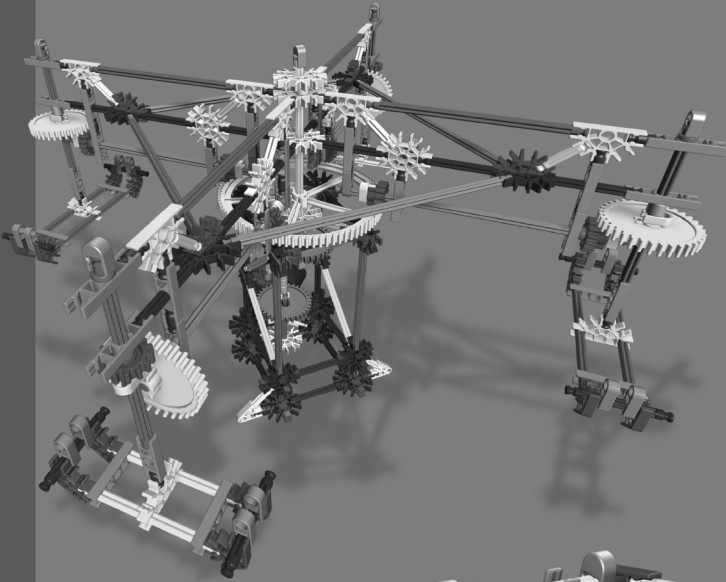


TEACHER'S GUIDE[™]

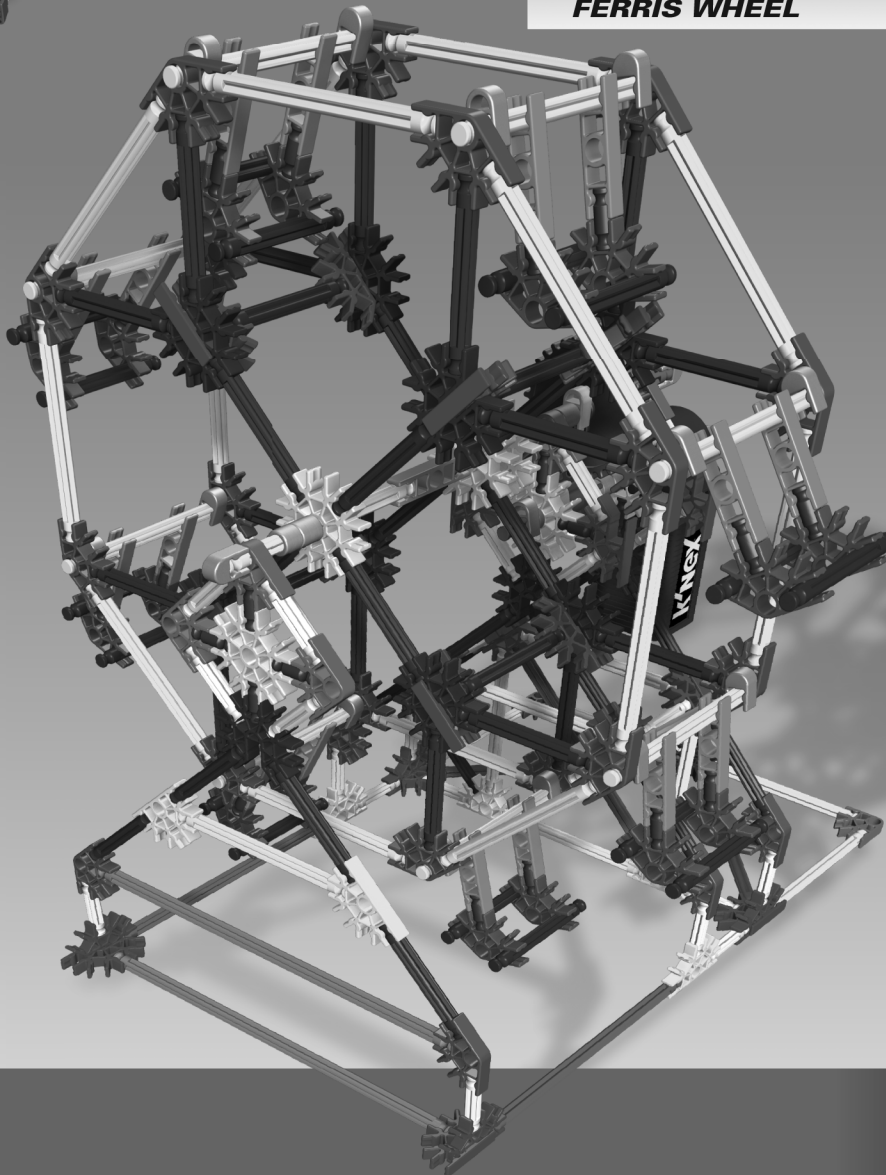
AMUSEMENT PARK EXPERIENCE[™]



FERRIS WHEEL



SCRAMBLER



Amusement Park Experience

Teacher's Guide

V2-03/11

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Authors:

Mike Long, Ed.D.
Assistant Professor of Mathematics,
Shippensburg University, Shippensburg, PA. 17257

Christine Anne Royce, Ed.D.

Assistant Professor of Education,
Shippensburg University, Shippensburg, PA. 17257
Pennsylvania Science Teachers' Association:
President-Elect (2005)

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A NOTE ABOUT SAFETY:

Safety is of primary concern in science and technology classrooms. It is recommended that you develop a set of rules that governs the safe, proper use of K'NEX in your classroom. Caution students to keep hands, face, hair and clothing away from all moving parts.



WARNING:

CHOKING HAZARD - Small parts.
Not for children under 3 years.



AVERTISSEMENT :

DANGER D'ÉTOUFFEMENT - Pièces de petite taille.
Ne convient pas aux enfants de moins de 3 ans.

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INTRODUCTION TO THE K'NEX EDUCATION AMUSEMENT PARK EXPERIENCE SET AND TEACHER'S GUIDE

The K'NEX Education Amusement Park Experience Set provides the teacher with an opportunity to combine real-world applications with science, mathematics, and technology in a classroom environment. The models in this construction set enable students to investigate not only the characteristic rides of an amusement park, but also the inclined planes and looped systems that they may have encountered at skateboard or in-line skating parks. Using these materials, students will be engaged and energized as they experience the interrelationships and further their knowledge and understanding of the science, math and technology concepts associated with such rides and structures.

Teacher's Guide

The accompanying Teacher's Guide offers ideas on how to use the Amusement Park Experience materials to introduce these concepts to students in Grades 6-9. A teaching approach that encourages students to take an active role in constructing their own knowledge by engaging in hands-on, inquiry-based learning, and by interacting and collaborating with other students while discussing ideas and concepts, informs the activities associated with the K'NEX Education Amusement Park set.

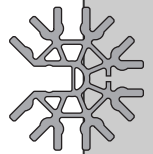
The lessons offered in the Teacher's Guide are sequenced so that new concepts can be built on earlier ones. Teachers, however, may be selective in their choice of activities, given their curriculum requirements, available teaching time, and student abilities and interests. To this end, each activity provides a **Review** section outlining what prior knowledge of concepts would be helpful.

Some of the activities provide step-by-step guidance for the students, while others are more open-ended and allow the students to plan and undertake their own investigations. This flexibility enables the teacher to not only provide directed activities designed to teach a certain concept, but also allows the students to ask questions and design experiments. Open-ended questions, facilitated by the teacher, encourage peer discussion and help develop critical thinking skills.

According to the National Council of Teachers of Mathematics¹, "In effective teaching, worthwhile mathematical tasks, which may be connected to the real-world experiences of students, are used to introduce important mathematical ideas and to engage and challenge students intellectually." (p. 19.) Most middle school students have real-world amusement park experiences upon which to construct new knowledge about the mathematical, scientific and technological concepts and processes that are demonstrated by the rides. In addition, these experiences are usually associated with high levels of enjoyment, so that drawing on them in order to meet the requirements of the curriculum will typically ensure more student engagement and motivation. Indeed, as pointed out in the National Science Education Standards², "With an appropriate curriculum and adequate instruction, middle-school students can develop the skills of investigation and the understanding that scientific inquiry is guided by knowledge, observations, ideas, and questions." (p. 143.) The K'NEX Education Amusement Park Experience kit provides a variety of activities designed to accommodate the needs of different levels of students in these specific areas. The activities ask students to follow a familiar format of making predictions about what will happen, providing their rationale for such predictions, engaging in the investigation, recording their observations throughout, and answering open-ended questions about what they are observing. Developing and applying these skills will add much to their learning experience.

¹National Council of Teacher's of Mathematics. 2000. Principles and Standards for School Mathematics. Reston, VA: NCTM

²National Research Council. 1996. National Science Education Standards. Washington, DC: National Academy Press.



Science Notebooks/Journals

The use of science notebooks/journals throughout each activity is encouraged and should be viewed as scientists and mathematicians view them – as records of their questions, processes, and experiences with a particular topic. The journal entries will help students make connections between the behavior of their models during investigations and the real-world mechanisms and structures that their models represent. Their entries will also enable them to make use of the newly learned scientific and technical vocabulary associated with the amusement park rides, and offer an opportunity for writing across the curriculum. In addition, the journals provide a place for students to practice drawing annotated diagrams of the investigations they undertake. Finally, the journals serve as an assessment vehicle for the Amusement Park Experience unit (see below.)

Assessment

Teachers have the opportunity to utilize a wide range of assessment techniques throughout each lesson, including classroom discussions, responses to guiding questions, and observations of the students as they undertake their investigations. As noted above, it is also expected that students will utilize science notebooks during each activity and these will allow the teacher to formally assess their understanding, knowledge, and construction of new knowledge.

Building Instructions

Building Instructions for the models are provided in two formats:

1. Printed, color-coded booklet containing step-by-step instructions for building the Carousel, Scrambler, Pirate Ship and Roller Coaster with Clothoid Loop models.
2. CD-ROM containing building instructions for the models listed above (including gearing/motorized options,) together with those for a Ferris Wheel, Boom Ride, Swing Ride, 2 Half Pipe systems (for balls and coaster cars), 2 Inclined Plane systems (for balls and coaster cars), 1 Inclined Plane with Circular Loop (for balls), and a model of the London Eye. A CD-ROM of the building instructions offers the teacher a number of advantages over a printed booklet:
 - a. Teachers can select and print instructions for just those models that they wish their students to use. While the instructions for most of the models* can be printed on either 8.5" x 11" or 11" x 17" paper, use of the larger size paper is recommended.
 - b. Multiple copies of instructions can be provided. This is particularly useful when four or more students are involved in constructing a large model.
 - c. Instructions can be displayed on a computer screen and students can then build the models on a table in front of the computer. No hard copies of the instructions are needed.

*Note: The instructions on the CD-ROM for the Carousel, Scrambler, Pirate Ship and Roller Coaster with Clothoid Loop models are provided ONLY in the 8.5" x 11" format. These are the models for which instructions are also provided in the printed booklet.

Building the Models

The K'NEX Education Amusement Park set contains sufficient parts for a combination of at least two of the smaller models (all the rides and inclined plane systems,) to be built simultaneously. This means that two groups of 3 - 4 students can use one set to build either the same model or two different models. The roller coaster can also be built at the same time as one of the rides, but it is not possible to build a combination of the large roller coaster and an inclined plane system simultaneously.

Depending on the time available, construction of the models can be accomplished in-class with student groups designating appropriate sub-assemblies for their members to complete. Alternatively, teachers may wish to have models built as an out-of-class activity.



INTRODUCTION

It should be noted that many of the component parts of the models are built in a similar way. The Scrambler and the Carousel, for example, use the same central tower structure so that students can reduce the building time for these models by reusing this particular structural component. Similarly, the Ferris Wheel and the Boom Ride have the same seat design.

Many of the models with gear systems have multiple build options. The Ferris Wheel, for example, can be constructed so that it is driven by a motor or with a hand crank. It can also be geared-up or geared-down in either of these drive options. This maximizes the flexibility of the set so that the same model can be built with these different options and rotated among the student groups for comparative observations.

Teachers should be aware that some of the models have more complex builds than others. Many of the inclined plane systems, for example, are fairly simple to construct, as is the Pirate Ship ride. The most complex and time-consuming of the rides is the Carousel so that, for this particular model, group construction is highly recommended.

Finally, teachers should ensure that everyone in the class understands how to build with the K'NEX materials and should remind students to carefully check the building instructions (including the 'tips' page) as they move from step to step. This is particularly important for those models that incorporate gear systems. As they complete each step in the construction, students should always test that the gears mesh by using the motor or the crank.

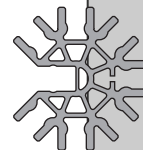
Web Sites

Teachers have been provided with suggested web sites throughout the manual. Some web sites are provided for additional information for both the teacher as well as the student. Other web sites, allow the students to be engaged on the Internet through animations or sites that have connections to the real world.

Interdisciplinary Applications

The K'NEX Education Amusement Park Experience set is an excellent resource for a team of middle school teachers to use as part of a comprehensive interdisciplinary unit. The obvious applications apply to science, mathematics, and technology programs, but there are certainly multiple options for the language arts and social studies programs as well. It is often difficult to select an appropriate interdisciplinary activity to use as a theme for a year, a marking period, or a month unless you have something as exciting and motivating as the Amusement Park Experience set to incorporate into your planning. Share the set and Teacher's Guide with your colleagues so they too can see the interdisciplinary unit possibilities for themselves.

Whether used as a complete kit that progresses from one activity to the next or for supplemental activities to existing curriculum, the K'NEX Education Amusement Park Experience set is designed to engage students in the thrill of learning.



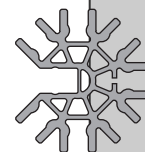
NATIONAL SCIENCE CONTENT STANDARDS ³	
Standards	Levels 5-8
Unifying Concepts and Processes (P. 104)	<ul style="list-style-type: none"> • Systems, Order and Organization. • Evidence, Models and Explanation. • Constancy, Change and Measurement.
Science as Inquiry (P. 143) (Content Standard A)	<ul style="list-style-type: none"> • Abilities Necessary to Do Scientific Inquiry. <ul style="list-style-type: none"> • Identify questions that can be answered through scientific investigations. • Design and conduct a scientific investigation. • Use appropriate tools and techniques to gather, analyze, and interpret data. • Develop descriptions, explanations, predictions, and models using evidence. • Think critically and logically to make the relationships between evidence and explanations. • Recognize and analyze alternative explanations and predictions. • Communicate scientific procedures and explanations. • Use mathematics in all aspects of scientific inquiry. • Understandings About Scientific Inquiry.
Physical Science (P. 149) (Content Standard B)	<ul style="list-style-type: none"> • Motions and Forces. • Transfer of Energy.
History and Nature of Science (P.170) (Content Standard G)	<ul style="list-style-type: none"> • Nature of Science.

³National Research Council. 1996. **National Science Education Standards**. Washington, DC: National Academy Press.



ITEA STANDARDS FOR TECHNOLOGICAL LITERACY ⁴	
Standards	Benchmark for Grades 6-8
<p>The Nature of Technology Standard 2. Students will develop an understanding of the core concepts of technology.</p> <p>Standard 3. Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.</p>	<ul style="list-style-type: none"> • Technological systems include input, processes, output, and at times feedback. • Systems thinking involves considering how every part relates to others. • Malfunctions in any part of the system may affect the function and quality of the system. • Different technologies involve different sets of processes. • Controls are mechanisms or particular steps that people perform using information about the system that causes systems to change. • Technological systems often interact with one another. • Knowledge gained from other fields of study has a direct effect on the development of technological products and systems.
<p>Design Standard 9. Students will develop an understanding of engineering design.</p> <p>Standard 10. Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.</p>	<ul style="list-style-type: none"> • Brainstorming is a group problem-solving design process in which each person in the group presents his or her ideas in an open forum. • Modeling, testing, evaluating, and modifying are used to transform ideas into practical solutions. • Troubleshooting is a problem-solving method used to identify the cause of a malfunction in a technological system. • Invention is a process of turning ideas and imagination into devices and systems. Innovation is the process of modifying an existing product or system to improve it.
<p>Abilities for a Technological World Standard 11. Students will develop abilities to apply the design process.</p>	<ul style="list-style-type: none"> • Apply a design process to solve problems in and beyond the laboratory-classroom. • Specify criteria and constraints for the design. • Make 2- and 3-D representations of the design solution. • Test and evaluate the design in relation to pre-established requirements. • Make a product or system and document the solution.

⁴International Technology Education Association. 2000. *Standards for Technological Literacy: Content for the Study of Technology*. Reston, VA: ITEA. Reprinted with permission.

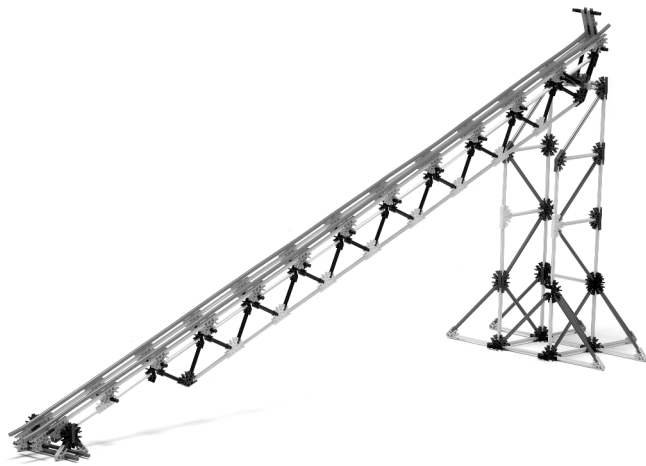


SCHOOL MATHEMATICS STANDARDS FOR GRADES 6-8⁵

Number and Operations	<ul style="list-style-type: none"> Understand numbers, ways of representing numbers, relationships among numbers, and number systems. Understand meanings of operations and how they relate to one another. Compute fluently and make reasonable estimates.
Algebra	<ul style="list-style-type: none"> Understand patterns, relations, and functions. Represent and analyze mathematical situations and structures using algebraic symbols. Use mathematical models to represent and understand quantitative relationships. Analyze change in various contexts.
Geometry	<ul style="list-style-type: none"> Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships. Apply transformations and use symmetry to analyze mathematical situations.
Measurement	<ul style="list-style-type: none"> Understand measurable attributes of objects and the units, systems, and process of measurement. Apply appropriate techniques, tools, and formulas to determine measurements.
Data Analysis and Probability	<ul style="list-style-type: none"> Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them. Develop and evaluate inferences and predictions that are based on data.
Problem Solving	<ul style="list-style-type: none"> Build new mathematics knowledge through problem solving. Solve problems that arise in mathematics and in other contexts. Apply and adapt a variety of appropriate strategies to solve problems.
Reasoning and Proof	<ul style="list-style-type: none"> Recognize reasoning and proof as fundamental aspects of mathematics. Make and investigate mathematical conjectures. Select and use various types of reasoning and methods of proof.
Communication	<ul style="list-style-type: none"> Organize and consolidate their mathematical thinking through communication. Communicate their mathematical thinking coherently and clearly to peers, teachers, and others. Use the language of mathematics to express mathematical ideas precisely.
Connections	<ul style="list-style-type: none"> Recognize and use connections among mathematical ideas. Recognize and apply mathematics in contexts outside of mathematics.
Representations	<ul style="list-style-type: none"> Create and use representations to organize, record, and communicate mathematical ideas. Select, apply, and translate among mathematical representations to solve problems. Use representations to model and interpret physical, social, and mathematical phenomena.

