Rollercoaster Lab

In this lab, students will explore different kinds of energy as well as the difference between potential and kinetic energy by designing a rollercoaster for the city of Providence.

I. (10 min) Introduction to energy, introduction to rollercoaster activity

Tell a story: “Mayor Cicilline wants to build a rollercoaster for the people of Providence and he’s asked us to design it. He also wants a very special feature in the rollercoaster: a jump. Today we will talk about rollercoasters, how we make them go, and we will do some testing for putting a jump in the rollercoaster.”

II. (15 min) Class discussion on energy: Ask the students, “How do we make a rollercoaster go?” Use kinds of energy matching worksheet.

Examples (with types of energy in italics):

- Pull it up to the top of a hill with an electric motor and let it go—gravity then pulls it down.
- Put a rocket or a motor on the back: gas powered ➔ chemical energy.
- Nuclear powered train (extreme example).
- Horses/animals/people pull the rollercoaster up the hill: mechanical energy or chemical energy (if you talk about how the horses get their energy). That then becomes gravitational energy.
- Thermal energy (via a steam engine, or something similar).

After the students have responded, make sure that they know that their suggestions were all different types of energy. Emphasize what they already knew and build on that to talk about the different forms of energy. Have them complete the matching worksheet.

Transition: since the only type of energy we seem to have on hand is gravity and each of you (to produce mechanical energy), we will have to use you and gravity to design our rollercoaster and perform the jump tests.

III. (15 min) Class demo of a rollercoaster
• Use large nylon tube and a brightly colored marble.
• Ask 3 or 4 students to volunteer to be ‘rollercoaster technicians.’
• All rollercoaster technicians stand in front of the class and hold a piece of the tube according to the ‘rollercoaster engineers’ (the rest of the class’) request.
• Use loops and hills and drops. The marble should pass from the beginning of the tube (dropped in) to the end of the tube (where it should pop out).
• If the marble does not make the whole path, the components should be adjusted until the rollercoaster works.
• If it works the first time, try a different configuration anyway.
• Every time a suggestion is made, try to make a reference to energy.
  → Hopefully the students will get the idea that the higher the ball starts, the more energy it has.
• Use this idea to transition into a potential/kinetic energy conversation. Students flip over worksheet to circle kinds of kinetic energy and put a square around kinds of potential energy.

IV. (1 hr) Rollercoaster Jump Lab

Students work in groups or pairs to complete the rollercoaster lab. There are 4 stations with a standard rollercoaster jump lab setup and 2 ‘exploration stations’ where students who have finished the lab portion of the day can explore different rollercoasters on their own with moveable parts.

i. Jump lab:

Materials:

- Jump lab setup: peg board, nylon tubing, ball bearings.
• Butcher paper for recording where the ball bearings land

• Cardboard backdrop for stopping the ball bearings from rolling across the room.

• Lab worksheet or worksheet components to glue into notebooks.

Setup:

A 1/2” nylon tube is attached to a 2x2’ piece of pegboard in a sloping shape. The bottom end of the tube is parallel to the ground. Two pegboard setups are connected by hinges so that they are freestanding and also fold together. The nylon tubing has 3 holes in it at various places along the tube of different heights. Students will drop the ball bearings into the holes and record the height of the drop and the horizontal distance traveled by the ball after it exits the tube until it hits the ground. The students should perform each measurement 3-5 times to determine reliability. Older students should calculate an average. The setup can be used from the floor or from a raised surface such as a table, as long as it remains level with the ground.

Goal:

To determine the relationship between the initial height of the ball bearing and its horizontal distance traveled. Advanced students should be able to make the connection to potential and kinetic energy: i.e. the more potential energy you start with, the more kinetic energy you end up with.

ii. Rollercoaster exploration station

Materials:

• Exploration station setup: pegboard, pieces of nylon tubing, masking tape, ball bearings, moveable pegboard hooks.

• Suggested questions sheet at station (i.e. can you make a hill in your rollercoaster bigger than the initial height? Why or why not?)

Setup:
Students must finish jump lab before moving to the exploration station. This activity is 100% student driven. Teachers can give direction if asked. Encourage the students to take notes in their notebooks.

Goal:

Give the students an opportunity to explore their own ideas and learn in their own way. Gives advanced students who get bored something to think about.

V. (10 min) Closing Q&A: debrief

GSEs:

(some things to keep in mind)

3-4th Grade: Students should be able to,

- (PS3.1) Describe motion: speed, direction.
  - Maybe add an observation section to the data section where they describe the motion of the ball bearing in words.

- (PS3.1) Describe the effects of various amounts of force.
  - Here, gravity does not apply various amounts of force. Perhaps ask students to describe what would happen if you pushed the ball bearing on its way down the tube, or what would happen if you blew up the tube as it was coming down. (External forces in addition to gravity will have to be used.)

