Sheet (1)

1- Calculate the specific weight, density and specific gravity of one litre of a liquid which weighs 7N.

Given :

Volume = l litre = $\frac{1}{1000}$m^3 (or)1 litre = 1000 cm^3

Weight = 7 N

Solution:

(i)Specific weight (w) = $\frac{weight}{volume} = \frac{7N}{\frac{1}{1000}m^3}$ = **7000 N/m3. Ans.**

(ii) Density (ρ) = $\frac{w}{g} = \frac{7000}{9.81}$ kg/m^3 = **713.5 kg/m3. Ans.**

(in) Specific gravity = $\frac{density\ of\ liquid}{density\ of\ water} = \frac{7000}{1000}$ (Density of water = 1000 kg/m^3)

= **0.7135 Ans.**

2- Calculate the density, specific weight and weight of one litre of petrol of specific gravity = 0.7

Volume = litre = x 1000 cm^3 = $\frac{1000}{10^6}$ m^3 = **0.001 m3**

Sp. gravity S , = 0.7

(i) Density (p) = S x 1000 kg/m^3 = 0.7 x 1000

= **700 kg/m3**

(ii) Specific weight (w)

w = ρ x g = 700 x 9.81 N/m^3

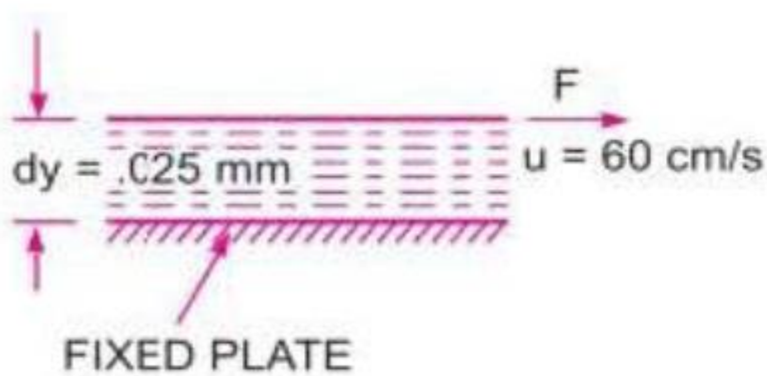
= **6867 N/m^3. Ans.**

(iii) Weight (W)

We know that, specific weight **=** $\frac{weight}{volume} = \frac{W}{0.001}$ or 6867

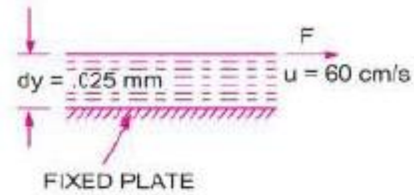
W = 6867 X 0.001 = **6.867 N. Ans.**

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



Distance between plates, $dy = .025$ mm

$= .025 \times 10^{-3}$ m



Velocity of upper plate, $u = 60$ cm/s $= 0.6$ m/s

Force on upper plate, $F = 2.0$ N/m^2

This is the value of shear stress i.e., τ

Solution:

Let the fluid viscosity between the plates is μ,

we know that, $\tau = \mu \frac{du}{dy}$

where, du = change of velocity

dy = change of distance = 0.025×10^{-3} m

= force per unit area = 2.0 N/m^2

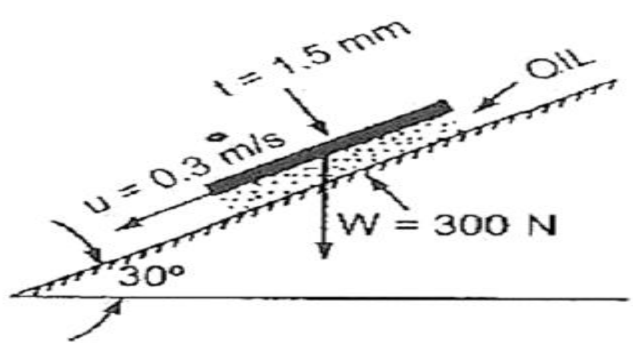
$$2.0 = \mu \frac{0.60}{0.025 * 10^{-3}}$$

$$\mu = \frac{2.0 \times 0.025 \times 10^{-3}}{0.60} = 8.33 \times 10^{-5} \text{ Ns/m}^2$$

$= 8.33 \times 10^{-5} \times 10$ poise

$\mu = 8.33 \times 10^{-4}$ poise

4- Calculate the dynamic viscosity of an oil, which is used for lubrication between a square plate of size 0.8 m x 0.8 m and an inclined plane with angle of inclination 30° as shown in Fig. 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.



