Q.2 A] Given :- $P_A = 100 \, kN/m^2$

Pressure head at A

$$h_A = \frac{100}{9.81} = 10.2 \, m$$

Pressure head at B

$$h_B = \frac{P_B}{w}$$

Considering pressure heads above the datum line x-x, we have

pressure head in the left limb-

$$= \frac{650}{1000} + h_A = 0.65 + 10.2 = 10.85 \, m$$

Pressure head in the right limb

$$= h_B + \frac{250}{1000} \times 0.85 + \frac{150}{1000} \times 13.6$$

$$= h_B + 2.25$$

Equate above pressure heads, we get-

$$10.85 = h_B + 2.25$$

$$h_B = 8.6 \, m$$

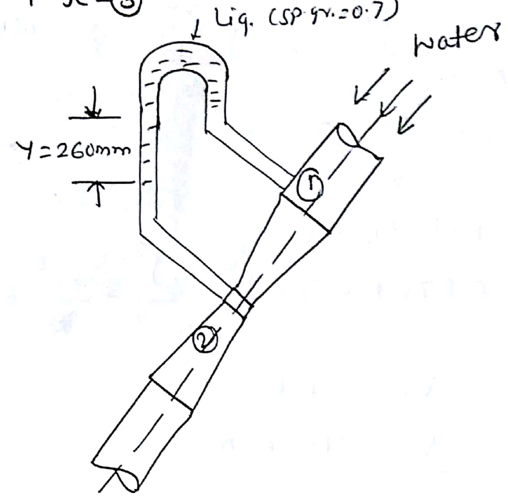
But, $h_B = \frac{P_B}{w}$

$$P_B = w h_B = 9.81 \times 8.6$$

$$P_B = 84.36 \, kN/m^2$$

$$P_B = 84.36 \, kPa$$ — Ans

Q. 2 B)



Given: Dia. at I/L $D_1 = 300\,mm = 0.3\,m$

Area of I/L $= A_1 = \pi/4 \times (0.3)^2 = 0.07\,m^2$

Throat Dia., $D_2 = 150\,mm = 0.15\,m$

Area of Throat. $A_2 = \frac{\pi}{4}(0.15)^2 = 0.01767\,m^2$

$Y = 260\,mm = 0.26\,m$

pressure head diff. $h = \left(\frac{P_1}{w} + Z_1\right) - \left(\frac{P_2}{w} + Z_2\right)$

Also $h = Y\left(1 - \frac{S_h}{S_p}\right)$

$= 0.26\left(1 - \frac{0.7}{1.0}\right)$

$h = 0.078\,m$ of water

Loss of head, $h_L = 0.3 \times$ kinetic head of pipe

Apply Bernoulli's eqn.

$$\frac{P_1}{w} + Z_1 + \frac{V_1^2}{2g} = \frac{P_2}{w} + Z_2 + \frac{V_2^2}{2g} + h_L$$

But $\left(\frac{P_1}{w} + Z_1\right) - \left(\frac{P_2}{w} + Z_2\right) = 0.078\,m$ of water

$h_L = 0.3 \times \frac{V_1^2}{2g}$

$\therefore 0.078 + \frac{V_1^2}{2g} - \frac{V_2^2}{2g} = 0.3 \times \frac{V_1^2}{2g}$

$0.078 + 0.7 \frac{V_1^2}{2g} - \frac{V_2^2}{2g} = 0$ — (1)

Apply continuity eqn.

$A_1V_1 = A_2V_2$

$V_1 = \frac{V_2}{4}$

put V_1 in (1)

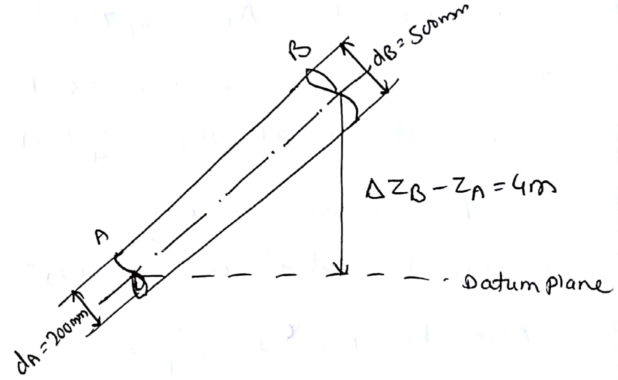
$0.078 + 0.7 \times \frac{(V_2/4)^2}{2g} - \frac{V_2^2}{2g} = 0$

