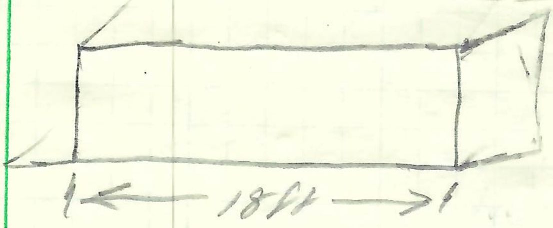
MET330 | Exam 2 Makeup | ERIAS-GARCIA

1.



width 18ft conveys water at 350 ft^3/s. temperature of water is at 50°C. channel Slope of .001

Purpose: Find liquid depth for uniform flow, Is flow supercritical or subcritical.

$A = by = 18y$

$WP = b + 2y = 18 + 2y$

$R = \frac{A}{wp} \Rightarrow \frac{by}{b+2y} \Rightarrow \frac{18y}{18+2y}$

$Q = \frac{1.49}{n}(18y)\left(\frac{18y}{18+2y}\right)^{2/3}(.001)^{1/2}$

$350 = \left(\frac{1.49}{.017}\right) 18y \left(\frac{18y}{18+2y}\right)^{2/3}(.031622777)$

$126.279 = 18y\left(\frac{18y}{18+2y}\right)^{2/3}$

$126.279 = 18y\,(18+2y)^{3/2} = (324y + 36y^2)^{3/2} =$

$126.279 = 47.17y + 10.90y^2\,(18y)^{2/3}$

$126.279 = 47.17y + 10.90y^2 \cdot \frac{1}{6.868y}$

$126.279 = 47.17y + \frac{10.90y^2}{6.868y}$

$126.279 = 47.17y + 1.59y$

Froude Number

$N_F = \frac{V}{\sqrt{gyh}}$

Manning's Equation

$V = \frac{1.49}{n} R^{2/3} S^{1/2}$

unfinished concrete

$n = .017$

Normal Discharge

$Q = \left(\frac{1.49}{n}\right) A R^{2/3} S^{1/2}$

$$\frac{126.279 = 48.76y}{48.76} \Rightarrow y = 2.59 \text{ ft}$$

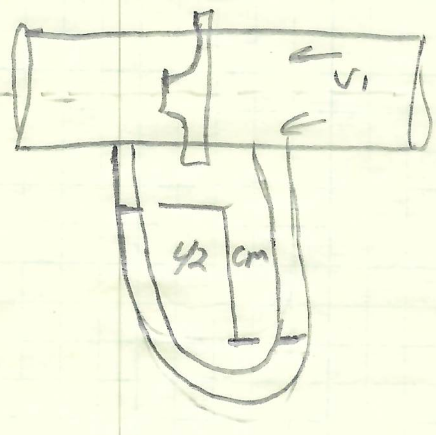
$$N_F = \frac{V}{\sqrt{gy_h}} = \frac{Q}{A\sqrt{gh}} = \frac{Q}{by\sqrt{gy}} = \frac{350}{18(2.59)\sqrt{32.2 \times 2.59}}$$

$$\frac{350}{46.62\sqrt{83.398}} = \frac{350}{425.746} = .822 < 1$$

$N_F < 1.0$ = Subcritical

laminar

2.



Ethylene glycol Specific $g = 1.100$

$\gamma = 10.79 \text{ kN/m}^3$

$\rho = 1100 \text{ kN/m}^3$

Kinematic $V = 1.47 \times 10^{-5} \text{ m}^2/\text{s}$

Mercury Specific $g = 13.54$

$\gamma = 132.8 \text{ kN/m}^3$ Kinematic V

$\rho = 13540 \text{ kN/m}^3$ $1.13 \times 10^{-7} \text{ m}^2/\text{s}$

Purpose: Determine actual Flow rate through the line.

