Roller Coaster Physics

Mega Skill: Problem Solving

Grade Level: 5th **Duration:** 15-20 hours

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Rationale: Roller Coaster Physics will provide an intertwining of science and math in every aspect and promote learning the big idea of Constancy, Change, and Measurement as related to Motions/Forces. The "why" of track design; measuring speed, distance, and angles; and application of laws of motion are all high-interest links to learning. Students will be motivated by and engaged in learning about the history of roller coasters, designing and testing their own online roller coasters, and utilizing problem solving skills to design, construct, test, and modify model roller coasters they build.

Measurable Objectives/Standards: (from Scope & Sequence)

By the end of this unit students will be able to:

1) Research roller coasters to identify variables that affect roller coaster design
2) Identify the physical laws that govern roller coaster design
3) Understand the difference between potential & kinetic energy
4) Apply knowledge in problem-solving situations integrating math/science

Essential Questions:

How can we design and build a roller coaster that creates thrills and chills without the spills?!!
What is the history of roller coasters?
What are Newton's Laws of Motion?
How do Newton's Laws of Motion apply to roller coasters?
What are potential and kinetic energy and how do they apply to roller coaster design?

Materials:

Model Coaster Explorations
Supplies per group: 5 lengths of pipe insulation, 5 marbles, masking tape, stopwatch, and meter stick

Height of Incline/Distance Exploration
1 marble, a meter stick, 1 length of pipe insulation, Cuisenaire flats, recording sheet

Wall Roller Coaster Activity
Supplies per group: 2 pieces of poster board, 5 note cards, masking tape, 1 marble, 1 paper cup, 2 meter sticks, scissors, pencil, angle ruler or protractor, stop watch, calculator, Wall Roller Coaster exploration guide sheet, Velocity Investigation Worksheet 2

Hand-outs:

Roller Coaster Website Explorations

Your Name:

Date:

1. Tell a little about the beginning of what later became the roller coaster.

2. Define energy:

3. Define force:

4. Define kinetic energy:

5. Define potential energy:

6. What are Newton's laws of motion?

Roller Coaster Website Explorations Key

Your Name:

Date:

1. Tell a little about the beginning of what later became the roller coaster.
   1600's in St. Petersburg, Russia
   Blocks of ice with seats carved out and covered with straw. The "sled" would slide down a 70-foot ice-covered wooden frame.

2. Define energy: **ability to do work**

3. Define force: **a push or pull acting upon an object**

4. Define kinetic energy: **energy of motion or energy of an object due to its motion**

5. Define potential energy: **stored energy or energy of an object due to its position or state**

6. What are Newton's laws of motion?
   1st: an object in motion will remain in motion along a straight line/objects at rest remain at rest

   2nd: an object moved by a force will move in the direction of the force. The greater the force, the faster the object will move.

   Acceleration is dependent upon two variables-force and mass. As force increases, so will acceleration. As mass increases, acceleration will decrease.

   3rd: for every force there is an equal and opposite force/for every action there is an equal and opposite reaction.

   Additional notes: Friction and air resistance work to dissipate kinetic energy

Height of Incline/Distance Exploration

Group members:

Length of Ramp:

Trial:	Ramp Height:	Distance Traveled:
1		
2		
3		
1		
2		
3		
1		
2		
3		
1		
2		
3		

Conclusions:

Problem Solving Activity—Wall Roller Coaster

Group Members:

Supplies per group:
2 pieces of poster board, 5 note cards, masking tape, 1 marble, 1 paper cone cup, 2 meter sticks, scissors, pencil, angle ruler, stop watch, calculator

Your task:
Working as a group, design, construct, and test a wall roller coaster. Cut strips of poster board 8 cm wide. Fold strips of poster board in half lengthwise to make your "track" pieces. Use tape to fasten your track to the wall. Your track must fit into the marked area (2 meters tall, 1 meter wide).

Design your completed coaster to fit these guidelines:
At least 1 acute angle
At least 1 obtuse angle
At least 1 right angle
At least 2 special features such as a bump, jump, loop, drop, or other feature of your design
Marble run takes at least 4 seconds
Marble drops into the cone cup at the end of the track

After your track is constructed and tested, measure the length of the track in cm. Conduct 3 timed trials to see how long it takes your "car" (marble) to complete the track.

