Name _____ Class _____ Date _____

Using a Pendulum to Measure the Acceleration Due to Force of Gravity

Background Information

A freely falling object accelerates at a rate that depends on the force of gravity. Near the surface of Earth, acceleration due to gravity (g) is equal to approximately 9.8 m/s^2. There are several ways to measure acceleration due to gravity. In this investigation, you will use a method that makes use of a pendulum. A pendulum consists of a weight, also known as a bob, that swings back and forth from a rope or string. Because the fixed end of the string is tied in place, it exerts a centripetal force that pulls the falling weight into a circular path. The time required for a pendulum to complete a back-and-forth swing is called the period of the pendulum. In Part A of this investigation, you will determine whether the period of a pendulum depends on the angle from which the bob is released.

Because the friction forces acting on the pendulum are neglible, it can be assumed that the pendulum is acted on by a single force—the force of gravity. A simple equation relating the acceleration due to gravity, the length of the pendulum, and the period of the pendulum can be written. In Part B of this investigation, you will design and carry out an experiment in which you will use a pendulum and this equation to determine the value of g.

Problem

How can you use a pendulum to determine the acceleration due to gravity?

Pre-Lab Discussion

Read the entire investigation. Then, work with a partner to answer the following questions.

1. **Designing Experiments** In Part A of this investigation, how will you determine the period of the pendulum?

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2. **Predicting** In Part A of this investigation, how will the angle from which the pendulum is released affect the period of the pendulum?

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Name _____ Class _____ Date _____

3. **Formulating Hypotheses** State a hypothesis that you could test in Part B of this investigation.

4. **Designing Experiments** Describe an experiment that you could perform to test your hypothesis.

5. **Controlling Variables** Identify the manipulated, responding, and controlled variables in the experiment described in Question 4.

6. **Evaluating** What experimental result would support your hypothesis? What result would contradict your hypothesis?

Materials *(per group)*

ring stand	meter stick
2 books	100-g mass
clamp	protractor
metal rod, approximately 30 cm long	stopwatch
2-m fishing line	graph paper

Ask your teacher to provide you with any additional materials that you will need to carry out Part B of this investigation.

Name _____ Class _____ Date _____

Safety

Wear safety goggles when performing this investigation. Note all safety alert symbols next to the steps in the Procedure and review the meaning of each symbol by referring to the Safety Symbols on page xiii.

