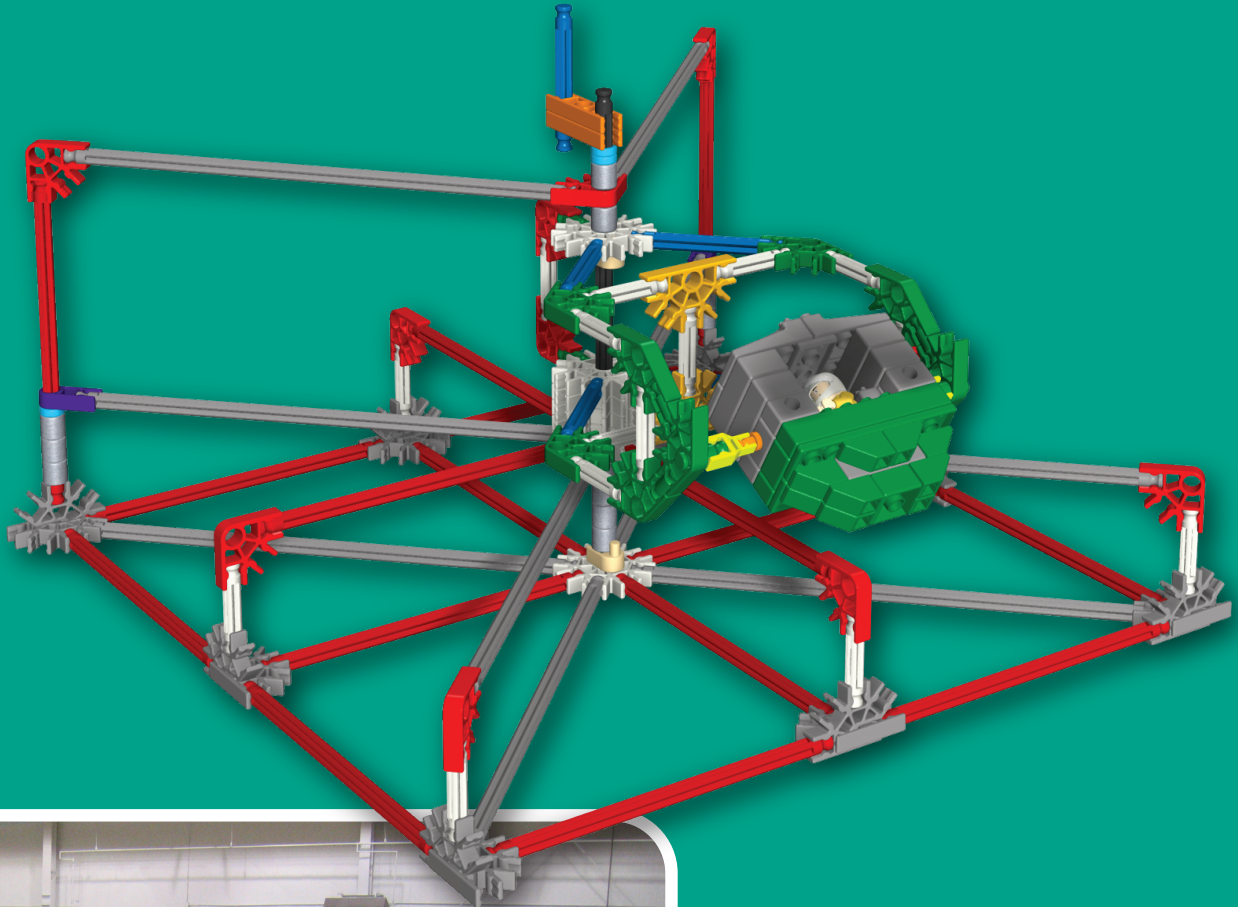


ENERGY, MOTION & AERONAUTICS™ Teacher's Guide



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Energy, Motion & Aeronautics™ Teacher's Guide

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Web site: www.knexeducation.com
Email: abcknex@knex.com
Phone: 1-888-ABC-KNEX (USA/CAN only)

K'NEX Limited Partnership Group
P.O. Box 700
Hatfield, PA 19440-0700
USA

 **WARNING: CHOKING HAZARD – SMALL PARTS.** Not for children under 3 years.

 **CAUTION - ELECTRIC TOY:**

Not recommended for children under 8 years of age. As with all electric products, precautions should be observed during handling and use to prevent electric shock.

The toy must only be used with the recommended transformer.

Disconnect transformer before cleaning any components.

The transformer is not a toy.

All components of this set must be regularly examined for damage. This includes the cord, plug, enclosure and other parts, and in the event of such damage, they must not be used until the damage has been repaired.

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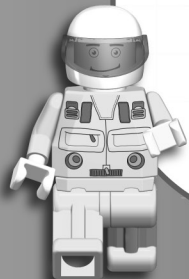
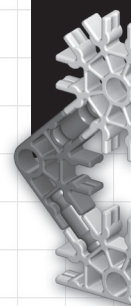


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Introduction to the K'NEX Education

Energy, Motion, & Aeronautics Set

Set Description

The design of this K'NEX Education construction set, and Teacher's Guide, allows students to investigate a variety of concepts related to Newton's Laws and aeronautics. These concepts include aeronautics as it applies to force and motion as well as the effects on individuals who work and live in space. Concepts and activities are fashioned around rigorous content and National Standards in Science, Technology, Engineering and Mathematics (STEM) education.

This set will allow students to construct the following models:

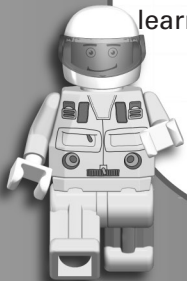
- Rocket Launcher (Lesson 1)
- Rubber Band Powered Dragster (Lesson 2)
- Balloon Racers (Lesson 3)
- Parachutists (Lesson 4)
- Airplane (Lesson 5)
- Centrifuge (Lesson 6)
- Spinning Stroboscope (Lesson 7)
- Thaumatrope (Lesson 8)
- Phenakistoscope (Lesson 9)

What is STEM Education?

To better understand the relationship between the four content areas that make-up STEM, it is important to consider each component individually.

