Celsius or Kelvin?

$0°C \rightarrow 273\,K$

difference in temp $100°C \rightarrow 373\,K$

Boiling - Freezing: $100°C$, $100\,K$

$$Q = m\,C_v\,\underline{\Delta T}$$

$$S = \int_{T_i}^{T_f} \frac{dQ}{T} = \frac{m C_v}{T}\,dT = m C_v \ln\left(\frac{T_f}{T_i}\right)$$

$$\frac{T_f}{T_i} = \frac{100\cancel{°C}}{0\cancel{°C}} \longrightarrow \left(\frac{373\cancel{K}}{273\cancel{K}}\right)$$

Water $\quad C_v = \dfrac{1\,\text{cal}}{\text{gram}\;°C} = \dfrac{\overset{4.18\,J}{1\,\text{cal}}}{\text{gram}\;°K}$

3 states H, T, S — 4 coins

$\cancel{4}^3$ $3^4 = 81$ microstates

macrostates = 15 — $\frac{N(N+1)}{2}$

HHHH 1

TTTT 1

SSSS 1

HTTT, THTT, TTHT, TTTH 4

THHH - - - - - 4

HHTT, HTTH, TTHH
HTHT, THTH, THHT 6

$\binom{4}{2} = \frac{4!}{2!2!}$

HS 4
4
6

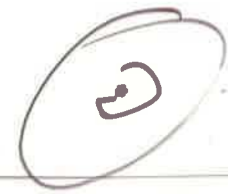
TS 4
4
6

HHTS — $\frac{4!}{2!1!1!} = 12$

TTHS — 12

SSTH — 12

Bowling Ball



$f = ?$

$f = 5$

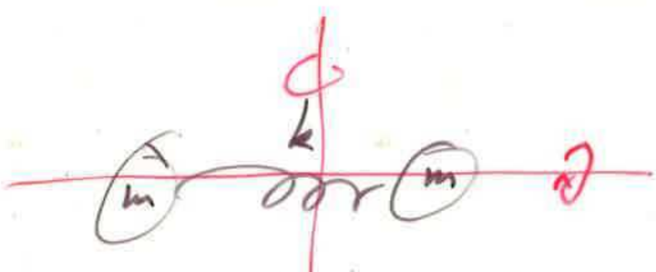
