24A Harmonic Motion NAME _____

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

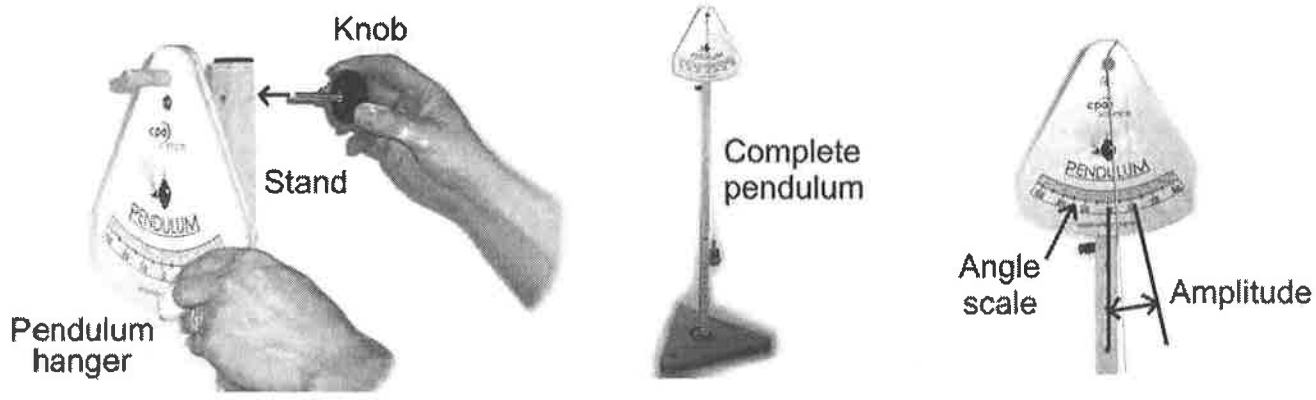
Harmonic motion is motion that repeats in cycles. Many important systems in nature and many useful inventions rely on harmonic motion. For example, the phases of the Moon and the seasons are caused by Earth's harmonic motion. This Investigation will explore harmonic motion using a pendulum. The concepts you learn with the pendulum will also apply to other examples of harmonic motion.

Materials

- Data Collector and 2 photogates
- Physics stand
- Pendulum
- Graph paper

1 Setting up the pendulum

Attach the pendulum to one of the top holes in the stand.



Start the pendulum swinging and watch it for a minute. Think about how to describe the motion.

a. Write one sentence about the motion using the word "cycle."

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_____

_____

b. The *amplitude* is the maximum amount the pendulum swings away from its resting position. The resting position is straight down. One way to measure amplitude is the angle the pendulum moves away from center. Write one sentence describing the motion of your pendulum using the word "amplitude."

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_____

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c. Draw a sequence of sketches that describe one complete cycle using arrows to indicate the direction the pendulum is going at that point in the cycle.

2 Oscillators and period

a. Use the stopwatch function of the Data Collector to measure the period of your pendulum. Time ten cycles. Do three trials and use Table 1 to record your data.

b. Divide the average time for ten cycles by 10 to get the period.

c. Write a one sentence description of how you measured the period.

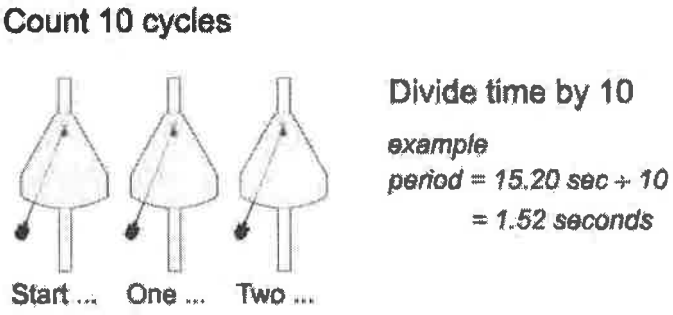
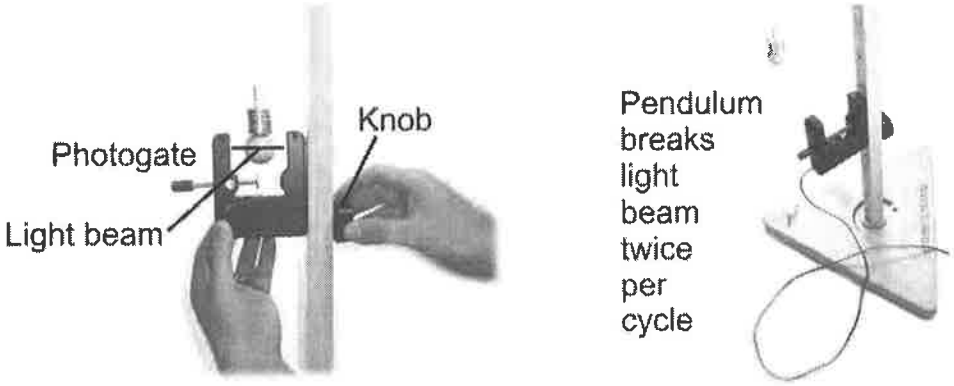


