Science Objectives

- Students will explore the potential energy (PE) and kinetic energy (KE) of a roller coaster.
- Students will explore energy transformations related to the motion of a roller coaster with and without friction.

Vocabulary

- conservative vs. non-conservative forces
- kinetic energy (PE)
- potential energy (PE)
- total energy
- work

About the Lesson

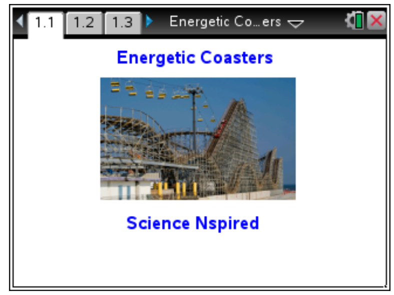
- This lesson begins with an exploration of the relationships between work, potential energy, and kinetic energy. The simulation uses a block that is either lifted and dropped or is pulled up an incline and allowed to slide back down. These concepts are then applied to a simulation of a roller coaster car moving along a track.
- As a result, students will:
    - Observe that an external force doing positive work increases the mechanical energy of an object, while friction causes a decrease in mechanical energy.
    - Describe how energy transforms between potential and kinetic forms, and, in the absence of friction, the total mechanical energy remains constant.
    - Relate the concepts of work and energy to the design and motion of a roller coaster.

TI-Nspire™ Navigator™

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

Activity Materials

- *Energetic_Coasters.tns* document
- TI-Nspire™ Technology
- *Energetic_Coasters_Student* Activity Handout



TI-Nspire™ Technology Skills:

- Download a TI-Nspire document
- Open a document
- Move between pages
- Use a minimized slider
- Grab a point with the cursor

Tech Tips:

Make sure that students understand how to use the Play/Pause and Reset buttons to control the animation on the simulation page.

To grab a point with the cursor, move the cursor over the point until it becomes a hand, and then press and hold until the hand closes. Use the touchpad to move the object. Press esc to release the object.

Lesson Materials:

Student Activity

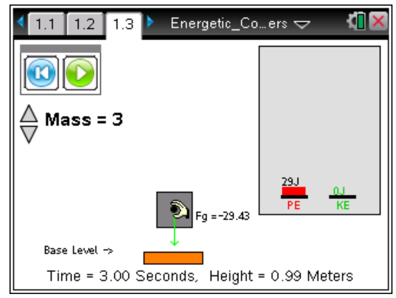
- Energetic_Coasters _Student.doc
- Energetic_Coasters _Student.pdf

TI-Nspire document

- Energetic_Coasters.tns

Discussion Points and Possible Answers

Allow students to read the background information on the student activity sheet.
This file is divided into four problems. Part 1 simulates a block that students lift and drop. Students calculate the work done and compare it to the energy acquired by the block. Part 2 explores these same ideas with a block on an incline. Part 3 introduces friction between the block and the incline. Part 4 simulates a roller coaster car moving along a track with and without friction.



<u>Part 1</u>:

Move to pages 1.2 and 1.3.

1. Have students read the instructions and background materials on page 1.2 before using the simulation on page 1.3. Students can click to close the directions on page 1.3.
2. Students should grab the block by the point in the middle of it and lift it above the surface. The instructions and questions in the student handout guide them through the exploration.

Students should answer questions 1–4 on their activity sheet as they work through the simulation.

Q1. Move the block to a height of 0.99 m. What is the PE of the block? What is the KE?

<u>Answer</u>: PE = 29 J; KE = 0 J

Q2. Press the play button . What happens to the PE and KE as the block drops?

<u>Answer</u>: They both change.

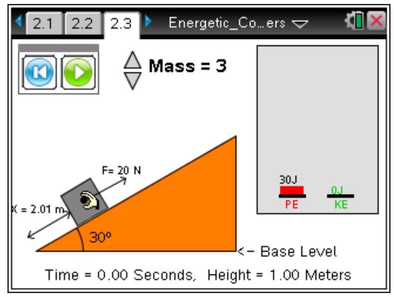
Q3. Run the simulation four more times, by setting the height of the block and then pressing play. You will need to press reset before running the simulation again. Complete the table below for each simulation.

