Section: Monday / Tuesday (circle one)

Name: ______________________________

Partners: ______________________________

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Total: /23 pts

PHYSICS 107 LAB #2: HARMONIC MOTION

Equipment: Computer & Lab Pro, PhET simulations, meter stick, motion detector, force probe, spring, mass set, tall beam, and right-angle clamp.

OBJECTIVES

1. To learn about the basic characteristics of periodic motion – period, frequency, and amplitude.
2. To study what affects the motion of a mass oscillating on a spring.

READINGS

To prepare for this lab, you should read the following sections of the text:
Sections 2.3, .4.

OVERVIEW

Any motion that repeats itself regularly is known as *harmonic* or *periodic* motion. The bouncing of a mass on a spring is a simple example; the vibrating of a violin string is a more complex one. Two of the most important definitions related to harmonic motion are the period (P) of an oscillation, which is the time that it takes for the motion to repeat itself, and the frequency (f), which is how often an oscillation occurs per unit time. These two are related by $f = 1/P$. The unit of frequency is 1/s or s^{-1}, also called a Hertz, (Hz).

In this lab we will be especially interested in a type of periodic motion known as Simple Harmonic Motion (often abbreviated SHM). SHM involves a displacement that changes sinusoidally in time. You will study the behavior of the mass on a spring.

ACTIVITIES

THEORY

All mechanical oscillations result from the interplay of a force that pulls the system toward an equilibrium state and inertia which makes it hard to change the system's state of motion. For an object hanging from a spring, the farther the spring is stretched beyond its equilibrium length, the harder it pulls the object back towards equilibrium; but since the object has mass, once in motion, it's hard to stop, so the object sails right past equilibrium, this compresses the spring, making it push back the other way…so the object oscillates. A good mathematical approximation for the relation between the force and length of compression or stretching is

$$F = -k\Delta x.$$

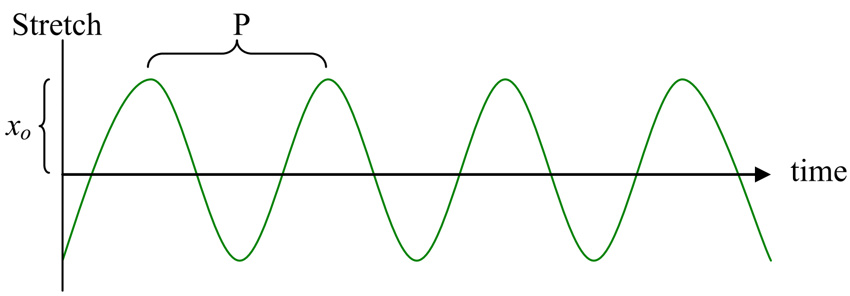
The minus means that the force is in the opposite direction of the stretch or compression; the spring constant (k) is a measure of how stiff a spring is (measured in N/m for force in Newtons and stretch in meters); and Δx is how far the spring is stretched from its equilibrium length. Real springs will approximate this behavior as long as they are not stretched or compressed too far. For an object of mass *m* dangling on the end of a spring, the stretch of the spring is:

$$\Delta x = x_0 \cos\left(\frac{2\pi}{P}(t - t_o)\right),$$

where x_o is the amplitude or maximum distance from equilibrium,

$$P = 2\pi\sqrt{m/k}$$

is the period (*m* is measured in kilograms where 1000 g = 1 kg), and t_o is the difference between when you happened to start keeping time (t=0) and when the object was maximally displaced. Plotting the spring's stretch as a function of time looks like



SIMULATION

First, you will look at a simulated mass-spring system.

1. From the Start menu, open the program "PhET Simulations;" this will open a page within Internet Explorer. Click on the "Simulations" header within the web page and then select the "Masses and Springs" simulation.

Determine the Spring Constant, k

You'll find the spring constant, k, by plotting force vs. distance stretched.

2. Hang three different masses from Spring 1 and enter the associated spring *forces* and *stretches* of the spring (not the spring's total length, but how much it is stretched from equilibrium; the ruler can be moved.)

