$$H = -\vec{\mu}\cdot\vec{B}$$

$$\vec{\mu} = g\frac{q}{2m}\vec{l}$$

$g = 1$ if only orbital motion

$g = 2$ if only spin contribution

$$g = \frac{3}{2} + \frac{- - - -}{J(J+1)}$$

$$\vec{\mu} = \frac{q}{2m}(\vec{L} + 2\vec{S})$$

$$\vec{\mu} = \frac{q}{2m}(\vec{J} + \vec{S})$$

$$\delta E_B = \langle \alpha; JM | -\vec{\mu}\cdot\vec{B} | \alpha; JM \rangle$$

$$\left\{ \langle \alpha; JM | \vec{\mu} | \alpha; JM \rangle = g\frac{q}{2m}\langle \alpha; JM | \vec{J} | \alpha; JM \rangle \right.$$

- distinguishable
- identicle
- indistinguishable

$$\psi_2(\vec{r}_1,\vec{r}_2) = \frac{1}{\sqrt{2}}\left[\psi_1(\vec{r}_1)\psi_2(\vec{r}_2) + \psi_1(\vec{r}_2)\psi_2(\vec{r}_1)\right]$$

$$\psi_2(\vec{r}_1,\vec{r}_2) = \psi_2(\vec{r}_2,\vec{r}_1) \Leftarrow \text{bosons}$$

for photons

$$\psi_2(\vec{r}_1,\vec{r}_2) = -\psi_2(\vec{r}_2,\vec{r}_1) \Leftarrow \text{fermions}$$

$$\psi = e^{\frac{i}{\hbar}S}$$

S: action (classical)

$\Leftarrow$ semi classical approximation

$$P_r \propto e^{-\beta E_r} \qquad \beta = \frac{1}{kT}$$

- Temperature needs to be defined
- System should be in equilibrium
- Thermodynamical limit.

micro canonical ensemble : isolated system all microstates have equal probability. (E = fixed)

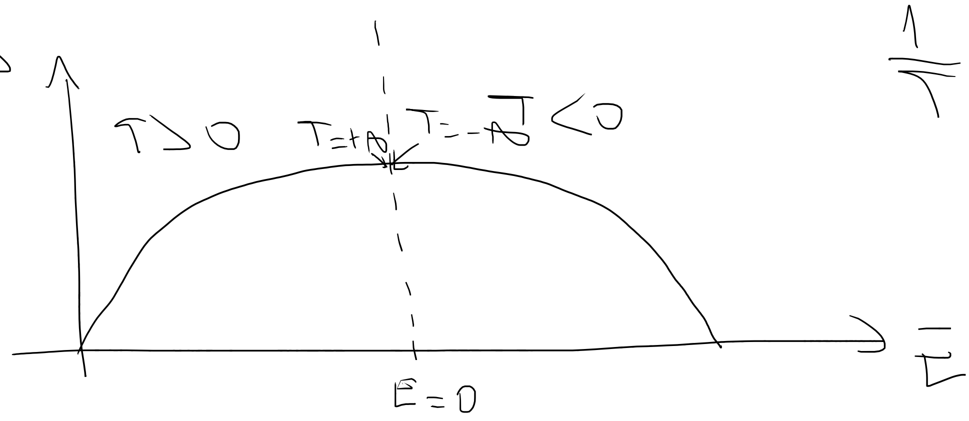
canonical ensemble : system is in contact with a heat reservoir (T = fixed)

$$H = H_1 + H_2 + H_3 + \cdots$$

$$T \overset{?}{=} T_1 + T_2 + T_3 + \cdots \Big\} \text{ No } T \text{ is intensive!}$$

$$\Delta U = \Delta Q - \Delta W \quad \text{first law}$$

$$\frac{1}{T} = \left(\frac{\partial S}{\partial E}\right)$$



$$dS = \frac{dQ}{T}$$

$$H = \sum_i \frac{p_i^2}{2m_i} + \cancel{\sum V(q_i)}$$

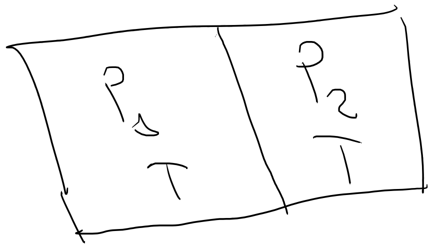
$$= \underbrace{\sum_{i=1}^{10} \frac{p_i^2}{2m_i}} + \underbrace{\sum_{i=11}^{N} \frac{p_i^2}{2m_i}}_{\text{ignore}}$$

$$H = H_{\text{nucl. dip.}} + H_{\text{rest}} + H_{\text{nucl. dip and rest interactions}}$$

- Immediate memory
- Working memory $\Leftarrow$
- Long term memory $\Leftarrow$

$$\frac{1}{T} = \frac{\partial S}{\partial E} = \text{const}$$

thermal equilibrium - system has a T
mechanical equilibrium - system has a P
thermodynamical equilibrium - system has a T & P



$$Q_N = \sum_r e^{-\beta E_r}$$

$$E_r = \underset{\overset{\shortparallel}{0}}{E^{cM}} + E\left(\begin{array}{l}\text{translational}\\ \text{motion of the particles}\end{array}\right)$$

$$E^{tr}(p_i) + E\left(\begin{array}{l}\text{interactions}\\ \text{between}\\ \text{particles}\end{array}\right)$$

$$E^{int}(q_i)$$

$$+ E^{\text{internal}}(P_i, Q_i) + E^{\text{mag. dipoles}}(d_i)$$

$$Q_N = \int \prod dp_i \, dq_i \prod dP_i \, dQ_i \prod d(d_i)$$

$$\exp\left\{-\beta\left(E^{tr} + E_{int} + E_{\text{internal}} + E_{\substack{\text{mag.}\\\text{dipoles}}}\right)\right\}$$

$$= \left(\int \prod dp_i \, e^{-\beta E^{tr}}\right)\left(\int \prod dq_i \, e^{-\beta E_{int}}\right)$$

$$\left(\int \prod dP \, dQ_i \, e^{-\beta E_{\text{internal}}}\right)\left(\prod d(d_i) e^{-\beta E_{\substack{\text{mag}\\\text{dipoles}}}}\right)$$

$$Q_N = Q_N^{tr} \, Q_N^{int} \, Q_N^{\text{internal}} \, Q_N^{\substack{\text{mag}\\\text{dipoles}}}$$

$$A = -kT \ln Q_N = A^{tr} + A^{int} + A^{\text{internal}} + A^{\substack{\text{mag}\\\text{dipoles}}} + \text{const}(N)$$

$$m = -\frac{\partial A}{\partial B} = -\frac{\partial A^{\substack{\text{mag}\\\text{dipoles}}}}{\partial B}$$

<u>HW</u> What should be the "unit volume" in phase space such that counting the number of microstates classically gives the same expression as the quantum mechanical case

$$\sum_{\phi} \Leftrightarrow \int \frac{\sin\theta \, d\theta \, d\phi}{w_0}$$

$w_0 = ?$

$$w_0 \stackrel{?}{=} h \qquad w_0 = [\theta \phi] = 1$$

$$\int \frac{dp \, dq}{w_0'} \qquad [w_0'] = [pq] = [h]$$

$$\int \frac{\overbrace{d\theta \, d\phi}^{\text{no } \sin\theta ?} \, dp_\theta \, dp_\phi}{h^{2(?)}}$$