Simulating Circular Motion

In this investigation, you will use a computer simulation program to look at the relationships among the magnitude and direction of the centripetal acceleration of an object moving in a circle, the magnitude and direction of the centripetal (net) force acting on the object, the speed of the object, and the radius of the circular motion. Note that in this simulation, you will consider an object that is attached to a string fixed in position at one end. We will not consider the force of gravity. The equation for calculating the centripetal acceleration is:

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

where v is the speed of the object and r is the radius of the circle. The equation for calculating the centripetal force acting on an object is:

$$F_c = \frac{mv^2}{r}$$

where m is the mass of the object.

Questions

(i) What is the mathematical relationship between the centripetal acceleration of an object in uniform circular motion and (a) the speed of the object and (b) the radius of the circle?

(ii) What is the mathematical relationship between the centripetal acceleration of an object in uniform circular motion and the radius of the circle?

Hypothesis/Prediction

(a) What is the relationship between the centripetal acceleration and the speed of an object? the centripetal acceleration of an object and the radius of the circle?

(b) Sketch two graphs to illustrate your answers to (a).

(continued)

Materials

a computer simulation program for uniform circular motion, such as *Interactive Physics*

Table 1 Data for Speed and Centripetal Acceleration of an Object

Speed v (m/s)	Centripetal Acceleration a_c (m/s^2)
1.0	
1.4	
1.8	
2.2	
2.6	
3.0	

Table 2 Data for Radius and Centripetal Acceleration of an Object

Radius r (m)	Centripetal Acceleration a_c (m/s^2)
1.0	
1.2	
1.4	
1.6	
1.8	
2.0	

Table 3 Mass, Acceleration, and Centripetal Force

Mass m (kg)	Centripetal Acceleration a_c (m/s^2)	Centripetal Force F_c (N)
0.20		
0.40		
0.60		
0.80		
1.00		
1.20		

Procedure

1. Use the computer simulation program to simulate an object on a 1.0-m string, moving in a circle at a speed of 1.0 m/s. For each of the speeds in **Table 1**, determine the magnitude of the centripetal acceleration of the object.

2. Set the object moving at a speed of 4.0 m/s, and vary the radius according to the values given in **Table 2**. Calculate and record the magnitude of the centripetal acceleration of the object for each radius.

3. Set the object moving at a speed of 4.0 m/s at a radius of 1.0 m. Determine and record the magnitude of the centripetal acceleration and the centripetal force of the object for each mass in **Table 3**.

Analysis

4. Plot a centripetal acceleration-speed graph and a centripetal acceleration-radius graph. From the shapes of your graphs, determine the relationship between the magnitude of the centripetal acceleration and the speed of the object. Determine the relationship between the magnitude of the centripetal acceleration and the radius.

5. What is the relationship between centripetal acceleration and centripetal force? Sketch the graph that depicts this relationship.

(continued)

6. Examine and describe the direction of the velocity vector in your simulation.

7. Examine and describe the direction of the centripetal acceleration vector in your simulation.

8. Examine and describe the direction of the centripetal force vector in your simulation.

Simulating Circular Motion, Solution

In this investigation, you will use a computer simulation program to look at the relationships among the magnitude and direction of the centripetal acceleration of an object moving in a circle, the magnitude and direction of the centripetal (net) force acting on the object, the speed of the object, and the radius of the circular motion. Note that in this simulation, you will consider an object that is attached to a string fixed in position at one end. We will not consider the force of gravity. The equation for calculating the centripetal acceleration is:

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

where v is the speed of the object and r is the radius of the circle. The equation for calculating the centripetal force acting on an object is:

$$F_c = \frac{mv^2}{r}$$

where m is the mass of the object.

Questions

(i) What is the mathematical relationship between the centripetal acceleration of an object in uniform circular motion and (a) the speed of the object and (b) the radius of the circle?

The centripetal acceleration is directly proportional to the square of the speed.

(ii) What is the mathematical relationship between the centripetal acceleration of an object in uniform circular motion and the radius of the circle?

