- **Engineering Thermodynamics: Work and Heat Transfer**

Book by G. F. C. Rogers and Y. R. Mayhew

- **Applied Heat for Engineers**

Octave Sneeden, Samuel Vallance Kerr

Thermodynamic

Dr. Mohammed Hussin Ahmed
College of Petroleum and Mining Engineering
University of Mosul

- **Fundamentals of classical Thermodynamics**

Gordon John Van Wylen

- **Fundamentals of Engineering Thermodynamics**

MICHAEL J. MORAN, The Ohio State University
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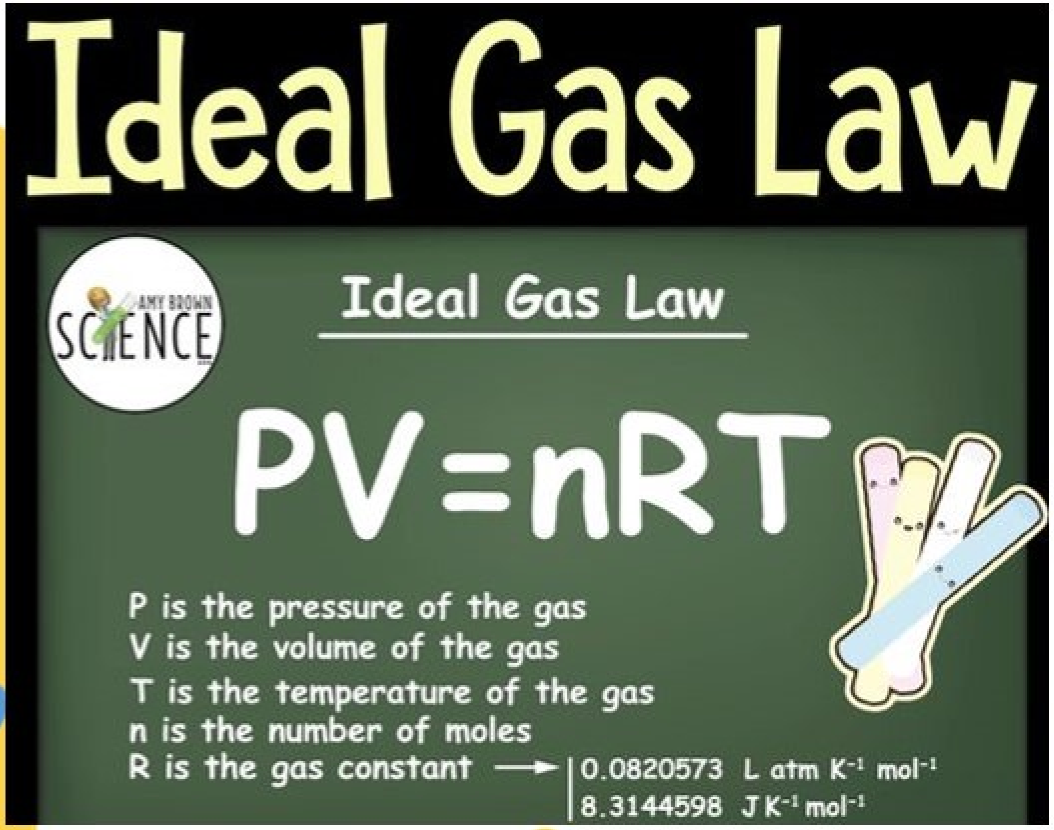
Lecture 3

- ✓ ***Specific Volume***
- ✓ ***Molecular Weight***
- ✓ ***Characteristic Gas Equation***
- ✓ ***Energy Forms***

Our lecture today contents :

- Specific volume
- Problem solutions
- Molecular weight
- Energy forms with equations



Specific volume ϑ (m^3/kg)

It is defined as the reciprocal of the density, $\vartheta = \frac{1}{\rho} = \frac{V}{m}$

