DIRECT FORMULA FOR $\bar{E}$ in H.O

$\bar{E} = \frac{1}{2}kT$ for each term (K.E & P.E)

e.g. In 3-D; 3 K.E & 3 P.E term

$\bar{E} = kT + kT + kT + kT + kT + kT = 3kT$

$\boxed{\bar{E} = 3kT}$

But If particles are non interacting

$V = 0$

$\Rightarrow \bar{E} = \frac{1}{2}kT + \frac{1}{2}kT + \frac{1}{2}kT$

$\Rightarrow \boxed{\bar{E} = \frac{3}{2}kT}$

For H.O.

$$Z = \sum_{n=0}^{\infty} e^{-\beta\left(n+\frac{1}{2}\right)\hbar\omega}$$

$$Z = e^{-\hbar\omega\beta/2} + e^{-3\hbar\beta/2} + \cdots$$

GP series

$$a = e^{-\hbar\omega\beta/2}, \quad r = e^{-\beta\hbar\omega}$$

$$\therefore Z = \frac{e^{-\beta\hbar\omega/2}}{1 - e^{-\beta\hbar\omega}}$$

For 3D H.O, $Z_N = \frac{1}{!N}\left(\frac{kT}{\hbar\omega}\right)^{3N}$

Average value of x = $\bar{x}$ = 0

Partition fn for particles in magnetic field

$$Z = e^{-\beta\bar{E}} = e^{-\beta(\vec{\mu}\cdot\vec{H})} = e^{-\beta(\vec{\mu}\cdot\vec{B})}$$

up $\rightarrow \mu B$, down $\rightarrow -\mu B$

$$Z = e^{-\mu\beta B} + e^{\mu\beta B}$$

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EXAMPLE → If $F = NkT\ln\left(\frac{aoV}{N}(kT)^{5/2}\right)$.

Find U.

Soln. As $F = -NkT\ln Z$

$$\Rightarrow Z = \frac{-aoV(kT)^{5/2}}{N}$$

$$U = \frac{-\partial}{\partial\beta}(\ln Z) = \frac{-\partial}{\partial\beta}\left(\ln\left(\frac{aoV}{N}\left(\frac{1}{\beta}\right)^{5/2}\right)\right)$$

$$= \frac{5N}{2\beta} = \frac{5}{2}NkT$$

$$\boxed{U = 5/2\,NkT}$$

Ensemble → system of collection of similar systems having some const parameter

Microcanonical
Walls are rigid impermeable well insulated

N_1, V_1, E		
N_2, V_2, E		
N_3, V_3, E		
N_4, V_4, E		

Canonical
Walls are rigid conducting impermeable

V_1, N_1, T		
V_2, N_2, T		
V_3, N_3, T		

Grand canonical
Walls are impermeable rigid conducting

μ_1, V_1, T		
μ_2, V_2, T		
μ_3, V_3, T		

μ canonical ↔ canonical ↔ Gcanonical

These quantities remain same in a particle ensemble i.e in microcanonical, canonical & Grand canonical resp → $\frac{1}{\sqrt{N}}$ ← Energy fluctuation → $\frac{1}{N}$

Maxwell Boltzmann dist^{n} law of velocities

No. of particles in velocity range b/w v_x & $v_x + dv_x$ is

$$n(v_x)dv_x = N\left(\frac{m}{2\pi kT}\right)^{1/2} e^{-\frac{mv_x^2}{2kT}} dv_x$$

$$P = \frac{n}{N} = \left(\frac{m}{2\pi kT}\right)^{1/2} e^{-\frac{mv_x^2}{2kT}} dv_x$$

$$P_{max} = \left(\frac{m}{2\pi kT}\right)^{1/2} \quad (P \propto T^{-1/2})$$

$$\bar{v}_x = \int_{-\infty}^{\infty} v_x P\, dv_x = 0$$

$$\boxed{\bar{v}_x = \bar{v}_y = \bar{v}_z = 0}$$

Ulg

$$\boxed{\langle v_x v_y \rangle = \langle v_y v_z \rangle = \langle v_z v_x \rangle = 0}$$

In 1-D

$$\langle v_x^2 \rangle = \langle v_y^2 \rangle = \langle v_z^2 \rangle = kT/m$$

In 2-D

$$\langle v_x^2 \rangle = \langle v_y^2 \rangle = \langle v_z^2 \rangle = 2kT/m$$

In 3-D

$$\langle v_x^2 \rangle = \langle v_y^2 \rangle = \langle v_z^2 \rangle = 3kT/m$$

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