

Unit operations

Unit 1

properties of fluids

- Fluid mechanics is branch of science which deals with the behaviour of the fluids (liquids or gases) at rest as well as in motion.
 - Fluid mechanics deals with
 - Statics
 - kinematics
 - Dynamics
 - The study of fluids at rest is called "fluid statics."
 - The study of fluids in motion where pressure forces are not considered is called fluid kinematics
 - The study of fluids in motion where pressure forces are considered is called fluid dynamics
- #### properties of fluids
- 1) Density or mass Density : It is the ratio of mass of a fluid to its volume

It is denoted by symbol ρ (rho)

$$\rho = \frac{\text{Mass of fluid}}{\text{Volume of fluid}}, \frac{\text{kg}}{\text{m}^3}$$

The value of density of water is $\frac{1000 \text{ kg}}{\text{m}^3}$.

2) Specific weight or weight density (w)

$$w = \frac{\text{Weight of fluid}}{\text{Volume of fluid}}$$

$$w = \frac{(\text{mass of fluid}) \times \text{acceleration due to gravity}}{(\text{volume of fluid})}$$

$$w = \text{Density of fluid} \times \text{acceleration}$$

$$w = \rho g \rightarrow \text{Imp.}$$

(3) Specific Volume :- Specific volume of a fluid is defined as the volume of a fluid occupied by a unit mass.

$$\text{Specific Volume} = \frac{\text{Volume of fluid}}{\text{Mass of fluid}}, \frac{\text{m}^3}{\text{kg}}$$

$$\text{Specific volume} = \frac{1}{\rho} \quad \text{where } \rho = \text{density}$$

(2) Specific Gravity (S)

Specific Gravity = $\frac{\text{Weight density of fluid}}{\text{Weight density of Std fluid}}$

Specific gravity of liquid = $\frac{\text{Weight density of liquid}}{\text{Weight density of water}}$

(5) Viscosity :- (μ)

It is defined as the property of a fluid which offers resistance to the movement of one layer of fluid over another adjacent layer of the fluid.

Units of Viscosity is Ns/m^2

(6) Surface tension ad capillarity

Surface tension is defined as the tensile force acting on the surface of a liquid in contact with a gas or on the surface between two immiscible liquids such that the contact surface behaves like a membrane under tension.

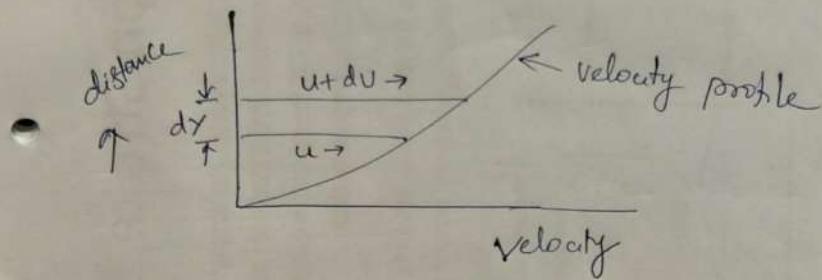
It is denoted by σ (sigma)

Its unit is N/m (SI unit)

Capillarity :- It is defined as a phenomenon of rise or fall of a liquid surface in a small tube relative to adjacent general level of liquid when the tube is held vertically in the liquid. The rise of liquid surface is known as capillary rise while the fall of the liquid surface is known as capillary depression.

It is expressed in terms of cm or mm of liquides
 (cm - Centimeter)
 (mm - millimeter)

Newton's law of Viscosity



When two layers of a fluid, a distance "dy" apart, move one over the other at different velocities say u and $u+du$ as shown in fig

- The Viscosity together with relative velocity causes a shear stress ~~is~~ 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).

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

$$\boxed{\tau = \mu \frac{du}{dy}} \rightarrow \text{Newton's law of Viscosity}$$

where μ is proportionality constant known as Viscosity or "dynamic viscosity".

$\frac{du}{dy}$ = rate of shear strain
or
Shear rate deformation
or
velocity gradient

Units of Viscosity

1) MKS units	$\frac{\text{Kg f - See}}{\text{m}^2}$
2) CGS unit	$\frac{\text{dyne - See}}{\text{cm}^2}$
3) SI unit	$\text{Ns/m}^2 = \text{Pa.S}$

Note The unit of Viscosity in CGS is also called Poise.

$$\text{Poise} = 1 \frac{\text{dyne - See}}{\text{cm}^2}$$

$$\text{One } \frac{\text{Kgf - See}}{\text{m}^2} = 9.81 \frac{\text{N - See}}{\text{m}^2}$$

$$(1 \text{Kgf} = 9.81 \text{ Newton})$$

$$(\text{dyne} = \text{gm} \times \frac{\text{cm}}{\text{sec}^2})$$

$$(\text{One poise} = \frac{1}{10} \frac{\text{Ns}}{\text{m}^2})$$

$$(1 \frac{\text{kg}}{\text{sec meter}} = 10 \text{ poise})$$

$$1 \text{ centipoise} = \frac{1}{100} \text{ poise}$$

Kinematic Viscosity (v)

$$V = \frac{\text{Viscosity}}{\text{Density}} = \frac{\mu}{\rho}$$

SI Units is (length)²/Time

Newton's law of viscosity

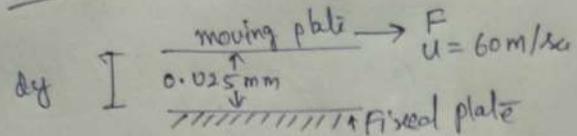
$$\tau = \mu \frac{du}{dy} \rightarrow \text{Newton's law of cooling}$$