Table 1: Pendulum period data: Time for 10 cycles (sec)

Trial 1	Trial 2	Trial 3	Average
Period of pendulum (average divided by 10)			

3 Measuring period with a photogate



1. Attach the photogate as shown in the diagram. The pendulum breaks the light beam when it swings through the photogate. Try to keep the string length close to the length you used in part 2.
2. Put the Data Collector in period mode and let the pendulum swing through the light beam.
3. If you press the GO button once the display freezes allowing you to write down a number before it changes. Pressing GO a second time starts another measurement.

4 Thinking about what you observed

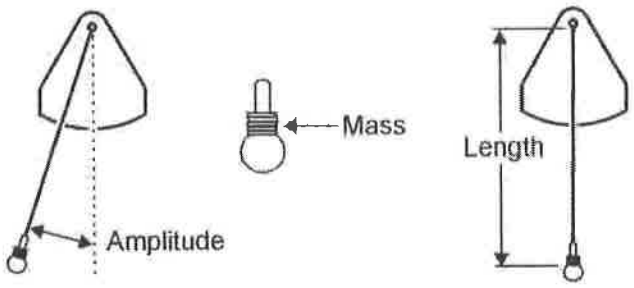
a. Write down the time measurement you get from the Data Collector.

b. Is the time you get from the Data Collector the period of the pendulum? Explain why the time is or is not the period of the pendulum (hint: compare to your results from part 2).

c. Explain how the time measured by the Data Collector is related to the period of the pendulum.

5 What variables affect the period of a pendulum?

In this experiment, the period of the pendulum is the only dependent variable. There are three independent variables: the mass of the bob, the amplitude of the swing, and the length of the string.



1. The amplitude can be changed by varying the angle that the pendulum swings.
2. There are washers that you can use to change the mass of the bob.
3. The length of the string can be changed by sliding it through the slot in the peg. Measure the length of the string from the bottom of the string peg to the bottom of the washers.

Design an experiment to determine which of the three variables has the largest effect on the period of the pendulum. Your experiment should provide enough data to show that one of the three variables has much more of an effect that the other two. Be sure to use a consistent technique that gives you consistent results.

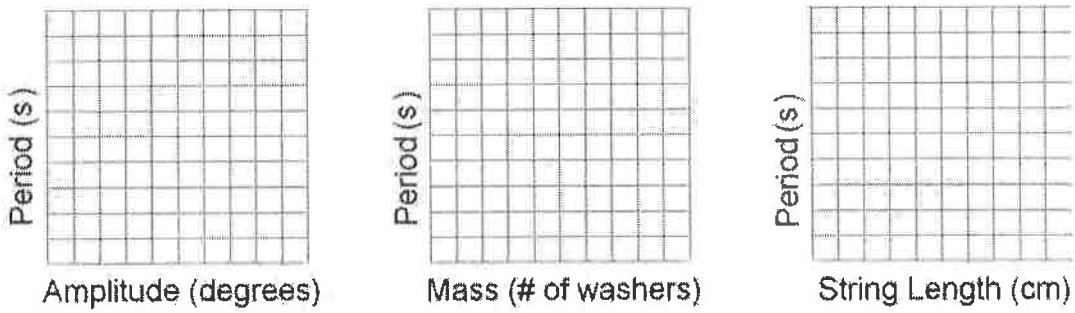
a. Think of three experiments you can do to see what variables affect the period of the pendulum. Write down one sentence describing each experiment.

b. Do the three experiments and record the measurements you make to assess the effect of changing each variable.

