

# HYDRAULICS- Coaching Notes (Nov. 2016)

## PROBLEM 11:

A triangular gate 1.20 m base and 1.80 m. high is placed on the face of a dam as shown in the figure. Its bases is hinged and the vertex is attached to a cylindrical buoy whose weight is 440 N. The external diameter of the buoy is 1.2 m. and the weight of the gate is 880 N. The mechanism is such that the buoy will open the gate if the water surface will rise higher than 4 m.

- ① Compute the hydrostatic force acting normal to the gate.
- ② Compute the location of the normal force from the hinge of the gate.
- ③ What is the length of the cable when the gate is about to open?

### Solution:

- ① Hydrostatic force:

$$P = \gamma_w \bar{h} A$$

$$P = \frac{9810(3)(1.2)(1.8)}{2}$$

$$P = 31784.4 \text{ N}$$

- ② Location of normal force:

$$e = \frac{I_g}{A \bar{y}}$$

$$e = \frac{1.2(1.8)^3/36}{\frac{1.2(1.8)}{2} (3.6)}$$

$$e = 0.05 \text{ m}$$

a, Location from the hinge = 0.65 m.

- ③ Length of cable when the gate is about to open:

$$\sum M_o = 0$$

$$880(0.60) \cos 56.4^\circ + 31784.4(0.65) = T(1.8) \cos 56.4^\circ$$

$$T = 21034 \text{ N}$$

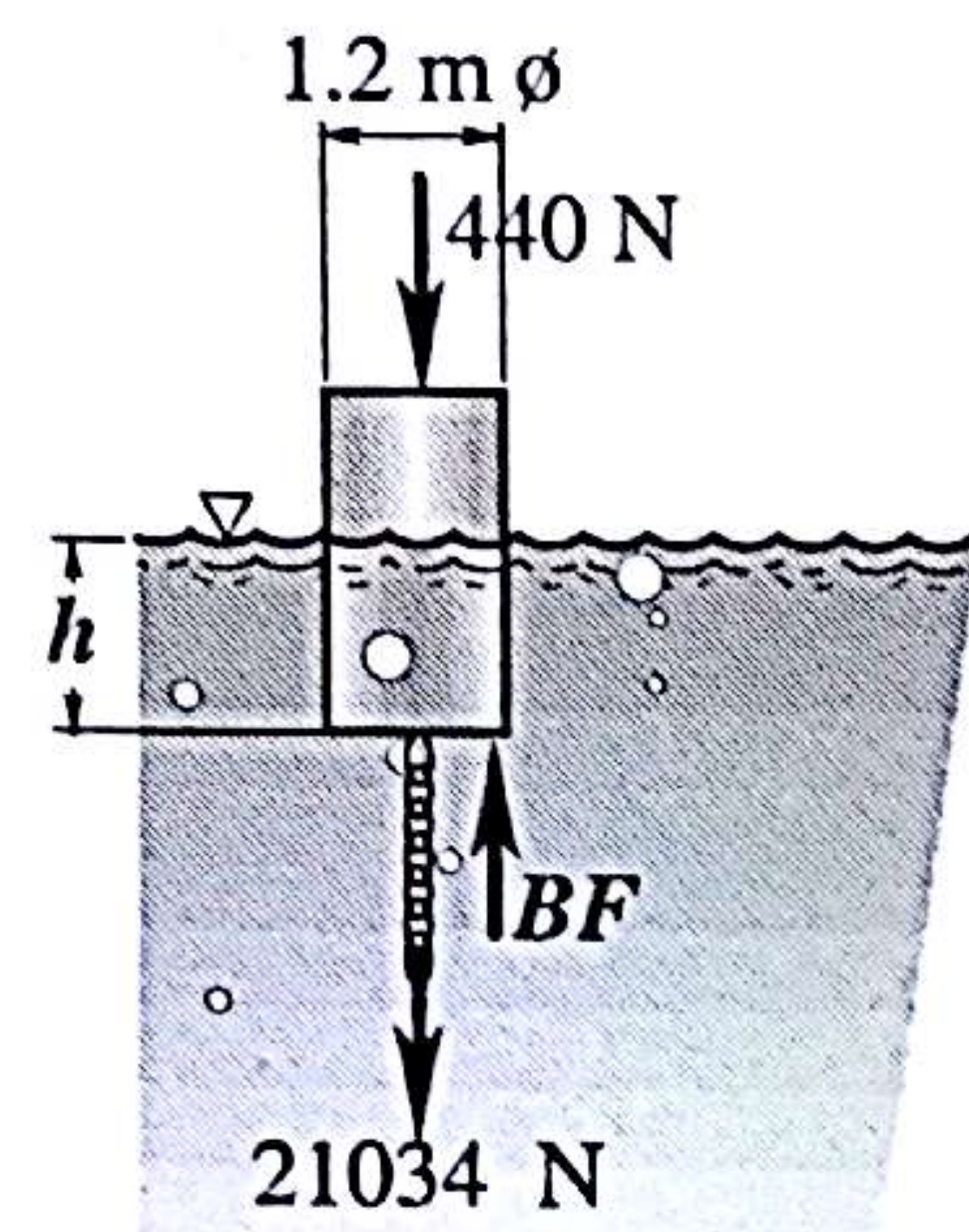
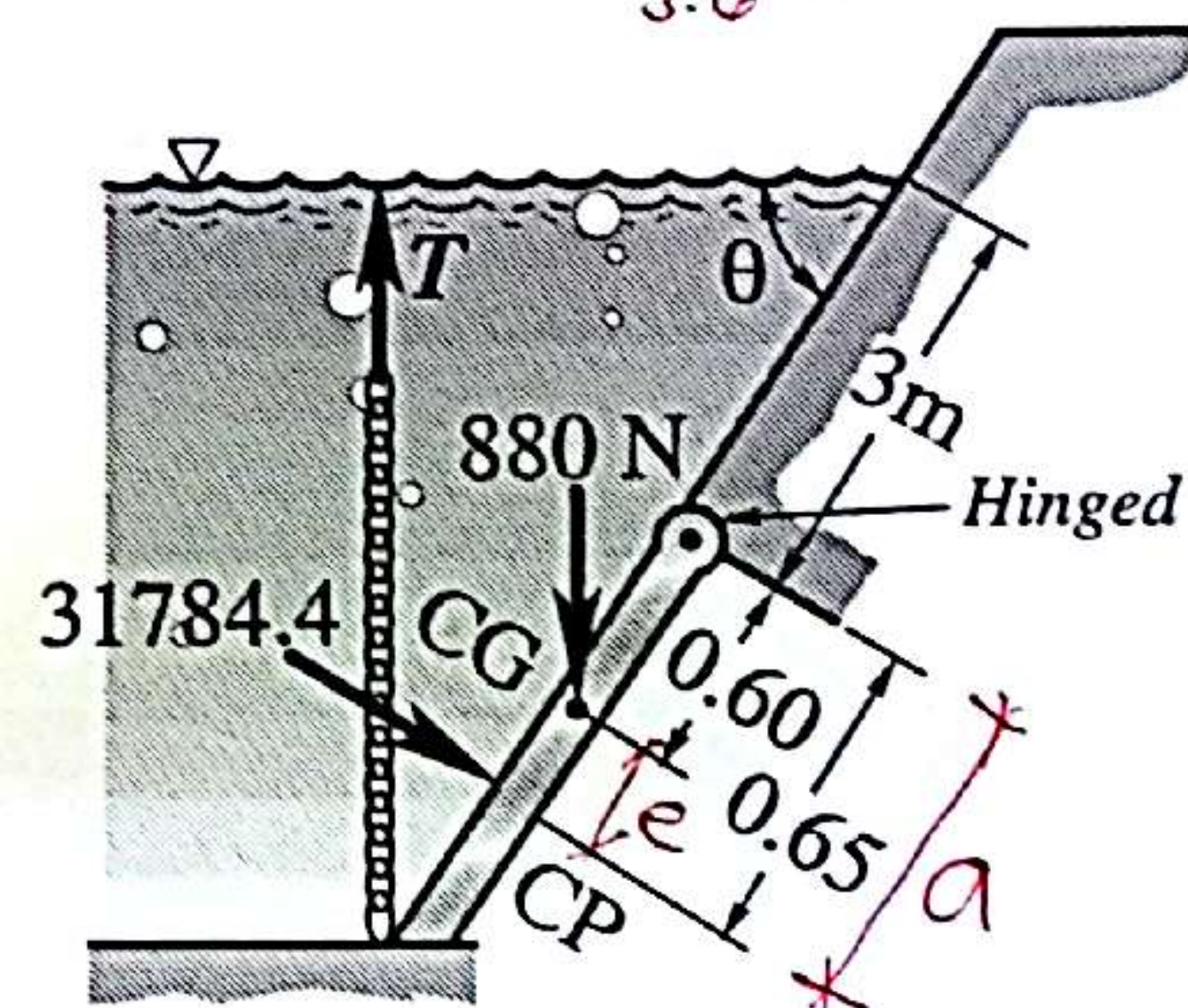
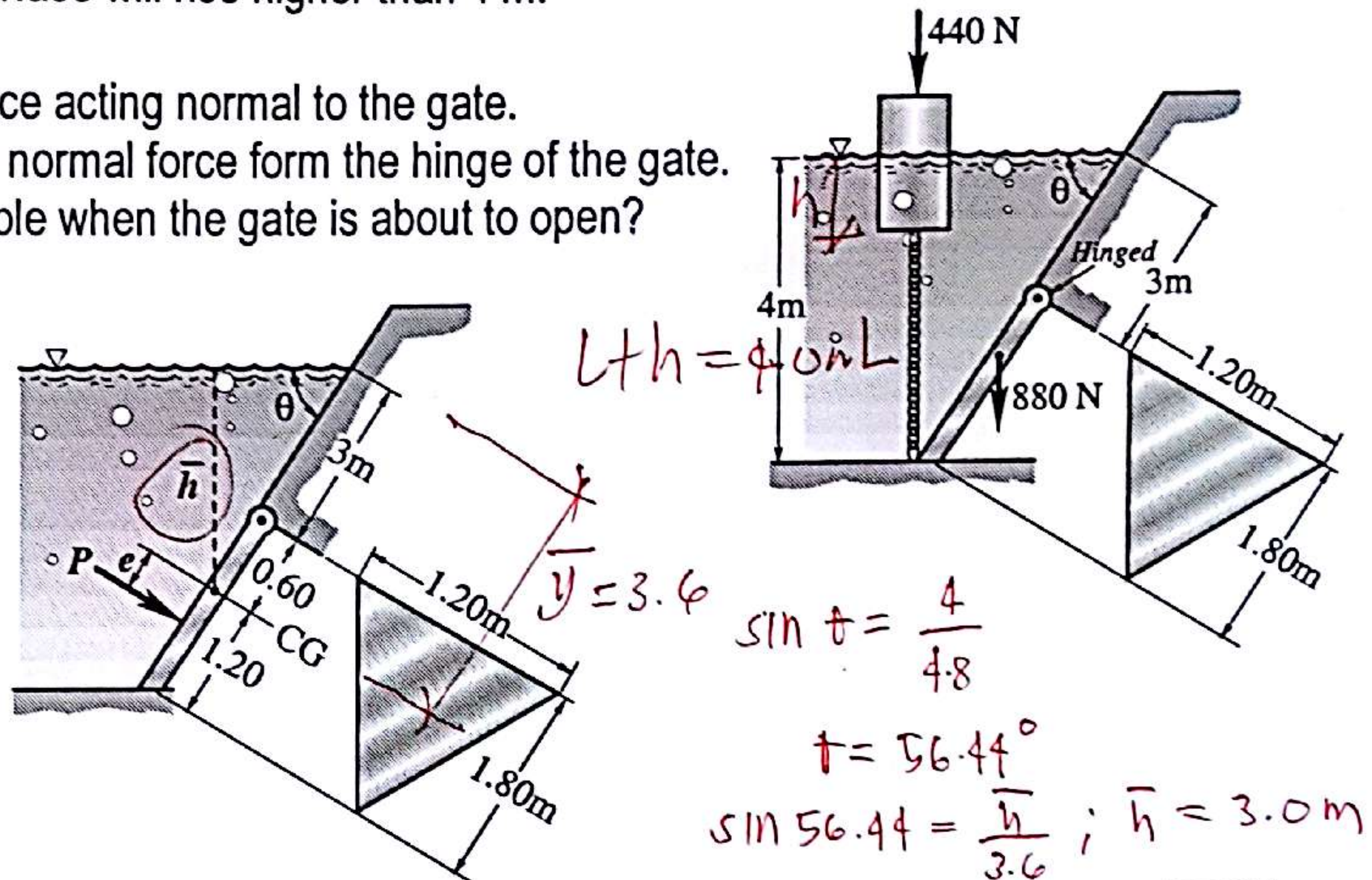
$$21034 + 440 = 9810 \left( \frac{\pi}{4} \right) (1.2)^2 h$$

$$\sum F_v = 0$$

$$h = 1.94 \text{ m.}$$

$$\text{Length of cable} = 4 - 2.06 = 1.94 \text{ m}$$

$$\text{Length of cable} = 2.06 \text{ m.}$$





## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 12:

A rectangular barge weighing 200,000 kg is 14 m long, 8 meters wide and 4.5 meters deep. It will transport to Cebu 20 mm diameter by 6 meters long reinforcing steel bars.

- ① If a draft (submerged depth of the barge) is to be maintained at 3 meters, how many pieces of the bars can it carry if density of salt water equal to 1026 kg/m<sup>3</sup> and steel weighs 7850 kg/m<sup>3</sup>.
- ② What is the draft from the barge when one half of its cargo is unloaded in fresh water?
- ③ If the draft of the barge in fresh water is equal to 2 m., determine the number of bars that it can carry.

#### Solution:

- ① Pieces of bars:

$x = \text{no. of bars}$

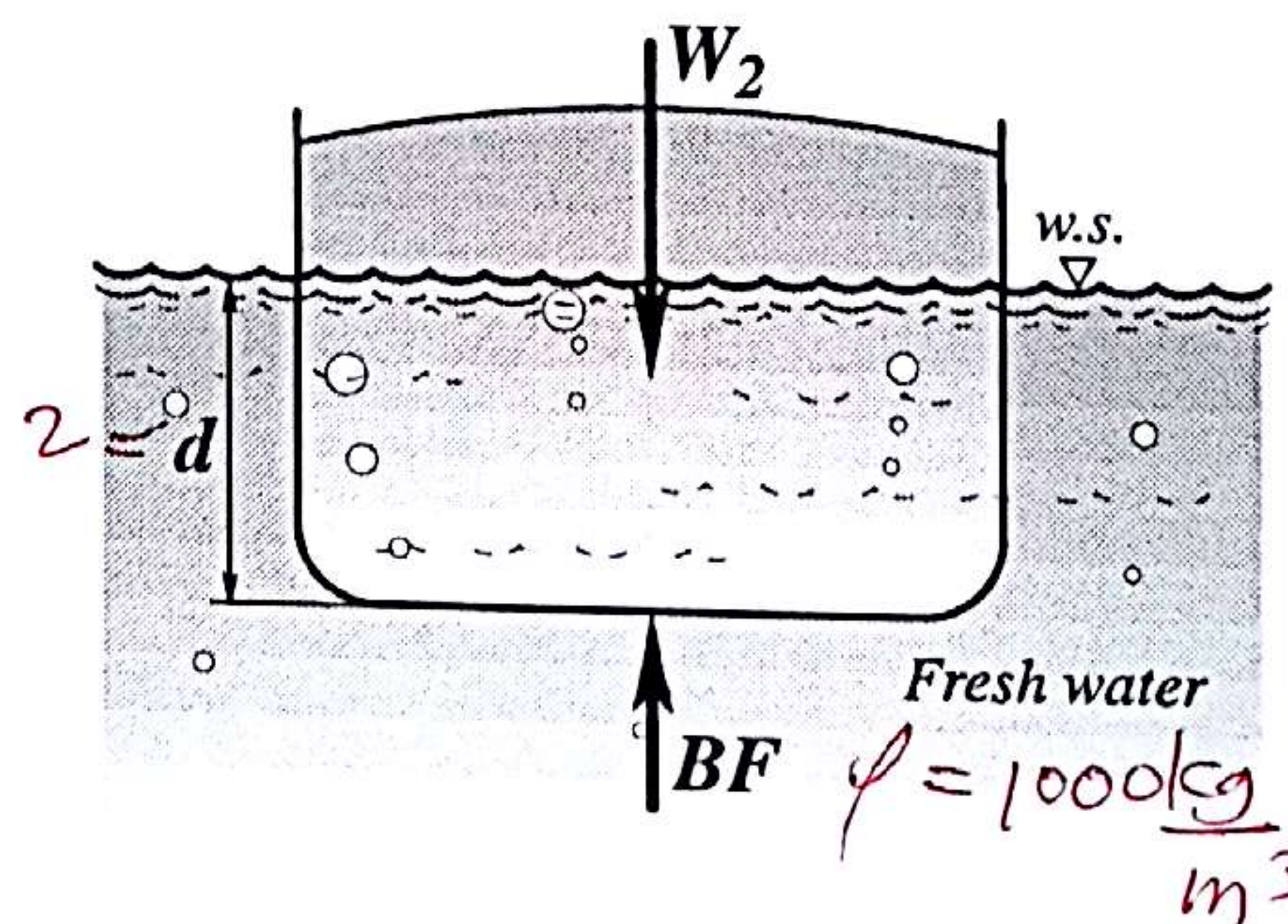
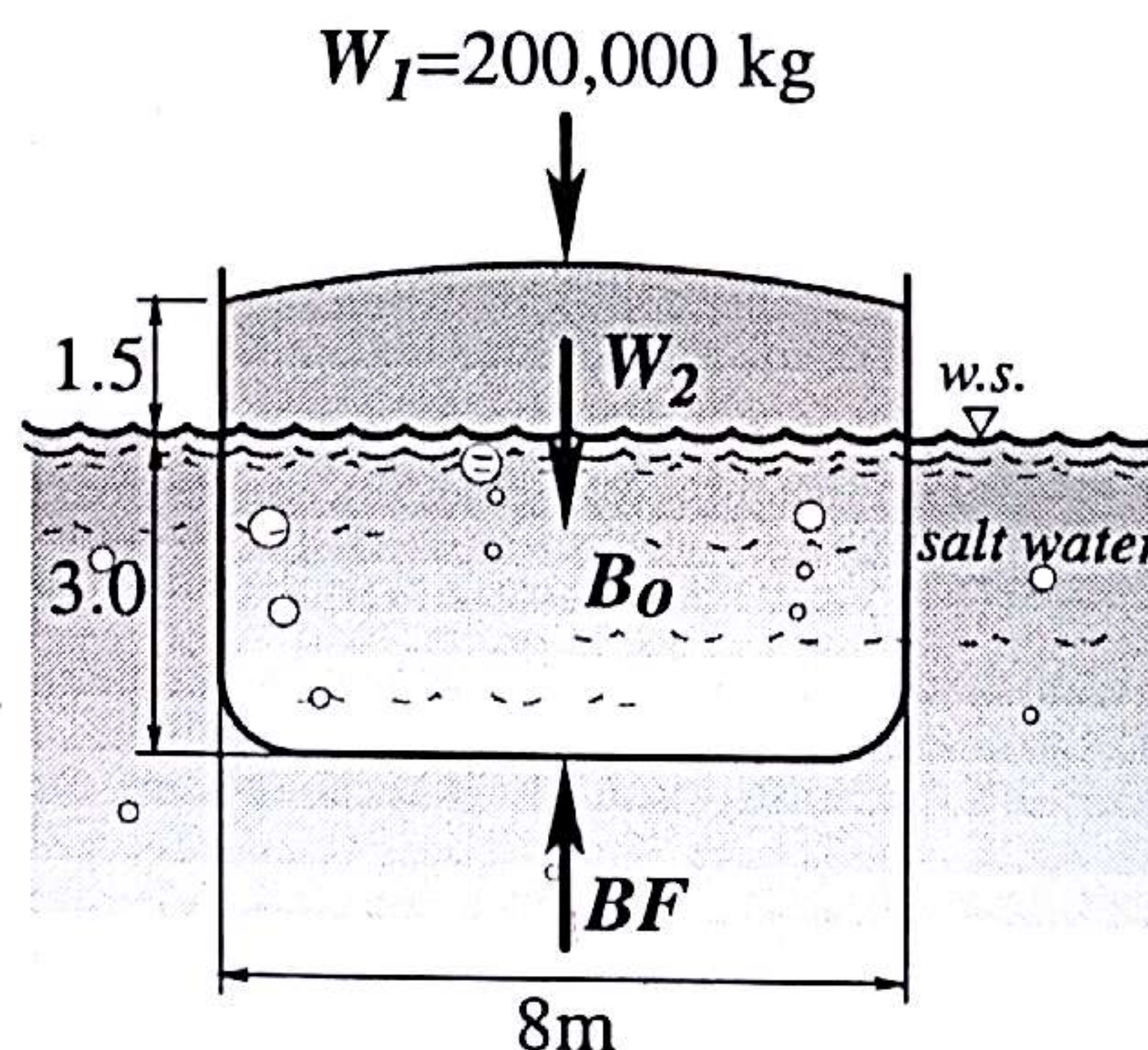
$$W_2 = \frac{\pi(0.02)^2}{4} (6)(7850) x$$

$$W_2 = 14.79 x \text{ kg (wt. of steel bars)}$$

$$W_1 + W_2 = BF \quad \sum F_v = 0$$

$$200,000 + 14.79x = 3(8)(14)(1026)$$

$$x = 9786 \text{ no. of bars} \quad \checkmark$$



- ② Draft from the barge:

$$\text{Total weight} = W_1 + W_2$$

$$W = 200,000 + 14.79(9786)$$

$$W = 200,000 + 144736$$

$$W = 344736 \text{ kg (total weight)}$$

When the barge is at the fresh water the total weight is only  $W_2$ .

$$W_2 = 200,000 + \frac{144736}{2}$$

$$W_2 = 272368 \text{ kg} \quad \checkmark$$

$$B.F. = W_2 = 272368 \quad \sum F_v = 0$$

$$272368 = d(8)(14)(1000)$$

$$d = 2.43 \text{ m. (draft in fresh water)} \quad \checkmark$$

- ③ Number of bars that it can carry:  $W_2$

$$(2)(8)(14)(1000) = 200,000 + 14.79x$$

$$x = 1623 \text{ bars} \quad \checkmark$$



## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 13:

A rectangular barge weighing 200000 kg is 14 m long, 8 m. wide and 4.5 m deep. It will transport to Manila 20 mm diameter; 6 m. long steel reinforcing bars having a density of 7850 kg/m<sup>3</sup>. Density of salt water is 1026 kg/m<sup>3</sup>.

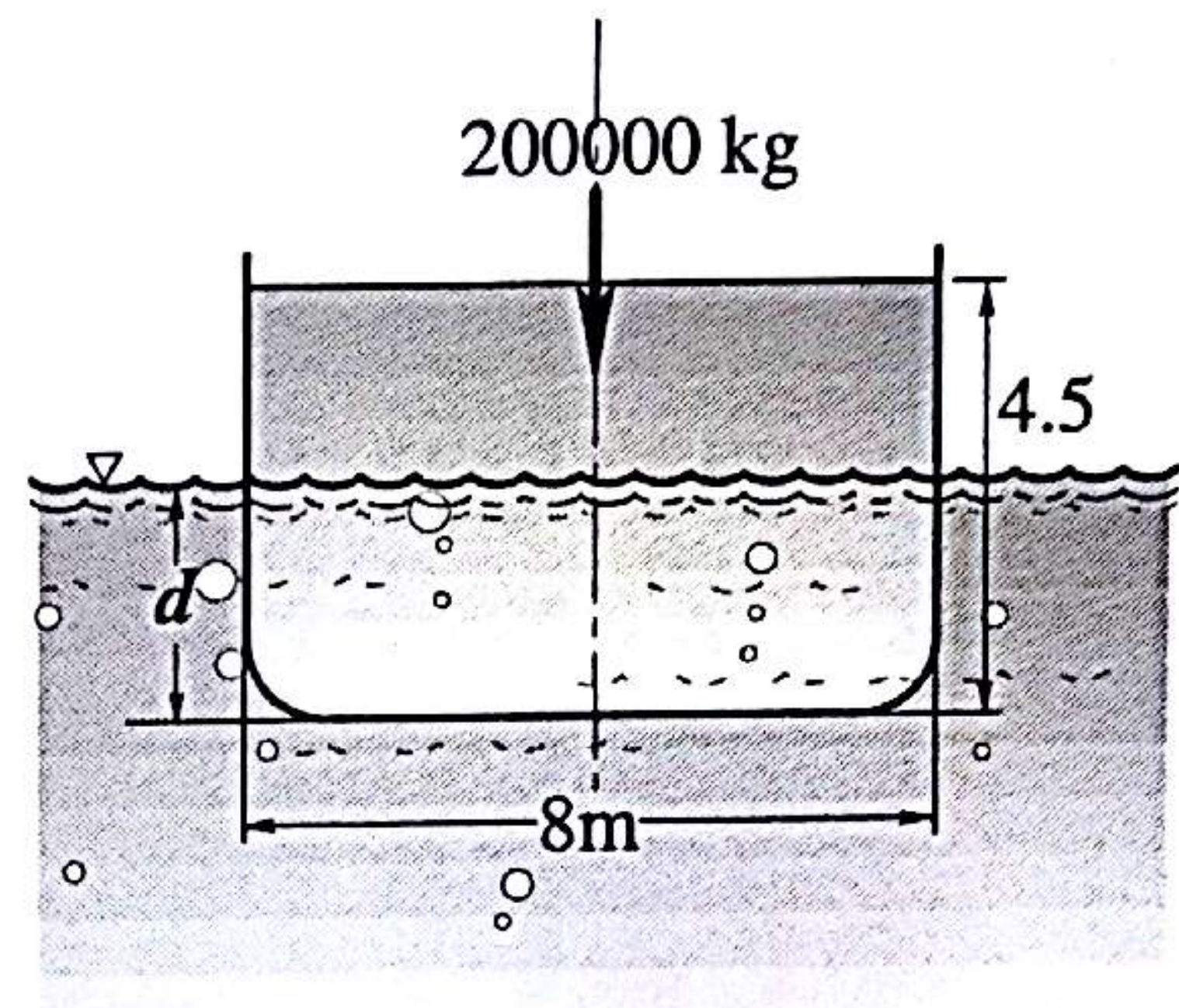
- ① Det. the draft of the barge on sea water before the bars was loaded.
- ② If a draft is to be maintained at 3 m., how many pieces of steel bars could it carry?
- ③ What is the draft of the barge when one half of its cargo is unloaded in fresh water?

### Solution :

- ① Draft of empty barge on sea water:

$$200000 = 14(8)(d)(1026)$$

$$d = 1.74 \text{ m.} \quad \checkmark$$



- ② No. of bars loaded:

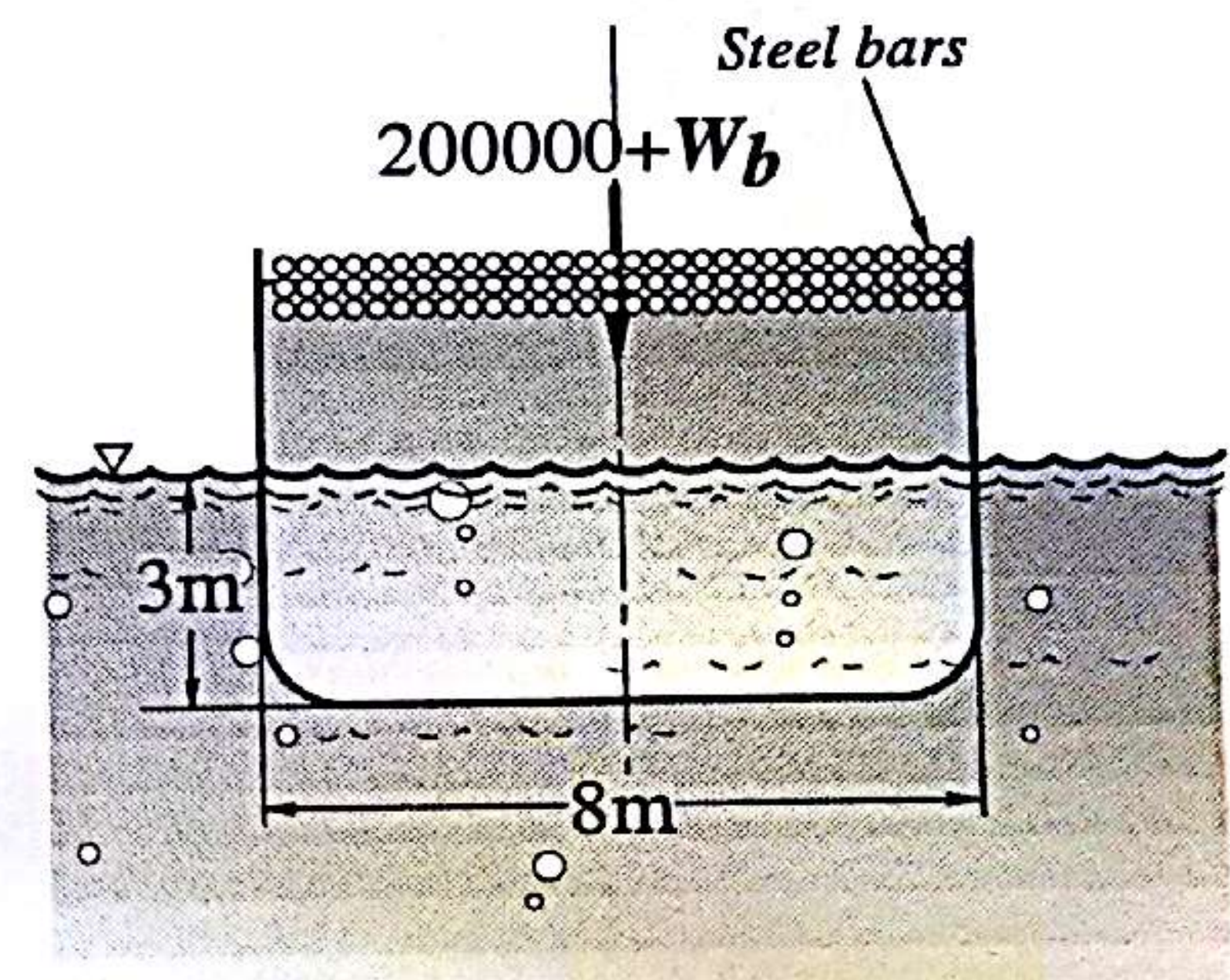
$$8(14)(3)(1026) = 200000 + W_b$$

$$W_b = 144736 \text{ kg} \quad \checkmark$$

$$W_b = \frac{\pi}{4} (0.02)^2 (6) N (7850)$$

$$144736 = \frac{\pi}{4} (0.02)^2 (6) (7850) N$$

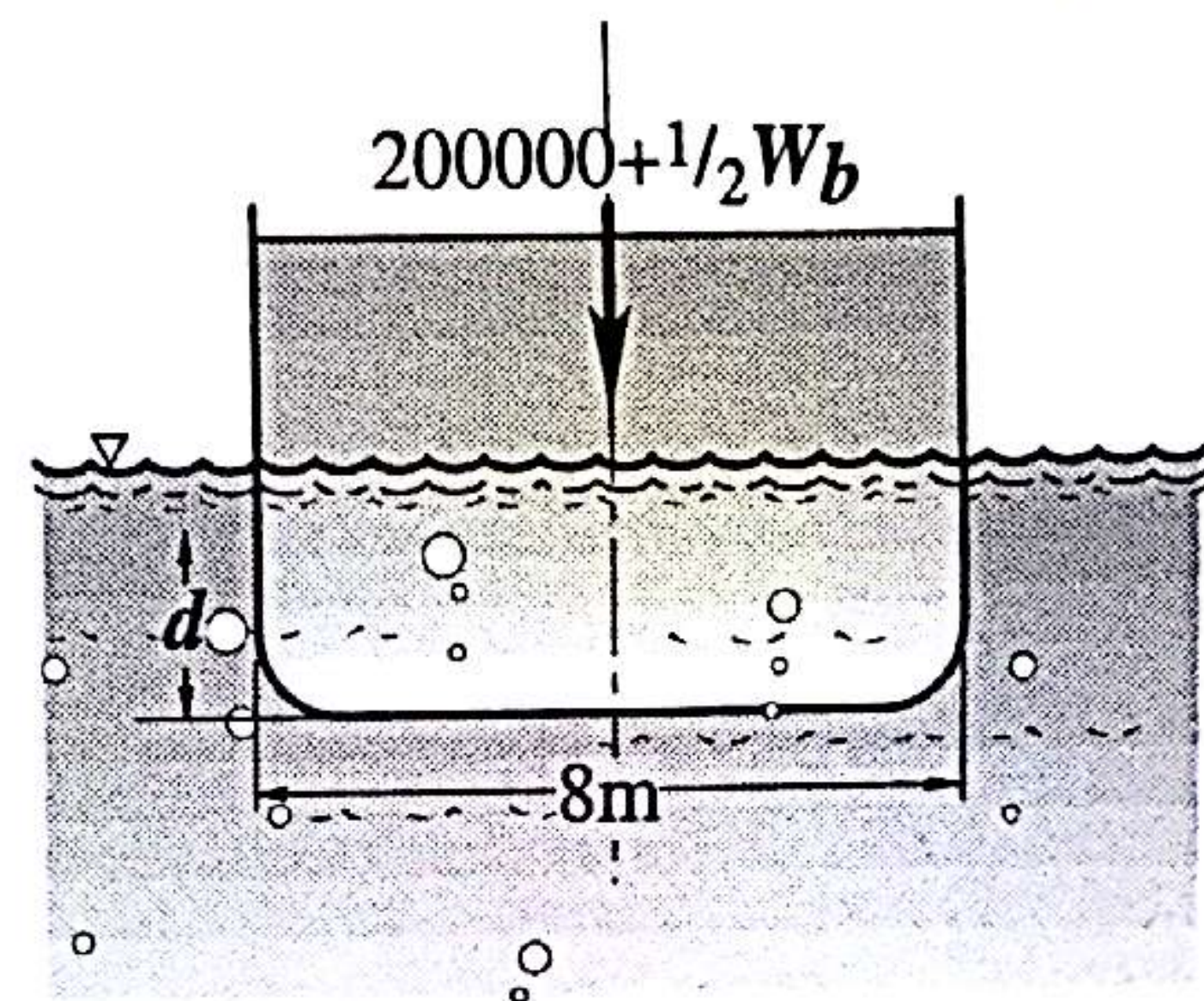
$$N = 9782 \text{ bars} \quad \checkmark$$



- ③ Draft of barge on fresh water when one half of its cargo is unloaded:

$$200000 + \frac{1}{2} (144736) = 8(14)(d)(1000)$$

$$d = 2.43 \text{ m.} \quad \checkmark$$





## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 14:

A triangle having a base of 1.20 m and altitude of 1.8 m wholly immersed in water, its base being in the surface and its plane vertical. If the triangle will be divided by a horizontal line through its center of pressure.

- ① Find the pressure on the lower area of the triangle.
- ② Find the pressure on the upper area of the triangle.
- ③ Find the ratio between the pressures on the two areas of the triangle.

