Ch 5: Solutions to HW Problems

P5.1 For the same force $F$, acting on different masses

\[ F = m_1a_1 \]

and

\[ F = m_2a_2 \]

(a) \[ \frac{m_1}{m_2} = \frac{a_2}{a_1} = \frac{1}{3} \]

(b) \[ F = (m_1 + m_2)a = 4m_1a = m_1 \left( 3.00 \text{ m/s}^2 \right) \]

\[ a = 0.750 \text{ m/s}^2 \]

P5.3 \[ m = 3.00 \text{ kg} \]
\[ \mathbf{a} = (2.00\mathbf{i} + 5.00\mathbf{j}) \text{ m/s}^2 \]
\[ \sum F = ma = (6.00\mathbf{i} + 15.0\mathbf{j}) \text{ N} \]
\[ \sum F = \sqrt{(6.00)^2 + (15.0)^2} = 16.2 \text{ N} \]

P5.9 \[ F_g = mg = 900 \text{ N} \]
\[ m = \frac{900 \text{ N}}{9.80 \text{ m/s}^2} = 91.8 \text{ kg} \]
\[ \left( F_g \right)_{\text{on Jupiter}} = 91.8 \text{ kg} \left( 25.9 \text{ m/s}^2 \right) = 2.38 \text{ kN} \]

P5.13 (a) You and the earth exert equal forces on each other: \( m_y g = M_e a_e \). If your mass is 70.0 kg,

\[ a_e = \frac{(70.0 \text{ kg}) (9.80 \text{ m/s}^2)}{5.98 \times 10^{24} \text{ kg}} = 10^{-22} \text{ m/s}^2 \]

(b) You and the planet move for equal times intervals according to \( x = \frac{1}{2} a_e^2 \). If the seat is 50.0 cm high,

\[ \sqrt{\frac{2x_y}{a_y}} = \sqrt{\frac{2x_e}{a_e}} \]
\[ x_e = \frac{a_e}{a_y} x_y = \frac{m_y}{m_e} x_y = \frac{70.0 \text{ kg} (0.500 \text{ m})}{5.98 \times 10^{24} \text{ kg}} \approx 10^{-23} \text{ m} \]
P5.21  (a) Isolate either mass
\[ T + mg = ma = 0 \]
\[ |T| = |mg| . \]
The scale reads the tension \( T \), so
\[ T = mg = 5.00 \text{ kg}(9.80 \text{ m/s}^2) = 49.0 \text{ N} . \]

(b) Isolate the pulley
\[ T_2 + 2T_1 = 0 \]
\[ T_2 = 2|T_1| = 2mg = 98.0 \text{ N} . \]

(c) \[ \sum F = n + T + mg = 0 \]
Take the component along the incline
\[ n_x + T_x + mg_x = 0 \]
or
\[ 0 + T - mg \sin 30.0^\circ = 0 \]
\[ T = mg \sin 30.0^\circ = \frac{mg}{2} = \frac{5.00(9.80)}{2} = 24.5 \text{ N} . \]

P5.22  The two forces acting on the block are the normal force, \( n \), and the weight, \( mg \). If the block is considered to be a point mass and the \( x \)-axis is chosen to be parallel to the plane, then the free body diagram will be as shown in the figure to the right. The angle \( \theta \) is the angle of inclination of the plane. Applying Newton’s second law for the accelerating system (and taking the direction up the plane as the positive \( x \) direction) we have
\[ \sum F_x = n - mg \cos \theta = 0 : n = mg \cos \theta \]
\[ \sum F_x = -mg \sin \theta = ma : a = -g \sin \theta \]

(a) When \( \theta = 15.0^\circ \)
\[ a = -2.54 \text{ m/s}^2 \]

(b) Starting from rest
\[ v_f^2 = v_i^2 + 2a(x_f - x_i) = 2ax_f \]
\[ v_f = \sqrt{2ax_f} = \sqrt{2(-2.54 \text{ m/s}^2)(-2.00 \text{ m})} = 3.18 \text{ m/s} . \]
First, consider the block moving along the horizontal. The only force in the direction of movement is $T$. Thus, \[ \sum F_x = ma \]

\[ T = (5 \text{ kg})a \quad (1) \]

Next consider the block that moves vertically. The forces on it are the tension $T$ and its weight, 88.2 N. We have \[ \sum F_y = ma \]

\[ 88.2 \text{ N} - T = (9 \text{ kg})a \quad (2) \]

Note that both blocks must have the same magnitude of acceleration. Equations (1) and (2) can be added to give \[ 88.2 \text{ N} = 14 \text{ kg}a \]. Then \[ a = 6.30 \text{ m/s}^2 \] and \[ T = 31.5 \text{ N} \].

**P5.36** For equilibrium: $f = F$ and $n = F_g$. Also, $f = \mu n$ i.e.,

\[ \mu = \frac{f}{n} = \frac{F}{F_g} \]

\[ \mu_s = \frac{75.0 \text{ N}}{25.0(9.80) \text{ N}} = 0.306 \]

and

\[ \mu_k = \frac{60.0 \text{ N}}{25.0(9.80) \text{ N}} = 0.245 \]

**P5.41** $m = 3.00 \text{ kg}$, $\theta = 30.0^\circ$, $x = 2.00 \text{ m}$, $t = 1.50 \text{ s}$

(a) \[ x = \frac{1}{2}at^2 \]

\[ 2.00 \text{ m} = \frac{1}{2}a(1.50 \text{ s})^2 \]

\[ a = \frac{4.00}{(1.50)^2} = 1.78 \text{ m/s}^2 \]

\[ \sum F = n + f + mg = ma: \]

Along $x$: \[ 0 - f + mg \sin 30.0^\circ = ma \]

\[ f = m(g \sin 30.0^\circ - a) \]

Along $y$: \[ n + 0 - mg \cos 30.0^\circ = 0 \]

\[ n = mg \cos 30.0^\circ \]

(b) \[ \mu_k = \frac{f}{n} = \frac{m(g \sin 30.0^\circ - a)}{mg \cos 30.0^\circ}, \quad \mu_k = \tan 30.0^\circ = \frac{a}{g \cos 30.0^\circ} = 0.368 \]
120 \hspace{1cm} \textit{The Laws of Motion}

(c) \quad f = m(g \sin 30.0^\circ - a), \quad f = 3.00(9.80 \sin 30.0^\circ - 1.78) = 9.37 \text{ N}

(d) \quad v_f^2 = v_i^2 + 2a(x_f - x_i)

where

\[ x_f - x_i = 2.00 \text{ m} \]

\[ v_f^2 = 0 + 2(1.78)(2.00) = 7.11 \text{ m}^2/\text{s}^2 \]

\[ v_f = \sqrt{7.11} \text{ m}^2/\text{s}^2 = 2.67 \text{ m/s} \]