Chapter 4

Many of the problems in this chapter involve a mass on an incline. The component of the weight perpendicular to the incline is \( w_\perp = mg \cos \theta \). The component of the weight parallel to the incline is \( w_\parallel = mg \sin \theta \).

59. A skier is pulled up a slope at a constant velocity by a tow bar. The slope is inclined at 25.0° with respect to the horizontal. The force applied to the skier by the tow bar is parallel to the slope. The skier’s mass is 55.0 kg, and the coefficient of kinetic friction between the skis and the snow is 0.120. Find the magnitude of the force that the tow bar exerts on the skier.

The normal force on the skier is \( F_N = mg \cos 25^\circ = (55.0)(9.80) \cos 25^\circ \). The frictional force on the skier is \( f_k = \mu_k F_N = (0.120)(55.0)(9.80) \cos 25^\circ = 58.62 \) N. The direction of the frictional force is down the slope.

The component of the skier’s weight parallel to the slope is \( w_\parallel = mg \sin 25^\circ = (55.0)(9.80) \sin 25^\circ = 227.8 \) N.

The sum of the frictional force and the skier’s weight is

\[
f_k + w_\parallel = 58.62 + 227.8 = 286 \text{ N}
\]

The tow bar must supply a force of this same magnitude to keep the skier moving at constant velocity.

61. A bicyclist is coasting straight down a hill at a constant speed. The mass of the rider and bicycle is 80.0 kg, and the hill is inclined at 15.0° with respect to the horizontal. Air resistance opposes the motion of the cyclist. Later, the bicyclist climbs the same hill at the same constant speed. How much force (directed parallel to the hill) must be applied to the bicycle in order for the bicyclist to climb the hill?

Going downhill, the forces acting on the bicycle are the weight, the normal force and the resistive forces. The normal force cancels part of the weight, leaving us with just the
parallel component \( w_\parallel = mg \sin 15^\circ = (80.0)(9.80)(\sin 15^\circ) = 202.9 \) N. Since the bicycle is not accelerating, the sum of the forces is zero.

\[
\begin{align*}
w_\parallel - R &= 0 \\
R &= w_\parallel = 202.9 \text{ N}
\end{align*}
\]

On the way back up, the resistive forces and the weight have the same direction. Therefore the sum of the forces is

\[
w_\parallel + R = 406 \text{ N}
\]

65. A 1380-kg car is moving due east with an initial speed of 27.0 m/s. After 8.00 s the car has slowed down to 17.0 m/s. Find the magnitude and direction of the net force that produces the deceleration.

The initial speed is \( v_0 = 27.0 \text{ m/s} \), the final speed is \( v = 17.0 \text{ m/s} \), and the time is \( t = 8.00 \text{ s} \). From the equation \( v = v_0 + at \) we get

\[
a = \frac{v - v_0}{t} = \frac{17.0 - 27.0}{8.00} = -1.25 \text{ m/s}^2
\]

The net force is

\[
F = ma = (1380)(-1.25) = -1730 \text{ N} = 1730 \text{ N west}
\]

67. In the drawing, the weight of the block on the table is 422 N and that of the hanging block is 185 N. Ignoring all frictional effects and assuming the pulley to be massless, find (a) the acceleration of the two blocks and (b) the tension in the cord.

The mass of the 422 N block is \( m_1 = \frac{w}{g} = \frac{422}{9.80} = 43.06 \text{ kg} \). The mass of the 185 N block is \( m_2 = \frac{w}{g} = \frac{185}{9.80} = 18.88 \text{ kg} \).

The net force on the 422 N block is the tension in the cord \( T \). Thus, \( T = m_1a = 43.06a \).

The net forces on the 185 N block are its weight and the tension in the cord. Thus, \( 185 - T = m_2a = 18.88a \).

We now have two equations with two variables.

\[
\begin{align*}
T &= 43.06a \\
185 - T &= 18.88a
\end{align*}
\]
We can solve this system of equations (by substitution, elimination, or calculator) to find
\[ T = 129 \text{ N} \quad \text{and} \quad a = 2.99 \text{ m/s}^2. \]

69. A student is skateboarding down a ramp that is 6.0 m long and inclined at 18° with respect to the horizontal. The initial speed of the skateboarder at the top of the ramp is 2.6 m/s. Neglect friction and find the speed at the bottom of the ramp.

