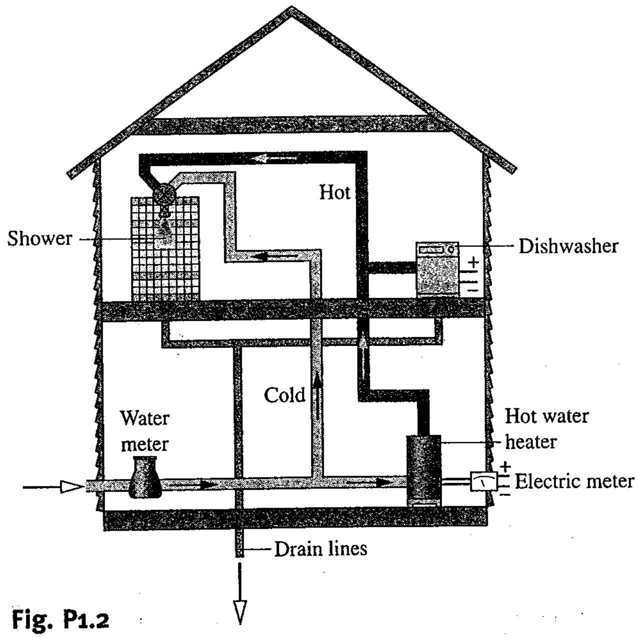

Fig. P1.2

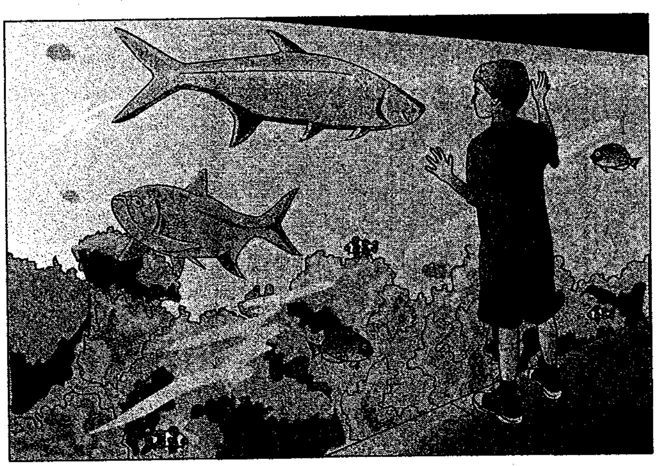

Fig. P1.3

Working with Units

1.4 Perform the following unit conversions:

(a) 1 L to in.^{3}
(b) 650 J to Btu
(c) 0.135 kW to ft · lbf/s
(d) 378 g/s to lb/min
(e) 304 kPa to lbf/in.^{2}
(f) 55 m^3/h to ft^3/s
(g) 50 km/h to ft/s
(h) 8896 N to ton (=2000 lbf)

1.5 Perform the following unit conversions:

(a) 122 in.^{3} to L
(b) 778.17 ft · lbf to kJ
(c) 100 hp to kW
(d) 1000 lb/h to kg/s
(e) 29.392 lbf/in.^{2} to bar
(f) 2500 ft^3/min to m^3/s
(g) 75 mile/h to km/h
(h) 1 ton (=2000 lbf) to N

Working with Force and Mass

1.6 If Superman has a mass of 100 kg on his birth planet Krypton, where the acceleration of gravity is 25 m/s^2, determine (a) his weight on Krypton, in N, and (b) his mass, in kg, and weight, in N, on Earth where g = 9.81 m/s^2.

1.7 A person whose mass is 150 lb weighs 144.4 lbf. Determine (a) the *local* acceleration of gravity, in ft/s^2, and (b) the person's mass, in lb and weight, in lbf, if g = 32.174 ft/s^2.

1.8 A gas occupying a volume of 25 ft^3 weighs 3.5 lbf on the moon, where the acceleration of gravity is 5.47 ft/s^2. Determine its weight, in lbf, and density, in lb/ft^3, on Mars, where g = 12.86 ft/s^2.

