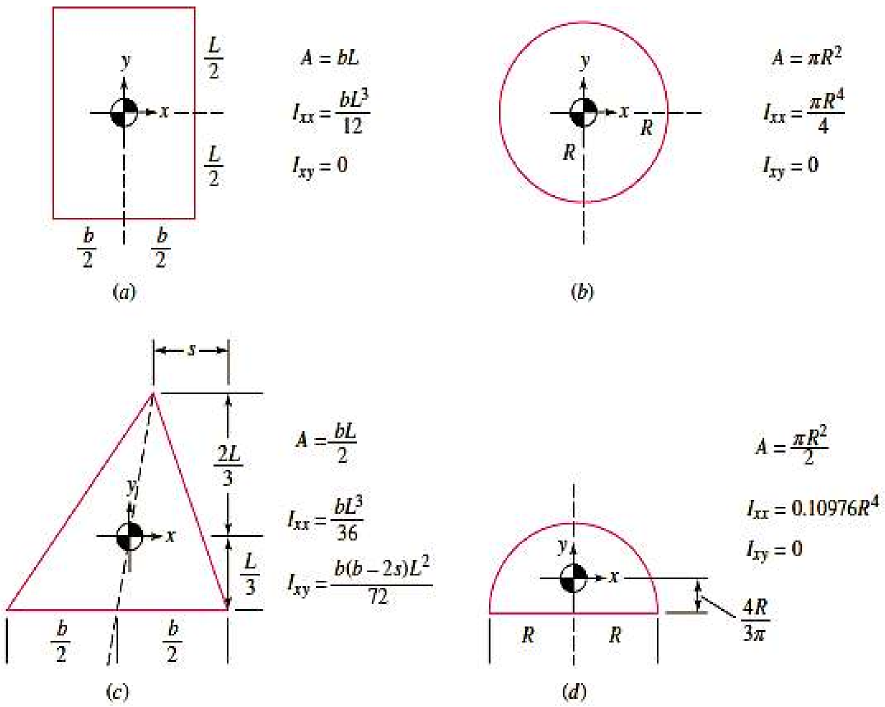
Thursday 27/7/1442 (11/3/2021) Time Allowed: 1:30 hours

Name: ________________________________ **Number:** ____________ **Section:** _____



Density of water, $\rho = 1000$ kg/ m^3

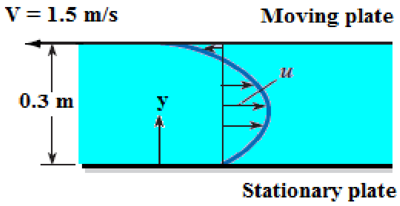
Problem #1

A Laminar flow of viscous fluid (μ = 1.44 kg/m .s) occurs between two horizontal parallel plates. The upper plate moves to the left at velocity V = 1.5 m/s. The expression for local velocity u(y) is given as

$$u(y) = 60(0.3y - y^2) - 5y$$

Where **y** is the vertical coordinate from the bottom surface. **Calculate:**

a. The shear stress at the stationary plate and the moving plate.
b. The position of zero shear stress and the velocity at that position.



Q1

(a) Shear stress $(\tau) = \mu \frac{du}{dy}$.

→ at the stationery plate, $y = 0$. and $\tau = \tau_s$

$$\tau_s = \mu \left.\frac{du}{dy}\right|_{y=0}.$$

$$\frac{du}{dy} = 60[0.3 - 2y] - 5.$$

$$\left.\frac{du}{dy}\right|_{y=0} = 60[0.3 - 0] - 5 = 18 - 5 = 13/s.$$

$$\tau_s = \mu \left.\frac{du}{dy}\right|_{y=0} = 1.44 * 13 \ N/m^2 = 18.72 \ N/m^2 = 18.72 \ Pa.$$

$\boxed{\tau_s = 18.72 \ Pa.}$ shear stress at stationery plate.