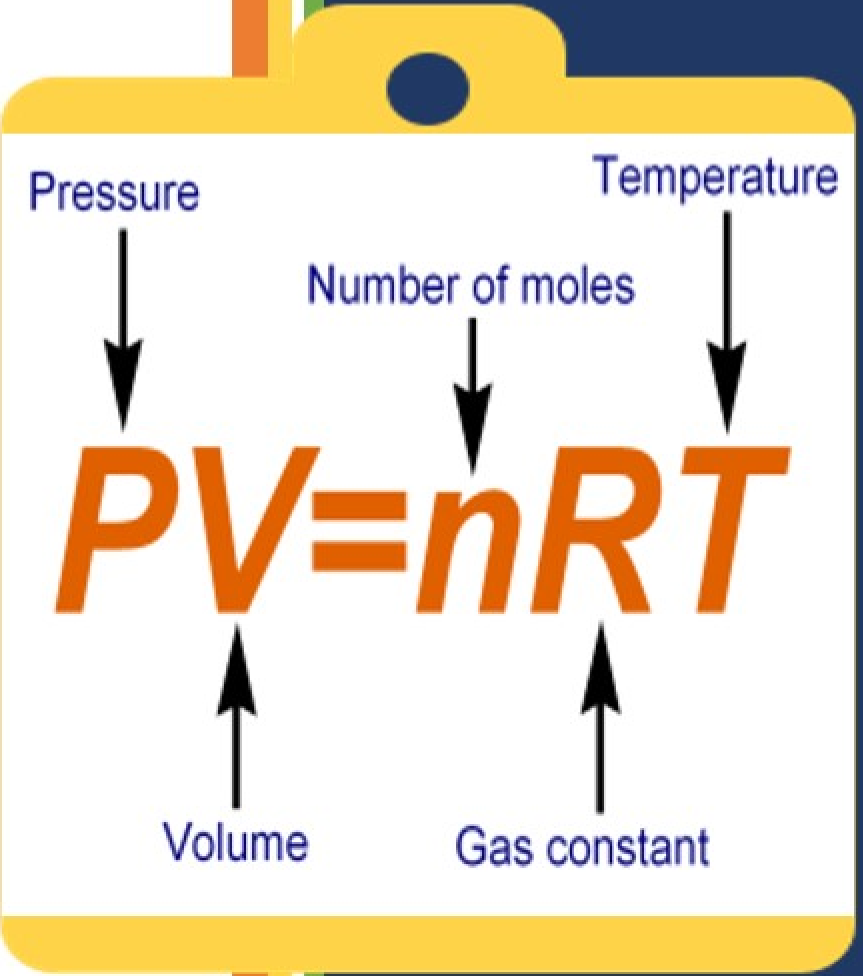
For 1 kg of gas , from the state equation, we can write the equation as:

$\frac{P.\vartheta}{T} = const.,$ $\qquad P.\vartheta = R.T$

This constant is called "the gas constant" and is denoted by (R)

, $\boldsymbol{R_o}$**= 8.314** $\left(^{J}/_{mol.K}\right)$

$$\boldsymbol{P.V = n.R.T}$$



This means that for air, you can use the value, **R = 287** $\left(^{J}/_{kg.K}\right)$

If you use this value of R, then technically the formula should be written as

$$\boldsymbol{P.V = m.R.T}$$

Where,

P= absolute pressure of the gas (N/m^2) or (Pa)

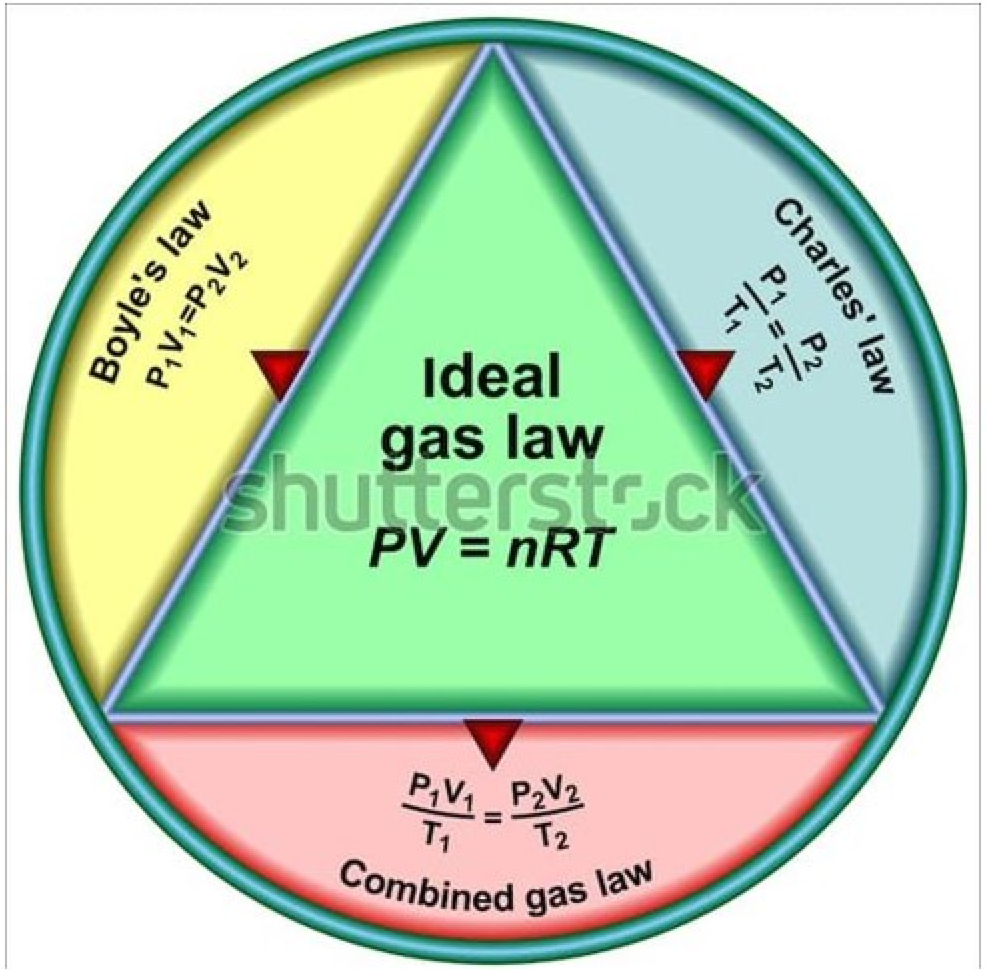
V= the volume of the gas (m^3)

