I. Objectives

1. Determine whether Hooke's Law describes the behavior of a rubber band, and whether the frequency formula can accurately predict the oscillation of a mass on a rubber band.

II. Introduction

This lab utilizes masses. You must wear closed-toed shoes during this entire lab.

A force exerted on a physical object will generally result in elastic deformation, a change in shape or size, which will revert to normal when the stress is removed. If the force is large enough, permanent deformation or even breakage may occur.

Rubber bands undergo elastic deformation, basically in one dimension. They can be stretched, they contract, and we can hang things from them to measure how much force is needed to deform them a given distance.

III. Calculations

Hooke's law states that for any object stretched or compressed through "relatively small" deformations:

$$F = -kx$$

$$-k = \frac{F}{x}$$

where F is the applied force, x is the distance of stretching or compression, and k is the force constant. These equations are related in the following ways:

$$x = \Delta L = L - L_0$$

The value of k will depend on the original length L_0 of the object, and the material from which it is made. Note that the negative sign means that the force exerted by the spring is always in the direction opposite to the displacement. For force exerted on the spring, the negative sign disappears according to Newton's Third Law.

Theory also tells us how fast an object should bounce:

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

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

$$\omega = \sqrt{\frac{k}{m}}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

implying that only the force constant *k* and the mass *m* of the suspended object should determine the frequency of oscillation.

IV. Equipment and Materials

Ring stand with right-angle clamp, large rubber band, cylinder masses with hooks, meter sticks, stopwatch, calculator

V. Procedure

1. Assemble the ring stand so that there is a cross bar to hang the rubber band from, and place it on a bench so that the bar hangs over the edge.

2. Measure and record the length of unstretched loop L_0 in Table 1.

3. Hang the rubber band from the cross bar, keeping it close to the edge of the table to avoid pulling over the ring stand assembly. If the bar and weights become unstable, steady the ring stand by holding and/or putting weight on its base.

Part 1 Spring Constant *k*

4. Starting with 0.1 kg and increasing each trial by 0.1 kg, to a maximum mass of 1.5 kg or breakage, hang each mass from the bottom of the rubber band and record its length.

5. Complete Table 1.

6. Graph *F* versus ΔL, using ΔL for the *x*-coordinate and *F* for the *y*-coordinate. The slope of this line is the value of *k*. You do not need to include the best fit line. Staple the graph to the lab.

Part 2 Frequency and Oscillations

7. Locate a part of your graph where the slope is fairly constant. Use this slope for the *k* value, which will help you determine the theoretical frequency of oscillation for the rubber band.

8. Choose three masses within this region, one near the center and one nearer each end.

9. Suspend each of these three masses, one at a time, from the rubber band. Pull the masses down a few centimeters and release.

10. Time and record ten complete cycles with a stopwatch for each of the three masses.

11. Convert your stopwatch data to actual frequency and compare your values to the theoretical values.

12. Complete Table 2.

VI. Data

Table 1 Rubber Band Force and Length

A	B	C = Bg	D	E	F	G
Trial	Mass m in kg	Weight F in N	Length L of rubber band in m	Unstretched loop length L_0 in m	$\Delta L = L - L_0$ in m	$k = \frac{F}{\Delta L}$ in N/m
1	0.1					
2	0.2					
3	0.3					
4	0.4					
5	0.5					
6	0.6					
7	0.7					
8	0.8					
9	0.9					
10	1.0					
11	1.1					
12	1.2					
13	1.3					
14	1.4					
15	1.5					

Table 2 Rubber Band Oscillation

A	B	C	D	E	F = E/10	G	H = | G – D |	I = H/D x 100
Trial from Table 1	Value of *k* for selected trial in N/m	Mass *m* in kg for selected trial	Calculated frequency $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$ in Hz	Total time for 10 oscilla-tions in s	Time *T* per oscilla-tion in s	Experi-mental frequency $f = \frac{1}{T}$ in Hz	Difference between experimental and calculated frequencies in Hz	Percent error between experimental and calculated frequency

VII. Discussion Questions

1. Did the rubber band behave as described in Hooke's Law all the time, some of the time, or never? Explain your answer.

2. Why would including the best fit line that used all of your data in this lab not make sense?

3. How well did theory predict the oscillation of the mass on the rubber band? What limits would there be on the usefulness of the formula?

4. What would be the effect on *k* if you used two loops of the same length instead of one? Find the numeric ratio of the *k* value with two loops compared to the *k* value using one loop.

5. What would be the effect on *f* if you used two loops of the same length instead of one? Find the numeric ratio of the *f* value with two loops compared to the *f* value using one loop.

6. What would be the effect on k if you folded the single loop to make two loops of half the original length? Find the numeric ratio of the k value with the folded loop compared to the k value using the single, unfolded loop.

7. What would be the effect on f if you folded the single loop to make two loops of half the original length? Find the numeric ratio of the f value with the folded loop compared to the f value using the single, unfolded loop.