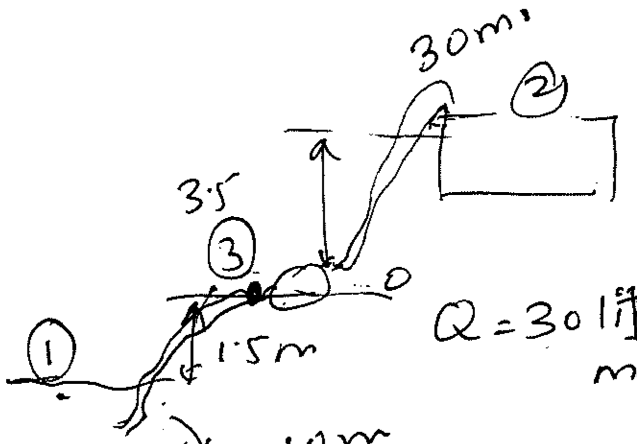
Pipeflow: Diesel sp. gr. 0.8, $\nu = 2.5\ mm^2/s = 2.5 \times 10^{-6}\ m/s$



$Q = 30\ \frac{liters}{min}$

$L = 10m$

$dia = 25mm$

$\epsilon = 10\mu m$

$K_{inlet} = K_{outlet} = 2.5$

$K_{pump\ fitting} = 2$

$$\frac{p_1}{\rho} + \frac{V_1^2}{2} + gz_1 + \frac{\dot{W}}{\dot{m}} = \frac{p_2}{\rho} + \frac{V_2^2}{2} + gz_2 + gh_{Loss}$$

$p_1 = p_2 = p_{atm}$

$$V_1 = V_2 = \frac{Q}{A} = \left(\frac{30 \times 10^{-3}}{60}\right) \Big/ \left(\frac{\pi}{4} \times 0.025^2\right) = 1.0186\ m/s$$

$z_1 = -1.5, \quad z_2 = +3.5$

$$h_{Losses} = h_{major} + h_{minor}$$

$$h_{major} = f\frac{L}{D}\frac{V^2}{2}, \quad h_{minor} = K\frac{V^2}{2}$$

$$Re = \frac{VD}{\nu} = \frac{(1.0186)(0.025)}{(2.5 \times 10^{-6})} = 10186 > 4000 \Rightarrow \text{flow is turbulent.}$$

$$f = \frac{0.25}{\left[\log_{10}\left(\frac{\epsilon/D}{3.7} + \frac{5.74}{Re^{0.9}}\right)\right]^2} = 0.0315$$

$$g h_{major} = \cancel{0.03}\ f \frac{L}{D} \frac{V^2}{2} = (0.0315)\left(\frac{40}{0.025}\right) \frac{1.018^2}{2} = 26.1$$

$$h_{major} = \frac{26.1}{g} = \frac{26.1}{9.8} = 2.66$$

$$f = \frac{0.25}{\left(\log_{10}\left[\frac{\frac{10\times10^{-6}}{0.025}}{3.7} + \frac{5.74}{1186^{0.9}}\right]\right)^2}$$

$$g h_{minor} = K \frac{V^2}{2} =$$

$$= \Big(\underbrace{2.5}_{\text{inlet}} + \underbrace{2.5}_{\text{outlet}} + \underbrace{2}_{\text{inlet of pump}} + \underbrace{2}_{\text{outlet of pump}}\Big) \frac{1.018^2}{2}$$

$$= 4.663$$

$$h_{minor} = \frac{4.663}{9.81} = 0.475$$

$$\text{total head loss} = (2.66 + 0.475) = 3.13\ m$$

$$g h_{losses} = (9.81)(3.13) = 30.76$$

$$\frac{\dot{W}}{\dot{m}} = g(z_2 - z_1) + g h_{Loss}$$

$$= (9.81)\big(\underbrace{3.5 - (-1.5)}_{\text{~~stata~~ elevation head.}}\big) + 30.76$$

