MARINE ENGINEERING DEPARTMENT

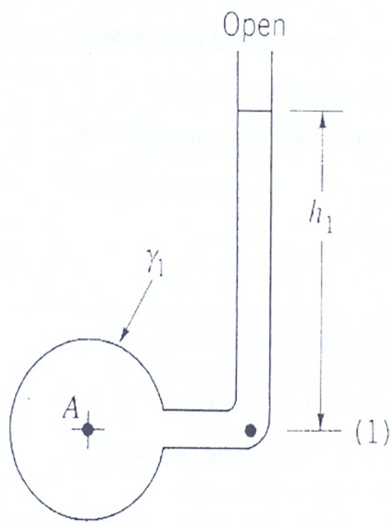
Final Model Answer – 2nd Term 2015/2016 – (02/06/2016)
Course: Hydraulics – (ME 362)

1. a Piezometer Tube and U-Tube Manometer.

- **Piezometer Tube:** It is the simplest type of manometer consists of a vertical tube, open at the top, and attached to the container in which the pressure is desired, as shown. Since manometers involve columns of fluids at rest, the fundamental equation describing their use is : $P = \gamma\ h + P_o$
Application of this equation to the Piezometer tube of indicates Figure that the gage pressure P_A can be determined by a measurement of h_1, through the relationship: $P_A = \gamma_1\ h_1$
Where γ_1 is the specific weight of the liquid in the container.

Since the tube is open at the top, and the pressure Po set equal to zero, then we are now using gage pressure.
Although the Piezometer tube is a very simple and accurate pressure measuring device, it has several disadvantages:

1. It is only suitable if the pressure in the container is greater than atmospheric pressure (otherwise air would be sucked into the system).
2. The pressure to be measured must be relatively small so the required height of the column is reasonable.
3. The fluid in the container in which the pressure is to be measured must be a liquid rather than a gas.



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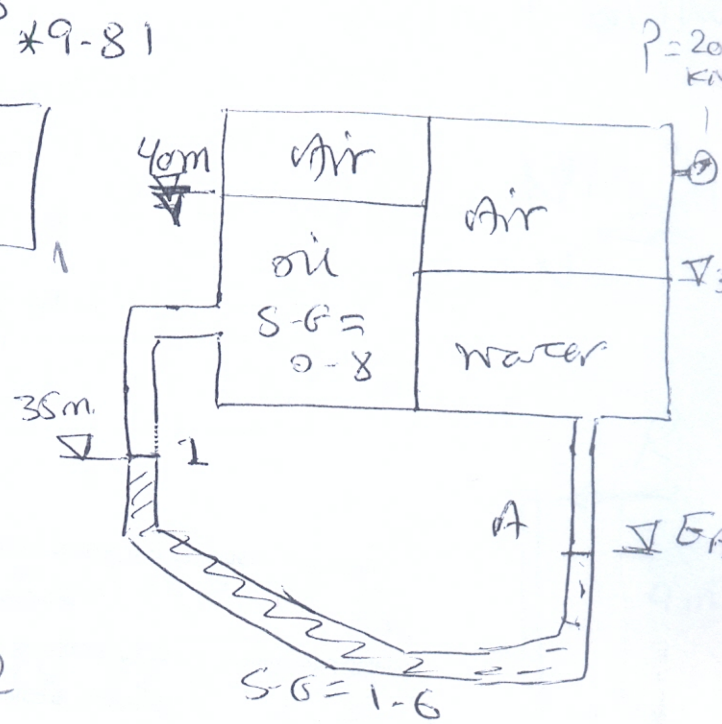
Air in Left tank

