I. Objectives

1. Determine whether or not an object behaves like a simple pendulum.
2. Determine which characteristics of an object and pendulum affect the pendulum's behavior.

II. Introduction

Simple harmonic motion is the motion of a simple harmonic oscillator, a motion that is neither driven nor damped. The motion is periodic, repeating itself at standard intervals in a specific manner, described as being sinusoidal, with constant amplitude. The amplitude is always positive and depends on how motion starts initially. Its period is the time for a single oscillation (http://en.wikipedia.org/wiki/Simple_harmonic_motion).

A simple pendulum is a simple harmonic oscillator and consists of a particle of mass *m* attached to a frictionless pivot by a string of length *L* that has negligible mass. In a physical pendulum, however, the mass consists of an extended object whose moment of inertia *I* must be considered when calculating the period, frequency, or angular speed (Cutnell & Johnson, 2004, 6th ed., p. 279).

III. Calculations

The relationship between the angular speed ω of a simple pendulum and its period *T* is:

$$\omega = \frac{2\pi}{T}$$

where ω is measured in rad/s and *T* is measured in s.

The relationship between the period *T* and the frequency *f* is:

$$f = \frac{1}{T}$$

Where *f* is measured in cycles/s or hertz.

It follows that the relationship between ω and *f* is:

$$\omega = 2\pi f$$

For small angles the relationship between ω and the length *L* of a simple pendulum is:

$$\omega = \sqrt{\frac{g}{L}}$$

where L is measured in m.

To calculate the percent difference use the following equation:

$$\%\ \text{difference} = \frac{experimental\ value - calculated\ \ value}{calculated\ \ value} x100$$

IV. Equipment and Materials

Plastic bottle, approximately 5.5 meters of non-stretching string, electronic balance, plastic graduated cylinder, plastic pail, meter stick, stop watch, calculator

V. Procedure

1. Determine the mass of the empty plastic bottle and record it in Table 1.

2. Securely attach the string to the cap of the plastic bottle.

3. Fill the plastic bottle with 250 mL of water.

4. One member of your team should slowly lower the plastic bottle from the 3rd floor sky bridge toward the 2nd floor. This bottle-string configuration is now a pendulum.

5. The remaining team members should go to the 2nd floor and stand a few meters from the bottle. Do not allow the bottle to hit anyone.

6. The team member on the 3rd floor should then swing the pendulum at a small angle. Be sure that you record the length of the string between the bottle and the hand of the person swinging the pendulum for every trial since the lengths may be different. If your team wants to use the same length pendulum for every trial, mark the location of the string from which it is swung with a piece of colored tape.

7. Time 10 cycles of the pendulum swing and record the time in Table 2.

8. Repeat this process for the remaining trials, using the volumes of water indicated in Table 1.

9. Complete Tables 2, 3, and 4.

VI. Data

Table 1 Water and Bottle Mass

A	B	C	D	E = C + D
Trial	Water volume in mL	Water mass in kg	Bottle mass in kg	Water + bottle mass in kg
1	250			
2	500			
3	750			
4	1000			

Table 2 Pendulum Experimental Length, Period, Angular Speed, and Frequency

A	F	G	H = G/10	J = 1/H	K = 2π J
Trial	Pendulum length L in m	Time for 10 cycles in s	Period T for 1 cycle in s	Experimental frequency f in cycles/s	Experimental angular speed ω in rad/s
1					
2					
3					
4					

Table 3 Pendulum Calculated Angular Speed, and Frequency

A	M = $\sqrt{9.81/L}$	N = $\sqrt{9.81/L}/(2\pi)$
Trial	Calculated angular speed ω in rad/s	Calculated frequency f in cycles/s
1		
2		
3		
4		

Table 4 Differences Between Experimental and Calculated Values

A	P = | J – N |	Q = | K – M |	R = P/N * 100	S = Q/M * 100
Trial	Difference between experimental and calculated frequency *f* in cycles/s	Difference between experimental and calculated angular speed ω in rad/s	Percent difference between experimental and calculated frequency *f* in cycles/s	Percent difference between experimental and calculated angular speed ω in rad/s
1				
2				
3				
4				

VII. Discussion Questions

1. If you know the volume of water in mL, how is its mass in kg determined?

2. What is the *specific equation* for the frequency *f* of a *simple pendulum*? The answer is *not* $f = \frac{1}{T}$

3. What is the equation to determine percent difference between experimental and calculated values?

4. Other than mathematical errors, what could explain the differences between the experimental and calculated frequency values?

5. Why are the percent differences for frequency *f* and angular speed ω the same for a given trial?

6. Other than mathematical errors, what could explain the differences between the experimental and calculated angular speed values?

7. Does the mass of the pendulum used in this lab have any affect on the period T ? Explain why or why not.

8. What characteristics of a physical pendulum affect its period, speed, and frequency?

9. What characteristics of a simple pendulum affect its period, speed, and frequency?

10. Does the pendulum used in this lab behave like a simple pendulum or a physical pendulum? Explain how you know.

11. In the past, why were pendulums used in clocks? You may need to do some research to find the answer. You must include references in order to receive credit for correctly answering this question.