Ch 12: Thermodynamics

$$\Delta E = W + Q$$

$$E_{th} \sim N K_{Avg} = N \left(\frac{3}{2} K_b T\right)$$

→ # particles

→ Avg kinetic energy

→ For an Ideal Gas

→ Boltzmann's const $= 1.38 \times 10^{-23} \frac{J}{K}$

$$\Delta E_{th} \sim \frac{3}{2} N K_b \Delta T$$

→ Say all particles have same mass

$$K_{Avg} = \frac{1}{2} \left(m_i v_i^2\right)_{Avg} = \frac{1}{2} m \left(v_i^2\right)_{Avg} = \frac{1}{2} m\, v_{rms}^2$$

(root-mean-square) $v_{rms} = \sqrt{\left(v^2\right)_{Avg}} = \sqrt{\dfrac{\sum_i v_i^2}{N}}$

Pressure: particles collide w/ objects

Exerting a net force per unit area.
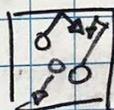
$$P = \frac{F}{A} \qquad \left(\frac{N}{m^2} = \text{Pascals (Pa)}\right)$$

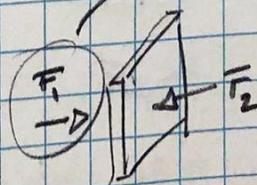Standard atmospheric pressure $= 101.3\ kPa = 1\ atm$

$$= 14.7\ psi$$

→ due to atmospheric pressure.

$$F_{net} = F_2 - F_1$$

$$= P_2 A - P_1 A$$

$$= A(P_2 - P_1)$$

$$= A\, \Delta P \quad \to \text{gauge Pressure}$$

$$P_g = \Delta p = \frac{F_{net}}{A}$$

$$\boxed{Vacuum = P \ll 1\ atm}$$

Ideal Gas Law

$$P \cdot V = n \boxed{R} T \quad \text{Gas Constant}$$

$$(\text{pressure})(\text{volume}) = (\# \text{ of moles})(8.31 \; J/mol \cdot K)(\text{temperature})$$
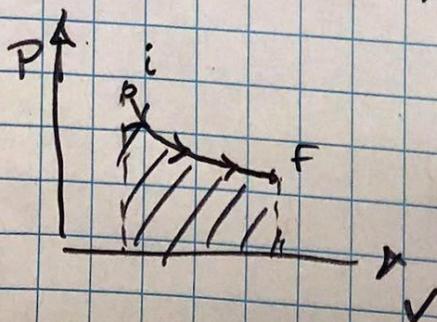
Ideal Gas Process... Constant (nR)

$$\frac{P_i V_i}{T_i} = nR = \frac{P_f V_f}{T_f}$$

$\Delta E_{th} = Q_H$

$T_2 > T_1$

$P_2 > P_1$

$V_2 = V_1 \equiv$ iso choric

$\Delta E_{th} = -P_{gas} \Delta V + Q_H$

$T_2 > T_1$

$V_2 > V_1$

$P_2 = P_1 \equiv$ iso baric

$W_2 = -W_{gas}$

$\Delta E_{th} = 0 = -W_{gas} + Q$

$V_2 < V_1$

$P_2 > P_1$

$T_2 = T_1 \equiv$ iso thermal

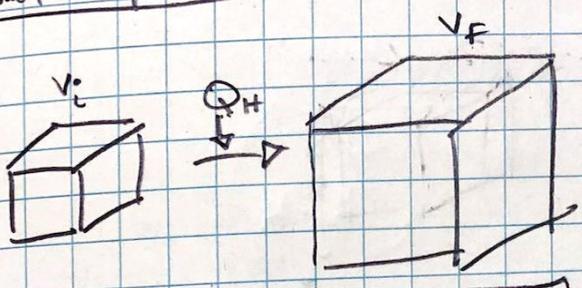$$W_{gas} = \text{Area under } (P,V) \text{ curve}$$