→ at moving plate, $y = 0.3m$ and $\tau = \tau_m$.

$$\left.\frac{du}{dy}\right|_{y=0.3} = 60[0.3 - 2(0.3)] - 5 = -18 - 5 = -23 /s.$$

$$\tau_m = \mu \left.\frac{du}{dy}\right|_{y=0.3} = 1.44(-23) \ Pa = -33 \ Pa.$$

$\boxed{\tau_m = -33 \ Pa}$ shear stress at the moving plate.

(b) Shear stress equation:-

$$\tau = \mu \frac{du}{dy} = \mu\left[60\,(0.3 - 2y) - 5\right]$$

To find position of zero stress:- put $\tau = 0$.

$$\mu\left[60\,(0.3 - 2y) - 5\right] = 0.$$

$$60(0.3 - 2y) - 5 = 0$$

$$60(0.3 - 2y) = 5.$$

$$0.3 - 2y = \frac{5}{60} = 0.0833.$$

$$0.3 - 0.0833 = 2y.$$

$$\frac{0.2167}{2} = y$$

$$\boxed{0.1083\ m = y} \rightarrow$$ Position of zero shear stress.

Velocity at that position is:-

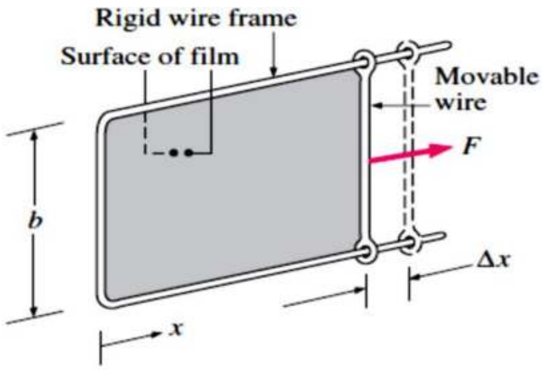
$$U_0 = 60\left[0.3(0.1083) - (0.1083)^2\right] - 5(0.1083) \quad \text{at } y = 0.1083\ m.$$

$$U_0 = 1.2456 - 0.5415\ m/s$$

$$\boxed{U_0 = 0.7041\ m/s}$$ velocity at position $(y = 0.1083m)$ of zero shear stress.

Problem #2

The surface tension of a liquid is to be measured using a liquid film suspended on a U–shaped wire frame with an 8-cm-long movable side (b).
If the force needed to move the wire is **0.012 N**, determine the surface tension of this liquid in air .



Step 1 of 1

Surface tension formula $\sigma_s = \frac{F}{2b}$

Where F: Required force

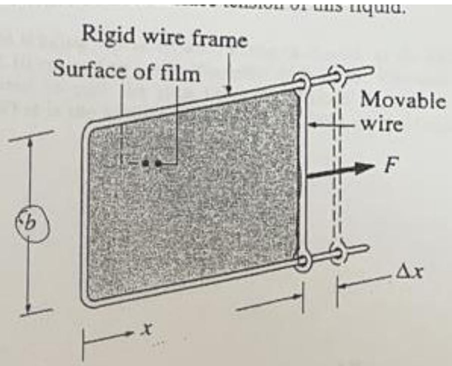
b:movable length

Substitute: $b = 8\,\text{cm} = 0.08\,\text{m}$, $F = 0.024\,\text{N}$

$$\sigma_s = \frac{0.024\ \text{N}}{2 \times 0.08\ \text{m}}$$

$$= 0.15\,\text{N/m}$$

Thus surface tension $\boxed{0.15\,\text{N/m}}$



$F = F_P$

$F = \gamma \times P$

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$0.012 = \gamma \times 2 \times 0.08$

$$\gamma = \frac{0.012}{2 \times 0.08} = 0.075\ \text{N/m}$$

OR

$$\gamma = \frac{F}{P} = \frac{F}{2L}$$

$$= \frac{0.012}{2 \times 0.08} = 0.075\ \text{N/m}$$

Problem #3

A steady, incompressible, two–dimensional velocity field is given by the following components in the xy–plane:

$$u = 1.1 + 2.8\,x + 0.65\,y, \quad v = 0.98 - 2.1\,x - 2.8\,y$$

Calculate a) The acceleration field components (a_x and a_y),

b) The acceleration at the point (-2, 3).