$$= 79.8 \quad \leftarrow \text{work done per unit mass.}$$

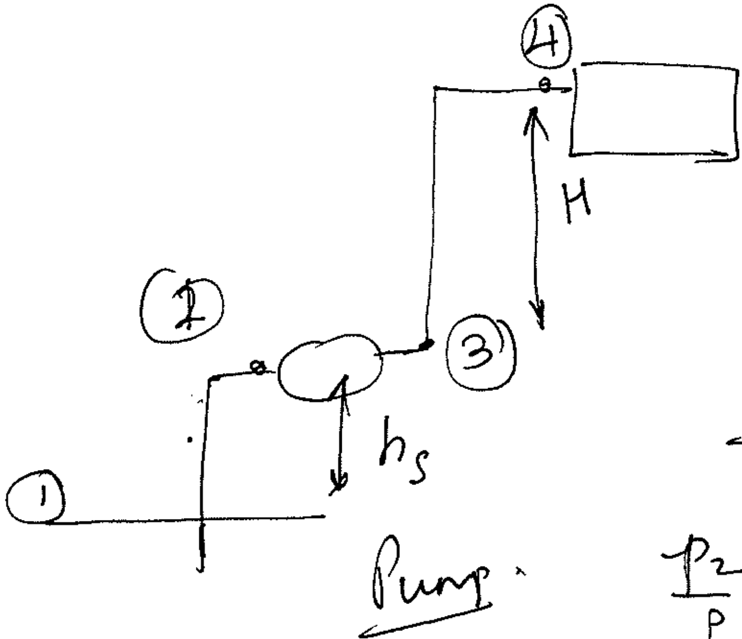
Power $\dot{W} = \dot{m}(79.81)$

$$\dot{m} = \rho Q = (0.8)(1000)\left(\frac{30 \times 10^{-3}}{60}\right) = 0.4 \text{ kg/s}$$

$$\dot{W} = (0.4)(79.81) = 31.9 \text{ W}$$

If efficiency $= 65\%$.

$$\text{Power input} = \frac{31.9}{.65} = 49 \text{ W}$$



Pump.

If inlet area @ pump = outlet area @ pump.

$$\frac{p_1}{\rho} + \cancel{\frac{V_1^2}{2}} + gz_1 - gh_{loss} = \frac{p_2}{\rho} + \frac{V_2^2}{2} + gz_2$$

$$\frac{p_2}{\rho} = \frac{p_1}{\rho} - gh_s - \underline{gh_{loss}} - \frac{V_2^2}{2}$$

$$\Rightarrow p_2 < p_1$$

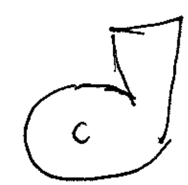
$$\frac{p_2}{\rho} + \cancel{\frac{V_2^2}{2}} + \cancel{gz_2} + \frac{\dot{W}}{\dot{m}} - \underbrace{gh_{loss}}_{\approx 0} = \frac{p_3}{\rho} + \cancel{\frac{V_3^2}{2}} + \cancel{gz_3}$$

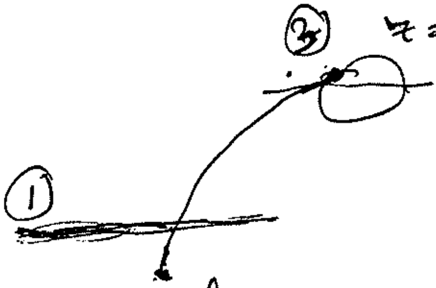
$$\frac{p_2}{\rho} + \frac{\dot{W}}{\dot{m}} = \frac{p_3}{\rho} \Rightarrow p_3 > p_2$$

$$\frac{p_3}{\rho} + \frac{V_3^2}{2} + gz_3 - gh_{loss} = \frac{p_4}{\rho} + \cancel{\frac{V_4^2}{2}}^{0} + gz_4$$

p_a

$$\frac{p_3}{\rho} + \frac{V_3^2}{2} - gH - gh_{loss} = \frac{p_4}{\rho}$$





$$\cancel{\frac{p_1}{\rho}} + \cancel{\frac{V_1^2}{2}} + g\cancel{z_1} + \cancel{\frac{\dot{W}}{\dot{m}}} - g\underline{\underline{h_{loss}}} = \frac{p_3}{\rho} + \frac{V_3^2}{2} + g z_3$$

$$p_a \qquad 0 \qquad g(-1.5) \qquad \qquad \frac{1.018^2}{2} \qquad 0$$

$$g h_{major} = f \frac{L}{D}\frac{V^2}{2} = (0.0315)\,\frac{10}{0.025}\,\frac{1.018^2}{2} = 6.53$$

$$g h_{minor} = K \frac{V^2}{2} = (2.5 + 2)\,\frac{1.018^2}{2} = \cancel{0.238}\ 2.332$$