⁵ National Council of Teachers of Mathematics. 2000. Principles and Standards for School Mathematics. Reston, VA: NCTM.

Disclaimer: Mathematics Standards are listed with the permission of the National Council of Teachers of Mathematics (NCTM). NCTM does not endorse the content or the validity of any alignments.



LESSON 1:

Understanding the Relationship Between Speed, Distance, and Time

Time

- 30 minutes (after construction of the model)

Objectives

Students will:

- Identify and describe the relationship between the two components of speed: distance and time.
- Obtain accurate measurements of distance and time.

Materials

Each group will need:

- Materials from 1 K'NEX Education Amusement Park Experience set
- Building Instructions from CD-ROM: File – Inclined Plane II (for a ball)
- 4 different types of balls (minimum size 4.5 cm)
- Flexible (sewing) tape measure
- Stopwatch
- Water-based markers

Each student will need:

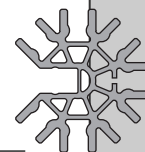
- Science notebook/journal
- Graph paper

OVERVIEW FOR THE TEACHER

The short ramp can be used as the basis for an introductory activity that allows students to practice some of the skills they will need as they investigate physical science concepts using the K'NEX Education Amusement Park Experience set. Students will, for example, take measurements of length using rulers, measurements of time using a stopwatch, and work with the concept of speed.

Teacher's Notes

- Students should work in small groups of 3-4 to construct their models and undertake their investigations.
- The K'NEX Education Amusement Park Experience set will allow two inclined plane systems to be built simultaneously.

**Teacher's Notes**

- The Building Instructions for this model are found on the CD-ROM that accompanies the set. Students can access the instructions directly from a computer screen or from printed hard copies. If students work from the computer screen we recommend that they use the file displaying instructions in the 11" x 17" format. If you select hard copies for your students you will need to prepare them in advance. Choose either the file to print instructions on 11" x 17" paper or the file to print onto 8.5" x 11" paper.
- Each group will need access to a model of the K'NEX Inclined Plane II (for a ball). The model can either be built in-class with groups identifying and then allocating sub-assemblies for members to construct, or it can be built as an out-of-class activity.
- Students should be encouraged to record their predictions and observations in their science notebooks/journals.

REVIEW

Students will be more successful with this activity if they understand the following concepts:

- How to measure distance in metric units.
- How to measure time (seconds, minutes, etc.) and use a stopwatch.
- What speed (velocity) represents.
- How to calculate the speed (velocity) of an object.

ACTIVITY 1: DISTANCE OVER TIME...WHAT MAKES IT HAPPEN?**PROCESS****Whole Class**

Explain to the students that the first activity with the K'NEX Education Amusement Park set will involve using an inclined plane model (ramp) to develop their building skills, to gain practice in taking various types of measurements, and to acquire knowledge of some basic scientific and mathematical concepts. In the first activity they will investigate whether or not the height at which a ball is released down a ramp impacts distance over time. In the second activity they will find an answer to the question, "Does the incline of the ramp impact distance over time?"

In Groups

1. If models are to be built in-class, distribute the K'NEX Education Amusement Park Experience sets to groups and allow time for construction. Make sure that all students are familiar with how to use the materials.
2. When the models are completed, ask each group to:
 - a. Use a water-based marker to label the following 5 positions on the model: the 3rd, 5th, 7th, 9th and 11th gold track support pieces. (These gold track support pieces are directly above the main support beams.)
 - b. Make a prediction about which position will give the ball the fastest average speed. Record this prediction.
 - c. Construct a four-column table in their individual journals in which to record their data. You may want to draw a table on the board.



LESSON 1

Height of labeled position (m)	Distance from labeled position to end of track (m)	Time taken by ball from labeled position to end of track (s)	Speed of ball from labeled position: distance/time (m/s)

3. Students should then:
 - a. Measure the distance from each of the labeled points to the end of the ramp and record these values in their table.
 - b. Release a ball from the lowest position and time how long it takes to travel to the end of the ramp. Record the time.
 - c. Repeat for each of the remaining positions.
 - d. Calculate the speed of the ball from each of the positions.
4. They should record and analyze their data by:
 - a. Drawing a line graph of their data. The height should be plotted on the x-axis and the speed on the y-axis.
 - b. Describing the shape of the line that is formed.
 - c. Stating if the shape of the line was expected or if it was a surprise.
 - d. Describing what the shape of the line indicates.
 - e. Predicting whether or not they will get the same shaped line when they make graphs using the other balls that have been provided.

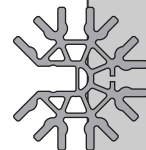
Teacher's Notes

If your students have studied slope in their math class, they should be able to provide a sound explanation of what the shape of the line indicates.

5. Students should then:
 - a. Repeat steps 3b - 4b with each of the other three balls.
 - b. Compare the four line graphs and write a paragraph comparing the shapes of the graphs and whether or not there were any factors that impacted the speed of the ball.

Teacher's Notes

This is an excellent opportunity to open a discussion on 'sources of error.'



Whole Class

6. Each group should display their four graphs with those created by other groups. For example: all graphs for a golf ball should be grouped together, all graphs for a tennis ball should be grouped together, etc. They should make comparisons between the graphs using the same balls and also the graphs using different balls.

Students may require some prompts to stimulate their comparisons:

- Do all of the graphs for a given type of ball look the same?
- Are the scales on each graph the same?
- Do all of the graphs, as a whole, look generally the same?

7. Students should discuss:

- a. The factors that impacted their data and thus their graphs. Specifically, does the mass or the height impact the speed? They should **write a short statement** that indicates the effect of mass, or height, or both, from their point of view. Can the students identify other factors that may have affected the shape of the graphs? Statements should be supported with an explanation.
- b. Whether or not the graph(s) show a linear relationship between height of release and speed?

Teacher's Notes

Student groups may be asked to mention any problems they had with data collection that may have caused their graph(s) to appear different from the graphs of other groups. (In a discussion such as this, 'experimental error' or 'measurement errors' are often not discussed.)

ACTIVITY 2: DOES THE INCLINE IMPACT DISTANCE OVER TIME?

PROCESS

Whole Class

Explain that in this activity students will vary the height of the ramp, and therefore the incline, to investigate what impact this has on the measurements of distance over time (or speed). The K'NEX Education Inclined Plane system allows the students to adjust the height of the end of the ramp. As the end of the ramp is lowered, the incline or slope of the ramp decreases. The students' investigations will help them to determine how the change in slope of the ramp affects the speed measured from each of the release marks they previously made on the track. In order to make this a 'fair test,' students will use only one of the balls that they used in Activity # 1.

Teacher's Notes

If students have not completed Activity 1 (above) ask them to use a water-based marker to label the following 5 positions on the model: the 3rd, 5th, 7th, 9th, and 11th gold track support pieces. (These gold track support pieces are directly above the main support beams.)

In Groups

1. Ask the groups to:
 - a. Predict whether changing the incline of the ramp will impact the speed of the ball they have been assigned. They should explain their reasoning, or the basis for their prediction.
 - b. Predict whether lowering the incline to 2/3 of its original incline will impact the speed by some factor.
 - c. Predict whether lowering the incline to 1/3 of its original incline will impact the speed by some factor.



LESSON 1

2. Students should then construct 3 tables in their notebooks/journals. These will be similar to the data table constructed for Activity 1. The following titles should be added to their tables:
 Table 1: Ramp in highest position on tower (largest incline)
 Table 2: Ramp in middle position on tower (incline 2/3 of original)
 Table 3: Ramp in lowest position on tower (incline 1/3 of original)

Teacher's Notes

Only Tables 2 and 3 will be necessary if they completed Activity # 1 as they will already have one set of completed data.

FOR EXAMPLE:

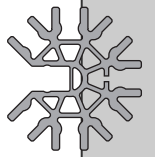
Table 2: Ramp in middle position on tower (incline 2/3 of original)

Height of labeled position (m)	Distance from labeled position to end of track (m)	Time taken by ball from labeled position to end of track (s)	Speed of ball from labeled position: distance/time (m/s)

Teacher's Notes

Students may not need to undertake steps 3 and 4 below if Activity 1 was completed, instead they can begin their investigations at step 5 below.

3. Students should then:
 - a. Measure the distance from each of the labeled points to the end of the ramp and record this in their table.
 - b. Release a ball from the lowest position and time how long it takes to travel to the end of the ramp.
 - c. Repeat for each of the remaining positions.
 - d. Calculate the speed of the ball from each of the positions.
4. They should record and analyze their data by:
 - a. Drawing a line graph of their data. The height should be plotted on the x-axis and the speed on the y-axis.
 - b. Describe the shape of the line that is formed and indicate if the shape of the line was expected or was a surprise. Describe what the shape of the line indicates.



5. Students should then:
 - a. Lower the ramp one level on the tower and complete steps 3a - 3d a second time using the same ball.
 - b. Graph the data as a second line on the previous graph using a different color. Note the colors, and the ramp height they represent, in a key on their graph paper.
 - c. Lower the ramp one more level on the tower and complete steps 3a - 3d a third time.
 - d. Using a third color to display it, plot the data obtained on the existing graph. Note the color and release height in the key.
6. Students will compare the speed of the ball for the same start positions, but with different ramp inclines, to see if each of their predictions (step 1, above) accurately reflects the factor by which the speed declined when the short ramp was moved to a lower position.
7. Using the graph as a guide, they should write a paragraph discussing the impact of lowering the ramp on the speed of the ball.

Whole Class

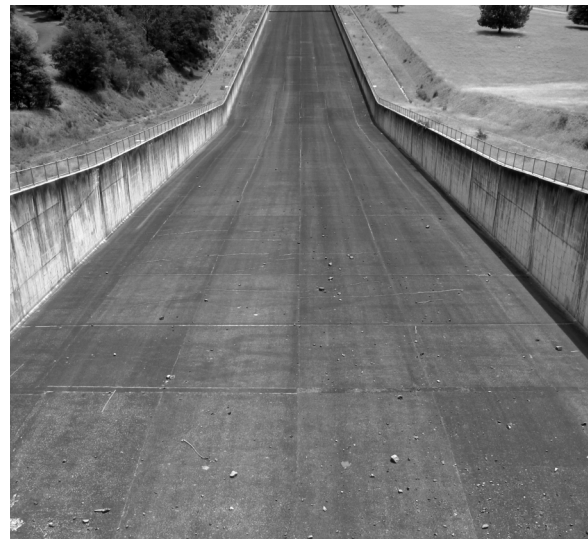
8. Students should share their predictions and their findings concerning (i) the speed of the ball when the incline is lowered and (ii) the factor by which the speed was impacted.
9. Encourage them to discuss the effect that lowering the ramp had on the speed of the ball.

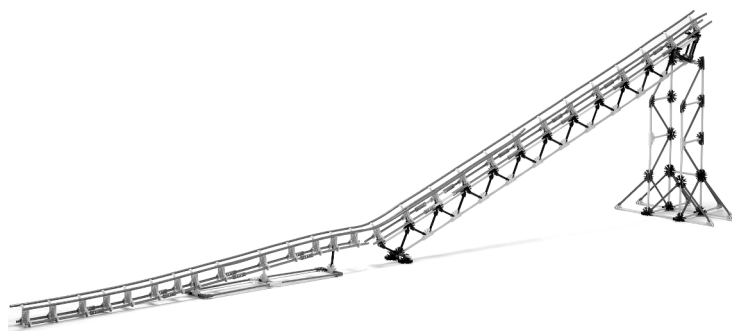
REVIEW

- Concepts associated with accurate measurements of distance and time.
- Calculating speed.
- Construction of graphs to represent data.
- Analyzing graphs.

ASSESSMENT

- Predictions and conclusions recorded in notebooks/journals.
- Graphs constructed during the activities.





LESSON 2:

How Mass Affects the Speed of a Coaster Car

Time

- 45 minutes (after construction of the model)

Objectives

Students will:

- Experiment and determine the speed of the coaster car, with different masses. The ramp will be set at its highest position (greatest incline).
- Experiment and determine the speed of the coaster car, with different masses. The ramp will be set at two alternative positions (lesser inclines).
- Draw conclusions as to the effect of different masses and different inclines on the speed of the car.

Materials

Each group will need:

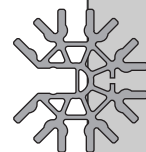
- Materials from 1 K'NEX Amusement Park Experience set
- Building Instructions from CD-ROM: File – Inclined Plane I (for a coaster car)
- 1 coaster car (provided with the construction set)
- 2 AA batteries or other masses
- Tape
- Flexible (sewing) tape measure
- Stopwatch
- Water-based marker

Each student will need:

- Science notebook/journal
- Graph paper

OVERVIEW FOR THE TEACHER

In a previous activity, students investigated how different release heights impacted the speed of balls on ramps with different inclines. In this activity, students use another object on the track, the coaster car. This allows students to explore how mass impacts the speed of the car when it is released. They may be surprised at the impact that mass has on the speed of an object. Students will also examine what happens to the speed of the car when the angle of elevation is reduced and mass is added.



REVIEW

Students will be more successful with this activity if they have an understanding of the following concepts and vocabulary:

- How to calculate speed (velocity).
- That acceleration results in an increase in speed and deceleration results in a decrease in speed.
- That mass is the “amount of stuff” that an object has and is affected by the force of gravity.

Introduction

The teacher may choose to introduce this lesson by inviting students to share any experiences of inline skating or skateboarding, or by having a general discussion comparing riding a bicycle on a flat surface versus on a hill.

Teacher's Notes

Students should work in small groups of 3-4 as they participate in these investigations and activities. They should be encouraged to record their predictions and observations in their notebooks/journals.

ACTIVITY 1: SPEEDING DOWN THE RAMP

PROCESS In Groups

1. Distribute K'NEX Education materials and allow the students to build the ramp with the coaster car, using the directions found on the CD-ROM.
2. Once built, students should predict which of the following coasters cars will travel down the ramp fastest:
 - An empty coaster car.
 - A coaster car with one AA battery placed in the front seat.
 - A coaster car with one AA battery placed in the back seat.
 - A coaster car with one AA battery placed in the back seat and one AA battery placed in the front seat.
3. Students should explain how they arrived at their predictions.
4. Ask the students to:
 - a. Select a common point at the top of the ramp from which to release the coaster car and mark this start point using a water-based marker.
 - b. Measure the length of the track from the start point to the end of the ramp and record the measurement in their notebook.
 - c. Have a stopwatch ready for use, place the empty coaster car at the top of the ramp and release it. Time the coaster car as it travels from the top of the ramp to the end of the ramp. Students should run three trials to determine an average time.
5. Students should repeat step 4c for each of the **other variations** of the car, as listed above.



LESSON 2

6. Once they have collected their data they can determine the speed (velocity) of the car for each variation using the following information:

$$v = d/t$$

given: t = average time determined through experimentation

d = length of the ramp from release point to the end of the ramp

Teacher's Notes

The teacher may want to review the appropriate units for speed, distance, and time at this point.

7. Students should make a bar graph of their data.
 - x-axis – Description of each car variation tested
 - y-axis – Speed of the cars
8. Ask the students to respond to the following questions in their science journals:
 - a. Do they notice any trends in their data?
 - b. Were their predictions correct? Explain.
 - c. Does any of their data provide insight into whether the position of the masses affected the speed of the car? Explain.

Whole Class

9. As a group, students should discuss their initial predictions, reasons for their results, and, if necessary, suggest reasons why their predictions and results differed.

ACTIVITY 2: CHANGING THE ANGLE OF THE RAMP

PROCESS

In Groups

1. Ask each group to repeat Activity # 1 (all steps) for each of the other two angle settings for the ramp. These are indicated in the Building Instructions with #2 and #3 designations.
2. In their journals, students should compare their results for:
 - a. Each of the differently loaded cars.
 - b. Each of the different release angles.

Whole Class

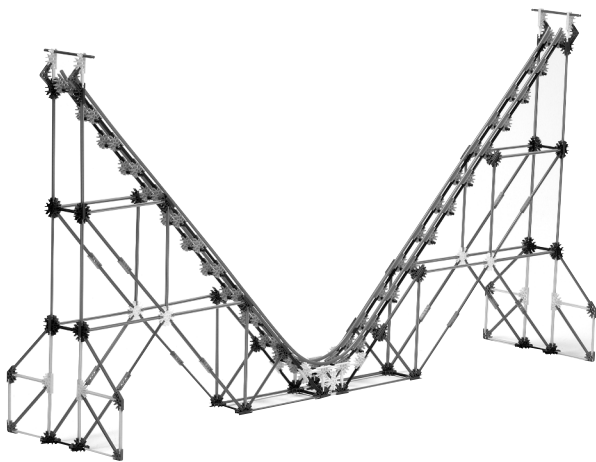
3. Invite the students to discuss their findings about the effect on the coaster car of lowering the ramp into the different positions.

REVIEW

- How does the angle of the ramp affect the speed of the various cars? Students can relate this back to their earlier comments about skating or riding a bike.

ASSESSMENT

- Using the student notebooks/journals and graphs, the teacher can determine if the students:
 1. Understand graphing concepts associated with the activity.
 2. Can use their data to present reasonable explanations of the effect of car mass on the speed of the car.
 3. Can use their data to present reasonable explanations of the effect of ramp incline (angle) on the speed of the car.



LESSON 3: Investigating Variables in a Half Pipe System

Time

- 45 minutes (after construction of the model)

Objectives

Students will:

- Explain the difference between potential and kinetic energy.
- Predict how balls with different weights will act in the half pipe system.
- Make observations about the motion and path of the ball.
- Predict and then calculate how many rotations the ball will make during its movement from one point to another point.

Materials

Each group will need:

- Materials from 1 K'NEX Education Amusement Park Experience set
- Building Instructions from CD-ROM: File – Half Pipe System II (for a ball)
- Assorted balls (soft rubber, hard rubber, plastic) with minimum 4.5cm diameter
- Tape Measure
- Masking Tape

Each student will need:

- Science notebook/journal

OVERVIEW FOR THE TEACHER

If the students completed the two ramp activities (Lessons 1 and 2), they were exposed to how raising the release level of an object impacts its speed as it travels down the ramp. The half pipe model comprises two ramps that meet at their lowest points. As the ball gains speed traveling down one ramp it will be able to climb the ramp on the other side due to the momentum it has gained. The release height of the ball on one ramp impacts how high it travels up the other ramp. Exactly what, however, is that relationship? Many students will be familiar with the idea that a roller coaster car gains speed going down the hill so that it can climb the next hill and they frequently identify speed as the determining factor. In fact it is energy, which has speed as a component, that allows the object to climb the other hill. This provides a rich context for a discussion of potential and kinetic energy, as well as of forces that impact energy loss within a system, specifically friction. These concepts underpin the activities set out in this lesson. Additionally, and where appropriate, teachers may want to introduce students to Newton's Three Laws of Motion, and to the concepts of momentum and inertia.