It states that the shear stress (τ) on a fluid element layer is directly proportional to the rate of shear strain,

The proportionality constant is called dynamic viscosity

Prob 1) A plate 0.025 mm distant from a fixed plate, moves at 60 cm/sec and requires a force of 2 N per m^2 i.e 2 N/m^2 to maintain this speed. Determine the fluid viscosity between the plates

Solution



$$dy = \text{Distance between plates} = 0.025 \text{ mm}$$

$$dy = 0.025 \times 10^{-3} \text{ m}$$

$$u = 60 \text{ cm/sec} = 0.6 \text{ m/sec} \leftarrow (\text{Velocity})$$

$$F = 2 \text{ N/m}^2$$

$$\text{WKT } T = \mu \frac{du}{dy}$$

$$\text{then } T = 2 \text{ N/m}^2$$

$$du = 0.6 \text{ m/sec} \quad dy = 0.025 \times 10^{-3} \text{ m}$$

$$\mu = \frac{T}{\left(\frac{du}{dy} \right)} = \frac{2}{\left(\frac{0.6}{0.025 \times 10^{-3}} \right)}$$

$$f_l = 8.33 \times 10^{-5} \frac{\text{Ns}}{\text{m}^2}$$

(2) A flat plate of area $1.5 \times 10^6 \text{ mm}^2$ is pulled with a speed of 0.4 m/sec relative to another plate located at a distance

of 0.15 mm from it. Find the force and power required to maintain this speed if the fluid separating them is having viscosity as 1 poise.

Solution

$$A = 1.5 \times 10^6 \text{ mm}^2 = 1.5 \text{ m}^2$$

$$du = 0.4 \text{ m/sec}$$

$$dy = 0.15 \times 10^{-3} \text{ m}$$

$$\mu = 1 \text{ poise} = \frac{1}{10} \frac{\text{Ns}}{\text{m}^2}$$

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

$$\tau = \frac{1}{10} \times \frac{0.4}{0.15 \times 10^{-3}}$$

$$\tau = 266.66 \text{ N/m}^2$$

(i) Shear force = $F = \tau \times \text{Area}$

$$F = 266.66 \times 1.5$$

$$F = 400 \text{ Newton}$$

(2) Power = $F \times \text{distance}$
 $= 400 \times 0.4 = 160 \text{ Watt}$

(3) Find the kinematic viscosity of an oil having density 981 kg/m^3 , the shear stress at a point in oil is 0.2452 N/m^2 and velocity gradient at that point is 0.2 per second .

$$\text{Solution} \quad \rho = 981 \text{ kg/m}^3$$

$$\tau = 0.2452 \text{ N/m}^2$$

$$\text{Velocity gradient } \frac{du}{dy} = 0.2 \text{ sec}^{-1}$$

$$\text{From } \tau = \mu \frac{du}{dy}$$

$$\mu = \frac{\tau}{\left(\frac{du}{dy}\right)} = \frac{0.2452}{0.2}$$

$$\boxed{\mu = 1.226 \text{ Ns/m}^2}$$

$$\text{Kinematic Viscosity } (\nu) = \frac{\mu}{\rho}$$

$$\nu = \frac{1.226}{981} = 0.0124$$

$$\boxed{\nu = 12.5 \times 10^{-4} \text{ m}^2/\text{sec}}$$

(4) Determine the specific gravity of a fluid having viscosity 0.05 poise and kinematic viscosity 0.035 stoke

Solution

$$\mu = 0.05 \text{ poise} = \frac{0.05}{10} \frac{\text{Ns}}{\text{m}^2}$$

$$\text{Kinematic Viscosity } \nu = 0.035 \text{ stoke}$$

$$\nu = 0.035 \text{ cm}^2/\text{sec}$$

$$\therefore (1 \text{ Stoke} = 1 \text{ cm}^2/\text{sec})$$

$$\nu = 0.035 \times 10^{-4} \text{ m}^2/\text{sec}$$

$$\text{Using } \nu = \frac{\mu}{\rho}$$

$$\rho = \frac{\mu}{\nu} = \frac{0.05}{10 \times 0.035 \times 10^{-4}}$$

$$\boxed{\rho = 1428.5 \text{ kg/m}^3}$$

$$\text{Sp. gravity of liquid} = \frac{\text{Density of liquid}}{\text{Density of water}}$$

(specific gravity)

$$\text{Sp. gravity of liquid} = \frac{1428.5}{1000} = 1.43$$

L → Ans.

(5) Determine the Viscosity of a liquid having Kinematic Viscosity 6 Stokes and Specific gravity 1.9

Solution

$$\nu = 6 \text{ Stokes} = 6 \text{ cm}^2/\text{sec} = 6 \times 10^{-4} \text{ m}^2/\text{sec}$$

$$\text{Sp gravity of liquid} = 1.9$$

$$\text{Sp gravity of liquid} = \frac{\text{Density of liquid}}{\text{Density of water}}$$

$$1.9 = \frac{\text{Density of liquid}}{1000}$$

$$\text{Density of liquid} = 1900 \text{ kg/m}^3$$

$$\text{Using } \nu = \frac{\mu}{S}$$

$$6 \times 10^{-4} = \frac{\mu}{1900}$$

$$\boxed{\mu = 1.14 \text{ NS/m}^2}$$

↳ required answer