Unit – I

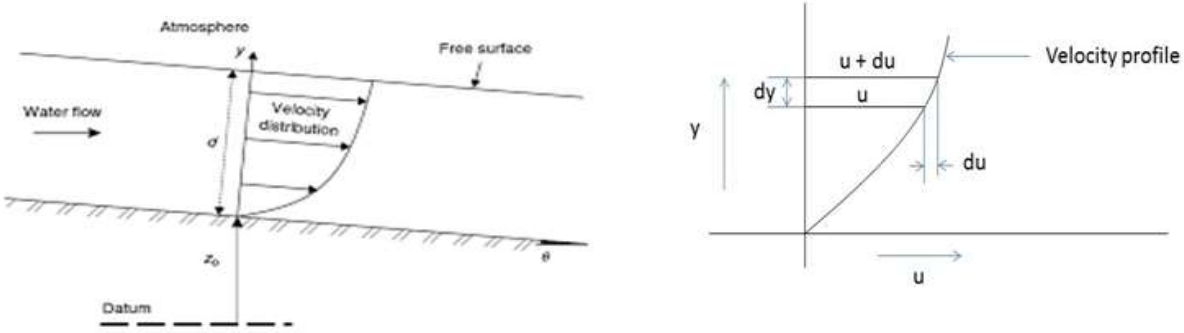
Pressure and Pressure Measurement

Session – II

❑ Viscosity

A. Definition

- It is defined as the property of a fluid which offers resistance to the movement of one layer of the fluid over another adjacent layer of the fluid.
- It is the measure internal fluid friction.
- **Explanation**



- When the two layers of a fluid, at a distance 'dy' apart, move one over the other at different velocities, say u and u+du.
- The viscosity together with relative velocities causes a shear stress acting between the fluid layers.
- The top layer causes a shear stress on the adjacent lower layer while the lower layer causes a shear stress on the adjacent top layer.
- This shear stress is proportional to the rate of change of velocity with respect to y. It is denoted by symbol τ (tau).

$$\tau \propto \frac{du}{dy}$$

$$\tau = \mu \times \frac{du}{dy}$$

- Where μ (mu) is the constant of proportionality and is known as the coefficient of viscosity. $\frac{du}{dy}$ represents the rate of shear strain or rate of shear deformation or velocity gradient.

- From the above equation, we have $\mu = \frac{\tau}{\left(\frac{du}{dy}\right)}$

B. Types of Viscosity

Viscosity is classified as :

a. Dynamic Viscosity

b. Kinematic Viscosity

a. Dynamic Viscosity

- Dynamic viscosity is also defined as the shear stress required producing unit rate of shear strain.
- It is also known as Absolute Viscosity or Viscosity
- It is denoted by 'μ'.

$$\mu = \frac{\tau}{\left(\frac{du}{dy}\right)} = \frac{\frac{\mathrm{N}}{\mathrm{m}^2}}{\frac{\mathrm{m/s}}{\mathrm{m}}} = \frac{\mathrm{N}}{\mathrm{m}^2} \times \frac{1}{\frac{\mathrm{m/s}}{\mathrm{m}}} = \frac{\mathrm{N}}{\mathrm{m}^2} \times \mathrm{s} = \mathrm{Pa.s}$$

- The SI unit of Dynamic viscosity is N-sec/ m² = Pa-sec
- The CGS unit of Dynamic viscosity is dyne-sec/ cm²
- The CGS unit of Dynamic viscosity is also called poise

$$1 \text{ poise} = 1 \text{ dyne} - \text{sec/cm}^2$$

$1\ \mathrm{N} = 10^5 \text{ dyne}$ **there fore** $1 \text{ dyne} = \frac{1}{10^5}\ \mathrm{N} = 10^{-5}\ \mathrm{N}$

$1\ \mathrm{m}^2 = (10^2)^2\ \mathrm{cm}^2 = 10^4\ \mathrm{cm}^2$ **there fore** $1\mathrm{cm}^2 = \frac{1}{10^4}\ \mathrm{m}^2 = 10^{-4}\ \mathrm{m}^2$

$$1 \text{ poise} = \frac{10^{-5}}{10^{-4}}\ \mathrm{N} - \mathrm{sec/m}^2$$

$$1 \text{ poise} = 0.1\ \mathrm{N} - \mathrm{sec/m}^2$$

$$1\ \mathrm{N} - \mathrm{sec/m}^2 = \frac{1}{0.1} \text{ poise}$$

$$1\ \mathrm{N} - \mathrm{sec/m}^2 = 10 \text{ poise}$$

b. Kinematic Viscosity

- It is defined as the ratio between dynamic viscosity and density of fluid.
- It is denoted by symbol 'ν' (nu)