Soln :-

$$\vec{V} = (2.8x + 0.65y + 1.1)\,\hat{i} + (0.98 - 2.1x + 2.8y)\,\hat{j}$$

$$\Rightarrow u = 2.8x + 0.65y + 1.1$$

$$\& \; v = 0.98 - 2.1x + 2.8y$$

(a) At stagnation point

$$u = 0 \quad \& \quad v = 0$$

$$2.8x + 0.65y + 1.1 = 0 \quad \text{—— (i)}$$

$$0.98 - 2.1x + 2.8y = 0 \quad \text{—— (ii)}$$

by solving equation (i) & (ii)

$$x = -0.2654$$

$$y = -0.549$$

so stagnation point $\equiv \boxed{(x, y) \equiv (-0.2654, -0.549)}$

(b) $V_x = u = u(-1.5, 2.0) = 2.8x + 0.65y + 1.1$

$$= 2.8(-1.5) + 0.65(2) + 1.1$$

$$\boxed{V_x = -1.8 \text{ m/sec.}}$$

$V_y = v(-1.5, 2.0) = 0.98 - 2.1x + 2.8y$

$$= 0.98 - 2.1(-1.5) + 2.8(2.0)$$

$$\boxed{V_y = 9.73 \text{ m/sec.}}$$

$$a_x = u\cdot\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = (2.8x + 0.65y + 1.1)(2.8) + (0.98 - 2.1 + 2.8y)(0.65)$$

$$a_x(-1.5, 2.0) = -1.8 \times 2.8 + 9.73 \times 0.65$$

$$\boxed{a_x = 1.2845}$$

$$a_y = u\cdot\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = (2.8x + 0.65y + 1.1)(-2.1) + (0.98 - 2.1x + 2.8y)(2.8)$$

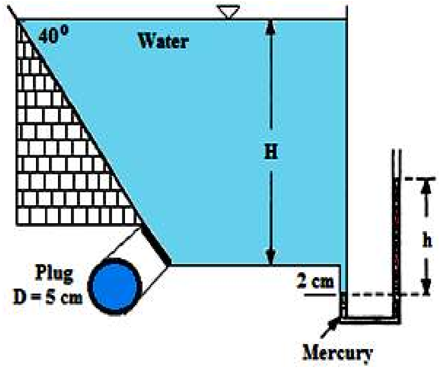
$$a_y(-1.5, 2.0) = (-1.8)(-2.1) + (9.73)(2.8)$$

$$\boxed{a_y = 31.024}$$

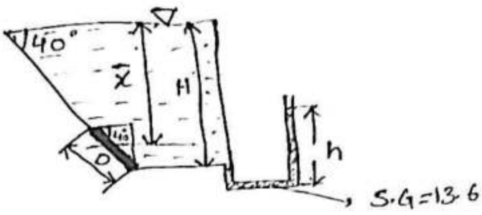
Problem # 4

The tank in the figure has a 5–cm diameter plug. If the hydrostatic force on the plug is 30 N, Calculate: a) The water height in the tank H and

b) The reading *h* of Mercury (SG = 13.6) the manometer



STEP-1:



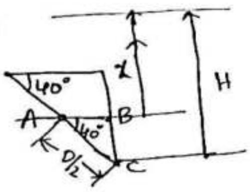
a) GIVEN:

DIAMETER OF PLUG $(D) = \frac{5}{100} = 0.05m$

HYDROSTATIC FORCE $(F) = 30N$

FOR PLUG:

FROM Δ^{le} ABC



$\sin 40 = \frac{BC}{D/2}$

$BC = \frac{D}{2}\sin 40$

$\therefore \bar{x} = H - BC$

$= H - \frac{D}{2}\sin 40$.