#### Solution:

- ① Pressure on the lower area of the triangle.

$$e = \frac{I_g}{S_s}$$

$$e = \frac{I_g}{A\bar{y}}$$

$$I_g = \frac{(1.2)(1.8)^3}{36}$$

$$I_g = 0.1944 \text{ m}^4$$

$$S_s = \frac{(1.2)(1.8)}{2} (0.6)$$

$$S_s = 0.648 \text{ m}^3$$

$$e = \frac{0.1944}{0.648}$$

$$e = 0.3 \text{ m}$$

$$\frac{1.2}{1.8} = \frac{x}{0.9} \quad \text{By R\&P:}$$

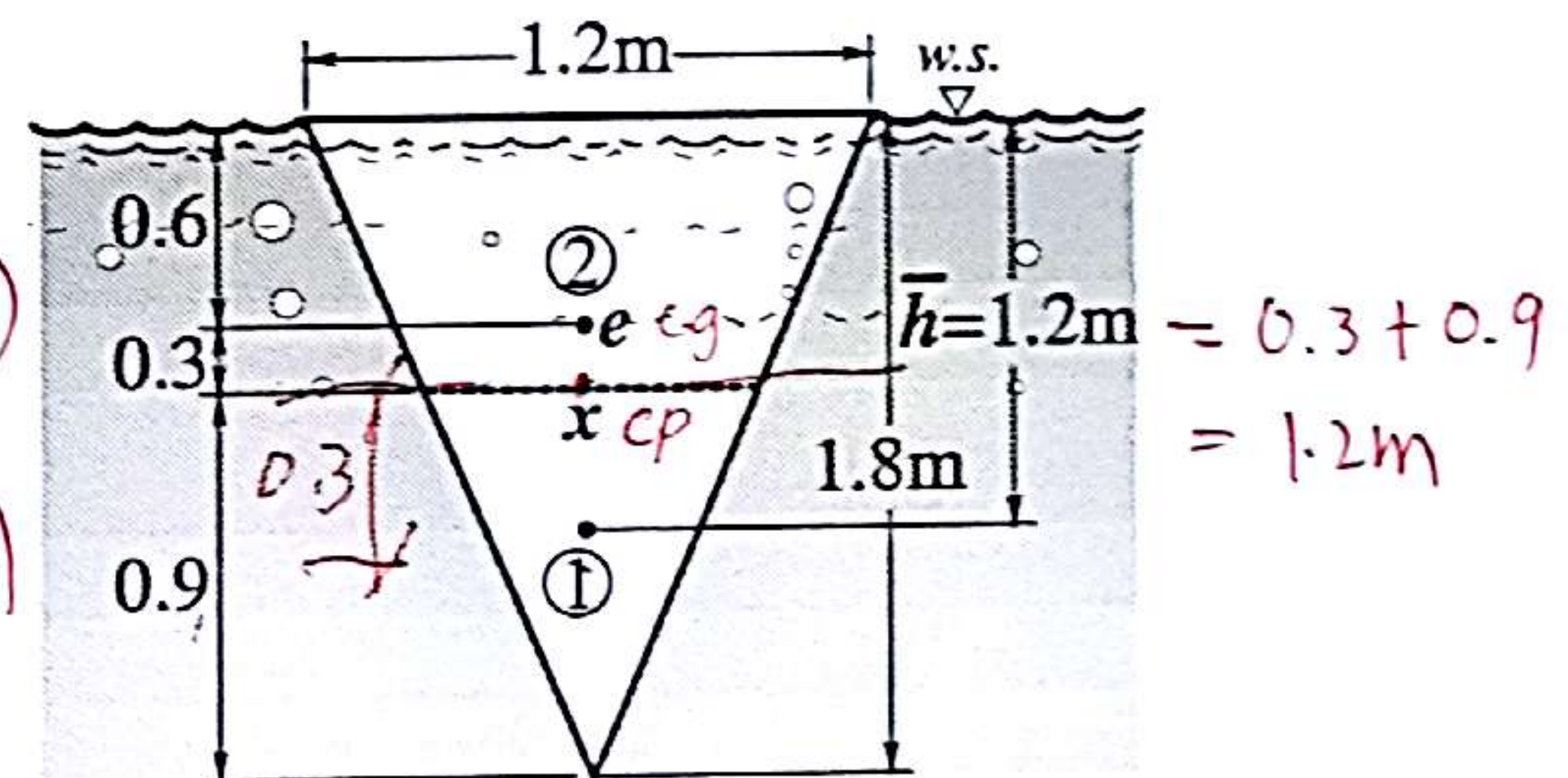
$$x = 0.6 \text{ m}$$

$$P_1 = \gamma \bar{h} A$$

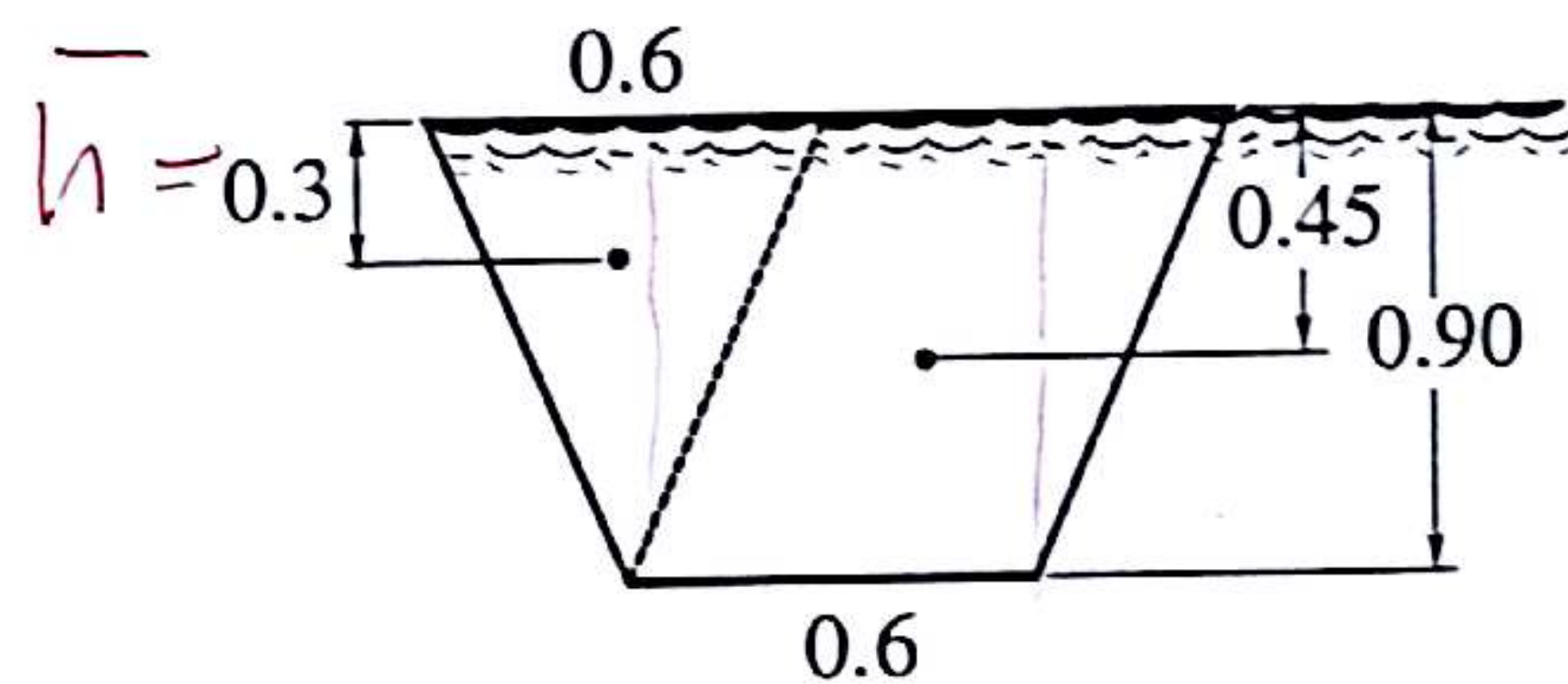
$$P_1 = 0.324 \gamma$$

$$P_1 = 0.324(9.81)$$

$$P_1 = 3.18 \text{ kN}$$



$$\bar{h}_1 = 0.9 + 0.3 = 1.2 \text{ m}$$



- ② Pressure on the upper area of the triangle.

$$P_2 = \gamma(0.45)(0.6)(0.9) + \gamma(0.3) \frac{0.9(0.6)}{2}$$

$$P_2 = 0.324 \gamma$$

$$P_2 = 0.324(9.81)$$

$$P_2 = 3.18 \text{ kN}$$

- ③ Ratio between the pressures on the two areas of the triangle.

$$\frac{P_1}{P_2} = \frac{0.324 \gamma}{0.324 \gamma} = 1$$



## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 15:

A vertical rectangular gate as shown is 2 m. wide, 6 m. high is hinged at the top, has oil (sp.gr. = 0.84) standing 7 m. deep on one side, the liquid surface being under a pressure of -18.46 kPa.

- ① Compute the hydrostatic force acting on the gate.
- ② How far is the force acting below the hinged.
- ③ How much horizontal force applied at the bottom is needed to open the gate.

### Solution :

- ① Force on the liquid on the gate:

$$h \text{ equivalent} = \frac{18.46}{9.81(0.84)}$$

$$h \text{ equivalent} = 2.24 \text{ m.}$$

$$P = \gamma h A$$

$$P = 9.81(0.84)(1.76)(2)(6)$$

$$P = 174.04 \text{ kN}$$

- ② Location of force below the hinged:

$$e = \frac{I_g}{A h}$$

$$e = \frac{(2)(6)^3/12}{2(6)(1.76)}$$

$$e = 1.705$$

$$\text{Location of force below hinged} = 3 + 1.705$$

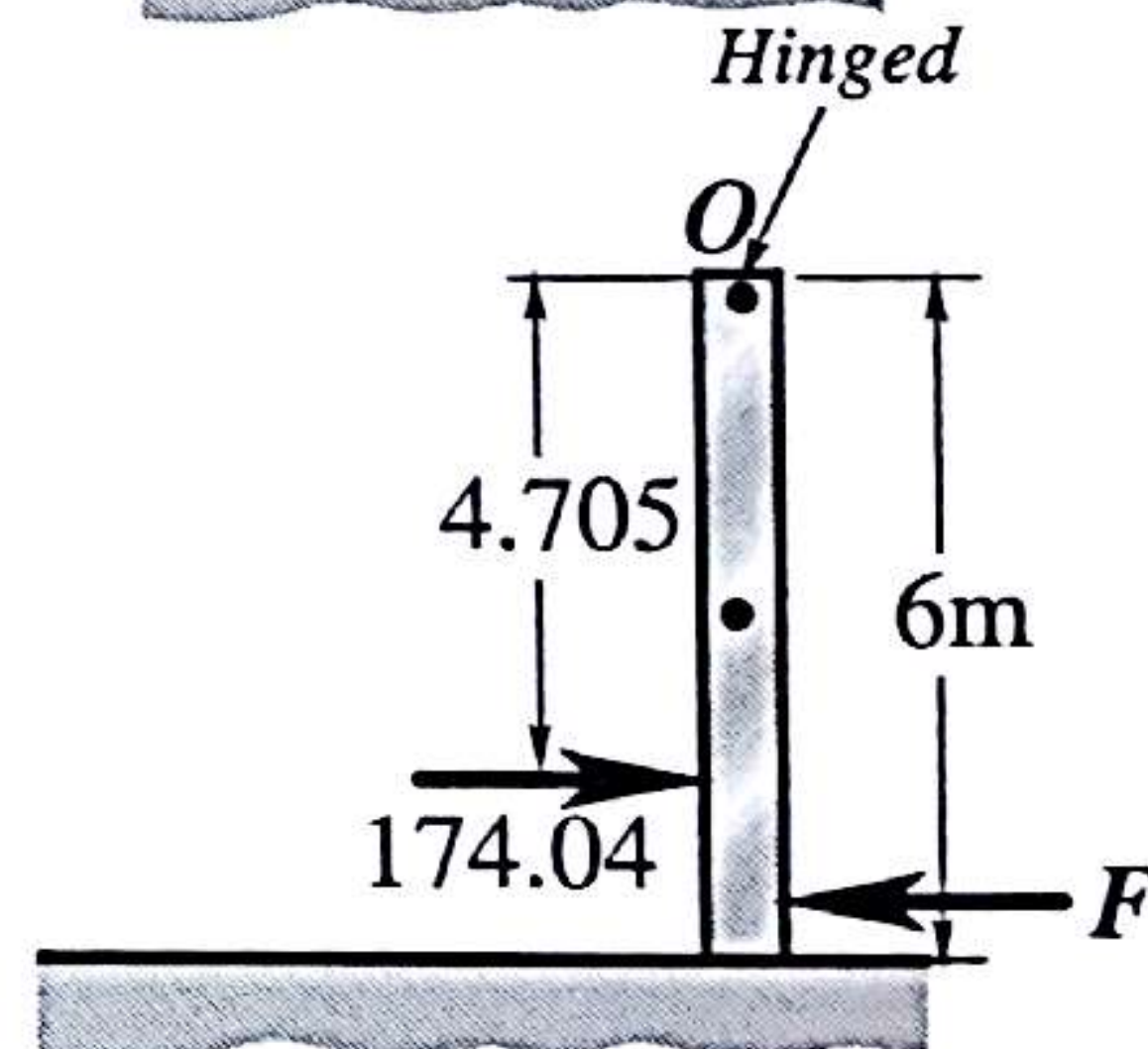
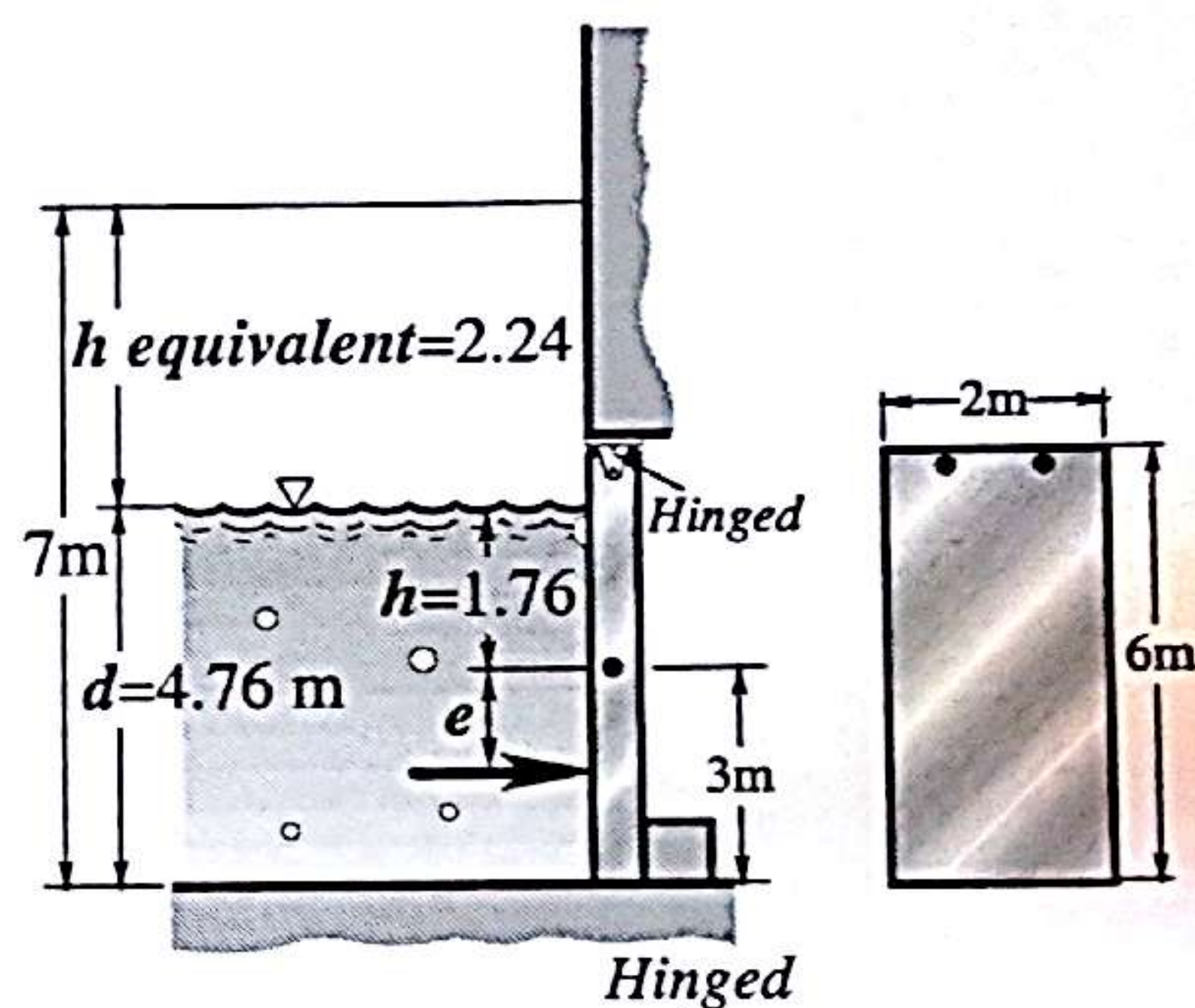
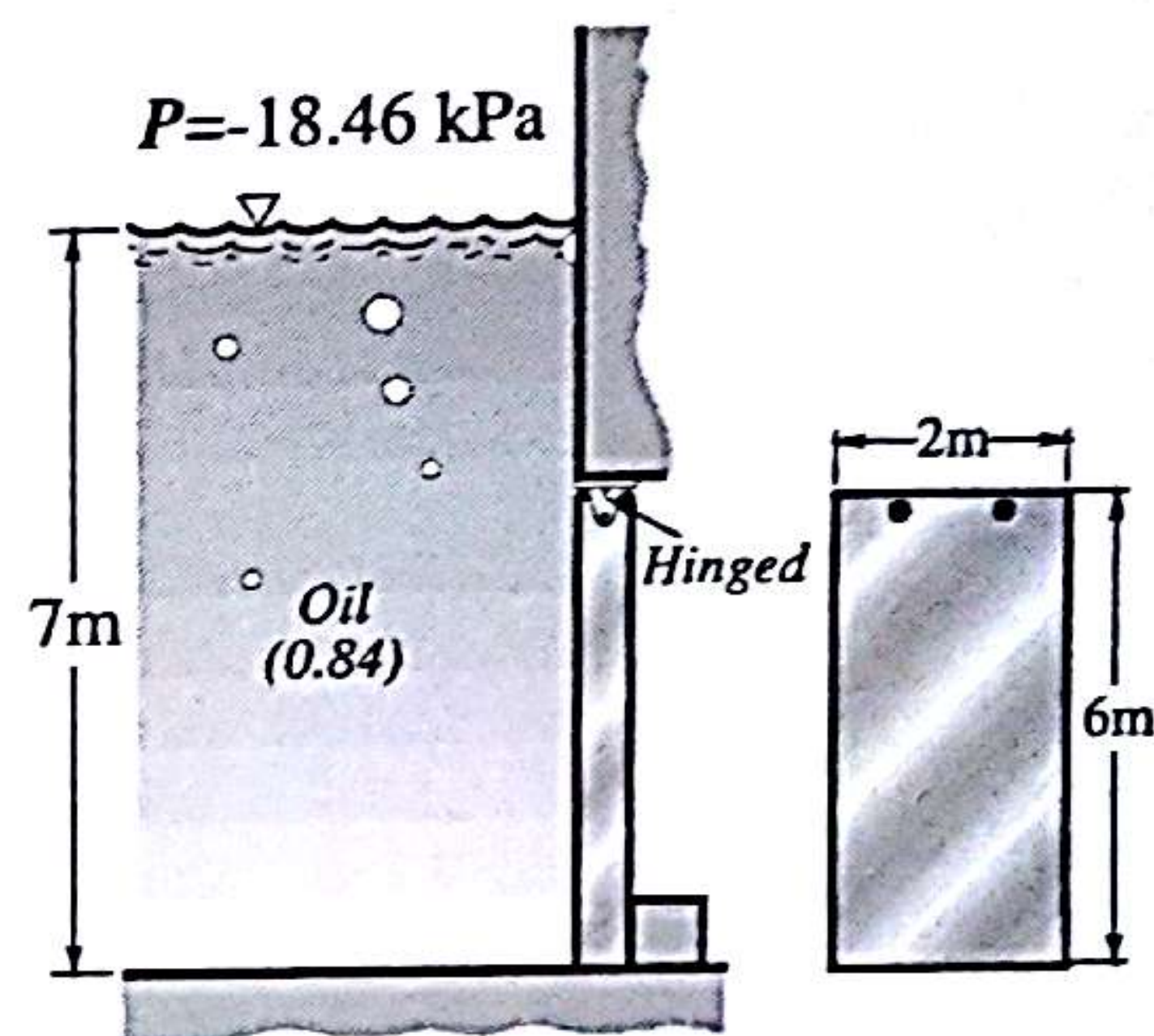
$$\text{Location of force below hinged} = 4.705 \text{ m.}$$

- ③ Horizontal force needed to open the gate:

$$\sum M_o = 0$$

$$F(6) = 174.04 (4.705)$$

$$F = 136.48 \text{ kN}$$





# HYDRAULICS- Coaching Notes (Nov. 2016)

## PROBLEM 16:

A rectangular channel 5.6 m. wide by 1.2 m. deep is lined with a smooth stone, well laid and has a hydraulic slope of 0.002. Using  $n = 0.013$ .

- ① What is the capacity of the channel in  $m^3/s$ .
- ② What savings in earth excavation could have been offered by using more favorable proportions but adhering to the same delivery and slope.
- ③ What savings in lining per meter length by using more favorable proportions but adhering to the same delivery and slope?

### Solution:

- ① Capacity of channel:

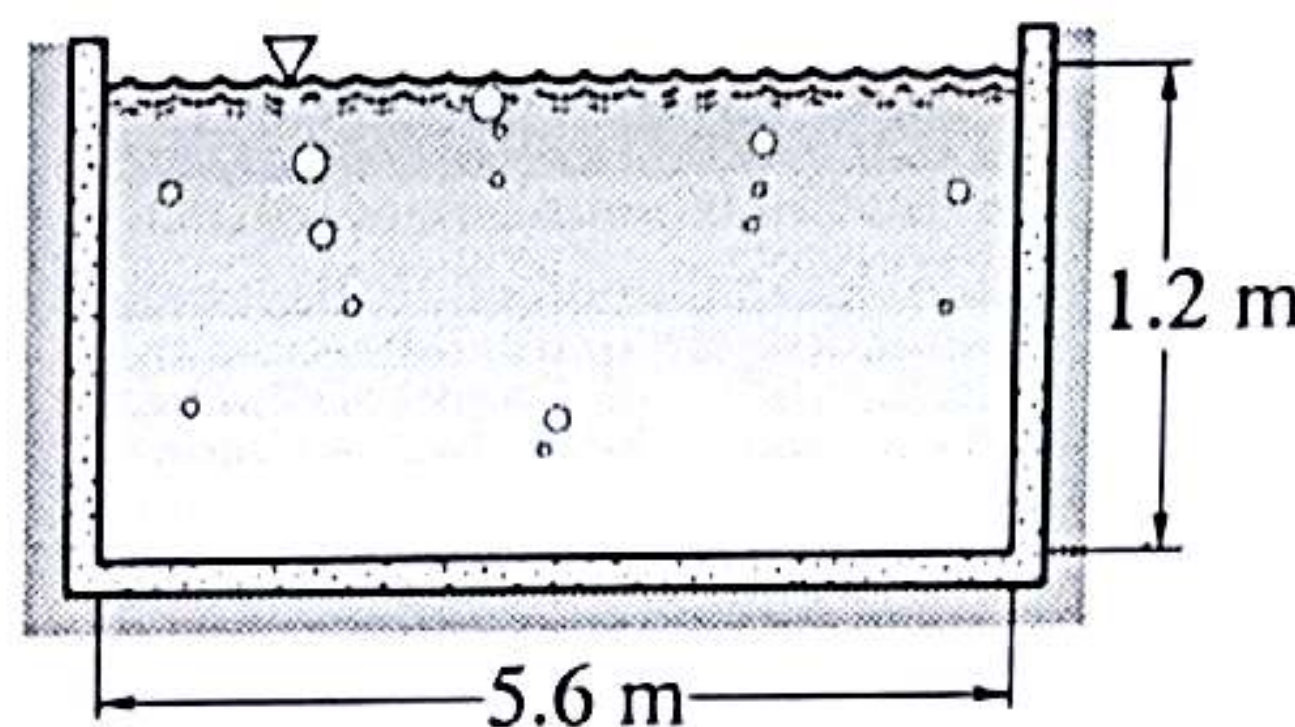
$$A = 5.6(1.2) = 6.72 \text{ m}^2$$

$$P = 1.2(2) + 5.6 = 8 \text{ m.}$$

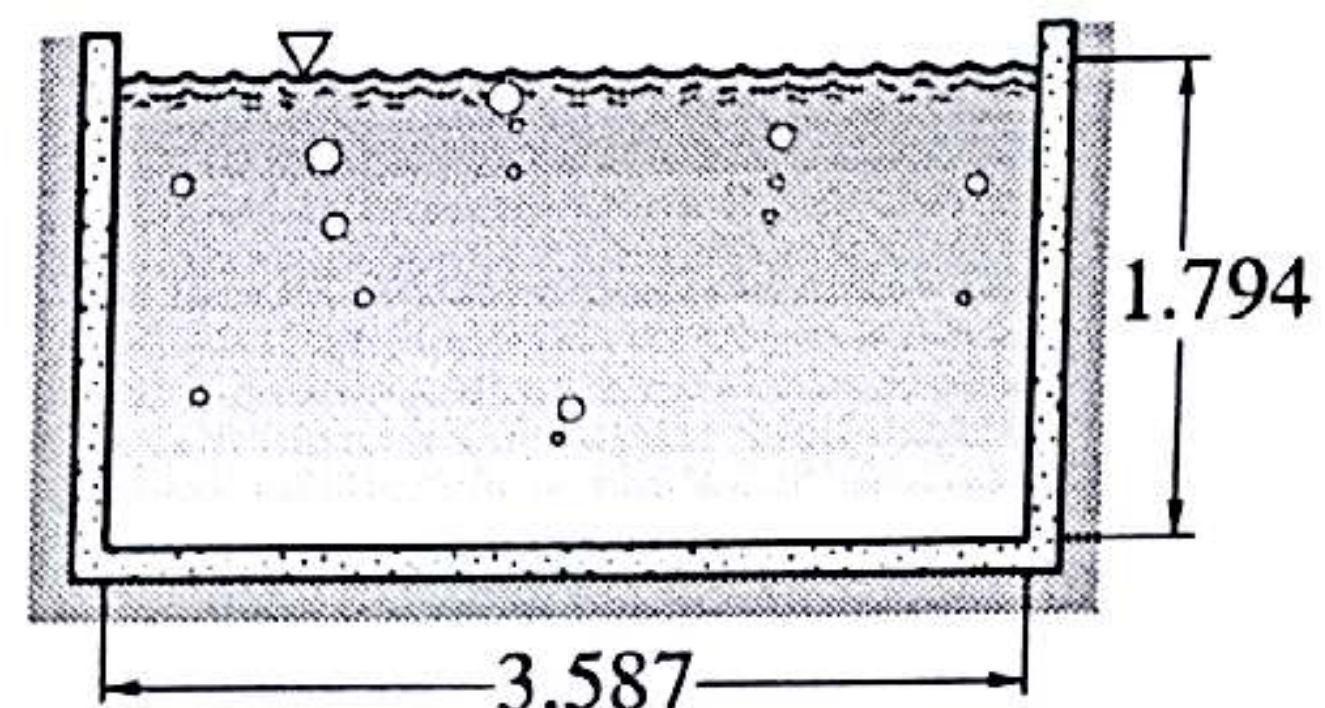
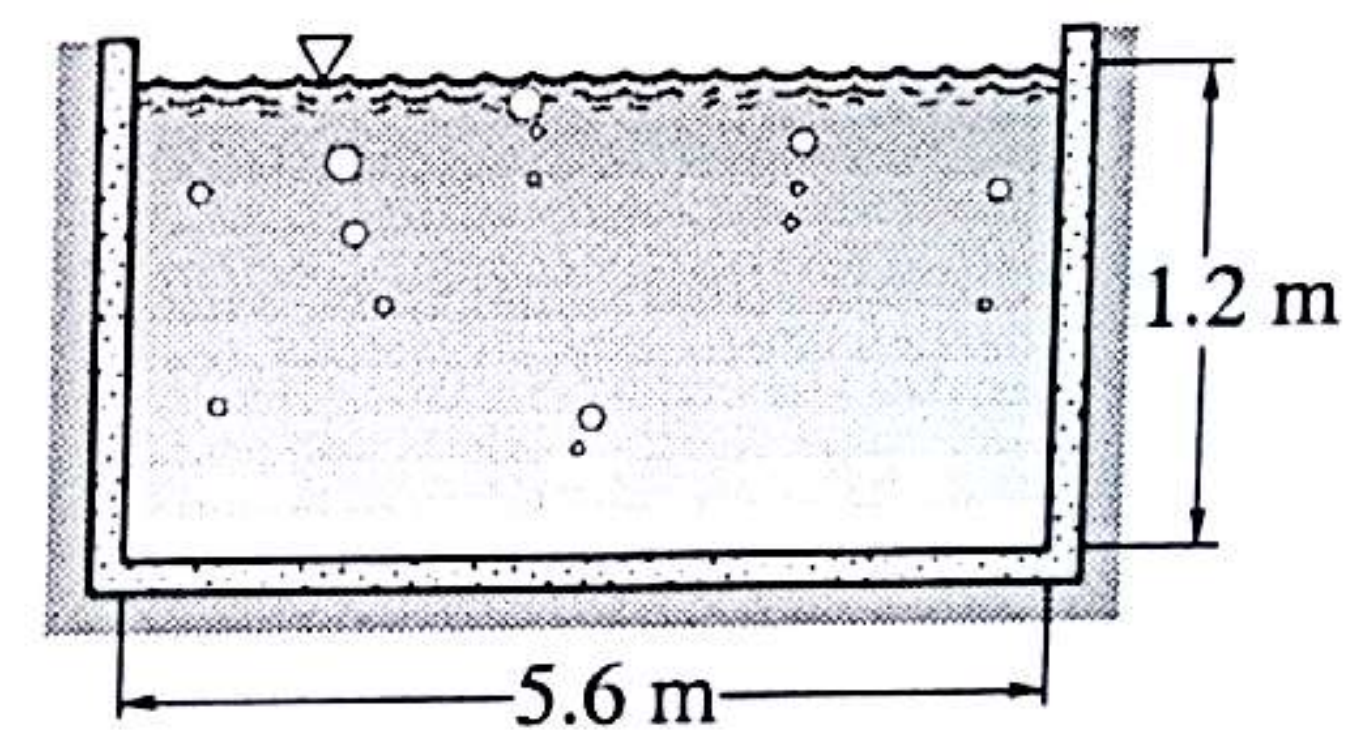
$$R = \frac{A}{P} = \frac{6.72}{8} = 0.84 \text{ m}$$

$$Q = \frac{A R^{2/3} S^{1/2}}{n}$$

$$Q = \frac{6.72(0.84)^{2/3} (0.002)^{1/2}}{0.013} = 20.58 \text{ m}^3 / \text{s}$$



- ③ Savings in lining per meter length:



- ② Savings in earth excavation by using more favorable proportions:  
Use most efficient section.

$$b = 2d$$

$$R = \frac{d}{2}$$

$$A = b d$$

$$A = 2 d^2$$

$$Q = \frac{A R^{2/3} S^{1/2}}{n}$$

$$20.58 = \frac{2d^2 (d/2)^{2/3} (0.002)^{1/2}}{0.013}$$

$$d = 1.794 \text{ m}$$

$$b = 2d = 2(1.794) = 3.587 \text{ m.}$$

Savings in excavation:

$$\text{Savings} = 5.6(1.2) - 1.794(3.587)$$

$$\text{Savings} = 0.2849 \text{ m}^2$$

$$\begin{aligned} \text{Lining of old channel} &= [1.2(2) + 5.6](1) \\ \text{Lining of old channel} &= 8 \text{ m}^2 \end{aligned}$$

$$\begin{aligned} \text{Lining of new channel} &= [1.794(2) + 3.587](1) \\ &= 7.175 \text{ m}^2 \end{aligned}$$

$$\begin{aligned} \text{Savings in lining} &= 8 - 7.175 \\ \text{Savings in lining} &= 0.825 \text{ m}^2/\text{m.} \end{aligned}$$



## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 17:

A square frame 3 m by 3 m in dimension is submerged in water vertically with its top 3 m from the surface. If oil ( $s = 0.80$ ) occupies the top meter,  ~~$\gamma = 9.79 \text{ kN/m}^3$~~

- ① Determine the horizontal pressure acting on the frame.
- ② Determine the pressure at the top of the gate.
- ③ Determine the pressure at the bottom of the gate.

### Solution:

- ① Horizontal pressure acting on the frame:

$$P = \gamma \bar{h} A$$

$$\bar{h} = 1(0.8) + 2 + 1.5$$

$$\bar{h} = 4.3 \text{ m}$$

$$P = 9.81(4.3)(3)(3)$$

$$P = \underline{379.65 \text{ kN}}$$

- ② Pressure at the top of the gate:

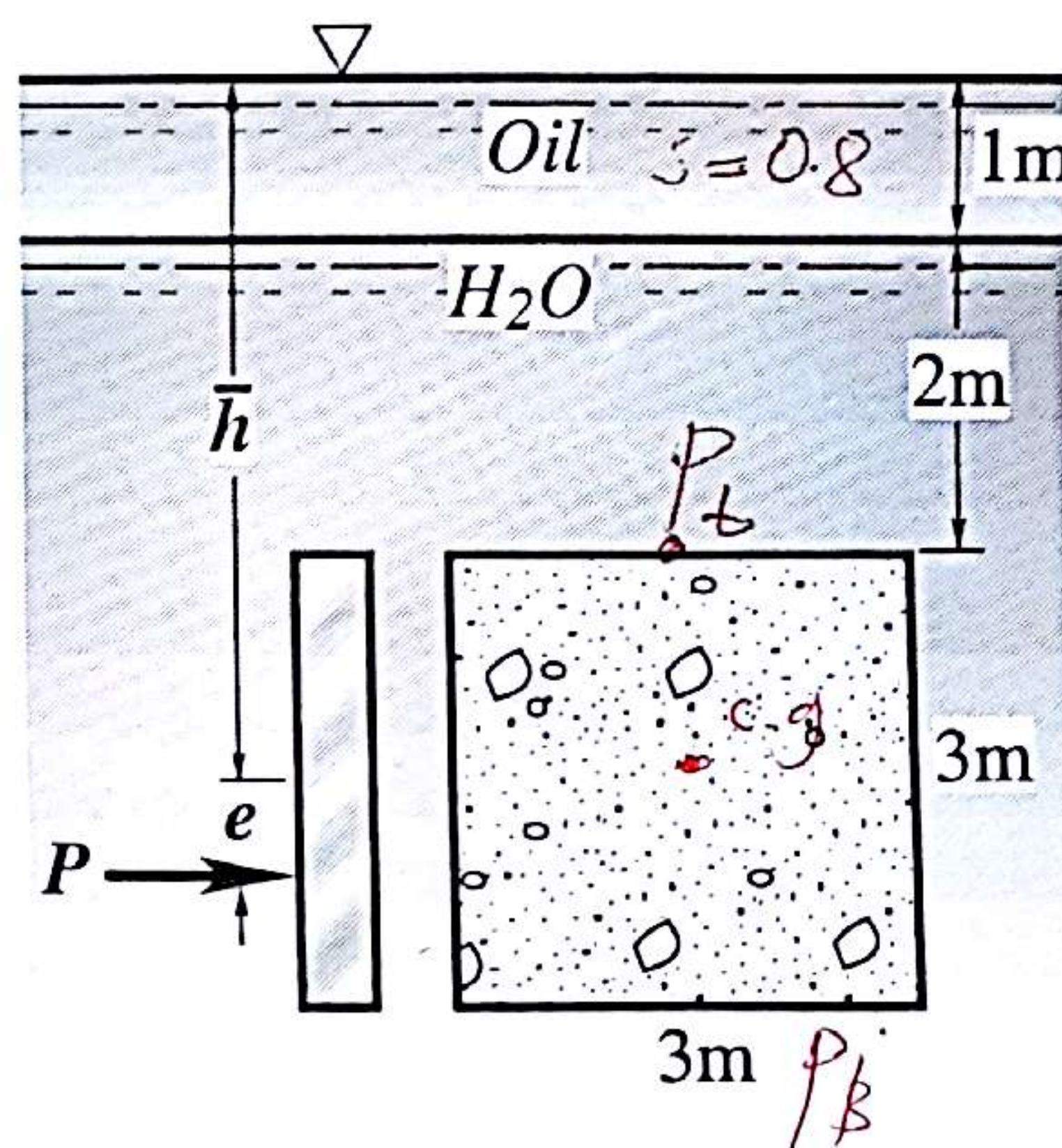
$$P = 9.79(0.8)1 + 9.79(2)$$

$$P_t = P = \underline{27.41 \text{ kPa}}, 27.47 \text{ kPa}$$

- ③ Pressure at the bottom of the gate:

$$P_B = P = 9.79(0.8)1 + 9.79(5)$$

$$P_B = P = \underline{56.78 \text{ kPa}}, 56.90 \text{ kPa}$$





## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 18:

Piston A has a cross-section of  $1,200 \text{ cm}^2$  while that of B is  $800 \text{ cm}^2$ . B is higher than A by  $2\text{m}$ . If the intervening passages are filled with oil having sp. gr. of  $0.8$  and a force of  $4 \text{ kN}$  is acting on B,

- ① What must be the pressure at piston B.
- ② What must be the pressure at piston A.
- ③ What must be the force exerted at piston A.

