Mansoura University Faculty of Engineering Dept. of Power Mech. Eng. Course Title: Fluid Mechanics		May 2016 Exam Type: Final Time: 2 hrs Full Mark: 50

Answer all the following questions.

Question (1)

a- A shaft 6.00 cm in diameter and 40 cm long is pulled steadily at V = 0.4 m/s through a sleeve 6.02 cm in diameter. The clearance is filled with oil, $\nu = 0.003\ m^2/s$ and SG = 0.88. Estimate the force required to pull the shaft. [5 Marks]

b- A manometer is attached to a pipe containing oil, as shown in Fig. (1). Calculate the pressure at point A. [5 Marks]

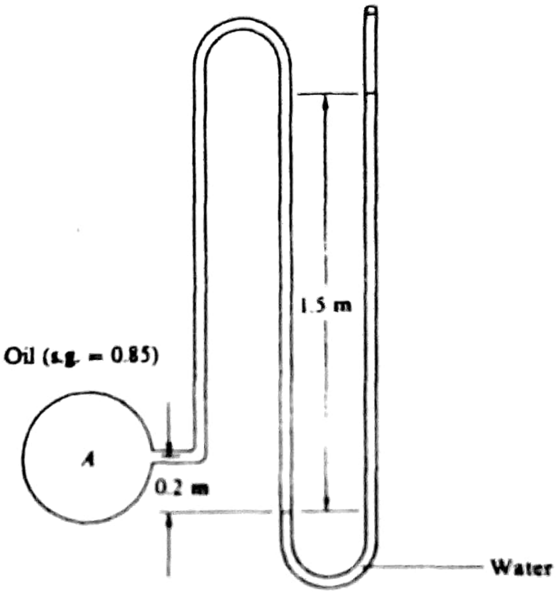


Fig. (1)

Question (2)

a- Circular gate ABC in Fig. 2 is 4 m in diameter and is hinged at B. Compute the force *P* just sufficient to keep the gate from opening when h is 8 m. [8 Marks]

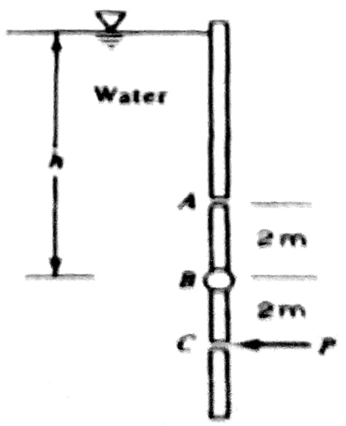


Fig. 2

P.T.O.

b- An open cylindrical tank, 2 m high and 1 m in diameter, contains 1.5 m of water. If the cylinder rotates about its geometric axis, (a) what is the maximum angular velocity can be attained without spilling any water? (b) What is the pressure at the bottom (at the center and the corner)? [8 Marks]

Question (3)

a- A velocity field is given by:

$u = 0.20+1.3x+0.85y \qquad v = -0.50+0.95x-1.3y$

1- Calculate the acceleration components at point $(x,y) = (1,2)$
2- Is this flow steady or unsteady?
3- Is this flow rotational or irrotational flow?
4- Is this flow satisfies the continuity equation? [6 Marks]

b- A Venturimeter having a throat diameter of 150 mm is installed in a horizontal 300 mm diameter water main. The coefficient of discharge is 0.982. Determine the pressure difference (in kpa) between the water main and the throat if the discharge is 0.142 m^3/sec. [8 Marks]

Question (4)

In Fig. 3, the 50 m long duct is 60 mm in diameter. Compute the flow rate if the fluid has ρ = 917 kg/m3 and μ = 0.29 Pa.s. $f = 64/Re$ [10 Marks]

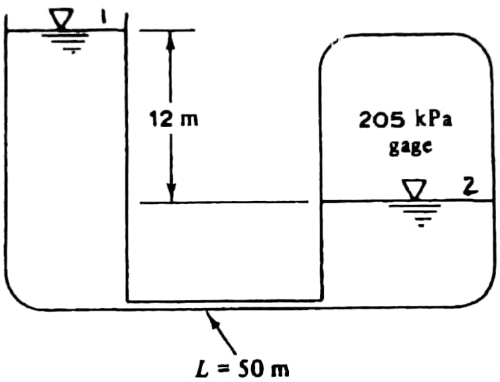


Fig. 3

Good Luck *Assoc. Prof. Mohamed Mansour*

Model Answer

1- A shaft 6.00 cm in diameter and 40 cm long is pulled steadily at V = 0.4 m/s through a sleeve 6.02 cm in diameter. The clearance is filled with oil, $\nu = 0.003\ m^2/s$ and SG = 0.88. Estimate the force required to pull the shaft.

