



## Example Lesson Plan: Roller Coaster Simulation

Key Topic/Concept: Mechanical Energy and Conservation of Energy in a Roller Coaster

*Note: See related lesson on pendulum motion for an example of another common system that displays the conversion of potential to kinetic energy.*

*Revisit this lesson with friction in the introduction to the thermal energy lesson.*

Materials:

- One review and one guide sheet for each student
- one ball, scale, and meter stick per small group
- one box of physics toys and books (or other heavy object)
- pendulums (a weight on string hung from the ceiling)
- computer with roller coaster simulation downloaded
- science notebook

The EJS Roller Coaster simulation can be downloaded from the comPADRE National Digital Library if it not available on the local computer:

< <http://www.compadre.org/OSP/items/detail.cfm?ID=8228> >

Safety Precautions: No special precautions needed for this lesson.

### ***North Carolina Curriculum Alignment (2004)***

This lesson addresses the following objectives in the NC SCOS 6<sup>th</sup> grade science curriculum:

1.05 Analyze evidence to:

- Explain observations.
- Make inferences and predictions.
- Develop the relationship between evidence and explanation.

1.06 Use mathematics to gather, organize, and present quantitative data resulting from scientific investigations:

- Measurement.
- Analysis of data.

- Graphing.
- Prediction models.

1.08 Use oral and written language to:

- Communicate findings.
- Defend conclusions of scientific investigations.

1.09 Use technologies and information systems to:

- Research.
- Gather and analyze data.
- Visualize data.
- Disseminate findings to others.

6.04 Evaluate data for qualitative and quantitative relationships associated with energy transfer and/or transformation.

6.07 Analyze the Law of Conservation of Energy:

- Conclude that energy cannot be created or destroyed, but only changed from one form into another.
- Conclude that the amount of energy stays the same, although within the process some energy is always converted to heat.
- Some systems transform energy with less loss of heat than others.

## I. ENGAGEMENT

Review potential and kinetic energy using the Energy Review sheet at the bottom. For the top half of the sheet, review as a whole group with a fast pace (about 15 minutes) and with students using their science notebooks.

A force is . . . Teacher walks slowly past a student previously told to give her a gentle push.

Work = . . . Student volunteer lifts the big crate of physics toys and books

Energy is . . . Ask if student straining to hold the heavy crate is doing work. No because distance is zero.

Kinetic Energy is . . . drop large rubber glitter ball

To calculate KE . . . write on whiteboard  $KE = 1/2mv^2$

The units are . . . for mass put ball on scale and say it weighs 600 g, which students have done in a previous lesson. On whiteboard show the conversion from g to kg. Reinforce concept of “multiplying by one” for conversions— $600g \times 1g/100kg = 0.6kg$

For the calculations of kinetic and potential energy, allow students to work in small groups with a visual timer set for 10 minutes. Students should round numbers (e.g.  $9.8 \text{ m/s}^2$  is rounded to 10) and not use calculators. If students finish early, have them calculate the velocity in the problem at the bottom of the review or help other groups. Each group should have a ball, scale, and meter stick. Teacher circulates and monitors the progress of each group.

Have the small groups go back to the pendulums and show where potential energy and kinetic energy are at their maximum.

## II. EXPLORATION

Have students work in pairs and open the EJS roller coaster. Allow students about 5 minutes to explore with the simulation.

## III. EXPLANATION/CONCEPT INVENTION

Ask students to reset the simulation to the ramp and begin with question 3 in the guide below. When most students have completed the guide, review the answers with the whole group.

## IV. EXPANSION OF THE IDEA

For students who finish early, have them compare the “Up and Down” track to the “Up and Down” track on the roller coaster with friction. Ask them to write a brief description or make sketches to show the comparison.

## V. EVALUATION

As students complete the guide, other students can move to the roller coaster with friction or continue with the exploration activity of designing roller coasters. Teacher circulates to check that the Energy Review and the Roller Coaster Gravitational Potential and Kinetic Energy Guide are correctly completed and stapled into the science notebook.

### ***Energy Review***

Use the metric system of units when answering the following questions.

A force is a \_\_\_\_\_ or a \_\_\_\_\_.

Work = \_\_\_\_\_ x \_\_\_\_\_

Energy is \_\_\_\_\_.

Kinetic energy is the energy of \_\_\_\_\_.

KE =

What is m and its units? \_\_\_\_\_.

What is v and its units? \_\_\_\_\_.

Potential energy is the energy of \_\_\_\_\_.

Gravitational PE =

What is m and its units? \_\_\_\_\_.

What is g and its units? \_\_\_\_\_.

What is h and its units? \_\_\_\_\_.

For KE and PE, what unit of energy have we used?

\_\_\_\_\_

A ball weighs 600 g. I roll it a distance of 3 meters and it takes 1.5 seconds.

What is the kinetic energy of the rolling ball?

I raise the ball off the floor to the top of a meter stick. What is the potential energy of the ball?

Please show your work to these two questions on the back. Include units in all parts of the calculation—it will help you!

Once you finish the two questions above, calculate the velocity of the ball at the bottom of the stick if it is dropped from the top of the meter stick.

### **Energy Review** *Answer Key*

A force is a push or a pull.

Work = Force x distance

Energy is the ability to do work.

