BALLS & TRACKS

KELVIN® Stock #651666

DESIGN IT! ENGINEERING IN AFTER SCHOOL PROGRAMS

Education Development Center, Inc.

Design It! Engineering in After School Programs

Balls and Tracks

Center for Science Education
Education Development Center, Inc.

Kelvin LP ◆ Farmingdale, NY

Lead Author: Charles Hutchison
Project Director: Bernie Zubrowski
Development Team: Charles Hutchison, Catherine McCulloch, Bernie Zubrowski
Editing and Design: Kerry S. Ouellet
Illustrator: Catherine McCulloch

We would like to thank the following individuals and groups for their contributions to the development of the *Design It!* projects.

EDUCATION DEVELOPMENT CENTER, INC.: Judith Opert Sandler, Carrie Traub, Silvia Tracanna, Melissa Hogue
NATIONAL INSTITUTE OF OUT-OF-SCHOOL TIME: Ellen Gannett, Lillian Coltin, David Alexander
PROJECT EVALUATORS: Campbell-Kibler Associates (Pat Campbell, Lesley Perlman, Leslie Hoey, Earl Hadley)
ADVISORS: Deanna Banks Beane, Yolanda George, Ellen Wahl, Ronald Todd, Joyce Newhouse, Kenneth Cray
COMMUNITY RESOURCE PROVIDERS: Sherry Kanode (Conn.), Andrea Woodus (Md.), Maria Cabrera (Mass.), Sharon Schweninger (Penn.), Kathryn Nelson (Mo.), Stacey Dahlstrom (Minn.)

LOCAL PILOT TEST SITES:
Agassiz Community School, Cambridge, Mass.
Agassiz Community Center, Kids Corner Program, Jamaica Plain, Mass.
Atrium School, Watertown, Mass.
Burbank After School Program, Belmont, Mass.
Community Arts Center, Cambridge, Mass.
Curley Afterschool Program, Jamaica Plain, Mass.
East End House Community Center, East Cambridge, Mass.
Graham and Parks Alternative Elementary School Summer Camp, Cambridge, Mass.
Hawthorne Youth and Community Center, Roxbury, Mass.
Hernandez Community School, Jamaica Plain, Mass.
Jackson Mann Elementary School, Brighton, Mass.
McCarthy Town School, Acton, Mass.
Spontaneous Celebration Afterschool Program, Jamaica Plain, Mass.
Watertown After School Program, Watertown, Mass.
YMCA, Cambridge, Mass.

SCIENCE CENTERS (Science Centers provided training and support for the community agencies listed below them. We thank the staff and children at all of these community centers.)

Baltimore Museum of Industry: Margaret Leonard, Pat Richardson
Catholic Community School: Heather Klemkowski, Sister Josephann Wagoneer
Dundalk United Methodist Child Care: Laura Foust, Addie Finn
Mary Frances Ministries: Elizabeth Langmead, Morgan Smith
Play Centers, Inc.: Justine Hoakum, Nicole DiBitonto
Play Keepers: Maxine Seidman, Sharon Stenner, Bob Smith
Progressive Life Center: Sheila Roberts
Roland Park Elementary After School Program: Kathleen Cain, Adele Murray, Tanya Harcum
YMCA: Mary LaCasse, James Thompson

Table of Contents

Overview

The *Balls and Tracks* project is an engineering challenge based on the designs of a ski jump and a roller coaster. Given specific materials the children will create a series of games involving a ball rolling through a series of twists and turns, just like an amusement park ride. During this process, the children will learn to anticipate how the ball will behave in various track shapes and configurations. They will come away from these activities with an increased understanding of the forces of motion and with a practical sense of how the materials they are using affect each other.

People who work extensively with materials eventually come to know a great deal about what can and cannot be done in their medium. Although they may not be able to explain how they know what they know, their knowledge is based on direct experience with handling the materials. In this project, the children will develop that same kind of intuitive knowledge about these materials while problem solving and working together to design a roller coaster. In addition, they are asked to use words to describe what they know about how this device works. Both the intuitive knowledge and the children's attempts to put their conclusions into words are excellent preparation for more formal science or engineering studies (in school and elsewhere), which use the experimental process and rules of "evidence" to form a scientific understanding of how things in our world work.

Materials

The materials recommended for this project have been tested by children ages 8–12 years. Most of the materials are generic in type, so virtually any brand will work as well as another. Be particularly careful when purchasing the pipe insulation, however (see details below). Generally, you should not give alternative materials to the children until you have tested them yourself.

Below is the master list of the materials children will need to complete all of the activities in this project. Each particular activity contains a list with amounts specific for that activity. Items marked with a [*] are available directly from Kelvin (see order form on page 67).

For each team

- 12 feet of foam pipe insulation
- 2–4 marbles (1/2-inch glass*, wood, and metal)
- 2–4 empty juice cans or paper towel rolls
- 4 empty metal coffee cans (or equivalent)
- 1 large, empty cardboard box
- furniture, boxes, blocks, etc.
- pencils, paper, and card stock
- Popsicle sticks
- yardstick or measuring tape
- pennies, nickels, quarters
- stiff paper (oak tag, index cards, file folders)
- masking tape* and/or string
- markers, paint, and construction paper

For the whole group

- stopwatch

For the program leader

- scissors
- craft knife
- chart paper

Here are some roles you might use:

Builder: Connects the pieces of track together. *All team members are builders all the time, unless they are actively fulfilling another role.*

Chief Engineer: Directs the team effort. Settles disputes between other team members. Takes measurements where appropriate and keeps records. Responsible for ensuring that all materials are used safely.

Other roles that should be shared among all the team members are listed below. Remember that each child may have more than one role.

Materials Coordinator: Collects initial materials for the project. Checks all materials to ensure they are working properly. Searches for additional materials that would solve problems as they come up.

Ambassador: Watches and talks with other teams to see how they solved problems with their designs.

Presenter: Presents the experience and the findings of the team to the whole group. Responsible for knowing what each team member thought or contributed to the design and construction process.

Watch out for children who dominate their team and exclude others from the process. Be alert also for children who disengage or willingly spend whole sessions collecting the ball after testing, while others do all the constructing, adjusting, and releasing of the ball.

To help ensure that everyone remains engaged and has a fair chance to participate, restate the job descriptions at the beginning of each session and be sure the children know who is officially assigned to each role for that period of time. Roles should be switched at least at the beginning of each session, and possibly in the middle as well.

Management of the Activities

Pacing

Some of the activities in this project could stretch out over two or even three sessions. Although some children may be able to put together a particular ski jump or roller coaster very quickly, the challenge is to refine its design and to discover the principles of its use. Therefore, try to motivate the children to continue working beyond their initial successes so that they take the time to troubleshoot and test their designs.

