PERIODIC MOTION

> **IDEA TO REMEMBER!**
>
> Oscillations are driven by exchanging energies!

OBJECTIVE:

Investigating the exchange of energy through analysis of the three elements of oscillation with respect to time.

MATERIALS:

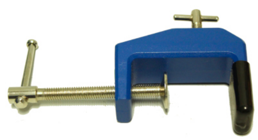

Table clamp

Right angle clamp

Long rod

Short rod (with pulley)

Pendulum clamp

Spring

Hooked weights

Meter stick

PASCO 550 Interface

PASCO Motion Sensor

PASCO Force Sensor

CONCEPT:

Similar to the Simple Harmonic Motion (SHM) lab, consider a mass m hanging vertically on a spring as shown in Figure (1). The mass stretches the spring to its equilibrium point, that is, the position where the spring-mass setup is stationary or undisturbed. For a particular spring-mass setup, the equilibrium position depends on the spring constant k and the mass. When the mass is displaced by some distance above or below the equilibrium point and released, it begins to move up and down, oscillating at regular time intervals. This type of motion is known as periodic motion and it is simply defined as **the regular and repetitive motion of an object**.

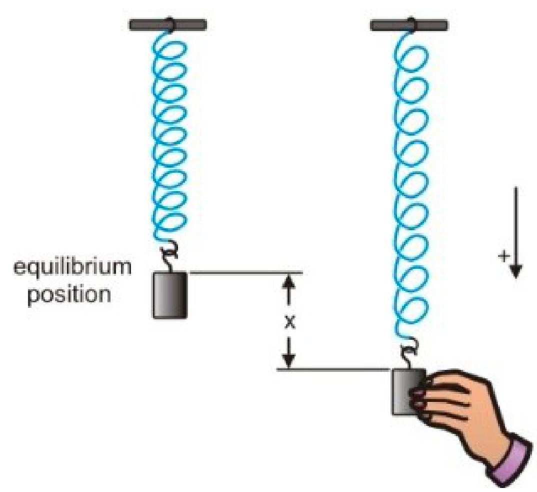

Figure 1

Now, when can plot the properties of oscillation, such as position, velocity, and acceleration, as shown in Figure (2), it makes a sine curve or sinusoidal wave! Notice that oscillations display three sinusoidal features: **equilibrium** (0 in y-axis), **amplitude** (maximum or minimum), and **period** (a full cycle of oscillation).

THINK: *What patterns or correlations do you see between the plot curves?*

The primary forces acting on the mass in this setup is the force due to gravity and the spring force, which according to Hooke's law, as shown in Equation (1), is proportional to the displacement above or below the equilibrium point.

THINK: *Can you recall the equation for Hooke's law from the SHM lab?*

$$F = -k\,\Delta y \qquad (1)$$

Also from SHM, Equation (2) gives the relationship between the period, mass, and spring constant:

$$T = 2\pi\sqrt{\frac{m}{k}} \qquad (2)$$

Now, let's dive deeper into why this happens!

Based on the conservation of energy law, in an isolated, ideal system, instead of energy being created or destroyed, energy is exchanged from one form to another. So, **the oscillation of the spring-mass is driven by the natural exchange of kinetic and potential energy!**

$$E_T = K.E. + P.E.$$

All of the periodic motions in nature are caused by this exchange of energies. So, at various points in Figure (2), there is a change in potential and kinetic energy!

$$K.E. = \frac{1}{2}mv^2 \qquad (3)$$

$$P.E. = \frac{1}{2}ky^2 \qquad (4)$$

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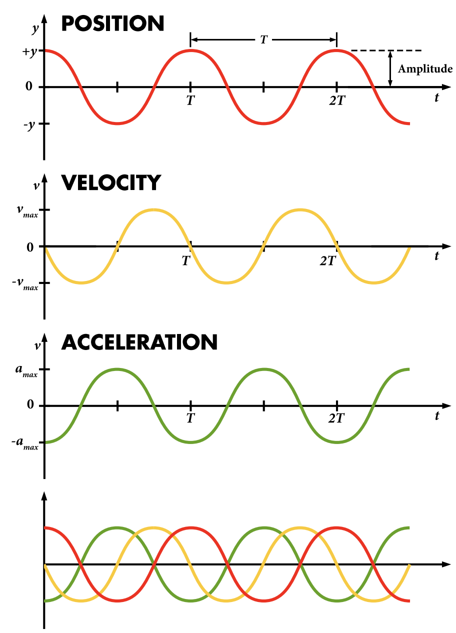

Figure 2

In the real world there are no isolated systems, which means damping forces and energy losses out of the system (heat, friction, etc.) would also apply.

