# Assignment #5

## Chapter 5 Questions:

5.62 The passenger experiences a centripetal acceleration due to the forces of the side of the car on their body. From Newton's third law, the body matches this force in magnitude, exerting a force on the side of the car that is directed away from the center of the turn. The force of the car on the body is toward the center of the turn.

## Chapter 5 Problems:

**5.39** Consider the 75.0 kg mass on the scale to be the system. When the scale reads zero, the forces on the 75.0 kg system are:

1. its weight $\vec{w}$; and
2. the force $\vec{T}$ of the rope on the system.

The 75.0 kg mass is not accelerating. Apply Newton's second law to this system, taking $\hat{j}$ to point up.

$$F_{y\ \text{total}} = ma_y \implies -mg + T = 0\ \text{N} \implies T = mg = (75.0\ \text{kg})(9.81\ \text{m/s}^2) = 736\ \text{N}.$$

Now consider the gymnast of mass $m'$ as the system. The forces on this system are:

1. the weight $\vec{w}'$ of the gymnast; and
2. the upward force $\vec{\mathbf{T}}$ of the rope on the gymnast, of magnitude 736 N, as determined above.

Apply Newton's second law to the gymnast system.

$$F_{y\ \text{total}} = m'a_y \implies -m'g + T = m'a_y \implies$$
$$a_y = \frac{-m'g + T}{m'} = \frac{(-50.0\ \text{kg})(9.81\ \text{m/s}^2) + 736\ \text{N})}{50.0\ \text{kg}} = 4.91\ \text{m/s}^2.$$

**5.60**

a) Take the textbook as the system. The forces on the text are:

1. its weight $\vec{w}$, directed down;
2. the normal force $\vec{N}$ of the reading surface on the book, directed perpendicularly to the surface at a 35° angle to the straight up direction;
3. the applied force $\vec{\mathbf{F}}$ along and up the incline, of magnitude 20 N; and
4. the kinetic frictional force $\vec{f}_k$, directed opposite to the velocity and $\vec{\mathbf{F}}$, with magnitude $f_k = \mu_k N$.

b) Introduce a coordinate system with $\hat{i}$ pointing in the direction of the applied force $\vec{F}$, and $\hat{j}$ perpendicular to the surface and in the same direction as $\vec{N}$. Let $\theta = 35°$. Apply Newton's second law to each coordinate direction. Since the velocity is constant, the acceleration is zero, so the total force is zero.

$x$ direction

$$F_{x\ \text{total}} = 0\ \text{N} \implies 20\ \text{N} - \mu_k N - mg\sin\theta = 0\ \text{N}$$
$$\implies \mu_k = \frac{20\ \text{N} - mg\sin\theta}{N}.$$

$y$ direction

$$F_{y\ \text{total}} = ma_y \implies N - mg\cos\theta = 0\ \text{N}$$
$$\implies N = mg\cos\theta.$$

Substitute the expression for $N$ from the $y$ equation into the $x$ equation.

$$\mu_k = \frac{20\ \mathrm{N} - mg\sin\theta}{mg\cos\theta} = \frac{20\ \mathrm{N} - (2.50\ \mathrm{kg})(9.81\ \mathrm{m/s^2})\sin 35^\circ}{(2.50\ \mathrm{kg})(9.81\ \mathrm{m/s^2})\cos 35^\circ} = 0.30.$$

c) Since the book is sliding, the coefficient is that of kinetic friction.

**5.64**

a) First convert the speed from km/h to m/s

$$v = 35\ \mathrm{km/h} = (35\ \mathrm{km/h})\left(\frac{10^3\ \mathrm{m}}{\mathrm{km}}\right)\left(\frac{\mathrm{h}}{3600\ \mathrm{s}}\right) = 9.7\ \mathrm{m/s}$$

The magnitude of the centripetal acceleration of the car is

$$a_{\text{centripetal}} = \frac{v^2}{r} = \frac{(9.7\ \mathrm{m/s})^2}{150\ \mathrm{m}} = 0.63\ \mathrm{m/s^2}.$$

b) Since the car travels around the curve at constant speed, the tangential acceleration of the car is $0\ \mathrm{m/s^2}$.

c) The force providing the centripetal acceleration of the car is found from Newton's second law. Use the magnitudes of the vectors.

$$F_{\text{total}} = ma = (1250\ \mathrm{kg})(0.63\ \mathrm{m/s^2}) = 7.9 \times 10^2\ \mathrm{N}.$$

This force is produced by the static force of friction between the tires and the road.

d) The forces acting on the car are:

1. its weight $\vec{w}$, directed downward;
2. the normal force $\vec{N}$ of the surface on the car, directed up; and
3. the static force of friction $\vec{f}_s$ between the tires and the roadway, directed horizontally towards the center of the turn (in the same direction as the centripetal acceleration).

