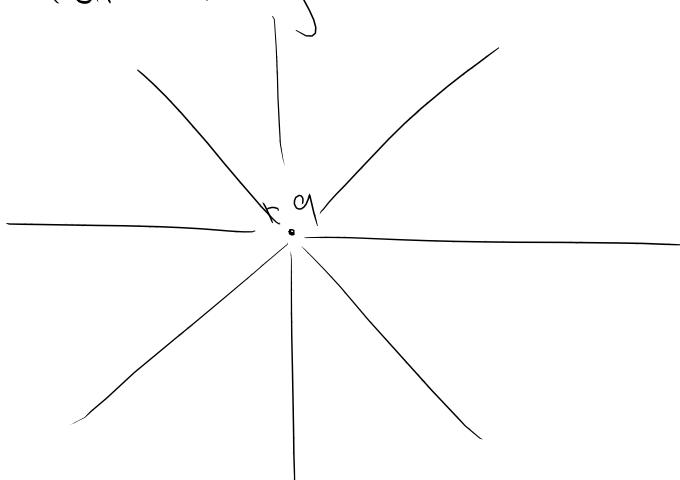
Electric Field Lines



The magnitude of the electric field is proportional to the density of field lines.



For ordinary observer



Example

$$\begin{aligned}
 \vec{E} &= \vec{E}_{+2q} + \vec{E}_{-q} \\
 &= \frac{1}{4\pi\epsilon_0} \frac{2q}{(d+x)^2} \hat{x} + \frac{1}{4\pi\epsilon_0} \frac{(-q)}{x^2} \hat{x} = 0 \quad x \rightarrow 0
 \end{aligned}$$

$$\Rightarrow \frac{2}{(d+x)^2} - \frac{1}{x^2} = 0 \Rightarrow d+x = \sqrt{2}x \quad d = (-1\sqrt{2})x \Rightarrow x = \frac{1}{-1\sqrt{2}}d$$

$$n \approx 1.4$$

$$x \approx \frac{1}{-1 \mp 1.4} d \Rightarrow x \approx \frac{1}{0.4} d \quad \text{or} \quad x \approx -\frac{1}{2.4} d$$

$$x \approx 2d$$



$$\begin{matrix} \oplus \\ x \end{matrix}$$

$x \approx -0.4d$
not a soln.
since x should
be $x > 0$

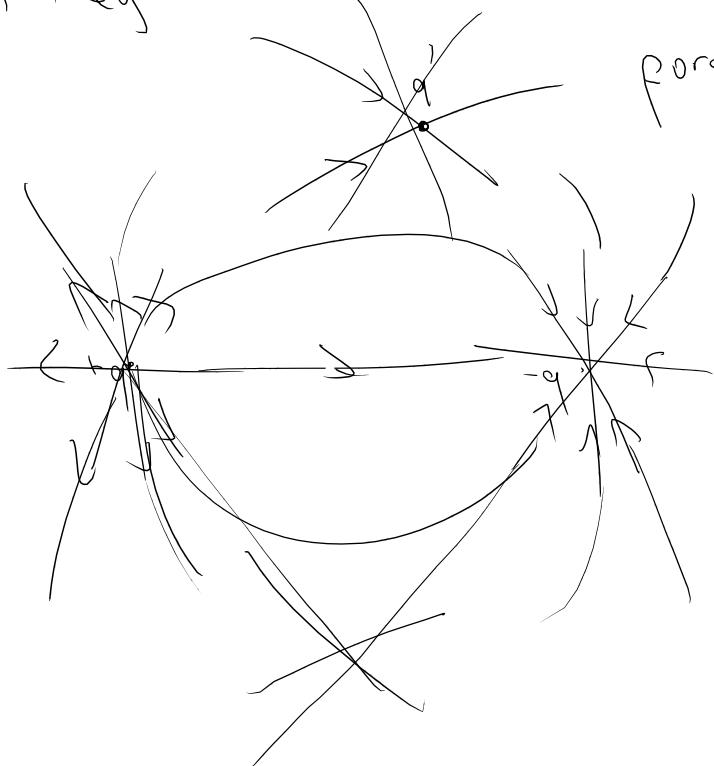
$$\vec{E}_{\text{of a point charge}} = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2} \hat{r}$$

$$\vec{E} = ?$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{2q}{x^2} (-\hat{x}) + \frac{1}{4\pi\epsilon_0} \frac{(-q)}{(d+x)^2} (-\hat{x}) ; \quad x > 0$$

