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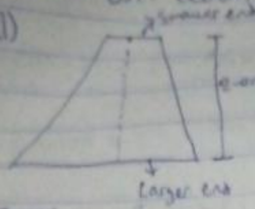
(1)



Given

→ length of tube $l = 2.0m$

Velocity $v_1 = 5m/s$

Velocity $v_2 = 2m/s$

Pressure head at the smaller end $= 2.5m$ $\left(\text{i.e } \frac{P_1}{w} = 2.5\right)$

Loss of head $h_L = \dfrac{0.35(v_1 - v_2)^2}{2g}$

$$\therefore h_L = \frac{0.35(5-2)^2}{2 \times 9.81}$$

$$h_L = \frac{0.35(9)}{19.62} \Rightarrow \frac{3.15}{19.62} \Rightarrow 0.16m$$

Pressure head at lower end ? $\left(\text{i.e } \frac{P_2}{w} = ?\right)$

Applying Bernoulli's equation, we have

$$\frac{P_1}{w} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{w} + \frac{v_2^2}{2g} + z_2 + h_L$$

Let $z_1 = 2.0m$
$z_2 = 0m$

$$2.5 + \frac{5^2}{2 \times 9.81} + 2 = \frac{P_2}{w} + \frac{2^2}{2 \times 9.81} + 0 + 0.16$$

$$\Rightarrow 2.5 + 1.27 + 2 = \frac{P_2}{w} + 0.204 + 0.16$$

$$\frac{P_2}{w} = 5.77 - 0.364$$

$$\frac{P_2}{w} \Rightarrow 5.41m \text{ of water.}$$

(2) Solution

→ Inlet diameter $D_1 = 20cm \rightarrow m$

$$\frac{20}{100} \Rightarrow 0.2m$$

→ Area A_1 of inlet $= \frac{\pi D_1^2}{4} = \frac{\pi (0.2)^2}{4} \Rightarrow 0.0314m^2$

→ Throat Diameter $D_2 = 10cm \rightarrow m$

$$\frac{10}{100} \Rightarrow 0.1m$$

→ Area of Throat $A_2 = \frac{\pi D_2^2}{4} = \frac{\pi (0.1)^2}{4} \Rightarrow 0.00785m^2$

→ Pressure at inlet $P_1 = 17.658N/cm^2 \Rightarrow 17658\,kN/m^2$

$$\frac{P_1}{\omega} = \frac{176.58}{9.81} \Rightarrow 18m$$

→ Vacuum pressure at the throat.

$$\frac{P_2}{\omega} = -30cm \rightarrow m \Rightarrow -0.3m$$

$$= -0.3m \text{ of mercury} = -0.3 \times 13.6 \Rightarrow -4.08m \text{ of water}$$

→ Coefficient of discharge $C_d = 0.98$

$\therefore$ Differential head, $h = \frac{P_1}{\omega} - \frac{P_2}{\omega} = 18 - (-4.08) \Rightarrow 22.08m$

Rate of flow, Q (Discharge of water through venturimeter)

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

$$Q = 0.98 \times \frac{0.0314 \times 0.00785}{\sqrt{(0.0314)^2 - (0.00785)^2}} \times \sqrt{2 \times 9.81 \times 22.08}$$

$$Q = \underline{\underline{0.165m^3/s}}$$

(3)

(3) Answer

→ Diameter of the pipe D_1 = 30cm → m

$\frac{30}{100} \Rightarrow 0.3m$

→ Area of the pipe $A_1 = \frac{\pi D_1^2}{4} = \frac{\pi (0.3)^2}{4} \Rightarrow 0.0706 m^2$

→ Diameter of the orifice D_0 = 15cm → m

$\frac{15}{100} \Rightarrow 0.15m$

→ Area of the orifice $A_0 = \frac{\pi D_0^2}{4} = \frac{\pi (0.15)^2}{4} \Rightarrow 0.0176 m^2$

→ Coefficient of discharge $C_d = 0.64$

→ Specific gravity of oil = 0.9

→ Reading of differential manometer, y = 50cm → m

$\frac{50}{100} = 0.5m$

∴ Differential head, $h = y \left[\frac{S_h}{S_0} - 1\right]$

and S_h = Sp gravity of heavier liquid = 13.6 (for mercury)

$= 0.5 \left[\frac{13.6}{0.9} - 1\right]$

$\Rightarrow 7.056$ m of oil

Discharge $Q = \frac{C_d \, A_0 \cdot A_1 \cdot \sqrt{2gh}}{\sqrt{A_1^2 - A_0^2}}$

$Q = \frac{0.64 \times 0.0176 \times 0.0706 \times \sqrt{2 \times 9.81 \times 7.056}}{\sqrt{0.0706^2 - 0.0176^2}}$

$Q = \underline{\underline{0.1369 m^3/s}}$

(4) Solution

→ Reading of the manometer, $y = 170mm \to m$

$$\frac{170}{1000} \Rightarrow 0.17m \text{ of mercury}$$

→ Sp. gravity of mercury, $S_{hl} \Rightarrow 13.6$

→ Sp. gravity of Seawater $S_l \Rightarrow 1.025$

→ Head $h = y\left(\frac{S_{hl}}{S_l} - 1\right)$

$$h = 0.17\left(\frac{13.6}{1.025} - 1\right) = 2.09$$

⇒ Speed of the Submarine

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

$$V = \sqrt{2 \times 9.81 \times 2.09}$$

$$V = \underline{\underline{6.40 m/s}}$$

(5) ~~Solution~~

(5)

Actual flowrate $= 5dm^3/min$

$$\frac{5\times10^{-3}}{60}\ m^3/sec$$

$$= 8\cdot33\times10^{-5}\ m^3/s$$

Change in pressure, $\delta p = 15 bar$

$$= 15\times10^5\ N/m^2$$

Speed of rotation, $N = 1700\ rev/min$

$$= \frac{1700}{60} = 28\cdot33\ rev/sec$$

Nominal displacement $= 10cm^3/rev$

$$= \frac{10}{10^6}\ m^3/rev = 1\times10^{-5}\ m^3/rev$$

Torque Input, $T = 15\ Nm$

1) Volumetric Efficiency

$$= \frac{\text{Actual flowrate}}{\text{Ideal flowrate}}\times100\%$$

Actual flow rate $= 8\cdot53\times10^{-5}\ m^3/sec$

$\therefore$ Ideal flow rate $=$ Speed of rotation $\times$ Nominal displacement

$$= 28\cdot33\times1\times10^{-5}$$

$$= 2\cdot833\times10^{-4}$$

$\therefore$ Volumetric Efficiency

$$= \frac{8\cdot33\times10^{-5}}{2\cdot833\times10^{-4}}\times100\%$$

$$= 29\cdot40\%$$

2) Fluid Power, $P_f = Q\times\delta p$

$$= 8\cdot33\times10^{-5}\times15\times10^5$$

$$\Rightarrow 124\cdot95\ watts$$

Shaft Power $= T\cdot\omega$

$T = 15Nm$

$\omega = 2\pi N\ rad/s$

$$= 2\times\frac{22}{7}\times28\cdot33$$

$$= 178\cdot07\ rad/s$$

$$\therefore \text{Shaft power} = 15 \times 178.07$$
$$= 2671.11 \text{ watts}$$

$$\text{Overall Efficiency} = \frac{\text{Fluid power}}{\text{Shaft power}} \times 100\%$$
$$= \frac{124.95}{2671.11} \times 100\%$$
$$= 4.678\%$$

$\therefore$ The overall efficiency is 4.68%