$$\nu = \frac{\text{Dy. Viscosity}}{\text{Mass density}} = \frac{\mu}{\rho}$$

- The SI unit of kinematic viscosity is m^2 /sec
- The CGS unit of kinematic viscosity is cm^2 /sec
- The unit of kinematic viscosity in CGS is called stroke

$$1 \text{ stroke} = 1 \ {}^{cm^2}/_{s}$$

$$1 \text{ stroke} = 1 \times 10^{-4} \ {}^{m^2}/_{s} = 10^{-4} \ {}^{m^2}/_{s}$$

C. Newton's Law of Viscosity

- **It states that the shear stress (τ) in fluid layers is directly proportional to the rate of shear strain.**
- **It is expressed as**

$$\tau \propto \frac{du}{dy}$$

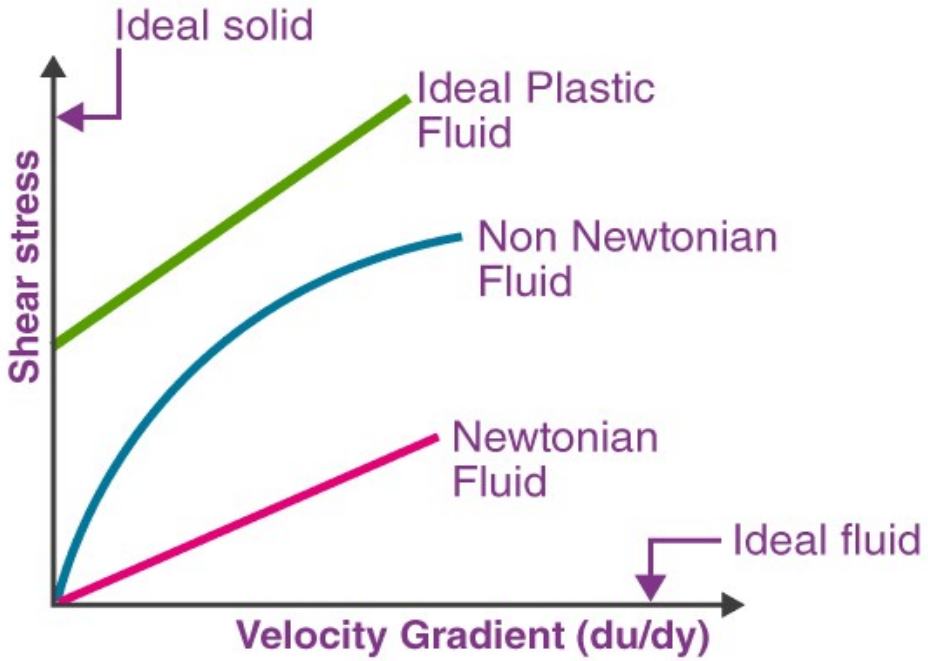
$$\tau = \mu \times \frac{du}{dy}$$

- **Where μ is the constant of proportionality and is known as the coefficient of viscosity. $\frac{du}{dy}$ represents the rate of shear strain or rate of shear deformation or velocity gradient.**
- **Fluids which obey above relation are known as Newtonian fluids (Water) and fluids which do not obey the above relation are called Non-Newtonian fluid (Glycerin)**

❑ D. Types of Fluids

On the basis of viscosity, the fluids may be classified in to the following five types.

- Ideal fluid
- Real fluid
- Newtonian fluid
- Non-Newtonian fluid
- Ideal plastic fluid



- **Ideal fluid:** A fluid which is compressible and is having no viscosity is known as ideal fluid. It is only an imaginary fluid as all fluids have some viscosity.
- **Real fluid:** A fluid possessing a viscosity is known as real fluid. All fluids in actual practice are real fluids.
- **Newtonian fluid:** A real fluid, in which the stress is directly proportional to the rate of shear strain, is known as Newtonian fluid.
- **Non-Newtonian fluid:** A real fluid in which shear stress is not proportional to the rate of shear strain is known as Non-Newtonian fluid.
- **Ideal plastic fluid:** A fluid, in which shear stress is more than the yield value and shear stress is proportional to the rate of shear strain is known as ideal plastic fluid.