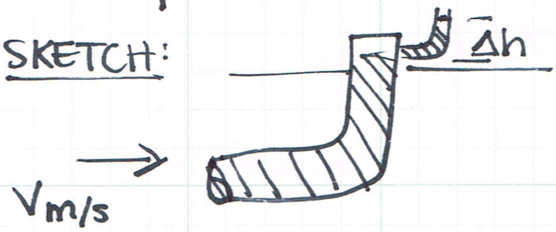
Name: SOLUTIONS

CE 3305 Engineering Fluid Mechanics
Exercise Set 11
Spring 2014

1. Problem 4.63, pg 162
2. Problem 4.86, pg 164
3. Problem 4.91, pg 165
4. Problem 4.103 pg 167

4.63) A pitot-static tube is used to measure the velocity at the center of a 12 in. pipe. If kerosene at 68°F is flowing and the deflection on a mercury-kerosene manometer connected to the pitot tube is 4 in., what is the velocity?

SKETCH:



KNOWN:

$D = 12in$
$T = 68°F$
$\Delta h = 4in$
$\gamma_{ker} = 51\ lb_f/ft^3$
$\rho_{ker} = 1.58\ lb_f/ft^3$
$\gamma_{Hg} = 847\ lb_f/ft^3$

GOVERNING EQNS:

$$\Delta P_z = \Delta h(\gamma_{HG} - \gamma_{ker})$$
$$V = \left(\frac{2\Delta P_z}{\rho}\right)^{1/2}$$

UNKNOWN:

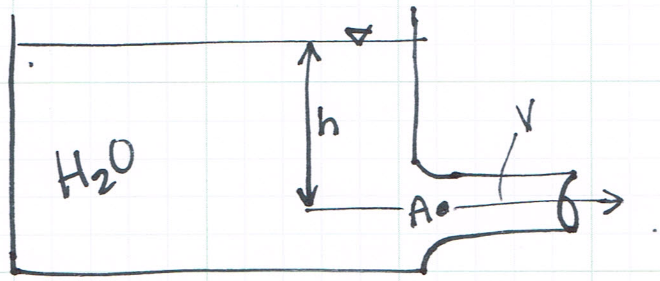
V = ? in ~~ft/s~~ ft/s

SOLUTION:

$$\Delta P_z = 4inch(847\ lbf/ft^3 - 51\ lb_f/ft^3)(1ft/12in)$$
$$\Delta P_z = 265.3\ lb_f/ft^2$$
$$V = \left(\frac{2(265.3\ lb_f/ft^2)}{1.58\ lb_f/ft^3}\right)^{1/2} = \boxed{18.3\ ft/s = V}$$

4.86) The velocity in the outlet pipe from this reservoir is 30ft/s and h=18ft. Because of the rounded entrance to the pipe, the flow is assumed to be irrotational. Under these conditions what is the pressure at A?

SKETCH:



KNOWN:

$h = 18\,ft$

$V = 30\,ft/s$

$\gamma_w = 62.4\,lb/ft^3$

UNKNOWN:

Pressure @ Point A

GOVERNING EQN:

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_A}{\gamma} + \frac{V_A^2}{2g} + z_A$$

SOLUTION:

$$\cancel{\frac{P_1}{\gamma}}^{0} + \underbrace{\cancel{\frac{V_1^2}{2g}}}_{0} + z_1 = \frac{P_A}{\gamma} + \frac{V_A^2}{2g} + \cancel{z_A}^{0}$$

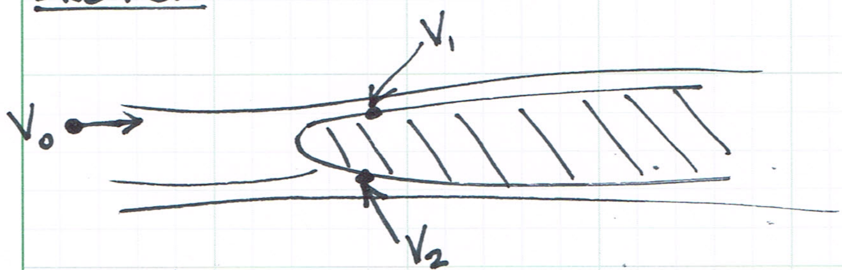
$$0 + 0 + z_1 = \frac{P_A}{\gamma} + \frac{V_A^2}{2g}$$

$$P_A = \left(z_1 - \frac{V_A^2}{2g}\right)\gamma = \left(18\,ft - \frac{(30\,ft/s)^2}{2(32.2\,ft/s^2)}\right) 62.4\,lb/ft^3 = 251\,psf_g$$

$$P_A = 251\,psf * \frac{ft^2}{144\,in^2} = \boxed{1.74\,psig = P_A}$$

4.91) Ideal flow theory will yield a flow pattern past an airfoil similar to that shown. If the approach air velocity V_0 is 80m/s, what is the pressure difference between the bottom and the top of this airfoil at points where the velocities are $V_1 = 85$ m/s and $V_2 = 75$ m/s? Assume ρair is uniform at 1.2 kg/m³.

