Roller Coaster Physics Answer Key

Vocabulary: friction, gravitational potential energy, kinetic energy, momentum, speed

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
[Note: The purpose of these questions is to activate prior knowledge and get students thinking. Students are not expected to know the answers to the Prior Knowledge Questions.]

An object's **momentum** reflects how easy it is to stop. Objects with greater momentum are harder to stop and can also inflict more damage when they collide with other objects.

1. Which do you think has more momentum, a moving car or a moving train? *The train*

2. The **speed** of an object is how fast it is moving. Which has more momentum, a car with a speed of 20 km/h (kilometers per hour) or a car moving at 100 km/h? *The 100 km/h car*

3. What are the *two* factors that affect an object's momentum? *Mass (or weight) and speed*

Gizmo Warm-up
The *Roller Coaster Physics* Gizmo™ shows a toy car on a track that leads to an egg. You can change the track or the car. For the first experiment, use the default settings (**Hill 1** = 70 cm, **Hill 2** = 0 cm, **Hill 3** = 0 cm, 35-g car).

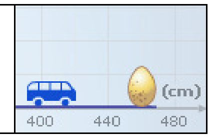
1. Press **Play** (▶) to roll the 35-gram toy car down the track. Does the car break the egg? *No*

2. Click **Reset** (⟲). Raise **Hill 1** to 100 cm, and click **Play** again. Does the car break the egg? *Yes*

3. Click **Reset**. Lower **Hill 1** back to 70 cm and select the 50-gram toy car. Click **Play**. Does the 50-gram car break the egg? *Yes*

4. What factors determine whether the car will break the egg?

   The mass of the car and the speed of the car affect whether the car will break the egg. The speed of the car is determined by the height of the hill.

Activity A: Momentum	Get the Gizmo ready: • Click **Reset**.	

Question: What determines whether the egg will break?

1. Form hypothesis: Which factor(s) determine whether the car breaks the egg? (Circle one.) *Hypotheses will vary.*

   A. The mass of the car only.

   B. The speed of the car only.

   C. The mass *and* speed of the car.

2. Collect data: Use the Gizmo to find five situations in which the car breaks the egg, and five in which the car does not break the egg. In each situation, record the mass of the car and the speed of the car when it hits the egg. Include units. Leave the last column blank for now. *Student results will vary. Five sample situations are shown below.*

Egg breaks		
Mass	**Speed**	***Momentum***
35 g	*443 cm/s*	*15,505 g•cm/s*
35 g	*401 cm/s*	*14,035 g•cm/s*
50 g	*346 cm/s*	*17,300 g•cm/s*
50 g	*280 cm/s*	*14,000 g•cm/s*
100 g	*247 cm/s*	*24,700 g•cm/s*

Egg does not break		
Mass	**Speed**	***Momentum***
35 g	*376 cm/s*	*13,160 g•cm/s*
35 g	*396 cm/s*	*13,860 g•cm/s*
50 g	*247 cm/s*	*12,350 g•cm/s*
50 g	*277 cm/s*	*13,850 g•cm/s*
100 g	*133 cm/s*	*13,300 g•cm/s*

3. Calculate: Momentum (p) is calculated by multiplying mass (m) by speed (v): $p = m \cdot v$. Label the third column in each table **Momentum**, and calculate the momentum in each situation. Because mass is measured in grams and speed is measured in centimeters per second, the units of momentum here are grams centimeters per second, or g•cm/s.

4. Analyze: Carefully analyze and compare the data in each table.

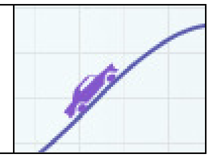
   A. Does the car's mass alone determine whether the egg breaks? *No*

   B. Does the car's speed alone determine whether the egg breaks? *No*

   C. Does the car's momentum determine whether the egg breaks? *Yes*

   Explain: *Only cars with a momentum greater than 14,000 g•cm/s broke the egg.*

5. Draw conclusions: What is the minimum momentum required to break the egg? *14,000 g•cm/s*

Activity B: **The speed of a roller coaster**	Get the Gizmo ready: • Click **Reset**. • Select the 35-g toy car.	

Question: What factors determine the speed of a roller coaster?

1. Observe: Set **Hill 1** to 100 cm, **Hill 2** to 0 cm, and **Hill 3** to 0 cm. Be sure the **Coefficient of friction** is set to 0.00. (This means that there is no **friction**, or resistance to motion.)

