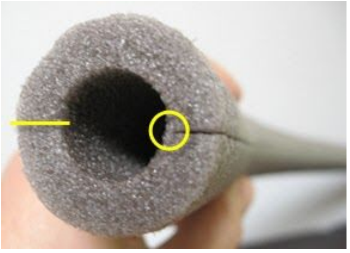
Potential and Kinetic Energy Lesson 3: *The Engineer*
Educator's Lesson Plan

Objective
In *The Engineer*, students will:
1. Design and build a roller coaster track system that maximizes potential and kinetic energy and has the following features:
    a. at least one loop, and
    b. one banked curve, and
    c. successfully delivers a marble into a cup at the end of the run.

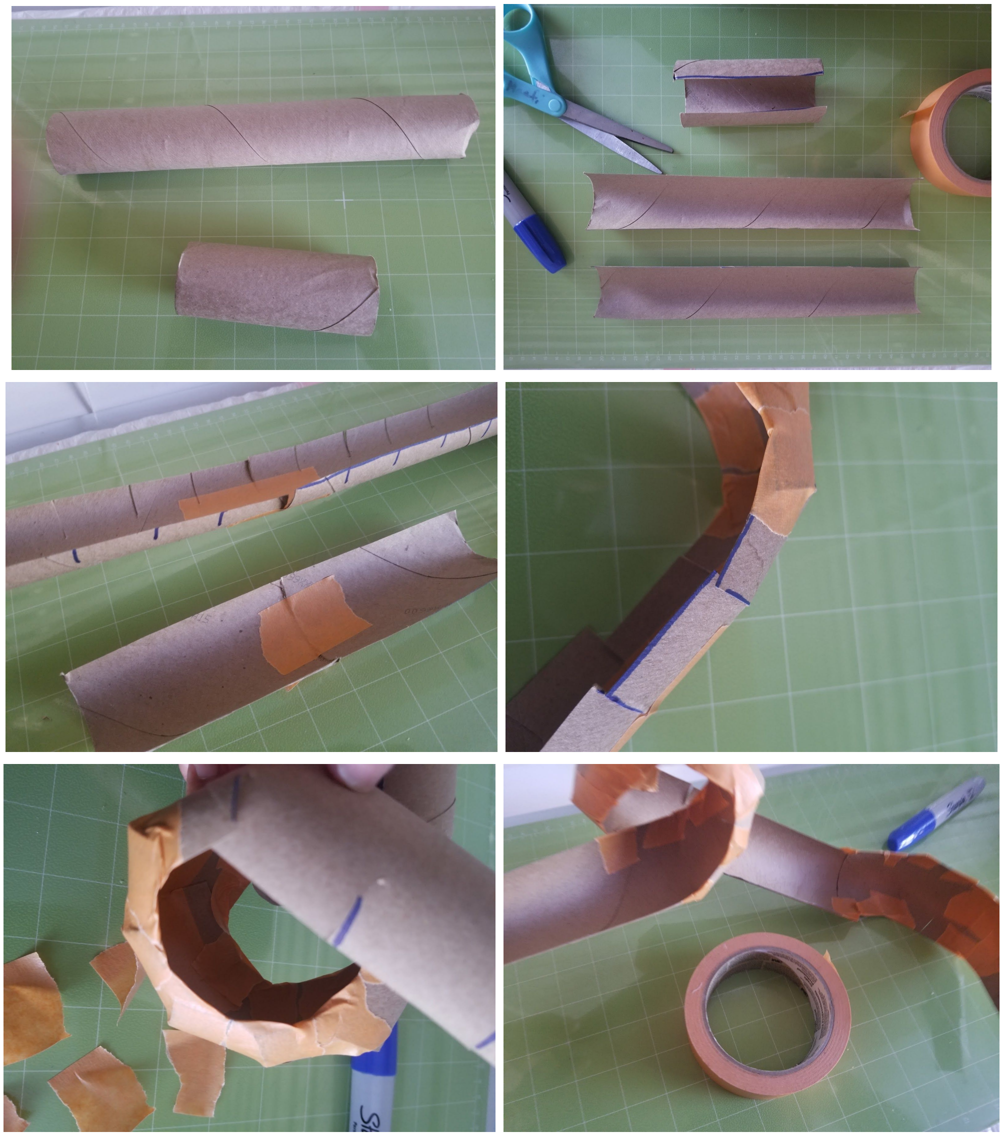
Extension: Marbles of different composition of the same size.