m= mass of the gas (kg)

n= the no. of moles (mol)

R= gas constant ($^J/_{kg.K}$)

T= absolute temperature (K)



$$\boldsymbol{R = Cp - Cv \ldots\ldots\ldots..1}$$

Where,

Cp *= specific heat at constant pressure* $({}^{J}/_{kg.K})$

Cv = *specific heat at constant volume* $({}^{J}/_{kg.K})$

The ratio of ${}^{Cp}/_{Cv} = \gamma$ *, its greater than 1 always*

$$\mathbf{Cv} = \frac{\boldsymbol{R}}{\boldsymbol{\gamma - 1}} \quad \& \quad \mathbf{Cp} = \frac{\boldsymbol{\gamma R}}{\boldsymbol{\gamma - 1}}$$

γ *: gas index or adiabatic index*

Ex.3/ Calculate the volume of 2 kg of gas at pressure of 1.5 bar and the temperature of 40 c and the gas constant R=190 J/kg.K ; if the gas heated under constant volume until the pressure is 2 bar. Calculate the final temp.

Solu.

$m = 2\ kg$

$P_1 = 1.5\ bar = 1.5 * 10^5\ N/m^2$

$T_1 = 40^\circ C + 273 = 313\ K$

$R = 190\ J/kg.K$

$V = C$

$P_2 = 2\ bar = 2 * 10^5\ N/m^2$

$T_2 = ?$

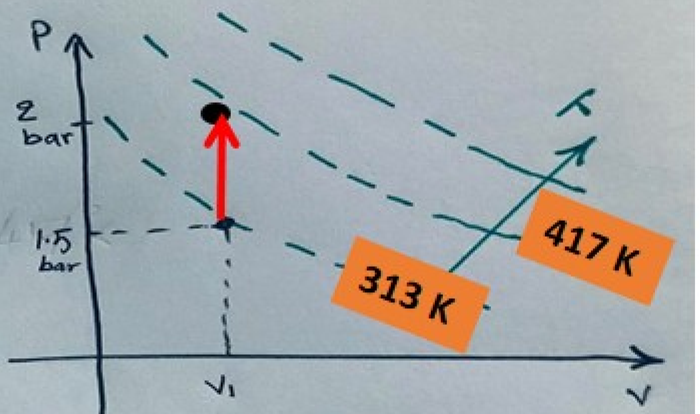
$V_1 = V_2 = ?$

By Gay-lussac law

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \Rightarrow T_2 = \frac{P_2 T_1}{P_1}$$

$$= \frac{2 * 10^5 * 313}{1.5 * 10^5}$$

$$= 417\ K$$



$P_1 V_1 = m R T_1$

$\therefore 1.5 * 10^5 * V_1 = 2 * 190 * 313$

$\Rightarrow \therefore V_1 = 0.793\ m^3$ Ans.

Ex.4 / A volume of 3.6 m^3 of O_2 at 220 °C and pressure 400 KPa, it compressed to reversibly at constant temperature to a final volume of 0.06 m^3 . Calculate the mass and the final pressure, where $R_{O_2} = 0.26$ (KJ/Kg.k). [11.23 kg, 240 bar]

Solu.