Track length: _____cm

Trial 1:_____seconds

Trial 2:_____ seconds

Trial 3:_____seconds

Average of your three trials: _____seconds

Draw a simple diagram of your group's final coaster design:

Did your coaster work?

On a scale of 1-5 (5 is best), rate your coaster for:

_____Speed
_____Design
_____Special Features
_____Safety of Passengers
_____Thrill Factor
_____Overall Enjoyment

What was successful about your coaster?

What would you change if you were designing from scratch again?

What math was utilized?

What science concepts were utilized?

Velocity Investigation Worksheet 2

Velocity = Distance traveled/ Time

To determine the velocity you will first need to measure your roller coaster track in centimeters using a metric tape measure, and then find out how fast a marble completes your roller coaster, using a stopwatch.

Length of track= _____ cm

Run Time= _____ seconds

Then you will simply divide your Length of Track by your Run Time to find out how many cm per second your marble travels!

_____cm ÷ _____ seconds = _____cm per second

Length of track Run Time

To find a more accurate **average velocity**, measure the run time 3 times and calculate the average:

Trial # 1:

_____cm ÷ _____ seconds = _____cm per second

Length of track Run Time

Trial # 2:

_____cm ÷ _____ seconds = _____cm per second

Length of track Run Time

Trial # 3:

_____cm ÷ _____ seconds = _____cm per second

Length of track Run Time

* Add the 3 scores and divide by 3 to find average _____ Average Velocity

To Convert Centimeters Per Second to Miles Per Hour:

_____ centimeters per second ÷ 100,000 = _____kilometers per second

_____ kilometers per second x 60 = _____kilometers per minute

_____ kilometers per minute x 60 = _____kilometers per hour

_____ kilometers per hour x 0.62 = _____miles per hour

For more Design Challenges, visit our website:

:http://www.thetech.org/education/teachers/curriculum.php

Roller Coaster Physics Study Feedback

Name:
Date:

What have you done as part of the roller coaster study?

What have you learned during the roller coaster study?

How would you rate your work during this unit on a 0-5 scale (5 is best)

What have you liked?

What suggestions do you have for changes?

Additional feedback?

Instructional Strategies & Activities:

Intro

Read Zoom! by Diane Adams

Pre-assess Knowledge

Discuss students' experiences with roller coasters. Begin a KWL chart. Use this information to assess prior knowledge & help structure the learning sequence.

Share Learning Goals

1) Research roller coasters to identify variables that affect roller coaster design
2) Identify the physical laws that govern roller coaster design
3) Understand the difference between potential & kinetic energy
4) Apply knowledge in problem-solving situations integrating math/science

View "Awesome Rides" video or another roller coaster overview to add to knowledge. Generate a list of words to help structure the study. Words should include force, motion, friction, gravity, inertia, variables, speed, velocity, Newton's Laws of Motion, kinetic energy, potential energy, circle/oval, acceleration, mass, loops, height, & length.

Website Explorations

Preview websites using the Smartboard and explain web explorations work. Provide the Website Explorations worksheet for each student. Explore websites using computers, working individually or in a larger group.

Website Explorations:
http://www.ultimaterollercoaster.com/coasters/history/start/history_early.shtml

http://jvsc.jst.go.jp/find/rikigaku/english/index.htm

http://www.glencoe.com/sec/science/cgi-bin/splitwindow.cgi?top=http://www.glencoe.com/sec/science/top2.html&link=http://www.learner.org/exhibits/parkphysics/

http://library.thinkquest.org/2745/data/ke.htm

http://www.glenbrook.k12.il.us/gbssci/phys/projects/frig/yepbyrji/coaster.html

http://www.funderstanding.com/k12/coaster/

http://dsc.discovery.com/games/coasters/interactive.html

You could spend days exploring the websites. Decide how many class periods you would like to devote to this. I suggest 2-3 periods. Remind students to complete the Website Explorations sheet as they work. Check that students are exploring all of the websites, not just the interactive construction sites.

