Mansoura University Faculty of Engineering Program of Biomedical Engineering. Course Title: Fluid Mechanics Course Code: MPE 171		Level: 100 Exam Type: Final Date: 29 December 2016 Time: 2 Hours Full Mark: 50

Answer all the following questions.

Question (1) [6 Marks]

In a 0.6 m diameter pipe carrying oil (μ=9.8 Poise), the velocity profile (distribution) is given by: $u = -5r^2 + 0.45$ m/s, where u is velocity at radius r. Find:

a) Shear stress at pipe wall and center. **b) Draw the shear stress distribution.**

c) The wall shear force along a length of pipe L=5m.

Question (2) [10 Marks]

Gate OAB in Fig.1 has a fixed hinge line at O and is 3 m wide into the paper. Find:

(a) Draw the pressure distribution on the gate.

(b) All the forces on the gate and the location of their line of action.

(c) The minimum force F necessary to keep the gate closed.

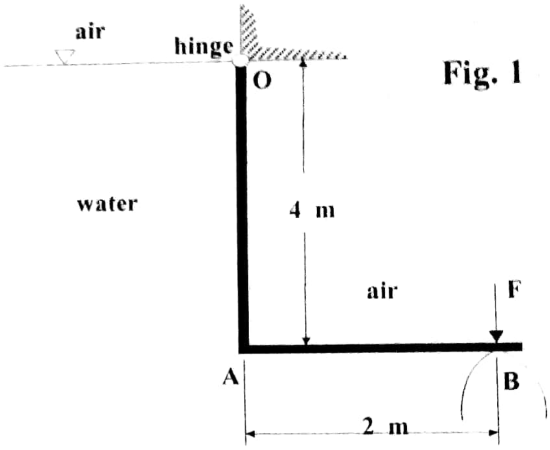


Fig. 1

Question (3) [4 Marks]

A piston having a cross-sectional area of 0.1 m^2 is located in a cylinder containing water as shown in Figure 2. An open U-tube manometer is connected to the cylinder as shown. Calculate the weight of the piston, *W*.

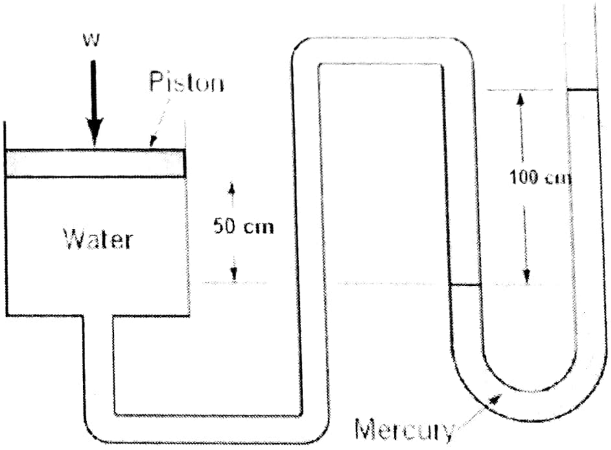


Fig. 2

Question (4) [5 Marks]

A uniform block of steel (SG= 6.85) will "float" at a mercury-water interface as in Fig. 3 . What is the ratio of the distances a and b for this condition?

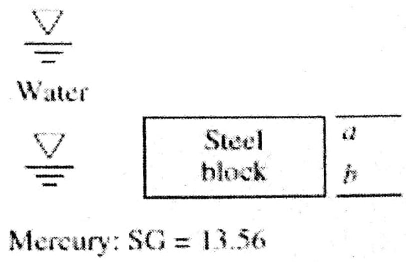


Fig. 3

Question (5) [7 Marks]

A tube can be used to discharge water from a reservoir as shown in Fig.4. Determine the speed of the free jet, flow rate of water and the minimum absolute pressure of water that occurs at the top of the bend. (Take cd=0.6)

