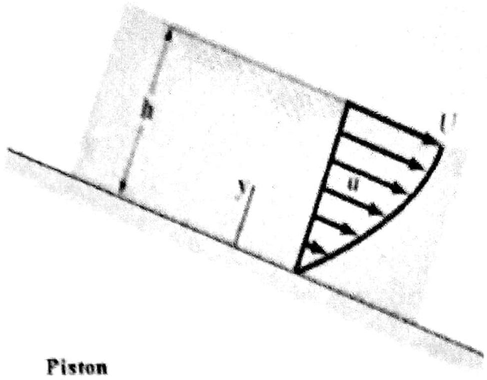
Mansoura University Faculty of Engineering Program of Biomedical Engineering Course Title: Fluid Mechanics Course Code: MPE 171		Level: 100 Exam Type: Final Date: 12 January 2019 Time: 2 Hours Full Mark: 50

Answer all the following questions.

Question (1) [5 Marks]

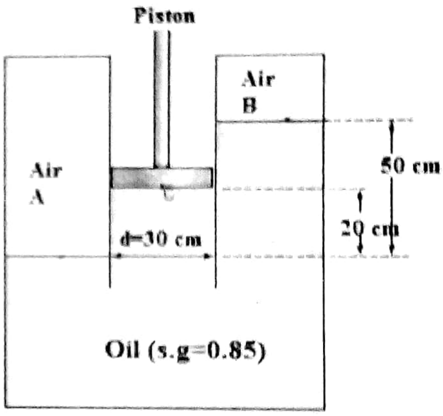
A layer of water flows down an inclined fixed surface with the velocity profile shown in Figure 1. Determine the magnitude of the shearing stress at wall and at y =0.1m. Also, draw the shear stress distribution for this profile. Put $\mu = 0.001\ Pa.s$ and $h = 0.1$.



The velocity profile is given by: $u = 40(y - 5y^2)$

Question (2) [4 Marks]

Two chambers with the same fluid at their base are separated by a piston, as shown in Fig. 2. Calculate the gage pressures in chamber B and mass of piston. If the gauge pressure in chamber A is 3500 Pa.

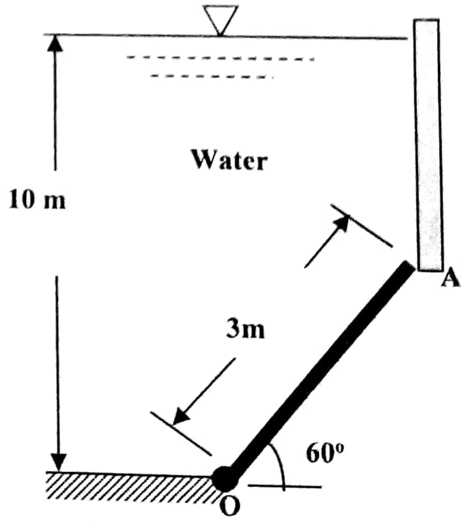


Question (3) [8 Marks]

Draw the pressure distribution on the gate OA.

Calculate the following:

a) the hydrostatic force on the gate (2 m wide) and the location of their line of action. b) the horizontal reaction P exerted by the wall at point A.



Question (4) [5 Marks]

Consider a wooden cylinder (sg=0.7) 1 m in diameter and 0.8 m long. Would this cylinder be stable if placed to float with its axis vertical in water?

Question (5) [7 Marks]

(a) Drive the following formula to determine the time to lower the liquid level in a tank of a constant cross section by means of an orifice.

$$t = \frac{2A}{cd\ a\sqrt{2g}}\left(\sqrt{H_1} - \sqrt{H_2}\right)$$

Where: A is the area of tank, a is the area of small orifice, cd is the discharge coefficient , H_1 is the liquid level at time=0 and H_2 is the liquid level at time t.

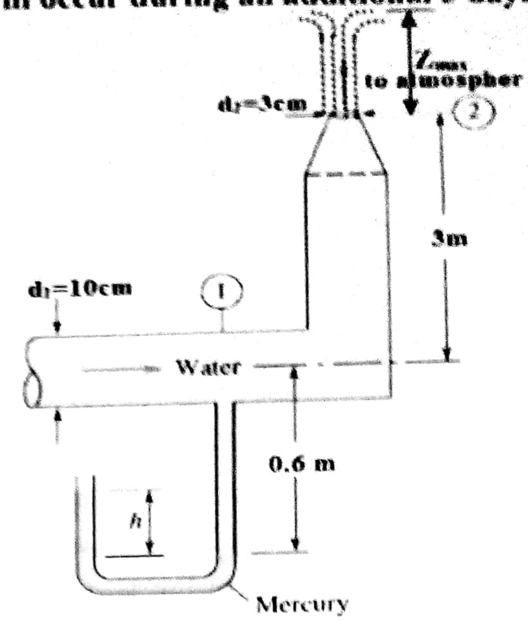
(b) Leakage in the bottom of a storage tank for oil is found to cause the surface level to decrease from 5 m to 4 m in 24 hours. What further drop in level will occur during an additional 5 days?

