Name Period Date

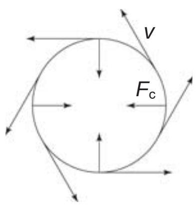
18. Circular Motion

Driving Question

What factors influence the motion of an object that travels in a circular path at a constant speed?

Background

Your prior study of the motion of objects has mostly included linear dynamics. When an object moves in a curved or circular path, the object is subject to a center-seeking force 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.



In this experiment, you will conduct several short investigations examining 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 are held 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
- Force sensor
- Rubber stopper, #10 single-hole
- Rod, short
- Plastic tube
- Timer
- Balance (1 per classroom)
- Table clamp
- Meter stick
- Plastic tie
- String, 3 m
- Scissors
- Marker

Safety

Add these important safety precautions to your normal laboratory procedures:

- Use appropriate eye protection.
- Have adequate space around your lab stations to rotate the mass above your heads in a 1 m radius.

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.

Press the "zero" button on the sensor.	Carefully begin rotating the mass above your head at the radius marked on the string.	Calculate the acceleration experienced by the mass.	Connect the force sensor to the data collection system.	Time 10 revolutions of the mass while maintaining a constant force on the sensor.

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.

Set Up

1. ☐ Start a new experiment on the data collection system. �(1.2)

2. ☐ Measure the mass of the stopper, and record the value in Table 1 in the Data Analysis section.

3. ☐ Connect the force sensor to the data collection system. �(2.1)

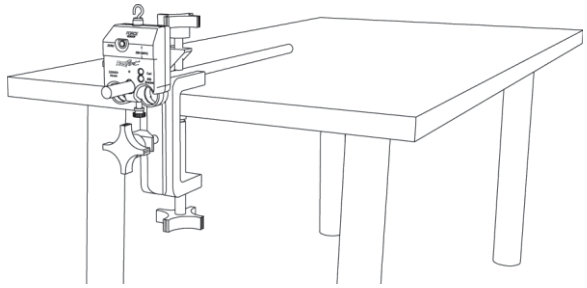
4. ☐ Display Force, pull positive in a digits display. �(7.3.1)

5. ☐ Configure the data collection system to monitor live data without recording. �(6.1)

6. ☐ Attach the table clamp to a table with the rod connector above the table.

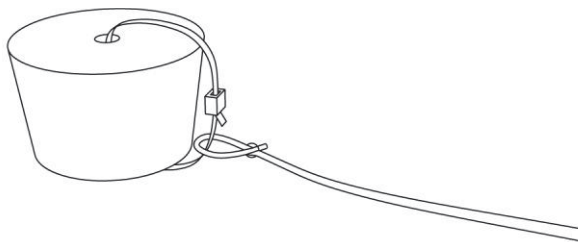
7. ☐ Attach the short rod to the rod connector on the table clamp such that the rod is parallel to the floor.

8. ☐ Attach the force sensor to the short rod such that the hook of the sensor points straight up, and then push the "zero" button on the force sensor.



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

10. ☐ Tie the string to the plastic tie.

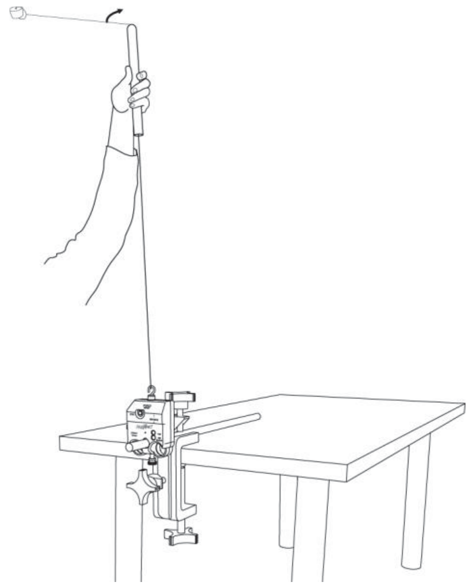


11. ☐ Measuring from the center hole of the stopper (approximately the center of mass), mark the string at 1.0 meter from the stopper's center of mass. Record the radius in Table 1 in the Data Analysis section.

