MeTEOR Learning Modules

STEM MEA (Model Eliciting Activity)

Designing a Roller Coaster

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CONNECTING THE DOTS

Designing a New Roller Coaster

Reflective Planning

Description/Summary of Lesson:
Students will complete research on current roller coasters to see how math and science are used in a real world setting for heights, angles and motion as they explore the physics exploited by engineers in designing roller coasters, including potential and kinetic energy, friction and gravity. Students will learn that all true roller coasters are completely driven by the force of gravity and the conversion between potential and kinetic energy is essential to all roller coasters. After completing research, students will make a scale drawing of a roller coaster they would like to design and construct to meet the requirements outlined in the proposal they will be given. For their roller coaster to be operational, it must be free standing, have at least one loop and carry a marble from the top of the roller coaster to the exit at the bottom. The model they make will be made from various types of paper and other items. Throughout this activity, students will consider the efficiency and safety of roller coasters they are constructing. In addition, students will gain an understanding of how the math and science processes they are performing relate to various careers in the world, such as engineering.

Essential Questions:
- How can energy neither be lost nor created, but only transferred from one form to another?
- Why is the first hill of a roller coaster always the highest point?

Suggested Grade Level: High School Algebra or Geometry

Approximate Time: Three-four days (50 minute class periods)

Teacher's Role: Facilitator

Class Set-Up: Groups of three students at tables or desks put together

Success Standards:
- Students can solve problems involving slope and midpoint.
- Students can describe the first two laws of motion.
- Students can solve real world problems using different types of energy.
- Students can define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution — taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- Students can develop and use models.

- Students can engage in argument from evidence.

Learning Purpose:

- Students will define the problem.
- Students will communicate their problem solving plan.
- Students will develop a procedure to design a new roller coaster.
- Students will use social, interaction skills for completing projects with peers.

Vocabulary:

- Acceleration
- Force
- G-Force
- Kinetic Energy
- Speed
- Banking Curves
- Newton's Laws of Motion
- Critical Velocity
- Friction
- Gravity
- Potential Energy
- Velocity
- Centripetal Force
- Clothoid

Math Practices:

- MP 1: Make sense of problems and persevere in solving them.
- MP 3: Construct viable arguments and critique the reasoning of others.
- MP 4: Model with mathematics.
- MP 6: Attend to precision.

Depth of Knowledge:

- DOK Level 3: Strategic Thinking

Materials:

Teacher Materials

- Foam Pipe Insulation, Tape, Marble (for the demonstration)
- Challenge Letter to Students
- Copies of Rubric
- Exit Slip

Student Materials

Student groups need a zip-lock bag per group with the following items:

- Marble
- Small Paper Cup (bathroom size)
- 2 Paper Towel Roll Tubes
- 2 Toilet Paper Roll Tubes
- 4 Paper Plates (smooth rimmed plates)
- 5 Pipe Cleaners
- 8 Popsicle Sticks (craft sticks)

- Roll of Tape
- 2 Pair of Scissors

Summary of Tasks/Experiences

Spark Activity:

Do you have a wish list of roller coasters you would like to ride? Have you ever gotten off an amusement ride and discussed in detail the experience with someone? Just about everyone likes the intense sensation of zooming through tunnels and flipping upside down while speeding on a roller coaster loop after loop. Does anyone know how roller coasters work? Do any of you remember riding a roller coaster that started out with a big hill? What do you think would happen if a roller coaster had a hill in the middle of the track that was taller than the first hill of the roller coaster? Would the cars be able to make it up a bigger hill using just gravity? *(Conduct a short demonstration to prove the point. Take a piece of foam pipe insulation cut in half lengthwise and shape it into a roller coaster by taping it to a desktop. Then, using marbles to represent the cars, show students that the first hill of a roller coaster must be the tallest point or the cars will not reach the end of the track.)* Do you have a dream ride you would like to design or create? While most designers are mechanical engineers, electrical engineers or structural engineers, today, you and your group will begin research on roller coasters and then have the opportunity to design, build and test one. You will be given a zip-lock bag with materials to aid you in your design.

