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

1.6 Which of the following food items weighs approximately 1 newton?

a. a grain of rice
b. a small strawberry
c. a medium-sized apple
d. a large watermelon

Working with Force and Mass

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 The *Phoenix* with a mass of 350 kg was a spacecraft used for exploration of Mars. Determine the weight of the *Phoenix*, in N, (a) on the surface of Mars where the acceleration of gravity is 3.73 m/s^2 and (b) on Earth where the acceleration of gravity is 9.81 m/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.

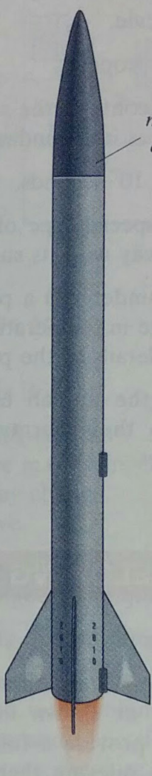

Fig. P1.15

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 A communications satellite weighs 4400 N on Earth where $g = 9.81$ m/s^2. What is the weight of the satellite, in N, as it orbits Earth where the acceleration of gravity is 0.224 m/s^2? Express each weight in lbf.

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 2-lb sample of an unknown liquid occupies a volume of 62.6 in.^{3} For the liquid determine (a) the specific volume, in ft^3/lb, and (b) the density, in lb/ft^3.

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 5 kg of water vapor at 1.5 MPa, 440°C is 0.2160 m^3/kg. Determine (a) the volume, in m^3, occupied by the water vapor, (b) the amount of water vapor present, in gram moles, and (c) 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?

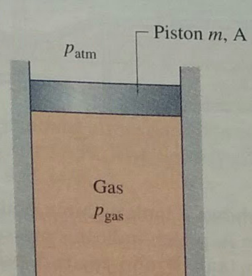

Fig. P1.25

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.

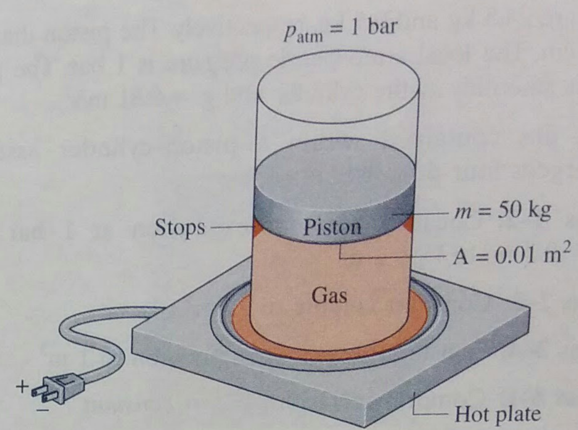

Fig. P1.26

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 4 lb of a gas undergoes a process during which the relation between pressure and volume *is* $pV^n = constant$. The process begins with $p_1 = 15$ lbf/in.^{2}, $v_1 = 1.25$ ft^3/lb and ends with $p_2 = 53$ lbf/in.^{2}, $v_2 = 0.5$ ft^3/lb. Determine (a) the volume, in ft^3, occupied by the gas at states 1 and 2 and (b) the value of n. (c) Sketch Process 1–2 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 m^3. The carbon monoxide expands to $p_2 = 40$ lbf/in.^{2} and a final volume of 3.5 m^3. During the process, the relationship between pressure and volume is linear. Determine the volume, in ft^3, 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 cm^2 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

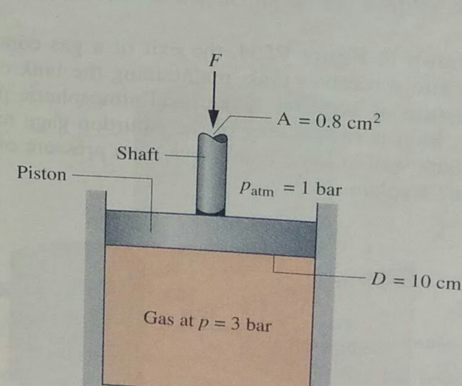

Fig. P1.30

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/s^2.