LESSON 3

Teacher's Notes

- The K'NEX Education Amusement Park Experience set will allow two half pipe systems (for balls) to be built simultaneously.
- The Building Instructions for this model are found on the CD-ROM that accompanies the set. Students can access the instructions directly from a computer screen or from printed hard copies. If students work from the computer screen we recommend that they use the file displaying instructions in the 11" x 17" format. If you select hard copies for your students you will need to prepare them in advance. Choose either the file to print instructions onto 11" x 17" paper or the file to print onto 8.5" x 11" paper.

REVIEW

Your students will be more successful if they have an understanding of the following concepts and associated vocabulary.

- Concepts associated with energy such as:
 - * Energy can be neither created nor destroyed.
 - * Energy can be converted from one form to another.
 - * Energy can be described as either potential or kinetic.
- Newton's Laws of Motion
- Circumference

INTRODUCTION

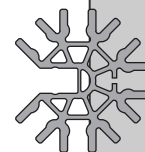
Explain to the students that in this activity they will use a K'NEX Education model of a half pipe system to investigate the movement of a ball. For the benefit of those students who are not already familiar with the term "half pipe," explain that it is a gully or "U-shaped" system often used for skateboarding or in-line skating. You may want to show a video clip of skateboarders using a half pipe.

Students will need to utilize science process skills as they make predictions, observations, and record these in their notebooks.



Teacher's Notes

- Students should work in small groups of 3-4 to construct their models and undertake their investigations.
- They should be encouraged to record their predictions and observations in their notebooks.



ACTIVITY 1: THINKING ABOUT THE HALF PIPE AND MAKING PREDICTIONS

PROCESS

In Groups

1. Distribute the K'NEX Education materials and ask each group to build the half pipe system. Building Instructions can be found on the CD-ROM included with the set.
2. Allow the students a few minutes to examine the model and then ask them to brainstorm real life examples of where they may have seen a similar system.
Possible answers may include examples used in snowboarding, in bike parks, or in some amusement park water rides.
3. Pose the following questions and ask the students to discuss them within their groups. You may want to record the questions on the board, one at a time:
 - a. What do you think will happen if you release a ball from the top of one side of the half pipe? Describe the motion that you expect to observe.
 - b. As the ball moves down the ramp and then up the other side, it is using energy. Where do you think the energy comes from?
 - c. Do you think different balls will act in different ways? Why?
 - d. If you use a larger ball, (one with a greater circumference,) do you think this will make a difference to the number of rotations it takes for the ball to reach the other side?

Whole Class

1. Have groups report back on their predictions to the class as a whole.
2. Make a record of them on the board or chart paper. Use probing questions to highlight answers that focus on energy, as well as reasons why the ball stops or slows down. (*Friction.*)

ACTIVITY 2: TESTING OUR PREDICTIONS AND DISCUSSING ENERGY

PROCESS

In Groups

1. Allow the students to use a soft rubber ball and experiment with Question 3a above. Have them record and make sketches of their observations in their science journals. Remind the students to practice good science by:
 - a. Making careful observations.
 - b. Undertaking multiple trials of the same test.
 - c. Identifying quantifiable data, where appropriate.
2. Encourage the students to try different points on the ramp from which to release the ball. Ask them to describe what happens and to record their findings.

Teacher's Notes

- The ball loses energy due to friction as it rolls down the ramp and up the other side. In a perfect system, the ball would reach the same height on the "upside" slope as its starting point on the "downside" slope. In this activity, the ball will not reach the same height as its starting point.



LESSON 3

Whole Class

3. Ask the student to report on their findings. Then pose the following guiding questions:
 - a. If energy can be neither created nor destroyed, why does the ball “slow down” and eventually come to a stop? (*Friction.*)
 - b. Where in the model can you identify maximum potential energy or kinetic energy?
(*Maximum potential energy is when the ball is at the top of the ramp before it is released - in this case holding the ball at the top of the ramp. Maximum kinetic energy is when the ball is at the bottom of the ramp traveling at its fastest speed.*)
 - c. A ball that starts at a lower point on the ramp does not roll as high on the other side as one that begins its course higher up. Why? (*The ball did not have the same amount of time to “gain speed” since it had less potential energy to start with.*)
 - d. What would need to be applied to the ball to make it “roll higher?” (*More force in the form of a push, for example, when the ball is released.*)

ACTIVITY 3: TAKE A BALL - DESIGN YOUR OWN EXPERIMENT

PROCESS

Whole Class

1. Review the process for designing experiments. This should include discussing the selection of only one variable to manipulate while making every effort to keep other variables constant.

In Groups

2. Ask the students to:
 - a. Select one of the other balls provided. This will allow a comparison of the soft rubber ball (Ball A) with one of their choice (Ball B).
 - b. Design an experiment that will test the question: “Does the movement of Ball A differ from the movement of Ball B?”
 - c. Conduct their experiment and record their findings.

Whole Class

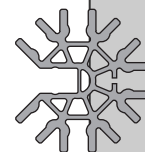
3. Each group should report their findings to the entire class.

ACTIVITY 4: DISTANCE ON THE TRACK

PROCESS

In Groups

1. Using “Ball B” from the previous activity, ask the students to:
 - a. Make a prediction about the number of times the ball rotates as it goes from the release point to the highest point on the “upside” of the ramp.
 - b. Support their predictions and record their answers in their notebooks.
2. Pose the question: “How could you determine the number of rotations of the ball?”
Students may suggest trying to count the rotations as the ball moves. This is extremely difficult. Help them understand that the circumference of the ball may provide a clue as to the number of rotations the ball makes.
3. Allow students to brainstorm ways they might determine the number of rotations the ball would make as it moves from one side of the half pipe system to the other using the circumference of the ball. When they reach a reasonable solution, let them begin their investigation.



Teacher's Notes

- Some groups may choose to measure the circumference of the ball and the distance along the track the ball travels. They can then divide to find the number of rotations.
- Others may choose to mark the circumference on the tape measure and move that section along the track to see how many times they must move the tape to reach the masking tape on the other side.

- The investigation should involve students undertaking the following:
 - Release 'Ball B' from the top of one side of the half pipe system.
 - Mark the highest point reached on the other side of the system with a piece of masking tape.
 - Determine the number of rotations made by the ball as it travels from one side of the system to the other.

Whole Class

- Have each group report back to the larger class with information on the circumference of their ball and the number of rotations that the ball made. A pattern will emerge that shows that the larger the circumference, the fewer the rotations necessary for the ball to cover the same distance.

REVIEW

- Discuss what the students have learned about energy in the half pipe system.

EXTENSION IDEAS

- Have the students predict what would happen if they had used a larger half-pipe system.
- If there are two or more balls with similar masses, but different circumferences, students can determine if there is any relationship between the number of rotations of similar mass balls and the height they reach on the other side.

ASSESSMENT

- Use the student science notebooks/journals for assessment purposes. These journals should include records of the students' predictions, diagrams, and their design of an experiment.

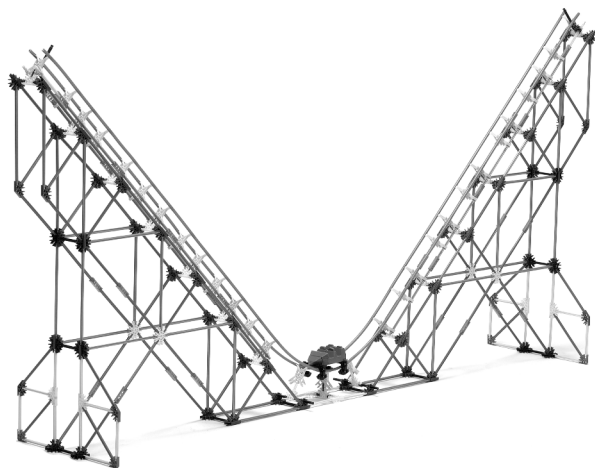
WEB SITES

http://www.findarticles.com/p/articles/mi_m1590/is_1_61/ai_n9525600

An article that discusses how a BMXer uses physics to break world records in the half pipe. (It may take a few seconds to load this article, even with a high speed Internet connection.)

<http://www.exploratorium.edu/skateboarding/trick04.html>

Exploratorium web site that discusses skateboarding and half pipes.



LESSON 4: Mass, Motion, and Energy Loss

Time

- 4 x 45 minutes (after construction of the model)

Objectives

Students will:

- Explore the concept of relationships between variables.
- Explore the concept of the impact of a variable on a system.
- Explore the concept of energy loss.

Materials

Each group will need:

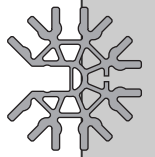
- Materials from 1 K'NEX Education Amusement Park Experience set
- Building Instructions from CD-ROM: File – Half Pipe System I (for a car)
- Coaster Car (provided with construction set)
- Tape Measure (flexible)
- Masking Tape
- AA Batteries
- Balance (for mass measurements)

Each student will need:

- Science notebook/journal
- Graph paper
- Colored pencils/markers

OVERVIEW FOR THE TEACHER

The half pipe system comprises two ramps that are fused together in the middle. The actual tubular tracks of the ramps are connected to the superstructure at different locations along the track. Those connection points will be the release points described in each activity. In this series of activities students will investigate the effect of mass on the motion of a car in a half pipe system. They will also have the opportunity to explore the relationship between the release height of a car and energy loss in the system.



ACTIVITY 1: MOVING MORE WITH HEIGHT

PROCESS

Whole Class

1. Using a model of the Half Pipe System I for a coaster car:
 - a. Raise the car to the highest point on one side of the half pipe.
 - b. Ask students to predict what will happen *if* you release the car.
 - c. Replace the car on the desk/bench and list the students' responses on the board. Help them to be as specific as they can with their predictions. Can they quantify their predictions?
 - d. Rather than releasing the car to demonstrate its action for the students, direct them to complete Activity # 1 to find out for themselves what happens.

In Groups

2. Distribute the K'NEX Education materials and ask each group to build the half pipe system for cars. Building instructions can be found on the CD-ROM included with the set.
3. Each student should then create a data table, such as the one shown below. The left column will be for the release height and the right columns for the number of passes through the center of the half pipe system.

	Passes of the Car Through the Center of the System			
Release Height	Trial 1	Trial 2	Trial 3	Average

4. Students should use centimeters to measure the height of each of the release heights. The actual tubular tracks of the ramps are connected to the superstructure at different locations along the track. Those connection points will be the release points. These measurements should be recorded in the appropriate column in the data table.
5. Students should:
 - a. Release the coaster car from the lowest release point, with the front of the coaster car over the connection point.
 - b. Count the number of times that the coaster passes through the center of the half pipe before stopping in the center of the system.
 - c. Record this number in their data table in the Trial # 1 column and then complete two other trials before determining the average.
 - d. Repeat the process for each of the release points.



LESSON 4

6. Students can then:
 - a. Graph this data, plotting the release height on the x-axis and the passes through the center on the y-axis.
 - b. Add a line of best fit for the data. This is the straight line that best fits the data point or that passes closest to all of the data points (in the vertical direction). It must be remembered that this line may not necessarily pass through any of the data points in order to be the line of best fit for the data.
7. In their journals students should record any relationship(s) they see between the release height of the car and the number of passes.

Whole Class

8. Invite the students to share their thoughts and discuss the relationship(s) they noted between the variables.

Teacher's Notes

- The relationship in this experiment should produce a straight line. Thus, the relationship is considered to be a linear relationship.

EXTENSION

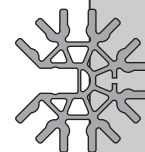
- Students in Algebra I or higher can determine the actual line of best fit.

ACTIVITY 2: DOES MASS MEAN MORE MOVEMENT?**PROCESS****Whole Class**

1. Using a model of the Half Pipe System for the Roller Coaster car:
 - a. Tape one AA battery into the front seat of the car.
 - b. Raise the car to the highest point on one side of the half-pipe. Ask students to predict what will happen if you release the car.
 - c. Replace the car on the table/bench and list the students' responses on the board. Since students have completed Activity # 1, their responses should draw upon what they learned during the previous investigations.
 - d. Rather than releasing the car to demonstrate its action for the students, direct them to complete Activity 2 to find out for themselves.

In Groups

2. Students should change the mass of the car and repeat **Activity # 1: Step 5** two additional times. The car will be changed for each of these two repetitions of Activity # 1:
 - a. One series of trials will use the car with one AA battery in its front seat.
 - b. The second series of trials will use the car with one AA battery in each of its two seats.



3. Students can be asked to graph their data for Activity # 1 and the two new trials on the same coordinates. They should use a different color pen/pencil to place the dots for each series of data on the graph, place a key on their graph, and label the best fit lines as follows:
 - a. empty car
 - b. car with one AA battery
 - c. car with two AA batteries
4. Each student should use the findings recorded in their data tables and graphs to write a paragraph in their science journals describing whether or not they think mass impacts the number of passes the coaster car makes through the center of the half pipe system.

Whole Class

5. Ask the students to share and discuss:
 - a. Whether mass impacted the number of passes and explain what data supported their conclusions.
 - b. What other factors may impact the number of passes.

EXTENSION

- Students in Algebra I or higher can determine the actual line of best fit for each of the three lines on their graph.

ACTIVITY 3: ENERGY LOSS IN A SYSTEM

PROCESS

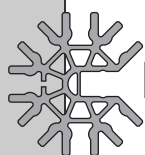
Whole Class

1. Using a model of the Half Pipe System for the Roller Coaster car:
 - a. Raise the car to the highest point on one side of the half pipe, ask the students to observe very carefully, and then release it.
 - b. Help the students to be as specific as possible with their observations as you list them on the board.
 - c. Repeat the demonstration if necessary to ensure that all students have clearly seen the movement of the car. Student responses should mention that the car never reaches a height equal to the release height on the second hill. Ask students to explain this observation in terms of energy.

Teacher's Notes

- *Students may respond that there wasn't enough energy to climb the second hill to a height equal to the release height. Other students may mention that the car had potential energy when it was released and that energy was converted to kinetic energy as the car moved, but there wasn't enough kinetic energy to reach the release height on the second hill.*

- d. Can students offer suggestions as to why the car was unable to reach the same height on the second hill? Some students may suggest friction is the cause. Some may even suggest that the turning wheels of the car used some of the energy that may have otherwise raised the car to the original release height.
- e. Challenge students to determine how much energy the car lost as it moved from one side of the system to the other.



LESSON 4

Teacher's Notes

- In a closed system energy is conserved. In the half pipe, the coaster should travel to the same height on the other side as that from which it was released.

- If necessary, review the following with the class:
Potential Energy is the energy that an object has due to its height above the ground. It is the product of the mass of the object in kilograms, the height of the object above the ground in meters, and the gravity constant: 9.8 meters per second squared.

$$PE = mgh$$

Where: PE = Potential Energy in $\text{kg} \cdot \text{m}/\text{sec}^2$ or $\text{kg} \cdot \text{m}/\text{sec}/\text{sec}$ (joules)
m = mass in kg
g = acceleration due to gravity or $9.81 \text{ m}/\text{sec}^2$ or $\text{m}/\text{sec}/\text{sec}$
h = height in meters

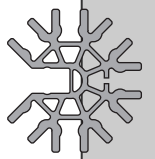
- Explain that the students will use the half pipe system to investigate the relationship between the release height of the car and the energy lost during its movement along the track.
- Suggest that students create a data table with five columns, as shown below, in which to record their findings and complete their calculations.

Release Height (m)	Potential Energy at Release (joules)	Height Attained (m)	Potential Energy Attained (joules)	Change in Potential Energy (joules)

In Groups

- Students should:
 - Use the same release heights as they used in previous activities. These numbers should be recorded in the appropriate column in the data table.
 - Determine the mass of the coaster car.
 - Release the coaster car from the lowest release point, with the front of the coaster car over the connection point.
 - Compute the Potential Energy for that release point and record it in the data table.
- Students should then:
 - Release the coaster car and mark, as best as possible, the height it reaches on the other side of the half pipe.
 - Record this height in the appropriate column in the data table using meters, calculate the Potential Energy at that point, and record that value in the appropriate column on the data table.
 - Determine the difference between the Potential Energy at the release point and the Potential Energy at the height that the coaster car attained on the other side of the half pipe from the release.



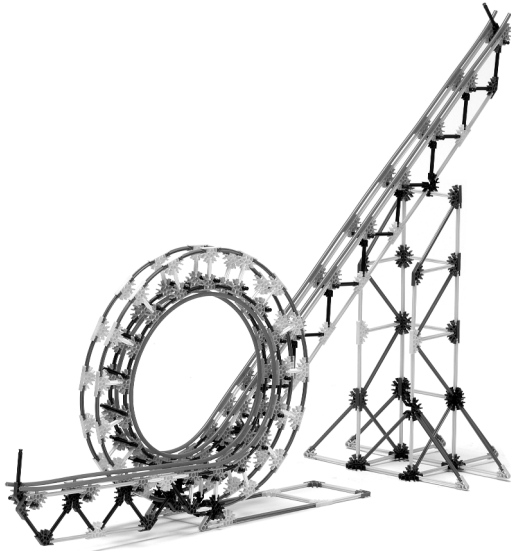


7. Ask students to repeat steps **5c through 6c** for the other release points.
8. Students should:
 - a. Make a graph of their data, plotting the release height on the x-axis and the energy lost on the y-axis.
 - b. Add a line of best fit for the data. This is the straight line that best fits the data point or that passes closest to all of the data points (in the vertical direction). It must be remembered that this line may not necessarily pass through any of the data points in order to be the line of best fit for the data.
9. Ask the students to describe in their science journals any relationship(s) they see between the release height of the car and the energy lost during its passage to the other side of the half-pipe.

Whole Class

10. Ask the students to share their findings and discuss the type of relationship that the variables have demonstrated. (*Variables have a linear relationship if a straight line almost fits the data, or almost passes through the data.*)





LESSON 5: Investigating Variables in a Loop

Time

- 45 minutes (after construction of the model)

Objectives

Students will:

- Determine the relationship between the mass of a ball and the height above the ground at which it must be released in order to pass through a loop.
- Determine the speed required to make the ball pass through the loop.

Materials

Each group will need:

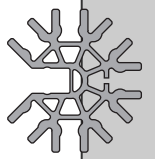
- Materials from 1 K'NEX Education Amusement Park Experience set.
- Building Instructions CD-ROM: File – Inclined Plane with Circular loop (for a ball)
- Four balls (minimum diameter 4.5 cm)
- Balance
- Flexible (sewing) tape measure
- Masking tape
- Stopwatch

Each student will need:

- Science notebook/journal
- Graph paper

OVERVIEW FOR THE TEACHER

Most students realize from their experiences of riding roller coasters that the necessary component for making a coaster train travel through a loop is **speed**. As they discovered in previous activities involving the ramp, the higher the height of release, the faster the balls (or a coaster car) will travel. In this activity they will use a ramp with a circular loop to identify the minimum release height for a ball that will allow it to travel through the loop without losing contact with the track.



