Level A Investigations

A-1 The Pendulum

How can you change the period of a pendulum?

Students are introduced to the vocabulary used to describe harmonic motion: cycle, period, and amplitude. This activity offers students the opportunity to test a system with three independent variables as they explore which has the greatest effect on the period of a pendulum: mass, amplitude, or string length.

A-2 Making a Clock

How can you use a pendulum to measure time?

Students use their graph of string length vs. period from *A-1 The Pendulum* to predict the string length needed to create a period of a desired length. Next, they use this information to build a pendulum which will accurately measure one minute of time.

Level B Investigations

B-1 Harmonic Motion

How do we describe the back-and-forth motion of a pendulum?

Students learn the basic concepts that describe harmonic motion. These include cycle, period, and amplitude. Students design and carry out experiments to determine how string length, mass, and amplitude affect the period of the pendulum. Then, they use what they have learned to design a clock that keeps accurate time using the pendulum. Finally, students explore damping and energy loss of the pendulum.

B-2 The Five Second Pendulum

What length of string would produce a 5-second pendulum?

Students will use data collected from Investigation *B-1 Harmonic Motion* to come up with a formula to calculate period from string length. They will compare calculated results with experimental results. Many students are amazed that math can be used to predict actual experimental results! They will solve their equation for string length and then extrapolate the string length required for a 5-second pendulum.

B-3 Graphs of Harmonic Motion

How do we make graphs of harmonic motion?

Students discuss and practice making several graphs of harmonic motion from provided data. The purpose is to become familiar with the basic characteristics of a harmonic motion graph, such as the cycle, period, and amplitude. The concept of superposition (although not specifically named) is introduced by having students create a graph that shows two harmonic motions added together. By graphing motions with a phase difference, the connections between circular motion and harmonic motion are made.

Level C Investigations

C-1 Energy Conservation and the Pendulum

How can we use the law of energy conservation to analyze the motion of the pendulum?

Students use well known physics principles to estimate the behavior of a system. The ability to construct approximate theories is a foundation of science and technology. In most situations, an approximation is all that is possible. For example, the formulas for deflection of beams under load rely on approximations which are not valid for all situations. The engineer must understand the approximations made to derive the formulas to ensure that the results accurately predict performance.

C-2 Newton's Second Law and the Pendulum

How can Newton's second law be used to establish a relationship for the period of the pendulum?

Students use reasonable approximation to find an expression which relates the period of the pendulum to the length of the string. This Investigation strengthens students' understanding of the value of approximation as a tool. As they compare their results with those of the previous Investigation, they will gain a new appreciation for the interdependence of scientific laws.

C-3 The Physical Pendulum

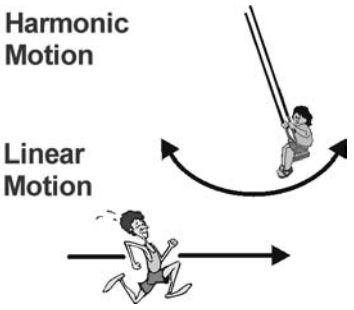
Can the period of a physical pendulum be predicted using the expression for the period of a simple pendulum?

Students expand their study of the pendulum. They use a constructed, physical pendulum and measure its period. They calculate the period using the expression for the period of a simple pendulum, and then compare predicted and measured values. After finding a more accurate expression for the period of a physical pendulum, students examine the effect of adding mass to the physical pendulum at different places along its length.

Question: How can you change the period of a pendulum?

In this Investigation, you will:

1. Learn how to describe the motion of a pendulum.
2. Explore how changes in the length, mass, and amplitude of a pendulum affect its motion.

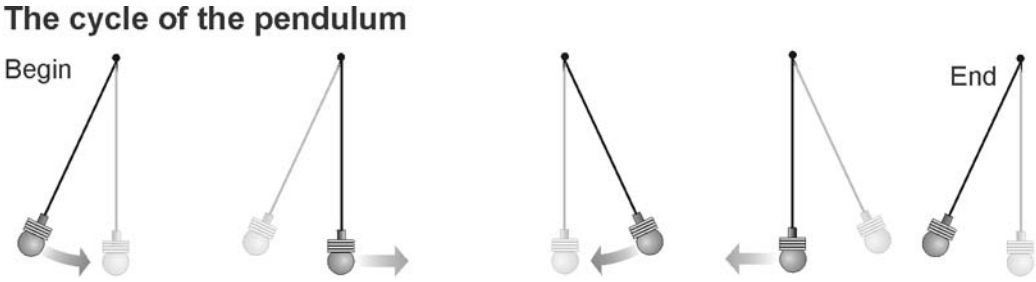


As you watch moving things, you see two kinds of motion. One kind of motion goes from one place to another, like a person walking from home to school. This is **linear motion**. We use words like distance, time, speed, and acceleration to describe linear motion.