Solution

Assuming a linear velocity distribution in the clearance, the force is balanced by resisting shear stress in the oil:

$$F = \tau A_{wall} = \left(\mu \frac{V}{\Delta R}\right)(\pi D_i L) = \frac{\mu V \pi D_i L}{R_o - R_i}$$

For the given oil,

$$\mu = \rho\nu = (0.88 \times 998\ kg/m^3)(0.003\ m^2/s) = 2.63\ N\cdot s/m^2\ (\text{or } kg/m\cdot s).$$

Then we substitute the given numerical values to obtain the force:

$$F = \frac{\mu V \pi D_i L}{R_o - R_i} = \frac{(2.63\ N\cdot s/m^2)(0.4\ m/s)\pi(0.06\ m)(0.4\ m)}{(0.0301 - 0.0300\ m)} = 795\ N$$

b- A manometer is attached to a pipe containing oil, as shown in Fig. (1). Calculate the pressure at point A. [4 Marks]

Solution

$$p_A + [(0.85)(9.79)](0.2) - (9.79)(1.5) = 0 \qquad p_A = 13.02\ kN/m^2$$

Question (2)

a- Circular gate ABC in Fig. 2 is 4 m in diameter and is hinged at B. Compute the force *P* just sufficient to keep the gate from opening when h is 8 m

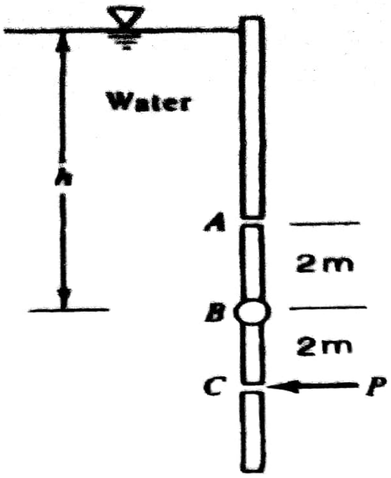


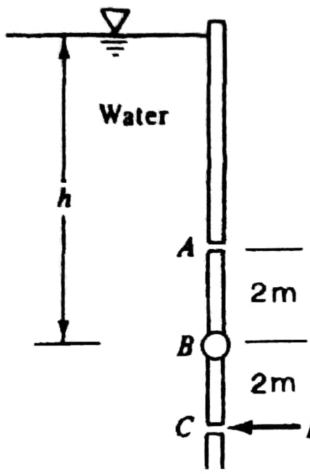
Fig. 2

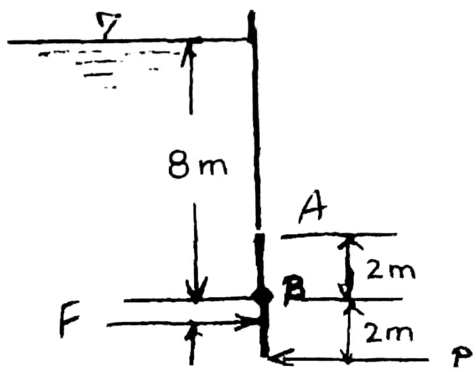
Solution

$$F = \gamma h_{cg} A = (9.79)(8)[\pi(4)^2/4] = 984.2\ \text{kN} \qquad I_{xx} = \pi d^4/64 = \pi(4)^4/64 = 12.57\ \text{m}^4$$

$$y_{cp} = \frac{-I_{xx}\sin\theta}{h_{cg}A} = \frac{-(12.57)(\sin 90^\circ)}{(8)[(\pi)(2)^2]} = -0.125\ \text{m}$$

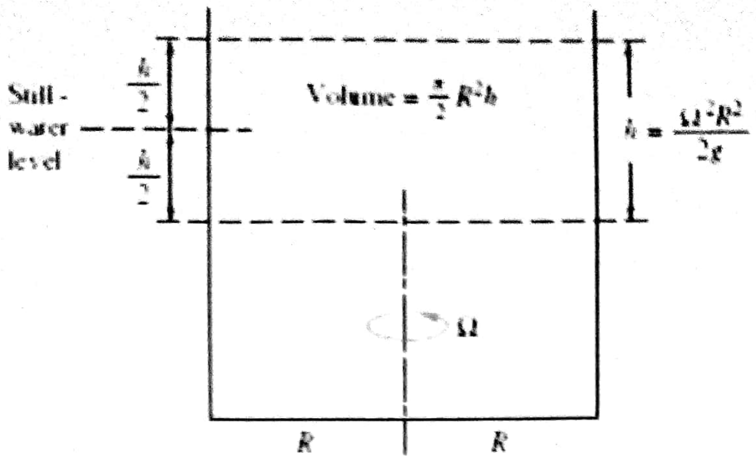
$$\sum M_B = 0 \qquad (P)(2) - (984.2)(0.125) = 0 \qquad P = 61.5\ \text{kN}$$





b- An open cylindrical tank, 2 m high and 1 m in diameter, contains 1.5 m of water. If the cylinder rotates about its geometric axis, (a) what is the maximum angular velocity can be attained without spilling any water? (b) What is the pressure at the bottom (at the center and the corner)?

