

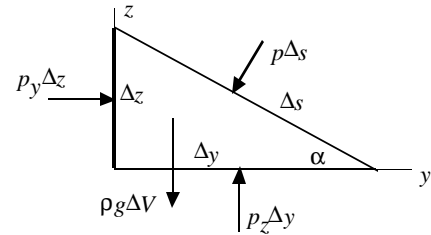
CHAPTER 2

Fluid Statics

2.1 $\Sigma F_y = ma_y: p_y \Delta z - p \Delta s \sin \alpha = \mathbf{r} \frac{\Delta y \Delta z}{2} a_y$

$\Sigma F_z = ma_z: p_z \Delta y - p \Delta s \cos \alpha = \mathbf{r} \frac{\Delta y \Delta z}{2} a_z + \mathbf{r} g \frac{\Delta y \Delta z}{2}$

Since $\Delta s \cos \alpha = \Delta y$ and $\Delta s \sin \alpha = \Delta z$, we have



$$p_y - p = \mathbf{r} \frac{\Delta y}{2} a_y \quad \text{and} \quad p_z - p = \mathbf{r} \frac{\Delta z}{2} (a_z + g)$$

Let $\Delta y \rightarrow 0$ and $\Delta z \rightarrow 0$:

$$\left. \begin{array}{l} p_y - p = 0 \\ p_z - p = 0 \end{array} \right\} \therefore p_y = p_z = p.$$

- 2.2 $p = \mathbf{g}h.$
- a) $9810 \times 10 = 98\,100 \text{ Pa}$ or 98.1 kPa
 - b) $(0.8 \times 9810) \times 10 = 78\,480 \text{ Pa}$ or 78.5 kPa
 - c) $(13.6 \times 9810) \times 10 = 1\,334\,000 \text{ Pa}$ or 1334 kPa
 - d) $(1.59 \times 9810) \times 10 = 155\,980 \text{ Pa}$ or 156.0 kPa
 - e) $(0.68 \times 9810) \times 10 = 66\,710 \text{ Pa}$ or 66.7 kPa

- 2.3 $h = p/\mathbf{g}$
- a) $h = 250\,000/9810 = \underline{25.5 \text{ m}}$
 - b) $h = 250\,000/(0.8 \times 9810) = \underline{31.9 \text{ m}}$
 - c) $h = 250\,000/(13.6 \times 9810) = \underline{1.874 \text{ m}}$
 - d) $h = 250\,000/(1.59 \times 9810) = \underline{16.0 \text{ m}}$
 - e) $h = 250\,000/(0.68 \times 9810) = \underline{37.5 \text{ m}}$

2.4 (C) $p = \mathbf{g}_{Hg} h = (13.6 \times 9810) \times (28.5 \times 0.0254) = 96600 \text{ Pa}$

2.5 $S = \frac{p}{\mathbf{g}h} = \frac{20 \times 144}{62.4 \times 20} = \underline{2.31}.$ $\mathbf{r} = 1.94 \times 2.31 = \underline{4.48 \text{ slug/ft}^3}.$

- 2.6
- a) $p = \mathbf{g}h = 0.76 \times (13.6 \times 9810) = 9810 h.$ $\therefore h = \underline{10.34 \text{ m}}.$
 - b) $(13.6 \times 9810) \times 0.75 = 9810 h.$ $\therefore h = \underline{10.2 \text{ m}}.$
 - c) $(13.6 \times 9810) \times 0.01 = 9810 h.$ $\therefore h = 0.136 \text{ m}$ or 13.6 cm.

- 2.7
- a) $p = \mathbf{g}_1 h_1 + \mathbf{g}_2 h_2 = 9810 \times 0.2 + (13.6 \times 9810) \times 0.02 = 4630 \text{ Pa}$ or 4.63 kPa.
 - b) $9810 \times 0.052 + 15\,630 \times 0.026 = 916 \text{ Pa}$ or 0.916 kPa.
 - c) $9016 \times 3 + 9810 \times 2 + (13.6 \times 9810) \times 0.1 = 60\,010 \text{ Pa}$ or 60.0 kPa.

2.8 $\Delta p = \mathbf{r}gh = 0.0024 \times 32.2 (-10,000) = -773 \text{ psf}$ or -5.37 psi.

2.9 (D) $p = p_0 - \mathbf{r}gh = 84000 - 1.00 \times 9.81 \times 4000 = 44760 \text{ Pa}$

2.10

$$\left. \begin{aligned} \Delta p_{outside} &= \mathbf{r}_o g \Delta h = \frac{pg}{RT_o} \Delta h = \frac{100 \times 9.81}{.287 \times 253} \times 3 = 13.51 \text{ Pa} \\ \Delta p_{inside} &= \mathbf{r}_i g \Delta h = \frac{pg}{RT_i} \Delta h = \frac{100 \times 9.81}{.287 \times 293} \times 3 = 11.67 \text{ Pa} \end{aligned} \right\} \therefore \Delta p_{base} = \underline{1.84 \text{ Pa}}$$

If no wind is present this Δp_{base} would produce a small infiltration since the higher pressure outside would force outside air into the bottom region (through cracks).

2.11 $p = \mathbf{r}gdh$ where $h = -z$. From the given information $S = 1.0 + h/100$ since $S(0) = 1$ and $S(10) = 1.1$. By definition $\mathbf{r} = 1000 S$, where $\mathbf{r}_{water} = 1000 \text{ kg/m}^3$.

Then $dp = 1000 (1 + h/100) gdh$. Integrate:

$$\int_0^p dp = \int_0^{10} 1000(1 + h/100)gdh$$

$$p = 1000 \times 9.81 \left(10 + \frac{10^2}{2 \times 100} \right) = 103\,000 \text{ Pa or } \underline{103 \text{ kPa}}$$

Note: we could have used an average S : $S_{avg} = 1.05$, so that $\mathbf{r}_{avg} = 1050 \text{ kg/m}^3$.

2.12
$$\begin{aligned} \vec{\nabla} p &= \frac{\mathcal{I}p}{\mathcal{I}x} \hat{i} + \frac{\mathcal{I}p}{\mathcal{I}y} \hat{j} + \frac{\mathcal{I}p}{\mathcal{I}z} \hat{k} \\ &= -\mathbf{r}a_x \hat{i} - \mathbf{r}a_y \hat{j} - \mathbf{r}a_z \hat{k} - \mathbf{r}g\hat{k} = -\mathbf{r}(a_x \hat{i} + a_y \hat{j} + a_z \hat{k}) - \mathbf{r}g\hat{k} \\ &= -\mathbf{r}\bar{a} - \mathbf{r}\bar{g} \\ \therefore \vec{\nabla} p &= \underline{-\mathbf{r}(\bar{a} + \bar{g})} \end{aligned}$$

2.13
$$\begin{aligned} p &= p_{atm} [(T_0 - \mathbf{a}z) / T_0]^{g/\mathbf{a}R} \\ &= 100 [(288 - 0.0065 \times 300) / 288]^{9.81 / .0065 \times 287} = \underline{96.49 \text{ kPa}} \\ p &= p_{atm} - \mathbf{r}gh = 100 - \frac{100}{.287 \times 288} \times 9.81 \times 300 / 1000 = \underline{96.44 \text{ kPa}} \\ \% \text{ error} &= \frac{96.44 - 96.49}{96.49} \times 100 = \underline{-0.052\%} \end{aligned}$$

The density variation can be ignored over heights of 300 m or less.

$$2.14 \quad \Delta p = p - p_0 = p_{atm} \left(\frac{T_0 - \mathbf{a}z}{T_0} \right)^{g/\mathbf{a}R} - p_{atm}$$

$$= 100 \left[\left(\frac{288 - 0.0065 \times 20}{288} \right)^{9.81/0.0065 \times 287} - 1 \right] = -0.237 \text{ Pa or } \underline{-0.000237 \text{ kPa}}$$

This change is very small and can most often be ignored.

$$2.15 \quad \text{Eq. 1.5.11 gives } 310,000 \times 144 = \mathbf{r} \frac{dp}{d\mathbf{r}}. \text{ But, } dp = \mathbf{r}g dh. \text{ Therefore,}$$

$$\mathbf{r}g dh = \frac{4.464 \times 10^7}{\mathbf{r}} d\mathbf{r} \quad \text{or} \quad \frac{d\mathbf{r}}{\mathbf{r}^2} = \frac{32.2}{4.464 \times 10^7} dh$$

Integrate, using $\mathbf{r}_0 = 2.00 \text{ slug/ft}^3$:

$$\int_2^{\mathbf{r}} \frac{d\mathbf{r}}{\mathbf{r}^2} = \frac{32.2}{4.464 \times 10^7} \int_0^h dh. \quad \therefore -\left(\frac{1}{\mathbf{r}} - \frac{1}{2} \right) = 7.21 \times 10^{-7} h \quad \text{or} \quad \mathbf{r} = \frac{2}{1 - 14.42 \times 10^{-7} h}$$

Now,

$$p = \int_0^h \mathbf{r}g dh = \int_0^h \frac{2g}{1 - 14.42 \times 10^{-7} h} dh = \frac{2g}{-14.42 \times 10^{-7}} \ln(1 - 14.42 \times 10^{-7} h)$$

Assume $\mathbf{r} = \text{const}$:

$$p = \mathbf{r}gh = 2.0 \times 32.2 \times h = 64.4h$$

a) For $h = 1500 \text{ ft}$: $p_{\text{accurate}} = \underline{96,700 \text{ psf}}$ and $p_{\text{estimate}} = \underline{96,600 \text{ psf}}$.

$$\% \text{ error} = \frac{96,600 - 96,700}{96,700} \times 100 = \underline{-0.103 \%}$$

b) For $h = 5000 \text{ ft}$: $p_{\text{accurate}} = \underline{323,200 \text{ psf}}$ and $p_{\text{estimate}} = \underline{322,000 \text{ psf}}$.

$$\% \text{ error} = \frac{322,000 - 323,200}{323,200} \times 100 = \underline{-0.371 \%}$$

c) For $h = 15,000 \text{ ft}$: $p_{\text{accurate}} = \underline{976,600 \text{ psf}}$ and $p_{\text{estimate}} = \underline{966,000 \text{ psf}}$.

$$\% \text{ error} = \frac{966,000 - 976,600}{976,600} \times 100 = \underline{-1.085 \%}$$

$$2.16 \quad \text{Use the result of Example 2.2:} \quad p = 101 e^{-gz/RT}.$$

a) $p = 101 e^{-9.81 \times 10,000/287 \times 273} = \underline{28.9 \text{ kPa}}$.

b) $p = 101 e^{-9.81 \times 10,000/287 \times 288} = \underline{30.8 \text{ kPa}}$.

c) $p = 101 e^{-9.81 \times 10,000/287 \times 258} = \underline{26.9 \text{ kPa}}$.

$$2.17 \quad \text{Use Eq. 2.4.8:} \quad p = 101(1 - 0.0065z/288)^{\frac{9.81}{0.0065 \times 287}}.$$

a) $z = 3000. \quad \therefore p = \underline{69.9 \text{ kPa}}$.

b) $z = 6000. \quad \therefore p = \underline{47.0 \text{ kPa}}$.

c) $z = 9000. \quad \therefore p = \underline{30.6 \text{ kPa}}$.

d) $z = 11,000. \quad \therefore p = \underline{22.5 \text{ kPa}}$.