6 Analyzing the data

a. Of the three things you can change (amplitude, mass, and string length), which one has the biggest effect on the pendulum, and why? In your answer you should consider how gravity accelerates objects of different mass.

b. Split up your data so that you can look at the effect of each of the three variables by making a separate graph showing how each one affects the period. To make comparison easier, make sure all the graphs have the same scale on the *y*-axis (period). The graphs should be labeled like the example below.



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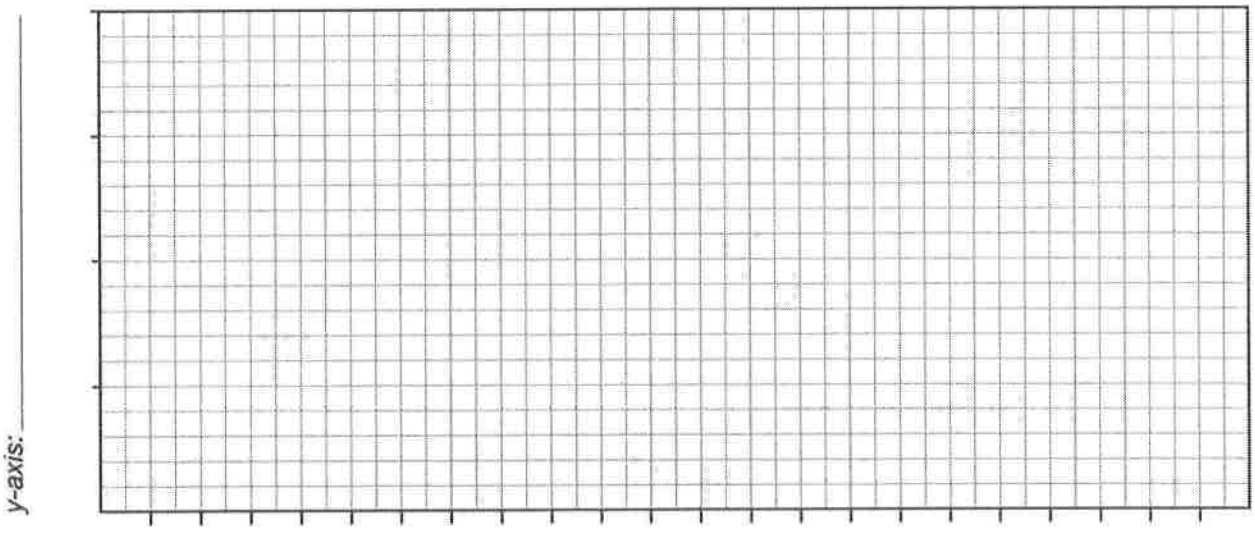
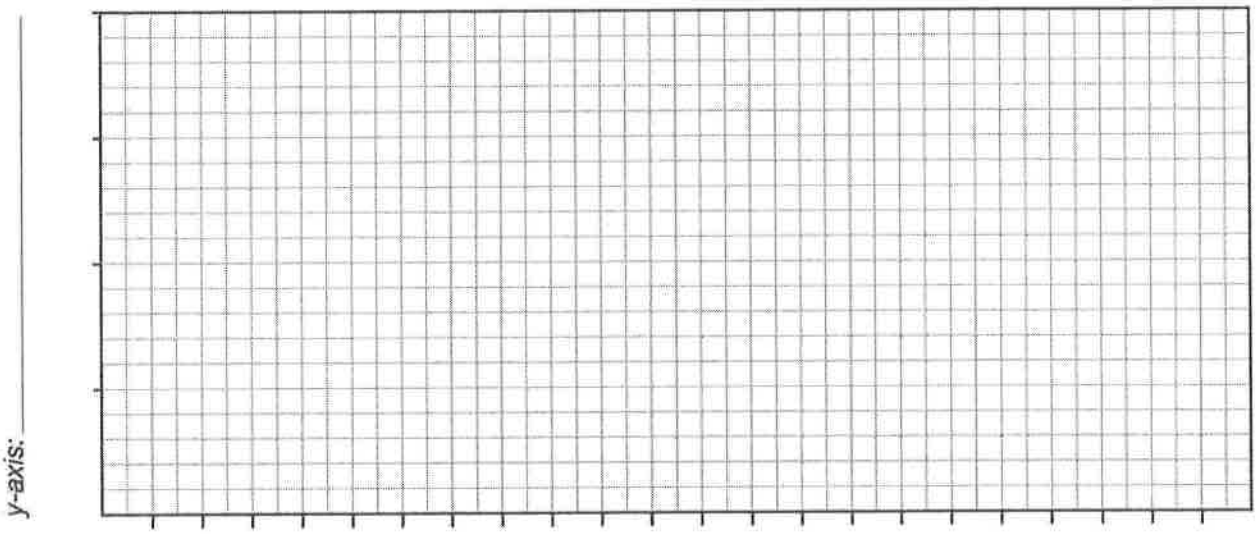