$V_1 = 3.6\ m^3$

$T_1 = 220\ °C + 273 = 493\ °K$

$P_1 = 400$ Kpa $= 400 * 10^3\ N/m^2$

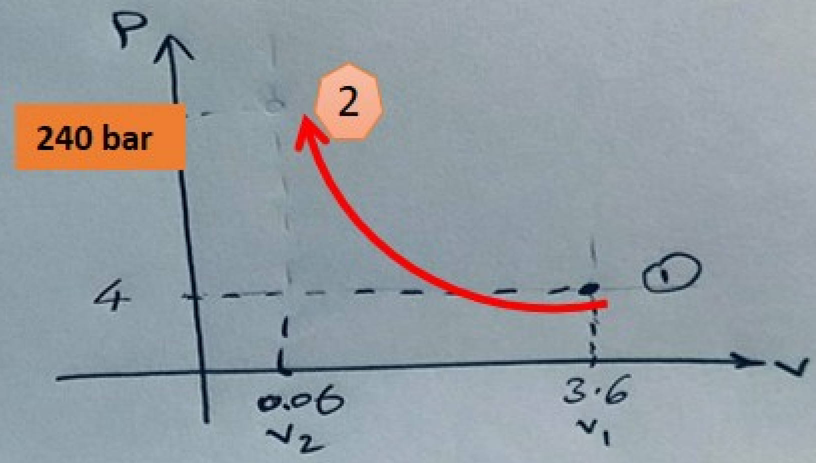
$R = 0.26$ KJ/Kg.K $= 260$ J/Kg.K

T=C

$V_2 = 0.06\ m^3$

$P_2 = ?$

$m = ?$



$P_1 V_1 = m R T_1$

$$m = \frac{P_1 V_1}{R T_1} = \frac{400 * 10^3 * 3.6}{260 * 493} = 11.23\ Kg$$

$P_1 V_1 = P_2 V_2$ (By Boyl's law)

$$P_2 = \frac{P_1 V_1}{V_2} = \frac{400 * 10^3 * 3.6}{0.06} = 240\ bar$$

Molecular weight (μ) ($^{kg}/_{mol}$)

Avogadro's theorem: volume of one mole of any gas is same for all gases at any temperature and pressure.

$$\boldsymbol{m = \mu . n} \qquad \& \qquad \boldsymbol{\vartheta = \frac{V}{m}}$$

$$\boldsymbol{\therefore \vartheta = \frac{V}{\mu . n} \implies \frac{V}{n} = \mu . \vartheta}$$

(i.e) $$\mu_1 . \vartheta_1 = \mu_2 . \vartheta_2 = \mu_3 . \vartheta_3 = cons.$$

n : no. of molecules (mol)

μ : Molecular weight ($^{kg}/_{mol}$)

$\mu . \vartheta$: the volume of kilogramme-mol, at standard conditions (P_o=1.01325 bar, T_o=0 °C, the value of one mole = 22.41 l)

Remember ……1 Liter=1 cubic decimeter (1dm^3)=0.001 m^3

$\mu.\vartheta$: **the volume of kilogramme-mol**

$P = P_o = 1.01325\ bar$

$T = T_o = 273\ k$

$V = (22.41 \times 10^{-3})\ \text{m}^3$

$$\boldsymbol{P.V = (\mu.n).R.T}$$

$$1.01325 \times 10^5 \times 22.41 \times 10^{-3} = (1).\text{R} \times 273 \implies R = 8.314\ (J/mol.k) = R_o$$

R_o: constant for all gases.

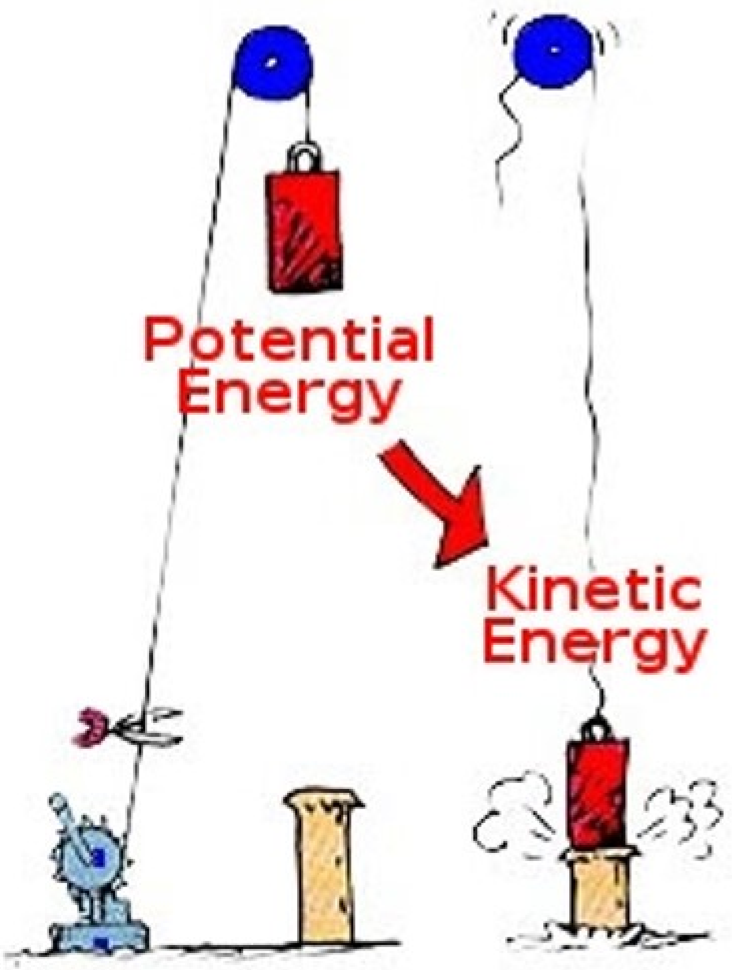
For μ of H_2 **= 2 g/mol** and the μ of O_2 **= 32 g/mol**

