

$$\textcircled{1} \quad Q_1 + Q_2 + Q_3 = Q_4$$

$$Q_1 + \frac{\pi}{4} (0.05)^2 (5) + Q_3 = \frac{120}{3600} \quad \textcircled{1}$$

As Q_3 inc. by 20% $\therefore Q_4$ inc by 10%.

$$Q_1 + \frac{\pi}{4} (0.05)^2 (5) + 1.2Q_3 = 1.1 \times \frac{120}{3600} \quad \textcircled{2}$$

$$\text{eq. } \textcircled{1} \rightarrow Q_1 + Q_3 = 0.0235$$

$$\text{eq. } \textcircled{2} \rightarrow Q_1 + 1.2Q_3 = 0.0268$$

By solving 2 eq.

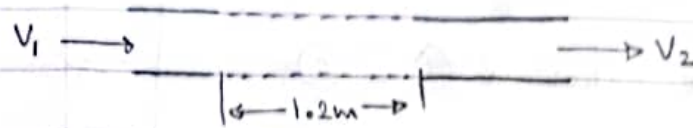
$$Q_1 = 7 \times 10^{-3} \text{ m}^3/\text{sec}, \quad Q_3 = 0.0165 \text{ m}^3/\text{sec}$$

$$V_1 = \frac{7 \times 10^{-3}}{\frac{\pi}{4} (0.04)^2} = 5.57 \text{ m/sec}$$

$$V_3 = \frac{0.0165}{\frac{\pi}{4} (0.06)^2} = 5.835 \text{ m/sec}$$

$$V_4 = \frac{120}{3600 \times \frac{\pi}{4} (0.09)^2} = 5.23 \text{ m/sec}$$

②



$$V_1 = 12 \text{ m/sec}$$

(a) $V_w = 15 \text{ cm/sec} = 0.15 \text{ m/sec}$ (out)

$$A_1 V_1 = A_w V_w + A_2 V_2 \rightarrow \frac{\pi}{4} (0.08)^2 (12) = 2\pi (0.04)(1.2)(0.15) + \frac{\pi}{4} (0.08)^2 V_2$$

$$\frac{1}{4} (0.08)^2 (12) = 2 (0.04)(1.2)(0.15) + \frac{1}{4} (0.08)^2 V_2$$

$$V_2 = 3 \text{ m/sec}$$

(b) $A_1 V_1 + A_w V_w = A_2 V_2 \rightarrow \frac{\pi}{4} (0.08)^2 (12) + 2\pi (0.04)(1.2)(0.1) = \frac{\pi}{4} (0.08)^2 V_2$

$$V_2 = 18 \text{ m/sec}$$

(c) Assume V_w (out)

$$A_1 V_1 = A_w V_w + A_2 V_2 \rightarrow \frac{\pi}{4} (0.08)^2 (12) = 2\pi (0.04)(1.2) V_w + \frac{\pi}{4} (0.08)^2 (9)$$

$$V_w = 0.05 \text{ m/sec.}$$

③

$$Q = \int u \cdot dA = \int u \cdot dy \quad \text{①} \quad \text{unit depth}$$

$$Q_{out} = \int_{y=0}^{y=\delta} U_0 \left(\frac{3\eta - \eta^3}{2} \right) dy \quad \eta = \frac{y}{\delta}$$

$$dy = \delta \cdot d\eta$$

$$Q_{out} = \int_{\eta=0}^{\eta=1} U_0 \left(\frac{3\eta - \eta^3}{2} \right) \cdot \delta \cdot d\eta$$

$$Q_{out} = \frac{\delta U_0}{2} \left[\frac{3\eta^2}{2} - \frac{\eta^4}{4} \right]_0^1$$

$$Q_{out} = \frac{1}{2} \delta U_0 \left(\frac{3}{2} - \frac{1}{4} \right) \rightarrow Q_{out} = \frac{5}{8} \delta U_0$$

$$\Sigma Q_{in} = \Sigma Q_{out}$$

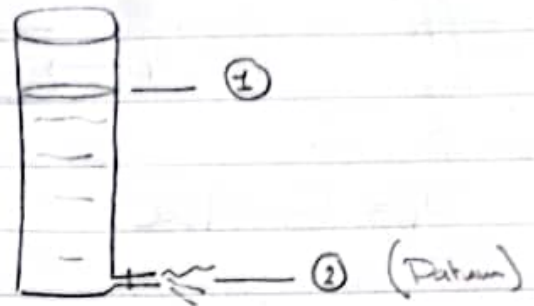
$$U_0 \delta = Q + \frac{5}{8} \delta U_0$$

$$Q = \frac{3}{8} \delta U_0$$

$$\text{average velocity} = \frac{3}{8} \cdot \frac{\delta}{y} U_0 = \frac{3}{8} \frac{U_0}{\eta}$$