12 in Nominal steel pipeline schedule 40

Flow nozzle $d/D = .50$

Pressure Drop 42 cm Mercury

outside Ø 323.9 mm

inside Ø 11.938 in 303.2 mm

wall thickness .406 in

Flow Area .7771 ft²

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

Flow Rate $\Rightarrow$ $Q = CA_1\sqrt{\dfrac{2g(P_1 - P_2)/\gamma}{(A_1/A_2)^2 - 1}}$

using Manometry

γ_m = Manometer
γ_f = fluid

$$V_1 = C\sqrt{\frac{2gh[(\gamma_m/\gamma_f)-1]}{(A_1/A_2)^2-1}}$$

$d = D \times .5$
$d = 303.2 \times .5$
$d = 151.6\,mm$

$$A_1 = \frac{\pi}{4}D^2 \Rightarrow \frac{\pi}{4}(.3032)^2 = .0722\,m^2$$

$$A_2 = \frac{\pi}{4}d^2 \Rightarrow \frac{\pi}{4}(.1516\,m)^2 = .0181\,m^2$$

$$V_1 = C\sqrt{\frac{2(9.81\,m/s^2)(.42\,m)\left[\left(\frac{132.8}{10.79}\right)-1\right]}{\left(\frac{.0722\,m^2}{.0181\,m^2}\right)^2-1}}$$

$$V_1 = C\sqrt{\frac{8.2404\,[11.308]}{14.912}}$$

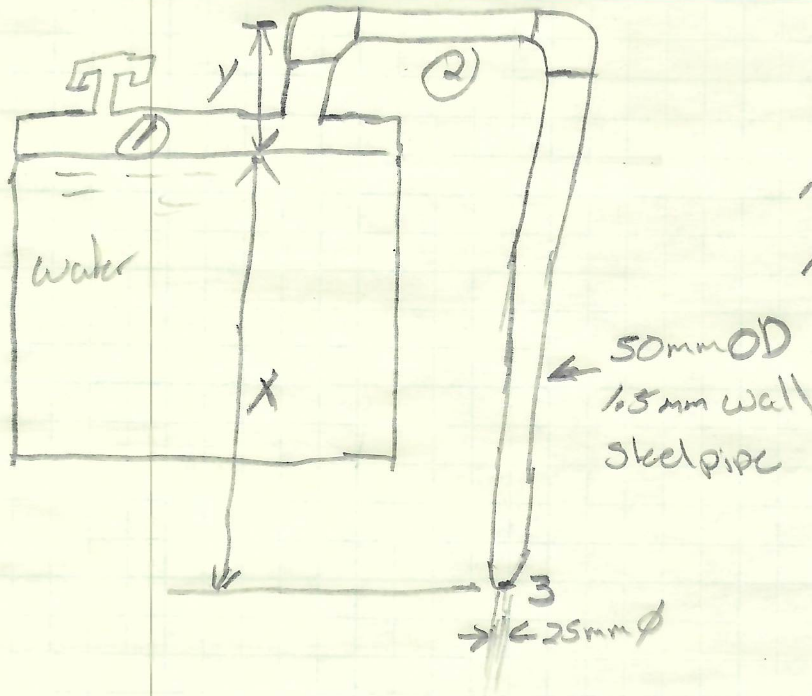
$$V_1 = C\sqrt{\frac{93.182}{14.912}} = V_1 = C\sqrt{6.249}$$

$$V_1 = C \cdot 2.4998\,m/s = .984 \times 2.4998\,m/s = \boxed{2.60\,m/s}$$

$$N_R = \frac{V_1 D}{\nu} = \frac{2.60 \times .3032}{5.03 \times 10^{-6}} = 156723.6581$$

1.57×10^5

3.