One technique that allows you to have more control over the pacing of the activity is to break for discussions fairly often. This allows you to get the children back on task if their attention has wandered. It also allows you to intervene in social problems within or between the teams. It is recommended that you break for discussion at least every hour, and that you never allow a session to run its full course without having a short group discussion or debriefing.

At first, children will resist stopping their activity to talk, particularly if they are having fun. But if you read the section on discussion (page 7), the hints within each activity, and the longer notes in the *Implementation Guide to Design It! Projects*, you will find useful strategies for making the talking portion of these projects as rewarding for all as the "doing."

After repeated attempts, children may be ready to give up. If this point arrives, offer a hint or clue that will get the children over the hump and allow them to resume being successful with the device. The Guiding the Activity section of each activity offers suggested solutions to common construction and design problems.

Discussion

The guidelines for each *Design It!* activity suggest that you hold a formal discussion with the children at some point during each day of hands-on work. We call this a *Discussion Circle*, and it is recommended that, during this time, the children *move away from their materials* and sit in a circle or group to talk about what they have achieved or noticed so far. If you or the children are new to this format, this discussion time should not be very long (5–10 minutes at most), but it should become a regular part of your *Design It!* routine from the very beginning.

The importance of "talk"

When children talk about what they are doing they discover much more about the project than if they only do the hands-on portions. When they talk, children have to reflect not only on *what* they did but also on *how* they did it and why. They have to think about their actions and about their thinking. This kind of discussion is sometimes called *reflective*, and it is one of the most powerful tools for bringing the learning process out into the open.

Talking openly about how they solved (or didn't solve) a problem serves several useful functions for children. It allows them to:

- share and celebrate what they know and what they have succeeded in doing;
- acknowledge what they don't know and what they cannot succeed in doing;
- hear what other people thought or did in a similar situation; and
- piece together their thinking (about engineering solutions or decisions) in a way that they are not yet experienced enough to do for themselves.

It is very important that these discussions be a positive experience for the children, a chance for them to share, think out loud, and feel good about their contributions. Avoid calling only on the articulate children or the first to respond. Try also to make time for the less verbal children to say what they can about their experiences. After all, they need the most practice. Avoid telling a child that he or she is either "right" or "wrong" about something; it closes the door for other ideas and approaches from that child or other children. Thank and praise children for contributing in a respectful and thoughtful way. Sharing ideas should be its own reward—it is not a way to show who is right and who is not.

? Specific questions are often suggested to help you lead your discussions. A question mark icon, as shown here, will help you identify where these questions are located in the text.

The importance of "non-talk"

Discussions during this project will strengthen the children's language skills. However, there are other ways to communicate and explain that do not use words. Throughout the discussions that you have with the children during this project, encourage them to use hand signs, drawings, made-up words, and any other creative strategy that they need to get their points across. Do not allow the conversation to be restricted only to those children who already have good English language skills. It is important that children learn the common words for things and ideas, but their lack of vocabulary should not get in the way of their feeling knowledgeable and involved in the problem-solving process.

SAFETY

Please discuss with the children the acceptable use of marbles during these activities. With clear rules and codes of practice in place and with normal supervision of the group, there is no reason this activity could not be perfectly safe for your children. However, make it clear from the very beginning that the following rules apply and do not allow children to participate in this project if they are unwilling to abide by these rules:

- Always use good sense and consideration towards other people.
- Marbles may be used only to roll on the track.
- The materials are to be used only for the purposes described on the Challenge Sheets.

SAFETY

Safety messages appear throughout the activities when necessary. You will be able to find them easily by looking for the safety icon at left.

IMPLEMENTATION GUIDE

The above issues and procedures are developed in more detail in a separate publication called *The Implementation Guide for Design It! Projects.* It is strongly recommended that you purchase this guide and consult it before carrying out any *Design It!* project with your children.

Activity 1: Building a Ski Jump

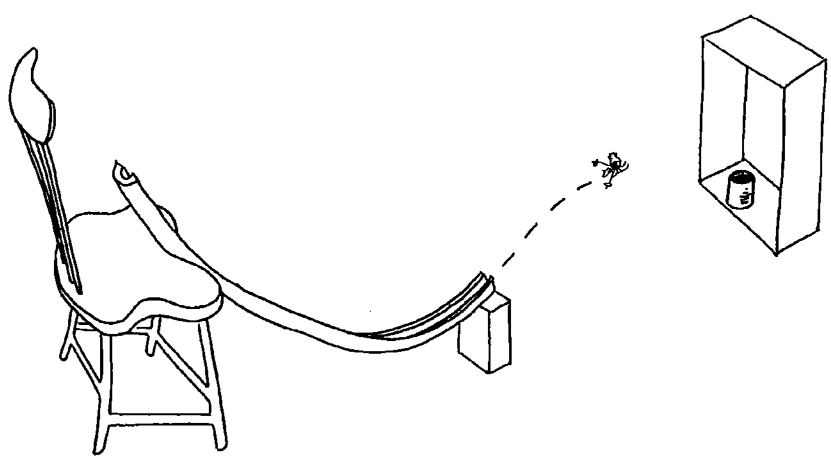
Have you ever watched ski jumpers at the Winter Olympics or skateboarders on a ramp? If you have, you know that you can become airborne if you get enough downhill speed and then turn up into a short uphill section. See if you can make the marble do the same with the track provided.

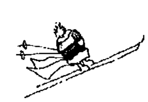
What Materials Do I Have?

- foam insulation tubing (6 feet total length)
- glass marbles
- 1 Popsicle stick
- empty coffee cans (or similar) to use as targets
- yardstick or measuring tape
- masking tape and string
- 1 large, empty cardboard box
- *Data Sheet—Activity 1*

The Challenge

Design a ski jump that makes your marble jump into a can without bouncing on the floor. How far can the marble jump and still land in a can?





Data Sheet—Activity 1

Team Members: ____________________

____

____

Make a diagram of your best ski jump below. show how high your released the marble for each target can.

Activity 1: Building a Ski Jump

Preparing Ahead

- Gather the materials for this activity. Slit the insulation tubing down the middle to make two half-round troughs from each. You will see that there is already a slit down one side. Open this up with your fingers and use sharp scissors or a craft knife to cut the other side. Try to make the halves as even as possible.
- Make your own ski jump before doing the activity with the children. See what works and what problems arise. Doing a test run will make it much easier for you to anticipate any problems the children may experience.
- Before the children begin, think about how to arrange the teams within the space you have available. Each team will work with 6 feet of track. The marble may jump almost 3 feet beyond that, so you need about 10 feet of floor space or corridor for each team to be comfortable. If you have a lot of free wall space, then you can space the teams out along this and the children can tape their tracks along the wall and floor. If you do not have enough wall for this, each team should attach the high end of their track to a table or chair (or wall or file cabinet) and use other furniture or books to support the rest of the track (see illustration on page 11).
- Prepare a folder and some drawing paper for the children to make diagrams of their ski jumps before they take them apart at the end of the session.
- Make enough copies of the Challenge Sheet, including *Data Sheet—Activity 1,* for each team.

