Name______________________________ Date_________________

PRE-LAB PREPARATION SHEET FOR LAB 12: PERIODIC MOTION

(*Due at the beginning of Lab 12*)

Directions:
Read over Lab 12 and then answer the following questions about the procedures.

1. How will you determine the spring constant in Activity 2-2 of this lab?

2. List the attributes of the oscillating system you will change in Investigation 2 in order to see how it affects the period.

3. What do you predict will happen to the period of the motion in Investigation 2 when you increase the amplitude of the oscillating object?

Name________________________________Date_____________________Partners______________________________

LAB 12: PERIODIC MOTION

OBJECTIVES

- To understand the characteristics of periodic motion
- Identify the relationships between mass, spring constant, and period for a mass-spring system.
- Analyze the relationships among distance, velocity, acceleration, and force for a mass-spring system.
- Analyze the relationships among kinetic, potential, and total energy for a mass-spring system.

OVERVIEW

Periodic motion is motion that repeats itself in regular time intervals. You can see the repetition in the position, velocity, or acceleration vs. time graphs. The length of time to go through one cycle and begin to repeat the motion is called the **period, T**, and is measured in seconds. The number of cycles in each second is called the **frequency, *f*.** The unit of frequency, cycles per second, is given a special name: Hertz.

INVESTIGATION 1: MOTION OF A MASS HANGING FROM A SPRING

Activity 1-1: Periodic Motion of a Spring and Mass

In this activity you will examine the graphical display of the motion of a mass hanging from a spring. Your goal is to identify the characteristics of periodic motion.

MATERIALS

- Graphical Analysis software
- LabQuest Mini Base
- Motion Detector and protective wire basket
- Various Springs and masses
- Support to hang spring and mass (e.g. a lab stand)

1. **1.** Launch Graphical Analysis and connect to the motion detector by clicking Sensor Channels. Select the box for Motion (cart), then click Done. If only one graph is displayed, click View, , and chose 2 Graphs. These should be position vs. time and velocity vs. time graphs. In Data Collection Settings, change End Collection to 10 seconds.

2. Set up a mass on a spring. Hang the longest spring available vertically from a support and attach a mass to the spring. Use an intermediate size mass, not the smallest or largest you have available. Label this spring S1 and this mass M1. Place the motion detector on the floor facing up directly below the spring. Protect the motion detector from falling masses with the wire basket.

   a. Push the mass straight downwards a few centimeters and let go. Adjust the height of the support so that the mass comes no closer than 15 cm to the detector.

   b. Click on Collect to begin graphing. Be sure the motion detector "sees" the mass over its full motion and that there are no flat portions of your graph where the mass came too close to the detector.

   c. Print the graphs and attach them to your lab.

Comment: Note that when an object returns to the same position, it does not necessarily mean that a cycle is ending. It must return to the same position, *and* the velocity and acceleration must also return to the same value in both *magnitude and direction* for this to be the start of a new cycle.

3. Label the graphs above with –

"B" at the Beginning of a cycle

"E" at the End of the same complete cycle

"A" on the first spot where the mass is moving Away from the detector fastest.

"T" on the first spot where the mass is moving Toward the detector fastest.

"S" on the first spot where the mass is standing Still.

"F" where the mass is Farthest from the motion detector.

"C" where the mass is Closest to the motion detector.

Question 1-1: Describe the velocity graph and compare it to the position graph. Do they appear to have the same period? Do their peaks occur at the same times? If not, how are the peaks related in time?

Activity 1-2: Properties of Periodic Motion – Period, Frequency, Amplitude

1. Measure the period and frequency of the motion represented by the graphs produced in Act. 1-1. Click the position graph to examine the data.