The centripetal acceleration is inversely proportional to the radius of the circle.

Hypothesis/Prediction

(a) What is the relationship between the centripetal acceleration and the speed of an object? the centripetal acceleration of an object and the radius of the circle?

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

(b) Sketch two graphs to illustrate your answers to (a).

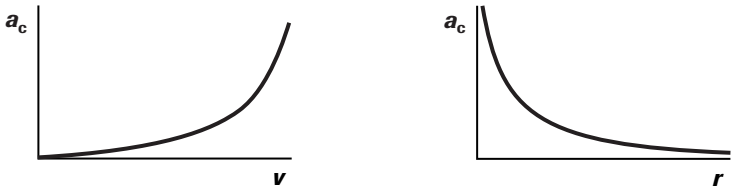

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Table 1 Data for Speed and Centripetal Acceleration of an Object

Speed v (m/s)	Centripetal Acceleration a_c (m/s^2)
1.0	1.0
1.4	2.0
1.8	3.2
2.2	4.8
2.6	6.8
3.0	9.0

Table 2 Data for Radius and Centripetal Acceleration of an Object

Radius r (m)	Centripetal Acceleration a_c (m/s^2)
1.0	16.0
1.2	13.3
1.4	11.4
1.6	10.0
1.8	8.9
2.0	8.0

Table 3 Mass, Acceleration, and Centripetal Force

Mass m (kg)	Centripetal Acceleration a_c (m/s^2)	Centripetal Force F_c (N)
0.02	16	3.2
0.04	16	6.4
0.60	16	9.6
0.80	16	12.8
1.00	16	16.0
1.20	16	19.2

Materials

a computer simulation program for uniform circular motion, such as *Interactive Physics*

Procedure

1. Use the computer simulation program to simulate an object on a 1.0-m string, moving in a circle at a speed of 1.0 m/s. For each of the speeds in **Table 1**, determine the magnitude of the centripetal acceleration of the object.

   Answers may vary.

2. Set the object moving at a speed of 4.0 m/s, and vary the radius according to the values given in **Table 2**. Calculate and record the magnitude of the centripetal acceleration of the object for each radius.

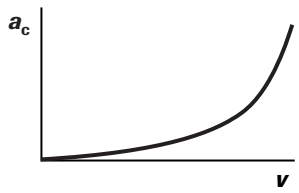
   Answers may vary.

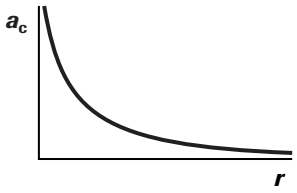
3. Set the object moving at a speed of 4.0 m/s, at a radius of 1.0 m. Determine and record the magnitude of the centripetal acceleration and the centripetal force of the object for each mass in **Table 3**.

   Answers may vary.

Analysis

4. Plot a centripetal acceleration-speed graph and a centripetal acceleration-radius graph. From the shapes of your graphs, determine the relationship between the magnitude of the centripetal acceleration and the speed of the object. Determine the relationship between the magnitude of the centripetal acceleration and the radius.





   The centripetal acceleration is directly proportional to the square of the speed. The centripetal acceleration is inversely proportional to the radius of the circle.

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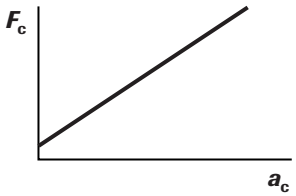
5. What is the relationship between centripetal acceleration and centripetal force? Sketch the graph that depicts this relationship.

   The centripetal force is directly proportional to the centripetal acceleration.



6. Examine and describe the direction of the velocity vector in your simulation.

   The velocity vector is directed perpendicular to the string.

7. Examine and describe the direction of the centripetal acceleration vector in your simulation.

   The centripetal acceleration vector is directed toward the centre of the circle.

8. Examine and describe the direction of the centripetal force vector in your simulation.

   The centripetal force vector is directed toward the centre of the circle.