# *Roller Coaster Physics:* Teacher's Guide

| **Grade Level:** 6-8 | **Curriculum Focus:** Physical Science | **Lesson Duration:** Three class periods |
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## Program Description

Thanks to friction, potential energy, gravity, and acceleration, you can take some terrifying amusement-park turns. Take a thrilling look at the applied physics of roller coasters, as well as the G-forces experienced by an aerobatics pilot. This program includes four short segments:

- A Potential Thrill (3 min.)
- G-Forces (9 min.)
- The Danger Zone (5 min.)
- Rides of the Future (4 min.)

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## Onscreen Questions

- How do rides create the illusion of increased or decreased weight?
- How do the basic laws of physics allow a ride to accelerate?

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## Lesson Plan

### *Student Objectives*

- Review energy types and how they affect movement.
- Create a miniature roller coaster that demonstrates the forces of mechanical energy.

### *Materials*

- *Roller Coaster Physics* video and VCR, or DVD and DVD player
- One tennis ball (or similar-sized ball) per group
- Two pieces corrugated cardboard or foam board (70 × 200 cm) per group
- Heavy-duty scissors
- Box knives

- Meter sticks
- Hot glue and glue guns

## Procedures

1. Review the principle of "conservation of energy" by analyzing a roller coaster ride from start to finish. You may want to view *Roller Coaster Physics* as an introduction to the discussion. Make sure you discuss the names of all relevant energy forms and where and when on the ride energy transformations are occurring.
2. Tell students they will be designing and constructing cardboard "tennis ball" roller coasters with three hills. The tennis ball in each design must start at the top of the first hill, roll up and down the other two hills, and exit the end of the track. Each roller coaster will be judged in a class competition. The track with the greatest total of vertical heights for all three hills—if the tennis ball completes the course—will be named the winning design.
3. Have students consider the following when designing their roller coasters:
    - Can all the hills be the same height? If not, why? Can they get bigger, or must they get smaller?
    - How will you determine how big or how small the hills can be and still win this contest?
    - Does the steepness of the hill count? Is it better to make the hills steep or not so steep? Why?
    - How curvy should the tops of the hills and the valleys be?
    - Should your design have sharp or smooth turns? Why?
    - What provides resistance on the roller coaster, causing the tennis ball to slow down? How can this resistance be reduced?
4. Divide students into small groups, give each group the materials listed earlier, and then provide the following directions.
    - The left and right roller coaster tracks will be made from the two pieces of corrugated cardboard and must be cut out as identical shapes.
    - Each valley in the roller coaster must dip to a low height of 20 centimeters from the bottom of the cardboard.
    - Have students use heavy-duty scissors or box knives to cut out both tracks. They can shape the roller coaster however they want as long as each hill is smaller than the previous one.
    - From the excess cardboard, students should cut out 25 rectangles, each 4 × 12 cm. These will serve as spacers between the two tracks. Put glue along the rectangles' 12-centimeter edges, and then fasten them between the two tracks so that the tracks are rigid and separated by a distance of 4 centimeters.
5. After the initial construction of the roller coasters, give students time to make revisions to their original design—an important factor in the worlds of design and engineering.

6. Hold the roller coaster competition. To score the contest, measure the heights of each of the three required hills and add them up. The roller coaster with the greatest total height of the three hills is the winner as long as its tennis ball successfully completed the journey.

## Assessment

Use the following three-point rubric to evaluate students' work during this lesson.

- **3 points:** Students recalled key principles of energy types and how they affect the motion of a roller coaster; participated actively in discussing the design features needed for a roller coaster to function properly; designed and built a cardboard roller coaster that successfully demonstrated the concepts of energy and motion.
- **2 points:** Students recalled some key principles of energy types and how they are used to design a roller coaster; participated somewhat in discussing the design features needed for a roller coaster to function properly; designed and built a cardboard roller coaster that was somewhat successful in demonstrating the concepts of energy and motion.
- **1 point:** Students recalled few or no key principles of energy types and how they are used to design a roller coaster; did not participate in discussing the design features needed for a roller coaster to function properly; did not design and build a cardboard roller coaster that demonstrated the concepts of energy and motion.