$$P_{air_{left}} = -22\ cmHg = -22\ cm * \rho_{Hg} * (g)$$

$$= -22 * 10^{-2} * 13.6 * 10^{3} * 9.81$$

$$\boxed{P_{air_{Left}} = -29351.52\ Pa}$$ 1



$$P_1 = P_{air_{Left}} + \gamma_{oil} * (40 - 35)$$

$$= -29351.52 +$$

$$9810 * 0.8 (5)$$

$$\boxed{P_1 = 9888.48\ Pa}$$ 2

Right Tank

$$P_{air_{Right}} = 20 * 10^{3} = 2000\ Pa.$$

$$P_A = P_{air_{Right}} + \gamma_w (37 - EA)$$

$$= 2000 + 9810(37 - EA) = 20000 + 362970 - 9810t$$

$$\boxed{P_A = 382970 - 9810\ EA}$$ 2

From Manometer

$$P_A - P_1 = \gamma_L (35 - EA)$$ 1

$$382970 - 9810\ EA - 9888.48 = 9810 * 1.6 (35 - EA)$$

$$382970 - 549360 = 9810\ EA - 15696\ EA$$

$$382970 - 9888.48 - 549360$$

$$-176278.48 = -5886\ EA$$

$$\boxed{EA = 29.95m}$$ 1 $$EA = 29.95m$$

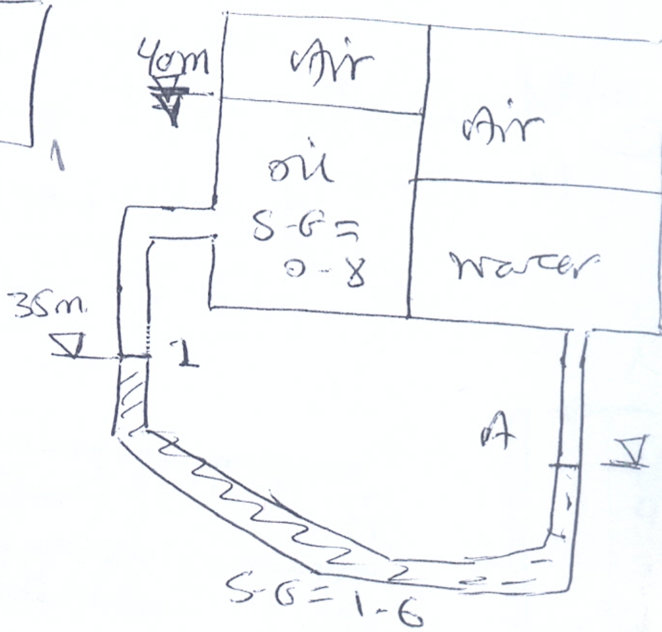
(7)

Air in Left tank.

$P_{air_{left}} = -22 \text{ cm Hg} = -22 \text{ cm} * \rho_{Hg} * (g)$

$= -22*10^{-2}*13.6*10^{3}*9.81$

$\boxed{P_{air_{left}} = -29351.52 \text{ Pa}}$ 1



$P_1 = P_{air_{left}} + \gamma_{oil}*(40-35)$

$= -29351.52 +$

$9810*0.8(5)$

$\boxed{P_1 = 9888.48 \text{ Pa}}$ 2

Right tank.

$P_{air_{Right}} = 20*10^{3} = 2000 \text{ Pa}.$

$P_A = P_{air_{Right}} + \gamma_w(37-E_A)$

$= 2000 + 9810(37-E_A) = 20000+362970-9810$

$\boxed{P_A = 382970 - 9810 E_A}$ 2

From Manometer

$P_A - P_1 = \gamma_L(35-E_A)$ 1

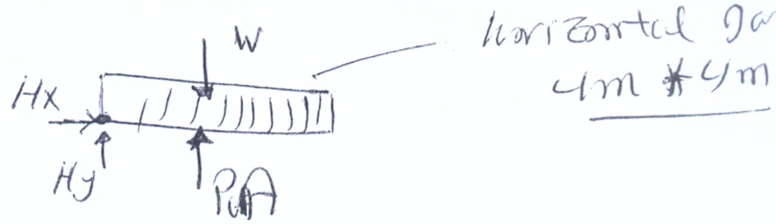
$382970 - 9810 E_A - 9888.48 = 9810*1.6(35-E_A)$

