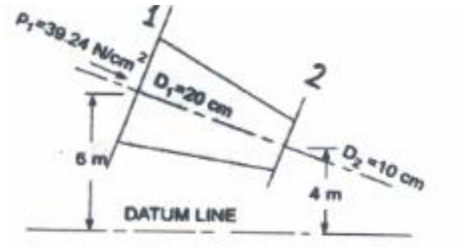
Problem 5.1 /

The water is flowing through a pipe having diameter 20 cm and 10 cm at section 1 and 2 respectively. The rate of flow through pipe is 35 L / s . The section 1 is 6 m above datum line and section 2 is 4 m above datum line. If the pressure at section 1 is 39.24 × 10^4 N / m^2. Find the pressure at section 2? If the flow is ideal.

Solution:



$Q = A_1V_1$

$$V_1 = \frac{Q}{A_1} = \frac{35\times 10^{-3}}{\frac{\pi}{4}\times 0.2^2} = 1.114 \text{ m/s}$$

$Q = A_2 V_2$

$$V_2 = \frac{Q}{A_2} = \frac{35\times 10^{-3}}{\frac{\pi\times 0.1^2}{4}} = 4.456 \text{ m/s}$$

Applying Bernoulli's equation between section 1 & section 2:

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

$$\frac{39.24\times 10^4}{1000\times 9.81} + \frac{(1.114)^2}{2\times 9.81} + 6 = \frac{P_2}{1000\times 9.81} + \frac{(4.456)^2}{2\times 9.81} + 4$$

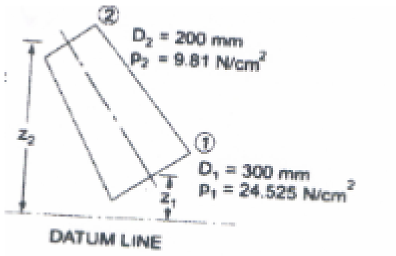
$$P_2 = 41.051 \times 9810 \text{ N/m}^2$$

Problem 5.2 /

Water is flowing through a pipe having diameter 300 mm and 200 mm at the bottom and upper end respectively. The pressure at the bottom end is 24.525× 10^4 N/m^2 and the pressure at the upper end is 9.81× 10^4 N/m^2. Determine

the difference in datum head (Z_2 - Z_1), if the rate of volume flow through pipe is 0.04 m^3 / s. (the flow is ideal)

Solution:



$$Q = A_1 V_1$$

$$V_1 = \frac{0.04}{\frac{\pi \times 0.3^2}{4}} = 0.565 \text{ m/s}$$

$$V_2 = \frac{0.04}{\frac{\pi \times 0.2^2}{4}} = 1.274 \text{ m /s}$$

Applying Bernoulli equation between section 1 & section 2 , we get :

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

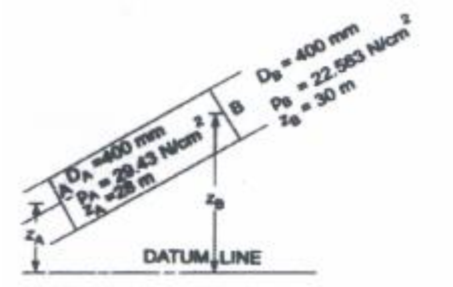
$$\frac{24.525 \times 10^4}{1000 \times 9.81} + \frac{(0.566)^2}{2 \times 9.81} + Z_1 = \frac{9.81 \times 10^4}{1000 \times 9.81} + \frac{(1.274)^2}{2 \times 9.81} + Z_2$$

$$Z_2 - Z_1 = 13.7 \text{ m}$$

<u>Problem 5.3</u> /

A pipe of diameter 400 mm carries water at a velocity of 25 m/s. The pressure at the points A and B are given as 29.43 × 10^4 N/m^2 & 22.563 × 10^4 respectively while the datum head at A & B are 28 m and 30 m respectively . Find the loss of head between A & B (H_L).

Solution:



Applying Bernoulli equation between section A & section B , we get :

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

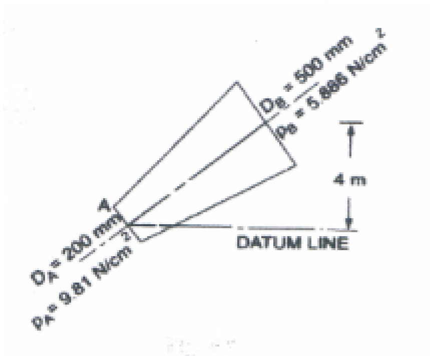
$$\frac{29.43 \times 10^4}{1000 \times 9.81} + \frac{(25)^2}{2 \times 9.81} + 28 = \frac{22.563 \times 10^4}{1000 \times 9.81} + \frac{(25)^2}{2 \times 9.81} + 30 + H_L$$

$$H_L = 5 \text{ m}$$

Problem 5.4 /

A pipeline carrying oil of specific gravity (S = 0.87) , changes in diameter from 200 mm diameter at a position A to 500 mm diameter at a position B which is 4 meter at a higher level . If the pressure at A and B are 9.81×10^4 N/ m^2 and 5.886×10^4 N/ m^2 respectively and the discharge is 200 L /s, determine the loss of head (H_L) and direction of flow? the flow is real (actual).