## Vocabulary

**conservation of energy**

*Definition:* The principle that within the universe, or any closed system, the total energy remains constant, although the energy may transform from one kind to another

*Context:* The conservation of energy principle states that as potential energy transforms into kinetic energy (and vice versa), the total energy should remain constant at all times and in all places on the roller coaster.

**friction**

*Definition:* The resistance to relative motion of two surfaces that are in contact with each other as they roll or slide across one another

*Context:* Due to frictional interactions between the roller coaster car and the track, mechanical energy is lost and transformed into heat.

**gravitational potential energy (GPE)**

*Definition:* The energy that a mass has because of its vertical separation (height) from the earth; calculated with GPE = mgh, where *m* is the mass, *g* is the acceleration due to gravity (-9.80m/s2 on Earth), and *h* is the height from some arbitrarily defined initial height

*Context:* All the energy needed to run a roller coaster car to the end of the track comes from the gravitational potential energy that it has when lifted to the top of the first and highest hill.

**heat (thermal energy)**

*Definition:* The atomic and molecular energy of matter due to the kinetic energy of the atoms and molecules vibrating and moving with random motions

*Context:* As the mechanical energy of a system, such as a roller coaster, is transformed into heat, we can expect that the temperature of that system and the environment in which it exists will rise somewhat.

**kinetic energy**

*Definition:* The energy a mass has because it is moving; calculated with KE = mv2/2, where *m* is the mass, and *v* is the velocity

*Context:* As the roller coaster car glides down each hill, gravitational potential energy is converted into kinetic energy; this makes you and the car go faster and faster.

**mechanical energy**

*Definition:* Energy generally associated with a moving mass or the action, or potential action, of a force being applied through a distance

*Context:* The two forms of mechanical energy that are relevant to the understanding of how a roller coaster works are gravitational potential energy and kinetic energy.

## Academic Standards

**National Academy of Sciences**

The National Science Education Standards provide guidelines for teaching science as well as a coherent vision of what it means to be scientifically literate for students in grades K-12. To view the standards, visit http://books.nap.edu.

This lesson plan addresses the following science standards:

- Physical Science: Transfer of energy
- Science and Technology: Abilities of technological design

**Mid-continent Research for Education and Learning (McREL)**

McREL's Content Knowledge: A Compendium of Standards and Benchmarks for K-12 Education addresses 14 content areas. To view the standards and benchmarks, visit http://www.mcrel.org/.

This lesson plan addresses the following national standards:

- Science—Physical Sciences: Understands the sources and properties of energy, Understands forces and motion
- Language Arts—Viewing: Uses viewing skills and strategies to understand and interpret visual media

## Support Materials

Develop custom worksheets, educational puzzles, online quizzes, and more with the free teaching tools offered on the Discoveryschool.com Web site. Create and print support materials, or save them to a Custom Classroom account for future use. To learn more, visit

- http://school.discovery.com/teachingtools/teachingtools.html

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## DVD Content

This program is available in an interactive DVD format. The following information and activities are specific to the DVD version.

### *How To Use the DVD*

The DVD starting screen has the following options:

***Play Video***—This plays the video from start to finish. There are no programmed stops, except by using a remote control. With a computer, depending on the particular software player, a pause button is included with the other video controls.

***Video Index***—Here the video is divided into four parts (see below), indicated by video thumbnail icons. Watching all parts in sequence is similar to watching the video from start to finish. Brief descriptions and total running times are noted for each part. To play a particular segment, press Enter on the remote for TV playback; on a computer, click once to highlight a thumbnail and read the accompanying text description and click again to start the video.

