Assignment 2

1. Pressure at 1 = Pressure at 2

$$P_{air} + \rho_{oil}\, g(h_1+h_2) = \rho_{Hg}\, g\, h_3$$

$$\therefore P_{air} = \rho_{Hg}\, g\, h_3 - \rho_{oil}\, g(h_1+h_2)$$

$$= 13.6\times10^{3}\,\frac{kg}{m^3} \times 9.8\,\frac{m}{s^2} \times 0.15\,m$$

$$- 0.90\times10^{3}\,\frac{kg}{m^3} \times 9.8\,\frac{m}{s^2} \times (0.70+0.10)\,m$$

$$= 1.3\times10^{4}\ \text{Pascal}$$

2. Pressure at Plate $P_{plate} = P_{air} + \rho_{oil}\, g\, h$

$$= 50\,kPa + 0.90\times10^{3}\,\frac{kg}{m^3} \times 9.8\,\frac{m}{s^2} \times 2.3\,m$$

Ave height of window

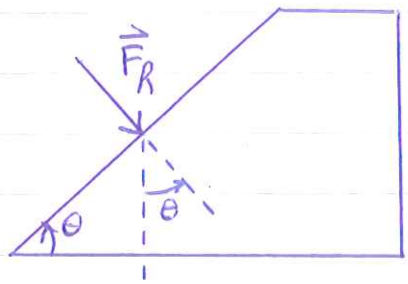
$$P_{plate} = 7.03\times10^{4}\ Pa.$$

Force on Plate $= P_{plate}\, A_{plate}$

$$= 7.03\times10^{4}\,Pa \times (0.60\,m)^2$$

$$= 2.53\times10^{4}\ Nt.$$

3.



$\tan\theta = \frac{5}{4} \Rightarrow \theta = 51.3^\circ$

Dam Mass per unit length $= \dfrac{23.6\,\frac{kNt}{m^3} \times 5m \times \left(2 + \frac{1}{2}4\right)}{9.8\,m/s^2}$

$= 4.82 \times 10^4\,kg.$

For a unit length of dam ($\perp$ to page) water exerts force:

$$F_R = \rho g h_{ave} \times \frac{4m}{\sin 51.3^\circ} \times 1m$$

$$= 10^3 \times 9.8 \times 2 \times \frac{4}{\sin 51.3^\circ} \times 1$$

$$= 10^5\,Nt.$$

Total normal force acting downward is:

$$N = N_{Dam\ Weight} + F_R \cos\theta$$

$$= M_{Dam}\, g + F_R \cos\theta$$

$$= 4.82 \times 10^4 \times 9.8 + 10^5 \cos 51.3^\circ$$

$$= 5.35 \times 10^5\,Nt.$$

Dam remains stationary if $F_{Fric} = F_R \sin\theta$

$$\mu N = F_R \sin\theta$$

$$\mu = \frac{10^5 \sin 51.3^\circ}{5.35 \times 10^5} = 0.146.$$

4. Buoyancy Force = Weight Displaced Fluid

$$= \rho_{oil} \times 0.5\,m \times g\,l^2 + \rho_{H_2O} \times 1.5\,m \times g\,l^2$$

where cube length $l = 2m$

$$= \left[0.9 \times 10^3 \frac{kg}{m^3} \times 0.5\,m + 10^3 \frac{kg}{m^3} \times 1.5\,m\right] 9.8 \frac{m}{s^2} (2m)^2$$

$$= 7.64 \times 10^4\ Nt.$$

$$\therefore \text{Mass of Cube} = \frac{7.64 \times 10^4\ Nt}{9.8\ m/s^2} = 7.8 \times 10^3\ kg.$$

$$\therefore \text{Cube Density} = \frac{7.8 \times 10^3\ kg}{(2m)^3} = 9.75 \times 10^2\ \frac{kg}{m^3}.$$

5. For steady, inviscid & incompressible flow, we can apply Bernoulli equation along streamline passing through points 1, 2 & 3.

$$\therefore P_1 + \frac{\rho}{2} v_1^2 = P_2 + \frac{\rho}{2} v_2^2 = P_3 + \frac{\rho}{2} v_3^2 \quad \text{since } z_1 = z_2 = z_3$$

For a large tank $v_1 = 0$ and $P_3 = 0$ we find

$$v_3 = \sqrt{\frac{2P_1}{\rho}}$$

and $P_2 = P_1 - \frac{1}{2} \rho v_2^2$

density of air in tank $\frac{N}{V} = \frac{P_1}{kT_1}$

$$= \frac{(3\times10^3 + 10^5)}{1.38\times10^{-23}\times288}$$

$$= 2.59\times10^{25}\ \text{part}/m^3$$

Mass density of air in tank $= 2.59\times10^{25}\ \frac{\text{part}}{m^3} \times 29 \times 1.67\times10^{-27}\ \frac{kg}{\text{part}}$

$$= 1.26\ kg/m^3$$

Speed out of hose $v_3 = \sqrt{\frac{2\times3\times10^3\ Pa}{1.26\ kg/m^3}} = 69\ m/s$

Volume flow rate out of hose $Q = A_3 v_3$

$$= \frac{\pi}{4}(.01m)^2\ 69\ m/s$$

$$= 5.4\times10^{-3}\ m^3/s$$

Continuity Eqn: $A_2 v_2 = A_3 v_3$

$$v_2 = \left(\frac{d}{D}\right)^2 v_3$$

$$= \left(\frac{.01m}{.03m}\right)^2 \times 69$$

$$= 7.67\ m/s$$

$\therefore\ P_2 = 3\times10^3\ Pa - \frac{1}{2}\ 1.26\ \frac{kg}{m^3}\left(7.67\ \frac{m}{s}\right)^2$

$$= 2.96\times10^3\ Pa$$