2.18 Use the result of Example 2.2: $\frac{P}{P_0} = e^{-gz/RT}$.

$$\ln \frac{P}{P_0} = -\frac{gz}{RT}. \quad \ln \frac{0.001}{14.7} = -\frac{32.2z}{1716 \times 455}. \quad \therefore z = \underline{232,700 \text{ ft.}}$$

2.19 $p = \rho gh = (13.6 \times 9810) \times 0.25 = 33\,350 \text{ Pa}$ or 33.35 kPa.

2.20 a) $p = \rho gh$. $450\,000 = (13.6 \times 9810) h$. $\therefore h = \underline{3.373 \text{ m}}$
 b) $p + 11.78 \times 1.5 = (13.6 \times 9810) h$. Use $p = 450\,000$, then $h = \underline{3.373 \text{ m}}$
 % error is 0.000 %.

2.21 Referring to Fig. 2.6a, the pressure in the pipe is $p = \rho gh$. If $p = 2400 \text{ Pa}$, then
 $2400 = \rho gh = \rho \times 9.81 h$.

a) $\rho = \frac{2400}{9.81 \times 36} = 680 \text{ kg/m}^3$. \therefore gasoline

b) $\rho = \frac{2400}{9.81 \times 272} = 899 \text{ kg/m}^3$. \therefore benzene

c) $\rho = \frac{2400}{9.81 \times 245} = 999 \text{ kg/m}^3$. \therefore water

d) $\rho = \frac{2400}{9.81 \times 154} = 1589 \text{ kg/m}^3$. \therefore carbon tetrachloride

2.22 Referring to Fig. 2.6a, the pressure is $p = \rho_w gh = \frac{1}{2} \rho_a V^2$. Then $V^2 = \frac{2\rho_w gh}{\rho_a}$.

a) $V^2 = \frac{2 \times 1000 \times 9.81 \times 0.6}{1.23} = 957$. $\therefore V = \underline{30.9 \text{ m/s}}$

b) $V^2 = \frac{2 \times 1.94 \times 32.2 \times 3 / 12}{.00238} = 13,124$. $\therefore V = \underline{115 \text{ ft/sec}}$

c) $V^2 = \frac{2 \times 1000 \times 9.81 \times 1}{1.23} = 1595$. $\therefore V = \underline{39.9 \text{ m/s}}$

d) $V^2 = \frac{2 \times 1.94 \times 32.2 \times 5 / 12}{.00238} = 21,870$. $\therefore V = \underline{148 \text{ ft/sec}}$

2.23 (C) $p_w = p_{atm} + \rho_x h_x - \rho_{water} h_w = 0 + 30000 \times 0.3 - 9810 \times 0.1 = 8020 \text{ Pa}$

2.24 See Fig. 2.6b: $p_1 = -\rho_1 h + \rho_2 H$.

$$p_1 = -0.86 \times 62.4 \times \frac{5}{12} + 13.6 \times 62.4 \times \frac{9.5}{12} = 649.5 \text{ psf}$$
 or 4.51 psi.

2.25 $p = p_0 + \rho_1 gh_1 + \rho_2 gh_2 + \rho_3 gh_3 + \rho_4 gh_4$
 $= 3200 + 917 \times 9.81 \times 0.2 + 1000 \times 9.81 \times 0.1 + 1258 \times 9.81 \times 0.15 + 1593 \times 9.81 \times 0.18$
 $= 10\,640 \text{ Pa}$ or 10.64 kPa

$$2.26 \quad p_1 - p_4 = (p_1 - p_2) + (p_2 - p_3) + (p_3 - p_4) \quad (\text{Use } \Delta p = \rho g \Delta h)$$

$$40\,000 - 16\,000 = 1000 \times 9.81(-.2) + 13\,600 \times 9.81 \times H + 920 \times 9.81 \times .3.$$

$$\therefore H = .1743 \text{ m or } \underline{17.43 \text{ cm}}$$

$$2.27 \quad p_1 - p_4 = (p_1 - p_2) + (p_2 - p_3) + (p_3 - p_4) \quad (\text{Use } \Delta p = \rho g \Delta h)$$

$$p_o - p_w = 900 \times 9.81(-.2) + 13\,600 \times 9.81(-.1) + 1000 \times 9.81 \times .15$$

$$= -12\,300 \text{ Pa or } \underline{-12.3 \text{ kPa}}$$

$$2.28 \quad p_1 - p_5 = (p_1 - p_2) + (p_2 - p_3) + (p_3 - p_4) + (p_4 - p_5)$$

$$p_1 = 9810(-.02) + 13\,600 \times 9.81(-.04) + 9810(-.02) + 13\,600 \times 9.81 \times .16$$

$$= 15\,620 \text{ Pa or } \underline{15.62 \text{ kPa}}$$

$$2.29 \quad p_w + 9810 \times .15 - 13.6 \times 9810 \times .1 - .68 \times 9810 \times .2 + .86 \times 9810 \times .15 = p_o.$$

$$\therefore p_w - p_o = 11\,940 \text{ Pa or } \underline{11.94 \text{ kPa.}}$$

$$2.30 \quad p_w - 9810 \times .12 - .68 \times 9810 \times .1 + .86 \times 9810 \times .1 = p_o.$$

$$\text{With } p_w = 15\,000, p_o = 14\,000 \text{ Pa or } \underline{14.0 \text{ kPa.}}$$

$$2.31 \quad \begin{array}{lll} \text{a) } p + 9810 \times 2 = 13.6 \times 9810 \times .1. & \therefore p = -6278 \text{ Pa} & \text{or } \underline{-6.28 \text{ kPa.}} \\ \text{b) } p + 9810 \times .8 = 13.6 \times 9810 \times .2. & \therefore p = 18\,835 \text{ Pa} & \text{or } \underline{18.84 \text{ kPa.}} \\ \text{c) } p + 62.4 \times 6 = 13.6 \times 62.4 \times 4/12. & \therefore p = -91.5 \text{ psf} & \text{or } \underline{-0.635 \text{ psi.}} \\ \text{d) } p + 62.4 \times 2 = 13.6 \times 62.4 \times 8/12. & \therefore p = 441 \text{ psf} & \text{or } \underline{3.06 \text{ psi.}} \end{array}$$

$$2.32 \quad p - 9810 \times 4 + 13.6 \times 9810 \times .16 = 0. \quad \therefore p = 17\,890 \text{ Pa or } \underline{17.89 \text{ kPa.}}$$

$$2.33 \quad (\mathbf{A}) \quad p_a = -\rho g H = -(13.6 \times 9810) \times 0.16 = -21350 \text{ Pa.}$$

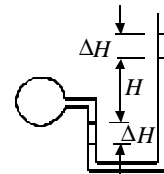
$$p_{a\text{after}} = -21350 + 10000 = -11350 = 13.6 \times 9810 H_{\text{after}}. \quad \therefore H_{\text{after}} = 0.0851 \text{ m}$$

$$2.34 \quad 8200 + 9810 \times .25 = 1.59 \times 9810 \times H. \quad \therefore H = 0.683 \text{ m}$$

$$H_{\text{new}} = .683 + .273 = .956 \text{ m.} \quad \Delta H = \frac{.273}{2} = .1365.$$

$$p + 9810 (.25 + .1365) = 1.59 \times 9810 \times .956.$$

$$\therefore p = 11\,120 \text{ Pa or } \underline{11.12 \text{ kPa.}}$$



$$2.35 \quad p + 9810 \times .05 + 1.59 \times 9810 \times .07 - .8 \times 9810 \times .1 = 13.6 \times 9810 \times .05.$$

$$\therefore p = 5873 \text{ Pa or } \underline{5.87 \text{ kPa.}}$$

Note: In our solutions we usually retain 3 significant digits in the answers (if a number starts with "1" then 4 digits are retained. In most problems a material property is used, i.e., $S = 1.59$. This is only 3 sig. digits! \therefore only 3 are usually retained in the answer!

- 2.36 Before pressure is applied the air column on the right is 48" high. After pressure is applied, it is $(4 - H/2)$ ft high. For an isothermal process $p_1 V_1 = p_2 V_2$ using absolute pressures. Thus,

$$14.7 \times 144 \times 4A = p_2(4 - H/2)A \quad \text{or} \quad p_2 = \frac{8467}{4 - H/2}$$

From a pressure balance on the manometer (pressures in psf):

$$30 \times 144 + 14.7 \times 144 = 13.6 \times 62.4 H + \frac{8467}{4 - H/2},$$

$$\text{or} \quad H^2 - 15.59 H + 40.73 = 0. \quad \therefore H = 12.27 \text{ or } \underline{3.32 \text{ ft.}}$$

- 2.37 a) $p_1 - p_5 = (p_1 - p_2) + (p_2 - p_3) + (p_3 - p_4) + (p_4 - p_5)$
 $4000 = 9800(0.16 - 0.22) + 15\,600(0.10 - 0.16) + 133\,400H + 15\,600(0.07 - H)$
 $\therefore H = .0376 \text{ m or } \underline{3.76 \text{ cm}}$
 b) $0.6 \times 144 = 62.4(-2/12) + 99.5(-2/12) + 849H + 99.5(2.5/12 - H)$
 $\therefore H = .1236 \text{ ft or } \underline{1.483 \text{ in.}}$