The acceleration of the student is the parallel component of the gravitational acceleration:
\[ a_{\|} = 9.8 \sin 18^\circ = 3.03 \text{ m/s}^2. \]

From the equation \( v^2 = v_0^2 + 2ax \), we get
\[ v = \sqrt{v_0^2 + 2ax} = \sqrt{2.6^2 + 2(3.03)(6.0)} = 6.6 \text{ m/s} \]

71. In a supermarket parking lot, an employee is pushing ten empty shopping carts, lined up in a straight line. The acceleration of the carts is 0.050 m/s². The ground is level, and each cart has a mass of 26 kg. (a) What is the net force acting on any one of the carts? (b) Assuming friction is negligible, what is the force exerted by the fifth cart on the sixth cart?

(a) \( F = ma = (26)(0.050) = 1.3 \text{ N} \).

(b) The fifth cart must push five other carts. The total force is \( F = ma = (5)(26)(0.050) = 6.5 \text{ N} \).

75. To hoist himself into a tree, a 72.0-kg man ties one end of a nylon rope around his waist and throws the other end over a branch of the tree. He then pulls downward on the free end of the rope with a force of 358 N. Neglect any friction between the rope and the branch, and determine the man’s upward acceleration.

The forces acting on the man are the two tensions upward and the weight downward.
\[ F = 358 + 358 - (72.0)(9.80) = 10.4 \text{ N} \]

The acceleration is
\[ a = \frac{F}{m} = \frac{10.4}{72.0} = 0.144 \text{ m/s}^2 \]

79. A box is sliding up an incline that makes an angle of 15.0° with respect to the horizontal. The coefficient of kinetic friction between the box and the surface of the incline is 0.180. The initial speed of the box at the bottom of the incline is 1.50 m/s. How far does the box travel along the incline before coming to rest?
The normal force is equal in magnitude to the perpendicular component of the weight.

\[ F_N = w_\perp = mg \cos 15^\circ \]

The frictional force is

\[ f_k = \mu_k F_N = \mu_k mg \cos 15^\circ \]

The parallel component of the weight is

\[ w_\parallel = mg \sin 15^\circ \]

The net force acting on the block is

\[ f_k + w_\parallel = \mu_k mg \cos 15^\circ + mg \sin 15^\circ \]

The acceleration is

\[ a = \frac{F}{m} = g \sin 15^\circ + \mu_k g \cos 15^\circ \]

We will insert a minus sign to show that this is a deceleration.

\[ a = \frac{F}{m} = -g \sin 15^\circ - \mu_k g \cos 15^\circ = -(9.80) \sin 15^\circ - (0.180)(9.80) \cos 15^\circ = -4.240 \text{ m/s}^2 \]

From the equation \( v^2 = v_0^2 + 2ax \), we get

\[ x = \frac{v^2 - v_0^2}{2a} = \frac{0 - 1.50^2}{2(-4.240)} = 0.265 \text{ m} \]

81. At an airport, luggage is unloaded from a plane into the three cars of a luggage carrier, as the drawing shows. The acceleration of the carrier is 0.12 m/s\(^2\), and friction is negligible. The coupling bars have negligible mass. By how much would the tension in each of the coupling bars A, B, and C change if 39 kg of luggage were removed from car 2 and placed in (a) car 1 and (b) car 3? If the tension changes, specify whether it increases or decreases.

(a) \( \Delta T_A = 0, \Delta T_C = 0, \Delta T_B = 4.68 \text{ N (decrease)} \)

(b) \( \Delta T_A = 0, \Delta T_B = 0, \Delta T_C = 4.68 \text{ N (increase)} \)
85. In the drawing, the rope and the pulleys are massless, and there is no friction. Find (a) the tension in the rope and (b) the acceleration of the 10.0-kg block. (Hint: The larger mass moves twice as far as the smaller mass.)

Since the 10.0-kg block moves twice as far as the 3.00-kg block, its velocity and acceleration must be twice as great.

The net force acting on the 10.0-kg block is the tension in the rope.

\[ T = m(2a) = (10.0)(2a) = 20.0a \]

The forces acting on the 3.00-kg block are its weight and the two upward tensions.

\[ mg - 2T = (3.00)(9.80) - 2T = 29.4 - 2T = ma = 3.00a \]
\[ 29.4 - 2T = 3.00a \]

We now have two equations with two variables.

\[ T = 20.0a \]
\[ 29.4 - 2T = 3.00a \]

Solving we get \( T = 13.7 \text{ N} \) and \( a = 0.6837 \text{ m/s}^2 \). The acceleration of the 10.0-kg block is \( 2a = 1.37 \text{ m/s}^2 \).