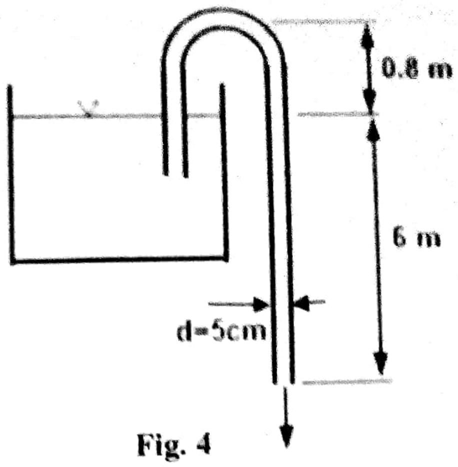


Fig. 4

Question (6) [7 Marks]

The model car in Fig 5. Weighs 20 N and is to be accelerated from rest by a 2-cm-diameter water jet moving at 70 m/s. Neglecting air drag and wheel friction, Estimate the velocity of the car after it has moved forward 1 m.

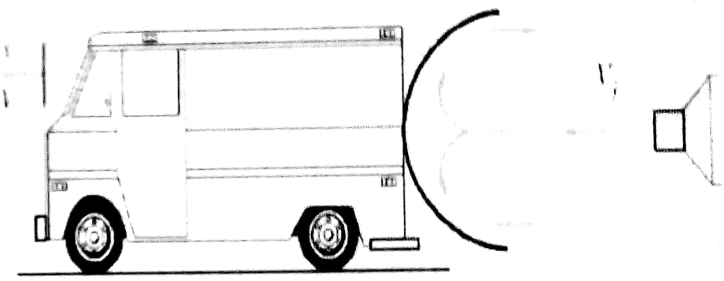


Fig. 5

Question (7) [11 Marks]

a- Calculate the volume flow rate Q in the piping system shown in Fig 6.

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 80 %, and *f*=0.02.

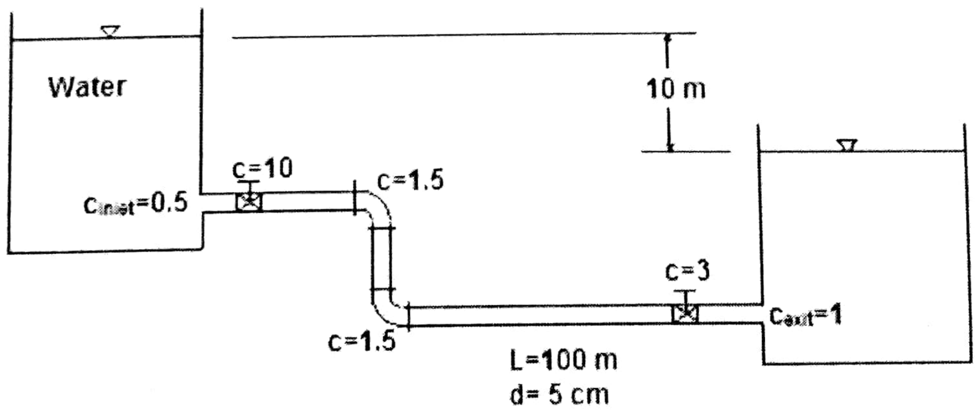


Fig. 6

Good Luck
Dr. Ahmed Abd-Elsalam

Model answer

Question (1) : In a 0.6 m diameter pipe carrying oil (μ=9.8 Poise), the velocity profile (distribution) is given by: $u = -5r^2 + 0.45$ m/s, where u is velocity at radius r. Find:

a) Shear stress at pipe wall and center. b) Draw the shear stress distribution.

c) The wall shear force along a length of pipe L=5m

Solution:

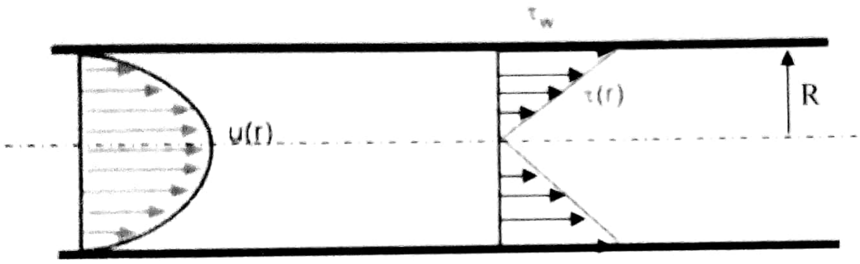
$$\mu = 0.98 \ Pa.sec$$

Shear stress $\tau = \mu \frac{du}{dy} = -\mu \frac{du}{dr} = -0.98 \times (-10\,r) = 9.8\,r$

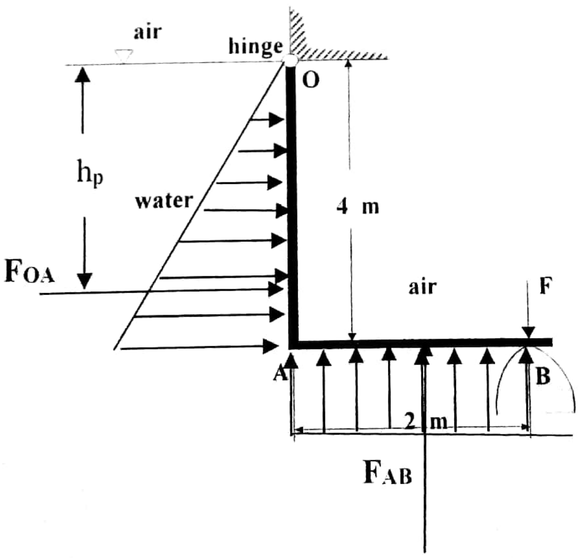
At pipe wall r=R , $\tau_w = 9.8 \times R = 9.8 \times 0.3 = 2.94$ Pa

At center of pipe r=0 , $\tau = zero$

The wall shear force= $\tau_w \times \pi d L = 2.94 \times 3.14 \times 0.6 \times 5 = 27.7\ N$



Question (2) (a) Draw the pressure distribution on the gate. (b) Calculate all the forces on the gate (3 m width) and the location of their line of action. (c) Calculate the minimum force F necessary to keep the gate closed.



Solution:

Gate OA:

h_c= 2 m , A=4×3= 12 m^2

$F_{OA}=\gamma_w$ A h_c= 9810×12×2= 235440 N

$$h_p = \frac{2}{3} \times 4 = 2.667\ m$$

Gate AB:

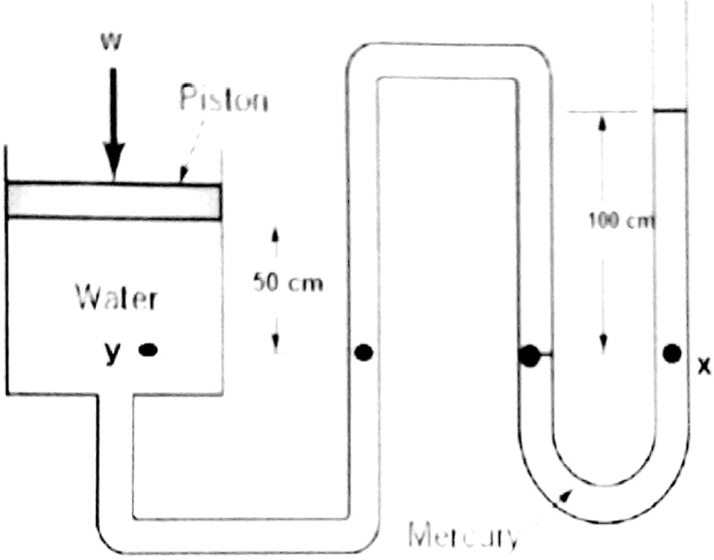
h_c=4m , A=2×3=6 m²
F_{AB}=9810×6×4=235440 N

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

$F_{OA} \times h_p + F_{AB} \times 1 = F \times 2$

F= 431679.24 N =431.68 KN

Question (3) : A piston having a cross-sectional area of 0.1 m² is located in a cylinder containing water as shown in Figure 2. An open U-tube manometer is connected to the cylinder as shown. Calculate the weight of the piston, *W*.



