

19. Centripetal Force

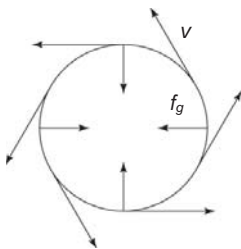
Driving Questions

What factors influence the force experienced by an object that travels on a circle at a constant speed?

Background

When an object moves in a curved or circular path, the object is subject to a center-seeking action called centripetal force. This force is directly related to the object's net inward acceleration. In uniform circular motion, the object moves with constant speed yet changing direction. Thus, its velocity is not constant, and the acceleration is non-zero.

Consider the planets orbiting the sun in their near-circular paths. What is the nature of the force that causes the planetary orbits?



In this experiment, you will conduct several short investigations that examine how the object's mass influences the period of a revolution under a constant force and constant radius. You will also examine how changing the radius of the circular path affects the period of a revolution while the object's mass and applied force remain constant. In the final investigation, you will vary the applied force to determine the effect on the period of a revolution when holding the radius and mass constant.

Materials and Equipment

For each student or group:

- | | |
|--------------------------|-----------------------------|
| ◆ Data collection system | ◆ Meter stick |
| ◆ Force sensor | ◆ Rod, short |
| ◆ Rubber stopper (4) | ◆ String, 3 m |
| ◆ Plastic tube | ◆ Balance (1 per classroom) |
| ◆ Table clamp | ◆ Scissors |
| ◆ Timer | ◆ Marker |

Safety

Add these important safety precautions to your normal laboratory procedures:

- ♦ Be sure to wear impact safety goggles or glasses.

Sequencing Challenge

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

<div></div> <div>Examine the graph of Force versus Period.</div>	<div></div> <div>Monitor the magnitude of the force using the data collection system.</div>	<div></div> <div>Connect the force sensor to your data collection system.</div>	<div></div> <div>Use a stopwatch to measure the time of 10 revolutions.</div>	<div></div> <div>Firmly hold the tube, and start the object in motion by swinging the system overhead.</div>
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Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

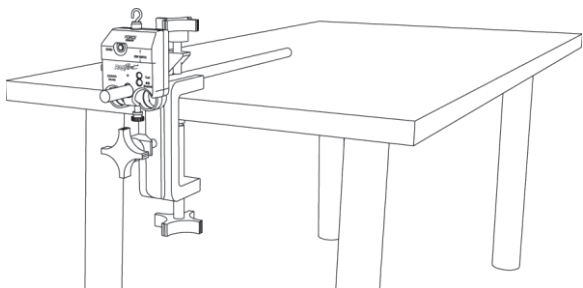
Note: When you see the symbol "♦" with a superscripted number following a step, refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There you will find detailed technical instructions for performing that step. Your teacher will provide you with a copy of the instructions for these operations.

Part 1 - Different Masses

Set Up

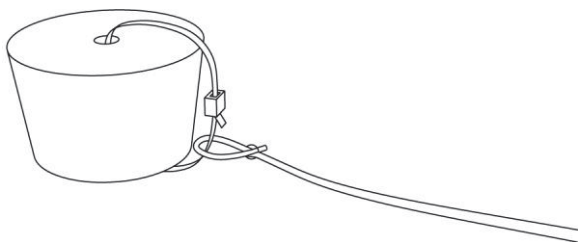
- ☐ Start a new experiment on the data collection system. ♦^(1.2)
- ☐ Connect the force sensor to the data collection system. ♦^(2.1)
- ☐ Configure the data collection system to monitor Force, pull positive in a digits display. ♦^(6.1)
- ☐ Attach the large table clamp to the edge of a table mount the small rod such that it is parallel to the floor.

5. ☐ Attach the force sensor to the short rod with the hook of the sensor pointed straight up, and then push the "zero" button on the force sensor.



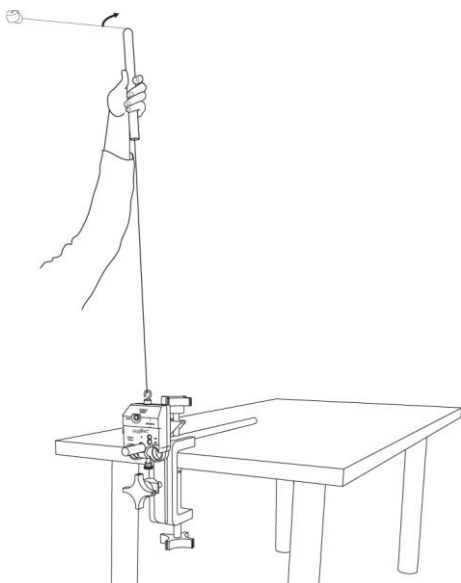
6. ☐ Attach a plastic tie to the stopper through the hole in the center of the stopper.

