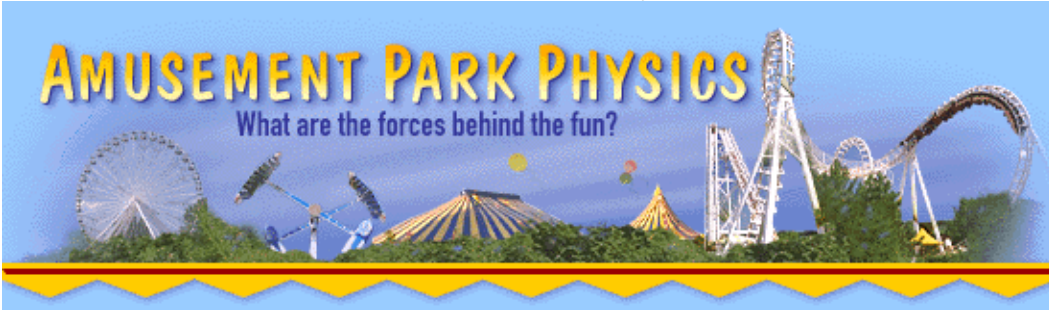


# NHU/NASA Summer Institute

## Lesson Plan

Student Name Kim Rogers

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<b>Lesson Plan Title</b>	<p style="text-align: center;"><b>Amusement Park Physics</b></p> 
<b>Grade Level</b>	<p>8<sup>th</sup>-12<sup>th</sup></p>
<b>Concept/ Topic to Teach</b>	<p>Astronauts orbiting the earth experience sensations of weightlessness. These sensations are the same as experienced by anyone who has been temporarily suspended above the seat on any amusement park ride. Both the weightless sensations for both astronauts and roller coaster riders (and the causes of those sensations) result from the same forces.</p> <ul style="list-style-type: none"> <li>• Principle of conservation of energy.</li> <li>• Newton’s First Law of Motion “... objects in motion tend to stay in motion with the same speed and the same direction unless acted upon by an unbalanced force.”</li> <li>• Centripetal Force</li> <li>• Mechanical energy forms gravitational potential energy and kinetic energy.</li> </ul>
<b>Content Standards</b>	<p><b>Grade 8:</b> Focus on Physical Science</p> <p><b>Motion</b></p> <p>1. The velocity of an object is the rate of change of its position. As a basis for understanding this concept:</p> <ol style="list-style-type: none"> <li>a. <i>Students know</i> position is defined in relation to some choice of a standard reference point and a set of reference directions.</li> <li>b. <i>Students know</i> that average speed is the total distance traveled divided by the total time elapsed and that the speed of an object along the path traveled can vary.</li> </ol>

- d. *Students know* the velocity of an object must be described by specifying both the direction and the speed of the object.
- e. *Students know* changes in velocity may be due to changes in speed, direction, or both.

**Forces**

- 2. Unbalanced forces cause changes in velocity. As a basis for understanding this concept:
  - a. *Students know* a force has both direction and magnitude.
  - b. *Students know* when an object is subject to two or more forces at once, the result is the cumulative effect of all the forces.
  - c. *Students know* when the forces on an object are balanced, the motion of the object does not change.
  - d. *Students know* how to identify separately the two or more forces that are acting on a single static object, including gravity, elastic forces due to tension or compression in matter, and friction.
  - e. *Students know* that when the forces on an object are unbalanced, the object will change its velocity (that is, it will speed up, slow down, or change direction).
  - f. *Students know* the greater the mass of an object, the more force is needed to achieve the same rate of change in motion.

**Physics (Grade 9-12):**

**Motion & Forces**

- 1. Newton's laws predict the motion of most objects. As a basis for understanding this concept:
  - b. *Students know* that when forces are balanced, no acceleration occurs; thus an object continues to move at a constant speed or stays at rest (Newton's first law).
  - c. *Students know* how to apply the law  $F = ma$  to solve one-dimensional motion problems that involve constant forces (Newton's second law).
  - d. *Students know* that when one object exerts a force on a second object, the second object always exerts a force of equal magnitude and in the opposite direction (Newton's third law).
  - e. *Students know* the relationship between the universal law of gravitation and the effect of gravity on an object at the surface of Earth.
  - f. *Students know* applying a force to an object perpendicular to the direction of its motion causes the object to change direction but not speed (e.g., Earth's gravitational force causes a satellite in a circular orbit to change direction but not speed).
  - g. *Students know* circular motion requires the application of a constant force directed toward the center of the circle.
  - h.\* *Students know* Newton's laws are not exact but provide very good approximations unless an object is moving close to the speed of light or is small enough that quantum effects are important.
  - j.\* *Students know* how to resolve two-dimensional vectors into their components and calculate the magnitude and direction of a vector from its components.
  - l.\* *Students know* how to solve problems in circular motion by using the formula for centripetal acceleration in the following form:  $a = v^2/r$ .

