Prob 1.6

a.) \[ F_{\text{gravity}} = mg = 100 \text{ kg} \times 25 \text{ m} \frac{1 \text{ N}}{\text{s}^2 \text{ kg m/s}^2} \]
\[ = 2500 \text{ N} \]

b.) Mass is constant
\[ F_{\text{gravity}} = mg = 100 \text{ kg} \times 9.81 \text{ m} \frac{1 \text{ N}}{\text{s}^2 \text{ kg m/s}^2} \]
\[ = 981 \text{ N on Earth} \]

Prob 1.7

a.) \[ g = \frac{F_{\text{gravity}}}{m} = \frac{144.4 \text{ lb}}{150 \text{ lbm}} \frac{32.174 \text{ lbm} \cdot \text{ ft/s}^2}{1 \text{ lb} \cdot \text{ ft/s}^2} \]
\[ = 30.97 \text{ ft/s}^2 \]

b.) Mass is constant
\[ F_{\text{gravity}} = mg = \frac{150 \text{ lbm}}{32.174 \frac{\text{lbm} \cdot \text{ ft/s}^2}{\text{s}^2}} \times 32.174 \frac{\text{lbm} \cdot \text{ ft}}{\text{s}^2} \]
\[ = 150 \text{ lbf} \]
Mass is constant
\[ F_g = mg \]
\[ m = \frac{F_g}{g} \]
\[ \left( \frac{F_g}{g} \right)_{\text{Mars}} = \left( \frac{F_g}{g} \right)_{\text{Moon}} \]

\[ F_g = \frac{g_{\text{Mars}}}{g_{\text{Moon}}} \]

\[ = \frac{12.86 \text{ ft/s}^2}{5.47 \text{ ft/s}^2} \]

\[ 3.516 = 8.23 \text{ lb/ft}^2 \]

\[ p = \frac{m}{V} \Rightarrow \frac{8.23 \text{ lb/ft}^2}{12.86 \text{ ft/s}^2} = \frac{32.174 \text{ lb-m ft/s}^2}{1 \text{ lb}} = 20.61 \text{ lb/m} = \text{ mass} \]

\[ p = \frac{20.61 \text{ lb/m}}{25 \text{ ft}^3} = 0.824 \text{ lb/m ft}^3 \]
Weight \sim \text{Gravity} = mg
\downarrow
119 \text{ lb}
\downarrow
downarrow 120 \text{ lbm}

\begin{align*}
g &= \frac{\text{Gravity}}{m} = \frac{119}{120} \frac{32.174 \text{ lbm ft}}{16 \text{ lb f}^2} \\
g &= 31.91 \text{ ft/s}^2
\end{align*}

If \( m = 120 \text{ lbm} \), \( g = 32.05 \text{ ft/s}^2 \)

\begin{align*}
\text{Gravity} = mg &= 120 (32.05) \frac{1}{32.174} \\
&= 119.54 \text{ lb}
\end{align*}

However, mass is constant.
1.20

\[ 0.5 \text{ kmol NH}_3 \quad \text{Eq 1.8} \quad n = nM = 0.5 \text{ kmol (17.03 kg/kmol)} \]
\[ = 8.52 \text{ kg} \]
\[ F_{\text{gravity}} = 8.52 \text{ kg} 9.81 \frac{M}{s^2} \frac{1N}{kgm} \]
\[ = 83.58 \text{ N} \]

\[ \overline{N} = \frac{V}{n} = \frac{6 \text{ m}^3}{0.5 \text{ kmol}} = 12 \text{ m}^3/\text{kmol} \]
\[ \overline{N} = \frac{V}{m} = \frac{6 \text{ m}^3}{8.52 \text{ kg}} = 0.704 \text{ m}^3/\text{kg} \]
The final specific volume, \( v_2 \), can be determined from

\[
p_1 v_1^{0.5} = p_2 v_2^{0.5}
\]

Solving for \( v_2 \) yields

\[
v_2 = v_1 \left( \frac{p_1}{p_2} \right)^{0.5}
\]

Specific volume at the initial state, \( v_1 \), can be determined by dividing the volume at the initial state, \( V_1 \), by the mass, \( m \), of the system

\[
v_1 = \frac{V_1}{m} = \frac{1.5 \text{ m}^3}{3 \text{ kg}} = 0.5 \text{ m}^3/\text{kg}
\]

Substituting values for pressures and specific volume yields

\[
v_2 = \left( 0.5 \frac{\text{m}^3}{\text{kg}} \right) \left( \frac{250 \text{ kPa}}{100 \text{ kPa}} \right)^{0.5} = 3.125 \text{ m}^3/\text{kg}
\]

The volume of the system increased while pressure decreased during the process.

