Group HW Problems:

2.2

2.2 Blood pressure is usually given as a ratio of the maximum pressure (systolic pressure) to the minimum pressure (diastolic pressure). As shown in **Video V2.1**, such pressures are commonly measured with a mercury manometer. A typical value for this ratio for a human would be 120/70, where the pressures are in mm Hg. **(a)** What would these pressures be in pascals? **(b)** If your car tire was inflated to 120 mm Hg, would it be sufficient for normal driving?

$p = \gamma h$

(a) For 120 mm Hg: $p = (133 \times 10^3 \frac{N}{m^3})(0.120 m) = \underline{\underline{16.0 kPa}}$

For 70 mm Hg: $p = (133 \times 10^3 \frac{N}{m^3})(0.070 m) = \underline{\underline{9.31 kPa}}$

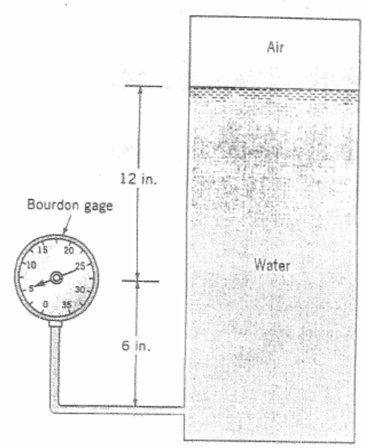
(b) For 120 mm Hg: $p = (16.0 \times 10^3 \frac{N}{m^2})(1.450 \times 10^{-4} \frac{lb/in.^2}{N/m^2})$

$= 2.32$ psi

Since a typical tire pressure is 30-35 psi, 120 mm Hg is <u>not sufficient</u> for normal driving.

2.5

2.5 Bourdon gages (see **Video V2.2** and Fig. 2.13) are commonly used to measure pressure. When such a gage is attached to the closed water tank of Fig. P2.5 the gage reads 5 psi. What is the absolute air pressure in the tank? Assume standard atmospheric pressure of 14.7 psi.



■ FIGURE P2.5

$p = \gamma h + p_o$

$p_{gage} - (\frac{12}{12} ft)\gamma_{H_2O} = p_{air}$

$p_{air} = (5 \frac{lb}{in.^2} + 14.7 \frac{lb}{in.^2}) - \frac{(1 ft)(62.4 \frac{lb}{ft^3})}{144 \frac{in.^2}{ft^2}}$

$p_{air} = \underline{\underline{19.3 \text{ psia}}}$

2.12

2.12 The basic elements of a hydraulic press are shown in Fig. P2.12. The plunger has an area of 1 in.^{2}, and a force, F_1, can be applied to the plunger through a lever mechanism having a mechanical advantage of 8 to 1. If the large piston has an area of 150 in.^{2}, what load, F_2, can be raised by a force of 30 lb applied to the lever? Neglect the hydrostatic pressure variation.

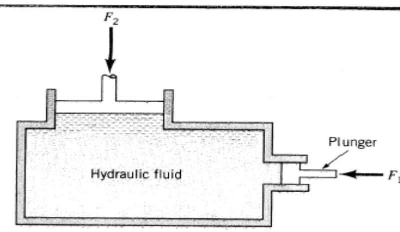


FIGURE P2.12

A force of 30 lb applied to the lever results in a plunger force, F_1, of $F_1 = (8)(30) = 240$ lb.
Since $F_1 = pA_1$ and $F_2 = pA_2$ where p is the pressure and A_1 and A_2 are the areas of the plunger and piston, respectively. Since p is constant throughout the chamber,

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

so that

$$F_2 = \frac{A_2}{A_1} F_1 = \left(\frac{150 \text{ in.}^2}{1 \text{ in.}^2}\right)(240 \text{ lb}) = \underline{\underline{36{,}000 \text{ lb}}}$$

2.25

2.25 A closed cylindrical tank filled with water has a hemispherical dome and is connected to an inverted piping system as shown in Fig. P2.25. The liquid in the top part of the piping system has a specific gravity of 0.8, and the remaining parts of the system are filled with water. If the pressure gage reading at A is 60 kPa, determine: **(a)** the pressure in pipe B, and **(b)** the pressure head, in millimeters of mercury, at the top of the dome (point C).