**Conservation of Energy and Momentum**

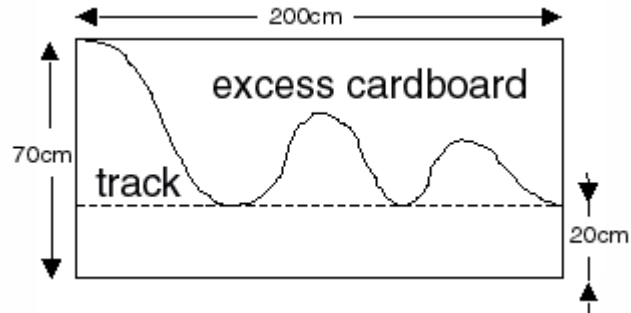
- 2. The laws of conservation of energy and momentum provide a way to predict and describe the movement of objects. As a basis for understanding this concept:
  - a. *Students know* how to calculate kinetic energy by using the formula  $E = (1/2)mv^2$ .
  - b. *Students know* how to calculate changes in gravitational potential energy near Earth by using the formula (change in potential energy) =  $mgh$  ( $h$  is the change in the elevation).

	<p>c. <i>Students know</i> how to solve problems involving conservation of energy in simple systems, such as falling objects.</p> <p>d. <i>Students know</i> how to calculate momentum as the product <math>mv</math>.</p> <p>e. <i>Students know</i> momentum is a separately conserved quantity different from energy.</p> <p>f. <i>Students know</i> an unbalanced force on an object produces a change in its momentum.</p> <p>g. <i>Students know</i> how to solve problems involving elastic and inelastic collisions in one dimension by using the principles of conservation of momentum and energy.</p>
<b>General Goals</b>	<p>The overall goal of the lesson is to “bring to life” physics concepts of motion (including Newton’s Laws of Motion), forces, and energy (changes from potential to kinetic) through project based learning.</p> <p>For the lower grades, the focus will be on introducing these topics and illustrating them through the design and use of a roller coaster. For more advanced grades, a greater emphasis can be placed on underlying physics and mathematics.</p>
<b>Specific Objectives</b>	<p>Students will:</p> <ul style="list-style-type: none"> <li>• Understand the principle of conservation of energy.</li> <li>• Know that mechanical energy forms <i>gravitational potential energy</i> and <i>kinetic energy</i>.</li> <li>• Explain the losses of mechanical energy to heat due to friction (high school).</li> <li>• Predict the conditions under which a person will feel lighter or heavier in a moving vehicle.</li> </ul>
<b>Required Materials</b>	<p>1. <u>Each team will require the following materials to build their roller coaster:</u> (It would be a good idea to have extra corrugated or foam board on hand for any design revisions by the teams.)</p> <ul style="list-style-type: none"> <li>• Tennis ball (or similar-size ball).</li> <li>• Two pieces of 70 cm x 200 cm corrugated or foam board.</li> <li>• Heavy-duty scissors.</li> <li>• Box knife.</li> <li>• Meter stick.</li> <li>• Hot glue and glue gun.</li> </ul> <p>2. <u>Animations and pictures</u> to further illustrate the vocabulary and math/physics concepts:</p> <ul style="list-style-type: none"> <li>• <a href="http://www.physicsclassroom.com/mmedia/energy/ce.html">http://www.physicsclassroom.com/mmedia/energy/ce.html</a></li> <li>• <a href="http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/energy/ce.html">http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/energy/ce.html</a></li> <li>• <a href="http://www.learner.org/exhibits/parkphysics/">http://www.learner.org/exhibits/parkphysics/</a></li> <li>• <a href="http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/circmot/rcd.html">http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/circmot/rcd.html</a></li> <li>• <a href="http://schoolweb.psdschools.org/boltz/depts/computer/S04coasters/s04coasters.htm">http://schoolweb.psdschools.org/boltz/depts/computer/S04coasters/s04coasters.htm</a></li> <li>• <a href="http://www.glencoe.com/sec/science/cgi-bin/splitwindow.cgi?top=http://www.glencoe.com/sec/science/top2.html&amp;link=http://coasters.eb.com/ride.html">http://www.glencoe.com/sec/science/cgi-bin/splitwindow.cgi?top=http://www.glencoe.com/sec/science/top2.html&amp;link=http://coasters.eb.com/ride.html</a></li> </ul> <p>3. <u>Vocabulary List:</u></p> <ul style="list-style-type: none"> <li>• Acceleration</li> </ul>