Given:

Area of plate, $A = 0.8 \times 0.8 = 0.64$ m

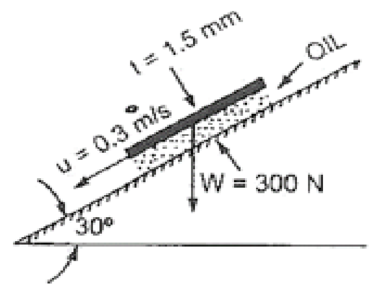
Angle of plane, $\theta = 30°$

Weight of plate, $W = 300$ N

Velocity of plate, u = 0.3 m/s

Thickness of oil film, $t = dy = 1.5$ mm

$= 1.5 \times 10^{3}$ m



Solution:

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

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

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

shear stress, $\tau = \frac{\text{Force}}{\text{Area}} = 150 / 0.64$ N/m²

Now using equation, we have

$$\tau = \mu \quad (du/dy)$$

where du = change of velocity = u - 0 = u = 0.3 m/s

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

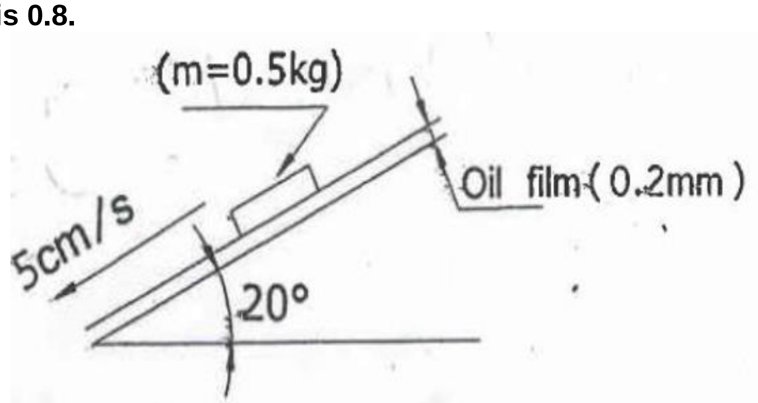
$150/0.64 = \mu\, (0.3 / 1.5 \times 10^{-3})$

$\mu = (150 \times 1.5 \times 10^{-3}) / 0.64 \times 0.3$

$\mu = 17$ N s/m² $= 1.17 \times 10$

μ = 11.7 poise Ans

5- Find the viscosity of oil in poise and pa.s. if the plate (0.6mx0.6m) as shown in figure slides down the plane with a velocity of 5 cm/sec. find the kinematic viscosity in Stokes and m²/sec. If the specific gravity is 0.8.



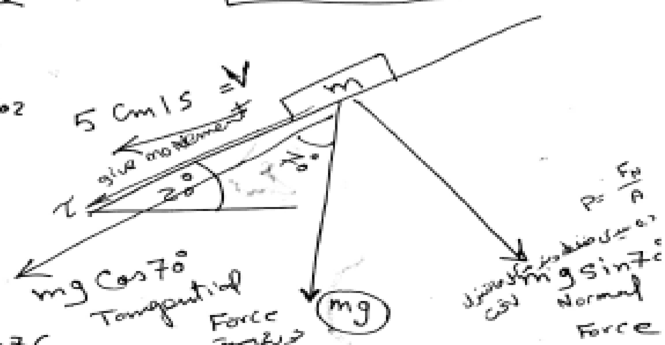
Poise = 0.1 Pa·s
Stokes = 10^{-4} m²/s

F_t : tangential force

$= mg \cos 70°$

$= 0.5 * 9.81 * 0.34202$

$= 1.6776$ N.



$\frac{du}{dy}$ = rate of strain

$\tau = \frac{F_t}{A} = \frac{1.6776}{0.6*0.6} = 4.66$ N/m²

shear stress.

$\tau = \mu \frac{du}{dy}$ (velocity gradient)

$\frac{du}{dy} = \frac{V}{h}$

Assume linear distribution.

h : oil film thickness.

$\therefore 4.66 = \mu \cdot \frac{5*10^{-2}}{0.2*10^{-3}} \Rightarrow \mu = 0.0186$ Pa·s

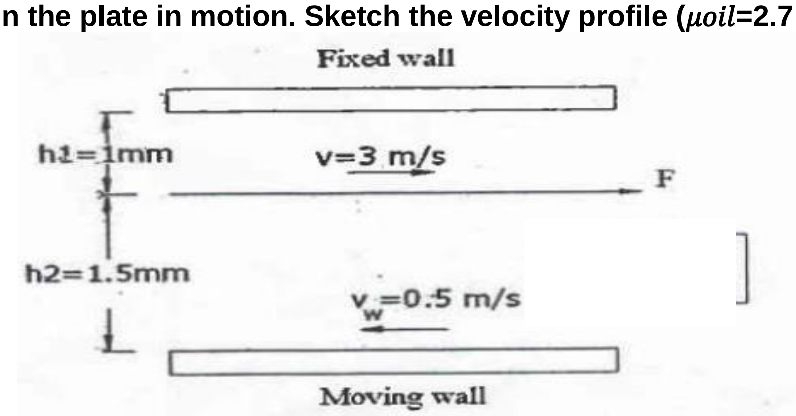
$= 0.1864$ Poise

$\rho = 0.8 * 1000 = 800$ kg/m³

$\nu = \frac{\mu}{\rho} = 0.0000233$ m²/s.

$\nu = 0.23$ stokes.

