Marble Rollercoasters

Lesson Type: Engineering + Building
Target Grade: Elementary School
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Brief Overview/Challenge

This lesson will introduce the concepts of potential and kinetic energy, as well as briefly introduce the transfer of energy from potential to kinetic to the kids. We will also apply the idea of energy into building marble rollercoaster tracks for the kids to test out!

Teaching Goals

- Introduce the idea of energy
- Explain the difference between potential and kinetic energy
- Describe the conversion from potential to kinetic energy (energy is transformed from one type to another – it isn't created or destroyed)
- Work on the engineering and design process

Agenda

Agenda for engineering type modules should mostly follow this outline

- **Introduction and Examples** (10-15 min)
    - Ask students what they think energy is
    - Where do they get their energy from?
    - Demonstrations with rubber bands and bouncy balls
- **Build and test** (50 min)
    - Challenge 1 (~15 min) – Building a simple rollercoaster
        - Conversion of potential energy to kinetic energy
        - How will increasing or decreasing the starting height affect the speed and distance at which the marble travels?
    - Challenge 2 (~15 min) – Getting over a hill
        - How high should the initial drop be in order for the marble to get over a hill in the middle of the rollercoaster?
    - Challenge 3 (~20 min) – Getting through a loop
        - How high should the initial drop be in order for the marble to travel through a loop in the rollercoaster without falling?

    - Challenge 4 (~10 minutes) ---Momentum for Middle Schoolers
    - Extra Challenge-(time permitting)
- **Recap** (~5-10 min)

Materials

- Introduction/Examples:
    - Rubber bands
    - Bouncy balls
    - Cups
    - String
    - Water
- Building Roller coasters
    - Foam pipe insulation
    - Masking tape
    - Cardboard
    - Marbles

Lesson Introduction – rubber bands and dropping ball:

- Ask students what they think energy is
    - Where do they get their energy from?
    - Are there different types of energy?
        - Examples: Food = chemical energy, battery = electrical energy, person standing on a chair = gravitational potential energy
    - Define energy: “The ability to do work”
        - Food gives you energy to run and jump and play on the playground
        - Batteries give energy to electronics like the computer and cell phones
    - We will be working with mechanical energy to build our rollercoasters:
        - Kinetic energy – energy in motion
            - Ex. moving water or wind
        - Potential energy – stored energy
            - Ex. The gasoline sitting in the tank of your car
- Demonstrations:
    - Have the kids stretch out a rubber band
        - Explain that when the rubber band is stretched out, there is potential energy present
        - As soon as the rubber band is released, it is moving and therefore the potential energy stored in the rubber band is converted into kinetic energy
    - Have the students hold up bouncy balls at different heights
        - At the top, before the ball is released, the ball has potential energy
        - Once it is released potential energy is converted into kinetic energy since the ball is moving
            - Which ball bounces back up the highest?
                - This one had more potential energy to start out with

        - Where does the energy go once the ball stops moving?
            - It stops moving because of friction that reduces the amount of kinetic energy the ball has and over time, stops the bounces

    - Friction is a force that acts in the opposite direction of a moving object and reduces the amount of energy
        - Ex. When a car comes to a stop, friction between the brakes and wheels slows the car down
        - You can feel the force of friction by rubbing your hands together quickly
            - The heat that you feel is a result of friction
        - The rubbing action between two objects generates friction
            - The smoother the surface the less friction is generated
                - Ex. Rolling a ball on ice vs. a dirt path

Note to Mentors Before Building Rollercoasters:

- Each group of 2 kids should receive 4 halves of piping
    - Each challenge can be done with just 3 so suggest using 3 halves first before adding on the 4th pipe
- Make sure that all rollercoaster structures are FREE STANDING
    - The kids should not have to hold any of the pipes for the rollercoaster to work
- When taping the pipes together or to the cardboard make sure that the tape is laying flat on the pipe so it will not stop the marble from rolling past
- The marbles should stay ON THE TRACK throughout the course of the whole ride
    - It shouldn't jump from one side to the other! The riders need to survive the trip ☺
    - This is especially important for the hill and the loop
        - The kids need to balance the starting height – too high and the marble may fall off the track but too low and the marble may not have enough momentum to get all the way through

Challenge 1 – Building a simple rollercoaster

- Introduction:
    - Explain that we will be using the idea of converting potential energy to kinetic energy to make a rollercoaster track for marbles
- Procedure:
    - Using pipe insulation tubing and tape create a track of certain height to the ground
    - Tracks can be propped up against doors, tables, chairs, walls, etc. as long as it is FREE STANDING!
    - Encourage students to create their tracks at different heights
        - This can be done by taping multiple pipes together to create a longer track and placing it at a higher starting point
    - Use a stopwatch to time how long it takes marbles to travel from the top of the rollercoaster to the end of the track
    - Encourage students to test out different things
- Questions to ask:

