Marble Roller Coasters Lesson Plan

Materials:

Per group

3 3-ft long ½ pipe insulations
~ 3 ft. masking tape
1 cup to catch marble
1 marble
1 steel ball of a different weight (for older groups only)
1 stopwatch (a cellphone works well for this)

Vocabulary:

For Regular Lesson:

Engineer – A person who uses math, science, and their creativity to design something to solve a problem
Design – The plan for making something, the process of figuring out how to construct something
Criteria – What you have to do
Constraints – What you can not do
Speed – How far an object moves in a given time
Force - A push or a pull that acts on an object
Gravity - The natural force that pulls objects toward each other. On Earth, all objects are pulled towards the center of Earth.
Energy – The ability to do work
Potential Energy – The position of an object above the Earth's surface.
Kinetic Energy – The energy of motion

For Advanced Lesson with two different balls:

Evidence - Data used to support claims. Evidence is based on observations and scientific data.
Experiment - An investigation designed to find out how variables affect outcomes
Variable - Anything you can change in an experiment that might affect the outcome
Independent Variable - The variable you control the value of in an experiment

Lesson:

Preparing Students for the Design Challenge

1. Introduce Materials to Students - Tell them that they will be building roller coasters.
    - Have one set of materials for each group. Allow about 5 minutes to mess around with the materials.

- At the end of the 5 minutes, have students place the materials somewhere will they will not be tempted to play with them for the next section of the activity.

2. Introduce the parameters of the design challenge and the vocabulary words *criteria* and *constraints*. (The criteria are in italics, the constraints are in bold)
    a. Build a roller coaster with *2 hills and one loop*.
    b. Your marble **must not fall off** until it gets to the end of the track.
    c. Your marble *must land in the cup* at the end of the run.
    d. **You may only use the materials provided**.
    e. You may tape your run to furniture.
    f. You may test your design as you go.

3. Introduce the Focus Question:
    How can you get your marble to go the fastest and still land in the cup? (Kid Friendly)
    Within the parameters given, how can you optimize the speed of your marble? (Academic Language Version)

4. Have students set up notebooks with title, date and focus question –
    Title - "Building and testing Marble Roller Coasters."
    Focus Question – "How can I get my marble to go the fastest and still land in the cup?"

Activity – The Design Challenge

- Have students imagine some possible designs. On their own, have them draw two different possible designs in their notebooks.
    - This would be a good time to have a brief discussion on the difference between designing something and building something. Introduce the concept that engineers usually design things and then contract out the building to someone else.
    - Alternately, you could use this time to do a mini-lesson on how to draw like an engineer with labels and directional force arrows.

- Have students share their ideas with their group. After they have a chance to share, have students come up with a plan that they will try as a group. The plan could be one person's design, or it could be a combination of designs.
    - This is a good time to use a scaffold to ensure that every student has a voice in the discussion.

- Give students ~ 15 minutes to build their design. Allow them to test it as they go so they can make modifications as necessary.
    - It tends to work best if you give them a hard cap on the time.

Data Collection and Calculations

- Show students how to set up the data table in their notebooks and do their timed trials.

  Data Collection:

Trial #	Time in Seconds
1	
2	
3	
4	
5	
Total time	

- Have students do timed trials and record results

- Demonstrate how to calculate average time and average speed. You may want to allow them to use calculators for this part.

  - *Average Time =* $\frac{\textit{trial 1 + trial 2 + trial 3 + trial 4 + trial 5}}{5}$
  - *Average Speed = distance ÷ time*
    = Track length ÷ Average Time

Making Sense of Data

- Pose the following questions for students to talk about in small groups.
  - What specific things did you notice affected the speed of the marble? Where was it the fastest? Where was it the slowest?
  - What do you think is happening to the "energy" of the marble at its highest point? At it's fastest?
  - What do you think you could change to make your design better?

- Have a group discussion on the questions using either a science talk format or another group discussion format. Allow students to make errors in their reasoning to make space for adjustments in their thinking.

- At this point you will probably notice that students need some vocabulary words to help describe their thinking. Make note of the ones that they need and stop the discussion when they appear to have come to a standstill.

- Teacher input. Explain the concepts that the students are struggling with and introduce the relevant vocabulary; *kinetic energy* and *potential energy*. A pictorial input chart would work well at this point.

- Give students a chance to discuss what they now understand.

- Have students answer the focus question in their notebooks.
  - Focus Question - How can I get my marble to go the fastest and still land in the cup?
  - They may want to draw a diagram to accompany their written answer

Continue the Engineering Design Process (Time dependent, but highly recommended)

- Return to the "Activity" section of the process and begin again. It generally takes at least three different tries for students to work out the application of the principals.
  - Given what they now know, have them imagine a new design
  - Have them draw two new or modified ideas in their notebooks
  - Have them share out with their groups and pick a new design to build
  - Have them build and test their second/third design
  - Between designs provide students a chance to talk about problems they encountered and how they solved them in building their designs.
  - Note - This is a great way to celebrate learning from mistakes and to point out that that this is how engineers operate in that they don't expect to have a perfect design the first time. They just keep testing out new ideas and making improvement. Students tend to internalize this concept and apply it to other disciplines.