University of Technology

Engineering Department of Building and Construction

Final Exam-First attempt 2013-2014

Subject: Fluid Mechanics
Division: All Divisions
Examiner: Fluid mechanics committee

Year: Second
Time: 3 hours.
Date :31/5/2014

Answer FIVE Questions Only

Q1: A- 1)) With reference to figure (1), show that the theoretical discharge of the open channel flow may be expressed by:- $Q = A_2\sqrt{\frac{2g(\Delta_y - h_f)}{1-(A_2/A_1)^2}}$,where A_1 and A_2 are the cross sectional areas of the flow at sections 1 and 2 respectively,hf is head losses and Δ_y is the drop in water surface between the sections. (7 Marks).

2)) State Chezy's formula. How is it derived? Also state the units of Chezy's constant in F.L.T and M.L.T dimensions. (7 Marks).

B – 1)) Define specific gravity? What is the relative density of water? Why? (3 Marks).

2)) What is the condition that causes the boiling of fluid? Explain it. (3 Marks).

Q2: A) –Fill in the blanks: - (8 Marks).

1- Surface tension is a phenomenon due to _____.

2- The piezometric head is expressed by______.

3- Cavitations will occur when the pressure is at a point _____ .

4- If a pump supplies energy to the flow the energy line _____.

5- In fully developed laminar flow in pipes the velocity distribution with radius is _____ .

6- The distance from the wall when the velocity is 99% of its asymptotic limit is known as _____ of a boundary layer.

7- The phenomenon of sudden increase in depth of flow in a channel is referred to as _____.

8- The flow depth in subcritical flow will be _____ compared to the flow depth a critical flow.

B) – Intravenous infusion usually is driven by gravity through hanging the fluid bottle at sufficient height to counteract the blood pressure in the vein and to force the fluid into the body as shown in figure (2).The higher the bottle is raised, the higher the flow rate will be. a) If it is observed that the fluid and the blood pressure balance each other when the bottle is 1.2m above the arm level, determine the gage pressure of blood. b) If the gage pressure of the fluid at the arm level needs 20KPa for sufficient flow rate, determine how high the bottle must be placed. Take the density of the fluid to be $1020 kg/m^3$. (7 Marks).

C) - How can you design a rectangular channel to obtain the minimum cost of lining? (5 Marks).

Q3: A) – Two pipes of lengths 2500m each and diameters of 80cm and 60cm respectively, are connected in parallels. The coefficient of friction for each pipe is 0.006 and the total flow is 250 liters per second. Find the rate of flow in each pipe. (8 Marks).

B) –What are the assumptions that must be considered in the derivation of Bernoulli's equation? (5 Marks).

C) – Classify the type of flow in pipes and open channels (show any necessary equations). (7 Marks).

Q4: A) – An automatic gate which will open beyond a certain head h is shown in Figure (3).Determine the ratio of h/L. Neglect the weight of the gate, friction etc.{ Consider 1 m width of the gate} (7 Marks).

B) - A pipe line is set up to draw water from a reservoir as shown in figure (4). The pipe line has to go over a barrier which is above the water level. The outlet is 8 m below water level. Determine the maximum height of the barrier if the pressure at this point should not fall below 1.0 m of water to avoid cavitations. Take atmospheric pressure equal to 10.3 m. (7 Marks).

C) – A rectangular open channel flow has energy at any section equal to $(Y+V^2/2g)$, draw the specific energy with depth and discharge with depth.(show any details required in your figures).(6 Marks).