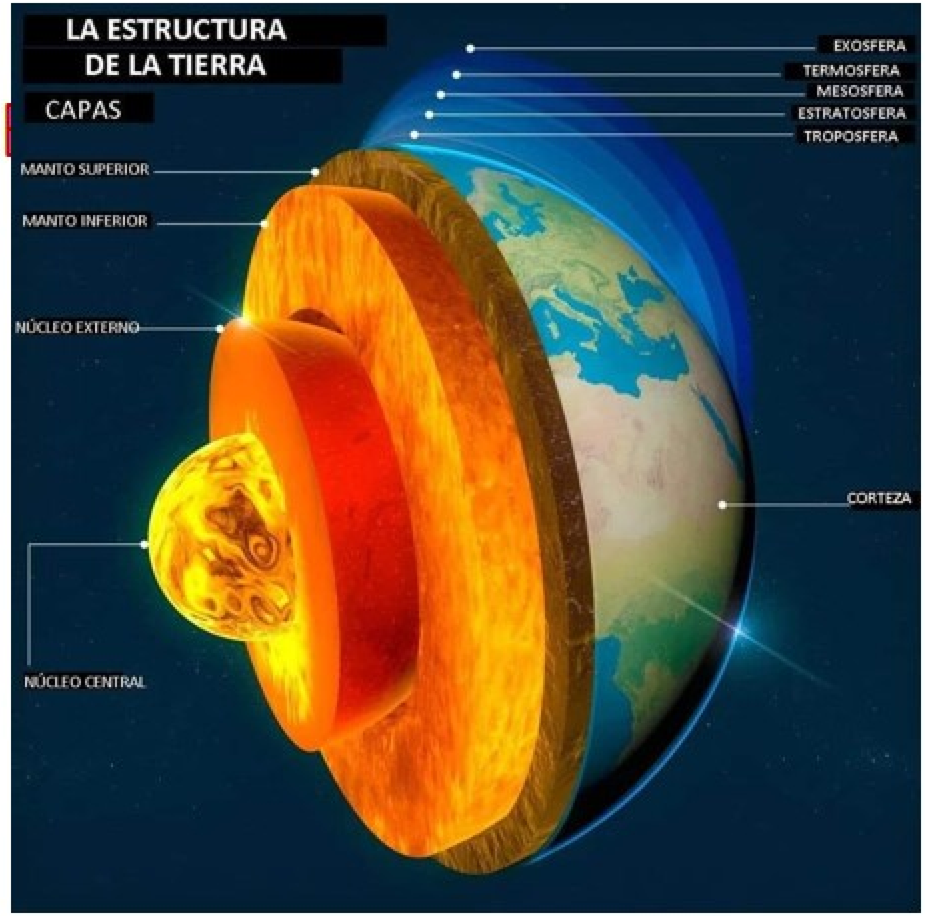
$$R_{O_2} = \frac{R_O}{32 \times 10^{-3}} = \frac{8.314}{0.032} = 259.8\ (^{\text{J}}/_{\text{Kg.K}})$$

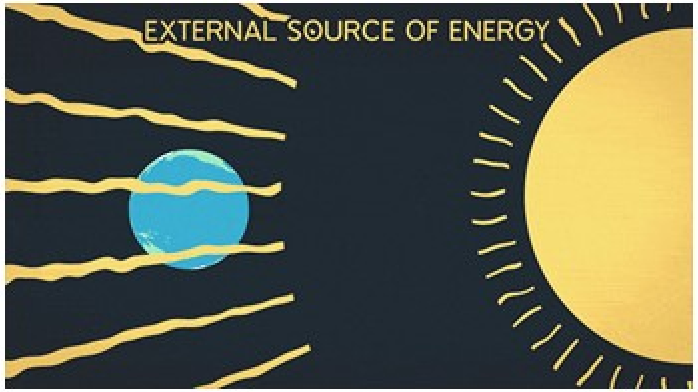
$$R_{H_2} = \frac{R_O}{2 \times 10^{-3}} = \frac{8.314}{0.002} = 4157\ (^{\text{J}}/_{\text{Kg.K}})$$

