Energy in Simple Harmonic Motion

SCIENCE NSPIRED

TEACHER NOTES

Science Objectives

- Students will analyze energy transformation for a mass attached to a spring as it oscillates in Simple Harmonic Motion.
- Students will explore the Conservation of Energy principle.

Vocabulary

- conservation of energy
- gravitational potential energy
- kinetic energy
- spring potential energy
- total mechanical energy

About the Lesson

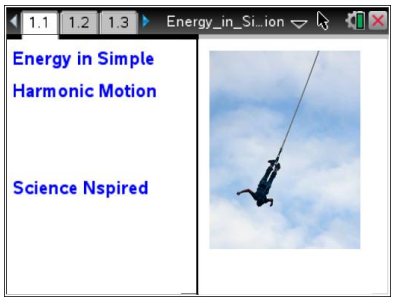
- This lesson simulates a mass attached to a spring as it oscillates in simple harmonic motion. In the first part of the lesson the mass oscillates across a frictionless, horizontal surface. In the second part, the mass is suspended from the spring and oscillates vertically. Bar graphs represent the potential and kinetic energies of the system.
- As a result, students will:
  - Observe how energy transforms between potential energy and kinetic energy as the mass moves through its cycle.
  - Describe factors that affect the total energy of the system and the maximum speed of the mass.
  - Observe that the total energy remains constant throughout the motion.

TI-Nspire™ Navigator™

- Send out the *Energy_in_Simple_Harmonic_Motion.tns* file.
- Monitor student progress using Class Capture.
- Use Live Presenter to spotlight student answers.

Activity Materials

- Compatible TI Technologies: TI-Nspire™ CX Handhelds, TI-Nspire™ Apps for iPad®, TI-Nspire™ Software



Tech Tips:

- This activity includes class captures taken from the TI-Nspire CX handheld. It is also appropriate for use with the TI-Nspire family of products including TI-Nspire software and TI-Nspire App. Slight variations to these directions may be required if using other technologies besides the handheld.
- Watch for additional Tech Tips throughout the activity for the specific technology you are using.
- Access free tutorials at http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials

Lesson Files:

Student Activity

- Energy_in_Simple_Harmonic_Motion_Student.doc
- Energy_in_Simple_Harmonic_Motion_Student.pdf

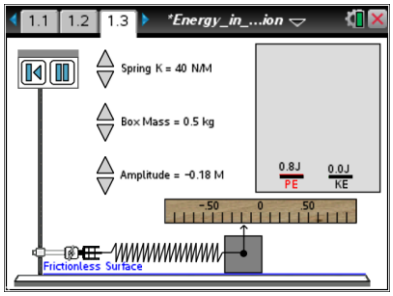
TI-Nspire document

- Energy_in_Simple_Harmonic_Motion.tns

Discussion Points and Possible Answers

Move to page 1.2.

This page gives background and instructions for the simulation. Students will be able to manipulate the mass of the object (*m*), the spring constant (*k*), and the amplitude of motion (*A*). Selecting the Play button displaces the mass (by an amount equal to the amplitude), and releases it. The mass will oscillate about the point of equilibrium. Two bar graphs measure the spring potential energy and the kinetic energy. The position and speed of the mass are also displayed. Students can pause the motion or reset the motion by selecting the appropriate buttons. Students should follow the instructions and answer the question in the .tns file as they explore this activity.



Tech Tip: To access the Directions again, have students select menu or **Document Tools ( ) > Energy in Simple Harmonic Motion> Directions.**

Tech Tip: To access the Directions again, have students select > **Directions.**

Move to page 1.3.

Students will use the simulation. Have students answer the questions on the activity sheet.

Q1. Set the mass to 0.5 kg, the spring constant to 40 N/M, and the amplitude to 0.10 m. Select the Play button and observe the bar graphs as the mass oscillates. Describe what appears to happen with the potential energy of the spring and the kinetic energy of the mass as the mass moves through its cycle.

Answer: The potential and kinetic energies are constantly changing. When one increases, the other decreases. The potential energy is greatest at the endpoints of the motion, and the kinetic energy is greatest in the middle.

Q2. As the mass oscillates, pause the motion at three locations: one of the endpoints (where the mass changes direction), at x = 0.00 m (as the mass passes through equilibrium), and somewhere between equilibrium and an endpoint. Record the values of position, speed, spring potential energy, kinetic energy, and the sum of the two energies for each location.