④

Apply Bernollic between ① & ②



$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2$$

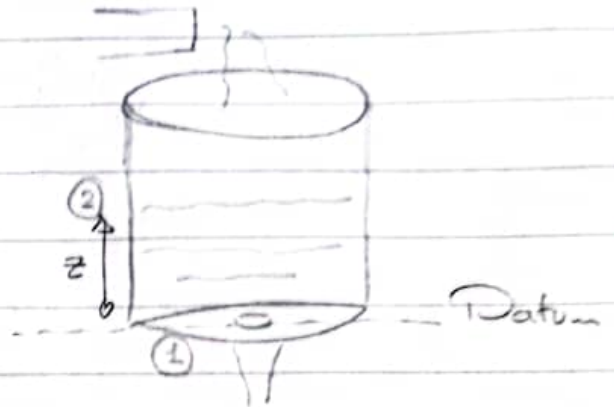
$$\frac{V_2^2}{2g} = \frac{(P_1 - P_2)}{\gamma} + z_1 \rightarrow V_2 = \sqrt{2g \left[\frac{P_1 - P_2}{\gamma} + z_1 \right]}$$

$$V_2 = \sqrt{2(9.8) \left(\frac{300 - 100}{9810} \times 10^3 + 3 \right)} = 21.4 \text{ m/sec}$$

$$Q = AV = \frac{\pi}{4} (0.1)^2 (21.4) = 0.168 \text{ m}^3/\text{sec}$$

(5)

Apply Bernoulli Equation
between point ① & ②



$$\frac{P_1}{\rho} + \frac{V_1^2}{2g} + h_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2g} + h_2$$

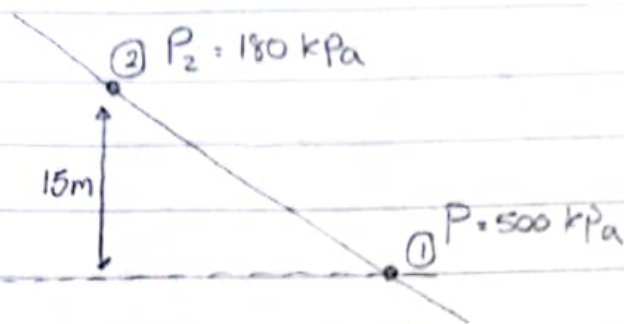
$$\frac{V_1^2}{2g} = h_2 \rightarrow V_1 = \sqrt{2gh}$$

→ The ^{mass} flow rate at orifice = $\rho A V_1$

$$\dot{m} = \rho \times \frac{\pi}{4} d^2 \times \sqrt{2gh}$$

$$h_{\max} = \left(\frac{4\dot{m}}{\rho \pi d} \right)^2 \times \frac{1}{2g}$$

⑥



Bernoulli Equation: $\frac{P}{\rho} + \frac{V^2}{2g} + h$

→ The point with the highest total energy, the flow will move from it to the other point.

$$\frac{P_1}{\rho} + \frac{V_1^2}{2g} + h_1 = \frac{500 \times 10^3}{9810} = 50.96 \text{ m}$$

$$\frac{P_2}{\rho} + \frac{V_2^2}{2g} + h_2 = \frac{180 \times 10^3}{9810} + 15 = 33.3 \text{ m}$$

→ Consider the pipe has uniform diameter then the velocity will be same at two points.

The fluid move from ① → ②

⑦

Torque = Force $\times$ distance

$$\text{Force} = \tau A = \mu \frac{V}{h} 2\pi r L, \quad V = \omega r, \quad \omega = \frac{2\pi n}{60}$$

$$\text{Force} = \mu \frac{2\pi n}{60} \times \frac{1}{h} \times r \times 2\pi r L = \mu \frac{4\pi^2 r^2 n L}{60 h}$$

$$\text{Torque} = \text{Force} \times r = \mu \frac{4\pi^2 r^3 n L}{60 h}$$

$$\text{Torque} = (0.86) \times \frac{4\pi^2 (0.05)^3 \times 900 \times 1.2}{60 \times 10^{-2}} = 7.63 \text{ N.m}$$

$$\text{Power} = \text{Torque} \times \omega = 7.63 \times \frac{2\pi 900}{60} = 719.9 \text{ Watt}$$