Kinetic energy is the energy of motion.

$$KE = \frac{1}{2} m v^2$$

What is m and its units? mass - kilograms.

What is v and its units? velocity - meter/second.

Potential energy is the energy of position.

$$\text{Gravitational PE} = mgh$$

What is m and its units? mass - kilograms.

What is g and its units? acceleration due to gravity - meters/second<sup>2</sup>.

What is h and its units? change in height - meters.

For KE and PE, what unit of energy have we used?

Joules

A ball weighs 600 g. I roll it a distance of 3 meters and it takes 1.5 seconds.

What is the kinetic energy of the rolling ball? *About 1.2 Joules*

I raise the ball off the floor to the top of a meter stick. What is the potential energy of the ball? *About 6 Joules*

Please show your work to these two questions on the back. Include units in all parts of the calculation—it will help you!

Once you finish the two questions above, calculate the velocity of the ball at the bottom of the stick if it is dropped from the top of the meter stick.

*About 4.5 meters/second*

### **Activity Guide: Roller Coaster Gravitational Potential and Kinetic Energy**

1. Run the EJS (Easy Java Simulation) roller coaster file by double clicking on the `ejs_middle_school_RollerCoaster.jar` file using the ramp (default) roller coaster track.
2. Run the simulation (hit Play button) and note the changes in the potential and kinetic energy as shown in the bar graphs.
3. In your notebook, sketch the bar graphs and the roller coaster car on the track to show maximum gravitational potential energy. Make a second sketch showing the bar graphs and the car on the track with maximum kinetic energy.

4. Place the cross hairs on the car to find the height. Use the "Steps the Simulation" button next to "Play" to find the velocity at the top and bottom of the track. Put your data in the following chart.

	At maximum PE	At maximum KE
Height		
Velocity		

Assume the car's mass is 1 kg.

Calculate Gravitational PE when velocity is zero.

Calculate KE when the height is zero.

Do your answers make sense? Why? \_\_\_\_\_

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Select a new track from the drop down menu. Sketch the bar graphs and the car on the track at various positions and use the heights of the graphs to show that mechanical energy is conserved.

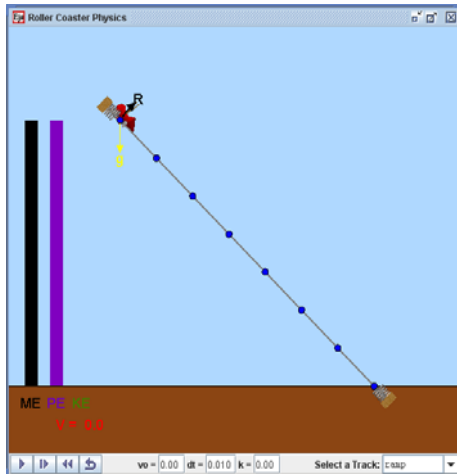
### **Advanced**

Try the simulation where you can add friction (k). What happens to the energy bar graphs? Why? Form a hypothesis about when mechanical energy is conserved.

### **Activity Guide: Roller Coaster Potential and Kinetic Energy Guide *Answer Key***

1. Open the EJS (Easy Java Simulation) roller coaster file.

- Run the simulation (hit Play button) and note the changes in the potential and kinetic energy as shown in the bar graphs.
- In your notebook, sketch the bar graphs and the roller coaster car on the track to show maximum potential energy. Make a second sketch showing the bar graphs and the car on the track with maximum kinetic energy.



- Place the cross hairs on the car to find the height in meters. Use the "Steps the Simulation" button next to "Play" to find the velocity at the top and bottom of the track. Put your data in the following chart.

	At maximum PE	At maximum KE
Height (meters)	20	0
Velocity (meter/sec)	0	20

Assume the car's mass is 1 kg.

Calculate PE when velocity is zero.

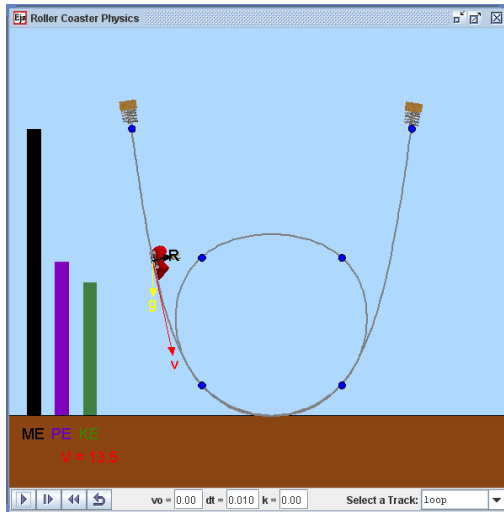
$$\text{Gravitational PE} = 200 \text{ J}$$

Calculate KE when the height is zero.

$$\text{KE} = 200 \text{ J}$$

Do your answers make sense? Why? \_\_\_\_\_ *Yes. As PE decreases, KE increases.  $PE + KE = \text{Total } E$  or Energy is not created nor destroyed, only changed in form. \_\_\_\_\_*

Select a new track from the drop down menu. Sketch the bar graphs and the car on the track at various positions and use the heights of the graphs to show that mechanical energy is conserved.



## Advanced

Try the simulation where you can add friction (k). What happens to the energy bar graphs? Why? Form a hypothesis about when mechanical energy is conserved.