2.38 a)
$$\frac{\Delta H}{\Delta p_1} = \frac{2D^2/d^2}{-g_1 + 2g_2 + 2(g_3 - g_2)D^2/d^2}$$

$$= \frac{2(.1/.005)^2}{-9800 + 2 \times 15\,600 + 2(133\,400 - 15\,600)(.1/.005)^2} = 8.487 \times 10H^{-6}$$

$$\therefore \Delta H = 8.487 \times 10^{-6} \times 400 = 0.0034 \text{ m or } 3.4 \text{ mm}$$

b)
$$\Delta H = \frac{2(4/.2)^2}{-62.4 + 2 \times 99.5 + 2(849 - 99.5)(4/.2)^2} \cdot .06 \times 144 = 0.01153 \text{ ft or } \underline{0.138 \text{ in.}}$$

2.39 $p_1 - p_4 = (p_1 - p_2) + (p_2 - p_3) + (p_3 - p_4)$ ($p_{oil} = 14.0 \text{ kPa}$ from No. 2.30)
 $15\,500 - 14\,000 = 9800(0.12 + \Delta z) + 680(0.1 - 2\Delta z) + 860(-0.1 - \Delta z)$
 $\therefore \Delta z = 0.0451 \text{ m or } \underline{4.51 \text{ cm}}$

2.40 a) $p_{air} = -6250 + 625 = -5620 \text{ Pa.}$
 $-5620 + 9800(2 + \Delta z) - 13\,600 \times 9.81(0.1 + 2\Delta z) = 0. \quad \therefore \Delta z = 0.0025.$
 $\therefore h = 0.1 + 2\Delta z = .15 \text{ m or } \underline{15 \text{ cm}}$
 b) $p_{air} = 18\,800 + 1880 = 20\,680 \text{ Pa.}$
 $20\,680 + 9800(0.8 + \Delta z) - 13\,600 \times 9.81(0.2 + 2\Delta z) = 0. \quad \therefore \Delta z = 0.00715 \text{ m}$
 $\therefore h = .2 + 2\Delta z = .214 \text{ or } \underline{21.4 \text{ cm}}$
 c) $p_{air} = -91.5 + 9.15 = -82.4 \text{ psf.}$
 $-82.4 + 62.4(6 + \Delta z) - 13.6 \times 62.4(4/12 + 2\Delta z) = 0. \quad \therefore \Delta z = 0.00558 \text{ ft.}$
 $\therefore h = 4/12 + 2(0.00558) = 0.3445 \text{ ft or } \underline{4.13 \text{ in.}}$
 d) $p_{air} = 441 + 44.1 = 485 \text{ psf}$
 $485 + 62.4(2 + \Delta z) - 13.6 \times 62.4(8/12 + 2\Delta z) = 0. \quad \therefore \Delta z = 0.0267 \text{ ft.}$
 $\therefore h = 8/12 + 2(0.0267) = 0.7205 \text{ ft or } \underline{8.65 \text{ in.}}$

2.41 $F = \bar{g}hA = 9810 \times 10 \times \pi \times .3^2/4 = \underline{6934 \text{ N}}$.

2.42 $(2 \times \frac{5}{3}) \times P = \frac{1}{3} \times (2 \times \frac{5}{3}) \times [9800 \times 1 \times 3 \times (2 \times \frac{5}{3})]$. $\therefore P = 32670 \text{ N}$ a) $F = p_c A = 9800 \times 2 \times 4^2 = 313\,600 \text{ N}$ or 313.6 kN

b) $F = p_c A = 9800 \times 1 \times (2 \times 4) + 9800 \times \frac{2}{3} \times 2 + 9800 \times \frac{2}{3} \times 1 = 98000 \text{ N}$ or 98.0 kN

c) $F = p_c A = 9800 \times 1 \times 2 \times 4 \times \sqrt{2} = 110\,900 \text{ N}$ or 110.9 kN

d) $F = p_c A = 9800 \times 1 \times 2 \times 4 / .866 = 90\,500 \text{ N}$ or 90.5 kN

2.43 For saturated ground, the force on the bottom tending to lift the vault is

$F = p_c A = 9800 \times 1.5 \times (2 \times 1) = 29\,400 \text{ N}$.

The weight of the vault is approximately

$W = r g V_{walls} = 2400 \times 9.81 [2(2 \times 1.5 \times 1) + 2(2 \times 1 \times 1) + 2(.8 \times 1.3 \times 1)] = 28\,400 \text{ N}$.

The vault will tend to rise out of the ground.

2.44 $F = p_c A = 6660 \times 2 \times \pi \times 2^2 = 167\,400 \text{ N}$ or 167.4 kN

Find g in Table B.5 in the Appendix.

2.45 a) $F = p_c A = 9800 (10 - 2.828/3) (2.828 \times 2/2) = 251\,000 \text{ N}$ or 251 kN

where the height of the triangle is $(3^2 - 1^2)^{1/2} = 2.828 \text{ m}$.

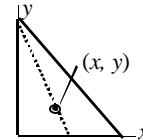
b) $F = p_c A = 9800 \times 10 (2.828 \times 2/2) = 277\,100 \text{ N}$ or 277.1 kN

c) $F = p_c A = 9800 (10 - 2.828 \times .866/3) (2.828 \times 2/2) = 254\,500 \text{ N}$ or 254.5 kN

2.46 a) $F = \bar{g}hA = 62.4 \times 27.33 \times 24 = \underline{40,930 \text{ lb}}$.

$y_p = 27.33 + \frac{6 \times 8^3 / 36}{27.33 \times 24} = 27.46'$. $\therefore y = 30 - 27.46 = 2.54'$.

$8/5.46 = 3/x$. $\therefore x = 2.05'$. (2.05, 2.54) ft.



b) $F = 62.4 \times 30 \times 24 = \underline{44,930 \text{ lb}}$. The centroid is the center of pressure.

$y = 2.667'$. $8/5.333 = 3/x$. $\therefore x = 2.000'$ (2.000, 2.667) ft.

c) $F = 62.4 (30 - 2.667 \times .707) \times 24 = \underline{42,100 \text{ lb}}$.

$y_p = 39.77 + \frac{6 \times 8^3 / 36}{39.77 \times 24} = 39.86'$. $y = 42.43 - 39.86 = 2.57'$

$8/5.43 = 3/x$. $\therefore x = 2.04'$. (2.04, 2.57) ft.

2.47 (B) The force acts 1/3 the distance from the hinge to the water line:

$(2 \times \frac{5}{3}) \times P = \frac{1}{3} \times (2 \times \frac{5}{3}) \times [9800 \times 1 \times 3 \times (2 \times \frac{5}{3})]$. $\therefore P = 32670 \text{ N}$

2.48 a) $F = \bar{g}hA = 9810 \times 6 \times p2^2 = 739\,700 \text{ N}$ or 739.7 kN.

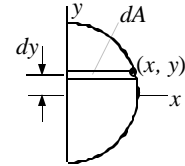
$$y_p = \bar{y} + \frac{\bar{I}}{A\bar{y}} = 6 + \frac{p \times 2^4 / 4}{4p \times 6} = 6.167 \text{ m.} \quad \therefore (x, y)_p = \underline{(0, -0.167) \text{ m}}$$

b) $F = \bar{g}hA = 9810 \times 6 \times 2p = 369\,800 \text{ N}$ or 369.8 kN.

$$y_p = 6 + \frac{p \times 2^4 / 8}{2p \times 6} = 6.167 \text{ m.} \quad x^2 + y^2 = 4$$

$$x_p F = \int \frac{x}{2} p dA = \frac{g}{2} \int_{-2}^2 x(6-y)x dy = \frac{g}{2} \int_{-2}^2 (4-y^2)(6-y) dy.$$

$$\therefore x_p g 6 \times 2p = \frac{g}{2} \int_{-2}^2 (24 - 4y - 6y^2 + y^3) dy = 32g. \quad \therefore x_p = 0.8488 \text{ m}$$

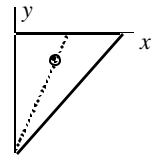


$$\therefore (x, y)_p = \underline{(0.8488, -0.167) \text{ m}}$$

c) $F = 9810 \times (4 + 4/3) \times 6 = 313\,900 \text{ N}$ or 313.9 kN.

$$y_p = 5.333 + \frac{3 \times 4^3 / 36}{5.333 \times 6} = 5.500 \text{ m.} \quad \therefore y = -1.5$$

$$4/2.5 = 1.5/x. \quad \therefore x = 0.9375. \quad \therefore (x, y)_p = \underline{(0.9375, -1.5) \text{ m}}$$

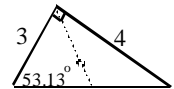


d) $F = 9810 \times (4 + \frac{2}{3} \times 4 \sin 36.9^\circ) \times 6 = 330\,000 \text{ N}$

$$y_p = 5.6 + \frac{5 \times 2.4^3 / 36}{6 \times 5.6} = 5.657 \text{ m.} \quad \therefore y = 0.343 \text{ m}$$

$$3 \cos 53.13^\circ = 1.8, \quad 2.5 - 1.8 = 0.7, \quad 2.4/2.057 = .7 / x_1. \quad \therefore x_1 = 0.6.$$

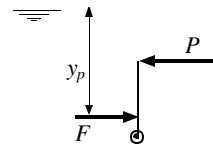
$$x = 1.8 + 0.6 = 2.4. \quad \therefore (x, y)_p = \underline{(2.4, 0.343) \text{ m}}$$



2.49 $F = \bar{g}hA = 62.4 \times 11 \times (6 \times 10) = 41,180 \text{ lb}$.

$$y_p = \bar{y} + \frac{\bar{I}}{\bar{y}A} = 11 + \frac{6 \times 10^3 / 12}{11 \times 60} = 11.758'$$

$$(16 - 11.758) 41,180 = 10P. \quad \therefore P = \underline{17,470 \text{ lb}}$$



2.50 $F = \bar{g}hA = 9810 \times 6 \times 20 = 1.177 \times 10^6 \text{ N}$, or 1177 kN.

$$y_p = \bar{y} + \frac{\bar{I}}{A\bar{y}} = 7.5 + \frac{4 \times 5^3 / 12}{7.5 \times 20} = 7.778 \text{ m}$$

$$(10 - 7.778) 1177 = 5P. \quad \therefore P = \underline{523 \text{ kN}}$$

2.51 $F = \bar{g}A = 9810 \times 12 \times 20 = 2.354 \times 10^6 \text{ N}$, or 2354 kN.

$$y_p = \bar{y} + \frac{\bar{I}}{A\bar{y}} = 15 + \frac{4 \times 5^3 / 12}{15 \times 20} = 15.139 \text{ m}.$$

$$(17.5 - 15.139) 2354 = 5 P. \quad \therefore P = \underline{1112 \text{ kN}}.$$

2.52 $y_p = \bar{y} + \frac{\bar{I}}{A\bar{y}} = \frac{H}{2} + \frac{bH^3 / 12}{bH \times H / 2} = \frac{H}{2} + \frac{H}{6} = \frac{2}{3}H$. y_p is measured from the surface.

$$\therefore \text{From the bottom, } H - y_p = H - \frac{2}{3}H = \frac{1}{3}H.$$

Note: this result is independent of the angle α , so it is true for a vertical area or a sloped area.