	<ul style="list-style-type: none"> <li>• Conservation of Energy</li> <li>• Force</li> <li>• Friction</li> <li>• Centripetal Force</li> <li>• Gravitational Force</li> <li>• Gravitational Potential Energy (GPE)</li> <li>• Heat (Thermal Energy)</li> <li>• Kinetic Energy (KE)</li> <li>• Mechanical Energy</li> <li>• Potential Energy (PE)</li> <li>• Weightlessness</li> </ul>
<b>Anticipatory Set</b>	<p>1. Amusement park rides, water park rides, and rides in the local playground provide thrills while gravitational potential energy (GPE) and kinetic energy (KE) transform from one to the other.</p> <ul style="list-style-type: none"> <li>• Make a list of such rides and explain where in the ride the GPE and the KE are the greatest.</li> <li>• Where do the forces act in each ride providing the resistance that converts the total GPE and KE into heat?</li> </ul> <p>2. On rides such as roller coasters (and even swings), the rider experiences fast changes in velocity due to increases or decreases in speed or simply changes in direction; the rider is subjected to unbalanced forces that give the rider an illusion of feeling heavier or lighter than normal. Through sensing of these unbalanced forces, the “thrill factor” of a ride is judged to be high when they occur frequently in a ride. Some of the best rides give the illusion of weightlessness for short periods of time.</p> <ul style="list-style-type: none"> <li>• Where on the roller coaster would you expect to feel heavier, and where would you feel lighter?</li> <li>• Use Newton's law of inertia to explain these illusions of heaviness and lightness, also known as positive and negative “g forces.”</li> </ul> <p>3. In a trip in a car (or bus), although not as thrilling as a ride on a roller coaster, you experience the same energy transitions at a slower rate.</p> <ul style="list-style-type: none"> <li>• Imagine you are a passenger in a car at a traffic light. The light turns green and the driver "steps on the gas." The car begins to accelerate forward, but relative to the seat which you are sitting on, your body begins to lean backwards. As the wheels of the car spin to generate a forward force upon the car to cause a forward acceleration, your body tends to stay in place. It certainly might seem to you as though your body were experiencing a backwards force causing it to accelerate backwards. The feeling of being thrown backwards is merely the tendency of your body to resist the acceleration and to remain in its state of rest. The car is accelerating out from under your body, leaving you with the false feeling of being thrown backwards.</li> </ul>

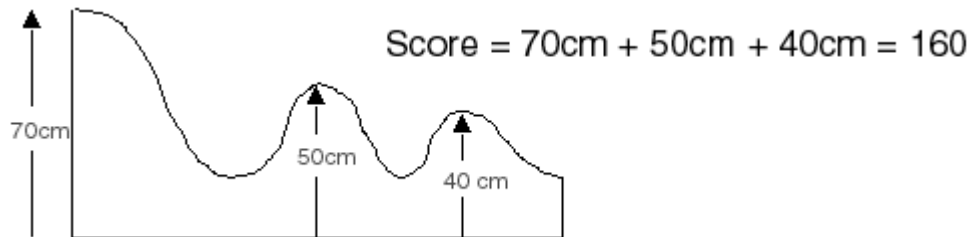
	<ul style="list-style-type: none"> <li>Imagine that you're driving along at constant speed and then suddenly approach a stop sign. The driver steps on the brakes. The wheels of the car lock and begin to skid across the pavement. This causes a backwards force upon the forward moving car and subsequently a backwards acceleration on the car. However, your body being in motion tends to continue in motion while the car is slowing to a stop. The feeling of being thrown forwards is merely the tendency of your body to resist the deceleration and to remain in its state of forward motion. This is the second aspect of Newton's law of inertia - "an object in motion tends to stay in motion with the same speed and in the same direction..." The unbalanced force acting upon the car causes it to slow down while your body continues in its forward motion.</li> </ul>
<b>Step-by-Step Procedures</b>	<p><b><u>Day 1: Introduction.</u></b></p> <ul style="list-style-type: none"> <li>Introduce topic</li> <li>Review vocabulary</li> <li>Design criteria: They will be designing and constructing cardboard “tennis ball” roller coasters with three hills. The tennis ball in each design must start from 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.</li> <li>Review rules of contest, and grading policy.</li> </ul> <p><b><u>Day 2: Investigation, &amp; design.</u></b></p> <ul style="list-style-type: none"> <li>Students will be assigned into teams (of four to five students) to begin their investigation &amp; design.</li> </ul> <p><b><u>Day 3 &amp; 4: Build the roller Coaster.</u></b></p> <ol style="list-style-type: none"> <li>Have students consider the following when designing their roller coasters: <ul style="list-style-type: none"> <li>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?</li> <li>Does the steepness of the hill count? Is it better to make the hills steep or not so steep? Why?</li> <li>How curvy should the tops of the hills and the valleys be? Should you design sharp turns or smooth turns? Why?</li> <li>What provides resistance on the roller coaster causing the tennis ball to slow down? How can this resistance be reduced?</li> <li>Note: Leave students with enough time to make revisions to their original design—an important factor in the world of design and engineering.</li> </ul> </li> <li>The left and right roller coaster tracks will be made from the two pieces of corrugated cardboard that must be cut out as identical shapes. Each valley in the roller coaster <i>must</i> dip to a height of 20 centimeters from the bottom of the</li> </ol>