6- **A thin flat plate (40cmx40cm) is pulled horizontally at 3m/sec between two parallel plates, one stationary and the other moving at a velocity of 0.5m/sec. Determine the force and the power required to maintain the plate in motion. Sketch the velocity profile (μoil=2.7 $poise$).**

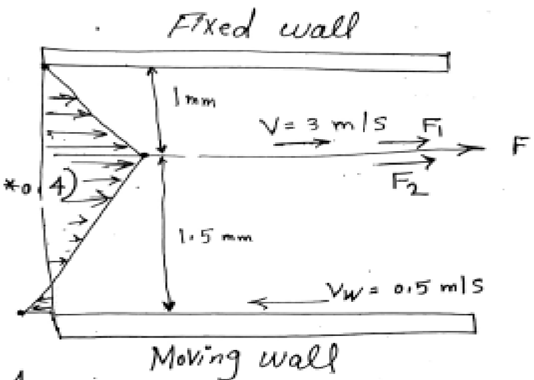


$$F_1 = \tau_1 A$$

$$= \mu \frac{du_1}{dy} A$$

$$= 2.7 * 10^{-1} * \frac{(3-0)}{1*10^{-3}} * (0.4*0.4)$$

$$= 129.6 \ N.$$



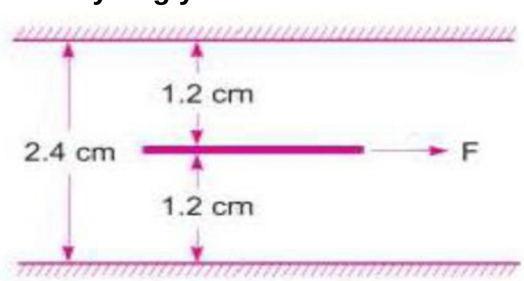
$$F_2 = \tau_2 A = \mu \frac{du_2}{dy} A$$

$$= 2.7 * 10^{-1} * \left(\frac{3-(-0.5)}{1.5*10^{-3}}\right)(0.4*0.4) = 100.8 \ N$$

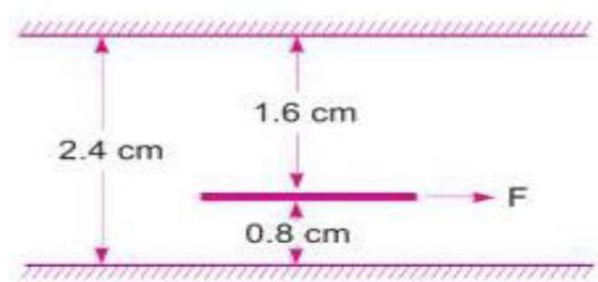
$$F = F_1 + F_2 = 230.4 \ N.$$

$$\text{Power} = F \cdot V = 230.4 * 3 = 691.2 \ W.$$

7- Two large plane surfaces are 2.4 cm apart. The space between the surfaces is filled with glycerin. What force is required to drag a very thin plate of surface area 0.5 square meter between the two large plane surfaces at a speed of 0.6 m/s, if:
(i) The thin plate is in the middle of the two plane surfaces, and
(ii) The thin plate is at a distance of 0.8 cm from one of the plane surfaces? Take the dynamic viscosity of glycerin = 8.10 x 10^{-1} N s/m^2.



Case I



Case II

Distance between two large surfaces = 2.4 cm

Area of thin plate, $A = 0.5\ m^2$

Velocity of thin plate, $u = 0.6$ m/s

Viscosity of glycerine, $\mu = 8.10 \times 10^{-1}\ N\ s/m^2$

Solution:

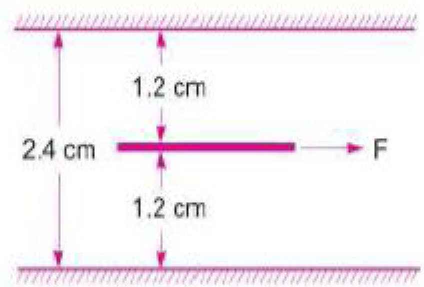
Case I: When the thin plate is in the middle of the two plane surfaces [Refer to Fig.]

Let F_1 = Shear force on the upper side of the thin plate Fig. 1.7 (a)

F_2 = Shear force on the lower side of the thin plate

F = Total force required to drag the plate

Then, $F = F_1 + F_2$



The shear stress (τ_1) on the upper side of the thin plate is given by equation.

$$\tau_1 = \mu \left(\frac{du}{dy}\right)_1$$

where, du = Relative velocity between thin plate and upper large plane surface

= 0.6 m/sec

dy = Distance between thin plate and upper large plane surface

= 1.2 cm = 0.012 m (plate is a thin one and hence thickness of plate is neglected)

$$\tau_1 = 8.10 \times 10\text{-}1 \times \left(\frac{0.6}{0.012}\right) = 40.5\ N/m^2$$