Let $\hat{i}$ point toward the center of the turn, and $\hat{j}$ point up. There is no acceleration along the $\hat{j}$ direction, so the total force component in this direction is 0 N. Thus

$$F_{y\ \text{total}} = 0\ \mathrm{N} \implies N - mg = 0\ \mathrm{N} \implies N = mg.$$

The maximum magnitude $f_{s\,\max}$ of the static force of friction is related to the magnitude of the normal force by

$$f_{s\,\max} = \mu_s N = \mu_s mg.$$

The static force of friction provides the centripetal acceleration, so

$$7.9 \times 10^2\ \mathrm{N} = \mu_s mg = \mu_s (1250\ \mathrm{kg})(9.81\ \mathrm{m/s^2}) \implies \mu_s = 0.064.$$

**5.65**

a) If the hanging mass is zero, the force of the cord on you is zero. In this case, the forces acting on you are:

1. your weight $\vec{w}$, acting downward;
2. the normal force $\vec{N}$ of the surface on you, directed perpendicular to the surface; and
3. a force of friction $\vec{f}$, directed parallel to the surface. (If you do not slip, this is a static force of friction.)

You will slip down the plane if the component of your weight down the plane exceeds the maximum magnitude of the static force of friction up the plane. The component of your weight down the plane is

$$m'g\sin\theta = (70\text{ kg})(9.81\text{ m/s}^2)\sin 40^\circ = 4.4\times 10^2\text{ N}.$$

There is zero acceleration of the system perpendicular to the plane. Choosing a coordinate system with $\hat{j}$ in this direction we have

$$F_{y\text{ total}} = m'a_y \implies N - m'g\cos\theta = m'(0\text{ m/s}^2) \implies N = m'g\cos\theta.$$

The maximum magnitude of the static force of friction is

$$f_{s\text{ max}} = \mu_s N = \mu_s m'g\cos\theta = 0.40(70\text{ kg})(9.81\text{ m/s}^2)\cos 40^\circ = 2.1\times 10^2\text{ N}.$$

Since the component of your weight down the incline is greater than the maximum magnitude of the static force of friction, you will slide down the plane.

b) Your weight $\vec{w}$ and the normal force of the inclined surface on you are unchanged. Since we need to determine the mass $m$ that enables you to accelerate up the inclined plane, the force of friction is the kinetic force of friction directed opposite to your velocity. There is an additional force acting on you too, the force of the cord.

Two forces act on the hanging mass $m$: its weight, which points down, and the tension of the cord, which points up. Choose $\hat{j}$ to point down. Then

$$mg - T = ma \implies T = m(g-a).$$

Now apply Newton's second law to the mass $m'$ on the inclined plane, choosing a coordinate system with $\hat{i}$ along the cord and $\hat{j}$ along $\vec{N}$. In this case,

$x$ direction

$$\begin{aligned} F_{x\text{ total}} &= m'a_x \\ &\implies T - m'g\sin\theta - f_k = m'a \\ &\implies T - m'g\sin\theta - \mu_k N = m'a. \end{aligned}$$

$y$ direction

$$\begin{aligned} F_{y\text{ total}} &= m'a_y \\ &\implies N - m'g\cos\theta = m'(0\text{ m/s}^2) \\ &\implies N = m'g\cos\theta. \end{aligned}$$

Substitute for $T$ and $N$ in the $x$-direction equation:

$$m(g-a) - m'g\sin\theta - \mu_k m'g\cos\theta = m'a$$

Solve for $m$:

$$\begin{aligned} m &= m'\left(\frac{g\sin\theta + \mu_k g\cos\theta + a}{g-a}\right) \\ &= 70\text{ kg}\left(\frac{(9.81\text{ m/s}^2)\sin 40^\circ + 0.35(9.81\text{ m/s}^2)\cos 40^\circ + 1.50\text{ m/s}^2}{9.81\text{ m/s}^2 - 1.50\text{ m/s}^2}\right) \\ &= 88\text{ kg} \end{aligned}$$

c) From b)

$$T = m(g-a) = (88\text{ kg})(9.81\text{ m/s}^2 - 1.50\text{ m/s}^2) = 7.3\times 10^2\text{ N}.$$