



PERIODIC MOTION

OBJECTIVE:

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

IDEA TO REMEMBER!

Oscillations are driven by exchanging energies!

MATERIALS:



PASCO 550 Interface



PASCO Motion Sensor



Pendulum clamp



Table clamp for rod



Rod



Meter stick



Hooked weights



Hanging spring

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**.

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)**.

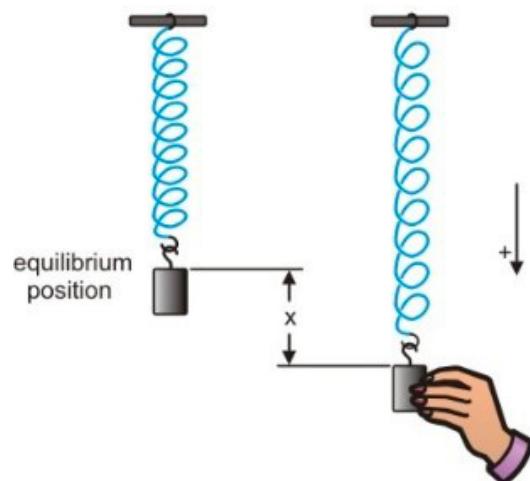


Figure 1



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?

$$F = -k\Delta y \quad (1)$$

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

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

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!

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

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

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)?

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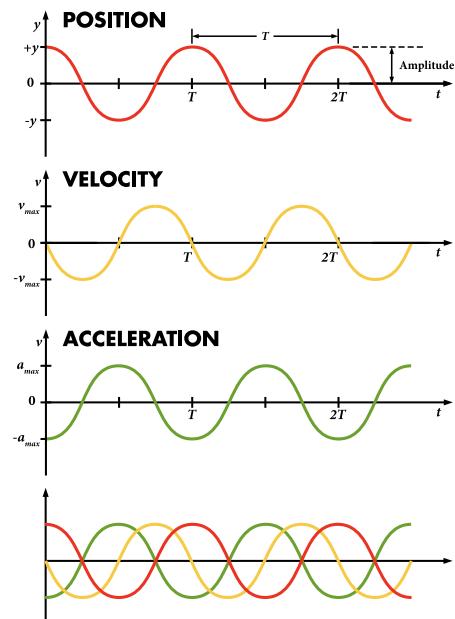


Figure 2

Real World Applications

- The suspension system in a car contains compressed springs and hydraulic dampers to help maintain a forward trajectory and prevent 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:

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.

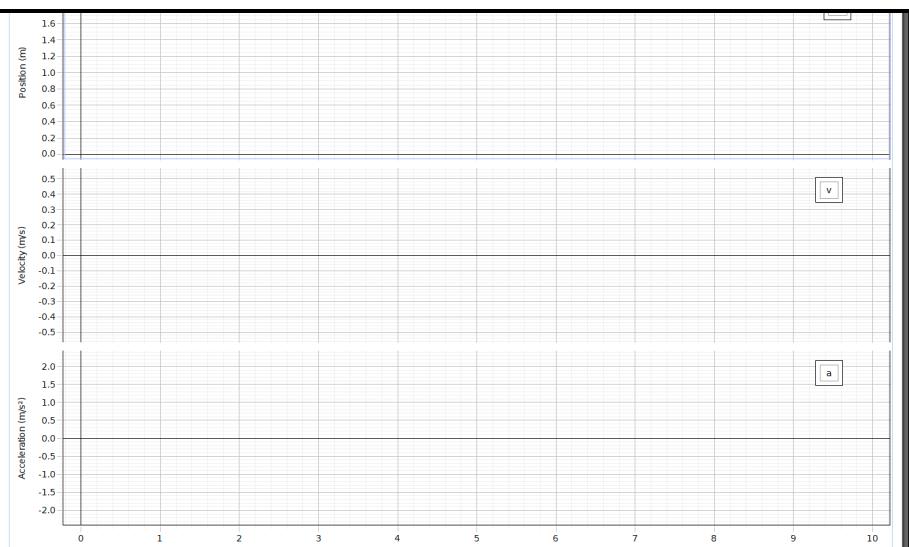
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CONCEPT & PROCEDURE VIDEOS:



(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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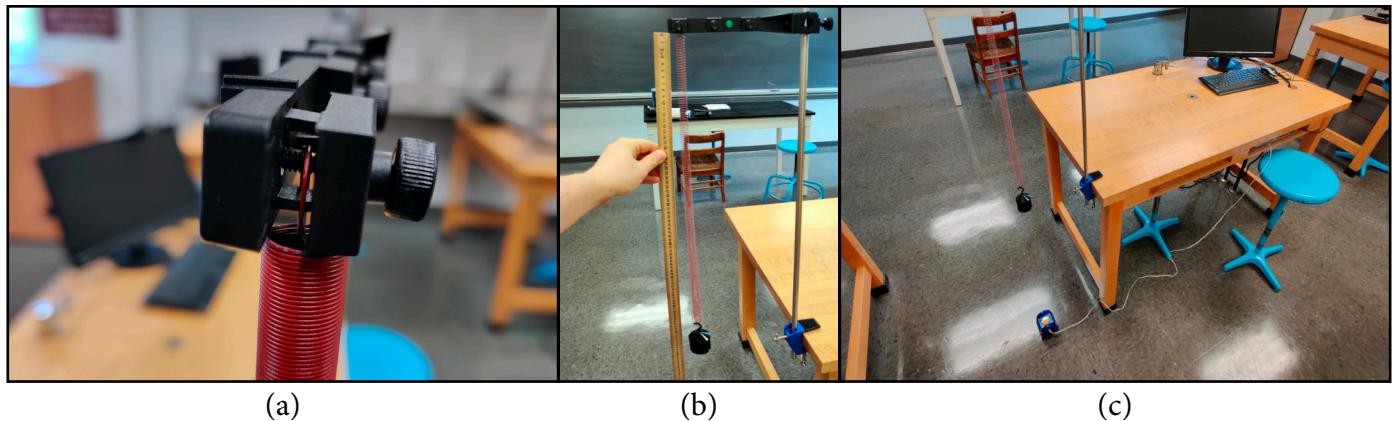


Figure 4

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*. 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 Trials 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 and follow the **Let's THINK!** instructions on the next page.



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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: _____

PH1123 Section #:_____

Name: _____

TA Name:_____

PERIODIC MOTION

WORKSHEET [70 POINTS]

Memory exercise [each 2 extra credit points]:

M1) Springs have a constant _____ called _____

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1) Equilibrium height of the spring: _____ m [1 point]

Table 1: Amplitude and Period Measurement [9 points]

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 all steps to gain full marks.) [10 points]

3) For **each** trial calculate the equilibrium point. How does each compare with the equilibrium position you measured? Show your work. [10 points]

Table 2: Forces at different displacements [12 points]

Points	Acceleration m/s^2	Displacement $x (\text{m})$	Reaction Force $F = ma$	Reaction Force $F = -kx$
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. [8 points]

5) Find the kinetic and potential energy of your system from your Capstone position and velocity curves at $t = 5\text{s}$. [10 points]

Knowns:

Position y :

Velocity v :

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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