A plot of the process or a pressure versus specific volume graph is as follows:
Known: Car of known weight travels from sea level to known elevation

Find: \( \Delta PE \)

\[ F_{\text{weight}} = 2500 \text{lb} \]

\[ \Delta PE = mg(z_2 - z_1) \]

\[ = 2500 \text{ lb} \left( 7000 \text{ ft} - 0 \text{ ft} \right) \]

\[ = 17.5 \times 10^6 \text{ lb} \cdot \text{ft} \left( \frac{1 \text{ lb} \cdot \text{ft}}{1.78 \times 10^7 \text{ lb} \cdot \text{ft}} \right) \]

\[ = 2.25 \times 10^4 \text{ BTU} \]
KNOWN: Data are provided for an automobile on the open road.

EINo. Determine the change in kinetic energy and gravitational potential energy for the automobile, \( \Delta KE \) and \( \Delta PE \).

SCHEMATIC & GIVEN DATA:

\[ m = 900 \text{ kg} \]

\[ v = 100 \text{ km/h} \]

\[ Z_f = 50 \text{ m} \]

\[ v_i = 0, KE_i = 0 \]

\[ Z = 0, PE = 0 \]

ENGINEERING MODEL:

1. As shown in the schematic, the automobile is the system.
2. The acceleration of gravity is constant \( g = 9.81 \text{ m/s}^2 \).
3. The damping for KE and PE are embedded in the road surface, where indicated by the stationary observer.

ANALYSIS:

The change in kinetic energy is:

\[
\Delta KE = \left( 0 - \frac{1}{2} m \frac{v^2}{2} \right) = - \frac{1}{2} \left( 900 \text{ kg} \right) \left( \frac{100 \text{ km}}{h} \right)^2 \left( \frac{3600 \text{ s}}{1 \text{ h}} \right)^2 \left( \frac{1 \text{ N}}{9.81 \text{ m/s}^2} \right) \left( \frac{1 \text{ N} \cdot \text{m}}{10^3 \text{ J}} \right)
\]

\[ = -347.2 \text{ kJ} \]

The change in potential energy is:

\[
\Delta PE = \left[ mgZ_f - 0 \right] = \left( 900 \text{ kg} \right) \left( 9.81 \text{ m/s}^2 \right) \left( 50 \text{ m} \right) \left( \frac{9 \text{ N}}{1 \text{ kg} \cdot \text{m/s}^2} \right) \left( \frac{1 \text{ kJ}}{10^3 \text{ J}} \right)
\]

\[ = 441.5 \text{ kJ} \]
Exercise value ~ 620 kcal

1 cup ice cream = 264 kcal

\[
\frac{\text{Exercise}}{\text{intake}} = \frac{620 \text{ kcal}}{264 \text{ kcal}} = 2.35 \text{ cups ice cream}
\]
PROBLEM 2025

KNOWN: A gas in a piston-cylinder assembly undergoes a process during which \( pV^2 \) is constant. State data are provided.

FIND: Determine the final volume occupied by the gas, \( V_f \), in \( m^3 \), and the work for the process, \( W \), in \( kJ \).

SCHEMATIC & GIVEN DATA:

\[
\begin{align*}
pV^2 &= \text{constant} \\
p_1 &= 1 \text{ bar} \\
V_i &= 0.1 \text{ m}^3 \\
p_2 &= 9 \text{ bar}
\end{align*}
\]

ENGINEERING MODEL:
1. The gas within the piston-cylinder is the closed system.
2. Volume change is the only work mode.
3. The process of the gas obeys \( pV^2 = \text{constant} \).

ANALYSIS:

(a) We have \( pV^2 = \text{constant} \). Thus, \( p_1V_i^2 = \text{constant} \) and \( p_2V_f^2 = \text{constant} \).

\[
p_2 V_f^2 = p_1 V_i^2 \\
V_f = \left[ \frac{p_1}{p_2} \right]^{\frac{1}{2}} V_i = \left[ \frac{1}{9} \right]^{\frac{1}{2}} (0.1 \text{ m}^3) = 0.033 \text{ m}^3
\]

(b) Calling on Eq. 2.17,

\[
W = \int_{V_i}^{V_f} p \, dV = \frac{P_2 V_f - P_1 V_i}{1-n}
\]

\[
W = \frac{\frac{P_2 [V_f/3] - P_1 V_i}{1-n}}{\left( -1 \right)} = \frac{0.1 m^3 [3-1] \times 10^5 N/m^2}{\left( -1 \right)} = \frac{1 \text{ kJ}}{10^5 \text{ N} \cdot \text{m}}
\]

\[
= -20 \text{ kJ}
\]

Energy is transferred to the air by work in the compression process.