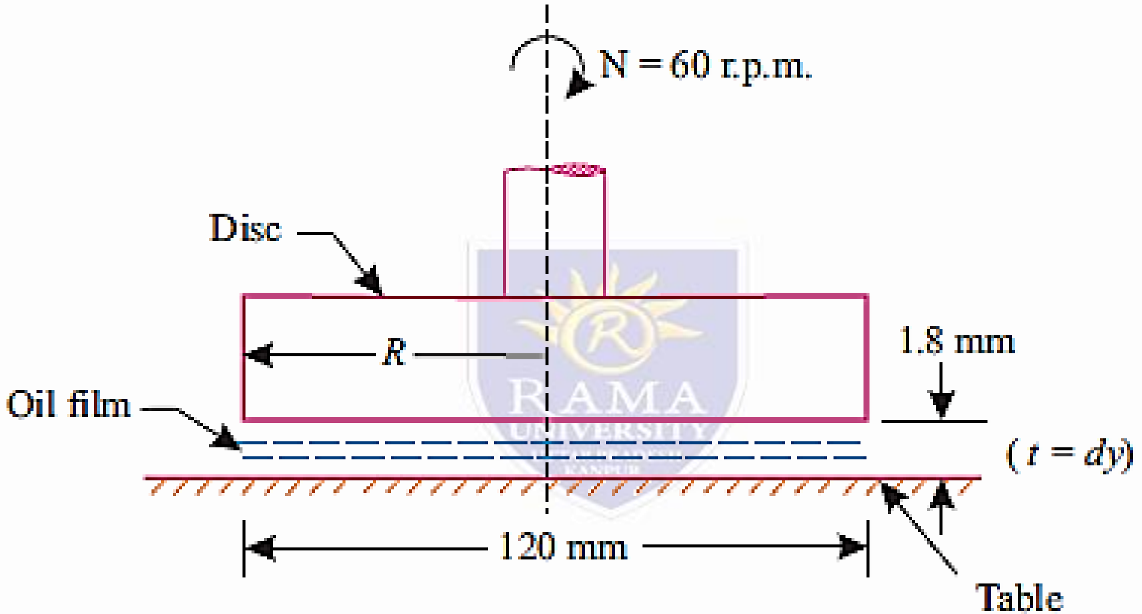
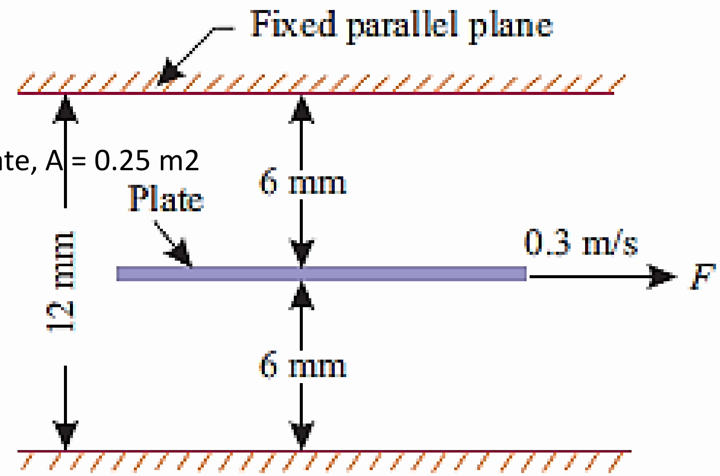
Fluid Properties

- A 120 mm disc rotates on a table separated by an oil film of 1.8 mm thickness. Find the viscosity of oil if the torque required to rotate the disc at 60 r.p.m is 3.6 × 10–4 Nm. Assume the velocity gradient in the oil film to be linear
- μ = 0.0506 poise (Ans.)