$\therefore$ HYDRO STATIC FORCE (F)

$F = \gamma_{water} \times A \times \bar{x}$

$= \rho_{water} \times g \times \frac{\pi}{4}(d^2) \times (H - \frac{D}{2}\sin 40)$

$= 1000 \times 9.81 \times \frac{\pi}{4}(0.05)^2 \times (H - \frac{0.05}{2} \times \sin 40)$

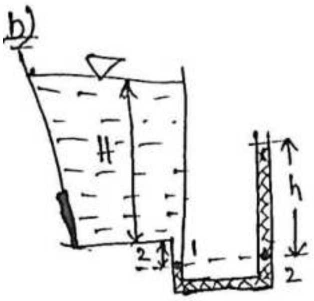
$F = 19.262 \times (H - 0.324)$

BUT $F = 30N$.

$\therefore 19.262(H - 0.324) = 30$

$\therefore \boxed{H = 1.57355\,m}$

b)



EQUATING PRESSURES AT ① & ②

$P_1 = P_2$

$\rho_{water} \times \cancel{g}(H + \frac{2}{100}) = \rho_{MERCURY} \times \cancel{g} \times h$

$(H + \frac{2}{100}) = \frac{\rho_{MERCURY}}{\rho_{water}} \times h$

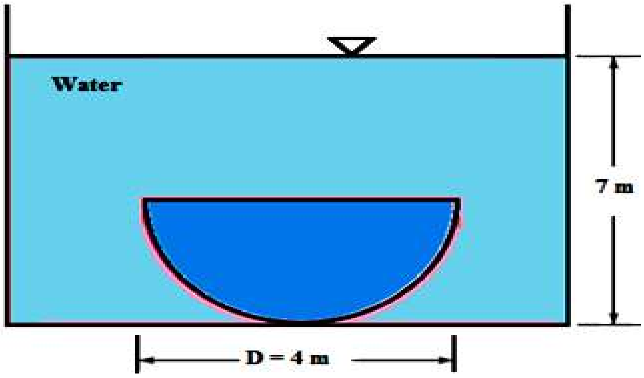
$H + \frac{2}{100} = 13.6 \times h$

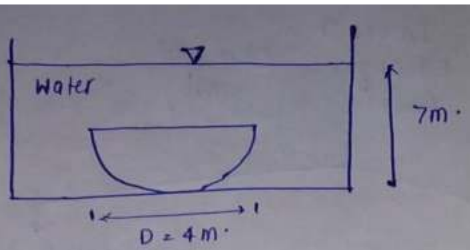
$1.57355 + 0.02 = 13.6 \times h$

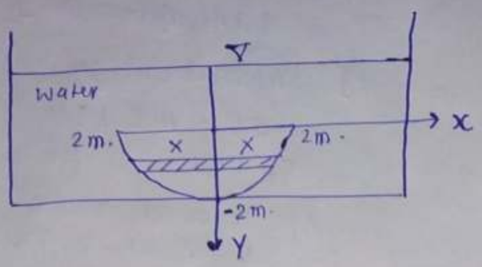
$\therefore \boxed{h = 0.117173\,m \text{ (or) } h = 11.7173\,cm}$

Problem # 5

A hemispherical object (SG = 7.8) is submerged in a water tank as shown in the figure. Determine the net hydrostatic force on the hemispherical object.







for water $W = 9800\ N/m^3$

depth $[h(y)] = -y$

$$x^2 + y^2 = R^2$$

$$x = \sqrt{4 - y^2}$$

$$\because \quad L = 2x$$

$$L(y) = 2\sqrt{4 - y^2}$$

$$F = W \int_c^d L(y)\, h(y)\, dy$$

$$= 9800 \int_{-2}^{0} -y \left(2\sqrt{4 - y^2}\right) dy$$

$$= 9800 \left[\frac{2(4 - y^2)^{3/2}}{3} \right]_{-2}^{0}$$

$$= \frac{9800 \times 2}{3} \left[(4 - 0)^{3/2} - (4 - 4)^{3/2} \right]$$

$$= 52266.67\ N$$

$$= \underline{52.27\ kN} \quad \underline{\text{Answer.}}$$