1.9 Atomic and molecular weights of some common substances are listed in Appendix Tables A-1 and A-1E. Using data from the appropriate table, determine

(a) the mass, in kg, of 20 kmol of each of the following: air, C, H_2O, CO_2.
(b) the number of lbmol in 50 lb of each of the following: H_2, N_2, NH_3, C_3H_8.

1.10 In severe head-on automobile accidents, a deceleration of 60 g's or more (1 g = 32.2 ft/s^2) often results in a fatality. What force, in lbf, acts on a child whose mass is 50 lb, when subjected to a deceleration of 60 g's?

1.11 At the grocery store you place a pumpkin with a mass of 12.5 lb on the produce spring scale. The spring in the scale operates such that for each 4.7 lbf applied, the spring elongates one inch. If local acceleration of gravity is 32.2 ft/s^2, what distance, in inches, did the spring elongate?

1.12 A spring compresses in length by 0.14 in. for every 1 lbf of applied force. Determine the mass of an object, in pounds mass, that causes a spring deflection of 1.8 in. The local acceleration of gravity = 31 ft/s^2.

1.13 At a certain elevation, the pilot of a balloon has a mass of 120 lb and a weight of 119 lbf. What is the local acceleration of gravity, in ft/s^2, at that elevation? If the balloon drifts to another elevation where g = 32.05 ft/s^2, what is her weight, in lbf, and mass, in lb?

1.14 Estimate the magnitude of the force, in lbf, exerted on a 12-lb goose in a collision of duration 10^{-3} s with an airplane taking off at 150 miles/h.

1.15 Determine the upward applied force, in lbf, required to accelerate a 4.5-lb model rocket vertically upward, as shown in Fig. P1.15, with an acceleration of 3 g's. The only other significant force acting on the rocket is gravity, and 1 g = 32.2 ft/s^2.

1.16 An object is subjected to an applied upward force of 10 lbf. The only other force acting on the object is the force of gravity. The acceleration of gravity is 32.2 ft/s^2. If the object has a mass of 50 lb, determine the net acceleration of the object, in ft/s^2. Is the net acceleration upward or downward?

1.17 An astronaut weighs 700 N on Earth where g = 9.81 m/s^2. What is the astronaut's weight, in N, on an orbiting space station where the acceleration of gravity is 6 m/s^2? Express each weight in lbf.

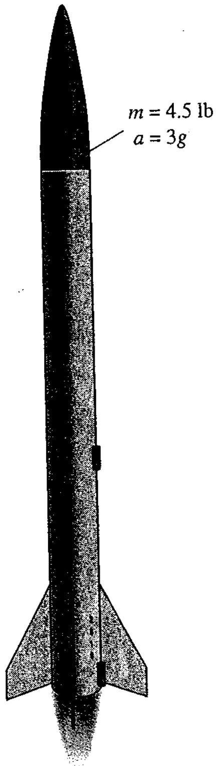

Fig. P1.15

1.18 Using local acceleration of gravity data from the Internet, determine the weight, in N, of a person whose mass is 80 kg living in:

(a) Mexico City, Mexico
(b) Cape Town, South Africa
(c) Tokyo, Japan
(d) Chicago, IL
(e) Copenhagen, Denmark

1.19 A town has a 1-million-gallon storage capacity water tower. If the density of water is 62.4 lb/ft^3 and local acceleration of gravity is 32.1 ft/s^2, what is the force, in lbf, the structural base must provide to support the water in the tower?

Using Specific Volume, Volume, and Pressure

1.20 A closed system consists of 0.5 kmol of ammonia occupying a volume of 6 m^3. Determine (a) the weight of the system, in N, and (b) the specific volume, in m^3/kmol and m^3/kg. Let $g = 9.81$ m/s^2.

1.21 A spherical balloon holding 35 lb of air has a diameter of 10 ft. For the air, determine (a) the specific volume, in ft^3/lb and ft^3/lbmol, and (b) the weight, in lbf. Let $g = 31.0$ ft/s^2.

1.22 A closed vessel having a volume of 1 liter holds 2.5×10^{22} molecules of ammonia vapor. For the ammonia, determine (a) the amount present, in kg and kmol, and (b) the specific volume, in m^3/kg and m^3/kmol.