Electric Field Lines

1) They can not intersect

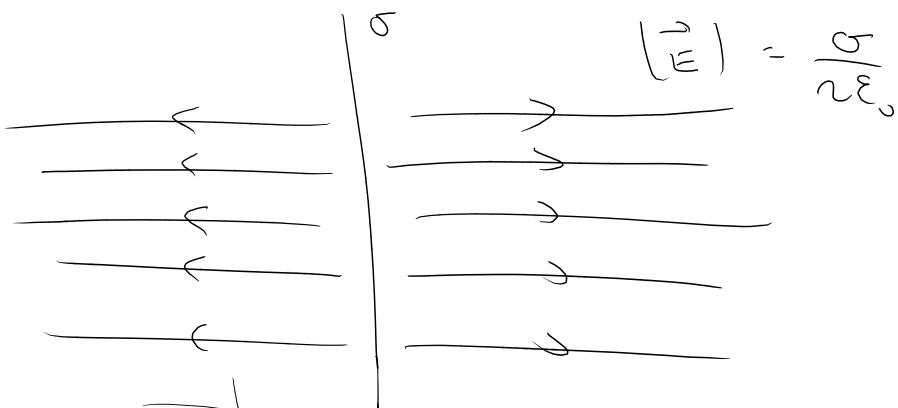


force has a unique direction

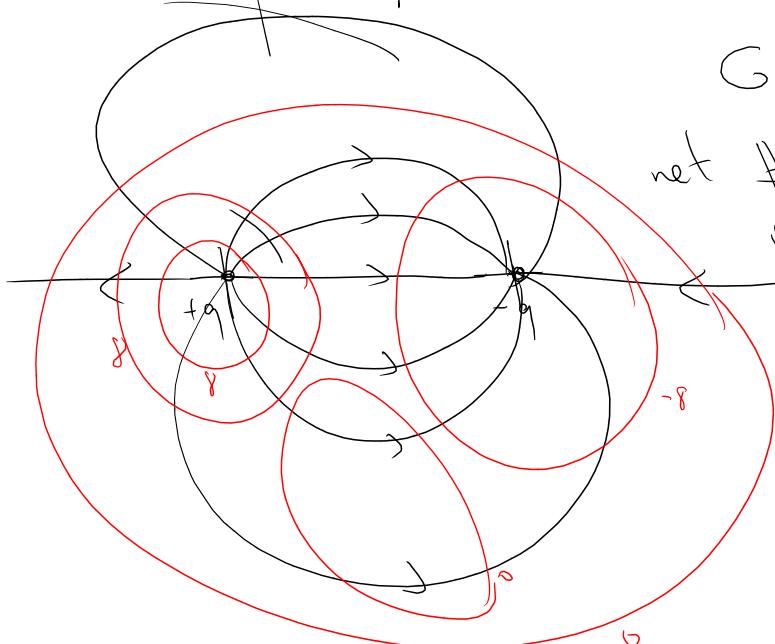
2) \exists electric field lines passing every point
(unless $\vec{E} = 0$)

- 3) at every point they are tangent to the \vec{E} field
- 4) density is proportional to the magnitude of E
- 5) they start from positive charges (or infinity) and end in negative charges (or infinity)

Planar charge distribution



$$|\vec{E}| = \frac{\sigma}{2\epsilon_0}$$



Gauss' Law:

net # of E field lines passing through a closed surface is proportional to the total charge inside.

