Fluid Properties

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

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

- Units of kinematic viscosity:
- In SI units: m2/s
- In M.K.S. units: m2/sec.
- In C.G.S. units the kinematic viscosity is also known as stoke (= cm2/sec.)
- One stoke = 10–4 m2/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 theinter-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: $\mu T = \dfrac{bT^{1/2}}{1 + a/T}$

where,

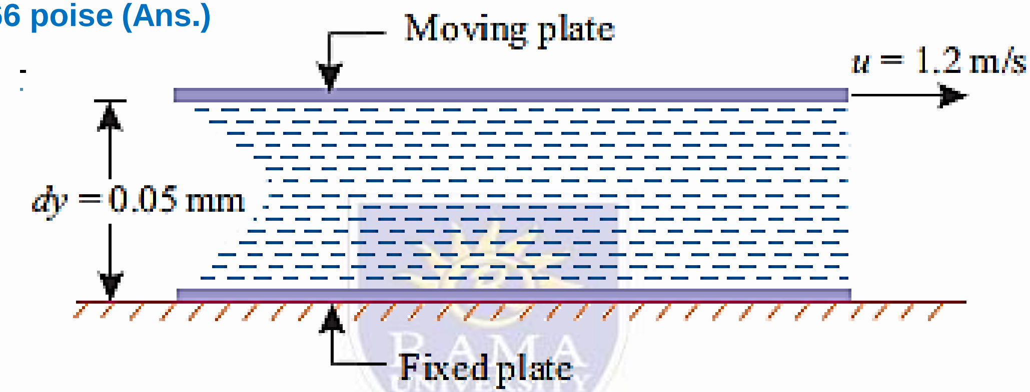
μ_T = Dynamic viscosity at absolute temperature T,

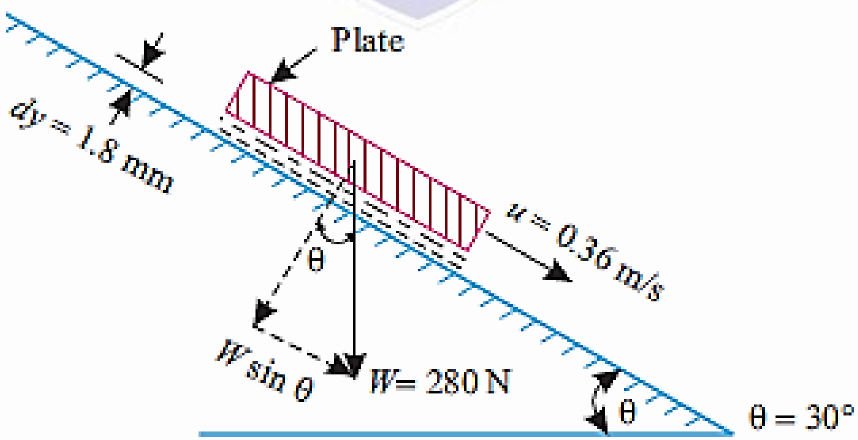
A, β = Constants (for a given liquid), and