$382970 - 9888.48 - 549360 = 9810 E_A - 15696 E_A$

$-176278.48 = -5886 E_A$

$\boxed{E_A = 29.95 m}$ 1 $E_A = 29.95 m$

For horizontal gate



$\Sigma M_H = 0$

So that

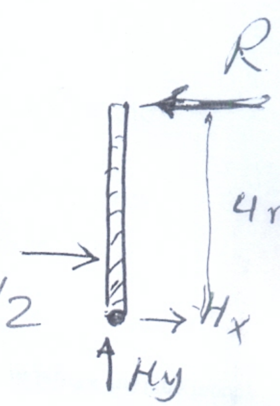
$W = PA$; where P: is the water pressure on th bottom surface.
A: contact area.

$P = \gamma_w * h_c = 9810 * 2 = 19620 \ N/m^2$

$W = PA = 9810 * 2 * (4 * 4) = 313920 \ N$

$\boxed{W = 313920 \ N = 313.92 \ KN}$ 2

For vertical gate



$F_R = \gamma_w * h_c * A = 9810 * (5+2) * (4*4)$

$\boxed{F_R = 1098720 \ N = 1098.72 \ KN}$ 2 1/2

$y_R = \frac{I_{xc}}{y_c A} + y_c = \frac{1/12 * 4 * 4^3}{7 * 16} + 7 = 7.19 \ m$

$\boxed{y_R = 7.19 m \text{ from the surface}}$ 2

$\Sigma M_H = 0$, so that

$R * 4 = F_R * (9 - 7.19)$

$R = \frac{1098.72 * (9 - 7.19)}{4}$

where (9) the distance from the surface to the bottom hinge

$\boxed{R = 497 \ KN}$ 2 1/2

3. a. **Explain what is the meaning by the following terms:**

- **Hydraulics:** A subcategory of hydrodynamics, which deals with liquid flows in pipes and open channels.

- **Specific Gravity**, denoted by SG, is defined as the ratio of a fluid density to a standard reference fluid density, water density (for liquids), and air density (for gases).

$$SG_{gas} = \frac{\rho_{gas}}{\rho_{air}} = \frac{\rho_{gas}}{1.205\ kg/m^3}$$

$$SG_{liquid} = \frac{\rho_{liquid}}{\rho_{water}} = \frac{\rho_{liquid}}{998\ kg/m^3}$$

- **The specific weight of a fluid,** (Known as the **unit weight**), is the **weight** per **unit** volume. The symbol of **specific weight** is γ (the Greek letter Gamma).

$$(\gamma = \rho g) \qquad N/m^3$$

Where:

g: is the local acceleration of gravity. Just as density is used to characterize the mass of a fluid system, g = 9.807 m/s^2.
The specific weight is used to characterize the weight of the system. Density and Specific Weight are simply related by gravity. **W = m g** & **m = W/ g.**

- **Viscosity:** A property that represents the internal resistance of a fluid to motion or the "fluidity". The viscosity of a fluid is a measure of its "*resistance to deformation.*" Viscosity is due to the internal frictional force that develops between different layers of fluids as they are forced to move relative to each other. Viscosity can then lead to energy loss.
There are two types of viscosity: Dynamic Viscosity (μ) and Kinematic Viscosity (ν).