2.53 $F = \bar{g} \frac{1}{2} l \sin 40^\circ \times 3l$. $F \times \frac{l}{3} = (l + 2)P \sin 40^\circ$. $\therefore \bar{g}l^3 = 2(l + 2)P$.

a) $9810 \times 2^3 = 2(2 + 2)P$. $\therefore P = \underline{9810 \text{ N}}$

b) $9810 \times 4^3 = 2(4 + 2)P$. $\therefore P = \underline{52\,300 \text{ N}}$

c) $9810 \times 5^3 = 2(5 + 2)P$. $\therefore P = \underline{87\,600 \text{ N}}$

2.54 $h = \sqrt{1.2^2 - .4^2} = 1.1314 \text{ m}$. $A = 1.2 \times 1.1314 + .4 \times 1.1314 = 1.8102 \text{ m}^2$

Use 2 forces: $F_1 = \bar{g}h_c A_1 = 9800 \times .5657 \times (1.2 \times 1.1314) = 7527 \text{ N}$

$$F_2 = \bar{g}h_c A_2 = 9800 \times \frac{1.1314}{3} \times (.4 \times 1.1314) = 1673 \text{ N}$$

$$y_{p1} = \frac{2}{3}(1.1314). \quad y_{p2} = \bar{y} + \frac{\bar{I}_2}{A_2 \bar{y}} = \frac{1.1314}{3} + \frac{.4 \times 1.1314^3 / 36}{.4 \times 1.1314 / 2 \times 1.1314 / 3} = 0.5657 \text{ m}$$

$$\Sigma M_{\text{hinge}} = 0: \quad 7527 \times \frac{1.1314}{3} + 1673 \times (1.1314 - 0.5657) - 1.1314 P = 0. \quad \therefore P = \underline{3346 \text{ N}}.$$

2.55 To open, the resultant force must be just above the hinge, i.e., y_p must be just less than h .

Let $y_p = h$, the condition when the gate is about to open:

$$\bar{y} = (h + H) / 3, \quad A = (h + H)^2, \quad \bar{I} = [2(h + H)](h + H)^3 / 36$$

$$\therefore y_p = \frac{h + H}{3} + \frac{2(h + H)^4 / 36}{(h + H)^2 (h + H) / 3} = \frac{h + H}{3} + \frac{h + H}{6} = \frac{h + H}{2}$$

a) $h = \frac{h + H}{2}$. $\therefore h = H = \underline{0.9 \text{ m}}$

b) $h = H = \underline{1.2 \text{ m}}$

c) $h = H = \underline{1.5 \text{ m}}$

2.56 The gate is about to open when the center of pressure is at the hinge.

a) $y_p = 1.2 + H = (1.8 / 2 + H) + \frac{b \times 1.8^3 / 12}{(.9 + H)1.8b}$. $\therefore H = \underline{0}$.

$$b) y_p = 1.2 + H = (2.0 / 2 + H) + \frac{b \times 2^3 / 12}{(1 + H)2b} \quad \therefore H = \underline{0.6667 \text{ m.}}$$

$$c) y_p = 1.2 + H = (2.2 / 2 + H) + \frac{b \times 2.2^3 / 12}{(1.1 + H)2.2b} \quad \therefore H = \underline{2.933 \text{ m.}}$$

2.57 (A) The gate opens when the center of pressure is at the hinge:

$$\bar{y} = \frac{1.2 + h}{2} + 5. \quad y_p = \bar{y} + \frac{\bar{I}}{A\bar{y}} = \frac{11.2 + h}{2} + \frac{b(1.2 + h)^3 / 12}{(1.2 + h)b(11.2 + h) / 2} = 5 + 1.2.$$

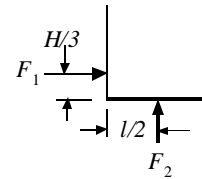
This can be solved by trial-and-error, or we can simply substitute one of the answers into the equation and check to see if it is correct. This yields $h = 1.08 \text{ m}$.

$$2.58 \quad F_1 = g \frac{H}{2} \times bH = \frac{1}{2} g b H^2$$

$$F_2 = g h \times \ell b = g b \ell h$$

$$\frac{1}{2} g b H^2 \times \frac{H}{3} = g b \ell h \times \frac{\ell}{2} \quad \therefore H = \sqrt{3} \ell$$

$$a) H = \sqrt{3} \times 2 = \underline{3.464 \text{ m}} \quad b) H = \underline{1.732 \text{ m}} \quad c) H = \underline{10.39'}$$



2.59 The dam will topple if the moment about "O" of F_1 and F_3 exceeds the restoring moment of W and F_2 .

$$a) W = (2.4 \times 9810)(6 \times 50 + 24 \times 50 / 2) = 21.19 \times 10^6 \text{ N}$$

$$d_w = \frac{300 \times 27 + 600 \times 16}{300 + 600} = 19.67 \text{ m.}$$

$$F_2 = 9810 \times 5 \times 11.09 = 0.544 \times 10^6 \text{ N.} \quad d_2 = \frac{11.09}{3} = 3.697 \text{ m.}$$

$$F_1 = 9810 \times \frac{45}{2} \times 45 = 9.933 \times 10^6 \text{ N.} \quad d_1 = 15 \text{ m.}$$

$$F_3 = 9810 \times \frac{45 + 10}{2} \times 30 = 8.093 \times 10^6 \text{ N.} \quad d_3 = \frac{2.943 \times 15 + 5.150 \times 20}{2.943 + 5.150} = 18.18 \text{ m.}$$

$$\left. \begin{aligned} Wd_w + F_2d_2 &= 418.8 \times 10^6 \text{ N} \cdot \text{m} \\ F_1d_1 + F_3d_3 &= 296.1 \times 10^6 \text{ N} \cdot \text{m} \end{aligned} \right\} \therefore \underline{\text{will not topple.}}$$

$$b) W = (2.4 \times 9810)(6 \times 65 + 65 \times 12) = 27.55 \times 10^6 \text{ N.}$$

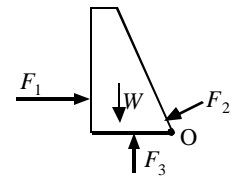
$$d_w = \frac{390 \times 27 + 780 \times 16}{390 + 780} = 19.67 \text{ m.}$$

$$F_2 \cong 0.54 \times 10^6 \text{ N.} \quad d_2 \cong 3.70 \text{ m.}$$

$$F_1 = 9810 \times 30 \times 60 = 17.66 \times 10^6 \text{ N.} \quad d_1 = 20 \text{ m.}$$

$$F_3 = 9810 \times \frac{60 + 10}{2} \times 30 = 10.3 \times 10^6 \text{ N.} \quad d_3 = \frac{2.943 \times 15 + 7.358 \times 20}{2.943 + 7.358} = 18.57 \text{ m.}$$

Assume 1 m deep



$$\left. \begin{aligned} Wd_w + F_2d_2 &= 543.9 \times 10^6 \text{ N} \cdot \text{m} \\ F_1d_1 + F_3d_3 &= 544.5 \times 10^6 \text{ N} \cdot \text{m} \end{aligned} \right\} \therefore \text{it will topple.}$$

c) Since it will topple for $H = 60$, it certainly will topple if $H = 75$ m.

2.60 The dam will topple if there is a net clockwise moment about "O."

a) $W = W_1 + W_2$. $W_1 = (6 \times 43 \times 1) \times 62.4 \times 2.4 = 38,640$ lb.

$$W_2 = (24 \times 43 / 2) \times 62.4 \times 2.4 = 77,280 \text{ lb.}$$

$$W_3 = (40 \times 22.33 / 2) \times 62.4 = 27,870 \text{ lb @ } 20.89 \text{ ft.}$$

$$F_1 = 62.4 \times 20 \times (40 \times 1) = 49,920 \text{ lb @ } 40/3 \text{ ft.}$$

$$F_2 = 62.4 \times 5 \times (10 \times 1) = 3120 \text{ lb @ } 3.33 \text{ ft}$$

$$F_3 = \begin{cases} F_{p1} = 18,720 \text{ lb @ } 15 \text{ ft} \\ F_{p2} = 28,080 \text{ lb @ } 20 \text{ ft} \end{cases}$$

$$\begin{aligned} \Sigma M_O: & (49,920)(40/3) + (18,720)(15) + (28,080)(20) - (38,640)(3) \\ & - (77,280)(14) - (27,870)(20.89) - (3120)(3.33) < 0. \therefore \text{won't tip.} \end{aligned}$$

b) $W_1 = 6 \times 63 \times 62.4 \times 2.4 = 56,610$ lb. $W_2 = (24 \times 63/2) \times 62.4 \times 2.4 = 113,220$ lb.

$$F_1 = 62.4 \times 30 \times 60 = 112,300 \text{ lb.} \quad W_3 = (60 \times 22.86/2) \times 62.4 = 42,790 \text{ lb.}$$

$$F_2 = 62.4 \times 5 \times 10 = 3120 \text{ lb}$$

$$F_{p1} = 62.4 \times 10 \times 30 = 18,720 \text{ lb.} \quad F_{p2} = 62.4 \times 50 \times 30 / 2 = 46,800 \text{ lb.}$$

$$\begin{aligned} \Sigma M_O: & (112,300)(20) + (18,720)(15) + (46,800)(20) - (56,610)(3) \\ & - (113,220)(14) - 42,790(21.24) = 799,000 > 0. \therefore \text{will tip.} \end{aligned}$$

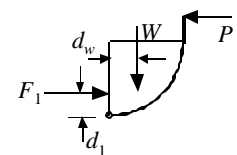
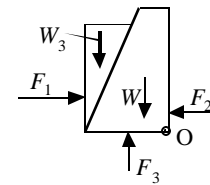
c) Since it will topple for $H = 60$ ft., it will also topple for $H = 80$ ft.