Amusement Park Facts

If loops were constructed as circles and friction did not exist, the coaster train need only be a height of two and one half times the radius of the loop above the ground for it to pass through the loop and not drop off.

The forces, however, experienced by riders on circular looped roller coasters – like those built in the late 19th and early 20th Centuries at Coney Island, NY and in Atlantic City, NJ – were enormous. It was not until the 1970s that engineers realized they could use a mathematical form, first described by Euler and known as the clothoid, to significantly reduce these forces on riders.

REVIEW

Your students will be more successful if they have an understanding of the following concepts and associated vocabulary.

- Concepts associated with energy such as:
 - * Energy can be neither created or nor destroyed.
 - * Energy can be converted from one form to another.
 - * Energy can be either potential or kinetic.
- Newton's Laws of Motion.
- Circumference.
- Speed/Velocity.
- Force.

ACTIVITY 1: MAKING IT THROUGH THE LOOP

PROCESS

Whole Class

1. Explain that this activity involves the use of an inclined plane with a circular loop and that students will investigate the height at which a ball must be released in order for it to travel through the loop.

In Groups

2. If models are to be built in-class, distribute the K'NEX Education Amusement Park Experience sets to groups and allow time for construction and investigation of how the model works.
3. When the models are completed ask each group to select four balls with different properties, and then:
 - a. Determine the mass of each ball.
 - b. Predict which ball will need to be released at the highest level on the ramp in order to make it through the loop, then predict which will be next highest, etc. until the balls are ranked in some order.
4. To test their predictions, students should:
 - a. Determine the minimum height of release that allows a ball to just pass through the loop. They should record the ramp's height above the surface on which it stands, not its length.
 - b. Repeat the measurements for the other three balls.



LESSON 5

5. Ask them to record their findings as follows:
 - a. Describe the properties (characteristics) of the balls they tested.
 - b. List the heights attained by the various balls.
 - c. Write a paragraph in their journal that explains their understanding of the results.
 - i) Were all of the heights attained the same? Different? Explain.
 - ii) Were the properties of the balls the same? Different? Explain.
 - iii) If the heights attained were different, do you think any property of the ball may have contributed to the difference? Explain.
 - d. Draw a bar graph to compare the masses of the balls and the heights they attained. Plot the mass of the ball on the x-axis and the height reached on the y-axis.
 - e. Describe any pattern that you see when you graph the results.

Whole Class

6. Students should discuss their predictions and their discoveries about the mass of the balls and the height needed to propel them through the loop. Observations that they made about the properties of the balls may give students ideas as to other factors that may have influenced the results, such as surface of the balls, ridges on the balls, dimples on the balls, etc.

ACTIVITY 2: SPEED IS NEEDED IN THE LOOP

Teacher's Notes

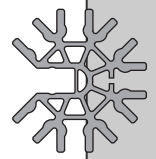
- The key to engineering a roller coaster with a loop is that the speed of the car as it moves through the loop should be just enough to keep it from falling. This means there needs to be some force to keep the coaster train moving in its circular path... that force is the centripetal force.

Whole Class

1. Explain that in this activity students will determine the speed at which each ball must travel in order to make it through the loop of the inclined plane.

In Groups

2. Ask the students to:
 - a. Watch each of the four balls travel through the loop and use their observations to mathematically determine how fast each must be traveling in order to accomplish this. They should report their findings in m/sec.
 - b. Determine the mass, in kilograms, of each of the balls.
 - c. Calculate the force needed to keep each of the balls from falling off the track in the loop by determining the weight of the ball. This is calculated by multiplying the mass (kg) by **9.81 m/sec² or m/sec/sec**. The units for the answers will be in Newtons. For simplicity, assume that there is no pressure from the track.
3. Students will then:
 - a. Find the center of the loop. Tape two strips of masking tape to the track for this task. Place one piece vertically from the top to the bottom of the loop and one piece horizontally across the middle of the loop so they cross and stick together at the loop's center
 - b. Put a small dot in the center of the cross – this is the center of the circle formed by the track on the loop.



- c. Find the radius from the center of the loop (or circle) to the track at the top of the loop. This must be measured in meters.
- d. Calculate the speed needed to keep each of the balls on the track/in the loop by solving for v in the following formula:

$$C = \frac{mv^2}{r}$$

Where:

C = the minimum force needed to keep the ball in the loop

r = radius of the loop

m = mass of the ball

Note: C is the minimum force needed to keep the ball in the loop since it is assumed that the pressure from the track is zero. Students calculated this force in Step 2c above.

4. Ask the students to record their findings by:
 - a. Constructing a line graph of their data. The mass of the ball should be recorded on the x-axis and the speed needed to keep it in the loop on the y-axis.
 - b. Writing a paragraph about the shape of the graph of their data.

Whole Class

5. Each group should be given the opportunity to share and discuss the shape of their line graphs with the rest of the class.
6. They should discuss what conditions, if any, could be changed on a roller coaster so that the coaster car does not have to go as fast in order to go through the loop. Students should also discuss other factors that impact a coaster car traveling through a loop.

REVIEW

- The key concepts to be reviewed in this lesson involve the components of the formula for determining speed, as well as calculating the force needed to keep the ball on the track to make it through the loop.

ASSESSMENT

- Students will calculate the force needed for a ball, with a different mass, (provided by the teacher,) to complete the loop.
- Science notebooks/journals.

WEB SITES

<http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/circmot/rcd.html>

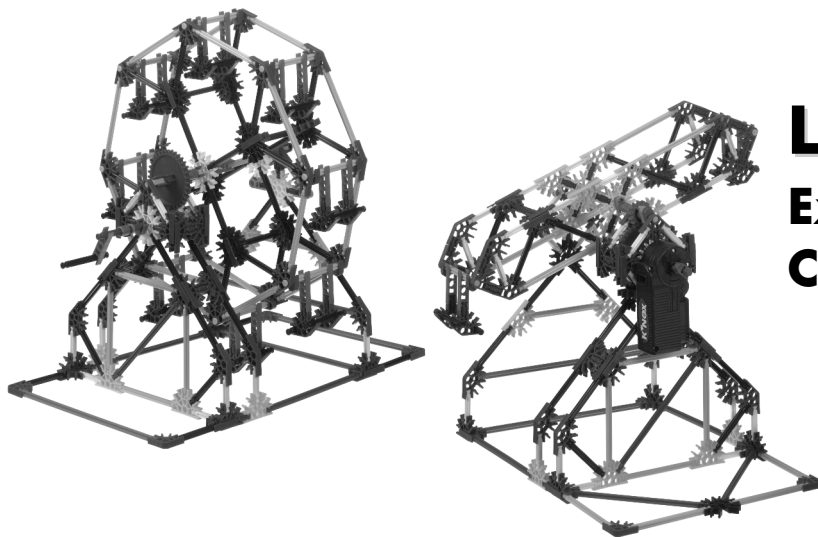
This web site has an animation about the forces needed to have a roller coaster go through a loop.

<http://www.pen.k12.va.us/Pav/Science/Physics/book/LoopDesign/home.html>

Another web site describing the loop in a roller coaster.

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

This web site allows students to change the shape of a “coaster” to see what happens.



LESSON 6: Examining Circular Rides

Time

- 3 x 45 minute periods (after construction of the model)

Objectives

Students will:

- Make and test predictions.
- Use measurement devices.
- Record, organize, and graph data.
- Investigate the effect of gearing-up and gearing-down on speed.
- Explore the concept of a periodic function and associated vocabulary.

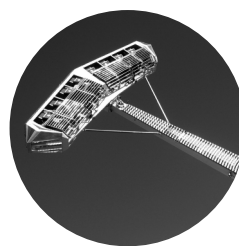
Materials

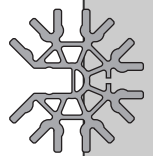
Each group will need:

- Materials from 1 K'NEX Education Amusement Park Experience set
- CD-ROM File: Ferris Wheel OR Boom Ride
- Protractor
- Calculator
- Stop Watch
- Ruler
- Masking tape
- Stickers for labeling the seats
- Marker for writing on the labels
- 8 - 16 AA batteries or other materials with common mass

Each student will need:

- Science notebook/journal
- Graph paper
- Colored markers/pencils
- Butcher paper or newsprint





Teacher's Notes

- One K'NEX Education Amusement Park Experience set will allow two Ferris Wheels OR two Boom Rides OR one Ferris Wheel and one Boom Ride to be built simultaneously.
- The Building Instructions for these models are found on the CD-ROM that accompanies the set. Students can access the instructions directly from a computer screen or from printed hard copies. If you select hard copies for your students you will need to prepare them in advance.
- Model Information:
 - Activities 1-3 require the use of motorized versions of EITHER the **Ferris Wheel** OR the **Boom Ride** models.
 - Activities 4-6 require the use of hand crank versions of EITHER the **Ferris Wheel** OR the **Boom Ride** models.
 - Allow time for students to make the necessary modifications to their models if they undertake Activities 1-3 and Activities 4-6.

OVERVIEW FOR THE TEACHER

The Ferris Wheel and Boom Ride differ from the other devices that have been analyzed in previous activities because of their motion. Both rides move along a constant circular path so that they provide opportunities for students to work with the properties of one of the most basic geometric structures, as well as with motion in a circular path.

The Ferris Wheel and Boom Ride are driven with gears. Students will have the opportunity to explore how different gear systems impact the distance traveled by 'riders' and, ultimately, the speed at which they travel. Additional mass can sometimes impact the speed of rides driven by gears and so many real world rides have motors and gear systems that are designed to compensate for this. In addition, many Ferris Wheel and Boom Ride operators are careful to balance their rides and in some cases do not permit those of larger mass to ride.

Rides that move in a circular path on a vertical plane offer students an opportunity to investigate several concepts of geometry and to understand how these concepts are integral to scientific concepts such as distance, height, and speed. In the activities described below, students will also be asked to graphically display the data so that it can be further analyzed. One such analysis will involve the concept of slope as a rate of change. Students will be asked to analyze a distance-time graph, which will be a straight line. As students determine the slope of the line, they will arrive at the speed of the ride. The slope is essentially the rate of change of distance over time and thus is the same as speed. The concept of distance traveled on a circular ride will also be contrasted with the height of the ride over time. This is similar to the concept of displacement that is explored in the Scrambler activity (Lesson 8).

As the teacher, you are the best judge of your students' abilities and interests. Feel free to complete this activity as described, or to complete those portions that are most appropriate for your students and the requirements of your program of study in science, technology, or mathematics. This lesson provides opportunities for an interdisciplinary exploration with the assistance of your teaching colleagues.



LESSON 6

REVIEW

Your students will be more successful if they have an understanding of the following concepts and associated vocabulary:

- Circumference of a circle – distance around a circle.
- Period – unit of measurement for one complete cycle.
- Amplitude – height of a wave above and below the major axis. In the context of the Ferris Wheel, this is half the height of the Ferris Wheel.

INTRODUCTION

Ask for volunteers to describe ways in which the Ferris Wheel and Boom Ride are similar, and ways in which they are different. You may want to use pre-built models of the two rides for the students to observe as they formulate their answers. Students should recognize that:

- The Ferris Wheel and Boom Ride have similar motions.
- Both load their riders near the ground and take them on circular paths high into the air, reaching the same maximum height many times, before returning to the original loading areas near the ground.
- The Ferris Wheel has an entire circle of seats and a more sophisticated framework supporting the seats.
- The Boom Ride has two seats and a rather simple supporting framework.

ACTIVITY 1: SLOWING DOWN THE RIDE - PART I

PROCESS

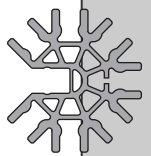
Whole Class

1. Ask:
 - a. Have you ever wondered if a ride at the amusement park moves faster or slower when it is filled with riders?
 - b. If you were getting on the Ferris Wheel, would you want to ride with classmates who were smaller than you or with classmates who were larger than you? Why?
 - c. **Do** you think the ride will move slower or faster if the riders are heavier than you are?

Explain to the students that they will use their model to investigate what happens to the speed of the ride when they add equal masses to all the seats.

In Groups

2. If models are to be built in-class, distribute the K'NEX Education Amusement Park Experience sets to groups and allow time for construction and for the students to investigate how their ride operates.
3. Each group should discuss whether they think the model will turn faster or slower if they add mass to the seats. At the conclusion of the discussion, each student should decide whether they agree with the group or not and enter their own prediction in their journal.
4. Ask students to develop a procedure to test their predictions. They will have AA batteries (or other materials of equal mass) and tape available to add mass to the seats. While this is a simple activity, some students may need clues to get started.
 - a. As you move about the room, ask students to share their procedures with you before they begin. This provides an opportunity to ask questions that will assist them with the design of a 'fair test' to verify their prediction.



- b. As you gather assessment data during your discussions with students and observations of their experiments, it is suggested that you reward groups who:
 - i) Propose and carry out multiple trials.
 - ii) Collect data related to the empty Ferris Wheel/Boom Ride as well as the loaded Ferris Wheel/Boom Ride
 - iii) Test more than one mass - possibly they will complete one experiment with a single mass on each seat and a second experiment to test two masses on each seat.
 - iv) Quantify the speed of the ride rather than commenting on the fact that the ride seemed to speed up or slow down.
5. Observations should be recorded in science journals and students should respond to the following:
 - a. Did the ride speed up or slow down when the masses were added to the seats?
 - b. What data or observations did you note that prove your statement?

Whole Class

6. Students will discuss their findings with respect to:
 - a. What happened to the ride when mass was added to the seats.
 - b. Why?

ACTIVITY 2: SLOWING DOWN WITH WEIGHT - PART II

Teacher's Notes

- The circular path followed by the seat is the same as the path traced out by the end of one of the arms. This information will help students calculate the circumference of the circle.

PROCESS

Whole Class

1. Teachers may want to frame this activity as follows: "We have discussed the experiments you used to show that the ride slowed down when mass was added to the seat. Our challenge now is to find a way to calculate by how much the speed is reduced."

Teacher's Notes

- Some students may have described the change in speed in Activity #1 using the unit rpm. Rotational motion can be quantified in several ways. In Activity #2 students will explore another technique to determine how much the ride slows.

In Groups

2. Ask the students to:
 - a. Determine the circular **distance** traveled by one of the seats during one revolution. (Students may need the formula for circumference: $C = 2\pi r$)
 - b. Determine the **time** that it takes for the ride to complete five revolutions. (Remember, complete multiple trials and average the results to arrive at your value for time.)



LESSON 6

6: EXAMINING CIRCULAR RIDES

Teacher's Notes

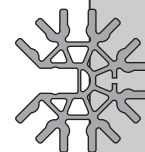
- This activity provides an excellent opportunity to discuss experimental error. Will the timing results be more accurate if students time one turn of the ride or many turns of the ride? Help students to realize that any timing errors on a single turn will have a large effect on the speed of the ride, while the same error will have a much smaller effect if five turns of the ride are timed.

- Determine the time it takes for 10 revolutions, 15 revolutions, and 20 revolutions.
- Calculate the speed/velocity of the ride.
 $v = d/t$
 Where: d = 5 times the circumference of the path the seats take during a revolution
 t = the time for 5 revolutions of the ride
- Complete the chart below: (Remember, the numbers in the distance column increase by 5 times the circumference as you move from 5 revolutions to 10 to 15, etc.)

TABLE 1

Number of Revolutions	Time (sec)	Distance (m)	Speed (m/sec)
5			
10			
15			
20			

- Record all measurements and calculations in individual science journals.
- Repeat steps 2b through 2e with the addition of:
 - One 'rider' (battery) in each seat.
 - Two 'riders' in each seat.
 - Prepare a graph to show your speed/velocity data.
 - x-axis - List 'Empty Car,' 'One Seat Filled,' and 'Two Seats Filled.'
 - y-axis - Velocity/speed of the ride.
 - Students should draw conclusions about what happens to the speed of the ride as more mass is added.
 - How fast did the ride move when it was empty? With one rider per seat? With two riders per seat?
 - What information did your chart provide?
 - Describe any trend that you notice as you read your data.
 - Describe how your graph demonstrates the reaction of the ride's speed to the added mass.



Whole Class

- Students should discuss their findings about the relationship between speed and additional mass.

ACTIVITY 3: SPEED AND SLOPE

Teacher's Notes

If your students are familiar with the mathematical concept of slope, the following activity will enable them to complete an investigation that provides an 'authentic' application of what is often an abstract concept in their mathematics classroom. If, on the other hand, the students do not have the mathematics background to complete the activity, they should skip Activity #3.

PROCESS

In Groups

- Ask the students to prepare a data table using two columns of findings from the chart they prepared during Activity # 2, as shown below.

TABLE 2

Time (sec)	Distance (m)

- Graph the data, placing Time on the x-axis and Distance on the y-axis
- Draw a line of best fit through the points on the graph.
- Identify two ordered pairs and determine the slope of the line.
- Label one of the order pairs as (x_1, y_1) and the other as (x_2, y_2) .
- Find the slope of each of the lines of best fit by calculating $\frac{y_2 - y_1}{x_2 - x_1}$.

Whole Class

- Students should discuss their findings for the slope. You may want to ask: "Was the slope related to your experimental value for the speed of the ride? Explain."



LESSON 6

6: EXAMINING CIRCULAR RIDES

Teacher's Notes

- Students will easily explain that the slope and the speed that they calculated in Activity # 2 are the same, but they may need some assistance with their explanations. Slope is a rate of change: how y changes as x changes, and speed is a rate of change: how distance changes as time changes. Mathematics offers a general formula that relates x and y . Science provides an application of the formula. In this case, as the time increases, the distance the seat of the ride moves increases. On their distance versus time graphs, distance was on the y -axis and time was on the x -axis, so in measuring the slope, they were not only measuring how y changes as x changes, they were also measuring how distance changes as time changes.
- The strategies for introducing the concept of equations of lines in slope-intercept form or standard form has changed from that of simply plotting two ordered pairs and finding the line through those two points. Students are typically asked to use real-world data, which has a linear shape, to identify the line of best fit. This is one straight line and is not a line connecting all of the data points. In fact, the straight line may not pass through any of the data points but can simply pass as close to all of the data points as possible. Once the line is physically added to the graph, two ordered pairs, through which the line passes, can be identified. Again, these will probably not be data points. The equation of the line can then be determined using the classic methods.

ACTIVITY 4: HANGING ABOVE THE GROUND

Teacher's Notes

- This activity requires using a non-motorized Ferris Wheel OR Boom Ride model.

PROCESS Whole Class

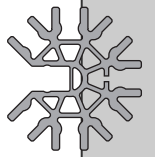
1. Encourage students to remember their experiences with rides like the Ferris Wheel and the Boom Ride, and by observing the models, to realize that much of the thrill of the rides relates to the fact that as the ride turns, its riders are constantly changing their height above the ground. This is particularly obvious as their car comes over the top and they appear to be rushing to the ground. While they complete this activity, students will be making height measurements and determining any pattern that might be used to demonstrate the changing height of the riders as the ride turns through several rotations.