Now, shear force, F_1 = shear stress x Area

$= \tau_1 \times A = 40.5 \times 0.5 = 20.25$ N

$\mathbf{F_1 = 20.25\ N}$

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

$$\tau_2 = \mu \left(\frac{du}{dy}\right)_2$$

$$\tau_2 = 8.10 \times 10\text{-}1 \times (\frac{0.6}{0.012}) = 40.5\ N/m^2$$

Now , shear force , F_2 = shear stress (τ_2) x Area

$= \tau_2 \times A = 40.5 \times 0.5 = 20.25$ N

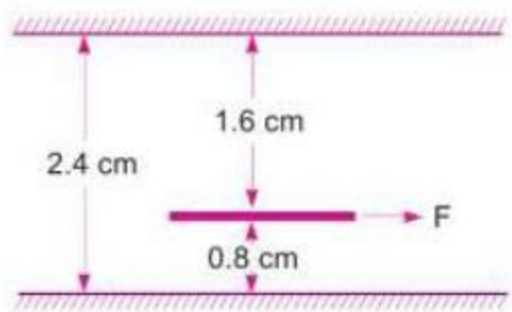
F_2 = 20.25 N

Then , Total force $F = F_1 + F_2 = 20.25 + 20.25$

F = 40.5 N

Case II. When the thin plate is at a distance of 0.8 cm from one of the plane surfaces [Refer to Fig]

Let the thin plate is at a distance 0.8 cm from the lower plane surface.



Then distance of the plate from the upper plane surface,

2.4 cm – 0.8 = 1.6 cm = .016 m

(Neglecting thickness of the plate)

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

F_1 = Shear stress (τ_1) x Area = $\tau_1 \times A$

$$= \mu \left(\frac{du}{dy}\right)_1 \times A = 8.10 \times 10^{-1} \times \left(\frac{0.6}{0.016}\right) \times 0.5$$

F_1 = 15.18 N

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

F_2 = Shear stress (τ_2) x Area = $\tau_2 \times A$

$$= \mu \left(\frac{du}{dy}\right)_2 \times A = 8.10 \times 10^{-1} \times \left(\frac{0.6}{0.8/100}\right) \times 0.5$$

F_2 = 30.36 N

Total force required, $F = F_1 + F_2 = 15.18 + 30.36$ **F = 45.54 N**

8- A plate 0.5mm thick is moving vertically downward under its own weight between two parallel plates filled with oil in between. The plate area is 1m^2. The oil has viscosity of 0.15kg/m.sec. The plates moves with uniform velocity of 0.4 m/sec. at equal distances from each of the fixed plates. The fixed plates are 2.5mm apart. Evaluate the weight of the plate.

[7] $A = 1\ m^2$, $V = 0.4\ m/s$, $\mu = 0.15\ \frac{kg}{m.s}$, $m = ??$

Sol:

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

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

$\because \tau_1 = \tau_2 \rightarrow \therefore F_1 = F_2$

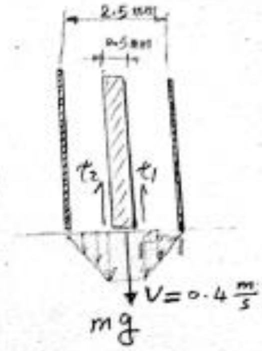
$\therefore F_1 = F_2 = (1)(0.15)\left(\frac{0.4-0}{1*10^{-3}}\right)$

$\therefore F_1 = F_2 = 60\ N$

$\therefore mg = F_1 + F_2 \rightarrow m = 12.23\ kg$

$mg = 120\ N$

Also: $\tau = \frac{F}{2A} = \frac{mg}{2A} = \mu \cdot \frac{du}{dy}$



9- 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 r.p.m. Calculate the power lost in the Bearing for a sleeve length of 90 mm. The thickness of the oil film is 1.5 mm.

Viscosity $\mu = 6$ poise

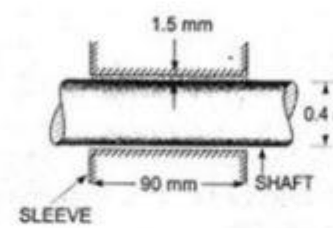
$= \frac{6}{10}\frac{Ns}{m^2} = 0.6\ \frac{Ns}{m^2}$

Dia. of shaft, $D = 0.4$ m

Speed of shaft, $N = 190$ r.p.m

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

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



Tangential velocity of shaft, $u = \frac{\pi DN}{60} = \frac{\pi \times 0.4 \times 190}{60} = 3.98$ m/s

Using the relation $\tau = \mu\ \frac{du}{dy}$

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

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

$$\tau = 10 \times \frac{3.98}{1.5 \times 10^{-3}} = 1592\ N/m^2$$

This is shear stress on shaft

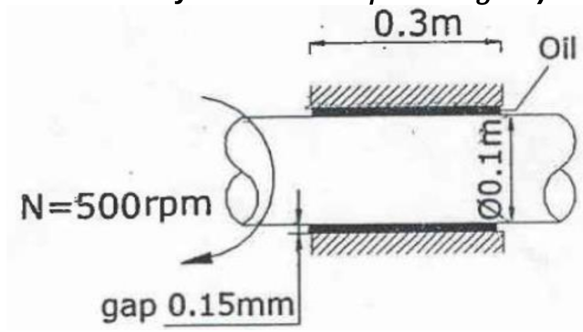
$\therefore$ Shear force on the shaft, F = Shear stress × Area