$$\nu = \mu / \rho$$

The Kinematic viscosity in m^2/s and the Dynamic viscosity in kg/m.s = N.s /m^2

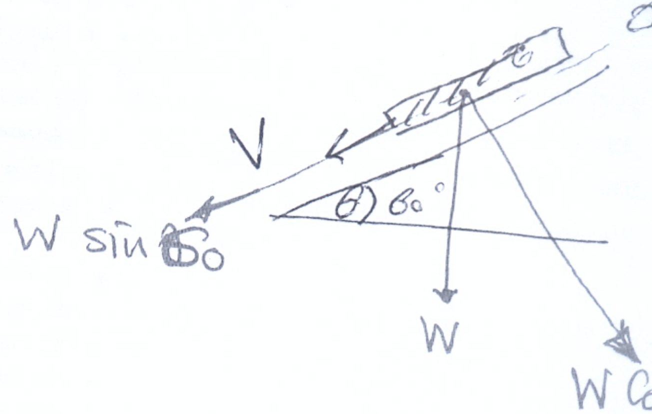
mass = 10 kg

$V = 0.22\ m/s$

gap = 0.1 mm

Area = 0.2 m^2

$\nu = 4.2 * 10^{-4}\ m^2/s$



$F = W \sin\theta = m * g * \sin 60$

$= 10 * 9.81 * \sin 60$

$\boxed{F = 84.957\ N}$

$F = \mu A \frac{du}{dy} = \mu . A \frac{u}{y}$

$\mu = \frac{F * y}{A * u} = \frac{84.957 * 0.1 * 10^{-3}}{0.2 * 0.22}$

$\boxed{\mu = 0.193\ N.s/m^2}$

$\nu = \frac{\mu}{\rho} \Rightarrow \rho = \frac{\mu}{\nu} = \frac{0.193}{4.2 * 10^{-4}}$

$\boxed{\rho = 459.72\ kg/m^3}$

$\boxed{S.G_{oil} = \frac{\rho_{oil}}{\rho_w} = \frac{459.72}{1000} = 0.4597}$

$\gamma_{oil} = \rho_{oil} * g = 459.72 * 9.81$

$\boxed{\gamma_{oil} = 4509.9\ N/m^3}$

$\tau = \frac{F}{A} = \frac{84.957}{0.2} = 424.785\ N/m^2$

$\tau = \mu . \frac{u}{y} = \frac{0.193 * 0.22}{0.1 * 10^{-3}} = 424.785$

4. a. What is the meaning of friction losses in pipes:

It is known that Bernoulli's equation can be applied along a streamline to analyze steady, incompressible and inviscid flow. Most flows in real practice, however, are viscous, and hence losses due to viscous dissipation (friction) are unavoidable. To analyze flow in a viscous pipe, Bernoulli's equation can be modified and applied to two sections of the pipe flow:

$$\frac{P_1}{\rho g}+\frac{V_1^2}{2g}+z_1=\frac{P_2}{\rho g}+\frac{V_2^2}{2g}+z_2+h_L$$

Where p is the static pressure, V is the average velocity, z is the elevation, and h_L accounts for the head loss due to friction between section (1) and (2). Based on dimensional analysis, the head loss over the length of the pipe is given by:

$$h_L=f\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)$$

For a constant-diameter horizontal pipe, the extended Bernoulli equation yields

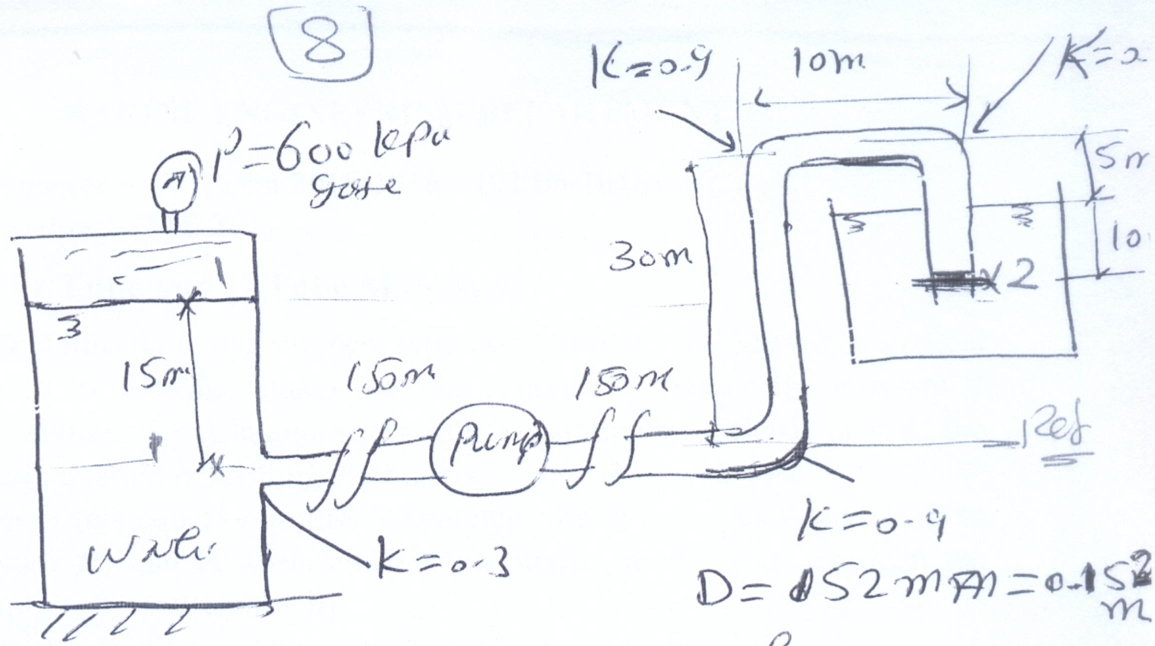
$$\Delta p=p_1-p_2=\rho g h_L$$

If elevations changes; so the equation is:

$$\Delta p=\rho g\left(z_2-z_1+h_L\right)$$

$H_P = 55\,m$

Pump Power $= ?$



$D = 152\,mm = 0.152\,m$

$f = 0.015$

Bernoulli betn ① & ②:

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 + H_P = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + h_L \quad (2)$$

$$\frac{600*10^3}{9.81*10^3} + 15 + 55 = 10 + \frac{V_2^2}{2g} + 15 + h_L \Rightarrow \text{eqn ①}$$

$$h_L = h_f + h_m = f\frac{L}{D}\frac{V_2^2}{2g} + \Sigma_m K_m * \frac{V_2^2}{2g}$$

$$= \left\{0.015 * \frac{355}{0.152} + \left(0.3 + 0.9 + 0.9 + 0.9 + 1\right)\right\}\frac{V_2^2}{2g}$$