cardboard. Have students use heavy-duty scissors or a box knife to cut out both tracks. They will probably have their own ideas on how the roller coaster should be shaped, but here is an idea on how to lay out the roller coaster on the cardboard.



3. From the excess cardboard, students should cut out twenty-five 4 cm × 12 cm rectangles. These rectangles will serve as spacers between the two cutout tracks. Put glue along both of the 12-centimeter edges and fasten them to various places between the two tracks so that the tracks are rigid and separated by a distance of 4 centimeters.

4. Here is an example of how the score for a roller coaster should be calculated for 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, whose tennis ball successfully completed its journey, is the winner.



**Day 5: Contest/Discussion.**

- Explain why (or why not) your tennis ball was able to complete the roller coaster.
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- Relate the principle of “conservation of energy” in an analysis of a roller coaster rides from start to finish. Include in your discussion the names of all relevant energy forms and where and when on the ride energy transformations are occurring. (For high school, include the formulas and calculations.)
- Imagine that you are among the first group of passengers to test out a newly constructed roller coaster. The slide down the first hill is thrilling, but before

	<p>you get to the top of the second hill, you start sliding backward and get trapped between the first two hills. Discuss what practicalities the designer forgot to include in transforming his creation from the idealized blueprint to the real world.</p> <ul style="list-style-type: none"> <li>• Some roller coasters feature an upside-down “loop.” Explain why these features are always placed at the beginning of the ride and never near the end.</li> <li>• It's all fun and games until somebody gets hurt. Imagine that you are designing the world's ultimate roller coaster. Describe the features you would incorporate into your design and explain what limits you would put on those features to prevent fun from becoming dangerous.</li> </ul>
<b>Plan for Guided Practice</b>	<ol style="list-style-type: none"> <li>1. Teacher lead introduction/discussion.</li> <li>2. Teacher demonstrates a sample roller coaster. Has sample available for inspection by groups during their investigation, design, and construction.</li> <li>3. Teacher available for consultation during investigation, design, and construction.</li> </ol>
<b>Plan for Independent Practice</b>	<p>Students will investigate, design, and test their roller coaster prior to the contest. Students will also write a group report/worksheet on their findings.</p>
<b>Assessment (based on objectives)</b>	<p>Students will be assessed through:</p> <ul style="list-style-type: none"> <li>• A series of questions for each group.</li> <li>• Performance of their roller coaster, based upon contest criteria.</li> <li>• Written worksheet/report (to be turned in no later than the day after the contest). For 8<sup>th</sup> grade the worksheet/report will focus more on observations, performance of their roller coaster, and general concepts that describe the behavior of the ball on the roller coaster. For high school physics, the report/worksheet will also include the calculations to describe the behaviors of the ball at strategic points on the roller coaster (top/bottom of hills, top/bottom of loops, and begin/end of ride).</li> </ul>
<b>Adaptations (ELL students or special populations)</b>	<p>Students will be grouped such that any additional support (ELL, other special needs) can be accommodated within each group.</p>
<b>Extensions (for gifted students)</b>	<p>Challenge students to make the following calculations and attach student answers next to the appropriate areas on their roller coasters.</p> <p><b><u>Challenge questions for 8<sup>th</sup> grade:</u></b></p> <ul style="list-style-type: none"> <li>• What is the gravitational potential energy (GPE) of the tennis ball at the</li> </ul>