### Solution :

- ① Pressure at piston B:

$$P_B (800) = 4,000$$

$$P_B = 5 \text{ N/cm}^2$$

$$P_B = 50,000 \text{ N/m}^2 \quad \checkmark$$

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

- ② Pressure at piston A:

$$P_A = P_B + wh$$

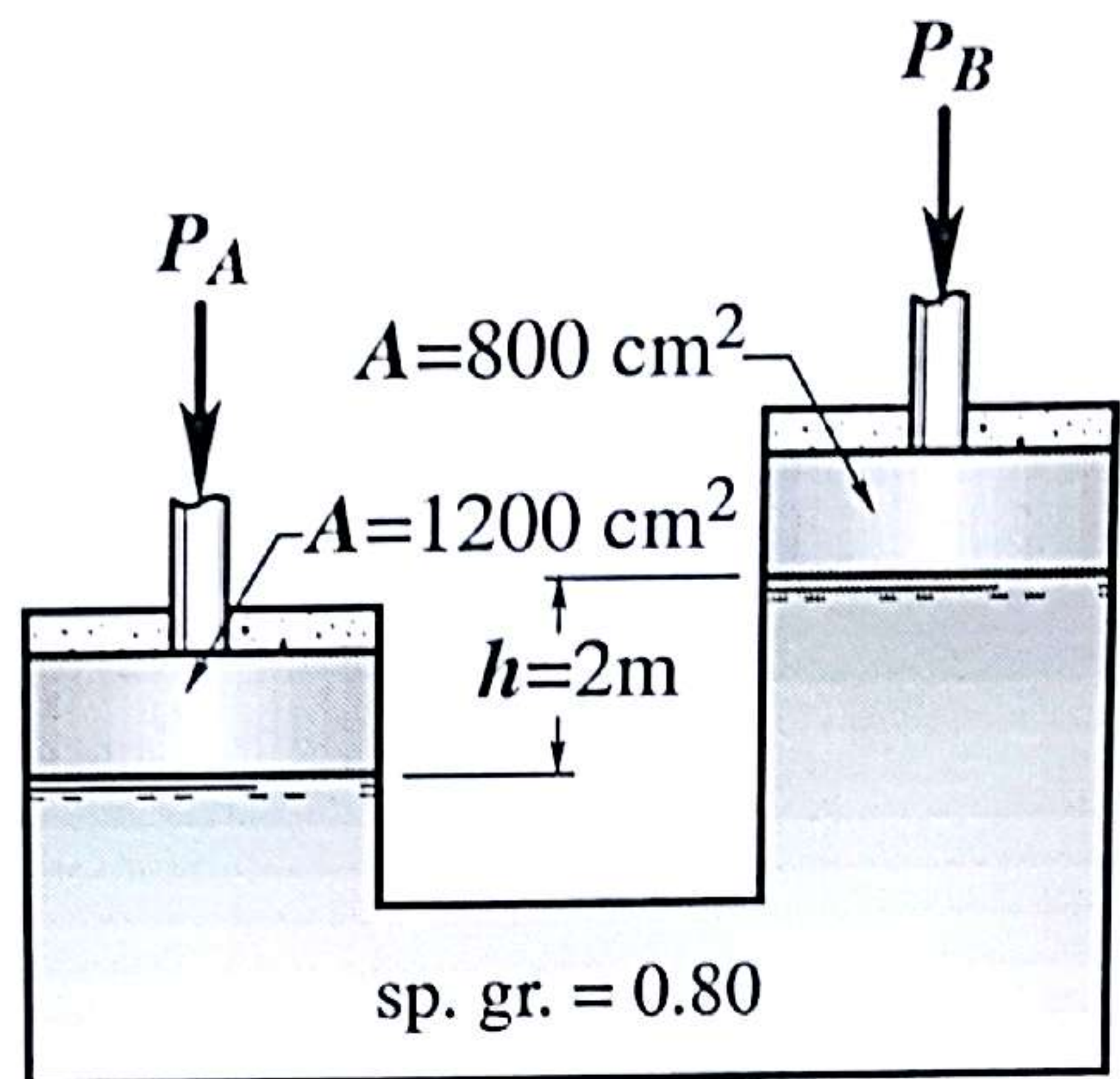
$$P_A = 50,000 + 9810 (.8) (2)$$

$$P_A = 65696 \text{ N/m}^2 \quad \checkmark$$

- ③ Force exerted at piston A:

$$P = \frac{65696 (1200) \text{ cm}^2}{(100)^2 \text{ cm}^2/\text{m}^2}$$

$$P = 7883.52 \text{ N} \quad \checkmark$$

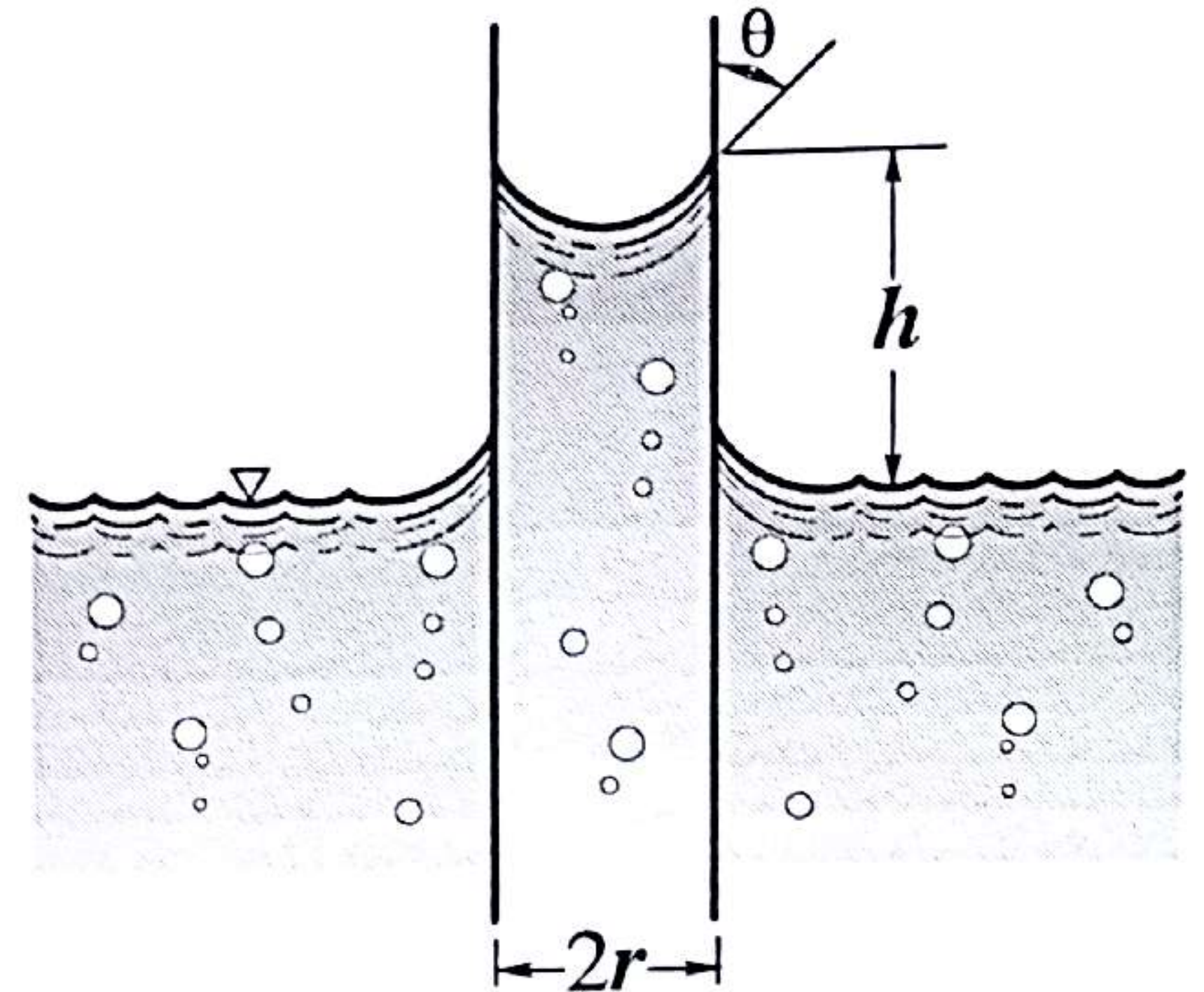




## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 19:

The radius of the tube as shown in the figure is 1 mm. The surface tension of water at 20°C is equal to 0.0728 N/m. For a water-glass interface  $\theta = 0^\circ$ .



- ① Compute the capillary rise in the tube in mm.
- ② Compute the total force due to surface tension.
- ③ Compute the weight of water above the surface due to surface tension.

### Solution:

- ① **Capillary rise in the tube in mm:**

$$h = \frac{2 \sigma \cos \theta}{\rho g r}$$

$$h = \frac{2 (0.0728) \cos 0^\circ}{1000 (9.81) (0.001)}$$

$$h = 0.0148 \text{ m.}$$

$$h = 14.8 \text{ mm.}$$

- ② **Total force due to surface tension:**

$$F = \sigma \pi d \cos \theta$$

$$F = 0.0728 (2\pi) (0.001) \cos 0^\circ$$

$$F = 4.57 \times 10^{-4} \text{ N}$$

- ③ **Weight of water:**

$$W = \gamma \text{Vol} = 9810 \pi (0.001)^2 (0.0148)$$

$$W = 4.56 \times 10^{-4} \text{ N}$$

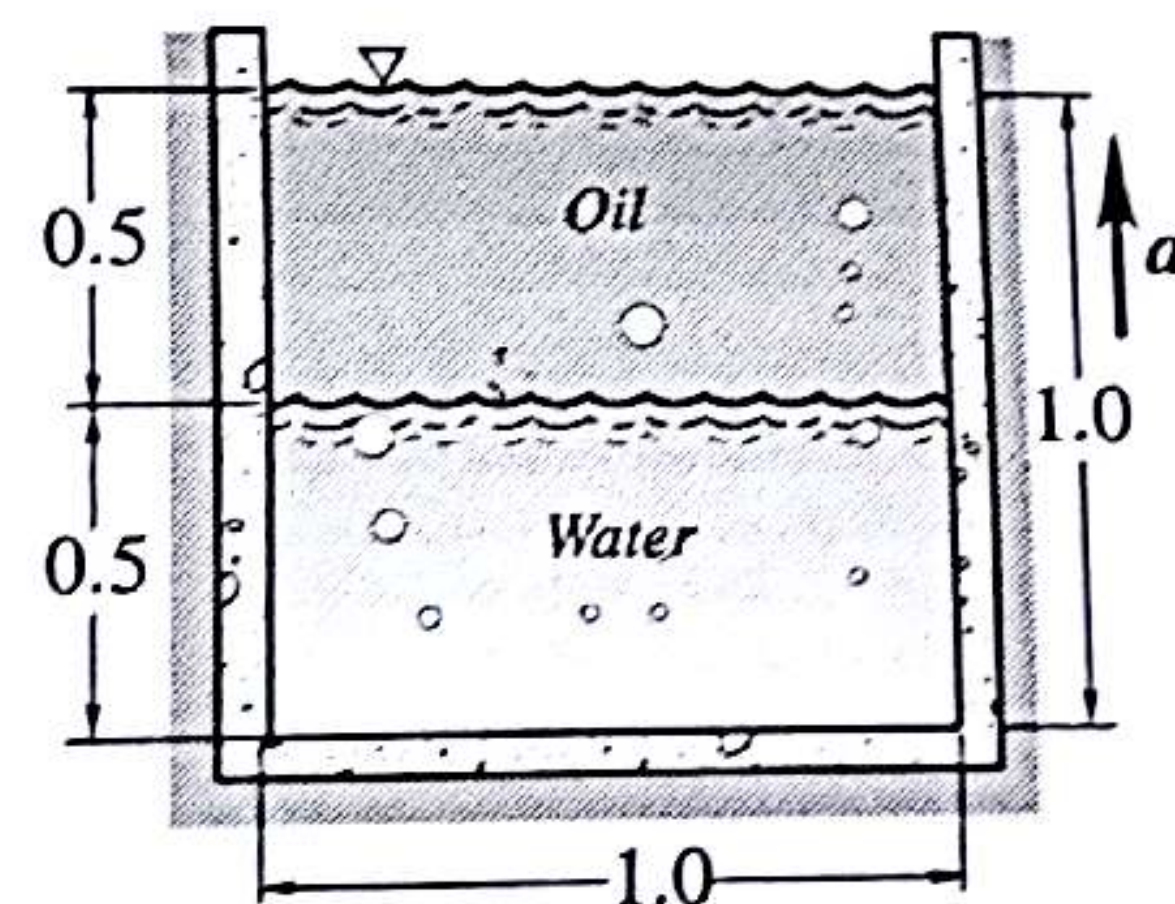


# HYDRAULICS- Coaching Notes (Nov. 2016)

## PROBLEM 20:

A 1 x 1 x 1 m. tank is 50% filled with oil (sp.gr. 0.82) and the remaining is water. When it is translated vertically upward at 5.10 m/s<sup>2</sup>.

- ① Determine the pressure at the bottom.
- ② Determine the velocity at the orifice 50 mm diam. located at the bottom of the tank.
- ③ Determine the discharge if the coefficient of discharge C is equal to 0.6.



### Solution:

- ① Pressure at the bottom.

$$P = P_{static} \left( 1 \pm \frac{a}{g} \right) \quad \begin{array}{l} + \rightarrow \text{UPWARD} \\ - \rightarrow \text{DOWNWARD} \end{array}$$

$$P_{static} = w h$$

$$h = 0.5 (0.82) + 0.5(1)$$

$$h = 0.91 \text{ m.}$$

$$P = 9.81(0.91) \left( 1 + \frac{5.10}{9.81} \right) = 13.57 \text{ kPa} \quad \checkmark$$

- ② Velocity at the orifice 50 mm diam. located at the bottom of the tank.

$$h = 0.91 \left( 1 + \frac{5.10}{9.81} \right)$$

$$h = 1.38 \text{ m.}$$

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

$$V = \sqrt{2(9.81)(1.38)}$$

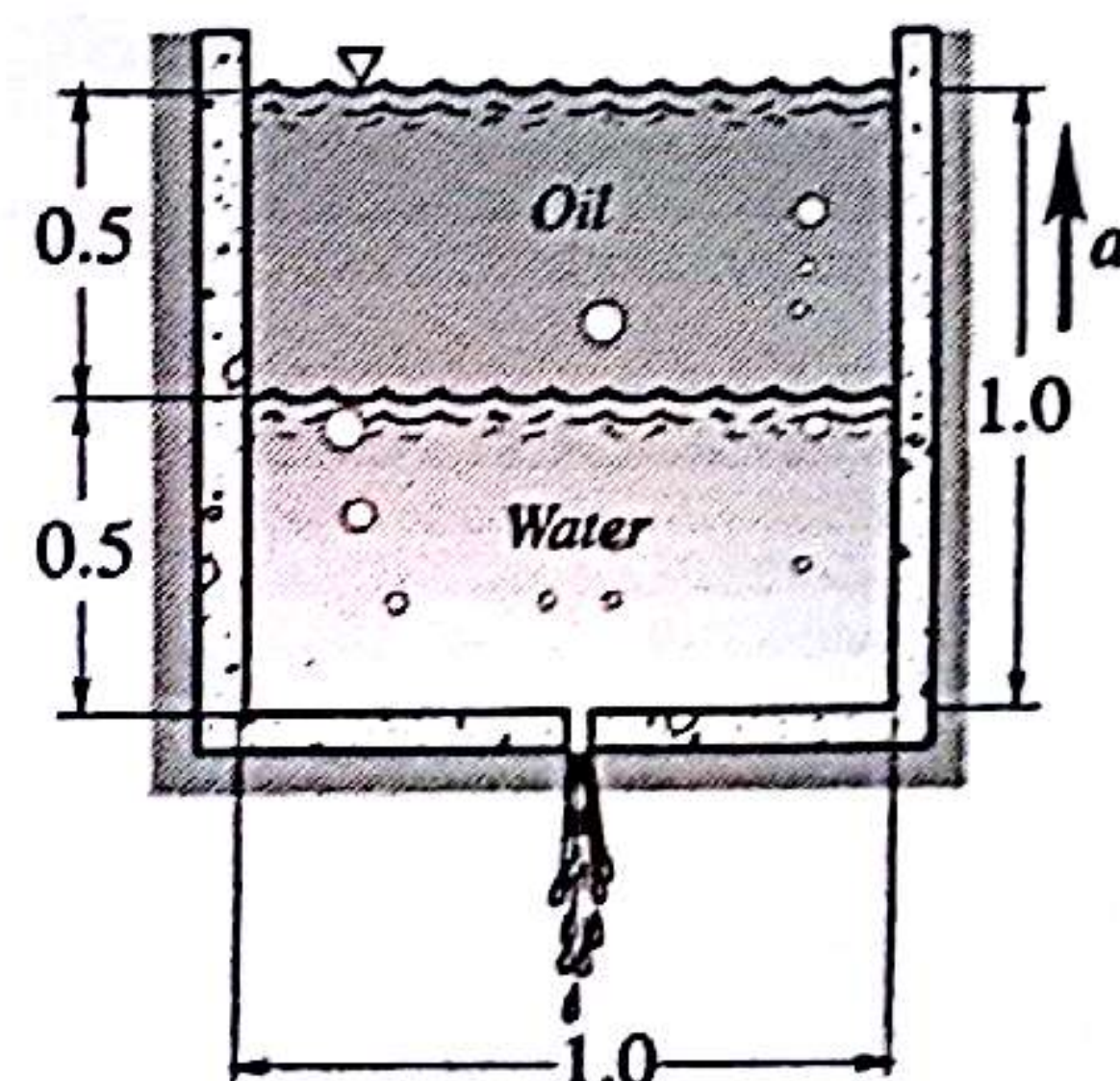
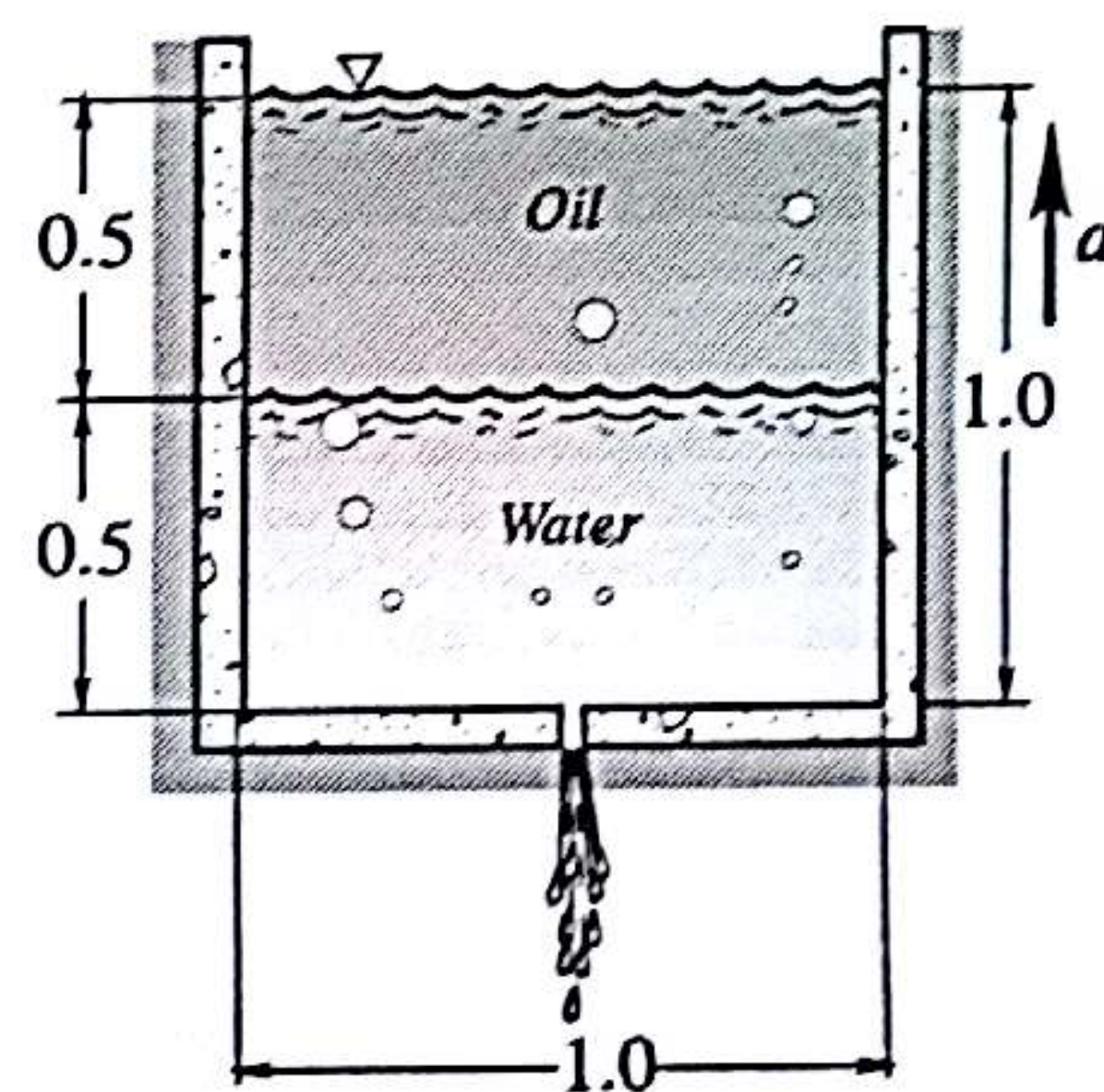
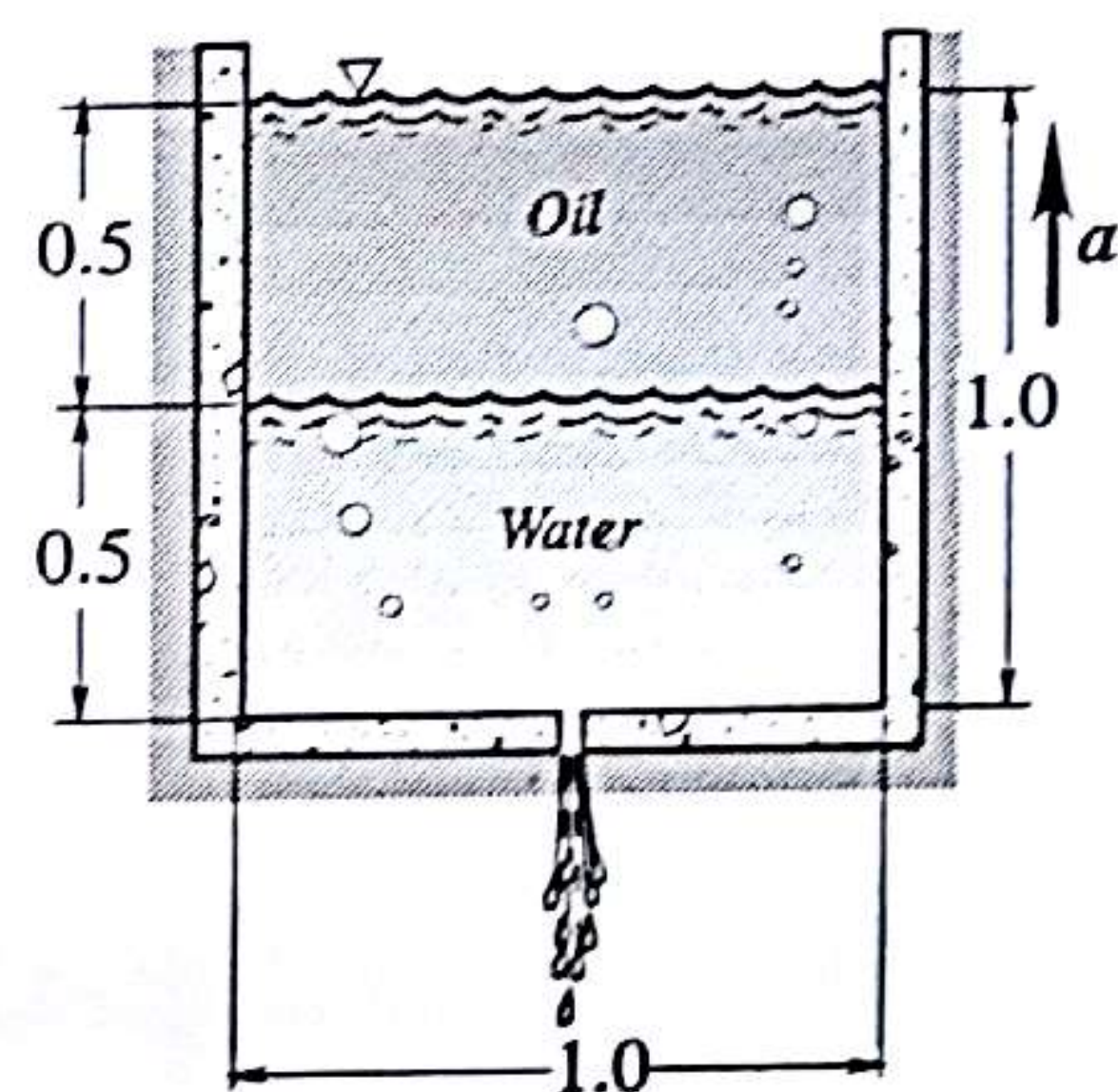
$$V = 5.20 \text{ m/s} \quad \checkmark$$

- ③ Discharge if the coefficient of discharge C is equal to 0.6.

$$Q = CA \sqrt{2gh}$$

$$Q = \frac{0.60(\pi)(0.05)^2}{4} \sqrt{2(9.81)(1.38)}$$

$$Q = 0.0061 \text{ m}^3/\text{s} \quad \checkmark$$





## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 21:

The cross section of a right triangular channel is shown with a coefficient of roughness  $n = 0.012$ . If the rate of flow =  $4 \text{ m}^3/\text{s}$ .

- ① Calculate the critical depth.
- ② Calculate the critical velocity.
- ③ Calculate the critical slope.

### Solution:

- ① Critical depth:

$$A = \frac{2d_c d_c}{2} = d_c^2$$

$$B = 2d_c$$

$$\boxed{\frac{Q^2}{g} = \frac{A^3}{B}}$$

$$\frac{(4)^2}{9.81} = \frac{(d_c^2)^3}{2d_c}$$

$$d_c^5 = 3.26$$

$$d_c = 1.267 \text{ m.} //$$

- ② Critical velocity:

$$\boxed{V_c = \sqrt{g \frac{A}{B}}}$$

$$A = (1.267)^2$$

$$A = 1.605 \text{ m}^2$$

$$B = 2(1.267)$$

$$B = 2.534 \text{ m}$$

$$V_c = \sqrt{\frac{9.81(1.605)}{2.534}}$$

$$V_c = 2.49 \text{ m/s} //$$

- ③ Critical slope:

$$\boxed{V_c = \frac{1}{n} R^{2/3} S_c^{1/2}}$$

$$P = 2\sqrt{2} d_c$$

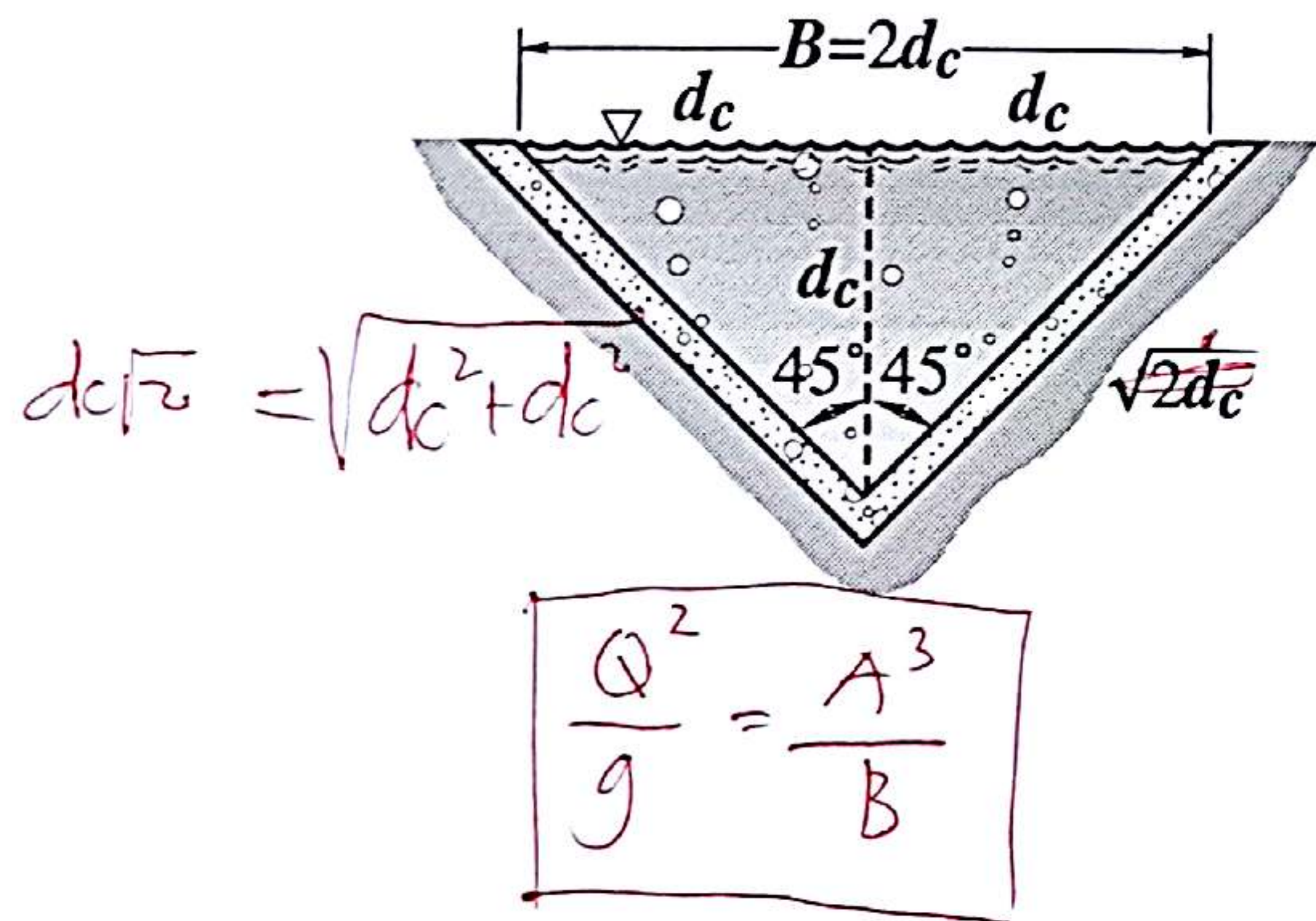
$$P = 2\sqrt{2} (1.267)$$

$$P = 3.58 \text{ m}$$

$$R = \frac{A}{P} = \frac{1.605}{3.58} = 0.448 \text{ m}$$

$$2.49 = \frac{1}{0.012} (0.448)^{2/3} S_c^{1/2}$$

$$S_c = 0.0026 //$$





# HYDRAULICS- Coaching Notes (Nov. 2016)

## PROBLEM 22:

A jet of water 250 mm in diameter impinges normally on a flat steel plate. If the discharge is 0.491 m<sup>3</sup>/s.

- ① Find the force exerted by the jet on the stationary plate.
- ② If the flat plate is moving at 2 m/s in the same direction as that of the jet, find the force exerted by the jet on the plate.
- ③ If the flat plate moving a 4 m/s in the same direction as that of the jet, find the work done on the plate per second.

## Solution:

- ① Force exerted by the jet on the stationary plate:

$$F = R$$

$$-R = \frac{Q \gamma_w}{g} (V_2 - V_1)$$

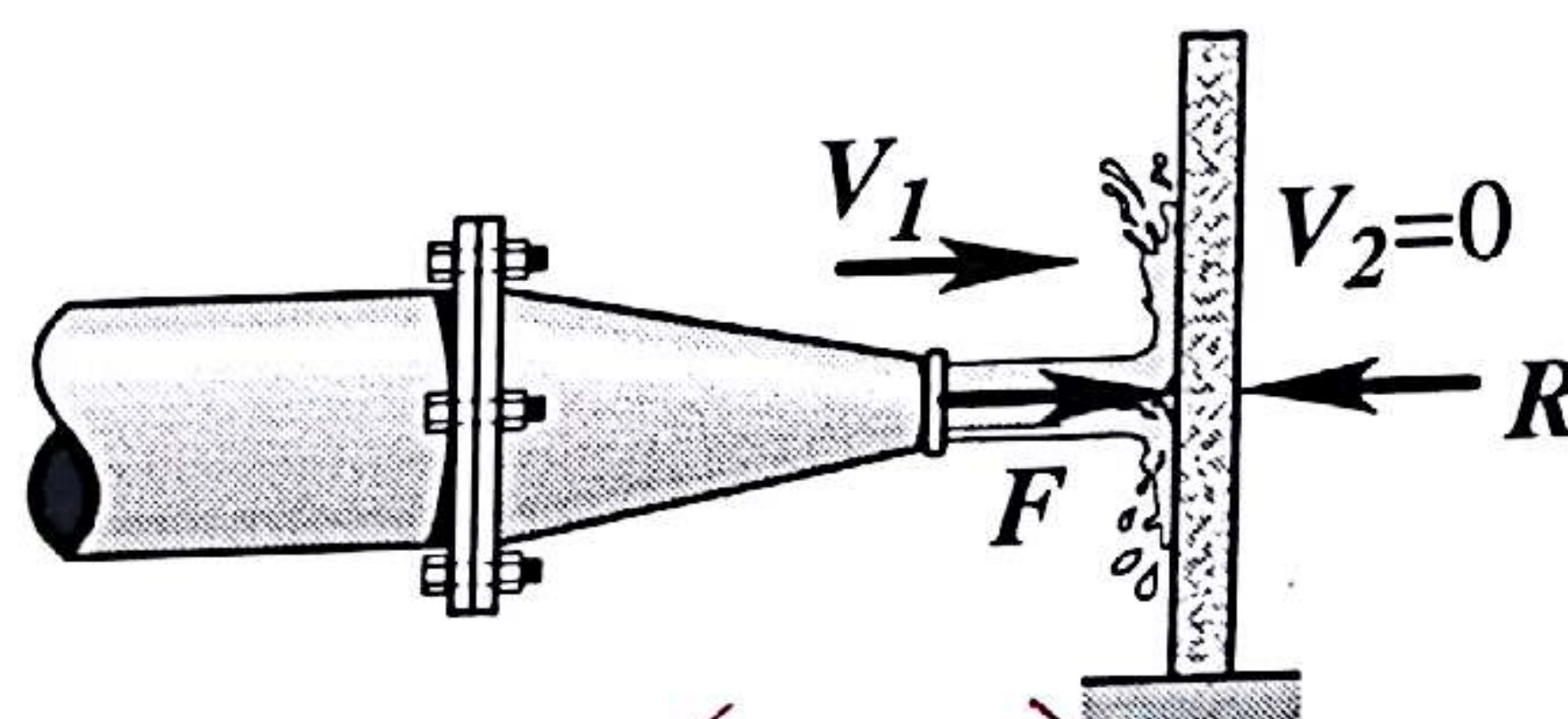
$$Q = A V$$

$$0.491 = \frac{\pi}{4} (0.25)^2 V_1$$

$$V_1 = 10 \text{ m/s}$$

$$-R = \frac{0.491(9.81)}{9.81} (0 - 10)$$

$$R = 4.91 \text{ kN}$$



$$F = \frac{\rho}{g} Q V = \rho A (V_1 - V_2)^2$$

$$= 1000 \left( \frac{\pi}{4} \right) (0.25)^2 (10)^2$$

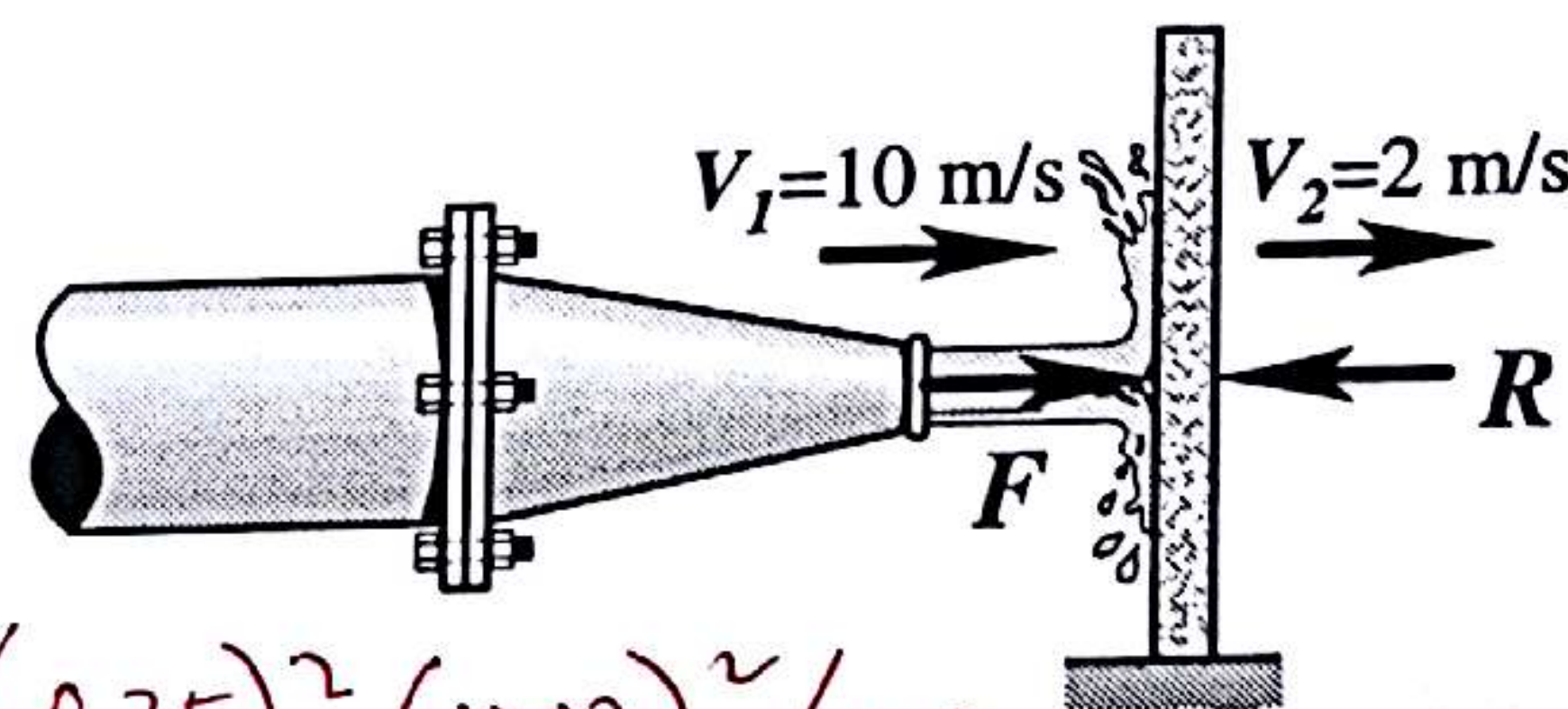
$$= 4,908.74 \text{ N} = 4.91 \text{ kN (ans.)}$$

- ② Force exerted by the jet on the plate:

$$-R = F = \frac{Q \gamma_w}{g} (V_2 - V_1)$$

$$-R = \frac{0.491(9.81)}{9.81} (2 - 10)$$

$$R = 3.928 \text{ kN}$$



$$F = 1000 \left( \frac{\pi}{4} \right) (0.25)^2 (10 + 2)^2 / 1000$$

$$F = 3.14 \text{ kN (ans.)}$$

- ③ Work done on the plate per second:

$$F = R$$

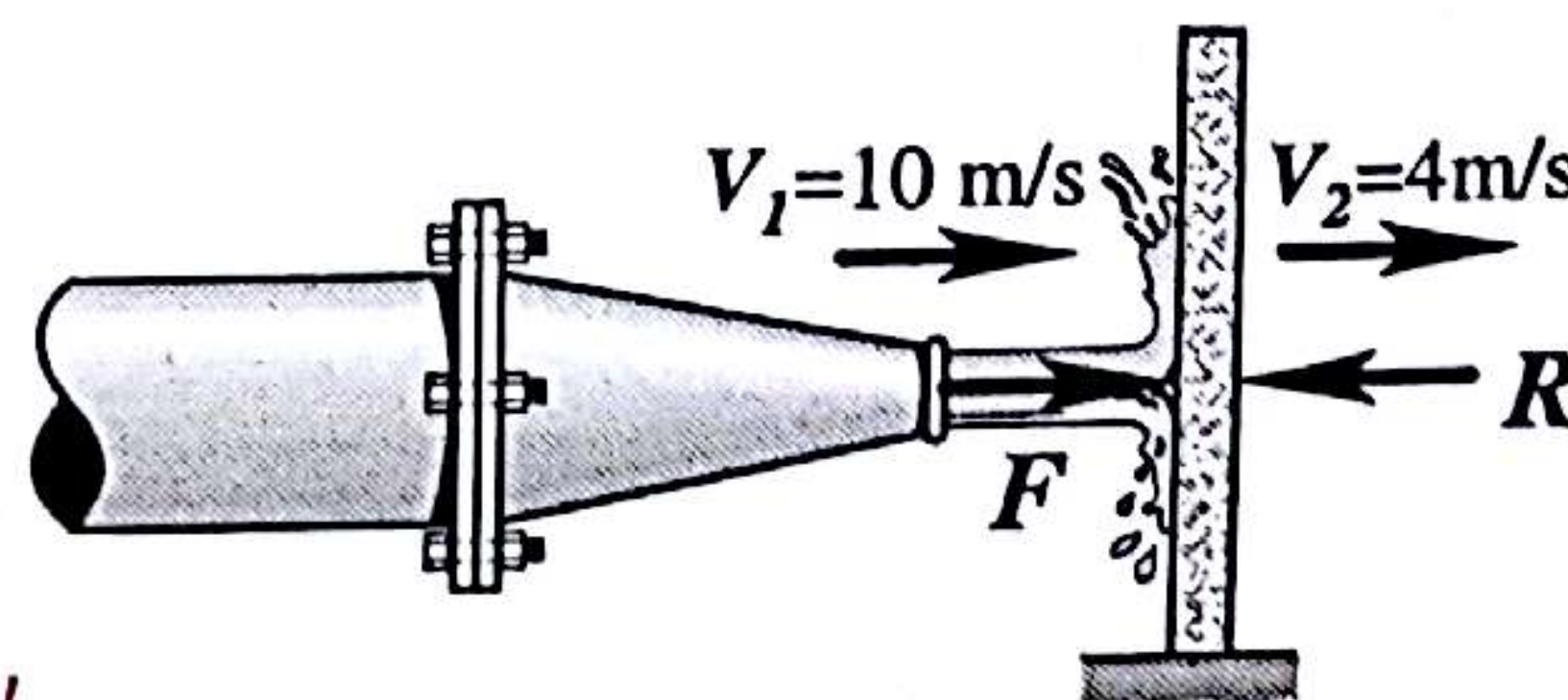
$$-R = \frac{Q \gamma_w}{g} (V_2 - V_1)$$

$$-R = \frac{0.491(9.81)}{9.81} (4 - 10)$$

$$R = 2.946 \text{ kN}$$

$$\text{Work} = 2.946 (1000)(4)$$

$$\text{Work} = 11784 \text{ N-m/s}$$



$$\text{Work} = F V'$$

$$F = 1000 \left( \frac{\pi}{4} \right) (0.25)^2 (10 - 4)^2 / 1000 = 1,767.15 \text{ N}$$

$$\text{Work} = 1,767.15 (4) = 7,068.6 \frac{\text{N-m}}{\text{s}} \text{ (ans.)}$$



## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 24:

A piece of wood floats in water with 50 mm projecting above the water surface. When placed in glycerine of sp.gr. 1.35, the block projects 75 mm above the liquid surface.