$$\boxed{h_L = (35.033 + 4)\frac{V_2^2}{2g} = 39.033\, V_2^2/2g} \quad (2)$$

substituting in eqn ①

$$\frac{600*10^3}{9.81*10^3} + 55 = 10 + \frac{V_2^2}{2g} + 39.033\, V_2^2/2g$$

$$61.162 + 55 - 10 = 40.033\,(V_2^2/2g)$$

$$2082.9 = 40.033\, V_2^2$$

$$\boxed{V_2 = 7.213\ m/s} \quad (1)$$

$$Q = AV = \frac{\pi}{4} * (0.152)^2 * 7.213$$

$$Q = 0.13088\ m^3/s \quad (1)$$

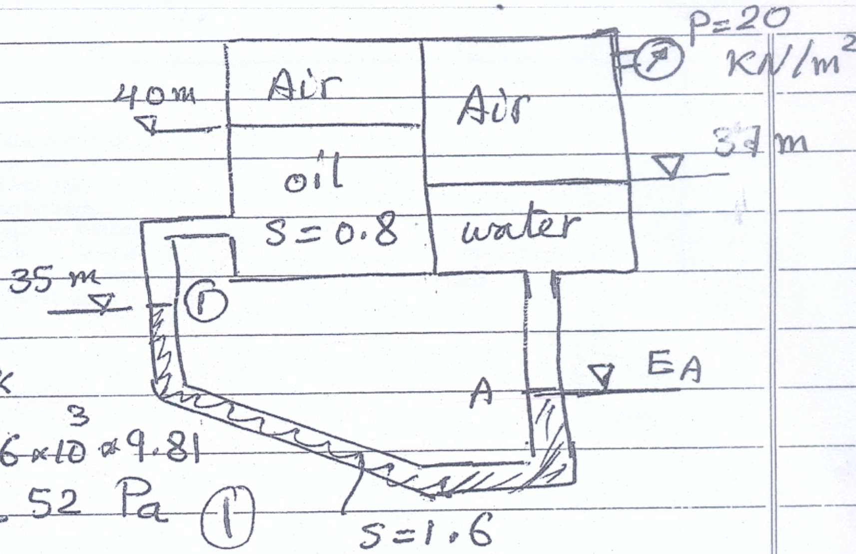
$$\text{pump power} = \gamma Q H_P$$

$$= 9.81*10^3 * 0.13088 * 55 = 70621\,W \simeq 70.62\ kW \quad (2)$$

1-b

7

5



Air in left tank

$$P_{air\,left} = -22\times10^{-2}\times13.6\times10^{3}\times9.81$$
$$= -29351.52 \text{ Pa} \quad (1)$$

$$P_1 = P_{air\,left} + \gamma_{oil}(40-35)$$
$$= 9888.48 \text{ Pa} \quad (2)$$

$$P_A = P_{air\,Right} + \gamma_w(37-E_A)$$
$$= 20\times10^{3} + 9.81\times10^{3}(37-E_A) \quad (2)$$

From Manometer

$$P_A - P_1 = \gamma_L(35 - E_A)$$

(1)

$$20\times10^{3} + 9.81\times10^{3}(37-E_A) - 9888.48 = 1.6\times10^{3}\times9.81(35-E_A)$$

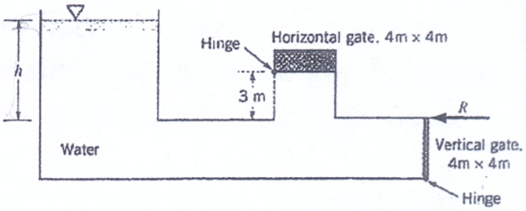
$$\therefore E_A = 29.95 \text{ m.} \quad (1)$$

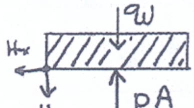
Q: 2

10

2.57

2.57 Two square gates close two openings in a conduit connected to an open tank of water as shown in Fig. P2.57. When the water depth, h, reaches 5 m it is desired that both gates open at the same time. Determine the weight of the homogeneous horizontal gate and the horizontal force, R, acting on the vertical gate that is required to keep the gates closed until this depth is reached. The weight of the vertical gate is negligible, and both gates are hinged at one end as shown. Friction in the hinges is negligible.





For horizontal gate,

$$\Sigma M_H = 0$$

so that

$$W = pA$$ where p is the water pressure on the bottom surface.

Thus, $p = \gamma_{H_2O}(2m)$

so that

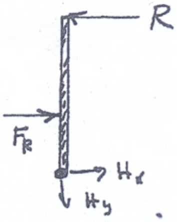
$$W = \left(9800 \frac{N}{m^3}\right)(2m)(4m \times 4m) = \underline{\underline{314\ kN}}$$

For vertical gate,

$F_R = \gamma h_c A$ where $h_c = 7m$

so that

$$F_R = \left(9800 \frac{N}{m^3}\right)(7m)(4m \times 4m)$$
$$= 1100\ kN$$



To locate F_R

$$y_R = \frac{I_{xc}}{y_c A} + y_c = \frac{\frac{1}{12}(4m)(4m)^3}{(7m)(4m \times 4m)} + 7m = 7.191\ m$$

For equilibrium

$\Sigma M_H = 0$ so that

$$R = \frac{(1100\ kN)(9m - 7.191m)}{4\ m} = \underline{\underline{497\ kN}}$$

3-b

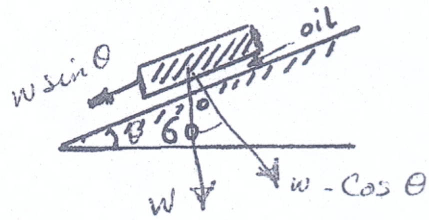
Quiz NO.1

6

Name:

A 10 kg block slides down a smooth inclined surface as shown in the figure with a velocity 0.22 m/s. The gap between the block and the surface is 0.1 mm. Assume the velocity distribution in the gap is linear and the area of the block in contact with oil is 0.2m^2. The Kinematic viscosity of oil is 4.2x10^{-4} m^2/s.

