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/s², 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/s².

1.7 A person whose mass is 150 lb weighs 144.4 lbf. Determine (a) the local acceleration of gravity, in ft/s², and (b) the person's mass, in lb and weight, in lbf, if \( g = 32.174 \) ft/s².

1.8 A gas occupying a volume of 25 ft³ weighs 3.5 lbf on the moon, where the acceleration of gravity is 5.47 ft/s². Determine its weight, in lb, and density, in lb/ft³, on Mars, where \( g = 12.86 \) ft/s².

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, \( \text{C}_2\text{H}_6\text{O}, \text{CO}_2 \),
(b) the number of lbmol in 50 lb of each of the following: \( \text{H}_2, \text{N}_2, \text{NH}_3, \text{C}_2\text{H}_6 \).

1.10 In severe head-on automobile accidents, a deceleration of 60 g's or more (1 g = 32.2 ft/s²) 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/s², 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/s².

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/s², at that elevation? If the balloon drifts to another elevation where \( g = 32.05 \) ft/s², 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/s².

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/s². If the object has a mass of 30 lb, determine the net acceleration of the object, in ft/s². Is the net acceleration upward or downward?

1.17 An astronaut weighs 700 N on Earth where \( g = 9.81 \) m/s². What is the astronaut's weight, in N, on an orbiting space station where the acceleration of gravity is 6 m/s²? 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 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 $2.5 \times 10^{22}$ 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, $P_{\text{atm}}$. 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?

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$^2$.

1.27 Three kg of gas in a piston–cylinder assembly undergo a process during which the relationship between pressure and specific volume is $pV^n = \text{constant}$. 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 $pV^n = \text{constant}$. The process begins with $p_1 = 20$ lbf/in$^2$, $V_1 = 10$ ft$^3$ and ends with $p_2 = 100$ lbf/in$^2$, $V_2 = 29$ ft$^3$. Determine (a) the value of $n$ and (b) the specific volume at
states 1 and 2, each in ft^3/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 $p_1 = 200$ lb/in.\(^2\), and occupying a volume of 2.0 m\(^3\). The carbon monoxide expands to $p_2 = 40$ lb/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 lb/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 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\(^2\).

![Fig. P1.30](image)

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, $V_1 = 1.0$ m\(^3\) to $V_2 = 0.2$ m\(^3\)
- **Process 2→3:** Constant-pressure expansion to $V_3 = 1.0$ m\(^3\)
- **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/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](image)

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](image)

1.35 The barometer shown in Fig. P1.35 contains mercury ($\rho = 13.59$ 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](image)

1.36 Water flows through a *Vesled* 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
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 lb/ft² (gage). The densities of the oil and mercury are 55 and 845, respectively, each in lb/ft³. Let \( g = 32.2 \text{ ft/s}^2 \).

![Figure P1.49](image)

**Fig. P1.49**

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°F and 500°F, respectively.

(a) Sketch the variation of temperature with position through the rod, \( x \).

(b) Is the rod in equilibrium? Explain.

![Figure P1.55](image)

**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?

**Exploring Temperature**

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 10⁴ 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/s² but 1 lbf does not equal 1 lb · ft/s².

(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.