Mansoura University Faculty of Engineering Program of Biomedical Engineering. Course Title: Fluid Mechanics Course Code: MPE 171		Level: 100 Exam Type: Final Date: 18 January 2018 Time: 2 Hours Full Mark: 50

Answer all the following questions.

Question (1) [6 Marks]

A square metal plate 3 m side and 2 mm thick weighting 120 N is to be lifted through a vertical gap of 50 mm of infinite extent. The oil in the gap has a specific gravity of 0.9 and kinematic viscosity of 12.3×10^{-4} m^2/s. If the metal plate is to be lifted at a constant speed of 1 m/s. Determine the friction force and power required.

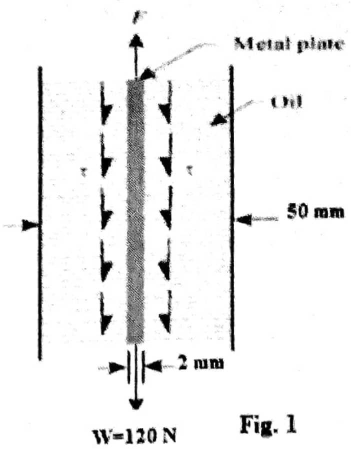

Fig. 1

Question (2) [5 Marks]

Calculate the gauge pressure of air in the tank shown in Figure 2.

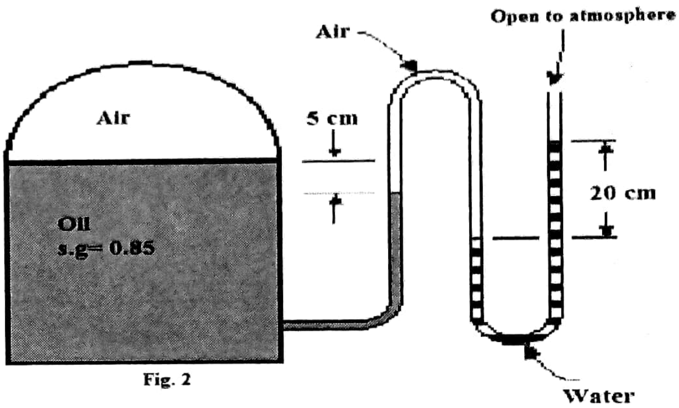

Fig. 2

Question (3) [10 Marks]

Rectangular gate ABC in the Fig. 3. is 1m width and is hinged at B. Compute the force P just sufficient to keep the gate from opening.

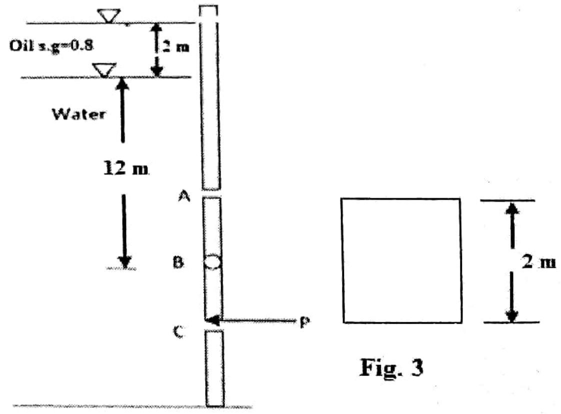

Fig. 3

Question (4) [5 Marks]

The weight of a certain crown in air was found to be 14 N and its weight in water 13.1 N. Assuming the crown is an alloy of gold (s.g=19.3) and silver (s.g=10.5). Compute the fraction of gold in the crown.

Question (5) [5 Marks]

In Figure 4, find the time for water level in the tank as increases from 0.2 m to 1.5 m. Neglect losses. (Take cd=0.65)

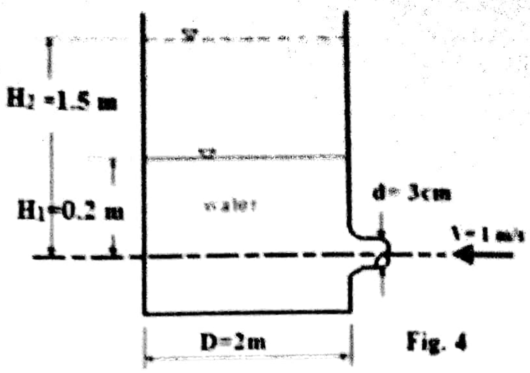

Fig. 4

Question (6) [8 Marks]

In Figure 5, Water flows through a pipe at a rate of 0.05 m^3/s. The pipe consists of two sections of diameters 20 cm and 10 cm with a smooth reducing section that connects them. The pressure difference between the two pipe sections is measured by a mercury manometer. Neglecting frictional effects, determine the differential height h of mercury between the two pipe sections h. Take the mercury density to be 13600 kg/m^3.