1.23 The specific volume of water vapor at 0.3 MPa, 160°C is 0.651 m^3/kg. If the water vapor occupies a volume of 2 m^3, determine (a) the amount present, in kg and kmol, and (b) the number of molecules.

1.24 The pressure of the gas contained in the piston–cylinder assembly of Fig. 1.1 varies with its volume according to $p = A + (B/V)$, where A, B are constants. If pressure is in lbf/ft^2 and volume is in ft^3, what are the units of A and B?

1.25 As shown in Figure P1.25, a gas is contained in a piston–cylinder assembly. The piston mass and cross-sectional area are denoted m and A, respectively. The only force acting on the top of the piston is due to atmospheric pressure, p_{atm}. Assuming the piston moves smoothly in the cylinder and the local acceleration of gravity g is constant, show that the pressure of the gas acting on the bottom of the piston remains constant as gas volume varies. What would cause the gas volume to vary?

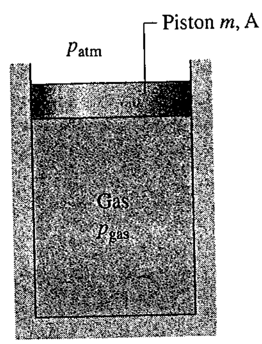

Fig. P1.25

1.26 As shown in Fig. P1.26, a vertical piston–cylinder assembly containing a gas is placed on a hot plate. The piston initially rests on the stops. With the onset of heating, the gas pressure increases. At what pressure, in bar, does the piston start rising? The piston moves smoothly in the cylinder and $g = 9.81$ m/s^2.

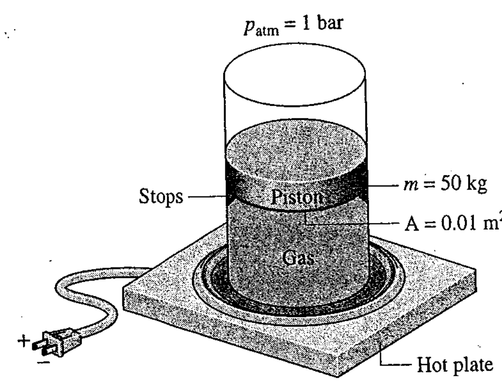

Fig. P1.26

1.27 Three kg of gas in a piston–cylinder assembly undergo a process during which the relationship between pressure and specific volume is $pv^{0.5} = constant$. The process begins with $p_1 = 250$ kPa and $V_1 = 1.5$ m^3 and ends with $p_2 = 100$ kPa. Determine the final specific volume, in m^3/kg. Plot the process on a graph of pressure versus specific volume.

1.28 A closed system consisting of 2 lb of a gas undergoes a process during which the relation between pressure and volume is $pV^n = constant$. The process begins with $p_1 =$ 20 lbf/in.^{2}, $V_1 = 10$ ft^3 and ends with $p_2 = 100$ lbf/in.^{2}, $V_2 = 2.9$ ft^3. Determine (a) the value of n and (b) the specific volume at states 1 and 2, each in ft³/lb. (c) Sketch the process on pressure-volume coordinates.

1.29 A system consists of carbon monoxide (CO) in a piston–cylinder assembly, initially at $p_1 = 200$ lbf/in.², and occupying a volume of 2.0 m³. The carbon monoxide expands to $p_2 = 40$ lbf/in.² and a final volume of 3.5 m³. During the process, the relationship between pressure and volume is linear. Determine the volume, in ft³, at an intermediate state where the pressure is 150 lbf/in.², and sketch the process on a graph of pressure versus volume.

1.30 Figure P1.30 shows a gas contained in a vertical piston–cylinder assembly. A vertical shaft whose cross-sectional area is 0.8 cm² is attached to the top of the piston. Determine the magnitude, F, of the force acting on the shaft, in N, required if the gas pressure is 3 bar. The masses of the piston and attached shaft are 24.5 kg and 0.5 kg, respectively. The piston diameter is 10 cm. The local atmospheric pressure is 1 bar. The piston moves smoothly in the cylinder and $g = 9.81$ m/s².