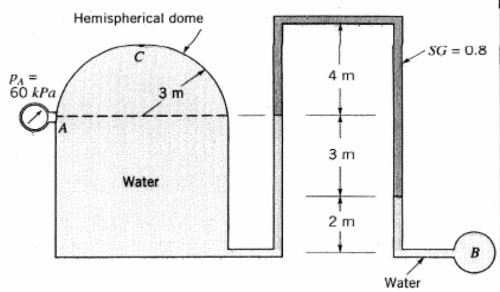


FIGURE P2.25

(a)

$$p_A + (SG)(\gamma_{H_2O})(3\text{ m}) + \gamma_{H_2O}(2\text{ m}) = p_B$$

$$p_B = 60\text{ kPa} + (0.8)\left(9.81\times10^3 \frac{\text{N}}{\text{m}^3}\right)(3\text{ m}) + \left(9.80\times10^3\frac{\text{N}}{\text{m}^3}\right)(2\text{ m})$$

$$= \underline{\underline{103\text{ kPa}}}$$

(b)

$$p_C = p_A - \gamma_{H_2O}(3\text{ m})$$

$$= 60\text{ kPa} - \left(9.80\times10^3\frac{\text{N}}{\text{m}^3}\right)(3\text{ m})$$

$$= 30.6\times10^3\ \frac{\text{N}}{\text{m}^2}$$

$$h = \frac{p_c}{\gamma_{Hg}} = \frac{30.6\times10^3\ \frac{\text{N}}{\text{m}^2}}{133\times10^3\ \frac{\text{N}}{\text{m}^3}} = 0.230\text{ m}$$

$$= 0.230\text{ m}\left(\frac{10^3\text{ mm}}{\text{m}}\right) = \underline{\underline{230\text{ mm}}}$$

2.26 A U-tube manometer contains oil, mercury, and water as shown in Fig. P2.26. For the column heights indicated what is the pressure differential between pipes A and B?

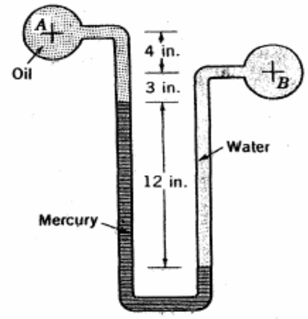


FIGURE P2.26

$$p_A + \gamma_{oil}\left[\frac{(3+4)}{12}\,ft\right] + \gamma_{Hg}\left[\frac{12}{12}\,ft\right] - \gamma_{H_2O}\left[\frac{(12+3)}{12}\,ft\right] = p_B$$

Thus,

$$p_A - p_B = \left(62.4\,\frac{lb}{ft^3}\right)\left(\frac{15}{12}\,ft\right) - \left(57.0\,\frac{lb}{ft^3}\right)\left(\frac{7}{12}\,ft\right) - \left(847\,\frac{lb}{ft^3}\right)(1\,ft)$$

$$= \underline{\underline{-802\,\frac{lb}{ft^2}}}$$

2.38

2.38 An air-filled, hemispherical shell is attached to the ocean floor at a depth of 10 m as shown in Fig. P2.38. A mercury barometer located inside the shell reads 765 mm Hg, and a mercury U-tube manometer designed to give the outside water pressure indicates a differential reading of 735 mm Hg as illustrated. Based on these data what is the atmospheric pressure at the ocean surface?