- ① Find the height of the piece of wood.
- ② Find the sp.gr. of wood.
- ③ Find the weight of the wood if it has a cross sectional area of 200 mm x 200 mm.

### Solution:

- ① Height of wood:

$$W = 9.81(A)(h - 0.05)$$

$$Sh(9.81)(A) = 9.81A(h - 0.05)$$

$$Sh = h - 0.05$$

$$W = 9.81(1.35)A(h - 0.075)$$

$$Sh(9.81)A = 9.81(1.35)A(h - 0.075)$$

$$Sh = 1.35(h - 0.075)$$

$$h - 0.05 = 1.35(h - 0.075)$$

$$0.35h = 0.05125$$

$$h = 0.146 \text{ m.}$$

- ② Sp.gr. of wood:

$$Sh = h - 0.05$$

$$S(0.146) = 0.146 - 0.05$$

$$S = 0.658$$

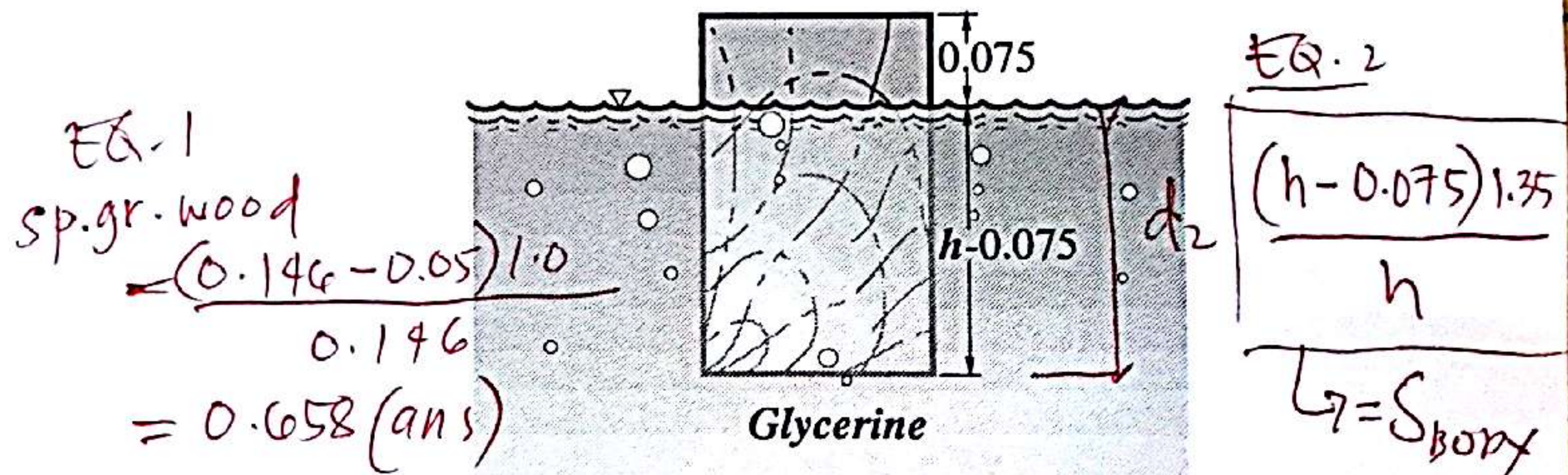
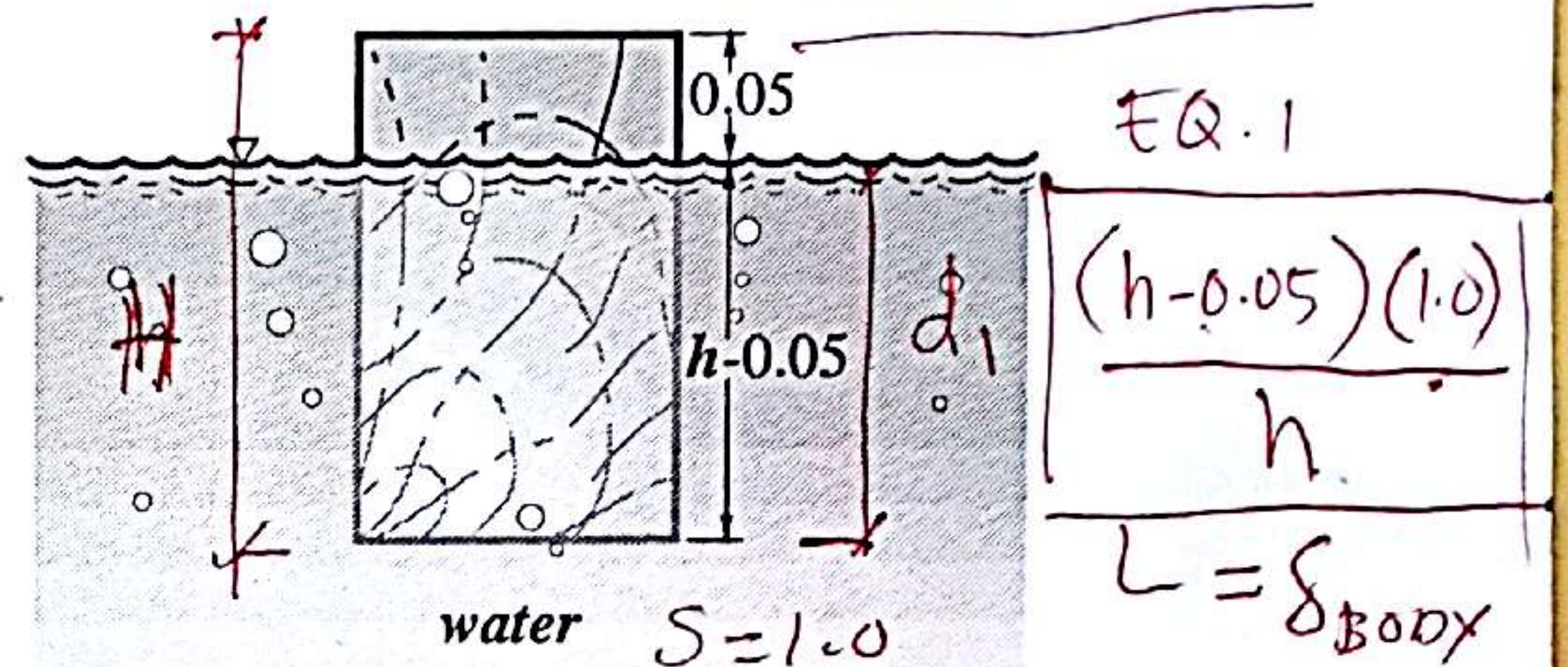
- ④ Wt. of wood:

$$W = 9.81(0.658)(0.146)(0.2)(0.2)$$

$$W = 0.038 \text{ kN}$$

$$W = 38 \text{ N}$$

$$d = \frac{S_{\text{BODY}}}{S_{\text{fluid}}} (H) \rightarrow H = \frac{d \cdot S_{\text{fluid}}}{S_{\text{BODY}}} = \frac{d \cdot S_{\text{fluid}}}{h}$$



EQ. (1) & (2)

$$S_{\text{BODY}} = \frac{(h-0.075)1.35}{h} = \frac{(h-0.05)(1.0)}{h}$$

$$h = 0.146 \text{ m (ans.)}$$

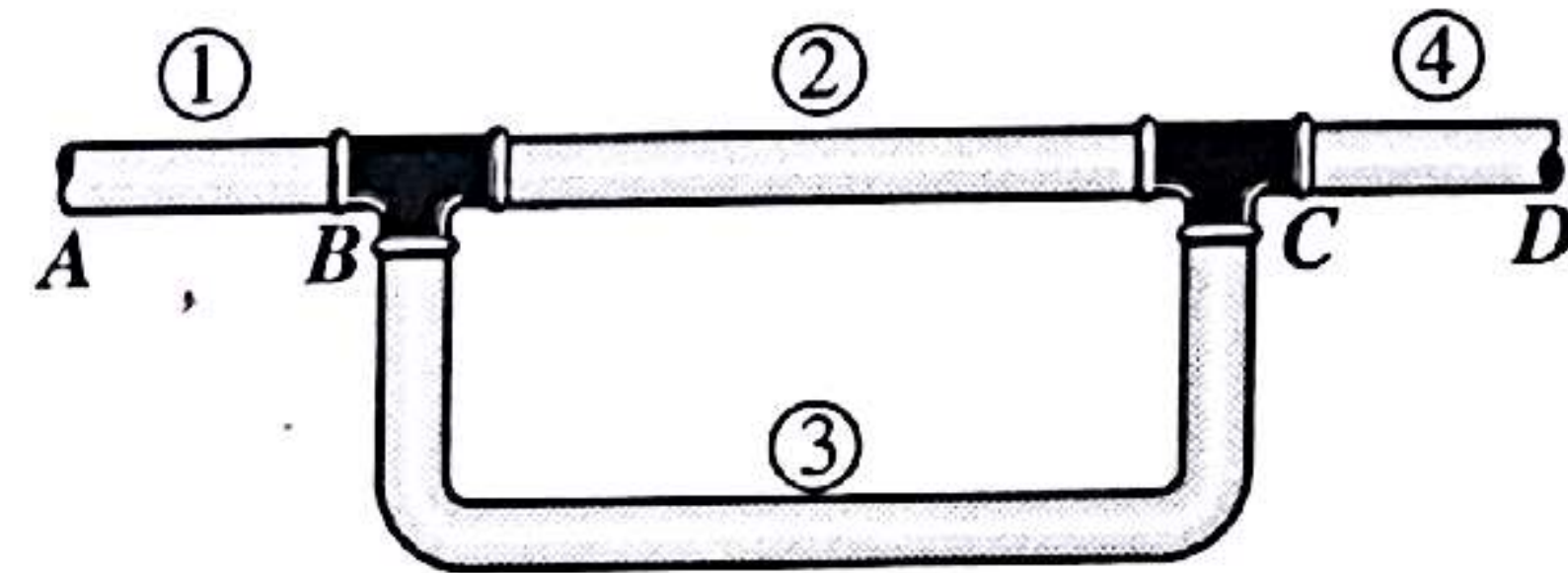


## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 26:

A pipe network consists of pipeline 1 from A to B, then at B it is connected to pipelines 2 and 3, where it merges again at joint C to form a single pipeline 4 up to point D. Pipelines 1, 2 and 4 are in series connection whereas pipelines 2 and 3 are parallel to each other. If the rate of flow from A to B is 10 liters/sec and assuming  $f = 0.02$  for all pipes, compute the following:

Pipelines	Diameter	Length
1	200 mm $\phi$	3000 m.
2	300 mm $\phi$	2200 m.
3	200 mm $\phi$	3200 m.
4	400 mm $\phi$	2800 m.



- ① Rate of flow of pipeline 3.
- ② Rate of flow of pipeline 2.
- ③ Total head loss from A to D.

#### Solution:

- ① Rate of flow of pipeline 3:

$$Q_1 = Q_2 + Q_3$$

$$Q_1 = Q_4$$

$$hf_2 = hf_3$$

$$hf = \frac{0.0826 f L Q^2}{D^5}$$

$$\frac{0.0826 f L (Q_2)^2}{(D_2)^5} = \frac{0.0826 f L (Q_3)^2}{(D_3)^5}$$

$$\frac{2200(Q_2)^2}{(0.3)^5} = \frac{3200(Q_3)^2}{(0.2)^5}$$

$$Q_2^2 = 11.045 Q_3^2$$

$$Q_2 = 3.323 Q_3 \quad \text{--- (2)}$$

$$Q_1 = Q_2 + Q_3$$

$$0.01 = 3.323 Q_3 + Q_3 \quad \text{subst. (2) in (1)}$$

$$Q_3 = 0.00231$$

$$Q_3 = 2.31 \text{ liters/s} \quad \checkmark$$

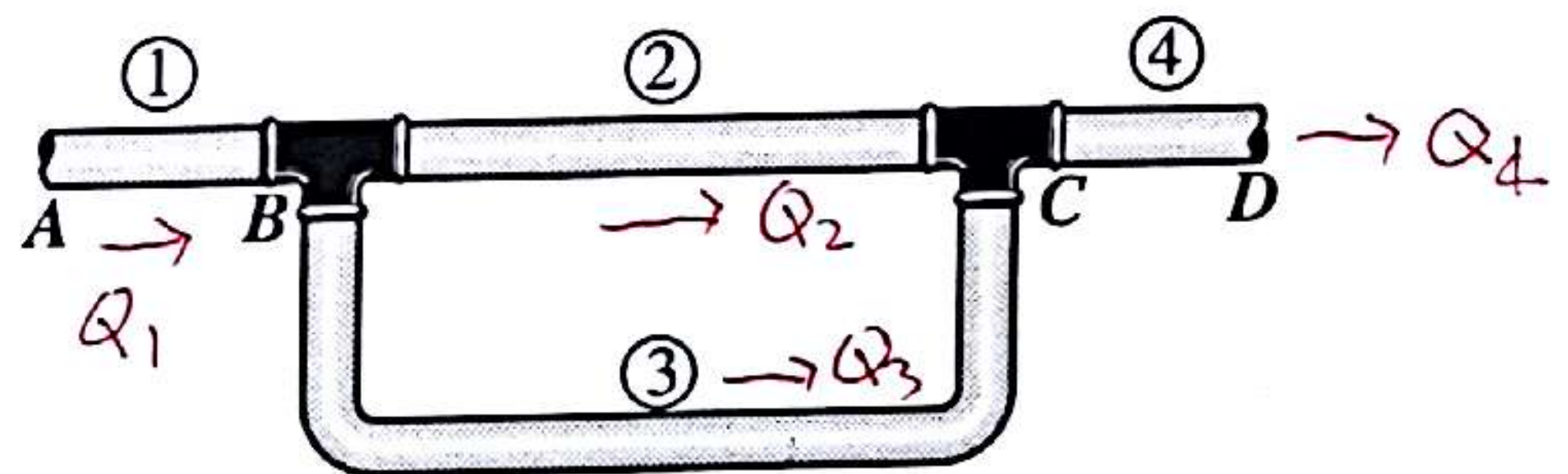
- ② Rate of flow in pipeline 2:

$$Q_2 = 3.323 Q_3$$

$$Q_2 = 3.323 (2.31)$$

$$Q_2 = 7.69 \text{ liters/sec.}$$

$$Q_1 = Q_4 = 10 \text{ lit/sec}$$



- ③ Total head loss from A to D:  $= hf_1 + hf_2 + hf_4$

$$hf_1 = \frac{0.0826 f L Q_1^2}{D_1^5}$$

$$hf_1 = \frac{0.0826(0.02) 3000(0.01)^2}{(0.2)^5}$$

$$hf_1 = 1.55 \text{ m.} \quad \checkmark$$

$$hf_2 = \frac{0.0826(0.02)(2200)(0.00769)^2}{(0.3)^5}$$

$$hf_3 = hf_2 = 0.088 \text{ m.} \quad \checkmark$$

$$hf_4 = \frac{0.0826(0.02)(2800)(0.01)^2}{(0.4)^5}$$

$$hf_4 = 0.045 \text{ m.}$$

Total head loss from A to D:

$$HL = hf_1 + hf_2 + hf_4$$

$$HL = 1.55 + 0.088 + 0.045$$

$$HL = 1.6838 \text{ m.} \quad \checkmark$$



# HYDRAULICS- Coaching Notes (Nov. 2016)

## PROBLEM 28:

The three reservoirs A, B and C are connected by pipelines A, B and C respectively. the elevation of reservoir A is equal to 200 m. while that of C is 178 m. The discharge flowing towards reservoir B is 0.60 m<sup>3</sup>/s. Reservoir B is higher than that of C.

Pipes	Diam.	Length	Friction factor "f"
A	800 mm	1500 m	0.0158
B	600 mm	450 m	0.0168
C	450 mm	1200 m	0.0175

- ① Compute the rate of flow out of reservoir A.
- ② Compute the rate of flow towards reservoir C.
- ③ Compute the elevation of reservoir

*Solution :*

- ① Rate of flow out of reservoir A:

$$hf_2 = \frac{0.0826fLQ_2^2}{D_2^5}$$

$$hf_2 = \frac{0.0826(0.0168)(450)(0.60)^2}{(0.6)^5} = 2.89 \text{ m.}$$

$$hf_1 + hf_3 = 200 - 178$$

$$hf_1 + hf_3 = 22 \text{ m.}$$

$$\frac{0.0826(0.0158)(1500)Q_1^2}{(0.8)^5} + \frac{0.0826(0.0175)(1200)Q_3^2}{(0.45)^5} = 22$$

$$5.974Q_1^2 + 94Q_3^2 = 22 \quad \text{--- (1)}$$

$$Q_3 = Q_1 - Q_2$$

$$Q_3 = Q_1 - 0.60 \quad \text{--- (2)}$$

$$5.974Q_1^2 + 94(Q_1 - 0.60)^2 = 22 \quad \text{subst. (2) in (1)}$$

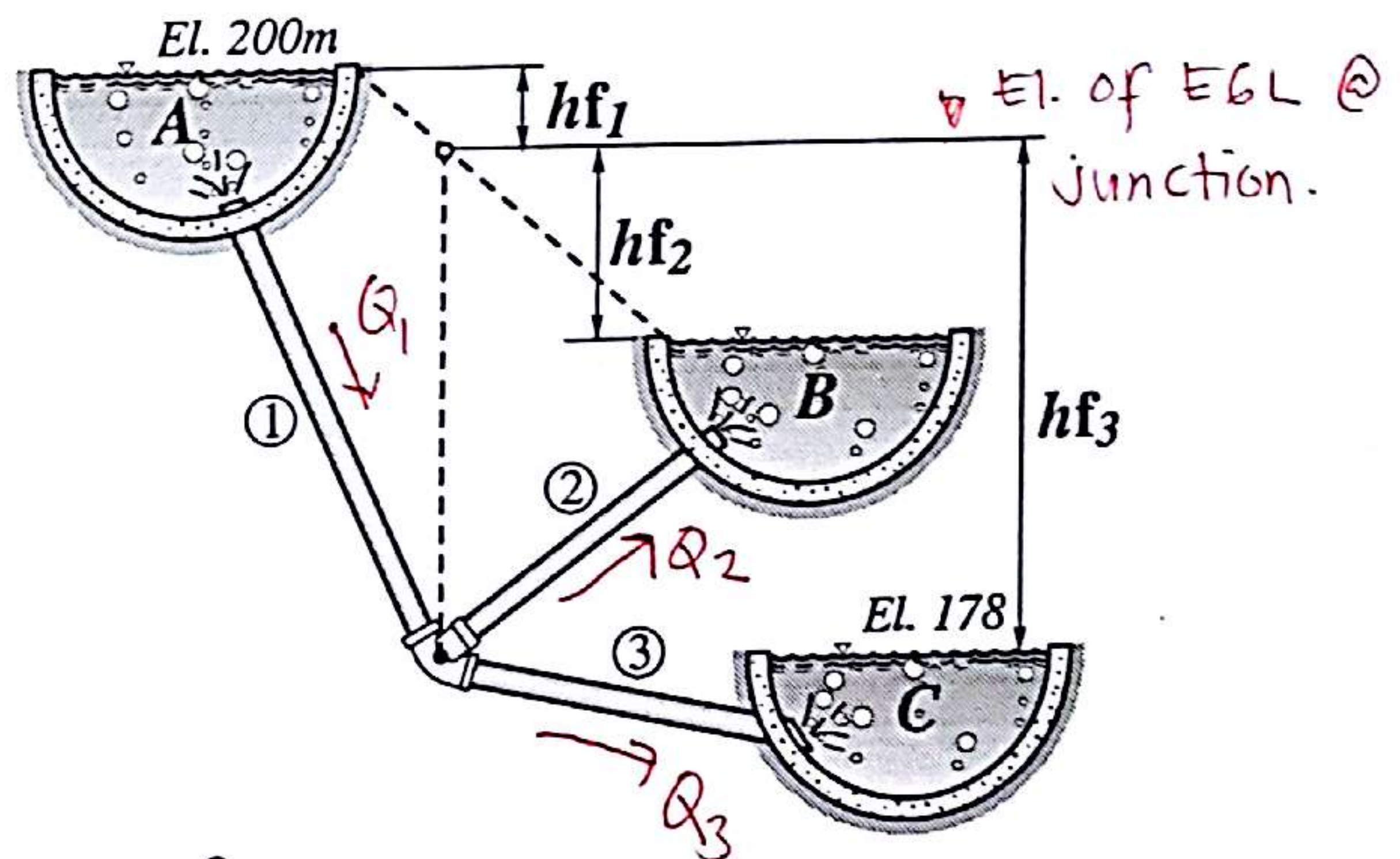
$$5.974Q_1^2 + 94(Q_1^2 - 1.20Q_1 + 0.36) = 22$$

$$99.974Q_1^2 - 112.8Q_1 + 33.84 = 22$$

$$99.974Q_1^2 - 112.8Q_1 + 11.84 = 0$$

$$Q_1^2 - 1.13Q_1 + 0.118 = 0$$

$$Q_1 = \frac{1.13 \pm 0.897}{2} = 1.0135 \text{ m}^3/\text{s}$$



- ② Rate of flow towards reservoir C:

$$Q_3 = Q_1 - 0.60$$

$$Q_3 = 1.0135 - 0.60$$

$$Q_3 = 0.4135 \text{ m}^3/\text{s}$$

- ③ Elev. of B:

$$hf_1 = \frac{0.0826(0.0158)(1500)(1.0135)^2}{(0.8)^5}$$

$$hf_1 = 6.14 \text{ m.}$$

$$\text{Elev. of B} = 200 - hf_1 - hf_2$$

$$\text{Elev. of B} = 200 - 6.14 - 2.89$$

$$\text{Elev. of B} = 190.97 \text{ m.}$$



## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 29:

Two reservoirs A and B have elevations of 250 m and 100 m respectively. It is connected by a pipe having a diameter of 250 mm and a length of 100 m. A turbine is installed at point in between reservoirs A and B. If  $C = 120$ , compute the following if the discharge flowing in the pipeline is 150 liters/sec.

- ① Headloss of pipe due to friction.
- ② The head extracted by the turbine.
- ③ The Power generated by the turbine.

### Solution :

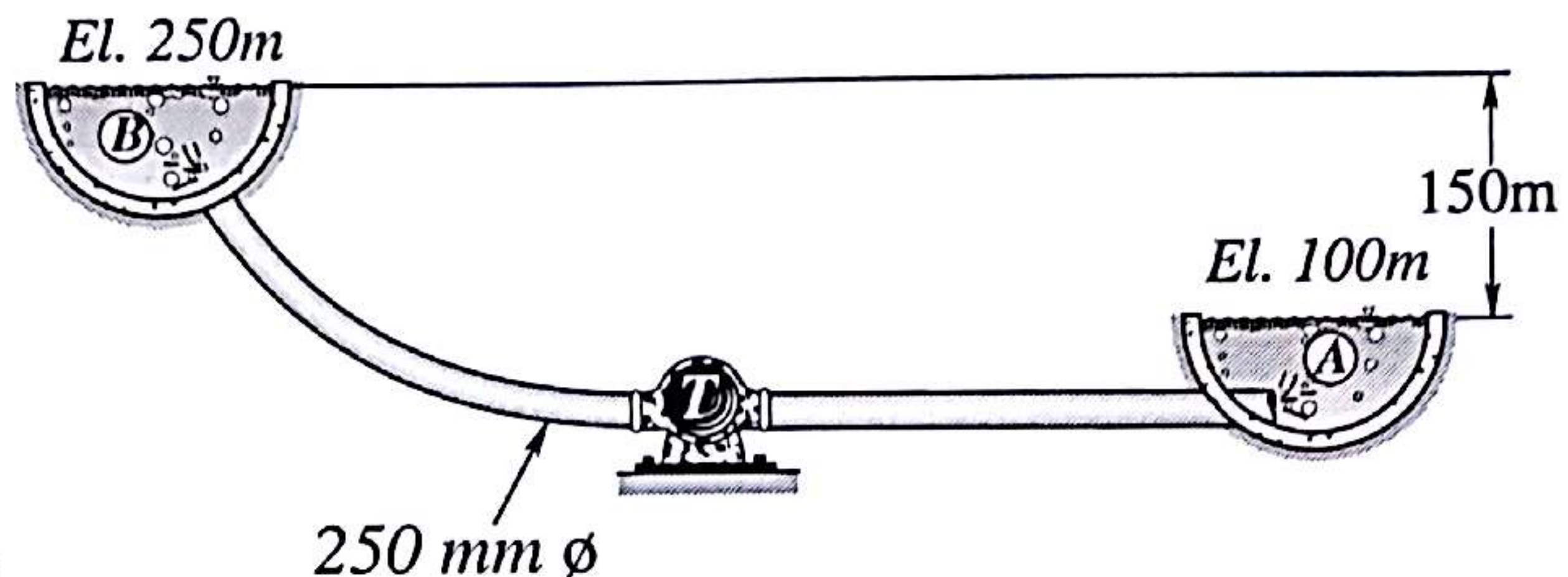
- ① Headloss of pipe:

$$h_f = \frac{10.64 L Q^{1.85}}{C^{1.85} D^{4.87}}$$

$$Q = 0.15 \text{ m}^3/\text{s}$$

$$h_f = \frac{10.64(100)(0.15)^{1.85}}{(120)^{1.85}(0.25)^{4.87}}$$

$$h_f = 3.87 \text{ m.}$$



- ② Head extracted by the turbine:

$$\frac{V_A^2}{2g} + \frac{P_A}{\gamma} + Z_A = \frac{V_B^2}{2g} + \frac{P_B}{\gamma} + Z_B + HE + HL$$

$$0 + 0 + 150 = 0 + 0 + HE + 3.87 + 250$$

$$HE = 150 - 3.87$$

$$HE = 146.13 \text{ m.}$$

- ③ Power generated by the turbine:

$$\text{Power} = Q \gamma H$$

$$\text{Power} = 0.15(9810)(146.13)$$

$$\text{Power} = 215030 \text{ watts}$$

$$\text{Power} = 215.03 \text{ kW}$$

B.E.E bet. B & A:

$$\frac{V_B^2}{2g} + \frac{P_B}{\gamma} + Z_B - (HE) - HL = \frac{V_A^2}{2g} + \frac{P_A}{\gamma} + Z_A$$

$$250 - HE - 3.87 = 100$$

$$HE = 146.13 \text{ m (ans)}$$



# HYDRAULICS- Coaching Notes (Nov. 2016)

## PROBLEM 30:

A rectangular scow 9 m. wide 15 m. long and 3.6 m. high has a draft in sea water of 2.4 m. Its center of gravity is 2.7 m. above the bottom of the scow.

- ① Determine the initial metacentric height.
- ② If the scow is tilted until one end is just submerged in water, find the sidewise shifting of the center of buoyancy.
- ③ Determine the final metacentric height.

## Solution:

- ① Initial metacentric height  $MG$

$\phi = 0$  (upright position)

$$MB_0 = \frac{(9)^2}{12(2.4)} (1 + 0)$$

$$MB_0 = 2.81 \text{ m.}$$

Alternate Solution:

$$MB_0 = \frac{I}{V}$$

$$I = \frac{15(9)^3}{12}$$

$$I = 911.25 \text{ m}^4 \text{ (moment of Inertia about the longitudinal axis)}$$

$$V = (2.4)(15)(9)$$

$$V = 324 \text{ m}^3$$

$$MB_0 = \frac{911.25}{324}$$

$$MB_0 = 2.81 \text{ m.}$$

$$GB_0 = 2.7 - 1.2$$

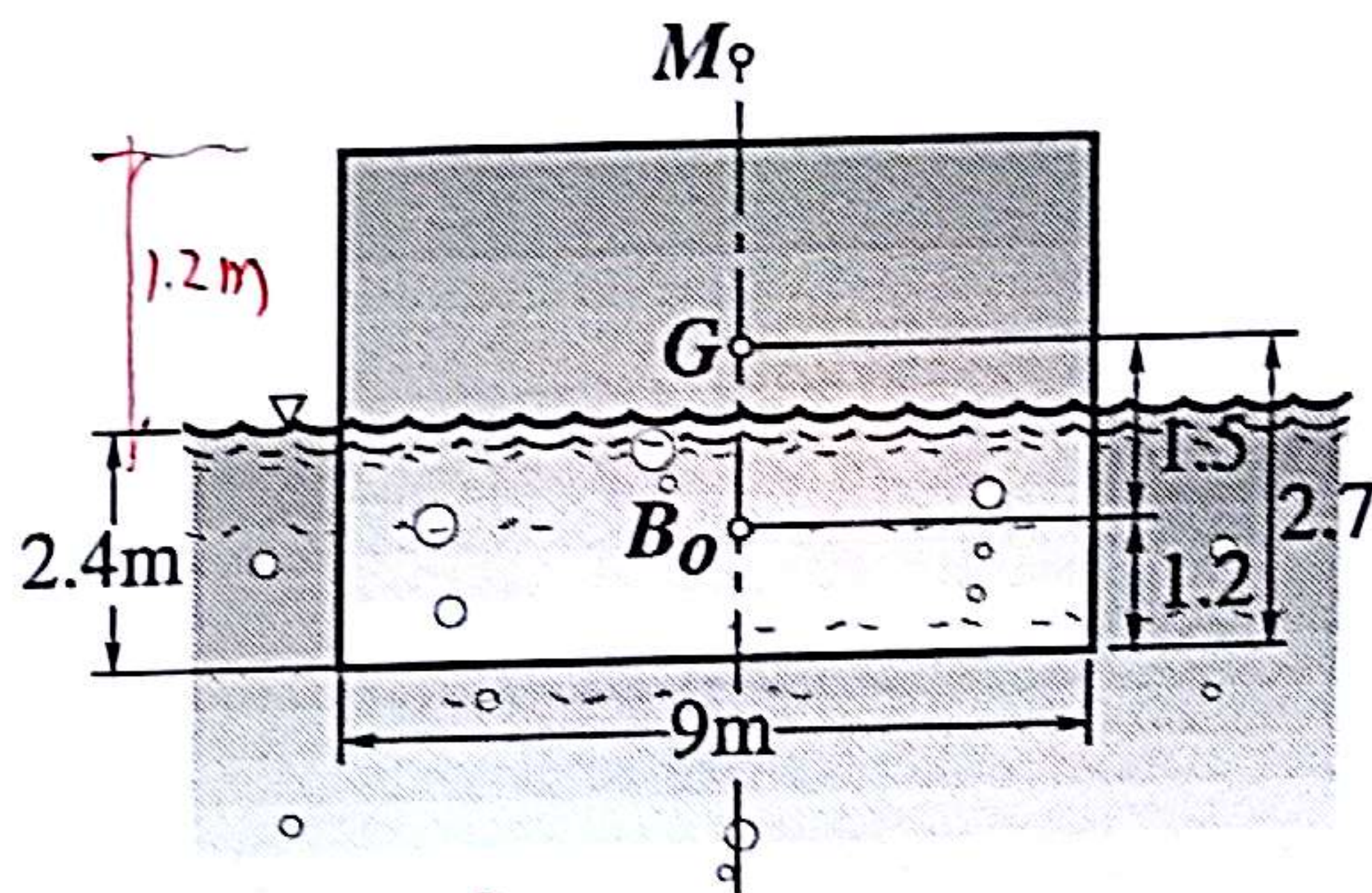
$$GB_0 = 1.5$$

$$MG = MB_0 - GB_0$$

$$MG = 2.81 \text{ m.} - 1.5$$

$$MG = 1.31 \text{ m.}$$

Upright Position



$$MB_0 = \frac{B^2}{12D} \left[ 1 + \frac{\tan^2 \phi}{2} \right]$$



## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 30: (CONTINUATION)

② Sidewise shifting of the center of buoyancy:

$$\tan \theta = \frac{1.2}{4.5}$$

$$\theta = 14.93^\circ$$

$$\sin \theta = \frac{x_B}{MB_0}$$

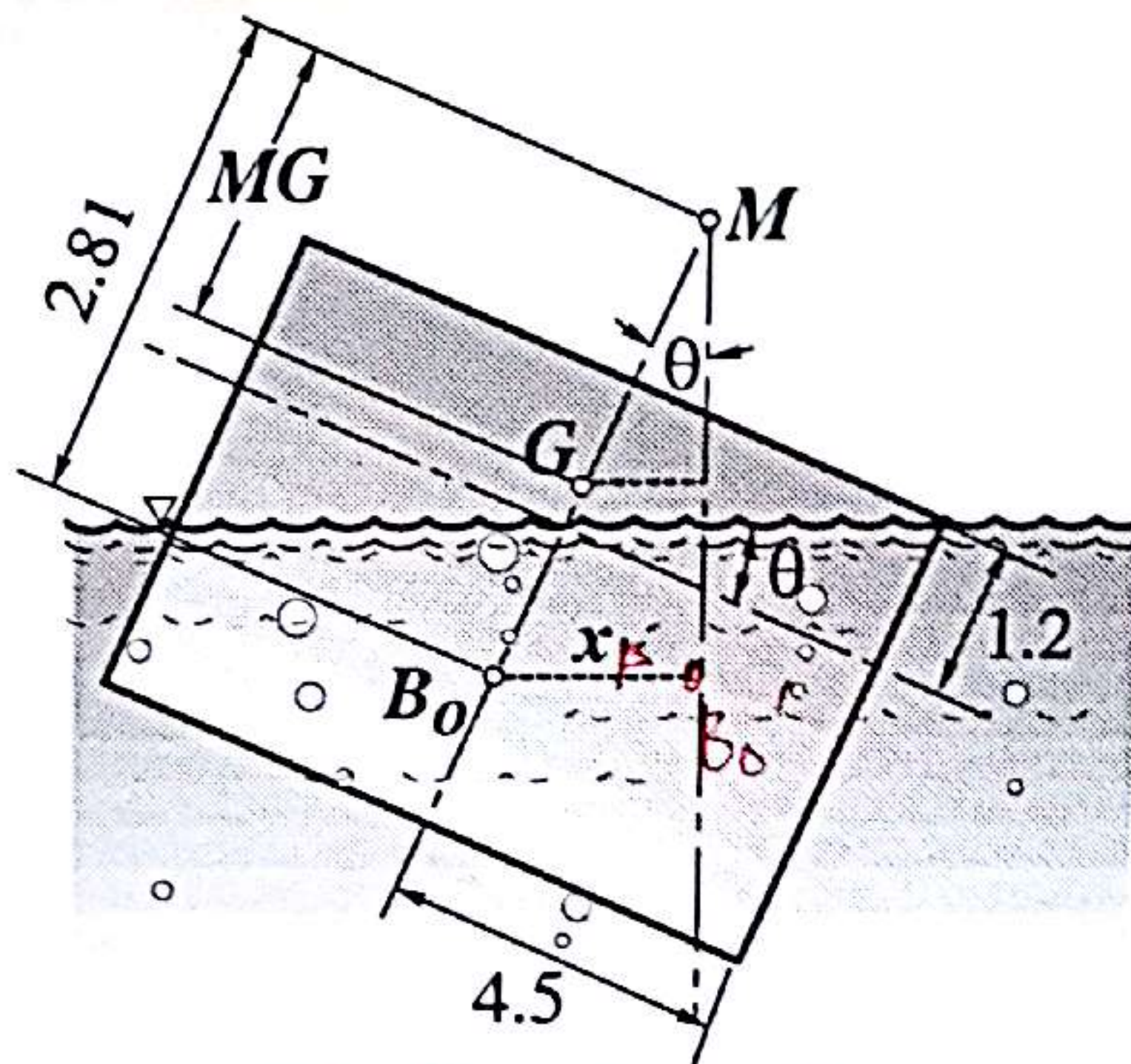
$$MB_0 = \frac{I}{V} \left[ 1 + \frac{\tan^2 \theta}{2} \right]$$

$$MB_0 = 2.81 \left[ 1 + \frac{\tan^2 14.93}{2} \right]$$

$$MB_0 = 2.91 \text{ m.}$$

$$x_B = 2.91 \sin 14.93^\circ$$

$$x_B = 0.75 \text{ m.}$$



$$MB_0 = \frac{B^2}{12D} \left[ 1 + \frac{\tan^2 \theta}{2} \right]$$

$$= \frac{(9)^2}{12(2.4)} \left[ 1 + \frac{\tan^2 (14.93)}{2} \right]$$

$$MB_0 = 2.91 \text{ m}$$

③ Final metacentric height.

$$MB_0 = \frac{(9)^2}{12(2.4)} \left( 1 + \frac{\tan^2 14.93^\circ}{2} \right)$$

$$MB_0 = 2.91$$

$$MG = MB_0 - GB_0$$

$$MG = 2.91 - 1.5$$

$$MG = 1.41 \text{ m}$$



## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 31:

An open tank, 10 m. long, is supported on a car moving on a level track and uniformly accelerated from rest to 30 kph. The tank was filled with water to within 15 cm. of its top, when it was accelerated.