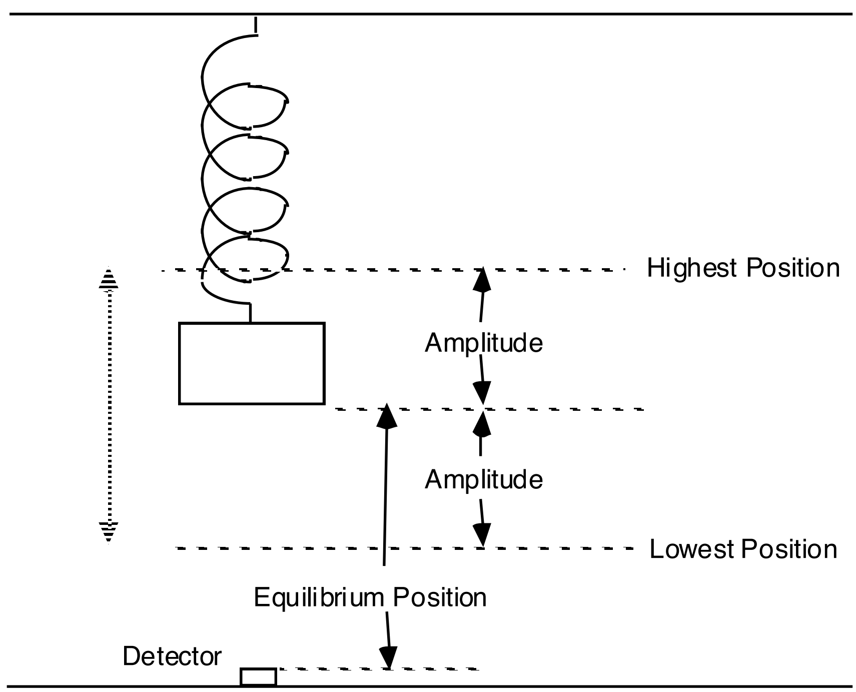
- **a.** Mark the beginning of each cycle with an arrow on the printout of your distance graph. You may start with any part of the cycle but be consistent once you pick a starting point. Remember: the time for one cycle is called the period.
- **b.** What is the period and frequency of the motion? (For better accuracy, measure the total time over as many complete cycles as possible and divide by the number of cycles.).

Number of Cycles Counted	Time for these cycles (sec)	Period (sec)	Frequency (Hz)

Table 1

Comment: The midpoint of the motion is also the point where the mass will hang at rest. This position is called the **equilibrium position.**

The **amplitude** of the motion is the maximum displacement (change in distance) from the equilibrium position. (For the motion of a mass and spring, it should be the same in both directions.) See the diagram below.



2. Find the equilibrium position and the amplitude.

- **a.** To find the equilibrium position of the mass, press Collect again with the mass hanging completely at rest. After collecting the data, draw a straight line on your distance graph printout at the equilibrium position. This is the equilibrium position in terms of distance from the motion detector.

Click on the Position graph to read the equilibrium position.

Equilibrium position:________________m

b. Click on the y-axis title “Position” and choose to show Data Set 1 (the oscillations) along with Data Set 2 (the equilibrium position). Calculate the amplitude as the difference between the maximum distance and the equilibrium position.

Maximum position: ________________ m

Amplitude:_______________________ m

INVESTIGATION 2: SIMPLE HARMONIC MOTION

The motion of a mass hanging from a spring that you looked at in Investigation 1 is a close approximation to a kind of periodic motion called **simple harmonic** motion (sometimes abbreviated to SHM). In this investigation you will use the same setup from Investigation 1 to examine the properties of simple harmonic motion.

Prediction 2-1: What can you do to change the period of the SHM of a mass on a spring? Consider the following possibilities: change the amplitude of the motion, the hanging mass, or the stiffness of the spring (the strength of the restoring force). Imagine changing one of these things and leaving all else the same. What do you predict will be the effect on the period if you:

Increase the amplitude?____

Increase the mass?____

Make the spring stiffer (more restoring force)? ________________________

Activity 2-1: The Period of SHM and the Amplitude

Check your prediction of the dependence of the period of SHM on the amplitude.

1. Record the results of Activity 1-2 in Table 2 as Run 1.

2. In Graphical Analysis, click View, , and chose 1 Graph. Make sure it is a position graph.

3. Using the same SHM setup as in Investigation 1, make a position vs. time graph with a different amplitude from Investigation 1. Use the same mass and spring. Make the amplitude about half or twice as large as in Investigation 1. (Warning: do not make the amplitude too big. It can ruin the spring. Push the mass up to start it moving instead of pulling it down.)