SKETCH:



KNOWN:

$V_0 = 80$ m/s
$V_1 = 85$ m/s
$V_2 = 75$ m/s
$\rho_{air} = 1.2$ kg/m³

UNKNOWN:

ΔP (kPa)

GOVERNING EQN:

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

SOLUTION:

$$P_2 - P_1 = \frac{\rho}{2}(V_1^2 - V_2^2)$$

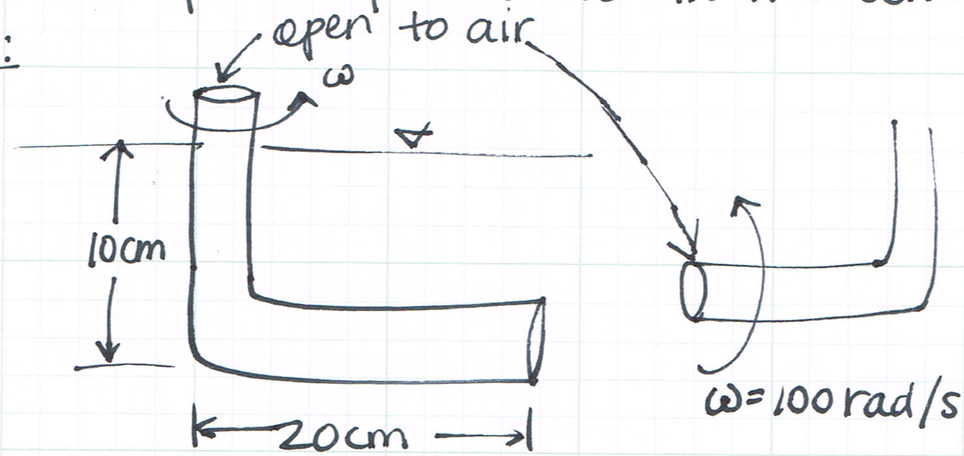
$$P_2 - P_1 = \frac{1.2\,\text{kg/m}^3}{2}((85\,\text{m/s})^2 - (75\,\text{m/s})^2)$$

$$= 960\ \text{Pa}$$

$$\boxed{\Delta P = 0.96\ \text{kPa}}$$

4.103) An arm with a stagnation tube on the end is rotated at 100 rad/s in a horizontal plane 10 cm below a liquid surface as shown. The arm is 20 cm long, and the tube at the center of rotation extends above the liquid surface. The liquid in the tube is the same as that in the tank and has a specific weight of 10,000 N/m³. Find the location of the liquid surface in the central tube.

SKETCH:



Elevation view   Plan view

KNOWN:

$\omega = 100$ rad/s $r = 20$cm $\gamma = 10{,}000$ N/m³

UNKNOWN:

location of liquid surface, ℓ.

GOVERNING EQN:

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

SOLUTION:

Pressure variation equation – rotating flow.

$$0 - 0 + (0.10 + \ell) = \frac{P_2}{\gamma} - \frac{r^2 \omega^2}{2g} - 0 \qquad \text{(eq 1)}$$

Where $z_1 = z_2$. Reference the velocity of the liquid to the tip of the Pitot tube then we have steady flow and Bernoulli's equation will apply from point 0 (point ahead of the pitot tube) to point 2 (point a tip of the pitot tube).

$$\frac{p_0}{\gamma} + \frac{V_0^2}{2g} + z_0 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2$$

$$\frac{0.1\gamma}{\gamma} + \frac{r^2\omega^2}{2g} = \frac{p_2}{\gamma} + 0 \qquad \text{(eq 2)}$$

solve eqs. (1) & (2) for l

$$(0.10 + l) = \frac{0.1\gamma}{\gamma}$$

$$l = \frac{0.1\cancel{\gamma}}{\cancel{\gamma}} - .10 = 0$$

$$\boxed{l = 0}$$

DISCUSSION:

Liquid surface in the tube is the same as the elevation as outside liquid surface.