Name______________________ Date_____________

PHYS 1401General Physics I

Hooke's Law, Simple Harmonic Motion

Equipment

Spring
Mass Hanger(50g)
Mass set
Newton Set
Meter Stick
Ring Stand
- Rod Clamp
- 12" Rod
- Motion Sensor(15cm)
- Triple Beam Balance
- Graphical Analysis

Figure 1

Objective

The objectives of this experiment are to study both Hooke's law and Simple Harmonic Motion by analyzing the forces and motion of the mass in a spring-mass system.

Introduction

Any motion that constantly repeats itself in time is called periodic motion. A special form of periodic motion is called Simple Harmonic Motion (SHM). SHM is defined as cyclical or oscillatory motion in which the magnitude of the net force on the oscillating body at any instant is directly proportional to its displacement from the equilibrium position with the direction of the net force opposite to the direction of the displacement. Mathematically this can be written as Hooke's law which is: $\Sigma \mathbf{F} = -k\mathbf{x}$ where $\Sigma \mathbf{F}$ is the resultant force on the oscillating body, $\mathbf{x}$ is the vector displacement from equilibrium position and k is the constant of proportionality called the "spring constant". The net force is referred to as a "restoring force" because it tends to return the oscillating object back to its equilibrium position.

A special feature of SHM is that the period, T, of the oscillating system does not depend on the amplitude of the displacement, thus making the system a good time-keeping device. The period is the time it takes the oscillating body to return to its starting point. In this lab we will study Hooke's law and SHM of a mass connected to a spring.

PART I

FINDING THE SPRING CONSTANT "k" USING HOOKE'S LAW

Procedure I

1. Mount the spring so that it hangs vertically with the small end up. Attach a *50 g* mass hanger. This separates the coils and will be considered as a "zero" load.

2. Adjust the meter stick on the ring stand or the clamp holding the spring so that the bottom of the weight hanger is even with an even point on the meter stick, which will act as our equilibrium position of the spring.

3. Now, add weights in *0.50 N* increments until you have added a total of 2.00 N to the mass hanger. Record the measured positions of the bottom of the mass hanger in the table below. Then calculate the displacement from equilibrium (the zero load position) by appropriately subtracting the current position from the equilibrium position. Be sure that this value is measured in meters.

Data Table I (Hooke's Law)

Load added to hanger (N)	Position of the bottom of the mass hanger	Displacement from the equilibrium position (m)
0		0
0.50		
1.00		
1.50		
2.00		

Analysis for Procedure I

For the spring, plot a graph of *load vs. displacement*. Find the slope with uncertainty of the best-fit line and record your data. The slope of this line is the spring constant, *k*, of the spring.

Spring Constant, *k*, with uncertainty from procedure I: k_I =__________ ± ________ *N/m*

PART II

FINDING THE SPRING CONSTANT "k" USING SIMPLE HARMONIC MOTION

The period of oscillation depends on the parameters of the system. For a mass on a spring, this is approximated as when the mass of the spring is negligible compared to the hanging mass. However, when the mass of the spring is not negligible, as in this experiment, then the correct expression for the period of a spring-mass system is:

Where $m_{\mathbf{eff}}$ is the effective mass of the spring which will be less than the actual spring mass, m_s. For a spring with a uniform mass distribution the effective mass is approximately (1/3)$m_{\mathbf{s}}$ where $m_{\mathbf{s}}$ is the actual mass of the spring. We will determine the effective spring mass and the spring constant in this part of the lab. This equation can be manipulated into the following form:

or as we will want to use it in our linear fit:

where with, $y = mx + b$, we have $\boldsymbol{y} = 4\pi^2 m$, $\boldsymbol{m} = k$, $\boldsymbol{x} = T^2$ and $\boldsymbol{b} = -4\pi^2 m_{eff}$.

Procedure II

1. Attach one end of the spring to the spring clamp and to the other end to a *50-gram* mass hanger. Place an additional *50-gram* mass on the mass hanger so your starting total is 100 grams, or 0.100 kg.

2. Have your lab tech set up the motion detector. Now open the Physics folder in the dock → click **Physics with Vernier** → click on **15 Simple Harmonic Motion.cmbl**.

3. Start the spring oscillating by pulling the mass about *5 cm* below the equilibrium position and then releasing.

4. Once you are ready click on the green play button to start the data collection.

4. From the graph on the computer, measure the time, *t*, from one peak on the sinusoidal wave to the tenth peak **after** that peak. Calculate the period by taking your time and dividing by ten, $T = t/10$.

5. Repeat three more times, each time adding *20-gram* masses to the hanger.

6. Remove the spring from the spring clamp and take off the mass hanger. Measure the actual mass of the spring.

Actual mass of the spring: m_s = __________________kg.

Data Table II

Hanging mass, m (kg)	Time for 10 peaks, t (s)	Period, T (s)	T^2 (s^2)	$4\pi^2 m$ (kg)
0.100				
0.120				
0.140				
0.160				

<u>Analysis for Procedure II</u>

Using graphing software, plot $4\pi^2 m$ *vs.* T^2 (mass is the total hanging mass = mass of the mass hanger plus any additional added masses) and find the slope and uncertainty of the best-fit line and the value of the y-intercept and the uncertainty in the y-intercept. Record these values on the next page.

<u>Results:</u>

Spring Constant Measurements

Spring Constant, *k*, with uncertainty from procedure **I**: k_I=__________ ± ____ __ N/m

Spring Constant, *k*, with uncertainty from procedure **II**: k_{II}=__________ ± _______ N/m

The y-intercept, b, with uncertainty from procedure **II**: $b \pm \sigma_b$ = ________ ± _____ N/m

Now calculate the percent difference between your values for "k" in **I** and **II**.

Do your two results agree with one another within experimental uncertainty? _________.

PART III

The effective mass of the spring

Calculate the effective mass of the spring by using $b = -4\pi^2 m_{eff}$ from the graph in Part II and solving for m_{eff} with:

$m_{eff} = -b/(4\pi^2)$ and the uncertainty with $\sigma_{meff} = \sigma_b$. Report your result here:

$m_{eff} \pm \sigma_{m_{eff}}$ = ______________________ ± _____ kg

How does this compare to the actual mass of the spring? Is it less than, approximately equal to, or greater than the actual spring mass.

Take your actual spring mass, divide it by 3, and record it here:

For a spring with a linear mass distribution: $m_{eff} \approx (1/3)\, m_s$. Is your result close to the value for a spring with a linear mass distribution? Does the $(1/3)\, m_s$ value fall within experimental uncertainty of your effective spring mass?

Why do we need to use an effective spring mass instead of the actual spring mass in this process?