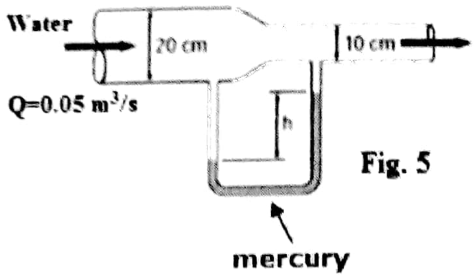

Fig. 5

Question (7) [4 Marks]

A water jet strikes a vane mounted on a tank with frictionless wheels, as in Fig. 6. The jet turns and falls into the tank without spilling out. If θ = 30°, evaluate the jet velocity V_j if the horizontal force F required to hold the tank stationary is 160N.

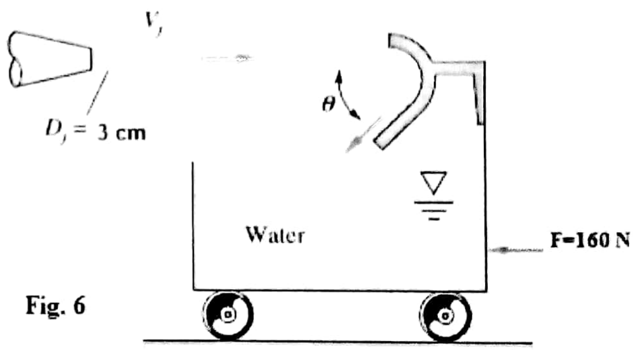

Fig. 6

Question (8) [10 Marks]

a- Calculate the volume flow rate Q in the piping system shown in Fig. 7.

b- In order to increase the flow rate through the system, a pump could be installed in the line. Determine the power required pump to double the flow rate. Assume pump efficiency is 85 %, and f=0.02.

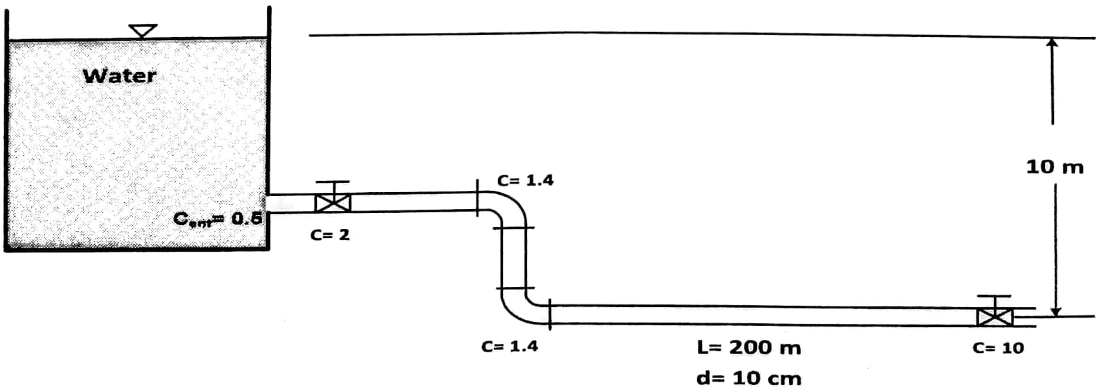

Fig. 7

Good Luck

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Program of Biomedical Engineering.
Date: 18 January 2018
MODEL ANSEWR
Fluid Mechanics

Question (1) [6 Marks]

Given:

$A = 9\ m^2$, $W = 120\ N$, $\rho = 900\ kg/m^3$

$v = 12.3\times10^{-4}\ m^2/s$, $U = 1\ m/s$

Required: F and Power

Solution:

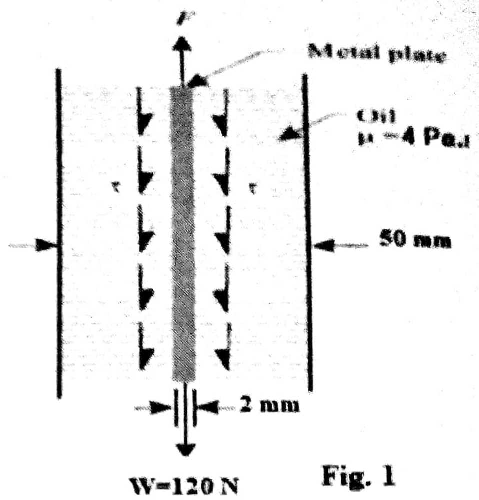

Fig. 1

$$y_1 = y_2 = \frac{50-2}{2} = 24mm = 24\times10^{-3}m$$

$$\mu = v\times\rho = 1.107\ Pa.s$$

$$F = F_1 + F_2 + W$$

$$F = \frac{\mu AU}{y_1} + \frac{\mu AU}{y_2} + W$$

$$F = 950.25\ N$$

$$Power = F\times\frac{U}{736} = 1.29\ hp$$

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(2) [5 Marks]

Required: P_{air}

Solution:

$P_x = P_y = P_z = P_m$

$$\gamma_w\times0.2 = P_{air} + \gamma_o\times0.05$$

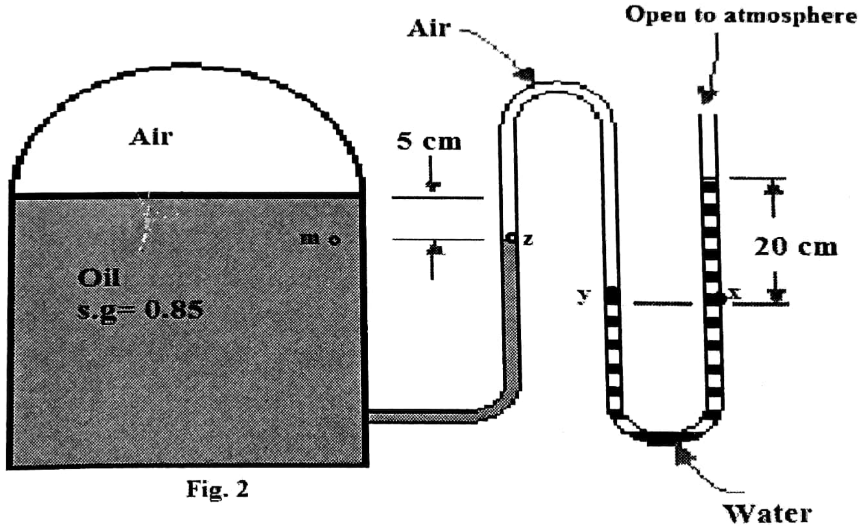


Fig. 2

$$9810\times0.2 = P_{air} + 0.85\times9810\times0.05$$

$$P_{air} = 1545.075\ \ Pa$$

Question (3) [10 Marks]

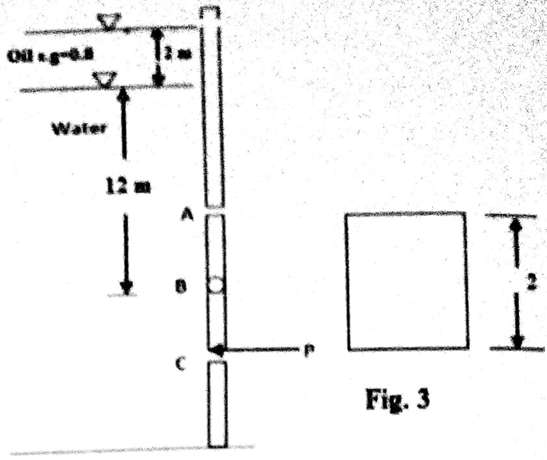


Fig. 3

Given: h_o=2 m, A=2 m²

Required: P

Solution:

$$P_W = P_O$$

$$9810 \times h_{eq} = 0.8 \times 9810 \times 2$$

$$h_{eq} = 1.6\, m$$

$$h_c = 13.6\, m$$

$$F_W = \gamma_w A h_c = 266832\ N$$

$$I_{cc} = \frac{bh^3}{12} = 0.667\ m^4$$

$$h_p = h_c + \frac{I_{cc}}{Ah_c} = 13.6245\ m$$

$$\sum_{B} \text{Moment} = 0$$

$$P \times 1 = F_W \times (h_p - h_C)$$

$$P = 6537.384\ N$$

Question (4) [5 Marks]

Given: W=14 N, T_w=13.1 N

$s.g_g$=19.3, $s.g_s$= 10.5

Required: X_g

Solution:

$$T_w = W - F_b$$

$$13.1 = 14 - 9810V$$

$$V = 9.174 \times 10^{-5}\ m^3$$

$$\gamma_b = \frac{W}{V} = 152600\ \frac{N}{m^3}$$

$$s.g_b = \frac{\gamma_b}{\gamma_w} = 15.55$$

$$s.g_b = x_g s.g_g + x_s s.g_s$$

$$15.55 = 19.3\, x_g + 10.5(1 - x_g)$$

$$x_g = 57.38\%$$

Question (5) [5 Marks]

Given: H_1= 0.2 m, H_2 =1.5 m, c_d=0.65

Required: time

Solution:

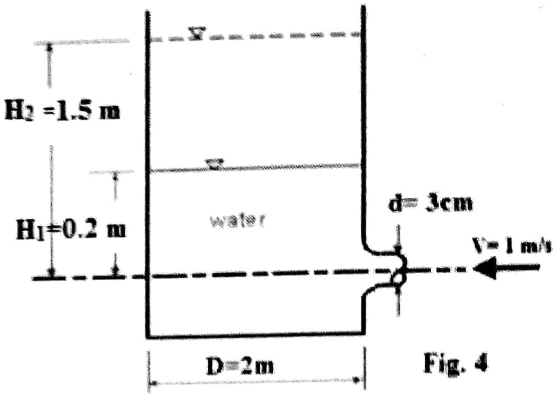


Fig. 4

$$\sum_{in} \dot{m} - \sum_{out} \dot{m} = \rho_w \frac{dVolume}{dt}$$

$$C_d \frac{\pi}{4} d^2 V - 0 = \frac{\pi}{4} D^2 \frac{dH}{dt}$$

$$\frac{dH}{dt} = C_d \frac{d^2}{D^2} V = 0.0146\ m/s$$

$$\int_0^t dt = \frac{1}{0.000146} \int_{H_1}^{H_2} dH$$

$$t = 6837.6(H_2 - H_1) = 6837.6(1.5 - 0.2) = 8888.89\ sec$$

Question (6) [8 Marks]

Given: Q=0.05 m³/s, d_1=0.2m, d_2= 0.1m

Required: h

Solution:

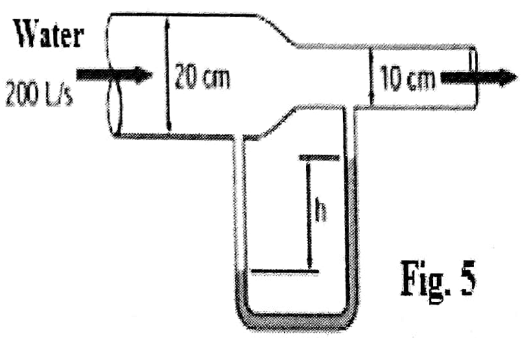


Fig. 5

$$Q = A_1 V_1 = A_2 V_2$$

$$0.05 = \frac{\pi}{4} d_1^2 V_1 = \frac{\pi}{4} d_2^2 V_2$$

we get V_1 =1.59 m/s, and V_2=6.37 m/s

Appling Bernoulli's equation:

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

$$\frac{P_1 - P_2}{\gamma_w} = \frac{V_2^2 - V_1^2}{2g} = 1.939\ m \quad \text{..................(1)}$$

P_x=P_y

$$P_1 + \gamma_w\, h = P_2 + \gamma_{hg}\, h$$

$$\frac{P_1 - P_2}{\gamma_w} = h\left(\frac{\gamma_{hg}}{\gamma_w} - 1\right) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

eq(1)=eq(2)

$$h(13.6 - 1) = 1.939$$

h=0.154 m=15.4 cm

Question (7) [4 Marks]