THINK: *Where is kinetic and potential energy at its maximum and minimum in Figure (2)?*

Real World Applications

- The suspension system in a car contains compressed springs and hydraulic dampers to help maintain the car's forward trajectory by preventing vertical movement.
- **Slingshots!** Rubber acts like a spring, but they do not exactly obey Hooke's law. Watch the videos to the right to find out more about their energy exchange and why your textbook may be wrong...

1) Smarter Every Day—Physics of Slingshots

2) More fun and facts with slingshots!

PRECAUTIONS:

Falling masses can cause serious damage or injury!

PROCEDURE:

Part 1

1. ☐ Fill out the top information **and** complete the memory exercise—Question M1—on the worksheet.

2. ☐ REQUIRED: Read the *Concept* section.

3. ☐ Set up the PASCO Capstone software with the Motion Sensor as shown in Figure (3).

   3.1. Connect the Motion Sensor to the PASCO 550 Interface, Figure (3a).

   3.2. Open the PASCO Capstone software and click *Hardware Setup* on the left sidebar to ensure that the *Motion Sensor* has been recognized.

   3.3. (If not recognized, click on one of the digital input ports on the PASCO interface icon and select *Motion Sensor* from the dropdown list.)

   3.4. Double-click on *Graph* on the right sidebar, then select *Position (m)* for the y-axis.

   3.5. In the graph toolbar, click *Add new plot* twice to add two new plots to the graph area. Select *Velocity (m/s)* and *Acceleration (m/s²)* for the y-axes of those graphs, as shown in Figure (3b).

   3.6. Change the sampling rate on the bottom of the screen to 25 Hz.

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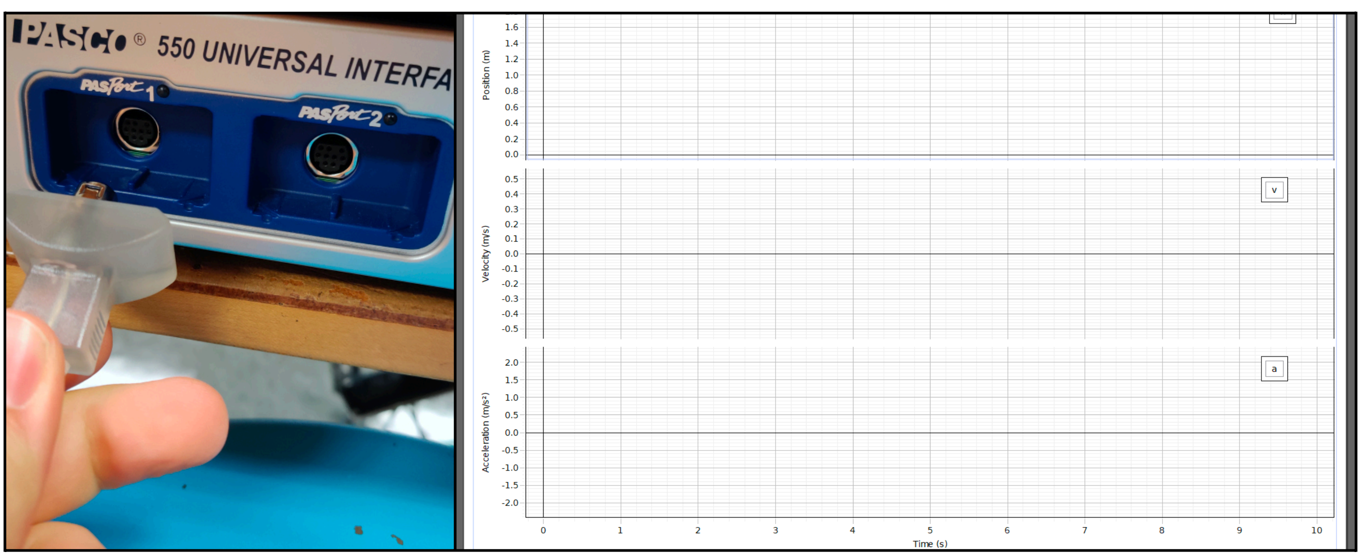
CONCEPT & PROCEDURE VIDEOS:



(a) (b)

Figure 3

4. ☐ Assemble the setup as shown in Figure (4).

