1. INTRODUCTION

IDEAL FLUID AND REAL FLUID

- **Ideal fluid:** A fluid is said to be ideal if it is assumed to be both incompressible and non-viscous. Its bulk modulus is infinite.
- **Real fluid:** Real fluid have viscosity, finite compressibility and surface tension.

> Remember
> - Ideal fluid has no surface tension.
> - Ideal fluid are imaginary and do not exist in nature.

SPECIFIC WEIGHT, SPECIFIC VOLUME, SPECIFIC GRAVITY

- $$\text{Specific weight } (\omega) \text{ or weight density} = \frac{\text{Weight}}{\text{Volume}} = \frac{mg}{V} = \rho g$$

Here, ρ = Density

g = Acceleration due to gravity

Specific weight of water = 9810 N/m^3

- $$\text{Specific Volume} = \frac{1}{\text{Density}}$$

- **Specific gravity (S) or Relative density**

$$\text{Specific gravity} = \frac{\text{Density of fluid}}{\text{Density of standard fluid}} = \frac{\text{Specific weight of fluid}}{\text{Specific weight of standard fluid}}$$

> Remember
> - Specific gravity for water is 1.0 at 4°C and for mercury it is 13.6
> - Specific gravity varies with temperature therefore it should be determined at specified temperature (4°C or 27°C).

NEWTON'S LAW OF VISCOSITY

$$\tau = \mu \cdot \frac{du}{dy} = \mu \frac{d\theta}{dt}$$

τ = shear stress

μ = coefficient of viscosity or absolute viscosity or dynamic viscosity

Here, $\frac{du}{dy}$ = Velocity gradient

$\frac{d\theta}{dt}$ = Rate of angular deformation or Rate of shear strain

- For newtonian fluid, coefficient of viscosity remains constant.

VISCOSITY/KINEMATIC VISCOSITY

Due to viscosity a fluid offer resistance to flow

(i) **Dynamic Viscosity (μ)**

- Its SI unit is pascal-second or **N-sec/m^2**
- Its CGS unit is Poise = Dyne-sec/cm^2
- 1 poise = **0.1** N-s/m^2

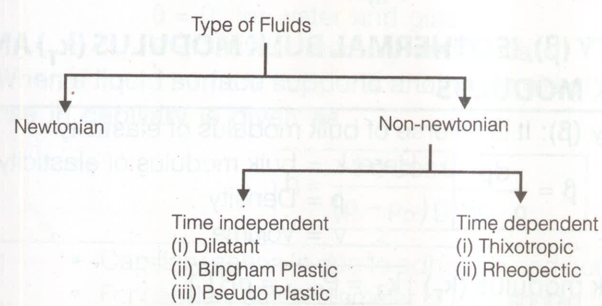
(ii) **Kinematic Viscosity**

$$\nu = \frac{\text{Dynamic viscosity } (\mu)}{\text{Mass density } (\rho)}$$

- Its SI unit is m^2/s.
- Its CGS unit is cm^2/s or stoke.
- 1 stoke = 10^{-4} m^2/s

> Remember
> - Viscosity of ***liquids*** decreases with temperature whereas viscosity of ***gases*** increases with increase in temperature.
> - Liquids with increasing order of viscosity are gasoline, water, crude oil, castor oil.
> - Viscosity of ***water*** at 1°C is 1 centipoise.
> - Viscosity of liquids is due to **cohesion** and for gases it is due to ***molecular momentum transfer.***

TYPE OF FLUID

- 

- **Non-Newtonian Fluids:** These do not follow Newton's law of viscosity. The relation between shear stress and velocity gradient is

$$\tau = A\left(\frac{du}{dy}\right)^n + B$$

where A and B are constants depending upon type of fluid and condition of flow.

(i) For Dilatant Fluids: $n > 1$ & $B = 0$,
Ex. Butter, Quick sand.

(ii) For Bingham Plastic Fluids: $n = 1$ & $B \neq 0$
Ex. Sewage sludge, Drilling mud, tooth paste and gel.
These fluids always have certain minimum shear stress before they yield.

(iii) For Pseudoplastic Fluids: $n < 1$ & $B = 0$
Ex. Paper pulp, Rubber solution, Lipsticks, Paints, Blood, Polymetric solutions etc.

(iv) For Thixotropic Fluids: $n < 1$ & $B \neq 0$
Viscosity increases with time.
Ex. Printers ink and Enamels.

(v) For Rheopectic Fluids: $n > 1$ & $B \neq 0$
Viscosity decreases with time.
Ex. Gypsum solution in water & Bentonite solution.

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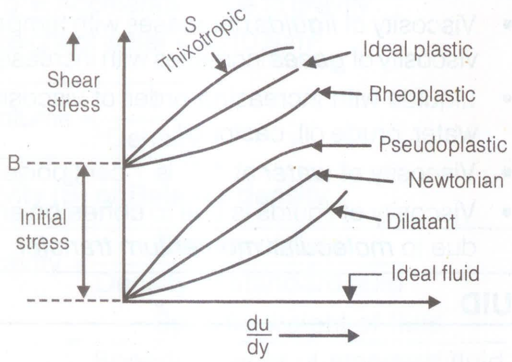

COMPRESSIBILITY (β), ISOTHERMAL BULK MODULUS (k_T) AND ADIABATIC BULK MODULUS

- **Compressibility (β):** It is inverse of bulk modulus of elasticity.

$$\beta = \frac{1}{k} = \frac{-dv}{vdp} \qquad \beta = \frac{d\rho}{\rho \cdot dP}$$

Here, k = bulk modulus of elasticity
ρ = Density
v = Volume

- **Isothermal bulk modulus (k_T)** $k_T = P_{final} = \rho RT$

- **Adiabatic bulk modulus** $k_a = \gamma \cdot P_{final}$

$$\gamma = \frac{C_p}{C_v}$$

Here, C_p = Specific heat at constant pressure
C_v = Specific heat at constant volume

SURFACE TENSION/PRESSURE INSIDE DROP, BUBBLE AND JET

Surface tension occur at the interface of liquid and a gas *or* at the interface of two liquid. Surface tension is inversely proportional to temperature and it also acts when fluid is at rest.

- **Pressure inside drop (Solid like sphere)** $P = \frac{4\sigma}{d}$
- **Pressure inside bubble** $P = \frac{8\sigma}{d}$
- **Pressure inside jet** $P = \frac{2\sigma}{d}$

Here, d = Diameter of drop
P = Gauge pressure

Remember
- It is a ***surface*** phenomenon
- It is force per unit length (N/m)
- For ***water-air*** interface at 20°C its value is 0.0736 N/m
- At critical point, liquid-vapour state are same thus surface tension = 0
- It is due to ***cohesion*** only

CAPILLARY ACTION

- **Height of water in capillary tube**

$$h = \frac{4\,\sigma\cos\theta}{\rho g d}$$

Where, h = rise in capillary
σ = surface tension of water & glass
d = dia of tube
θ = angle of contact between the liquid and the material.
θ = 0° for water and glass
θ = 128° for mercury and glass

- **When a liquid surface supports another liquid of density "ρ_b", then rise in capillary is given as**

$$h = \frac{4\,\sigma\cos\theta}{(\rho - \rho_b)gd}$$

Remember
- Capillary action is due to adhesion and cohesion, *both*.
- For capillary action diameter of tube should be *less* than 3 cm.

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