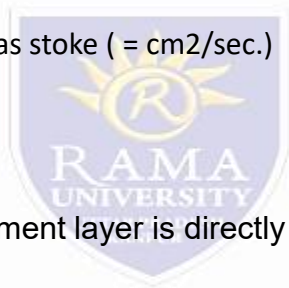


Fluid Properties

- Kinematic Viscosity :
- Kinematic viscosity is defined as the ratio between the dynamic viscosity and density of fluid. It is denoted by ν (called nu).

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

- Units of kinematic viscosity:
- In SI units: m^2/s
- In M.K.S. units: m^2/sec .
- In C.G.S. units the kinematic viscosity is also known as stoke (= cm^2/sec .)
- One stoke = $10^{-4} \text{ m}^2/\text{s}$



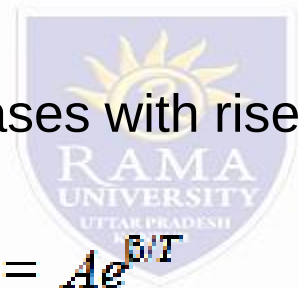
Newton's Law of Viscosity

This law states that the shear stress (τ) on a fluid element layer is directly proportional to the rate of shear strain. The constant of proportionality is called the co-efficient of viscosity.

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

The fluids which follow this law are known as Newtonian fluids.

- **Effect of Temperature on Viscosity**
- Viscosity is effected by temperature. The viscosity of *liquids decreases* but that of *gases increases with increase in temperature*.
- This is due to the reason that in *liquids* the shear stress is due to the inter-molecular cohesion which *decreases* with increase of temperature
- In gases the inter-molecular cohesion is negligible and the shear stress is due to exchange of momentum of the molecules, normal to the direction of motion.
- The molecular activity increases with rise in temperature and so does the viscosity of gas.



For liquids:

$$\mu_T = Ae^{\beta/T}$$

For gases:

$$\mu T = \frac{bT^{1/2}}{1 + a/T}$$

where,

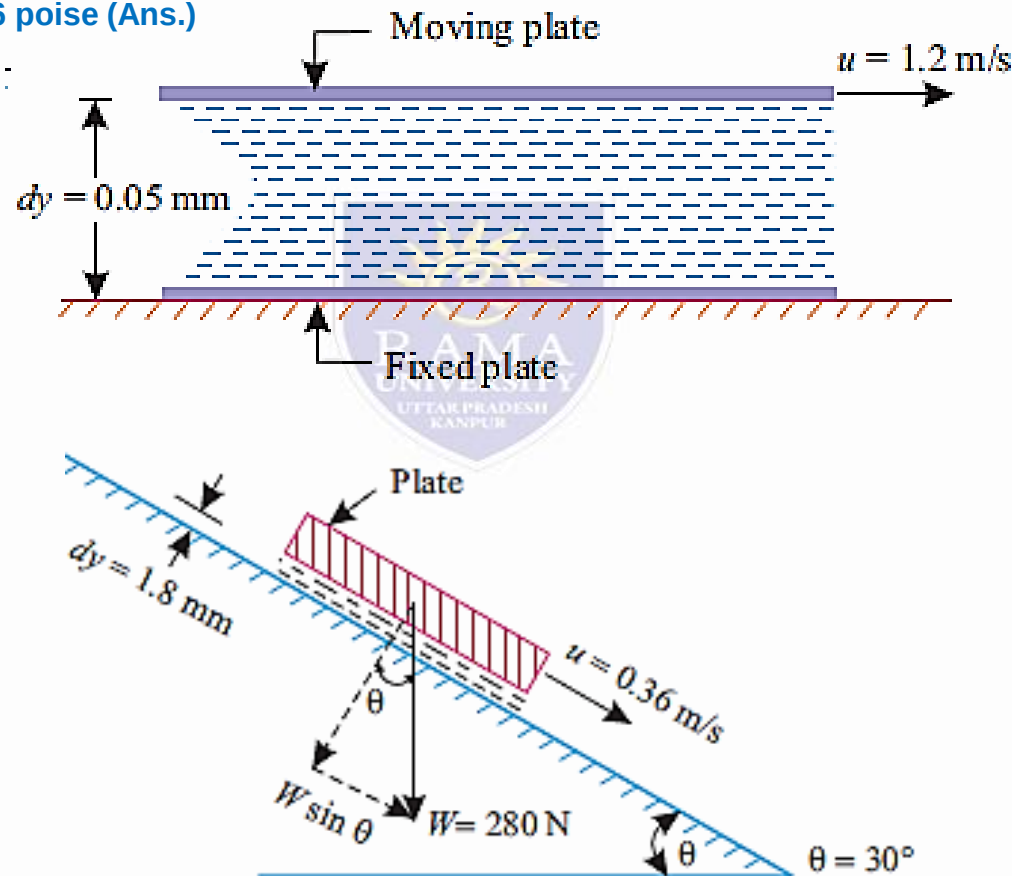
μ_T = Dynamic viscosity at absolute temperature T ,

A, β = Constants (for a given liquid), and

a, b = Constants (for a given gas).