The second kind of motion is motion that repeats itself over and over, like a child going back and forth on a swing. This motion is called **harmonic motion**. The word harmonic comes from the word *harmony* which means "multiples of."

Many moving things have both linear and harmonic motion. A bicycle, for example, moves forward, but the wheels and pedals go around and around in harmonic motion.

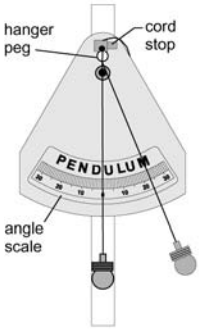
You will need to learn some new words in order to describe and measure harmonic motion:



- A **cycle** is one complete back and forth motion. For a pendulum, you could define a cycle as starting when the pendulum is all the way to the left. The cycle would be complete when the pendulum has swung as far to the right as it will go and has come all the way back to the left again.
- The **period** is the time it takes to complete one full cycle. The period of a pendulum is the time it takes for the pendulum to swing from left to right and back again.
- The **amplitude** describes the size of the cycle. The diagram below shows the difference between a pendulum with a small and a large amplitude. For a pendulum, the amplitude is measured as the maximum distance or the maximum number of degrees that it moves from the center.

1 Setting up the experiment

1. Attach the pendulum to one of the top holes in the physics stand.
2. Slip the pendulum string through the slot in the hanger peg. Use the cord stop to keep the string from slipping.
3. Make sure that when the pendulum is not moving, the string lines up with zero degrees on the angle scale. If it doesn't, adjust the pendulum hanger until the angle scale is centered properly.



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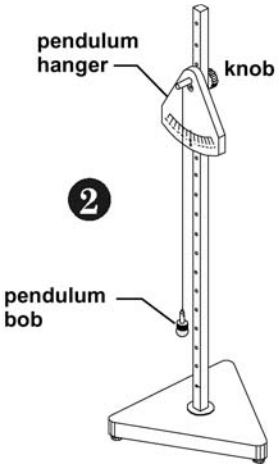

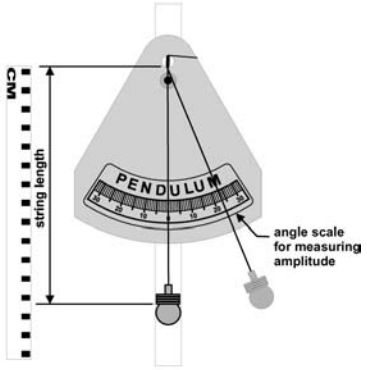

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2 What happens to the period when you change the mass of the pendulum?

You can change the mass of the pendulum by sliding washers down the string. The washers will rest on the pendulum bob. In this experiment, you will start with zero washers. Add two washers each time you repeat the experiment. You will need to keep the string length and the amplitude constant during this part of the experiment.

1. Decide with your group how long you want the string to be. Measure the string from the bottom of the string peg to the bottom of the stack of washers.
   String length: _____
2. Decide with your group how large you would like the amplitude to be. The amplitude is measured using the angle scale on the pendulum hanger.
   Amplitude: _____
3. You will use the timer in stopwatch mode to measure the time it takes for the pendulum to complete ten cycles. Assign one person in your group to count the cycles, and another person to start and stop the timer.

   HINT: Rather than trying to start the pendulum at the exact amplitude you have chosen, start the pendulum at a slightly larger amplitude. Friction will cause the amplitude to get a little bit smaller with each cycle. When the amplitude has decreased to the correct size, start counting the cycles. Record your data in Table 1 on the next page.
4. Divide the time you measured for ten cycles by 10 to find the period of the pendulum. Record your data in Table 1.
5. Repeat the experiment four more times, adding two more washers to the pendulum each time.

Table 1: Changing the Mass of the Pendulum

Number of washers	Time for ten cycles (seconds)	Period (seconds)

3 What happens to the period when you change the amplitude?

This time, you will change the amplitude of the pendulum, while keeping its weight and string length constant.