Introducing the Activity

Being an engineer

Set the scene by telling the children they will be forming teams of *engineers* to build games using marbles and tracks. Ask them what they think engineers usually do and how they work. Have the children brainstorm some of their ideas, record them on chart paper, and then hang the list on the wall. Write down whatever the children say, but be on the lookout for the ideas mentioned in the first section of the *Implementation Guide to Design It! Projects.*

Ski jumps

Ask the children if they have ever seen a real ski jump in the Winter Olympics, either on TV or in person. If you can, find a picture in a magazine or on the Internet of a skier flying through the air. Ask the children, "What's pushing this person through the air?" and "How did he or she get to be going so fast?"

Materials

FOR EACH TEAM

- foam insulation tubing (6 feet total length)
- glass marbles
- 1 Popsicle stick
- masking tape and string
- empty coffee cans
- yardstick or measuring tape
- 1 large, empty card-board box
- *Data Sheet—Activity 1*

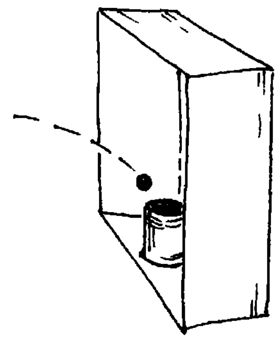
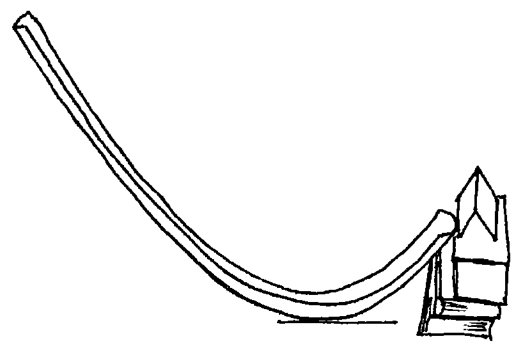
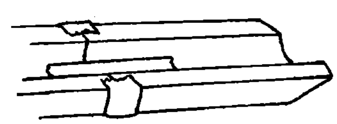
FOR THE PROGRAM LEADER

- craft knife

Troubleshooting

It should be possible to make a glass marble jump between 2 and 3 feet from the end of the ski jump. Table 1.1 gives you some hints on what might be happening if the children are having trouble achieving this result.

Table 1.1

Problem	Possible Solution	Image
Marble gets lost when it misses the can.	Set up a large cardboard box behind the farthest can to catch stray marbles.	
Marble won't jump up off the end of the track.	Make the last 6–12 inches of track turn upwards. Use a box or books to hold the end up. Adjust the angle of the upturn to find the best arrangement.	
Track wobbles or will not stay in constant position.	Where possible, fix the track securely to walls or furniture using masking tape or string.	NO DIAGRAM
Marble jumps off track where two pieces are joined.	Make sure the joint is smooth. Lay tape lengthwise along the trough over the joint.	

Activity 1: Building a Ski Jump

Rationale

Many children and adults have ridden on a roller coaster at an amusement park. Few have tried a ski jump. Anyone who has ridden a bicycle or skateboard over a ramp or a bump in the road, however, knows that if you are going fast enough before you hit the ramp or bump, you suddenly feel as though you have defied gravity and *taken off!* Activity 1 introduces the children to the materials they will use throughout the project and introduces the issue of "take-off," which will come up again and again as they move on to designing different roller coasters during this project.

This activity, and those that follow, introduce children to basic engineering challenges. Children have to arrive at workable arrangements using the materials available to them. For the ski jump (and later, the roller coaster) to function well, the tracks must be supported so they stay in a fixed position.

Introducing the Activity

A skier flying through the air after taking off from a ski jump is similar to a car, bike, or skateboard going over a speed bump or off a ramp at high speed. If you feel comfortable, you might extend this initial conversation by drawing out the children's personal experiences with any of the devices that launch a person upwards in the way that a ski jump does.

Leading the Activity

Questions

This is your opportunity to model the types of questions that you want the children to ask themselves as they are engaged in the activity and that are important to the design process (such as those on page 16). The purpose of the questions is to get the children to observe how their construction works and how changes that they make affect its functioning.

Pacing

The children will probably prefer to play with the materials in an uninterrupted way from the beginning of the session to the end, and may resist when you break into their playtime for a Discussion Circle. Nonetheless, it is strongly recommended that you keep control of the pace of the activity and intervene in the way described. Although exploration with the materials is essential to the learning process, stopping from time to time to consider what is happening is also an essential part of making sense of the experience. By looking at other people's ski jumps and finding something

- The **higher** you release the marble, the faster it travels at the bottom of the slope.
- The **steeper** the down slope, the faster the marble travels at the bottom...
- ... but if the slope is **too steep**, the marble bounces off at the curve.
- The **faster** the marble travels at take-off, the **farther** it goes (for a fixed launch angle).
- There is **one particular launch angle** that sends the marble farthest.

Keep track of these statements on the *What Works?* chart (or create a new chart as described below). Add items to the list whenever there is general agreement about them. If there is controversy about a particular point, you might keep a separate list or you might add it to the list in such a way that it is clearly temporary until it is finally admitted or rejected altogether based on later experience. Another option is to have a chart with two columns labeled: "What we know FOR SURE" and "What we THINK we know."

It is important that you do not say whether you think a proposed finding is right or wrong. Your role is to insist that before a statement is accepted as true, it must be tested. So if someone says that the best angle for the launching end of the tube is about halfway between straight up and level, you can ask: "How do we know that? Have you tested it? How could you test it?"

Consistency and accuracy

For most man-made objects and devices to be considered "useful," they must function in a consistent manner. Part of the engineering challenge for the children is to get the ball to fall in a can most or all of the time. Given the nature of the materials and the support system, this may not happen.

When they are testing their set-ups, you should encourage children to find out how consistent their tracks are. Does the ball always travel the full course of the tubing without falling off? If not, can they adjust the track so the ball stays on for the full ride?

Then, can they get the ball to fall into a can every time? This is a matter of accuracy. It is partly dependent on a consistent track and where and how the ball is released. If the track is at the right angle and the ball is released consistently at the same height and in the same way, it is highly likely that it will land in a can making the system accurate.

Once a product has been designed, constructed, and given its final tests, engineers need to carry out multiple testing to see if the product is consistent in its function and that it performs within the prescribed limits.

EXTENSIONS

High jump

If time allows, have each team set up a high jump at the end of their tracks.

