Name:___________________________

Science Lab #1

Simple Harmonic Motion

In this experiment, you will explore the simple harmonic motion exhibited by a mass hanging on a spring. The spring force increases linearly as the object moves away from its equilibrium position:

$$F_{spring} = -kx, \quad (1)$$

where x is the displacement from the equilibrium position and k is called the stiffness constant. Such a force is called a restoring force since the force tends to pull the object back to the equilibrium position: the farther the object is away from equilibrium, the larger the force pulling it back. The motion of an object acted on by such a force is described by

$$x(t) = A\sin(2\pi ft), \quad (2)$$

where the amplitude, A, is the maximum displacement of the system from its equilibrium position and f is the frequency of oscillation (Recall $f = 1/T$, where T is the period, the time for one complete cycle). An important property of simple harmonic motion is that f is independent of A. It only depends on k and the object's mass m:

$$f = \frac{1}{2\pi}\sqrt{k/m} \quad (3)$$

In this laboratory, you will be investigating the extent to which the oscillatory motion of a mass on a spring can be described as simple harmonic motion.

A spring provides one of the simplest examples of a linear restoring force. The simplest case occurs when the motion is horizontal and the mass slides on a horizontal frictionless plane. Having few such planes available, we will instead study the vertical motion of a mass suspended from a spring. Fortunately, the behavior turns out to be the same; in addition, it allows a simple way to determine the spring's stiffness constant, k.

Start off by using the scales to measure the mass of both of your masses as well as the mass of the spring itself. *Record your results here*:

$m_{Aluminum}$	m_{Brass}	m_{spring}

Now hang the spring from the horizontal rod (with no mass attached), let it settle down and measure its length. We'll call this its original equilibrium length. *Record*: Attach one of the masses (which one:) and gently lower it to avoid producing oscillations. *Now measure the length of the spring again*: We'll call this the new equilibrium length. The amount that it has stretched is the displacement from equilibrium x. *Calculate this*:

Now we need to figure out what *k* is. To do this we need to **analyze the forces acting on the mass**. There are two forces, gravity (or weight), and the spring force. *Draw a diagram indicating these forces with arrows that point in the direction of each force and label the arrows F_g (for the force of gravity) and F_s (for the spring force), respectively:*

After we attached the mass and let it settle down, we say that it is in *equilibrium*. *What does this mean qualitatively? What does it imply about the relationship between the two forces acting on the mass?*

Use your answer to the above question and the fact that the force of gravity has magnitude $F_g = mg$, where g = 10 m/s^2 is the "acceleration due to gravity", to *calculate k*:

Set your mass oscillating with an amplitude less than 15 centimeters. Use the ruler to estimate your amplitude. *Record the amplitude in the table below*. *Make a diagram for each of the following situations: 1) when the mass is at the top of its oscillation, 2) the middle, on its way down, 3) the bottom and 4) the middle on is way up*. In each diagram, indicate the direction of the velocity and acceleration.

In which of the above situations, if any, is there equilibrium? Explain.

Using the stopwatch, measure the time for 50 complete oscillations and then calculate the period T and the frequency f, then repeat for another amplitude (make one amplitude "small" and one "large", but make sure both are less than 15 cm). *Record your results in this table*:

A (cm)	t_{50} (seconds)	*T* (seconds)	*f* (Hertz)

Do your results indicate any dependence of f on A? Justify your answer.

Why is it better to measure the time for 50 oscillations than for just 1 or a few oscillations?

Compare your measured values of f with what you calculate using Eq. (3) above, the value of k you determined as well as the masses you measured. In your calculation, use the *total effective mass*: $m_{tot} = m_{hanging} + (1/3)m_{spring}$, which takes into account the fact that the spring's mass is also oscillating.

Remove the mass from the spring and replace it with the second mass. Measure the period of its motion for one amplitude. Again compare your measured value of *f* with that predicted by Eq. (3) using the new mass in your calculation.

A (cm)	t_{50} (seconds)	*T* (seconds)	*f* (Hertz)

For homework:

Explain qualitatively why the dependences of f on k and m in Eq. (3) make sense. That is, why does it make sense that k is in the numerator and m is in the denominator? Don't worry about explaining the square-root dependence. Note: I am NOT looking for any derivation here. Try to give a simple argument employing physical principles we discussed in class. One paragraph should be sufficient.