<u>Sample Answers</u>: Student data will vary.

Height	PE pre-drop	KE pre-drop	PE + KE pre-drop	PE post-drop	KE post-drop	PE + KE post-drop
0.99 m	29 J	0 J	29 J	0 J	29 J	29 J
2.12 m	62 J	0 J	62 J	0 J	62 J	62 J
3.40 m	100 J	0 J	100 J	0 J	100 J	100 J
5.80 m	171 J	0 J	171 J	0 J	171 J	171 J

Q4. What do you notice about the total energy (PE + KE) throughout the block's drop?

<u>Answer</u>: The sum of PE and KE is constant.



Part 2:

Move to pages 2.1–2.2.

3. Students should read the information on pages 2.1 and 2.2. Students can click to close the directions on page 2.3.

Move to page 2.3.

4. Students should grab the point in the middle of the 3-kg block to move it up the incline. The force, *F*, required to pull the block and the distance pulled, Δx, are shown on the screen. The incline is frictionless. Students should observe that the gain in gravitational potential energy is still equal to the work done in pulling the block to the top. The applied force is equal to the component of the block's weight, which is parallel to the incline.

Students should answer questions 5-7 on their activity sheet before moving on to page 2.4.

Q5. Move the block to the 1-m mark. Record the information from the bar graph in the table below. Press the play button . Record the information in the last three columns in the table below. Run the simulation four times to gather enough data to complete the table. You will need to press reset before running the simulation again.

Sample Answers: Student data will vary.

Height	PE pre-drop	KE pre-drop	PE + KE pre-drop	PE post-drop	KE post-drop	PE + KE post-drop
1.00 m	30 J	0 J	30 J	0 J	30 J	30 J
1.95 m	57 J	0 J	57 J	0 J	57 J	57 J
2.99 m	88 J	0 J	88 J	0 J	88 J	88 J
3.91 m	115 J	0 J	115 J	0 J	115 J	115 J

Q6. What do you notice about the total energy (PE + KE) throughout the block's drop?

Answer: The sum of PE and KE is constant.

Q7. Describe what happens with the potential and kinetic energies as the block slides down the hill. Compare the kinetic energy of the block when it reaches the bottom to the gravitational potential energy at the point of released.

Answer: The kinetic energy increases as the potential energy decreases when the block slides down the incline. The sum of the two energies remains constant. All of the initial potential energy is transformed into kinetic energy.

Move to pages 2.4–2.6.

Have students answer questions 8-10 on either the handheld, on the activity sheet, or both.

Q8. The potential energy of an ideal roller coaster at its highest point is equal to the work required to get it to the top of the hill.

Answer: A. True

Q9. Choose the correct statement(s) about kinetic energy (KE) and potential energy (PE) based on your observations of the block on the frictionless incline. (There is more than one correct statement.)

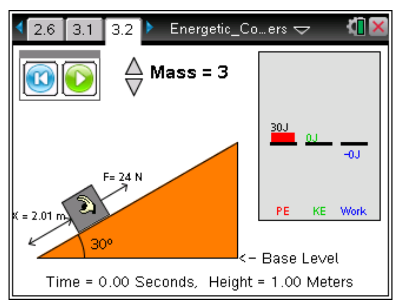
Answers: B. As the block slides down the hill, its KE increases at the same rate as its PE decreases.
C. As the block slides, the sum of its KE and PE remains constant.
E. The greater the height of the block when it is released, the more KE it will have when it reaches the bottom.

Q10. On a real roller coaster, how does it gain its initial potential energy?

Answer: It is pushed up the hill, where it gains its PE.

Part 3:

Move to pages 3.1 and 3.2.



5. Students should read the information on page 3.1.

6. After reading the directions on page 3.2, students can press  to close the window.

This simulation includes a friction force acting on a 3-kg block as the block slides down a 30° incline. The friction force does negative work on the block as it slides down the incline. Students should observe that this decreases the mechanical energy of the block.

Have students answer questions 11 and 12 on their activity sheet before moving on to page 4.1.