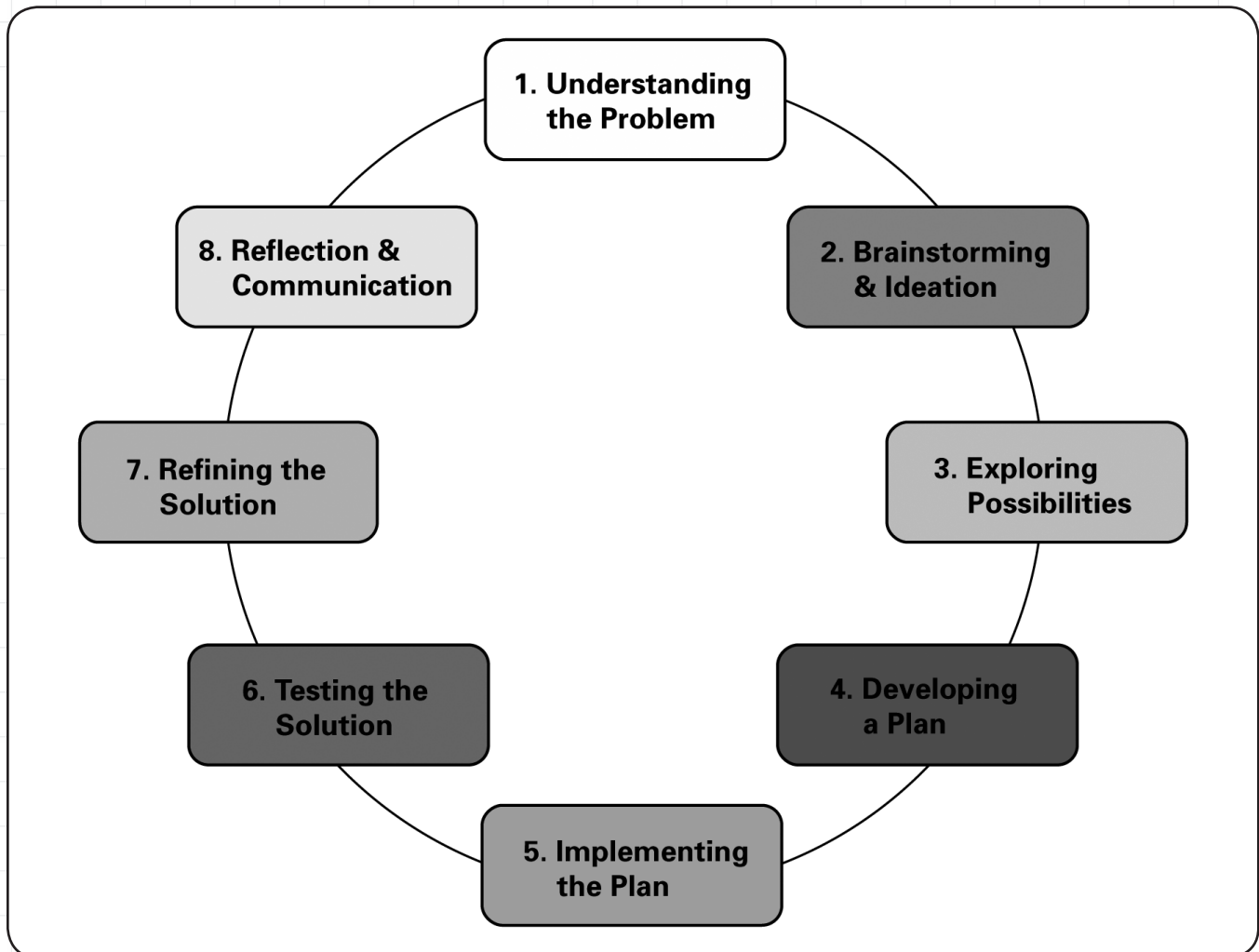
- **SCIENCE:** According to the National Research Council (NRC), Science is the pursuit of understanding of the natural world.
- **TECHNOLOGY:** According to the International Technology and Engineering Educator's Association's (ITEEA) Standards for Technological Literacy, technology is "innovation, change or modification of the natural environment in order to suit perceived wants and needs" or simply put, technology is everything that is human made.
- **ENGINEERING:** According to an official definition by the Accreditation Board of Engineering and Technology (ABET), engineering is "the profession in which a knowledge of mathematical and natural sciences gained by study, experience and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind"
- **MATHEMATICS:** Webster's Dictionary defines Mathematics as "the science of numbers and their operations, interrelations, combinations, generalizations, and abstractions and of space configurations and their structure, measurement, transformations, and generalizations."

According to William E. Dugger, Jr., Professor Emeritus at Virginia Tech and a Senior Fellow of the ITEEA, STEM Education is a trans-disciplinary subject. STEM is an integration of Science, Mathematics, and Technology through Engineering. Through this inter-disciplinary or meta-disciplinary approach to learning, students learn content through **real world applications of knowledge** from many educational subjects rather than in an isolated manner. This knowledge can come from the arts and social sciences as well as the traditional STEM subject areas. There truly are no limits to the integration that can take place in a STEM learning environment.



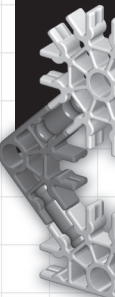
The Engineering Design Process

The Engineering Design Process, used throughout the lessons in this Teacher's Guide, is the process used to guide Engineers as they work to solve problems. This process has a series of steps that are followed which include:



While different sources may use other names for each of these steps, the general principles remain the same. The process always begins with an understanding of the problem. It then proceeds through stages of research and the production of ideas. Proposed solutions are developed and produced. Next, testing takes place to ensure the solution adequately solves the problem. If not, the solution can be refined or redesigned. Finally, the process ends when the solution is communicated to others for feedback.

In reality, the Engineering Design Process is a never ending, cyclical process that is continually repeated because there is no such thing as 'The Perfect Design.' There is always room for innovation and improvement: new technologies are invented, new discoveries are made by the science community, and new engineering strategies are developed. For this reason, students should be encouraged to look to discoveries and innovations made throughout history while completing these lessons.



Inquiry Process

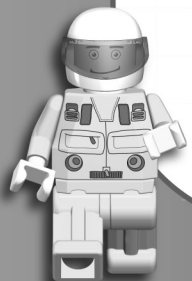
The Scientific Inquiry Process is similar to the Engineering Design Process in many ways. Throughout the lessons included in the K'NEX Education Energy, Motion, and Aeronautics Set students will use both processes extensively as they explore, create, invent, and innovate.

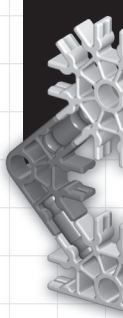
According to Southwest Center for Education and the Natural Environment, "The scientific method is the inquiry process by which scientists raise and answer new questions." (<http://scene.asu.edu/habitat/inquiry.html>) There are many versions of the scientific method/inquiry process in existence. We have chosen the following steps to outline the inquiry process as it applies to this teacher's guide.

Process of Scientific Inquiry



Students will complete at least two inquiries during each lesson. The first will be a guided inquiry activity that enables students to explore the operation and potential of the various models that they have built. The second inquiry activity will be student designed and implemented. At the conclusion of each of the design challenge students will design experiments to test the effectiveness of their solutions. This series of inquiries will allow students to support their challenge solutions with verifiable tests and experiments.





Instructional Strategy

The majority of lessons provided in this guide follow a modified version of the 5E instructional model. *This teaching strategy includes:*

- **ENGAGEMENT:** The teacher creates interest and elicits responses from the students through interactive demonstrations and discussions.
- **EXPLORATION:** Student teams work together to build the K'NEX models and to explore how they operate. Guided inquiry activities and experiments will focus their exploration. Student teams will then complete a design challenge and follow the Design Process Guide as they develop their solution. During the design process, students will complete a Pro and Con Chart to analyze and evaluate the ideas and suggestions offered by their teammates. Students will design and complete experiments following the process of scientific inquiry to verify the effectiveness of their solution to the challenge.
- **EXPLAIN:** Students will present the solutions they developed during the Engineering Design Process through the creation of a variety of documents, visual aides, and presentations.
- **ELABORATE:** Students will individually complete a *Daily Research and Design Log form* during each lesson. These logs will provide a day-by-day record of the student's activities and can also be used for assessment purposes. These logs, along with other documentation created during the lesson will make up the student's Design Journal. This journal is a collection of all of the forms, drawings, Student Response Sheets, etc. that students create.
- **EVALUATION:** Students will self-evaluate their work and the work of their team using the *Teamwork and Self-Assessment Form*. In addition, a rubric for each lesson is provided for the students to evaluate their performance. You, as the teacher, may add your comments to the students' rubrics in the space provided or create another rubric of your own design as you evaluate student performance.