- Fold a piece of stiff paper (index card, oak tag, or file folder) in half so it can stand on its own.
- Place the folded paper (high jump bar) on top of books (see Figure 1.2) and have the children release a marble to see if it can jump over the bar. Change the position of the bar and the shape of the track until you get the marble to jump as high as possible.
- The bottom curve of the track should be taped to the floor so as to make measuring the height of the jump easy and standard for all teams. Measure the height of the jump from the floor to the tip of the bar that the marble jumped over (see Figure 1.3).

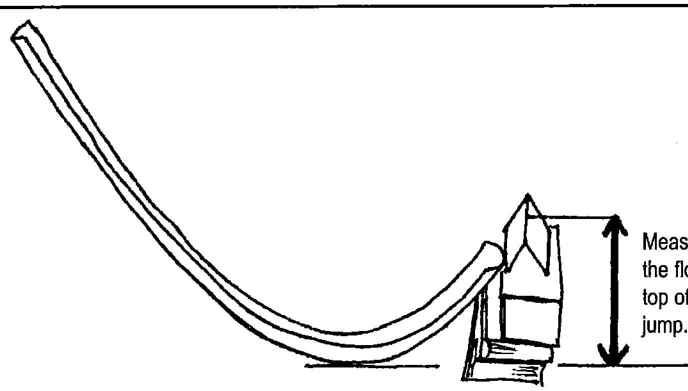


Figure 1.3

Which marble works best?

Investigate whether one type of marble is a better jumper than another.

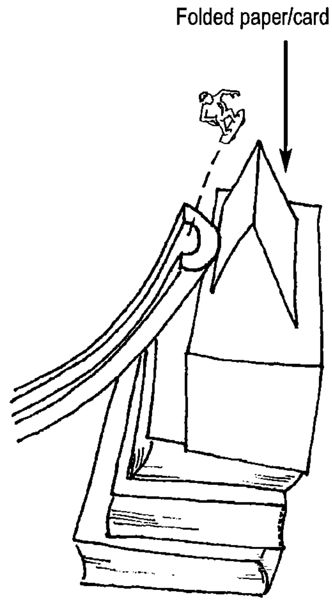


Figure 1.2
High jump.

Activity 2: Creating Hills and Valleys

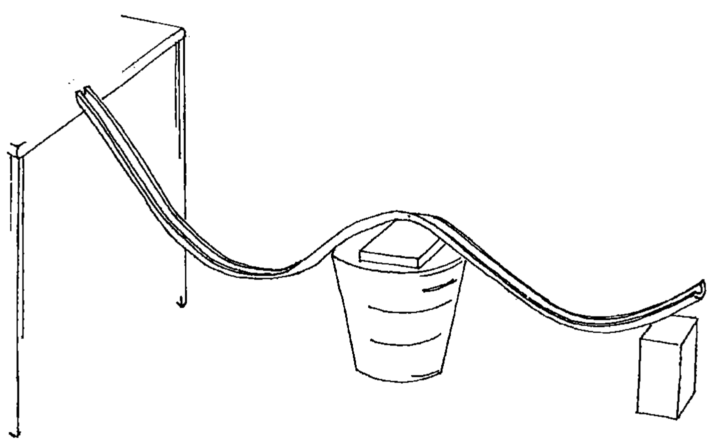
Now you are going to use the same materials to make a roller coaster with hills and valleys. Try to keep the marble on the track as long as possible while creating the most exciting ride you can.

What Materials Do I Have?

- foam pipe insulation (9–12 feet long)
- marbles (glass, wood, metal)
- empty juice cans or paper towel rolls
- masking tape and string
- 1 empty metal can
- 1 large, empty cardboard box
- *Data Sheet—Activity 2*

THE CHALLENGE

Set up a roller coaster with as many hills and valleys as you can arrange. Make the ride last as long as possible.



Data Sheet—Activity 2

Team Members: ____________________

____

____

How high was the highest hill that your marble traveled over (going upward)? __________ inches

What was the height of all of your hills added together? __________ inches

Make a diagram of your best track below. Write the measurements on each hill.

Activity 2: Creating Hills and Valleys

PREPARING AHEAD

- Cut up enough pipe insulation so each team has a total of 9–12 feet (including their tracks from Activity 1).
- Make up sets of different-sized marbles made out of various materials (wood, metal, glass, etc.). Put each set in a plastic bag, one for each team.
- Look in magazines or on the Internet for pictures of roller coasters or make copies of Figures 2.4 and 2.5 on page 36 to share with the children.
- Make enough copies of the Challenge Sheet, including *Data Sheet—Activity 2,* for each team.

INTRODUCING THE ACTIVITY

Ask the children if any of them have ever been on a roller coaster. Have them describe their experiences as well as the shapes and sizes of the rides. What were the good parts, which parts were scary, and so on? Then ask them if they can think of any other rides or experiences that are similar. (They may mention water slides or swing sets or elevators going down fast.) Finally, ask them to describe what they think the best shape is for a really exciting roller coaster ride.

Tell the children that they are now going to make their own roller coaster rides. Explain that they must make a ride that is both exciting (for the marble) and that lasts as long as possible.

Check in about the role assignments. Rotate or reshuffle them to keep things fair. Make sure all the teams have enough materials and set them to work.

THE CHALLENGE

Set up a roller coaster with as many hills and valleys as you can arrange. Make the ride last as long as possible.

LEADING THE ACTIVITY

While the children are constructing their roller coasters, walk around the room and talk to them about what they are noticing and how it is working for them. Here are some questions you could use to start the conversations with:

?

- How did you make the track sections stay together?
- How did you hold your track in place— (keeping the hills up and the valleys down)?
- How did you stop the marble from jumping off the track?
- What is the best shape for a hill?

Materials

FOR EACH TEAM

- foam pipe insulation (9-12 feet long)
- marbles (glass, wood, metal)
- empty juice cans or paper towel rolls
- masking tape and string
- empty metal can
- large, empty cardboard box
- *Data Sheet—Activity 2*

Leading the Discussion

After the children have assembled a working arrangement and tested it, call them together away from their materials for a Discussion Circle. There are two kinds of questions you can ask:

Construction Questions refer to the details of how the roller coaster was actually put together. Typical questions in this category are:

- How did you get the pipes to stick together?
- Did you have a problem with wobbling? How did you solve that?
- How did you hold the track in place at the top of a hill or the bottom of a valley?

Design Questions may help you and the children assess whether their tracks are the best possible designs.

- Where do you release the marble? What happens when you release it higher/lower?
- How high is the highest hill you can have?
- What's the best shape for a hill (e.g., steeper on one side than the other)?
- Can you have a high hill after a low hill?
- Is there a limit to how many hills you can have?
- How high did the marble climb altogether?
- Do different marbles travel at different speeds on this track?

Whenever a child gives an answer to any of these questions, you should be ready to ask the standard follow-up questions, "How do you know that?" or "How did you find that out?" These questions should be asked in a genuine spirit of interest and not as a challenge. You really do want to know what actions or observations lead the child to his or her conclusion, and you also want to reinforce the point that opinions should always be backed up by direct evidence.