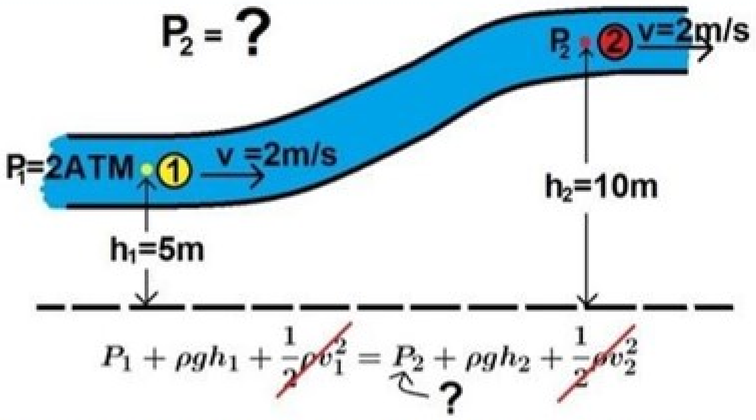
Ex.5 / A volume of 2.5 m^3 of O_2, μ = 32 g/mol at 510 °C and pressure 70 KPa, it compressed to reversibly at constant temperature to a final volume of 0.5 m^3 . Calculate the number of moles $\boldsymbol{n} =?$ and the final pressure of O_2 . where $R_o = 8.314$ (J/mole. k).

1. Potential energy
2. Kinetic energy
3. Heat
4. Work
5. Internal energy
6. Flow energy
7. Enthalpy





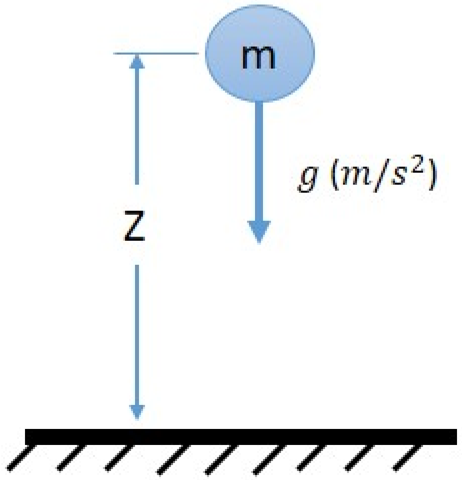


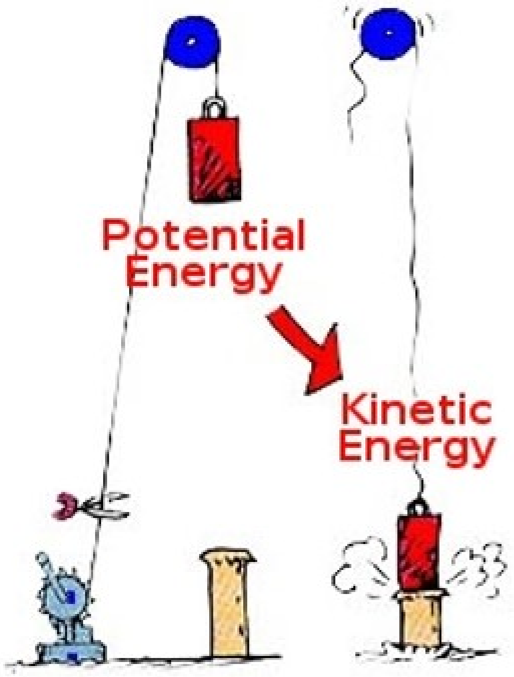


1. Potential energy (P.E)

$$P.E = mg\,Z \quad \ldots\ldots\ldots 1$$

J = (kg).(m/s^2).(m) = N.m





2. Kinetic energy (K.E)

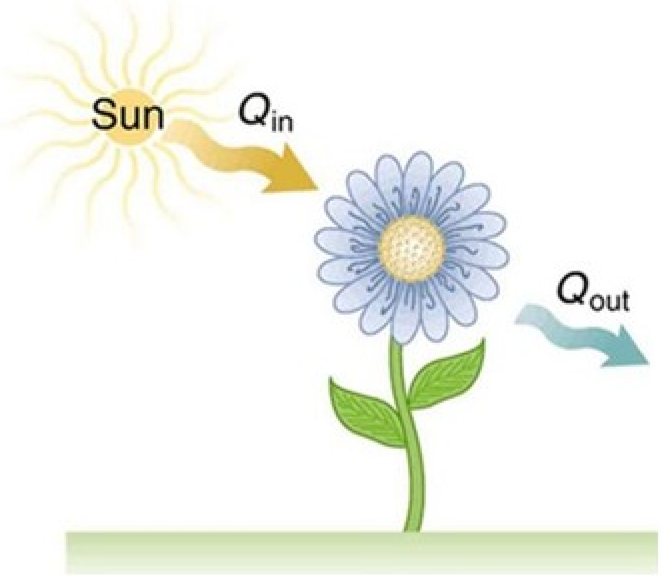
$$K.E = \frac{1}{2}\,m\,C^2 \quad \ldots\ldots 2$$

J = (kg). $(m/s)^2$= N.m

3. Heat (Q), (J , K J)

Heat is taken (+ve) when added to the system,

while it taken (-ve), when rejected from the system.