Find for oil; 1- The mass density
2- The specific gravity
3- The specific weight
4- The shear stress.



$F = w \cdot \sin\theta = 10 * 9.8 \sin 60 = 84.87$ N

$\mu = \dfrac{F * y}{A * u} = \dfrac{84.87 * 0.1 * 10^{-3}}{0.2 * 0.22} = 0.19288 \ \dfrac{N-S}{m^2}$

1½ $\nu = \dfrac{\mu}{\rho} \quad \therefore \rho = \dfrac{\mu}{\nu} = \dfrac{0.19288}{4.2 * 10^{-4}} = 459.2559 \ Kg/m^3$

1½ $S = \dfrac{\rho_{oil}}{\rho_w} = \dfrac{459.26}{1000} = 0.459$

1½ $\gamma = \rho * g = 4500.7 \ N/m^3$

1½ $\tau = \dfrac{F}{A} = \dfrac{84.87}{0.2} = 424.35 \ N/m^2$

4-6

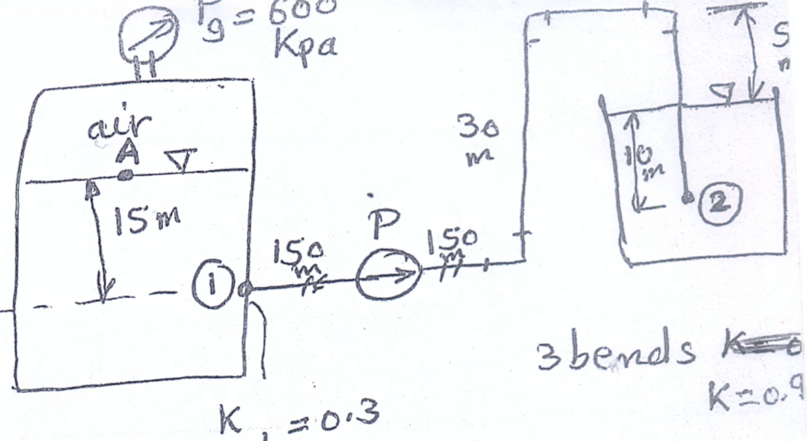
8

$Z_A = 15$ m

$Z_1 = 0$ m

$Z_2 = 15$ m

$H_p = 55$ m



point ① in the pipe entrance

B.L $A \rightarrow 1$

$$\frac{P_A}{\gamma} + Z_A + \frac{V_A^2}{2g} = \frac{P_1}{\gamma} + Z_1 + \frac{V_1^2}{2g}$$

$$\frac{600 \times 10^3}{9.81 \times 10^3} + 15 + 0 = \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + 0$$

2

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} = 76.162 \text{ m water}$$

B.L $1 \rightarrow 2$

$$\frac{P_1}{\gamma} + Z_1 + \frac{V_1^2}{2g} + H_p - H_L = \frac{P_2}{\gamma} + Z_2 + \frac{V_2^2}{2g}$$

$$76.162 + 0 + 55 - H_L = 10 + 15 + \frac{V_2^2}{2g}$$

2

$$H_L = h_f + h_M = f \frac{L_t}{d} \cdot \frac{V^2}{2g} + \Sigma K \frac{V^2}{2g}$$

$$= 0.015 \frac{355}{0.152} \cdot \frac{V^2}{2g} + (0.3 + 3 \times 0.9 + 1) \frac{V^2}{2g}$$

$$= 39.03 \frac{V^2}{2g}$$

substituting in B.L.

$$76.162 + 55 - 39.03 \frac{V^2}{2g} = 25 + \frac{V^2}{2g}$$

$$106.162 = 40.03 \, V^2/2g$$

2

$$V = 7.213 \text{ m/s}$$

$$Q = A \times V = \frac{\pi}{4} (0.152)^2 \times 7.213 = 0.1308 \text{ m}^3/\text{s}$$

2

$$\text{pump power} = \gamma . Q . H_p$$

$$= \underline{70.584} \text{ Kw}$$