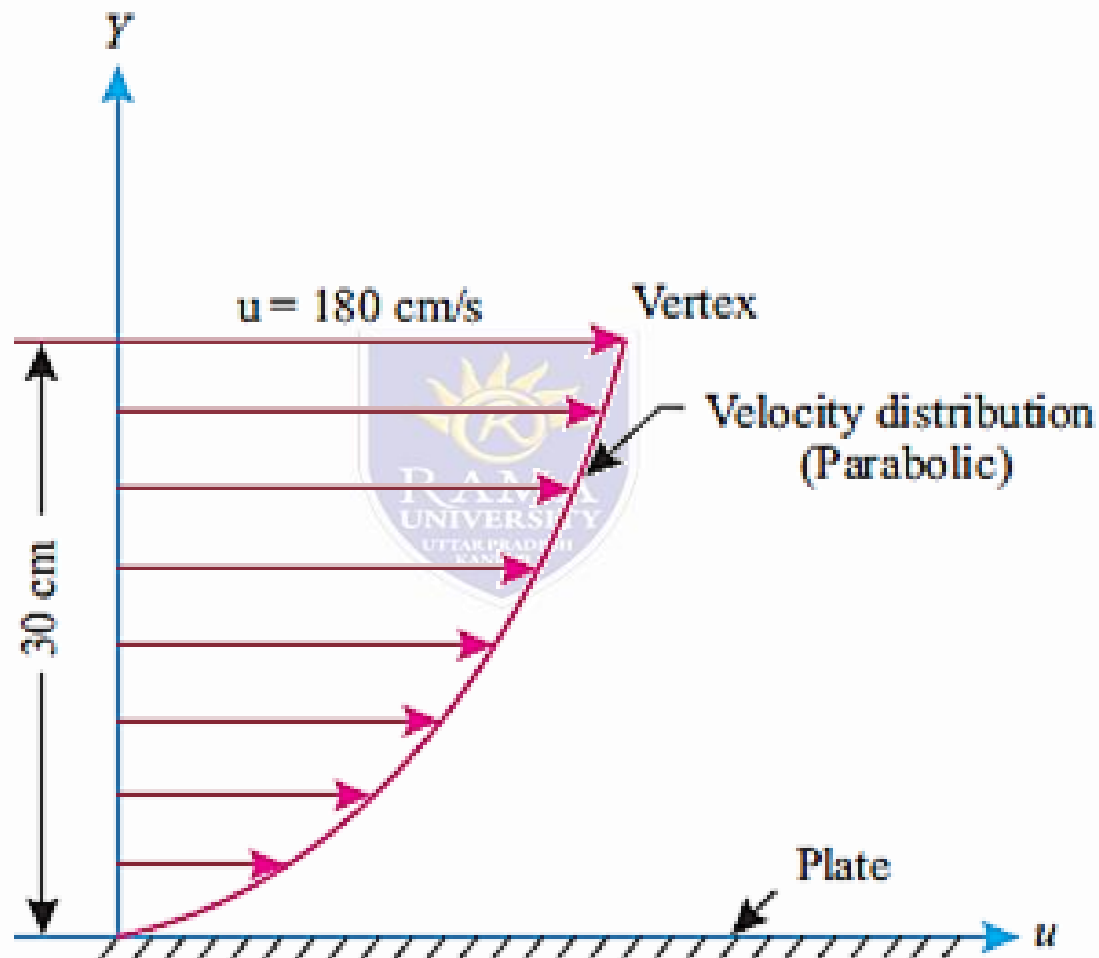
Lecture -03 - Fluid Properties

- Effect of Pressure on Viscosity
- The viscosity under ordinary conditions is not appreciably affected by the changes in pressure. However, the viscosity of some oils has been found to increase with increase in pressure.
- *A plate 0.05 mm distant from a fixed plate moves at 1.2 m/s and requires a force of 2.2 N/m² to maintain this speed. Find the viscosity of the fluid between the plates. 9.16×10^{-4} poise (Ans.)*
- *A plate having an area of 0.6 m² is sliding down the inclined plane at 30° to the horizontal with a velocity of 0.36 m/s. There is a cushion of fluid 1.8 mm thick between the plane and the plate. Find the viscosity of the fluid if the weight of the plate is 280 N. 11.66 poise (Ans.)*



Fluid Properties

- The velocity distribution of flow over a plate is parabolic with vertex 30 cm from the plate, where the velocity is 180 cm/s. If the viscosity of the fluid is $0.9 \text{ N}\cdot\text{s}/\text{m}^2$ find the velocity gradients and shear stresses at distances of 0, 15 cm and 30 cm from the plate.



Fluid Properties

- A 400 mm diameter shaft is rotating at 200 r.p.m. in a bearing of length 120 mm. If the thickness of oil film is 1.5 mm and the dynamic viscosity of the oil is 0.7 N.s/m^2 , determine:
- (i) Torque required to overcome friction in bearing;
- (ii) Power utilised in overcoming viscous resistance.
- Assume a linear velocity profile.