$V_2^2 = 1.6 m^2$

$V_2 = 1.26$ m/s

Rate of flow $Q = A_2V_2 = 0.0222 m^3/s$ — Ans

Q.3 A)



$\Delta Z = 4m$

Volm. flow rate = 200 lit/sec = 0.2 m^3/s

$P_A = 1 kgf/cm^2 = 1 \times 9.81 \times 10^4 = 9.81 \times 10^4 N/m^2$

$P_B = 0.6 kgf/cm^2 = 0.6 \times 9.81 \times 10^4 = 5.98 \times 10^4 N/m^2$

C/S area of pipe A = $\pi/4 \, d_A^2 = 0.0314 m^2$

C/S area of pipe B = $\pi/4 \, d_B^2 = 0.196 m^2$

vel. of oil at A $u_A = Q/A_a = 6.36$ m/s

vel. of oil at B $u_B = 1$ m/s

Total energy at A $= \frac{P_A}{Sg} + \frac{u_A^2}{2g} + Z_A = 13.55 m$

Total energy at B $= \frac{P_B}{\rho g} + \frac{u_B^2}{2g} + z_B$

$= 11.0509 \text{ m}$

The total energy at A is greater than B

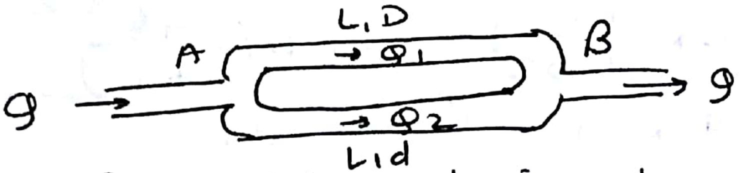
Loss of head from A to B $= 13.55 - 11.0509$

$= 2.49 \text{ m}$ — Ans

Direction of flow is from A to B. — Ans

Q.3 B) When pipes are connected to parallel

$$Q = Q_1 + Q_2 \quad \text{—— (1)}$$



Loss of head in each pipe = h

For pipe AB, $\frac{4 f L_1 V_1^2}{d_1 \times 2g} = h$

$$V_1 = \frac{Q_1}{A_1} = \frac{Q_1}{\frac{\pi}{4} D^2} = \frac{4 Q_1}{\pi D^2}$$

$$\therefore h = \frac{4fL\left(\frac{4Q_1}{\pi D^2}\right)^2}{D \times 2g} = \frac{32 f L Q_1^2}{\pi^2 D^5 \times g} \quad \text{—— (2)}$$

For pipe AC

$$h = \frac{32 f L Q_2^2}{\pi^2 d^5 \times g} \quad \text{—— (3)}$$

$$\therefore \frac{32 f L Q_1^2}{\pi^2 D^5 \times g} = \frac{32 f L Q_2^2}{\pi^2 d^5 \times g} \quad \text{or} \quad \frac{Q_1^2}{D^5} = \frac{Q_2^2}{d^5}$$

$$\left(\frac{Q_1}{Q_2}\right)^2 = \frac{D^5}{d^5} = \frac{(2d)^5}{d^5} = 2^5 = 32$$

$$\frac{Q_1}{Q_2} = \sqrt{32} = 5.657 \quad \text{or} \quad Q_1 = 5.657 Q_2$$

Put the valued of Q_1 in eqn (1)

$$Q = 5.657 Q_2 + Q_2 = 6.657 Q_2$$

$Q_2 = 0.15 Q$ —— (4) From eqn (1) $Q_1 = Q - Q_2 = Q - 0.15 Q$

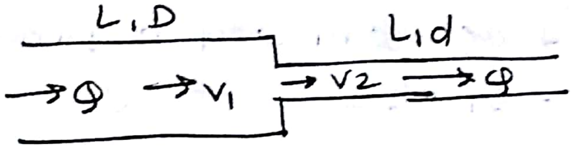
$$\boxed{Q_1 = 0.85 Q} \quad \text{—— (5)}$$