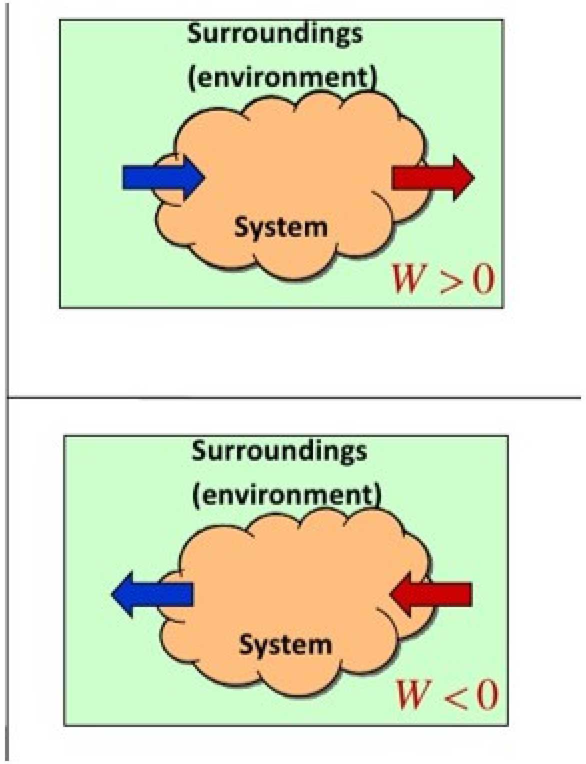


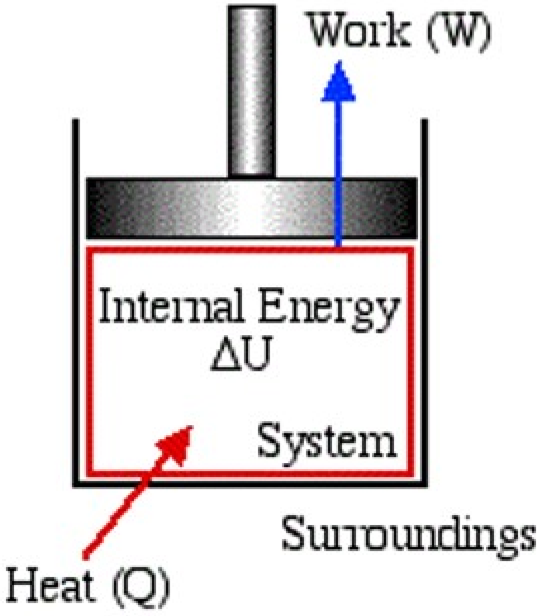
4. Work (J, kJ)

It's a mechanical energy which is transfer across the system and equals the multiplying the force and the moving distance toward the force.

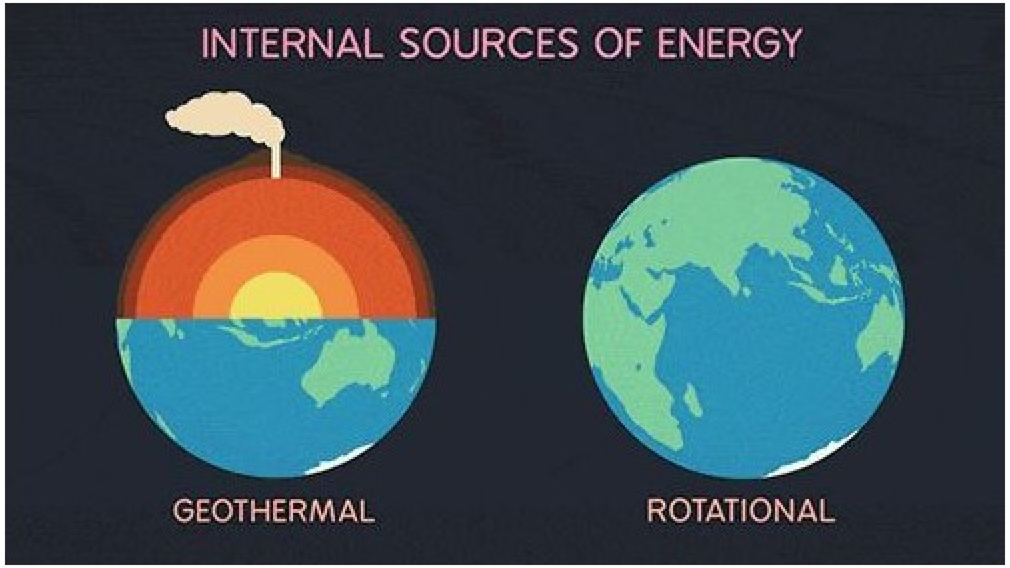
***Q* = positive value**
***W* = positive value**