1. With your group, decide how many washers you want the pendulum to carry.
   Number of washers: _____
2. With your group, decide how long you want the string to be.
   String length:_____
3. With your group, decide on five different amplitudes to measure. Your data will be easier to graph if your amplitudes are spread out evenly. For example, you might want the amplitude to increase by three degrees, or five degrees, between each trial.
4. Follow the same procedure as before to measure the time for ten cycles. Record your data in the table below.
5. Divide the time for ten cycles by 10 to find the period of the pendulum. Record your data in the table below.
6. Repeat the experiment using different starting amplitudes.

Table 2: Changing the Amplitude of the Pendulum

Amplitude (degrees)	Time for ten cycles (sec)	Period (seconds)

4 Examining your data so far

a. How does adding weight to the pendulum affect its period?

b. How does changing the amplitude of the pendulum affect its period?

5 What happens when you change the string length of the pendulum?

A-1

The third experiment looks at whether changing the length of the string changes the period. It is important to keep the amplitude and the number of weights constant throughout this part of the Investigation.

1. With your group, decide what the amplitude will be.
   Amplitude: _____
2. With your group, decide how many weights the pendulum will carry.
   Number of weights: _____
3. With your group, choose five different string lengths to measure. Again, your data will be easier to graph if the string length increases or decreases by the same amount between each trial. Record the string lengths you choose in Table 3.
4. Follow the same procedure as before to measure the time for ten cycles. Record your data in Table 3.
5. Divide the time for ten cycles by 10 to find the period of the pendulum. Record your data in Table 3.
6. Repeat the experiment using the four other string lengths chosen by your group.

Table 3: Changing the String Length

String length (cm)	Time for ten cycles (sec)	Period (seconds)

6 Thinking about what you have learned

a. Make a graph of each of your data tables. On each graph, the variable that you changed should go on the *x*-axis. The period of the pendulum should go on the *y*-axis. The scale for the period should be the same for all three graphs. Remember to label your axes. Give each graph a title.

b. Which of the three variables (weight, amplitude, or string length) changed the pendulum's period the most?

c. Suppose you wanted to make a pendulum with a period of exactly two seconds. Describe how you would do this.

Name: _____

A-1 The Pendulum

Question: How can you change the period of a pendulum?

1 Setting up the experiment

There are no questions to answer in Part 1.

2 What happens to the period when change the mass of the pendulum?

String length: _____

Amplitude: _____

Table 1: Changing the Mass of the Pendulum

Number of washers	Time for ten cycles (seconds)	Period (seconds)

3 What happens to the period when you change the amplitude?

Number of washers: _____

String length: _____

Table 2: Changing the Amplitude of the Pendulum

Amplitude (degrees)	Time for ten cycles (seconds)	Period (seconds)

4 Examining your data so far

a. How does adding weight to the pendulum affect its period?

_____

_____

_____

b. How does changing the amplitude of the pendulum affect its period?

_____

_____

_____

5 What happens when you change the string length of the pendulum?

Amplitude: _____

Number of weights: _____

Table 3: Changing the String Length

String length (cm)	Time for ten cycles (seconds)	Period (seconds)