Flow Rate of water at 30°C is 5.6 L/s

neglect length of pipe.

neglect minor losses

$\gamma_{water} = 9.77 kN/m^3$

$\rho = 996 kN/m^3$

kinematic $\nu = 8.03 \times 10^{-7} m^2/s$

$z_1 = x$

$z_2 = x + 2y$

Purpose: Determine the Maximum allowable distance y if you Want to aviod cavitation.

$$\frac{\cancel{P_1}^{0}}{\gamma} + \frac{\cancel{V_1^2}^{0}}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 = \frac{\cancel{P_3}^{0}}{\gamma} + \frac{V_3^2}{2g} + \cancel{z_3}^{0}$$

$Q = VA$

$$z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 = \frac{V_3^2}{2g}$$

$$\frac{5.6 L}{s} \Big| \frac{m^3}{1000 L} = .0056 m^3/s$$

$$\frac{P_3}{\gamma} = \frac{V_2^2}{2g} - \frac{V_3^2}{2g} + z_1 - z_2$$

Cavitation

$$\frac{P_{suct}}{\gamma} = \frac{P_0}{\gamma} - \frac{V_s^2}{2g} - z_2 - h_{L_{1-2}}$$

$$P_2 = \frac{V_2^2}{2g} + (z_1 - z_2) \quad ①$$

$$V = \frac{Q}{A} \Rightarrow .0056 m^3/s \Big/ \left[\frac{\pi}{4}\left((.05)^2 - (.05 - 2 \times .0015)^2\right)\right]$$

P_{suct} = abs pressure

table 13.2

$$V = \frac{.0056 m^3/s}{.000228551} = 24.50 m/s$$

Water Vapor at 30°C

$P = 4.243$ kPa (abs)

Specific weight = $9.765 kN/m^3$

$$P_2 = \frac{-V_2^2}{2g} + (z_1 - z_2)$$

$$P_{abs} = P_g + P_{atm}$$

$$P_g = P_{abs} - P_{atm}$$

$$-97.082 = \frac{-(24.5\,m/s)^2}{2 \times 9.81\,m/s^2 \times 1000} + (X - (X + 2y))$$

$$P_g = 4.243\,kPa - 101.325\,kPa$$

$$P_g = -97.082$$

$$-97.082 = -.030593782 + (X - (X + 2y))$$

$$-97.0514 = X - (X + 2y)$$

$$\frac{-97.0514}{-2} = \frac{-2y}{-2} = \boxed{y = 48.5257\,m}$$

$$Q_3 = V_3 \times A_3 \qquad \frac{P_3}{\gamma} + \frac{V_3^2}{2g} + z_3$$

$$V_3 = \frac{Q_3}{A_3} \Rightarrow \frac{.0056\,m^3/s}{\frac{\pi}{4}(.025)^2} = V_3 = 11.408\,m/s$$

$$\cancel{\frac{P_1}{\gamma}}^{0} + \frac{V_1^2}{2g} + z_1 = \cancel{\frac{P_3}{\gamma}}^{0} + \frac{V_3^2}{2g} + z_3$$

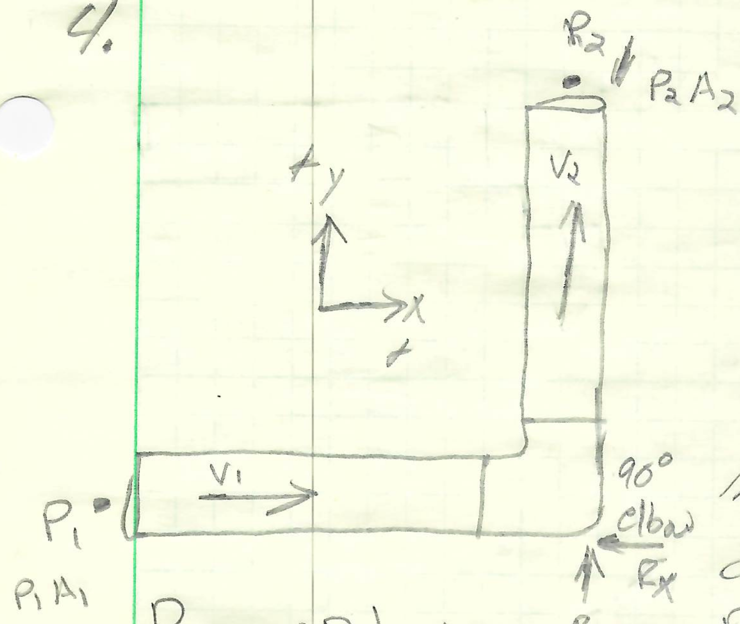
$$\frac{V_1^2}{2g} = \frac{V_3^2}{2g} = (z_1 - z_3) \Rightarrow \frac{V_3^2}{2g} = (X - 0)$$