7. ☐ Tie the string to the plastic tie.



8. ☐ Measuring from the center hole of the stopper (approximately the center of mass), mark the string at 1.0 meter from the stopper's center of mass. Record this value as the radius for Part 1 below Table 1 in the Data Analysis section.

9. ☐ Thread the other end of the string through the plastic tube, and attach the string to the hook on the force sensor. Adjust the length of the string to allow the mass to rotate overhead with the 1 m mark at the top of the tube.



Collect Data

- 10. ☐ Measure the mass of the stopper, and record the value in Table 1.
- 11. ☐ Begin swinging the rubber stopper overhead in a circular motion at a constant speed. Watch the force measurements on the data collection system, and try to maintain a constant force while keeping the plane of rotation parallel to the floor.
- 12. ☐ With the system in uniform circular motion, use the stopwatch to measure the time for 10 full revolutions.
- 13. ☐ Record the time and number of revolutions in Table 1.
- 14. ☐ Repeat data collection three additional times, using two stoppers, three stoppers, and four stoppers. (Or, replace the stopper with a stopper of different mass, depending on the equipment you have available.) Be sure to achieve and maintain the same constant force in each trial.
- 15. ☐ Record the constant applied force used in all four trials as well as the amount of mass used in each trial into Table 1 in the Data Analysis section.

Part 2 - Different Radii

Set Up

- 16. ☐ Using the same setup as Part 1, select one stopper, and attach it to the end of the string opposite the force sensor.
- 17. ☐ Measure the mass of the stopper, and record the value below Table 2.
- 18. ☐ Lay the string along the meter stick with the center of the stopper at the 0 m mark, and then mark the string in 0.25 m intervals from 0 m to 1 m from the stopper.

Collect Data

- 19. ☐ Begin swinging the rubber stopper overhead in a circular motion at a constant speed. Watch the force measurements on the data collection system, and try to maintain a constant force while keeping the plane of rotation parallel to the floor.
- 20. ☐ With the system in uniform circular motion, use the stopwatch to measure the time for 10 full revolutions.
- 21. ☐ Record the time and number of revolutions in Table 2.

- 22.** ☐ Repeat data collection three additional times, using the three different radii (0.75 m, 0.50 m, and 0.25 m). For each additional trial, be sure to achieve and maintain the same constant force as the first trial.
- 23.** ☐ Record the constant applied force in the space below Table 2 in the Data Analysis section.

Part 3 - Different Velocities

Set Up

- 24.** ☐ Using the same set up as Part 1, select one stopper, and begin with a radius of one meter. During data collection, you will change the force from trial to trial.

Collect Data

- 25.** ☐ Begin swinging the rubber stopper overhead in a circular motion at a constant speed. Watch the force measurements on the data collection system, and try to maintain a constant force while keeping the plane of rotation parallel to the floor.
- 26.** ☐ With the system in uniform circular motion, use the stopwatch to measure the time for 10 full revolutions.
- 27.** ☐ Record the time and number of revolutions in Table 3 in the Data Analysis section.
- 28.** ☐ Record the constant force from the trial in Table 3.
- 29.** ☐ Repeat data collection at least three additional times, using different applied forces for each trial. For example, 1.5 N, 2.0 N, 2.5N, and if possible, 3.0 N.
- 30.** ☐ Record the length of the radius and the mass of the stopper you chose in the spaces below Table 3 in the Data Analysis section.

Data Analysis

Table 1: Changing Mass

Mass (kg)	Interval of Time (s)	Number of Revolutions	Period (s)

Radius for Part 1: _____

Constant force for Part 1: _____

1. ☐ Complete the Period column in Table 1 by dividing the interval of time by the number of revolutions for each mass.
2. ☐ Using your Mass and Period data, plot a graph of Mass versus Period.

