

# Amusement Park Ride: Ups and Downs in Design

Making the Connection  
Women in Engineering Programs &  
Advocates Network (WEPAN) Project  
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## Sports

1. This unit has students design and build foam tubing roller coasters.
2. The design process integrates kinetic and potential energy concepts as they test and evaluate their designs that address the task as an engineer would do.
3. This activity has a resource page that provides background information.

Grades 7 & 8 (suggested)

### Objective

The goal is for students to understand the basics of engineering design associated with kinetic and potential energy to build an optimal roller coaster. The marble starts with potential energy that is then converted to kinetic energy as it moves along the track. The diameter of the loops that the marble will traverse without falling out is dependent on the kinetic energy obtained by the marble.

### Skills & Standards

1. Modeling, testing, evaluating, and modifying a design.
2. Invent a product to meet a need.
3. Use science, math and engineering principles to design and optimize the product.

### Activity Outline

#### Materials required:

- 5-7 6' lengths of foam pipe insulation tubing cut in half lengthwise per group. (Home Depot sells this for .99 per 6' length.)
- 2 rolls of masking tape.
- 2 boxes round toothpicks (approx. 20 per group)
- 16mm marbles ( 5 per group)

#### Each group will need:

- container to catch marbles
- flexible tape measure
- scissors and ruler
- two different colored stickers: one marked "P", the other "K"

This activity needs a large work area. Each group needs about 6' x 6' of space.

#### Time frame:

- Part 1: 50 minutes
- Part 2: 50 minutes

### Overview of Presentation

#### Briefly explain engineering. (See Presenter's Guide for more detail.)

Engineers use scientific information to design and create useful and fun things. In designing and creating, the engineer goes through a problem solving process in which both math and science are important components.

#### Introduce the activity to the students.

Have a general discussion about amusement park rides, focusing on roller coasters. What do the students know about these rides? What else is similar to roller coasters? (matchbox & hotwheels tracks)

#### Begin the activity.

Before doing the activity, present the '*problem*' and '*who wants to know*'.

#### Do the activity.

Break the class into groups of 2-4 students. As the students work on the activity ask them to note the locations in their designs where the kinetic and potential energies are the greatest.

#### Reflect on the activity.

After the activity is completed, spend time discussing what was discovered and learned. Look at the sizes and number of loops that were used in the design. What are the advantages and disadvantages of the different options? How does the potential and kinetic energy play a role?

#### Career Connection

Discuss what types of jobs are involved with developing and producing roller coasters. Asking '*Who can help you solve the problem*' may get students to think about the type of people who would know.

## Activity: Staying on Track

The students will design, build, and perform tests on prototype roller coasters, analyze the test results, and use the information gathered to decide which design is optimum. The activity has been developed based on a traditional engineering design process which pose key questions – all identified in boldface type, that help the students approach the problem as engineers.

### **PART 1: Design and Preliminary Testing**

**What's the problem?** Every section of a roller coaster has different characteristics. Some portions have very tight turns while other sections have more gentle curves and turns. Each scenario has its limits for whether or not it will work. Lead a discussion about kinetic and potential energy. See Activity Resource Page and *Worksheet 1: Reference Diagram*. Worksheet 1 can be shown on an overhead or given to students.

**Who wants to know?** The city of Wahoo wants to build a new roller coaster ride on their town common as part of the celebration of their 300<sup>th</sup> year. For consistency with the round number, they want the design to be as 'loopy' as possible while keeping the cost to a minimum. They are looking for engineering designs that optimize the ratio (inches of loop diameter)/(material costs) and are aesthetically pleasing (look good!).

1. Hand out *Worksheet 2: Building Guidelines* to all of the students. Review the task and design criteria.
2. Break the class into groups of 2-4 students.
3. Give each group a copy of Worksheet 2, one marble, a container to catch the marble, one foam piece, one toothpick, and a one-foot piece of masking tape.
4. Have each group design and test a preliminary prototype.
5. As they test, each group should be planning their final design and the amount of materials that will be needed. They should sketch their ideas out on paper and fill in quantities of materials on in *Worksheet 3: Cost & Evaluation Sheet*. After 20 minutes, have the students return the materials from the preliminary prototypes and obtain the materials listed in Worksheet 3 from the "store" (An adult assistant helping with the distribution of materials). If this is done at two separate times, the materials can be ready for students when they arrive for the second meeting.

### **PART 2: Final Design and Testing**

**How can you help solve the problem?** Designing and testing a variety of loops, and the materials required to make them will help students understand. By prioritizing loops and cost of materials, an effective and aesthetic engineering design can be built.