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

Process 1–2: Constant-pressure expansion at 1 bar from V_1 = 0.5 m^3 to V_2 = 2 m^3

Process 2–3: Constant volume to 2 bar

Process 3–4: Constant-pressure compression to 1 m^3

Process 4–1: Compression with pV^{-1} = *constant*

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/m^3 as the manometer liquid. Let g = 9.81 m/s^2.
(b) determine L, in cm, if the manometer liquid is mercury with a density of 13.59 g/cm^3 and the gas pressure is 1.3 bar. A barometer indicates the local atmospheric pressure is 750 mmHg. Let g = 9.81 m/s^2.

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/cm^3, and g = 9.81 m/s^2, determine the pressure of the natural gas, in kPa.

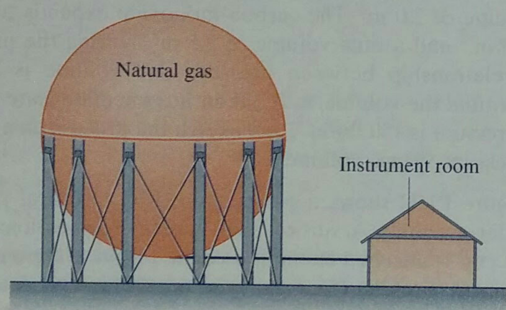

Fig. P1.33

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.

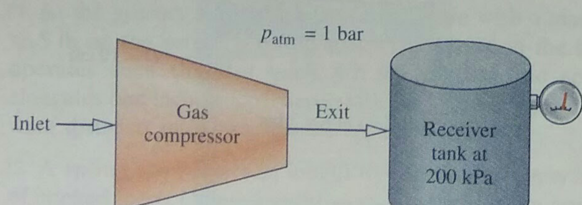

Fig. P1.34

1.35 The barometer shown in Fig. P1.35 contains mercury (ρ = 13.59 g/cm^3). If the local atmospheric pressure is 100 kPa and g = 9.81 m/s^2, determine the height of the mercury column, L, in mmHg and inHg.

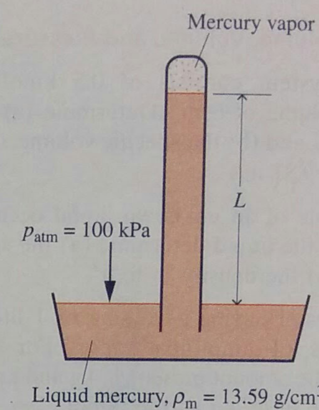

Fig. P1.35

1.36 Liquid kerosene flows through a Venturi meter, as shown in Fig. P1.36. The pressure of the kerosene in the pipe supports columns of kerosene that differ in height by 12 cm. Determine the difference in pressure between points a and b, in kPa. Does the pressure increase or decrease as the kerosene flows from point a to point b as the pipe diameter decreases? The atmospheric pressure is 101 kPa, the specific volume of kerosene is 0.00122 m^3/kg, and the acceleration of gravity is g = 9.81 m/s^2.

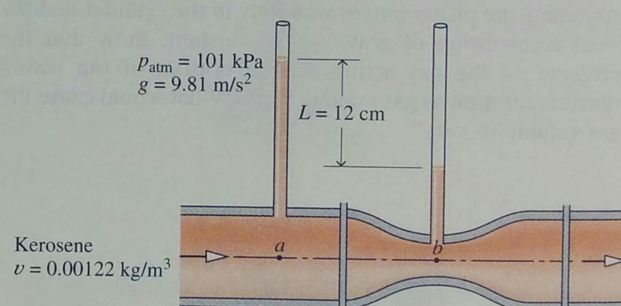

Fig. P1.36

1.37 Figure P1.37 shows a tank within a tank, each containing air. Pressure gage A, which indicates pressure inside tank A, is located inside tank B and reads 5 psig (vacuum). The U-tube manometer connected to tank B contains water with a column length of 10 in. Using data on the diagram, determine the absolute pressure of the air inside tank B and inside tank A, both in psia. The atmospheric pressure surrounding tank B is 14.7 psia. The acceleration of gravity is g = 32.2 ft/s^2.