Question (6) [8 Marks]

The pipe bend of Fig. 4 has d_1=10 cm and d_2= 3 cm. If V_1 = 0.6 m/s and losses are neglected, what is the following:

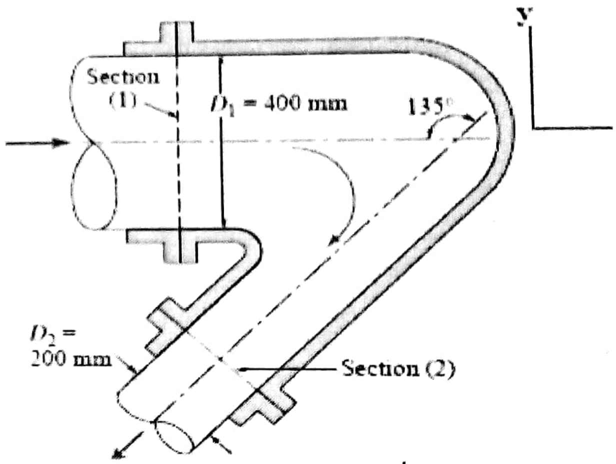
a) The manometer reading h .

b) The height to which the jet will rise Z_{max}.



Question (7) [8 Marks]

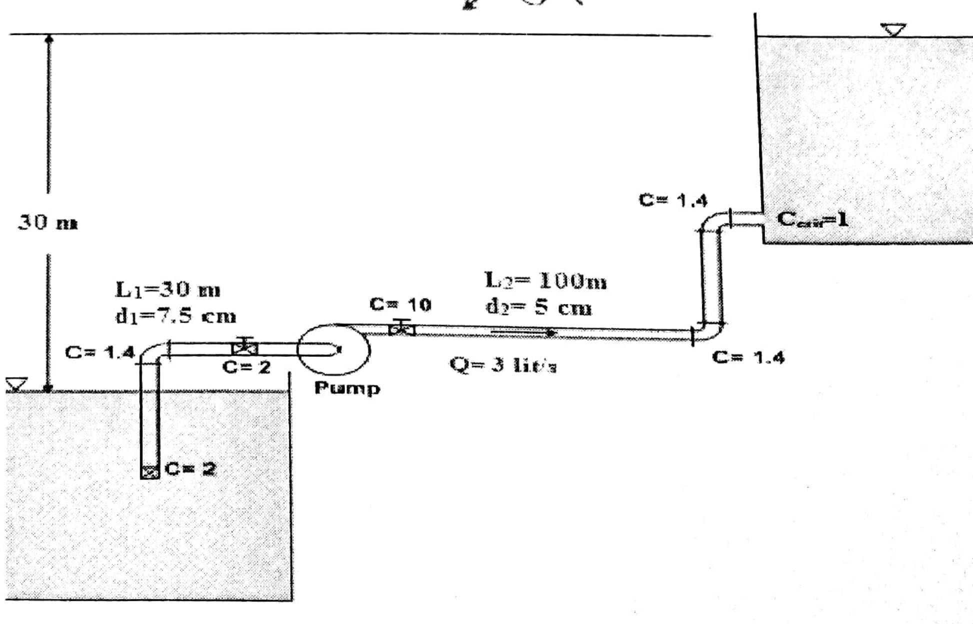
A converging elbow (see Fig. 5) turns water through an angle of 135° a horizontal plane. The flow cross sectional diameter is 400 mm at the elbow inlet, section (1), and 200 mm at the elbow outlet, section (2). The volume flow rate of water is 0.4 m³/s and the elbow inlet pressure is 150 kPa. Calculate the net resultant horizontal force required to hold the elbow in place.



Question (8) [8 Marks]

Calculate the pump power for the water piping system shown in Figure 6.

Assume pump efficiency is 75%, and f=0.02.