Creating the Design Journal

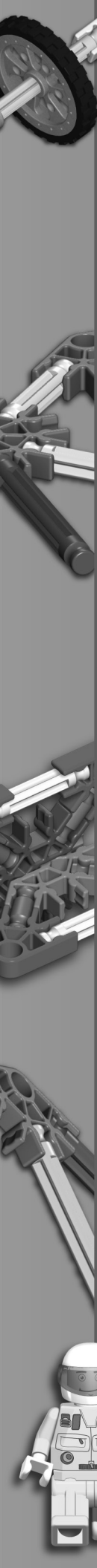
Scientists, technologists, engineers, and mathematicians all keep extensive records of their work. It is highly recommended that students maintain a comprehensive journal of all of their daily work including experiments, ideas, conclusions, etc. Throughout this Teacher's Guide you will see reference to a Design Journal. This should be a folder or notebook consisting of all of the materials produced by the student during their work with the K'NEX Education Energy, Motion, and Aeronautics Set.

The Design Journal will include:

- Daily Research and Design Logs
- Student Response Sheets
- Challenge Design Briefs
- Pro & Con Charts
- Teamwork & Self-Assessment Forms
- Assessment Rubrics
- Any other drawings, sketches, and notes created during the course of the design process for each activity

Consider providing students with a folder to organize their Design Journals. If students have access to computers each day, consider allowing them to keep an electronic Design Journal. This is a great way to reduce paper and 'go green.'

These Design Journals are similar to the Engineering Design Journals created by inventors and innovators throughout history. They provide both a visual and written record of the processes students completed as they developed solutions to the assigned challenges. They also serve as a way for students to review and reflect upon what they learned. The Design Journal provides a unique opportunity for the teacher to explore the students' thought processes and decisions during the lesson. The insights gained by reviewing the Design Journals will provide important assessment data.



To view examples of the Design Journals created and used in the development of many well-known inventions, visit the *Edison Papers* website managed and hosted by Rutgers University in Camden, New Jersey at <http://edison.rutgers.edu/>. Click on the Digital Edition button to the left and 'a document sampler' in the first paragraph of the next window to view examples of Thomas Edison's own Design Journals.

Daily Research and Design Logs

Students should be provided a blank copy of the Daily Research & Design Log for each day or provide students with the questions on the chalkboard or electronically and have the students complete their logs on notebook paper. Drawings can be completed on pieces of graph paper.

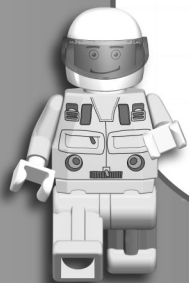
Review the Daily Research and Design Logs with students to clarify the requirements and your expectations as students complete these forms.

The Daily Research and Design Log includes 5 areas for students to complete daily:

- **Actions Completed & What I Learned** – Students are expected to list the actions that they and/or their team completed during that day's work session. Students should be encouraged to write in complete sentences as they describe the steps of the design process they completed and the actions they took to complete those steps. Additionally, students should list what they learned during the day's activities.
- **Resources Used** – Students will list the print and/or online resources that they used during the course of that day's activities. Website URLs and citations for print resources should be included.
- **Problems Encountered** – Students should share the challenges, if any, they experienced while completing the day's activities. This can include problems with the design, planning, or implementation of their plans as well as problems with team dynamics.
- **My Contributions** – This is a chance for students to be reflective on the work that they completed and to consider whether what they were doing that day contributed to the potential success of their team.
- **Brainstorming and Design Sketch Area** – Students will complete the sketches and drawings that are often required by their assigned activities. Labels, a materials list, and written notes will improve the information presented by these sketches and drawings.

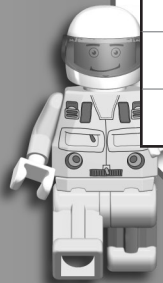
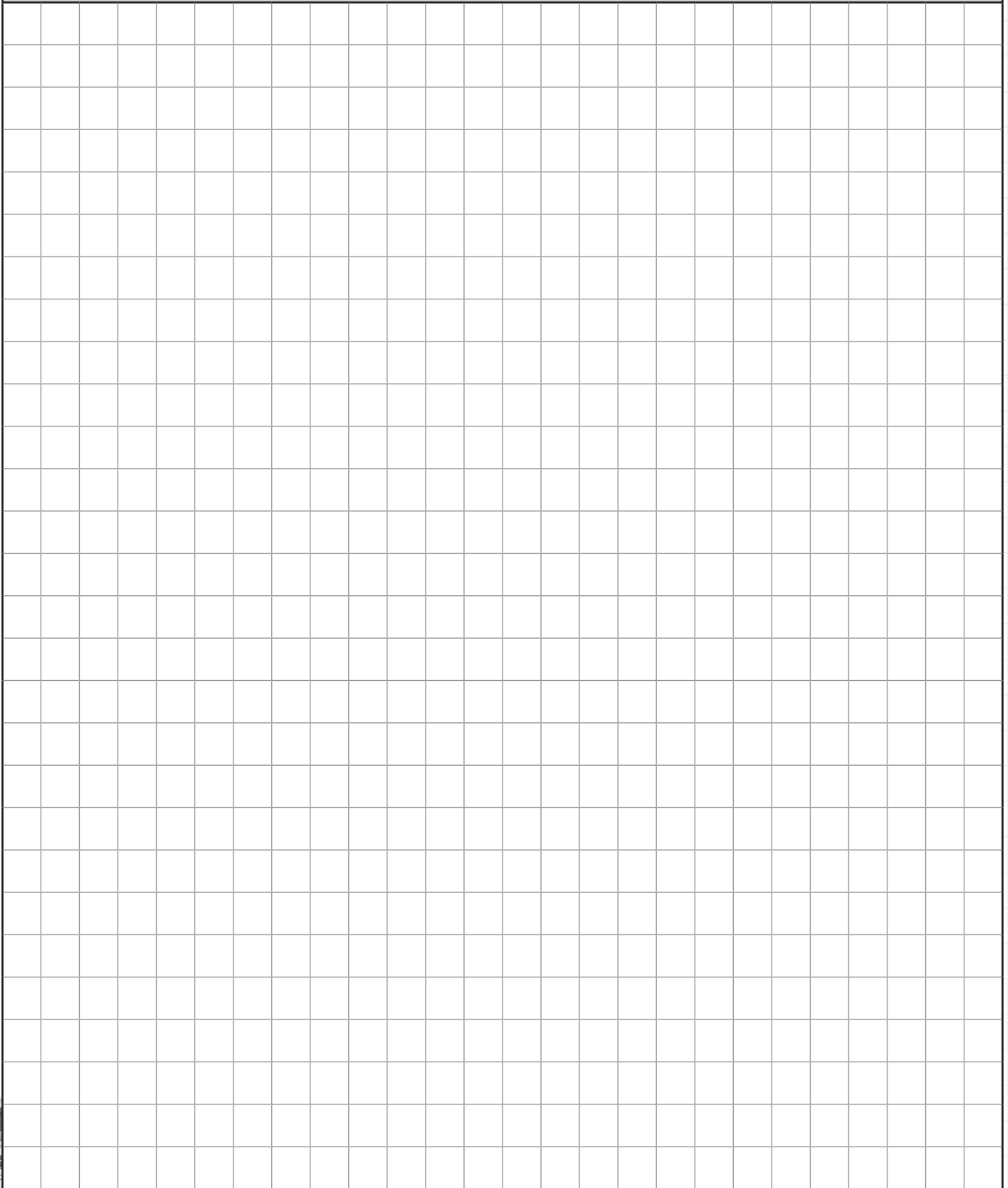
This log can also be a source of useful information for students when they are required to create presentations of their work for the rest of the class. Students should be reminded that these forms will be partially evaluated based on spelling and grammar.

A template for the Daily Research and Design Log can be found on the next two pages.