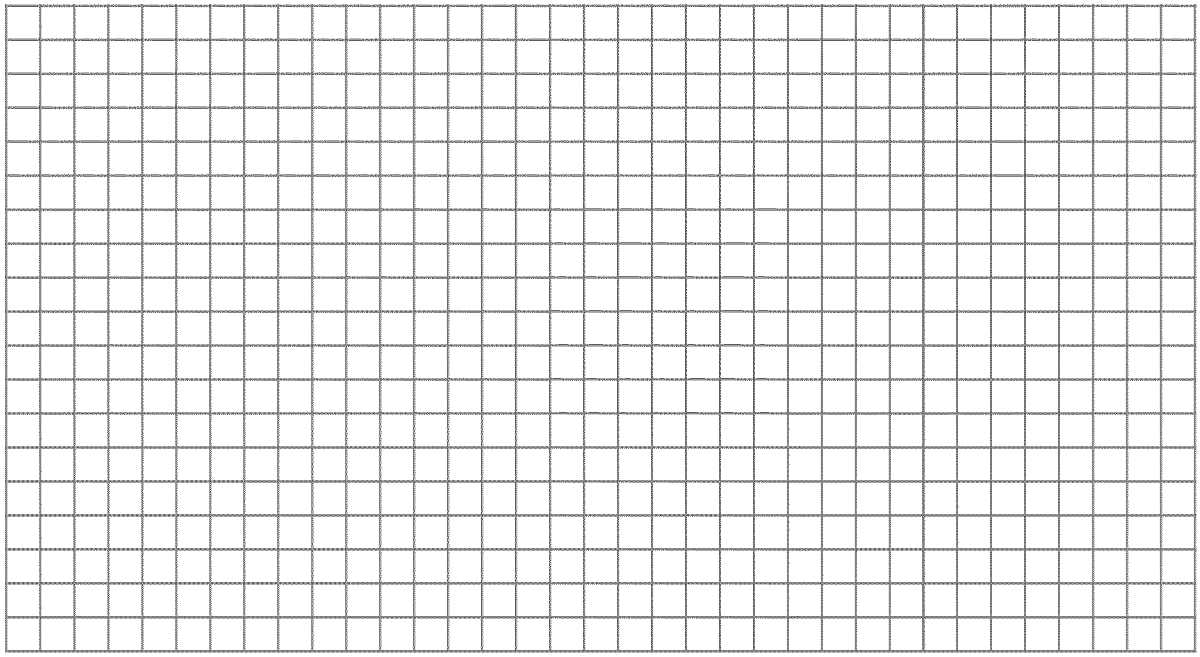
6 Thinking about what you have learned

a. Make a graph of each of your data tables. Use the grids on the next two pages to make your graphs.
On each graph, the variable that you changed should go on the *x*-axis. The period of the pendulum should go on the *y*-axis. The scale for the period should be the same for all three graphs.
Remember to label your axes. Give each graph a title.

Graph 1:

Title: _____

y label: _____

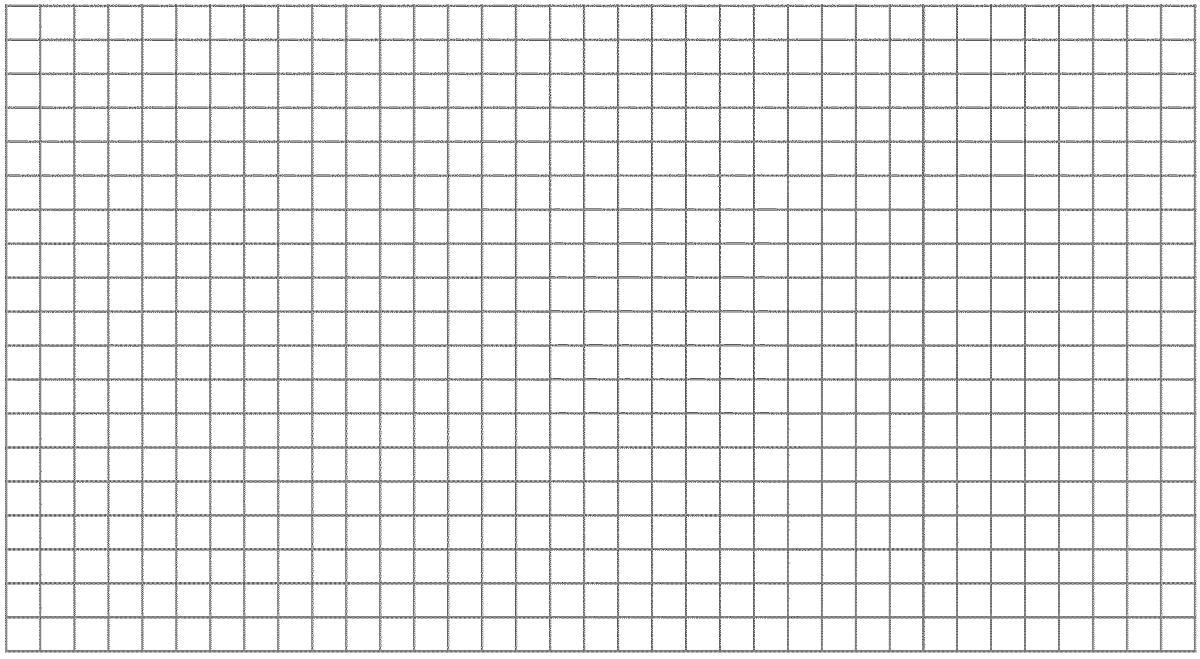


x label: _____

Graph 2:

Title: _____

y label: _____

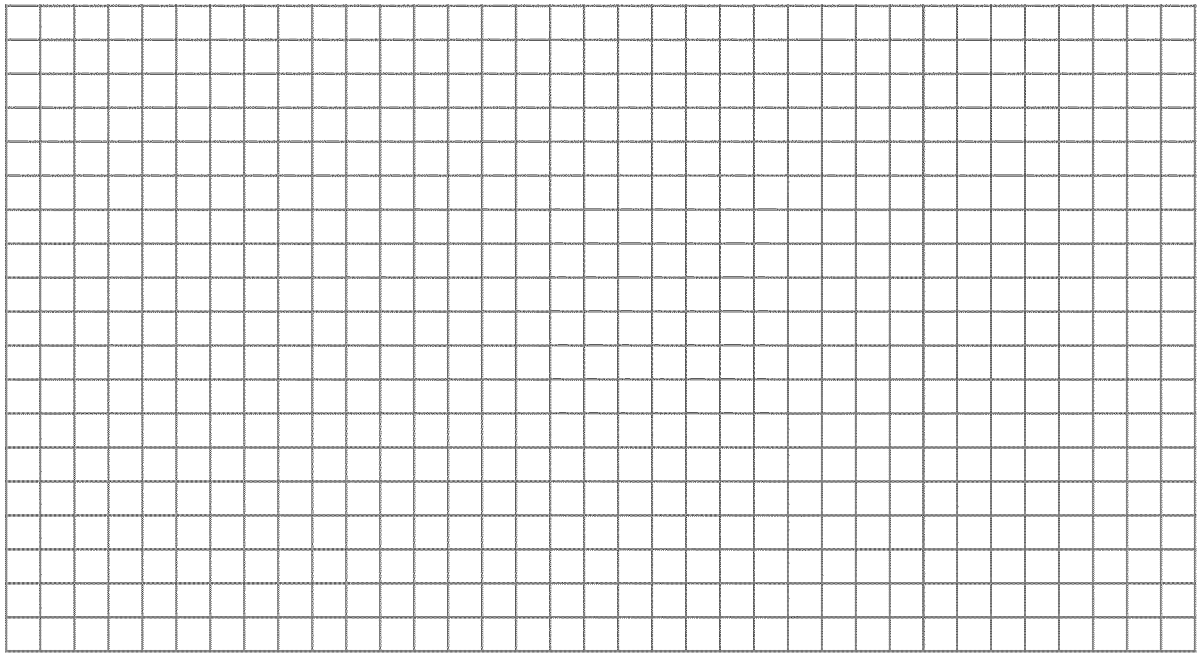


x label: _____

Graph 3:

Title: _____

y label: _____



x label: _____

b. Which of the three variables (weight, amplitude, or string length) changed the pendulum's period the most?

_____

_____

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c. Suppose you wanted to make a pendulum with a period of exactly two seconds. Describe how you would do this.

_____

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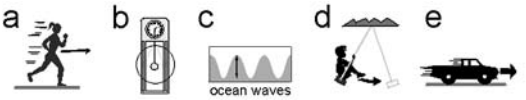
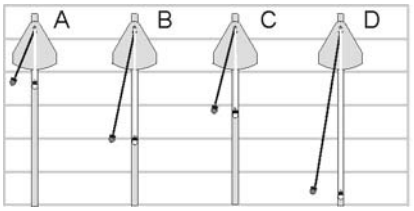
Questions

1. Which pictures show periodic motion?
a. A girl running a 100 m race
b. The swinging pendulum of a clock
c. An ocean wave rising and falling
d. A boy riding a swing
e. a truck moving down the street.



2. Match the four measured periods with the most likely pendulum.



Group	Period	Pendulum
1	1.0 sec	
2	1.2 sec	
3	1.4 sec	
4	1.7 sec	

3. There are several periodic motions associated with Earth. One is that Earth rotates once every 24 hours. List at least two other examples, and give the period of each.

_____

_____

_____

4. Which of the four experiments has the longest period? Why?

_____

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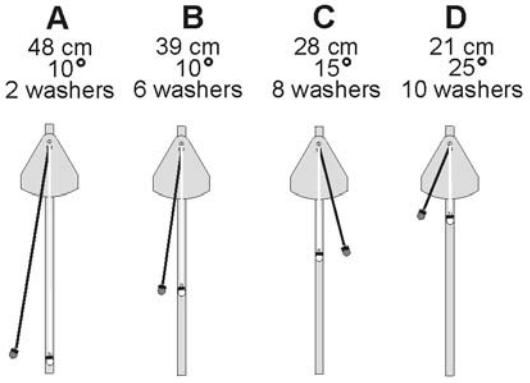

5. CHALLENGE! A pendulum swings past its pole 20 times in 18 seconds. What is the period of the pendulum?

_____

_____

_____

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_____

Curriculum Resource Guide: Pendulum

Credits

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