In Groups

2. Students should:
 - a. Remember that they already know the circumference of the circle that a seat makes during one rotation of the ride.
 - b. Design a way to stop the ride for measurement purposes each time the seat has moved through 45° or, in other words, each time the ride has completed $1/8^{\text{th}}$ of a rotation.

Teacher's Notes

- This is actually very simple if the students do some investigation of the model. The blue Rod that is the handle for the ride turns around the white Connector holding the ride's axle. The white Connector just happens to have 8 connection points on it that are exactly 45° degrees apart. For measurement purposes, the students should simply move the blue Rod (handle) so that it lines up with each successive connection point on the white Connector to move the ride through a series of 45° rotations.



- c. Determine the distance traveled by multiplying the fraction of the circle by the circumference. Refer to the previous activity for circumference data.
- d. Use a ruler to measure the height above the ground, in centimeters, of a specific seat on the ride at the specified measurement points.

TABLE 3

Circumference of ride (cm)	Fraction of the circle	Distance Traveled (cm)	Height (cm)
	0		
	$\frac{1}{8}$		
	$\frac{1}{4}$		
	$\frac{3}{8}$		
	$\frac{1}{2}$		
	$\frac{5}{8}$		
	$\frac{3}{4}$		
	$\frac{7}{8}$		
	1		
	$1 \frac{1}{8}$		
	$1 \frac{1}{4}$		
	$1 \frac{3}{8}$		
	$1 \frac{1}{2}$		
	$1 \frac{5}{8}$		
	$1 \frac{3}{4}$		
	$1 \frac{7}{8}$		
	2		



LESSON 6

3. Students should:
 - a. Construct a graph of their data by plotting the fractional turn values on the x-axis, and the distance and height on the y-axis. Different colors should be used to plot distance and height data.

Teacher's Notes

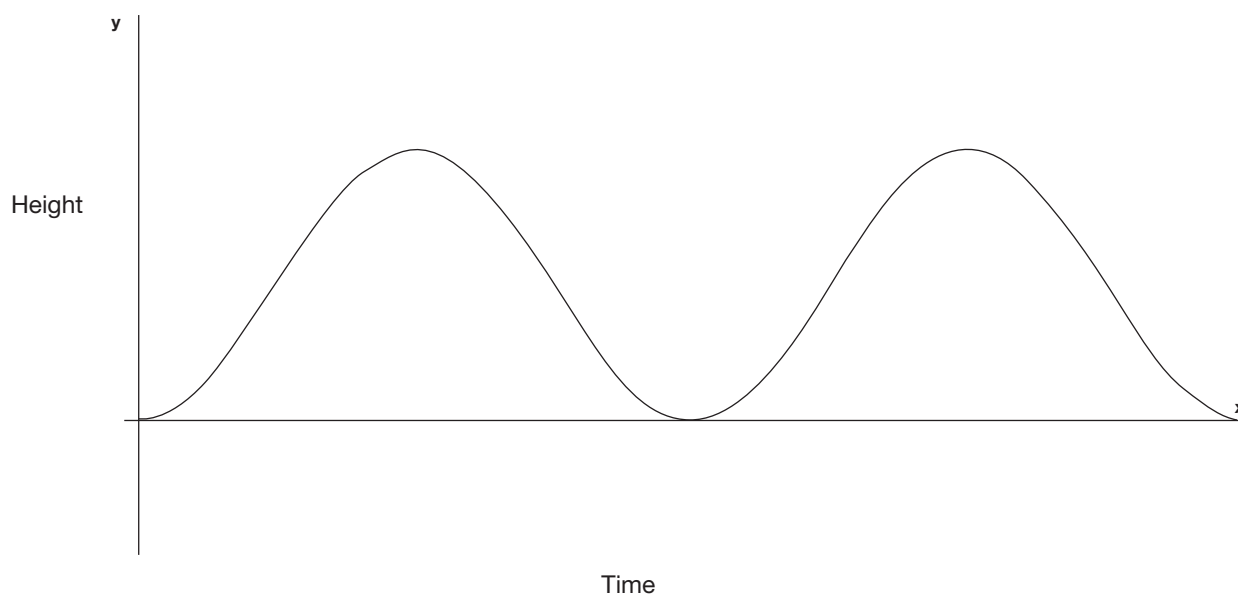
- If students use red dots and a red line to plot the distance data and a blue dot and blue line to plot the height data, their analysis will be much easier.

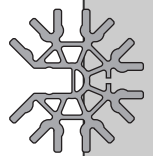
- b. Comment on the shape of the lines on their graphs in their science journals. (For the distance plot, students should display the line of best fit. For the height data, the students will notice a wave-like pattern. They should draw the wave as a smooth curve.)

Whole Class

4. Students should discuss the shape of the height versus turns line and the distance versus turns line on the graphs they created.
5. Teachers should discuss:
 - a. The concept of a wave, using the graph of the function below.
 - b. The concept of (i) the period and (ii) the amplitude of a wave with reference to the Ferris Wheel and the Boom Ride.

Fig. 1





ACTIVITY 5: GEAR-UP OR GEAR-DOWN... FASTER OR SLOWER?

Teacher's Notes

- This activity can be undertaken as a class demonstration or you can have groups work collaboratively with two versions of the model. One group should construct the geared-up version of the crank driven ride and a second group should construct the geared-down version. They will need to switch models once they have observed and thought about the model they have constructed.
- Your students may need a review of the concepts of gearing-up and gearing-down to be successful with this activity.

PROCESS

Whole Class

1. Explain to the class that this activity, and the next, involves investigating how changing the arrangement of the gears in the model impacts the ride.
2. Assign either the geared-up or the geared-down version of the model to each group. Once completed, students should not turn the crank on their models.

In Groups

3. Students should:
 - a. Carefully observe each of the models **without turning the cranks**.
 - b. Predict which of the models will move faster when the cranks are turned at the same rate:
 - i) the model with the **RED** gear attached to the crank or
 - ii) the model with the **BLUE** gear attached to the crank.
 - c. In their journals, give reasons for their prediction.

Whole Class

4. Students should share their ideas about the relationship between the gear arrangement and the **speed** of the Ferris Wheel/Boom Ride.

ACTIVITY 6: TURN THE CRANK

Teacher's Notes

- Use either the hand crank driven Ferris Wheel OR Boom Ride for this activity.
- The circular path followed by the seat is the same as the path traced out by the end of one of the arms. This information will help students calculate the circumference of the circle.

PROCESS

Whole Class

1. Explain that this activity is an extension of Activity 5. Students will investigate how the different gear arrangements affect the **distance** the ride travels. Ask students to suggest how they could carry out this investigation. What measurements will they need to make? How will they record their findings?
2. Suggest that groups pair up, as in Activity 5, so that the same model can be set up with different gear arrangements.



LESSON 6

In Groups

3. Ask each group to:
 - a. Predict how far one of the seats would travel for one complete turn of the crank.
 - b. Determine the circumference of the circle made by the hanging seats.
 - c. Place a piece of masking tape on one of the seats that they will follow as the ride turns.
 - d. Turn the crank of the model once and note the number of turns the seat with the tape makes. They can estimate partial turns of the seat by using the white Connector connection points to represent $1/8^{\text{th}}$ turns.
 - e. Students can then complete the table by using multiplication and determine the distance traveled by riders on the two different rides for one, two, three, four, and five cranks of the handle.
 - f. Students will then make side-by-side bar graphs of the data on the same set of axes, with the number of cranks on the x-axis and the distances on the y-axis. They should use different color bars for the two versions of the ride.

TABLE 4

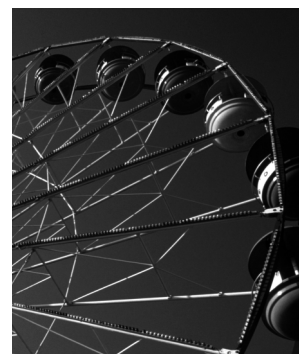
Number of Cranks	Distance traveled when the BLUE gear is attached to the RIDE itself	Distance Traveled when the RED gear is attached to the RIDE itself
0		
1		
2		
3		
4		
5		

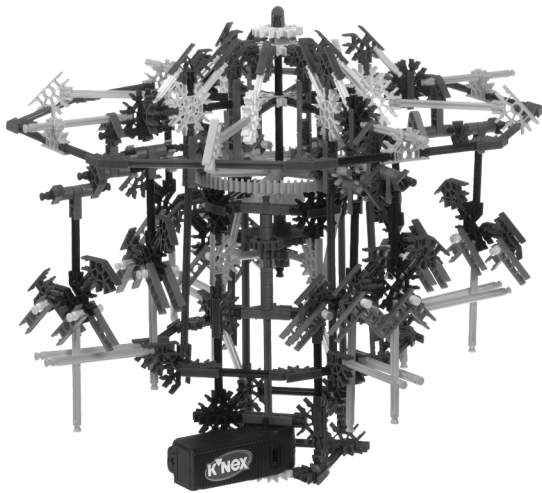
Whole Class

4. Students should discuss:
 - a. How far the Ferris Wheel/Boom Ride travels during one turn of the crank for each of the gear configurations.
 - b. Whether the geared-up or geared-down ride travels further during one crank.
 - c. The way in which gearing-up or gearing-down is related to speed.

EXTENSION

- For students in Algebra I or higher, the actual equation of the line of best fit can be computed. Students will need to display the data using a line graph. Different symbols should be used for the two different versions of the ride and the line of best fit must be constructed for each. Students will first find two ordered pairs that the line of best fit passes through to compute the slope and then use the slope intercept form of one of the ordered pairs to find the equation of the line.





LESSON 7:

Examining Slope as a Rate of Change

Time

- 60 minutes (after construction of the model)

Objectives

Students will:

- Describe slope and apply the concept of slope as a rate of change and the linear regression line.
- Utilize geometric formulas involving circles.
- Determine speed and distance traveled using experimental data and mathematical formulas.

Materials

Each group will need:

- Materials from 1 K'NEX Education Amusement Park Experience set
- Building Instructions Booklet, Page 12: Carousel OR CD-ROM – File: Carousel
- Stopwatch
- Tape Measure
- Calculator
- Tape/string

Each student will need:

- Science notebook
- Graph paper
- Ruler, pencil

Teacher's Notes

- 1 K'NEX Amusement Park Experience set contains sufficient materials for 2 Carousel models to be constructed simultaneously.
- Because this is an intricate model, you should allow adequate time for its construction. Groups should be provided with a few minutes of planning time to allocate appropriate subsections for each member to build.



LESSON 7

OVERVIEW FOR THE TEACHER

Most children have ridden on a carousel or merry-go-round and are very eager to share their experiences. How did the horses move? Did the rider next to them have a horse that followed the same path? These valuable insights into the operation of the ride will be built upon through the exploration of the K'NEX Education Carousel Ride model. Like the Ferris Wheel and the Boom Ride, the Carousel is a circular ride, but its circular motion is in a horizontal plane as opposed to the vertical plane observed in the Ferris Wheel and Boom Ride.

The Carousel also introduces a more sophisticated gearing system in that it is not only responsible for moving the ride in its circular motion, as is the case with the Ferris Wheel and the Boom ride, but it is also responsible for making the “horses” or “animals” in the Carousel menagerie travel in the up and down motion associated with the ride. Students will be asked to investigate the famous question about whether or not riders on the outside row of horses move faster or slower than riders on the inside row. Most students will have a preconceived notion as to the answer to that question. A unique mathematical connection is made here to slope, with the intent that students begin to understand that slope is more

than $\frac{y_2 - y_1}{x_2 - x_1}$, that it has a much deeper meaning as a measure of the rate of change. In this case

slope will be a measure of the speed of the riders on the Carousel.

REVIEW

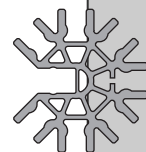
Your students will be more successful if they have an understanding of the following concepts and vocabulary:

- Distance traveled: Total length of the path traveled by a person or object, which can be on either a curved or straight path.
- Speed: Rate of change where a measured distance is compared to a unit of time.
- Slope: Rate of change which measures how one variable changes as another changes, typically in

algebra: $\frac{\text{Change in } y \text{ values}}{\text{Change in } x \text{ values}}$

ACTIVITY 1: MOVING FASTER WHERE?**PROCESS****Whole Class**

1. Encourage the students to discuss their experiences of riding on a carousel compared to, for example, a roller coaster. Ask them to describe the features associated with a carousel, such as the circular and vertical motions, the artistic design of the overall structure, including the horses, and the music. Discuss the fact that, although carousels are not nearly as thrilling as roller coasters, their motions are just as complex and rely on many of the same concepts from physics that are associated with other rides.
2. Explain that in this lesson they will build the K'NEX Education Carousel Ride, (or use a previously built model,) to investigate the following questions:
 - a. Do the horses on the inside and outside of the ride move at the same linear speed?
 - b. How does the computed slope of the graph of distance traveled versus time compare with the speed of the riders?



In Groups

3. Distribute the K'NEX Education materials and ask the students to build the carousel. Directions for the building activities can be found on the CD-ROM and in the instruction booklet, both of which are included in your set. The model is motorized and can operate in both a forward and backward direction. Please advise students that continued operation of the ride when observations are not being collected drains energy from the batteries.
4. Allow the students to make observations about the motion of the carousel. Pose the following questions:
 - a. What are the different motions that can be observed on this carousel?
(Forward, backwards, circular on a horizontal plane, up and down on a vertical plane, etc.)
 - b. Are all of the horses moving at the same speed? How can you tell?
(Student answers will vary. Some students may point out that the horses are making the same number of rotations per minute while others may distinguish the speed of the inside and out side rows of horses. Accept all suggested answers at this point and indicate to the students that their experimentation will enable them to determine the answer for sure.)
 - c. Based on the other activities already conducted, what are some of the concepts that are observable in this ride?
(Students should provide responses that include concepts presented in the earlier lessons they have completed.)
5. Ask the students to use a measuring tape to determine, in centimeters:
 - a. The radius of the circle for the outer row of horses.
 - b. The radius of the circle for the inner row of horses.

Teacher's Notes

- Allow students to design their own technique to gather these measurements. This is an excellent opportunity to observe their techniques for assessment purposes.

6. Using each of the radii, students can apply the formula: $C = 2\pi r$ to calculate the circumference for each of the circles.

Teacher's Notes

- Students should record all their collected data and calculations in their science notebooks. Many of these diagrams, measurements, and calculations can be utilized as formative assessment throughout the activities and summative assessment at the end of the lesson.

Whole Class

7. Once the students have calculated the circumferences of each of the circles traveled by the horses, bring the class back together for continued discussion. Remind the students that one rotation of the carousel would return each horse back to its original position. Focusing on questions such as, "Which horse covers more distance in one rotation of the carousel?" or, "What if there was a third row of horses on the outside of the carousel, would the circumference traveled be smaller or larger than the existing outer circle?" will help teachers determine if there are any initial problems in student understanding.





LESSON 7

8. Introduce the students to the idea that they will now be moving from the circumference of the circle to determining the distance traveled by the horses and the speed of the horses.

Teacher's Notes

- Depending on the background knowledge of your students, you may need to review the idea that science uses the metric system. Speed will use units such as centimeters/second. Reviewing terms and the format for different units will be helpful.

In Groups

9. Ask the students to calculate:
 - a. The total distance traveled by a horse on the inner row of the carousel as it rotates 1 through 5 times.
 - b. The total distance traveled by a horse on the outer row of the carousel as it rotates 1 through 5 times.

In each case they should use the inner and outer circumference measurements, as determined in step 5 (above), multiplied by the number of rotations (1, 2, 3 etc.) Suggest that they create a table in their notebooks in which to record their calculations.

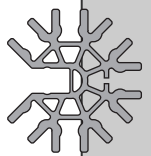
10. Helping students to realize that distance traveled is a multiple of the number of rotations will reinforce the idea that the horse is covering the same distance on each rotation of the carousel. Pose the following question:
 "Which horse (inner or outer) travels a greater distance? Why do you think this happens?
 (Students should respond that horses on the outer circle travel further because the circumference of the circle they travel along is greater than that traveled by the inner row.)
11. Ask each group to mark one horse with a piece of tape or string to serve as a reference point and then set the ride in motion.
12. Have the students calculate the time in seconds that it takes for the ride to make one complete rotation, using the tape or string as a reference point. They should record the times for 1 through 5 rotations on the data chart they prepared in their notebook/journal.

Teacher's Notes

- This is an opportunity to ask students about experimental error and to discuss whether or not they feel they would gather more reliable results if they used multiple trials to arrive at the time traveled for each of their measurements.

13. Now that the students have both the time and distance traveled, they can calculate the average speed for each rotation. Remind students to include units. Suggest that they complete their calculations in table format, as shown below. You may want to display these tables on the board.





Horses on the Inner Circle

Number of Rotations	Distance Traveled Inner	Time for Number of Rotations	Average Speed for Number of Rotations
0			
1			
2			
3			
4			
5			

Horses on the Outer Circle

Number of Rotations	Distance Traveled Outer	Time for Number of Rotations	Average Speed for Number of Rotations
0			
1			
2			
3			
4			
5			

Whole Class

13. Ask each group to review their findings and report back to the whole class. Ask them to consider what may account for variations (if any), in the measurements of different groups.

ACTIVITY 2: EXAMINING THE SLOPES**PROCESS****Whole Class**

As students complete this activity, they will graph the data that they collected earlier and then mathematically determine the slope of the lines that result from their data points. When they have completed this exercise they will readily see that the computed slopes are actually similar to, if not equal to, the speeds they have computed for the horses.

During the framing of the activity, it is suggested that students know only that they are going to graph two lines and analyze those graphs mathematically to determine if the lines on the graphs provide them with more information than they originally thought.



LESSON 7

In Groups

1. Ask the students to use the data from the tables completed in Activity #1, step 13, to construct two sets of line graphs, side-by-side, and drawn as follows:

Graph 1:

- (1) x-axis = **time**
- (2) y-axis = **distance** traveled by the inner circle horses

Graph 2:

- (3) x-axis = **time**
- (4) y-axis = **distance** traveled by the outer circle horses

Each graph will include five data points (ordered pairs) from their data chart.

2. Once plotted they should draw a line of best fit through the points. Students should be reminded that a line of best fit may not necessarily pass through any of the ordered pairs but represents the best linear relationship between the points.

Teacher's Notes

- The idea of a "line of best fit" may need to be reviewed with the students. There is an opportunity for the teacher to discuss why data isn't perfect and why a line of best fit is used.

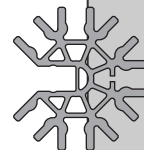
3. Students should now calculate the slope of the lines of best fit on the distance-time graphs. They will compute one value for each graph. Students should do this by identifying two ordered pairs the line passes through. One of the ordered pairs should be identified as (x_1, y_1) and the other as (x_2, y_2) .