When you have a good graph, find the period and the amplitude using the method described in Activity 1-1. Record the results as Run 2. To view both runs together, click on the y-axis title “Position” and choose to show Data Set 1 (Run 1) and the most recently produced data set.

	Amplitude (m)	Period (sec)
Run 1		
Run 2		
Ratio		

Table 2

Question 2-1: Is there evidence that the period depends on amplitude? Did the change in amplitude result in a comparable change in period? Explain

Note: If you found that the period depended significantly on the amplitude, be sure to use the same amplitude in all of the following activities so that you are changing only one variable at a time.

Comment: The sinusoidal shape of the position vs. time graph in this activity is characteristic of simple harmonic motion. It is relatively easy to show mathematically that if the restoring force (whatever produces the motion) is proportional to the distance away from the equilibrium position, SHM is the result.

Mathematically, **F = -kx**, where x is the position coordinate (+ or -) in a system where the equilibrium position is at x=0. The constant k is called the spring constant, and the minus sign assures that the force points back toward the equilibrium position. This relationship is called Hooke's Law.

Activity 2-2: Spring Restoring Force and SHM

1. Measure the spring constant of your spring S1. Use four different masses. Carefully measure and record the position of the spring when it is at rest with each of these four masses hanging from it.

Using a meter stick, measure the equilibrium position for the end of the spring at rest. Record the change in position of the end of the spring as each new mass is added. Calculate the force on the spring caused by each mass and record your information in below.

Spring S1

Added Mass (kg)	Added Force (N)	Equil. Position (m)	Change in Position (m)
0			

2. Plot a graph of force vs. position. You may use the graphing features of Graphical Analysis or any other graphic software. If you wish to use Graphical Analysis, open a new experiment and choose Manual Entry (instead of Sensor Data Collection). A graph and data table will appear. Use Column Options to change the x-axis and y-axis titles to Position Change and Force, respectively, and include appropriate units. Click on Graph Tools, , and choose Curve Fit, which has a Linear option, to do a mathematical fit of your data. Print the graph.

3. Find the force constant of spring S1: k_1 = ___________ N/m

Question 2-2: Explain how you found k below.
(Hint: for a spring obeying Hooke's law, F = kx, where x is the distance the spring is stretched from its unstretched length, how would you find k from a graph of F vs. x?)

4. <u>Find the spring force constants for two other springs, S2 and S3</u>. Use the same method. Record your data and print and attach your graphs.

<u>Spring S2</u>

Added Mass (kg)	Added Force (N)	Equil. Position (m)	Change in Position (m)
0			

<u>Spring S3</u>

Added Mass (kg)	Added Force (N)	Equil. Position (m)	Change in Position (m)
0			

k_2 = ___________ N/m k_3 = ___________ N/m

Question 2-3: Which spring had the largest force constant, the stiffest or the least stiff? Explain.

Prediction 2-4: Do you now think that the period of SHM for a spring depends on the spring constant? If so, describe how you think changes in k will affect the period T.

Activity 2-3: The Dependence of the Period of SHM on the Spring Constant

1. <u>Measure the periods</u>. Set up the motion detector and Graphical Analysis. You will need a position vs. time graph. Always using mass M1, the mass you used in Activity 1-1, carefully measure the period using the two other springs (S2 and S3) whose spring constants you determined in Activity 2-2.

We want to keep the total mass being accelerated constant, and this will include approximately 1/3 of the mass of the spring. If the mass of any of the springs is much smaller than S1, you may have to add a small amount of mass to the hanger to make up for this difference.

Record these in the table below along with the period you measured for the combination S1 and M1 in Investigation 1.

Combination Mass	**Period (s)**	**k (N/m)**
M1 and S1		
M1 and S2		
M1 and S3		

Question 2-4: Does the period depend on the spring constant? Does it regularly increase or decrease as k is increased, keeping the hanging mass constant?