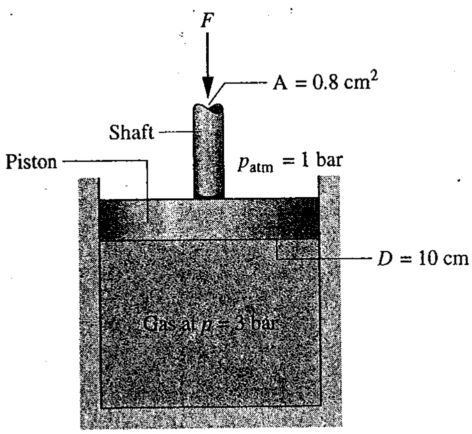

Fig. P1.30

1.31 A gas contained within a piston–cylinder assembly undergoes three processes in series:

Process 1–2: Compression with $pV = constant$ from $p_1 = 1$ bar, $V_1 = 1.0$ m³ to $V_2 = 0.2$ m³

Process 2–3: Constant-pressure expansion to $V_3 = 1.0$ m³

Process 3–1: Constant volume

Sketch the processes in series on a p–V diagram labeled with pressure and volume values at each numbered state.

1.32 Referring to Fig. 1.7,

(a) if the pressure in the tank is 1.5 bar and atmospheric pressure is 1 bar, determine L, in m, for water with a density of 997 kg/m³ as the manometer liquid. Let $g = 9.81$ m/s².

(b) determine L, in cm, if the manometer liquid is mercury with a density of 13.59 g/cm³ and the gas pressure is 1.3 bar. A barometer indicates the local atmospheric pressure is 750 mmHg. Let $g = 9.81$ m/s².

1.33 Figure P1.33 shows a storage tank holding natural gas. In an adjacent instrument room, a U-tube mercury manometer in communication with the storage tank reads $L = 1.0$ m. If the atmospheric pressure is 101 kPa, the density of the mercury is 13.59 g/cm³, and $g = 9.81$ m/s², determine the pressure of the natural gas, in kPa.

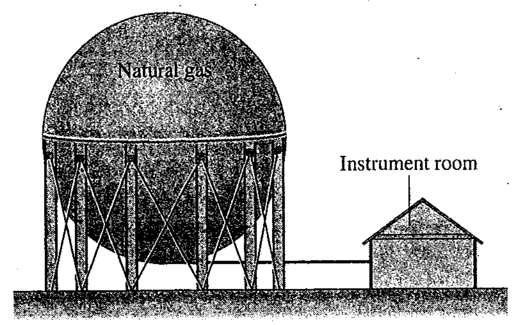

Fig. P1.33

1.34 As shown in Figure P1.34, the exit of a gas compressor empties into a receiver tank, maintaining the tank contents at a pressure of 200 kPa. If the local atmospheric pressure is 1 bar, what is the reading of the Bourdon gage mounted on the tank wall in kPa? Is this a *vacuum* pressure or a *gage* pressure? Explain.

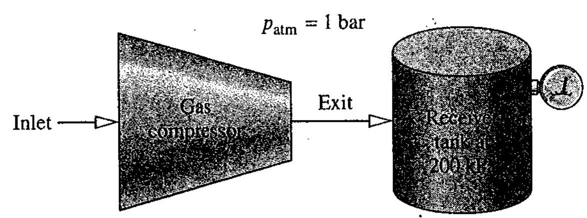

Fig. P1.34

1.35 The barometer shown in Fig. P1.35 contains mercury ($\rho = 13.59$ g/cm³). If the local atmospheric pressure is 100 kPa and $g = 9.81$ m/s², determine the height of the mercury column, L, in mmHg and inHg.

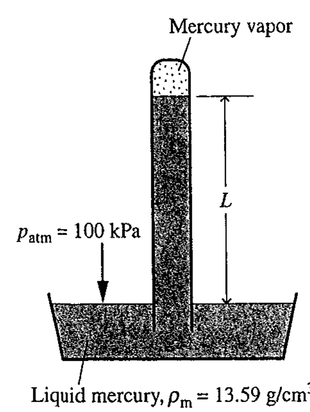

Fig. P1.35

1.36 Water flows through a *Venturi meter,* as shown in Fig. P1.36. The pressure of the water in the pipe supports columns of water that differ in height by 10 in. Determine the difference in pressure between points a and b, in lbf/in.² Does the pressure increase or decrease in the direction of flow? The atmospheric pressure is 14.7 lbf/in.^{2}, the specific volume of water is 0.01604 ft^3/lb, and the acceleration of gravity is $g = 32.0$ ft/s^2.