- Which rollercoaster caused the marbles to travel the fastest down the rollercoaster?
- Which track caused the marble to travel the furthest distance?
    - The higher the height the faster the marble moves and the further distance it travels

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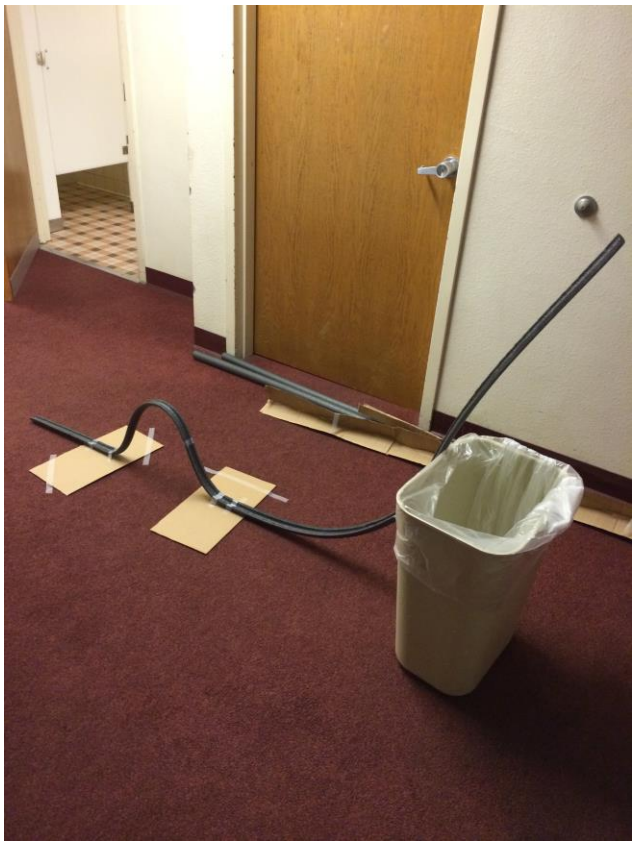
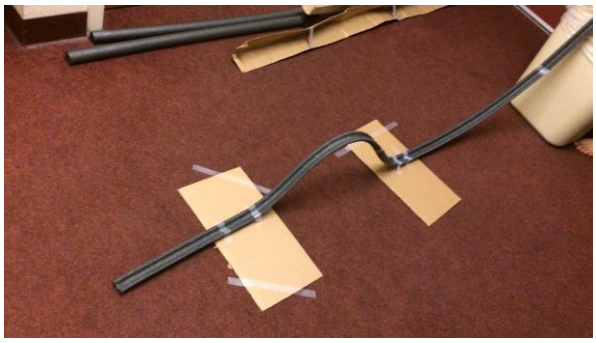
Challenge 2 – Getting over a hill

- Introduction:
    - What do you think needs to happen if the marble needs to get over a hill in the middle of the track?
    - Would more or less potential energy be needed at the beginning of the rollercoaster?
    - What happens if the hill is taller? What happens if the hill is shorter?
    - How can you increase or decrease potential energy?
- Procedure:
    - Similar to the last challenge, use the same materials to build a rollercoaster with a hill in the middle of the track
    - Start by creating a rollercoaster with a very short hill (5-6 inches tall)
        - How high or how steep should the starting point be to get the marble over this hill?
    - Continue to increase the size of the hill and play around with the starting height to see if the kids can get the marble over the hill

- The ultimate challenge is to see if the kids can design a track with a hill that is at least 1ft high and can get a marble over
    - Note: the height of the hill can easily be adjusted by moving the cardboard closer or further apart

- Questions to ask:
    - Did the original height from which the marble was released need to be higher or lower as the height of the hill increased?
    - Was more or less potential energy needed for each case?
        - The higher the height of the hill, the more potential energy is needed in order for the marble to have enough kinetic energy to get over the hill



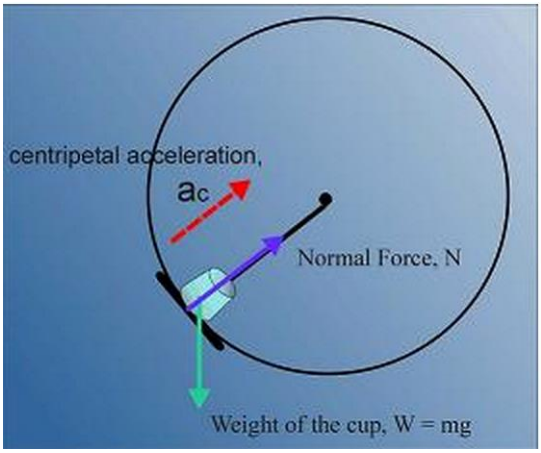


    - Note to mentors: Although the steeper the starting slope of the track is, the faster the marble will go, this also causes the track to be less stable and increases the chances of the marble falling off the track. On the other hand, the less steep the starting slope of the track, the more energy is lost due to friction.