if $\Delta V = 0$, $W = 0$
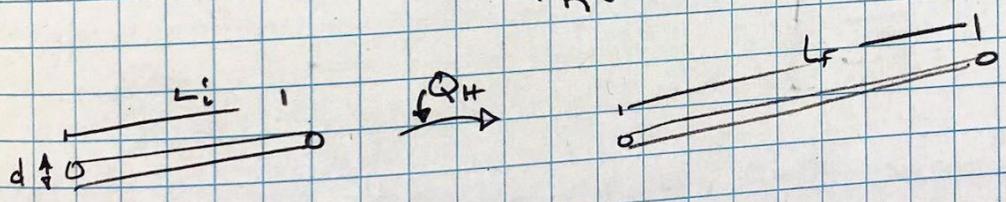
Adiabatic $\equiv (Q=0)$

Liquids + Solids

thermal expansion

$$V_f - V_i = \beta V_i \Delta T$$

or

$$\frac{\Delta V}{V_i} = \beta \Delta T$$

$\left(\frac{1}{K}\right) = $ thermal expansion coefficient — Volume

IF $L_i \gg d_i$ then...

$$L_F - L_i = \alpha L_i \Delta T$$

or

$$\frac{\Delta L}{L_i} = \alpha \Delta T$$

$\left(\frac{1}{K}\right) = $ thermal expansion coefficient — length

Specific Heat :

Heat (J) required to increase temperature 1°C (1K) of 1Kg of substance

$$Q = M c \Delta T \quad \rightarrow \text{Temp change}$$

↳ specific heat $\left(\dfrac{J}{Kg \cdot K} \right)$

↓ Heat added

↳ Mass

recall: $1000 cal = 4190 J \Rightarrow 1 \, Kg \cdot K$ increases water temp

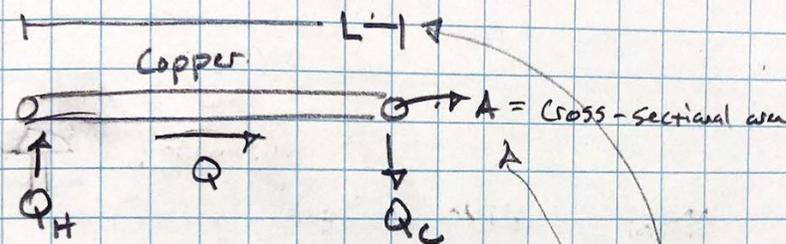$$C_{water} = 4190 \, \dfrac{J}{Kg \cdot K}$$

$$\Delta T = \dfrac{Q}{Mc}$$

⟹ Changing phase requires extra Energy due to intermolecular bonds.

$$Q = \begin{cases} \pm M L_F & (\text{Melt } (+) \text{ or Freeze } (-)) \\ \pm M L_v & (\text{evaporate } (+) \text{ or condense } (-)) \end{cases}$$

Heat Transfer:

Convection: transport by fluid (molecules) joining 2 systems

Conduction: transfer due to contact
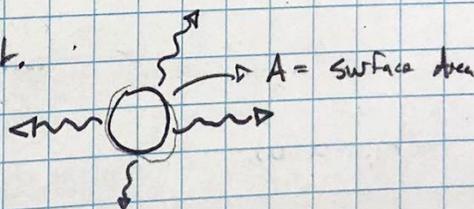

A = cross-sectional area

$$\frac{Q}{\Delta t} = \Gamma \, \Delta T$$

↳ "Gamma" $\Gamma = \gamma \dfrac{A}{L}$

↳ thermal conductivity $\left(\dfrac{W}{m \cdot K}\right)$

Radiation: Light emitted by object. A = surface area

energy

$$\frac{Q}{\Delta t} = e \, \sigma A T^4$$

↳ Stefan-Boltzmann's constant = 5.67×10^{-8} W/m$^2 \cdot$K^4

↳ emissivity of the surface (white = low, dark = high)
↳ (also depends on roughness, etc.)

Diffusion:

random molecular interactions + convection (turbulence) cause materials to disperse.