Sample answers:

x = 0.10 m v = 0 m/s U_s = 0.2 J K = 0 J $U_s + K$ = 0.2 J

x = 0.00 m v = 0.89 m/s U_s = 0 J K = 0.2 J $U_s + K$ = 0.2 J

x = 0.05 m v = 0.77 m/s U_s = 0.05 J K = 0.15 J $U_s + K$ = 0.2 J

Q3. The sum of the spring potential energy and the kinetic energy is the total mechanical energy of the system. What do you observe about the total mechanical energy as the mass oscillates?

Answer: The total mechanical energy stays constant at 0.2 J.

Q4. Where is the mass moving the fastest? Describe the distribution of energy at this position.

Answer: The mass moves the fastest as it passes through the midpoint of the motion. At this point all of the energy is kinetic energy, and none of it is potential energy.

Q5. Where is the mass moving the slowest? Describe the distribution of energy at this position.

Answer: The mass stops at the endpoints where it turns around. At this point all of the energy is spring potential energy, and none of it is kinetic energy.

Q6. Increase the mass to 1.0 kg, but keep the spring constant and the amplitude the same. Repeat the measurements made in Question 2 above and record the values below.

Answers:

x = 0.10 m v = 0 m/s U_s = 0.2 J K = 0 J $U_s + K$ = 0.2 J

x = 0.00 m v = 0.63 m/s U_s = 0 J K = 0.2 J $U_s + K$ = 0.2 J

x = 0.05 m v = 0.55 m/s U_s = 0.05 J K = 0.15 J $U_s + K$ = 0.2 J

Q7. Compare the measurements in Question 6 to the measurements in Question 2. What appears to be the effect of increasing the mass of the object? What changes and what stays the same?

Answer: Increasing the mass decreases the speed of the object. The energy values are not affected.

Q8. Change the mass back to 0.5 kg, increase the spring constant to 80 N/m, and keep the amplitude at 0.1 m. Repeat the measurements made in Question 2 and record the values below.

Answers:

x = 0.10 m	v = 0 m/s	U_s = 0.4 J	K = 0 J	$U_s + K$ = 0.4 J
x = 0.00 m	v = 1.26 m/s	U_s = 0 J	K = 0.4 J	$U_s + K$ = 0.4 J
x = 0.05 m	v = 1.10 m/s	U_s = 0.1 J	K = 0.3 J	$U_s + K$ = 0.4 J

Q9. Compare the measurements in Question 8 to the measurements in Question 2. What appears to be the effect of increasing the spring constant of the spring? What changes and what stays the same?

Answer: Increasing the spring constant increased the energy of the system. Doubling the spring constant doubled the energy. This causes the mass to move faster.

Q10. Keep the mass at 0.5 kg, change the spring constant back to 40 N/m, and increase the amplitude to 0.2 m. Repeat the measurements made in Question 2 and record the values below.

Answers:

x = 0.20 m	v = 0 m/s	U_s = 0.8 J	K = 0 J	$U_s + K$ = 0.8 J
x = 0.00 m	v = 1.79 m/s	U_s = 0 J	K = 0.8 J	$U_s + K$ = 0.8 J
x = 0.10 m	v = 1.55 m/s	U_s = 0.2 J	K = 0.6 J	$U_s + K$ = 0.8 J

Q11. Compare the measurements in Question 10 to the measurements in Question 2. What appears to be the effect of increasing the amplitude of the motion? What changes and what stays the same?

Answer: Increasing the amplitude causes a dramatic increase in energy and speed. Doubling the amplitude causes the total energy to increase by a factor of four. The maximum speed doubles.

Move to pages 1.4 – 1.6.

Have students answer the next three questions, which summarize Problem 1, in their student activity sheets and/or on the device.

Q12. Choose the factors that determine the total mechanical energy of a mass on a spring system. (More than one response may be correct.)

Answers: B. spring constant of the spring C. amplitude of the motion

Q13. As the mass moves from maximum displacement back toward equilibrium _____.

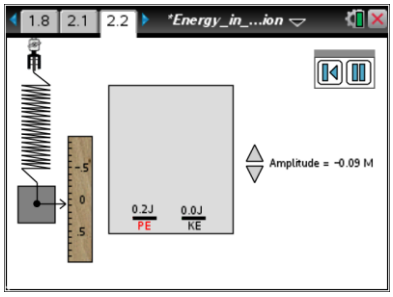
Answer: C. the spring potential energy decreases, the kinetic energy increases, and the total energy stays constant

Q14. Choose the combination that will give the mass the greatest speed as it passes through equilibrium.

Answer: D. small mass, large spring constant, large amplitude

Move to page 2.1.

This page introduces the simulation on the next page, which includes gravitational potential energy. The mass oscillates vertically with the activation of the Play button . As the mass oscillates, bar graphs show the gravitational potential energy (U_g), the spring potential energy (U_s), and the kinetic energy (K) of the system. The display shows the height of the mass above this point and the speed of the mass.



