Name: _____ Date: _____

Student Exploration: Period of a Pendulum

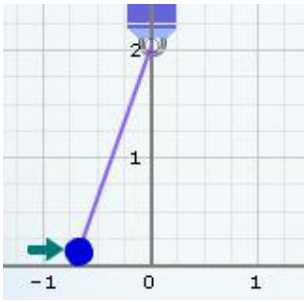
Vocabulary: controlled experiment, mean, pendulum, period

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
A **pendulum** is a weight that can swing freely back and forth. The **period** of a pendulum is the amount of time required to make one full back-and-forth swing.

In each of the comparisons below, circle the pendulum that you think will have a *shorter* period.

Long pendulum	vs.	Short pendulum
Heavy pendulum	vs.	Light pendulum
Pendulum on Earth	vs.	Pendulum on Moon
Pendulum with a large arc	vs.	Pendulum with a small arc

Gizmo Warm-up
The *Period of a Pendulum* Gizmo™ allows you to explore the factors that control how quickly a pendulum swings back and forth.

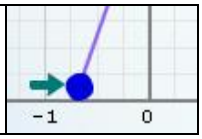


To begin, practice measuring the period of the pendulum. On the Gizmo, check that all variables are set to their original values: ***m*** = 0.5 kg, ***L*** = 2.0 m, ***g*** = 9.8 m/s^2, and ***θ*** = 20°. Open the **POINTER** tray and drag an arrow so that it just touches the pendulum at its left-most position, as shown at right.

1. A full "swing" of the pendulum is one complete back-and-forth movement. Select the TABLE tab. Click **Mark time** each time the pendulum touches the arrow. Mark 10 times. What values do you get for the period of the pendulum?

   _____ _____ _____ _____ _____ _____ _____ _____ _____ _____

2. What is the **mean** of these values? (Note: To find the mean, add up the values and divide by the number of values, or 10.) _____

Activity A: **Factors affecting period**	Get the Gizmo ready: • On the TABLE tab, click **Reset**.	

Introduction: The *Period of a Pendulum* Gizmo allows you to investigate four factors: mass (***m***), length (***L***), gravitational acceleration (***g***), and angle (***θ***).

Question: Which factors affect the period of a pendulum?

1. Measure: Click **Mark time**. Carefully count 10 swings of the pendulum, and click **Mark time** again at the conclusion of the last swing.

   A. What is the time for 10 swings? _____

   B. Divide the time by 10. What is the measured period of the pendulum? _____

   C. How does this value compare to the mean period you found in the Gizmo Warm-up?

   _____

2. Design an experiment: To conduct a fair test of the factors that could affect the period of a pendulum, change only one factor at a time. This is known as a **controlled experiment**.

   First, design a controlled experiment to find the effect of mass (***m***) on period. Describe your experiment below.

   _____

   _____

   _____

3. Gather data: Record the results of your experiment in the table below.

m **(kg)**	***L*** **(m)**	***g*** **(m/s^2)**	***θ*** **(°)**	**Time for 10 swings (s)**	**Period (s)**

4. Analyze: What was the effect of pendulum mass on the period of the pendulum? _____

   _____

(Activity A continued on next page)

Activity A (continued from previous page)

5. Investigate: Conduct similar controlled experiments on the effects of length, gravitational acceleration, and angle on the pendulum period. Record your results below.

Length experiment

m (kg)	*L* (m)	*g* (m/s^2)	*θ* (°)	Time for 10 swings (s)	Period (s)

Gravitation experiment

m (kg)	*L* (m)	*g* (m/s^2)	*θ* (°)	Time for 10 swings (s)	Period (s)

Angle experiment

m (kg)	*L* (m)	*g* (m/s^2)	*θ* (°)	Time for 10 swings (s)	Period (s)

6. Analyze: Look at your data.

   A. How did changing the length (*L*) affect the period? _____

   _____

   B. How did changing the gravitational acceleration (*g*) affect the period? _____

   _____

   C. How did changing the initial angle (*θ*) affect the period? _____

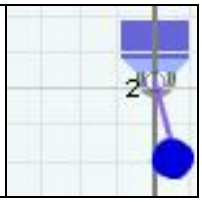
   _____

7. Compare: How did the results of your experiments compare to the predictions you made in the Prior Knowledge Questions? _____

   _____

   _____

   _____

Activity B: **Length and period**	Get the Gizmo ready: • Click **Reset**. • Set ***L*** to 0.2 m, ***g*** to 10.0 m/s^2, and ***θ*** to 20°. (Note: You can type values directly into the text boxes.) • You can set the mass ***m*** to any value.	