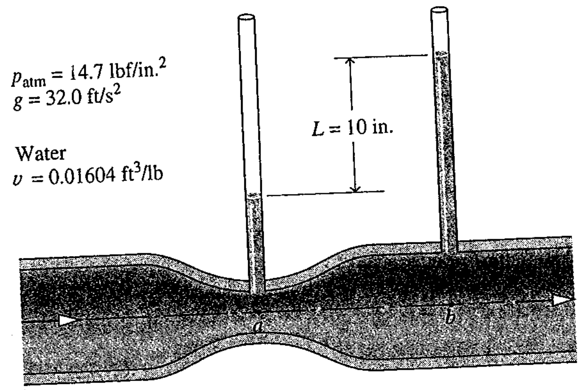

Fig. P1.36

1.37 Figure P1.37 shows a tank within a tank, each containing air. The absolute pressure in tank A is 267.7 kPa. Pressure gage A is located inside tank B and reads 140 kPa. The U-tube manometer connected to tank B contains mercury. Using data on the diagram, determine the absolute pressure inside tank B, in kPa, and the column length L, in cm. The atmospheric pressure surrounding tank B is 101 kPa. The acceleration of gravity is $g = 9.81$ m/s^2.

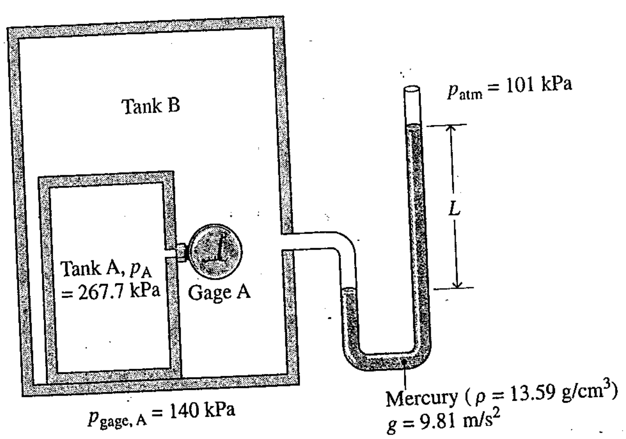

Fig. P1.37

1.38 As shown in Fig. P1.38, an underwater exploration vehicle submerges to a depth of 1000 ft. If the atmospheric pressure at the surface is 1 atm, the water density is 62.4 lb/ft^3, and $g = 32.2$ ft/s^2, determine the pressure on the vehicle, in atm.

1.39 A vacuum gage indicates that the pressure of carbon dioxide in a closed tank is −10 kPa. A mercury barometer gives the local atmospheric pressure as 750 mmHg. Determine the absolute pressure of the carbon dioxide, in kPa. The density of mercury is 13.59 g/cm^3 and $g = 9.81$ m/s^2.

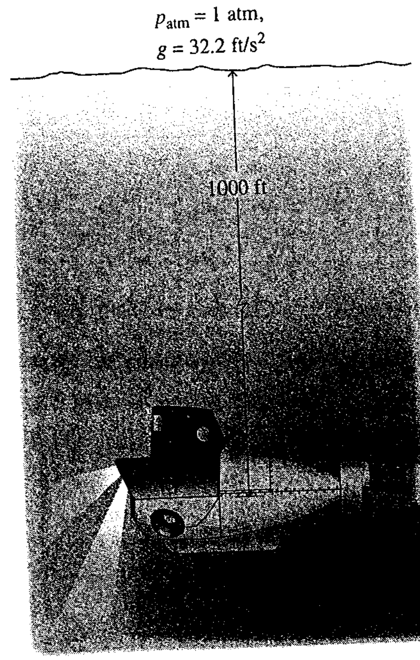

Fig. P1.38

1.40 A gas enters a compressor that provides a pressure ratio (exit pressure to inlet pressure) equal to 8. If a gage indicates the gas pressure at the inlet is 5.5 psig, what is the absolute pressure, in psia, of the gas at the exit? Atmospheric pressure is 14.5 lbf/in.^{2}