Lesson Descriptions:

Introduction: Day 1

The teacher will:

- complete the spark activity presented.
- discuss the real world challenge listed above.
- hand out the challenge letter to each group.
- show the students the materials in the zip-lock baggies they get to use on day three.
- hand out copies of the rubric for evaluation.
- allow students to collaborate around a plan of action to accomplish their goal.

Day 1 and 2

The students will:

- research information needed on computers or student electronic devices regarding roller coasters.
- apply the thoughts gained from their research to the design of their roller coaster and the scale model in groups.
- discuss learned information regarding ideas for the new roller coaster design and construction process.

- write their proposal to the company explaining and defending what type of chair they are going to build for both efficiency and safety along with a scale drawing.

Day 3 and 4

The students will:

- build and test their roller coaster.
- answer questions on their exit slip independently. (If needed, students can finish for homework and turn in the next day.)

Teacher facilitates class asking guiding questions as students work in groups:

- Can you explain why it is important for engineers to know how roller coasters work?
- How does the effects of gravity and friction enter into your roller coaster design?
- Can you use the principle of conservation of energy to explain the layout of roller coasters?
- How do you identify points in a roller coaster track at which a car has maximum kinetic energy and maximum potential energy?
- Where are the points in a roller coaster track where a car accelerates and decelerates?
- What causes gravity?
- What is friction?
- How do potential and kinetic energy differ?
- What is the difference between speed and velocity?
- How is acceleration related to velocity?
- How can you determine the slope of the climb of the coaster?
- How can you determine the midpoint of the slope?
- What formula can you use to calculate the height of the track halfway up the climb?

Student Engagement

Social/Emotional Engagement: Students will use social, interaction skills for completing projects with peers.

Physical Engagement: Students will collaborate while completing research regarding roller coasters through the use of electronic devices and discourse while working in groups of two or three.

Cognitive Engagement: Students will work together using math and science concepts such as angles, scale drawings and the laws of motion to complete their task.

Evidence of Learning

Checks for Understanding/Expected Outcomes:

- Students will complete their written proposal.
    - Proposals should have a roller coaster designed with at least one loop, should include the measurements of the design and explain why they are going to build that type of roller coaster.
- Students will build their roller coaster.
    - The structure should match their scaled drawing function by allowing the marble to exit the end of the ride.
- Students will complete an exit slip.
    - The exit slip will allow the students to show they did some research as requested and reflect on their success or lack thereof.
- Students will be evaluated using the included rubric.
    - The rubric should be given as a guide to help students as they write their proposal and design their roller coaster.

Designing a New Roller Coaster
RUBRIC

CATEGORY	4	3	2	1
Plan	Plan is well thought out. A scale drawing with at least one loop is present. Measurements are included and purpose for design is evident.	Plan is thought out. A scale drawing with at least one loop is present. Measurements are included and purpose for design is evident.	Plan exists. A scale drawing with at least one loop is present. Some measurements are included but, purpose for design is weak.	Plan exists. A scale drawing with at least one loop is present. Measurements are not included and purpose for design is not present.
Research	Research shown with much detail about the needs for an effective roller coaster.	Research shown with some detail about the needs for an effective roller coaster.	Research shown with little detail about the needs for an effective roller coaster.	Research shown with little to no detail about the needs for an effective roller coaster.
Construction	Great care taken in construction process so that the structure is neat, attractive and follows plans accurately.	Construction was careful and accurate for the most part, but one-two details could have been refined for a sounder product.	Construction accurately followed the plans, but three-four details could have been refined for a sounder product.	Construction appears careless or haphazard. Many details need refinement for a sounder product.
Function	Roller coaster functions extraordinarily well, has a loop and marble exits at the end.	Roller coaster functions, has a loop, but the marble stops before hitting the exit.	Roller coaster functions but, no loop is present. The marble exits at the end.	Flaws in function due to incomplete roller coaster.
Group Member	The student worked well with team members throughout the entire course of the project, and was present each day.	The student worked well with team members throughout most of the project and was present each day.	The student worked with team members on some of the project and was absent one day.	The student worked with team members only slightly throughout the project, and was absent more than one day.