$= 1592 \times \pi D \times L = 1592 \times \pi \times .4 \times 90 \times 10^{-3} = 180.05$ N

Torque on the shaft, $T = \text{Force} \times \frac{D}{2} = 180.05 \times \frac{0.4}{2} = 36.01$ Nm

$\therefore$ *Power lost $= \frac{2\pi NT}{60} = \frac{2\pi \times 190 \times 36.01}{60} =$ **716.48 W**

10- **What is the torque and the power required for the shaft shown in figure to rotate at a speed of 500 rpm (oil grade, kinematic viscosity = 3.2St. and ρ=760 kg/m^3)**

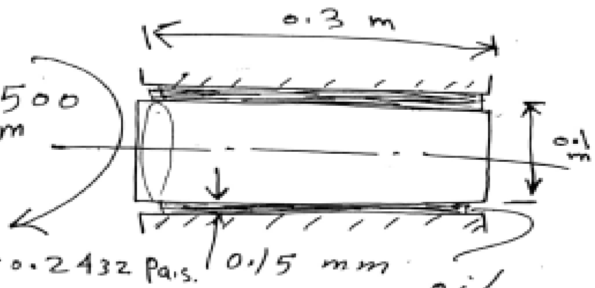


ν = 3.2 stokes

= $3.2 * 10^{-4}$ m^2/s.

n = 500 rpm

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



$\Rightarrow \mu = 3.2 * 10^{-4} * 760 = 0.2432$ Pa.s.

$\omega = 2\pi n = 2 * 3.14 * \frac{500}{60} = 52.3$ rad/s.

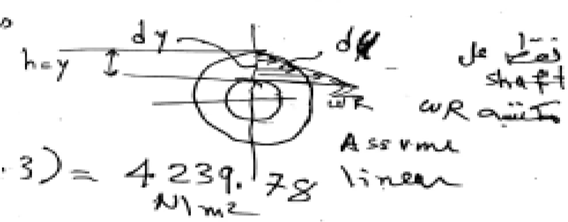
$R = \frac{0.1}{2} = 0.05$ m.

$A = \pi D L = 3.14 * 0.1 * 0.3 = 0.0942$ m^2.

$\frac{du}{dy} = \frac{\omega R - 0}{h} = \frac{52.3 * 0.05}{0.15 * 10^{-3}} = 17433.3$ [1/s]

τ: shear stress

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



(0.2432)(17433.3) = 4239.78 N/m^2

$F = \tau \cdot A = (4239.78)(0.0942) = 399.4$ N

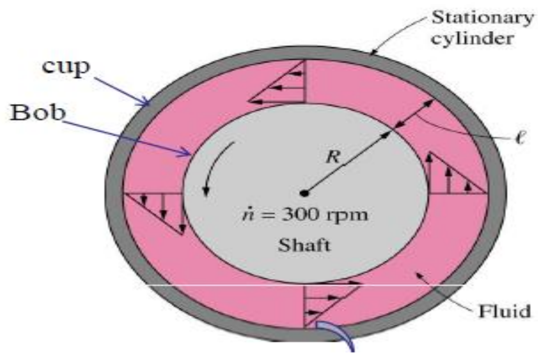
$T = F \cdot R = (399.4)(0.05) = 19.97$ [N.m]

Power = $T \cdot \omega$ = 19.97 * 52.3 =

1044.4 watt = 1.04 kW

Power = F. V
(V = wr)

11- The viscosity of a fluid is to be measured by an viscometer constructed of two 75-cm-long concentric cylinders. The outer diameter of the inner cylinder is 15 cm, and the gap between the two cylinders is 1 mm. The inner cylinder is rotated at 300 rpm, and the torque is measured to be 0.8 N·m. Determine the viscosity of the fluid.



Given

- Length of the concentric cylinders, L=75 cm
- Gap between two concentric cylinders = 1 mm
- The frequency of inner cylinder = 300 rpm
- Torque acting $\tau = 0.8 \text{ N.m}$
- Outer diameter of the inner cylinder=15 cm

The **Area** is given by

$$A = \pi dL$$
$$= \pi \times 0.15 \times 0.75$$
$$= 0.35 \text{ m}^2$$

The **velocity of the layer** is layer is given by

$$v = \frac{\pi dN}{60}$$
$$= \frac{\pi \times 0.15 \times 300}{60}$$
$$= 2.356 \text{ m/s}$$