   4.1. Attach the spring securely under the Pendulum clamp clip, as shown in Figure (4a).

   4.2. Hang a 500g hooked weight on the spring and allow it to be stationary, and use the meter stick to find the equilibrium height of the spring and then **record it in the appropriate place on the worksheet**. See Figure (4b).

   4.3. Place the motion sensor so that the weight hangs directly over it and adjust the pendulum clamp until the distance between the weight and motion sensor is 30 to 40cm. See Figure (4c).

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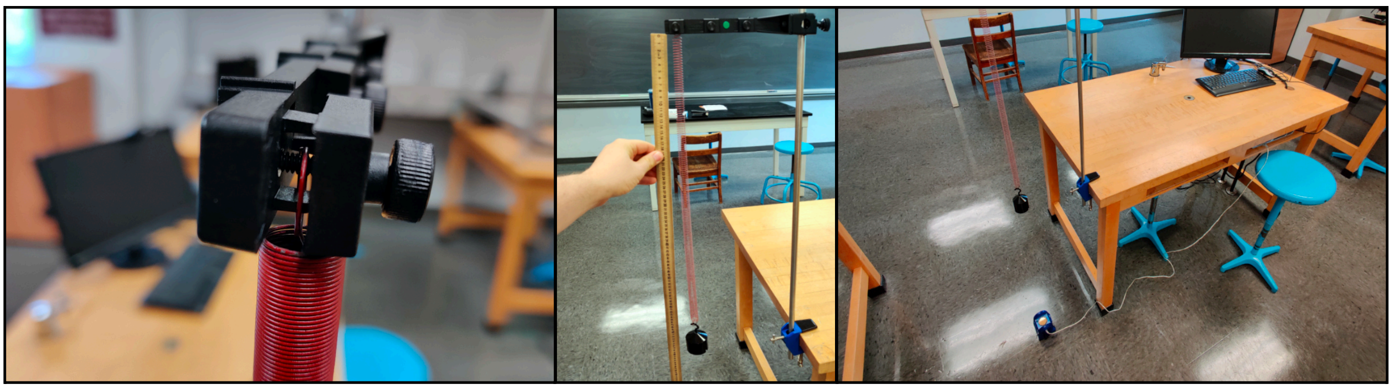

(a) (b) (c)

Figure 4

5. ☐ Pull the mass down 4cm *very precisely* from its equilibrium position and release it to oscillate freely, then click on *Record* on the bottom-left of the Capstone software.

6. ☐ After 10s click *Stop* recording. Click on *Scale-to-fit* to fit all the plots on the graph.

7. ☐ Click on *Add Coordinate tool* and select the *Add Multi Coordinate tool* to mark a maximum position and minimum position of a cycle of your choice and record as Trial 1 in Table 1 on your worksheet. You may need to increase the decimal places of the tool: right-click > *Tool Properties* > *Numerical Format* > *Vertical Coordinate* > increase the value of *Number of decimal places*.

8. ☐ Select any two consecutive maximums and record times t_1 and t_2.

9. ☐ Repeat Steps 5–9 to complete Table 1. Displace the mass 5cm and 10cm from the equilibrium point for Trails 2 and 3, respectively.

10. ☐ Complete Questions 2–3 on the worksheet.

11. ☐ Using data from Trial 3, select 3 points between a maximum position and its consecutive minimum position. For each point record the position and acceleration and complete Table 2.

12. ☐ Complete Questions 4–5 on the worksheet.

Part 2

1. ☐ Set up the PASCO Force Sensor.
    1.1. Attach the Right angle clamp to the Long rod around 10cm above the table.
    1.2. Secure the Short rod to the Long rod with the Right angle clamp.
    1.3. Slide the Force Sensor onto the Short rod through its middle hole with the hook facing down, as shown in Figure (6a).