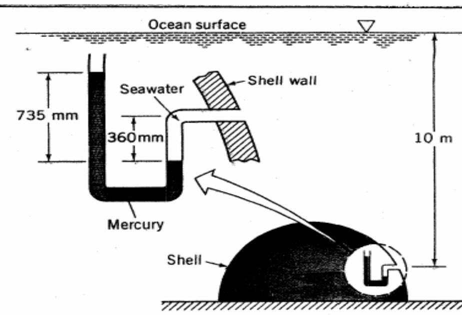


FIGURE P2.38

Let: $p_a \sim$ absolute air pressure inside shell $= \gamma_{Hg}\,(0.765\,m)$

$p_{atm} \sim$ surface atmospheric pressure

$\gamma_{sw} \sim$ specific weight of seawater

Thus, manometer equation can be written as

$$p_{atm} + \gamma_{sw}\,(10\,m) + \gamma_{sw}\,(0.360\,m) - \gamma_{Hg}\,(0.735\,m) = p_a$$

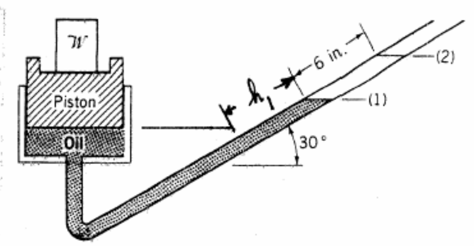
so that

$$p_{atm} = p_a - \gamma_{sw}\,(10.36\,m) + \gamma_{Hg}\,(0.735\,m)$$

$$= \left(133\,\frac{kN}{m^3}\right)(0.765\,m) - \left(10.1\,\frac{kN}{m^3}\right)(10.36\,m) + \left(133\,\frac{kN}{m^3}\right)(0.735\,m)$$

$$= \underline{\underline{94.9\,kPa}}$$

2.41 A 6-in.-diameter piston is located within a cylinder which is connected to a $\frac{1}{2}$-in.-diameter inclined-tube manometer as shown in Fig. P2.41. The fluid in the cylinder and the manometer is oil (specific weight = 59 lb/ft^3). When a weight $\mathcal{W}$ is placed on the top of the cylinder the fluid level in the manometer tube rises from point (1) to (2). How heavy is the weight? Assume that the change in position of the piston is negligible.



■ FIGURE P2.41

With piston alone let pressure on face of piston = p_p, and manometer equation becomes

$$p_p - \gamma_{oil}\, h_1 \sin 30° = 0 \qquad (1)$$

With weight added pressure p_p increases to p_p' where

$$p_p' = p_p + \frac{W}{A_p} \qquad (A_p \sim \text{area of piston})$$

and manometer equation becomes

$$p_p' - \gamma_{oil}\left(h_1 + \tfrac{6}{12}\,ft\right)\sin 30° = 0 \qquad (2)$$

Subtract Eq.(1) from Eq.(2) to obtain

$$p_p' - p_p - \gamma_{oil}\left(\tfrac{6}{12}\,ft\right)\sin 30° = 0$$

or

$$\frac{W}{A_p} = \gamma_{oil}\left(\tfrac{6}{12}\,ft\right)\sin 30°$$

so that

$$\frac{W}{\frac{\pi}{4}\left(\frac{6}{12}\,ft\right)^2} = \left(59\,\frac{lb}{ft^3}\right)\left(\tfrac{6}{12}\,ft\right)(0.5)$$

and

$$W = \underline{\underline{2.90\ lb}}$$

2.46 Determine the change in the elevation of the mercury in the left leg of the manometer of Fig. P2.46 as a result of an increase in pressure of 5 psi in pipe A while the pressure in pipe B remains constant.