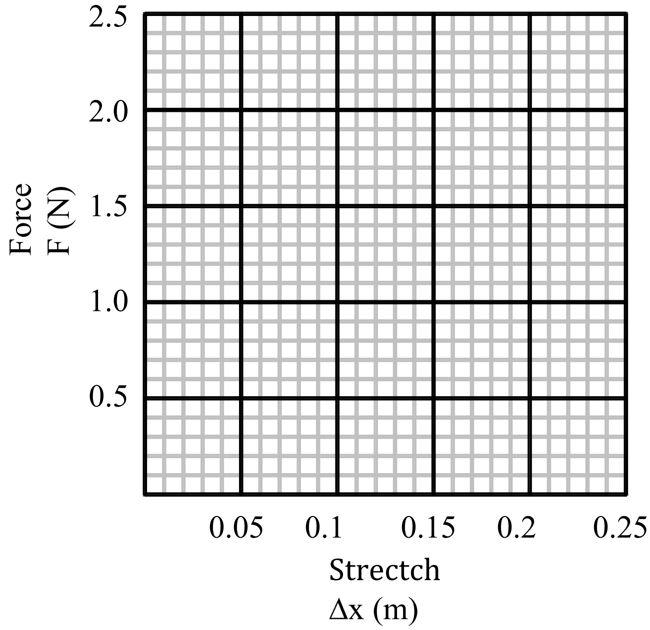
/3 pts

stretch Δx (m)	**Mass** *m* (kg*)	**Force** F = *m**9.8 m/s^2 (N)

*1 kg = 1000 g

3. Plot the Force vs. Distance Stretched, and sketch a best-fit straight line.

/2 pts



4. Since $F = -k\Delta x$, the spring constant (k) should be the absolute value of the line's slope. To determine that, pick two distant points on the line (they need not be actual data points) and find the 'rise' over the 'run': $k = |slope| = \left|\frac{F_b - F_a}{\Delta x_b - \Delta x_a}\right|$. So, determine the spring constant (k) of Spring 1 using your graph. Show your work and write your result below including units.

/1 pt

k = ________

Measuring the Period

Measure the period, P, and compare with the theoretical prediction.

5. In the green control box, select "stop watch." Now use this to determine the period, T, of Spring 1 when the 250 gm mass is hung from it. You will probably want to let the stop watch run for a number of consecutive oscillations, and then divide by the number to determine the period of just one oscillation. You can run the simulation in slow motion by selecting "1/2 time", "1/4 time", etc.

/1 pt $P=$ _______________

6. According to theory, there is a simple relation between period, spring constant, and mass (see the very top of page 2.) Given the mass and spring constant values in this situation, what is the period predicted by theory?

In this simulation, the two values you get for the period should be virtually identical (only differing due to measurement errors), if that is not the case, try to find and fix your mistake; your instructor will be happy to help.

EXPERIMENT

Now, you'll follow the same procedures as you did with the simulation to find the spring constant, k, and period, T, for a real *mass-on-spring.*

Set-up (much of this will already have been done by your instructor)

1. Close Internet Explorer and open **Mass on Spring** (in Physics Experiments / Physics 220 – 221/ Harmonic Motion). Connect the detectors according to the directions on the screen.
2. Calibrate (under the "Experiment" menu) the Force Probe with no mass and a 100-g mass (use 0 N for the weight on an unloaded probe and 0.98 N for the weight on a probe loaded with 100g.)
3. Hang a spring from the force probe's hook. On the Experiment menu, select Zero, then select the Motion Detector (or *un*-select the force probe).

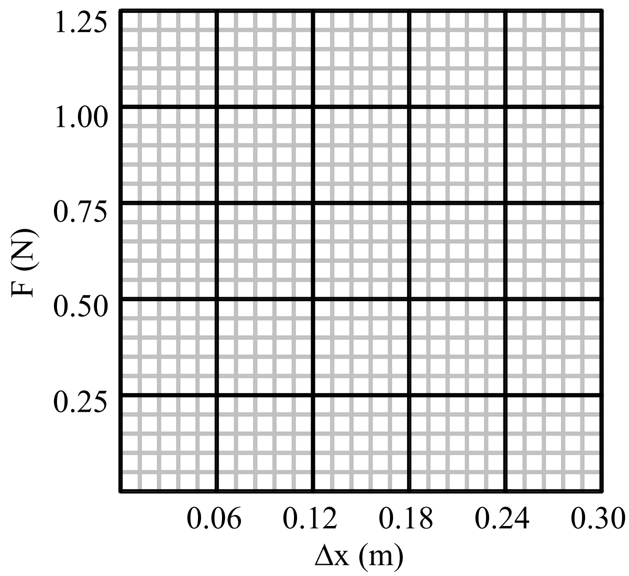
Experimentally Determine Spring Constant, k

4. Use the force probe and a meter stick or ruler to measure the force needed to stretch the spring for the distances in the table, and fill in the table's force values. You'll read the force values from the 'live' read-out near the upper left corner of the LoggerPro screen. Note: you won't be hanging a mass form the spring, just grabbing its end and pulling down. *Be sure to measure how far the spring is stretched from its equilibrium length, not the total length of the spring.*

Stretch (m)	Force (N)
0.12	
0.18	
0.24	
0.30	

5. Plot the force vs. distance stretched and sketch a best-fit straight line (to not force the line to go through the origin since these real springs may be incapable of compressing to their ideal length – their rungs hit each other first.)