1.41 As shown in Fig. P1.41, air is contained in a vertical piston-cylinder assembly fitted with an electrical resistor. The atmosphere exerts a pressure of 14.7 lbf/in.^{2} on the top of the piston, which has a mass of 100 lb and face area of 1 ft^2. As electric current passes through the resistor, the volume of the air increases while the piston moves smoothly in the cylinder. The local acceleration of gravity is $g = 32.0$ ft/s^2. Determine the pressure of the air in the piston-cylinder assembly, in lbf/in.^{2} and psig.

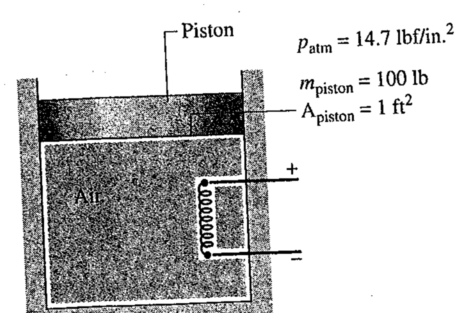

Fig. P1.41

1.42 Warm air is contained in a piston-cylinder assembly oriented horizontally as shown in Fig. P1.42. The air cools slowly from an initial volume of 0.003 m^3 to a final volume of 0.002 m^3. During the process, the spring exerts a force that varies linearly from an initial value of 900 N to a final value of zero. The atmospheric pressure is 100 kPa, and the area of the piston face is 0.018 m^2. Friction between the piston and the cylinder wall can be neglected. For the air in the piston-cylinder assembly, determine the initial and final pressures, each in kPa and atm.

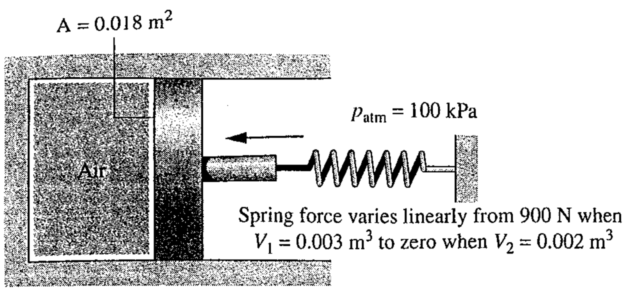

Fig. P1.42

1.43 The pressure from water mains located at street level may be insufficient for delivering water to the upper floors of tall buildings. In such a case, water may be pumped up to a tank that feeds water to the building by gravity. For an open storage tank atop a 300-ft-tall building, determine the pressure, in lbf/in.^{2}, at the bottom of the tank when filled to a depth of 20 ft. The density of water is 62.2 lb/ft^3, g = 32.0 ft/s^2, and the local atmospheric pressure is 14.7 lbf/in.^{2}

1.44 Figure P1.44 shows a tank used to collect rainwater having a diameter of 4 m. As shown in the figure, the depth of the tank varies linearly from 3.5 m at its center to 3 m along the perimeter. The local atmospheric pressure is 1 bar, the acceleration of gravity is 9.8 m/s^2, and the density of the water is 987.1 kg/m^3. When the tank is filled with water, determine

(a) the pressure, in kPa, at the bottom center of the tank.
(b) the total force, in kN, acting on the bottom of the tank.

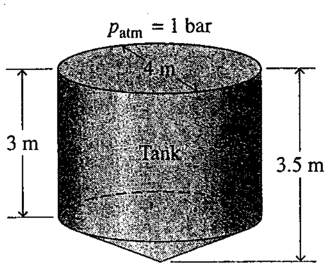

Fig. P1.44

1.45 If the water pressure at the base of the water tower shown in Fig. P1.45 is 4.15 bar, determine the pressure of the air trapped above the water level, in bar. The density of the water is 10^3 kg/m^3 and g = 9.81 m/s^2.