Force acting by one layer of the fluid to other is given by F

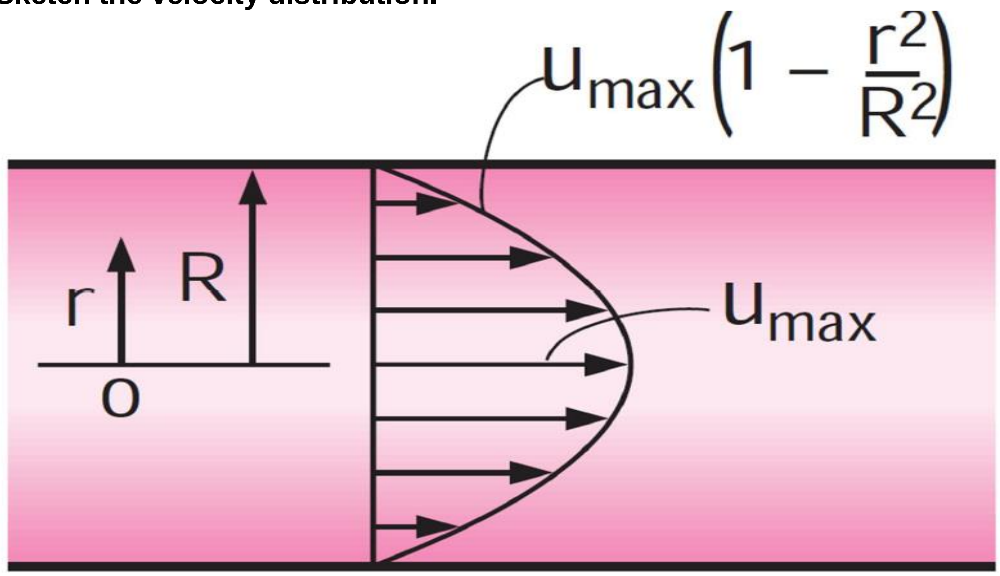
$$F = \frac{\tau}{r}$$
$$= \frac{0.8}{0.075}$$
$$= 10.7 \text{ N}$$

Now from the **Law of viscosity** we have

$$F = \mu A \frac{du}{dy}$$
$$10.7 = \mu \frac{0.353 \times 2.356}{0.001}$$
$$\mu = 0.013 \text{ kg/m.s}$$

Hence the viscosity of the fluid is $\mu = 0.013 \text{ kg/m.s}$

12- If the velocity distribution in a circular pipe of radius R is given by u= U_{max} $(1-r^2/R^2)$ where r is the radial distance from center and U_{max} is the maximum flow velocity at the center, find the drag force on a section of pipe 15m long , 0.16m diameter. Use U_{max}=3m/s and μ= 0.001kg/m. s.. Sketch the velocity distribution.



Solution

a)

The shear stress at the **surface of the pipe (at r = R)** is given by:

$$\tau = -\mu \frac{du}{dr} \rightarrow \text{(Negative sign is because u decresed with r increased)}$$

$$\tau = -\mu \times \frac{d}{dr}\left(u_{max}\left(1 - \frac{r^2}{R^2}\right)\right) \quad \text{(But, } u_{max} \text{ is constant)} \rightarrow$$

$$\tau = -\mu u_{max} \times \frac{d}{dr}\left(1 - \frac{r^2}{R^2}\right) = -\mu u_{max} \times \left(0 - \frac{2r}{R^2}\right) \quad \text{(because R is constant)}$$

$$\rightarrow \tau = \frac{2r\mu u_{max}}{R^2} \quad \text{(at the surface of the pipe} \rightarrow r = R) \rightarrow \tau = \frac{2\mu u_{max}}{R}.$$

Note: Always we calculate the shear stress at the **fixed surface** (like pipe surface in the above problem) because it gives maximum shear stress.

The drag force that causes shear stress on the pipe surface is:

$$\sum F = 0.0 \rightarrow F_D = \tau \times A$$

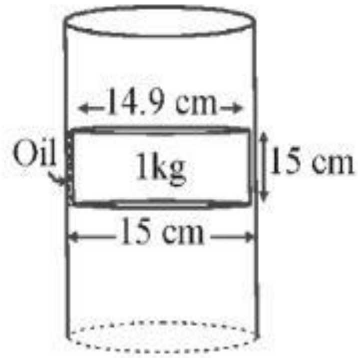
$$(A = \text{side area of tube} = 2\pi RL) \rightarrow F_D = \frac{2\mu u_{max}}{R} \times 2\pi RL$$

$$\rightarrow F_D = 4\pi L\mu u_{max} \checkmark.$$

b)

$$F_D = 4\pi L\mu u_{max} \rightarrow F_D = 4\pi \times 15 \times 0.001 \times 3 = 0.565\ N \checkmark.$$

13- **A sliding fit cylindrical body of 1 kg mass drops vertically down at a constant velocity 5 cm/sec. Estimate the viscosity of the oil.**