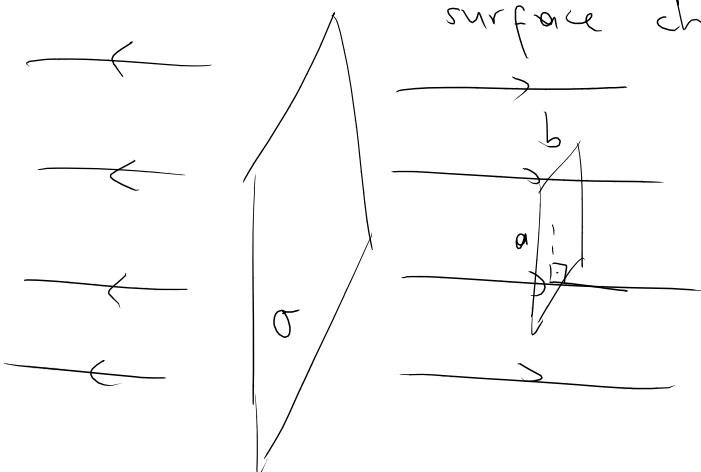
$$|\vec{E}| \propto \text{Density of electric field lines} = \frac{\# \text{ of lines passing on area } A}{A} \quad \left(\begin{array}{l} \text{Area } A \\ \text{is perpendicular} \\ \text{to electric field lines} \end{array} \right)$$