As the discussion progresses over the next few sessions there are a number of findings that the children may discover about this system. Continue to add to the *What Works?* chart, constantly checking in with the children about whether they still believe each finding to be true. Here are several findings they may come up with.

- A marble can never climb higher than the level it started at unless it is pushed.
- Each hill must be lower than the one before it.
- Faster marbles climb higher.
- Rougher surfaces (of marble or track) slow the marble down.
- Too much contact area (between the marble and the track) slows the marble down.

Activity 2: Creating Hills and Valleys

RATIONALE

The challenge this time is to make the ride last as long as possible; you do not want the marble to reach the end of the track at top speed. If it has enough energy to jump off the end, then that energy would be better used climbing another hill and making the ride last longer. In this activity, therefore, the children have to change their definition of a "good ride" and see what they can change about the track and the ball to make the ride last as long as it can.

INTRODUCING THE ACTIVITY

In this activity, a good ride means *lasting as long* as possible rather than *moving as fast* as possible. Explain this to the children and suggest that they try to add as many hills and valleys to their tracks as possible (thus creating a roller coaster) to make the ride last much longer than the ski jump they designed in Activity 1.

LEADING THE ACTIVITY

Allow the children some free-play time with the materials. Since the new track is longer than the ski jump and the new design uses both up-slopes and down-slopes, the children will have to solve some new problems. Let them invent their own shapes for the coaster, the only requirement being that they get as many hills and valleys into the track as they can and still have a marble roll from one end to the other.

Encourage the children to rearrange the parts of their tracks from time to time and experiment with different hills in different places. Tell them to keep doing this until they are sure they cannot include any more hills or make the ride last any longer.

Encourage the children to experiment with different-sized marbles as well as those made of different materials to see whether the marbles travel farther or not as far as the standard glass marbles. Make time for them to draw their final track shape and record its measurements on *Data Sheet—Activity 2*. Keeping good records is an important aspect of being a designer or engineer.

LEADING THE DISCUSSION

Begin with questions about the materials themselves to get conversations going with the children. When the children have shared all they have to say about basic construction techniques, steer the conversation towards design questions—issues relating to the best possible design or use of the materials.

SCIENCE BACKGROUND

Friction

Whenever the marble moves on this track, friction steals some of its energy (and turns it into heat or sound). So, every time a marble climbs a hill, it has slightly less energy than it had at the top of the last hill. This means that each hill in the sequence must be slightly lower than the one before it. In this system, friction depends on three things:

- The nature of the materials themselves (glass, metal, foam, tape, etc.).
- The angle of the track (the steeper the slope, the less the friction).
- The shape of the track (on a narrower track, the marble may rub against the sides).

Scientists don't understand everything about friction, but most people would agree that the rougher the surfaces (high friction), the less speed the marble will have when (and if) it gets to the end of the track. More difficult to see directly is that as the track gets steeper, the friction decreases because the ball presses less heavily on the track at steep angles. Also, no matter what the slope of the track, the heavier the ball, the more friction there will be (because the ball presses more heavily on the track). Whatever you can do to lessen the friction on the track, the faster the marble will travel.

ASSESSMENT

Changes in behavior and attitude towards design and science tend to happen slowly in children. As they continue to work on this project keep an eye out for the following details of how individuals (or the group as a whole) approach the design problems they come up against.

- Do the children make changes to their designs to improve how they work?
- Do they make these changes to only one factor at a time?
- Do they keep data and records?
- Do they focus on what they actually see happening rather than what they think should happen?

EXTENSION

Big hill, little hill, big hill

Do hills always have to get smaller as you go down the line, or can the size order vary in any way you like? Ask the children what they believe about this question and see if there is interest in testing it. Especially ask if anyone would like to try to create the following sequence:

big hill ⟶ little hill ⟶ big hill

It is possible, but tricky, to set up the arrangement above (also see Figure 2.3). If the marble is going fast enough to clear both the second and third hills, it may fly off the track at the crest of the second hill. Only if it lands

Activity 3: Adding Loops and Spirals

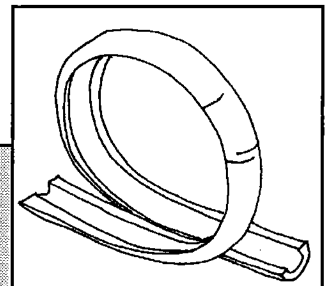
All your track designs, thus far, have been "in line" rides. But things get exciting when you make a ride that defies gravity. For this challenge, you will make rides that include loop-the-loops and spirals.

What Materials Do I Have?

- foam pipe insulation (12 feet)
- marbles
- empty juice cans or paper towel rolls
- masking tape and string
- 1 large, empty cardboard box
- *Data Sheet—Activity 3*

Loops

Rides that go over the top (vertically) are called Loops.

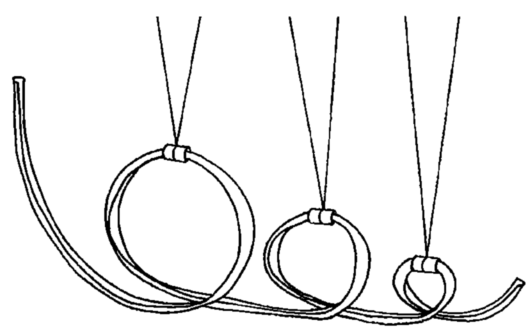


Largest Loop Challenge

Design the largest successful over-the-top loop you can with the available materials.

What Do I Do?

1. Connect all of your pipe into one continuous track.
2. Fix the track to the wall or furniture so that it makes a complete loop (circle). Use tunnels to keep the track fixed in place, if necessary.
3. Release a marble at the top of the track and see if it makes it around the loop. If it does not, adjust the track until it makes a successful trip around.
4. Make the loop larger until you reach the largest loop that a marble can get around.
5. Try different marbles to see if one type works better than the others.
6. After you've found the biggest loop, see instead how many small loops you can fit into your track.
7. Keep a record of your loops on *Data Sheet—Activity 3.*



Data Sheet—Activity 3

Team Members: ____________________

____

____

How high (diameter) was your largest successful LOOP? ________

How many complete LOOPS did you put successfully into your track? ________

How wide (diameter) was your largest successful SPIRAL? ________

How many complete SPIRAL TURNS did you put successfully into your track? ________

Draw your best LOOP track	Draw your best SPIRAL track

Activity 3: Adding Loops and Spirals

PREPARING AHEAD

- Try out both challenges yourself before the children begin the session to give you an idea of the problems they may run into. Spirals, although similar to loops, are more difficult to make and use successfully. If you are using a kind of insulation pipe that is different from the type recommended, check whether the pipe bends smoothly. Thinner insulation pipes crimp when you bend them too sharply.
- If the teams have not had 12 feet of track for the previous challenges, prepare to give them an extra section this time to make at least that length.
- There are two related challenges in this activity. It is recommended that you introduce them separately to the children, so that they try one at a time. Later there will be a chance to combine the two forms into a single roller coaster track.
- Make enough copies of the Challenge Sheet, including *Data Sheet—Activity 3*, for each team.

