Homework 2.3 Chapter 15 4,9,15 Chapter 16 6,11,20,29

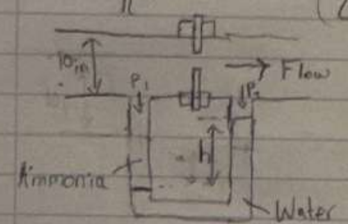
15.4 A Sharp edged orifice is placed in a 10-in diameter pipe carrying ammonia. If the volume flow rate is 25gal/min. Calculate the deflection of a water manometer. (a) If the orifice diameter is 1.0 in & if the orifice diameter is 7.0 in. The ammonia has an S.G. of 0.83 and dynamic viscosity of 2.5×10^{-6} lb/ft^2

$$Q = 25\,gal/min \times \left(\frac{1\,ft^3}{7.48\,gal}\right) \times \left(\frac{1\,min}{60\,s}\right) = 0.0557\,ft^3/s$$ * Volume Flow Rate *

$$V = \frac{Q}{A} = \frac{(0.0557\,ft^3/s)}{\frac{\pi (10\,in \times \frac{1ft}{12in})^2}{4}} = 0.1021\,ft/s$$ * Velocity *

$A_1 = 0.545\,ft^2$

$$N_R = \frac{vD\rho}{\eta} = \frac{(0.1021\,ft/s)(0.833\,ft)(0.83)(1.94\,slug/ft^3)}{(2.5 \times 10^{-6}\,lb/ft^2)} = 54{,}778.6 \approx 5.5 \times 10^4$$ * Reynolds Number



* Discharge Coefficient

a. $\frac{d_o}{D_p} = \frac{1.0\,in}{10\,in} = 0.10$, $C_a = 0.595$

b. $\frac{d_o}{D_p} = \frac{7.0\,in}{10\,in} = 0.70$ $C_b = 0.617$

From Figure 15.7

$$Q = CA_1\left(\frac{2g(P_1 - P_2)/\gamma}{(A_1/A_2)^2 - 1}\right)^{1/2} = Q^2 = C^2A_1^2\left(\frac{2g(P_1-P_2)/\gamma}{(A_1/A_2)^2-1}\right) \Rightarrow$$

$$\Rightarrow P_1 - P_2 = \frac{\gamma Q^2 (A_1/A_2)^2 - 1}{2gC^2A_1^2} *$$

Part (a). $d_o = 1.0\,in$, $A_2 = \frac{\pi}{4}(1.0\,in \times \frac{1ft}{12in})^2 = 0.00545\,ft^2$, $A_1/A_2 = \frac{0.545\,ft^2}{0.00545\,ft^2} = 100$

$$P_1 - P_2 = \frac{(0.83)(62.4\,lb/ft^3)(0.0557\,ft^3/s)^2(100^2-1)}{2(32.2\,ft/s^2)(0.595)^2(0.545\,ft^2)^2} = 237.26\,lb/ft^2$$

Water Manometer * deflection *

$P_1 + \gamma_A h - \gamma_w h = P_2$

$P_1 - P_2 = h(\gamma_w - \gamma_A)$

$$h = \left(\frac{P_1 - P_2}{\gamma_w - \gamma_A}\right) = \frac{237.26\,lb/ft^2}{62.4\,lb/ft^3 - (0.83)(62.4\,lb/ft^3)} = 22.37\,ft$$

$\rightarrow 51.792\,lb/ft^3$

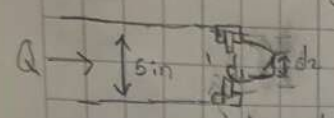
Part (b). $d_o = 7\,in$, $A_2 = \frac{\pi}{4}(7.0\,in \times \frac{1ft}{12in}) = 0.267\,ft^2$, $A_1/A_2 = \frac{0.545\,ft^2}{0.267\,ft^2} = 2.04$

$$P_1 - P_2 = \frac{(0.83)(62.4\,lb/ft^3)(0.0557\,ft^3/s)^2(2.04^2-1)}{2(32.2\,ft/s^2)(0.617)(0.545\,ft^2)^2}$$