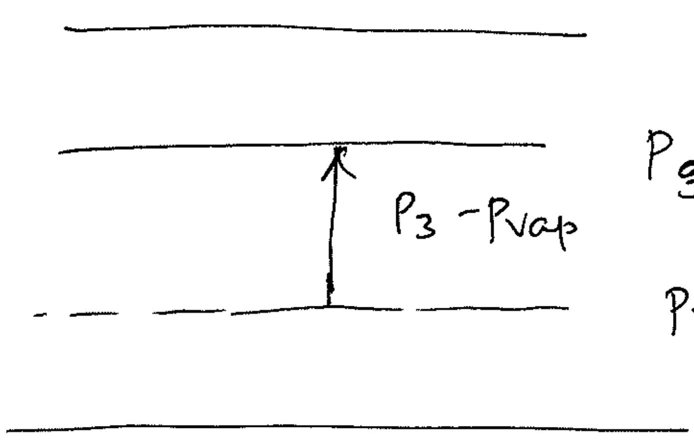
$$g h_{losses} = (6.53 + 2.332) = 8.862 \Leftarrow$$ loss per unit mass flow rate.

$$\frac{p_a}{\rho} + (-g)(1.5) - 8.862 = \frac{p_3}{\rho} + \frac{1.018^2}{2}$$

$$\Rightarrow \frac{p_a}{\rho} - \frac{p_3}{\rho} = (1.5)(9.81) + 8.862 + \frac{1.018^2}{2} = 19.6$$

$$\frac{101.3 \times 10^3}{.8 \times 10^3} - \frac{p_3}{800} = 19.6 \Rightarrow p_3 = 85.6\ \text{kPa}$$

(abs)



$P_{atm} = 101.3$

$P_3 = 85.6 \text{ kPa}$

$P_{vap} @ 38^\circ C = 10 \text{ kPa}$

$P = 0$

$$\frac{P_3 - P_{vap}}{\rho g} = \frac{(85.6 - 10)(10^3)}{(.8 \times 10^3)(9.81)}$$

$$= 9.63 \text{ m}$$ ← Net positive suction head (NPSH)

Momentum Balance

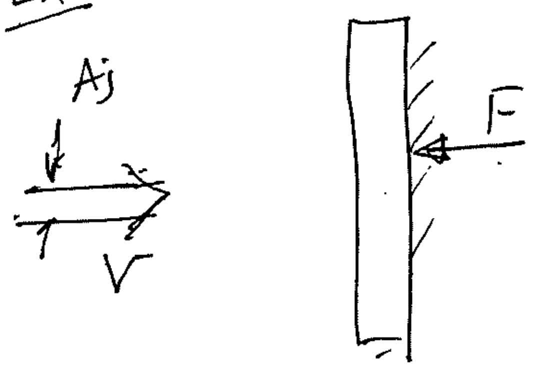
L = momentum

$$\dot{L}_{in} - \dot{L}_{out} + \sum F_{\substack{\text{external}\\\text{forces}}} = \frac{dL_{cv}}{dt}$$

$L = mv$

CV = control volume

Ex



X:
$\dot{L}_{in} = \dot{m}V$

$\dot{L}_{out} = 0$

$\dot{m}V - 0 - F = 0$

$\Rightarrow F = \dot{m}V$

Since $\dot{m} = \rho A V$

$F = \rho A V^2$

In Y direction:

$\dot{L}_{in} = 0$

$\dot{L}_{out} = \underbrace{\left(\frac{\dot{m}}{2}\right)V}_{\text{going up}} - \underbrace{\dot{m}\frac{V}{2}}_{\text{going down.}}$

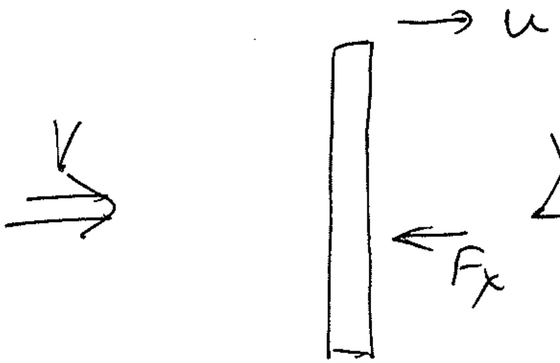


plate moves at constant speed u.