Solution:



$$V_A = \frac{Q}{A_A} = \frac{200 \times 10^{-3}}{\frac{\pi \times 0.2^2}{4}} = 6.369 \text{ m/s}$$

$$V_B = \frac{Q}{A_B} = \frac{200 \times 10^{-3}}{\frac{\pi \times 0.5^2}{4}} = 1.018 \text{ m/s}$$

Applying Bernoulli's equation between section A & section B , we get :

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

$$\frac{9.81 \times 10^4}{870 \times 9.81} + \frac{6.369^2}{2 \times 9.81} + 0 = \frac{5.886 \times 10^4}{870 \times 9.81} + \frac{1.018^2}{2 \times 9.81} + 4 + H_L$$

$$H_L = 2.609 \text{ m}$$

Problem 5.5 /

A horizontal venturimeter with inlet and throat diameter 30 cm and 15 cm respectively is used to measure the flow of water. The reading of differential manometer connected to the inlet and the throat is 20 cm of mercury. Determine the rate of flow. Take C_d = 0.98.

Solution:

x = 20 cm

$$h = x \left[\frac{S_h}{S_o} - 1 \right] = 20 \left[\frac{13.6}{1} - 1 \right] = 252 \text{ cm of water .}$$

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

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

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

$$Q = 0.98 \times \frac{0.0706 \times 0.0176}{\sqrt{(0.0706)^2 - (0.0176)^2}} \times \sqrt{2 \times 9.81 \times 0.252}$$

$$Q = 0.125756 \text{ m}^3/\text{s}$$

Problem 5. 6 /

An oil of sp.gr. 0.8 is flowing through a venturimeter having inlet diameter 20 cm and throat diameter 10 cm. The oil – mercury differential manometer shows a reading of 25 cm. Calculate the discharge of oil through the horizontal venture meter. Take C_d = 0.98.

Solution:

x = 0.25 m

$$h = x \left[\frac{S_h}{S_o} - 1 \right] = 0.25 \left[\frac{13.6}{0.8} - 1 \right] = 4 \text{ m of oil}$$

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

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

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

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

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

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:

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

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

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

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

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

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

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

$$x = 0.181 \text{ m} = 18.1 \text{ cm}$$

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.

Solution :

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

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

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

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

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

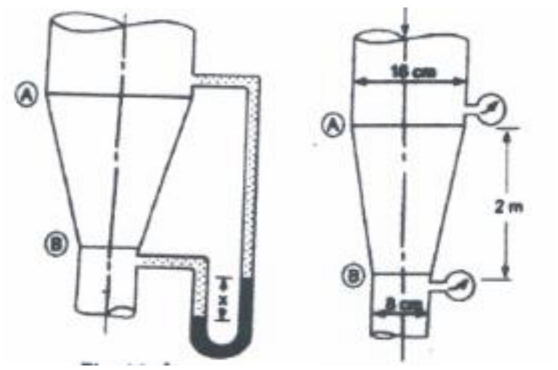
$$Q = 0.98 \times \frac{0.0314 \times 0.0078}{\sqrt{(0.0314^2 - 0.0078^2)}} \times \sqrt{2 \times 9.81 \times 22.08}$$

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

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/ m^2. 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)

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

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

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

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

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

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

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

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

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

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

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

$$Q = V_A\ A_1 = 0.99 \times 0.0201 = 0.01989\ \ m^3/s$$

(Case 2):

Let, h – difference of mercury level.

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

$$h = \frac{9810}{0.8 \times 1000 \times 9.81} + 2 - 0 = 0.75$$

$$h = X\,[\,\frac{S_g}{S_o} - 1\,]$$

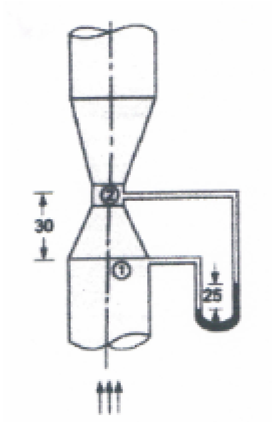
$$0.75 = X\,[\,\frac{13.6}{0.8} - 1\,]$$

$$X = 0.0468\ \ m = 4.68\ cm$$

Problem 5.10 /

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:



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

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

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

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

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

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

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

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

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

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

<u>Problem 5.11</u> /

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/ m^2 and 9.81 × 10^4 N/m^2 respectively. Coefficient of discharge for the orifice meter is given as 0.6. Find the discharge of water through pipe?

<u>Solution</u>:

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

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

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

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

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

<u>Problem 5 . 12</u> /

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.

<u>Solution</u>:

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

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

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

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

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

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/ m^2 . 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:

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

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

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

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

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

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

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

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