/2 pts



6. As you did for the simulation, determine the spring constant (*k*) of your spring using your graph (remember, the points you use to calculate the slope must be on the best-fit line but needn't be actual data points.) Show your work and write your result below <u>including units</u>.

/3 pts

k = ________

Experimentally Determine the Period, P

7. Attach a 50-g mass to the spring. Aim the motion detector upward and position it directly below where the mass will oscillate (setting it on a chair if need be.)
8. To get a sense of how far to stretch the spring, do a dry run first. Pull down on your spring to obtain a reasonable amplitude. (Do not overstretch the spring so much that it remains permanently distorted, it launches the mass, or it comes within 0.1 m of the motion detector which is a tad far sighted.) Let the mass go. The mass should oscillate smoothly up and down. If the mass oscillates too violently, don't stretch it as far.
9. Stop the mass and Zero the Motion Detector with the mass hanging stationary from the spring (so it calls the current location of the mass 0). To do this, click on the blue **0** button (or go to the Experiment

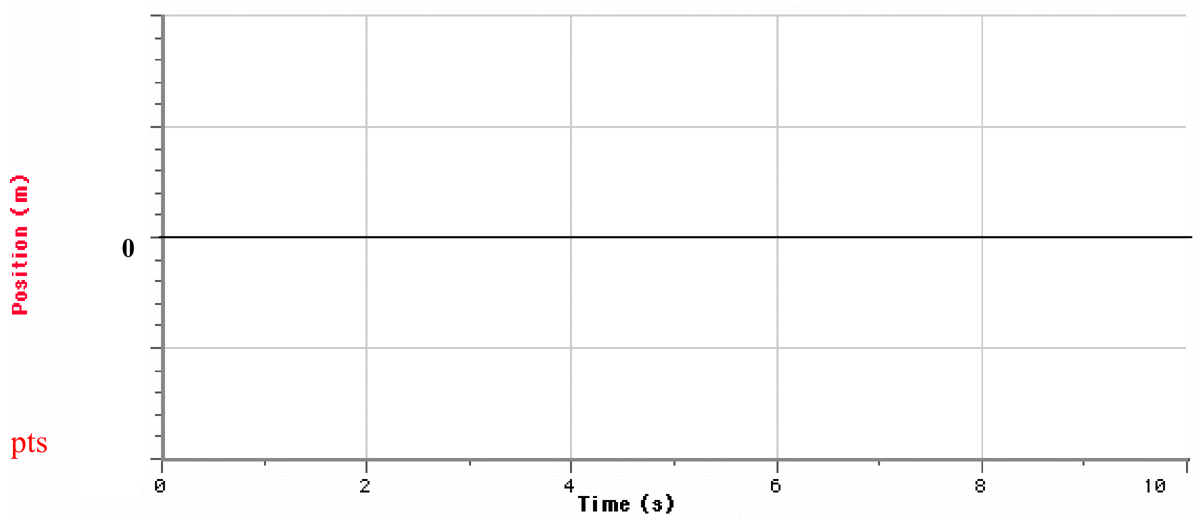
menu, select Zero), and then select the Motion Detector (or *un*-select the force probe).

10. Record the value of the mass used below.

/1 pt

$m =$ ________ kg

11. Give your mass approximately the same amplitude you gave it for your dry run, then push "Collect" to collect data. Carefully sketch your results below.



/3 pts

12. Use the graph to find the period (P_{exp}) and frequency (f_{exp}) of the oscillations. Also find the amplitude of the motion (x_0). Your instructor can help you.

$P_{exp} =$ ________________ s

/3 pts

$f_{exp} =$ ________________ Hz

$x_o =$ ________________ m

13. As you did for the simulation, now calculate the theoretically-expected period (equation at the top of page 2).

/1 pt

$P_{theory} =$ ______________ s

Question: Hopefully the experimentally and theoretically determined periods will be quite similar (within about 10%). What is the percent difference between them?

/1 pt

$$\% \text{ difference} = \left|\frac{P_{\exp} - P_{theory}}{P_{theory}}\right| \cdot 100\% =$$