Case-2 when pipes are connected in series

Total loss = sum of head losses in two pipes

$$H = \frac{4fLv_1^2}{d_1 \cdot 2g} + \frac{4fLv_2^2}{d_2 \cdot 2g}$$

$$v_1 = \frac{Q}{\frac{\pi}{4}D^2} = \frac{4Q}{\pi D^2}, \quad v_2 = \frac{Q}{\frac{\pi}{4}d^2} = \frac{4Q}{\pi d^2}$$



$$H = \frac{4fL \times \left(\frac{4Q}{\pi D^2}\right)^2}{D \times 2g} + \frac{4fL\left(\frac{4Q}{\pi d^2}\right)^2}{d \times 2g}$$

$$H = \frac{32fLQ^2}{D^5 \pi^2 \times g} + \frac{32fLQ^2}{d^5 \pi^2 g} \quad \text{— (6)}$$

From eqn. (ii) $\frac{32fL}{\pi^2 D^5 g} = \frac{h}{Q_1^2}$

From eqn. (iii) $\frac{32fL}{\pi^2 d^5 \times g} = \frac{h}{Q_2^2}$

Put values in eqn (6)

$$H = Q^2 \times \frac{h}{Q_1^2} + Q^2 \times \frac{h}{Q_2^2}$$

$$= \frac{Q^2}{Q_1^2} h + \frac{Q^2}{Q_2^2} h$$

$$\frac{H}{h} = \frac{Q^2}{Q_1^2} + \frac{Q^2}{Q_2^2}$$

From eqn. (4) & (5), $Q_1 = 0.85Q$ & $Q_2 = 0.15Q$

$$\therefore \frac{H}{h} = \frac{Q^2}{0.85^2 Q^2} + \frac{Q^2}{0.15^2 Q^2} = \frac{1}{0.85^2} + \frac{1}{0.15^2}$$

$$\boxed{\therefore \frac{H}{h} = 45.828}$$

Q.4 A) C/S area of pipe $A = \frac{\pi}{4}d^2 = 0.0706 m^2$

vel $= Q/A = 5 m/s$

$Re = \frac{Dv\rho}{\mu} = 15 \times 10^5$

friction factor $f = 0.046(Re)^{-0.2}$

$f = 0.0026$

Head lost due to friction

$$(-\Delta H_f) = \frac{4 f l u^2}{2 g d} = \frac{4 \times 0.0026 \times 80 \times (5)^2}{0.3 \times 2 \times 9.81}$$

$= 3.5 m$

Head developed by the pump

$H = 30 + 3.5 + 1.5 = 35 m$

Work done per second by the pump

$$= \frac{(G)(g)(H)}{\eta_{pump}} \quad G = \text{mass flow rate}$$

$$= \frac{0.35 \times 1000 \times 35 \times 9.81}{0.55}$$

$= 218 kW$ — Ans

Q.5. B) Area $= \pi/4 d^2 = \pi/4 \times 0.15^2 = 0.01767 m^2$

i) Dynamic viscosity of oil

$$\bar{u} = Q/A = \frac{0.015}{0.01767} = 0.849 m/s$$

h_f is loss of head then

$w Q h_f = \eta \times P$

$$h_f = \frac{\eta \times P}{w Q} = \frac{0.68 \times (7.5 \times 10^3)}{(0.82 \times 9810) \times 0.015}$$