6. Additional materials may be purchased during the first phase of design and testing, about 30 minutes. Once materials have been obtained from the store, they may not be returned or exchanged at the store.
7. Allow 10 minutes to finalize designs. Give each group one "P" sticker and one "K" sticker. Remind groups to use the stickers to mark the places on their roller coaster that have the greatest kinetic and potential energy.
8. When time is up, have each group step back from their roller coaster. Test each roller coaster individually by having a team member release the marble to go through it. Remember, each roller coaster must be able to stand alone and the marble must travel completely from start to finish. Two tries are allowed per roller coaster though more testing can be included if time allows.
9. Identify an "aesthetic rating". Have each group look at all of the roller coasters and come up with an aesthetic rating (1-6 if there are 6 groups with 1 being the best). Based on the group responses, the leader will announce the rating.
10. Have groups measure the diameter of each loop in the roller coaster and total the cost of purchased materials. Add the values to Worksheet 3.
11. Have students compute the loop diameter to cost ratio, then add the aesthetic rank.
12. After all groups have completed the tests, come to a consensus as a class about the results. Lead a discussion on observations about effective and non-effective solutions. Was there a stronger design/construction that seemed to work? How did potential and kinetic energy play a role?

**Will your suggestion(s) work?** Along with justifying a best design, did your group consider structural integrity? Is the ride safe for people to go on?

**Who can help you solve the problem?** What type of information or knowledge is needed to understand roller coaster design? The structural support is important information to make the ride safe. Transfer of energy between potential and kinetic is what makes the ride fun and feasible. Mechanical and Civil engineering have strong backgrounds in structures. Almost all engineering disciplines work with transfer of energy. Engineers also need to deal with issues such as cost and aesthetics.

**Engineering Summary:** Finish with a discussion about how students approached the problem like engineers.

## Activity Resource Page

### Background Information for Activity Leader

Roller coasters at amusement parks utilize potential energy and kinetic energy. Typically the roller coaster car is pulled up by a motor, gaining its initial potential energy. Once at the peak point, there are no motors connected to the car in anyway. The car begins its winding and looping decent along a track that has been designed to safely transfer the potential energy into kinetic energy while making it a thrilling ride.

If the car is going through a loop-de-loop, and does not have enough kinetic energy, the car will not stay on the track as it reaches the peak of the loop.

Potential energy is measured as  $PE = m \times g \times h$  where  $m$  is the mass of the object,  $g$  is the gravitational force, and  $h$  is the distance above the reference point where the mass starts.

Kinetic energy is measured as  $KE = (m \times V^2)/2$  where  $m$  is the mass and  $V$  is the velocity.

Ideally, all the potential energy is converted to kinetic energy. This never holds true, as some of the energy is lost to friction. Because of the loss of energy, the peak of the loops must be lower than the initial starting point of the car. See Worksheet 3 for a reference diagram.

### Questions to Ask

As you go through this activity with the students you should have them continually think about the potential and kinetic energy of the system. Where are they maximum and how do they compare? Ask questions that prompt those comparisons.

Explain to the students that engineers can be involved in production, design, development, research, marketing and consulting. While they are doing the activity, ask them in which engineering role they are involved.

Q: Where is the potential energy greatest in your system?

A: Potential energy is greatest where the marble is at its highest location.

Q: Why do most roller coasters have corkscrew turns instead of loop-de-loops?

A: It takes a lot of kinetic energy to make it all the way around a loop-de-loop. Corkscrew turns (twisty downhill turns) simply use the potential energy to gain speed through the turn.

Q: How does the track have to be designed to keep the car on in corkscrew turns?

A: The track has to be designed so that it is at an angle, tilting inward, instead of level with the ground.

### TIPS

Involve local experts to enhance the activity. Contact an engineering school at a local university, WEPAN at [www.wepan.org](http://www.wepan.org), or the Society of Women Engineers at [www.swe.org](http://www.swe.org).

### Potential Safety Issues

None

### Vocabulary Words

Kinetic energy – energy associated with motion of an object

Potential energy – energy an object has because of its relative location

Gravitational force – force exerted between the earth and an object that attracts the object toward the earth

### Expanding the Activity

1) Have students research either the history or safety of roller coasters. When was the first loop-de-loop used?

2) Have students calculate the potential and kinetic energy of the marble at several locations along their tracks.

