Roller coaster physics project answer key

After this activity, students should be able to: Explain why it is important for engineers to understand how roller coasters work. Explain in terms of physics how your model roller coasters work. Discuss the effects of gravity and friction in the context of your roller coaster designs. Use the principle of energy conservation to explain the design and design of roller coasters. Identify points on a roller coaster track where a car has maximum kinetic and potential energy. Identify points on a roller coaster track where a car experiences more or less than 1 g of force. Identify points on a roller coaster track where a car accelerates and slows down. NGSS Performance Expectation MS-PS3-2. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. (Grades 6 - 8) Do you agree with this alignment? Thank you for your feedback! Click to view another curriculum aligned with this performance expectation This activity focuses on the following aspects of NGSS Three-Dimensional Learning: Science & Engineering Practices Disciplinary Core Ideas Crosscutting Concepts Develop a model to describe non-observable mechanisms. Alignment Agreement: Thank you for your feedback! An object system can also contain stored (potential) energy, depending on its relative positions. Alignment Agreement: Thank you for your feedback! When two objects interact, each exerts a force on the other that can cause energy to transfer to or from the object. Alignment Agreement: Thank you for your feedback! Models can be used to represent systems and their interactions, such as inputs, processes and outputs, and energy and matter flows within systems. Alignment Agreement: Thank you for your feedback! NGSS Performance Expectation MS-PS3-5. Construct, use, and present arguments to support the claim that when an object's kinetic energy changes, energy is transferred to or from the object. (Grades 6 - 8) Do you agree with this alignment? Thank you for your feedback! Click to see another curriculum aligned with this performance expectation This activity focuses on the following aspects of NGSS Three-Dimensional Learning: Science & Engineering Practices Disciplinary Core Ideas Crosscutting Concepts Construct, use, and present oral and written arguments backed by empirical evidence and scientific reasoning to support or refute an explanation or model for a phenomenon. Alignment Agreement: Thank you for your feedback! Knowledge of science is based on logical and conceptual connections between evidence and explanations. Alignment Agreement: Thank you for your feedback! When the energy of of an object changes, inevitably there is some other change in energy at the same time. Alignment Agreement: Thank you for your feedback! Energy can take different forms (e.g. field energy, thermal energy, motion energy). Alignment Agreement: Thank you for your feedback! NGSS Performance Expectation MS-ETS1-4. Develop a model model generate data for iterative testing and modification of a proposed object, tool, or process in such a way that optimal design can be achieved. (Grades 6 - 8) Do you agree with this alignment? Thank you for your feedback! Click to see another curriculum aligned with this performance expectation This activity focuses on the following aspects of NGSS Three-Dimensional Learning: Science & Engineering Practices Disciplinary Core Ideas Crosscutting Concepts Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs. Alignment Agreement: Thank you for your feedback! Models of all kinds are important for testing solutions. Alignment Agreement: Thank you for your feedback! The iterative process of testing the most promising solutions and modifying what is proposed based on test results leads to greater refinement and ultimately an optimal solution. Alignment Agreement: Thank you for your feedback! Seamlessly divide multi-digit numbers using the standard algorithm. (Grade 6) More details View aligned curriculum Do you agree with this alignment? Thank you for your feedback! Use relationship reasoning to convert units of measure; properly manipulate and transform units by multiplying or dividing quantities. (Grade 6) More details View aligned curriculum Do you agree with this alignment? Thank you for your feedback! Add, subtract, multiply multi-digit decimals fluently using the standard algorithm for each operation. (Grade 6) More details View aligned curriculum Do you agree with this alignment? Thank you for your feedback! Construct and interpret scatter plots for bivariate measurement data to investigate association patterns between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association. (Grade 8) More details View aligned curriculum Do you agree with this alignment? Thank you for your feedback! Students will develop an understanding of engineering design. (Grades K - 12) More details View aligned curriculum Do you agree with this alignment? Thank you for your feedback! Students will develop an understanding of design attributes. (Grades K - 12) More details View aligned curriculum Do you agree with this alignment? Thank you for your feedback! Students will develop an understanding of the role of problem solving, research and development, invention and innovation, and experimentation in problem solving. (Grades K - 12) More details View aligned curriculum Do you agree with this alignment? Thank you for your feedback! Design is a creative planning process that leads to useful products and systems. (Grades 6 - 8) More details See curriculum Do you agree with this alignment? Thank you for your feedback! Design requirements are made up of criteria and constraints. (Grades 