Students should then compute the following $\frac{y_2 - y_1}{x_2 - x_1}$, which is the slope of the line.

4. Students should compare the slope they have computed to the speed values they determined experimentally for the two sets of horses.
5. Students should report their findings in their notebooks/journals and describe any relationship they discovered when they compared the slopes of the two lines to the speeds they computed.

Whole Class

6. This lesson covers concepts drawn from both mathematics and science. It is important to review both the terminology presented, as well as the concepts developed.
7. Have students describe the relationships they discovered when they compared the slopes of the lines and the speeds they had calculated.
8. Can students offer any suggestions as to the benefits of the relationship they determined? *(Students may suggest that they would not have had to compute all of the speed data since the slope of the graph would have provided them with the same information. They should realize that the slope of a straight line comparing distance traveled versus time provides the speed of the object measured.)*

**EXTENSION IDEAS**

- Have the students make predictions about what would happen to their data if the carousel were larger (had a greater circumference).
- Students can be asked to write a paragraph explaining what the slope of the line tells them in this particular case and how the line of regression can be used.

Teacher's Notes

- *If you do not have a clear understanding of the term 'line of regression,' consult with a colleague who teaches mathematics in order to determine a strategy to use when introducing this concept - one that will correlate with its explanation in your students' math classroom.*

ASSESSMENT

- Science notebooks/journals.
- Students include the following terms in a written paragraph about their investigation: **radius**, **circumference**, **speed**, **rotation**, and **distance traveled**.

WEB SITES

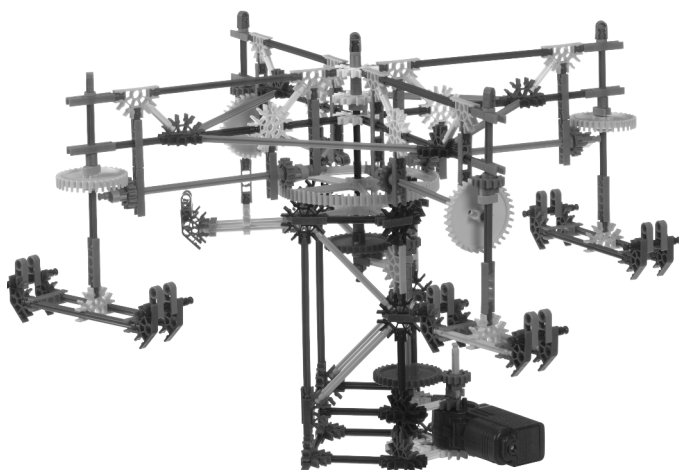
<http://www.learner.org/exhibits/parkphysics/carousel.html>

Discusses carousels and has FAQs about carousel physics.

<http://www.nca-usa.org/NCAlinks.html>

Homepage of the National Carousel Association with links to a variety of carousel pages.





LESSON 8: Understanding Displacement

Time

- 125 minutes (after construction of the model)

Objectives

Students will:

- Determine the circumference of the different parts of the Scrambler Ride.
- Discover that the arrangement of gears will impact the speed of the ride.
- Understand that there is a relationship between speed and distance traveled.
- Understand the concept of displacement.

Materials

Each group will need:

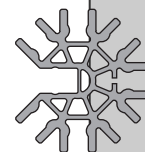
- Materials from 1 K'NEX Education Amusement Park Experience set.
- Building Instructions booklet, Pages 4 and 8 (Tower and Scrambler) OR
- Building Instructions CD-ROM: File - Scrambler
- Butcher paper
- Sharpie® markers (at least 3)
- Tape
- Metric measuring tapes
- Water-based markers

Each student will need:

- Science notebook/journal

OVERVIEW FOR THE TEACHER

The Scrambler incorporates into its mechanism several simultaneously occurring rotational motions. These serve to heighten dimensions that have already been discussed - circular motion, distance traveled, and speed - so that the rider experiences more of a "thrill." When working with the Ferris Wheel and the Boom Ride, students were introduced to some of the concepts involving gears, especially those of 'gearing-up' and 'gearing-down.' The Scrambler is yet another ride that involves gears, but these are quite sophisticated so as to produce the ride's unique motion. Much like the Carousel (Lesson 7), the gears on the Scrambler are not only responsible for the main circular motion of the large arms, but also for the motion of the smaller ones (Lesson 6).



Students will also have an opportunity to engage in an activity that somewhat demonstrates an optical illusion. The smaller arms, attached to rods that are supported by larger arms, are of different sizes and turn at different speeds, which sets up an illusion. Do the slower moving, but larger arms travel further during one rotation of the large arms, or do the faster moving, but smaller arms travel further during one rotation of the large arms? Finally, students will be able to explore the concept of displacement and should notice striking similarities to their explorations of height on the Ferris Wheel and Boom Rides (Lesson 6.)

Teacher's Notes

- The Scrambler seats operate like the beaters on a hand mixer used in a kitchen. For simplicity sake, the four large arms that support the extensions holding the seats will be known as the **large arms**. The smaller arms, (of two different sizes), which hold the seats will be known as the **small arms**. One pair of small arms includes yellow Rods and the other pair of small arms includes red Rods.
- Building instructions for this model are found in both the booklet and on the accompanying CD-ROM. Instructions for the central supporting structure begin on Page 4 (Tower) of the booklet; once this has been built the ride can be completed by following the instructions provided on Pages 8-11 (Scrambler).

Amusement Park Fact

Some students may notice a major difference between the K'NEX model and a real scrambler ride at a park. The real ride has three large, arched arms and each of these large arms support four, rotating arms that, in turn, each hold one seat for two riders. True ride enthusiasts would say the K'NEX model is like the classic and, today, rarely seen Merry Mixer ride. That ride, like the K'NEX model, has four large arms each supporting four smaller arms. The Merry Mixer, however, uses cables to turn the smaller arms while the real-world Scrambler uses a series of gears and rods to operate the ride. The Scrambler, produced by the Eli Bridge company, made its debut in 1955, while the Merry Mixer, produced by Garbuck Manufacturing, made its debut in 1960.

REVIEW

Your students will be more successful if they have an understanding of the following concepts and associated vocabulary.

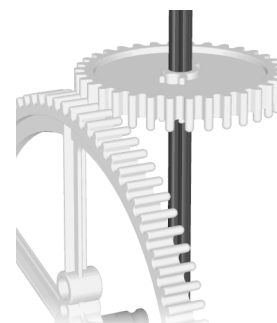
- Multiplication and division of mixed numbers.
- Circumference, radius.

ACTIVITY 1: GEAR STRUCTURE

PROCESS

Whole Class

1. Explain that gears are unique parts of this amusement park ride. This particular ride has parts that are "geared-up" and others that are "geared-down." When the teeth of the gears mesh and the gears turn, they transfer force and/or motion. The larger gear will rotate at a slower rate but with more force. If a large gear turns a small gear, the small gear will spin faster but the mechanical advantage of the system will be lower (less force will be the outcome). If a small gear turns a large gear, the large gear will spin more slowly but the mechanical advantage of the system will be higher (more force will be the outcome).





LESSON 8

In Groups

2. Distribute the necessary K'NEX Education materials for building the Scrambler. Directions for construction can be found in the Building Instructions booklet and on the CD-ROM, both of which are included in this set.
3. Before they turn on the ride, ask students to:
 - a. Examine the gear structure and make predictions about which smaller arms, those of shorter length (yellow) or those of longer length (red), will turn faster.
 - b. Record their predictions and reasoning in their journal. Students should use the terms “gears,” “rotation,” and “revolution” in their explanations.
 - c. Predict the number of times each of the seats attached to the different sized smaller arms will rotate during one rotation of the large arms.
4. Students will test their predictions by turning on the ride and observing which seats turn faster (complete more rotations), during one rotation of the large arms:
 - a. those attached to the smaller arms (yellow) of shorter length, or
 - b. those attached to the longer arms (red) of shorter length

Teacher's Notes

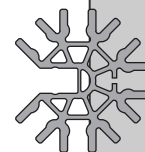
- Suggest that students place a piece of masking tape on one of the large arms and one on each on each of the two types of short arms. These pieces of tape will make the counting process much easier.

Whole Class

5. Students will share their findings related to the motion of the smaller arms. Teachers may want to focus the students' attention on questions such as:
 - a. Which arm would you want to be on to travel the fastest/slowest?
 - b. Why do you think the different arms turned at different rates?
6. After this discussion, invite students to record written responses to the following in their journals:
 - a. How many times did the small arms with yellow Rods turn as the large arms made one complete rotation?
 - b. How many times did the small arms with red Rods turn as the large arms made one complete rotation?
 - c. How did the arrangement of gears on each of the small arms cause these results?

ACTIVITY 2: WHICH SCRAMBLER SEATS TRAVEL FURTHER?**In Groups**

1. Ask students to predict which seats travel the greatest distance in their small circular paths as the large arms make one complete rotation:
 - a. Those attached to the yellow arms (smaller arms of shorter length).
 - b. Those attached to the red arms (smaller arms of longer length).
 They should enter their predictions in their journals.



2. Students will determine the circumference of the circle traveled by the smaller arms of different sizes. In order to carry out this experiment, the students will first need to complete some mathematical calculations.
 - a. Determine the circumference of the circle that a seat travels through as it makes a complete rotation:
 - i) Place a sheet of paper under a seat with a yellow Rod forming its small arm.
 - ii) One member of the student group looks directly down onto the seat being investigated and directs his/her partner to place a dot on the paper directly below the Rod that hangs from the larger arm. (This point represents the center of the circle that the small arm traces as it turns.)
 - iii) The observer then directs his/her partner to place a dot directly under the location of one of the seats on the small arm. The distance between the two dots represents the radius of the circle that the seat travels as it rotates.
 - iv) Students will determine the distance the seat travels using the formula: $C = 2\pi r$, then enter the data, calculations and distances in their journals.
 - v) Students will determine the distance the other seat travels by repeating the above steps for one of the seats on a red Rod.
 - b. Students can now determine the exact distance that each of the two different sized smaller arms travel during one revolution of the large arms.
 - i) Refer to the data collected in Activity # 1. List the value measured for the number of times a small arm with a red Rod turns in one rotation of the large arms. List the value measured for the small arm with the yellow Rod.
 - ii) Multiply the number of turns made by the small arm with the red Rod by the circumference of the circle traced by the seats on that same small arm of the ride. The resultant value is the distance through which a seat on the small arm with the red Rod travels during one rotation of the large arms.
 - iii) Repeat step # 2b.ii for the small arm with the yellow Rod.
 - iv) Compare the findings for the two different small arms.

Whole Class

3. Discuss the findings with students.
 - a. Have students describe their experimental techniques.
 - b. Have students present their results.
 - c. Did experimentation support their original predictions or not? Explain.
 - d. Were the students surprised by their results? Explain.
 - e. Students should record any pertinent information from the class discussion in their journals.

Just for Fun

A popular toy, found in cereal boxes, is a small plastic device that makes different spirals on paper. Surprisingly, the Scrambler acts just like this toy. Place the Scrambler model on a piece of butcher paper and attach a Sharpie® marker, (using a rubber band or piece of tape), to one of the seats attached to a short arm of longer length. Activate the ride and watch the design it traces out.



LESSON 8

8: UNDERSTANDING DISPLACEMENT

ACTIVITY 3: WHICH SCRAMBLER SEATS TRAVEL FASTER?

PROCESS

Whole Class

- Now that the students know how far seats on a small arm with a yellow Rod travel and how far seats on a small arm with a red Rod travel, they can determine the speed that each travels using the formula:

$$v = d/t$$

Where: v = velocity or speed
 d = distance
 t = time

In Groups

- Ask students to predict which of the small arm seats will travel with the greatest speed and record this prediction in their journals.
- Students should then:
 - Activate the ride and determine the time it takes for the large arms to make one complete revolution.
 - Use that time to calculate the speed of the seats attached to the smaller arms of two different sizes using the formula below. This activity will require a separate calculation for the seats on the small arm with the yellow Rod and another for the seats on the small arm with the red Rod.

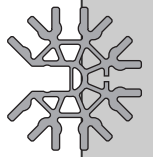
$$\text{speed} = \frac{\text{distance traveled in the small circles on the small arms}}{\text{time for one complete revolution of the large arms}}$$

- Have students compare their predictions with the actual speeds they determined experimentally.

Whole Class

- Students should:
 - Discuss their findings about the distances traveled by the seats on each of the small arms.
 - Discuss their findings about the speed of the seats. Did they predict accurately? Why or why not?"





ACTIVITY 4: DISPLACEMENT OF THE SEATS

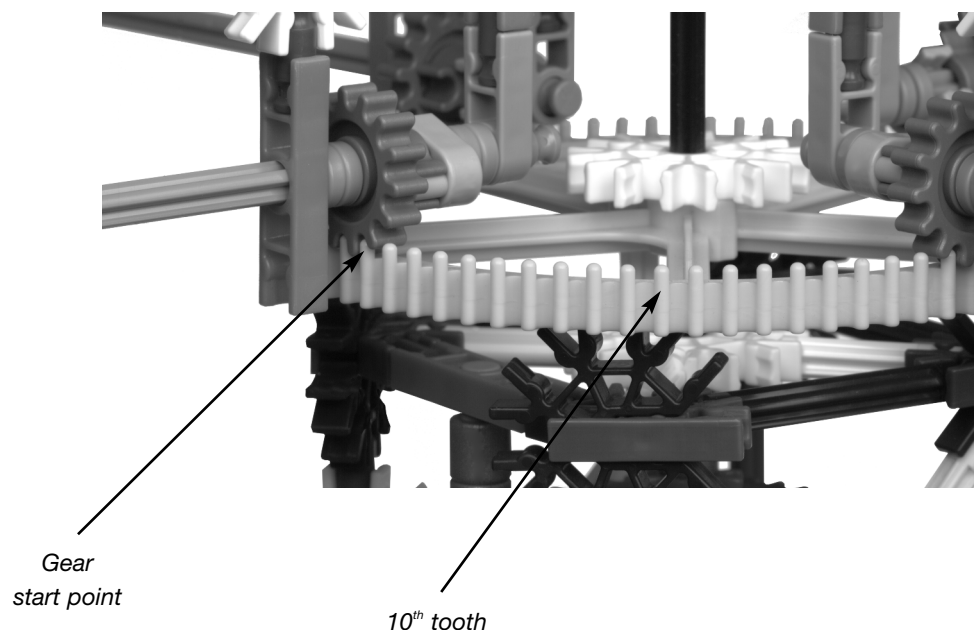
PROCESS

Whole Class

1. Displacement refers to the distance between the original position of an object and its later position. In this activity, students will investigate and experiment to determine whether or not there is any pattern that occurs when the displacement of the seats on the Scrambler Ride is measured over three rotations of the large arms.

In Groups

2. Ask the students to set up their experiment in the following way:
 - a. Remove the yellow Rod from the motor on the Scrambler so the ride can be turned by hand.
 - b. Place one or more sheets of butcher paper or newsprint under the ride. Be sure to use enough paper - as you look down from above the ride as it turns, the seats should always pass over the paper.
 - c. Select one seat on a small arm with a red Rod and mark it with masking tape. Do the same for one seat with a yellow Rod.
 - d. With a marker, mark a tooth on the large yellow, horizontal Gear that is directly below one of the blue Gears that travels around the yellow Gear. (See Fig. 1 below)
 - e. Move the seats on the two small arms that have been marked with tape in (c) above so they are farthest from the center of the ride as possible. You do not want to move the blue Gear riding on the large yellow Gear. Have your partner hold the blue Gear and yellow Gear in place while you temporarily separate the Gears at the end of the large arm to swing the two seats into position.
 - f. Place a dot on the paper just below the seat (with the masking tape) on the yellow Rod that is furthest from the center of the ride. Mark this dot 'Y start.' Do the same for the marked seat on the red Rod and label the dot 'R start.' You will measure all of your displacements from these starting dots.





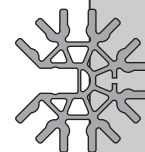
LESSON 8

8: UNDERSTANDING DISPLACEMENT

3. Students can now begin their experiment. One member of each student group should control the spinning of the ride and the others should be responsible for making displacement marks on the paper under the ride.
4. The student controlling the ride counts 10 teeth on the large yellow Gear and marks the 10th tooth from their starting point with a water-based marker. The student then turns the original blue Gear so it sits directly above this marked tooth on the large yellow Gear. The ride should be held in this position as the new seat locations are marked.
5. The other members of the group place a dot on the paper under the new location of the seats that are marked with masking tape. Label the new dots with 'Y 2' and 'R 2' respectively.
6. Repeat steps 4 and 5 a total of nineteen more times. Change the labels on the dots to reflect the trial number (Y 3, R 3, Y 4, R 4, etc). This will allow the ride to make just over three rotations.
Caution: the individual that is counting teeth on the large yellow Gear will eventually reach a point where s/he passes previously marked teeth. That student may choose to wipe off previous marks or to be a very careful counter to avoid confusion.
7. When all points are marked, remove the ride from the paper and prepare to make measurements. Students should prepare a data chart in their journals in which they will enter their measurements.

Point Number	Yellow Seat Displacement (cm)	Red Seat Displacement (cm)	Large Yellow Gear Teeth Moved
Start	0	0	0
2			10
3			20
4			30
5			40
... ect.			

8. Students will:
 - a. Measure the distance from 'Y start' to 'Y 2' and, opposite Point #2, enter the value in centimeters (cm) under the column labeled 'Yellow Seat Displacement.'
 - b. Measure the distance from 'R start' to 'R 2' and, opposite Point #2, enter the value in centimeters (cm) under the column labeled 'Red Seat Displacement.'
 - c. Measure the displacement for each of the other points for the seat on the yellow Rod and the points for the seat on the red Rod. **Each measurement is always made from the start points.**



9. Students should prepare two graphs to present their data. They should connect the points of their graphs using smooth curves rather than just connecting the dots.
 - a. Graph #1: for the seat attached to a yellow Rod:
 - i) x-axis – number of teeth moved along the large yellow Gear: 10, 20, 30, 40, 50, etc.
 - ii) y-axis – displacement values that correspond to the teeth numbers above.
 - b. Graph #2: for the seat attached to a red Rod. Follow the same graphing format as used above.
10. Students should describe their results in their journals.
 - a. Were they able to determine any patterns in the data from their data table?
 - b. Were they able to determine any patterns in the data from their graphs?
 - c. How are the two graphs similar? How are they different?
 - d. What information do the graphs provide about the motion of the seats?

Whole Class

11. Students should share their graphs and discuss what happened with the displacement of each type of seat as the large arms rotate.
 - a. What patterns emerged as the data was plotted? Was the pattern obvious when the data table was reviewed?
 - b. What do the patterns suggest?
 - c. Can you think of other systems that might produce a similar pattern?

Teacher's Notes

The students' ability to answer 11c above will be dependent on their prior knowledge. Please provide other examples if necessary.

ASSESSMENT

- Student notebooks and their explanations.
- The teacher can also have small group discussions with the students regarding the motion and path that each small arm takes.

WEB SITES

<http://homepage.mac.com/teast/scrambler.html>

Animation of how a scrambler works.

