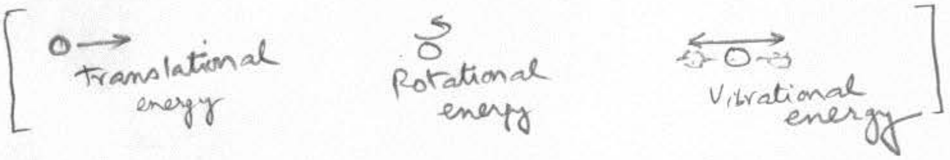
THERMODYNAMICS.

* Thermodynamics is the study of the thermal energy (often called the internal energy) of systems.

* The internal energy of a system depends on the size of the system (i.e. number of particles in the system) and properties of the system (like its Temperature)

* Temperature ↑ Internal energy ↑

Energy of the molecules(/atoms) of the system.



Total Internal Energy.

* Temperature : Temperature of a body is a measure of the degree of hotness / coldness of a body.

There is no upper limit to the total internal energy of a body but there is a zero internal energy (when all molecular motion ceases to exist)

The temperature at which this happens is zero Kelvin.

The temperature at which all molecular motion ceases to exist.

i.e. At T= 0K all molecular motion ceases to exist.

$\boxed{\text{Absolute zero}}$

$U(T=0) = 0$

* melting point of ice, is 273 K

room temperature is 290 K

boiling pt. of water (at 1atm) is 373 K

1 K change in temperatu
= 1°C change in temp.

* Heat flows from a hot body to cold body

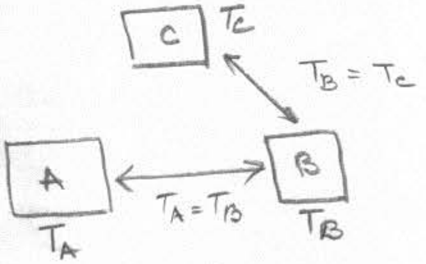
Higher temp to lower temperature

heat flow is like a flow of energy.

The Zeroth Law of Thermodynamics.

If A & B are in thermal equilibrium [at same temperature] with each other and B & C are in thermal equilibrium then A & C must be in thermal equilibrium.

Then, $T_A = T_C$ must be true.



Measuring temperature.

Need to calibrate a temperature sensitive object and make it a thermometer

properties of ideal gases (experimentally observed)

Boyles Law: $P \propto \frac{1}{V} \Rightarrow P_1V_1 = P_2V_2$

$\Downarrow$

$P = \underset{\substack{\downarrow \\ \text{const}}}{k} \frac{1}{V} \Rightarrow PV = k$

Charle's Law. $V \propto T \Rightarrow \frac{V_1}{T_1} = \frac{V_2}{T_2}$

$\Downarrow$

$V = CT$

$\Downarrow$

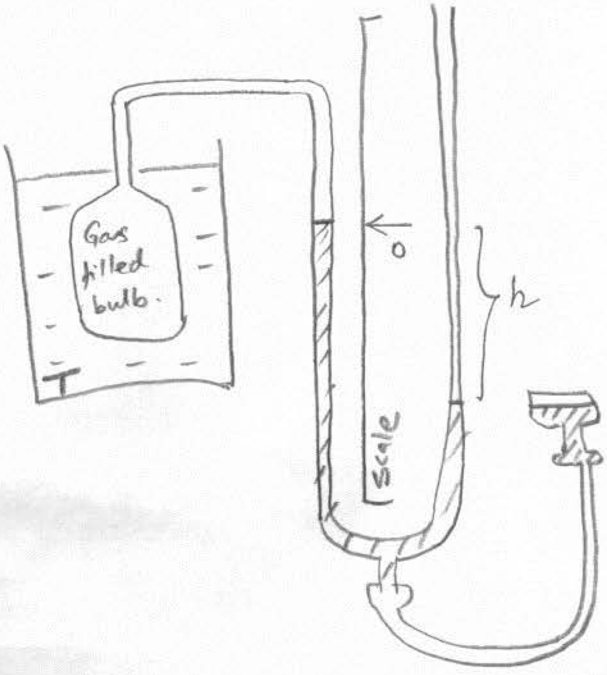
$\frac{V}{T} = C$ $\nearrow$

Ideal gas Law: $PV = \underset{\substack{\downarrow \\ \text{number of molecules}}}{N} k_B T$, $T \rightarrow$ temp., $k_B \rightarrow$ Boltzmann constant.