of lines passing \propto $|\vec{E}| A$ = electric flux ϕ_E

$$\phi_E = EA = E_\perp A$$

E_\perp is the perpendicular component of the electric field

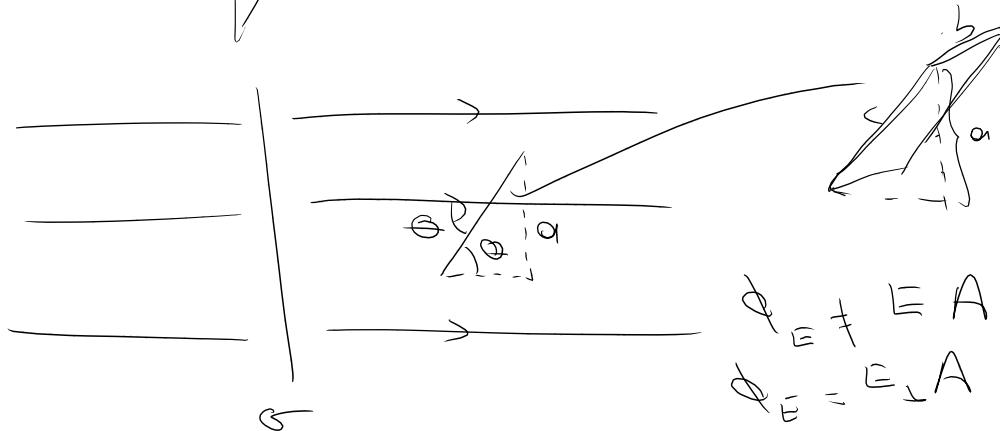
Example



infinite surface planar charge with
charge density σ

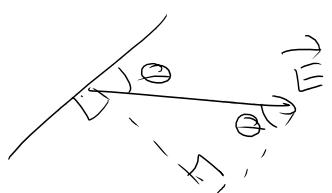
$$E = \frac{\sigma}{2\epsilon_0}$$

$$\phi_E = \frac{\sigma}{2\epsilon_0} ab \quad \boxed{= E \sigma b = \phi_E}$$



$$\phi_E \neq EA$$

$$\phi_E = E_\perp A$$



$$E_\perp = E \sin \theta$$

$$\phi_E = E \sin \theta b c$$

$$= E b (\sin \theta c)$$

$$\boxed{\phi_E = E \sigma b}$$

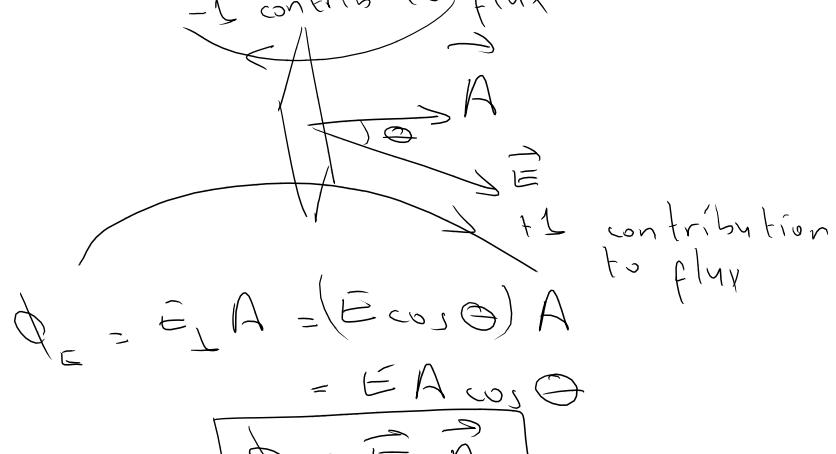
Scalar Product

$$\vec{A} \cdot \vec{B} = AB \cos \theta = BA_{\parallel} = AB_{\parallel}$$

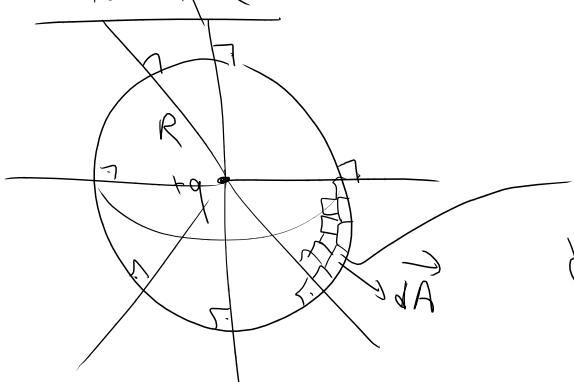


$$\phi_E = \vec{E} \cdot \vec{A}$$

define \vec{A} s.t. \vec{A} is perpendicular to the area and has magnitude equal to the area.



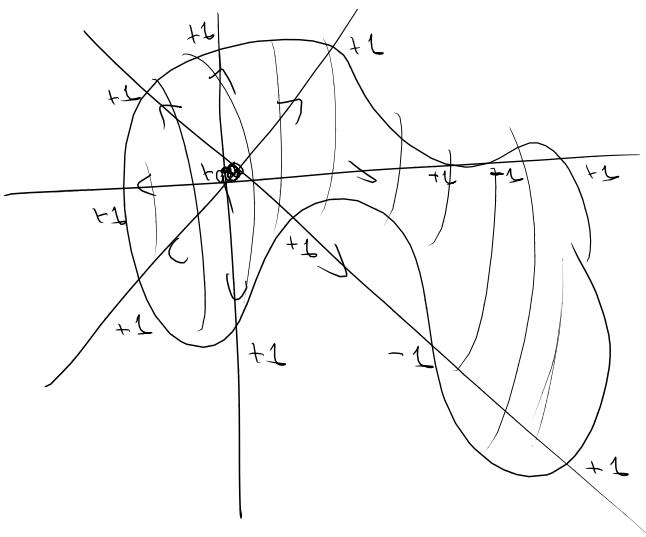
Example



$$d\phi_E = \vec{E} \cdot \vec{dA} = E dA \cos \theta = \frac{1}{4\pi\epsilon_0} \frac{q}{R^2} dA$$

$$\begin{aligned} \phi_E &= \sum d\phi_E = \sum \frac{1}{4\pi\epsilon_0} \frac{q}{R^2} dA \\ &= \frac{q}{4\pi\epsilon_0 R^2} \sum dA \\ &= \frac{q}{4\pi\epsilon_0 R^2} \cancel{\pi R^2} = \frac{q}{\epsilon_0} \end{aligned}$$

$$\phi_E = \frac{q}{\epsilon_0}$$



$$\oint \vec{E} \cdot d\vec{A} = \frac{q}{c}$$

$$\frac{1}{350000}$$

Af
350 km

$$U = 0.6 C$$

0.2 seconds

$$M_c = \frac{C^3}{G} \left[\frac{5}{56} \pi^{-8/3} f^{-11/3} \cdot f^{7/5} \right]$$

$$M_c = \frac{(m_1 m_2)^{3/5}}{(m_1 + m_2)^{11/5}}$$

$$D = \frac{5}{96 \pi^2 h} \frac{C}{f^3}$$