2.61 $\Sigma M_{\text{hinge}} = 0$. $2.5P - d_w \sim W - d_1 \sim F_1 = 0$.

$$\therefore P = \frac{1}{2.5} \left[\frac{2}{3} \times 9800 \times 1 \times 8 + \frac{4 \times 2}{3p} \times 9800 \times \frac{p \times 2^2}{4} \times 4 \right] = \underline{62,700 \text{ N}}$$

Note: This calculation is simpler than that of Example 2.7. Actually, We could have moved the horizontal force F_H and a vertical force F_V (equal to W) simultaneously to the center of the circle and then $2.5P = 2F_H = 2F_V$. This was outlined at the end of Example 2.7.

assume 1 m deep



2.62 Since all infinitesimal pressure forces pass thru the center, we can place the resultant forces at the center. Since the vertical components pass thru the bottom point, they produce no moment about that point. Hence, consider only horizontal forces:

$$(F_H)_{\text{water}} = 9810 \times 2 \times (4 \times 10) = 784,800 \text{ N}$$

$$(F_H)_{\text{oil}} = 0.86 \times 9810 \times 1 \times 20 = 168,700 \text{ N}$$

$$\Sigma M: 2P = 784.8 \times 2 - 168.7 \times 2. \therefore \underline{P = 616.1 \text{ kN.}}$$

- 2.63 Place the resultant force $\bar{F}_H + \bar{F}_V$ at the center of the circular arc. \bar{F}_H passes thru the hinge showing that $P = F_V$.
- a) $P = F_V = 9810(6 \times 2 \times 4 + p \times 4) = 594\,200 \text{ N}$ or 594.2 kN.
- b) $P = F_V = 62.4(20 \times 6 \times 12 + 9\pi \times 12) = \underline{111,000 \text{ lb}}$.
- 2.64 (D) Place the force $\bar{F}_H + \bar{F}_V$ at the center of the circular arc. F_H passes through the hinge:
- $$\therefore P = F_V = 4 \times 1.2w \times 9800 + (p \times 1.2^2 / 4)w \times 9800 = 300000. \quad \therefore w = 5.16 \text{ m.}$$
- 2.65 Place the resultant $\bar{F}_H + \bar{F}_V$ at the circular arc center. \bar{F}_H passes thru the hinge so that $P = F_V$. Use the water that could be contained above the gate; it produces the same pressure distribution and hence the same F_V .
- $$P = F_V = 9810(6 \times 3 \times 4 + 9\pi) = 983\,700 \text{ N}$$
- or
- 983.7 kN
- .
- 2.66 Place the resultant $\bar{F}_H + \bar{F}_V$ at the center. \bar{F}_V passes thru the hinge
- $$2 \times (9810 \times 1 \times 10) = 2.8 P. \quad \therefore P = 70\,070 \text{ N}$$
- or
- 70.07 kN
- .
- 2.67 The incremental pressure forces on the circular quarter arc pass through the hinge so that no moment is produced by such forces. Moments about the hinge gives:
- $$3 P = 0.9 W = 0.9 \times 400. \quad \therefore P = \underline{120 \text{ N}}$$
- 2.68 The resultant $\bar{F}_H + \bar{F}_V$ of the unknown liquid acts thru the center of the circular arc. \bar{F}_V passes thru the hinge. Thus we use only $(F_H)_{oil}$. Assume 1 m wide.
- a) $\Sigma M: \frac{R}{3} \left(9810 \frac{R}{2} R \right) + \frac{4R}{3p} \left(9800S \frac{pR^2}{4} \right) = R \left(g_x \frac{R}{2} R \right). \quad \therefore g_x = \underline{4580 \text{ N/m}^3}$
- b) $\Sigma M: \frac{R}{3} \left(62.4 \frac{R}{2} R \right) + \frac{4R}{3p} \left(62.4S \frac{pR^2}{4} \right) = R \left(g_x \frac{R}{2} R \right). \quad \therefore g_x = \underline{29.1 \text{ lb/ft}^3}$
- 2.69 The force of the water is only vertical $(F_V)_w$, acting thru the center. The force of the oil can also be positioned at the center:
- a) $P = (F_H)_o = (0.8 \times 9810) \times 0.3 \times 3.6 = \underline{8476 \text{ N}}$.
- $$\Sigma F_y = 0 = W + (F_V)_o - (F_V)_w$$
- $$0 = S \times 9810 \pi \times .6^2 \times 6 + \left(.36 - \frac{.36p}{4} \right) \times 6 \times (.8 \times 9810) - 9810 \times \pi \times .18 \times 6$$
- $$-9810 \times .8 \times 2 \times .6^2 - 6. \quad \therefore S = \underline{0.955}$$
- b) $rgV = W. = \underline{1996 \text{ lb}}$.
- $$\Sigma F_y = 0 = W + (F_V)_o - (F_V)_w$$

$$0 = S \times 62.4 \times \pi \times 2^2 \times 20 + \left(4 - \frac{4p}{4}\right) \times 20 \times .8 \times 62.4 - 62.4 \times \pi \times 2 \times 20 - 62.4 \times .8 \times 2 \times 2^2 \times 20. \quad \therefore S = \underline{0.955}.$$

2.70 The pressure in the dome is

a) $p = 60\,000 - 9810 \times 3 - 0.8 \times 9810 \times 2 = 14\,870$ Pa or 14.87 kPa.

The force is $F = pA_{\text{projected}} = (p \times 3^2) \times 14.87 = \underline{420.4}$ kN.

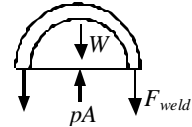
b) From a free-body diagram of the dome filled with oil:

$$F_{\text{weld}} + W = pA$$

Using the pressure from part (a):

$$F_{\text{weld}} = 14\,870 \times p \times 3^2 - (.8 \times 9810) \times \frac{1}{2} \left(\frac{4}{3} p \times 3^3 \right) = -23\,400 \text{ N}$$

or $\underline{-23.4}$ kN



2.71 A free-body diagram of the gate and water is shown.

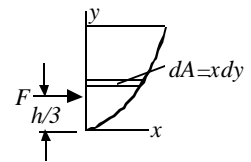
$$\frac{H}{3} F + d_w W = H \times P.$$

a) $H = 2$ m. $F = 9810 \times 1 \times 4 = 39\,240$ N.

$$W = 9810 \int_0^2 2x dy = 9810 \int_0^2 2 \frac{y^{1/2}}{\sqrt{2}} dy = \frac{2 \times 9810}{\sqrt{2}} \frac{2^{3/2}}{3/2} = 26\,160 \text{ N}.$$

$$d_w = \bar{x} = \frac{\int \frac{x}{2} x dy}{\int x dy} = \frac{\frac{1}{2} \int_0^1 4x^3 dx}{\int_0^1 4x^2 dx} = \frac{1}{2} \left(\frac{1/4}{1/3} \right) = 0.375 \text{ m}.$$

$$\therefore P = \frac{1}{3} \times 39\,240 + \frac{0.375}{2} \times 26\,160 = 17\,980 \text{ N} \text{ or } \underline{17.98} \text{ kN}.$$



b) $H = 8'$. $F = 62.4 \times 4 \times 32 = 7,987$ lb.

$$W = 62.4 \int 4x dy = 62.4 \times 4 \int_0^2 4x^2 dx = 62.4 \times 16 \times 2^3 / 3 = 2,662 \text{ lb}.$$

$$d_w = \bar{x} = \frac{\frac{1}{2} \int_0^2 4x^3 dx}{\int_0^2 4x^2 dx} = \frac{1}{2} \left(\frac{16/4}{8/3} \right) = 0.75'.$$

$$P = \frac{1}{8} \left(\frac{8}{3} \times 7,987 + 0.75 \times 2,662 \right) = \underline{2910} \text{ lb}$$

2.72 (A) $W = gV$

$$900 \times 9.81 = 9810 \times 0.01 \times 15w. \quad \therefore w = 6 \text{ m}$$

- 2.73 $W =$ weight of displaced water.
 a) $20\,000 + 250\,000 = 9810 \times 3(6d + d^2/2)$. $\therefore d^2 + 12d - 18.35 = 0$. $\therefore d = \underline{1.372\text{ m}}$.
 b) $270\,000 = 1.03 \times 9810 \times 3(6d + d^2/2)$. $d^2 + 12d - 17.81 = 0$. $\therefore d = \underline{1.336\text{ m}}$.

2.74 $25 + F_B = 100$. $\therefore F_B = 75 = 9810 \Psi$. $\therefore \Psi = 7.645 \times 10^{-3} \text{ m}^3$
 $g \times 7.645 \times 10^{-3} = 100$. $\text{or } \underline{7645 \text{ cm}^3}$
 $\therefore g = \underline{13\,080 \text{ N/m}^3}$.

2.75 $3000 \times 60 = 25 \times 300 \Delta d \times 62.4$. $\therefore \Delta d = 0.3846'$ or $\underline{4.62''}$.

2.76 $100\,000 \times 9.81 + 6\,000\,000 = (12 \times 30 + 8h \times 30) 9810$
 $\therefore h = 1.465 \text{ m}$. \therefore distance from top $= 2 - 1.465 = \underline{0.535 \text{ m}}$

2.77 $T + F_B = W$. (See Fig. 2.11 c.)
 $T = 40\,000 - 1.59 \times 9810 \times 2 = 8804 \text{ N}$ or $\underline{8.804 \text{ kN}}$.

- 2.78 The forces acting on the balloon are its weight W , the buoyant force F_B , and the weight of the air in the balloon F_a . Sum forces:

$$F_B = W + F_a \quad \text{or} \quad \frac{4}{3} \rho R^3 r g = 1000 + \frac{4}{3} \rho R^3 r_a g$$

$$\frac{4}{3} \rho \times 5^3 \frac{100 \times 9.81}{.287 \times 293} = 1000 + \frac{4}{3} \rho \times 5^3 \frac{100 \times 9.81}{.287 T_a} \quad \therefore T_a = 350.4 \text{ K or } \underline{77.4^\circ \text{C}}$$

- 2.79 The forces acting on the blimp are the payload F_p , the weight of the blimp W , the buoyant force F_B , and the weight of the helium F_h :

$$F_B = F_p + W + F_h$$

$$1500 \rho \times 150^2 \times \frac{100 \times 9.81}{.287 \times 288} = F_p + 0.1 F_p + 1500 \rho \times 150^2 \times \frac{100 \times 9.81}{2.077 \times 288}$$

$$I_o = \rho d^4 / 64 \dots \quad N_{\text{people}} = \frac{9.86 \times 10^8}{800} = \underline{1.23 \times 10^6}$$

Of course equipment and other niceties such as gyms, pools, restaurants, etc., would add significant weight.