$\mu = ??$

[8] $F = mg = (1 * 9.81) = 9.81\ N$

$Y = \frac{0.15 - 0.149}{2} = 5 * 10^{-4}\ m$

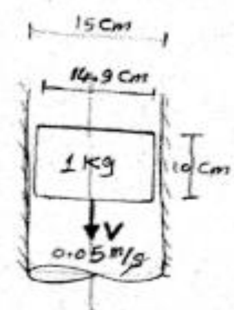
$A = \pi D L = \pi(0.149)(0.10)$

$A = 0.04681\ m^2$

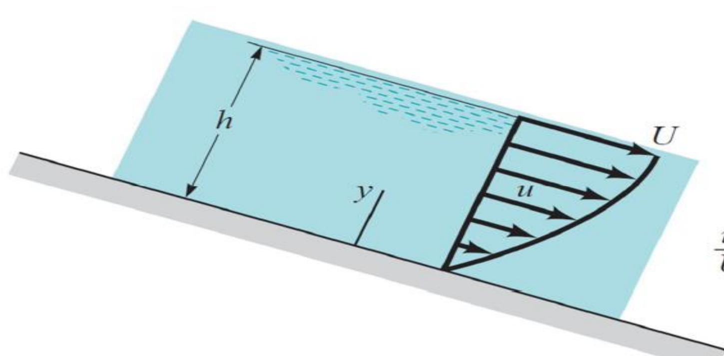
$\because \tau = \mu \cdot \frac{du}{dy} = \frac{F}{A}$

$\therefore \mu = \frac{(9.81)(5 * 10^{-4})}{(0.04681)(0.05)} = 2.096\ Pa.S$

$= 20.96$ Poise



14- **A layer of water flows down an inclined fixed surface with the velocity profile given in figure. Determine the magnitude and the direction of the shear stress that water exerts on the fixed surface for U=2m/s, h=0.1m,μ=1.12$*10^{-3}$ m^2/s.**



$\frac{u}{U} = 2\frac{y}{h} - \frac{y^2}{h^2}$

Solution

The shear stress at the **fixed surface (at y = 0.0)** is given by:

$\tau = +\mu \frac{du}{dy} \rightarrow$ (Positive sign is because u incresed with y increased)

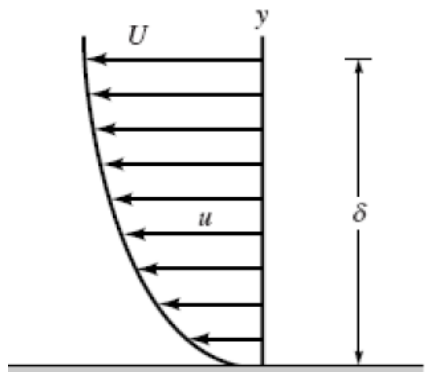
$\frac{u}{U} = 2\frac{y}{h} - \frac{y^2}{h^2} \rightarrow u = U\left(2\frac{y}{h} - \frac{y^2}{h^2}\right)$ (But, U = 2m/s and h = 0.1m) $\rightarrow$

$$u = 2\left(\frac{2y}{0.1} - \frac{y^2}{0.1^2}\right) \rightarrow u = 40y - 200y^2$$

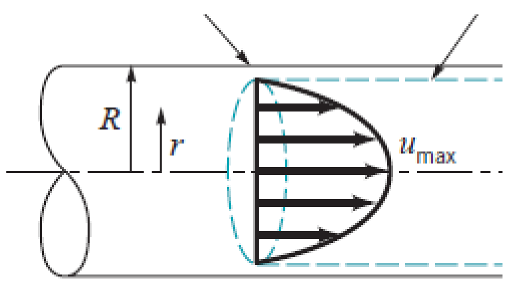
$$\rightarrow \frac{du}{dy} = 40 - 400y \;\; (\text{But, at the fixed surface } y = 0.0) \rightarrow \frac{du}{dy} = 40$$

$$\rightarrow \tau = 1.12 \times 10^{-3} \times 40 = 44.8 \times 10^{-3} N/m^2 \checkmark.$$

15- A Newtonian fluid (S.G. = 0.9) and (v = 4 Stokes) flows past a flat plate. Determine the magnitude and direction of wall shear stress if U = 1 m/s and δ = 10 mm. What is the shear stress at y=δ. $\frac{u}{U} = sin\left(\frac{\pi}{2}\frac{y}{\delta}\right)$



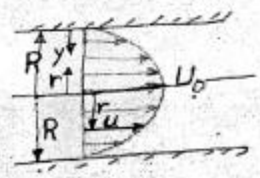
16- For the flow given, find the shear stress at the wall and centerline, when U_{max} = 4 m/s, R =10 cm and μ = 1.5 $Pa.s$



$$u_1 = u_{max}\left[1 - \left(\frac{r}{R}\right)^2\right]$$

6 $u = U_o\left(1 - \frac{r^2}{R^2}\right)$ $\mu = 1.5$ Pa.s

$U_o = 4$ m/s $R = 0.1$ m



Sol: $r + y = R \rightarrow dy = -dr$

$\because \tau = \mu \frac{du}{dy} = \mu \frac{-du}{dr}$

$\because \frac{du}{dr} = U_o\left(0 - \frac{2r}{R^2}\right) = \frac{-2rU_o}{R^2}$

at wall: $r = R \rightarrow \frac{du}{dr} = \frac{-2(0.1)(4)}{(0.1)^2} = -80\ s^{-1}$

at Centerline $r = 0 \rightarrow \frac{du}{dr} = \text{Zero}\ s^{-1}$

$\tau)_{wall} = -(1.5)(-80) = 120$ Pa [illegible]