$\frac{PV}{T} = \text{const}$ $\nearrow$

Use these properties of ideal gases to measure temperature.

Example. Constant - volume Gas thermometer



$V = \text{constant}$

$T = Cp$

$p = P_{atm} \pm \rho g h$

Calibration, put in Triple pt bath

$T_0 = C p_0$

$\therefore \quad \frac{T}{p} = \frac{T_0}{p_0}$

$\Rightarrow \quad T = \left(\frac{T_0}{p_0}\right) p$

$$\boxed{T = (273.16\ \text{K})\left(\frac{p}{p_0}\right)}$$

Celsius and Farenheit scales.

$T_c = T - 273$

$T_F = \frac{9}{5} T_c + 32^\circ \longrightarrow (\because\ 0^\circ\text{C} = 32^\circ\text{F})$

Thermal Expansion.

(i) $\boxed{\Delta L = L_0 \alpha \, \Delta T}$ Linear expansion

α = coeff of linear expansion

L_0 = initial length

(ii) Volume expansion : $\Delta V = V_0 \underset{\downarrow}{\beta} \, \Delta T$

coefficient of volume expansion.

(iii) Relation : $\beta = 3\alpha$

Heat causing Temp change

Heat Capacity.

The heat capacity C of an object is the proportionality constant between the heat Q the object absorbs or loses and the resulting temperature change ΔT of the object.

$$Q = C \, \Delta T = C(T_f - T_i)$$

unit of C ; $\frac{\text{cal}}{°\text{C}}$ or $\left(\frac{\text{J}}{\text{K}}\right)$

Specific Heat (c)

$$Q = \underset{\downarrow}{c} m \, \Delta T = c m (T_f - T_i)$$

sp. heat

unit of c, $\frac{\text{cal}}{\text{g} \, °\text{C}}$ or $\frac{\text{J}}{\text{g K}}$

Heat causing phase change.

$$\underset{\text{ice}}{\text{solid}} \xrightarrow{+Q} \underset{\text{water}}{\text{liquid}}$$ (No temp change)

liquid ⟶ gas (at T temp)

$$Q = L_F m$$

↓

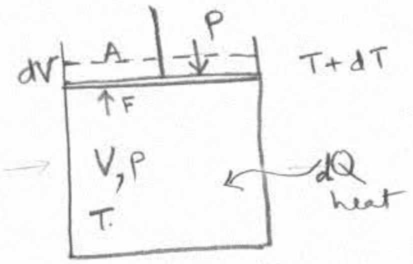
Latent heat of fusion

$$Q = L_v m$$

↓

Latent heat of vaporization

Heat and Work.



microscopic change

$$dW = (PA)\, dl = P\, dV$$

initial internal energy $U(T)$

finally, $U(T+dT) = U(T) + dU$.

$$dU = U(T+dT) - dU$$

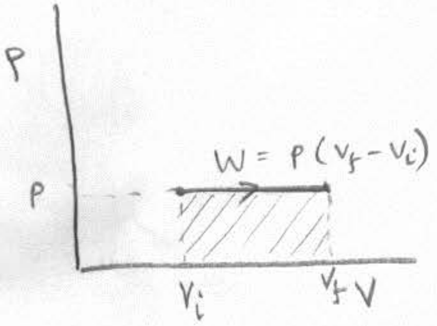
∴ Conservation of Energy:

$$\boxed{dQ = dU + dW}$$ 1st Law of thermodynamics.

$dQ = dU + PdV$ (in this case of expansion).