- 2.80 Neglect the buoyant force of air. A force balance yields

$$F_B = W + F$$

$$= 50 + 10 = 60 = 9800 \Psi \quad \therefore \Psi = .006122 \text{ m}^3$$

Density: $\rho g \Psi = W$.

$$\rho \times 9.81 \times .006122 = 50. \quad \therefore \rho = \underline{832.5 \text{ kg/m}^3}$$

Specific wt: $g = \rho g = 832.5 \times 9.81 = \underline{8167 \text{ N/m}^3}$

Specific gravity: $S = \rho / \rho_{\text{water}} = 832.5 / 1000 = \underline{0.8325}$

2.81 From a force balance $F_B = W + pA$.

a) The buoyant force is found as follows ($h > 16'$):

$$\cos q = \frac{h - 15 - R}{R}, \quad \text{Area} = qR^2 - (h - 15 - R) R \sin q$$

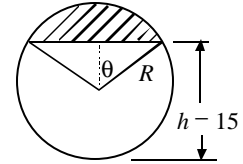
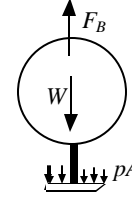
$$\therefore F_B = 10 \times 62.4 [pR^2 - qR^2 + (h - 15 - R) R \sin q].$$

$$F_B = 1500 + ghA.$$

The h that makes the above 2 F_B 's equal is found by trial-and-error:

$$h = 16.5: \quad 1859 \stackrel{?}{=} 1577 \quad h = 16.8: \quad 1866 \stackrel{?}{=} 1858$$

$$h = 17.0: \quad 1870 \stackrel{?}{=} 1960 \quad \therefore h = \underline{16.82 \text{ ft.}}$$



b) Assume $h > 16 \frac{1}{3}$ ft. and use the above equations with $R = 1.333'$:

$$h = 16.4: \quad 1857 \stackrel{?}{=} 1853 \quad \therefore h = \underline{16.4 \text{ ft.}}$$

c) Assume $h < 16 \frac{2}{3}$ ft. With $R = 1.667'$,

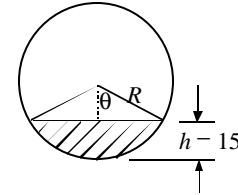
$$F_B = 10 \times 62.4 [qR^2 - (R - h + 15) R \sin q].$$

$$F_B = 1500 + ghA. \quad \cos q = \frac{R - h + 15}{R}$$

Trial-and-error for h :

$$h = 16: \quad 1849 \stackrel{?}{=} 1374 \quad h = 16.2: \quad 1853 \stackrel{?}{=} 1765$$

$$h = 16.4: \quad 1857 \stackrel{?}{=} 2170 \quad \therefore h = \underline{16.25 \text{ ft.}}$$



2.82 a) $W = F_B$. $[0.01 + 13.6 \times 1000 \times hp \times 0.015^2 / 4] \times 9.81 = 9810 \Psi$.

$$\Psi = \frac{p \times 0.015^2}{4} \times 15 + \frac{p \times 0.005^2}{4} \times 0.06 = 2.769 \times 10^{-5} \text{ m}^3. \quad \therefore h = 7.361 \times 10^{-3} \text{ m}$$

$$\therefore m_{Hg} = 13.6 \times 1000 \times hp \times 0.015^2 / 4 = \underline{0.01769 \text{ kg}}$$

$$\text{b) } (0.01 + 0.01769) 9.81 = 9810 \left[\frac{p \times 0.015^2}{4} \times 15 + \frac{p \times 0.005^2}{4} \times 12 \right] S_x. \quad \therefore S_x = \underline{0.959}$$

$$\text{c) } (0.01 + 0.01769) 9.81 = 9810 \frac{p \times 0.015^2}{4} \times 15 S_x. \quad \therefore S_x = \underline{1.045}$$

2.83 $(0.01 + m_{Hg}) 9.81 = 9810 \left[\frac{p \times 0.015^2}{4} \times 15 + \frac{p \times 0.005^2}{4} \times 12 \right]$. $\therefore m_{Hg} = 0.01886$.

$$\text{a) } (0.01 + 0.01886) 9.81 = 9810 \frac{p \times 0.015^2}{4} \times 15 S_x. \quad \therefore S_x = \underline{1.089}$$

$$\text{b) } m_{Hg} = \underline{0.01886 \text{ kg.}}$$

2.84 a) $I_o = \frac{p d^4}{64} = \frac{p \times (10/12)^4}{64} = 0.02367 \text{ ft}^4$.
 $\Psi = \frac{W}{r_{H_2O}} = \frac{.8 \times 62.4 \times p \times (5/12)^2 \times 12/12}{62.4} = 0.4363$. depth = $\frac{.4363}{p(5/12)^2} = 0.8'$
 $\therefore \overline{GM} = .02367 / .4363 - (.5 - .4) = -0.0457'$. \therefore It will not float with ends horizontal.

b) $I_o = 0.02367 \text{ ft}^4$, $\Psi = 0.3636 \text{ ft}^3$, depth = 0.6667'
 $\overline{GM} = .02367 / .3636 - (5 - 4) / 12 = -0.01823'$. \therefore It will not float as given.

c) $\Psi = 0.2909$, depth = 6.4", $GM = \frac{.02367}{.2909} - \frac{4 - 3.2}{12} = 0.0147$. \therefore It will float.

2.85 With ends horizontal $I_o = p d^4 / 64$. The displaced volume is
 $\Psi = g_x p d^2 h / 4 \times 9800 = 8.014 \times 10^{-5} g_x d^3$ since $h = d$. The depth the cylinder will sink is

$$\text{depth} = \frac{\Psi}{A} = 8.014 \times 10^{-5} g_x d^3 / p d^2 / 4 = 10.20 \times 10^{-5} g_x d$$

The distance \overline{CG} is $\overline{CG} = \frac{h}{2} - 10.2 \times 10^{-5} g_x d / 2$. Then

$$\overline{GM} = \frac{p d^4 / 64}{8.014 \times 10^{-5} g_x d^3} - \frac{d}{2} + 10.2 \times 10^{-5} g_x d / 2 > 0.$$

This gives (divide by d and multiply by g_x):

$$612.5 - .5 g_x + 5.1 \times 10^{-5} g_x^2 > 0.$$

Consequently,

$$g_x > 8369 \text{ N/m}^3 \quad \text{or} \quad g_x < 1435 \text{ N/m}^3$$

2.86 $\Psi = \frac{W}{g_{water}} = \frac{S g_{water} d^3}{g_{water}} = S d^3$. $\Psi = \frac{W}{g_{water}} = \frac{S g_{water} d^3}{g_{water}} = S d^3$. $\therefore h = Sd$.

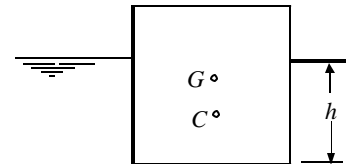
$$\overline{GM} = \frac{d^4 / 12}{S d^3} - (d / 2 - Sd / 2) = d \left(\frac{1}{12S} - \frac{1}{2} + \frac{S}{2} \right).$$

If $\overline{GM} = 0$ the cube is neutral and $6S^2 - 6S + 1 = 0$.

$$\therefore S = \frac{6 \pm \sqrt{36 - 24}}{12} = 0.7887, 0.2113.$$

The cube is unstable if $0.2113 < S < 0.7887$.

Note: Try $S = 0.8$ and $S = 0.1$ to see if $\overline{GM} > 0$. This indicates stability.



2.87 As shown, $\bar{y} = \frac{16 \times 9 + 16 \times 4}{16 + 16} = 6.5 \text{ cm}$ above the bottom edge.

$$G = \frac{4g \times 9.5 + 16g \times 8.5 + 16S_A g \times 4}{.5g \times 8 + 2g \times 8 + S_A g \times 16} = 6.5 \text{ cm}.$$

$$\therefore 130 + 104 S_A = 174 + 64 S_A. \quad \therefore S_A = \underline{1.1}.$$

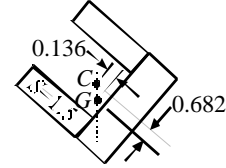
$$2.88 \quad \text{a) } \bar{y} = \frac{16 \times 4 + 8 \times 1 + 8 \times 7}{16 + 8 + 8} = 4. \quad \bar{x} = \frac{16 \times 1 + 8 \times 4 + 8 \times 4}{16 + 8 + 8} = 2.5.$$

$$\text{For } G: y = \frac{1.2 \times 16 \times 4 + .5 \times 8 \times 1 + 1.5 \times 8 \times 7}{1.2 \times 16 + .5 \times 8 + 1.5 \times 8} = 4.682.$$

$$x = \frac{1.2 \times 16 + .5 \times 8 \times 4 + 1.5 \times 8 \times 4}{1.2 \times 16 + .5 \times 8 + 1.5 \times 8} = 2.364.$$

G must be directly under C .

$$\tan q = \frac{.136}{.682}. \quad \therefore \underline{q = 11.3^\circ}.$$



$$\text{b) } \bar{y} = \frac{4 \times 2 + 2 \times \frac{1}{2} + 2 \times 3.5}{4 + 2 + 2} = 2. \quad \bar{x} = \frac{4 \times \frac{1}{2} + 2 \times 2 + 2 \times 2}{4 + 2 + 2} = 1.25$$

$$\text{For } G: y = \frac{1.2 \times 4 \times 2 + .5 \times 1 + 1.5 \times 7}{1.2 \times 4 + .5 \times 2 + 1.5 \times 2} = 2.34. \quad x = \frac{1.2 \times 2 + .5 \times 4 + 1.5 \times 4}{1.2 \times 4 + .5 \times 2 + 1.5 \times 2} = 1.182$$

$$\Delta y = 0.34, \quad \Delta x = 0.068. \quad \tan q = \frac{.068}{.34}. \quad \therefore \underline{q = 11.3^\circ}.$$