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.

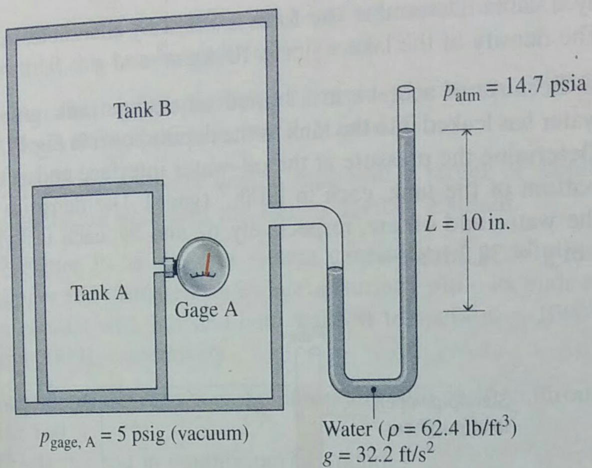

Fig. P1.37

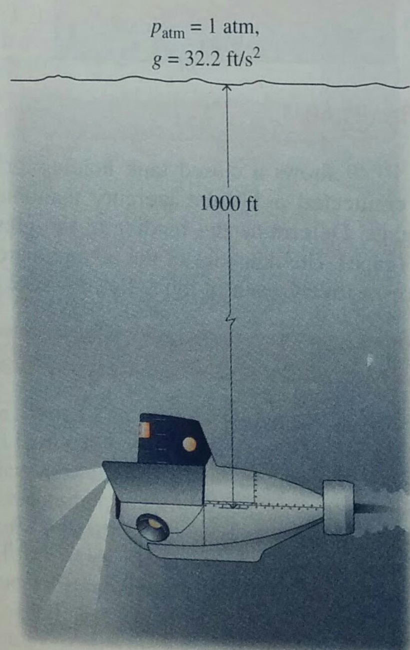

Fig. P1.38

1.39 Show that a standard atmospheric pressure of 760 mmHg is equivalent to 101.3 kPa. The density of mercury is 13,590 kg/m^3 and $g = 9.81\ m/s^2$.

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 Figure P1.41, air is contained in a vertical piston–cylinder assembly such that the piston is in static equilibrium. The atmosphere exerts a pressure of 14.7 $lbf/in.^2$ on top of the 6-in.-diameter piston. The absolute pressure of the air inside the cylinder is 16 $lbf/in.^2$ The local acceleration of gravity is $g = 32.2\ ft/s^2$. Determine (a) the mass of the piston, in lb, and (b) the gage pressure of the air in the cylinder, in psig.

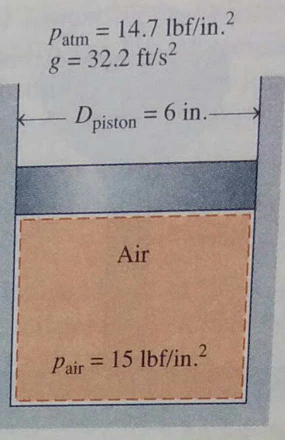

Fig. P1.41

1.42 Air is contained in a vertical piston–cylinder assembly such that the piston is in static equilibrium. The atmosphere exerts a pressure of 101 kPa on top of the 0.5-m-diameter piston. The gage pressure of the air inside the cylinder is 1.2 kPa. The local acceleration of gravity is $g = 9.81\ m/s^2$. Subsequently, a weight is placed on top of the piston causing the piston to fall until reaching a new static equilibrium position. At this position, the gage pressure of the air inside the cylinder is 2.8 kPa. Determine (a) the mass of the piston, in kg, and (d) the mass of the added weight, in kg.

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.

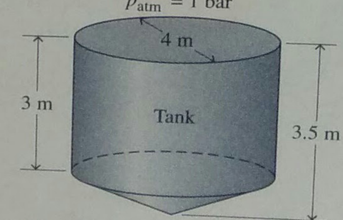

Fig. P1.44

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 $g = 9.81\ m/s^2$.