Brainstorming & Design Sketch Area

Use the space below to complete the drawings assigned today. If no drawings were assigned today, this space can be used to draw or sketch any changes you made to your model. If this is your final, refined drawing for a concept or idea, it should be drawn to scale or include dimensions. All drawings must be labeled.



Using the Pro & Con Charts

As students work through the design process, it is important for them to evaluate the possible advantages or disadvantages of the design solutions they and their teammates develop. The Pro & Con Charts offer students a chance to step back and reconsider brainstormed ideas before they begin planning and implementing their ideas.

Review the Pro & Con Chart with students to ensure they understand the chart and your expectations.

These forms include the response spaces:

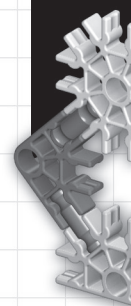
- **Design Option Name:** Students should come up with a simple name to differentiate one design from another. Students will find that descriptive names will be much more helpful than single word names as they attempt to keep track of their various ideas.
- **Advantages:** These should be the elements that are positive about a particular design or idea. For example, the design is easy to construct or the finished device will be easy to use.
- **Disadvantages:** These should be the elements of the design or idea that are negative. For example, it will take too long to build or the reason the device may not work.

Lead a discussion with students that highlights the fact that there is no such thing as 'The Perfect Design.' Inventor and innovators often face obstacles that must be overcome before they can be successful.

The important thing for students is to:

- Choose the best possible solution to implement, and,
- Be willing to change and refine their designs and ideas when necessary.

A template for the Pro and Con Chart can be found on the next page.

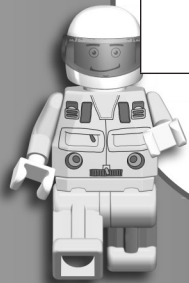


Pro and Con Chart

Use this chart to list and evaluate the designs and/or experiments suggested by your teammates. When finished, team members should share their charts in an effort to help the team decide which solution offers the most promise.

List possible advantages and disadvantages of each suggested design. Just because one design option has many disadvantages it does not mean that you can not incorporate some of the advantages of one design to fix disadvantages of another.

Design Option Name <i>(Designer's name or the name of the object)</i>	Pros	Cons
1.		
2.		
3.		
4.		
5.		



Assessment Opportunities

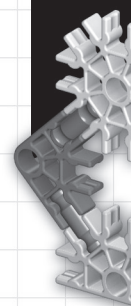
There are a number of assessment opportunities presented with each lesson, these include:

- Daily Research and Design Logs
- Student Response Sheets
- Pro and Con Charts
- Presentations of Challenge Solutions
- Models and Devices Prepared by Students
- Design Journals
- Assessment Rubrics
- Teamwork and Self-Evaluation Forms

Additionally, students should be assessed on their ability to work with one another as well as how they work individually.

Students will be encouraged to assess themselves and their solutions throughout the design process. Allowing students to self-assess will help them realize strengths and weakness of their own work through reflective evaluation. At the conclusion of the challenge activity of each lesson instruct students to complete a Teamwork and Self-Assessment Form. This form provides students with the opportunity to reflect on their team and themselves. They will provide some information about their team and they will assess their contribution to their team's success and suggest ways they could contribute even more in the future.

A template for the Teamwork and Self-Assessment Form can be found on the next page.



Teamwork and Self-Assessment Form

Team Members: _____

Using a scale from 1 to 5, please rate the following:

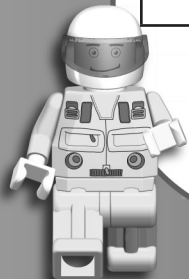
1 = Strongly Agree 2 = Agree 3 = Neutral 4 = Disagree 5 = Strongly Disagree

All members provided equal contributions to the success of the team.	1	2	3	4	5
We worked well together as a team.	1	2	3	4	5
Our team was able to meet all deadlines.	1	2	3	4	5
My team members encouraged me to do my best at all times.	1	2	3	4	5
I would be happy to work with this same team again.	1	2	3	4	5

Self-Assessment

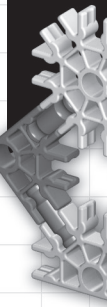
During the course of this activity, I contributed to my team's success by the following actions:

I would do the following to help my team be even more successful in the future:



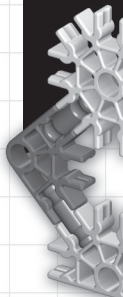
Suggested Extension Activities

Extension opportunities have been provided at the end of each lesson. These extension activities allow students to explore beyond the content provided in the lessons. Be aware that the extensions as well as the Design Brief challenges are approachable in a number of ways and that the students should be given the encouragement and time to pursue these divergent, open-ended invitations to inquiry and design.



ITEEA Standards Alignments

ITEEA Standards Grades 5-8 <i>Students will develop an understanding of:</i>	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7	Lesson 8	Lesson 9
The characteristics and scope of technology									
• New products and systems can be developed to solve problems or to help do things that could not be done without the help of technology.	☼	☼	☼	☼	☼	☼			
• Technology is closely linked to creativity which has resulted in innovation.	☼	☼	☼	☼	☼	☼	☼	☼	☼
• Inventions and innovations are the results of specific, goal directed research. (Grade 9–12 Standard)	☼	☼	☼	☼	☼	☼	☼	☼	☼
The core concepts of technology									
• Systems thinking involves considering how every part relates to others.				☼	☼	☼	☼		☼
• Technological systems can be connected to one another.		☼	☼	☼	☼	☼			
• Requirements are the parameters placed on the development of a product or system.	☼	☼	☼	☼	☼	☼	☼	☼	☼
• Different technologies involve different sets of processes.					☼	☼			☼
• Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.	☼	☼	☼	☼	☼	☼	☼	☼	☼
Relationships among technologies and the connections between technology and other fields of study									
• Knowledge gained from other fields of study has a direct effect on the development of technological products and systems.	☼	☼	☼	☼	☼	☼	☼	☼	☼
The cultural, social, economic, and political effects of technology									
• Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.	☼	☼	☼	☼	☼	☼	☼	☼	☼
The attributes of design									
• Design is a creative planning process that leads to useful products and systems.	☼	☼	☼	☼	☼	☼	☼	☼	☼
• There is no perfect design.	☼	☼	☼	☼	☼	☼	☼	☼	☼
• Requirements for design are made up of criteria and constraints.	☼	☼	☼	☼	☼	☼	☼	☼	☼
Engineering Design									
• Design involves a set of steps, which can be performed in different sequences and repeated as needed.	☼	☼	☼	☼	☼	☼	☼	☼	☼
• 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.	☼	☼	☼	☼	☼	☼	☼	☼	☼



