Summary

An object moving in a circle of radius r with constant speed v is said to be in **uniform circular motion**. It has a **radial acceleration** a_R that is directed radially toward the center of the circle (also called **centripetal acceleration**), and has magnitude

$$a_R = \frac{v^2}{r}. \qquad \textbf{(5–1)}$$

The velocity vector and the acceleration vector $\vec{\mathbf{a}}_R$ are continually changing in direction, but are perpendicular to each other at each moment.

A force is needed to keep an object revolving in a circle, and the direction of this force is toward the center of the circle. This force could be due to gravity (as for the Moon), to tension in a cord, to a component of the normal force, or to another type of force or combination of forces.

[*When the speed of circular motion is not constant, the acceleration has two components, tangential as well as centripetal.]

Newton's **law of universal gravitation** states that every particle in the universe attracts every other particle with a force proportional to the product of their masses and inversely proportional to the square of the distance between them:

$$F_G = G\frac{m_1 m_2}{r^2}. \qquad \textbf{(5–4)}$$

The direction of this force is along the line joining the two particles, and the force is always attractive. It is this gravitational force that keeps the Moon revolving around the Earth, and the planets revolving around the Sun.

Satellites revolving around the Earth are acted on by gravity, but "stay up" because of their high tangential speed.

Newton's three laws of motion, plus his law of universal gravitation, constituted a wide-ranging theory of the universe. With them, motion of objects on Earth and in space could be accurately described. And they provided a theoretical base for **Kepler's laws** of planetary motion.

The four fundamental forces in nature are (1) the gravitational force, (2) the electromagnetic force, (3) the strong nuclear force, and (4) the weak nuclear force. The first two fundamental forces are responsible for nearly all "everyday" forces.

Questions

1. How many "accelerators" do you have in your car? There are at least three controls in the car which can be used to cause the car to accelerate. What are they? What accelerations do they produce?
2. A car rounds a curve at a steady 50 km/h. If it rounds the same curve at a steady 70 km/h, will its acceleration be any different? Explain.
3. Will the acceleration of a car be the same when a car travels around a sharp curve at a constant 60 km/h as when it travels around a gentle curve at the same speed? Explain.
4. Describe all the forces acting on a child riding a horse on a merry-go-round. Which of these forces provides the centripetal acceleration of the child?
5. A child on a sled comes flying over the crest of a small hill, as shown in Fig. 5–32. His sled does not leave the ground, but he feels the normal force between his chest and the sled decrease as he goes over the hill. Explain this decrease using Newton's second law.

FIGURE 5–32 Question 5.

6. Sometimes it is said that water is removed from clothes in the spin dryer by centrifugal force throwing the water outward. Is this correct? Discuss.
7. A girl is whirling a ball on a string around her head in a horizontal plane. She wants to let go at precisely the right time so that the ball will hit a target on the other side of the yard. When should she let go of the string?
8. A bucket of water can be whirled in a vertical circle without the water spilling out, even at the top of the circle when the bucket is upside down. Explain.
9. Astronauts who spend long periods in outer space could be adversely affected by weightlessness. One way to simulate gravity is to shape the spaceship like a cylindrical shell that rotates, with the astronauts walking on the inside surface (Fig. 5–33). Explain how this simulates gravity. Consider (*a*) how objects fall, (*b*) the force we feel on our feet, and (*c*) any other aspects of gravity you can think of.

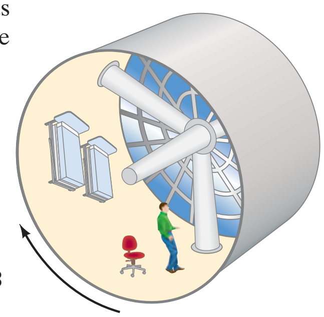

FIGURE 5–33 Question 9.

10. A car maintains a constant speed v as it traverses the hill and valley shown in Fig. 5–34. Both the hill and valley have a radius of curvature R. At which point, A, B, or C, is the normal force acting on the car (*a*) the largest, (*b*) the smallest? Explain. (*c*) Where would the driver feel heaviest and (*d*) lightest? Explain. (*e*) How fast can the car go without losing contact with the road at A?

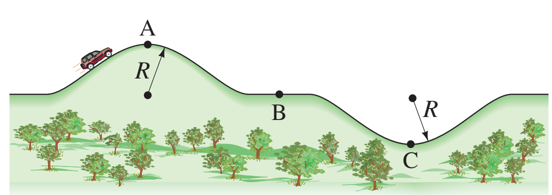

FIGURE 5–34 Question 10.

11. Can a particle with constant speed be accelerating? What if it has constant velocity? Explain.
12. Why do airplanes bank when they turn? How would you compute the banking angle given the airspeed and radius of the turn? [*Hint*: Assume an aerodynamic "lift" force acts perpendicular to the wings. See also Example 5–7.]