$h_f = 42.26 m$

For viscous / laminar flow

$$(P_1 - P_2) = \frac{32 \mu \bar{V} L}{D^2}$$

or $$h_f = \left(\frac{P_1 - P_2}{w}\right) = \frac{32 \mu \bar{V} L}{D^2}$$

$$42.26 = \frac{32 \times \mu \times 0.849 \times 3000}{(0.82 \times 9810) \times 0.15^2}$$

$$\mu = 0.0938 \ Ns/m^2 \quad \text{- Ans}$$

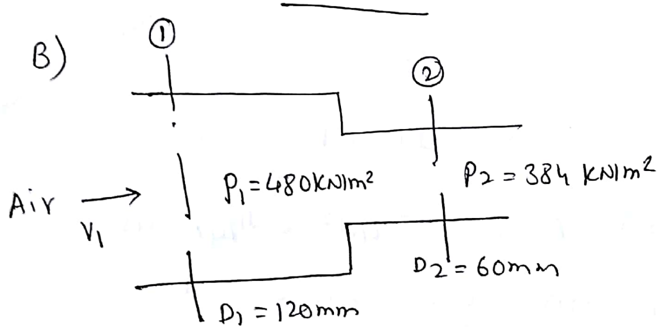
2) Is the flow laminar?

$$Re = \frac{DV\rho}{\mu} = \frac{(0.82 \times 1000) \times 0.849 \times 0.15}{0.0938}$$

$$Re = 1113.3 < 2000$$

Flow is Laminar

Q.6 B)



$$A_1 = \frac{\pi}{4} D_1^2 = 0.01131 \ m^2$$

$$A_2 = \frac{\pi}{4} D_2^2 = 2.827 \times 10^{-3} \ m^2$$

$$T_1 = T_2 = 298 K \quad (\text{Isothermal})$$

① Densities ρ_1 & ρ_2

For Isothermal $\frac{P_1}{\rho_1} = \frac{P_2}{\rho_2}$

$$\frac{P_1}{P_2} = \frac{\rho_1}{\rho_2} \text{ or } \frac{480}{384} = \frac{\rho_1}{\rho_2} = 1.25$$

$P_1 = \rho_1 R T_1$ or $\rho_1 = \frac{P_1}{RT_1}$

$\rho_1 = 5.61\ kg/m^3$ — Ans

$\rho_2 = \frac{\rho_1}{1.25} = 4.488\ kg/m^3$ — Ans

ii) continuity eqn.

$\rho_1 A_1 V_1 = \rho_2 A_2 V_2$

$\frac{V_2}{V_1} = \frac{\rho_1 A_1}{\rho_2 A_2} = 1.25 \times \frac{0.01131}{2.827 \times 10^{-3}}$

$\frac{V_2}{V_1} = 5.0$

Bernoulli's eqn.

$\frac{P_1}{\rho_1 g} \ln(P_1) + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho_2 g} \ln(P_2) + \frac{V_2^2}{2g} + Z_2$

Assume $Z_1 = Z_2$

$\frac{P_1}{\rho_1} \ln(P_1) - \frac{P_2}{\rho_2} \ln(P_2) = \frac{V_2^2 - V_1^2}{2g}$

$\frac{P_1}{\rho_1} \ln\left(\frac{P_1}{P_2}\right) = 12 V_1^2$

$\therefore V_1^2 = 1590$

$V_1 = 39.87\ m/s$ — Ans

$V_2 = 5 V_1 = 5 \times 39.87 = 199.35\ m/s$ — Ans

iii) mass rate

$m = \rho_1 A_1 V_1 = 2.53\ kg/s$ — Ans

Solution

Fluid Flow / Dec-2017 / Chemical / Sem-III

QP code: 25833 Exam Date-05/12/17

Q.1 B] $D = 40\ cm = 40 \times 10^{-2}\ m$

$V = 4\ m/s$

$P = 30 \times 10^{4}\ N/m^2$

$Z = 6\ m$

$\rho = 1000\ kg/m^3$

$$\text{Total Head} = \frac{P}{\rho g} + \frac{u^2}{2g} + Z$$

$$= \frac{30 \times 10^4}{1000 \times 9.81} + \frac{(4)^2}{2 \times 9.81} + 6$$

$$= 30.58 + 0.8155 + 6$$

$$\text{Total Head} = 37.39\ m \text{ — Ans.}$$

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