- ① Compute the acceleration of the car.
- ② Find the shortest time in which the acceleration maybe accomplished without liquid spiling over the edge of the tank.
- ③ The height of water is 1 m. when the tank is at rest. Determine the total force acting on the bottom of the tank when the tank was accelerated if it has a width of 2 m.

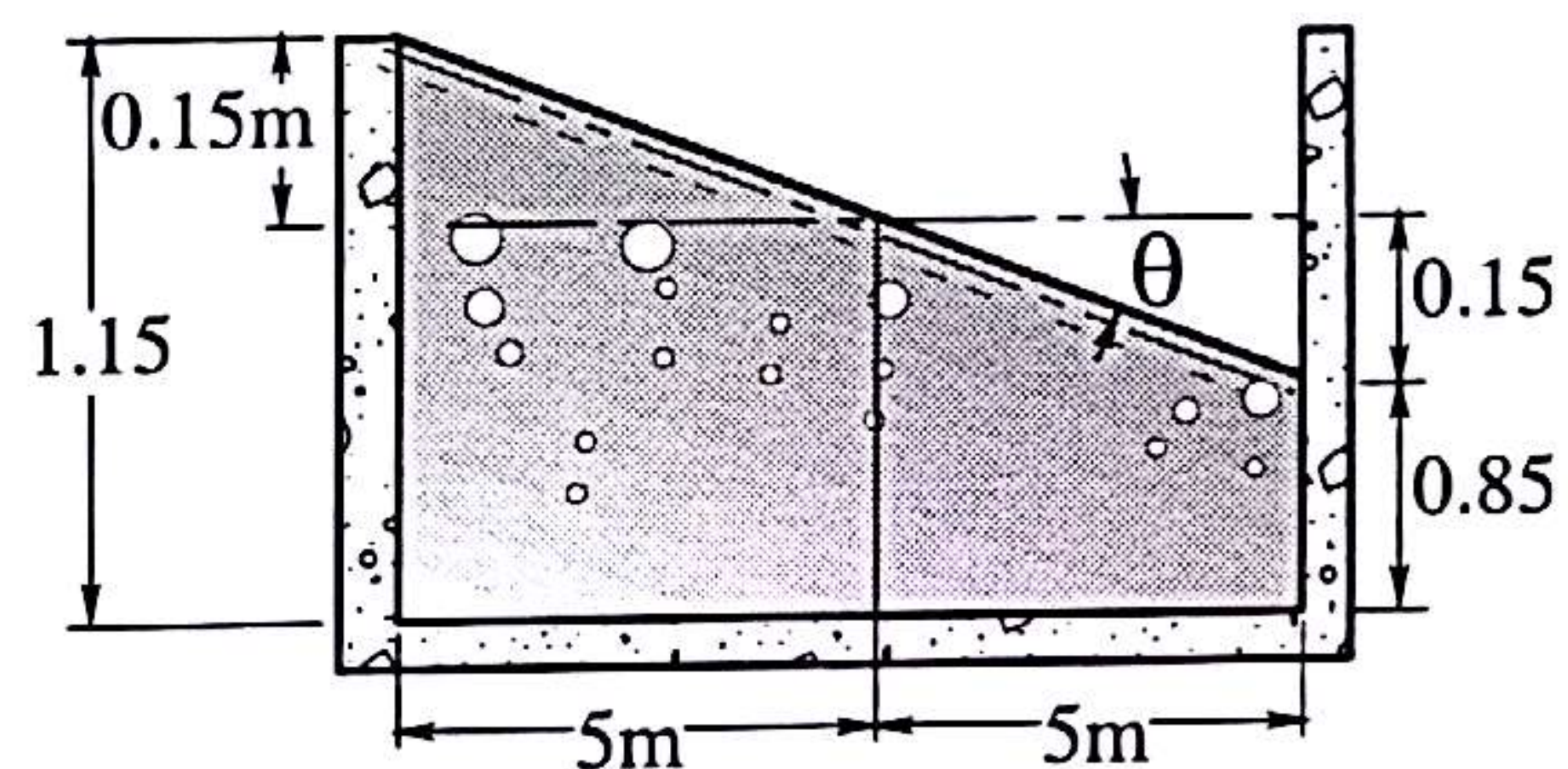
### Solution :

- ① Acceleration of the car.

$$\tan \theta = \frac{a}{g}$$

$$\frac{0.15}{5} = \frac{a}{g}$$

$$a = 0.29 \text{ m/s}^2$$



- ② Shortest time in which the acceleration maybe accomplished without liquid spiling over the edge.

$$V_1 = 0$$

$$V_2 = \frac{30000}{3600} = 8.33 \text{ m/s}$$

$$V_2 = V_1 + at$$

$$8.33 = 0 + 0.29 t$$

$$t = 28.74 \text{ sec}$$

- ③ Total force acting on the bottom of the tank if the width of the tank is 2 m.

$$P_1 = \gamma_w h_1$$

$$P_1 = 9.81(1.15)$$

$$P_1 = 11.28 \text{ kPa}$$

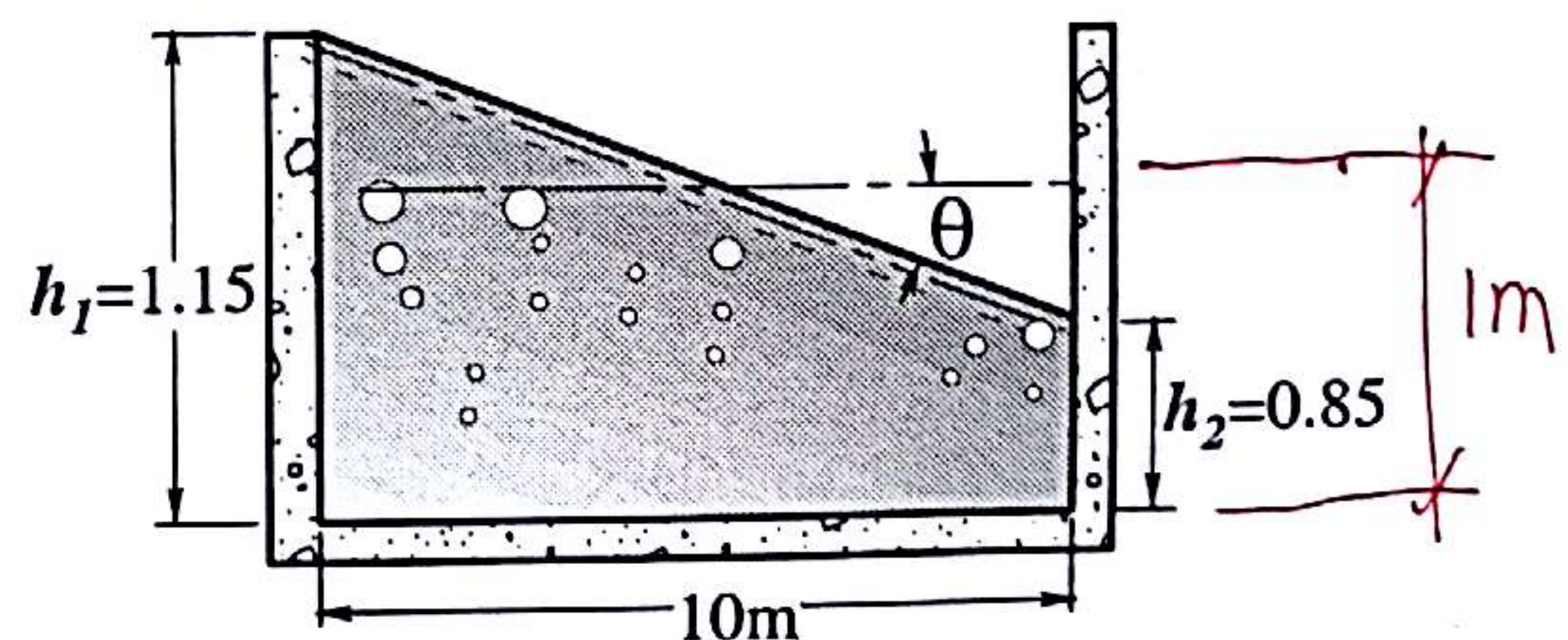
$$P_2 = \gamma_w h_2$$

$$P_2 = 9.81(0.85)$$

$$P_2 = 8.34 \text{ kPa}$$

$$F = \frac{(P_1 + P_2)}{2} A$$

$$F = \frac{(11.28 + 8.34)}{2} (10)(2) = 196.2 \text{ kN}$$



### PROBLEM 32:



## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 33. Prob. 32

An open cylindrical tank having a radius of 0.30 m. and a height of 1.20 m. is filled with water at a depth of 0.90 m.

- ① How fast will it be rotated about its vertical axis if half of its volume is spilled out?
- ② How fast will it be rotated about its vertical axis so that no water will be spilled out?
- ③ How fast will it be rotated about its vertical axis so as to produce a zero pressure with 0.20 m. from the center of the tank.

### Solution:

- ① Speed of rotation so that one half of its volume is spilled out:

$$\frac{\pi(0.30)^2 y}{2} - \frac{\pi(0.30)^2 (0.60)}{2} - \frac{\pi x^2 (y - 1.2)}{2} = 0.50\pi(0.30)^2 (0.90) = V_{air\_final} - V_{air\_initial} = V_{sp}$$

$$0.045y - 0.027 - 0.5(x^2)(y - 1.2) = 0.0405$$

$$0.045y - 0.5x^2(y - 1.2) = 0.0675 \quad \text{--- (1)}$$

$$x^2 = ky \quad \text{EQ. OF PARABOLA}$$

$$\text{when } x = 0.30$$

$$(0.30)^2 = ky$$

$$k = \frac{0.09}{y}$$

$$\text{when } x = x$$

$$y = y - 1.20$$

$$x^2 = k(y - 1.20)$$

$$x^2 = \frac{0.09}{y} (y - 1.20) \quad \text{--- (2)}$$

$$0.045y - 0.5x^2(y - 1.2) = 0.0675 \quad \text{subst. (2) in (1)}$$

$$0.045y - \frac{0.5(0.09)(y - 1.2)^2}{y} = 0.0675$$

$$0.090y^2 - 0.09(y - 1.2)^2 = 0.135y$$

$$0.090y^2 - 0.09y^2 + 0.216y - 0.1296 = 0.135y$$

$$0.081y = 0.1296$$

$$y = 1.6 \text{ m. } \checkmark$$

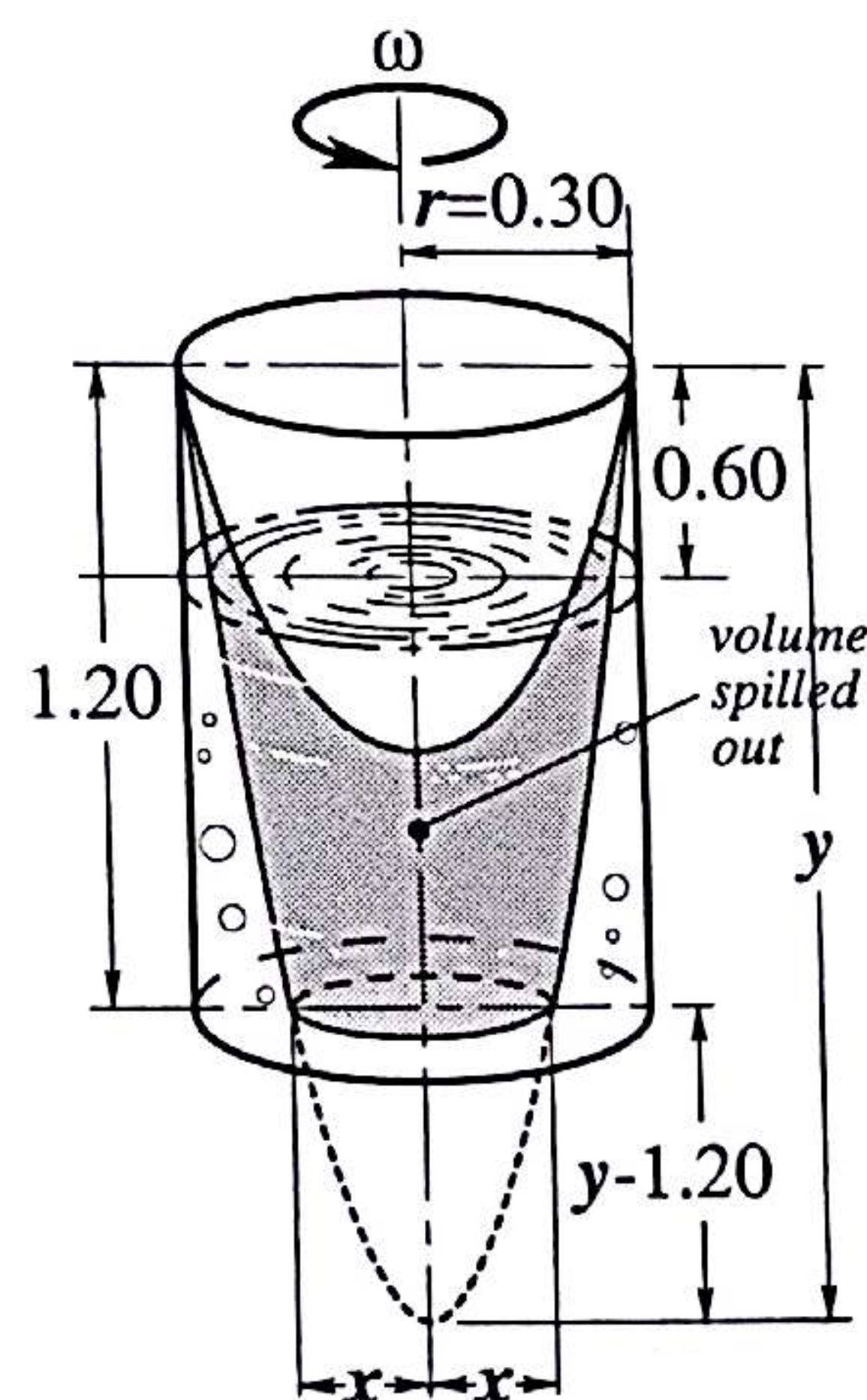
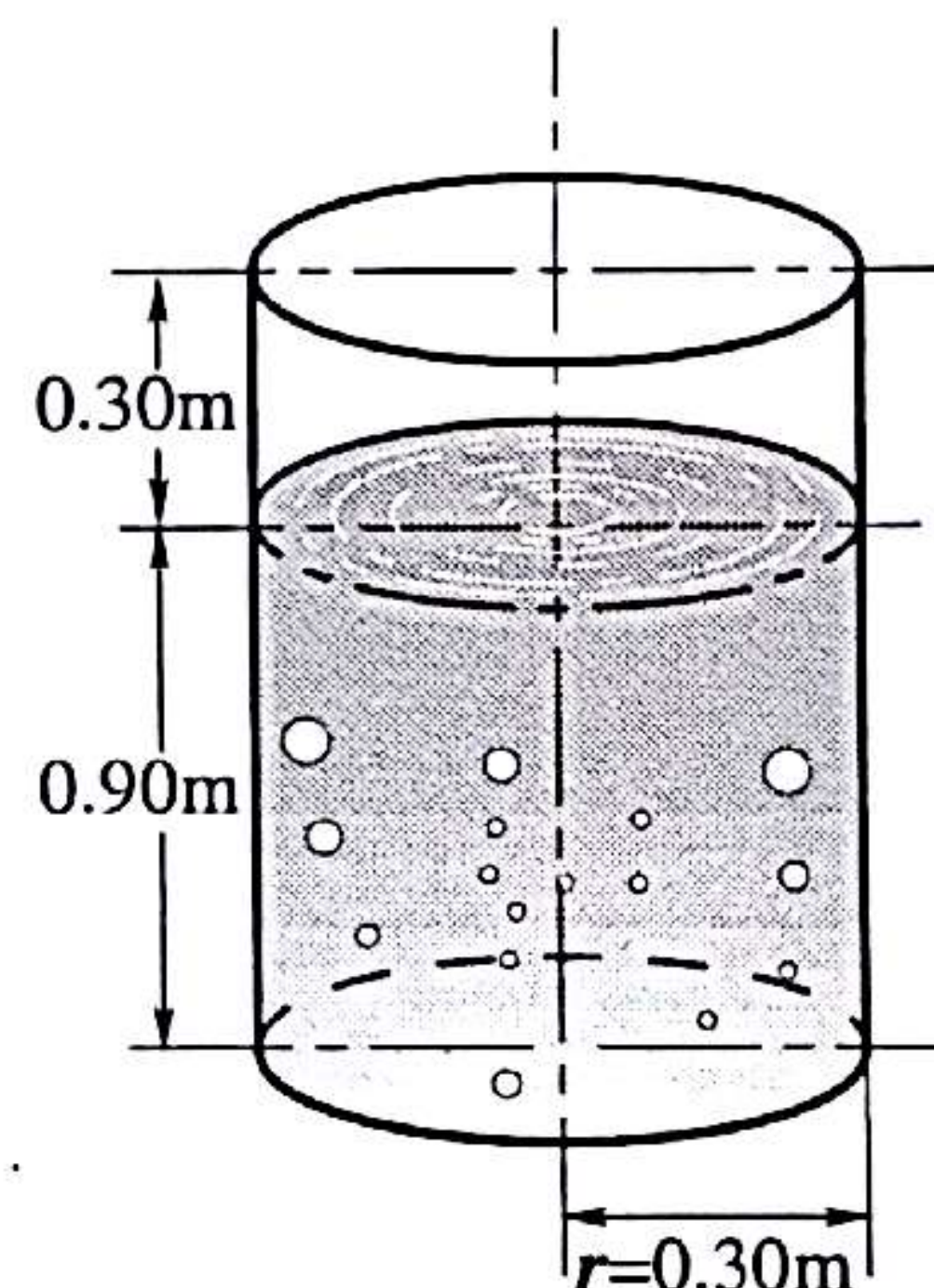
$$y = \frac{\omega^2 r^2}{2g}$$

$$1.6 = \frac{\omega^2 (0.3)^2}{2(9.81)}$$

$$\omega = 18.68 \text{ rad/sec}$$

$$\omega = \frac{18.68(60)}{2\pi}$$

$$\omega = 178.34 \text{ rpm}$$





# HYDRAULICS- Coaching Notes (Nov. 2016)

## PROBLEM 33: (CONTINUATION)

② Speed of rotation so that no water will be spilled out:

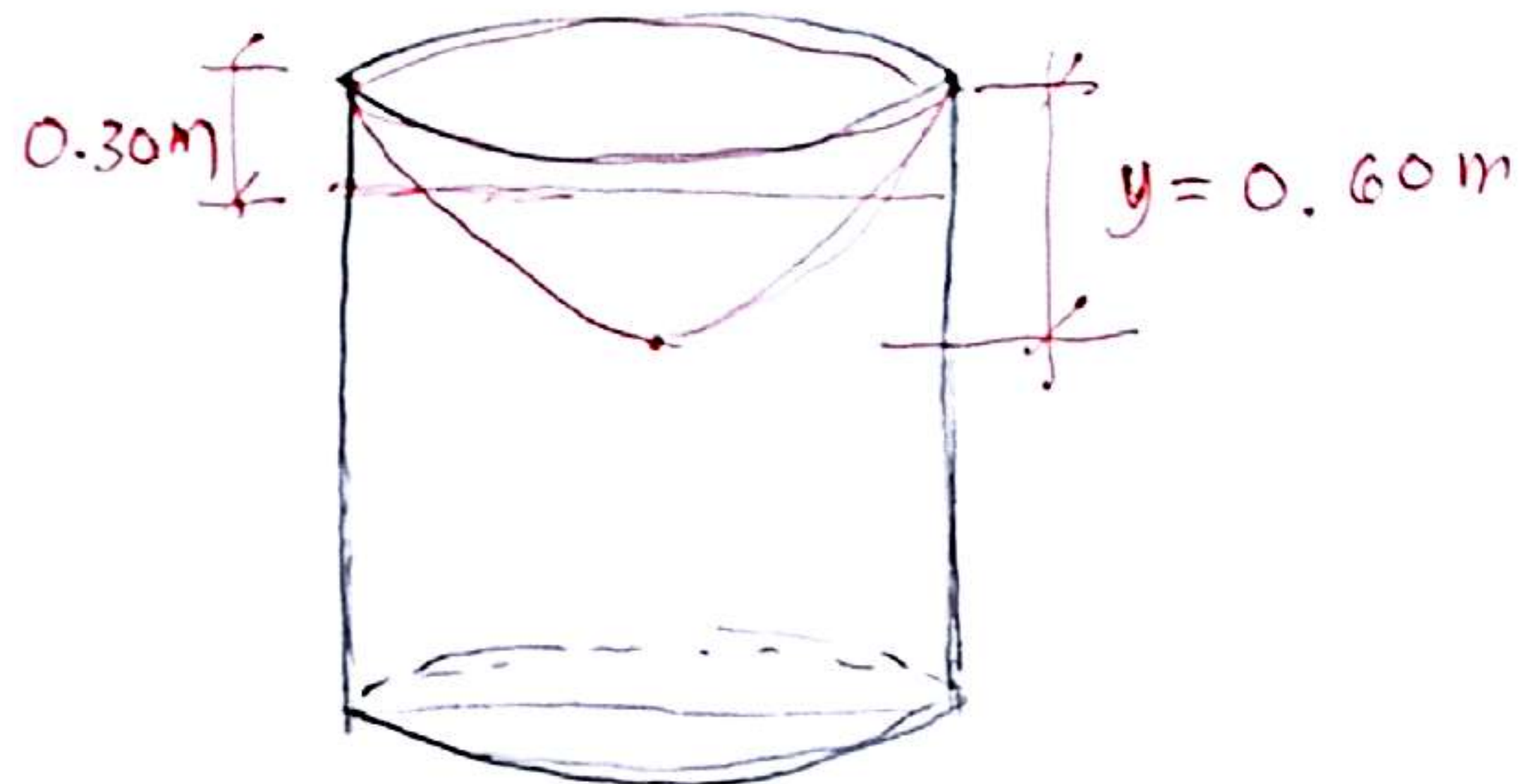
$$y = \frac{\omega^2 r^2}{2g}$$

$$0.60 = \frac{\omega^2 (0.3)^2}{2(9.81)}$$

$$\omega = 11.44 \text{ rad/sec}$$

$$\omega = \frac{11.44(60)}{2\pi}$$

$$\omega = 109.21 \text{ rpm}$$



③ Speed of rotation when ~~x = 0.15~~:

$$x = 0.20 \text{ m}$$

$$x = 0.30 = r$$

$$y = y$$

$$y = y - 1.20$$

$$\frac{(0.30)^2}{y} = \frac{(0.20)^2}{y - 1.20} \quad \text{by spp}$$

$$0.09y - 0.108 = 0.04y$$

$$0.05y = 0.108$$

$$y = 2.16 \text{ m}$$

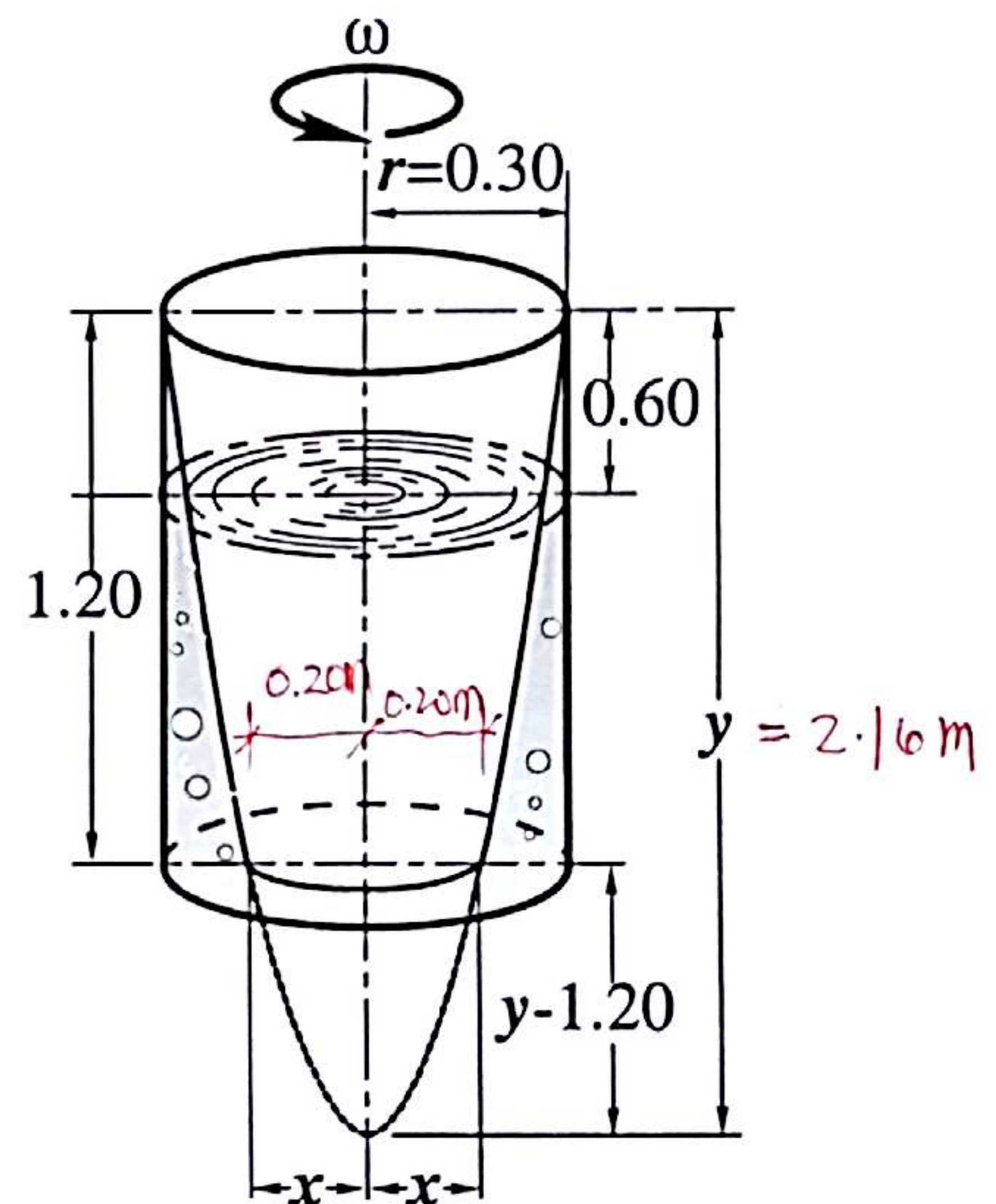
$$y = \frac{\omega^2 r^2}{2g}$$

$$(2.16) = \frac{\omega^2 (0.30)^2}{2(9.81)}$$

$$\omega = 21.70 \text{ rad/sec}$$

$$\omega = \frac{21.70(60)}{2\pi}$$

$$\omega = 207.22 \text{ rpm}$$





## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 34:

A 1.8 m. diameter closed cylinder 2.7 m. high is completely filled with glycerine sp.gr. is 1.60 under a pressure of 245.25 kPa at the top. The steel plates which form the cylinder are 15 mm. thick and can withstand an allowable tensile stress of 82404 kPa.

- ① Compute the max. pressure at the bottom of the tank to resist hoop tension if it is rotated about its vertical axis.
- ② What is the equivalent height of imaginary water at the top of the tank on its sides?
- ③ What is the max. speed in rpm that can be imposed on the cylinder?

#### Solution :

- ① Max. pressure at the bottom of the tank:

Consider 1 m. strip

$$2T = P_D(1)$$

$$T = \frac{P(1.8)(1)}{2}$$

$$T = 90.9 P$$

$$T = S t (1)$$

$$T = 82404(0.015)(1)$$

$$T = 1236 \text{ kN}$$

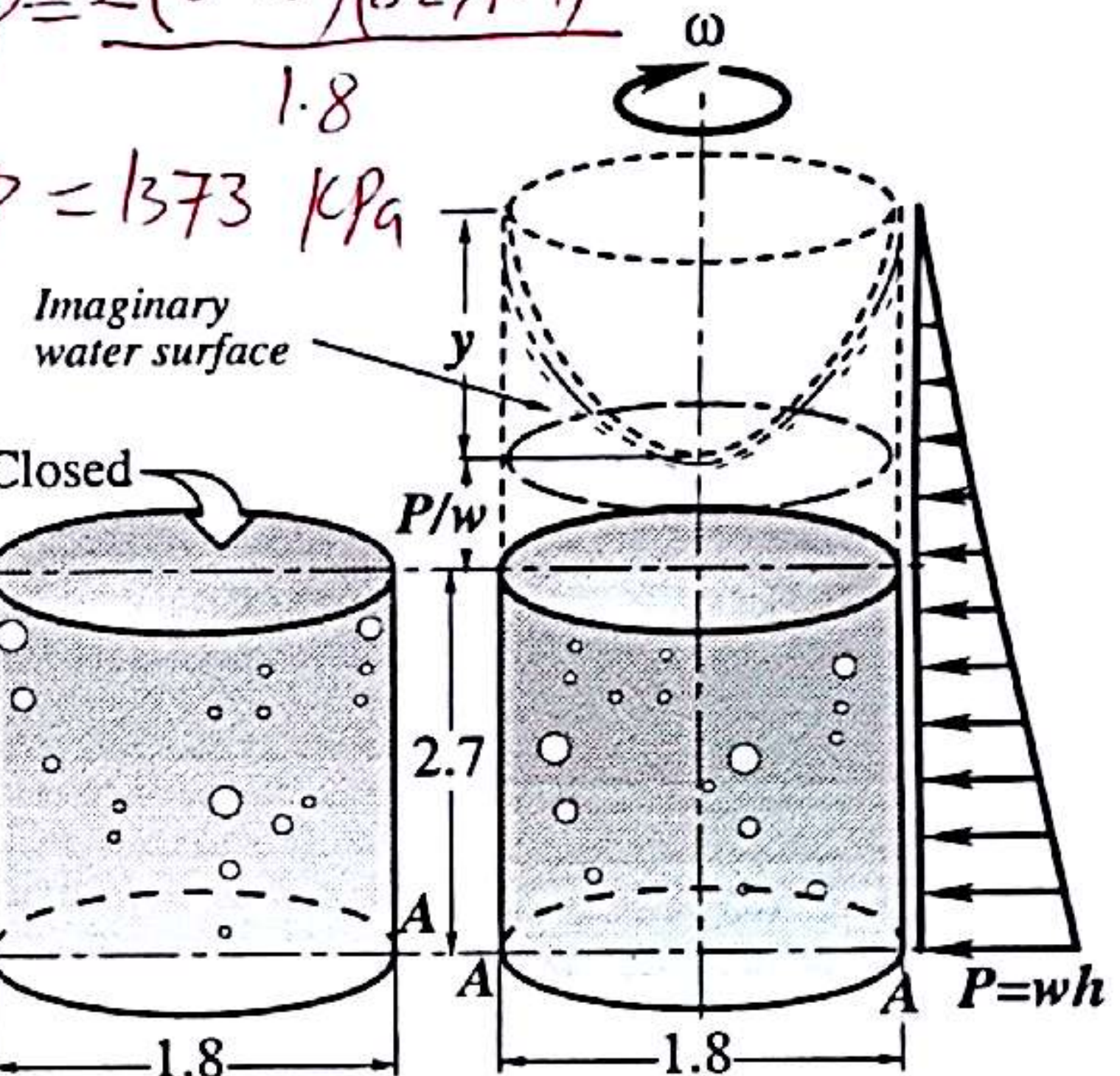
$$1236 = 0.9 P$$

$$P = 1373 \text{ kPa}$$

$$\sigma = \frac{PD}{2t} \rightarrow P = \frac{2t\sigma}{D}$$

$$P = \frac{2(0.015)(82404)}{1.8}$$

$$P = 1373 \text{ kPa}$$



- ② Equivalent height of imaginary water at the top of the tank on its sides:

$$\text{Equivalent: } h + \frac{P}{\gamma_w}$$

$$1373 = 245.25 + 9.81h + 2.7(9.81)(1.6)$$

$$h = 110.64 \text{ m.}$$

$$\text{Equivalent ht} = 110.64 + \frac{245.25}{9.81} = \frac{P}{\gamma_w} + y$$

$$\text{Equivalent ht} = 135.64 \text{ m.}$$

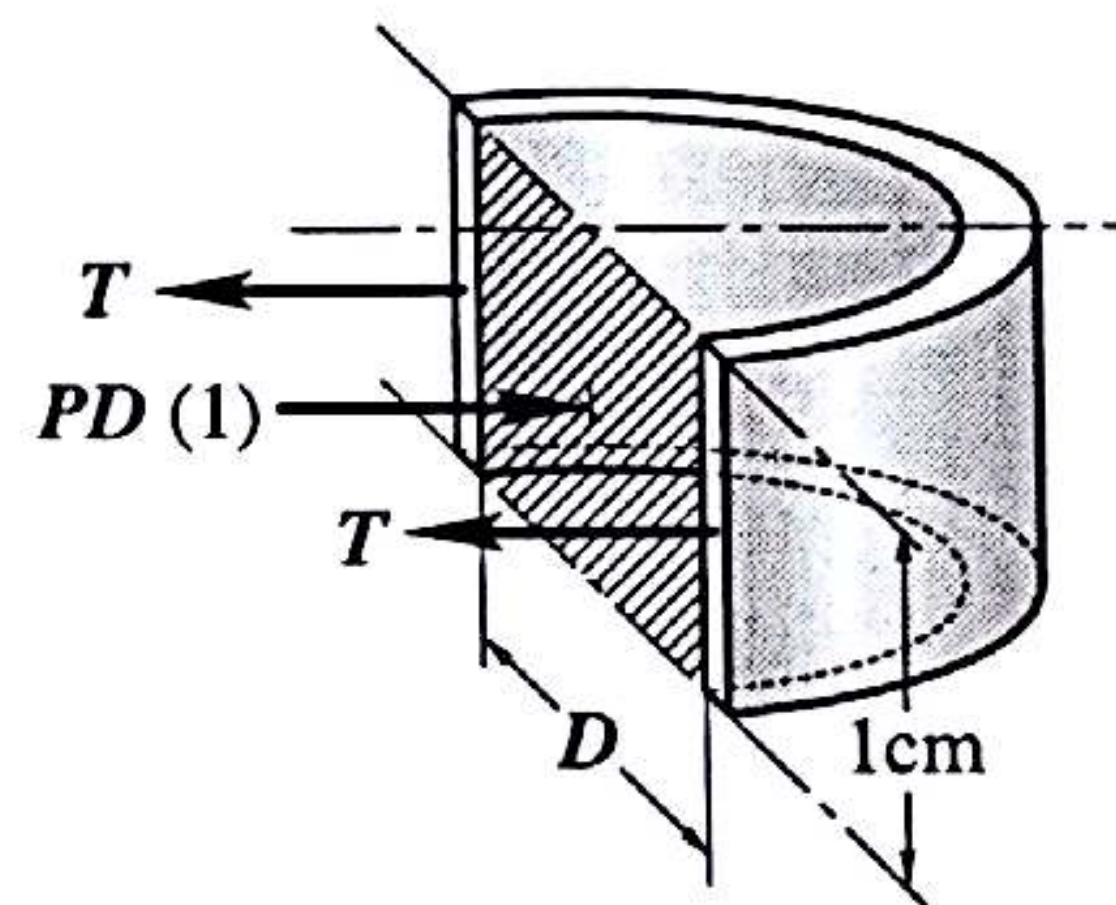
- ③ Max. speed in rpm that can be imposed on the cylinder:

$$y = \frac{\omega^2 r^2}{2g}$$

$$110.64 = \frac{\omega^2 (0.9)^2}{2(9.81)}$$

$$\omega = 51.77 \text{ rad/sec.}$$

$$\omega = \frac{51.77(60)}{2\pi} = 494.4 \text{ rpm}$$

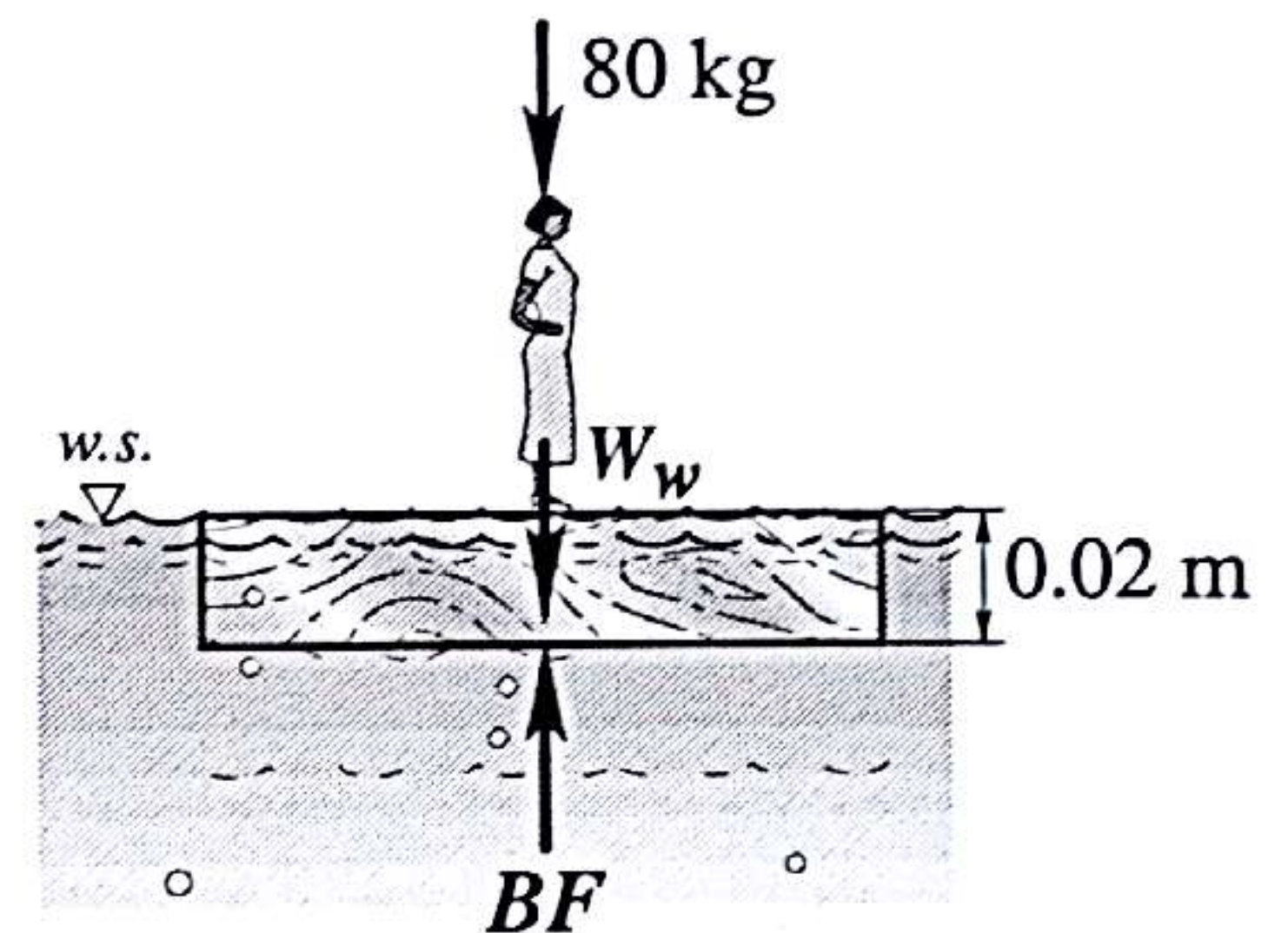




## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 35:

A block of wood is 20 mm thick floating in seawater. The specific gravity of wood is 0.65 while that of seawater is 1.03. Find the area of a block of wood, which will just support a man weighing 80 kg when the top surface is just at the water surface.