x-axis: _____

Title: _____



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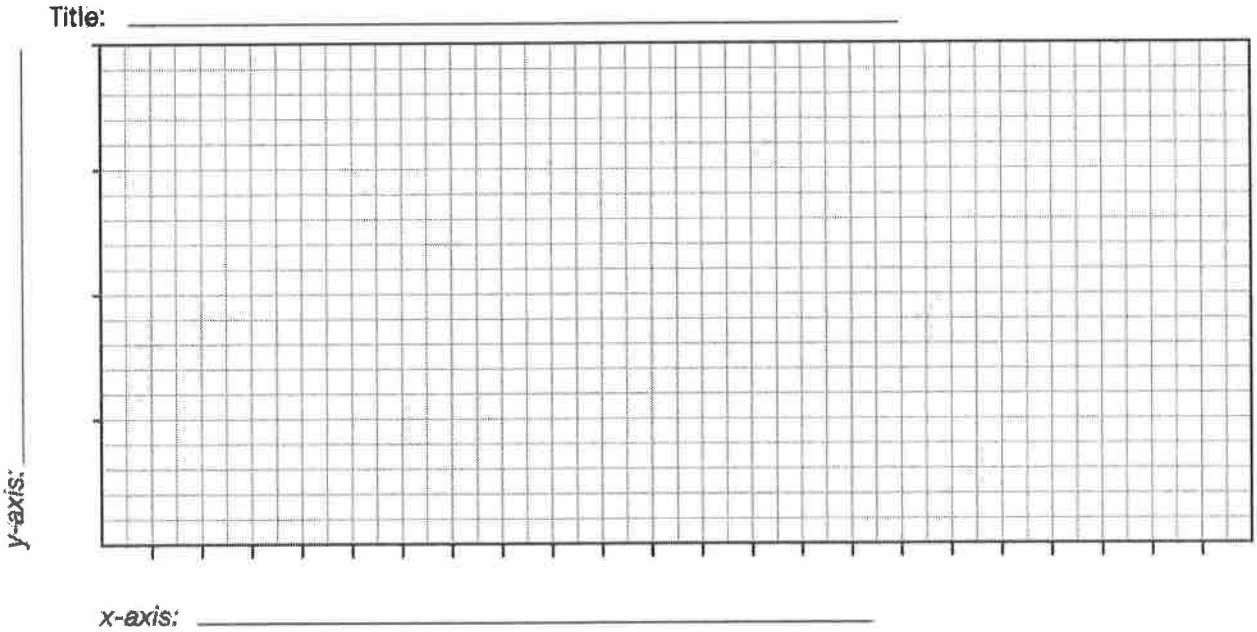

7 Applying what you know

Pendulum clocks were once among the most common ways to keep time. It is still possible to find beautifully made pendulum clocks for sale today. To make a pendulum clock accurate, the period must be set so a certain number of periods equals a convenient measure of time. For example, you could design a clock with a pendulum that has a period of 1 second. The gears in the clock mechanism would then have to turn the second hand 1/60th of a turn per swing of the pendulum.

a. Using your data, design and construct a pendulum that you can use to accurately measure a time interval of 30 seconds. Test your pendulum clock against the electronic stopwatch.

b. Mark on your graph the period you chose for your pendulum.

c. How many cycles did your pendulum complete in 30 seconds?

d. If mass does not affect the period, why is it important that the pendulum in a clock is heavy?

e. Calculate the percent error in your prediction of time from your pendulum clock. The percent error is 100 times the difference between your prediction and 30 seconds, divided by 30 seconds.

f. You notice in a magazine that a watch manufacturer advertises that its quartz watch loses no more than 5 seconds per month. Assume that the watch loses the maximum amount (5 seconds) in 31 days. Calculate the percent error of the quartz watch by comparing 5 seconds to the number of seconds in a month.