8

$$\sum F_x = \eta r \sin \theta - \gamma A = ma$$

as Terminal Velocity
is required, consider
 $a_x = \text{zero}$.

$$\eta r \sin \theta = \mu \frac{V}{h} A$$

$$V = \frac{\eta r \sin \theta h}{\mu A} = \frac{6 \sin(15) \cdot 10^{-3}}{0.29 (35 \times 10^{-4})} = 1.53 \text{ m/sec.}$$

9

(a) estimate the wall shear stress

(b) the position in the boundary layer where shear stress is one-half of wall shear stress

$$\tau_w = \mu \frac{du}{dy} \Big|_{y=0} = \mu \left(U \frac{\pi}{2\delta} \cos \frac{\pi y}{2\delta} \right)_{y=0} = -\frac{\mu U \pi}{2\delta}$$

$$\mu \text{ (water at } 20^\circ\text{C \& 1 atm)} = 0.001 \text{ kg/m}\cdot\text{sec}$$

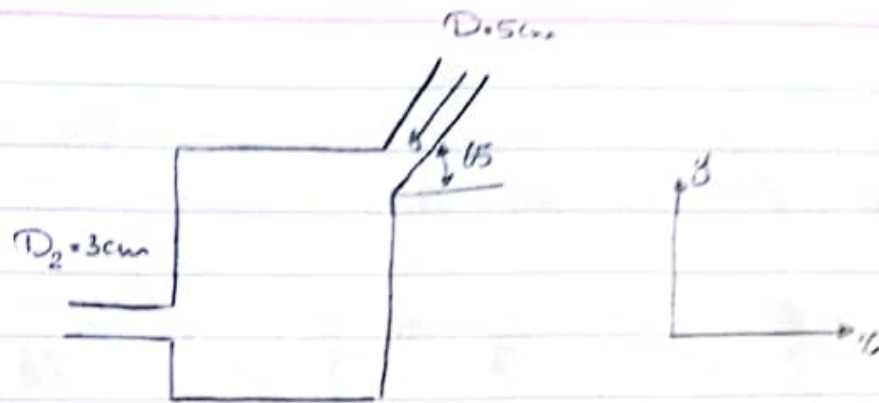
$$\tau_w = 0.001 (10.8) \frac{\pi}{2(0.03)} = 0.565 \text{ Pa} \quad \boxed{a}$$

$$\tau(y) = \frac{\mu U \pi}{2\delta} \cos \left(\frac{\pi y}{2\delta} \right) = \tau_w \cos \left(\frac{\pi y}{2\delta} \right) = \frac{\tau_w}{2}$$

$$\cos \left(\frac{\pi y}{2\delta} \right) = \frac{1}{2} \rightarrow \frac{\pi y}{2\delta} = \frac{\pi}{3} \rightarrow y = \frac{2\delta}{3}$$

$$y = \frac{2}{3} \times 3 = 2 \text{ cm} \quad \boxed{b}$$

(11)



$$\Sigma F_x = \Sigma \dot{m} V$$

$$= -(\rho A_1 V_1) V_1 - (\rho A_2 V_2) V_2 = -\rho [A_1 V_1^2 - A_2 V_2^2] \quad \begin{aligned} V_1 &= 1 \cos 65 \\ &= 2 \cos 65 \\ &= 0.845 \\ &= 1 \text{ m/s} \end{aligned}$$

$$= -998 \left(\frac{\pi}{4} (0.05)^2 (0.845)^2 + \frac{\pi}{4} (0.03)^2 (5.55)^2 \right)$$

$$\left\{ \begin{aligned} Q &= AV = \frac{\pi}{4} (0.05)^2 (2) = 3.926 \times 10^{-3} \text{ m}^3/\text{sec} \\ V_2 &= \frac{Q}{A_2} = \frac{3.926 \times 10^{-3}}{\frac{\pi}{4} (0.03)^2} = 5.55 \text{ m/sec} \end{aligned} \right.$$

$$\Sigma F_x = -23.12 \text{ N} \quad , \quad \text{opposing force } F_x = 23.12$$

$$\Sigma F_y = -(\rho A_1 V_1) V_1 = -998 \left(\frac{\pi}{4} (0.05)^2 2 \sin 65 \right) 2 \sin 65 = -6.4 \text{ N}$$

$$\text{opposing force } F_y = 6.4 \text{ N.}$$