

UNIT 7 CIRCULAR MOTION

Objectives

- To be able to apply Newton's second law to objects in circular motion.
- To understand acceleration as a vector quantity in the case when the speed of an object is constant.

This clip is an example of circular motion. This [video](#) shows a medical device called a centrifuge. In the medical field one takes a sample of blood, treats it with an agent to prevent clotting, and spins it in a centrifuge, the red cells settle to the bottom and the white cells settle on top of the red blood cells.



Equipment:

- 2-D kinematics cart
- Rope
- 1 Meterstick

1.1

- a. Pull someone on a 2-D kinematics cart in a circle of 1m radius.
- b. Draw a force diagram for the person and cart.

Equipment:

- 2-D kinematics cart
- Rope
- 1 Meterstick
- Spring or spring scale

1.2

- a. Push or pull someone on a 2-D kinematics cart in a circle at constant speed.
- b. Is there a net force tangent to the circle?

c. Is there a net force towards the center of the circle? Devise a way to tell if there is a net force towards the center of the circle. Test your prediction.

d. Draw a force diagram for the person-cart.

Equipment:

1 string (about 1m long)

1 Rubber stopper

1 plastic tube

1 200g mass

1.3

a. Tie a small object to one end of a string, put the other end of the string through a straw and then tie about 200g of mass to the other end. Holding the straw, twirl the object around in a circle (Try to make the circle as horizontal as possible.)

b. Draw a force diagram for the object and for the mass on the other end of the string. Is there a net force on the object?

Discuss your diagrams with an instructor.

c. Consider an object moving in the x-direction. If you were to apply a force perpendicular to the x-direction, would the magnitude of the velocity of the object in the x-direction change? Would the magnitude of the velocity of the object in the y-direction change? Explain. If you were to constantly apply a force perpendicular to the motion of an object, would the magnitude of the velocity of the object change? Explain. Would the direction of the velocity of the object change? Explain.

Discuss with an instructor.

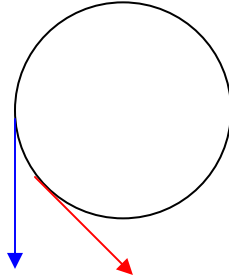
d. If you were to constantly apply a force perpendicular to the motion of an object, what path would the object follow? Watch the [animation](#) that shows an object acted on by a force perpendicular to the velocity. The blue arrow indicates the direction of the force. The red arrow indicates the direction of the velocity.

e. Acceleration is the change in velocity over a period of time. If the magnitude of the velocity does not change, but the direction of the velocity changes, is there an acceleration?

Consider an object moving in a circle, as in the diagram below. Two vectors are drawn on the circle to represent the velocity, v_1 and v_2 , at times t_1 and t_2 . The acceleration is defined as

$$\mathbf{a} = \frac{\mathbf{v}_2 - \mathbf{v}_1}{t_2 - t_1},$$

where \mathbf{v}_1 and \mathbf{v}_2 are vectors. Move the vectors in the diagram to determine the vector $\Delta\mathbf{v} = \mathbf{v}_2 - \mathbf{v}_1$. Add $-\mathbf{v}_1$ to \mathbf{v}_2 by using the Draw toolbar. Draw the vector $\Delta\mathbf{v}$ in the diagram. Which direction does the vector $\Delta\mathbf{v}$ point?



The vector $\Delta\mathbf{v}$ points in the direction of the acceleration. What is the direction of the acceleration for an object moving in a circle?

In the experiment in part **a** and in the animation, there was a net force toward the center of the circle. Is this consistent with the direction of the acceleration for an object moving in a circle?

f. If there is a force toward the center of the circle for an object in circular motion and no other forces are acting in the plane of the circle, then what direction would the object move, if the force were stopped? (For example, what would happen to the object in part **a**, if the string were cut?) Explain.

Discuss with an instructor.

It can be shown that the magnitude of the acceleration for an object moving at constant speed in a circle is:

$$a = \frac{v^2}{r}$$

where v is the magnitude of the velocity (speed) of the object and r is the radius of the circle.

g. For the object in part **a**, as the radius increases, does the speed of the object increase or decrease? Explain.

Equipment:

- 1 bucket
- Water

1.4

- a.** Obtain a bucket of water, swing it (fast) around in a vertical circle. Did the water stay in the bucket? Is it possible to swing it at any speed and keep the water in the bucket? (Try it out.) Explain your reasoning.
- b.** Draw a force diagram for the water both at the top and at the bottom of the circle.
- c.** Apply Newton's Second law to the water at the top of the circle. Which of the forces could change as the velocity changes? What is the condition for the water to fall out of the bucket? Explain.
- d.** At what speed would the water fall out of the bucket? Show your work.

SUMMARY

You should understand that the net force acting on an object moving at constant speed in a circle is directed towards the center of the circle. You should understand that acceleration is a vector quantity and that an object moving at constant speed can be accelerating. You should be able to apply Newton's second law to objects in circular motion.