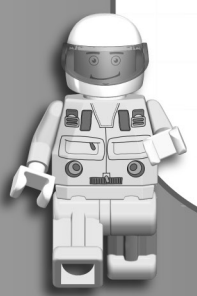
ITEEA Standards Grades 5-8 <i>Students will develop an understanding of:</i>	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7	Lesson 8	Lesson 9
<ul style="list-style-type: none"> Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly. (Grade 9-12 Standard) 	✱	✱	✱	✱	✱	✱	✱	✱	✱
The abilities to apply the design process									
<ul style="list-style-type: none"> Apply a design process to solve problems in and beyond the laboratory-classroom. 	✱	✱	✱	✱	✱	✱	✱	✱	✱
<ul style="list-style-type: none"> Specify criteria and constraints for the design. 	✱	✱	✱	✱	✱	✱	✱	✱	✱
<ul style="list-style-type: none"> Make two-dimensional and three-dimensional representations of the designed solution. 	✱	✱	✱	✱	✱	✱	✱	✱	✱
<ul style="list-style-type: none"> Test and evaluate the design in relation to pre-established requirements, such as criteria and constraints, and refine as needed. 	✱	✱	✱	✱	✱	✱	✱	✱	✱
<ul style="list-style-type: none"> Make a product or system and document the solution. 	✱	✱	✱	✱	✱	✱	✱	✱	✱
<ul style="list-style-type: none"> Develop and produce a product or system using a design process. (Grade 9-12 Standard) 	✱	✱	✱	✱	✱	✱	✱	✱	✱
<ul style="list-style-type: none"> Use computers and calculators in various applications. 	✱	✱	✱	✱	✱	✱	✱	✱	✱
<ul style="list-style-type: none"> Interpret and evaluate the accuracy of the information obtained and determine if it is useful 	✱	✱	✱	✱	✱	✱			
Selection and use of energy and power technologies									
<ul style="list-style-type: none"> Energy is the capacity to do work. 	✱	✱	✱						
<ul style="list-style-type: none"> Energy can be used to do work, using many processes. 	✱	✱	✱						
<ul style="list-style-type: none"> Power systems are used to drive and provide propulsion to other technological products and systems 	✱	✱	✱		✱	✱			
Selection and use of transportation technologies									
<ul style="list-style-type: none"> Transportation vehicles are made up of subsystems, such as structural propulsion, suspension, guidance, control, and support that must function together for a system to work effectively. 		✱	✱		✱				

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NSES Content Standards Alignments

National Science Education Standards grades 5-8 <i>Students will develop an understanding of:</i>	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7	Lesson 8	Lesson 9
Unifying Concepts and Processes									
• Systems, order, and organization	✱	✱	✱	✱	✱	✱	✱	✱	✱
• Evidence, models, and explanation	✱	✱	✱	✱	✱	✱	✱	✱	✱
• Measurement	✱	✱	✱	✱	✱	✱	✱	✱	✱
• Form and function	✱	✱	✱	✱	✱	✱	✱	✱	✱
A. Science as Inquiry									
• Abilities necessary to do scientific inquiry	✱	✱	✱	✱	✱	✱	✱	✱	✱
• Understandings about scientific inquiry	✱	✱	✱	✱	✱	✱	✱	✱	✱
B. Physical Science									
• Motions and Forces	✱	✱	✱	✱	✱	✱			
• Transfer of energy	✱	✱							
E. Science and Technology									
• Abilities of technological design	✱	✱	✱	✱	✱	✱	✱	✱	✱
• Understandings about science and technology	✱	✱	✱	✱	✱	✱	✱	✱	✱
G. History and Nature of Science									
• Understanding of science as a human endeavor	✱	✱	✱	✱	✱	✱	✱	✱	✱
• Understanding the Nature of Science	✱	✱	✱	✱	✱	✱	✱	✱	✱

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NCTM Standards Alignments

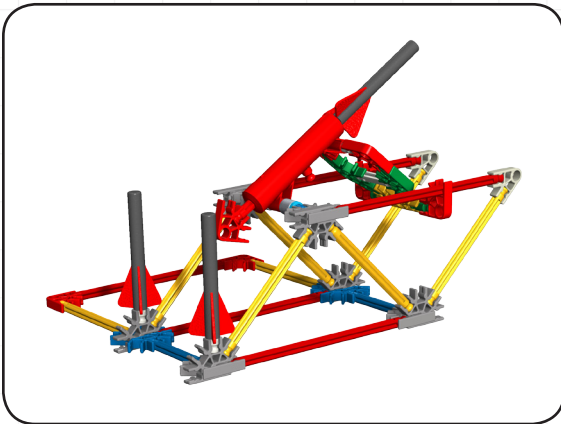
National Council of Teachers of Mathematics Education Standards and Expectations for grades 5-8 <i>Students will develop an understanding of:</i>	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7	Lesson 8	Lesson 9
Numbers and Operations									
• Understand numbers, ways of representing 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									
• 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									
• Use visualization, spatial reasoning, and geometric modeling to solve problems	✱	✱	✱	✱	✱	✱	✱	✱	✱
Measurement									
• Understand measurable attributes of objects and the units	✱	✱	✱	✱	✱	✱	✱	✱	✱
• Apply appropriate techniques	✱	✱	✱	✱	✱	✱	✱	✱	✱
Data Analysis and Probability									
• Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them	✱	✱	✱	✱	✱	✱			
• Select and use appropriate statistical methods to analyze data	✱	✱	✱			✱			
Data Analysis and Probability (cont.)									
• Develop and evaluate inferences and predictions that are based on data	✱	✱	✱			✱			
• Understand and apply basic concepts of probability	✱	✱	✱			✱			
Process									
• Communication	✱	✱	✱	✱	✱	✱	✱	✱	✱
• Connections	✱	✱	✱	✱	✱	✱	✱	✱	✱
• Representation	✱	✱	✱	✱	✱	✱			

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LESSON #1: SPLASH DOWN RESCUE



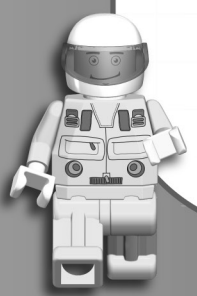
Model: Rocket Launcher



Main Concepts:

- **Science**
 - Projectile Motion, Newton’s First Law of Motion
- **Technology & Engineering**
 - Engineering Design Process, Systems
- **Mathematics**
 - Algebra, Measurement, Data Analysis & Probability

Objectives:	Required Materials:	Optional Materials:
<p><i>Student will be able to:</i></p> <ul style="list-style-type: none"> • Work effectively both independently and in collaborative teams. • Design and develop a device or method to accurately fire a projectile a given distance. • Correctly identify a number of similarities and differences between Scientific Inquiry and Engineering Design. • Properly apply the steps of the Engineering Design Process as they related to this activity. • Correctly describe Newton’s First Law of Motion. • Understand that mathematics is an integral part of inquiry, experimentation, design, and development of human made items. 	<p><i>Teacher will need:</i></p> <ul style="list-style-type: none"> • K’NEX Rocket Launcher model <p><i>Students will need:</i></p> <ul style="list-style-type: none"> • Parts and building instructions for the K’NEX Rocket Launcher • Ruler (30 cm, meter stick, metric tape) • Protractor • Graph Paper • Copies of all Student Response Sheets and forms for inclusion in the students’ Design Journals 	<ul style="list-style-type: none"> • Printer paper • Cardboard • Construction paper • Computers with spreadsheet software. • Additional materials at the discretion of the teacher.



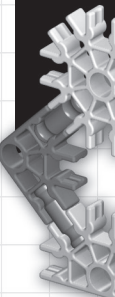
Process

Engagement

1. Students should view the video clip of a catapult launch, and then discuss the path that the projectile took from the time it was released to the time that it struck the ground.
2. Review Newton's three laws of motion using textbooks or other available resources. Inform students that this lesson will focus on Newton's First Law of Motion and inertia. Help students to understand the difference between these two statements:
 - An object at rest tends to stay at rest until acted upon by an unbalanced force.
 - An object in motion will remain in motion at a constant speed until acted on by an outside force.
3. Choose 3 students to do a projectile motion demonstration for the class.
 - a. Give each student a wadded up ball of paper to use as their projectile.
 - b. Place a trashcan in the front of the classroom with the students. Each student will throw their ball, underhanded into the trashcan placed 3 meters away.
 - c. Have the class watch the trajectory of the balls as they are thrown into the trashcan.
 - d. Instruct one student to throw their paper ball as high as they can, as they aim at the trashcan.
 - e. Instruct the second student to throw their paper ball about $\frac{1}{2}$ as high as the first student, as they aim at the trashcan.
 - f. Instruct the final student to throw their paper ball at the lowest possible height, as they aim at the trashcan.
4. Lead a discussion beginning with observations students made about the trajectories of the various throws. Introduce the concept of an arc shaped path if it is not mentioned by students. This is a great opportunity to introduce the vocabulary terms: parabolic arc, ascent, apogee, decent and range.
5. Ask students if they noticed any difference in the speed each of the students used as they threw the balls. Students should mention the fact that the lower the arc on the throw, the harder the ball had to be thrown. If this is not apparent have the students repeat the activity with a child's ball or tennis ball.
6. Use a whiteboard or chalkboard to diagram the parabolic path the first ball took to the trashcan. Label the ascent, apogee it reaches, decent, and the range of the ball.

