Box 7904 / 118 Page Hall
Raleigh, NC 27695-7904
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# ROLLER COASTERS

**Grade Level:** 3-5

**Group/Team Size:** 4-5 (4 is optimal

**Time Required:** 30-45 minutes

**Mest-Up Factor:** 1 (Setup and Mess Factor: 1 to 10 scale – 10 being the most intense)

**Expendable Cost Per Group:** 1 US Dollars, initial cost; all materials reusable

**Summary:** Students use plastic tubing and and small spherical objects like ball bearings, marbles, and air beads to first create a successful roller coaster then experiment with various design challenges.

**Engineering Connection:** Mechanical engineers frequently work at amusement parks and design rides of all types. At the conclusion of the activity are some roller coaster milestones that might be of interest to students. Forces and motion are an important part of most types of engineering, mechanical engineering most specifically.

**Educational Standards:**
From the North Carolina Standard Course of Study (http://www.ncpublicschools.org/curriculum/ncscos)

- **Grade 5:** Competency Goal 4: : The learner will conduct investigations and use appropriate technologies to build an understanding of forces and motion in technological designs.

  - 4.01 Determine the motion of an object by following and measuring its position over time.
  - 4.02 Evaluate how pushing or pulling forces can change the position and motion of an object.
  - 4.03 Explain how energy is needed to make machines move.
    - Moving air.
    - Gravity.
  - 4.05 Determine factors that affect motion including:
    - Force
    - Friction
    - Inertia
    - Momentum
  - 4.06 Build and use a model to solve a mechanical design problem.
    - Devise a test for the model.
    - Evaluate the results of test.

**Learning Objectives:**

- Evaluate how potential and kinetic energy are related
- Observe and evaluate the motion of the roller coaster “car” over time under different conditions
- Evaluate the effects of friction, inertia, momentum and gravity on the motion of the roller coaster “car”

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**Materials:**

Instructor needs:

- One rubber band
- Two equal size, clear cups with water in one (label one PE and one KE, optional)
- Stop Watch

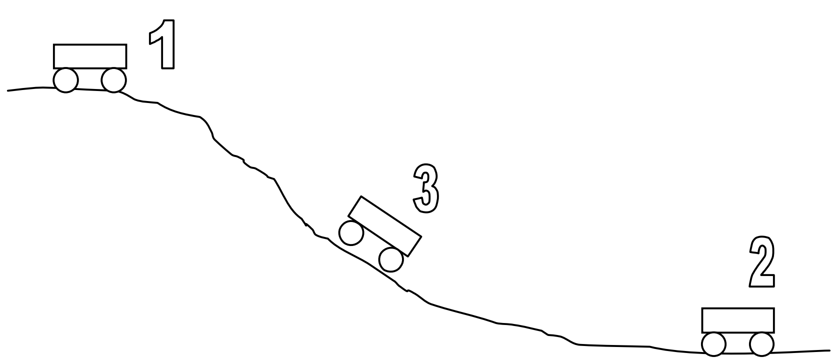
Each group will need:

- One piece of plastic tubing, diameter at least ¾ inch (1 inch preferred), length at least 10 feet
- One spherical object of varying size – ball bearing or air bead. Distribute one at a time; groups may exchange for a different type or size during the activity.

**Safety:** Students should be cautioned against standing on desks, although standing on chairs may be allowed if the facilitator takes care to make sure they are used safely. If ball bearings are spilled/dropped on the floor, there may be a falling hazard. Caution them not to put the tubes in their mouths to blow on them….this will ruin the activity for them as condensation collects in the tube and will significantly slow their "car". Also caution students not to throw the bearings and to have one person designated as a 'catcher' at the end of the roller coaster so that the bearings do not get lost.

**Introduction:** Introduce potential and kinetic energy by writing the words on the board. Tell the students that potential energy is the energy of "what *could* happen." Quickly take a rubber band from your pocket and stretch it as if you will fire it at someone. When they flinch, ask them why. Because the rubber band *could* hit them, if you let it go. It has potential energy. Shoot the rubber band at the ceiling. Tell them that while it is moving, it has kinetic energy, the energy of motion.