6 - 8) More details View aligned curriculum Do you agree with this alignment? Thank you for your feedback! Brainstorming is a problem-solving group process in which each person in the group presents their ideas in an open forum. (Grades 6 - 8) More details View aligned curriculum Do you agree with this alignment? Thank you for your feedback! Make two-dimensional and three-dimensional representations of the designed solution. (Grades 6 - 8) More details View aligned curriculum Do you agree with this alignment? Thank you for your feedback! Energy is the ability to get the job done. (Grades 6 - 8) More details View aligned curriculum Do you agree with this alignment? Thank you for your feedback! Energy can be used to get the job done, using many processes. (Grades 6 - 8) More details View aligned curriculum Do you agree with this alignment? Thank you for your feedback! Add, subtract, multiply multi-digit decimals fluently using the standard algorithm for each operation. (Grade 6) More details View aligned curriculum Do you agree with this alignment? Thank you for your feedback! Seamlessly divide multi-digit numbers using the standard algorithm. (Grade 6) More details View aligned curriculum Do you agree with this alignment? Thank you for your feedback! Use relationship reasoning to convert units of measure; properly manipulate and transform units by multiplying or dividing quantities. (Grade 6) More details View aligned curriculum Do you agree with this alignment? Thank you for your feedback! Construct and interpret scatter plots for bivariate measurement data to investigate association patterns between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association. (Grade 8) More details View aligned curriculum Do you agree with this alignment? Thank you for your feedback! Understand the characteristics of energy transfer and the interactions of matter and energy. (Grade 6) More details View aligned curriculum Do you agree with this alignment? Thank you for your feedback! Explain how kinetic and potential energy contribute to an object's mechanical energy. (Grade 7) More details View aligned curriculum Do you agree with this alignment? Thank you for your feedback! Explain how energy can be transformed from one form to another (specifically potential energy and kinetic energy) using a model or diagram of a moving object (roller coaster, pendulum or cars on ramps as examples). (Grade 7) More details View aligned curriculum Do you agree with this alignment? Thank you for your feedback! Understand the forms of energy, energy transfer and transformation and conservation in mechanical systems. (Grade 7) More details View aligned curriculum Do you agree with this alignment? Thank you for your feedback! Suggest an alignment not listed above Each group needs: foam tube 2 meters (6 feet) long (1/2 insulation of cut in half along (Usually, one side of the tube comes perforated, making it easy to use scissors or a utility knife to cut through the perforation and the other side of the tube to form two halves, essentially making two long channels perfectly perfectly to hold marbles; therefore, a cutting tube provides the track material for two groups; see Figures 1 and 2.) marble marble paper marble marble marble marble or plastic roll cup duct tape set markers, Crayons or Pencils Blank Sheet Paper Stopwatch Roller Coaster Specifications Worksheet, one per student or one per group Roller Coaster Specification Sheet Worksheet (pdf) Roller Coaster Specifications Worksheet (docx) Suggested Rubric Score (pdf) Suggested Rubric Score (docx) Visit [www.teachengineering.org/activities/view/duk_rollercoaster_music_act] Students need basic prior knowledge about forces, particularly gravity and friction, as well as some familiarity with the power. They should also know Newton's second law of motion and understand basic concepts of movement, such as position, speed, and acceleration. Before performing this activity, teach students the concepts of physics and engineering in the Roller Coaster Physics lesson. During today's activity, you will design your own roller coaster model using foam tubes and marbles. I'd like you to start drawing your roller coaster on paper before you built it. Along with your drawing, give your roller coaster a funny and descriptive name and make a sign for him. (At this point, show students pictures of some real roller coasters to help them imagine the possibilities of their own roller coasters. See examples of some of the country's best current roller coasters in When engineers design objects and structures, such as home appliances and other products you use, bridges and roads, skyscrapers, and other structures such as amusement park rides, or even bike and chair lanes in ski resorts, they operate within what they call restrictions. Restrictions are project requirements and/or limitations. Engineers must consider these limitations in order to come up with successful design solutions. In the case of roller coaster design, what might be some limitations that engineers would have to consider? (Let students think about this and make some suggestions.) Yes, they may have some practical limitations, such as available or preferred building materials, a budget and a construction deadline, safety measures for users, continuous maintenance requirements and/or expected weather conditions. The amusement park customer can also give requirements for the type of movement you want for the trip, such as loops upside down, corkscrews, specific grade turns, fall length or maximum speed, or safety guarantees for users (safe for more than four feet tall). Another basic