Exploration

1. Students will develop an understanding of Newton's First Law of Motion through research and experimentation using the K'NEX Rocket Launcher model.
 - a. Students should complete the Understanding Newton's First Law of Motion - Student Response Sheets to demonstrate an understanding of the information and vocabulary presented in the Engagement section of this lesson and their own research.
 - b. Have students construct the K'NEX Rocket Launcher model following the building instructions provided. Using the Rocker Launcher Testing Chart students will test fire the K'NEX Rocket Launcher at nine set angles to determine which angle produces the longest launch.
 - c. Have the students discuss their findings as a group prior to leading a class discussion of the findings. Encourage students use the vocabulary they have learned during the class discussion.



TEACHER'S NOTES:

- Provide students with a copy of the Rocket Launcher Testing Chart that provides their data collection table and space for questions and observations.
- Provide a sheet of graph paper for students. Remind students to place all of their Student Response Sheets, calculations, and graphs in their Design Journal.
- A great resource to use as reinforcement for this activity is http://phet.colorado.edu/sims/projectile-motion/projectile-motion_en.html. This site allows students to conduct virtual experiments related to projectile motion. An on-screen cannon fires golf balls, bowling balls, shells, etc. and the software draws each trajectory. Students control the variables and the website provides them with the range, height, and travel time for their projectiles. Students should be encouraged to design and complete one or more experiments using this on-screen simulation and to keep records of experiments in their Design Journals.

2. Students will complete a Splash Down Rescue Challenge Design Brief. Discuss the Design Brief and the criteria for the challenge with students.
 - a. Introduce the Splash Down Rescue Challenge Design Brief. Review the Design Brief in detail with the students.
 - b. Introduce the Design Process Guide to the students. Explain that they will use the Design Process Guide to direct their activities while working on this challenge.
 - c. Students will demonstrate their understanding of the Splash Down Rescue Challenge Design Brief by completing the Design Process Guide. Review each team's responses to ensure they understand the challenge and the criteria before continuing.
 - d. Have students complete a Daily Research and Design Log sheet

TEACHER'S NOTES:

- At the conclusion of the Splash Down Rescue Challenge activity, provide each team with 3 distances that are within the range of the K'NEX Rocket Launcher. Have each team fire three rockets with the goal of having them land as close as possible to the distances you assigned.
- Teams will be judged based on how many of their rockets land near the designated distances. As students experiment with their designs, observe their rockets so that you can determine how close a rocket needs to land to the assigned distance to be counted as near.

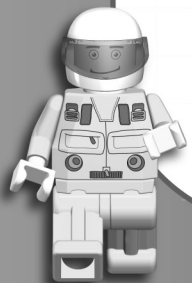
Explanation

Assign teams to design and present their solution to the challenge to the class. *The presentation should include:*

- An oral description
- Visual aids
- A demonstration of their model or technique.

Student Reflection

Students will self-evaluate their challenge solutions based on the criteria provided in the rubric for this activity. Additionally, students will complete a Teamwork and Self-Assessment Form to assess their individual efforts and team's efforts on the challenge.



TEACHER'S NOTES:

- Give the Splash Down Rescue Assessment Rubric to students so they can complete a self-evaluation of their work. The rubric score and your evaluation will make up a portion of the assessment data for this lesson.
- Provide students with a Teamwork and Self-Assessment Form and review the form with students before they fill them out.

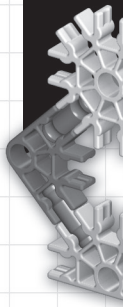
Evaluation

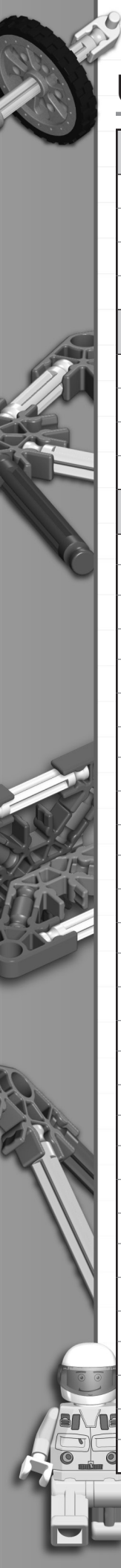
You may use some or all of the following to evaluate student's performance:

- Splash Down Rescue Assessment Rubric
- Presentation of the Challenge Solution
- Daily Research and Design Logs
- Student Response Sheets
- Graphs, Charts, and Forms
- Design Journal

Extension

Many sports require students to have a working knowledge of parabolic arcs. The experienced basketball player knows just the right force to put into the shot and the exact angle to shoot the ball to have it pass through a perfect arc to the basket. Similarly, tennis players can use a lob shot to place the ball in the exact spot they wish on their opponent's side of the court. Pneumatic devices use compressed gases like air as a power source to create motion. The K'NEX Rocket Launcher students used during this lesson is one example. Students will research and present what they have learned specific to pneumatic devices that operate things like amusement park ride safety systems, train and bus brakes, CO2 powered vehicles, and more.





Understanding Newton's First Law of Motion

Describe Newton's First Law of Motion in your own words.

How do you think this law relates to the way a rocket launches?

Define the terms listed below. Be sure to write the definitions in your own words.