2.89 The centroid C is 1.5 m below the water surface. $\therefore \overline{CG} = 1.5$ m.

$$\text{Using Eq. 2.4.47: } \overline{GM} = \frac{\ell \times 8^3 / 12}{\ell \times 8 \times 3} - 1.5 = 1.777 - 1.5 = 0.277 > 0.$$

\therefore The barge is stable.

$$2.90 \quad \bar{y} = \frac{8.485 \times 3.414 + 16.97 \times 1}{8.485 + 16.97} = 1.8 \text{ m.} \quad \therefore \overline{CG} = 1.8 - 1.5 = 0.3 \text{ m.}$$

$$\text{Using Eq. 2.4.47: } \overline{GM} = \frac{\ell \times 8.485^3 / 12}{34.97 \ell} - .3 = 1.46 - .3 = 1.16. \quad \therefore \underline{\text{Stable.}}$$

$$2.91 \quad \text{(A)} \quad p_{plug} = 20000 + gh = 20000 + 6660 \times \left(1.2 \times \frac{5}{9.81}\right) = 24070 \text{ Pa}$$

$$F_{plug} = p_{plug} A = 24070 \times \pi \times 0.02^2 = 30.25 \text{ N}$$

$$2.92 \quad \text{a) } \tan a = \frac{20}{9.81} = \frac{H}{4}. \quad \therefore H = 8.155 \text{ m.} \quad p_{max} = 9810 (8.155 + 2) = \underline{99\,620 \text{ Pa}}$$

$$\text{b) } p_{max} = \rho(g + a_z) h = 1000 (9.81 + 20) \times 2 = \underline{59\,620 \text{ Pa}}$$

$$\text{c) } p_{max} = 1.94 \times 60 (-12) - 1.94 (32.2 + 60) (-6) = 2470 \text{ psf or } \underline{17.15 \text{ psi}}$$

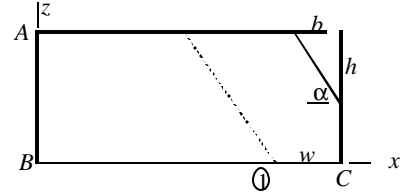
$$\text{d) } p_{max} = 1.94 (32.2 + 60) (-6) = 1073 \text{ psf or } \underline{7.45 \text{ psi}}$$

2.93 The air volume is the same before and after.

$$\therefore 0.5 \times 8 = hb/2. \quad \tan \alpha = \frac{10}{9.81} = \frac{h}{b}$$

$$4 = \frac{h}{2} \frac{9.81}{10} h. \quad \therefore h = 2.856. \quad \therefore \text{Use dotted line.}$$

$$2.5w + \frac{1}{2} \times 2.5 \times 2.452 = 4. \quad \therefore w = 0.374 \text{ m.}$$



a) $p_A = -1000 \times 10 (0 - 7.626) - 1000 \times 9.81 \times 2.5 = 51\,740 \text{ Pa}$ or 51.74 kPa

b) $p_B = -1000 \times 10 (0 - 7.626) = 76\,260 \text{ Pa}$ or 76.26 kPa

c) $p_C = 0$. Air fills the space to the dotted line.

2.94 Use Eq. 2.5.2: Assume an air-water surface as shown in the above figure.

a) $60\,000 = -1000 a_x (0-8) - 1000 \times 9.81 \left[0 - \left(2.5 - \sqrt{\frac{8a_x}{9.81}} \right) \right]$

$$4 = \frac{h^2 \times 9.81}{2a_x} \quad 60 = 8 a_x + 24.52 - 9.81 \sqrt{\frac{8a_x}{9.81}}. \quad a_x - 4.435 = 1.1074 \sqrt{a_x}.$$

$$a_x^2 - 10.1 a_x + 19.67 = 0 \quad \therefore a_x = 2.64, \underline{7.46 \text{ m/s}^2}$$

b) $60\,000 = -1000 a_x (-8) - 1000 (9.81 + 10) \left(-2.5 + \sqrt{\frac{8a_x}{9.81}} \right)$

$$60 = 8 a_x + 49.52 - 19.81 \sqrt{\frac{8a_x}{19.81}}. \quad a_x - 1.31 = 1.574 \sqrt{a_x}.$$

$$a_x^2 - 5.1 a_x + 1.44 = 0 \quad \therefore a_x = 0.25, \underline{4.8 \text{ m/s}^2}$$

c) $60\,000 = -1000 a_x (-8) - 1000 (9.81 + 5) \left(-2.5 + \sqrt{\frac{8a_x}{14.81}} \right)$

$$60 = 8 a_x + 37.0 - 14.81 \sqrt{\frac{8a_x}{14.81}}. \quad a_x - 2.875 = 1.361 \sqrt{a_x}.$$

$$a_x^2 - 7.6 a_x + 8.266 = 0 \quad \therefore a_x = 1.32, \underline{6.28 \text{ m/s}^2}$$

2.95 a) $a_x = 20 \times .866 = 17.32 \text{ m/s}^2$, $a_z = 10 \text{ m/s}^2$. Use Eq. 2.5.2 with the peep hole as position 1. The x -axis is horizontal passing thru A. We have

$$p_A = -1000 \times 17.32 (0 - 1.232) - 1000 (9.81 + 10) (0 - 1.866) = \underline{58\,290 \text{ Pa}}$$

b) $p_A = -1000 \times 8.66 (0 - 1.848) - 1000 (9.81 + 5) (0 - 2.799) = \underline{57\,460 \text{ Pa}}$

c) The peep hole is located at (3.696, 5.598). Use Eq. 2.5.2:

$$p_A = -1.94 \times 51.96 (0 - 3.696) - 1.94 (32.2 + 30) (0 - 5.598) = \underline{1048 \text{ psf}}$$

d) The peep hole is located at (4.928, 7.464). Use Eq. 2.5.2:

$$p_A = -1.94 \times 25.98 (-4.928) - 1.94 (32.2 + 15) (-7.464) = \underline{932 \text{ psf}}$$

2.96 a) The pressure on the end AB (z is zero at B) is, using Eq. 2.5.2,

$$p(z) = -1000 \times 10 (-7.626) - 1000 \times 9.81(z) = 76\,260 - 9810 z$$

$$\therefore F_{AB} = \int_0^{2.5} (76\,260 - 9810z)4dz = 640\,000 \text{ N or } \underline{640 \text{ kN}}$$

b) The pressure on the bottom BC is

$$p(x) = -1000 \times 10 (x - 7.626) = 76\,260 - 10\,000x.$$

$$\therefore F_{BC} = \int_0^{7.626} (76\,260 - 10\,000x)4dx = 1.163 \times 10^6 \text{ N or } \underline{1163 \text{ kN}}$$

c) On the top $p(x) = -1000 \times 10 (x - 5.174)$ where position 1 is on the top surface:

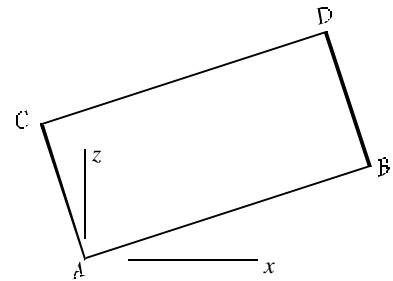
$$\therefore F_{top} = \int_0^{5.174} (51\,740 - 10\,000x)4dx = 5.35 \times 10^5 \text{ N or } \underline{535 \text{ kN}}$$

2.97 a) The pressure at A is 58.29 kPa. At B it is

$$p_B = -1000 \times 17.32 (1.732 - 1.232) - 1000 (19.81) (1 - 1.866) = 8495 \text{ Pa.}$$

Since the pressure varies linearly over AB, we can use an average pressure times the area:

$$F_{AB} = \frac{58\,290 + 8495}{2} \times 1.5 \times 2 = 100\,200 \text{ N or } \underline{100.2 \text{ kN}}$$



b) $p_D = 0$. $p_C = -1000 \times 17.32 (-.5 - 1.232) - 1000 \times 19.81 (.866 - 1.866) = 49\,810 \text{ Pa.}$

$$F_{CD} = \frac{1}{2} \times 49\,810 \times 1.5 \times 2 = 74\,720 \text{ N or } \underline{74.72 \text{ kN.}}$$

c) $p_A = 58\,290 \text{ Pa.}$ $p_C = 49\,810 \text{ Pa.}$ $\therefore F_{AC} = \frac{58.29 + 49.81}{2} \times 1.5 = \underline{81.08 \text{ kN.}}$

2.98 Use Eq. 2.5.2 with position 1 at the open end:

a) $p_A = 0$ since $z_2 = z_1$.

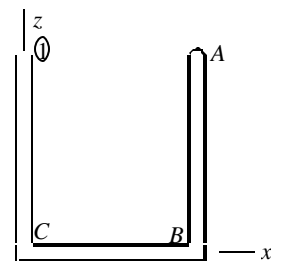
$$p_B = 1000 \times 19.81 \times 0.6 = \underline{11\,890 \text{ Pa.}}$$

$$p_C = \underline{11\,890 \text{ Pa.}}$$

b) $p_A = -1000 \times 10 (.9 - 0) = \underline{-9000 \text{ Pa.}}$

$$p_B = -1000 \times 10 (.9) - 1000 \times 9.81 (-.6) = \underline{-3114 \text{ Pa}}$$

$$p_C = -1000 \times 9.81 \times (-.6) = \underline{5886 \text{ Pa.}}$$



c) $p_A = -1000 \times 20 (0.9) = \underline{-18\,000 \text{ Pa.}}$

$$p_B = -1000 \times 20 \times 0.9 - 1000 \times 19.81 (-0.6) = \underline{-6110 \text{ Pa.}} \quad p_C = \underline{11\,890 \text{ Pa}}$$

d) $p_A = 0$. $p_B = 1.94 \times (32.2 - 60) \left(\frac{25}{12} \right) = \underline{-112 \text{ psf.}} \quad p_C = \underline{-112 \text{ psf.}}$

e) $p_A = 1.94 \times 60 \left(-\frac{37.5}{12} \right) = \underline{-364 \text{ psf.}}$

$$p_B = 1.94 \times 60 \left(-\frac{37.5}{12} \right) - 1.94 \times 32.2 \left(-\frac{25}{12} \right) = \underline{-234 \text{ psf.}}$$

$$p_C = -1.94 \times 32.2 \left(-\frac{25}{12} \right) = \underline{130 \text{ psf.}}$$

$$f) p_A = 1.94 \times 30 \left(\frac{37.5}{12} \right) = \underline{182 \text{ psf.}}$$

$$p_B = -1.94(-30) \left(\frac{37.5}{12} \right) - 1.94 \times 62.2 \left(-\frac{25}{12} \right) = \underline{433 \text{ psf.}}$$

$$p_C = -1.94 \times 62.2 \times \left(-\frac{25}{12} \right) = \underline{251 \text{ psf.}}$$