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2. ☐ Set up Capstone to display the Force Sensor data.
    2.1. Connect the Force Sensor to the PASCO Interface, as shown in Figure (6b).
    2.2. Press the *Zero* button on the Force Sensor.
    2.3. Select *Calibration* on the left sidebar to calibrate the Force Sensor: click *Next*, then *Next* again to confirm the "Two Standards (2 point)" method.
    2.4. Hang 100g on the Force Sensor hook and type 0.98 into the *Standard Value* box. Click *Set Current Value to Standard Value*.
    2.5. Hang 1000g (1kg) on the Force Sensor hook and type 9.8 into the *Standard Value* box. Click *Set Current Value to Standard Value*.
    2.6. Click *Finish* and then *Calibration* to minimize the tool menu. Remove the 1000g weight, also.
    2.7. Click *Calculator* in the left sidebar and enter the equations for *P.E.*, *K.E*, and E_T. For mass m, use force F over g—click Insert Data to input your force sensor *Force (N)* as force F. PASCO will automatically ask for the unknown variables. Use your spring stiffness constant k from Question 2.
    2.8. Click *Add new plot* and select *P.E (N-m)* for the y-axis, then click on the y-axis selector again and go to *Add Similar Measurement* at the top and select *K.E. (N-m)*. The y-axis will now display *Energy (N-m)*, as shown in Figure (6c).

(a) (b) (c)

Figure 6

3. ☐ Use the *Multi-Coordinates tool* to analyze the exchange of energy as the position, velocity, and acceleration change.

4. ☐ Answer Questions 7–8 on the worksheet.

5. ☐ Follow the **Let's THINK!** instructions below.

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Let's THINK!

- **Ask questions**: What are you learning here?… Why is this Physics concept important and how can it be used?… What do you not understand?… (For more information on this Physics topic, scan the QR codes in the *Real World Applications* and at the start of the *Procedure* section.)
- **Discuss** the concept and demonstration with your partner to help each other understand better. Discussion makes learning active instead of passive!
- For **FULL PARTICIPATION [15 points]** you must call on the TA when you have finished your group discussion to answer some comprehensive questions. If you do not fully understand and the TA asks you to discuss more, you must call on them one more time to be dismissed with full marks.
- **CONCLUSION [10 points]**: In the Conclusion section at the end of the worksheet, write 3 or more sentences summarizing this concept, how this lab helped you understand the concept better, and the real world implications you see. Do you still have questions? If so, write those as well.

Updated Date	Personnel	Notes
2022.08	Chase Boone, Bernard Osei, Brooks Olree, Ahmad Sohani	2022 Summer Improvement: Created new format.
2023.01	Chase Boone	Edits

Name: ______________________________ *PH2233* Section #: __________

Name: ______________________________ TA Name: __________________

PERIODIC MOTION
WORKSHEET [70 points]

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Memory exercise [each 2 extra credit points]**:**

M1) Springs have a constant __________________ called ________

1) Equilibrium height of the spring: ______________m [1 point]

Table 1: Amplitude and Period Measurement [9 points; 0.5 point per cell]

Trial	Max. Position (m)	Min. Position (m)	Amplitude (m)	T_1 (s)	T_2 (s)	Period (s)
1						
2						
3						

2) From Table 1, calculate the average period and the spring constant k. **Show your work**. [7 points]

3) For **each** trial calculate the equilibrium point. How does each compare with the equilibrium position you measured? Show your work. [7 points]

Table 2: Forces at displacements [6 points; 0.5 point per cell]

Points	Acceleration m/s^2	Displacement y (m)	Reaction Force $F = ma$	Reaction Force $F = -ky$
1				
2				
3				

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4) Draw a plot like Figure (3) for kinetic and potential energy in relation to position, velocity, and acceleration. [6 points]

5) Find the kinetic and potential energy of your system from your Capstone position and velocity curves at *t = 5s*. **Show your work**. [7 points]

Knowns:

Position *y*:

Velocity *v*:

7) A) What do you notice about the kinetic and potential energy curves in relation to position, velocity, and acceleration? [6 points]
B) How did the Capstone curves compare to your K.E. and P.E. plots in Question 4? [3 points]

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8) To further explain the relationship between kinetic and potential energy and why total energy remains the same, substitute the position *x(t)* and velocity *v(t)* equations into the total energy E_T equation and reduce the coefficients by their units to find the foundational equation that explains the total energy E_T plot curve. **Show your work**, and **draw a plot of the equation you get**. [8 points]

Conclusion

Write 3 or more sentences summarizing this concept, how this lab helped you understand the concept better, and the real world implications you see. Do you still have questions? If so, write those here as well. [10 points]

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