Ballistics -

Trajectory -

Acceleration -

Range -

Drag -

Projectile -

Inertia -

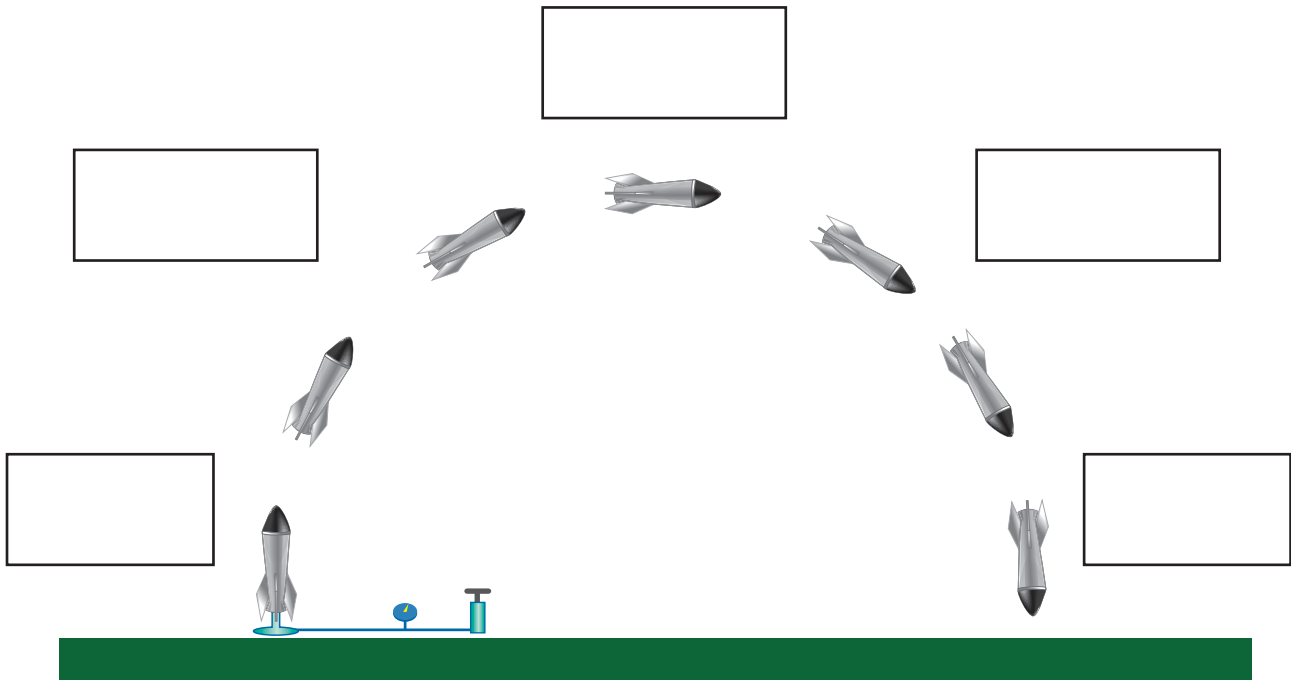
Velocity -

Ascent -

Descent -

Projectile Motion Worksheet

Below is a series of images that represents the flight path of a rocket. Label the various stages of the projectile's path using the key terms provided.



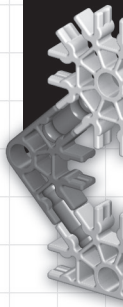
Launch

Coasting Decent

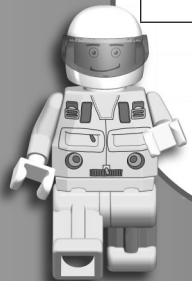
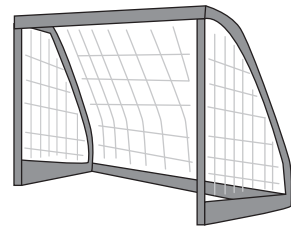
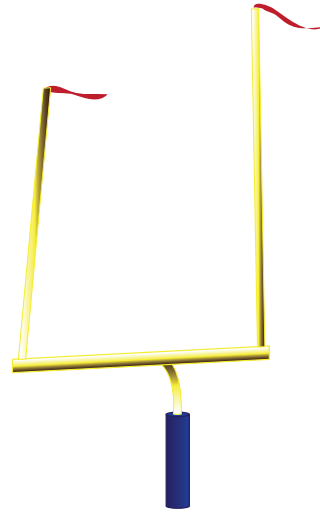
Coasting Ascent

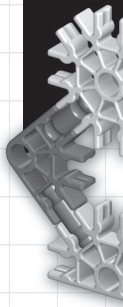
Recovery

Maximum Altitude



Draw the most likely trajectory for the projectiles on the left side of each image as they travel to the right side of the image.





K'NEX Rocket Launcher Testing Chart

Use a protractor and set the K'NEX Rocket Launcher to the angles indicated in the chart below. Measure how far the rocket travels before it hits the ground or table. Run three trials at each angle and average your results to determine the average range of the rocket for each angle. Include all of your calculations in your Design Journal.

Launch Angle (i) (degrees)	Trial 1 Range (Meters)	Trial 2 Range (meters)	Trial 3 Range (meters)	Average Range (meters)
5				
15				
25				
35				
45				
55				
65				
75				
85				

Which angle(s) resulted in the rocket traveling the greatest distance? _____.

Graph your average range data. The angles represent the independent variable and should be placed on the X-axis of the graph. The range (distance traveled) is the dependent variable and should be placed on the Y-axis of the graph. Place the data points on the graph and draw a smooth curve that passes through the data points. Label the axes of the graph and provide a title for the graph. Include this page and the graph in your Design Journal.

Describe the shape of the graph.

Based on the results of this experiment, write a general rule that would help other rocket launcher operators as they fire their rockets.

Splash Down Rescue Challenge

Design Brief

The Challenge

Your team members are part of the crew on a Coast Guard rescue vessel. Your primary mission is to rescue people stranded at sea. You have been challenged to design a device or technique that will allow a crew member to deliver a floatation device and rescue line to a drowning victim. The device or technique must include a scale that allows the operator to quickly set the range to match the distance to the victim.

Your Task

- Develop a device or technique to accurately set the angle of the K'NEX Rocket Launcher so it can fire a rescue rocket a distance provided.

Rules & Constraints of the Challenge

- Use the data you collected during your experiment to help with this challenge. Complete other experiments as needed to refine your device or technique. You may only use materials provided by your teacher for this challenge.
- Your team may not change or alter the rocket used with the K'NEX Rocket Launcher.
- Once the device or technique has been created, conduct a number of experiments to ensure that you can choose and then reach a desired target location using your solution.

The Process

This activity will include the following phases:

- Phase 1 – Class Exploration
 - Projectile Motion Student Response Sheet
 - Construction of the K'NEX Rocket Launcher
 - K'NEX Rocket Launcher Testing Chart
 - Splash Down Rescue Design Brief Introduction by teacher

(Follow the steps on the Design Process Guide to direct your team through the remainder of the challenge.)

- Phase 2 – Independent Exploration
 - Understanding the Problem
 - Design Process Guide Student Response Sheet
 - Brainstorming & Ideation
- Phase 3 – Team Exploration
 - Explore Possibilities and Develop a Plan
 - Pro and Con Chart
 - Implement Your Plan
 - Testing and Refining the Plan
- Phase 4 – Classroom Competition
 - Taking the Challenge
- Phase 5 – Wrapping It Up
 - Reflection/Evaluation
 - Splash Down Rescue Assessment Rubric
 - Teamwork & Self Assessment Forms

Note: Complete a Daily Research and Design Log each day during this challenge.

Design Process Guide

Understanding the Problem

To demonstrate your understanding of the challenge, complete the following.

The Challenge:

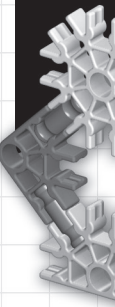
Restate the challenge, in your own words.

Criteria:

Describe what your device or technique must be able to accomplish and any specific performance levels that it needs to meet, in your own words.

Constraints:

Describe the limitations you have been given for this challenge.





Brainstorming and Ideation

Brainstorm possible solutions to the challenge. List your individual ideas and show rough sketches in the box below and in more detail on your Daily Research and Design Log.

Ideas and Sketches

Develop an experiment that will allow you to test your solution. The experiment should enable your team to verify that your device or technique can be used to fire a rescue rocket any distance your teacher assigns.

Exploring Possibilities and Developing a Plan

Fill out the Pro and Con Chart provided by your teacher. Describe each of the team members' ideas and list advantages and disadvantages of their devices or techniques and their experimental plans. This information should be used to develop your team's final plan.

Once evaluation of team members' ideas is complete, develop one final plan. This plan can be based on one team member's idea or a combination of elements from each of the ideas your team members offered. Put a detailed explanation of the final plan in your Design Journal along with detailed, labeled, scale drawings of the solution. Include the plan for your team's experiment and details of how your team will collect, organize and report experimental data.

Implement Your Plan

With your teacher's approval, put your team's plan into action.