$$V_3 = \sqrt{2g\,(X - 0)} \Rightarrow 11.408\,m/s = \sqrt{2 \times 9.81 \times (X - 0)}$$

$$11.408 = \sqrt{19.62 \times (X - 0)} = 11.408 = 4.429 \times (X - 0)$$

$$\frac{11.408 = 4.429X}{4.429} = \boxed{X = 2.659\,m}$$

4.



Water at 30°C is deflected through an angle of 90°

elbow is steel size 1in nominal Schedule 40

Flow Rate is .4 liters/s

Inlet & outlet gauge pressure are 160 kPa. elbow on horizontal plane.

Purpose: Determine Forces Exerted on by the moving water.

Table F.1

$1in = .025m$ $\quad .4L/s \left(\frac{m^3}{1000L}\right) = .0004\,m^3/s$

$$V = \frac{.0004\,m^3/s}{\frac{\pi}{4}(.025m)^2} = .8149\,m/s \quad U_1$$

$Q = VA$

$V = \frac{Q}{A}$

water at 30°C Table A.1

$\gamma = 9.77\,kN/m^3$

$\rho = 996\,kN/m^3$

kinematic $\nu = 8.03 \times 10^{-7}\,m^2/s$

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

Force Equation $\vec{F} = m\vec{a} = m\frac{\Delta \vec{V}}{\Delta t} \rightarrow \dot{m} = \rho Q$

$$\vec{F} = \rho Q \Delta \vec{V}$$

$$\Sigma F_x = \rho Q \Delta v_x = \rho Q (v_{2x} - v_{1x})$$

$$\Sigma F_y = \rho Q \Delta v_y = \rho Q (v_{2y} - v_{1y})$$

$$\Sigma \Sigma F = \rho Q (v_{2x} - v_{1x})$$

$$P_1A_1 - R_x = \rho (v_1A_1)(0 - v_1)$$

$$R_x = P_1A_1 + \rho A_1 v_1^2$$

$$R_x = (160000)(.000490874) + (996)(.000490874)(.8149)^2$$

$$R_x = 78.53984 + .324666892 = \boxed{78.86\,N}$$

$$\uparrow \Sigma F_y = \rho Q (V_{2y} - V_{1y})$$

$$-P_2 A_2 + R_y = \rho V_1 A_1 (V_2 - 0)$$

$$R_y = \rho V_1 A_1 (V_2) + P_2 A_2$$

$$R_y = \rho A_2 V_2^2 + P_2 A_2$$

$$R_y = (996)(.000490874)(.8149)^2 + (160000)(.000490874)$$

$$R_y = .324666892 + 78.53984 = \boxed{78.86\ N}$$

$$\text{Net Force on elbow} = \sqrt{R_x^2 + R_y^2}$$

$$= \sqrt{(78.86)^2 + (78.86)^2} = \sqrt{12437.799} = \boxed{111.52\ N}$$

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5. Airplane with NACA 23012 airfoil flies at an altitude of 20,000 ft ($P = 6.8$ psia; $T = 450°R$). weight of plane 6300 lbf.

purpose: Determine velocity of plane for angle of attack of 8°. Compute drag force & power needed to fly the airplane