Mass versus Period

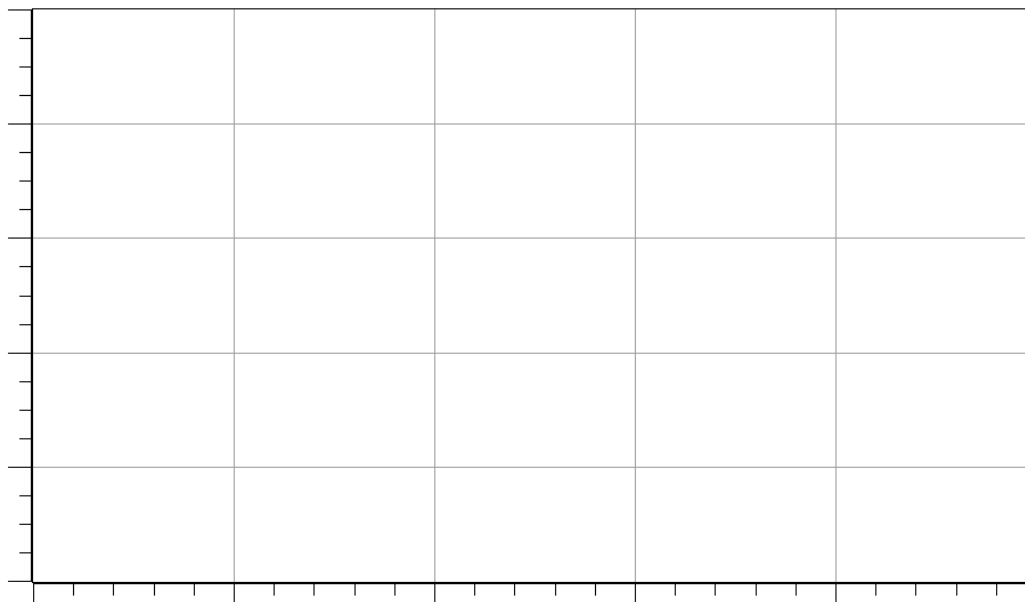


Table 2: Different Radii

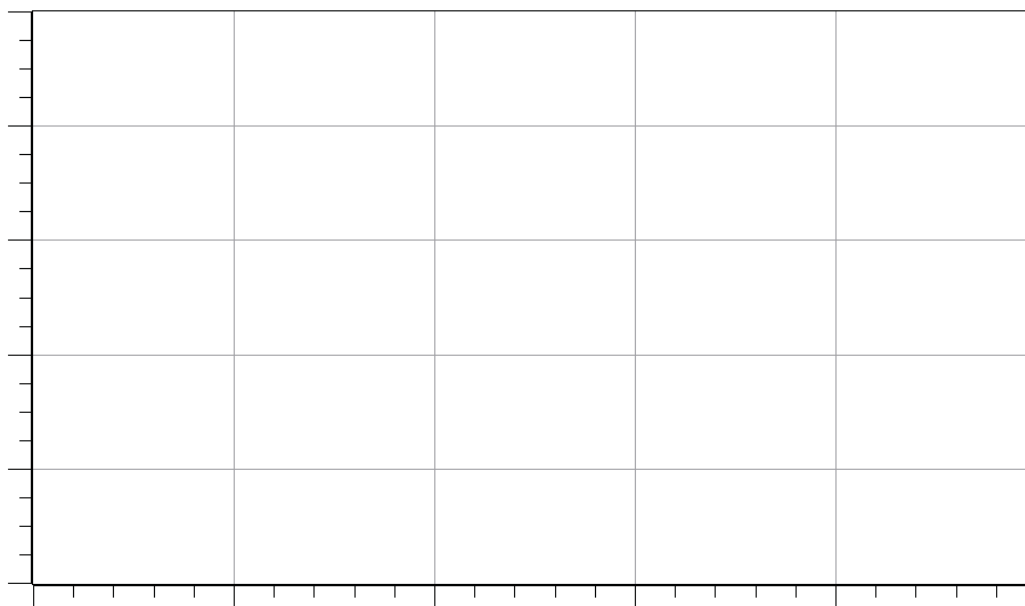
Radius (m)	Interval of Time (s)	Number of Revolutions	Period (s)

Mass of the stopper for Part 2: _____

Constant force for Part 2: _____

3. ☐ Complete the Period column in Table 2 by dividing the interval of time by the number of revolutions for each radius.
4. ☐ Using your Radius and Period data, plot a graph of Radius versus Period.

