POSTAL BOOK PACKAGE 2026

MADE EASY PUBLICATIONS

MECHANICAL ENGINEERING

CONVENTIONAL Practice Sets

CONTENTS

FLUID MECHANICS AND FLUID MACHINERY

Fluid Properties

Q.1 The velocity distribution for flow over a flat plate is given by $u = \frac{3}{4}y - y^2$ in which u is the velocity in metre per second at a distance y metre above the plate. Determine the shear stress at y = 0.15 m. Take dynamic viscosity of fluid as 8.5 poise.

Solution:

Given, $u = \frac{3}{4}y - y^2$

Viscosity, $\mu = 8.5\text{poise} = \frac{8.5}{10}\text{Ns/m}^2$ $\left(\because 10 \text{ poise} = 1 \text{ Ns/m}^2\right)$

$\therefore$ $\frac{du}{dy} = \frac{3}{4} - 2y$

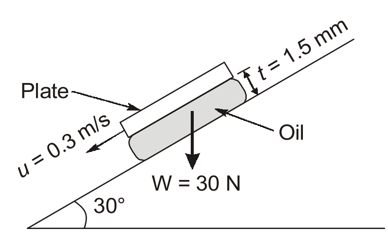
At y = 0.15, $\frac{du}{dy} = \frac{3}{4} - 2 \times 0.15 = 0.75 - 0.30 = 0.45$

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

$$= \frac{8.5}{10} \times 0.45 \text{ N/m}^2 = 0.3825 \text{ N/m}^2$$

Q.2 Calculate the dynamic viscosity of an oil, which is used for lubrication between a square plate of size 0.8 m × 0.8 m and an inclined plane with angle of inclination 30° as shown in figure. The weight of the square plate is 300 N and it slides down the inclined plane with a uniform velocity of 0.3 m/s. The thickness of oil film is 1.5 mm.

Solution:



Given: Area of plate, $A = 0.8 \times 0.8 = 0.64 \text{ m}^2$

Angle of plane, $\theta = 30°$

Weight of plate, $W = 300 \text{ N}$

Velocity of plate, $u = 0.3 \text{ m/s}$

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

Let the viscosity of fluid between plate and inclined plane is μ.

Component of weight W, along the plane = $W \cos 60° = 300 \cos 60° = 150$ N

Thus the shear force, F, on the bottom surface of the plate = 150 N

and shear stress, $\boxed{\tau = \frac{F}{\text{Area}}} = \frac{150}{0.64}\text{N/m}^2$

Now, $\boxed{\tau = \mu \frac{du}{dy}}$

Assuming linear velocity profile,

$$du = \text{change of velocity} = u - 0 = 0.3 \text{ m/sec}$$

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

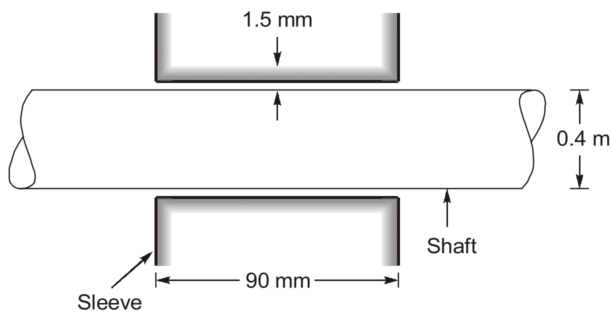
$$\therefore \quad \frac{150}{0.64} = \mu \times \frac{0.3}{1.5 \times 10^{-3}}$$

$$\mu = \frac{150 \times 1.5 \times 10^{-3}}{0.64 \times 0.3} = 1.17 \text{ Ns/m}^2 = 11.7 \text{ Poise}$$

Q.3 The dynamic viscosity of an oil, used for lubrication between a shaft and sleeve is 6 poise. The shaft is of diameter 0.4 m and rotates at 190 rpm. Calculate the power lost in teh bearing for a sleeve length of 90 mm. The thickness of the oil film is 1.5 mm.