Time Required: 170–175 minutes

Materials Required
If doing this in class, provide the following **for each team of 3**:
- 2–3 half-pipe sections, six feet in length (183 cm), and 1 section, three feet in length (91 cm), of foam pipe insulation. The pipe insulation should have an inner diameter of ⅝" or ¾". *Pipe insulation can be purchased at Home Depot or Lowe's for about $1 per section, from which you will get two half-pipes.*
- 1 glass marble
- Masking tape
- Bookshelf, table, chairs, and various surfaces to support roller coaster
- Paper cup
- Poster paper for final presentation

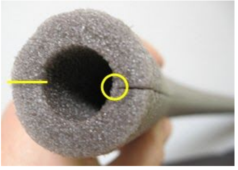


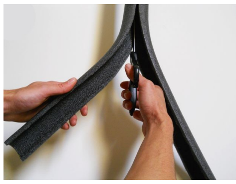
If doing this remotely, students can use paper tubes from paper towels or toilet paper. Students will cut the paper towel roll lengthwise and attach it to a flat sturdy surface (like a wall or large piece of cardboard) before putting the marbles down the run. See images below as an example:



Science & Engineering Practices	Safety/Other Considerations
• Designing Solutions	Students must exercise caution as they attempt to affix sections of the roller coaster to elevated areas to obtain maximum potential energy.

Materials Prep – Teacher





Cut the foam pipe insulation in half lengthwise to make two U-shaped channels.

1. The illustration shows the foam pipe insulation, end-on.
2. The insulation comes with one partial cut along the entire length. Complete this cut with the scissors (yellow circle in the illustration above).
3. Make a second cut on the other side of the tube (yellow line in the illustration above), along the entire length of the tube.
4. You'll end up with two separate U-channel foam pieces. Students can use masking tape to attach pieces end-to-end to make the roller coaster track as long as they want.

Inquiry Scale: Leveling Information

Level 1 (*recommended for grades 4–5)*

Lead students as a class through each step of the Student Guide Planning Organizer. Student teams execute roller coaster designs independently. To support successful execution within the time frame, lead a class-wide checkpoint for each key feature (for example, every 10 minutes, pause students and have progress check-in as a class), allowing student teams the opportunity to test and revise each section as they go, or as needed.

Level 2 (*recommended for grades 5–6)*

Lead students as a class through each step of the Student Guide Planning Organizer, as needed. Student teams execute roller coaster designs independently. To support successful execution within the time frame, write time goals on the board to indicate when you'd like each group to complete each section of the design process. For example, "for the first 10 minutes of class, groups will be working on that first loop." Do the same for each key feature and allow student teams the opportunity to test and revise each section as they go, or as needed.

Level 3 (*recommended for grades 6–7)*

Student teams go through the Student Guide Planning Organizer, with teacher support as needed. Student teams execute roller coaster designs independently.

Level 4 (*recommended for grades 7–8)*

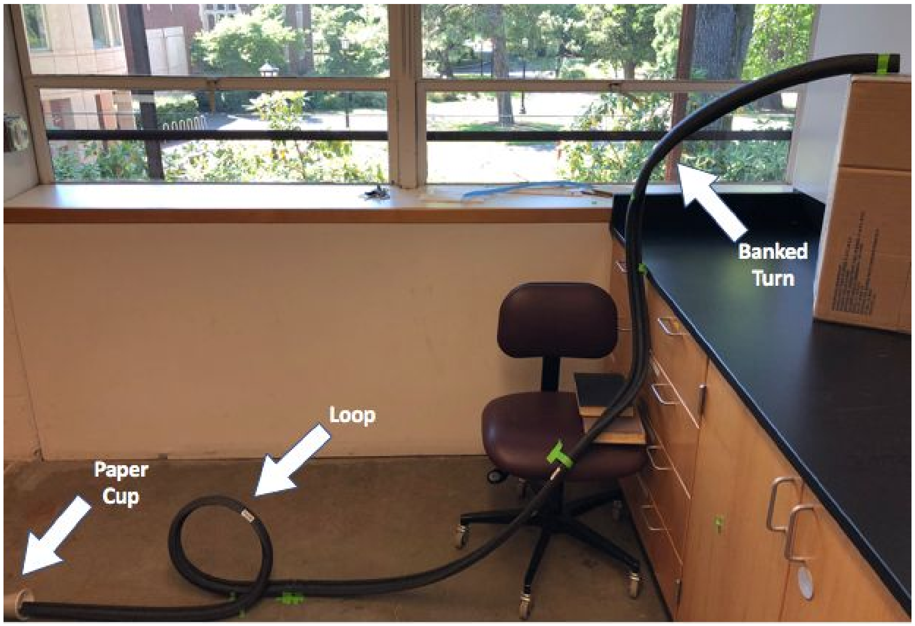
Students independently complete all aspects of *The Engineer* process.