Good Luck Dr. Ahmed Abd-Elsalam

Question (1) [6 Marks]

A layer of water flows down an inclined fixed surface with the velocity profile shown in Figure 1. Determine the magnitude of the shearing stress at wall and at y =0.1m. Also, draw the shear stress distribution for this profile. Put $\mu = 0.001\ Pa.s$ and $h = 0.1$.

The velocity profile is given by:$u = 40(y - 5y^2)$

Solution:

$$= \mu \frac{du}{dy} = \mu[40(1 - 10y]$$

at wall y=0 $\therefore \tau = 40\mu = 0.04\ Pa$

at y=h=0.1m $\therefore \tau = zero$

Two chambers with the same fluid at their base are separated by a piston, as shown in Fig. 2. Calculate the gage pressures in chamber B and mass of piston. If the gauge pressure in chamber A is 3500 Pa.

$P_x = P_y = P_z$

Solution:

$$P_A = \frac{mg}{A} + \gamma_{\text{oil}} \times 0.2$$

$$m = (P_A - 0.85 \times 9810 \times 0.2)\frac{3.14}{4 \times 9.81} \times 0.3^2 = 13.203\text{kg}$$

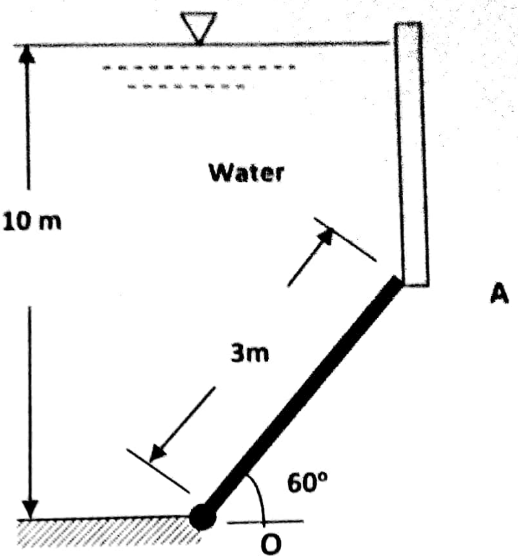
$$P_B = P_A - \gamma_{\text{oil}} \times 0.5 = -669.25Pa$$

Question (3) :

Given: b=2 m

Required: F, P

Solution:



$A = 3 \times 2 = 6m^2$

$h_c = 10 - 1.5\,sin60 = 8.7m$

$F = \gamma_w A h_c = 512082\ N$

$I = \frac{2\times3^3}{12} = 4.5\ m^4\ ,\quad y_c = \frac{h_c}{sin60} = 10.045m$

$y_p = y_c + \frac{I}{Ay_c} = 10.12\ m$

$\sum_o M = 0$

$P \times 3 \times \sin(60) = F \times (1.5 - (y_p - y_c))$

P=243238.95 N=243.238 kN

Question (4)

Consider a wooden cylinder (sg=0.7) 1 m in diameter and 0.8 m long. Would this cylinder be stable if placed to float with its axis vertical in water?

$h = \frac{\rho_b}{\rho_f} L = sg\ L = 0.7 \times 0.8 = 0.56\ m$

$$\overline{BG} = \frac{L}{2} - \frac{h}{2} = 0.12m$$

$$\overline{BM} = \frac{I}{V_s} = \frac{\frac{\pi}{64} D^4}{\frac{\pi}{4} D^2 h} = \frac{D^2}{16\ \times sgL} = 0.1116\ m$$

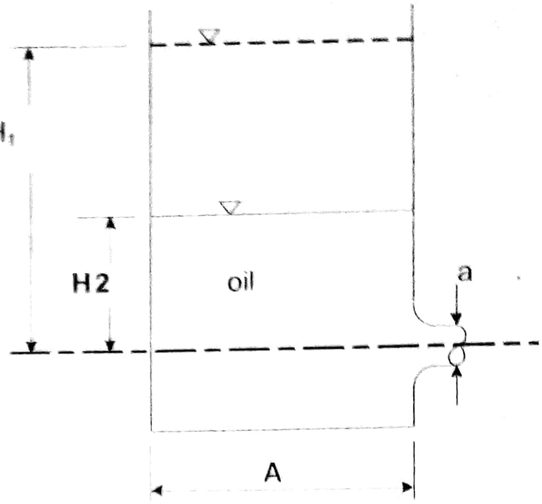
$$\overline{BM} < \overline{BG}$$

The cylinder is unstable

Question (5)

(a) Drive the following formula to determine the time to lower the liquid level in a tank of a constant cross section by means of an orifice.

