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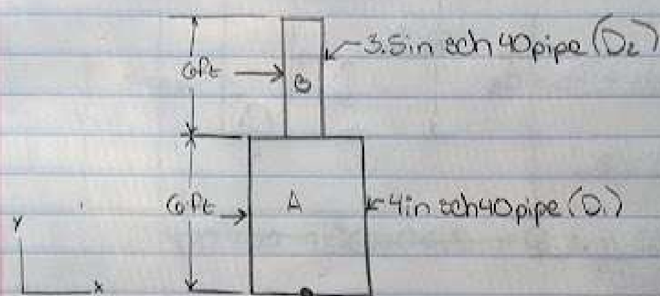
exam 3
Problem 1

Purpose:
Compute the moment at the base of a vertical pole

Drawing



Sources
Mott Robert L, Untener, Joseph Applied fluid mechanics
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Design considerations
The follow must be assumed:
1) Incompressible fluid
2) Isothermal Process
3) Steady State

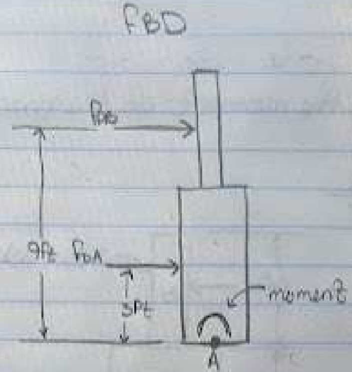
Data and Variables
$D_1 = 4.5in \rightarrow 0.375ft$
$D_2 = 4.0in \rightarrow 0.333ft$
Temp 71°
$\rho = 2.28 \times 10^{-3}$ slugs/ft²
$V = 80$ mi/h $\rightarrow 117.35$ ft/s
$\nu = 1.69 \times 10^{4}$ ft²/s

Procedure:

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

$$Re = \frac{VD}{\nu}$$

$$M = F_D \times d_A + F_{D_2} \times d_B$$



Calculations

$$Re_1 = \frac{117.33\,(0.375)}{1.69\times10^4} = 2.60\times10^3 = C_D = 0.9$$

$$Re_2 = \frac{117.33\,(0.333)}{1.69\times10^4} = 2.31\times10^3 = C_D = 0.9$$

$A_A = 6\times0.375 = 2.25\,ft^2$
$A_B = 6\times0.333 = 1.998\,ft^2$

$$F_{DA} = 0.9\left(\frac{2.28\times10^{-3}\times117.33^2}{2}\right)2.25 = 31.78\ lbf$$

$$F_{DB} = 0.9\left(\frac{2.28\times10^{-3}\times117.33^2}{2}\right)1.998 = 28.22\ lbf$$

$$M = 31.78\times3 + 28.22\times9 = \boxed{349.32\ lb\cdot ft}$$

Summary:

The moment at the base of the pole is 349.32 lb·ft.

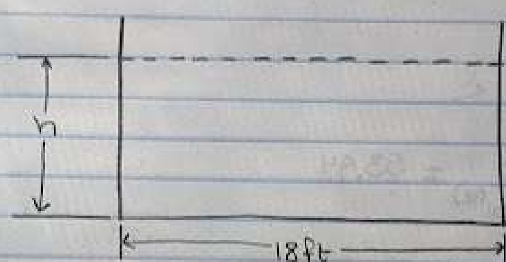
Problem 2

Purpose

Determine the liquid height

Is the flow Supercritical or subcritical?

Drawings



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Design considerations

The following must be assumed

1) Incompressible fluid

2) Isothermal Process

3) Steady State

Data and Variables

$Q = 150\ ft^3/s$

$W = 18ft$

$n = 0.017$

$S = 0.001$

Procedure:

$$AR^{2/3} = \frac{nQ}{1.49S^{1/2}}$$

$$R = \frac{A}{WP}$$

Calculations

$$AR^{2/3} = \frac{0.017*150}{1.495*0.001^{(1/2)}} = 53.94$$

$$A = 18(h)$$

$$R = \frac{18(h)}{2h+18}$$

See excel $\boxed{h = 1.11ft}$

$$18(h)\left(\frac{18(h)}{2h+18}\right)^{2/3} = 53.94$$

$$E = y + \frac{Q^2}{2g(18 \cdot y)^2} = 1.11 + \frac{150^2}{2 \cdot 32.2\,(18 \cdot 1.11)^2} = 2.86$$

$$V = \frac{Q}{A} = \frac{150}{19.98} = 7.51\ ft/s$$

$$N_F = \frac{V}{\sqrt{g y_h}} = \frac{7.51}{\sqrt{32.2 \cdot (19.98/18)}} = 1.26$$