Q5: A) - A ship having a wetted perimeter of 50 m and length of 140 m is to travel at 5 m/s. Determine the power required to overcome the skin friction. Assume kinematic viscosity $\nu = 1.4 \times 10^{-4}$ m^2/s, density 1025 kg/m^3.{ *For the range* $5 \times 10^5 > Re < 10^9$ *take* $CD = \frac{0.455}{(\log R_e L)^{2.58}} - \frac{1610}{R_e L}$ } *(6 Marks).*

B) - What will happen if we mix oil with water? Why? *(4 Marks).*

C) – A garden hose attached with a nozzle is used to fill a 0.757L/s bucket. The inner diameter of the hose is 2cm,and it reduces to 0.8cm at the nozzle exit as shown in figure(5).If it take 50 second to fill the bucket with water. Determine: a) the volume and the mass rate of water through the hose. b) the average velocity of water at the nozzle exit. *(10 Marks).*

Q6: Answer *two* of the following:-

A) – Two pipes each of length L and diameters $D_1$and D_2 are arranged in parallel, the loss of head, when a total quantity of Q flows through them, being h_1.If the pipes are arranged in series and the same quantity of water ,Q, flows through them, the loss of head is h_2.If D_1=2D_2,find the ratio of $h_1$to h_2.Neglect minor loss and friction factor ,f, to be constant. *(10 Marks).*

B) – A sluice gate across a channel 6m wide discharges a stream 1m deep as shown in figure(6). What is the flow rate when the depth upstream of the sluice is 7m? On the downstream side concrete blocks have been placed to create conditions for hydraulic jump to occur. Calculate the force on the blocks if the downstream depth is 3m.Also determine the type of flow at section 3-3.

(10 Marks).

C) – Water has to be supplied to a town with a rate of 150litre/person /day from a river 2000m away. the difference in elevation between the lowest water level in the sump and reservoir is 40m.If the demand has to be supplied in 8hours,determine the size of the main and brake horsepower of the pumps required. Assume maximum demand as 1.5times the average demand. Take f=0.03, velocity in the pipe 2.4m/s and efficiency of pump 80percent, and number of the people in this town 100000 person *(10 Marks).*

With Best Wishes For Your Success

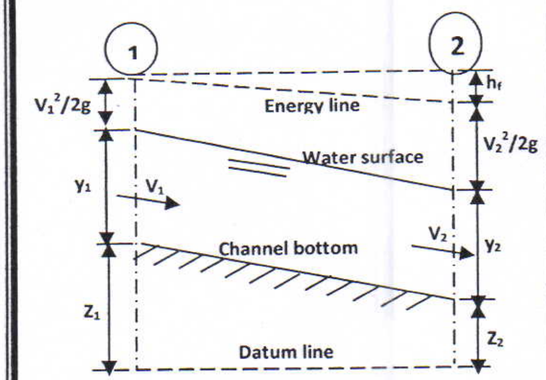


Fig. (1).

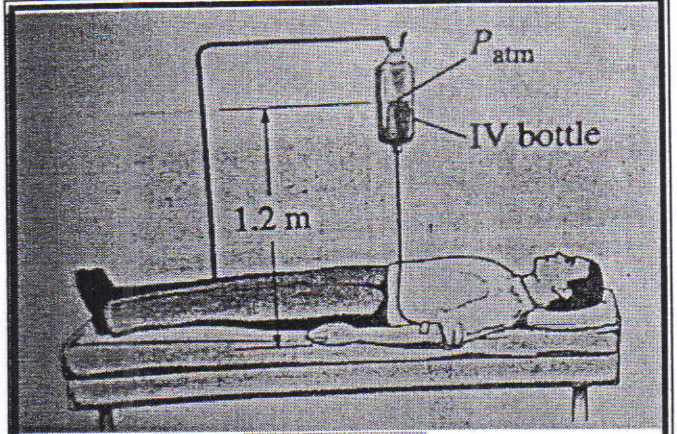


Fig. (2).

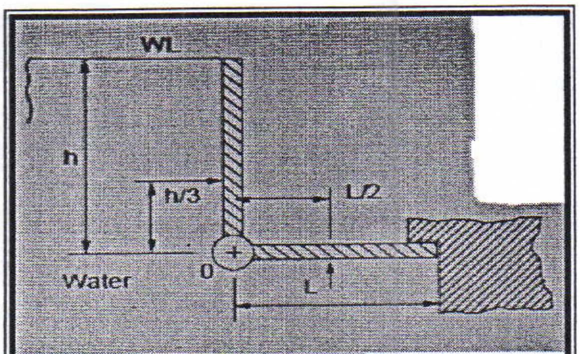


Fig. (3).

