Name: _____   Date: _____

Student Exploration: Roller Coaster Physics

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

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
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? _____

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? _____

3. What are the *two* factors that affect an object's momentum? _____

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? _____

2. Click **Reset** (↺). Raise **Hill 1** to 100 cm, and click

   Play again. Does the car break the egg? _____

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? _____

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

   _____

   _____

Activity A:	Get the Gizmo ready:	
Momentum	• 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.)

    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.

Egg breaks				Egg does not break		
Mass	**Speed**			**Mass**	**Speed**	

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? _____

    B. Does the car's speed alone determine whether the egg breaks? _____

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

       Explain: _____

5. Draw conclusions: What is the minimum momentum required to break the egg? _____

   Use the Gizmo to test and refine your answer.

Activity B:	Get the Gizmo ready:	
The speed of a roller coaster	• 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? _____

    B. Try the other cars. Does the mass of the car affect its final speed? _____

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	
40 cm	0 cm	0 cm		
40 cm	30 cm	0 cm		
60 cm	50 cm	20 cm		
60 cm	0 cm	0 cm		
60 cm	45 cm	0 cm		
90 cm	75 cm	30 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? _____

    B. Did hill 2 have any effect on the final speed? _____

    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? _____

    _____

4. Draw conclusions: When there is no friction, what is the *only* factor that affects the final

    speed of a roller coaster? _____

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

    _____

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. <u>Observe</u>: 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? _____

2. <u>Experiment</u>: 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? _____

   B. What happens to potential energy as the car goes up the hill? _____

3. <u>Experiment</u>: 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? _____

   B. What happens to kinetic energy as the car goes up the hill? _____

4. <u>Compare</u>: 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.
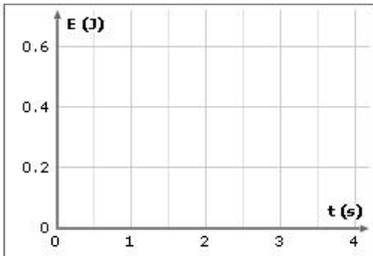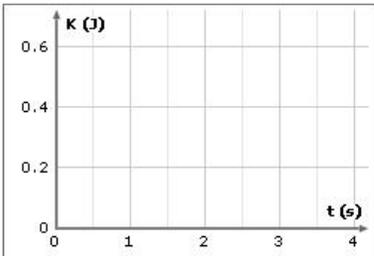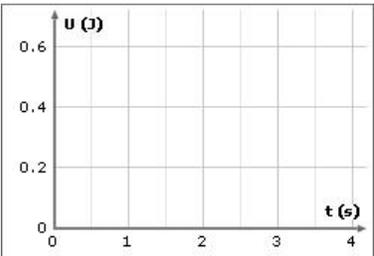
5. <u>Draw conclusions</u>: Based on the graphs, how are potential energy, kinetic energy, and total energy related to one another?

   _____

   _____

   _____