12. ☐ If the radius of the circle of motion is 1.0 m, what is the distance the stopper travels in one revolution?

13. ☐ Thread the other end of the string through the plastic tube, and attach the string to the hook of the force sensor. Adjust the length of the string to allow the mass to rotate overhead.

Collect Data



14. ☐ Carefully begin rotating the mass overhead. Keep the mark on the string at the mouth of the tube to insure the radius remains 1 m.

Note: Always try to keep the plane of rotation parallel to the floor.

15. ☐ Use the stopwatch to time 10 revolutions of the mass while maintaining a constant speed.

Note: One way to determine if you are maintaining a constant speed it to maintain a constant force on the force sensor.

16. ☐ Record the force and time of 10 revolutions in Table 1 in the Data Analysis section.

17. ☐ Repeat data collection, rotating the mass at a higher speed

Analyze Data

18. ☐ Calculate the time it took to complete a single cycle, and record the value in Table 1 in the Data Analysis section for both the high speed and low speed data sets.

19. ☐ Calculate the distance travelled by the mass in a single revolution, and record the value in Table 1 in the Data Analysis section for both the high speed and low speed data sets.

20. ☐ Calculate the speed of the mass in a single revolution, and record the value in Table 1 in the Data Analysis section for both the high speed and low speed data sets.

Data Analysis

Table 1: Circular motion

Experiment parameter	Low speed	High speed
Mass of the stopper (kg)		
Radius of rotation (m)		
Time for 10 revolutions (s)		
Time for a single revolution (s)		
Force, measured (N)		
Distance traveled in 1 rotation (m)		
Speed (m/s)		
Acceleration (m/s^2)		
Force, calculated (N)		

Analysis Questions

1. If the centripetal acceleration experienced by a mass undergoing uniform circular motion is v^2/r, calculate the centripetal acceleration experienced by the rotating mass in this experiment for each speed. Record the results in Table 1.

2. What direction is the acceleration?

3. **Using $F = ma$, calculate the force exerted by the string to keep the mass in a circular path. Record the value in Table 1 in the Data Analysis section for both the high speed and low speed data sets.**

4. **How does the calculated force compare to the measured force?**

5. **What factors do you think contribute to any difference between the calculated and measured force?**

Synthesis Questions

Use available resources to help you answer the following questions.

1. **An automobile with a 750 kg mass goes around a corner in a circular path with a radius of 22 m at 45 km/hr. What is the acceleration experienced by the car?**

2. **If the moon rotates around the earth once every 28 days at a radius of 384,000 km, what is the speed of the moon in m/s? What is acceleration the moon experiences?**

Multiple Choice Questions

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

1. The inertia of an object is related to the object's

- **A.** Speed
- **B.** Mass
- **C.** Velocity
- **D.** Force

2. As the frequency of motion increases, the distance per unit time traveled by the stopper

- **A.** Decreases
- **B.** Increases
- **C.** Remains the same
- **D.** Not enough information to answer

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

- **A.** Inward toward the center
- **B.** Outward from the center
- **C.** Tangent to the path at the position of the stopper
- **D.** Upward above the plane of the motion

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. An object's speed and direction is called _________________. If an object is tied to a string such that its speed remains constant as it travels around a central point, it undergoes uniform _________________ motion. Even though the object's _________________ is constant, its velocity is constantly changing.

2. According to Newton's second law, a one newton force causes a 1 kilogram object to accelerate at 1 m/s^2. An inward, or center-seeking, force is called the _________________ force. A constant force means a constant _________________, which makes sense if the object undergoing circular motion has a constantly changing velocity. If the centripetal force is constant, variables such as _________________ and _________________ are proportional to the time it takes to complete a revolution.

Key Term Challenge Word Bank

Paragraph 1	Paragraph 2
Circular	Magnitude
Force	Centripetal
Tension	Newtons
Friction	Acceleration
Velocity	Mass
Speed	Radius