Solution:

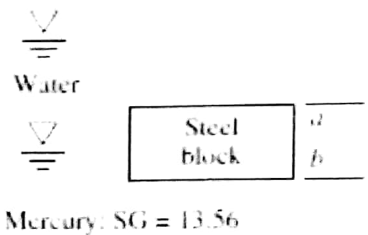
$P_X = P_Y$

$$\gamma_{hg} \times 1 = \frac{W}{A} + \gamma_w \times 0.5$$

$$13600 \times 9.81 \times 1 = \frac{W}{0.1} + 9810 \times 0.5$$

W= 12851.1 N

Question (4) A uniform block of steel (SG= 6.85) will "float" at a mercury-water interface as in Fig. 3 . What is the ratio of the distances a and b for this condition?



Solution:

$$W = F_B = F_{B,water} + F_{B,Mercury}$$

$$\rho_b \times g \times A(a+b) = \rho_{hg} \times g \times A(b) + \rho_w \times g \times A(a)$$

Divided by $\rho_w \times g \times A \times b$

$$6.85\left(\frac{a}{b}+1\right) = 13.56 + \frac{a}{b}$$

$$\frac{a}{b} = 1.147$$

Question (5) A tube can be used to discharge water from a reservoir as shown in Fig.4. Determine the speed of the free jet and the minimum absolute pressure of water that occurs at the top of the bend.

Solution:

Bernoulli's Eq.

$$\frac{P_O}{\gamma_w} + \frac{V_O^2}{2g} + Z_O = \frac{P_b}{\gamma_w} + \frac{V_b^2}{2g} + Z_b$$

$$0 + 0 + 6 = 0 + \frac{V^2}{2g} + 0$$

$$\therefore V = \sqrt{2 \times 9.81 \times 6} = 10.85\,\frac{m}{s}$$

$$Q = c_d \frac{\pi}{4} d^2 V = 0.6 \times \frac{\pi}{4} \times 0.05^2 \times 10.85$$

$$= 0.0127\,\frac{m^3}{s}$$

$$\frac{P_O}{\gamma_w} + \frac{V_O^2}{2g} + Z_O = \frac{P_a}{\gamma_w} + \frac{V_a^2}{2g} + Z_a$$

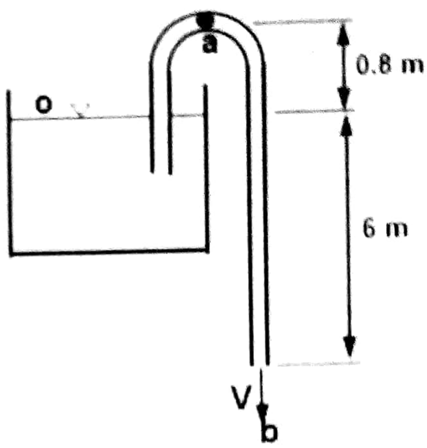
$$0 + 0 + 6 = \frac{P_a}{\gamma_w} + \frac{V^2}{2g} + 6.8$$

$$6 - 6.8 - \frac{10.85^2}{2 \times 9.81} = \frac{P_a}{9810}$$

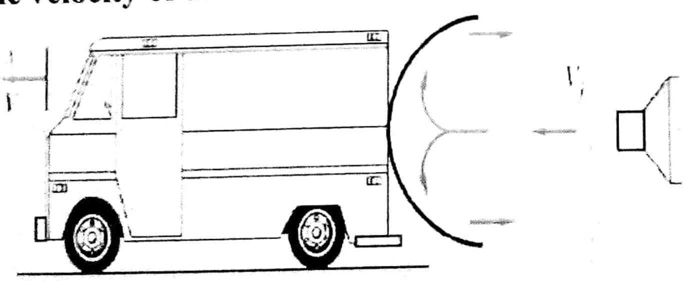
$$\therefore P_a = -66709.25\ Pa, gauge$$

$$\therefore P_a = -66709.25 + 100000$$

$$= 33290.75 Pa, absolute$$



Question (6) The model car in Fig 5. Weighs 20 N and is to be accelerated from rest by a 2-cm-diameter water jet moving at 70 m/s. Neglecting air drag and wheel friction, Estimate the velocity of the car after it has moved forward 1 m.