restriction that always applies is the consideration of the natural physical laws that exist in our world, such as the limits of gravity and the effects of slope, speed and friction. This is an example of how an engineer's understanding of physics is very important to the success of a project. Developing a design solution that takes all these factors into account and works reliably, safely and as expected is what engineers do. When designing your roller coaster, what are the physics concepts you've learned that will be useful and very important to apply? (Listen to students' ideas. Correct and amended as needed. Expect them to suggest ideas of the content they learned in the associated lesson about gravitational potential energy, kinetic energy, gravity, and friction.) That's right, all real roller coasters are driven by the force of gravity. The excitement of a walk comes from the continuous conversion between potential energy and kinetics, which we know from the law of energy conservation. Friction is important to reduce the speed of roller coaster cars and acceleration plays a role in the experience provided by roller coaster cars as they move along a track. And how do these concepts translate into your challenge of designing a roller coaster that provides an exciting experience that's safe for pilots? (Listen to students' responses. Expect to hear them mention the following points, which they must understand to build and analyze their model roller coasters: The top of the first hill should be the highest point of the roller coaster. Cars move faster on the bottoms of the hills and slower on hilltops. Friction converts useful energy into heat and should be minimized. G-forces greater than 1 occur at the bottoms of the hills. G-forces under 1 occur at hilltops. To avoid falls, cars must have a certain speed at the top of the loops.) That's right. These are limitations that we must take seriously. The first hill should be the highest point or the roller coaster will not work. If a car does not move fast enough at the top of a loop it will fall off the track. Pay attention to the friction between the car and the track, so it's as small as possible for cars to move fast enough to get through the entire track. Start! Before the Collect Materials activity, make copies of the worksheet and punctuation rubric. Cut each tube in half lengthwise, so each group receives a channel-shaped tube length to serve as the roller coaster track for marbles (cars). Use scissors or a utility knife to cut through the perforated side of the tube to form two halves. Give each group one of these halves. This process is shown in Figures 1 and 2. Figure 1. Final view of cutting an insulation tube longitudinally. Figure 2. Side view of cutting an insulation tube longitudinally. Review the TeachEngineering, Time for that describes the steps in the engineering design process. Following these steps as they build their roller coasters helps students learn exactly how roller coaster engineers solve problems. With students Divide the class into engineering groups of three or four students each. Deliver qualifying rubrics for class The list of creative points provides students with guidance on the characteristics of the roller coaster (height, turns, loops, and corkscrew) desired in the design, and the list of performance points provides a way to judge the safety of coasters. Tell students: In our roller coaster models, glass marble simulates a normal car, wood marble represents an empty car, and a steel marble represents a complete car. Your team will earn points for each type of marble (passenger load) that successfully completes your runway and lands safely in the cup. A class contest will determine the most innovative and successful roller coasters. Ask the groups to start designing their roller coasters, brainstorming, and share ideas and agree on a design. Ask students to draw their roller coasters on paper, name them, and make signs. Wait up to 30 minutes for this. Examine your drawings to make sure your proposed designs are physically possible. If not, point out aspects of roller coaster design that you may want to rethrorder. Give them time to iterate their designs. Give each group a foam tube caterpillar, duct tape, and cup, and let them build their roller coasters using class materials. Expect students to build their first design in 10 minutes or less. Use the cup to catch the marble at the end of the track. Give students marbles so they can test their roller coasters and make the necessary changes. This is the most time-consuming step and students may need up to 45 minutes to redesign their tracks. Give each group a stopwatch and give them time to complete the worksheet, in which they determine certain specifications of their roller coasters. Start class competition by telling students: Similar to what you did today, engineers create small-scale models to help them test and analyze their structural designs. For example, engineers who designed the Golden Gate Bridge in San Francisco pioneered the new theory of hanging bridge design. They checked their complex calculations (all made without computers in the 1930s) of the forces they would need to endure by testing a 1:56 scale steel tower model. That's 56 times smaller than one of the towers on the royal bridge. Tests confirmed that the tower's calculations of expected forces, including wind/earthquake deviations, were solid, and the bridge is still standing today, more than 75 years later. Ask each group to present their roller coaster model to class. Use the scoring rubric to evaluate the designs of the roller coaster model. Analyze