$= 0.0691\,lb/ft^2$

$$h = \frac{P_1 - P_2}{\gamma_w - \gamma_A} = \frac{0.0691\,lb/ft^2}{62.4\,lb/ft^3 - 51.792\,lb/ft^3} = 0.00651\,ft$$

15.9 Flow Nozzle for 5in copper pipe. Flow rate between 700gal/min to 1,000gal/min. Manometer scale ranges from 0 to 8in of Mercury. Find appropriate orifice diameter



Linseed oil at 77°F

$\gamma_l = 58.0 lb/ft^3$

$\nu = 3.84 \times 10^{-4} ft^2/s$

Diameter $= 4.750in = d_1$ $\quad A_1 = \frac{\pi}{4}\left(4.750in \times \frac{1ft}{12in}\right)^2$

$A_1 = 0.1231 ft^2$

$Q_{min} = \frac{700gal}{min} \times \frac{0.1337ft^3}{1gal} \times \frac{1min}{60s} = 1.560 ft^3/s$

$Q_{max} = \frac{1{,}000gal}{min} \times \frac{0.1337ft^3}{1gal} \times \frac{1min}{60s} = 2.228 ft^3/s$

$V_{min} = \frac{Q_{min}}{A_1} = \frac{1.560 ft^3/s}{0.1231ft^2} = 12.67 ft/s$

$V_{max} = \frac{Q_{max}}{A_1} = 18.099 ft/s$

* Reynolds Number *

$N_R(min) = \frac{V_{min}(d_1)}{\nu}$

$N_R(min) = \frac{(12.67ft/s)\left(\frac{4.750in}{12in}\right)ft}{3.84 \times 10^{-4} ft^2/s}$

$N_R(min) = 1.32 \times 10^4$

$N_R(max) = \frac{(18.099ft/s)\left(\frac{4.750in}{12in}\right)ft}{3.84 \times 10^{-4} ft^2/s}$

$N_R(max) = 1.87 \times 10^4$

Fig * 15.5 C_{min} approximately 0.956

C_{max} approximately 0.963

$h = in Hg = \frac{8in}{12in} = 0.667ft$

$\gamma_m = 844.9 lb/ft^3$

$A_2 = \frac{A_1}{\sqrt{\frac{BhC^2}{V_1} + 1}}$; using max

$B = 2g(\gamma_m/\gamma_L - 1)$

$B = 2(32.2ft/s^2)(13.567)$

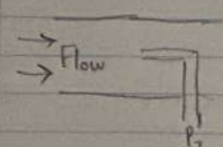
$873.71 ft/s^2$

$A_2 = \frac{0.1231 ft^2}{\sqrt{\frac{(873.71ft/s^2)(0.667ft)(0.963)^2}{(18.099 ft/s)^2} + 1}} = 0.7562 ft^2 = \frac{\pi}{4} d_2^2$

$d_2(Throat) = (0.3103 ft) \times \frac{12in}{1ft}$

$d_2 = 3.724 in$

15.15 Pitot - Static tube at standard atm pressure at 50°C. Differential manometer reads 0.24 in of H_2O. Find velocity



$\gamma_w = \gamma_g = 62.4\,lb/ft^3$
$\gamma_a = 0.0736\,lb/ft^3$

$h = 0.24\,in\ H_2O$

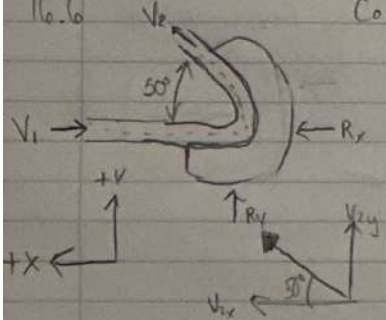
$0.24\,in \times \frac{1\,ft}{12\,in} = 0.02\,ft$

$V = \sqrt{2gh(\gamma_w - \gamma_a)/\gamma_a}$

$V = \sqrt{2(32.2\,ft/s^2)(0.02\,ft)(62.4\,lb/ft^3 - 0.0736\,lb/ft^3)/0.0736\,lb/ft^3}$