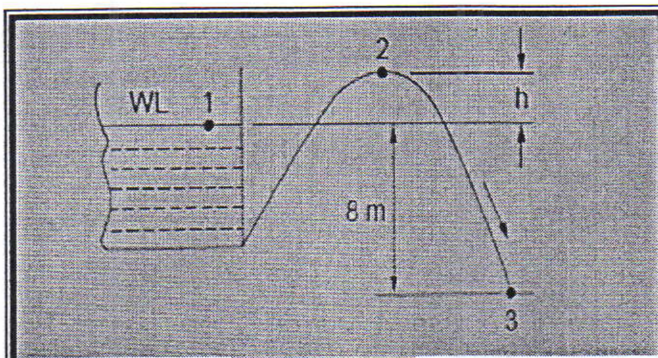


Fig. (4).

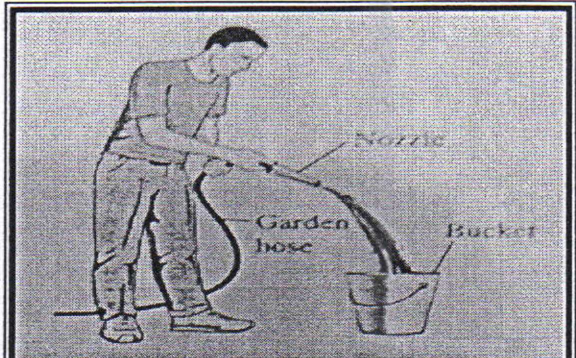


Fig. (5).

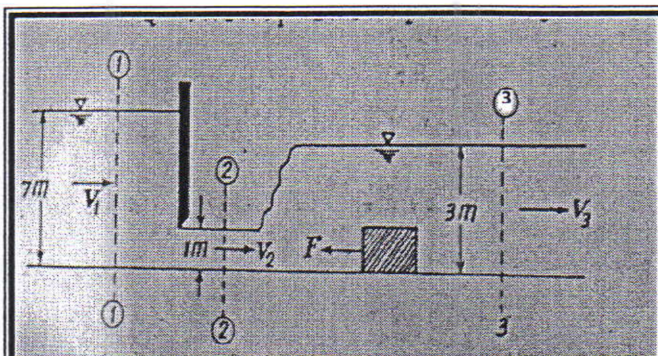


Fig. (6).

Typical Solution for Fluid Mechanics First attempt 2014

Q.1 A) ① By applying Bernoulli eq. between sec ① & ②

$$y_1 + z_1 + \frac{V_1^2}{2g} = y_2 + z_2 + \frac{V_2^2}{2g} + h_f \Rightarrow y_1 + z_1 - y_2 - z_2 - h_f = \frac{V_2^2}{2g} - \frac{V_1^2}{2g}$$

Since $\Delta y = y_1 + z_1 - y_2 - z_2$, $Q = V_1 A_1 = V_2 A_2$ [Continuity eq.]

$$\Delta y - h_f = \frac{Q^2}{2g}\left(\frac{1}{A_1^2} - \frac{1}{A_2^2}\right)$$