- Two large fixed parallel planes are 12 mm apart. The space between the surfaces is filled with oil of viscosity 0.972 N.s/m2. A flat thin plate 0.25 m2 area moves through the oil at a velocity of 0.3 m/s. Calculate the drag force:



- (i) When the plate is equidistant from both the planes, and
- (ii) When the thin plate is at a distance of 4 mm from one of the plane surfaces
- Given: Distance between the fixed parallel planes = 12 mm = 0.012 m Area of thin plate, A = 0.25 m2
- Velocity of plate, u = 0.3 m/s Viscosity of oil = 0.972 N.s/m2
- Drag force, F:
- (i) When the plate is equidistant from both the planes:
- Let, F1 = Shear force on the upper side of the
- thin plate,
- F2 = Shear force on the lower side of the thin plate,
- F = Total force required to drag the plate (= F1 + F2).
- The shear τ1, on the upper side of the thin plate is given by:

The shear τ_1, on the upper side of the thin plate is given by:

$$t_1 = \mu . \left(\frac{du}{dy}\right)_1$$

where, $du = 0.3$ m/s (relative velocity between upper fixed plane and the plate), and dy = 6 mm = 0.006 m (distance between the upper fixed plane and the plate)

(Thickness of the plate neglected).

$$\therefore \qquad \tau_1 = 0.972 \times \frac{0.3}{0.006} = 48.6 \text{N/m}^2$$

$$\therefore \qquad \text{Shear force, } F_1 = \tau_1 \cdot A = 48.6 \times 0.25 = 12.15 \text{ N}$$

Similarly shear stress (τ_2) on the lower side of the thin plate is given by

$$\tau_2 = u . \left(\frac{du}{dy}\right)_2 = 0.972 \times \frac{0.3}{0.06} = 48.6 \text{ N/m}^2$$

$$\text{and} \qquad F_2 = \tau_2 . A = 48.6 \times 0.25 = 12.15 \text{ N}$$

$$\therefore \qquad F = F_1 + F_2 = 12.15 + 12.15 = 24.30 \text{ N (Ans.)}$$

- (ii) When the thin plate is at a distance of 40 mm from one of the plane surfaces: Refer to Fig

The shear force on the upper side of the thin plate,

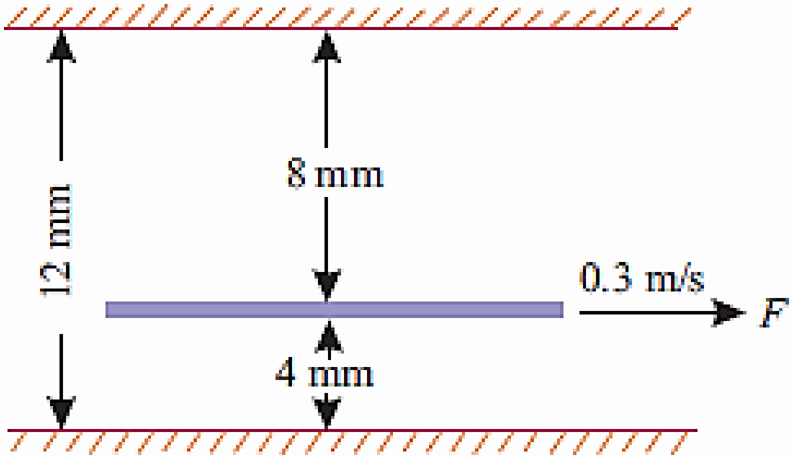
$$F_1 = \tau_1 \, . \, A = \mu \, . \left(\frac{du}{dy}\right)_1 \times A$$