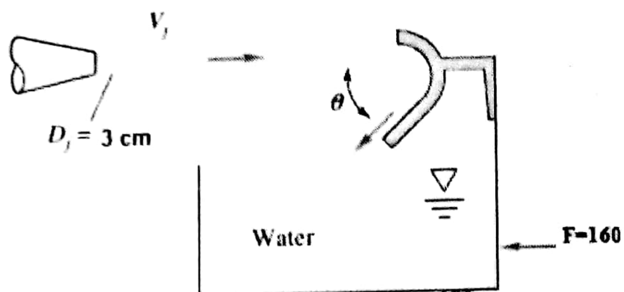


Fig. 6

Given: d_j= 3cm, F=160 N

Required: V_j

Solution:

$$\sum Forces = \sum_{out} \dot{m}V - \sum_{in} \dot{m}V$$

$$-F = 0 - \dot{m}V_j$$

$$F = \rho \frac{\pi}{4} \times d_j^2 \times V_j^2$$

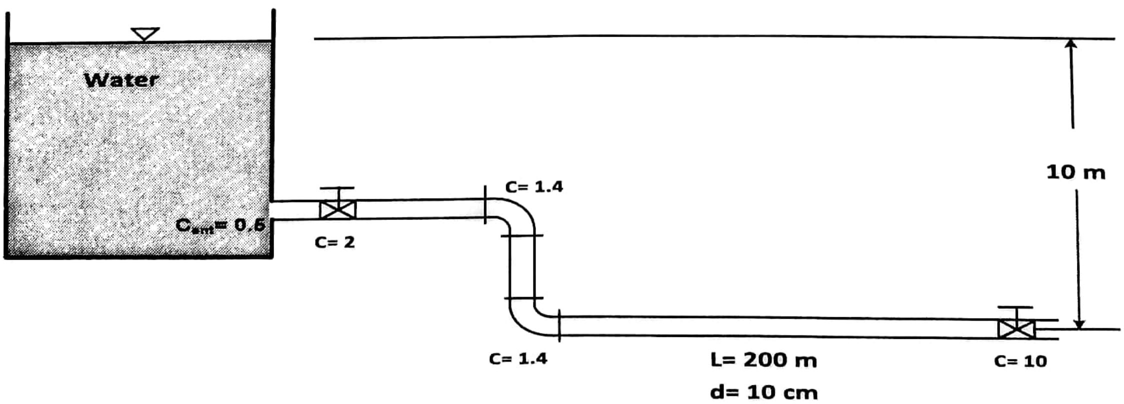
$$160 = 1000 \times \frac{\pi}{4} \times 0.03^2 \times V_j^2$$

$$V_j = 15.05 \quad m/s$$

Question (8) [10 Marks]

Given: f=0.02, η_p= 0.85

Required: Power



Solution:

$$\frac{P_a}{\gamma_w} + \frac{V_a^2}{2g} + Z_a = \frac{P_b}{\gamma_w} + \frac{V_b^2}{2g} + Z_b + hL$$

$$0+0+10=0+\frac{V^2}{2g}+0+f\frac{L}{d}\frac{V^2}{2g}+(0.5+2+1.4+1.4+10)\frac{V^2}{2g}$$

$$10=\frac{V^2}{2\times 9.81}+0.02\times\frac{200}{0.1}\times\frac{V^2}{2\times 9.81}+(15.3)\frac{V^2}{2\times 9.81}$$

$$\therefore V=1.867\ m/s$$

$$Q=VA=1.867\times\frac{3.14}{4}\times 0.1^2=0.0146\frac{m^3}{s}$$

b)

$$Q_{II}=2Q=0.0293\frac{m^3}{s}$$

$$V_{II}=\frac{0.0293}{\frac{3.14}{4}\times 0.1^2}=3.734\ m/s$$

$$\frac{P_a}{\gamma_w}+\frac{V_a^2}{2g}+Z_a+H_P=\frac{P_b}{\gamma_w}+\frac{V_b^2}{2g}+Z_b+hL$$

$$0+0+10+H_P=\frac{{V_{II}}^2}{2g}+f\frac{L}{d}\frac{{V_{II}}^2}{2g}+(0.5+2+1.4+1.4+10)\frac{{V_{II}}^2}{2g}$$

$$H_P=\frac{3.734^2}{2g}+0.02\times\frac{200}{0.1}\times\frac{3.734^2}{2\times 9.81}+(0.5+2+1.4+1.4+10)\frac{3.734^2}{2g}$$
$$-10=30.72\ m$$

$$Power=\frac{\gamma_w Q_{II} H_P}{\eta_P}=\frac{9810\times 0.0146\times 30.72}{0.85}=10043\ W=11.67\ hp$$