$$t = \frac{2A}{cd\ a\ \sqrt{2g}}\left(\sqrt{H_1} - \sqrt{H_2}\right)$$



Solution:

(a)

$$v = \sqrt{2gh}$$

Assume that dV of liquid flows out in time dt with the liquid level falling by -dh. Then

$$dV = C_d a\sqrt{2gh}\,dt = -dh\,A$$

$$dt = -\frac{A}{C_d a}\frac{dh}{\sqrt{2gh}}$$

$$\int_0^t dt = \frac{-A}{C_d a\sqrt{2g}}\int_{H1}^{H2}\frac{dh}{\sqrt{h}}$$

The time needed for the liquid level to descend from H_1 to H_2 is

$$t = \frac{2A}{cd\ a\ \sqrt{2g}}\left(\sqrt{H_1} - \sqrt{H_2}\right)$$ b)

$24 = K(\sqrt{5} - \sqrt{4})$, **K=101.06**

$5x24 = 101.06(\sqrt{3.5} - \sqrt{H_2})$

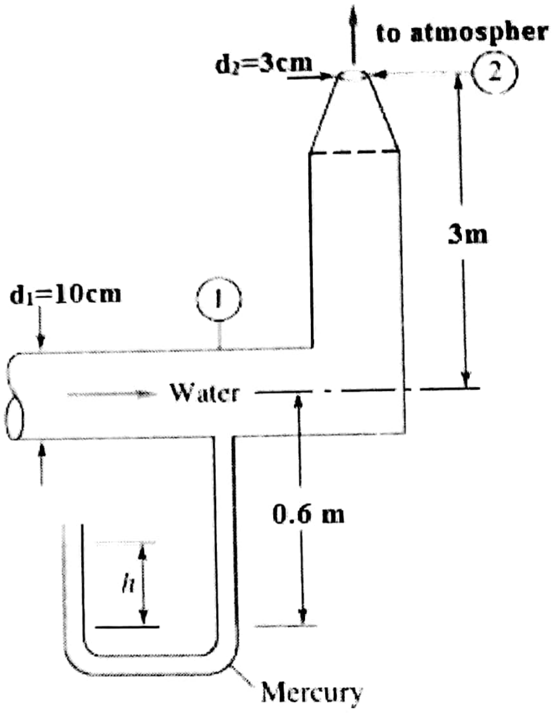
H_2= 0.672 m

Question (6)

The pipe bend of Fig. 6 has d_1=10 cm and d_2= 3 cm. If V_1 = 0.6 m/s and losses are neglected, what is the following:

a) The manometer reading *h* .

b) The height to which the jet will rise Z_{max}.



Solution:

$$A_1V_1 = A_2V_2$$

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

$$V_2 = 6.67\ m/s$$

Appling Bernoulli's equation:

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

$$\frac{P_1}{\gamma_w} + \frac{V_1^2}{2g} + 0 = 0 + \frac{V_2^2}{2g} + 3 + 0$$

$$P_1 = 51474.445\ \text{Pa}$$

$P_x = P_y$

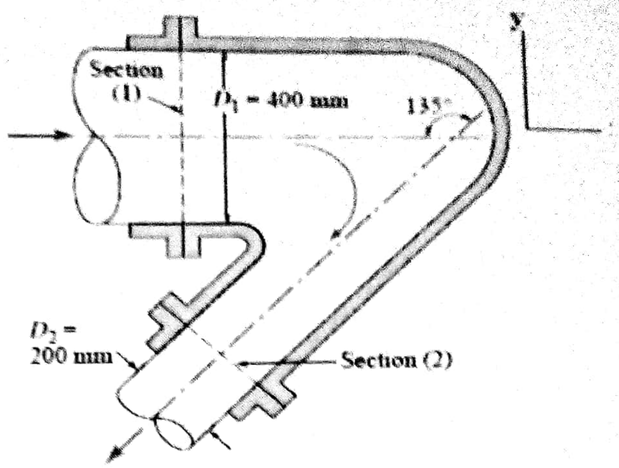
$$P_1 + \gamma_w \times 0.6 = 0 + \gamma_{hg}\ h$$

h= 0.4299 m

$$Z_{max} = \frac{V_2^2}{2g} = 2.26\ m$$

Question (7) [8 Marks]

A converging elbow (see Fig. 5) turns water through an angle of 135° a horizontal plane. The flow cross sectional diameter is 400 mm at the elbow inlet, section (1), and 200 mm at the elbow outlet, section (2). The volume flow rate of water is 0.4 m³/s and the elbow inlet pressure is 150 kPa. Calculate the net resultant horizontal force required to hold the elbow in place.