***Curriculum Units***—These are specially edited video segments pulled from different sections of the video (see below). These nonlinear segments align with key ideas in the unit of instruction. They include onscreen pre- and post-viewing questions, reproduced below in this Teacher's Guide. Total running times for these segments are noted. To play a particular segment, press Enter on the TV remote or click once on the Curriculum Unit title on a computer.

***Standards Link***—Selecting this option displays a single screen that lists the national academic standards the video addresses.

***Teacher Resources***—This screen gives the technical support number and Web site address.

### *Video Index*

**I. A Potential Thrill (3 min.)**

Although they seem to defy nature, roller coasters actually obey the laws of physics. Learn how potential and kinetic energy help create our favorite thrill rides.

**II. G-Forces (9 min.)**

Come with a seasoned aerobatics pilot as he compares the G-forces felt while pulling radical moves in the air to those experienced on a death-defying roller coaster.

**III. The Danger Zone (5 min.)**

Roller coasters are designed to give the illusion of danger while working within the limits of safety and physics. Explore some of the built-in safety features.

**IV. Rides of the Future (4 min.)**

"Superman: The Escape" upped the ante in the quest to design faster, more-thrilling roller coaster rides. But just what are the physical limits for coasters of the future?

## *Curriculum Units*

**1. Shifting Energy**

*Pre-viewing question*
Q: What is potential energy?
A: This stored, inactive energy has the capability of doing work but is not presently doing so.

*Post-viewing question*
Q: At what point in a roller coaster ride does potential energy become kinetic energy?
A: Gravity comes into play as soon as the roller coaster cars move into their first drop, turning the stored energy into moving, kinetic energy.

**2. Positive G-Forces**

*Pre-viewing question*
Q: What is the most thrilling roller coaster you have ridden?
A: Answers will vary.

*Post-viewing question*
Q: How come people feel a "rush" when riding roller coasters?
A: Blood rushes towards the bottom half of the body, leaving the brain struggling for oxygen. This creates a near-blackout sensation and a sense of danger, which provide a "rush."

**3. Negative Gs**

*Pre-viewing question*
Q: What is inertia?
A: It's the tendency of matter to resist changes in velocity. Newton's first law of motion states: An object in motion tends to stay in motion, and an object at rest tends to stay at rest, unless the object is acted upon by an outside force.

*Post-viewing question*
Q: How do negative G-forces affect your body?
A: Negative G-forces create a sense of weightlessness. For example, you may experience negative G-forces when you come over a hill on a roller coaster and start to descend. Your body feels very light, and blood rushes to your head.

**4. Aerobatic Piloting**

*Pre-viewing question*
Q: How many positive Gs do you think your body could handle?
A: Answers will vary.

*Post-viewing question*
Q: What are some similarities between aerobatic flying and riding a roller coaster?
A: Answers will vary but should focus on the effects of G-forces.

**5. Riding a Safe Snake**

*Pre-viewing question*
Q: Are roller coasters safe?
A: Answers will vary.

*Post-viewing question*
Q: What are some safety features found on roller coasters?
A: Answers will vary but may include seatbelts, emergency brakes, and the twists and corkscrews that slow the coaster cars down, preventing dangerous levels of G-forces.

**6. Illusion of Danger**

*Pre-viewing question*
Q: What should safety officials look for when inspecting roller coasters?
A: Answers will vary.

*Post-viewing question*
Q: What are the three sets of wheels on roller coasters for?
A: Running wheels support the coaster cars. Up-stop wheels keep the cars from going off the track when upside down or going over hills. Friction wheels hold the cars steady during side-to-side motion.

**7. Challenging Physics**

*Pre-viewing question*
Q: What would your dream roller coaster be like?
A: Answers will vary.

*Post-viewing question*
Q: How does the magnetic propulsion system work on Superman?
A: Strong electro-magnets, known as linear synchronous motors, are set in a line of posts down the center of the track. They repel their opposite magnets, which are mounted on the cars. When activated, the magnet on the first post pushes the cars down to the second post and so on, accelerating it at increasing speeds down the track.