$\tau_{Center} = \text{Zero}$

Point at which $\tau = \frac{1}{2}\tau_{wall}$

$\therefore 60 = (1.5)\left(\frac{2r}{(0.1)^2}\right)(4)$

$\therefore r = 0.05$ m #

17- When a 2-mm-diameter tube is inserted into a liquid in an open tank, the liquid is observed to rise 10 mm above the free surface of the liquid. The contact angle between the liquid and the tube is zero, and the specific weight of the liquid is 1.2×10^4 N/m^3. Determine the value of the surface tension for this liquid.

Start from the formula for the height of the liquid climb, caused by the **capillary action**:

$$h = \frac{2\sigma\ \cos\theta}{\gamma\ R}$$

Where θ is **the angle of contact** between the tube, and the fluid. Next, express σ from the previous formula:

$$\sigma = \frac{\gamma\ h\ R}{2\cos\theta} = \frac{(1.2\cdot 10^4\ \frac{\text{N}}{\text{m}^3})\cdot(10\cdot 10^{-3}\ \text{m})\cdot\left(\frac{2\cdot 10^{-3}\ \text{m}}{2}\right)}{2\cdot\cos(0)}$$

$$\boxed{\therefore \sigma = 0.060\ \frac{\text{N}}{\text{m}}}$$

18- The pressure outside the droplet of water of diameter 0.04 mm is 10.32 N/cm^2 (atmospheric pressure). Calculate the pressure within the droplet if surface tension is given as 0.0725 N/m of water.

Dia. of droplet, $d = 0.04$ mm $= .04 \times 10^{-3}$ m

Pressure outside the droplet $= 10.32$ N/cm^2 $= 10.32 \times 10^4$ N/m^2

Surface tension, $\sigma = 0.0725$ N/m

The pressure inside the droplet, in excess of outside pressure is given by equation

$$p = \frac{4\sigma}{d} = \frac{4\times 0.0725}{.04\times 10^{-3}} = 7250\ \text{N/m}^2 = \frac{7250\ \text{N}}{10^4\ \text{cm}^2} = 0.725\ \text{N/cm}^2$$

$\therefore$ Pressure inside the droplet $= p +$ Pressure outside the droplet

$= 0.725 + 10.32 = \mathbf{11.045\ N/cm^2}$

19- Calculate the capillary rise in a glass tube of 2.5 mm diameter when immersed vertically in (a) water and (b) mercury. Take surface tension is 0.0725 N/m for water and 0.52 N/m for mercury in contact with air. The specific gravity for mercury is given as 13.6 and angle of contact is 130°.

Dia. of tube, $d = 2.5 \text{ mm} = 2.5 \times 10^{-3}$ m

Surface tenstion, σ for water $= 0.0725$ N/m

σ for mercury $= 0.52$ N/m

Sp. gr. of mercury $= 13.6$

$\therefore$ Density $= 13.6 \times 1000 \text{ kg/m}^3$.

(*a*) **Capillary rise for water ($\theta = 0$)**

Using equation
$$h = \frac{4\sigma}{\rho \times g \times d} = \frac{4 \times 0.0725}{1000 \times 9.81 \times 2.5 \times 10^{-3}}$$
$$= .0118 \text{ m} = \mathbf{1.18 \text{ cm.}}$$

(*b*) **For mercury**

Angle of constant between mercury and glass tube, $\theta = 130°$

Using equation
$$h = \frac{4\sigma \cos\theta}{\rho \times g \times d} = \frac{4 \times 0.52 \times \cos 130°}{13.6 \times 1000 \times 9.81 \times 2.5 \times 10^{-3}}$$
$$= -.004 \text{ m} = \mathbf{-0.4 \text{ cm.}}$$

The negative sign indicates the capillary depression.

20- 13.Find out the minimum size of glass tube that can be used to measure water level if the capillary rise in the tube is to be restricted to 2 mm. Consider surface tension of water in contact with air as 0.073575 N/m.

Capillary rise, $h = 2.0 \text{ mm} = 2.0 \times 10^{-3}$ m

Surface tension, $\sigma = 0.073575$ N/m

Let dia. of tube $= d$

The angle θ for water $= 0$

The density for water, $\rho = 1000 \text{ kg/m}^3$

Using equation
$$h = \frac{4\sigma}{\rho \times g \times d} \text{ or } 2.0 \times 10^{-3} = \frac{4 \times 0.073575}{1000 \times 9.81 \times d}$$
$$\therefore \quad d = \frac{4 \times 0.073575}{1000 \times 9.81 \times 2 \times 10^{-3}} = 0.015 \text{ m} = \mathbf{1.5 \text{ cm.}}$$

Thus minimum diameter of the tube should be 1.5 cm.