	<p>top of each hill?</p> <ul style="list-style-type: none"> <li>• Calculate the amount of GPE lost between each hill and the total energy lost to heat due to frictional interactions.</li> <li>• Determine the kinetic energy at the bottom of each hill and calculate the velocity at those locations.</li> </ul> <p><b><u>Challenge question for high school physics:</u></b></p> <ul style="list-style-type: none"> <li>• Perform those same calculations if the roller coaster was on another planet. On which planet would the ride be more thrilling or less thrilling than on Earth? Explain your choices.</li> </ul>
<b>Extensions</b>	<ul style="list-style-type: none"> <li>• Use the web page to build a roller coaster: <a href="http://www.learner.org/exhibits/parkphysics/coaster/">http://www.learner.org/exhibits/parkphysics/coaster/</a></li> <li>• Use this web page to view animations that show the energy transfers during roller coaster ride: <a href="http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/energy/ce.html">http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/energy/ce.html</a></li> <li>• Visit The Tech Museum of Innovation and design a roller</li> <li>• Build-your-own accelerometer (<a href="http://library.thinkquest.org/2745/data/meter.htm">http://library.thinkquest.org/2745/data/meter.htm</a> ) and use it on a field trip to an amusement park to measure the G-forces on amusement park rides or simply a swing in the park.</li> <li>• Field trip to an amusement park to experience the “thrills” first-hand.</li> <li>• Experiment with other amusement park rides: <ul style="list-style-type: none"> <li>○ Swings (illustrate centripetal acceleration)</li> <li>○ Carousel</li> <li>○ Bumper cars (illustrate Newton’s third law, “for every action there is an equal and opposite reaction”).</li> </ul> </li> </ul>
<b>For more information</b>	<ul style="list-style-type: none"> <li>• <a href="http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Microgravity-Earth.and.Space/Microgravity.Earth.and.Space.Guide.pdf">http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Microgravity-Earth.and.Space/Microgravity.Earth.and.Space.Guide.pdf</a></li> <li>• <a href="http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Microgravity-Earth.and.Space/Microgravity.Earth.and.Space.Guide.pdf">http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Microgravity-Earth.and.Space/Microgravity.Earth.and.Space.Guide.pdf</a></li> <li>• <a href="http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Microgravity-Fall.Into.Mathematics/Fall.Into.Mathematics.pdf">http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Microgravity-Fall.Into.Mathematics/Fall.Into.Mathematics.pdf</a></li> <li>• <a href="http://www.rollercoaster.com/designers_corner/physics/physics_book_01.html">http://www.rollercoaster.com/designers_corner/physics/physics_book_01.html</a></li> <li>• <a href="http://www.discovery.com/exp/rollercoasters/thrills/thrills.html">http://www.discovery.com/exp/rollercoasters/thrills/thrills.html</a></li> <li>• <a href="http://themeparks.about.com/gi/dynamic/offsite.htm?zi=1/XJ&amp;sdn=themeparks&amp;zu=http%3A%2F%2Flibrary.thinkquest.org%2FC005075F%2FEnglish_Version%2Findex.html">http://themeparks.about.com/gi/dynamic/offsite.htm?zi=1/XJ&amp;sdn=themeparks&amp;zu=http%3A%2F%2Flibrary.thinkquest.org%2FC005075F%2FEnglish_Version%2Findex.html</a></li> <li>• <a href="http://microgravity.grc.nasa.gov/drop2/">http://microgravity.grc.nasa.gov/drop2/</a></li> <li>• <a href="http://teacherweb.com/MD/OxonHillMS/TechEffectScreamMachineWebQuest/wqr2.stm">http://teacherweb.com/MD/OxonHillMS/TechEffectScreamMachineWebQuest/wqr2.stm</a></li> <li>• <a href="http://www.physicsclassroom.com/mmedia/energy/ce.html">http://www.physicsclassroom.com/mmedia/energy/ce.html</a></li> </ul>
<b>Credits</b>	<p>This lesson plan was adapted from:</p> <p><a href="http://school.discovery.com/lessonplans/programs/rollercoaster/">http://school.discovery.com/lessonplans/programs/rollercoaster/</a></p>