Viscosity

1. **Viscosity:** The property of a liquid by virtue of which it opposes the relative motion between the layers of the liquid is called viscosity (or) internal friction of the liquid.

2. **Viscous force (Newton's formula)**: The viscous force (F) acting tangentially on a layer of a fluid is directly proportional to the (i) surface area A of the layer, (ii) velocity gradient $\left(\frac{dV}{dx}\right)$ which is perpendicular to the direction of flow. $F = -\eta A \frac{dV}{dx}$

   The constant of proportionality η is called the coefficient of viscosity.

3. **Coefficient of viscosity "η**

   a) The viscous force acting tangentially on unit area of the liquid when there is a unit velocity gradient in the direction perpendicular to the flow is called the coefficient of viscosity. It is also called coefficient of dynamic viscosity.

   b) The S.I unit of coefficient of viscosity is $\frac{N-S}{m^2}$ or Pa-s or decapoise.

   c) The CGS unit of η is poise.

   1 Pa-s=10 poise

   d) The dimensional formula of η is $ML^{-1}T^{-1}$

4. **Coefficient of kinematic viscosity "μ"**

   a) The ratio of the coefficient of dynamic viscosity to the density of liquid $\left(\frac{\eta}{\rho}\right)$ is called coefficient of kinematic viscosity.

   b) Dimensional formula L^2T^{-1}

   c) The S.I unit of 'μ' is m^2s^{-1}

   d) The unit in CGS system is stoke and 1 stoke=10^{-4} m^2s^{-1}

5. **Factors that influence viscosity**

   a) Pressure

i) Viscosity of a liquid increases with the increase of pressure even though the effect is small.

ii) Viscosity of a gas is independent of pressure. However at low pressures, viscosity decreases with the decrease of pressure due to the increase of mean free path.

b) Temperature

i) As temperature increases viscosity of liquid decreases due to the decrease of cohesive forces.

ii) In summer high viscous and in winter low viscous lubricants are used for machine parts.

iii) Increase of temperature increases the viscosity of a gas due to the increase in momentum of the gas molecules.

6. Poiseuille's equation

a) For less viscous liquids (ex. Water), flowing in a capillary tube of radius r and length l, the volume of the liquid flow per sec (or) volume flux is given by

$$V = \frac{\pi P r^4}{8\eta l}$$

Where η the co-efficient of viscosity of the liquid and P is is is the pressure difference between the ends of the capillary tube.

$R = \frac{8\eta l}{\pi r^4}$ is known as fluid resistance.

b) Poiseuille's equation is applicable under the following conditions.

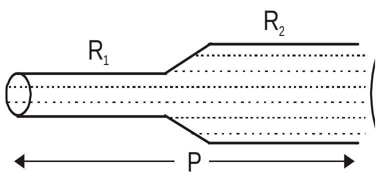
i) The flow must be steady and laminar.

ii) The liquid in contact with the walls of the capillary tube must be at rest.

iii) The pressure at any cross-section of the capillary tube must be same.

c) When a liquid is flowing through a tube, the velocity of the flow of a liquid at a distance x from the axis of the tube is given by $V=\frac{P}{4\eta l}\left[r^2 - x^2\right]$.

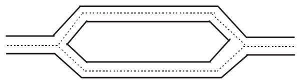
d) When two capillaries are joined in series across constant pressure difference P the fluid resistance $R=R_1+R_2$.



$$R = \frac{8\eta l_1}{\pi r_1^4} + \frac{8\eta l_2}{\pi r_2^4} \text{ and } Q = \frac{P}{R_1 + R_2}$$

The total pressure difference $P=P_1+P_2$

g) If two capillaries are joined in parallel, the pressure difference across the two tubes is the same but the volume of fluid flowing through the two tubes is different. The total volume of the fluid flowing through the tubes is one second is $Q = Q_1 + Q_2$.



Fluid resistance R is given by $\frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2}$ where $R_1=\frac{8\eta l_1}{\pi r_1^4}$ and $R_2=\frac{8\eta l_2}{\pi r_2^4}$

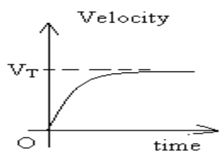
The volume of liquid flowing through first capillary $Q_1=\frac{P}{R_1}$ and the volume of liquid flowing through second capillary $Q_2=\frac{P}{R_2}$.

7. Stoke's law

a) The viscous force of high viscous liquids like castor oil, glycerin is given by $F = 6\pi\eta rv$

Where r is the radius of the spherical body falling through a medium of coefficient of viscosity η and V_T is the velocity of the body.

b) Terminal velocity of a spherical body $v_T=\frac{2}{9}\frac{r^2(\rho-\sigma)g}{\eta}$

c) 

d) where ρ = density of the body

σ = density of the fluid through which the body is falling.

e) $V_T\ \alpha\ \frac{1}{\eta}$, greater the viscosity, lesser the terminal velocity.

f) $V_T\ \alpha\ r^2$, bigger rain drops acquire more velocity.

g) $V_T\ \alpha\ (\rho - \sigma)$, if σ is more the body rises up. Ex: Air bubble in water rises up.

h) When n drops of same size each having terminal velocity V combine, the terminal velocity of the single drop is $V_T = n^{2/3}V$

i) If m is the mass , then $V\ \alpha\ m^{\frac{2}{3}}$