$V = 33.02\,ft/s$

16.6



Compute Forces

$V_1 = 22.0\,ft/s \quad A = 2.95\,in^2$

$Q = Av$

$Q = (2.95\,in^2)\times\left(\frac{1\,ft^2}{144\,in^2}\right)(22.0\,ft/s) \qquad V_2 = V_1$

$Q = 0.451\,f^3/s$

$R_x = \rho Q\,(V_{2x} - V_{1x}) = \rho Q\,(V_2 \cos(50°) + V_1)$

$R_x = \rho Q V_1 (\cos(50° + 1)$

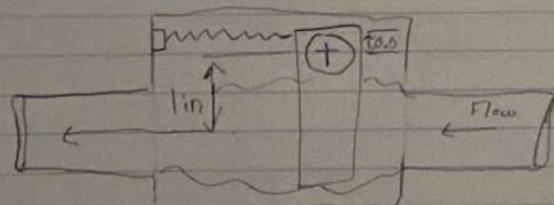
$R_x = \left(\frac{1.88\,lb\cdot s^2}{ft^4}\right)\times\left(\frac{0.451\,ft^3}{s}\right)\times\left(\frac{22.0\,ft}{s}\right)\times 1.643$

$R_x = 30.6\,lb$

$R_y = \rho Q\,(V_{2y} - V_{1y}) = \rho Q(V_2 \sin(50°) - 0) = \frac{1.88\,lb\cdot s^2}{ft^4}\times\left(\frac{0.451\,ft^3}{s}\right)\times(22\sin(50°))$

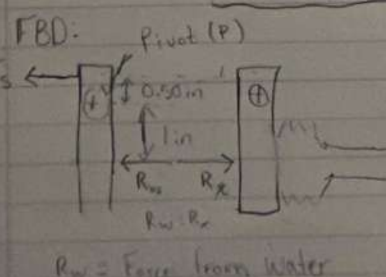
$R_y = 14.3\,lb$

16.11



Calculate Spring Force required to hold Vane in vertical position when water at 100 gal/min flows from the 1in Schedule 40 pipe

FBD:



$Q = 100\,gal/min \times \frac{0.1337\,ft^3}{1\,gal} \times \frac{1\,min}{60\,s} = 0.223\,ft/s$

$V_1 = \frac{Q}{A} = \frac{0.223\,ft^3/s}{\frac{\pi}{4}(1.08)^2} = 37.17\,ft/s$

$R_x = \rho Q(V_{2x} - V_{1x}) = \rho Q V_1$

$R_x = \frac{1.94\,lb\cdot s^2}{ft^4} \times \frac{0.223\,ft^3}{s} \times \frac{37.17\,ft}{s} = 16.08\,lb$

R_w = Force from water
R_x - Forces from vane

f

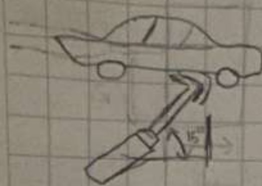
$\circlearrowright + \sum M_P = 0$

$R_w = R_x$

$0 = F_s(0.5in) - R_w(1.0in)$

$$F_s = R_w \frac{(1.0in)}{0.5in} = (16.07lb)(2) = 32.14lb$$

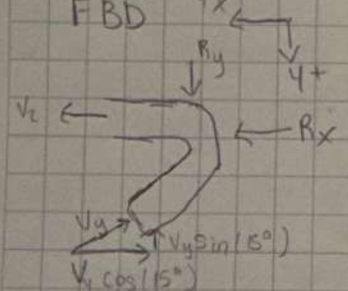
6.20



Jet has velocity of 30m/s and issues from nozzle with a diameter of 200mm. Compute the force on a) stationary vehicle b) moving at 12m/s

$$Q = Av = \frac{\pi}{4}\left(200mm \times \frac{1m}{1000mm}\right)^2 (30m/s)$$

FBD



a.) $Q = 0.942\ m^3/s$

$R_x = \rho Q(V_{2x} - V_{1x}) = \rho Q(V_2 - (-V_1 \cos 15°))$

$R_x = \rho Q v(1 + \cos(15°)) = 1.966 \rho Q v$

$$R_x = 1.966\left(\frac{1000 kg}{m^3}\right)\left(\frac{0.942 m^3}{s}\right)\left(\frac{30 m}{s}\right)$$