Equations: $\text{Aspect Ratio} = \frac{b}{c}$ b = span

Aspect Ratio = 6 c = chord

From figure

$C_D = .014$

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} = \frac{P_s}{\gamma} \qquad P_s = P_1 + \frac{\rho v_1^2}{2} \qquad \rho = \frac{\gamma}{g}$$

Span = 12 m

$$P_s = P_1 + \frac{\gamma V_1^2}{2g} \qquad \text{Drag Force: } F_D = C_D (\rho v^2/2) A \qquad C = \frac{b}{6} = \frac{12}{6} = 2\ m$$

$$A = 12 \times 2 = 24\ m^2$$

$$T = (450°R - 491.67) \times \frac{5}{9} = -21.15°C$$

$$\rho = 1.27 \times 10^{-3}\ \text{slugs/ft}^3 \rightarrow .65\ \text{kg/m}^3 \qquad \frac{\text{Pressure on airfoil}}{\text{Dynamic pressure}} = \frac{P}{\frac{1}{2}\rho v^2}$$

$$\frac{1\ ft^3}{1728\ in^3} \qquad 6.8\ lb/in^2 \rightarrow 979.2\ lbf/ft^2$$

$$\frac{P}{\frac{1}{2}\rho V^2} \Rightarrow V^2 = \frac{P}{\frac{1}{2}\rho} = \frac{979.2\ lbf/ft^2}{\frac{1}{2}\ 1.27\times10^{-3}\ slugs/ft^3} = 1542047.244$$

$$V = \sqrt{1542047.244} = \boxed{1241.79\ ft/s}$$

Conversions

$1.27\times10^{-3}\ slugs/ft^3$
$\downarrow$
$.655\ kg/m^3$

$1241.79\ ft/s$
$\downarrow$
$378.498\ m/s$

$24\ m^2$
$\downarrow$
$258.334\ ft^2$

Drag Force: $F_D = C_D\left(\frac{\rho V^2}{2}\right)A$

$$F_D = .014\left(\frac{(1.27\times10^{-3})(1241.79)^2}{2}\right)258.334\ ft^2$$

$$F_D = .014\,(979.1969265)\,258.334\ ft^2$$

$$\boxed{F_D = 3541.438023N}$$

Power $= (P + \frac{1}{2}\rho v^2 + \rho g h)Q$

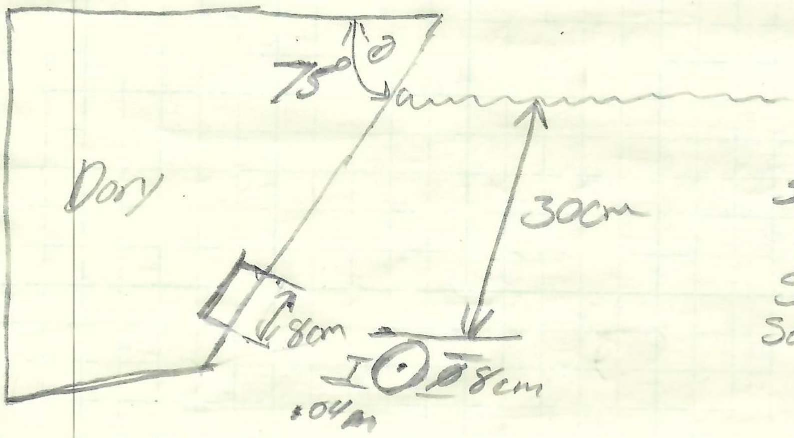
$$\left[979.2 + \frac{(1.27\times10^{-3})(1241.79)^2}{2} + (1.27\times10^{-3})(6300)(32.2)\right]\ 1241.79\times258.3$$

$$[1958.396927 + 257.6322]\ 320796.5779$$

$$(2216.029127)\times(320796.5779)$$

$$\boxed{710894560.5\ lbf/s} = \text{Power}$$

6.



liquid Density
1,025 kg/m³

$\gamma = 10.10$ kN/m³
Seawater

Specific Gravity = 1.030
Seawater

Purpose: Determine the force & its location on the cork due to saltwater.