**Solution:**  $\Sigma F_v = 0 \uparrow = \downarrow$

$$80 + W_w = BF$$

$$80 + 1000(0.65)(A)(0.02) = 1000(1.03)(A)(0.02)$$

$$A = 10.50 \text{ m}^2 \checkmark$$

### PROBLEM 36:

A wooden spherical ball with sp.gr. of 0.42 and a diameter of 0.30 m. is dropped from a height of 4.2 m. above the surface of the water at the deep end of the swimming pool. If the ball barely touch the bottom of the pool before it began to float, how deep is the pool at that point?

**Solution:** Positive Work = Negative Work

$$\text{Vol. of ball} = \frac{4}{3} \pi r^3$$

$$\text{Vol. of ball} = \frac{4}{3} \pi (0.15)^3 = 0.014 \text{ m}^3$$

Weight of ball:

$$W = V \gamma_s (\text{s.g.})$$

$$W = 0.014(9.81)(0.42)$$

$$W = 0.05768 \text{ KN} \checkmark$$

Bouyant force:

$$BF = V \gamma_s$$

$$BF = 0.014(9.81)$$

$$BF = 0.1373 \text{ KN}$$

Positive work = Negative work

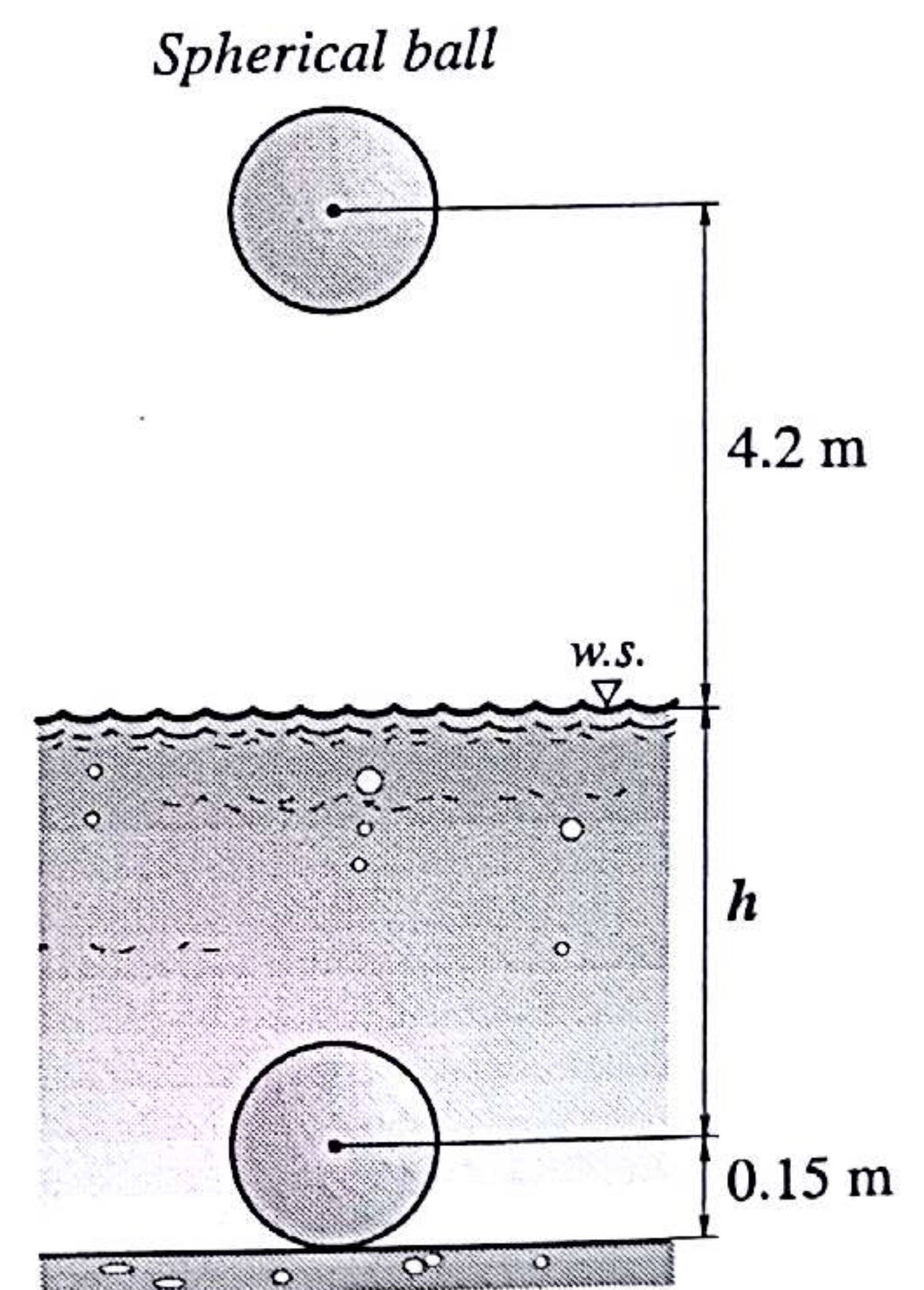
$$W(4.2 + h) = BF(h)$$

$$0.05768(4.2 + h) = 0.1373h$$

$$h = 3.04$$

$$\text{Depth} = 3.04 + 0.15$$

$$\text{Depth} = 3.19 \text{ m.}$$





## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 37:

An orifice at the side of the tank is located 1 meter above the bottom of the tank which is resting on the ground. The jet of water strikes a distance of 2.75 m. horizontally away from the orifice with  $C_v = 0.98$ . The height of the tank is 4 m. and it is filled with water 2 m. depth and on top of it is another liquid having a depth of 1 meter.

- ① Determine the velocity of the jet.
- ② Determine the equivalent constant head of water that causes flow out of the tank.
- ③ Determine the specific gravity of the liquid.

### Solution:

- ① Velocity of jet:

$$y = \frac{1}{2} g t^2$$

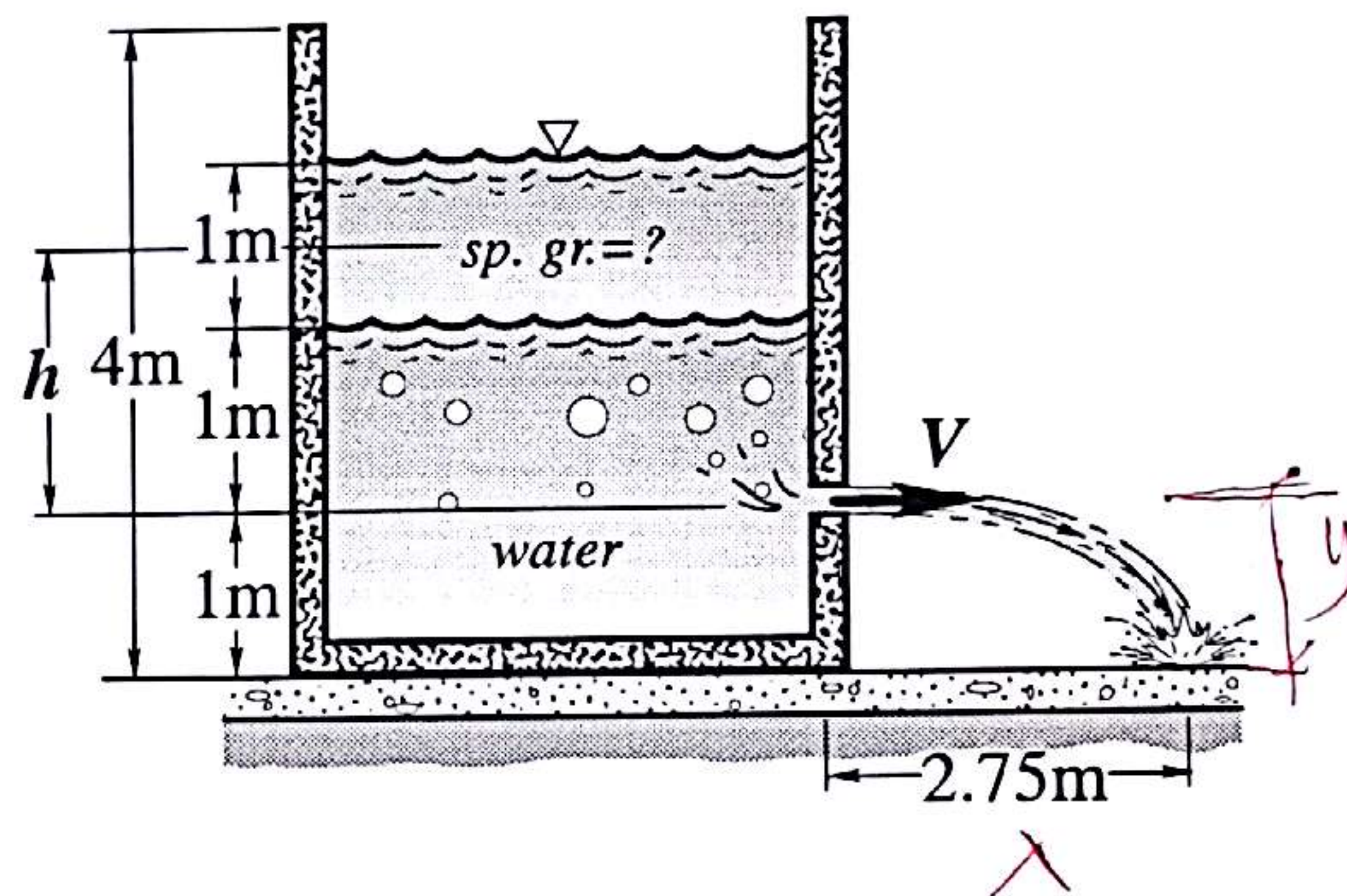
$$1 = \frac{1}{2} (9.81) t^2$$

$$t = 0.45 \text{ sec.}$$

$$x = V t$$

$$2.75 = V (0.45)$$

$$V = 6.11 \text{ m/s}$$



- ② Equivalent constant head of water:

$$V = C_v \sqrt{2gh}$$

$$6.11 = 0.98 \sqrt{2(9.81) h}$$

$$h = 1.98 \text{ m.}$$

- ③ Specific gravity of liquid:

$$h = 1 + 1(\text{sp.gr.})$$

$$1.98 = 1 + \text{sp.gr.}$$

$$\text{sp.gr.} = 0.98$$



## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 38:

The length of weir of a reservoir is 200 m. long. After a heavy down pour the depth of water over the weir was 4 m. The total discharge through the weir was 1,000,000 m<sup>3</sup>.

- ① Compute the average rate of flow of the water, until the flow over the weir lasted.
- ② How long did the flow over the weir lasted?
- ③ What is the depth of water after 300 sec. when the discharge through the weir is only 540000 m<sup>3</sup>.

#### Solution:

- ① Average rate of flow:

$$Q_1 = 1.84 L H^{3/2}$$

$$Q_{ave} = \frac{Q_i + Q_f}{2}$$

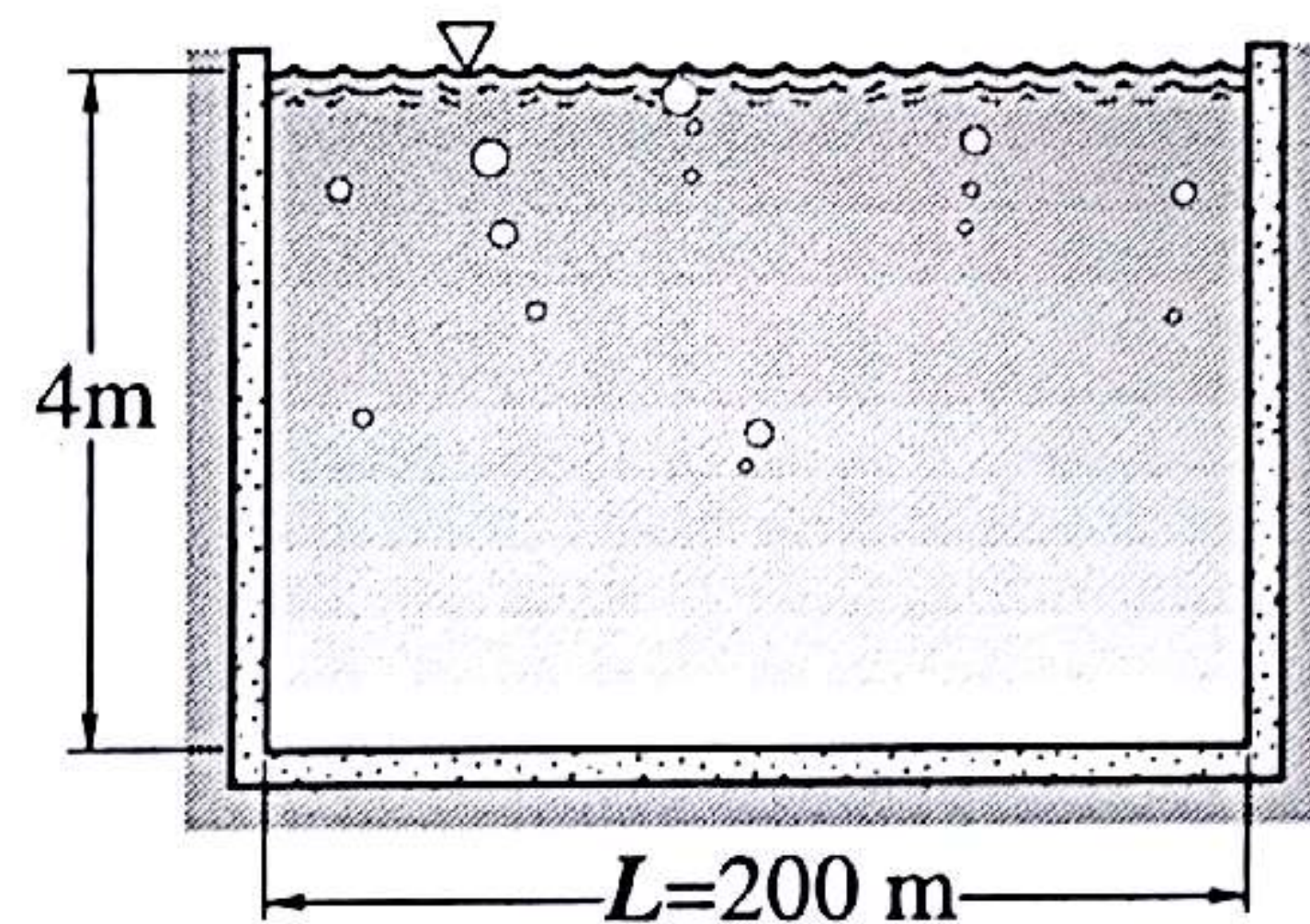
$$Q_f = Q_1 = 1.84(200)(4)^{3/2}$$

$$Q_1 = 2944 \text{ m}^3/\text{s}$$

$$Q_i = Q_2 = 1.84(200)(0)^{3/2}$$

$$Q_2 = 0$$

$$Q_{ave} = \frac{2944 + 0}{2} = 1472 \text{ m}^3/\text{s} \quad \checkmark$$



- ② Time the flow over the weir lasted:

$$t = \frac{\text{Volume}}{Q_{ave}}$$

$$t = \frac{1000000}{1472}$$

$$t = 679.35 \text{ sec.} \quad \checkmark$$

- ③ Depth of water after 300 sec:

$$t = \frac{\text{Vol.}}{Q}$$

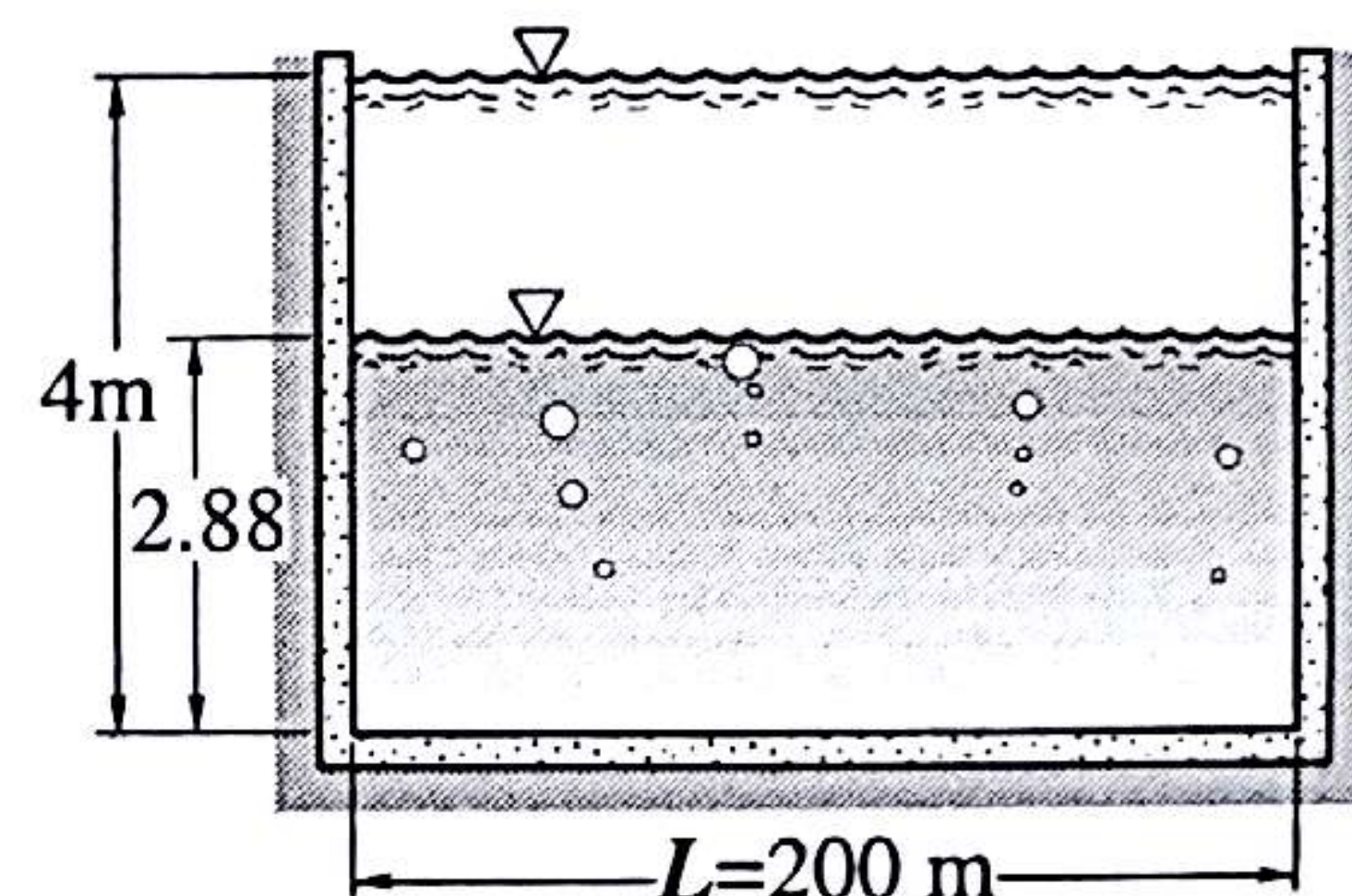
$$300 = \frac{540000}{Q_{ave}}$$

$$Q_{ave} = 1800 \text{ m}^3/\text{s} \quad \checkmark$$

$$Q_1 = 1.84(200) H^{3/2}$$

$$1800 = 1.84(200) H^{3/2}$$

$$H = 2.88 \text{ m.} \quad \checkmark$$





## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 39:

A jet of water 250 mm in diameter impinges normally on a flat steel plate. If the discharge is  $0.491 \text{ m}^3/\text{s}$ .

- ① Find the force exerted by the jet on the stationary plate.
- ② If the flat plate is moving at 2 m/s in the same direction as that of the jet, find the force exerted by the jet on the plate.
- ③ If the flat plate moving a 4 m/s in the same direction as that of the jet, find the work done on the plate per second.

*Solution :*

- ① Force exerted by the jet on the plate:

$$V = \frac{Q}{A}$$

$$V = \frac{0.491}{\frac{\pi}{4} (0.25)^2}$$

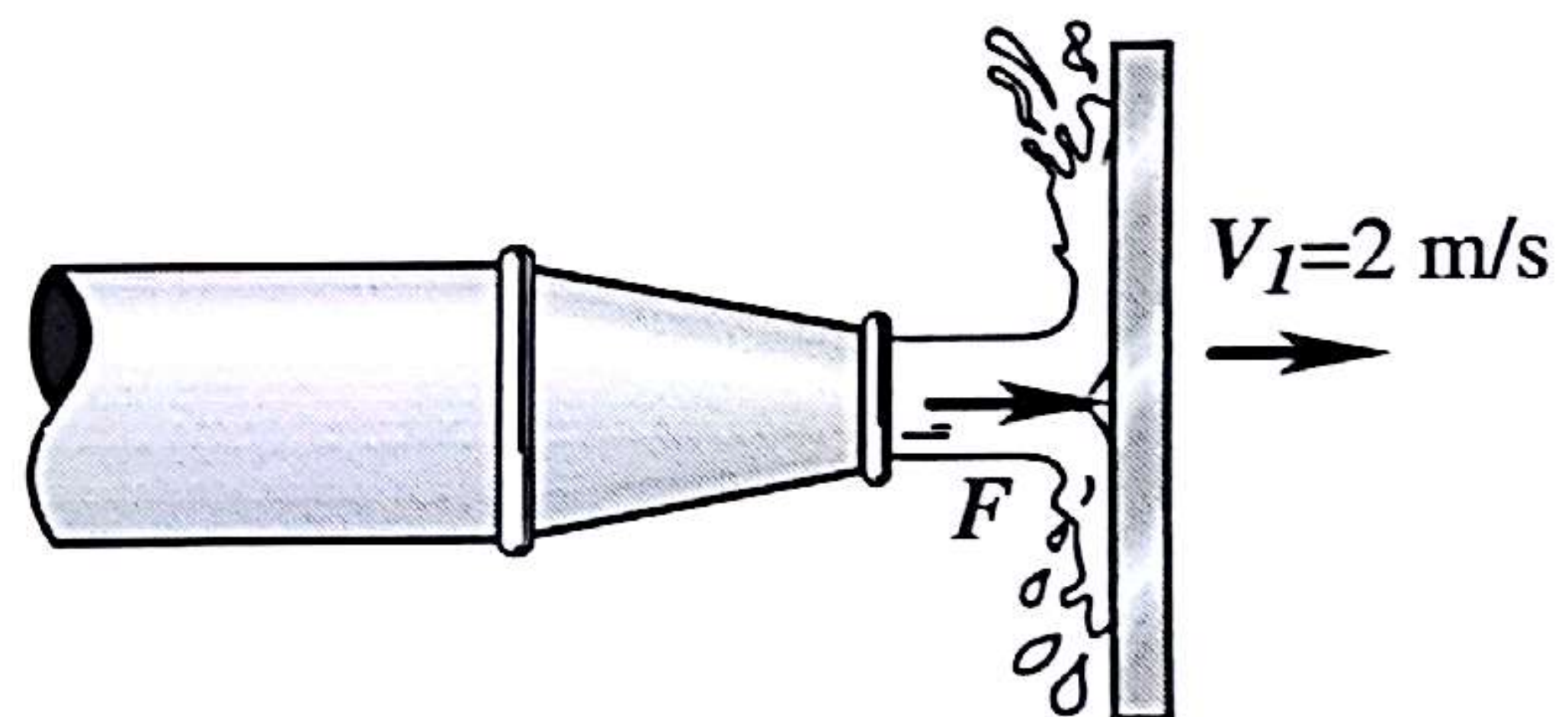
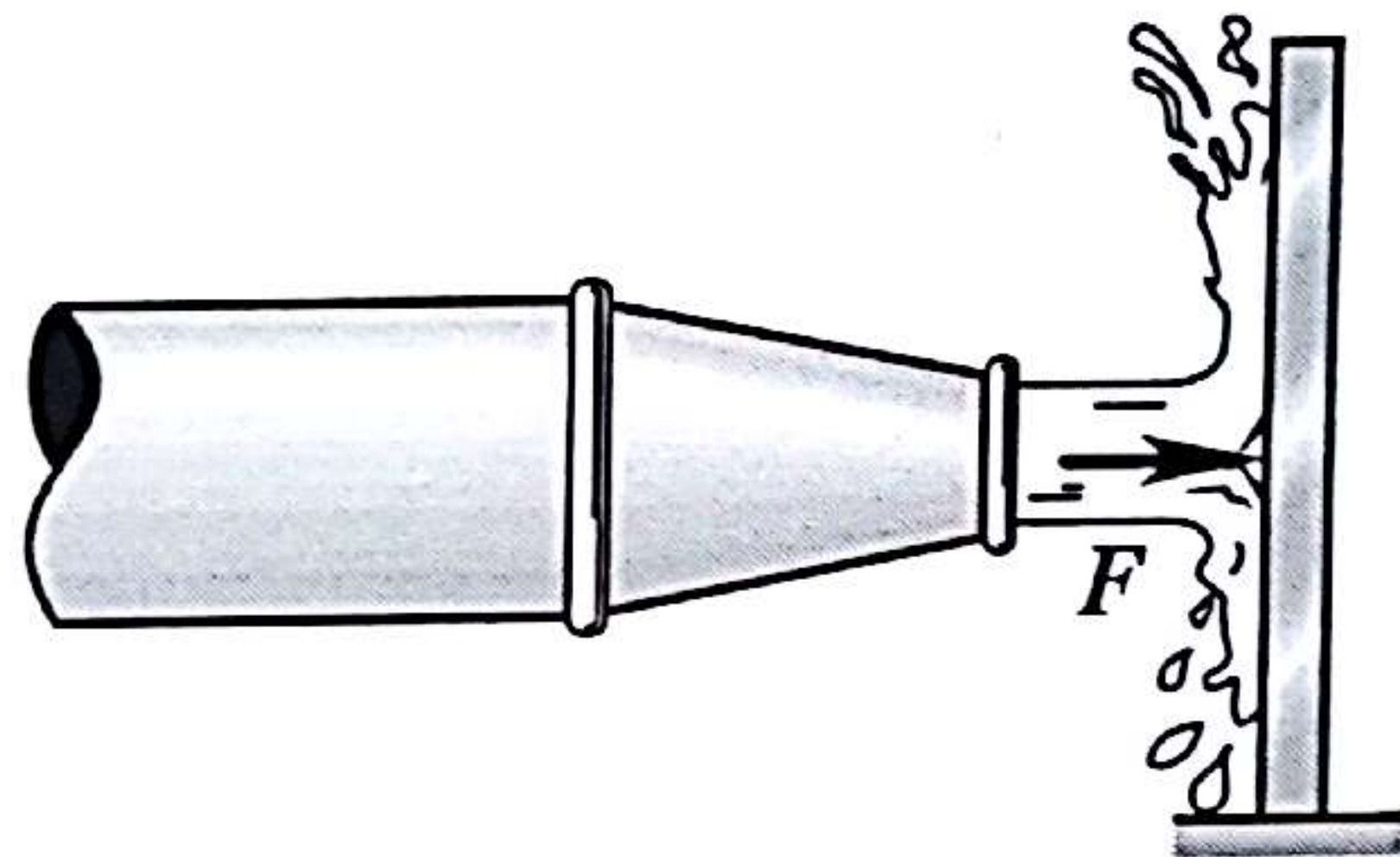
$$V = 10 \text{ m/s}$$

$$F = \rho A V^2$$

$$F = 1000 \left( \frac{\pi}{4} \right) (0.25)^2 (10)^2$$

$$F = 4908.7 \text{ N}$$

$$F = 4.91 \text{ kN} \quad \checkmark$$



- ② Force exerted by the jet on the plate if the plate is moving at 2 m/s in the same direction at the jet:

$$F = \rho A (V - V_1)^2$$

$$F = 1000 \left( \frac{\pi}{4} \right) (0.25)^2 (10 - 2)^2$$

$$F = 3142 \text{ N}$$

$$F = 3.142 \text{ kN} \quad \checkmark$$

- ③ Work done per second if the plate is moving at 4 m/s in the same direction as the jet:

$$F = \rho A (V - V_1)^2$$

$$F = 1000 \left( \frac{\pi}{4} \right) (0.25)^2 (10 - 4)^2$$

$$F = 1767 \text{ N}$$

$$\text{Work done} = 1767(4)(1)$$

$$\text{Work done} = 7068 \text{ N.m/sec.}$$

$$\text{Work} = F \cdot V$$



## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 40:

A rectangular canal is to discharge  $1.86 \text{ m}^3/\text{s}$  per meter of width, with a minimum energy content. The channel is 12 m. wide and  $n = 0.017$ .

- ① Compute the minimum energy content.
- ② Compute the corresponding depth.
- ③ What slope would be necessary to maintain this depth and rate of discharge?

#### Solution:

- ① Min. energy content:

$$q = 1.86 \text{ m}^3/\text{s}$$

$$d_c = \frac{2}{3} E_{\min}$$

$$\frac{V^2}{2g} = \frac{1}{3} E$$

$$V = \sqrt{\frac{2gE}{3}}$$

$$q = A V$$

$$1.86 = d_c (1) \sqrt{\frac{2gE}{3}}$$

$$1.86 = \frac{2}{3} E (1) \sqrt{\frac{2gE}{3}}$$

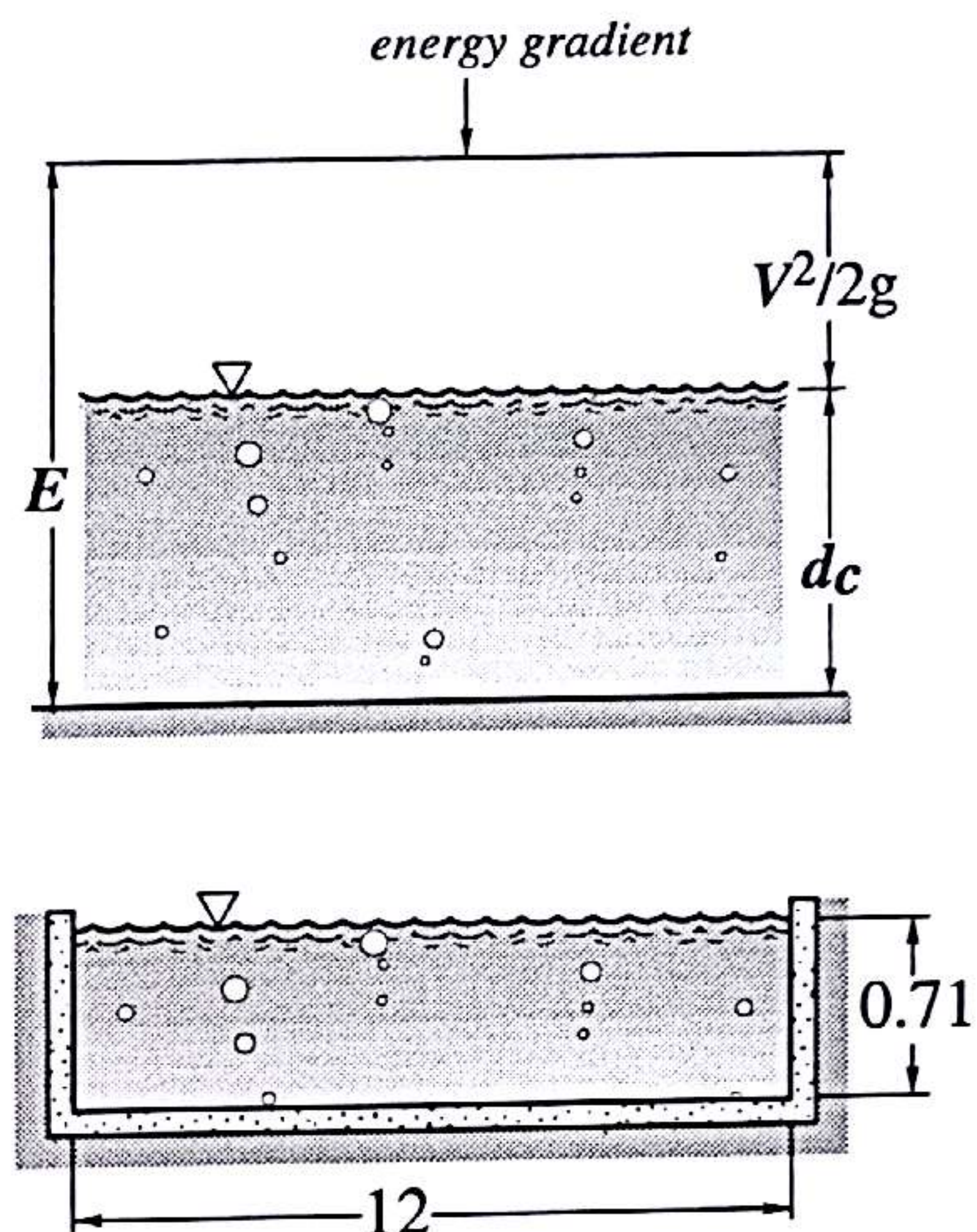
$$7.7841 = \frac{2(9.81) E^3}{3}$$

$$E_{\min} = 1.0598 \text{ m.}$$

- ② Corresponding depth:

$$d_c = \frac{2}{3} (1.0598)$$

$$d_c = 0.71 \text{ m.}$$



- ③ Slope to maintain this depth:

$$Q = A V$$

$$1.86(12) = 0.71(12) V$$

$$V = 2.633 \text{ m/s}$$

$$R = \frac{A}{P}$$

$$R = \frac{12(0.71)}{12 + 2(0.71)}$$

$$R = 0.635$$

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

$$2.633 = \frac{(0.635)^{2/3} S^{1/2}}{0.017}$$

$$S = 0.00367$$

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

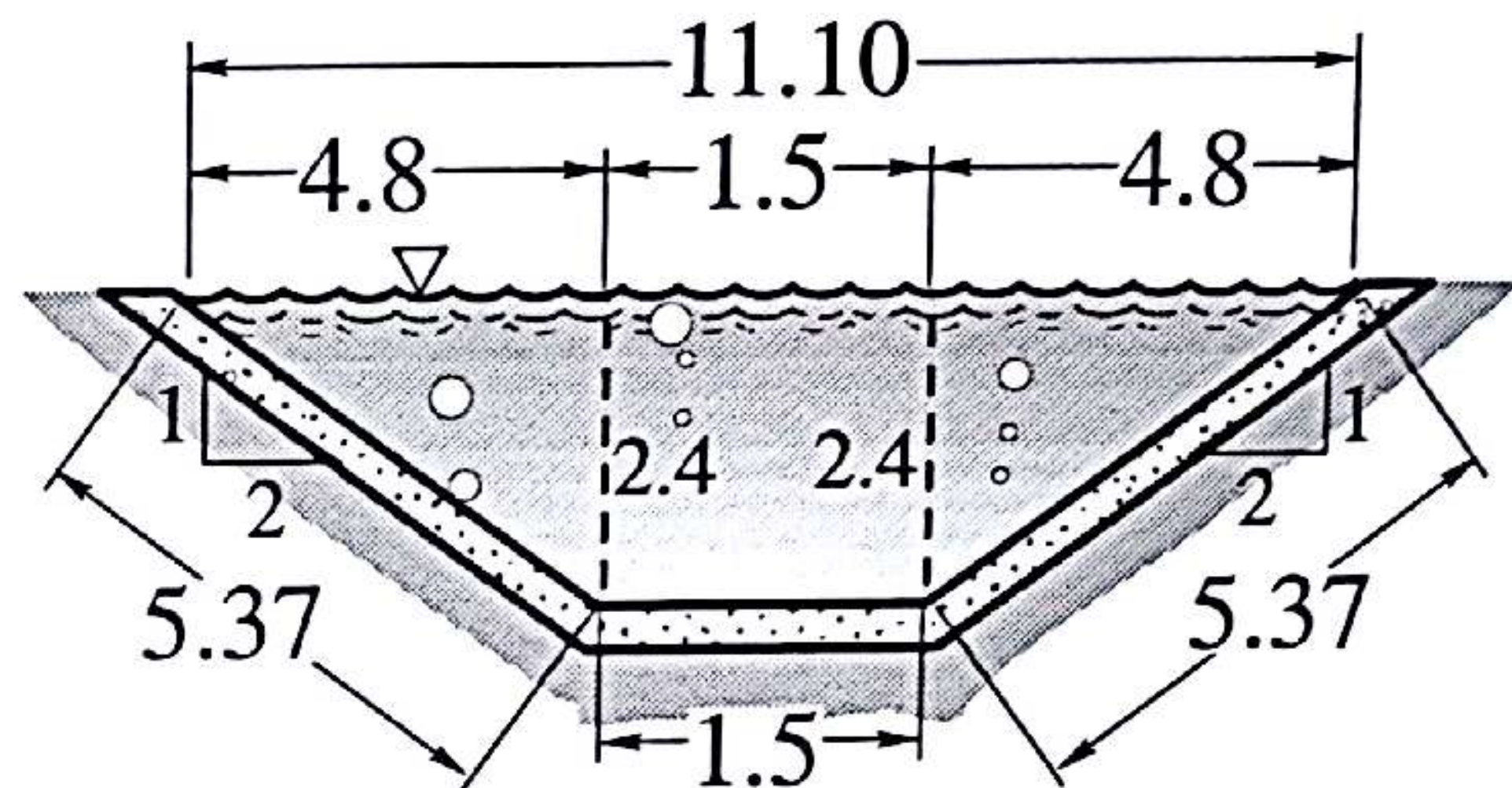


A trapezoidal canal with a bottom width of 1.5 m. and with side slopes of 2 horizontal to 1 vertical has a velocity of 1.2 m/s. If the depth of flow is 2.4 m. and has a slope of channel bed of 0.000212, compute the following.