Trans in x $\quad \frac{1}{2} m v_x^2$

Trans in y $\quad \frac{1}{2} m v_y^2$

rotations $\quad \frac{1}{2} I_x \omega_x^2$

$\frac{1}{2} I_y \omega_y^2$

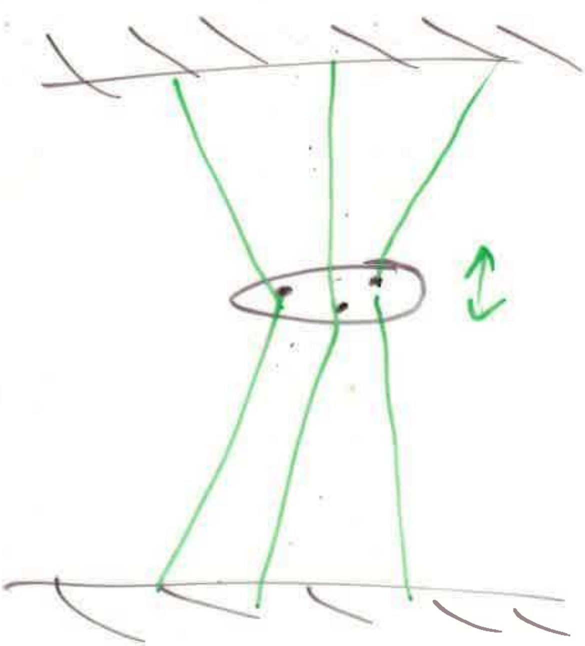
$\frac{1}{2} I_z \omega_z^2$



$N \sim U^f$

$KE = \frac{1}{2} \mu v_r^2$

$PE = \frac{1}{2} k \ell^2$ $\quad f = 2$



Vertical vibrations

$\frac{1}{2} m v_z^2, \frac{1}{2} k z^2$ $\quad 2$

x vibration $\quad 2$

y vibrations $\quad 2$

twisting vibrations

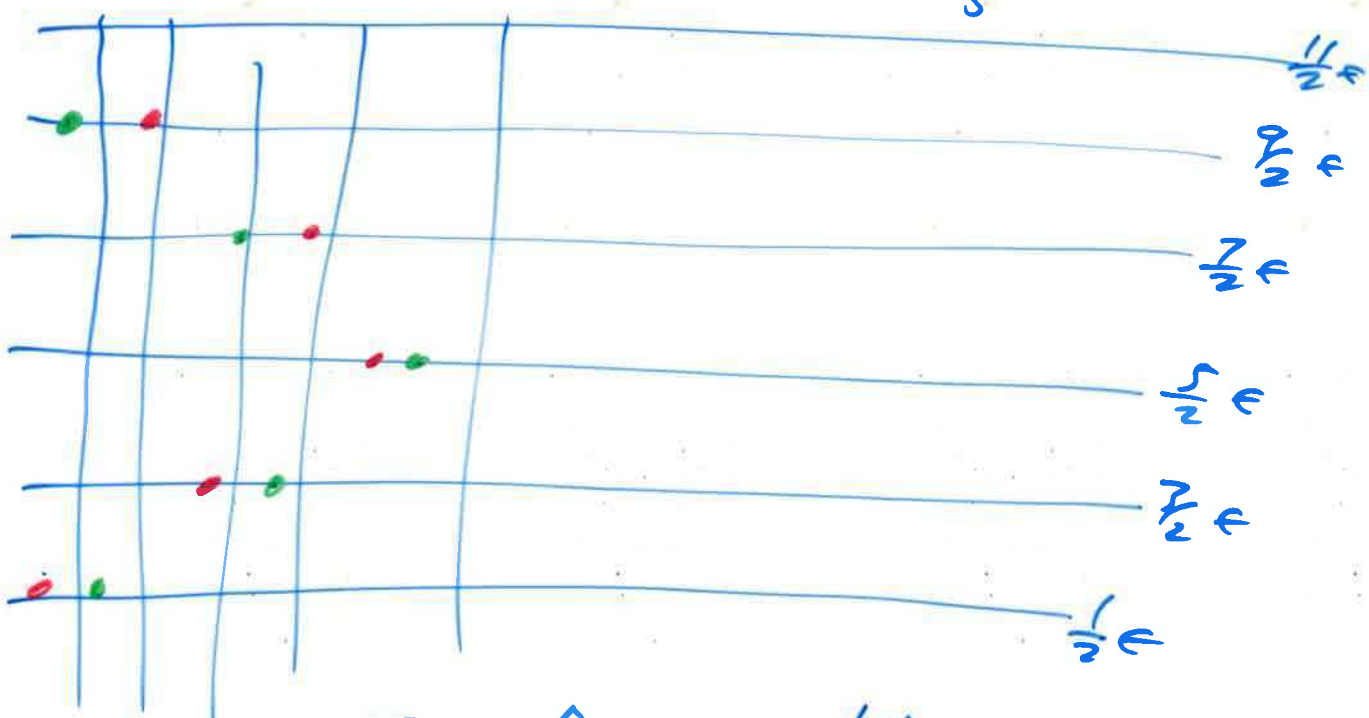
$\frac{1}{2} I_z \omega^2 + \frac{1}{2} N \theta^2$ $\quad 2$

2 particles mass m, distinguishable
in a SHO potential

$U = \frac{1}{2} m\omega^2 x^2$

Total energy $= 5\epsilon$, how many microstates

5



$\bar{\epsilon} = \frac{5}{2}\epsilon \qquad kT \gg \epsilon$

for green particle $r = \frac{P(\frac{3}{2}\epsilon)}{P(\frac{1}{2}\epsilon)} = \frac{e^{-\beta(\frac{3}{2}\epsilon)}}{e^{-\beta(\frac{1}{2}\epsilon)}} < 1$