Equations

$I_C = \sum_{i=1}^{N} (I_{Ci} + d_i^2 - A_i)$ $F = \gamma \cdot h_c \cdot A$ $L_p = L_c + \frac{I_C}{L_c \cdot A}$

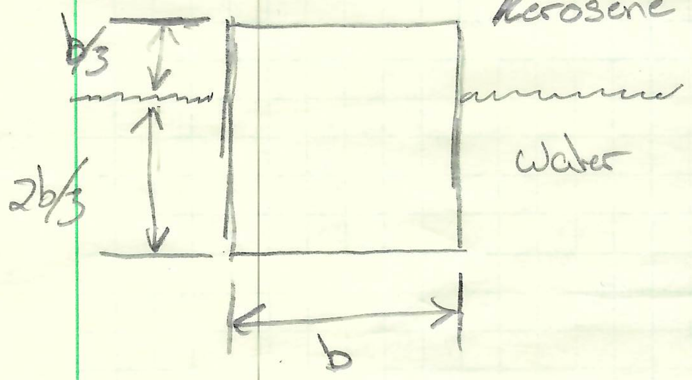
$\bar{x} \cdot A_T = \sum_{i=1}^{N} x_i \cdot A_i$ $I_C = \frac{\pi D^2}{64}$

$F = 10.10 \cdot (.30) \cdot (\frac{\pi}{4}(.08)^2)$

$F = 10.10 \cdot (.30) \cdot (.005026548)$

$F = .01523044\text{1 } N \rightarrow 1.5230441 \times 10^{-2} N$

7.



Cube of Material is 4in on a side & floats at the interface between kerosene & water.

Purpose: Find the specific gravity of Material. Why could the cube be stable?

$\gamma_{water} = 9.81\,kN/m^3$ $\qquad \gamma_{kerosene} = 8.07\,kN/m^3$ $\qquad F = PA$

$\rho = 1000\,kN/m^3$ $\qquad$ Specific $G = .823$ $\qquad \rho = m/V$

$\rho = 823\,kN/m^3$ $\qquad \gamma = W/V$

$SG = \frac{\gamma_s}{\gamma_w @ 4°C} = \frac{\rho_s}{\rho_w @ 4°C}$

$F_u = \rho_{kero}\, g z_1 b^2$ $\qquad \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2$

$F_i = \rho_{kero}\, g (z_1 + b/3) b^2 + \rho_{water}\, g \left(\frac{2b}{3}\right) b^2$

$W = \gamma_c V_c \Rightarrow \rho_c g V_c \Rightarrow \rho_c g b^3$

$R_b = W \Rightarrow F_i - F_u = W$

$\rho_{kero}\, g (z_1 + b/3) b^2 + \rho_{water}\, g \left(\frac{2b}{3}\right) b^2 - \rho_{kero}\, g z_1 b^2 = \rho_c g b^3$

$\rho_{kero}\, g z_1 + \rho_{kero}\, g\, b/3 + \rho_{water}\, g \left(\frac{2b}{3}\right) - \rho_{kero}\, g z_1 = \rho_c g b$

$\rho_{kero}\, g + 2\rho_{water}\, g = 3\rho_c g$

$\frac{\rho_{kero}}{\rho_{water}} + 2 = 3\frac{\rho_c}{\rho_{water}}$ $\qquad .823 + 2 = 3\,\text{Specific}\,G_{cube}$

$SG_{kero} + 2 = 3SG_c \rightarrow$ $\qquad \frac{2.823 = 3\,\text{Specific}\,G_{cube}}{3}$

$\boxed{\text{Specific Gravity}_{cube} = .941}$