<http://www.mos.org/sln/Leonardo/InventorsToolbox.html>

This web site has pictures and descriptions of different gear types.



LESSON 9: Predicting the Pattern of Rides

Time

- 3-4 x 45 minutes (after construction of the model)

Objectives

Students will:

- Make predictions about the shape/pattern that the swings trace as the ride begins.
- Measure the speed of the swing ride with different weights on the swings.
- Work with the concept of area of a circle.
- Make predictions about the circular paths made by the swings when weight is added to them.

Materials

Each group will need:

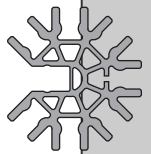
- Materials from 1 K'NEX Education Amusement Park Experience set
- Building Instructions CD-ROM – Files: Swing Ride and Swing Ride 2
- Ruler
- Rubber Band
- 1-2 Sheets of butcher paper
- Sharpie® markers with narrow points in 3 different colors
- Stopwatch
- Unit squares
- Calculator
- 6 AA Batteries (or other objects of the same mass to add weight to the seats)

Each student will need:

- Science notebook/journal

OVERVIEW FOR THE TEACHER

The Swing Ride is a quintessential amusement park ride that also lends a new dimension to the **Amusement Park Experience** set. The free moving seats on the Swing Ride are similar in character to those of the Ferris Wheel and Boom Ride in that they hang down on rods from overhead beams and remain upright as a result of gravity acting on them. Unlike the seats on the Ferris Wheel and Boom Ride, however, these will tend to be pushed outward as the ride accelerates and gains speed.



They ultimately trace a large circle once maximum speed is reached, but the path along which they travel is unique. Students are invited to make predictions about this path. Middle school students can also explore other attributes of circles and continue their explorations of circular motion.

Students may come to the lesson with misconceptions about the ride such as, people with more weight are put on the outside of the ride so they don't fly out and collide with other riders. Students can explore the truth of this statement and begin to examine the effects of centripetal force – a term many of them have heard of, but few fully understand at this stage in their science education.

REVIEW

Your students will be more successful if they have an understanding of the following concepts and associated vocabulary:

- Circle; area of the circle; circumference of the circle; radius of the circle.
- Rotation; Revolution.
- The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a single graph. (NSES, 1996, p. 154.)

Teacher's Notes

- *Swing Ride building instructions (provided on the CD-ROM), include two motorized option: one incorporating gears (Swing Ride) and one with direct drive (Swing Ride 2). Please make a note of which version of the model is required for the various activities.*
- *The base of the ride will sit on sheets of butcher paper lying side by side. It is very important to note the exact location of the base throughout the activities. Make certain that as soon as they tape the paper together and center the ride on it, students trace an outline of the base for reference.*

ACTIVITY 1: THE SPIRAL

PROCESS

Whole Class

1. Explain to the class that they will experiment with the flying swings amusement park ride. Ask for volunteers who have ridden the swings to describe the ride. Traditionally these rides have side-by-side, suspended swings that “fly outward” when the ride begins to turn.
2. Students will continue to make predictions and observations in this activity.

In Groups

1. Distribute the K'NEX Education materials and ask each group to build the Swing Ride. They should construct the version of the ride in which the **red Gear** is attached directly to the motor (file name: Swing Ride).





LESSON 9

Investigation A: Geared Model

2. Students will first observe the swing ride where the **red Gear** is attached to the motor. Allow students time to observe the ride while stationary. You may want to ask the following guiding questions:
 - a. Describe the positions of the swings while at rest.
 - b. Are the swings an equal distance from each other?
 - c. What do you think will happen when the motor is turned on?
3. Depending on the size of the paper, one or two sheets of butcher paper should be placed side-by-side on the table and taped down. Ask the students to:
 - a. Center the Swing Ride on the butcher paper and carefully trace its outline; label the center of the ride. Students may need some direction as to how to identify the point that would represent the center of the ride.
 - b. Attach a Sharpie® marker (using a small rubber band) to one of the outer seats so that it touches the paper. See Fig. 1 below.

Teacher's Notes

- You will want to assist the students in the appropriate placement of the marker as this can be challenging. **Please see illustration of marker placement.**
- A marker with a narrow point works best for this activity.

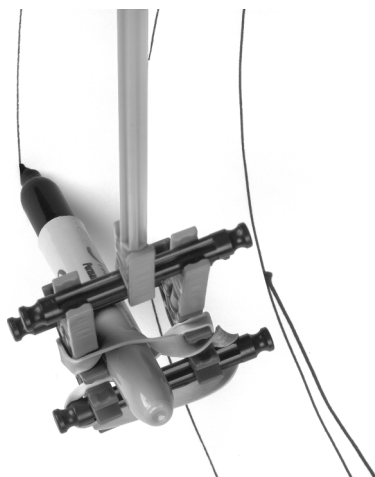
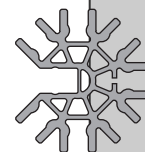


Fig. 1

3. Pose the following questions and ask the students to record their predictions and sketch their ideas in their journals. Predictions should be made before the ride is set in motion.
 - a. If you are sitting on a swing seat and turn a bottle of orange juice upside down as the ride begins to move, predict what design the spilled drink will make.
 - b. How will you know when the ride reaches full speed?"
 - c. Predict the number of rotations on its axis that the ride will make before it reaches full speed.



4. Ask the students to set the ride in motion in order to compare their predictions to the actual observations of the path.

(Students will know when it reaches full speed because the marker will create a circle that does not increase in diameter. The marker starts to “trace over” itself.)

Investigation B: Direct Drive Model

Students will now use the direct drive version of swing ride (CD-ROM File: Swing Ride 2). This requires some rebuilding of the model. (See CD-ROM for building instructions.) Without observing the ride in motion students should repeat step 3 above. They should then repeat step #4.

5. After students have had an opportunity to observe both rides and trace their paths, have them return to the following questions for discussion:
 - a. Which version of the Swing Ride travels faster?
 - b. What happens to the swings when the speed is faster?
 - c. Why do you think this happens?
6. As part of their discussion, students should provide a possible explanation for their answers based on their observations.

Whole Class

7. Invite the student groups to report back to the class by sharing their spirographs and discussing their findings about the speed of the two versions of the ride. The teacher can ask clarifying questions as the students explain their findings.

ACTIVITY 2: THE SPEEDING SWINGS

PROCESS

In Groups

1. Explain to the students that they will use the butcher paper diagrams from Activity 1 to calculate the distance traveled by the two different swings during one rotation of the ride operating at full speed.
2. Help the students to understand that they can easily accomplish this by determining the radius of the circle and then using the formula: $C = 2\pi r$ to find its circumference. This information should be recorded in their notebooks/journals. If your students have completed the earlier activities from this set, they should have a good working knowledge of the formula and the process of determining circumference.

Teachers can pose questions such as:

- a. What does the circumference of the circle represent? *(The path of the swing.)*
- b. How can you determine when the ride has completed one full rotation? *(Mark a start/finish point on the butcher paper. Add a piece of tape to a chair and observe when it passes the start/finish point.)*
3.
 - a. Discuss the idea that the circumference of the circle is the path taken by the swings.
 - b. Have students calculate the time that it takes for one swing to revolve around the axis once the ride is operating at full speed.



LESSON 9

Teacher's Notes

- If necessary, either in small groups, or by bringing the class back as a whole, review the idea that the circumference of the circle is the distance that the swing travels and that the students can determine the time it takes by using a stopwatch.

- After discussing the ideas of distance traveled and time, students can be asked to calculate the speed of the swings using the formula:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

Distance is the circumference of the circle (in centimeters) and time is measured in seconds. Based on their earlier investigations, they should be able to design a strategy to determine the linear speed of the seats.

Whole Class

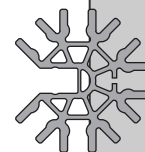
- Students should share their information about the speed of their swing rides. If there are noticeable differences, the class should discuss what might be causing them.
(Possible answers may include friction, construction problems with the model, battery age, etc.)

ACTIVITY 3: AREAS OF THE CIRCLES**PROCESS****In Groups**

- Begin by having each group identify the traces of the different circles created by their model. Then they should look at those of other groups in the classroom. Once the circles have been identified, the students should make predictions about the areas of these different circles. Ask them to predict:
 - The **difference** between the area of a circle that would be formed if the ride were barely moving (while the swing is still hanging straight down), and the area of a circle formed when the swing ride is at full speed. Students should do this for both versions of the ride – geared and direct drive.
 - The **difference** between the area of the circle created if the ride with the **red Gear** attached to the motor was moving at full speed and the area of the circle created if the ride with the **direct drive** was moving at full speed.
- Students will test their predictions first by using unit squares to “fill in the area” of the circles. This will help them to better understand the concept of area. Unit squares are 1-centimeter x 1-centimeter squares cut from graph paper or other 1-centimeter x 1-centimeter manipulatives. As students reach the edge of the circles they will have to estimate some of their values, as the squares will not fit neatly into the circles.
- Once the students have used manipulatives to test their predictions, they can find the actual area of each circle using the formula:

$$\text{Area of a Circle} = \pi r^2$$

- Students can then determine the difference in the areas of the various circles.



- Can students make a general statement about the area of the circle traced out by the seats on a swing ride that would hold true for any swing ride of similar design?

(For example: Up to the limit of the ride, the faster the ride turns, the larger the circle traced out by the seats as they spin.)

ACTIVITY 4: WHAT HAPPENS WHEN RIDERS ARE ADDED?

Teacher's Notes

- The concept of centripetal force is the key in this activity. Centripetal force is a concept that appears in Grades 9-12 National Science Education Standards, but is not referenced for Grades 5-8. This information is provided should students ask, since some may have heard of centripetal force in other contexts.
- Centripetal force is equal to the mass of the object times the square of the velocity, divided by the radius of the circle.
- In the loop of a roller coaster, the centripetal force keeps the car on the track and the riders in their seats. It is also the force that keeps the Swing Ride moving in a circular path. The centripetal force is actually an acceleration toward the center of the circular path.
- Students are often intrigued by questions about where amusement park staff place small and large riders on the swing ride. Do they put the heavier riders on the inside section of the ride? Do they put the smaller riders on the outside section of the ride? Will collisions between riders occur as the ride spins? Will someone collide into me? Misconceptions arise in students' minds because they are thinking of the sensations that they feel as the ride turns. The total effect of the forces (centripetal and gravity) acting on the riders keeps them from crashing into each other so that everyone can ride safely. Centripetal force working toward the center of the ride and gravity working down toward the ground keep all of the riders in place.

PROCESS

Whole Class

- Explain that the purpose of this activity is for students to predict and then test what happens to (a) the circular path traced by the swings and (b) the speed of the swings when a small mass is added to the ride.

Teacher's Notes

- You may want two groups to work together on this investigation and exchange their data. One group can use the Swing Ride model driven by the red Gear while the other group uses the direct drive version.





LESSON 9

In Groups

2. Groups make their predictions and then undertake their investigation. They should:
 - a. Place the swing ride back on the butcher paper if it is not there already.
 - b. Affix a Sharpie® marker on one of the outside seats (use a different color for this investigation.)
 - c. Add one AA battery (or other mass) to the seat where the marker is affixed.
 - d. Add a second AA battery to the outside seat directly opposite the one on which the first battery was placed. (See Fig. 2.) The second battery will act to balance the ride so the center section does not wobble.
 - e. Test their predictions by comparing (a) the new path traced out when weight was added, with (b) the path created when there was no additional weight.

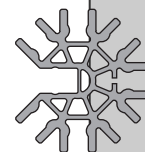


Fig. 2

Teacher's Notes

- Batteries are placed on both outside seats simply to balance the ride and make it run more smoothly.

3. Students can find:
 - a. The circumference of the circle traced when the swing ride is at full speed by determining the radius of the circle and using the formula: $C = 2\pi r$
 - b. The speed of the swing by using the formula: $\text{speed} = \frac{\text{distance}}{\text{time}}$
4. Ask the students to predict and then test what happens to the circular paths traced by the swings when one AA battery is placed in an outer seat and two AA batteries are placed in an inner seat. Will the seats collide?
5. Remind the students that they will need to balance the ride and so will use 6 AA batteries in total. You may want students to experiment themselves or provide directions for arranging the batteries:
 - a. Use the butcher paper from previous investigations and a different colored marker or turn the butcher paper over for this investigation.



- b. Place one AA battery in an outer seat and two AA batteries in the inner seat adjacent to it.
 - c. Repeat on the opposite side of the ride.
6. Students should write a paragraph in their science journals about their observations and their reflections about results.
 - a. What results surprised them?
 - b. Will they feel safer the next time they ride the swing ride? Why or why not? Explain their answers. What did they find out through experimentation that supported their conclusions?

Whole Class

7. Students should be encouraged to discuss:
 - a. What happens to the swings when different weights are added. They should show their traces on the butcher paper and also talk about their speed calculations. Teachers can ask questions such as:
On a real world ride, does it make a difference if a person has more mass?
 - b. Why inner seats with larger masses do not slam into outer seats with smaller masses.
8. After allowing students to experiment with mass, the teacher can pose questions such as:
 - a. What would need to be done to have the swings move out further when mass is added?
 - b. How is this model ride different from a real world swing ride at an amusement park?

EXTENSIONS

- Students can examine what happens when more mass (more batteries) is added. Students can then graph the data and see if there is a relationship between the number of batteries added and the speed of the ride.
- Students can try moving the mass to different locations on the ride and see what happens to the circular paths and to the speed.

REVIEW

- Teachers may choose to review the concepts covered in this activity:
area of a circle; radius; rotation; circumference; distance; speed

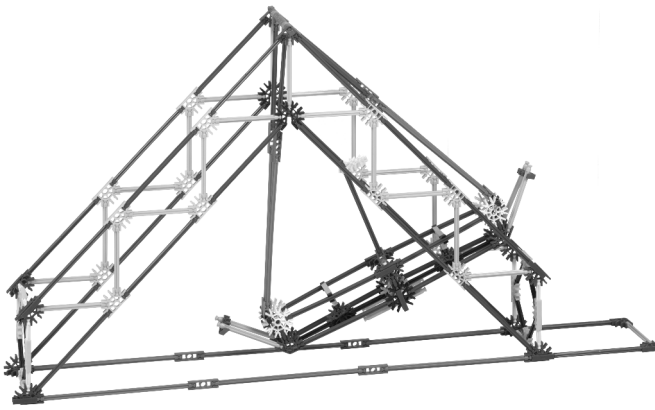
ASSESSMENT

- Student science notebooks.
- After the activities have been completed, students should be given a copy of a separate spirograph created by the teacher and reproduced for the students. They should be asked to label the circumference, area, diameter, and radius of the spirograph.

WEB SITES

<http://www.coasterimage.com/pictures/lakemontpark/otherrides04.htm>

This site has several good pictures of different flying swing rides that could be used for discussion points.



LESSON 10: Investigating the Period of a Pendulum

Time

- 90 minutes (after construction of the model)

Objectives

Students will:

- Explore periodic motion.
- Explore and investigate the concept of the period of a pendulum.
- Explain how the length of its arm affects the period of a pendulum.
- Determine if a change of mass affects the period of the pendulum, as demonstrated by the Pirate Ship Ride.

Materials

Each group will need:

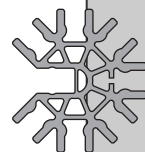
- Materials from 1 K'NEX Education Amusement Park Experience set
- Pirate Ship Building Instructions: Page 18 or CD-ROM – File: Pirate Ship
- Stopwatch
- Ruler
- 3 oz. bathroom-style paper cups (1 or 2)
- Pennies or other weights
- Balance
- Alternate K'NEX Rods for changing the length of the arm of the ship
- Books to hold the ride in place

Each student will need:

- Science notebook/journal

Teacher's Notes

- The motion of the Pirate Ship ride will transfer some of its energy to the frame of the ride and cause it to creep across the tabletop if students do not place books on the extensions provided.



OVERVIEW FOR THE TEACHER

The Pirate Ship ride at the amusement park introduces a new type of motion for students to explore, that of periodic motion. Granted, the motion of Pirate Ship is part of a circle and so is similar to the circular rides in terms of the path that it follows; it also has similarities to the back and forth motion of the balls in the half pipe systems. In addition to these motions, however, the Pirate Ship is also an excellent representation of a pendulum. The activities designed for this ride allow students to experiment with, and understand, the period of a pendulum and periodic motion. They will be able to investigate variables that have an impact on periodic motion. These will include the mass of the Pirate Ship, the length of its support members, and the release height of the ride.

REVIEW

Students will be more successful with these activities if they have had an opportunity to observe other periodic motion systems (metronome, clock pendulum, etc.)



ACTIVITY 1: PREDICTIONS

PROCESS

Whole Class

1. Display images of a Pirate Ship ride and introduce the class to the idea that while this ride demonstrates some of the motions that they have already investigated, it also introduces a new type of motion for experimentation. Ask for volunteers to describe their experiences of this ride and to describe its motion. Students should be helped to understand that the ride represents the motion of a pendulum.

Teacher's Notes

- Consider using a string and a weight to demonstrate periodic motion, as it would appear using a pendulum.

In Groups

2. Distribute the K'NEX Education materials and ask the groups to build the Pirate Ship model following the directions provided on either Page 18 of the Building Instructions booklet or on the CD-ROM.
3. Once the ride is completed ask students to place books on the extension provided on the ride to ensure it stays in place on the table/bench. Allow the students time to explore the motion of the ride and ask them to consider the following questions. You may want to record these on the board and have the students write their predictions in their journals.



LESSON 10

- How is the pirate ship similar to a swing set?
- As the ride moves, when does it have the greatest (i) potential energy (ii) kinetic energy?
- As the ride moves, when does it have the least (i) potential energy (ii) kinetic energy?
- If the ride were twice as tall would the ship move faster? Slower? Explain your answer.
- Do you think the ride will move faster when it is empty, or when it is filled with people? Explain your answer and your reasoning.

Whole Class

- Each group will share their predictions with the rest of the class. Record their responses on the board or chart paper and highlight answers that focus on the period of the ride and the height of the ride.

Teacher's Notes

- Students may not identify the period of the ride as an indication of its speed. You may need to lead an investigation that will help students to understand that one way to measure the speed of the ride is to determine how many complete swings the ride makes per minute. This concept can be developed using the ride or using strings with weights attached. Please refer to Activity 2, #1 below for more details.*

ACTIVITY 2: IMPACTS ON THE PERIOD

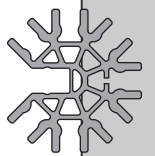
PROCESS

Whole Class

- Explain that the next step is for students to test their predictions by measuring the time required for one complete vibration/cycle. Help students to understand the term 'periodic' as a motion that repeats itself in a cyclical manner and that the time taken to complete one cycle is referred to as a period. Using a model of the Pirate Ship, discuss the 'period' of a pendulum as it relates to the ride and ask for suggestions as to how this can be measured.
- Help students to realize that the period of the pendulum is the **dependent** variable for their experiments. The **independent** variables that they will be testing may include: the length of the Rods that support the ship, the mass of the ship, and the release height of the ship. All of the independent variables are under the control of the students while the dependent variable is a response to the changes the students make to the ride.
- Emphasize the importance of accuracy and consistency when making measurements of mass, distance, or time. Ask students if they will get a better sense of the period of the ride if they count its full swings for 15 seconds and divide their finding into 15 seconds or if they count its full swings for one minute and then divide their finding into 60 seconds. Can students support their answers with reasonable explanations?