Move to page 2.2.

Students will use the simulation. Have students answer the questions on the activity sheet.

Q15. Set the amplitude to 0.10 m and start the animation. Describe qualitatively the energy changes you observe as the mass oscillates.

Answer: The three bar graphs are constantly changing. The spring potential energy never decreases all the way to zero. Its maximum is at the lowest point, and its minimum is at the highest point. The gravitational potential energy is zero at the lowest point and maximum at the highest point. The kinetic energy is zero at the lowest and highest points and maximum in the middle.

Q16. As the mass oscillates, pause the motion at the lowest point in the motion, at the midpoint of the motion, and at the highest point of the motion. Record the values of the height, speed, spring potential energy, gravitational potential energy, kinetic energy, and the sum of all three energies.

Answers:

h = 0.00 m	v = 0 m/s	U_s = 2.25 J	U_g = 0 J	K = 0 J	$U_s + U_g + K$ = 2.25 J
h = 0.10 m	v = 0.71 m/s	U_s = 1.00 J	U_g = 1.00 J	K = 0.25 J	$U_s + U_g + K$ = 2.25 J
h = 0.20 m	v = 0 m/s	U_s = 0.25 J	U_g = 2.00 J	K = 0 J	$U_s + U_g + K$ = 2.25 J

Q17. In this scenario, the total mechanical energy is the sum of the spring potential energy, the gravitational potential energy, and the kinetic energy. What do you observe about the total mechanical energy of the system as the mass oscillates?

Answer: The total mechanical energy remains constant as the mass oscillates.

Q18. Describe the energy transformations which occur as the mass rises from its lowest point to the midpoint of its motion.

Answer: The spring potential energy decreases as the gravitational potential energy and kinetic energy increase. Most of the spring potential energy is transformed into gravitational potential energy. Only a small fraction turns into kinetic energy.

Q19. Describe the energy transformations which occur as the mass rises from the midpoint of its motion to the highest point of its motion.

Answer: The spring potential energy continues to decrease as the gravitational potential energy continues to increase. The kinetic energy decreases to zero.

Q20. Increase the amplitude of the motion to 0.20 m, and repeat the measurements made in Question 16. Record the values below.

Answers:

h = 0.00 m	v = 0 m/s	U_s = 4.00 J	U_g = 0 J	K = 0 J	$U_s + U_g + K$ = 4.00 J
h = 0.20 m	v = 1.41 m/s	U_s = 1.00 J	U_g = 2.00 J	K = 1.00 J	$U_s + U_g + K$ = 4.00 J
h = 0.40 m	v = 0 m/s	U_s = 0 J	U_g = 4.00 J	K = 0 J	$U_s + U_g + K$ = 4.00 J

Q21. Summarize the effects of increasing the amplitude on the motion of the mass and the energy of the system.

Answer: Increasing the amplitude increases the total energy of the system. The mass moves faster through the midpoint.

Move to pages 2.3 – 2.7.

The next five questions summarize Problem 2. Have students answer the questions on either the device, on the activity sheet, or both.

Q22. The kinetic energy of the mass as it oscillates vertically is _____.

Answer: B. maximum at the midpoint

Q23. At what point in the motion is all of the energy in the form of kinetic energy?

Answer: D. at no point in the motion

Q24. Increasing the amplitude of the motion produces which of the following changes? (More than one response may be correct.)

Answers: A. The total mechanical energy increases. B. The maximum speed of the mass increases. C. The distance traveled by the mass increases.

Q25. The maximum height above the lowest point reached by the mass is _____.

Answer: B. equal to twice the amplitude of the motion.

Q26. When the mass stops and turns around _____.

Answer: D. the sum of the gravitational potential and the spring potential energies is equal to the total mechanical energy.

TI-Nspire Navigator Opportunities

Make a student a Live Presenter to illustrate energy changes as the mass oscillates. Throughout the lab, discuss the activity with students using Slide Show. At the end of the lab, collect the .tns files and save to Portfolio.

Wrap Up

When students are finished with the activity, pull back the .tns file using TI-Nspire Navigator and collect the student activity handout. Save grades to Portfolio. Discuss activity questions using Slide Show.

Assessment

- Formative assessment will consist of questions embedded in the .tns file and questions on the handout. The questions will be graded when the .tns file is retrieved by TI-Nspire Navigator. The TI-Nspire Navigator Slide Show can be utilized to give students immediate feedback on their assessment.
- Summative assessment will consist of questions/problems on the chapter test, inquiry projects, performance assessment, or an application/elaborate activity.