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

Lecture -03 - Fluid Properties

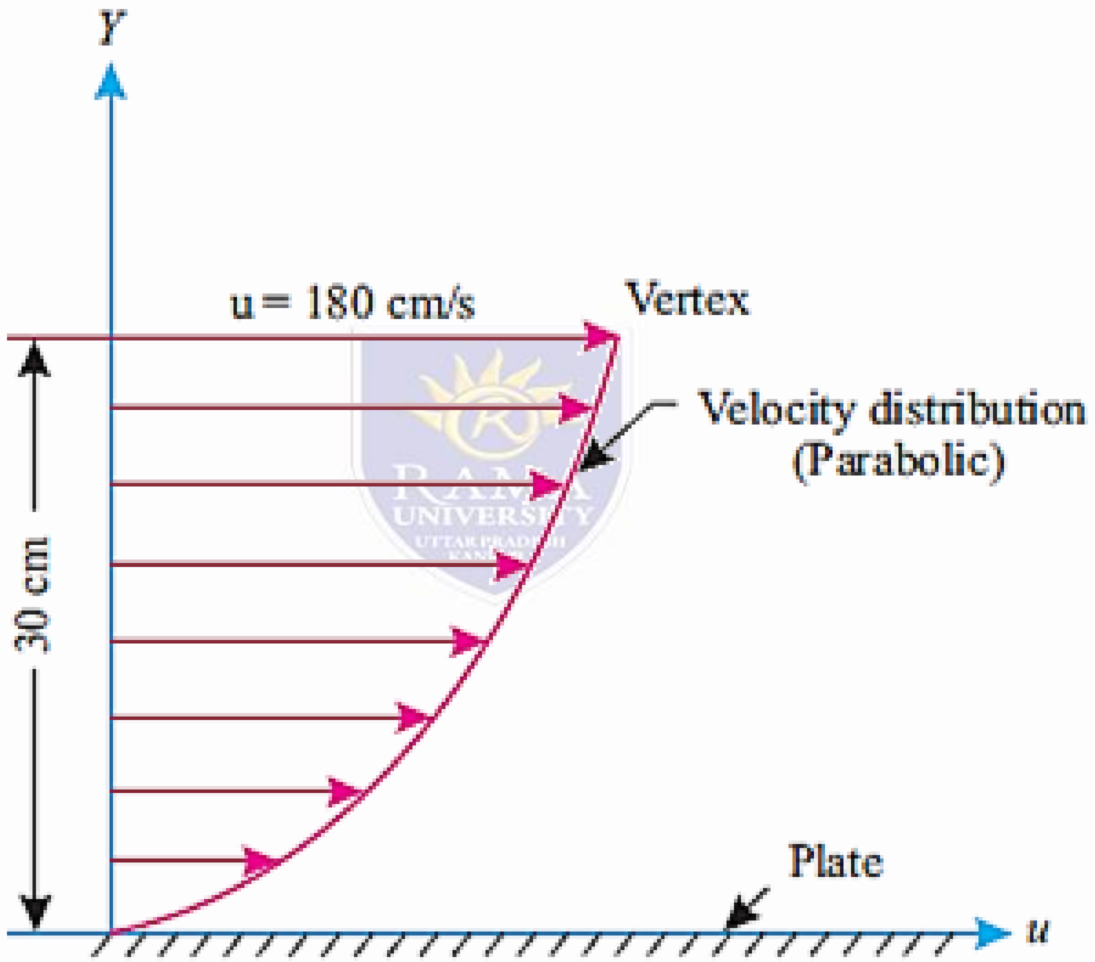
- Effect of Pressure on Viscosity
- The viscosity under ordinary conditions is not appreciably affected by the changes in pressure. However, the viscosity of some oils has been found to increase with increase in pressure.
- ***A plate 0.05 mm distant from a fixed plate moves at 1.2 m/s and requires a 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.)**