Challenge Letter to Students:

Screams and Dreams Theme Park has cleared a large area of land in the front of the park for a new thrill ride. They are hoping the ride will be a new roller coaster to add for more excitement for their patrons as they enter the park. They are considering new designs from the upcoming engineers still in high school and have selected your school to pick designs from.

You are to research roller coasters. Then, collaborate with your team and decide what type of roller coaster your team will design and why. Then, you are to submit your proposal, along with a scaled drawing of your roller coaster back to us. Include measurements in your proposal. In addition, for your roller coaster to be considered, there must be at least one loop (clothoid) in the ride. In your proposal, you must explain and defend why your team has selected to build this type of roller coaster. Be sure to include why this design would be the most efficient model to build.

If we approve your design, you will have up to two class periods to build your submitted roller coaster using any of the materials from the bag you are given. You may not add any additional materials. For your roller coaster to be successful, you will test it with a marble in class, which must safely exit the end of the ride.

Team Members:

Proposal:

Number of Loops: _____ **Height of roller coaster:** _____

Accepted: _____ **Declined:** _____

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Exit Slip

Name:

Upon completion of this lesson you are to answer the following:

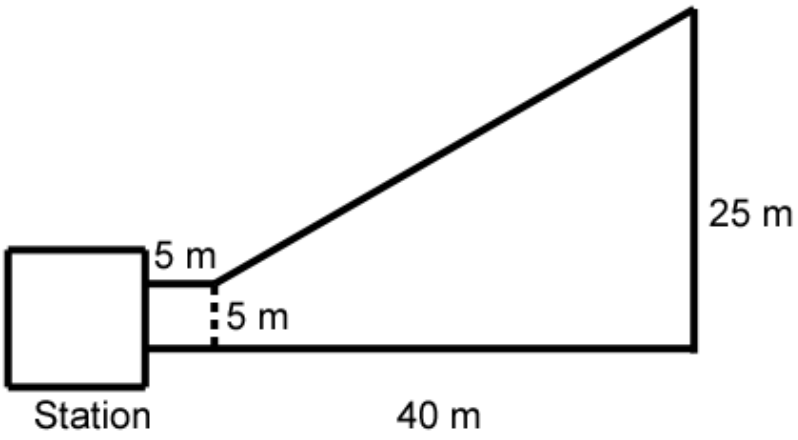
1. What is the difference between a kiddie and junior coaster?

2. How are hypercoasters, giga coasters and strata coasters similar?

3. Compare and contrast Newton's first and second laws of motion:

4. When the coaster ascends one of the smaller hills that follows the initial lift hill, its kinetic energy changes back to _____ energy.

5. In the drawing below, you've determined that the climb starts 5 meters from the loading station at a height of 5 meters. What is the slope and the height of the track halfway up the climb?



6. Why are loops no longer circular?

ADDITIONAL TEACHER INFORMATION:

Answers to Proposal:

- Proposals will vary, must make logical argument, include measurements and have a scale drawing. As the teacher, accept all complete proposals that are convincing due to their measurements and design if at least one loop is in the design. The loop must be in the shape of a tear drop (clothoid).
- Students should mention some of the following vocabulary words in describing and defending their design: acceleration, critical velocity, force, gravity, kinetic and/or potential energy, speed, velocity, centripetal force, banking curves and the laws of motion.

Answers to Exit Slip:

1. A kiddie coaster is up to 25 feet and a junior goes to 45 feet.
2. They are all over 200 feet and complete a full circuit.
3. Newton's First Law of Motion, also commonly referred to as the Law of Inertia, states that 'an object at rest tends to stay at rest until acted upon by an unbalanced force'. Newton's Second Law of Motion states that 'when a force acts upon an object that has a specified mass, a corresponding acceleration is produced'.
4. Potential
5. Slope is ½ or 0.5 midpoint of half way up the 15 meters
6. The G-force often caused people to lose consciousness.