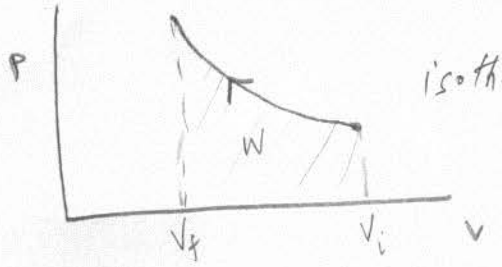
∴ $dW = p\,dV$.

macroscopic change $\int dW = \int_{V_i}^{V_f} P\,dV \Rightarrow W = \int_{V_i}^{V_f} p\, dV$



This example was a constant pressure process.

(isobaric process)



isothermal compression $T = \text{constant}$.

First Law of Thermodynamics

$$dQ = dU + dW$$

Macroscopic form : $Q = \underbrace{\Delta U}_{\text{Change in internal Energy}} + \underbrace{W} \rightarrow \text{Work done}$

Special cases of The first Law of thermodynamics :

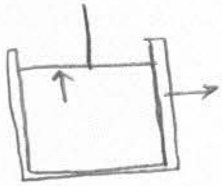
i) Adiabatic process :

No heat transfer $Q = 0$.

$\Delta U = -W$ (adiabatic process)

eg: well insulated system

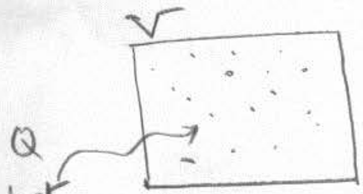
$W = \underset{\text{-ive decrease.}}{\underset{\downarrow}{-\Delta U}}$



→ Adiabatic Walls [Doesnot allow heat transfer]

(ii) Constant Volume process, $dW = P\,dV = 0$.

$$Q = \Delta U$$



by putting more heat in the system (increase Temperature) increase molecular motion $U_f > U_i$

(iii) Cyclical process : System is restored to initial state

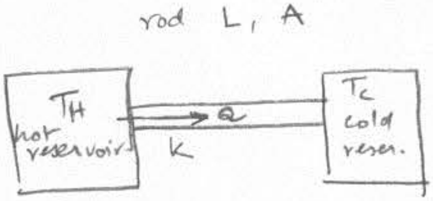
$\Delta U = 0 \Rightarrow Q = W$

closed loop on PV plot

Heat Transfer Mechanisms

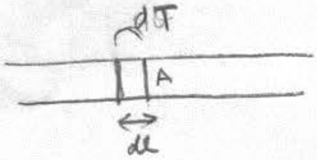
(i) Conduction
(ii) Convection
(iii) Radiation

Conduction:



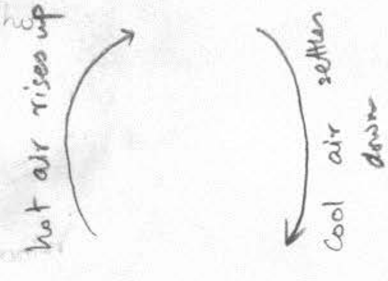
R = rate of heat conduction

$$R = kA\frac{(T_H - T_c)}{L}$$ k depends on the material of the rod.



$$R = kA\underbrace{\left(\frac{dT}{dl}\right)}_{} \longrightarrow \text{Temperature gradient.}$$

Convection:



for hot air the density decreases
$(\because T\uparrow \; V\uparrow \; \therefore \rho\downarrow)$

$\therefore$ it rises up.

Convection involves flow of the material medium due of density changes (occurs in fluids)

Radiation:

Every body radiates heat (/energy)

<u>Thermal radiation</u>
<u>No Medium required</u> $\because$ Electromagneti radiation

$$P_{rad} = \sigma \varepsilon A T^4$$

rate of emitting energy (power) of radiation $\nearrow P_{rad}$

$\sigma = 5.67 \times 10^{-8}\ W/m^2K^4$ Stefan-Boltzmann constant

ε = emissivity of surface $0 < \varepsilon < 1$

A = surface area T = Temp.