Procedure

Part A: Determining If the Angle of Release Affects the Period of a Pendulum

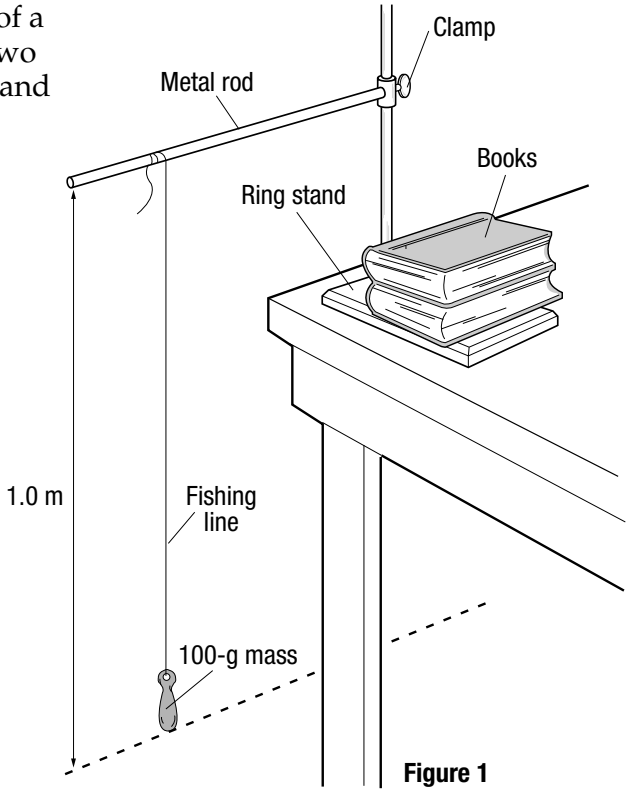

Figure 1

1. Place the ring stand near the edge of a table, as shown in Figure 1. Place two textbooks on the base of the ring stand to prevent it from falling over. Use the clamp to attach the metal rod to the ring stand so that it extends beyond the edge of the table.
2. Tie one end of the fishing line to the portion of the metal rod that extends over the table. Tie the 100-g mass to the other end of the fishing line so that the center of the mass is 1.0 m below the metal rod, as shown in Figure 1.
3. Using the protractor to measure the angle, position the mass at an angle of 10 degrees. **Note:** *When the mass hangs straight down, the angle is 0 degrees.* Hold the mass in this position so that the fishing line is straight and extended. Have a group member start the stopwatch at the instant that you release the mass. Measure the time that the pendulum takes to make 20 complete back-and-forth swings. Record this time in Data Table 1. Also make note of the speed with which the pendulum swings back and forth.
4. Repeat Step 3 two more times, first releasing the mass at a 20-degree angle and then a 30-degree angle. For each trial, record in Data Table 1 the time the pendulum takes to complete 20 back-and-forth swings.
5. Calculate the period of the pendulum by dividing the time the pendulum takes to make 20 complete swings from each of the three positions by 20. Record these values in the appropriate places in Data Table 1.
6. Make a graph of your data. Plot the angle (10, 20, and 30 degrees) on the horizontal axis (x -axis) and the period of the pendulum on the vertical axis (y -axis). Draw a straight line through the data points.

Name _____ Class _____ Date _____

Part B: Design Your Own Investigation

7. Plan an experiment that will make use of a pendulum to determine the acceleration due to gravity (g). The acceleration due to gravity of the pendulum bob can be calculated by dividing the length of the pendulum (L) by the period of the pendulum (T) squared.

$$g = \frac{39.5L}{T^2}$$

Record the hypothesis that you will test.

_____

_____

_____

8. Identify the manipulated, responding, and controlled variables in your experiment.

a. Manipulated variable

_____

b. Responding variable

_____

c. Controlled variables

_____

9. Write out a detailed step-by-step procedure that you will use. Your procedure should produce data that will test your hypothesis. As you plan your experiment, think about what equipment you will need, what measurements you will make, and how you will record and display your data (tables, graphs). Include any safety precautions that you need to take. Construct Data Table 2 in which to record your observations in the space provided on page 127.

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Name _____ Class _____ Date _____

Safety Precautions

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10. Submit your written experimental plan to your teacher. When your teacher has approved your plan, carry out your experiment and record your observations in Data Table 2.

Observations

DATA TABLE 1

Starting Position (degrees)	Time for 20 Swings (seconds)	Period (seconds)
10		
20		
30		

DATA TABLE 2

If you need more space, attach additional sheets of paper.

Name _____ Class _____ Date _____

Analysis and Conclusions

1. **Observing** In Part A of this investigation, how did the angle from which you released the pendulum affect the maximum speed of the pendulum's motion?

2. **Analyzing Data** What did your results in Part A indicate about the relationship between the period of the pendulum and the position from which you released the pendulum?

3. **Evaluating and Revising** Did your results in Part B support or contradict your hypothesis? Explain your answer.

4. **Evaluating and Revising** Use the equation below to determine the experimental error for each of the calculated values for g. Record these error values in Data Table 2.

$$\text{Experimental error} = \left(\frac{\text{Experimental value} - \text{Accepted value}}{\text{Accepted value}} \right) \times 100\%$$

Why might your calculated values of g differ from the accepted value?

Go Further

Predict how the mass of a pendulum affects the period of the pendulum and the calculated value of g. Design an experiment to test your predictions. Show your teacher a detailed description of your experimental plan. When your teacher approves, carry out your experiment and report your results.