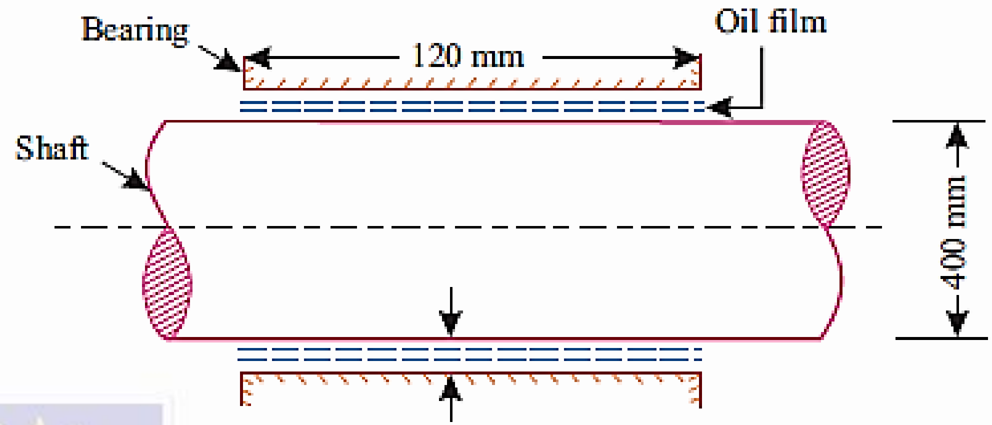
Fluid Properties

- 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 N.s/m2 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/m2, 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, $N = 200$ 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, $u = \dfrac{\pi d N}{60} = \dfrac{\pi \times 0.4 \times 200}{60} = 4.19$ m/s

(*i*) Torque required to overcome friction, *T* :

We know, $\tau = \mu . \dfrac{du}{dy}$

where du = change of velocity $= u - 0 = 4.19$ m/s

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

$$\therefore \quad \tau = 0.7 \times \frac{4.19}{1.5 \times 10^{-3}}$$

$$= 1955.3 \text{ N/m}^2.$$

$\therefore$ Shear force, F = shear stress × area

$$= \tau \cdot \pi d l$$

$$= 1955.3 \times \pi \times 0.4 \times 0.12$$

$$= 294.85 \text{ N}$$

Hence, viscous torque $= F \times d/2 = 294.85 \times \dfrac{0.4}{2}$

$$= 58.97 \text{ Nm } \textbf{(Ans.)}$$

(*ii*) Power utilised, *P*:

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

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

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).

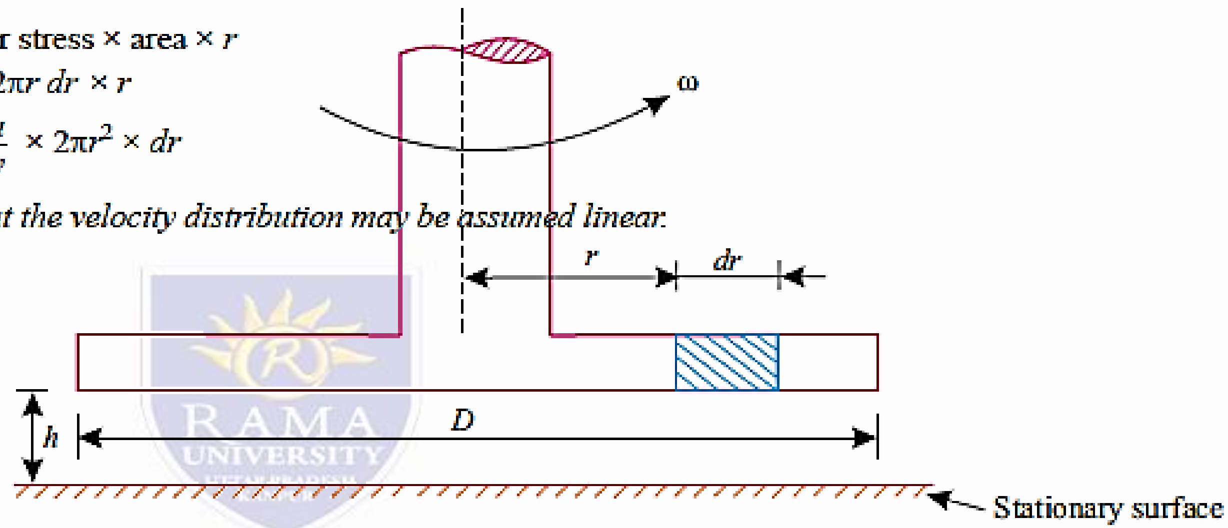
Consider an elementary ring of disc at radius r and having a width dr. Linear velocity at this radius is ωr.

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

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

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

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



∴ Torque on the element

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

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

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

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