Solution. Diameter of the shaft, $d = 400 \text{ mm} = 0.4 \text{ m}$

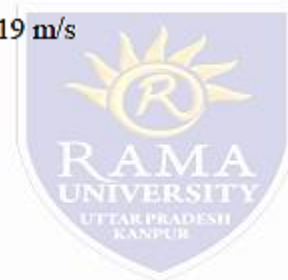
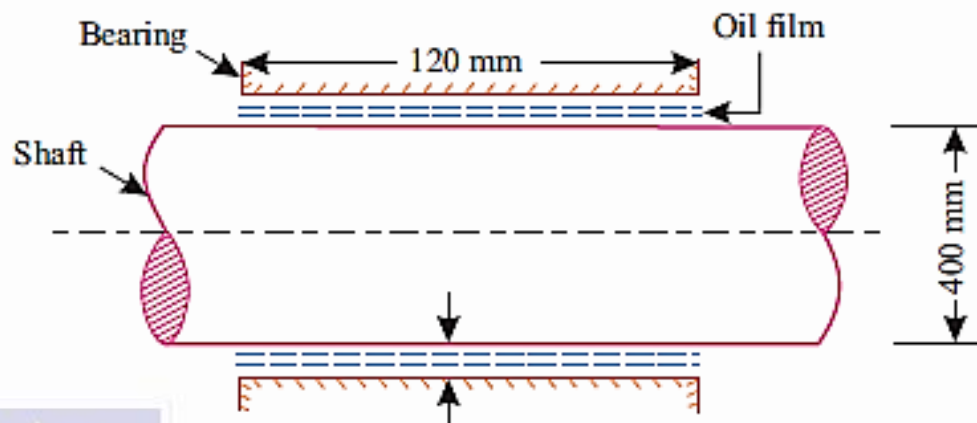
Speed of the shaft, $N = 200 \text{ r.p.m.}$

Thickness of the oil film, $t = 1.5 \text{ mm} = 1.5 \times 10^{-3} \text{ m}$

Length of the bearing, $l = 120 \text{ mm} = 0.12 \text{ m}$

Viscosity, $\mu = 0.7 \text{ N.s/m}^2$

Tangential velocity of the shaft, $u = \frac{\pi d N}{60} = \frac{\pi \times 0.4 \times 200}{60} = 4.19 \text{ m/s}$



(i) Torque required to overcome friction, T :

We know, $\tau = \mu \cdot \frac{du}{dy}$

where du = change of velocity $= u - 0 = 4.19 \text{ m/s}$

$$dy = t = 1.5 \times 10^{-3} \text{ m}$$

$$\therefore \tau = 0.7 \times \frac{4.19}{1.5 \times 10^{-3}} = 1955.3 \text{ N/m}^2.$$

$$\therefore \text{Shear force, } F = \text{shear stress} \times \text{area} \\ = \tau \cdot \pi d l \\ = 1955.3 \times \pi \times 0.4 \times 0.12 \\ = 294.85 \text{ N}$$

$$\text{Hence, viscous torque} = F \times d/2 = 294.85 \times \frac{0.4}{2} \\ = 58.97 \text{ Nm (Ans.)}$$

$$P = T \times \frac{2\pi N}{60} \text{ watts, where } T \text{ is in Nm}$$

$$P = 58.97 \times \frac{2\pi \times 200}{60} = 1235 \text{ W or } 1.235 \text{ kW (Ans.)}$$

Fluid Properties

- A circular disc of diameter D is slowly rotated in a liquid of large viscosity (μ) at a small distance (h) from a fixed surface. Derive an expression of torque (T) necessary to maintain an angular velocity (ω).

Consider an elementary ring of disc at radius r and having a width dr . Linear velocity at this radius is ωr .

$$\text{Shear stress, } \tau = \mu \frac{du}{dy}$$

$$\begin{aligned} \text{Torque} &= \text{shear stress} \times \text{area} \times r \\ &= \tau \times 2\pi r \, dr \times r \\ &= \mu \frac{du}{dy} \times 2\pi r^2 \times dr \end{aligned}$$

Assuming the gap h to be small so that the velocity distribution may be assumed linear:

$$\frac{du}{dy} = \frac{\omega r}{h}$$

$\therefore$ Torque on the element

$$dT = \mu \frac{\omega r}{h} \times 2\pi r^2 \times dr = \frac{2\pi\mu\omega}{h} r^3 \times dr$$

$$\therefore \text{Total torque, } T = \int_0^{D/2} \frac{2\pi\mu\omega}{h} r^3 \times dr$$

$$\text{or } T = \frac{2\pi\mu\omega}{h} \left[\frac{r^4}{4} \right]_0^{D/2} = \frac{2\pi\mu\omega}{h} \cdot \frac{1}{4} \left(\frac{D}{2} \right)^4$$

$$\text{or } T = \frac{\pi\mu\omega D^4}{32h}, \text{ which is the required expression. (Ans.)}$$