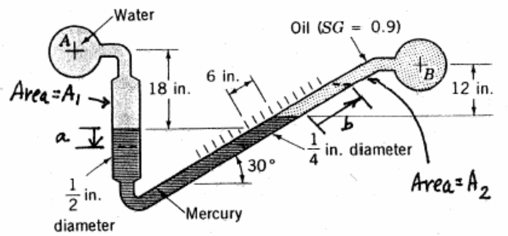


FIGURE P2.46

For the initial configuration:

$$p_A + \gamma_{H_2O}\left(\tfrac{18}{12}\right) - \gamma_{Hg}\left(\tfrac{6}{12}\sin 30^\circ\right) - \gamma_{oil}\left(\tfrac{12}{12}\right) = p_B \qquad (1)$$

where all lengths are in ft. When p_A increases to p_A' the left column falls by the distance, a, and the right column moves up the distance, b, as shown in the figure. For the final configuration:

$$p_A' + \gamma_{H_2O}\left(\tfrac{18}{12}+a\right) - \gamma_{Hg}\left(a + \tfrac{6}{12}\sin 30^\circ + b\sin 30^\circ\right) - \gamma_{oil}\left(\tfrac{12}{12} - b\sin 30^\circ\right) = p_B \qquad (2)$$

Subtract Eq. (1) from Eq. (2) to obtain

$$p_A' - p_A + \gamma_{H_2O}(a) - \gamma_{Hg}(a + b\sin 30^\circ) + \gamma_{oil}(b\sin 30^\circ) = 0 \qquad (3)$$

Since the volume of liquid must be constant $A_1 a = A_2 b$,

or $$\left(\tfrac{1}{2}\text{ in.}\right)^2 a = \left(\tfrac{1}{4}\text{ in.}\right)^2 b$$

so that $$b = 4a$$

Thus, Eq. (3) can be written as

$$p_A' - p_A + \gamma_{H_2O}(a) - \gamma_{Hg}(a + 4a\sin 30^\circ) + \gamma_{oil}(4a\sin 30^\circ) = 0$$

and

$$a = \frac{-(p_A' - p_A)}{\gamma_{H_2O} - \gamma_{Hg}(3) + \gamma_{oil}(2)} = \frac{-\left(5\ \frac{lb}{in.^2}\right)\left(144\ \frac{in.^2}{ft^2}\right)}{62.4\ \frac{lb}{ft^3} - \left(847\ \frac{lb}{ft^3}\right)(3) + (0.9)\left(62.4\ \frac{lb}{ft^3}\right)(2)}$$

$$= \underline{\underline{0.304\text{ ft (down)}}}$$

Individual HW Problems:

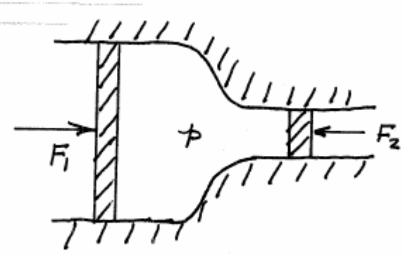
2.8 The drain plug in a bathtub is designed to seal properly when there is a 0.05 psi pressure applied to it. How deep must the water be in the tub for the plug to seal?

$$p = \gamma h$$

$$\left(0.05 \frac{lb}{in^2}\right)\left(144 \frac{in^2}{ft^2}\right) = \left(62.4 \frac{lb}{ft^3}\right)(h)$$

$$h = 0.115 \text{ ft} = \underline{\underline{1.38 \text{ in.}}}$$

2.13 A 0.3-m-diameter pipe is connected to a 0.02-m-diameter pipe and both are rigidly held in place. Both pipes are horizontal with pistons at each end. If the space between the pistons is filled with water, what force will have to be applied to the larger piston to balance a force of 80 N applied to the smaller piston? Neglect friction.



$$F_1 = p A_1$$

$$F_2 = p A_2$$

Thus,

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

or

$$F_1 = \frac{A_1}{A_2} F_2 = \frac{(0.3 m)^2}{(0.02 m)^2} (80 N) = \underline{\underline{18,000 N}}$$

2.16 On the suction side of a pump a Bourdon pressure gage reads 40-kPa vacuum. What is the corresponding absolute pressure if the local atmospheric pressure is 100 kPa (abs)?

$$p(abs) = p(gage) + p(atm)$$

$$= -40 \text{ kPa} + 100 \text{ kPa} = \underline{\underline{60 \text{ kPa}}}$$

2.27 A U-tube manometer is connected to a closed tank as shown in Fig. P2.27. The air pressure in the tank is 0.50 psi and the liquid in the tank is oil ($\gamma = 54.0 \text{ lb/ft}^3$). The pressure at point A is 2.00 psi. Determine: **(a)** the depth of oil, z, and **(b)** the differential reading, h, on the manometer.