- Solution:***

- $$Q = AV$$

$$Q = 18.144 \text{ m}^3/\text{s}$$



$$\sqrt{4.8^2 + 2.4^2} = 5.37 \text{ m}$$

- $$\rightarrow V = \frac{1}{n} R^{2/3} S^{1/2}$$

$$n = 0.014$$

- $$\tau = 2.58 \text{ N/m}^2$$



# HYDRAULICS- Coaching Notes (Nov. 2016)

## PROBLEM 42:

A trapezoidal flume of most efficient proportion has a base of 1.5 m. Its full discharge is 3 m<sup>3</sup>/s. If the same material is used for a most efficient rectangular section.

- ① Compute the average depth of the trapezoidal section.
- ② Compute the normal depth of the rectangular section.
- ③ Compute the decrease in the discharge.

### Solution:

- ① Ave. depth of trapezoidal section:

$$d = b \sin 60^\circ$$

$$d = 1.5 \sin 60^\circ$$

$$d = 1.299 \text{ m.}$$

$$B = 2b$$

$$B = 2(1.5) = 3$$

$$A = \frac{(B + b)d}{2}$$

$$P = 3(1.5)$$

$$P = 4.5 \text{ m}$$

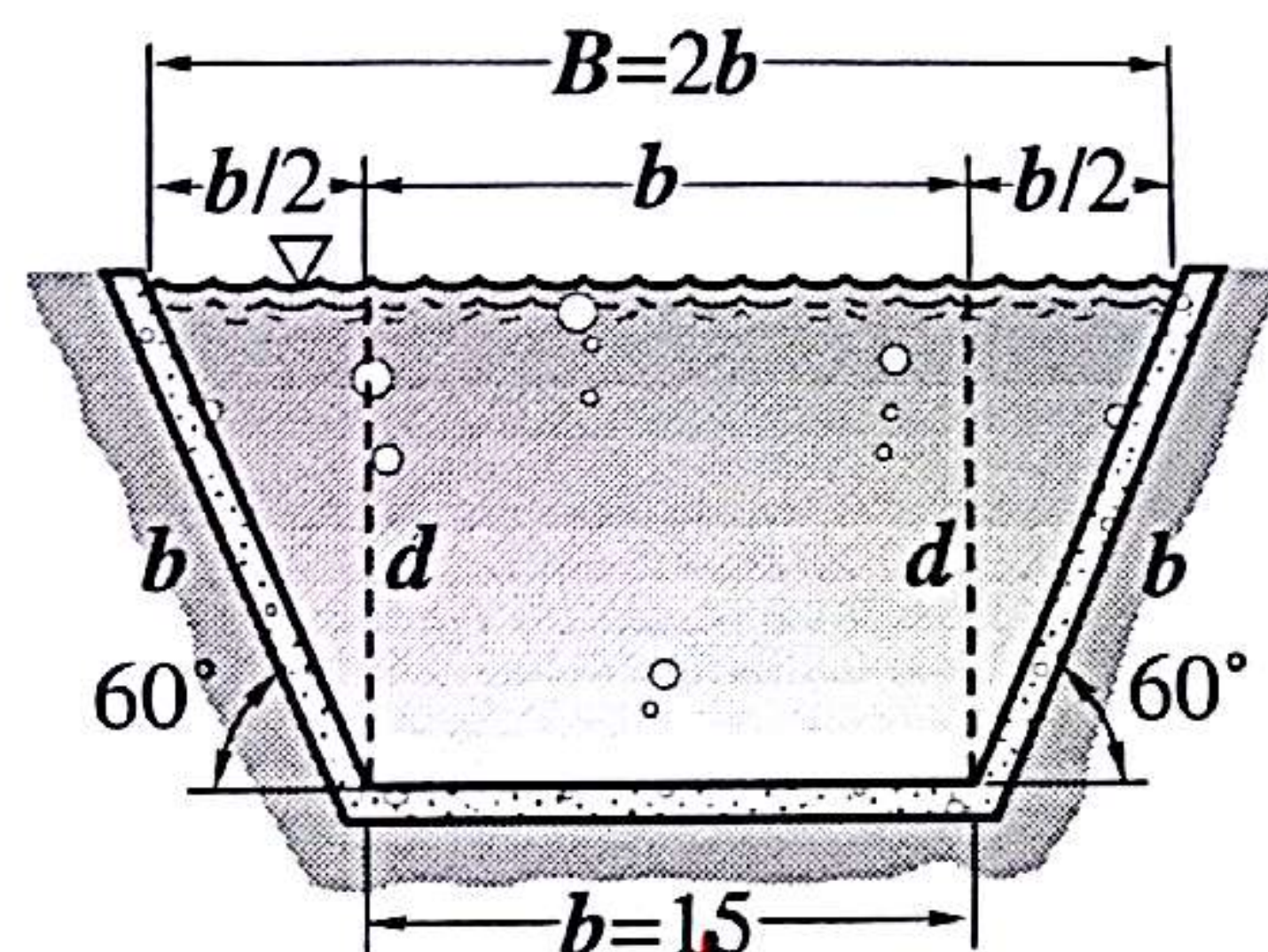
$$A = \frac{(3 + 1.5)(1.299)}{2}$$

$$A = 2.92275 \text{ m}^2$$

$$\text{Average depth} = \frac{A}{B} = d_m$$

$$\text{Average depth} = \frac{2.92275}{3}$$

$$\text{Average depth} = 0.974 \text{ m.}$$



- ② Depth of rectangular section:

For trapezoidal section:

$$R = \frac{d}{2} = \frac{A}{P}$$

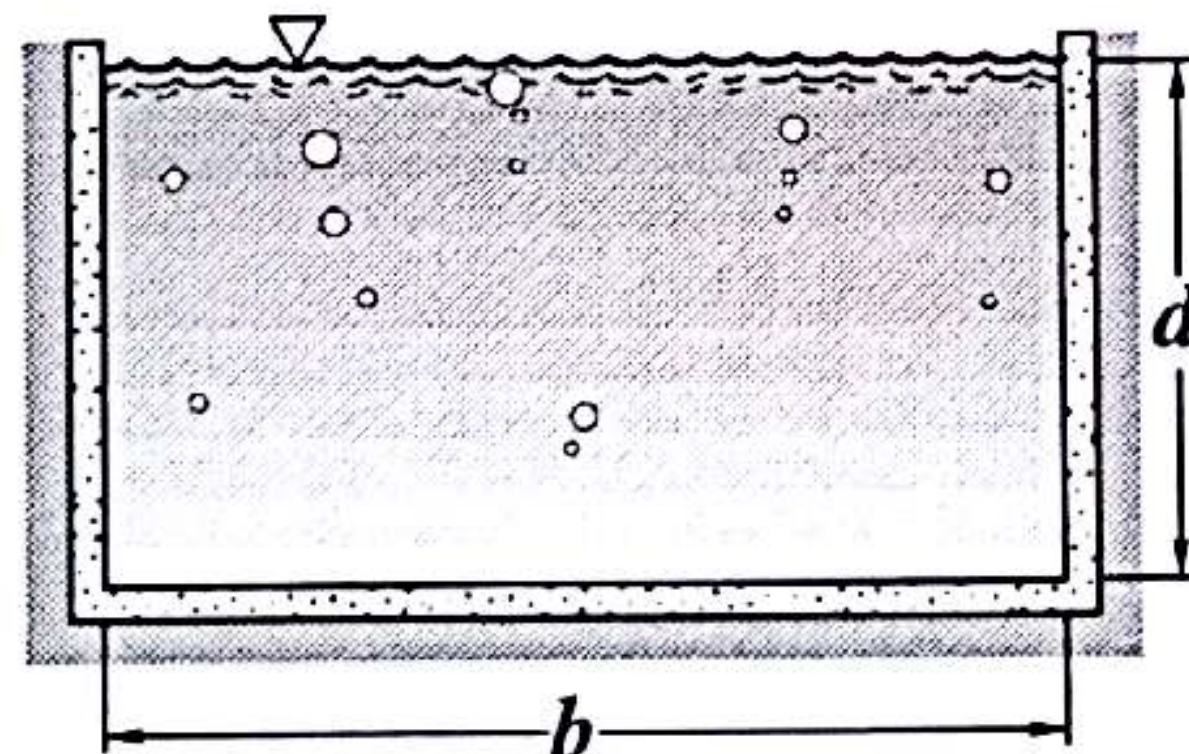
$$R = \frac{1.299}{2} = 0.6495$$

$$Q = AV$$

$$Q = \frac{AR^{2/3}S^{1/2}}{n}$$

$$3 = 2.92275(0.6495)^{2/3} \frac{S^{1/2}}{n}$$

$$\frac{S^{1/2}}{n} = 1.3688$$



For the rectangular section (most efficient)

$$P = 4.5 \text{ m}$$

$$b = 2d$$

$$R = \frac{d}{2}$$

$$4.5 = 2d + b$$

$$4.5 = 2d + 2d$$

$$d = 1.125 \text{ m.}$$

- ③ Decrease in discharge:

$$R = \frac{d}{2}$$

$$R = \frac{1.125}{2}$$

$$R = 0.5625 \text{ m}$$

$$b = 2(1.125)$$

$$b = 2.25 \text{ m}$$

$$A = 2.25(1.125)$$

$$A = 2.53125 \text{ m}^2$$

$$Q = \frac{AR^{2/3}S^{1/2}}{n}$$

$$Q = 2.53125(0.5625)^{2/3} \frac{S^{1/2}}{n}$$

$$Q = 2.53125(0.5625)^{2/3}(1.3688)$$

$$Q = 2.36 \text{ m}^3/\text{s}$$



## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 43:

Water flows over a spillway into a rectangular channel forming a hydraulic jump in order to dissipate mechanical energy. The spillway and the settling basin is 20 meters wide. Before the jump the water has a depth of 1 m. and a velocity of 18 m/s.

- ① Determine the depth after the jump.
- ② Determine the velocity after the jump.
- ③ Determine the Froude No. after the jump.

#### Solution:

- ① *Depth after the jump:*

$$\frac{q^2}{g} = \frac{d_1 d_2 (d_1 + d_2)}{2}$$

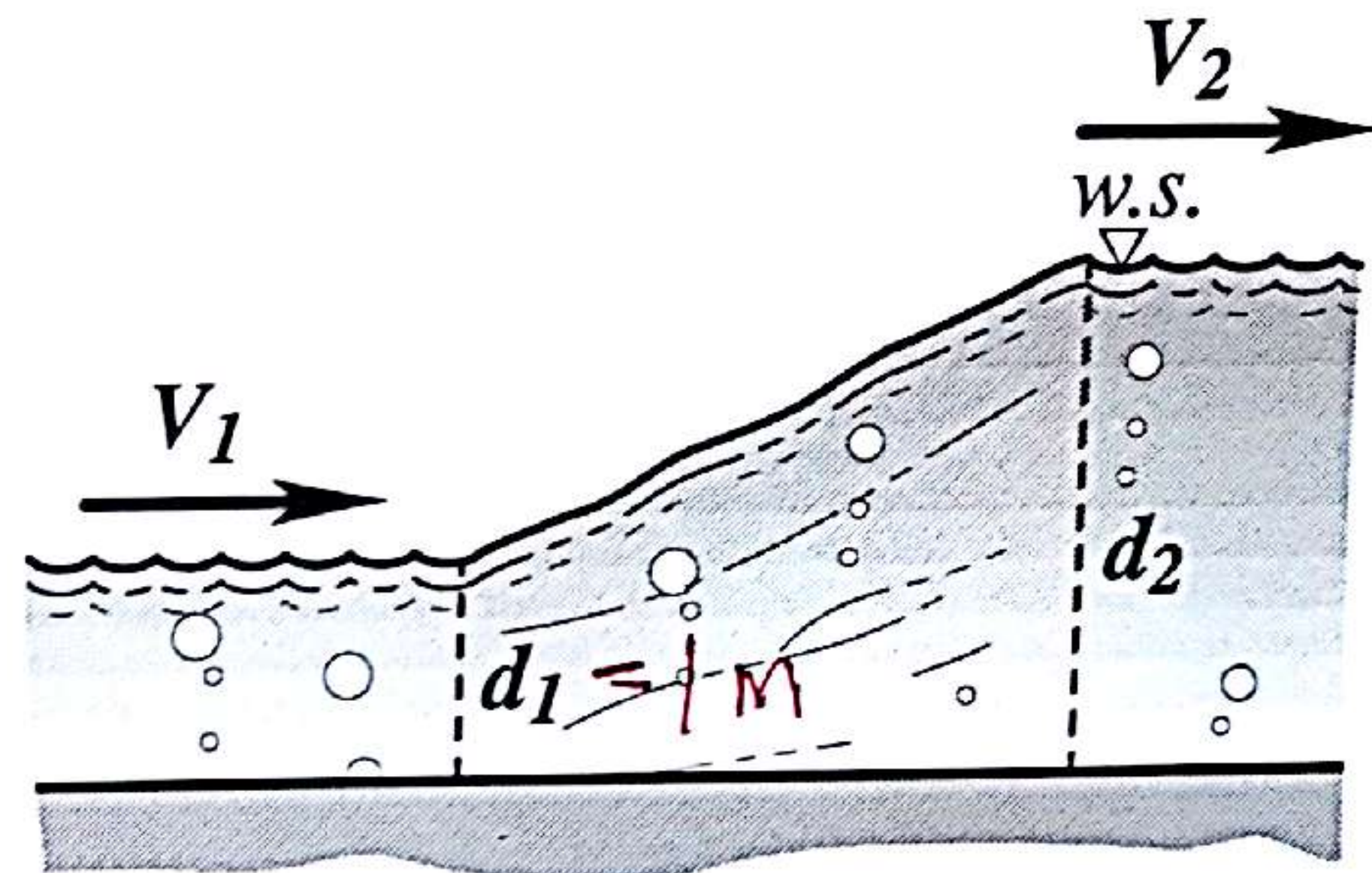
$$q = A_1 V_1$$

$$q = (1)(1)(18)$$

$$q = 18 \text{ m}^3/\text{s}$$

$$\frac{(18)^2}{9.81} = (1) d_2 \frac{(1 + d_2)}{2}$$

$$d_2 = 7.64 \text{ m.} \quad \checkmark$$



- ② *Velocity after the jump:*

$$q = A_2 V_2$$

$$18 = 7.64(1) V_2$$

$$V_2 = 2.36 \text{ m/s} \quad \checkmark$$

- ③ *Froude No:*

$$F = \frac{V_2}{\sqrt{g d_2}}$$

$$F = \frac{2.36}{\sqrt{9.81(7.64)}}$$

$$F = 0.273$$



# HYDRAULICS- Coaching Notes (Nov. 2016)

## PROBLEM 44:

A trapezoidal masonry dam with vertical upstream face is 6 m. high, 0.6 m. at the top and 3 m. wide of the bottom. Wt. of concrete is  $23.5 \text{ kN/m}^3$ .

- ① Find the depth of water on the vertical upstream face if the pressure at the toe is twice the average pressure at the base.
- ② Using the computed depth of water, compute the hydrostatic uplift force if the uplift varies from full hydrostatic pressure at the heel to zero at the toe.
- ③ Compute the factor of safety against sliding if the coefficient of friction on the base is equal to 0.80. Consider the hydrostatic uplift.

### Solution:

- ① Depth of water:

$$P = \gamma_w h A$$

$$P = 9.81 \left( \frac{h}{2} \right) (h)(1)$$

$$P = 4.905 h^2$$

$$W_1 = 0.6(6)(1)(23.5)$$

$$W_1 = 84.6 \text{ kN}$$

$$W_2 = \frac{6(3)}{2} (1)(23.5)$$

$$W_2 = 211.5 \text{ kN}$$

$$R = 84.6 + 211.5$$

$$R = 296.1 \text{ kN}$$

$$RM = 84.6 (2.7) + 211.5(1.6)$$

$$RM = 566.82 \text{ kN}$$

$$OM = P \left( \frac{h}{3} \right)$$

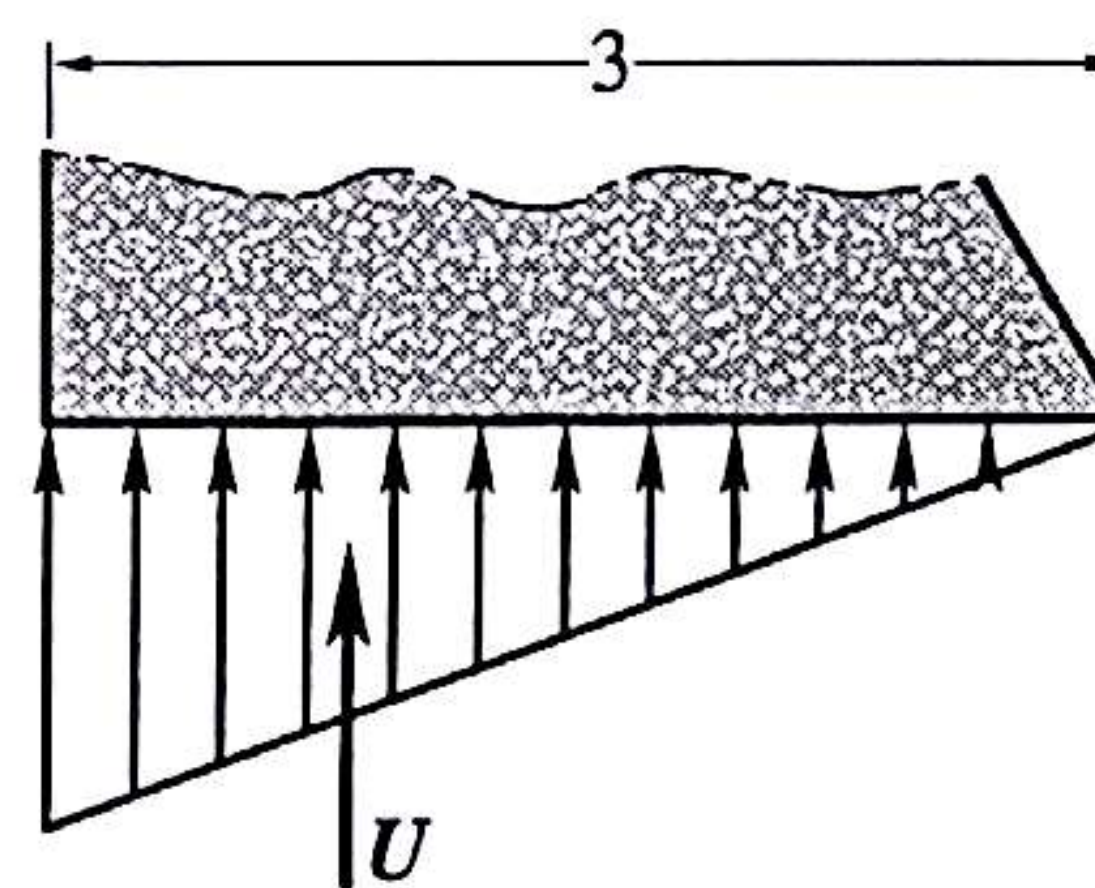
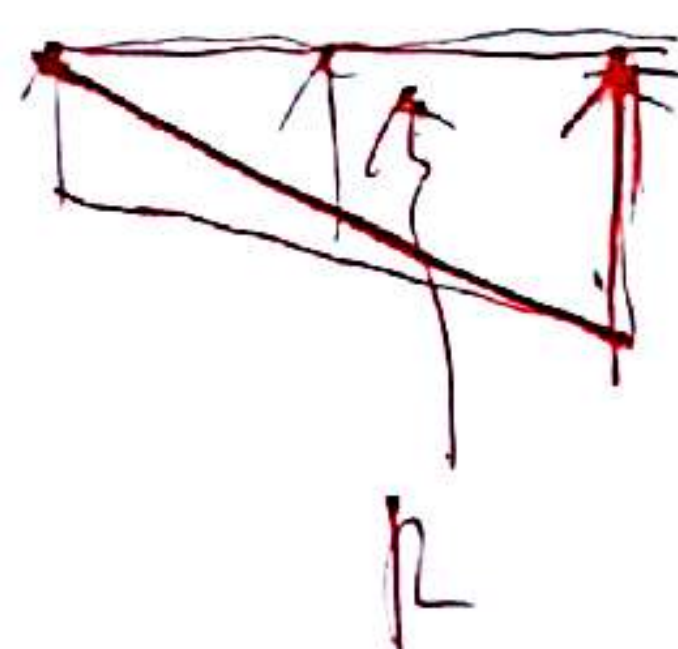
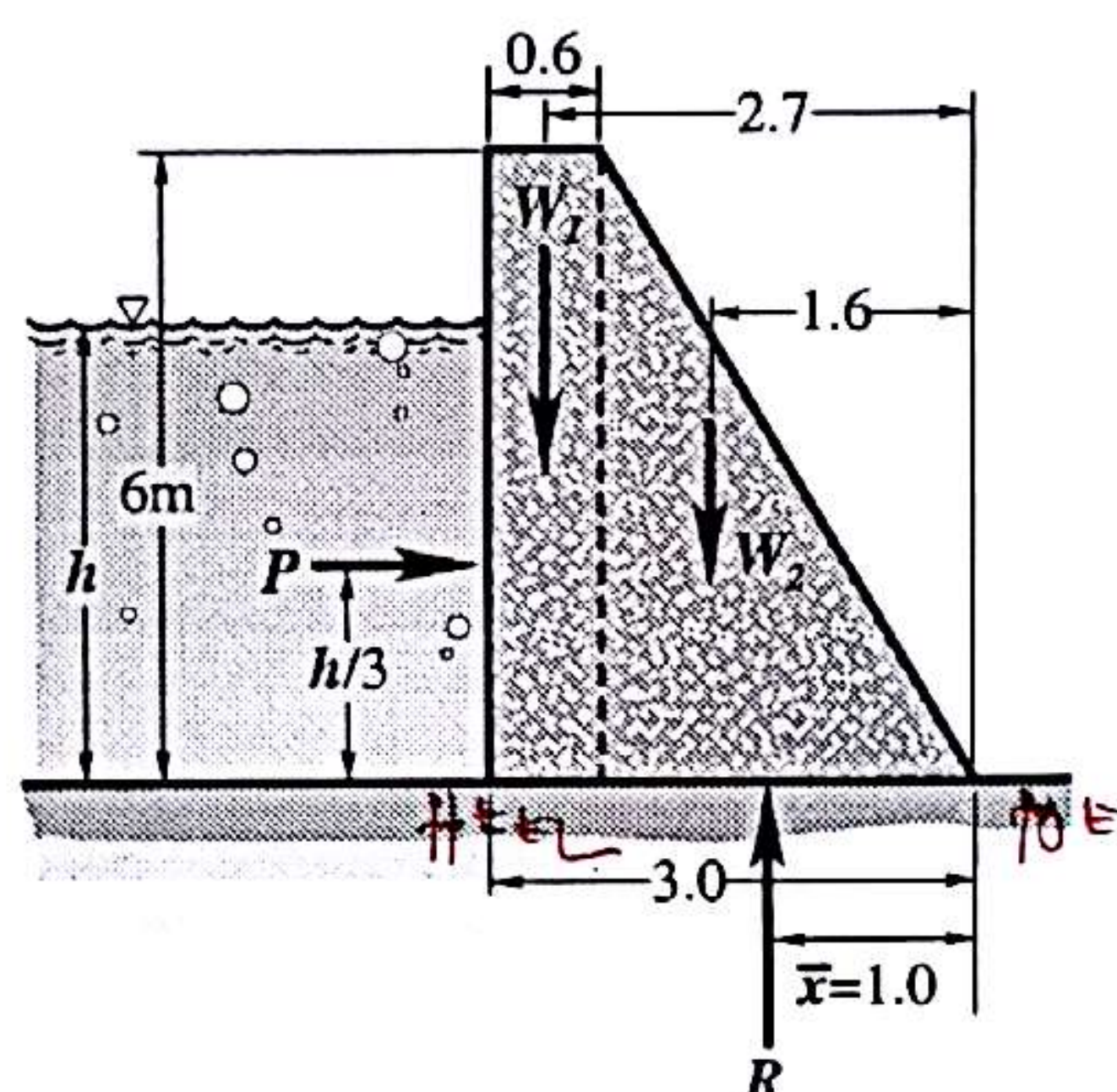
$$OM = \frac{4.905 h^2}{3} (h)$$

$$OM = 1.635 h^3$$

$$R x = RM - OM$$

$$296.1(1) = 566.82 - 1.635 h^3$$

$$h = 5.49 \text{ m.}$$



- ② Uplift force:

$$\gamma_w h = 9.81(5.94)$$

$$\gamma_w h = 58.27 \text{ kN/m}^2$$

$$U = \frac{58.27(3)}{2}$$

$$U = 87.41 \text{ kN}$$

- ③ Factor of safety against sliding:

$$FS = \frac{\mu R}{P}$$

$$R = 296.1 - 87.41$$

$$R = 208.69 \text{ kN}$$

$$P = 4.905 h^2$$

$$P = 4.905(5.49)^2$$

$$P = 147.84 \text{ kN}$$

$$F.S. = \frac{0.80(208.69)}{147.84}$$

$$F.S. = 1.13$$



## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 45:

The crest gate shown consists of a cylindrical surface of which AB is the trace, supported by a structural frame hinged at C. The length of the gate is 10 m.

- ① Compute the horizontal force acting on AB.
- ② Compute the vertical force acting on AB.
- ③ Compute the location of resultant force horizontally from C.

### Solution:

- ① Horizontal force acting on AB:

$$F_x = \gamma \bar{h} A$$

$$F_x = 9.81(4.33)(8.66 \times 10)$$

$$F_x = 3678.53 \text{ kN}$$

- ② Vertical distance of  $F_x$  from A

$$h = \frac{8.66}{3}$$

$$h = 2.89 \text{ m.}$$

$$\text{Area ABD} = \text{Area ADBC} - \text{Area ABC}$$

$$\text{Area ABD} = \frac{1}{2} (5 + 10) 8.66 - \frac{\pi(10)^2(60^\circ)}{360^\circ}$$

$$\text{Area ABD} = 12.59 \text{ m}^2$$

$$F_y = 9.81(12.59)(10)$$

$$F_y = 1235.08 \text{ kN}$$

- ③ Horizontal distance of  $F_y$  from C = z

From similar triangles,

$$\frac{z}{3678.53} = \frac{2.89}{1235.08}$$

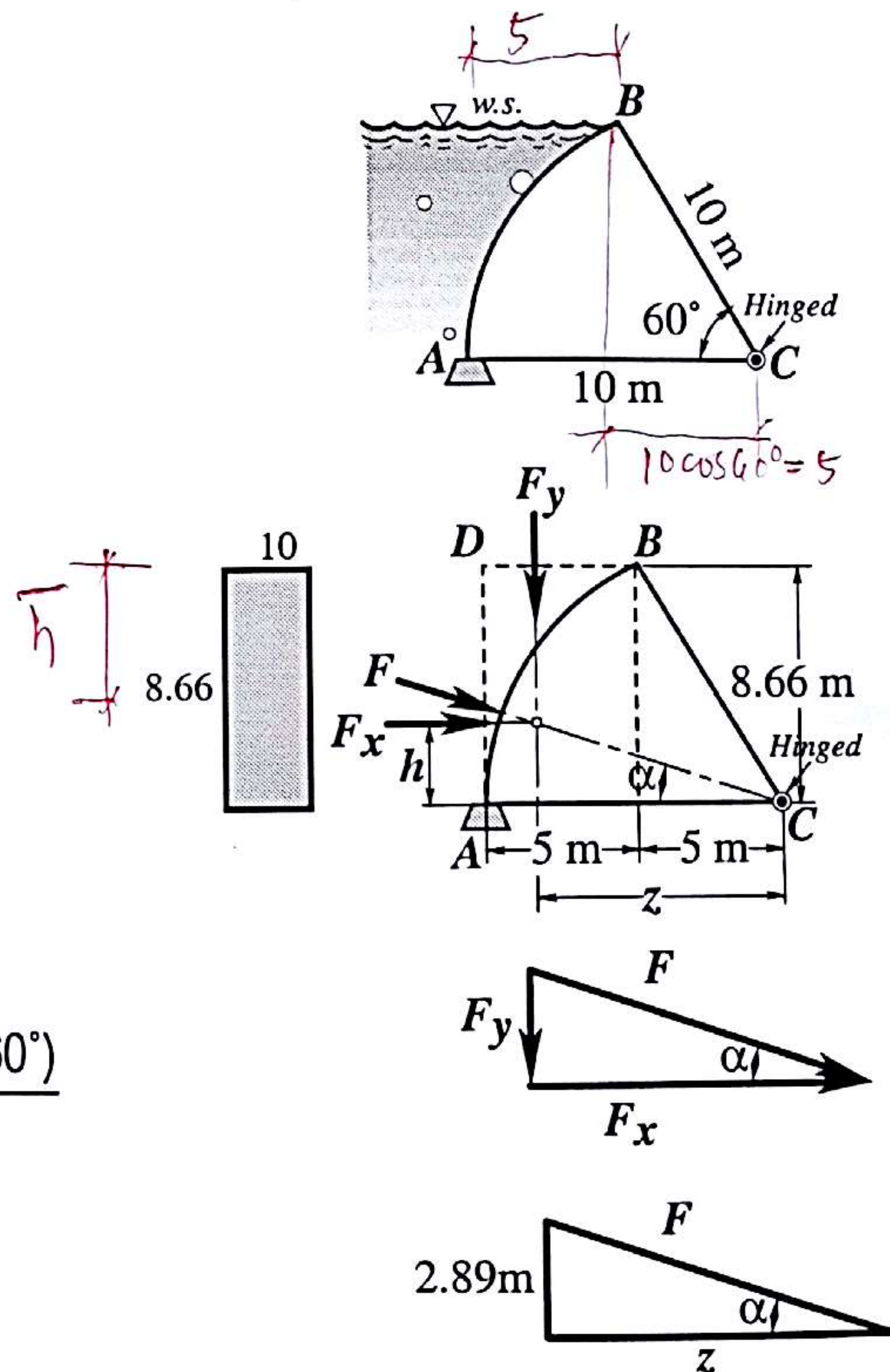
$$z = 8.61 \text{ m.}$$

$$\text{or } \sum M_C = 0$$

$$F_x(h) = F_y(z)$$

$$3678.53 \left( \frac{8.66}{3} \right) = 1235.08(z)$$

$$z = 8.61 \text{ m (ans)}$$



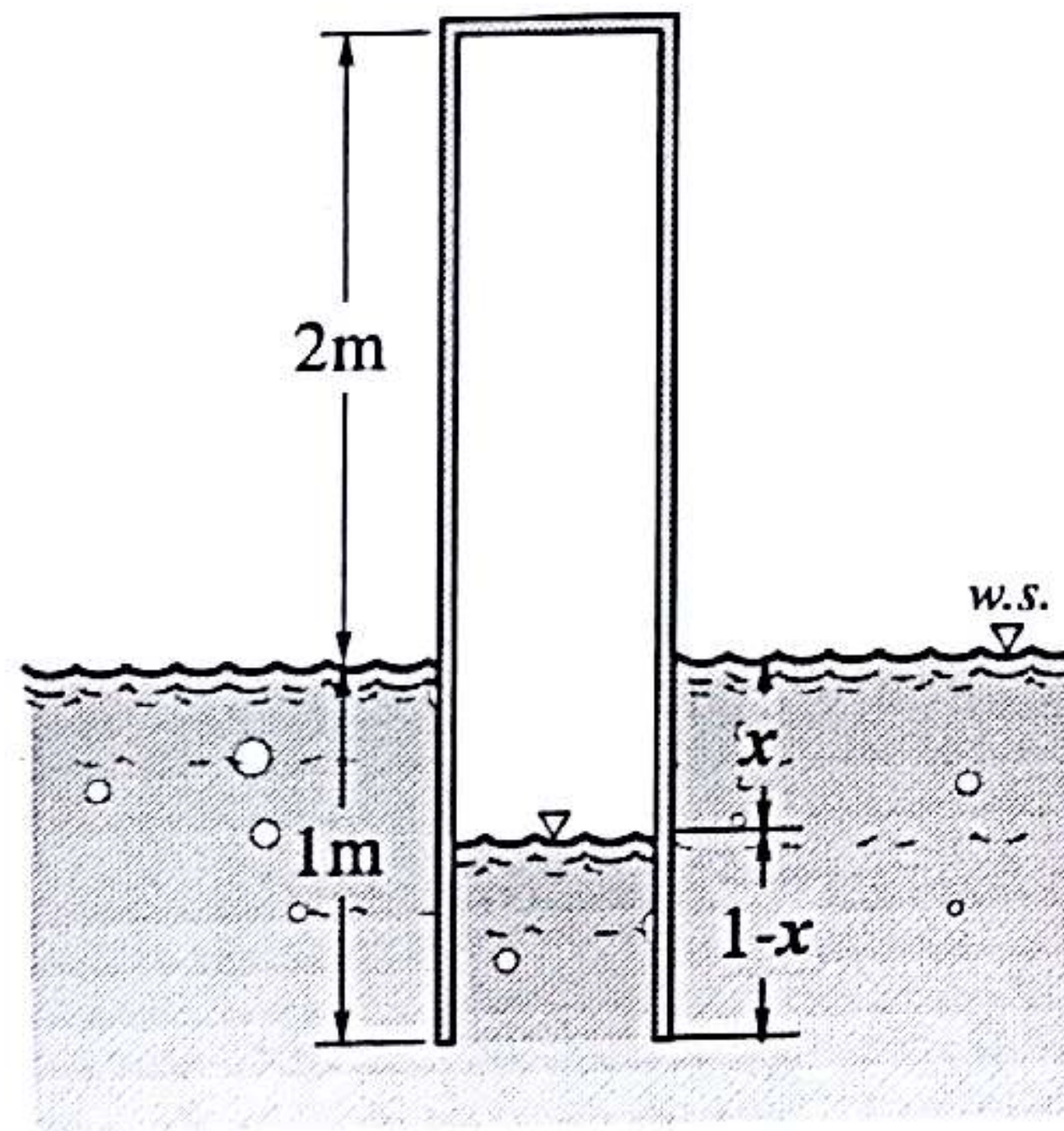


## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 46:

A vertical tube 3 m. long with one end closed is inserted vertically with the open end down, into a tank of water until the open end is submerged to a depth of 1.0 m. Assume absolute atmospheric pressure is 101.5 kPa. Neglecting vapor pressure, how far will the water level in the tube be below the level in the tank?

### Solution:



Let  $A$  = cross-sectional area of tube

$$P_1 V_1 = P_2 V_2$$

$$P_1 = 101.5 \text{ kN/m}^2$$

$$V_1 = 3A$$

$$P_2 = P_1 + wh$$

$$P_2 = 101500 + 9810x$$

$$V_2 = (2 + x) A$$

$$101500(3A) = (101500 + 9810x)(2 + x) A$$

$$304500 = 203000 + 19620x + 101500x + 9810x^2$$

$$x^2 + 12.35x - 10.35 = 0$$

$$x = 0.787 \text{ m.}$$



# HYDRAULICS- Coaching Notes (Nov. 2016)

## PROBLEM 47:

A circular aluminum ( $n = 0.020$ ) channel 2.44 m. in diameter has a Froude Number of 0.50. in uniform half-full flow.

- ① Compute the critical velocity.
- ② Compute the channel slope.
- ③ Compute the specific energy.

### Solution:

- ① Critical velocity:

$$V_c = \sqrt{\frac{gA}{B}}$$

$$A = \frac{\pi(1.22)^2}{2}$$

$$A = 2.34 \text{ m}^2$$

$$B = 2(1.22)$$

$$B = 2.44 \text{ m.}$$

$$V_c = \sqrt{\frac{9.81(2.34)}{2.44}}$$

$$V_c = 3.07 \text{ m/s}$$

- ② Channel slope:

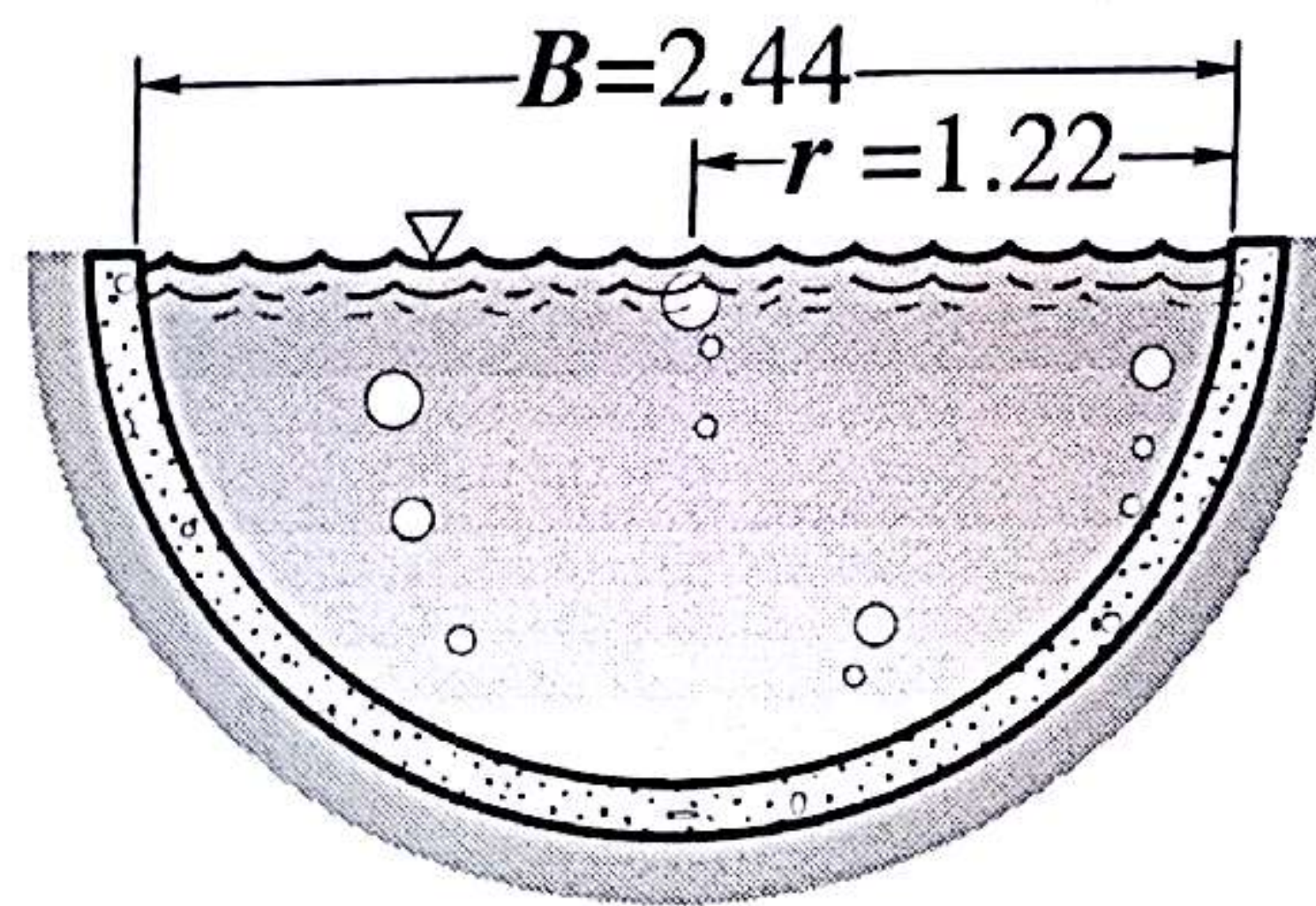
$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

$$F = \frac{V}{\sqrt{gdm}}$$

$$F = \frac{V}{\sqrt{\frac{gA}{B}}}$$

$$0.50 = \frac{V}{\sqrt{\frac{9.81(2.34)}{2.44}}}$$

$$V = 1.535 \text{ m/s}$$



$$R = \frac{D}{4}$$

$$R = \frac{2.44}{4}$$

$$R = 0.61$$

$$V = \frac{R^{2/3} S^{1/2}}{n}$$

$$1.535 = \frac{(0.61)^{2/3} S^{1/2}}{0.020}$$

$$S = 0.00182$$

- ③ Specific energy:

$$E = \frac{V^2}{2g} + d$$

$$E = \frac{(1.535)^2}{2(9.81)} + 1.22$$

$$E = 1.34 \text{ m.}$$



# HYDRAULICS- Coaching Notes (Nov. 2016)

## PROBLEM 48:

If water flows full in a trapezoidal canal having a base width of 1.8 m., width at the top of 2.8 m. and a depth of 1.2 m. Slope of channel bed is 0.002, coefficient of roughness is 0.012.

- ① Compute the rate of flow in the canal.
- ② Compute the critical depth.
- ③ Determine the type of flow.

### Solution:

- ① Rate of flow:

$$A = \frac{(2.8 + 1.8)(1.2)}{2} = 2.76 \text{ m}^2$$

$$P = 1.30(2) + 1.8 = 4.4 \text{ m}$$

$$R = \frac{A}{P}$$

$$R = \frac{2.76}{4.4}$$

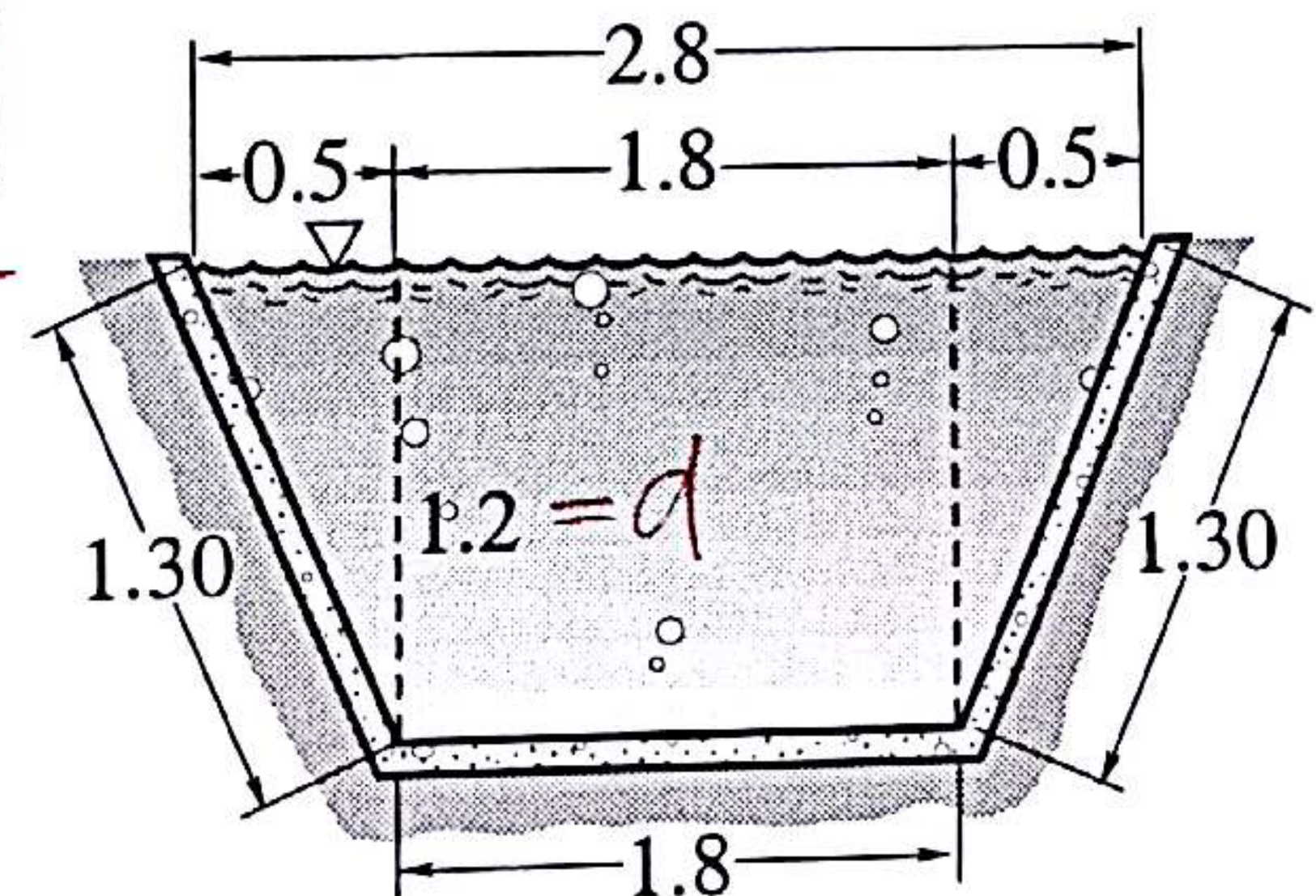
$$R = 0.63 \text{ m}$$

$$Q = A \cdot V = \frac{A R^{2/3} S^{1/2}}{n}$$

$$Q = \frac{A R^{2/3} S^{1/2}}{n}$$

$$Q = \frac{2.76(0.63)^{2/3} (0.002)^{1/2}}{0.012}$$

$$Q = 7.56 \text{ m}^3/\text{s}$$



- ② Critical depth:

$$\frac{Q^2}{g} = \frac{A^3}{B}$$

$$\frac{x}{d_c} = \frac{0.5}{1.2}$$

$$x = 0.417 d_c$$

$$B = 1.8 + 2(0.417) d_c$$

$$B = 1.8 + 0.834 d_c$$

$$A = \frac{(1.8 + 0.834 d_c + 1.8) d_c}{2}$$

$$A = (1.8 + 0.417 d_c) d_c$$

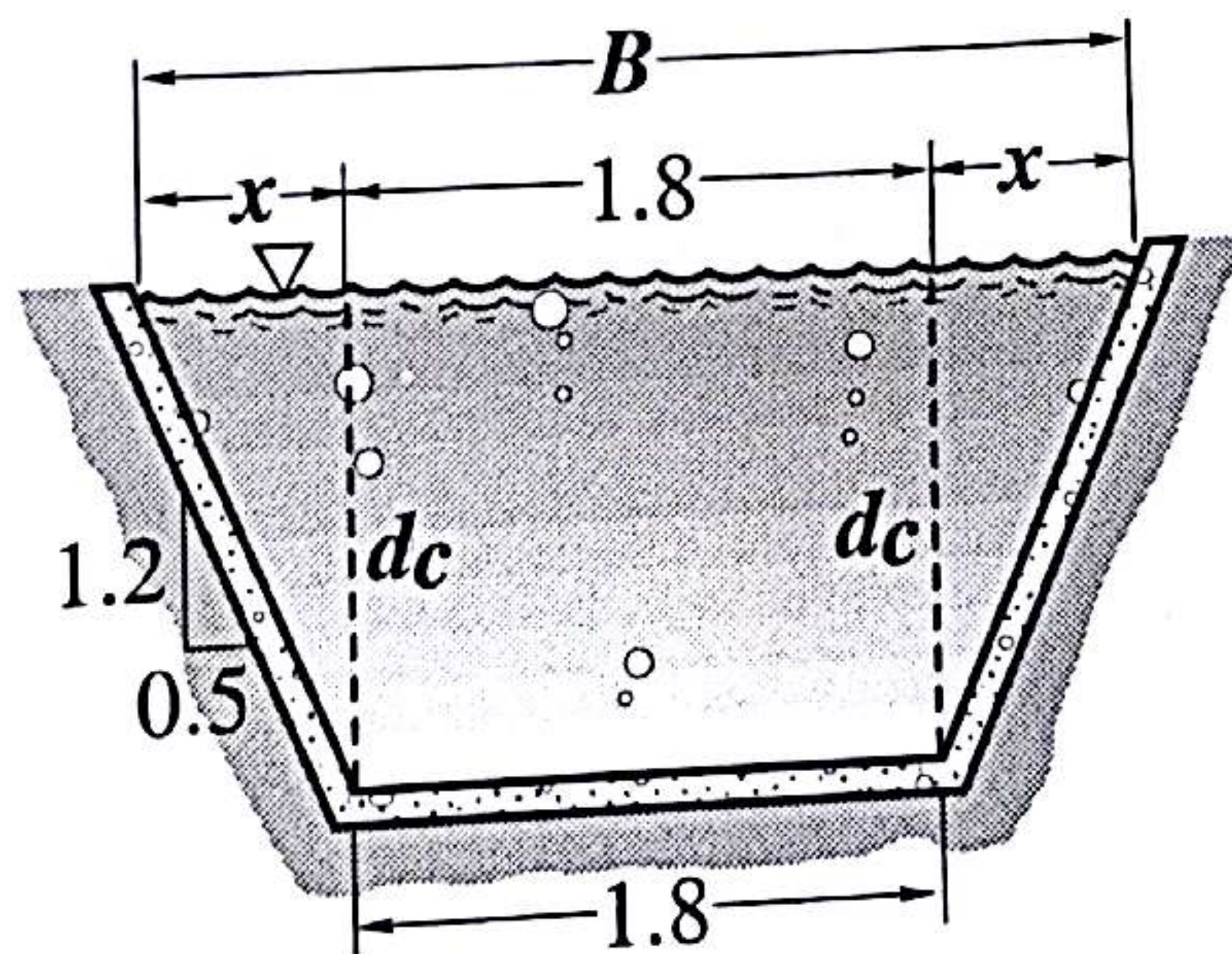
$$A = 1.8 d_c + 0.417 d_c^2$$

$$\frac{Q^2}{g} = \frac{(A)^3}{B}$$

$$\frac{(7.56)^2}{9.81} = \frac{[1.8 d_c + 0.417 d_c^2]^3}{1.8 + 0.834 d_c}$$

$$5.826 = \frac{[1.8 d_c + 0.417 d_c^2]^3}{1.8 + 0.834 d_c}$$

$$T_{cr} d_c = 1.11 \text{ m.}$$



- ③ Type of flow:  
 when  $d > d_c$  the flow is subcritical (ans.)  
 $1.20 > 1.11$   
 when  $d < d_c$  the flow is supercritical  
 when  $d = d_c$  the flow is critical



## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 1:

Assuming seawater to be incompressible ( $w = 10070 \text{ N/m}^3$ ), what is the pressure in bars, 3200 m. below the surface of the ocean?

**Solution:**  $p = w \cdot h = 10,070 \times 3200$

$$p = 32224000 \text{ N/m}^2$$

$$p = 32224 \text{ kPa}$$

$$1 \text{ bar} = 100 \text{ kPa}$$

$$p = 322.24 \text{ bars}$$

### PROBLEM 2:

A gage on the suction side of a pump shows a vacuum of 250 mm of mercury.

- ① Compute the pressure head in meters of water.
- ② Compute the pressure in kPa.
- ③ Compute the absolute pressure in kPa, if the barometer reads 725 mm of Mercury.

#### Solution:

- ① Pressure head in meters of water

$$h = -250(13.6) = -3400 \text{ mm} = -3.4 \text{ meters of water}$$

- ② Pressure head in meters of water

$$p = wh = 9.81(-3.4) = -33.354 \text{ kPa}$$

- ③ Absolute pressure

$$\frac{P_a}{725} = \frac{101.356}{760}$$

$$P_a = 96.69 \text{ kPa}$$

$$P_{abs} = -33.354 + 96.69$$

$$P_{abs} = 63.33 \text{ kPa (absolute)}$$

$$P_{atm} = 725(13.6) \times 9.81$$

$$1 \text{ ATM} = 101.325 \text{ kPa} \\ = 760 \text{ mm Hg}$$



## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 3:

The pump in the figure discharges water at 30 liters/sec. Neglecting losses and elevation changes. Assume unit weight of water is  $9.79 \text{ kN/m}^3$ .

- ① Determine the energy added to the water by the pump.
- ② Determine the power delivered to the water by the pump.
- ③ Determine the mechanical efficiency of the pump if the power input recorded is 27.34 hp.

### Solution:

- ① Energy added to the water by the pump: B.E.E. bet. ① & ②:

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

$$Q_1 = A_1 V_1$$

$$0.030 = \frac{\pi}{4} (0.10)^2 V_1$$

$$V_1 = 3.82 \text{ m/s}$$

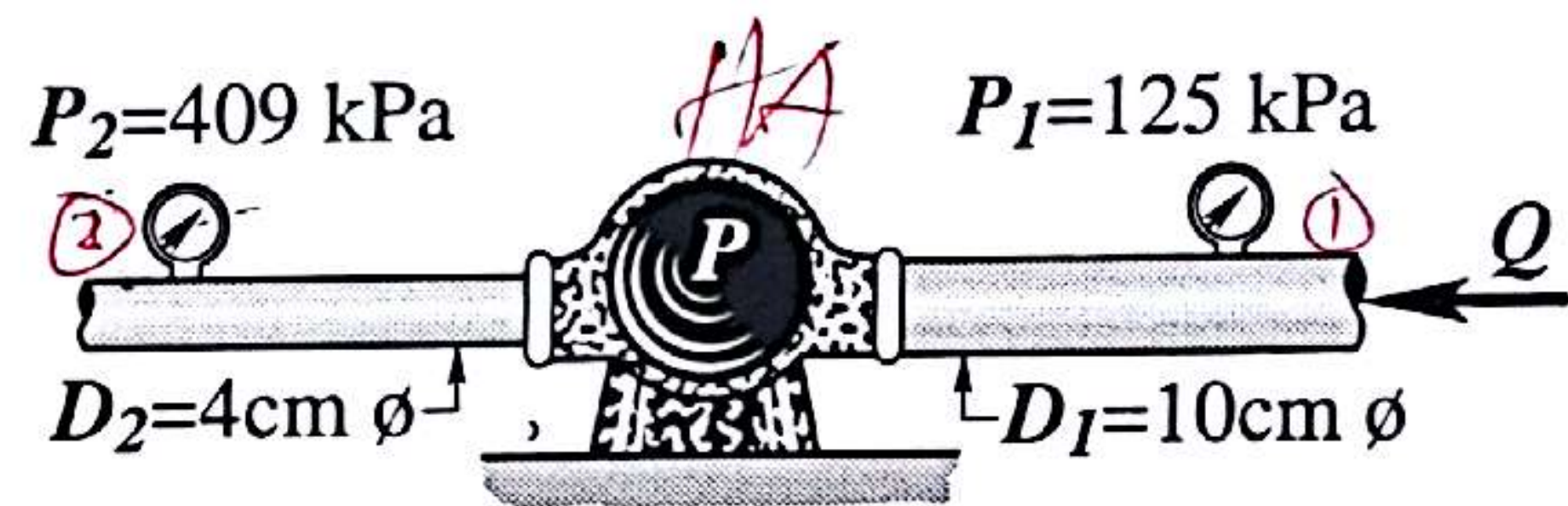
$$Q_2 = A_2 V_2$$

$$0.030 = \frac{\pi}{4} (0.04)^2 V_2$$

$$V_2 = 23.87 \text{ m/s}$$

$$\frac{(3.82)^2}{2g} + \frac{125}{9.79} + 0 + HA = \frac{(23.87)^2}{2g} + \frac{409}{9.79} + 0 + 0$$

$$HA = 57.31 \text{ m.}$$



$$g = 9.81 \text{ m/s}^2$$

- ② Power delivered to the water by the pump:

$$\text{Power} = Q \gamma_w HA \quad P = Q \gamma_w (HA)$$

$$\text{Power} = 0.030 (9.790) (57.31)$$

$$\text{Power} = 16830 \text{ watts}$$

$$\text{Power} = 16.83 \text{ KW}$$

output power

- ③ Mechanical efficiency of pump:

$$\text{Output hp} = \frac{16830}{746}$$

$$1 \text{ hp} = 746 \text{ watts}$$

$$\text{Output hp} = 22.56 \text{ hp}$$

$$\text{Eff.} = \frac{22.56}{27.34} \times 100\%$$

$$\text{Eff.} = 82.52\%$$

$$\text{Eff.} = \frac{P_{\text{out}}}{P_{\text{in}}} \times 100\%$$



## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 4:

A sharp edge orifice, 75 mm in diameter lies in a horizontal plane, the jet being directed upward. If the jet rises to a height of 8 m. and the coefficient of velocity is 0.98.

- ① Determine the velocity of the jet.
- ② Determine the head loss of the orifice.
- ③ Determine the head under which the orifice is discharging neglecting air resistance.

### Solution:

- ① Velocity of the jet:

$$V_2^2 = V_1^2 - 2g h$$

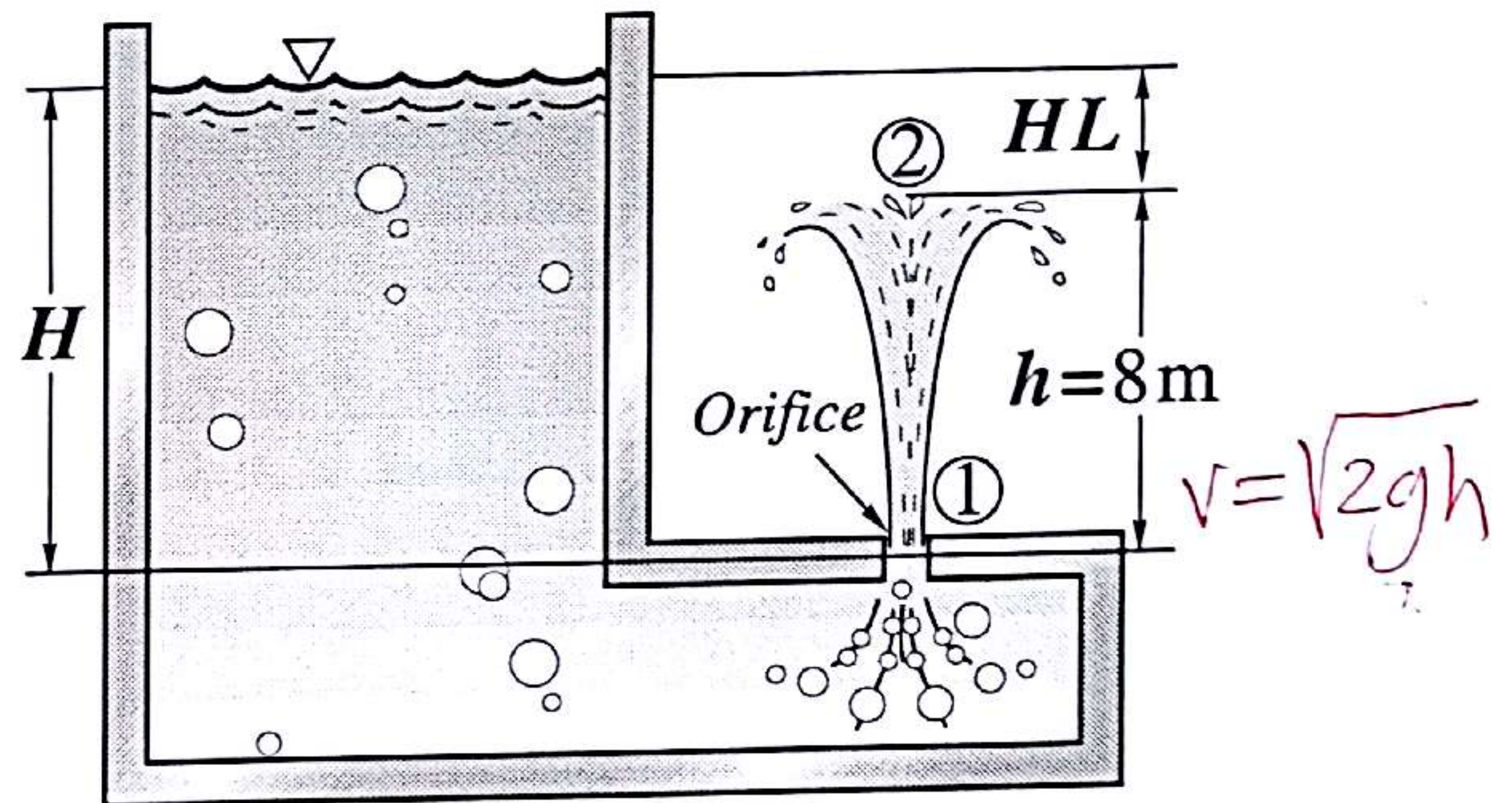
$$0 = V_1^2 - 2(9.81)(8)$$

$$\frac{V_1^2}{2g} = 8$$

$$V_1 = 12.53 \text{ m/s}$$

or  $V_1 = \sqrt{2gh}$

$$V_1 = \sqrt{2(9.81)(8)}$$



- ② Head loss of orifice:

$$HL = \frac{V_1^2}{2g} \left[ \frac{1}{C_v^2} - 1 \right]$$

$$HL = 8 \left[ \frac{1}{(0.98)^2} - 1 \right]$$

$$HL = 0.33 \text{ m.}$$

- ③ Head of orifice:

$$H = 0.33 + 8$$

$$H = 8.33 \text{ m.}$$



## **HYDRAULICS- Coaching Notes (Nov. 2016)**

### **PROBLEM 5:**

An orifice 150 mm in diameter, having a coeff. of contraction of 0.62 discharges oil (sp.gr. = 0.80) under a head of 7.50 m. The average actual velocity of the jet is 11.65 m/s.

- ① Compute the coeff. of velocity.
- ② Compute the headloss of the orifice.
- ③ Compute the diameter of the jet at the vena contracta.

### **Solution:**

- ① *Coeff. of velocity:*

$$V = C_v \sqrt{2gh}$$

$$11.65 = C_v \sqrt{2(9.81)(7.5)}$$

$$C_v = 0.96$$

- ② *Head loss:*

$$HL = \frac{V^2}{2g} \left( \frac{1}{C_v^2} - 1 \right)$$

$$HL = \frac{(11.65)^2}{2(9.81)} \left[ \frac{1}{(0.96)^2} - 1 \right]$$

$$HL = 0.59 \text{ m.}$$

- ③ *Dia. of the jet at Vena contracta:*

$$\frac{a}{A} = C_c$$

$$C_c = \frac{\text{Area of the jet}}{\text{Area of orifice}}$$

$$\frac{\pi d^2}{4} = \frac{\pi(0.150)^2}{4} (0.62)$$

$$d = 0.118$$

$$d = 118 \text{ mm.}$$



## ***HYDRAULICS- Coaching Notes (Nov. 2016)***

### ***PROBLEM 6:***

The absolute viscosity of the liquid is  $1.8 \times 10^{-3}$  Pa.s and its sp.gr. is 0.90.

- ① Compute the equivalent kinematic viscosity in  $\text{m}^2/\text{s}$ .
- ② Compute the equivalent value in stokes.
- ③ If the viscosity is 0.0126 stokes what is the equivalent kinematic viscosity in  $\text{m}^2/\text{s}$ .

### ***Solution:***

- ① *Kinematic viscosity:*

$$\boxed{v = \frac{\mu}{\rho}}$$

$$v = \frac{1.8 \times 10^{-3}}{0.90(1000)}$$

$$v = 2 \times 10^{-6} \text{ m}^2/\text{s} \quad \checkmark$$

- ② *V in stokes*

$$V = 2 \times 10^{-6} \left[ \frac{1 \text{ stoke}}{1 \times 10^{-4} \text{ m}^2/\text{s}^2} \right]$$

$$V = 0.02 \text{ stokes} \quad \checkmark$$

$$1 \text{ STROKE} = 1 \times 10^{-4} \text{ m}^2/\text{s}^2$$

- ③ *Kinematic viscosity:*

$$\text{Kinematic viscosity} = 0.0126 (10)^{-4}$$

$$\text{Kinematic viscosity} = 1.26 \times 10^{-6} \text{ m}^2/\text{s} \quad \checkmark$$



## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 7:

During a flow of 500 liters, the gage pressure is +68 kPa in the horizontal 300 mm supply line of a water turbine and a - 41 kPa at a 450 mm section of the draft tube 2 m. below. Estimate the horsepower output of the turbine under such conditions assuming efficiency of 85%.

- ① Compute the total head extracted by the turbine.
- ② Compute the output horsepower of the turbine.
- ③ Assuming an efficiency of 85%, compute the horsepower input of the turbine.

### Solution:

- ① Total head extracted by the turbine:

$$Q_1 = Q_2 = 0.50 \text{ m}^3/\text{s}$$

$$V_A = \frac{0.50}{\frac{\pi}{4}(0.3)^2}$$

$$V_B = \frac{0.50}{\frac{\pi}{4}(0.45)^2} = 3.144 \text{ m/s}$$

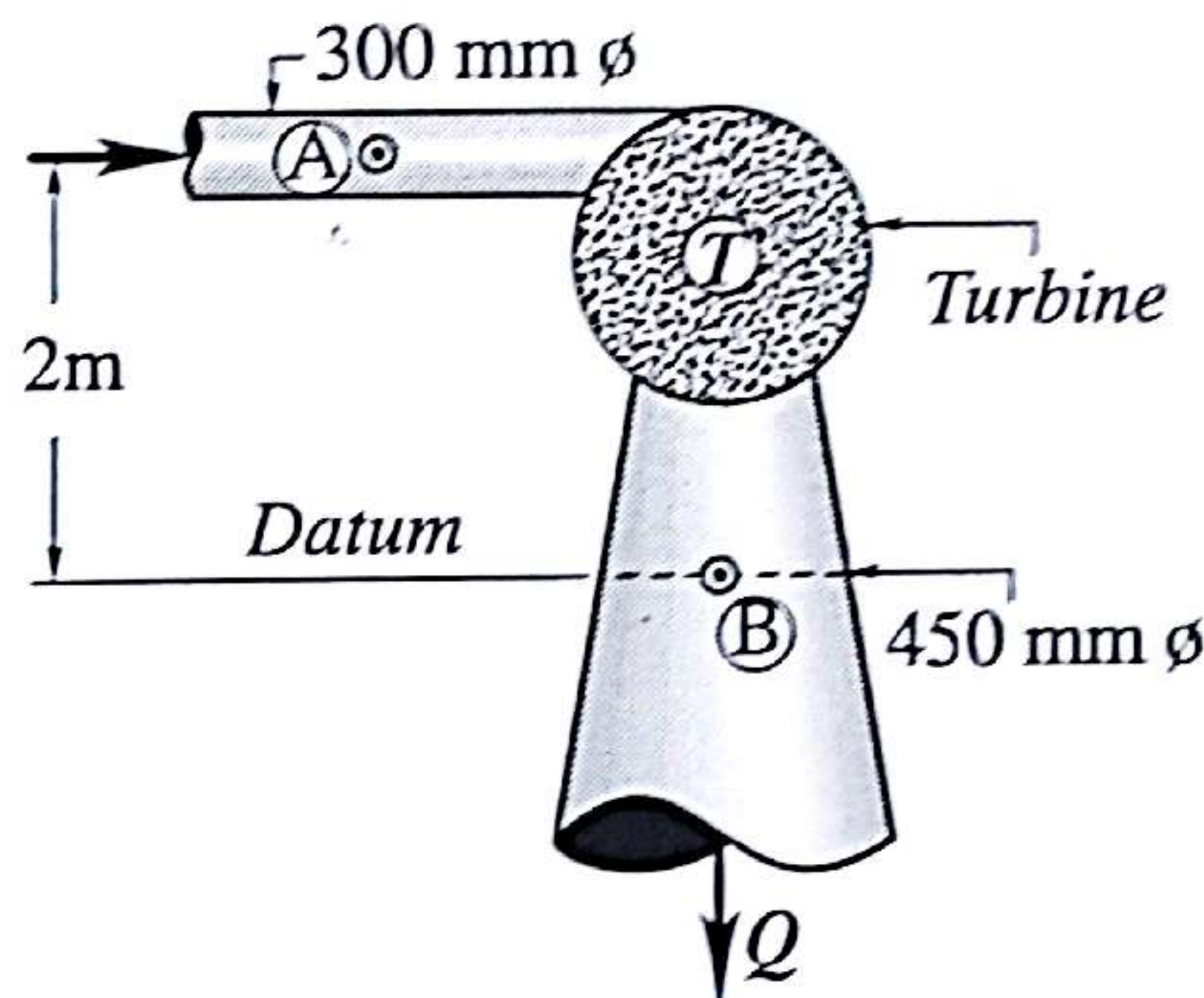
$$V_A = 7.08 \text{ m/s}$$

B.E.E. bet A & B

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

$$\frac{(7.08)^2}{2(9.81)} + \frac{68}{9.810} + 2 = \frac{(3.14)^2}{2(9.81)} - \frac{41}{9.81} + 0 + HE$$

$$H.E. = 15.16 \text{ m.}$$



- ② Output horsepower of the turbine:

$$HP = \frac{Q \gamma_w E}{746} \times \text{Eff.} \rightarrow \text{output power}$$

$$HP = \frac{0.50(9810)(15.16)}{746} \text{ (input)}$$

$$HP = 99.68 \text{ input hp}$$

$$HP = 99.68(0.85)$$

$$HP = 84.73 \text{ output hp}$$

- ③ Horsepower input of the turbine:

$$\text{Eff.} = \frac{\text{Output}}{\text{Input}}$$

$$0.85 = \frac{84.73}{\text{Input hp}}$$

$$\text{Input hp} = 99.68 \text{ hp}$$



## HYDRAULICS- Coaching Notes (Nov. 2016)

### PROBLEM 8:

Assuming normal barometric pressure, how deep is the ocean at point where an air bubble, upon reaching the surface, has six times the volume than it had at the bottom?

#### Solution:

$W = 10104 \text{ N/m}^3$  for salt water (sp.gr. = 1.03)

Using Boyle's Law:  $P_1 = 101.356 \text{ kPa}$  (barometric pressure)

$$P_1 V_1 = P_2 V_2$$

$$P_2 = 101.356 + 9.81h(1.03)$$

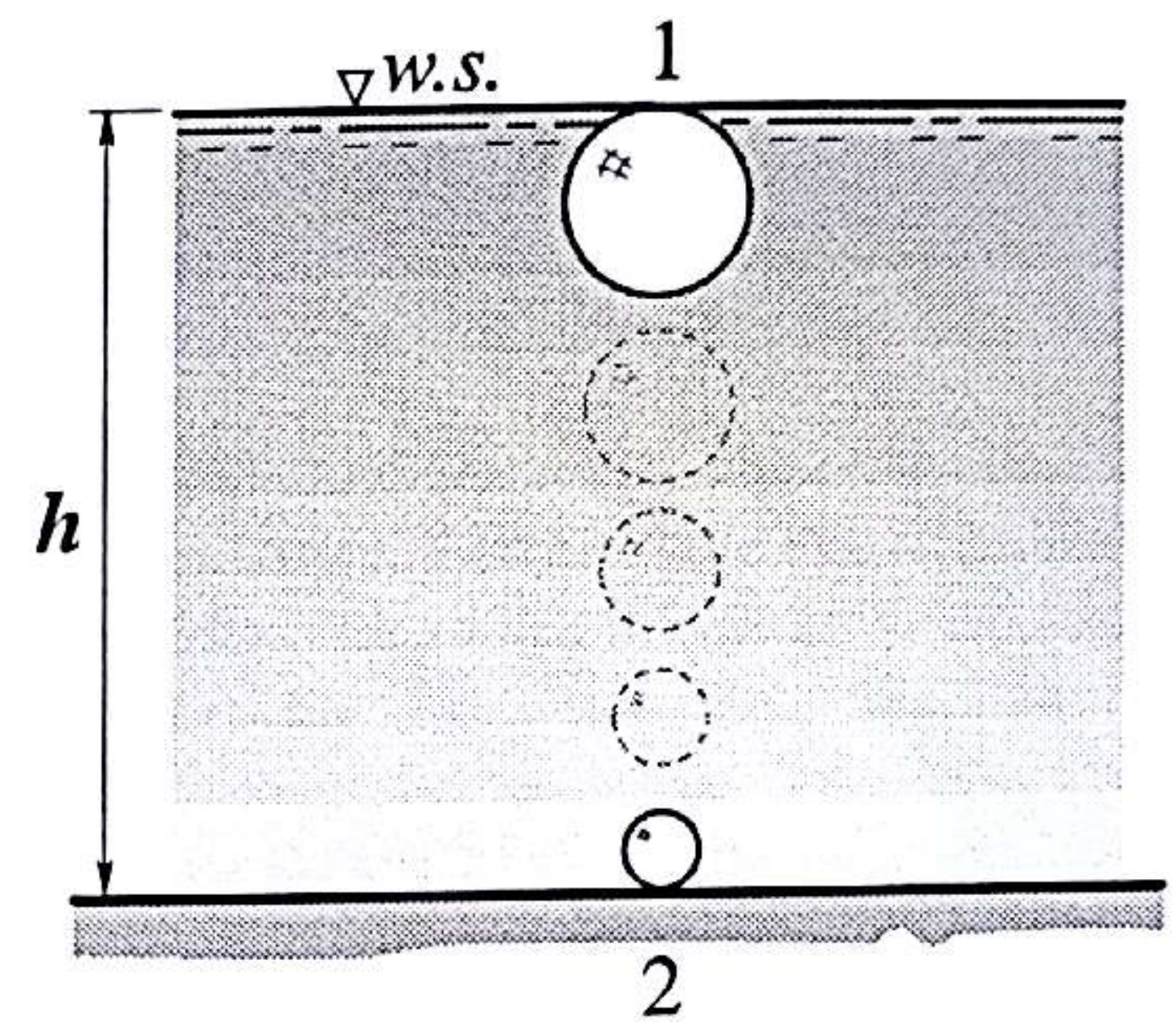
$$P_2 = 101.356 + 10.104h \rightarrow \text{KPa}$$

$$P_1 = 101.356 \rightarrow \text{KPa}$$

$$V_1 = 6V_2$$

$$101.356(6)V_2 = [101.356 + 10.104h](V_2)$$

$$h = 50.16 \text{ m}$$



### PROBLEM 9:

A vertical tube 3 m long, with one end closed, is inserted vertically with the open end down, into a tank of water until the open end is submerged to a depth of 1.2 m. Neglecting vapor pressure, how far will the water level in the tube be below the level in the tank?

#### Solution:

Boyle's Law:

$$P_1 V_1 = P_2 V_2 \quad \text{--- (1)}$$

$$P_1 = 101.356 \text{ kPa}$$

$$V_1 = (3)(A)$$

$$P_2 = 101.356 + 9.81x$$

$$V_2 = (1.8 + x)A$$

Substituting,

$$101.356(3A) = [101.356 + 9.81x](1.8 + x)A$$

$$304.07 = 101.356 + 9.81x(1.8 + x)$$

$$304.07 = 182.44 + 119.01x + 9.81x^2$$

$$9.81x^2 + 119.01x - 121.63 = 0$$

$$x = 0.948 \text{ m}$$