Ask students whether they have ever ridden or seen a roller coaster. Ask them to recall that all roller coasters have hills, and the first one usually involves the cars being dragged up via some sort of connection to a chain and a motor (make the click, click, click noise to invoke their memory). Use guided inquiry questions about their experiences with roller coasters to let the class tell you how they work. Note that most roller coasters have the highest hill as the first one. The motor puts energy into the system (what kind of energy?). Draw a picture of a hill on the board. (I draw the cars one at a time, rather than all at once.)




Tell students that roller coasters, when the motor has pulled them to the top of the first hill, pause there to let everyone get nervous, and actually stop moving for a short time. Ask the students what kind of energy the car in position one has. Make sure they understand that the car is not moving. Get them to say potential and discuss why there is no kinetic. Label that car PE=high and KE=0. Ask that question again about car 2. Emphasize that it is at the bottom of the hill and moving fast. Label that car PE=0 and KE=high. Using the cups, have water in the one labeled PE. Slowly pour the water into the other cup labeled KE. Tell students that there is a concept called conservation of energy that says energy is

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neither created nor destroyed, just transformed. Tell them that, in a roller coaster, potential energy comes from the energy of the motor dragging the car up the first hill. Then the energy converts to kinetic energy (which means speed), as the car goes down hills. That is what happened when the water was poured from one cup to another, just like the car going down one hill. When the car goes up the *next* hill, it is like water being poured from KE back into PE. Ask the students: If the next hill isn't as tall as the first hill, what happens? Answer: the car retains some speed as it goes over the hill, like some water remaining in the KE cup as you pour back and forth. Show them this with water. Say: This means, that unless something else goes on, the roller coaster could be infinitely many hills (or a circle of hills) all the same size, with the car going down, then up until it just loses all its speed, then back down. Ask them if this could really happen. If not, then something must happen to the energy, because it cannot be just destroyed or lost. Ask them if they have heard of friction. Tell them to rub their hands together quickly and see what happens. (They get warm.) This is friction converting mechanical energy to heat. This happens in the roller coaster too. Demonstrate with the water by, while pouring back and forth, spilling a little water on the floor. Then ask if a second hill could be as tall as the first…in other words, is there enough water (energy) to get the car back up as far? The answer is no, because some energy was converted to heat through friction. Conclude the discussion by asking the students to tell you what kind of energy the car has at position 3. Label it PE=half and KE=half.

**Procedure:**

1. Put the students into groups of four or five students. Tell each group that they will have a tube and one roller coaster car (ball bearing) at a time. Ask them to build a successful roller coaster: the ball goes in one end and comes out the other without their moving the tube. If they want to try different sizes of ball bearings, they can trade theirs in as many times as they like, but may only have one at a time.
2. Give them five minutes to do this, then get the class's attention and ask each group to share one thing they have learned.
3. Tell them they have ten minutes to make the sickest roller coaster that they can. They should name it and be prepared to demonstrate it to the class. While they build, circulate and ask them questions about what they are doing. Look for difficulties in teamwork (not including everyone, not trying everyone's ideas, etc.) and for frustrations with making things work. Ask questions or make small suggestions to help. They should feel that they have done this.
4. Additional challenges might include asking the students to build the curviest roller coaster that they can, or asking the groups to design the slowest roller coaster that they can. You can time the teams and compete if you wish.
5. Have each group tell the coaster name and show it to the class. Make sure that everyone claps for each group, even if not successful.

Take questions.

**Inquiry Questions:**

1. Ask them if different sizes of ball bearing made a difference.
2. Ask them if they succeeded in making a loop. Would it matter if the loop was at the beginning or end of the coaster?
3. Ask them if they saw friction playing a role and how.
4. Fundamentally, the students should understand that height and speed trade off with one another in a roller coaster. Ask them about this trade and reiterate the concepts of potential (height) and kinetic (speed) energy.

**Activity/Age Scaling:** Younger kids would not want as much discussion up front. Older kids should be challenged to explain things more. A stop watch can be used to time how long the coaster takes. Kids can be challenged to make the ride as long as possible.

**Additional Resources:** ultimaterollercoaster.com (see attachment)

**Sources:** Activity invented by Dr. Bottomley.