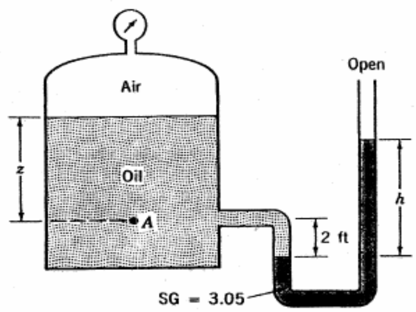


FIGURE P2.27

(a) $$p_A = \gamma_{oil}\, z + p_{air}$$

Thus,

$$z = \frac{p_A - p_{air}}{\gamma_{oil}} = \frac{\left(2 \frac{lb}{in.^2} - 0.5 \frac{lb}{in.^2}\right)\left(144 \frac{in.^2}{ft^2}\right)}{54.0 \frac{lb}{ft^3}} = \underline{\underline{4.00 \text{ ft}}}$$

(b) $$p_A + \gamma_{oil}\,(2 \text{ ft}) - (SG)(\gamma_{H_2O})\, h = 0$$

Thus,

$$h = \frac{p_A + \gamma_{oil}\,(2 \text{ ft})}{(SG)(\gamma_{H_2O})}$$

$$= \frac{\left(2 \frac{lb}{in.^2}\right)\left(144 \frac{in.^2}{ft^2}\right) + \left(54.0 \frac{lb}{ft^3}\right)(2 \text{ ft})}{(3.05)\left(62.4 \frac{lb}{ft^3}\right)}$$

$$= \underline{\underline{2.08 \text{ ft}}}$$

2.32 For the inclined-tube manometer of Fig. P2.32 the pressure in pipe A is 0.6 psi. The fluid in both pipes A and B is water, and the gage fluid in the manometer has a specific gravity of 2.6. What is the pressure in pipe B corresponding to the differential reading shown?

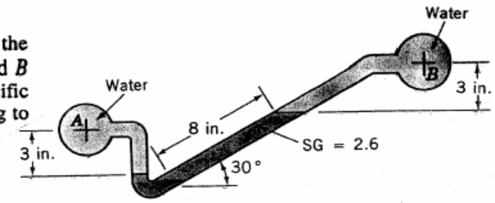


FIGURE P2.32

$$p_A + \gamma_{H_2O}\left(\tfrac{3}{12}\text{ ft}\right) - \gamma_{gf}\left(\tfrac{8}{12}\text{ ft}\right)\sin 30° - \gamma_{H_2O}\left(\tfrac{3}{12}\text{ ft}\right) = p_B$$

(where γ_{gf} is the specific weight of the gage fluid)

Thus,

$$p_B = p_A - \gamma_{gf}\left(\tfrac{8}{12}\text{ ft}\right)\sin 30°$$

$$= \left(0.6\ \frac{lb}{in.^2}\right)\left(144\ \frac{in.^2}{ft^2}\right) - (2.6)\left(62.4\ \frac{lb}{ft^3}\right)\left(\tfrac{8}{12}\text{ ft}\right)(0.5) = 32.3\ \frac{lb}{ft^2}$$

$$= 32.3\ lb/ft^2 / 144\ in.^2/ft^2 = \underline{\underline{0.224\ psi}}$$

2.35 The cyclindrical tank with hemispherical ends shown in Fig. P2.35 contains a volatile liquid and its vapor. The liquid density is 800 kg/m³, and its vapor density is negligible. The pressure in the vapor is 120 kPa (abs), and the atmospheric pressure is 101 kPa (abs). Determine: (a) the gage pressure reading on the pressure gage; and (b) the height, h, of the mercury manometer.