$$2g(\Delta y - h_f) = \frac{Q^2 (A_1^2 - A_2^2)}{A_2^2 A_1^2}$$

$$Q^2 = A_2^2 \cdot 2g(\Delta y - h_f)$$

$$\therefore \quad Q = A_2 \frac{\sqrt{2g(\Delta y - h_f)}}{1 - (A_2/A_1)^2}$$

② referred to fig(1) Applying Momentum eq. in the direction of flow

$$F_1 + A\gamma L \sin\theta - F_2 - PL\tau_o = 0$$

$$A\gamma L \sin\theta = PL\tau_o$$

Since (θ) is small so, $\sin\theta \cong \tan\theta = \frac{h_f}{L} = S_o = S_e$

$A\gamma L S_e = PL\tau_o$, So, $\tau_o = \gamma R_h S_e$

For pipe flow $\tau_o = f\rho V^2/8 = \gamma R_h S_e$

$$V = \left(\frac{8g}{f}\right)^{0.5} R_h^{0.5} S_e^{0.5}$$

let $\left(\frac{8g}{f}\right)^{0.5} = C$ friction Coeff. for open channel

$\therefore$ Chezy formula $V = C R_h^{0.5} S_e^{0.5}$

$C = (m)^{0.5}$ in M.L.T $C = L^{0.5}$

in F.L.T $C = L^{0.5}$

B) ① specific gravity is the ratio of the mass density (or weight density) of fluid to the mass (weight) density of water referred r.d or S.g
r.d for water = 1 because r.d = $\frac{\gamma_{fluid}}{\gamma_w} = \frac{9.81}{9.81} = 1$

② when the vapour pressure equal to atmospheric pressure the boiling occurs.

Q.2 A) 1. differnes in magntinde between the force due to adhesion and Cohesion.

2. $\frac{P}{\gamma}+z$ 3. goes below the vapour pressure of the fluid at that temprature.

4. will increase by a step. 5. parabolic 6. thickness

7. hydraulic Jump. 8. higher.

B) ① $P_{gage(arm)} = P_{abs} - P_{atm} = \rho g h_{(arm-bottle)}$

$= 1020 * 9.81 * 1.2 \left(\frac{1\ kN}{1000\ kg.\frac{m}{s^2}} \right) \left(\frac{1\ kpa}{1\ kN/m^2} \right)$

$= 12\ kpa.$

② $P_{gage(arm)} = \rho g h_{(arm-bottle)}$

$h_{arm-bottle} = \frac{P_{gage,arm}}{\rho g} = \frac{20}{(1020)(9.81)} \cdot \left(\frac{1000}{kN} \right) * \frac{1\ kN}{1\ kpa)}$

$= 2\ m.$

c) to design the channel to obtain in minumum cost of lining must be design the best Hydraulic Section.

$y = \frac{B}{2} \Rightarrow A = 2y \cdot y = \boxed{2y^2}$

Q.3 A) Head loss must be the same in parallel pipe

$$h_f = \frac{f . L Q^2}{12 d_1^5} = \frac{f . L Q^2}{12 d_2^5} \Rightarrow \left(\frac{Q_1}{Q_2}\right)^2 = \left(\frac{d_1}{d_2}\right)^5 = \left(\frac{0.8}{0.6}\right)^5 = 4.21$$

$$\frac{Q_1}{Q_2} = 2.05$$

Given that $Q_1 + Q_2 = 250 \ L/s = 0.25 \ m^3/s$

$2.05 Q_2 + Q_2 = 0.25 \Rightarrow Q_2 = 0.082 \ m^3/s$

$Q_1 = 0.168 \ m^3/s$

B) (1) The fluid is ideal and incomprisible

(2) the flow is study and continuous.

(3) the flow is along the stream line i.e. it is one dimension

(4) the velocity is uniform over the sec. & is equal to mean velocity.

(5) the only force acting on the fluid are the gravity force

c) in pipe (1) steady & unstey $\frac{\partial v}{\partial t} = 0$ steady, $\frac{\partial v}{\partial t} \neq 0$ unsteady

(2) uniform & non uniform $\frac{\partial v}{\partial D} = 0$ uniform

$\frac{\partial v}{\partial D} \neq 0$ non uniform

(3) laminar & turbulent $Re \leq 2100$ laminar

$4000 \geq Re > 2100$ transition

$Re > 4000$ turbulent

(4) Ideal & Real having viscosity & the second not having viscosity

in open channel (1) Study & unsteady

(2) uniform & non uniform

(3) supercritical & subcritical $Fr > 1$ supercritical

$Fr = 1$ critical

$Fr < 1$ subcritical

Q.4 A) The vertical force on the gate = $L\gamma h$ & acts at a distance $L/2$ from O.

the horizontal force on the gate = $\gamma h \cdot h/2$ & acts at $h/3$ distance from O.