Solution:

Given:



Viscosity, $\mu = 6$ Poise

$$= \frac{6}{10}\ \frac{\text{Ns}}{\text{m}^2} = 0.6 \text{Ns/m}^2$$

Diameter of shaft, $D = 0.4$ m

Speed of shaft, $N = 190$ rpm

Sleeve length, $L = 90 \text{ mm} = 90 \times 10^{-3}$ m

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

Tangential velocity of shaft, $\boxed{u = \frac{\pi D N}{60}}$

$$u = \frac{\pi \times 0.4 \times 190}{60} = 3.98 \text{ m/s}$$

Using the relation and assuming linear velocity profile,

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

where, du = Change of velocity $= u - 0 = u = 3.98$ m/s

dy = Change of distance $= t = 1.5 \times 10^{-3}$ m

$$\tau = 10 \times \frac{3.98}{15 \times 10^{-3}} = 1592 \text{ N/m}^2$$

This is shear stress on shaft,

$\therefore$ Shear force on the shaft, $\boxed{F = \text{Shear stress} \times \text{Area}}$

$$= 1592 \times \pi D \times L = 1592 \times \pi \times 0.4 \times 90 \times 10^{-3} = 180.05 \text{ N}$$

Torque on the shaft, $\boxed{T = \text{Force} \times \frac{D}{2}}$

$$= 180.5 \times \frac{0.4}{2} = 36.01 \text{ Nm}$$

$\therefore$ $\boxed{\text{Power lost} = \frac{2\pi NT}{60}}$

$$= \frac{2\pi \times 190 \times 36.01}{60} = 716.48 \text{ W}$$

Q.4 A vertical gap 23.5 mm wide of infinite extent contains oil of specific gravity 0.9 and viscosity 2.5 N-s/m^2. A metal plate 1.5 m × 1.5 m × 1.5 mm weighing 50 N is to be lifted through the gap at a constant speed of 0.1 m/sec. Estimate the force required to lift the plate.

Solution:

Given: Width of gap = 23.5 mm

Viscosity, μ = 2.5 Ns/m^2

Specific gravity oil = 0.9

$\therefore$ Weight density of oil = $0.9 \times 1000 = 900$ kgf/m^3

$= 900 \times 9.81$ N/m^3 ($\because$ 1 kgf = 9.81 N)

Assuming that the plate lies in the middle of the gap

Volume of plate = 1.5 m × 1.5 m × 1.5 mm

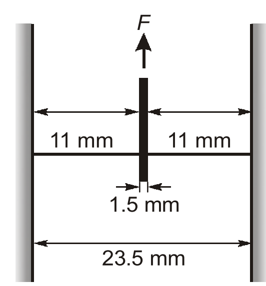
$= 1.5 \times 1.5 \times 0.0015$ m^3

$= 0.003375$ m^3

Thickness of plate = 1.5 mm

Velocity of plate = 0.1 m/sec

Weight of plate = 50 N



When the plate is in the middle of the gap, the distance of plate from

$$\boxed{\text{Vertical surface of the gap} = \left(\frac{\text{Width of gap} - \text{Thickness of plate}}{2}\right)}$$

$$= \left(\frac{23.5 - 1.5}{2}\right) = 11 \text{ mm} = 0.011 \text{ m}$$

Now, shear force on left side of the metallic plate

$$\boxed{F_1 = \text{Shear stress} \times \text{Area}}$$

$$= \mu\left(\frac{du}{dy}\right)_1 \times (1.5 \times 1.5) = 2.5 \times \left(\frac{0.1}{0.011}\right) \times 1.5 \times 1.5 = 51.136 \text{ N}$$

Similarly, the shear force on the right side of the metallic plate,

$$\boxed{F_2 = \text{Shear stress} \times \text{Area}}$$

$$= 2.5 \times \left(\frac{0.1}{0.011}\right) \times (1.5 \times 1.5) = 51.136 \text{ N}$$

$\therefore$ **Total shear force,** $F = F_1 + F_2 = 51.136 + 51.136 = 102.273$ N

In this case the weight of plate (which is acting downward) and upward thrust is also to be taken into account.