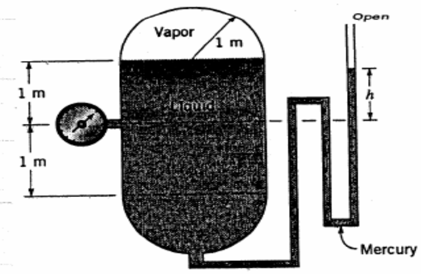


FIGURE P2.35

(a) Let γ_ℓ = sp. wt. of liquid $= \left(800\ \frac{kg}{m^3}\right)\left(9.81\ \frac{m}{s^2}\right) = 7850\ \frac{N}{m^3}$

and

$$p_{vapor}\ (gage) = 120\ kPa\ (abs) - 101\ kPa\ (abs) = 19\ kPa$$

Thus,

$$p_{gage} = p_{vapor} + \gamma_\ell\ (1 m)$$

$$= 19 \times 10^3\ \frac{N}{m^2} + \left(7850\ \frac{N}{m^3}\right)(1 m)$$

$$= \underline{\underline{26.9\ kPa}}$$

(b) $p_{vapor}\ (gage) + \gamma_\ell\ (1 m) - \gamma_{Hg}\ (h) = 0$

$$19 \times 10^3\ \frac{N}{m^2} + \left(7850\ \frac{N}{m^3}\right)(1 m) - \left(133 \times 10^3\ \frac{N}{m^3}\right)(h) = 0$$

$$h = \underline{\underline{0.202\ m}}$$

2.44 The inclined differential manometer of Fig. P2.44 contains carbon tetrachloride. Initially the pressure differential between pipes A and B, which contain a brine ($SG = 1.1$), is zero as illustrated in the figure. It is desired that the manometer give a differential reading of 12 in. (measured along the inclined tube) for a pressure differential of 0.1 psi. Determine the required angle of inclination, θ.

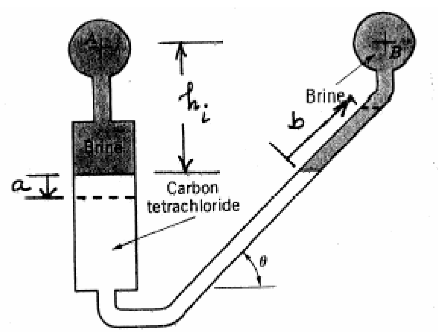


FIGURE P2.44

When $p_A - p_B$ is increased to $p_A' - p_B'$ the left column falls a distance, a, and the right column rises a distance b along the inclined tube as shown in figure. For this final configuration:

$$p_A' + \gamma_{br}(h_i + a) - \gamma_{CCl_4}(a + b\sin\theta) - \gamma_{br}(h_i - b\sin\theta) = p_B'$$

or

$$p_A' - p_B' + (\gamma_{br} - \gamma_{CCl_4})(a + b\sin\theta) = 0 \qquad (1)$$

The differential reading, Δh, along the tube is

$$\Delta h = \frac{a}{\sin\theta} + b$$

Thus, from Eq. (1)

$$p_A' - p_B' + (\gamma_{br} - \gamma_{CCl_4})(\Delta h \sin\theta) = 0$$

or

$$\sin\theta = \frac{-(p_A' - p_B')}{(\gamma_{br} - \gamma_{CCl_4})(\Delta h)}$$

and with $p_A' - p_B' = 0.1\,\text{psi}$

$$\sin\theta = \frac{-\left(0.1\,\frac{lb}{in.^2}\right)\left(144\,\frac{in.^2}{ft^2}\right)}{\left[(1.1)\left(62.4\,\frac{lb}{ft^3}\right) - 99.5\,\frac{lb}{ft^3}\right]\left(\frac{12}{12}\,ft\right)} = 0.466$$

for $\Delta h = 12$ in.

Thus,

$$\underline{\underline{\theta = 27.8^\circ}}$$