***Q* = negative value**
***W* = negative value**





5. Internal Energy U, u(J, kJ)



$\frac{du}{dt} = C_v,$ at constant volume

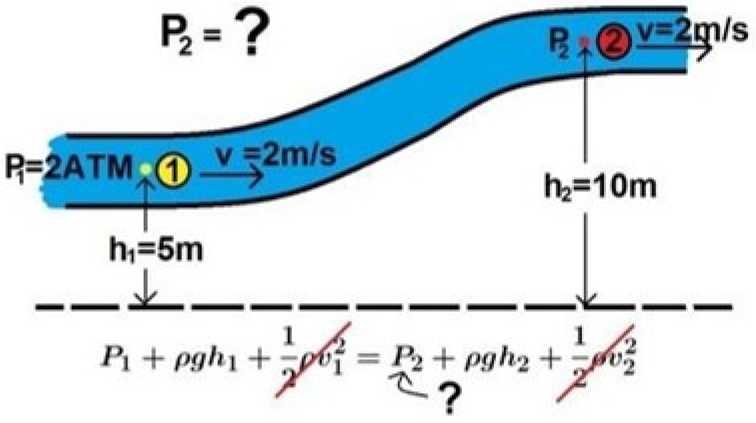
(i.e.) $du = C_v\, dT$, $\int_{u1}^{u2} du = C_v \int_{T1}^{T2} dT$

$$u_2 - u_1 = C_v\,(T_2 - T_1)$$

$$\therefore\ \Delta u_{12} = C_v\,(T_2 - T_1)\text{.......... 3} \quad (J/kg)$$

$$\Delta u_{12} = m\,C_v\,(T_2 - T_1)\text{..(if there is mass)} \quad (J)$$

6. Flow Energy (FE) (J)



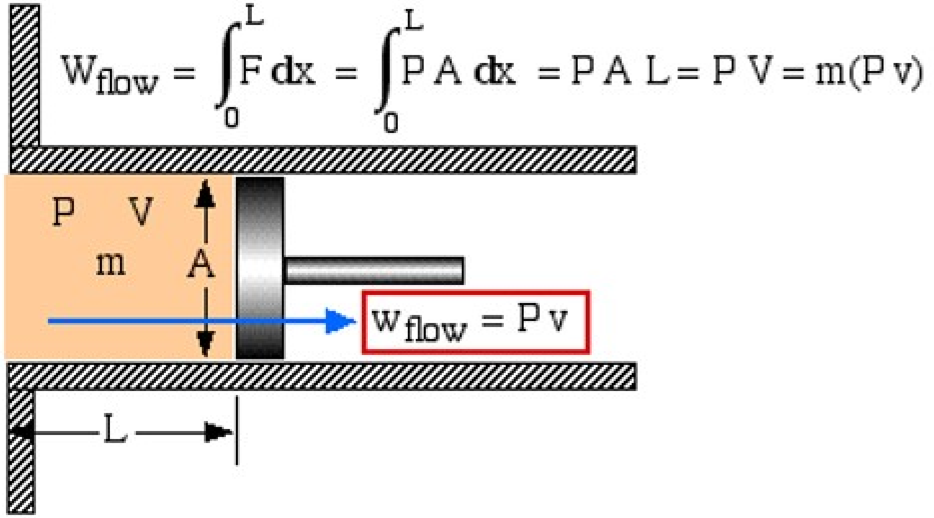
It's a constant energy used to move the fluid in constant flow rate without changing the fluid state (pressure and temperature)

$$FE = F.L \; \ldots\ldots\ldots\ldots.4$$

$F.E. = P.A.L$

$F.E. = P.Volume, \qquad N.m = J$

Flow energy per unit mass = $P.V \;\; (J/kg)$



7. Enthalpy (H) (J)

Summation of internal energy and work done on the system

$$H = u + P.V \; \ldots\ldots\ldots 5$$

$$h = u + P.\vartheta \; \ldots\ldots\ldots 6$$

$$\Delta h_{12} = \Delta u_{12} + \Delta\,(P.\vartheta) \; \ldots\ldots\ldots 7$$

Thank you

Next lecture will be the

- ✓ **Solving Equations Of Ideal Gas**
- ✓ **Properties Of Pure Substance**