- (PS3.1) Describe the effects of gravity
  - Included in lab structure. A prompt could ask the students to explicitly state the effects of gravity on the ball bearing.
• (PS2.1) Predict the observable effects of energy.
  o Directly included in the lab via hypothesis.

5-6th Grade: Students should be able to,

• (PS2.1) Show that within a system potential energy changes into kinetic energy.
  o Included in the lab setup. A direct question could be asked to prompt a direct answer.

• (PS2.1) Identify and classify different kinds of energy.
  o Directly included via energy worksheet.

• (PS2.1) Give examples of how energy is stored
  o Included via energy worksheet

• (PS3.1) Recognize that a force is a push or a pull
  o Not included, but could be if we talk about external forces on the ball bearings. Also could be included in “how do we make the rollercoaster go?” discussion.

• (PS3.1) Explain that a change in speed or direction requires a push or a pull.
  o Similar to above.
Rollercoaster Jump Lab:
Student Instructions and Method Handout

**Instructions:** After listening to instructions as a class, follow the instructions below *in order*. Work with your partner or group. If you have a question, make sure the answer is not in the instructions before you ask a teacher for help.

1. Title: Rollercoaster Jump Lab

2. Purpose: to find out how far a rollercoaster can jump when you drop it from different heights.

3. Hypothesis: do you think a jump will work in a rollercoaster ride? Why or why not? Do you think the rollercoaster would jump farther or less far if it starts from a higher place? Why or why not?

4. Materials:
   - Pegboard setup: a clear tube with 3 holes in it mounted on a board.
   - 5 ball bearings (check these out from a teacher when you are ready. You are responsible for returning all of them.)
   - A meter stick or measuring tape
   - A big piece of butcher paper (approx. 1 m²)
   - A cardboard backstop

5. Method:

Once you have prepared your notebook to take data (use your notebook checklist!), follow the steps below to do the rollercoaster jump lab with your group.

1. Set up your pegboard on a flat tabletop (this may have been done for you).

2. Lay out your butcher paper on the floor to catch the ball bearings as they pop out of the tube.

3. Do a test run by dropping one ball bearing in the highest hole and one in the lowest hole. Make sure they both land on the paper.

4. Set up your cardboard backstop to stop the balls from rolling across the classroom.

5. Use a piece of tape to make a mark on the floor directly below the end of the tube (where the ball pops out).
6. Measure the height of all of the holes (A-C) from the floor. We will use the letter ‘h’ to abbreviate the word ‘height’. Record these heights in your data table.

7. Start at hole A, drop a ball bearing in the hole and watch where it lands carefully. If you are sure about where it landed, mark this spot on your paper with a marker.

8. Measure the distance from your tape marker on the floor to where the ball lands. This distance is called ‘d’. Record it in your data table.

9. Repeat the measurement for hole A until you have 5 trials completed.

10. Do the same thing for holes B, and C. Your data table should be full now.

11. Return to your desks and begin the analysis section.

6. Analysis:

1. Using the data in your data table, calculate the sum distance for each height.

2. Using the data in your table, calculate the average of the distances for each height.

   (Remember that the average is the sum divided by the number of trials.)

Example:

h = 50 cm

d = 13 cm, 12 cm, 11.5 cm, 12.5 cm, 14 cm

The average measurement is the sum of all the measurements divided by the number of measurements. Here, the number of measurements is 5. We would calculate the average distance measured like this:

\[
\text{average } d = \frac{13 cm + 12 cm + 11.5 cm + 12.5 cm + 14 cm}{5} = 12.6 cm
\]

(Please use a calculator)
3. Graph your data onto the graph paper provided.

On the X-axis (horizontal) plot your average distance. On the Y-axis (vertical) plot the height.

Example: (*note, not real data)

h = 30 cm, 50 cm, 75 cm
average d = 5 cm, 12 cm, 25 cm
7. Conclusion

1. How do you make a rollercoaster jump a big gap? Will it jump farther or less far if you start it from a higher place? (Use your data)

2. What will you tell Mayor Cicilline?

3. Make a prediction using your data: choose a height you did not use and predict where the ball bearing should land on the ground using your graph. What is your prediction?

4. If you did this test with the real rollercoaster setup, would you be able to tell Mayor Cicilline exactly how to build his jump?

8. Discussion/Reflection (can be done after exploration station)

How did you like this lab? What other things could we learn with it?
Exploration Station!

Suggested questions to try to answer 😊

(Try to take notes in your notebook as you work!)

◊ Can you make a hill in your rollercoaster higher than the starting height? What’s the highest you can make your hill if you don’t change the starting height?

◊ What are the “rules” for including a loop? Do all loops work? If not, which ones don’t work?

◊ Can you make the height of the loop higher than the starting height? Why or why not (guess)?

◊ Does the steepness of the drop matter? What happens to the motion of the ball when the drop is really steep?

◊ Make up your own questions and try to answer them!