$\boxed{N_f > 1.0 \therefore \text{Supercritical}}$

h (ft)	LHS	%diff
2	165.0656	101%
1.5	95.77408	56%
1.15	57.58066	7%
1.13	55.66843	3%
1.11	53.78612	0%

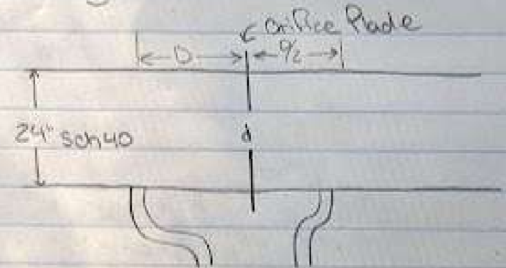
Summary:
The height of the liquid is 1.11 ft and the flow is supercritical.

Problem 3

Purpose:

Compute the reading of a mercury manometer

Drawings:



Data and Variables:

$Q = 6000 gpm \rightarrow 13.37 ft^3/s$

$D = 24" \rightarrow ID = 1.886 ft \quad A = 2.792 ft^2$

$\beta = 0.5$

$\gamma_{water} = 62.4 \quad \nu = 1.21 \times 10^{-5}$ @ 60°F

$\gamma_m = 844.9\ lb/ft^3$

Sources

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Design considerations

The following must be assumed.

1) Incompressable fluid

2) Isothermal process

3) Steady state

Procedure:

$$\beta = \frac{d}{D} \quad \therefore \quad d = \beta D$$

$$Re = \frac{VD}{\nu}$$

C = from Chart

$$h = \frac{\left(\frac{Q}{A_1 \times C}\right)^2 \times \left[\left(\frac{A_1}{A_2}\right)^2 - 1\right]}{2g\left(\frac{\gamma_m}{\gamma_w} - 1\right)}$$

Calculations

$d = 0.5(1.886) = 0.943\text{ft} \quad A_2 = \pi(0.943)^2/4 = 0.70\text{ft}^2$

$$Q = \frac{V}{A} \quad \therefore \quad V = QA = 13.37 * 2.792 = 37.33\ \text{ft/s}$$

$$Re = \frac{37.33 * 1.886}{1.21 \times 10^{-5}} = 5.82 \times 10^{6}$$

C = 0.602 (from table)

$$h = \frac{\left(\frac{13.37}{2.792 * 0.602}\right)^2 \times \left[\left(\frac{2.792}{0.70}\right)^2 - 1\right]}{2 * 32.2\left(\frac{844.9}{62.4} - 1\right)} = \frac{63.28 * 14.91}{807.58} = \boxed{1.168\text{ft}}$$

Summary

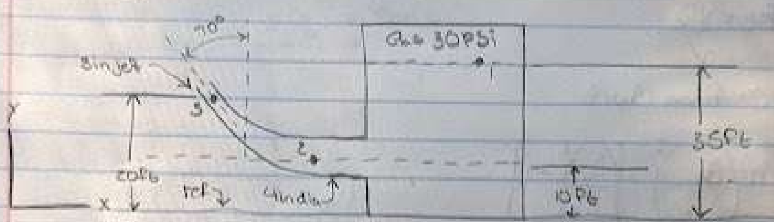
The mercury deflection is 1.168 ft or 14.016 in.

Problem 4

Purpose:

Compute the force on the curve pipe section

Drawing:



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Design considerations:

The following must be assumed

1) Incompressable fluid

2) Isothermal process

3) Steady state

Data and Variables:

$P_1 = 30PSi \rightarrow 4320\ lb/ft^2$

$L_{curve} = 10ft$

$\gamma = 55\ lb/ft^3$

$D_{jet} = 3in \rightarrow 0.25ft$

$D_{discharge}\ 4in \rightarrow 0.33ft$

$A_2 = 8.727 \times 10^{-2}\ ft^2$

$A_3 = 4.909 \times 10^{-2}\ ft^2$

Procedure

Find Q

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

$$\frac{P_1}{\gamma} + z_1 = \frac{V_3^2}{2g} + z_3$$

$$V_3 = \sqrt{\left(\frac{P_1}{\gamma} + z_1 - z_3\right) 2g}$$

$$Q = V_3(A_3) \qquad V_2 = \frac{Q}{A_2}$$

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

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

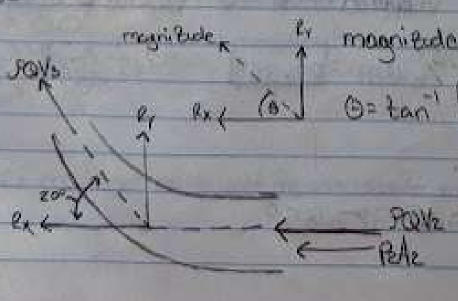
$$P_1 - P_2 = \gamma\left(\frac{V_2^2}{2g}\right) + (z_2 - z_1)$$