Solution



(i) $h/_2 = \dfrac{\omega^2 R^2}{4g}$

$$0.5 = \frac{\omega^2 (0.5)^2}{4g}$$

ω = 8.86 rad/s

(ii) For water, ρ = 1000 kg/m^3.

P_A (at the center of the bottom) = ρ g Δz_1 = 1000*9.81*(1.5 – h/2) = 9810 Pa

P_B (at the corner of the bottom) = ρ g Δz_2 = 1000*9.8 *(1.5 + h/2) = 19620 Pa

Question (3):

b) A velocity field is given by:

$u = 0.20 - 1.3x + 0.85y \qquad v = -0.50 + 0.95x - 1.3y$

i- calculate the acceleration components at the point (x,y) = (1,2)
ii- is this flow steady or unsteady?
iii- is this flow rotational or irrotational flow?
vi- is this flow satisfies the continuity equation?

Solution

i-

$$a_x = \frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} = 0 + (0.20 + 1.3x - 0.85y)(1.3) + (-0.50 + 0.95x - 1.3y)(0.85) + 0$$

$$a_y = \frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} = 0 - (0.20 + 1.3x + 0.85y)(0.95) - (-0.50 - 0.95x - 1.3y)(-1.3) - 0$$

where the unsteady terms are zero since this is a steady flow, and the terms with w are zero since the flow is two dimensional.

Acceleration components:

$$\boxed{a_x = -0.165 + 2.4975x \qquad a_y = 0.84 + 2.4975y}$$

Acceleration components at (1,2) $a_x = 2.3325 \cong 2.33$ $a_y = 5.835 \cong 5.84$

i- The flow is steady

iii- $\xi = \partial v / \partial x - \partial u / \partial y$

$= 0.95 - 0.85 = 0.1$

Then the flow is rotational (counter clockwise)

vi- continuity equation

$\partial u/\partial x + \partial v/ \partial y = 0$

$1.3 - 1.3 = 0$

Then the flow satisfies the continuity equation

b-A Venturimeter having a throat diameter of 150 mm is installed in a horizontal 300 mm diameter water main. The coefficient of discharge is 0.982. Determine the pressure difference (in kpa) between the water main and the throat if the discharge is 0.142 m^3/sec.

Solution

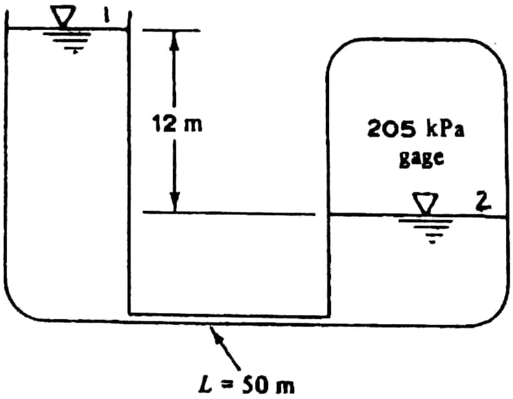
$$Q = c_d \frac{A_2}{\sqrt{1 - \left(\frac{A_2}{A_1}\right)^2}} \sqrt{2\Delta p / \rho}$$

$$= 0.982 \frac{\frac{\pi}{4}(0.15)^2}{\sqrt{1-(0.5)^4}} \sqrt{2\Delta p / 1000}$$

$$\Delta p = 35.711\ m$$

Question (4)

In Fig. 3, the 50 m long duct is 60 mm in diameter. Compute the flow rate if the fluid has ρ = 917 kg/m3 and μ = 0.29 Pa.s. [10 Marks]



Solution

Assume laminar flow from 1 to 2.

$$p_1/\rho g + v_1^2/2g + z_1 = p_2/\rho g + v_2^2/2g + z_2 + h_L$$

$$h_L = h_f = \frac{128\mu LQ}{\pi\rho g d^4} = \frac{(128)(0.29)(50)(Q)}{(\pi)(917)(9.807)(0.060)^4} = 5069Q$$

$$0 + 0 + 12 = (205)(1000)/[(917)(9.807)] + 0 + 0 + 5069Q \qquad Q = -0.002130\ \text{m}^3/\text{s} \quad \text{or} \quad -7.67\ \text{m}^3/\text{h}$$

Since Q is negative, flow is from 2 to 1.

$$v = Q/A = 0.002130/[(\pi)(0.060)^2/4] = 0.7533\ \text{m/s}$$
$$N_R = \rho dv/\mu = (917)(0.060)(0.7533)/0.29 = 143 \qquad \text{(laminar)}$$