Height of Incline/Distance Exploration
A lesson in which students vary ramp height in 3, 6, & 9 cm increments & measure the distance a marble rolls allows math/science integration & application of the big idea of CCM. Materials needed per group: a marble, a meter stick, 1 length of pipe insulation, Cuisenaire flats (to make the top level to attach the pipe insulation), recording sheet. This exploration leads to student understanding that the height of the incline is directly correlated to distance moved. Students apply the concept of mean as they complete 3 trials for each height of incline. This exploration allows assessment of each student's skill in metric measurement, mean calculation, understanding of impact of variables on results, & group interaction skills.

Model Coaster Explorations
The Task: Design & build a model roller coaster.

Supplies per group: 5 lengths of pipe insulation, 5 marbles, masking tape, stopwatch, meter stick Brainstorm assessment of coasters before construction to help focus efforts. The list should include speed, safety, # of turns/loops/hills, & originality of design.

After testing of hypotheses & experimentation, each group shares their final design.

Each group assesses their finished roller coaster using the criteria list the class developed or one the teacher has developed.

Wall Roller Coasters
The Task: Work as a team to design, construct, and test a "wall roller coaster" meeting designated criteria & to complete the data sheet demonstrating understanding of targeted math/science concepts. The track must fit into the marked wall area. Teacher note: Each group needs an open area of wall 2 meters tall and 1 meter wide. Have those areas marked off with masking tape prior to beginning the activity. Separate the groups as much as possible to allow ample working space for each group.

See the Problem Solving Activity-Wall Roller Coaster exploration guide sheet for details.

Supplies per group: 2 pieces of poster board, 5 note cards, masking tape, 1 marble, 1 paper cup, 2 meter sticks, scissors, pencil, angle ruler or protractor, stop watch, calculator, Wall Roller Coaster exploration guide sheet, Velocity Investigation Worksheet 2

Each group should review the exploration guide sheet and determine a design for their Wall Roller Coaster. Sketch the design diagram. Cut poster board into 8 cm wide strips and fold strips in half to make the track pieces. Begin construction of the track, incorporating the required elements. Test the track using the marble as the coaster. Make revisions, continue testing. Complete the exploration guide sheet as a small group. The Velocity Investigation Worksheet is an extra optional challenge. Spend two-three class periods in the construction/testing phase.

Allow each group to share their final Wall Roller Coaster and discuss the information on their exploration guide sheet. Have a group discussion comparing and contrasting the various Wall Roller Coaster designs.

Final group discussion/debriefing should focus on problem solving applications, math/science integration, & demonstrated understanding of motion and forces science concepts. Revisit the KWL chart from the unit intro and discuss concepts learned during the roller coaster study. Each student should complete the Roller Coaster Unit Feedback sheet.

Extensions

See websites for a variety of great extensions

Student Reflection/Evaluation

In hand-outs section

Assessments/Rubrics:

KWL chart for preassessment of knowledge
Website Explorations recording sheet
Height of Incline/Distance Exploration observations and recording sheet
Observation and analysis of students' work in constructing model roller coasters
Observation and analysis of students' work in constructing wall roller coasters
Wall Roller Coaster recording sheets
Roller Coaster Physics Study Feedback Sheet

Resource List:

Websites:

Excellent Teacher Resource:
http://www.thetech.org/education/downloads/dconline/physicsRollercoasters.pdf

Student/Teacher Explorations:

http://www.ultimaterollercoaster.com/coasters/history/start/history_early.shtml

http://jvsc.jst.go.jp/find/rikigaku/english/index.htm

http://www.glencoe.com/sec/science/cgi-bin/splitwindow.cgi?top=http://www.glencoe.com/sec/science/top2.html&link=http://www.learner.org/exhibits/parkphysics/

http://library.thinkquest.org/2745/data/ke.htm

http://www.glenbrook.k12.il.us/gbssci/phys/projects/frig/yepbyrji/coaster.html

http://www.funderstanding.com/k12/coaster/

http://dsc.discovery.com/games/coasters/interactive.html

Print Resources:

Zoom! by Diane Adams
Roller Coasters by A. R. Schaefer
Using Math to Design a Roller Coaster by Hilary Koss, Steve Mills, and Korey T. Kiepert