LOOPS

INTRODUCING THE ACTIVITY

Ask the children if they have ever seen anything do a loop-the-loop in real life (not on a movie)—a real roller coaster, a skateboard stunt rider, an airplane. Hold up a section of track in a loop shape and ask them if they think it is possible for the marble to do a loop-the-loop in a track made of these materials. If they think it is possible, ask them to explain how a marble could go around a loop and not fall off. Encourage them to speculate about what details need to be in place for the loop to work. Make a list of their ideas on a sheet of chart paper.

After this discussion has run its course, tell the children to disassemble any roller coaster that may still be in use because they will use the same materials, plus some extra track, to make the new shapes.

Check in about the role assignments and rotate or reshuffle them to keep things fair. Then explain the first challenge.

LARGEST LOOP CHALLENGE

Design the largest successful over-the-top LOOP you can with the available materials.

Materials

FOR EACH TEAM

- 12 feet of foam pipe insulation
- marbles
- empty juice cans or paper towel rolls
- masking tape and string
- 1 large, empty cardboard box
- *Data Sheet—Activity 3*

SPIRALS

Introducing the Activity

When you have done all you can with the loops, turn your attention to spirals. Gather the children together again and ask them if they have ever, in real life, seen anything travelling fast around a spiral. Their most direct experience may be on the playground or at a water amusement park. Both often have spiral slides. Ask them now to try to imagine what their body felt like as they went down one of these slides—what forces did they feel as they went around the turns?

If they think carefully, they may remember that as they sped around the turns, their body felt as though it was being pulled out the sides of the chute—they seemed to defy gravity and slide along the walls of the chute instead of the bottom. Now ask them to imagine what would have happened if there were no sidewalls to the spiral chute. Most will agree that without sidewalls, they would have been thrown off the chute at the first turn. Ask which direction they would have been thrown, and perhaps they will all agree that it would have been outward—away from the center of the spiral curve/circle.

Once they have visualized the situation, draw their attention to Figure 3.1, showing two extremes of how you could set up a spiral track for a marble. One is very steep, like the spiral staircase or the stripes on a candy cane, and the other is very shallow, like the coils of a slinky or a spring that is not stretched out very far.

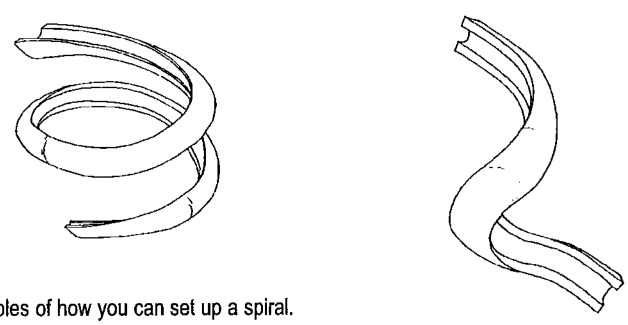


Figure 3.1
Two examples of how you can set up a spiral.

Ask the children to think about which would be more fun to ride on if they were the marble. What would be good and what would be disappointing about each ride? Make sure that they have taken down any previous roller coasters, explain the challenge, and set them on their way.

USEFUL TERM

Banking: The sidewalls on the curves of high speed auto racetracks, or on a bobsled or waterslide track, that keep the car or rider from flying off the track at high speed.

Loops

- The faster the marble is traveling, the bigger the loop it can get around.
- If you have several loops in a row, they must get smaller as you go down the line.
- You need a lot of steep track before a large loop or a set of small ones for the marble to make it all the way through.

Spirals

- The faster the marble is traveling around a curve, the more steeply the track must be banked.
- If the marble flies off the top of the track, you need more banking.
- If the marble falls off the bottom edge of the track, you need less banking.

Activity 3: Loops and Spirals

RATIONALE

Loop-the-loops and spirals are fun to set up and fun to watch in action. Sometimes the marble won't quite make it over the loop, and at others times, it will travel through too fast for the eye to follow. Spirals are similar to loops in some ways, but because the marble is always traveling downhill (at least slightly), it does not always have to have a lot of speed at the outset. Getting the shape and slope of the curves precise for both loops and spirals is what makes this an interesting set of challenges.

LEADING THE ACTIVITY

Stability

The stability of the track is a problem the children must tackle constantly with these materials. If the track is wobbly or unstable, the force of the moving marble will tend to distort the track and may even cause the marble to jump off the track. A wobbly track may also cause the marble to slow down more than it would on a stable track, and it might make it hard to get the same results over and over again with a certain track shape.

Children have the opportunity in this activity to do what engineers must do all the time—make materials that are not perfect for the job do what the engineers want them to do. In addition to taping the track to chairs and boxes, the children can experiment with using string to hold the track up (or down). For a rigid loop, try taping the track along a flat wall or window. Juice tubes work well for holding the track snugly in such an arrangement.

Speed

Going into a loop, the marble needs a lot of speed to get over the top and down the other side without losing contact with the track on the way down. To give the marble the necessary speed, children may need to use much (maybe most) of their limited amount of track for the run-up before the loop itself.

Spirals present a different problem. Since every part of a spiral track slopes slightly downward, the marble continually picks up speed as it goes down and does not need to enter the spiral at high speed. This means that there may not have to be much of a run-up section of track before a spiral.

LEADING THE DISCUSSION

It is hard to believe that a marble can travel upside down or sideways on the track and not fall off. The same is true of a real roller coaster or an airplane flying upside down. But the children have observed that it clearly can happen.

Activity 4: Running the Obstacle Course

Before this activity, you were thinking of your marble as a car on a roller coaster ride. Suppose you think of it now as a horse on a steeple chase course. Let's give the horse some obstacles that a roller coaster car couldn't handle—fences and gaps!

What Materials Do I Have?

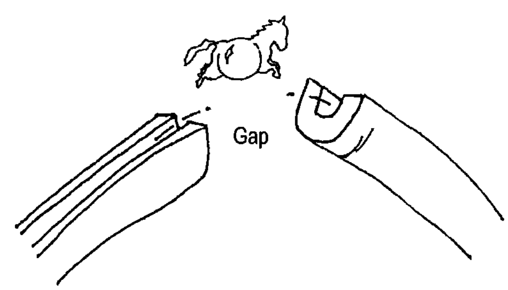
- 12 feet of foam pipe insulation
- marbles
- empty juice cans or paper towel rolls
- masking tape
- 1 large, empty cardboard box
- pennies, nickels, quarters
- stiff paper (oak tag, index cards, file folders)
- string
- *Data Sheet—Activity 4*

THE CHALLENGE

Create the highest fence and the widest gap you can make the marble jump over.

What Do I Do?

GAP



1. Take your track apart and set it up again with a 3-inch gap somewhere along the route. Fix the track to the wall or furniture so that the marble ("horse") jumps over the gap and continues on to the end of the track.
2. Increase the size of the gap and adjust the track so that the horse can still get across. Keep increasing the size and adjusting the shape of the track before and after the gap until the horse just makes it across each time.

Data Sheet—Activity 4

Team Members: ________________

____

____

1. How high was the highest fence that your marble (horse) jumped over? ______
2. How wide was the widest gap your marble (horse) jumped over? ______
3. Draw a diagram of what the track looks like with the fence and the gap.

Activity 4: Running the Obstacle Course

Preparing Ahead

- There is not a lot of preparation needed for this activity. Only a few extra materials are needed to stop the marbles ("horses") from jumping the track as they jump over or collide with the fence. Have various types of paper, card stock (file folder), or other material on hand that will deflect the marbles back onto the track if they start to jump off. If you can find a picture in a magazine or book to show horses racing over an obstacle course, it would help you set the context for this challenge.
- Make enough copies of the Challenge Sheet, including *Data Sheet—Activity 4*, for each team.

Introducing the Activity

Ask the children if they have ever seen a steeple chase—a horse race in which the horses must jump over fences and water holes on the way to the finish line. If you collected pictures, show them now.

Then ask the children to consider how their marbles (horses) are going to be able to get over the obstacles since, unlike real horses, marbles do not have legs and cannot jump on their own. Ask them to think about their previous experiences with the marbles on this kind of track. Where on the track does the marble seem to want to "jump"? A marble does not have energy inside itself to jump over things, but sometimes the track seems to give it energy to "take off." The challenge in this activity is to make a track that gives "take-off" energy to the marble in certain places—and as much of it as you can achieve!

The Challenge

Create the highest fence and widest gap you can make the marble jump over.

Leading the Activity

As always, ask the three basic questions as you watch the children working on their obstacle courses.

- What works (and what doesn't)?
- What have you tried (and what happened)?
- What has worked for other teams? (Has the ambassador been looking at what other teams have been doing?)

Materials

FOR EACH TEAM

- 12 feet of foam pipe insulation
- marbles
- empty juice cans or paper towel rolls
- masking tape
- large empty cardboard box
- pennies, nickels, quarters
- stiff paper (oak tag, index cards, file folders)
- string
- *Data Sheet—Activity 4*

Activity 4: Running the Obstacle Course

Rationale

Making the marble (horse) jump over obstacles and stay on the track requires considerable ingenuity, so this challenge demands that children use whatever materials and ideas they can come up with to make it all work.

Introducing the Activity

Not all children have seen, or paid attention to, a horse race. But many have seen a skateboarder, inline skater, or biker doing stunts (either in person or in video games and movies). We have chosen to illustrate a horse jumping over the obstacles, but if you think other images would be more helpful in setting the context, by all means substitute.

Leading the Activity

What's fair?

Some teams may discover that you can combine the fence and the gap challenges together! One way is to put the fence immediately *before* the gap—so the horse jumps over both together. Another way is to put the fence right *after* the gap, with the jump-off side of the gap **higher than the fence**. As written, the challenge does not disqualify either solution, but both of them may seem *unfair* to some children. The solution is rather ingenious, and it is good to give children every chance to be clever designers. But, if someone in your group designs a track that uses either of these strategies, and if someone else calls foul, you should put the matter to the whole group, asking them, "Is this a fair way to meet the challenge?"

During that discussion you might want to think about the following points.

- **Putting the fence right before the gap** and having the horse successfully jump over them both is probably more difficult to achieve than if the fence and gap were separated by a downhill slope. Because of the added difficulty, this one may pass the test of fairness.

- **Putting the gap before and *higher* than the fence** is fair as long as the size of the gap is still measured in a purely horizontal way. The vertical drop should not count as part of the size of the gap.

Activity 5: Designing a Super Coaster

Make a roller coaster that uses all the features you have worked with already—hills, valleys, loops, spirals, fences, and gaps—and finishes with the marble jumping off the end of the track into a metal can. Choose a challenge: Make the **fastest** ride or the **longest** ride. Record the time it takes the marble to travel from beginning to end.

What Materials Do I Have?

- 24 feet of foam pipe insulation (the track from two teams' previous roller coasters)
- assorted marbles
- empty juice cans or paper towel rolls
- masking tape
- 1 empty metal can
- 1 large, empty cardboard box
- string
- materials for decorating the track

The Challenge

1. Make a roller coaster using 24 feet of track that has all of the following features:
   - 360 degree loop-the-loop
   - 12 inches of tunnel
   - 1 spiral with 2 complete turns OR 1 spiral and 1 extra loop
   - a 1/2-inch fence OR 4-inch gap
2. Make the marble land in a can at the end of the track five times in a row.

Fastest Ride: The winning team will be the one whose marble travels this course the FASTEST—from release (no push) to striking the inside of the can.

Longest Ride: The winning team will be the one whose marble travels this course the SLOWEST—from release (no push) to striking the inside of the can.

Activity 5: Designing a Super Coaster

PREPARING AHEAD

The teams double up in this final session to allow more space for these larger roller coasters and to give more track to each design. Consider using this final design as a showcase: Invite parents or other children to see the different designs in action, and talk to the children about how they might explain to their audience how the different parts of their designs work.

INTRODUCING THE ACTIVITY

If you have not already shown the children pictures of real roller coasters, do so now. If you have access to the Internet, do a search on the phrase "roller coaster" and you will quickly find hundreds of photos of fascinating and exciting rides. Talk about the different features that you see in these designs—loops, spirals, and so on. Explain that most roller coaster cars are "powered" so they do not rely completely on gravity. That is why the designs can be so complicated and so long. Even so, with just the force of gravity, it is possible to make an exciting ride. An example of a super coaster is shown in Figure 5.1 on page 60.

Tell the children that they will now have a chance to put together everything they know about balls and tracks to create an "Olympic" coaster. After describing the challenges (fast or slow), ask the children which one each child would like to work on. Then, divide the class into design teams of five or six children, each child (wherever possible) working on the challenge of his or her choice.

All teams should use exactly the same amount of track (24 feet is recommended) and standard 1/2-inch glass marbles. Other materials are optional.

LEADING THE ACTIVITY

Any design is acceptable as long as all minimum conditions listed in the challenge are met. Encourage the children to decorate their tracks and give them names. Use a stopwatch to time each ride. The marble should be released as usual, by first holding it in place with a Popsicle stick at the top of the track and then pulling the stick away. On the command "GO!" children should release the marble and start the watch. The clock should be stopped when the marble strikes the inside of the metal can. Time the track several times—three times, if possible. Count the best time (fast or slow) as the qualifying run.