2.99 Use Eq. 2.6.4 with position 1 at the open end:

$$\omega = \frac{50 \times 2\pi}{60} = 5.236 \text{ rad/s.}$$

$$a) p_A = \frac{1000 \times 5.236^2}{2} \times (.6 \times 1.5)^2 = \underline{11\,100 \text{ Pa.}}$$

$$p_B = \frac{1}{2} \times 1000 \times 5.236^2 \times .9^2 + 9810 \times .6 = \underline{16\,990 \text{ Pa.}}$$

$$p_C = 9810 \times .6 = \underline{5886 \text{ Pa.}}$$

$$b) p_A = \frac{1}{2} \times 1000 \times 5.236^2 \times 0.6^2 = \underline{4935 \text{ Pa.}}$$

$$p_B = \frac{1}{2} \times 1000 \times 5.236^2 \times 0.6^2 + 9810 \times 0.4 = \underline{8859 \text{ Pa.}}$$

$$p_C = 9810 \times 0.4 = \underline{3924 \text{ Pa.}}$$

$$c) p_A = \frac{1}{2} \times 1.94 \times 5.236^2 \times \left(\frac{37.5}{12} \right)^2 = \underline{259.7 \text{ psf.}}$$

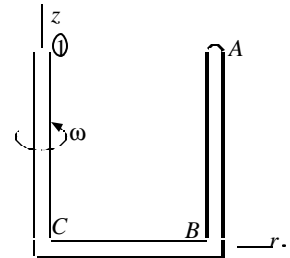
$$p_B = \frac{1}{2} \times 1.94 \times 5.236^2 \times \left(\frac{37.5}{12} \right)^2 + 62.4 \times \frac{25}{12} = \underline{389.7 \text{ psf.}}$$

$$p_C = 62.4 \times \frac{25}{12} = \underline{130 \text{ psf.}}$$

$$d) p_A = \frac{1}{2} \times 1.94 \times 5.236^2 \times \left(\frac{22.5}{12} \right)^2 = \underline{93.5 \text{ psf.}}$$

$$p_B = \frac{1}{2} \times 1.94 \times 5.236^2 \times \left(\frac{22.5}{12} \right)^2 + 62.4 \times \frac{15}{12} = \underline{171.5 \text{ psf.}}$$

$$p_C = 62.4 \times \frac{15}{12} = \underline{78 \text{ psf.}}$$



2.100 Use Eq. 2.6.4 with position 1 at the open end.

$$a) p_A = \frac{1}{2} \times 1000 \times 10^2 (0 - 0.9^2) = \underline{-40\,500 \text{ Pa.}}$$

$$p_B = -40\,500 + 9810 \times 0.6 = \underline{-34\,600 \text{ Pa.}}$$

$$p_C = 9810 \times 0.6 = \underline{5886 \text{ Pa.}}$$

$$b) p_A = \frac{1}{2} \times 1000 \times 10^2 (0 - 0.6^2) = \underline{-18\,000 \text{ Pa.}}$$

$$p_B = -18\,000 + 9810 \times 0.4 = \underline{-14\,080 \text{ Pa.}}$$

$$p_C = 9810 \times 0.4 = \underline{3924 \text{ Pa.}}$$

$$c) p_A = \frac{1}{2} \times 1.94 \times 10^2 \left(0 - \frac{37.5^2}{144} \right) = \underline{-947 \text{ psf.}}$$

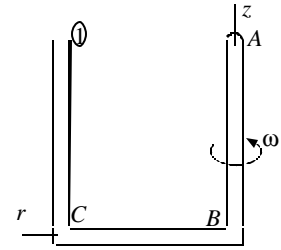
$$p_B = -947 + 62.4 \times \frac{25}{12} = \underline{-817 \text{ psf.}}$$

$$p_C = 62.4 \times \frac{25}{12} = \underline{130 \text{ psf.}}$$

$$d) p_A = \frac{1}{2} \times 1.94 \times 10^2 \left(-\frac{22.5^2}{12^2} \right) = \underline{-341 \text{ psf.}}$$

$$p_B = -341 + 62.4 \times \frac{15}{12} = \underline{-263 \text{ psf.}}$$

$$p_C = 62.4 \times \frac{15}{12} = \underline{78 \text{ psf.}}$$



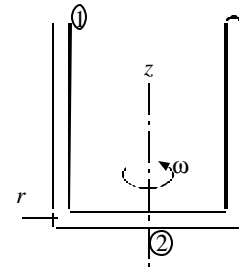
2.101.1 Use Eq. 2.6.4 with position 1 at the open end and position 2 at the origin. Given: $p_2 = 0$.

$$a) 0 = \frac{1}{2} \times 1000 \omega^2 (0 - 0.45^2) - 9810 (0 - 0.6). \quad \therefore \omega = \underline{7.62 \text{ rad/s.}}$$

$$b) 0 = \frac{1}{2} \times 1000 \omega^2 (0 - 0.3^2) - 9810 (0 - 0.4). \quad \therefore \omega = \underline{9.34 \text{ rad/s.}}$$

$$c) 0 = \frac{1}{2} \times 1.94 \omega^2 \left(0 - \frac{18.75^2}{12^2} \right) - 62.4 \left(-\frac{25}{12} \right). \quad \therefore \omega = \underline{7.41 \text{ rad/s.}}$$

$$d) 0 = \frac{1}{2} \times 1.94 \omega^2 \left(-\frac{11.25^2}{12^2} \right) - 62.4 \left(-\frac{15}{12} \right). \quad \therefore \omega = \underline{9.57 \text{ rad/s.}}$$



2.102 The air volume before and after is equal.

$$\therefore \frac{1}{2} p r_0^2 h = p \times 0.6^2 \times 2. \quad \therefore r_0^2 h = 0.144.$$

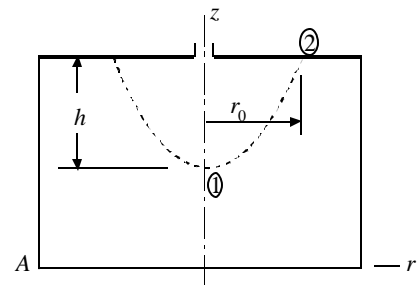
$$a) \text{ Using Eq. 2.6.5: } r_0^2 \times 5^2 / 2 = 9.81 h$$

$$\therefore h = 0.428 \text{ m}$$

$$\therefore p_A = \frac{1}{2} \times 1000 \times 5^2 \times 0.6^2 - 9810 (-0.372) \\ = \underline{8149 \text{ Pa.}}$$

$$b) r_0^2 \times 7^2 / 2 = 9.81 h. \quad \therefore h = 0.6 \text{ m.}$$

$$\therefore p_A = \frac{1000}{2} \times 7^2 \times 0.6^2 + 9810 \times 0.2 = \underline{10\,780 \text{ Pa.}}$$



c) For $w = 10$, part of the bottom is bared.

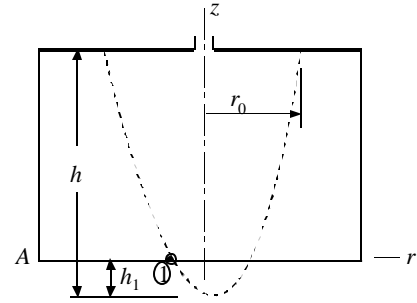
$$p \times .6^2 \times 2 = \frac{1}{2} p r_0^2 h - \frac{1}{2} p r_1^2 h_1.$$

Using Eq. 2.6.5:

$$\frac{w^2 r_0^2}{2g} = h, \quad \frac{w^2 r_1^2}{2g} = h_1.$$

$$\therefore 0.144 = \frac{2g}{w^2} h^2 - \frac{2g}{w^2} h_1^2 \quad \text{or}$$

$$h^2 - h_1^2 = \frac{0.144 \times 10^2}{2 \times 9.81}.$$



Also, $h - h_1 = 0.8$. $1.6h - 0.64 = .7339$. $\therefore h = 0.859$ m, $r_1 = 0.108$ m.

$$\therefore p_A = \frac{1}{2} \times 1000 \times 10^2 (0.6^2 - 0.108^2) = \underline{17\,400 \text{ Pa}}.$$

d) Following part (c): $h^2 - h_1^2 = \frac{0.144 \times 20^2}{2 \times 9.81}$. $1.6h - .64 = 2.936$. $\therefore h = 2.235$ m.

$$\therefore p_A = \frac{1}{2} \times 1000 \times 20^2 (0.6^2 - 0.265^2) = \underline{57\,900 \text{ Pa}} \quad r_1 = 0.265 \text{ m}$$

2.103 The answers to Problem 2.102 are increased by 25 000 Pa.

- a) 33 150 Pa b) 35 780 Pa c) 42 400 Pa d) 82 900 Pa

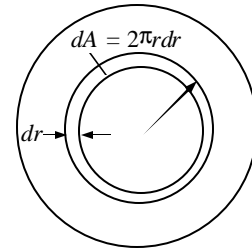
2.104 $p(r) = \frac{1}{2} r w^2 r^2 - r g [0 - (.8 - h)]$.

$$p(r) = 500 w^2 r^2 + 9810(.8 - h) \quad \text{if } h < .8.$$

$$p(r) = 500 w^2 (r^2 - r_1^2) \quad \text{if } h > .8.$$

a) $F = \int p 2\pi r dr = 2\pi \int_0^{.6} (12\,500 r^3 + 3650 r) dr = \underline{6670 \text{ N}}.$

(We used $h = .428$ m)



b) $F = \int p 2\pi r dr = 2\pi \int_0^{.6} (24\,500 r^3 + 1962 r) dr = \underline{7210 \text{ N}}.$ (We used $h = 0.6$ m)

c) $F = \int p 2\pi r dr = 2\pi \int_{-.108}^{.6} (50\,000(r^3 - .108^2 r)) dr = \underline{9520 \text{ N}}.$ (We used $r_1 = 0.108$ m)

d) $F = \int p 2\pi r dr = 2\pi \int_{.265}^{.6} (200\,000(r^3 - .265^2 r)) dr = \underline{26\,400 \text{ N}}.$ ($r_1 = 0.265$ m)