P201 Day 22

Notes to be posted

Thermal Physics : More Optics in Lab

Temperature:

- How hot something is.
- Glow into visible when hot
  "red" hot → yellow → white → blue

$\overline{E}_K \propto T^1$

translational E_K of gas: $\frac{1}{2} m \overline{v^2}$

$\overline{E}_K = \frac{3}{2} k_B T$

Boltzman's Constant

$k_B = 1.38 \times 10^{-23} \frac{J}{K}$ ← Joules of Energy ; K ← Kelvin, unit of T.

Common units of T:

Fahrenheit (°F)

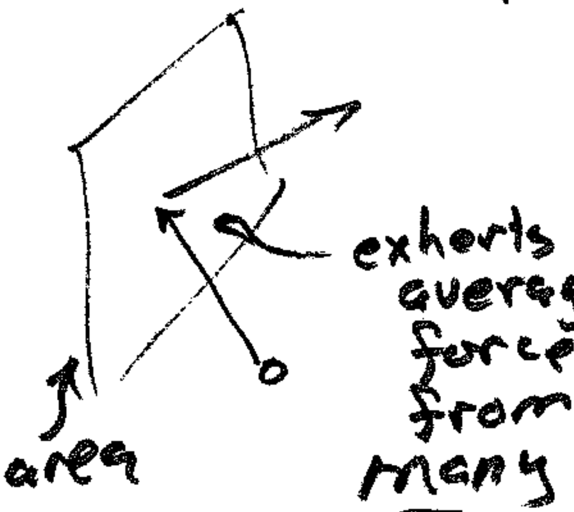
Celsius (°c)

Kelvin (K)

$T(°c) = T(K) - 273.15\ °c$

$T(°c) = \frac{5}{9} T(°F) - 32\ °c$

Ideal Gas Law:
What is Pressure?



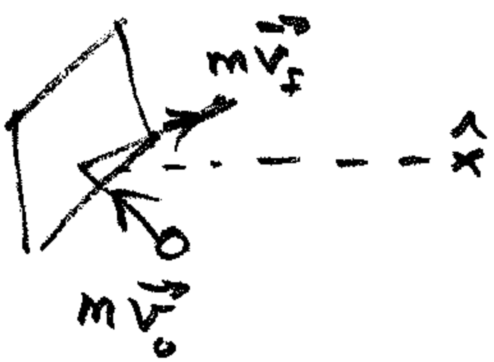
unit of Pressure: $\frac{\text{Newton}}{\text{meter}^2} = \text{Pa}$ ← Pascal

$P = \frac{\text{force}}{\text{unit area}}$

1 atm of pressure $= 1.013 \times 10^5$ Pa

many other units of Pressure:
torr, bar, mmHg, psi $= \frac{\text{pound}}{\text{inch}^2}$,

Collisions, on average can produce force:



in $\hat{x}$ dir:

$mv_{0x} \longrightarrow mv_{fx}$

elastic: (ideal gas)

$v_{0x} = -v_{fx}$ didn't loose energy.

$F = ma$ $\quad$ Δmomentum

$F = \frac{\Delta \vec{p}}{\Delta t} = \frac{2mv_x}{\Delta t}$

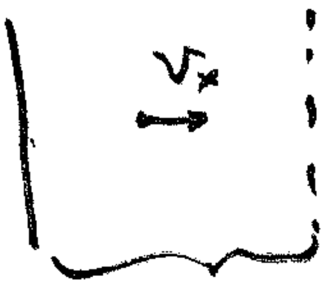
Consider container, $L \times L \times L$ = Volume V

↑ length

full of N particles, each mass m

and temperature T.

$$P = \frac{F}{\text{area}} = \frac{F}{\underset{\uparrow\ \text{one wall}}{L^2}} = \frac{N\,\overbrace{2mv_x/\Delta t}^{\Delta p\ \text{force}}}{L^2}$$



$$\frac{2L}{\Delta t} = v_x \qquad \Delta t = \frac{2L}{v_x}$$

what is Δt between strikes on left wall?

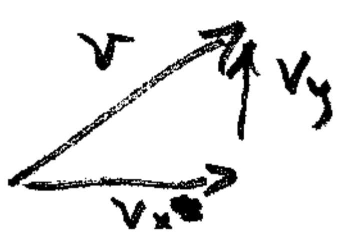
$$P = \frac{N\cancel{2}mv_x \overbrace{\frac{v_x}{\cancel{2}L}}^{\frac{1}{\Delta t}}}{L^2} =$$

← L^3 = the Volume

$$\overline{E_K} = \frac{3}{2}k_BT = \frac{1}{2}m\overline{v^2}$$

$$3k_BT = m\overline{v^2} = m(\overline{v_x^2} + \overline{v_y^2} + \overline{v_z^2})$$

$$m\overline{v_x^2} = k_BT$$



$$P = \frac{N k_B T}{V} \rightarrow PV = N k_B T$$

$$PV = nRT$$

n = # mols

R = the gas constant

$$n = \frac{N}{N_A}$$ ← Avogadro's Number

$$R = k_B \cdot N_A$$

$$\overset{\parallel}{8.315\,\frac{J}{K}} = 1.38\times10^{-23}\,\frac{J}{K}\cdot 6.022\times10^{23}$$

$$\frac{3}{2}k_B T = \overline{E_K}$$

 3-D motion $\Rightarrow \frac{3}{2}k_B T$

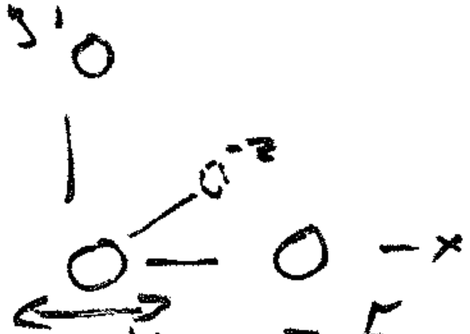
3 from "equipartition" of energy theorm

each "available" $\underbrace{\text{place you can put energy}}_{\text{degree of freedom}}$

governed by quantum mechanics

gets $\frac{1}{2}k_B T$ of energy, on average

Solids at (near) room T:



motion → E_K → 3 d.o.f. ← $\underbrace{}$ degree of freedom

the trivial d.o.f.
almost always have them
and usually available.

and potential energy:
3 more dof

6 total: $\bar{U} = \frac{6}{2} k_B T = 3 k_B T$

and this linked to "specific heat" = c

$$C = \frac{d\bar{U}}{dT} = 3 k_B \text{ per molecule}$$

$$C = \underline{3R} \text{ per mole of material}$$

↳ a law... Dulong & Petit

d.o.f. linked to specific heat
↓
easy to measure

pecific heat of liquid water

$$1 \frac{cal}{g \cdot {}^\circ C} = 4.184 \frac{J}{g\,{}^\circ C}$$

also half if you freeze it.

about $\frac{1}{2}$ in steam (vapor)

Thermal Expansion:

$$L(T) = L_0 (1 + \alpha \Delta T)$$

final length

init length

coefficient of thermal expansion

change in T

α generally > 0

$\alpha < 0$ for water $(0 \to 4.2^\circ C)$

unusual.