Position-Time Graph of a Pendulum

Greg C. Jacobs
Woodberry Forest School
Woodberry Forest, VA 22989

Abstract

An object in simple harmonic motion, such as a pendulum, oscillates about a central point. It can be shown mathematically that the position-time graph of a pendulum is sinusoidal, with a period that depends on the pendulum's length. In this laboratory exercise, you will produce a position-time graph for a pendulum that you design yourself; using this graph you will verify the relationship between the pendulum's period and its length.

Objectives

After this experiment, you will be able to

- Describe conceptually why harmonic oscillation leads to a sinusoidal position-time graph
- Understand experimental methods for producing position-time graphs
- Explain the relationship between the period and length of a simple pendulum

Materials/Procedure:

Your assigned task is to build a simple pendulum and determine its period by means of a position-time graph of the pendulum's motion. The crux of this task is the production of the position-time graph – this may require considerable skill and ingenuity.

You may use any equipment you can salvage or find. Basic laboratory supplies, including some art and craft items, will be available.

Safety and Disposal

Assuming common sense lab protocols (i.e. no poking each other with ring stands!), there should be no safety issues with this experiment. If your procedure could be construed as dangerous, you should come up with a different method.

Lab Tips:

- Most groups will create a pendulum with a bob which somehow indicates its location. The position-time graph will usually be made either by dragging the pendulum at constant speed over some paper, or by dragging some paper at constant speed beneath the pendulum. (Note that many variations of this basic setup can be created; also note that other equally valid methods exist.)

  For example, one possibility is:

  Fill a small balloon with fine sand, and attach the balloon to a string. Poke a small hole in the balloon so that the sand falls out slowly. Let the balloon swing on the string. On the floor, attach a long strip of paper to a constant-speed vehicle. Allow the vehicle to pull the paper under the oscillating balloon. The sand will trace a sinusoidal graph on the paper. Use glue to set the sand in place for analysis.

- For the analysis, you will need to know the time scale of the horizontal axis. Thus, it is useful to use a stopwatch to find the total time during which the position-time graph is made.

Data / Observations

Don't expect your graph to look like a "perfect" sine function. The goal of this exercise is to determine the pendulum's period using the position-time graph. The period can be found even if the graph is a little bit spiky, or if the amplitude is inconsistent, or… Just be sure that the position-time graph accurately represents the motion of the pendulum you created.

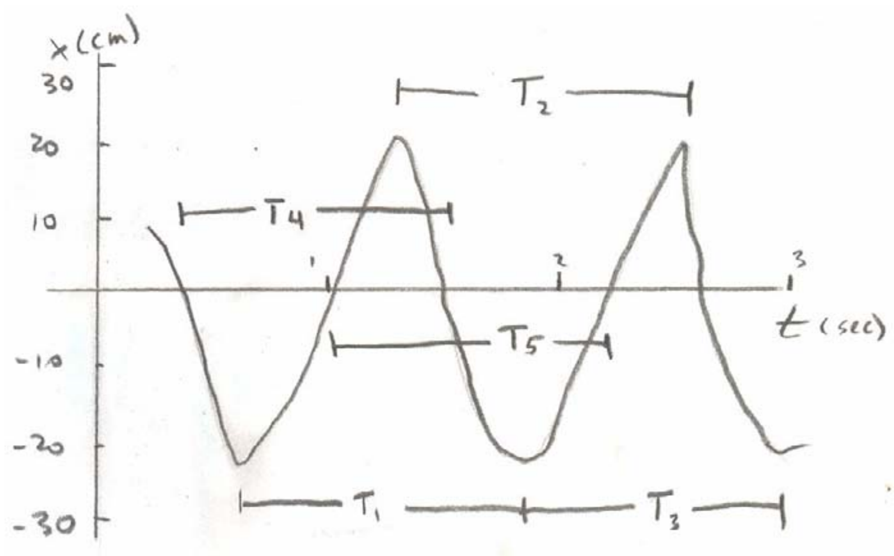
Pay attention to how the pendulum itself moves while the graph is made. Note where the pendulum moves quickly or slowly, and how that speed is reflected in the graph.

Measure the length of your pendulum. If the bob is very long or large, measure two lengths – one to the top of the bob, and one to the very end of the bob; the length of the pendulum for the purpose of the equation for the period will be between these two extreme length measurements.

Analysis

1. Copy a scale version of your position-time graph onto graph paper. To make this copy, it is easiest to label and scale the axes before you start. Measure on the original graph to find the coordinates of critical points, such as peaks, troughs, and places where the graph crosses the time axis.

2. The period of the pendulum is defined as the time elapsed between two identical points in a cycle: for example, from peak to the next. Graphically measure at least five periods, designating each measurement on the graph paper. A sample graph is shown below; T_1, T_2, etc. represent the periods.



3. Determine the average period of your pendulum. Include an uncertainty on this measurement.

4. Using the period calculated in #3, calculate the length of your pendulum. Include an uncertainty on this measurement.

<u>Questions to answer:</u>

1. Based on your observation, when in its cycle was the pendulum moving the fastest? When was it moving slowest? How are these observations consistent with the position-time graph that you made?

2. Where does the pendulum bob spend more time: near the center of its motion, or near the endpoints? Justify your answer with reference to your graph and/or your observations.

3. Compare the length calculated from the period measurements to the length of the pendulum that you measured in lab.