Agenda

I. Show PowerPoint to introduce *The Engineer* Activity (10–15 minutes)
The PowerPoint will review essential concepts learned in *The Make* and provide context for students' upcoming *Engineer* challenge.

II. *The Engineer* Activity (150 minutes)
As guided by the organizer, students will:

a. Design a roller coaster with three key features.
   If students are doing this remotely, they will work independently.
   If they are doing this in class, they will work in groups.
b. Execute the roller coaster design.
c. Test and refine the design as needed. Demonstrate a successful run. If students are doing this remotely, they can either send a video or photo of the successful run or sketch what the final run looked like.
   Sketch, annotate, and present the design solution
d. Reflect on their design strategy, specifically how they maximized potential and kinetic energy.



Student Guide Planning Organizer Potential Answers for Presentation Preparation

How will the following concepts be displayed in your project?	
Potential Energy (hint: relate to mass and position)	• The starting height of the roller coaster is increased. • Adding a heavier marble (more mass). *For students who prefer to see the relationship in a mathematical form, introduce the equation itself (**PE= mgh**, or **Potential Energy = mass x gravity x height**)*
Kinetic Energy (hint: relate to mass and speed)	• The mass of the marble is increased. For students who prefer to see the relationship in a mathematical form, introduce the equation itself (**KE= ½mv^2**, or **Kinetic Energy = ½ x mass x velocity squared**)

Construction Tips and Notes

- Students may initially think that bigger loops are better, but they'll find that if loops are *too* big, the marble can't make it through, regardless of the initial potential energy. Encourage students to notice that tighter loops will work best.
- Loops may wobble a bit as the marble passes through them. If this happens, it means the marble is losing energy to the track (since it is the energy of the marble that makes this happen). The energy that the marble is losing to the track means less energy is available to make the marble itself move. Encourage students to first notice this energy transfer if it occurs and second, to make the loops as stable as possible.

Extension

- If you can find marbles that have equal diameter but are made from different materials, students can investigate how the mass of the marble affects how well it travels along the track.

III. Presentation and Assessment (10 minutes)

Students present their final design solutions as if they are presenting to an audience of their peers or community members; assessment parameters are suggested below.

***The Engineer* Assessment:** Project Grade and Rubric Score Sheet – Potential & Kinetic Energy

Project Submitted by ____

The Engineer Checklist

Your Challenge: Design a roller coaster track system that maximizes potential and kinetic energy to successfully deliver a marble into a cup at the end of the run.

Project Completeness:

- ❏ Roller coaster model complete
  - ❏ At least one loop
  - ❏ Banked curve
  - ❏ Lands a marble in a cup
- ❏ Sketch of roller coaster complete. Has labels for:
  - ❏ Greatest potential energy
  - ❏ Greatest kinetic energy
- ❏ All labels have a short caption explaining what the label is showing
- ❏ Sketch has a heading and (if doing this in class) all team members' names

DCI Standards Checklist:

- ❏ Roller Coaster Design:
  - ❏ Functions to deliver marble into a cup at the end of the run
  - ❏ Concepts of potential and kinetic energy are effectively applied in order to create an effective design

Cognitive Skills Rubric

	Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Designing Solutions	Applies no scientific principles and/or data to design, construct, and/or test a design of an object, tool, process or system.	Applies minimal scientific principles and/or data to design, construct, and/or test a design of an object, tool, process or system.	Applies adequate scientific principles and/or data to design, construct, and/or test a design of an object, tool, process or system.	Applies complete scientific principles and/or data to design, construct, and/or test a design of an object, tool, process or system.

Teacher Comments:

Final Score: Final Grade: