Learning Objectives

- Students will comprehend basic physics concepts that are applicable to roller coaster construction, including potential energy, kinetic energy, and momentum.
- Students will apply their understanding of those concepts as they construct and text their roller coaster.
- Through a cycle of building, testing, observing and revision, students will gain an experiential understanding of fundamental physics concepts and the basics of successful roller coaster

Vocabulary:

Momentum - a force that keeps something moving in the direction it's already going in
Speed - how fast an object is moving
Energy- how much force an object has because it is moving (explored below)

Activity 1: Introduction to energy, kinetic (motional) and potential (stored)

Ask the students what they think energy is. Note that this is a tricky question. A quick look on wikipedia yields the following Feynman quote "*It is important to realize that in physics today, we have no knowledge what energy is. We do not have a picture that energy comes in little blobs of a definite amount."* But let them think about it and talk about it. One could use phrases like "energy is motion or things happening" or the "ability to make them happen".

Next ask the students to name different types of energy. Have them, or help them, write down the types they come up with on their sheet of paper. Help them categorize the energy into motional (me jumping up and down, water flowing over a dam, wind blowing) and stored/hidden (gravity or stuff high up, a battery, food)

Now with your bouncy balls do experiments. Here are some things you can try.

- Have the students hold their ball high but still. Ask them if it has energy. Let them drop it. Ask them if the ball had energy when they let go (hopefully they will say yes). Explain that this means that it had energy when it was still but up high- just the energy was potential/stored/hidden. This energy is gravitational energy.
- One student can hold both balls and drop them from different heights. Which goes faster? Which bounces higher? Why?
- Let them compare dropping a ball and throwing a ball of the ground. Which has more energy? Where does the energy come from?
- Put the ball on floor or table. Give it an initial velocity by knocking it with finger. First, knock it slightly, then hard. See for which time it can go faster. Where does the energy come from?
- Let the student throw the paper. Ask them where they the energy came from. Go as far back as you like. For example: paper moving-> student/muscles contracting ->food ->animal ->plant->sun.

Activity 2 Marble Roller Coasters

Discussion:

- Tell students we will be building marble roller coasters and show them the parts we will be using: the foam tubing (roller coaster track), marbles, tape.
- Demonstrate how the marble can roll in the track
- Show students the construction techniques from steps 1-3 in 5 minutes or less

- Identify the 4 big mistakes (step 6)

Step 0: Have students design their roller coaster by drawing it on a piece of paper.

Step 1: Begin by placing a strip of tape on the end of a piece of tubing and affixing it to a smooth, flat surface. Then place another piece of tape across the first piece to secure the tubing in place.

Let your students know that the higher the roller coaster is when it starts, the more energy your marble will have when it begins rolling. More energy means that the students' marble will be able to travel farther and faster. For this reason, I allow my students to stand on chairs, but not on tables.

Step 2: Connect the tubes.To connect two pieces of tubing together, lay a piece of tape along the middle of the tube with about half of it hanging off of the end. Pick up the second piece of track and use your finger to press the tape onto it. Use your fingers to smooth out the tape. And finally, tape the underside of the tubes together, too.If students are working together, then one person can hold the track pieces in place while the other tapes them together.

It's important to have nice smooth connections. You should definitely emphasize this with students because no matter how awesome the roller coaster looks, if the connections are sloppy, it won't work well. 

Step 3: Secure to a flat surface. Most of the time, your students' roller coasters will need to touch down onto a flat surface like the floor. To secure the tubing to the floor, use two smaller pieces of tape and secure the sides of the roller coaster. Do not tape across the entire tube. Leaving the track clear of tape helps ensure that the marble will roll smoothly.

Step 4: Turning the track. And finally, show your students how to make turns. The track must be turned on it's side if the marble is travelling even moderately fast. In roller coaster construction, this is called 'track banking.'

This is a good opportunity to explain the negative effects of momentum. A marble travelling forward will continue moving in that direction because of it's momentum. If a curved track is not banked, the marble may fly off of the edge of the track. However banking the track allows the marble to run along the 'bottom' of the track. Once the turn is complete, the track should be straightened out.

Step 5: Make it awesome! A roller coaster that just goes in a straight line can be fun, but I find it much more satisfying to include exciting elements.

Loops can be created by securing the track to a flat surface, then bending the track upside down and securing the other end. You can explain that loops work because of centripetal force. Centripetal force is like momentum: it's when an object wants to keep moving forward, except that it's forced into a circular

path.

Hills can be made by securing the track to a flat surface, then lifting the middle of the track up and securing the other end. This is another good opportunity to illustrate the negative effects of momentum. If the hill is too small and the marble is travelling too fast, the marble's momentum will carry it up the hill and then continue its trajectory off the track.

Upside-down loops are created by taping a piece of track upside-down onto the end of a track, then curving the upside-down piece so that it becomes right-side up. In the photo with the upside-down loop, you can also see how to secure track alongside a wall by using a long piece of tape.

These are the most common roller coaster elements, but I've also seen funnels made of newspaper, jumps, tunnels, corkscrews, helixes, double and triple loops, suspended tracks, and configurations that don't have a name. Encourage experimentation!

Step 6: Mistakes and how to avoid them.

1. Bad connections. Remind the students that the tape needs to be smoothly applied.
2. Not enough energy. Marbles have a limited amount of energy, so encourage the students to plan their roller coaster according to how much energy the marble has. I often see students wistfully creating awesome-looking features that don't work because they do not account for how much energy the marble has. Start the coaster high and test regularly.
3. Too much momentum. Remember, momentum is the force that keep the marble going in the direction it's currently moving. Sudden turns or drops that do not account for the marble's momentum may result in the marble flying off of the track.
4. Not enough testing. This is the biggest mistake. I've seen students make awesome looking roller coasters, but because of a lack of testing, it fails right at the start. Emphasize the importance of constant testing. Always test a new addition. Always test before adding onto the roller coaster. If the marble is falling off of the track halfway through, then everything that is built after that point won't matter until the problem is fixed. Experiment, observe, and make corrections!