Lab 9

The Simple Pendulum

Experimental Objectives

- Determine the relationship between the period of the pendulum and its amplitude.
- Determine the relationship between the period of the pendulum and its mass.
- Determine the relationship between the period of the pendulum and the length of the pendulum.
- Use a graphical analysis to investigate these relationships, and from the best linear graph determine an empirical equation for the period of a pendulum.
- Gravity also plays a part in this experiment, so include gravity into your empirical equation, and use unit analysis to help figure out this relationship.

Introduction

A simple pendulum consists of a small bob of mass (m) suspended by a light (assumed to be massless) string of length (L), and the string is firmly attached at its upper end. This pendulum is a mechanical system which we will assume exhibits simple harmonic motion. That is, the restoring force on the pendulum is proportional to the displacement from the equilibrium position.

Oscillatory motion is one of the most common types of motions and can occur in any physical system. Mechanical systems can experience a periodic motion, and then will vibrate at a natural frequency. This phenomenon is called resonance. Sound is a vibration in the air, which we hear with our ears; light is an oscillation of electric and magnetic fields, which we can see. The atoms and molecules in all objects are in a state of continual vibration, which we can detect as the temperature of the object, and the atomic vibrations of a quartz crystal can be used as a very accurate timer. The study of repetitive motion is not just an intellectual exercise, but actually enables us to model complicated systems with simple harmonic motion.

Galileo (1564-1642) investigated the natural motions of a simple pendulum. From his observations he concluded that "vibrations of very large and very small amplitude all occupy the same time." Galileo's time interval of measurement was his own pulse rate. With today's modern technology we have much more precise measuring instruments. This experiment will investigate the relationships between the physical characteristics of the pendulum and the period of the pendulum.

9.1 Procedure

You will have available for your use: pendulum bobs, string, timers, and a protractor. Be careful to fix the string to a point of support which will not move or vibrate as the pendulum swings. You will test each of the three relationships above (period vs amplitude, vs mass, and vs length). While measuring one relationship, you should ensure that – if they matter – then the other two variables are not varied. For example, when changing the pendulum mass do not vary the pendulum's length or its amplitude.

Some considerations while doing this lab:

- It turns out that the convenient quantity when graphing is not the period, T, but rather $T/(2\pi)$.
- The amplitude of oscillation is the maximum angle which the string makes from the vertical.
- In general when testing the mass or the length, it is best to keep the amplitude of oscillation small.
- When testing any of the relationships, you should measure a few widely-separated values. If these seem to vary significantly, then fill in the gaps between those measurements to make a reliable graph. See Question 9.2.3.
- If you can prove that the period is not affected by one of these variables, then you do not need to worry about keeping it constant while you measure the other variables.
- Your graphical analysis will be better if your graph is linear. Consider Question 9.2.7 for advice on making your graphs.

9.2 Questions

1. Was Galileo's statement precise?

2. Does this pendulum follow simple harmonic motion?

3. How many observations should you take in order to obtain good data?

4. Air resistance gradually decreases the amplitude of the pendulum. What effect does this have on the period of the pendulum?

5. What effect would stretching of the string have on your results?

6. How does gravity affect this experiment? What would happen to the results if this experiment were conducted on the moon?

7. If you have a parabolic graph, such as $y = ax^2$, then you might consider graphing y versus x^2 to get a linear graph. (See also Section C.2.) What is the physical meaning of the slope and the intercept of each of your graphs?

8. Why is it a good idea to keep the amplitude of vibration small?

9. Where to and how should the pendulum length be measured?

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A PDF version might be found at pendulum.pdf (67 kB)