2. <u>Determine the mathematical relationship between the period T and the spring constant k.</u> Plot a graph of T vs. k. You may us the graphing features of Graphical Analysis or any other graphing software. If you wish to use Graphical Analysis, open a new experiment and choose Manual Entry (instead of Sensor Data Collection). A graph and data table will appear. Use Column Options to change the x-axis and y-axis titles to Spring Constant and Period, respectively, and include appropriate units.

Question 2-5: How would you describe the relationship in this graph? Is there a linear relationship between T and k? Is T proportional to k? Inversely proportional to k? Explain.

Click on Graph Tools, , and choose Curve Fit to do a mathematical fit of your data and determine the relationship between T and k. Print the graph.

Question 2-6: What mathematical relationship did you determine between T and k? What did you plot to verify this relationship?

Prediction 2-7: Do you think the period of SHM for a spring depends on the mass? If so, describe how you think changes in M affect the period T.

Activity 2-4: The Dependence of the Period of SHM on the Mass

1. Measure the periods. Set up the motion detector and Graphical Analysis. You will need a position vs. time graph. Always using the spring S1, carefully measure the period (T) for the other two masses (M2 and M3).

Record these in the table below along with the period you measured for the combination S1 and M1 in Investigation 1.

Combination Mass	Period, T (s)	Mass (kg)
M1 and S1		
M2 and S1		
M3 and S1		

Question 2-8: Does the period depend on the mass? Does it regularly increase or decrease as M is increased while using the same spring?

2. Determine the mathematical relationship between the period T and the mass M. Plot a graph of T vs. M. You may use the graphing features of Graphical Analysis, or any other graphing software. If you wish to use Graphical Analysis, open a new experiment and choose Manual Entry (instead of Sensor Data Collection). A graph and data table will appear. Use Column Options to change the x-axis and y-axis titles to Mass and Period, respectively, and include appropriate units.

Click on Graph Tools, , and choose Curve Fit to do a mathematical fit of your data and determine the relationship between T and k. Print the graph.

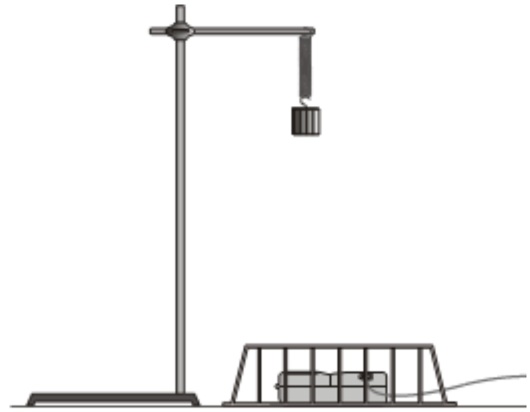
Question 2-9: What mathematical relationship did you determine between T and M? What did you plot to verify this relationship?

INVESTIGATION 3: VELOCITY, ACCELERATION, FORCE, AND ENERGY

In this investigation you will look more carefully at the distance, velocity, and acceleration graphs for simple harmonic motion. You will also look at the force graph and will examine the energy associated with simple harmonic motion.

MATERIALS

- Graphical Analysis software
- LabQuest Mini Base
- Motion Detector and protective wire basket
- Force probe
- Spring, masses, and support



Activity 3-1: Velocity and Acceleration of a Mass Undergoing SHM

1. Set up the motion detector and force sensor. Place the motion detector on the floor. Hang the force sensor from a support directly above the motion detector. Connect the force sensor into the LabQuest Mini Base.

2. Prepare the graph. Launch Graphical Analysis. In this experiment, you will need one position vs. time graph. Set the y-axis value accordingly. Click Data Collection Settings. Change End Collection to 10 s, then click done.

3. Set up a mass and spring. Using what you have learned about simple harmonic oscillation, choose a mass and spring combination available which will produce an intermediate-sized period.

Hang the mass and spring from the end of the force probe. Adjust the height of the force probe so that the mass can oscillate without coming closer than 0.5 meters away from the motion detector.

4. With the mass completely at rest, zero the force probe. Collect data with the mass completely at rest. This data is automatically stored.