Now taking moment about O

$$L\gamma h(L/2) = \gamma h(h/2)(h/3)$$
$$L^2 = h^2/3 \text{ or } L = h/(3)^{0.5} = 0.5774h$$

b) $z_3 = 0$, $z_1 = 8$, $v_1 = 0$, $P_1 = P_3$

$$8 = \frac{v_3^2}{2g} \quad \therefore v_3 = 12.53 m/s$$

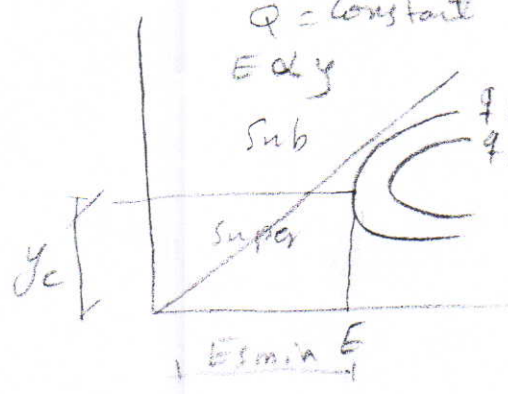
Considering the barrier top as level

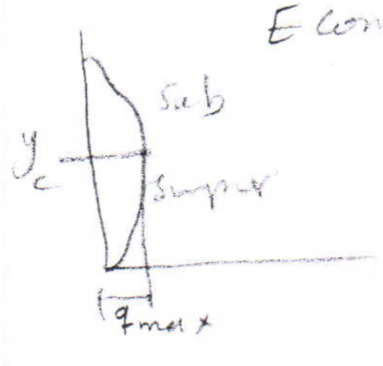
$$\frac{P_2}{\gamma} + \frac{v_2^2}{2g} + z_2 = \frac{P_3}{\gamma} + \frac{v_3^2}{2g} + z_3 \quad \text{as } v_2 = v_3, z_3 = 0 \; P_2/\gamma = 1$$

$$1 + z_2 = 10.3$$

$z_2 = 9.8m$ therefor the barrier can be 1.3 m above water level.

c)





Q.5 A) $Re = 5 * \frac{140}{1.4*10^{-6}} = 0.5*10^{9}$

$\therefore \quad CD = \frac{0.455}{(\log 0.5*10^{9})^{2.58}} - \frac{1610}{0.5*10^{9}} = 1.719*10^{-3}$

$F_D = C_D A/2\, \rho u^2 = (1.7179*10^{-3})(\frac{1}{2}) * 140*50*1025*5^2$
$= 0.154*10^{6}\ N$

power $= F_D u = 0.154*10^{6}*5 = 0.77*10^{6}$ watt

B) the oil float over the water because having a low density

c) ① volume $= 0.757 \frac{L}{sec} * 50 sec. = 37.85\ L = \boxed{0.03785 m^3}$

mass rate of flow $= 0.757 \frac{L}{s} \cdot \frac{m^3}{1000L} \cdot \rho$

$= 0.757 * \frac{1000}{1000} = \boxed{0.757 kg/s}$

② $V = \frac{Q}{A} \Rightarrow A = \frac{\pi}{4}(\frac{0.8}{100})^2 = .5027*10^{-4}$

