STEM IN THE LAB

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Idaho National Laboratory

BUILD A ROLLER COASTER

Have you ever ridden a roller coaster? Have you ever wanted to design your own? There are plenty of expensive toys and even video games that will let you build your own coasters—but in this project you'll make one out of paper and tape and learn about roller coaster physics along the way!

We use physics every day at Idaho National Laboratory. A physicist is someone who explores and identifies the basic principles that govern the structure and behavior of matter, the interaction between energy and matter, and the generation and transfer of energy. An INL reactor physicists might study reactor physics and particle transport modeling (i.e., how neutrons and gamma rays move inside a nuclear reactor), and how their interactions affect the reactor's physical parameters (e.g., reactor power).

GRADE LEVELS: K-5

VOCABULARY

Physics- *the branch of science concerned with the nature and properties of matter and energy. The subject matter of physics, distinguished from that of chemistry and biology, includes mechanics, heat, light and other radiation, sound, electricity, magnetism, and the structure of atoms.*

Gravitational Potential Energy- *energy an object possesses because of its position in a gravitational field.*

Kinetic energy- *energy which a body possesses by virtue of being in motion.*

Air resistance- *a force that is caused by air. The force acts in the opposite direction to an object moving through the air.*

Friction- *the resistance that one surface or object encounters when moving over another.*

Conservation of Energy- *a principle stating that energy cannot be created or destroyed but can be altered from one form to another.*

MATERIALS

- *Paper*
- *Tape*
- *Scissors*
- *Ruler*
- *Pencil*
- *Corrugated cardboard*
- *Marble*

INSTRUCTIONS

PREP WORK

1. *Before you try building an entire roller coaster, practice building the individual track segments. You can print this template- https://www.sciencebuddies.org/science-activities/paper-roller-coaster-template-v2.pdf- and cut out the pieces, or follow the instructions to draw your own with a pencil and ruler.*
2. *To build a straight segment:*
    a. *Cut a 7.5 cm (3 inch) wide strip of paper.*
    b. *Draw two parallel lines that divide it into three 2.5 cm-wide strips.*
    c. *Fold the two sides up 90 degrees along those lines to form walls.*
3. *To build a loop or a hill:*
    a. *Cut a 7.5 cm (3 inch) wide strip of paper.*
    b. *Draw two parallel lines that divide it into three 2.5 cm-wide strips.*
    c. *Make marks every 2.5 cm along the long edges of the paper.*
    d. *Cut inward 2.5 cm from these marks to form tabs.*
    e. *Fold the tabs up 90 degrees.*
    f. *Bend the track into the shape you want and tape the tabs together to hold it in place. This step is easier with two people, one to hold the track in place and one to do the taping.*
4. *To build a curve:*
    a. *Cut a 7.5 cm (3 inch) wide strip of paper.*
    b. *Draw two parallel lines that divide it into three 2.5 cm-wide strips.*
    c. *Make marks every 2.5 cm along one long edge of the paper.*
    d. *Cut inward 5 cm (2 inches) from these marks.*
    e. *Fold up the uncut side of the paper 90 degrees to form a wall.*
    f. *Fold up the tabs on the other side to form the other wall.*
    g. *Since the bottom portion of the track is cut into segments, you can bend it horizontally to form a curve. Tape the tabs together to hold the curve in place.*

5. *To build a support strut:*
    a. *Cut a 6.25 cm (2.5 inch) wide strip of paper.*
    b. *Draw four parallel lines that divide it into five 1.25 cm (0.5 inch) wide strips.*
    c. *Cut inward 2.5 cm along these lines from one edge.*
    d. *Fold along the lines to form a square shape (so two of the segments overlap) and use tape to hold in place.*
    e. *Fold the tabs you cut at the end outward. This will allow you to tape the tabs flat to a piece of cardboard, so your strut can stand upright.*

PROCEDURE

1. *Before you start building, plan out a design for your roller coaster. Draw your design on paper. Figure out how many supports and pieces of track you will need. Make sure your marble starts at the top of a hill.*
2. *Using a piece of corrugated cardboard as a base, assemble your track according to your plan. Tape the track segments together end-to-end to connect them.*
3. *Place the marble at the top of your track and let it go. Watch carefully.*

    What happens? Does it make it the whole way through the track?

4. *If the marble made it the whole way to the end, try making your track longer by adding more pieces.*

    How long can you make your track before the marble comes to a stop?

5. *If your marble didn't make it to the end, try to figure out why. Is there a spot in your track where the marble got stuck? Was the marble going too slow to make it through a loop? If necessary, make changes to your design, like making the curves more gradual or the starting hill taller, and try again.*

What Happened?

If you made your starting hill tall enough, and all the curves and loops of your roller coaster were gradual, your marble should have been able to get all the way to the end. However, if your coaster had any sharp turns or corners, your marble might have gotten stuck. If you tried to have your marble go up a hill or through a loop that was taller than the hill it started on, it wouldn't make it all the way through. Why not? It is all about energy! Read the next section to learn more about the physics behind roller coasters.

THE SCIENCE BEHIND IT

Roller coasters are all about physics! Unlike other vehicles like cars and trains, roller coasters do not have an engine that propels them along the track. Instead, they rely on gravitational potential energy, which they gain by initially being towed up a large hill. Potential energy is "stored" because of an*

object's elevation, or height off the ground. When the coaster starts going down the hill, the potential energy is converted to kinetic energy, or the energy of the motion. When the coaster goes back up another hill, it will lose kinetic energy (it will slow down) and gain some potential energy again. Some of the energy is also converted to heat due to air resistance and friction with the track, gradually causing the coaster to slow down. This process continues as the coaster goes through loops, hills, and turns, until eventually it comes back to the beginning.

Due to conservation of energy (the total amount of energy in the system must be conserved, or stay the same), the total amount of kinetic energy and energy lost due to friction can never be greater than the initial amount of potential energy that the coaster has. That means coaster designers must make sure the coaster has enough initial potential energy to make it through the rest of the track. This places some limits on the design. For example, the coaster cannot go through a loop or over a hill that is taller than the starting hill, because going higher would require more energy than it has available. If the track is too long, friction might eventually cause the coaster to come to a complete stop.

To build a successful paper coaster, you had to take these factors into consideration. Since some energy is always lost to friction, your starting hill must be taller than any other hills or loops in your coaster. If you had any long, flat segments, the marble might have rolled to a stop because of friction. You must make sure your marble has enough potential energy to make it through your whole track. So, if you had trouble, go back and try making your starting hill taller.

**Note that there are other kinds of potential energy, like elastic potential energy (the energy you get when you stretch a rubber band). In this project, we are only talking about gravitational potential energy.*

EXTENSIONS

Instead of using paper, you can make roller coasters from foam pipe insulation, available at a hardware store. This will allow you to make a much bigger coaster more quickly since it doesn't involve as much cutting, folding, and taping.

RESOURCES

https://www.sciencebuddies.org/stem-activities/paper-roller-coaster

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