Name: ______________________

Partner(s): ______________________

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Date: ______________________

Hooke's Law

1. *Purpose:*

The primary purpose of the lab is to study Hooke's Law and simple harmonic motion by studying the behavior of a mass on a spring. Your goal will be to extract a measure of the stiffness of one particular spring.

2. *Theory*

The shape of a body will distort when a force is applied to it. Bodies which are "elastic" distort by compression or tension, and return to their original, or equilibrium, position when the distorting force is removed (unless the distorting force exceeds the elastic limit of the material). Hooke's Law states that if the distortion of an elastic body is not too large, the force tending to restore the body to equilibrium is proportional to the displacement of the body from equilibrium. Stated mathematically:

$$\vec{F} = -k\vec{x} \tag{1}$$

where $\vec{F}$ is a restoring force, k is a constant of proportionality and x is the distance the object has been displaced from its equilibrium position. The minus sign signifies that the restoring force acts in the opposite direction to the displacement of the body from the equilibrium position.

If a body, which obeys Hooke's Law, is displaced from equilibrium and released, the body will undergo "simple harmonic motion". Many systems, such as water waves, sound waves, ac circuits and atoms in a molecule, exhibit this type of motion.

A particularly easy example to study is a massive object on a spring. From class or your text, you know that this system will undergo simple harmonic motion with a period, P, given by Equation (2).

$$P = 2\pi\sqrt{M/k} \tag{2}$$

where k is the constant from Hooke's Law and M is the "combined mass," defined by Equation 3, which can be found from a full, detailed derivation.

$$M = \text{mass of object \& pan on spring} + 1/3 \text{ mass of spring} \tag{3}$$

3. Procedure

In this lab, you will observe a mass on a spring and, from this, determine the value of k for that spring. There are two straight-forward ways of doing this. The first method is referred to as the "static method," which utilizes Hooke's Law, given in Equation (1). The second method, the "dynamic method", makes use of the fact that the system exhibits simple harmonic motion. Thus, you are able to perform two independent experiments to extract a property of spring – it's spring constant.

3.1 Part 1: The Static Method

Suppose we hang a mass, m, on the spring and a *new* equilibrium position is established, as seen in Figure 1. According to Newton's 2nd Law the magnitude of the restoring force is equal to the magnitude of the weight of the hanging mass,

$$W = mg \tag{4}$$

Thus,

$$W = -F \tag{5}$$

Therefore, Equation 1 can be written as:

$$W = kx \tag{6}$$

or

$$mg = kx \tag{7}$$

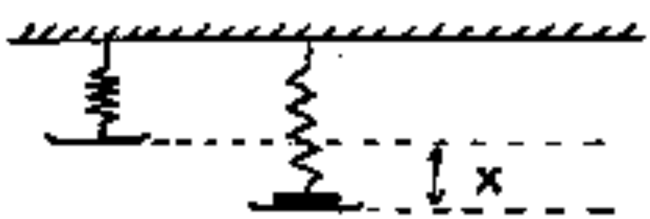

Figure 1

- Begin by measuring the position of the spring. This is your equilibrium position.
- Add the 50 g mass pan from the spring and measure the position of the mass pan.
- Add 100 g masses to the pan and measure resulting positions of the system, until you have a five 100 g masses on the mass pan.
- Then remove the masses in reverse order, one at a time, again noting the corresponding displacement. This will effectively give you two trials, which can be averaged; you may wish to comment on any trends or differences you see between the trials).
- Graph and analyze of your data.

Note: Displacements are to be calculated relative to the equilibrium position (for instance, if the average equilibrium position is 20 cm, you would subtract 20 cm from all of your position measurements.

Mass	Weight	Actual meterstick reading ( )			Displacement
(kg)	(N)	Down	Up	Average	(m)
0.00	0.00				0.00

- Attach any analysis below.

Spring Constant ____________

3.2 Part 2: Dynamic Method

By displacing the spring from equilibrium, the system will oscillate. By measuring the mass of the system and its period of oscillation, the value of the spring constant can be deduced using Equation 2.

- Use approximately 200 grams for the total mass of the system, where the total mass is given by Equation 3.
- Record your data below and describe how you took this data.

Period	________________
Mass pan	________________
Added Mass	________________
Spring Mass	________________
Total Mass	________________

- Attach any analysis below.

Spring Constant __________________

4. Results

Dynamic Method k_2 = _________ N/m

Static Method: k_1 = _________ N/m

Average $k = \bar{k}$ = _________ N/m

Compute the % difference between the two values:

$$\frac{\Delta k}{\bar{k}} = \frac{|k_1 - k_2|}{\bar{k}}$$

% difference = _________%

- Comments:

5. Questions

i. Large numerical values of k imply that a spring is very "stiff" and conversely, small values of k signify a "soft spring." Why?

ii. Is the period of the mass-spring system dependent upon the amplitude of oscillation? Answer this question twice, once on the basis of theory and once on the basis of an experiment that you perform.

iii. Is the period of oscillation dependent upon the mass of the system? Answer this question twice, once on the basis of theory and once on the basis of an experiment that you perform.

iv. Try to explain the *degree* of discrepancy between k_1 and k_2, as well as which method for determining the spring constant ought to be more accurate. (We aren't looking for one "clear cut" answer here so much as a reasonable amount of consideration on your part. Feel free to muse.)

6. Initiative

<u>Possible ideas:</u>

- ❖ Compare and contrast the properties of a pendulum's motion with that of a mass-spring system (*e.g*., factors affecting the period).

- ❖ You could consider the difference between concepts of inertial and gravitational mass.

- ❖ Using your best value for k, you could predict the period for a given mass (not yet used) and then test your prediction.

- ❖ In your box of sensors, there is a motion sensor, which measures the position of an object up to 120 times a second (depending on the trigger rate), in the same that a bat "sees." Design an experiment to measure the position of the mass spring system and see how it compares to Figure 1 in the pre-lab reading. The Science Workshop software will find the velocity and acceleration data from the position data. How do these compare to the figures in the pre-lab reading? Be sure that the masses do ***NOT*** fall on the motion sensor.

7. Conclusions