Introduction: The Dutch scientist Christiaan Huygens is credited as the first to create a formula that describes the period of a pendulum. In this and the next activity, you will derive Huygens's formula by measuring the effect of length and gravitation on the period of a pendulum.

Question: What is the effect of length on the period of a pendulum?

1. Predict: How do you think a pendulum's period will change if its length is multiplied by 2?

   _____

2. Measure: Keeping ***g*** and ***θ*** constant, measure the period for each of the following lengths. Leave the last three columns blank for now. Include all units.

L **(m)**	**Time for 10 swings (s)**	**Period (s)**	**Length factor**	**Time factor**	$\sqrt{\text{Length factor}}$
0.2 m					
0.4 m					
0.8 m					
1.0 m					
1.8 m					

3. Calculate: Divide each length by the original length (0.2 m). Record in the "Length factor" column. Fill in the "Time factor" column by dividing each period by the original period.

4. Calculate: Find the square root of each length factor, and fill in the last column of the table.

   A. What do you notice? _____

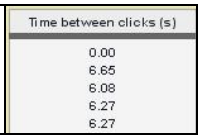
   B. How does the period of a pendulum relate to the square root of the length factor?

   _____

5. Apply: A pendulum with a length of 10 meters has a period of 6.34 seconds.

   A. What is the period of a pendulum with a length of 90 meters? _____

   B. What is the period of a pendulum with a length of 160 meters? _____

Activity C: **Gravity and period**	Get the Gizmo ready: • Click **Reset**. • Set ***L*** to 1.0 m, ***g*** to 1.0 m/s^2, and ***θ*** to 20°.	

Question: What is the effect of gravitational acceleration on the period of a pendulum?

1. Predict: How do you think the period of a pendulum will change if ***g*** was multiplied by 2?

   _____

   What if ***g*** was multiplied by 4? _____

2. Measure: Keeping ***L*** and ***θ*** constant, measure the period for each of the following values of ***g***. Leave the last two columns of the table blank for now.

g **(m/s^2)**	**Time for 10 swings (s)**	**Period (s)**	**Time factor**	$\frac{\mathbf{1}}{\mathbf{Time\ factor}}$
1.0 m/s^2				
2.0 m/s^2				
4.0 m/s^2				
9.0 m/s^2				
16.0 m/s^2				
25.0 m/s^2				
36.0 m/s^2				
49.0 m/s^2				

3. Calculate: Divide each period by the original period, and fill in these values under "Time factor." Then, take the reciprocal of each of these values, and fill in the last column.

4. Analyze: Compare the value of *g* to the time factors and reciprocals.

   A. How did the period change when *g* was multiplied by 2? _____

   B. How did the period change when *g* was multiplied by 4? _____

   C. How did the period change when *g* was multiplied by 9? _____

   D. In general, what is the relationship between the reciprocal of the time factor and the value of *g*? _____

(Activity C continued on next page)

Activity C (continued from previous page)

5. Generalize: How does the period relate to the square root of the value of *g*? _____

   _____

6. Challenge: Put together what you learned in the previous activity and this activity to come up with a formula for the period of a pendulum (*T*) based on its length and the strength of gravity. The format of the formula is shown below. (Note: In the equation, *a* is a constant that takes the shape of a pendulum's arc into account.)

$$T = a\sqrt{\frac{x}{y}}$$

   Write your formula here:

   Have your teacher check your formula when it is complete.

7. Measure: Find the period when *L* is 1.0 m and *g* is 1.0 m/s^2. This is the value of the constant *a* in your formula. What is the value of *a*? _____

8. Apply: Use your formula to find the periods of pendulums with the following parameters. Use the Gizmo to check the first three pendulums. (The Gizmo cannot be used to check the last two sets of parameters.)

***L* (m)**	***g* (m/s^2)**	**Calculated period (s)**	**Measured period (s)**
1.6 m	16.0 m/s^2		
2.0 m	25.0 m/s^2		
1.2 m	6.0 m/s^2		
5.0 m	15.0 m/s^2		
32.0 m	9.0 m/s^2		

9. Think and discuss: The formula you created does not include the initial angle of the pendulum. How do you think the initial angle would affect the formula? Experiment with the Gizmo, and then discuss your results with your classmates and teacher.

   _____

   _____