the results as a class, as described in the Evaluation section. Acceleration: The speed with which an object accelerates, slows down, or changes direction. It's equal to a change in speed divided by time. Critical speed: The speed needed at the top of a loop for a car to do it through the loop without falling off the track. Strength: Any thrust or pull. friction: A force caused by rubbing between two objects. g-force: Abbreviation of Force. It is equal to the force exerted on an object by the gravity of the Earth at sea level. gravitational constant: The acceleration caused by Earth's gravity at sea level. It is equal to 9.81 m/sec2 (32.2 ft/sec2). Gravity: A force that draws two objects to each other. kinetic energy: The energy of a moving object, which is directly related to its velocity and mass. Potential energy: The energy stored by an object ready to be used. (In this lesson, we use gravitational potential energy, which is directly related to the height of an object and its mass.) Speed: The speed at which an object moves and is equal to the distance at which the object travels divided by the time it takes. Speed: A combination of speed and the direction in which an object travels. Activity Embedded Assessment Applied Physics: Verify that each group understands how and why your roller coaster works. If a roller coaster doesn't work, ask students what they think the problem is. See if they can identify physics restrictions and explain problems like Not High Enough, or Marbles rub too much in terms of physics as It doesn't have enough potential energy because it's not high enough, or The friction between the marble and the track is too large. Speed Determination: Ask students to measure the length of their roller coaster (that is, you can measure the distance of the tube length) and the time it takes for the marble to complete the track. Ask students to calculate the marble speed in m/s, as well as in ft/s. Graphs: During testing, plot the relationship between the height of the first (independent) hill and the average marble speed (dependent); Describe the relationship (for example, as the height increases, speed increases), Post-activity evaluation worksheet: Have each student (or group) complete the roller coaster specification worksheet, which asks them to identify some roller coaster hotspots, as well as other specifications such as height and number of loops and turns. Review students' responses to measure their understanding of concepts. Presentations: Have each group present their roller coaster model to the class. Use the suggested scoring rubric to evaluate roller coasters for class competition. Discuss the results as a class, asking students: Which roller coasters were most exciting? Which ones were the safest? What did you gain for creativity? What did you gain for performance and security? Which model best faced the overall challenge for both exciting design and safety? What were the compensations? (Point to perform: Engineers call this optimization, balancing the requirements of the competition project.) What did you learn when you tried your model? Yes your roller coaster, what improvements would you make and why? What if you/engineers ignored the fundamental laws of physics in your designs? How important is it for you for engineers to test their designs (for appliances, cars, bridges, stairs, roller rollers etc.) before they are built and people use them? What engineering design steps and techniques do we use today? (Answer: Brainstorming, modeling, simulation, testing, analysis, redesign, optimization.) Make sure students don't swallow or throw away marbles. Sliding on marbles on the ground could be dangerous. Ask students to immediately collect fallen marbles. If students have difficulty having their roller coasters work, review basic physics considerations: Make sure the highest point of the roller coaster is at the beginning. Reduce friction by checking that the track is wide enough for marbles to pass through. Any deformation of the track that occurs when the marbles are rolled around the track results in a loss of energy, making the roller coaster as stable as possible by channeling it to the supports (textbooks, walls, desks, chairs, shelves) at various points. For lower grade levels, remove much of the physical scan behind the lesson content. Ask students to build their own roller coasters and discover for themselves many of the concepts discussed in detail at higher grade levels (such as energy conservation, friction, and gravity), and may also be able to understand some basic explanations of friction and gravity. For higher grades, enter equations for potential and kinetic energy so students can calculate both forms of energy and verify the energy conservation law. Ask students to explore loops along with the concept of critical speed. Ask students to find the initial height of a roller coaster needed to complete a loop of a certain height. History of Bridge Design and Construction: Engineering Design. Published 2006-2012. Golden Gate Bridge Highway & Transportation District. Retrieved 20 November 2013. Explore the NGSS Engineering-Aligned Physics Curriculum Center for an additional Physics and Physical Sciences with Engineering curriculum. This content was developed by the MUSIC (Math Understanding through Science Integrated with Curriculum) Program at Duke University Pratt School of Engineering under the GK-12 National Science Foundation no. DGE 0338262. However, these content does not necessarily represent NSF policies, and you should not assume the support of the federal government. Last modified: August 3, 2020 2020