$V = \frac{.757/1000}{.5027*10^{-4}} = \boxed{15.0 m/s}$

Q.6 A) Case (1) Pipes in parallel

$$Q = Q_1 + Q_2 \quad \text{--- (1)}$$

$$h_f = \frac{f \cdot L V^2}{D \cdot 2g} \Rightarrow V_1 = \sqrt{\frac{2gD_1h_1}{f \cdot L}}$$

$$\& \quad V_2 = \sqrt{\frac{2gD_2h_1}{f \cdot L}}$$

$$\& \quad Q_1 = \frac{\pi D_1^2}{4} V_1 = \frac{\pi D_1^2}{4} \sqrt{\frac{2gD_1h_1}{f \cdot L}}$$

$$= \frac{\pi}{4} \sqrt{\frac{2g}{f \cdot L}} D_1^{5/2} h_1^{1/2}$$

$$Q_2 = \frac{\pi}{4} \sqrt{\frac{2g}{f \cdot L}} D_2^{5/2} h_1^{1/2}$$

Sub Q_1 & Q_2 in eq (1)

$$Q = \frac{\pi}{4} \sqrt{\frac{2g}{f \cdot L}} \left[D_1^2 \sqrt{D_1 h_1} + D_2^2 \sqrt{D_2 h_1} \right] \quad \text{--- (2)}$$

Case (II) Pipes in series

$$Q = Q_1 = Q_2$$

$$\text{Head loss } h_2 = \frac{f \cdot L V_2^2}{D_2 2g} + \frac{f \cdot L V_1^2}{D_1 2g} = \frac{f \cdot L}{2g D_2}\left(\frac{4Q}{\pi D_2}\right)^2 + \frac{f \cdot L}{2g D_1}\left(\frac{4Q}{\pi D_1}\right)^2$$

$$h_2 = \left(\frac{4Q}{\pi}\right)^2 \frac{f \cdot L}{2g} \left[\frac{1}{D_1^5} + \frac{1}{D_2^5}\right]$$

$$Q = \frac{\pi}{4} \sqrt{\frac{2g}{f \cdot L}} \sqrt{\left[\frac{D_1^5 D_2^5}{(D_1^5 + D_2^5)}\right]} \sqrt{h_2} \quad \text{--- (3)}$$

بمساواة التصريف بمعادلة (2) ب (3) وتعويض

$$D_1 = 2D_2$$

$$\sqrt{\frac{h_1}{h_2}} = 0.1286$$

$$\frac{h_1}{h_2} = 0.01654$$

Q.6 B Bernoulli's eq (1) & (2) $7 + \frac{V_1^2}{2g} = 1 + \frac{V_2^2}{2g}$

From continuity eq $V_2 = 7V_1$

$$7 + \frac{V_1^2}{2g} = 1 + 49\frac{V_1^2}{2g} \Rightarrow V_1 = 1.565 \text{ m/s}$$

$$Q = 6 \times 7 \times 1.565 = 65.7$$

Applying momentum eq (2) & (3)

$$P_2 - F_1 - P_3 = \frac{\gamma Q}{g}(V_3 - V_2)$$

$$\frac{6 \times 9810(1)^2}{2} - F - \frac{6 \times 9810 \times (3)^2}{3} = \frac{9810 \times 65.7}{9.81}\left[\left(\frac{7}{3}V_1 - 7V_1\right)\right]$$

∴ **$F = 244 \times 10^3$ N $= 244$ kN**

Q.6 C Average demand $= 10{,}0000 \times \frac{150}{1000} \times \text{m}^3/\text{day} = 15000 \text{ m}^3/\text{day}$

this average demand is to be supplied in 8 hours of pumping

$$\text{Average dischg} = \frac{15000}{8 \times 60 \times 60} = 3.125 \text{ m}^3/\text{s}$$

Max. discharge $= 1.5$ average discharge $= 1.5 \times 3.125 = 4.68 \text{ m}^3/\text{s}$

$$h_f = \frac{f \cdot L\, V^2}{D \cdot 2g} = \frac{f \cdot L}{D}\frac{(4Q/\pi d^2)^2}{2g} = \frac{8 f L Q^2}{g\pi^2 d^5}$$

$$\therefore\ d = 1.222 \text{ m} \simeq 1.25$$

$$\text{brake horse power} = \frac{\eta_p\, \gamma Q H}{1000} = \frac{0.8 \times 9810 \times 4.658 \times}{1000}$$

$$= 147.66 \text{ kw}$$