Materials

FOR EACH TEAM

- 24 feet of foam pipe insulation (the track from two teams' previous rollercoasters)
- assorted marbles
- empty juice cans or paper towel rolls
- masking tape
- 1 empty metal can
- 1 large empty cardboard box
- string
- 1 Popsicle stick
- materials for decorating the track

FOR THE WHOLE GROUP

- stopwatch

Activity 5: Designing a Super Coaster

RATIONALE

In this final activity, the children get a chance to put everything together in one super coaster. Their final designs should incorporate as many features as possible. The challenge is divided into two parts—fast and slow—in order to encourage different types of arrangements.

LEADING THE ACTIVITY

By this time the children should be pretty good at setting up the track and should not need a lot of help completing this challenge. Let them be as creative as your space or situation allows, including introducing new materials into the design in whatever way the children can make them work. Particularly, make time for them to decorate the track. This often brings children into the process who have not felt fully included up until now.

If the space and schedule in your center allows, let the children leave their final roller coasters assembled for a while so that other children and parents can see them. If you can arrange a show-and-tell time where the parents stop by to see a demonstration, that would be an extra incentive for the children to take care with their designs and to think about what they have learned.

LEADING THE DISCUSSION

Thinking and talking about these design challenges is just as important to the children's learning as actually doing them. Having the children make a presentation to others is a very good way to find out what they know and what they have learned during this project. If you do decide to have the children present their designs to an audience from outside of your program, talk with them about what is important to remember when giving such a presentation. Here are some things to bear in mind for such a conversation.

- Be sure the tracks are set up firmly and accurately before the audience arrives.
- Decorate the tracks. Add tunnels and bridges and other ornaments to the basic designs to make the whole construction more interesting.
- Let your audience try out the tracks; audiences usually enjoy participating.
- Explain how the tracks work. Describe what was hard and what was easy to do.
- Talk to the audience slowly and clearly; the audience really wants to hear what you say.

Appendix

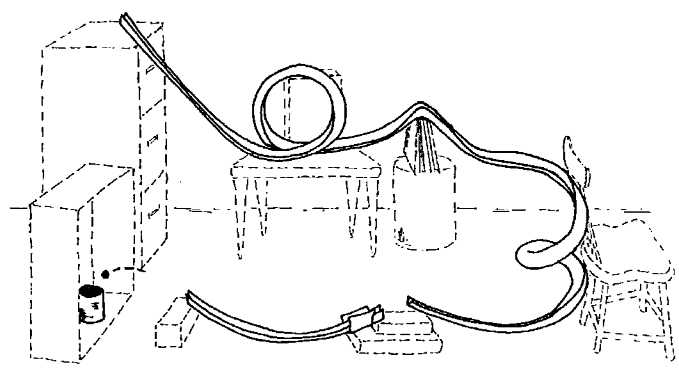
Design It! Engineering in After School Programs

Balls and Tracks

Dear Family:

For the next few weeks, your child will be designing roller coasters using foam tubing and other simple materials as part of *Design It! Engineering in After School Programs*. All of the children will test each of their designs and make changes based on the results. In the process, we hope they will learn valuable engineering and science skills that will be useful to them in school and in other areas of their lives.

We may need your help finding additional materials to help the children. Would you please look over the list of items below. If you are able to donate any of these items to the center, we would appreciate it. Please check with the program leaders about particular needs before bringing things in, and if you have any other items that you think might work well, please suggest these also. After the activities start, you might have a discussion with your child about his or her roller coaster. Together you may think of other materials that you can donate or suggest to us. We welcome your input.



Materials Requested:

- juice cans (with the top and bottom removed)
- wooden, plastic, glass, or metal balls (the size of small marbles)
- string
- paper towel rolls
- Popsicle sticks
- coffee cans
- cardboard boxes

If you would like to extend your child's experience with roller coasters at home, here are some suggestions:

- Gather materials for your child to create his or her own roller coaster.
- Read books about roller coasters. You can find interesting information on amusement park physics at the following Internet address: http://www.learner.org/exhibits/parkphysics/coaster.html
- If you have the opportunity, visit an amusement park.

If you have any questions about these activities, please let us know.

KELVIN®.com

PHONE: 1-800-KELVIN-World™ (1-800-535-8469) or 1-631-756-1750
FAX: 1-800-756-1025 or 1-631-756-1763 **HOURS:** 9:00am-5:00pm E.S.T.
E-MAIL: kelvin@kelvin.com
MAIL: KELVIN®, 280 Adams Blvd., Farmingdale, NY, 11735 USA

Billing

Name (Please Print or Type)	KELVIN® Customer Order No. 01 - _ _ _ _ _ _ _ _ _ _	Date
School/Dept.	School E-Mail Address	School Fax Number
Address	Personal E-mail	
City, State, Zip Code	(Area Code) School Phone	(Area Code) Home Phone

Shipping If Different Than Above

Name (Please Print or Type)	School/Dept.	Phone
Address	City, State, Zip Code	

Payment Net 30 Days or Check in Advance - **Payable to: KELVIN Technology®**

We also Accept MasterCard or VISA

[ ] Purchase Order	Purchase Order No.	Authorized Signature
[ ] Check	Check No.	Authorized Signature
[ ] Credit Card: Vias, MasterCard, American Express Exp. Date:	No. _ _ _ _ - _ _ _ _ - _ _ _ _ - _ _ _ _	Authorized Signature

Order We request that minimum orders be at least $20.

STOCK NO.	DESCRIPTION/PAGE NO.	QTY.	UNIT PRICE	TOTAL
870037	game marbles* (9/16" diameter)		1.45	.
340067	masking tape (1" W x 60 yds)		2.75	.
470065	snap blade craft knife		1.15	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.

See Kelvin catalog for more information and availability of bulk discounts.

SALES TAX applicable to individuals, companies & NYS residents.

SHIPPING CHARGES are 7% of the order or a minimum of $7. Additional shipping charges will apply to orders shipped via trucker, overnight, overseas or for hazardous materials.

RETURNS: Please call for a return authorization number. A restocking fee may apply.

Avoid duplicating orders! Please **DO NOT FAX AND MAIL** your order in (unless asked to by KELVIN® Staff. If so, mark the order 'Confirmation.')

Prices are subject to change without notice. We will notify you only if the price exceeds 10% of the total order. **Prices in this catalog are discounted for educational institutions**; retail customers may have to pay more. Some items are not available to the public and are sold only to schools.

SUB-TOTAL	.
Applicable Sales Tax *Not Applicable to Public Schools*	.
Shipping Charges	.
GRAND TOTAL	.

Thank You for Your Order