   A. Click **Play**. What is the final speed of the toy car? *442.9 cm/s*

   B. Try the other cars. Does the mass of the car affect its final speed? *No*

2. Collect data: Find the final speed of a toy car in each situation. Leave the last column blank.

Hill 1	Hill 2	Hill 3	Final speed	***Total height lost***
40 cm	0 cm	0 cm	*280.1 cm/s*	*40 cm*
40 cm	30 cm	0 cm	*280.1 cm/s*	*40 cm*
60 cm	50 cm	20 cm	*280.1 cm/s*	*40 cm*
60 cm	0 cm	0 cm	*343.1 cm/s*	*60 cm*
60 cm	45 cm	0 cm	*343.1 cm/s*	*60 cm*
90 cm	75 cm	30 cm	*343.1 cm/s*	*60 cm*

3. Analyze: Look at the data carefully. Notice that it is organized into two sets of three trials.

   A. What did each set of trials have in common? *The final speed was the same.*

   B. Did hill 2 have any effect on the final speed? *No.*

   C. Label the last column of the table **Total height lost**. Fill in this column by subtracting the height of hill 3 from the height of hill 1.

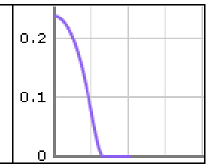
   D. What do you notice about the **Total height lost** in each set of trials?

   In each set of trials, the total height lost was the same.

4. Draw conclusions: When there is no friction, what is the *only* factor that affects the final speed of a roller coaster? *The only factor that affects the final speed is the total height lost.*

   What factors do *not* affect the final speed of a roller coaster?

   The final speed is not affected by the mass of the car or the height of the middle hill.

Activity C: **Energy on a roller coaster**	Get the Gizmo ready: • Click **Reset**. • Set **Hill 1** to 100 cm, and **Hill 2** and **3** to 0 cm. • Select the 50-g car.	

Question: How is energy expressed in a moving roller coaster?

1. Observe: Turn on **Show graph** and select **E vs t** to see a graph of energy (*E*) versus time. Click **Play** and observe the graph as the car goes down the track.

   Does the total energy of the car change as it goes down the hill? *No, it stays the same*

2. Experiment: The **gravitational potential energy** (*U*) of a car describes its energy of position. Click **Reset**. Set **Hill 3** to 99 cm. Select the **U vs t** graph, and click **Play**.

   A. What happens to potential energy as the car goes down the hill? *It decreases*

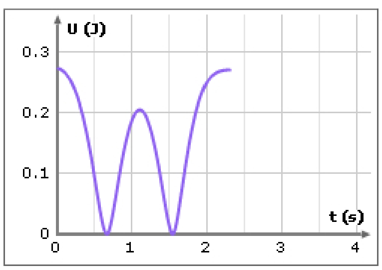
   B. What happens to potential energy as the car goes up the hill? *It increases*

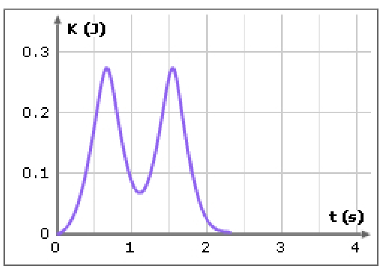
3. Experiment: The **kinetic energy** (*K*) of a car describes its energy of motion. Click **Reset**. Select the **K vs t** (kinetic energy vs. time) graph, and click **Play**.

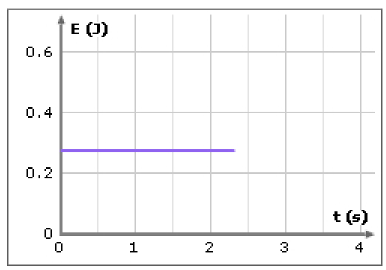
   A. What happens to kinetic energy as the car goes down the hill? *It increases*

   B. What happens to kinetic energy as the car goes up the hill? *It decreases*

4. Compare: Click **Reset**. Set **Hill 1** to 80 cm, **Hill 2** to 60 cm, and **Hill 3** to 79 cm. Be sure the 50-g toy car is selected, and press **Play**. Sketch the **U vs t**, **K vs t**, and **E vs t** graphs below.







5. Draw conclusions: Based on the graphs, how are potential energy, kinetic energy, and total energy related to one another?

   Answers will vary. [The total energy of the car is equal to the sum of its gravitational potential energy and its kinetic energy. As the car goes down a hill, gravitational potential energy is converted to kinetic energy, but the total energy of the car remains the same. As the car goes up a hill, kinetic energy is converted to gravitational potential energy.]