5. Record a position graph with the mass oscillating. Push the mass up and start it oscillating up and down with an amplitude of 10 to 20 cm. (Be sure that the mass does not come closer than 0.5 to the motion detector).

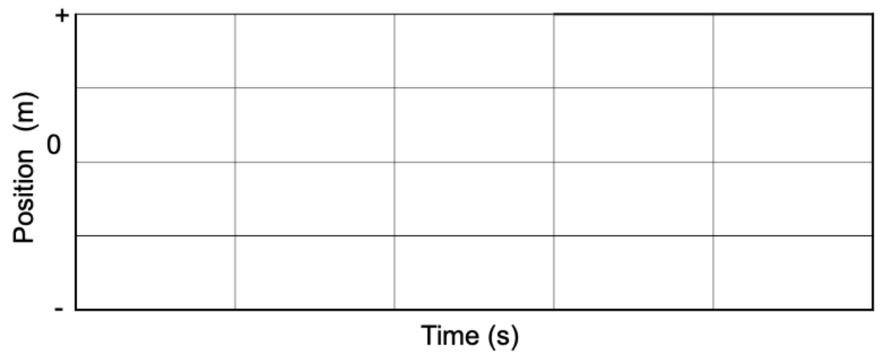
Change the time axis to display three complete cycles of the motion.

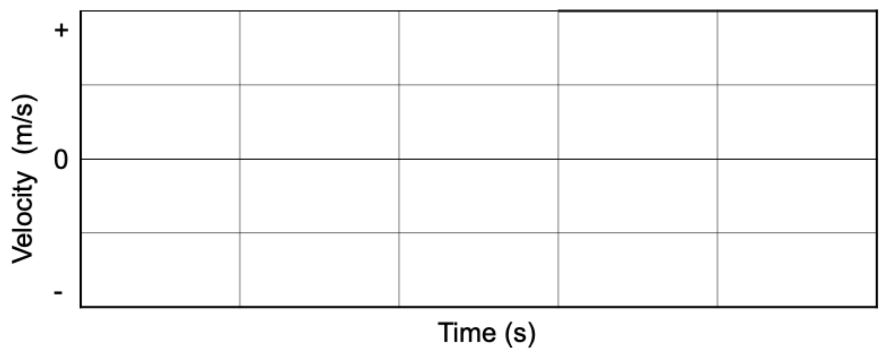
Draw the position graph carefully on the axes on the next page. Fill in the appropriate time and position scales.

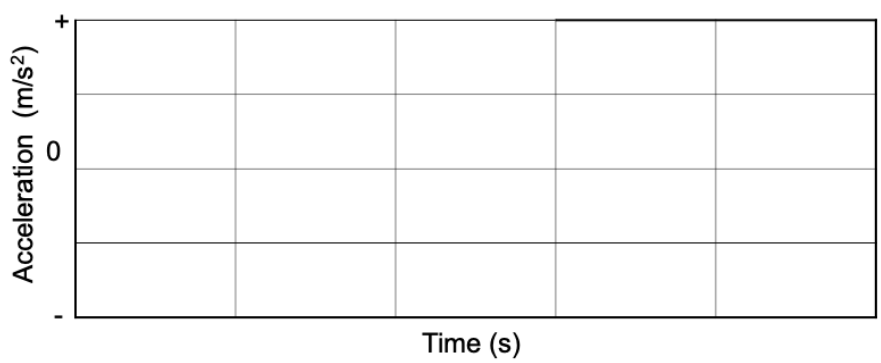
6. Predict the velocity, acceleration, and force graphs. Draw your predictions of the velocity, acceleration, and force graphs with dashed lines on the axes on the next page. Do this before displaying them.