Solution:

$$\dot{m} = \rho_w A V_j = 1000 \times \frac{\pi}{4} 0.02^2 \times 70 = 21.98\ kg/s$$

$$\sum force = \sum_{out} mV - \sum_{in} mV$$

$$F = \dot{m} V_j - \dot{m}(-V_j) = 2\dot{m} V_j = 2 \times 21.98 \times 70 = 3077.2\ N$$

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$$F = \frac{W_{car}}{g} \times a_x$$

$$\therefore a_x = 3077.2 \times \frac{9.81}{20} = 1509.366 \frac{m}{s^2}$$

$$V_f^2 = V_i^2 + 2da_x = 0 + 2 \times 1 \times 1509.366$$

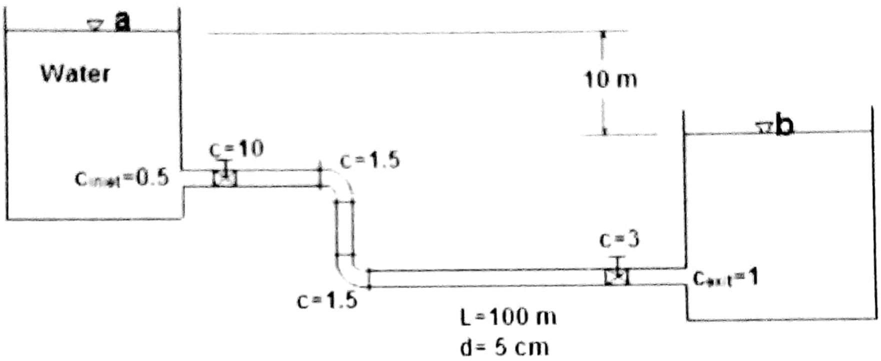
$$\therefore V_f = 54.94\ m/s$$

Question (7) [11 Marks]

a- Calculate the volume flow rate Q in the piping system shown in Fig 6.

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 80 %, and f=0.02.

Solution:



a)

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

$$0 + 0 + 10 = 0 + 0 + 0 + f\frac{L}{d}\frac{V^2}{2g} + (0.5 + 10 + 1.5 + 1.5 + 3 + 1)\frac{V^2}{2g}$$

$$10 = 0.02 \times \frac{100}{0.05} \times \frac{V^2}{2 \times 9.81} + (0.5 + 10 + 1.5 + 1.5 + 3 + 1)\frac{V^2}{2 \times 9.81}$$

$$\therefore V = 1.847\ m/s$$

$$Q = VA = 1.847 \times \frac{3.14}{4} \times 0.05^2 = 3.625 \times 10^{-3} \frac{m^3}{s}$$

b)

$$Q_{II} = 2Q = 7.25 \times 10^{-3} \frac{m^3}{s}$$

$$V_{II} = \frac{7.25 \times 10^{-3}}{\frac{3.14}{4} \times 0.05^2} = 3.694\ m/s$$

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

- $$0 + 0 + 10 + H_P = f\frac{L}{d}\frac{V_{II}^2}{2g} + (0.5 + 10 + 1.5 + 1.5 + 3 + 1)\frac{V_{II}^2}{2g}$$

$$H_P = 0.02 \times \frac{100}{0.05} \times \frac{3.694^2}{2 \times 9.81} + (0.5 + 10 + 1.5 + 1.5 + 3 + 1)\frac{3.694^2}{2g} - 10 = 29.99$$
$$= 30\ m$$

$$Power = \frac{\gamma_w Q_{II} H_P}{\eta_P} = \frac{9810 \times 7.25 \times 10^{-3} \times 30}{0.8} = 2667.09\ W = 3.624\ hp$$