Demo – Water Loop

- Before building the third part of the challenge with a loop in the track the mentors should perform the water-spinning demo to show why the marble is able to stay on the track when it is going through the loop
- Questions to ask:
    - Have the kids make predictions of what they think will happen to the water when the cup is spun.

    - Afterwards ask them to describe what they saw actually happen.
- Procedure:
    - The cups should already have holes poked in them with string attached
    - Fill the cups a little less than halfway with water
    - Spin the cup in a loop
        - This should be done fast enough that the water does not spill out of the cup



- SAFETY:
    - For all of the mentors, make sure when you're doing this demo that the kids are standing far enough back and not in the axis of the loop where they can get hit if the cup happens to fly off the string
- What to teach:
    - The main goal of this demo is to show the kids that the marble needs enough momentum (speed) entering the loop of the rollercoaster to get all the way through without falling off just like enough speed is needed in the demo for the water to stay in the cup.

Challenge 3 – Getting through a loop

- Introduction:
    - How much potential energy converted to kinetic energy is needed for a marble to travel through a loop?
    - Should the marble be moving faster or slower?
        - Does this mean there is more or less kinetic energy?

- Procedure:
    - Using the foam pipe insulation create a rollercoaster with a loop in the middle
    - See which groups can successfully create a track that allows the marble to get through the loop
        - The kids can choose the size of the loop that they want to make but mentors should help make sure the loop isn't too small or too big
        - If the kids are able to get the marble through the loop fairly easily, see if they can continue to build bigger and bigger loops and still be as successful

- Note to mentors:
    - If any of the groups are finished early, see if they can make a bigger loop
        - With the materials/ amount of track provided a loop up to 1.5ft tall is feasible
    - Another challenge to propose is making a roller coaster with 2 loops or 2 hills (maybe even one of each) if they would like

Challenge 4 –Momentum/Multiple Marbles-Advanced Students

Ask students if the think that energy is always conserved? Give the example of a car crash to show that it is not: in a head on crash both cars are moving with high speed and high kinetic energies but after they crash both cars are now still and have lost their KE. Momentum also describes how massive an object is and its motion but also takes the direction of the motion into account while energy does not. Explain to the students that and object moving up or down has the same kinetic energy but not the same momentum. Momentum is always conserved. What will happen when a moving marble hits a stationary one? What if they are different sizes?

- Challenge your mentees to create several collisions of marbles in their roller coasters and still have the rollercoaster be completed

More Background for mentors

- p=mv (p=momentum, m=mass, v=velocity)
- Marbles with more mass with the same velocity as smaller marbles will have a greater momentum. This means that when more massive marbles collide with smaller marbles the smaller marbles will move faster when leaving the collision than the larger marble did coming in.
- There are three types of collisions: elastic, inelastic, perfectly inelastic
    - Elastic-energy is conserved and momentum is conserved
    - Inelastic-energy is not conserved, momentum is conserved
        - The energy can dissipate as heat or friction
    - Perfectly Inelastic-a special type of inelastic collision where the objects colliding stick together following the collision

Extra Challenge

- Have your class work together to build one gigantic rollercoaster. See if you can get it to run!

References

- http://www.enwin.com/kids/electricity/types_of_energy.cfm
- http://www.sciencebuddies.org/science-fair-projects/project_ideas/Phys_p036.shtml#materials

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Summary Materials Table

- For Logistics' convenience, have a summary materials table for each modules at the very end of the lesson on a separate page
- Make sure to include a vendor link or picture to ensure that logistics buys exactly what you want

Material	Amount per Group	Expected $$	Vendor (or online link)
1/2” Pipe insulation	1 – 6ft tube per group of 2 kids	$0.78 per tube	http://www.thetoolworkshop.com/itplimited12pipeinsulationpr38058uw.aspx
Marbles	2-3 per group	$3/100ct marbles (+shipping)	https://www.google.com/shopping/product/2817235571292979615?es_sm=91&sclient=psy-ab&q=buy+marbles+&oq=buy+marbles+&pbx=1&bav=on.2,or.r_qf.&bvm=bv.62333050,d.cGU,pv.xjs.s.en_US.V_LfeUcmUN4.O&biw=1280&bih=641&tch=1&ech=1&psi=OTgVU7rXCMz1oAS84YHYDQ.1393899625077.3&ei=ezgVU_DnB83ioASV2oHACg&ved=0COICEKYrMBE
Masking Tape	1 roll per site	-	
Cardboard	3-4 pieces per group	-	
Rubber bands	1 per kid		
Bouncy Balls	2 per site	$6.28/ 48 balls	http://www.amazon.com/Glow-Bouncing-Balls-dozen-balls/dp/B003B7HYBC/ref=sr_1_3?ie=UTF8&qid=1393913662&sr=8-3&keywords=bouncy+balls+bulk