Teacher's Notes

- The following investigation can be introduced and implemented as either a teacher directed activity or as a student directed inquiry activity. If used as an inquiry activity, students will plan, organize, and carry out their own investigations. These may or may not mirror the strategies described on pages 69 and 70.*

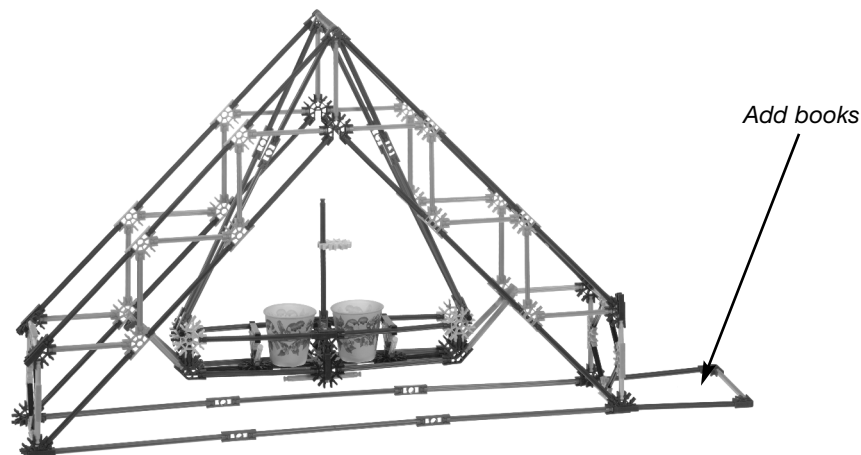


In Groups

4. Ask the student groups to:
 - a. Determine a height from which to release the ship in order to start it swinging. This release height must remain consistent throughout this activity until another direction is given to change it.
 - b. Measure the height from what would be considered the pointed end of the ship that is highest in the air.
 - c. Use the stopwatch to determine the length of the **period** of the ship (a pendulum.) This will be the time it takes the pendulum to complete one vibration – from one crest to the next.
 - d. Repeat 3-5 times, record findings in a data table and determine the average of their trials.

The average is the period of the pendulum. Other data in future investigations will be compared to this as students determine whether the various independent variables have altered the period of the Pirate Ship system.

5. Changing the Rod length:
 - a. Change the color of Rod holding the ship. The new Rods should be shorter than those used originally.
 - b. Release the ship from the same height as you did in the previous activity.
 - c. Repeat steps 4b-4d.
 - d. Repeat the entire investigation once more using a third (shorter) Rod length.
 - e. Write a paragraph about what happens to the period of the pendulum when the **length of the rod** holding the ship is changed.
6. Changing the mass:
 - a. Replace the original red Rods that were used to support the ship.
 - b. Place a quantity of pennies in a 3 oz. bathroom-style paper cup and find its mass.
 - c. Place the cup into the ship. (There is space for two, 3 oz. cups to be placed into the body of the ship.)
 - d. Repeat Steps 4b-4d.
 - e. Repeat Steps 4b-4d with (i) double the mass of pennies (ii) quadruple the mass of pennies.
 - f. Write a paragraph about what happens to the period of the pendulum when **mass** is added to the ship.





LESSON 10

7. Changing the release height:
 - a. Remove the mass from the ship.
 - b. Change the release height of the ship so that it is half as high as it was before.
 - c. Repeat steps 4b-4d above.
 - d. Repeat the investigation once more with a release height that is one half as high as that used in step 7b.
 - e. Write a paragraph about what happens to the period of the pendulum when the **release height** of the ship is changed.

Whole Class

8. Review the class results and discuss their findings regarding the period when:
 - a. The length of the Rod supporting the Pirate Ship gets shorter.
 - b. Mass is added to the ship.
 - c. The release height is changed.

REVIEW

- After completing these activities, the teacher can review the effect of mass on the movement of the pendulum.

ASSESSMENT

- Predictions recorded in science notebooks/journals.
- Participation in the class discussion of the questions.

WEB SITES

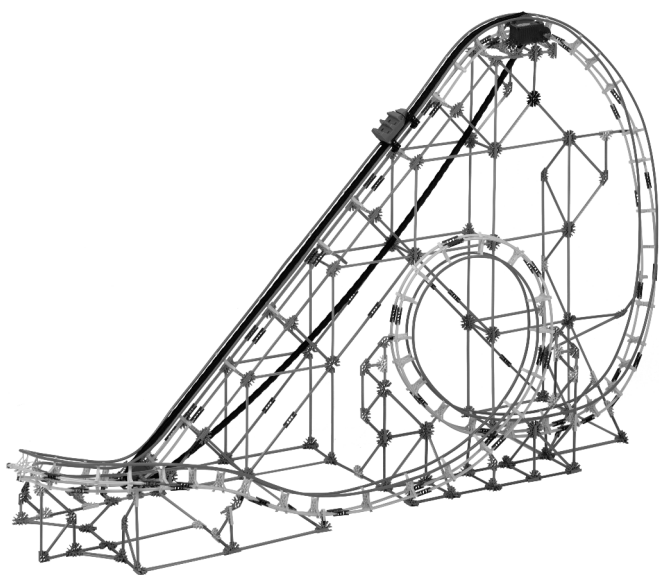
<http://www.physicsclassroom.com/mmedia/energy/pe.html>

This site shows an animation of a swinging pendulum and how kinetic and potential energy change as it swings.

<http://www.learner.org/exhibits/parkphysics/pendulum.html>

A helpful web site that answers many questions about the “Pirate Ship” ride in amusement parks.





LESSON 11:

Coasting to the End - Applying the Concepts Learned

Time

- 90 minutes (after construction of the model)

Objectives

Students will:

- Make predictions and test which part of the coaster track allows the coaster car to travel the fastest.
- Determine whether the model coaster car is moving faster or slower than a real-world coaster.
- Compare the displacement versus the distance traveled on a roller coaster.
- Understand the characteristics of the clothoid (tear drop shape) loop and why it is used on a coaster.
- Design an experiment to determine the number of riders per hour for the coaster.

Materials

Each group will need:

- Materials from 1 K'NEX Education Amusement Park Experience set
- Building Instructions booklet, Page 26: Roller Coaster with Clothoid Loop
- OR CD-ROM: File – Roller Coaster with Clothoid Loop
- Flexible (sewing) tape measure
- Masking Tape
- Stop watch
- Water-based marker

Each student will need:

- Science notebook/journal

OVERVIEW FOR THE TEACHER

For many, the ultimate experience at any amusement park is the roller coaster – it's fast, it's thrilling, it's exhilarating, and it serves as a great physics laboratory. At many parks, roller coasters are the centerpiece attractions, with their large lift hills and huge elements being the first sight visitors see as they drive up and enter a park. Bigger and wilder roller coasters are constantly being constructed to encourage repeat visits from enthusiasts. The activities in this lesson allow students to explore the components of speed - distance and time - as they explore which elements of the coaster are fastest.



LESSON 11

Students are typically surprised because they have not considered the components of speed, especially when the distance is not uniform. Students will also be given another opportunity to explore the concept of displacement, previously explored in the Scrambler activities. In this activity the concept may even be clearer because the coaster car always return to its original location each time around.

Students are also surprised to learn how fast the model rides travel compared to their real-world counterparts. They will be given the opportunity to explore scaled speed and determine whether or not the model coaster is moving at a speed comparable to the real ride. Its speed (and ultimately the energy) is what makes the coaster travel through the loop, but there are many other forces that must be considered when constructing the loop. The loop has some unique properties, such as a changing radius. It is this changing radius that allowed the construction of loops on modern coasters because it helps to lessen the forces acting on the rider. The changing radius concept is not new but dates back to the work of Leonard Euler who gave such tear-drop figures the name **clothoid**. Students will collect and display some data that will show that the loop is actually a **clothoid**.

Finally, students will undertake data collection to determine the numbers per hour that could ride the model coaster. Maximizing the number of riders per hour is important to park operators as they want more people to enjoy the ride and also spend less time in the lines.

REVIEW

Students will be more successful in this activity if they have an understanding of the following concepts:

- Measurement
- Distance and Displacement

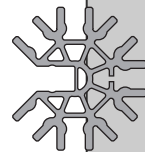
ACTIVITY 1: FASTEST SEGMENT

PROCESS

In Groups

1. Distribute the K'NEX Education materials to build the roller coaster. Directions are found in the Building Instructions booklet, Page 26 or on the accompanying CD-ROM. The model can either be built in class with groups identifying, and then allocating, sub-assemblies for members to construct, or it can be built as an out-of-class activity.
2. After construction, ask the students to examine the coaster and predict which part of the coaster track enables the coaster car to travel at the fastest speed:
 - a. the first hill
 - b. the loop
 - c. the last hill

They should record their predictions in their science journals.
3. Students should then measure the length of each of three identifiable segments of the coaster:
 - a. The initial drop - measured from the where the track reaches the top of the lift hill to the point where the track runs onto the base of the loop.
 - b. The loop - measured from where the track moves onto the base of the loop to the point where the track leaves the base of the loop.
 - c. The final turn - measured from the location where the track enters the final 180-degree turn to where the track runs into the lift hill.

**Teacher's Notes**

- Suggest using a water-based marker or masking tape to identify the beginnings and ends of the track segments.
- Students should also decide whether the timings begin when the front of the car or when the rear of the car passes the marked locations.
- You may want to have groups develop their own fair tests or offer the suggestions provided below.

4. Suggest that students:
 - a. Use a stopwatch to determine the time that it takes for the coaster car to travel each segment of the track. This cannot be accomplished during one trip of the car but requires three separate runs.
 - b. Make at least three measurements for the times, then average the times to lessen the impact of experimental error.
 - c. Compute the speed using the formula:

$$v = d/t$$

Where: v = velocity or speed (m/sec)
 d = distance (m)
 t = time (sec)

5. Students should display their data as a bar graph where:
 - a. x-axis – First Hill, Loop, Return Section
 - b. y-axis – Speed/Velocity

Whole Class

6. Students should be asked to:
 - a. Share the bar graphs that they made.
 - b. Discuss why they think the portion that they found to be the fastest is actually the fastest. They should consider the track length of each of their segments.

ACTIVITY 2: FASTER OR SLOWER THAN THE REAL THING?**PROCESS****Whole Class**

1. Remind students that there is only one instant where a roller coaster reaches the maximum speed that is advertised. This is referred to as an instantaneous **speed** (or velocity) and was a classic problem that plagued such great scientists as Newton and ultimately led to the branch of mathematics known as Calculus.
2. In this activity students will employ a simplified version of Calculus to find an instantaneous speed.



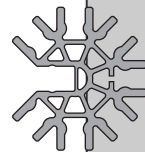
LESSON 11

In Groups

3. Students should:
 - a. Select a location on the coaster where they will determine the speed. They should use a water-based marker to label this location on the track.
 - b. Measure 10 cm on each side of the original mark and identify those locations on the track. Students will know the distance between the two marks on either side of the original mark. (20 cm.)
 - c. Run the coaster and determine the time that it takes for the coaster to travel between the two marks on either side of the original mark.
 - d. Calculate the speed of the coaster over that portion of the track and record it in their science journals.
4. Students will then:
 - a. Erase the marks made 10cm on each side of the original mark and complete the same steps for the following distances on each side of the original point: 6 cm, 4 cm, and 2 cm.
 - b. Describe in their journals the impact that decreasing the distance on either side of the original mark has on measuring the speed at an instant.
5. Students should use each of the speeds and convert it to miles per hour to determine how fast the car is moving in comparison to those on a real roller coaster.
 - a. Divide the each speed by 2.58 to convert the centimeters per second to inches per second.
 - b. Divide those terms by 12 to convert inches per second to feet per second.
 - c. Divide that term by 5280 to convert feet per second to miles per second.
 - d. Multiply that term by 60 to convert miles per second to miles per minute.
 - e. Then multiply that term by 60 to convert miles per minute to miles per hour.

Whole Class

6. Invite the students to discuss the speeds they determined in terms of finding instantaneous speed. You may want to pose the following questions:
 - a. Were you able to determine an instantaneous speed? Why or why not?
 - b. Do you think experimental error is increased as the distances get smaller? Why or why not?
 - c. Are you aware of any technical instruments that might enable you to approach an instantaneous speed? (*Photogates and other electronic timing devices.*)
7. They should discuss:
 - a. Why their calculations are not instantaneous speeds and why finding instantaneous speeds is actually impossible.
 - b. What should be done to get as close to an instantaneous speed as possible.
8. Students now have speeds for their coaster car that are expressed in miles per hour. They should refer to the Internet to determine how these speeds compare to the maximum, posted speed for some of the coasters that exist in parks around the country. How does the model measure up?



ACTIVITY 3: THE COASTER ALWAYS RETURNS

PROCESS

Whole Class

1. Introduce some background information about roller coasters to the class. The original wooden coasters, for example, were referred to as '**Out and Back Woodies**' because a coaster always brought the riders back to the station. Today's coasters are simply modified versions of the out and back concept. They may twist around and some simply go forward and backward. All, however, continue to complete a circuit of some sort and return to their original position, even though many of today's coasters travel a distance of a mile or more.
2. Explain that in this activity students will compare the distance moved by the coaster car along the track with its displacement from its starting point.

Teacher's Notes

- Displacement is measured as a straight line from the coaster car to its starting point. It is a measure of how far **out of place** the coaster car is from its starting point.
- In this activity all displacement measurements will be taken from the base of the lift hill.

In Groups

1. Students should:
 - a. Use a water-based marker to mark increments of 10 cm on the coaster track. This will be the distance traveled by the coaster.
 - b. Make a two-column table in their journals. The left column should have the distances traveled, which will be multiples of 10. The right column will record the displacement of the coaster car from its starting point.
 - c. Measure the displacement of the car at each of the points. The starting point from which all measurements will be taken is the base of the lift hill.
2. When the table is complete students should be asked to:
 - a. Make a line graph of their data with **distance** on the x-axis and **displacement** on the y-axis. They should plot their ordered pairs first and then connect the dots with a smooth curve.
 - b. Write a description of the shape of the graph. Students should describe if they could use this graphical representation to identify where the different parts of the coaster - hill, loop, and turn - are located.

Whole Class

3. Invite the students to discuss:
 - a. How they measured the displacement. Did they lay the tape on the ground or did they suspend it in the air and stretch it?
 - b. The shapes of their graphs and their response to the questions of finding the different parts of the coaster by looking at the graph.



LESSON 11

ACTIVITY 4: WHY THE TEARS**Teacher's Notes**

- The loop was the illusive element for a long time during the modern coaster era. Loops formed from perfect circles were used during the late 1800s, but few people rode such rides because of the intensity of the **g**-forces. Finally, in 1976, engineers discovered that there was a shape that could be used to turn riders upside down and not impose extreme **g**-forces on them and the first modern looping coaster was constructed at the then Magic Mountain in California. The shape of the loop resembled a teardrop and was known as a **clothoid**. The clothoid was actually a mathematical function that was studied extensively by Euler. The clothoid was effective at reducing the **g**-forces because of the changing radius of the loop.
- The **g**-forces on the riders at the bottom of the loop have **centripetal force** as a component.

To calculate the centripetal force, one uses the formula $C = \frac{mv^2}{r}$,

where *m* is the mass, *v* is the speed, and *r* is the radius of the circle. At the bottom of the loop, where the **g**-forces are greatest the radius is larger. This means that the centripetal force is reduced, since the divisor in the expression, *r*, will be larger. Likewise, the centripetal force at the top of the loop and other locations where the loop is tighter will be greater since the radius, *r*, is smaller.

PROCESS**Whole Class**

1. Explain to the students that in this activity they will investigate the characteristics of the clothoid (tear drop shape) loop and why it is used on a coaster.

In Groups

2. Students could use the following procedure for their investigation:
 - a. Use masking tape to connect the left track at the two supports that climb half way up the loop on both sides.
 - b. Use masking tape to connect the left track at the very top of the loop to the bottom of the loop. This will create a plus sign made of masking tape. The crossing represents the center of the circle. This central point should be marked by a small dot.
 - c. Mark the top of the loop on the left track, using a water-based marker, and measure six 5 cm increments in each direction from the left and right of the mark at the top.
 - d. Label each of the marks in order, starting with the mark that is closest to the lift hill on the track.
3. Ask the students to:
 - a. Construct a 2-column table in their journals, with the labels that they have chosen in the left column.
 - b. Measure and record (in the right column of the table) the distance from each of the labeled points to the center of the circle (the dot on the masking tape). In other words, find the radius.



4. Students should use their data to construct a line graph with the labeled points evenly distributed on the x-axis and the distance values they measured on the y-axis.
5. Students should complete their investigation by:
 - a. Describing the shape of the graphs in their science journals, paying close attention to the radius.
 - b. Writing about why they think the smaller radius at the top of the loop and the larger radius at the bottom are so important.

Whole Class

6. Ask the students to:
 - a. Share their graphs.
 - b. Share their descriptions of the graphs.
 - c. Discuss what they wrote in reference to why they thought the smaller radius at the top of the loop and the larger radius at the bottom were so important.

Teacher's Notes

- *The centripetal force is the key here. Centripetal force is equal to the mass of the object times the square of the velocity, divided by the radius of the circle. In the loop, the centripetal force is what keeps the train moving in a circular path.*

ACTIVITY 5: RIDERS PER HOUR

PROCESS

Whole Class

1. An important feature of many of the new high-tech roller coasters is the number of riders per hour that the coaster can handle. In this activity students will set up an experiment to determine the number of riders per hour for their coaster without actually running it for one hour.

In Groups

- **Design Brief:** Develop a method to determine the number of riders that will ride on your coaster in one hour.
- **Time:** 10 minutes.
- **Assumptions:** Your coaster car is always full (4 riders) when it runs and there is a 60-second down time between runs to load and unload the car.



LESSON 11

Whole Class

2. Students should be asked to:
 - a. Discuss their methods for determining the riders per hour.
 - b. Discuss other factors that may influence the number of riders per hour on a real coaster or on the model coaster.

ASSESSMENT

- The mathematical calculations, graphs, and tables constructed in this activity will allow the teacher to assess the students' understanding of the concepts.

EXTENSION

- Some parks still charge riders a separate fee for each ride on their roller coasters. Use the data that was collected in this activity, relating to the number of riders per hour, to determine the income the ride could produce in an hour, in a typical 10-hour day, in a week, in a month, and in a season of operation. Students should be able to check the length of the season for a park in their area by referring to the park's website and checking their seasonal calendar. They should either research the separate fee charges for riding on a coaster or come up with a suitable figure.