Radius versus Period



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Table 3: Changing velocity

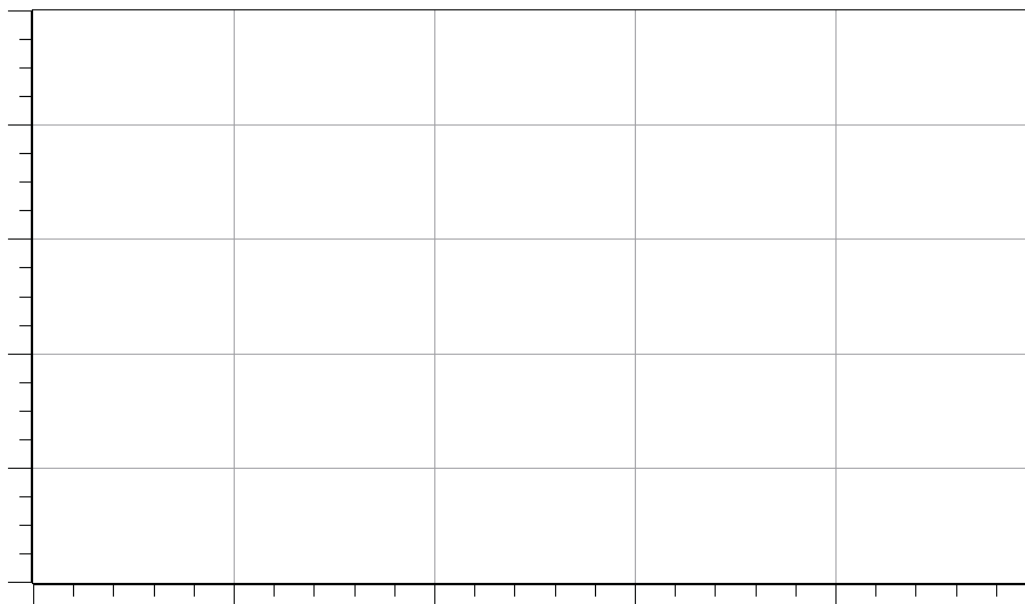
Force (N)	Interval of Time (s)	Number of Revolutions	Period (s)	Velocity (m/s)

Mass of the stopper for Part 3: _____

Length of the radius for Part 3: _____

5. ☐ Complete the Period column in Table 3 by dividing the interval of time by the number of revolutions for each force.
6. ☐ Complete the Velocity column in Table 3 by dividing the circumference of the circle by the period.
7. ☐ Using your Force and Period data, plot a graph of Force versus Period.

Force versus Period



Analysis Questions

- 1.** How did the period change as a result of increasing the mass of the object?

- 2.** How did the period change as a result of decreasing the radius?

- 3.** How did the period change as a result of increasing the applied force?

Synthesis Questions

Use available resources to help you answer the following questions.

- 1.** A space station is built in the form of a large circular structure with a radius of 100 m. The rooms of the station are all built such that the outer surface is the floor of each room. How fast would the space station have to spin for the floor to exert a force on a 75 kg station crew member equivalent to the normal force exerted by a floor on the surface of Earth?

- 2.** A 1,200 kg car is driving around a banked circular track with a radius of 500 m and an inward bank of 30° . How fast will the car need to travel so that the inward force of the track is the only force required to keep the car in circular motion?

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3. What would happen to this same car if it were travelling at this speed and hit a patch of the track that was nearly frictionless because of an oil spill?

4. How fast will the car have to travel if the track was only 200 m in diameter?

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. The centripetal force experienced by an object is related to the object's

- A.** Speed
- B.** Mass
- C.** Velocity
- D.** Radius of rotation
- E.** All of the above

2. As the frequency of revolutions increase, the centripetal force experienced by the stopper

- A.** Decreases
- B.** Increases
- C.** Remains the same
- D.** Not enough information to decide
- E.** Is always equal to zero

3. The direction of the stopper's net acceleration is

- A.** In the same direction as the centripetal force
- B.** In the same direction as the velocity
- C.** Tangent to the circular path of the stopper
- D.** Downward below the plane of the motion

4. The base units of the newton are represented by

- A. $\text{kg}\cdot\text{m}/\text{s}$
- B. $\text{kg}\cdot\text{m}^2/\text{s}$
- C. $\text{kg}\cdot\text{m}/\text{s}^2$
- D. $\text{kg}\cdot\text{m}^2/\text{s}^2$

Key Term Challenge

Fill in the blanks from the list of randomly ordered words in the Key Term Challenge Word Bank.

1. The force that acts through a string is referred to as _____. A _____ sensor can measure the tension through a string in newtons. When an object rotates around a central point with a string, the tension in the string equals the _____ force experienced by the object. An object's _____, mass, and _____ of rotation all contribute to the magnitude of the centripetal force. Newton's _____ law holds true for rotational motion in that the centripetal acceleration is proportional to centripetal force and is in the same direction. The proportionality constant is the _____ of the object.
2. If a force of _____ 1 N causes a 1 kg object to accelerate at 1 m/s^2 in a circular path, the _____ of rotation is equal to the _____ squared. Even if an object in circular motion is travelling at a constant speed, it still experiences an _____ due to the change in direction.

Key Term Challenge Word Bank

Paragraph 1

Centripetal

Circular

Force

Tension

Mass

Friction

Velocity

Second

Radius

Third

Distance

Paragraph 2

Magnitude

Centripetal

Newtons

Acceleration

Mass

Radius

Velocity