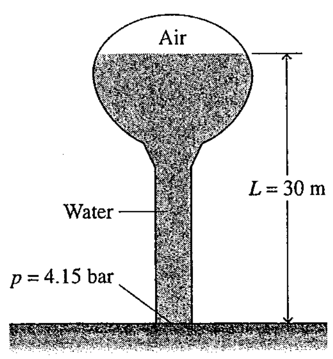

Fig. P1.45

1.46 As shown in Figure P1.46, an *inclined* manometer is used to measure the pressure of the gas within the reservoir. (a) Using data on the figure, determine the gas pressure, in lbf/in.^{2} (b) Express the pressure as a gage or a vacuum pressure, as appropriate, in lbf/in.^{2} (c) What advantage does an inclined manometer have over the U-tube manometer shown in Figure 1.7?

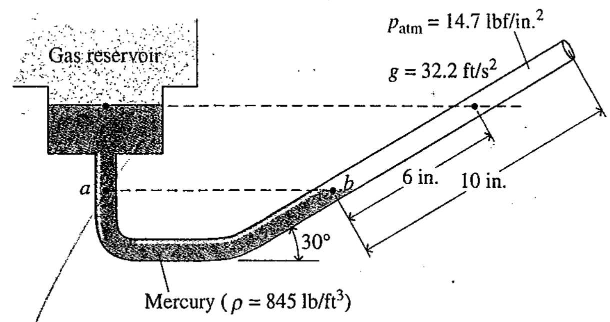

Fig. P1.46

1.47 Figure P1.47 shows a spherical buoy, having a diameter of 1.5 m and weighing 8500 N, anchored to the floor of a lake by a cable. Determine the force exerted by the cable, in N. The density of the lake water is 10^3 kg/m^3 and g = 9.81 m/s^2.

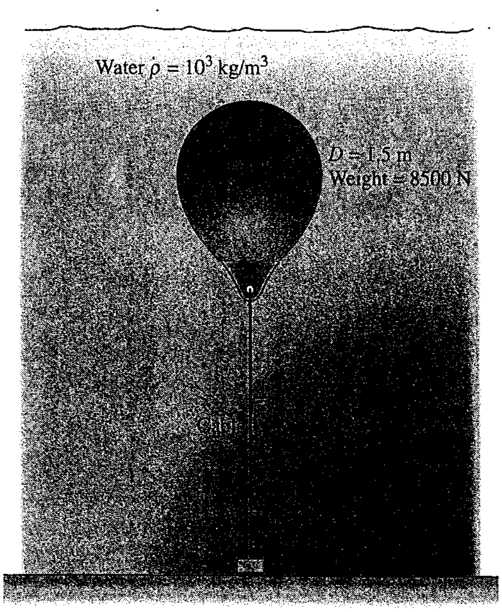

Fig. P1.47

1.48 Because of a break in a buried oil storage tank, groundwater has leaked into the tank to the depth shown in Fig. P1.48. Determine the pressure at the oil–water interface and at the bottom of the tank, each in lbf/in.^{2} (gage). The densities of the water and oil are, respectively, 62 and 55, each in lb/ft^3. Let g = 32.2 ft/s^2.

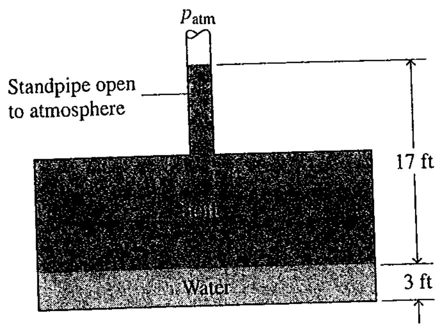

Fig. P1.48

1.49 Figure P1.49 shows a closed tank holding air and oil to which is connected a U-tube mercury manometer and a pressure gage. Determine the reading of the pressure gage, in lbf/in.^{2} (gage). The densities of the oil and mercury are 55 and 845, respectively, each in lb/ft^3. Let g = 32.2 ft/s^2.