x:
$$\dot{L}_{in} = \dot{m} V$$
$$\dot{L}_{out} = \dot{m} u$$

$$\dot{L}_{in} - \dot{L}_{out} + \Sigma F = \frac{dL_{cv}}{dt}$$

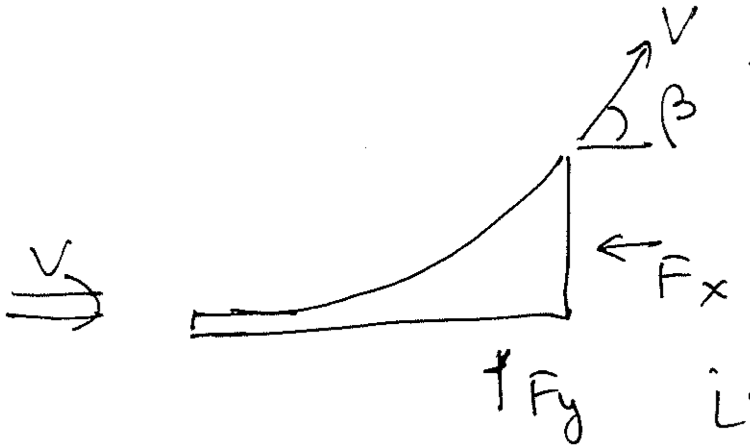
$$\dot{m} V - \dot{m} u - F_x = 0$$

$$F_x = \dot{m}(V-u)$$

$$\dot{m} = (V-u)\rho A$$

$$F_x = \rho A (V-u)(V-u)$$

$$F_x = \rho A (V-u)^2$$



X:

$$\dot{L}_{in} = \dot{m} V$$

$$\dot{L}_{out} = \dot{m} V \cos\beta$$

$$\dot{L}_{in} - \dot{L}_{out} + \Sigma F = \frac{dL_{cv}}{dt}$$

$$\dot{m} V - \dot{m} V \cos\beta - F_x = 0$$

$$F_x = \dot{m} V (1 - \cos\beta)$$

$$F_x = \rho A V^2 (1 - \cos\beta)$$

Y:

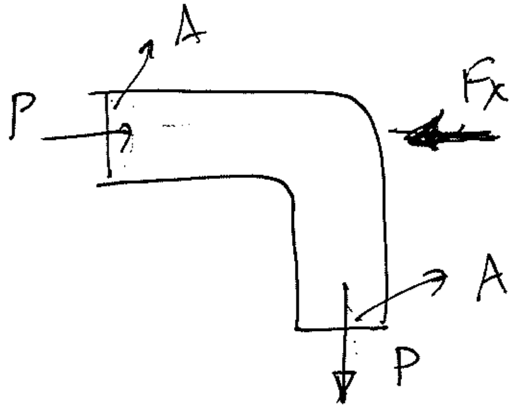
$$\dot{L}_{in} = 0$$

$$\dot{L}_{out} = \dot{m} V \sin\beta$$

$$\Sigma F = F_y$$

$$0 - \dot{m} V \sin\beta + F_y = 0 \Rightarrow F_y = \dot{m} V \sin\beta$$

$$= \rho A V^2 \sin\beta$$



X:

$$\dot{L}_{in} - \dot{L}_{out} + \Sigma F = \cancel{\frac{dL_{cv}}{dt}}^{0}$$

$$\dot{L}_{in} = \dot{m} V$$

$$\dot{L}_{out} = 0$$

$$F = -F_x + pA$$

$$\dot{m}V - 0 - F_x + pA = 0$$

$$F_x = \dot{m}V + pA$$

Y:

$$\dot{L}_{in} = 0$$

$$\dot{L}_{out} = -\dot{m}V \quad (\text{-ve because velocity is downwards}).$$

$$F = pA + F_y$$

$$0 + \dot{m}V + pA + F_y = 0$$

$$F_y = -(\dot{m}V + pA)$$