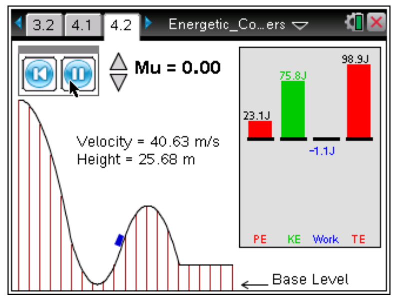
Q11. Move the block to the top of the incline. Note the gravitational potential energy of the block at the top of the hill. Click the play button . Observe the work and energy bar graphs as the block slides. Describe the changes you observe in the gravitational potential energy and the kinetic energy of the block as it slides. Compare the kinetic energy at the bottom of the hill to the gravitational potential energy at the top.

<u>Answer</u>: The potential energy decreases and the kinetic energy increases as the block slides down the incline, but the kinetic energy of the block at the bottom is less than the potential energy of the block at the top. Some energy is missing.

Q12. How much work was done by the friction force? What effect did this appear to have on the energy of the block?

<u>Answer</u>: The amount of work done by friction is equal to the missing energy. Friction appears to take energy away from the block.

<u>Part 4</u>:



Move to pages 4.1 and 4.2.

7. Read the information on page 4.1.

   The following page simulates a roller coaster car moving along a track. The height and speed of the car along with the distance traveled along the track are displayed. On the right side of the screen are bar graphs for potential energy, kinetic energy, total mechanical energy, and work done by friction. The total mechanical energy is the sum of the potential and kinetic energies.

8. After reading the directions students can press to close the window. The roller coaster car is already at the top of the track. Clicking the play button will release the car. Clicking the reset button will place the car back at the top of the roller coaster. Students can change the friction, μ, by clicking the up and down arrows (▲ or ▼) for Mu.

   Students should note the velocity as the coaster moves up and down hills. The bar graph shows the corresponding changes in potential, kinetic, and total energy.

Have students answer questions 13-17 on their activity sheet before moving on to page 4.3.

Q13. Set the value of Mu to zero. Press the down arrow ▼ a couple times after it shows Mu = 0.00. What do you notice about the total energy (TE) throughout the car's ride along the track?

<u>Answer</u>: TE is constant, or stays the same.

Tech Tip: Pressing the reset button will reset the car to the top of the hill AND reset the friction value. Make sure students set the appropriate friction value before pressing play.

Q14. Set the value of Mu to 0.10. Press the up arrow ▲ a couple times after it shows Mu = 0.10. What do you notice about the total energy (TE) throughout the car's ride along the track?

Answer: TE constantly decreases.

Q15. What do you think accounts for the changing TE when Mu = 0.10?

Answer: The energy is lost due to friction.

Q16. At what part along the track is the PE of the car the maximum? Is this true whether there is friction or not?

Sample Answers: At the top of the track. Yes.

Q17. At what part along the track is the KE of the car the maximum? Is this true whether there is friction or not?

Sample Answers: At the bottom of the track. Yes.

Move to pages 4.3–4.6.
Have students answer questions 18-21 on the handheld, on the activity sheet, or both.

Q18. A roller coaster achieves maximum speed (ignore friction) _______________.

Answer: B. at the lowest position of the track

Q19. To increase the maximum speed of a roller coaster, a designer should _______________.

Answer: D. make the first hill taller

Q20. In the absence of friction, the greatest height a roller coaster can achieve _______________.

Answer: C. is equal to the height of the first hill

Q21. A roller coaster is not moving _______________.

Answer: A. when the total energy is PE only

TI-Nspire Navigator Opportunities

Take screenshots of the entire class to show the car along various parts of the track. Discuss with students the variation in the PE, KE, and TE. Throughout the activity, discuss the simulations with students using Slide Show. At the end of the activity, collect the .tns files and save to Portfolio.

Wrap Up

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

Assessment

- Formative assessment will consist of questions embedded in the .tns file and student responses on the handout. The questions will be graded when the .tns file is retrieved. The Slide Show will be utilized to give students immediate feedback on their assessment.
- Summative assessment will consist of questions/problems on the chapter test.