$$Q = A_1V_1 = A_2V_2 = 0.4$$

$$V_1 = 3.18\, m/s$$
$$V_2 = 12.74\, m/s$$

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

$$\frac{150000}{9810} + \frac{3.18^2}{2 \times 9.81} = \frac{P_2}{9810} + \frac{12.74^2}{2 \times 9.81}$$

$$P_2 = 73902.4\, Pa$$

$$F_X + P_1A_1 + P_2A_2 = -\dot{m}V - \dot{m}(-V)$$

$$F_X + P_1A_1 + P_2A_2COS(45) = \dot{m}(-V_2COS(45)) - \dot{m}(V_1)$$

$$F_X = -25368.083\text{N}$$

$$\longleftarrow F_X = 25368.083\text{ N}$$

$$F_Y + P_2A_2SIN(45) = \dot{m}(-V_2SIN(45)) - \dot{m}(0)$$

$$F_Y = -5245.327N$$

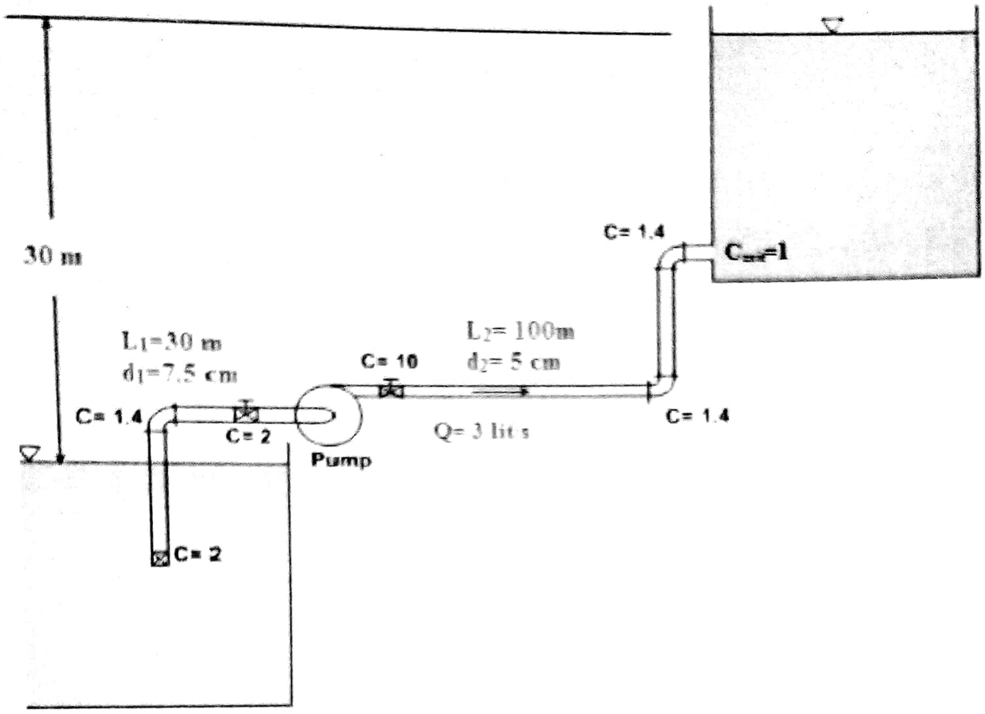
$$F_Y = 5245.327N \downarrow$$

$$F = \sqrt{F_X^2 + F_Y^2} = 25904.693\ N$$

Question (8) [8 Marks]

Calculate the pump power for the water piping system shown in Figure 8.

Assume pump efficiency is 75%, and f=0.02.



$$Q = A_1 V_1 = A_2 V_2 = 0.003$$

$$V_1 = 0.679 \frac{m}{s}, \qquad V_2 = 1.528 \frac{m}{s}$$

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

$$0 + 0 + 0 + H_p = 0 + 0 + 30 + f\frac{L_1}{d_1}\frac{V_1^{\,2}}{2g} + f\frac{L_2}{d_2}\frac{V_2^{\,2}}{2g} + (2 + 1.4 + 2)\frac{V_1^{\,2}}{2g} + (10 + 1.4 + 1.4 + 1)\frac{V_2^{\,2}}{2g}$$

$$H_p = 36.717\ m$$

$$\eta_p = \frac{\gamma Q H_p}{Power}$$

$$Power = 1.957\ HP$$