$$= 0.972 \times \frac{0.3}{0.008} \times 0.25 = 9.11\text{N}$$

The shear force on the lower side of the thin plate,

$$F_2 = \tau_2 \times A = \mu \, . \left(\frac{du}{dy}\right)_2 \times A$$

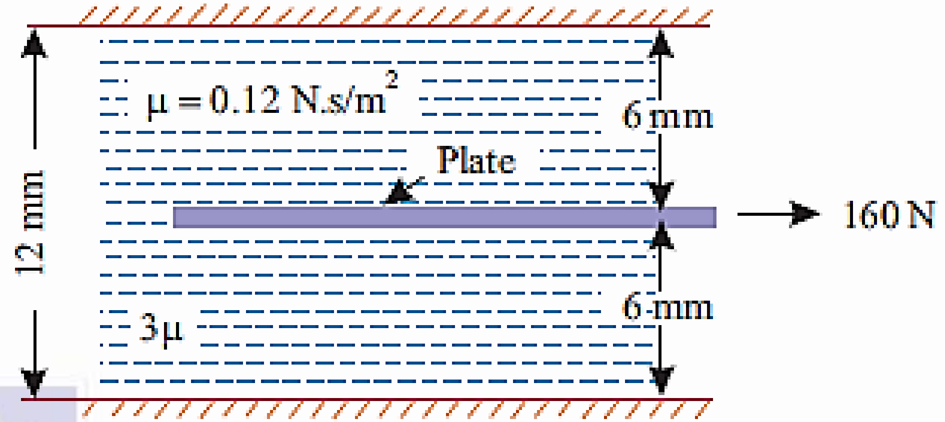
$$= 0.972 \times \left(\frac{0.3}{0.004}\right) \times 0.25 = 18.22\text{N}$$



- **∴ Total force F = F1 + F2 = 9.11 + 18.22 = 27.33 N (Ans.)**

Fluid Properties

- In the Fig. 1.14 is shown a central plate of area 6 m2 being pulled with a force of 160 N. If the dynamic viscosities of the two oils are in the ratio of 1:3 and the viscosity of top oil is 0.12 N.s/m2 determine the velocity at which the central plate will move.



- Solution: Area of the plate, A = 6 m2
- Force applied to the plate, F = 160 N
- Viscosity of top oil, μ = 0.12 N.s/m2
- Velocity of the plate, u:
- Let F1 = Shear force in the upper side of thin (assumed) plate,
- F2 = Shear force on the lower side of the thin plate, and
- F = Total force required to drag the plate (= F1 + F2)
- Then, F = F1 + F2 = τ1 × A + τ2 × A

$$= \mu\left(\frac{\partial u}{\partial y}\right)_1 \times A + 3\mu\left(\frac{du}{dy}\right)_2 \times A$$

(where τ_1 and τ_2 are the shear stresses on the two sides of the plate)

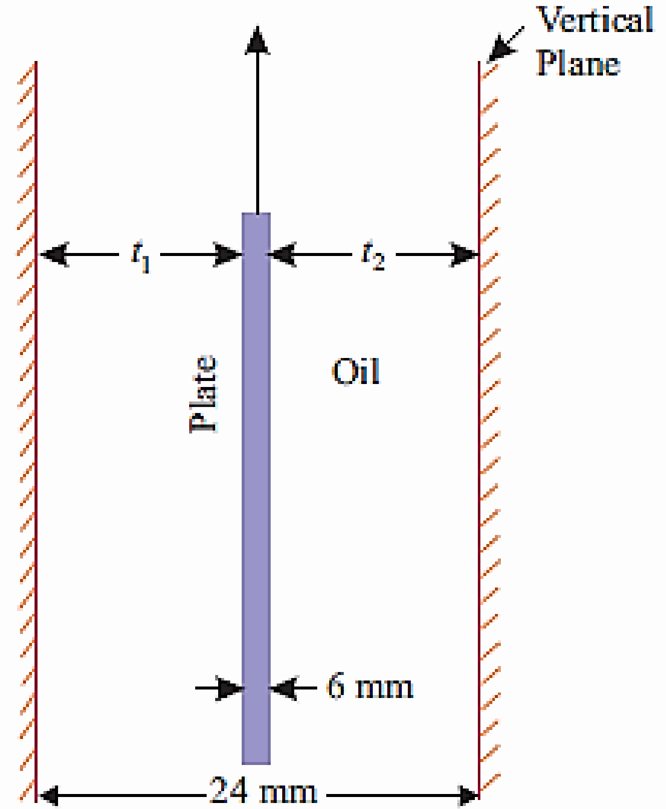
$$160 = 0.12 \times \frac{u}{6 \times 10^{-3}} \times 6 + 3 \times 0.12 \times \frac{u}{6 \times 10^{-3}} \times 6$$