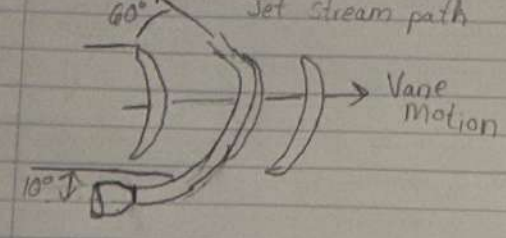
$R_x = 55{,}559.16\ N \leftarrow$

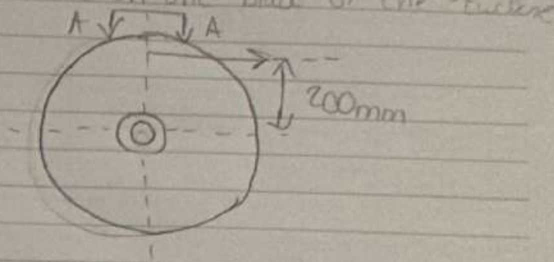
$R_y = \rho Q(V_{2y} - V_{1y}) = \rho Q(0 - (-V_1 \sin(15°)) = \rho Q v \sin(15°)$

$$R_y = \left(\frac{1000 kg}{m^3}\right)\left(\frac{0.942 m^3}{s}\right)\left(\frac{30m}{s}\right)(0.2588)$$

$R_y = 7{,}314.23\ N \uparrow$

16.29 Stream of water at 15°C has a diameter of 7.50mm and is moving with a velocity of 25m/s. Compute the force on one blade of the turbine





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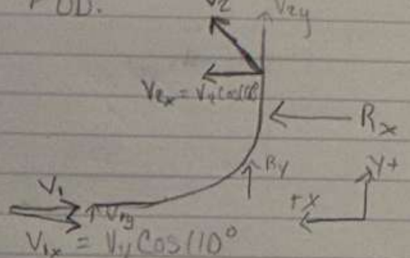

$R_x = \dot{M}(\Delta V_2) = M = V_{2x} - V_{1x}$ $\quad M = \rho AV$

$A = \frac{\pi d^2}{4} = \frac{\pi}{4}\left(7.5mm \times \frac{1m}{1000mm}\right)^2$

$A = 4.418 \times 10^{-5} m^2$

$\dot{M} = \rho AV = (1,000 kg/m^3)(4.418 \times 10^{-5} m^2)(25m/s)$

$\dot{M} = 1.104 kg/s$

$V_{1x} = V_1\cos(10°) = (25 m/s)(0.985) = 24.62 m/s$

$V_{1y} = V_1\sin(10°) = (25m/s)(0.174) = 4.34 m/s$ $\quad V_2 = V_1 = 25m/s$

$V_{2x} = V_2\cos(60°) = (25 m/s)(0.5) = 12.5m/s$

$V_{2y} = V_2\sin(60°) = (25m/s)(0.0866) = 21.65m/s$

$R_x = \dot{M}(\Delta V_x) = \dot{M}(V_{2x} - V_{1x}) = 1.104 kg/s(12.5m/s - (-24.62 m/s))$

$R_x = 41.0N$

$R_y = \dot{M}(\Delta V_y) = \dot{M}(V_{2y} - V_{1y}) = 1.104 kg/s(21.65m/s - 4.34 m/s))$

$R_y = 19.1N$

Water hammers are experienced under high pressure while cavitation is under low pressure. Must utilize the bulk modulus of a fluid for compression that we talked about in chapter 1. To help mitigate these processes we could slowly close valves or stop a pump slowly. Also pipe thickness and materials can have an effect on this surge on the system. The sudden disruption in flow can cause vibrations and damage to not only piping systems, but anything surrounding it.