$\therefore$ The upward thrust = Weight of fluid displaced = $\rho v g$

= (unit weight of fluid) × Volume of fluid displaced

= 9.81 × 900 × 0.003375 = 29.80 N

The net force acting in the downward direction due to the weight of the plate and upward thrust

= Weight of plate – Upward thrust = 50 – 29.80 = 20.20 N

$\therefore$ Total force required to lift the plate up

= Total shear force + 20.20 = 102.273 + 20.20 = 122.473 N

Q.5 **Find the surface tension in a soap bubble of 40 mm diameter when the inside pressure is 2.5 N/m² above atmospheric pressure.**

Solution:

Given: Diameter of bubble, $d = 40 \text{ mm} = 40 \times 10^{-3}$ m

Pressure in excess of outside, $p = 2.5$ N/m²

For a soap bubble, $\boxed{\Delta p = \dfrac{8\sigma}{d}}$

or
$$2.5 = \frac{8 \times \sigma}{40 \times 10^{-3}}$$

$$\sigma = \frac{2.5 \times 40 \times 10^{-3}}{8} = 0.0125 \text{ N/m}$$

Q.6 **Calculate the capillary effect in mm in a glass tube 3 mm in diameter when immersed in (a) water (b) mercury. Both the liquids are at 20°C and the values of the surface tensions for water and mercury at 20°C in contact with air are respectively 0.0736 N/m and 0.51 N/m. Contact angle for water = 0° and for mercury = 130°.**

Solution:

The capillary rise (or depression) is given as

$$\boxed{h = \frac{2\sigma\cos\theta}{\rho g r}}$$

(a) For water $\theta = 0$,
$\cos\theta = 1$

$\sigma = 0.0736$ N/m

$\rho g = 9810$ N/m³

$d = 3$ mm

$$r = \frac{3}{2} = 1.5 \text{ mm} = 1.5 \times 10^{-3} \text{ m}$$

By substitution, we get
$$h = \frac{2 \times 0.0736 \times 1}{9810 \times 1.5 \times 10^{-3}}$$

$= 1.00 \times 10^{-2}$ m = 10 mm

(b) For mercury $\theta = 130°$,
$\cos\theta = -0.6428$

$\sigma = 0.51$ N/m

$\rho g = (13.6 \times 9810)$ N/m³

$$r = \frac{3}{2} = 1.5 \text{ mm} = 1.5 \times 10^{-3} \text{ m}$$

By substitution, we get
$$h = \frac{2 \times 0.51 \times (-0.6425)}{13.6 \times 9810 \times 1.5 \times 10^{-3}} = -3.276 \times 10^{-3} \text{ m}$$

= –3.276 mm

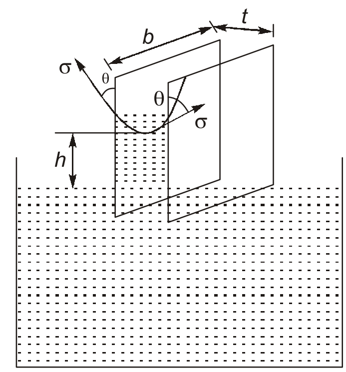
The negative (–) sign in the case of mercury indicates that there is capillary depression.

Q.7 Determine capillarity rise between two thin vertical plates spaced '*t*' distance apart. Calculate the distance between the plates when the capillarity rise is not to exceed 60 mm. Assume surface tension of water at 20°C as 0.075 N/m.

Solution:

For two vertical plates, '*t*' distance apart

Let width of plate be '*b*' and contact angle be 'θ'



$$\text{Force due to surface tension} = \text{Force due to gravity}$$

$$2\sigma \cos\theta \, b = \rho g \, (b \times t) h$$

Height of capillarity rise,
$$\boxed{h = \frac{2\sigma\cos\theta}{\rho g t}}$$

For $\sigma = 0.075$ N/m and $h = 60$ mm

Assuming $\theta = 0°$ i.e., $\cos\theta = 1$

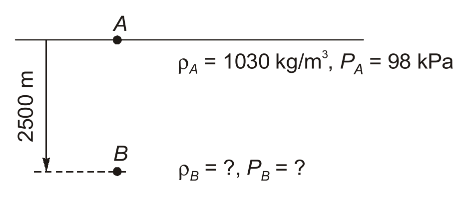
$$0.06 = \frac{2 \times 0.075 \times 1000}{9.81 \times 1000 \times t}$$

$$t = 0.255 \text{ mm}$$

Q.8 The density of sea water at free surface where pressure is 98 kPa is 1030 kg/m^3. Taking bulk modulus of sea water to be 2.34×10^9 N/m^2 (assume constant), determine the density and pressure at a depth of 2500 m. Neglect the effect of temperature

Solution:

Calculation of density:



$$K = 2.34 \times 10^9 \text{ N/m}^2$$

$$K = \rho \frac{dP}{d\rho}$$

Since $$dP = \gamma dh$$

$\Rightarrow$ $$K = \frac{\rho\gamma dh}{d\rho} = \rho^2 g \frac{dh}{d\rho}$$

$$\int_{\rho_A}^{\rho_B} \frac{d\rho}{\rho^2} = \int_0^H \frac{g}{K} dh$$

$\Rightarrow$ $$\left. \frac{1}{\rho(-1)} \right|_{\rho_A}^{\rho_B} = \frac{g}{K} \times H$$

$\Rightarrow$ $$\frac{1}{\rho_A} - \frac{gH}{K} = \frac{1}{\rho_B}$$

$\therefore$ $$\rho_B = \frac{1}{\left(\frac{1}{\rho_A} - \frac{gH}{K}\right)}$$

$$\rho_B = \frac{1}{\frac{1}{1030} - \frac{9.81 \times 2500}{2.34 \times 10^9}} = 1041.24 \text{ kg/m}^3$$

Calculation of pressure:

$$K = \frac{dP}{\left(\frac{d\rho}{\rho}\right)}$$

$$\int_{P_A}^{P_B} dP = K.\int_{\rho_A}^{\rho_B} \frac{d\rho}{\rho}$$

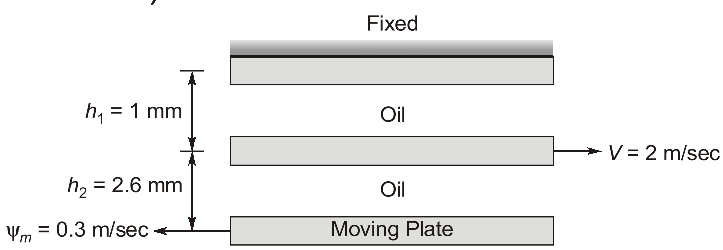
$$P_B - P_A = K[\ln\rho]_{\rho_A}^{\rho_B}$$

$$P_B = P_A + K\ln\left(\frac{P_B}{P_A}\right)$$

$$P_B = 98 + 2.34\times10^6 \ln\left(\frac{1041.24}{1030}\right)$$

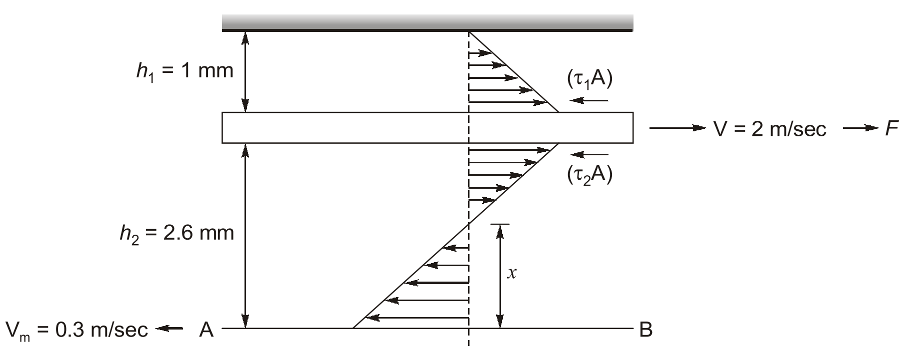
$$= 25495.20 \text{ kPa} = 25.5 \text{ MPa}$$

Q.9 A thin 40 cm × 40 cm flat plate is pulled at 2 m/sec horizontally through a 3.6 mm thick oil layer sandwitched between two plates, one stationary and other moving at a constant speed of 0.3 m/sec as shown in figure. Determine the force that is required to be applied on the plate to maintain this motion. Take (μ_{oil} = 0.027 Pa-s).



Solution:

Given:



Let at a distance x from plate AB, where the velocity of oil will be zero.
From the property of similarly of triangle

$$\frac{x}{2.6 - x} = \frac{0.3}{2}$$

$$2x = 2.6 \times 0.3 - 0.3x$$

$$2.3x = 2.6 \times 0.3$$

$$x = \frac{2.6\times0.3}{2.3} = 0.34 \text{ mm}$$

Now, force, F required to maintain this motion

$$\boxed{F = (\tau_1 A + \tau_2 A)}$$

$$= \mu\left[\frac{V}{h_1} + \frac{V-(-V_m)}{h_2}\right]A = 0.027\left[\frac{2}{1\times10^{-3}} + \frac{2+0.3}{2.6\times10^{-3}}\right]\times0.4\times0.4$$

$$= 12.46 \text{ N}$$