or $$160 = 120u + 360u = 480u \quad \text{or} \quad u = \frac{160}{480} = 0.333 \text{ m/s (Ans.)}$$

Fluid Properties

- A metal plate 1.25 m × 1.25 m × 6 mm thick and weighing 90 N is placed midway in the 24 mm gap between the two vertical plane surfaces as shown in the Fig. . The gap is filled with an oil of specific gravity 0.85 and dynamic viscosity 3.0 N.s/m2. Determine the force required to lift the plate with a constant velocity of 0.15 m/s.
- Given: Dimensions of the plate = 1.25 m × 1.25 m × 6 mm
- ∴ Area of the plate, A = 1.25 × 1.25 = 1.5625 m2
- Thickness of the plate = 6 mm
- (Since the plate is situated midway in the gap) Specific gravity of oil = 0.85
- Dynamic viscosity of oil = 3 N.s/m2
- Velocity of the plate = 0.15 m/s
- Weight of the plate = 90 N
- Force required to lift the plate:
- Drag force (or viscous resistance) against the motion of the plate,
- F = τ1 . A + τ2 . A (where τ1 and τ2 are the shear stresses on two sides of the
- plate)

$$t_1 = t_2 = \frac{24-6}{2} = 9 \text{ mm}$$



$$= \mu \cdot \left(\frac{du}{dy}\right)_1 \times A + \mu\left(\frac{du}{dy}\right)_2 \times A$$

$$= \mu \cdot \frac{u}{t_1} \times A + \mu \cdot \frac{u}{t_2} \times A$$

$$= \mu A u \cdot \left(\frac{1}{t_1} + \frac{1}{t_2}\right)$$

or

$$F = 3 \times 1.5625 \times 0.15 \left(\frac{1}{9 \times 10^{-3}} + \frac{1}{9 \times 10^{-3}}\right)$$

$$= 3 \times 1.5625 \times 0.15 \times \frac{2}{9 \times 10^{-3}} = 156.25 \text{ N}$$

Upward thrust or buoyant force on the plate = specific weight × volume of oil displaced

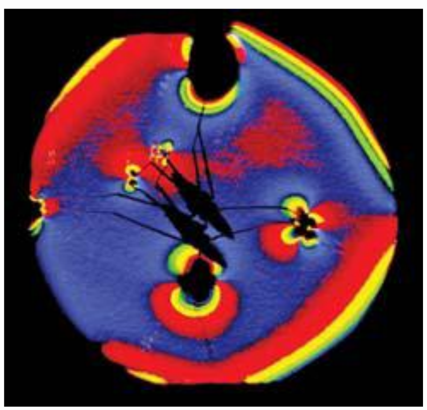
= 0.85 × 9810 × (1.25 × 1.25 × 0.006) = 78.17 N

Effective weight of the plate = 90 – 78.17 = 11.83 N, ∴ Total force required to lift the plate at velocity of 0.15 m/s = F + effective weight of the plate = 156.25 + 11.83 = 168.08 N (Ans.)

Lecture Fluid Properties

- SURFACE TENSION

- A drop forms when liquid is forced out of a small tube. The shape of the drop is determined by a balance of pressure, gravity, and surface tension forces.



Some consequences of surface tension: (a) drops of water beading up on a leaf, (b) a water strider sitting on top of the surface of water, and (c) a color schlieren image of the water strider revealing how the water surface dips down where its feet contact the water (it looks like two insects but the second one is just a shadow).