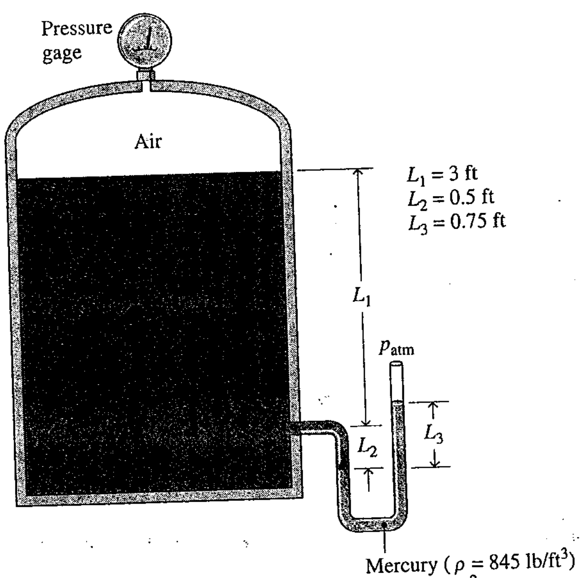

Fig. P1.49

Exploring Temperature

1.50 The 30-year average temperature in Toronto, Canada, during summer is 19.5°C and during winter is –4.9°C. What are the equivalent average summer and winter temperatures in °F and °R?

1.51 Convert the following temperatures from °F to °C: (a) 86°F, (b) –22°F, (c) 50°F, (d) –40°F, (e) 32°F, (f) –459.67°F. Convert each temperature to K.

1.52 Natural gas is burned with air to produce gaseous products at 1985°C. Express this temperature in K, °R, and °F.

1.53 The temperature of a child ill with a fever is measured as 40°C. The child's normal temperature is 37°C. Express both temperatures in °F.

1.54 Does the Rankine degree represent a larger or smaller temperature unit than the Kelvin degree? Explain.

1.55 Figure P1.55 shows a system consisting of a cylindrical copper rod insulated on its lateral surface while its ends are in contact with hot and cold walls at temperatures 1000°R and 500°R, respectively.

(a) Sketch the variation of temperature with position through the rod, x.
(b) Is the rod in equilibrium? Explain.

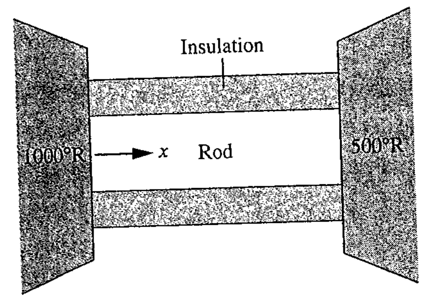

Fig. P1.55

1.56 What is (a) the lowest *naturally* occurring temperature recorded on Earth, (b) the lowest temperature recorded in a laboratory on Earth, (c) the lowest temperature recorded in the Earth's solar system, and (d) the temperature of deep space, each in K?

1.57 What is the maximum increase and maximum decrease in body temperature, each in °C, from a normal body temperature of 37°C that humans can experience before serious medical complications result?

1.58 For liquid-in-glass thermometers, the *thermometric* property is the change in length of the thermometer liquid with temperature. However, other effects are present that can affect the temperature reading of such thermometers. What are some of these?

Reviewing Concepts

1.59 Answer the following true or false. Explain.

(a) A closed system always contains the same matter; there is no transfer of matter across its boundary.
(b) The volume of a closed system can change.
(c) One nanosecond equals 10^9 seconds.
(d) When a closed system undergoes a process between two specified states, the change in temperature between the end states is independent of details of the process.
(e) Body organs, such as the human heart, whose shapes change as they perform their normal functions can be studied as control volumes.
(f) This book takes a *microscopic* approach to thermodynamics.

1.60 Answer the following true or false. Explain.

(a) 1 N equals 1 kg · m/s^2 but 1 lbf does *not* equal 1 lb · ft/s^2.
(b) Specific volume, the volume per unit of mass, is an intensive property while volume and mass are extensive properties.
(c) The kilogram for mass and the meter for length are examples of SI base units defined relative to fabricated objects.
(d) If the value of *any* property of a system changes with time, that system cannot be at steady state.