### Additional References

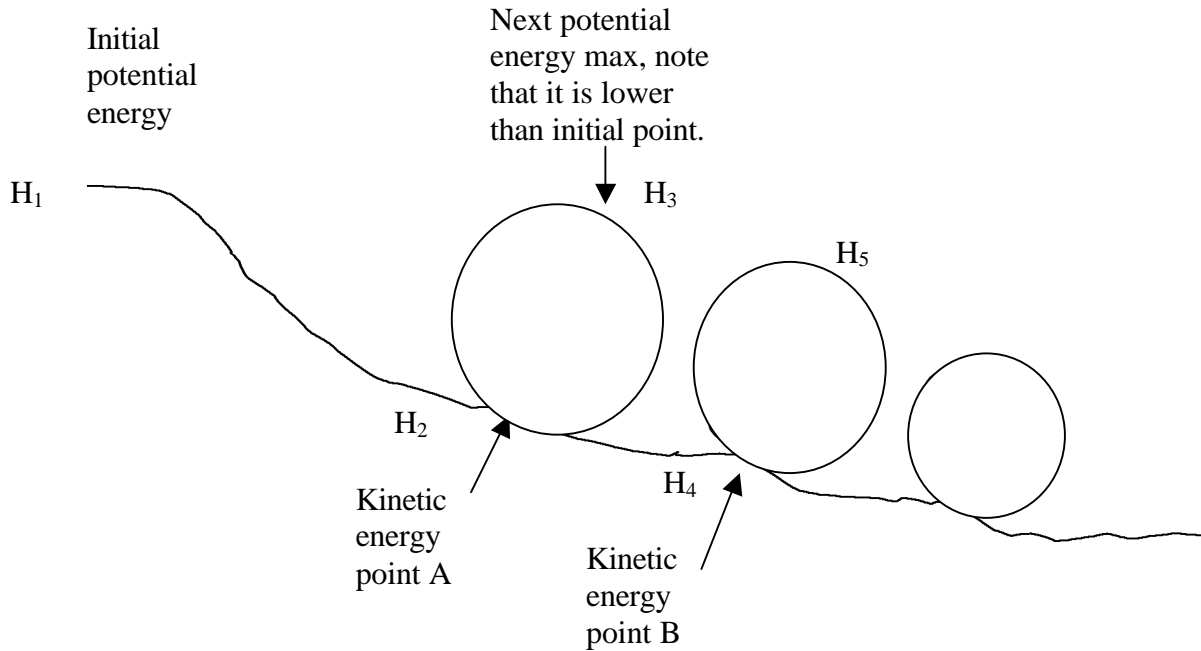
<http://141.104.22.210/Anthology/Pav/Science/Physics/book/home.html>

<http://www.rcdb.com/> (roller coaster data base)

[http://www.worldofcoasters.com/roller\\_coaster\\_history/](http://www.worldofcoasters.com/roller_coaster_history/) (roller coaster history)

<http://www.landfield.com/faqs/roller-coaster-faq/part2/> (roller coaster terms)

# Worksheet 1: Reference Diagram



Ideal Kinetic Energy at point A       $KE = PE = (\text{mass}) \times (H_1 - H_2) \times (\text{gravity})$

Ideal Kinetic Energy at point B       $KE = PE \text{ at } H_3 + KE \text{ at } H_3$   
 $= (\text{mass}) \times (H_3 - H_4) \times (\text{gravity}) + (\text{mass}) \times (\text{velocity at } H_3)^2 / 2$

If the marble has little or no velocity at  $H_3$  then the kinetic energy is negligible and the kinetic energy at point B is a function of the potential energy, or height difference from the top of the previous loop-de-loop to the start of the next one.

## Worksheet 2: Building Guidelines

### TASK

To design and construct a roller coaster based on the criteria below that results in the greatest total of loop diameter inches at the lowest cost with the most interesting design.

### DESIGN CRITERIA

1. The marble must travel the entire length of the roller coaster to be considered.
2. One or more loops may be in the design. The total number of inches of all loop diameters is used.
3. Roller coasters must be self-supporting. (Tape and design enable the roller coaster to stand on its own.)
4. Only materials listed below can be used.

Team Score = Total cost of materials purchased *divided by* total loop diameter inches *added* to the aesthetic rating.

Materials: Your team may use only these materials:

6' pieces of foam tubing

Toothpick(s)

Masking tape (sold by the foot)

Your team may purchase up to 6 pieces of foam tubing.

### Cost of Materials:

--Foam Tubing: \$1.00 per 6' piece

--Toothpick: \$0.10 per toothpick

--Masking Tape: \$0.10 per foot

**IMPORTANT:** Your final score will be based on the total cost of materials purchased (not total cost of materials used in final design).

## HAVE FUN & DESIGN WELL!

Sketch your design on the back of this page.

## Worksheet 3: Cost & Evaluation Sheet

Team Name: \_\_\_\_\_

Members: \_\_\_\_\_

**Supplies purchased:**

<i>ITEM</i>	Quantity	Amount	Total
<i>Foam Tubing:</i>	_____ 6 ft. sections	@ \$1.00 =	\$
<i>Toothpicks:</i>		@ \$.10 =	\$
<i>Masking Tape:</i>	_____ 1 ft. sections	@ \$.10 =	\$
"K" kinetic energy sticker	1	No charge	
"P" potential energy sticker	1		
		<b>Total Cost:</b>	\$

**Total Loop Diameter Inches:** \_\_\_\_\_

**Aesthetic Rating:** \_\_\_\_\_ (1-6, with 1 having the best look)

**FINAL TEAM SCORE**

**Cost & Aesthetic Ratio**  
(total cost divided by total loop diameter inches added to the aesthetic rating divided by 10)

$$\begin{array}{ccccccc}
 & \text{(total cost)} & & & \text{(aesthetic rating)} & & \\
 \text{-----} & & + & \text{-----} & = & \text{-----} & \\
 & \text{(total loop diameter)} & & 10 & & & 
 \end{array}$$

**Team Rank:** \_\_\_\_\_

(lowest cost & aesthetic ratio wins)

