$$Q = C_d \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \times \sqrt{2gh}$$

$$Q = 0.98 \times \frac{0.0314 \times 0.00785}{\sqrt{(0.0314)^2 - (0.00785)^2}} \times \sqrt{2 \times 9.81 \times 4}$$

$$Q = 0.0704 \quad m^3/s$$

Problem 5.7 :

A horizontal venturimeter with inlet diameter 20 cm and throat diameter 10 cm is used to measure the flow of oil of sp.gr.0.8. The discharge of oil through ventuimeter is 60 L/s. Find the reading of the oil – mercury differential manometer? Take $C_d = 0.98$.

Solution:

$$A_1 = \frac{\pi}{4} d_1^2 = \frac{\pi}{4} \times (0.2)^2 = 0.0314 \ m^2$$

$$A_2 = \frac{\pi}{4} d_2^2 = \frac{\pi}{4} \times (0.1)^2 = 0.00785 \ m^2$$

$$Q = C_d \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \times \sqrt{2gh}$$

m^3/s

$$\frac{60 \times 1000}{1000} = \frac{0.0314 \times 0.00785}{\sqrt{(0.0314)^2 - (0.00785)^2}} \times \sqrt{2 \times 9.81 \times h}$$

$$h = 2.89 \ m \ of \ oil.$$

$$h = x \left[\frac{S_h}{S_o} - 1 \right]$$

$$2.89 = x \left[\frac{13.6}{0.8} - 1 \right]$$

$$x = 0.181 \ m = 18.1 \ cm$$

Problem 5.8 /

A horizontal venturimeter with inlet diameter 20 cm and throat diameter 10 cm is used to measure the flow of water. The pressure at inlet is 17.658×10^4 N/ m^2 and the vacuum pressure at the throat is 30 cm of mercury. Find the discharge of water through venturemeter? Take $C_d = 0.98$.

$$A_1 = \frac{\pi}{4} d_1^2 = \frac{\pi}{4} \times (0.2)^2 = 0.0314 \ m^2$$

$$A_2 = \frac{\pi}{4} d_2^2 = \frac{\pi}{4} \times (0.1)^2 = 0.0078 \ m^2$$

$$h = \frac{P_1}{\rho g} - \frac{P_2}{\rho g} = \frac{17.658 \times 10^4}{1000 \times 9.81} - (h_{Hg} \times S_{Hg})$$

$$h = 18 - (-0.3 \times 13.6) = 18 + 4.08 = 22.08 \ m \ of \ water$$

$$Q = C_d \ \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \times \sqrt{2 \ gh}$$

$$Q = 0.98 \times \frac{0.0314 \times 0.0078}{\sqrt{(0.0314^2 - 0.0078^2)}} \times \sqrt{2 \times 9.81 \times 22.08}$$

$$Q = 165555 \ m^3/s.$$


Problem 5.9 :

In a vertical pipe conveying oil of sp. gr. 0.8, two pressure gages have been installed at A & B where the diameter are 16 cm and 8 cm respectively. A is 2 m above B . The pressure gauge readings have shown that the pressure at B is greater than at A by 9810 N/ m². Neglecting all losses, calculate the flow rate (Q) (discharge) , if the gauges at A & B are replaced by tubes filled with the same liquid and connected to a U – tube containing mercury , calculate the difference of level of mercury in the two legs of the U – tube (x) .

Solution: (Case 1):
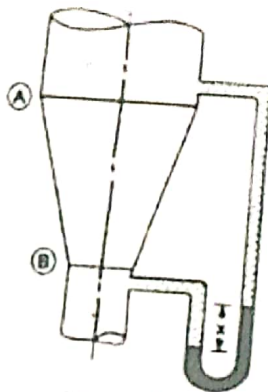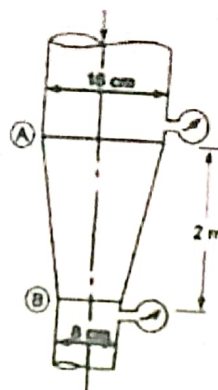
(case 2)   (case 1)

$$A_1 = \frac{\pi}{4} d_1^2 = \frac{\pi}{4} (0.16)^2 = 0.0201 \ m^2$$

$$A_2 = \frac{\pi}{4} \, d_2^2 = \frac{\pi}{4} \, (0.08)^2 = 0.00502 \ \text{m}^2$$

Applying Bernoulli's equation between A & B, and taking the reference line passing through section B, $(Z_B = 0)$, we get :

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

$$\frac{P_A}{\rho g} - \frac{P_B}{\rho g} + Z_A = \frac{V_B^2}{2g} - \frac{V_A^2}{2g} + 0$$

$$\frac{P_A - P_B}{\rho g} + Z_A = \frac{V_B^2}{2g} - \frac{V_A^2}{2g}$$

Now applying Continuity equation at A & B, we get :

$$V_A \, A_1 = V_B \, A_2 \quad , \quad V_B = \frac{V_A A_1}{A_2} = \frac{0.0201 \, V_A}{0.00502} = 4 \, V_A$$

$$\frac{9810}{0.8 \times 1000 \times 9.81} + 2 = \frac{16 \, V_A^2}{2g} - \frac{V_A^2}{2g}$$

$$0.75 = \frac{15 \, V_A^2}{2g}$$

$$V_A = \sqrt{\frac{0.75 \times 2 \times 9.81}{15}} = 0.99 \ \text{m/s}$$

$$Q = V_A \, A_1 = 0.99 \times 0.0201 = 0.01989 \ \text{m}^3/\text{s}$$

(Case 2):

Let, h – difference of mercury level.

$$h = \frac{P_A - P_B}{\rho g} + Z_A - Z_B$$

$$h = \frac{9810}{0.8 \times 1000 \times 9.81} + 2 - 0 = 0.75$$
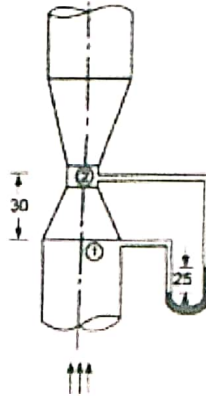
$$h = X \left[\frac{S_g}{S_o} - 1 \right]$$

$$0.75 = X \left[\frac{13.6}{0.8} - 1 \right]$$

$$X = 0.0468 \ \text{m} = 4.68 \ \text{cm}$$

A 30 cm × 15 cm venturimeter is provided in a vertical pipe line carrying oil of sp.gr. 0.9, the flow being upwards. The difference in elevation of the throat section and entrance section of the venturimeter is 30 cm. The differential U – tube mercury manometer shows a gauge deflection of 25 cm. Calculate: (1) the discharge of oil, (2) the pressure difference between the entrance section and the throat section. Take $C_d = 0.98$.

Solution:

$$A_1 = \frac{\pi}{4} d_1^2 = \frac{\pi}{4} \times (0.3)^2 = 0.07 \text{ m}^2$$

$$A_2 = \frac{\pi}{4} d_2^2 = \frac{\pi}{4} \times (0.15)^2 = 0.0176 \text{ m}^2$$

$$h = x \left[\frac{S_g}{S_o} - 1 \right] = 0.25 \left[\frac{13.6}{0.9} - 1 \right] = 3.52 \text{ m of oil}$$

$$Q = C_d \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \times \sqrt{2g\,h}$$

$$Q = 0.98 \frac{0.07 \times 0.0176}{\sqrt{0.07^2 - \sqrt{0.0176^2}}} \sqrt{2 \times 9.81 \times 3.52}$$

(1) $Q = 0.148 \text{ m}^3 / \text{s}$

$$h = \left(\frac{P_1}{\rho g} + Z_1 \right) - \left(\frac{P_2}{\rho g} + Z_2 \right)$$

$$3.52 = \left(\frac{P_1 - P_2}{\rho g} \right) - (Z_2 - Z_1)$$

$$\frac{P_1 - P_2}{\rho g} = 3.52 + 0.3$$

$$P_1 - P_2 = 3.83 \times 0.9 \times 1000 \times 9.81 = 33815 \text{ N/m}^2$$

Problem 5.11 /

An orifice meter with orifice diameter 10 cm is inserted in a pipe of 20 cm diameter. The pressure gauges fitted upstream and downstream of the orifice meter gives reading of 19.62×10^4 N/ m² and 9.81×10^4 N/m² respectively. Coefficient of discharge for the orifice meter is given as 0.6. Find the discharge of water through pipe?

Solution:

$$A_0 = \frac{\pi}{4} \, d_o^2 = \frac{\pi}{4} \times (0.1)^2 = 0.0078 \ m^2$$

$$A_1 = \frac{\pi}{4} (d_1^2) = \frac{\pi}{4} \times (0.2)^2 = 0.0314 \ m^2$$

$$h = \frac{P_1}{\rho g} - \frac{P_2}{\rho g} = \frac{19.62 \times 10^4}{1000 \times 9.81} - \frac{9.81 \times 10^4}{1000 \times 9.81} = 20 - 10 = 10 \ m \ water$$

$$Q = C_d \, \frac{A_o \, A_1}{\sqrt{A_1^2 - A_o^2}} \times \sqrt{2 \, g \, h}$$

$$Q = 0.6 \times \frac{0.0078 \times 0.0314}{\sqrt{(0.0314^2 - 0.0078^2)}} \times \sqrt{2 \times 9.81 \times 10} = 0.0682 \ m^3/s$$

Problem 5 . 12 /

An orifice meter with orifice diameter 15 cm is inserted in a pipe of 30 cm diameter. The pressure difference measured by a mercury oil differential manometer on the two sides of the orifice meter gives a reading of 50 cm of mercury. Find the rate of flow of oil of sp.gr. 0.9 when the coefficient of discharge of the orifice meter is 0.64.

Solution:

$$A_0 = \frac{\pi}{4} \, d_o^2 = \frac{\pi}{4} (0.15)^2 = 0.0176 \ m^2$$

$$A_1 = \frac{\pi}{4} \, d_1^2 = \frac{\pi}{4} (0.3)^2 = 0.0706 \ m^2$$

$$h = x \, [\frac{S_g}{S_o} - 1] = 50 \, [\frac{13.6}{0.9} - 1] = 705.5 \ cm \ of \ oil .$$

$$Q = C_d \, \frac{A_o \, A_1 \, \sqrt{2gh}}{\sqrt{A_1^2 - A_o^2}} = 0.64 \times \frac{0.0176 \times 0.0706 \, \sqrt{2 \times 9.81 \times 7.05}}{\sqrt{(0.0706)^2 - (0.0176)^2}}$$

$$Q = 0.137 \ m^3 / s$$

Problem 5.13 /

Find the velocity of the flow of an oil through a pipe, when the difference of mercury level in a differential U – tube manometer connected to the two tappings of the pitot – tube is 100 mm. Take coefficient of pitot – tube 0.98 and sp. gr. of oil is 0.8.

Solution:

$$h = x \left[\frac{S_g}{S_o} - 1 \right] = 0.1 \left[\frac{13.6}{0.8} - 1 \right] = 1.6 \text{ m of oil}$$

$$V = C_v \sqrt{2 \, g \, h} = 0.98 \times \sqrt{2 \times 9.81 \times 1.6} = 5.49 \text{ m/s}$$

Problem 5. 14:

A pitot – tube is inserted in a pipe of 300 mm diameter. The static pressure in pipe is 100 mm of mercury (vacuum). The stagnation pressure at the center of the pipe, recorded by the pitot – tube is 9810 N/ m² . Calculate the rate of flow of water through pipe, if the mean velocity of flow is 0.85 times the central velocity. Take C_v is 0.98.

Solution:

$$A = \frac{\pi}{4} d^2 = \frac{\pi}{4} (0.3)^2 = 0.0707 \text{ m}^2$$

$$h_w = - S_{hg} \, h_{hg} = - 13.6 \times 0.1 = - 1.36 \text{ m water. (static pressure head)}$$

$$P_{stagn.} = \rho \, g \, h_{stagn.}$$

$$h_{stagn} = \frac{P_{stagn.}}{\rho \, g} = \frac{9810}{1000 \times 9.81} = 1 \text{ m}$$

$$h = h_{stagn.} - h_w = 1 - (- 1.36) = 2.36 \text{ m of water}$$

$$V = C_v \sqrt{2 \, g \, h} = 0.98 \sqrt{2 \times 9.81 \times 2.36} = 6.668 \text{ m /s}$$

$$V' = 0.85 \times 6.668 = 5.6678 \text{ m/ s}$$

$$Q = A \, V = 0.0707 \times 5.6678 = 0.4006 \text{ m}^3 \text{ /s}$$