$$= -P_2 = P_1 + \gamma\left(\frac{V_2^2}{2g}\right) + (z_2 - z_1)$$

$$R_x = P_2 A_2 - \rho Q \cos 20^\circ + \rho Q V_2$$

$$R_y = \rho Q V_3 \sin 20^\circ$$

FBD



$$\text{magnitude} = \sqrt{R_x^2 + R_y^2}$$

$$\theta = \tan^{-1} R_y / R_x$$

Calculations

$$V_3 = \sqrt{\left(\frac{4320}{55} + 25\right) 2(32.2)} = 81.66 \ \text{ft/s}$$

$A_3 = 4.909 \times 10^{-2}$ (from table)

$Q = 81.66 * 4.909 \times 10^{-2} = 4.009 \ \text{ft}^3/\text{s}$

$$V_2 = \frac{4.009}{8.727 \times 10^{-2} \text{ (from table)}} = 45.93 \ \text{ft/s}$$

$$P_2 = 4320 + 55\left(\frac{45.93^2}{2 * 32.2}\right) + 25 = 6146.05 \ \text{lb/ft}^2$$

$$\cancel{\text{Volume} = \frac{\pi L}{12}\left(D_{pipe}^2 + D_{pipe} * D_{discharge} + D_{discharge}^2\right)}$$

$$\cancel{= \frac{\pi 10}{12}\left(0.25^2 + 0.25 * 0.33 + 0.33^2\right) = 0.665 \ \text{ft}^3}$$

$$\rho = \frac{\gamma}{g} = \frac{55 \times 10}{32.2} = 17.08 \ \text{slugs/ft}^3$$

$R_x = 6146.05(8.727 \times 10^{-2}) - 17.08 * 4.009 \cos 20° + 17.08 * 4.009 * 45.93$

$= \boxed{3618.91 \text{ lbf}}$

$R_y = 17.08 * 4.009 * 81.66 \sin(20) = \boxed{1912.43 \text{ lbf}}$

$\text{magnitude} = \sqrt{(3618.91)^2 + (1912.43)^2} = \boxed{4093.15 \text{ lbf}}$

$\Theta = \tan^{-1} 1912.43/3618.91 = \boxed{27.85°}$

Summary

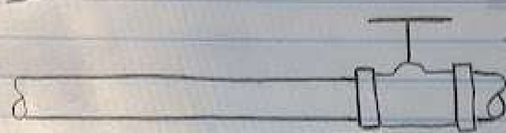
The force one the curve of the pipe section is 4093 lbf at 27.85°.

Problem 5

Purpose:

Calculate the pressure increment when the Valve closes all of a sudden.

Drawing



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Design considerations

The following must be assumed

1) Incompressable fluid
2) Isothermal process
3) Steady State

Data and Variables:

$D = 600mm \rightarrow 0.6m$

$V = 1.0 m/s$

$E = 2\times10^{7}\ N/cm^2 \rightarrow 2\times10^{11}$

$\sigma = 10mm \rightarrow 0.01$

$E_0 = 2.03\times10^{5}\ N/cm^2 \rightarrow 2.03\times10^{9}$

$\rho = 978\ kg/m^3$

Procedure:

$$\Delta P = \rho C V$$

$$C = \frac{\sqrt{\frac{E_a}{\rho}}}{\sqrt{1 + \frac{E_a D}{E \sigma}}}$$

Calculations:

$$C = \frac{\sqrt{\frac{2.03 \times 10^{9}\ N/m^2}{978\ kg/m^2}}}{\sqrt{1 + \frac{2.03 \times 10^{9}\ N/m^2 * 0.6m}{2 \times 10^{11}\ N/m^2 * 0.01m}}} = \frac{1440.72}{1.27} = 1135.80$$

$$\Delta P = 978 * 1135.80 \cdot 1.0 = \boxed{1110811.63\ KPa}$$

Summary:

The pressure increment when the valve shuts suddenly is 1110811.63KPa.