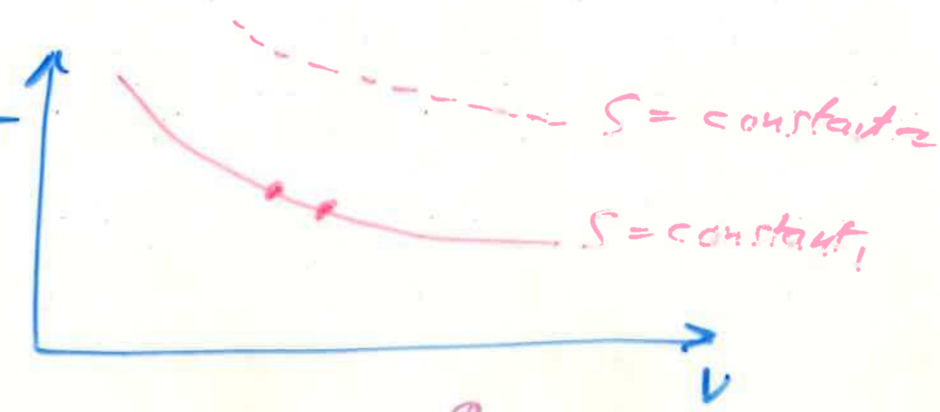
$\beta = \frac{1}{k_B T}$

low T: $r \sim 0$
high T: $r \sim 1 < 1$

Prove that $\left(\frac{\partial U}{\partial V}\right)_{SN} = \left(\frac{\partial U}{\partial V}\right)_{TN} - \left(\frac{\partial U}{\partial S}\right)_{VN}\left(\frac{\partial S}{\partial V}\right)_{TN}$

Fix N.

$dN = 0$



Remember $U(S, V, \cancel{N}) = U(S[T, V, \cancel{N}], V, \cancel{N})$

$= U(T, V)$

$$dU = \left(\frac{\partial U}{\partial V}\right)_{TN} dV + \left(\frac{\partial U}{\partial T}\right)_{VN} dT \quad \star$$

$S[T, V, \cancel{N}] \Rightarrow$

$$dS = \left(\frac{\partial S}{\partial V}\right)_{TN} dV + \left(\frac{\partial S}{\partial T}\right)_{VN} dT = 0$$

on the curve $S = \text{constant}$

$$\left(\frac{\partial S}{\partial V}\right)_{TN} dV = -\left(\frac{\partial S}{\partial T}\right)_{VN} dT$$

$$\Rightarrow \left(\frac{\partial T}{\partial V}\right)_{SN} = -\frac{\left(\frac{\partial S}{\partial V}\right)_{TN}}{\left(\frac{\partial S}{\partial T}\right)_{VN}}$$

$$\frac{\cancel{d}}{dV} \Rightarrow \left(\frac{\partial U}{\partial V}\right)_{SN} = \left(\frac{\partial U}{\partial V}\right)_{TN} \cancel{\frac{dV}{dV}}^{\,1} + \left(\frac{\partial U}{\partial T}\right)_{VN} \left(\frac{\partial T}{\partial V}\right)_{SN}$$

$$\left(\frac{\partial U}{\partial V}\right)_{SN} = \left(\frac{\partial U}{\partial V}\right)_{TN} \overset{-}{+} \underbrace{\left(\frac{\partial U}{\partial T}\right)_{VN} \left(\frac{\partial T}{\partial S}\right)_{VN}}_{-\left(\frac{\partial U}{\partial S}\right)_{VN}} \left(\frac{\partial S}{\partial V}\right)_{TN}$$

$$\left(\frac{\partial U}{\partial V}\right)_{SN} = \left(\frac{\partial U}{\partial V}\right)_{TN} - \left(\frac{\partial U}{\partial S}\right)_{VN} \left(\frac{\partial S}{\partial V}\right)_{TN} \quad \blacksquare$$

$$\left(\frac{\partial U}{\partial P}\right)_{TN} = 0$$