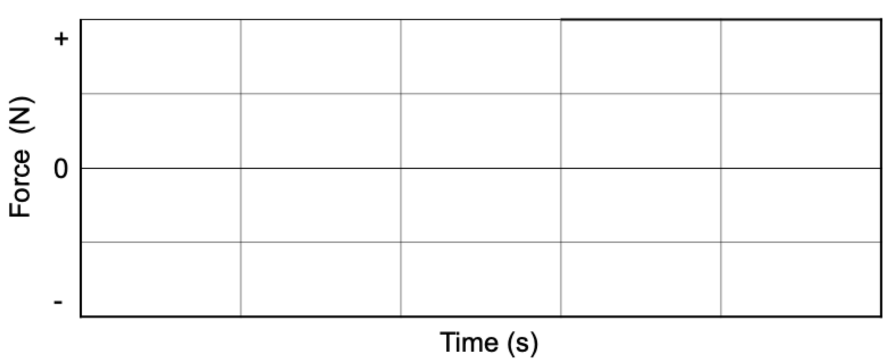
7. Display the actual velocity, acceleration, and force graphs. Click on View and choose 3 Graphs. Adjust those graphs so they display the velocity, acceleration, and force as a function of time.

8. Keep Graphical Analysis open. The data will save automatically and you will use them in the next activity.









Question 3-1: When the mass is at its maximum distance from the detector, is the velocity a maximum, minimum, or some other value according to your graphs? Does this agree with your predictions? Does this agree with your observations of the oscillating mass? Explain.

Question 3-2: When the mass has its maximum positive velocity, is its distance from the detector a maximum, minimum, the equilibrium value or some other value according to your graphs? What about when it reaches maximum negative velocity? Does this agree with your predictions? Does this agree with your observations of the oscillating mass? Explain.

Question 3-3: According to your graphs, for what distances from the detector is the acceleration maximum? For what distance is the acceleration zero? What is the velocity in each of these cases?

Question 3-4: Compare the force and acceleration vs. time graphs. Describe any similarities. Does the force graph agree with your prediction?

Question 3-5: From your graphs, what would you say is the relationship between force and acceleration?

Question 3-6: Compare the force and position vs. time graphs. What would you say is the relationship between force and position?

Activity 3-2: Energy of a Mass Undergoing SHM

Now use the data from Activity 3-1 to examine the energy relationships in simple harmonic motion.

Question 3-7: At what points is the kinetic energy of the mass zero? Label these points on your position and velocity graphs from Activity 3-1 with a K.

1. Calculate the elastic potential energy due to the spring at one of these points. Label the point you use on your velocity and position graphs with a (1).

Use PE = $\frac{1}{2}kx^2$ where x is the distance from the equilibrium position and k is the force constant of the spring which you have already measured in Investigation 2.

You will need to read the distance and the equilibrium distance from your graph. Click on the graph to read the values. Show any calculations necessary.

Distance read from graph: ____________ m
Equilibrium distance: _____________ m
Distance from equilibrium (x): _____________ m
Force constant of spring: _____________ N/m
Elastic Potential Energy: _____________ J

Question 3-8: At which points is the potential energy zero? Label these points with a P on your position and velocity graphs.

Prediction 3-1: If you measure the kinetic energy at one of these points, what would you expect its value to be? Explain

Check your prediction.

2. Calculate the kinetic energy at one of these points. Label the point you use on your velocity graph with a (2).
Use KE = $\frac{1}{2}mv^2$. Click on the velocity graph to read the value. Show your calculation.

Velocity read from graph:	___________	m/s
Hanging mass:	___________	kg
Kinetic Energy:	____________	J

Question 3-9: Did your calculated kinetic energy agree with your prediction?

Prediction 3-2: If you calculated the potential and kinetic energies at a point where neither of these was zero, what would you expect the total energy to be? Explain.

Check your prediction.

3. Pick a point where the mass has both kinetic and potential energy and calculate them both. Label this point on your distance and velocity graphs with a (3). Show your calculations.

Distance from graph:	__________	m
Hanging mass:	__________	kg
Velocity from graph:	__________	m/s
Force constant of spring:	__________	N/m
Equilibrium distance:	__________	m
Dist. From equilibrium (x):	__________	m
Kinetic Energy:	__________	J
Elastic Potential Energy:	___________	J
Total Energy:	___________	J

Question 3-10: Does your result agree with your prediction? Does it appear that energy is conserved? Explain.