Testing and Refining the design

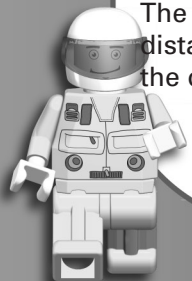
When the device or technique is ready, begin testing its performance and collecting data. Use masking tape to mark rocket landing areas.

As you experiment, refine your model to make it as accurate as possible.

Keep testing and experimenting as long as time allows. Record each of the refinements you make and the results of testing.

Taking the Challenge!

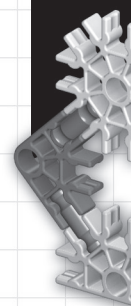
The time has come! You and your team will be challenged to fire your rescue rocket to reach 3 different distances. While some devices may be more accurate and successful than others, ultimately if you followed the design process you will all be winners!



The Rocket Launcher that can Hit the Target

K'NEX Rocket Launcher devices or techniques will be evaluated based on their ability to launch a rocket to land at three distances, defined by your teacher. Mark an area on the floor where the K'NEX Rocket Launchers are to be placed. When it is your team's turn, place a masking tape mark on the floor at the distance your rocket must attain. Fire the rocket, record your results, and prepare for your next distance. Rocket Launchers will be ranked as follows

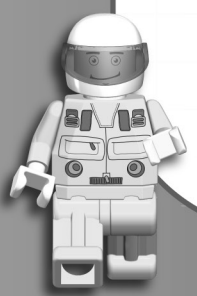
- **Right on Target** – All of the rockets hit near the required distances specified.
- **Life Saver** – Two of the rockets hit near the distances specified.
- **Swim for It** – One of the rockets hit near the distances specified.



Complete a Splash Down Rescue Assessment Rubric to provide your teacher with your impression of how you did with this lesson.

Splash Down Rescue Challenge		Assessment Rubric	
	Excellent	Good	Acceptable
Design Journal & Worksheets	Student Response Sheets and Design Journal completed in their entirety with no spelling or grammar errors. Answers on Student Response Sheets are accurate. 8	Student Response Sheets and Design Journal completed in their entirety with a few (2-4) spelling and grammar errors. Most answers on Student Response Sheets are accurate. 6	Student Response Sheets and Design Journal completed in their entirety with many (5 or more) spelling or grammar errors. Fewer answers on Student Response Sheets are accurate. 4
Design & Construction	Your device is very neatly constructed, easy to use, and meets or exceeds expectations related to the criteria and constraints listed in the design brief. 6	Your device is neatly constructed, easy to use, and meets expectations related to the criteria and constraints listed in the design brief. 5	Your device has been constructed, is in a useable form, and meets the materials criteria listed in the design brief. 4
Teamwork/ Work Ethic	You worked well with your teammates and interacted well with others. You demonstrated excellent reliability and initiative when working on this challenge. 5	You worked well with your teammates and interacted well with others. You were reliable and demonstrated initiative when working on this challenge. 3	You usually worked well with your teammates and others. You were generally reliable and usually demonstrated initiative when working on this challenge. 1
Device Performance	<i>Circle Results for each:</i> Accuracy Tests		
	Right on Target (6)	Life Saver (4)	Swim for It (2)
Total Score	_____ /25		

Teacher Comments: _____



Reflection on the Activity

Now that your device or technique has been tested and is being used regularly in life saving situations, your teacher will provide you with a Teamwork and Self-Assessment Form. Use the form to reflect on your team and your contributions to your team's efforts.

Extension Activities

1. Now that you understand concepts related to projectile motion, you should realize that success in many sports depends on a knowledge of projectile motion. When an athlete throws a baseball or shoots a basketball, the object typically travels in a parabolic arc. Your task is to research a sport and explain how projectile motion relates to that sport. Your explanation will include 1-2 paragraphs as well as at least two images that illustrate projectile motion at work in that sport.
2. Pneumatic devices use air pressure or compressed gases to produce force that can cause a motion or action. One example is the NASTAR Center's Ejection Seat Simulator. Your task is to create a poster that illustrates real-world applications of pneumatics. Use library or internet resources to gather at least 5-7 examples of real-world pneumatic devices. Print and include pictures of each of these devices on your poster and add to captions that explain how the device uses pneumatics.



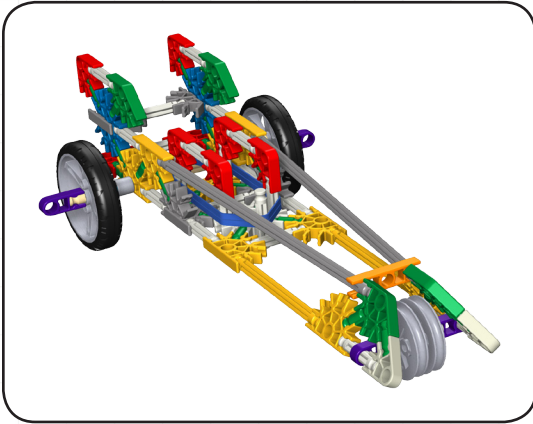
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LESSON #2: NEWTON'S DRAGSTER



x4

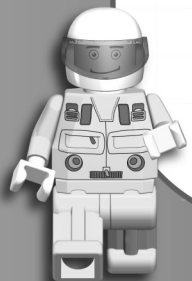
Model: K'NEX Rubber Band Powered Dragster



Main Concepts:

- **Science**
 - Newton's Second Law of Motion
- **Technology & Engineering**
 - Engineering Design Process
- **Mathematics**
 - Measurement, Data Collection, & Probability

Objectives:	Required Materials:	Optional Materials:
<p><i>Student will be able to:</i></p> <ul style="list-style-type: none"> • Demonstrate understanding that an object's acceleration is directly proportional to the force acting on it and inversely proportional to its mass. • Describe the difference between potential and kinetic energy. • Demonstrate understanding that mathematics is integral to Engineering Design and Scientific Inquiry • Identify the similarities and differences between Engineering Design and Scientific Inquiry. • Demonstrate the ability to list, describe, and apply the steps of the Engineering Design Process. 	<p><i>Teacher will need:</i></p> <ul style="list-style-type: none"> • K'NEX Rubber Band Powered Dragster model <p><i>Students will need:</i></p> <ul style="list-style-type: none"> • Parts and building instruction for the K'NEX Rubber Band Powered Dragster • Balance(s) • Stopwatches • Meter sticks or tapes • Mass Sets • Protective eyewear • Fresh, un-stretched rubber bands (# 32 size) • Copies of all Student Response Sheets and forms for inclusion in the students' Design Journals 	<ul style="list-style-type: none"> • Cardstock paper, foil or cardboard for modifications to the vehicle mass holder • Additional materials at the discretion of the teacher • Graph paper or computers with spreadsheet software • Calculators (Optional)



Process

Engagement

1. Review Newton's three Laws of Motion with the students using their textbooks or other available resources.
2. Introduce and demonstrate Newton's Second Law of Motion using the K'NEX Rubber Band Powered Dragster.

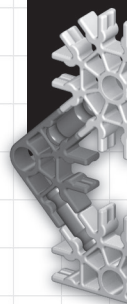
Exploration

1. Students will develop an understanding of Newton's Second Law of Motion through research and experiments using the K'NEX Rubber Band Powered Dragster model.
 - a. Students will complete the Understanding Newton's Second Law of Motion Student Response Sheet to demonstrate an understanding of the information and vocabulary presented in the Engagement section of this lesson and their own research.
 - b. Students will construct the K'NEX Rubber Band Powered Dragster using the building instructions provided. They will use the model to explore the impact of various design changes on the performance of their vehicle and report their findings on the Vehicle Performance Evaluation Student Response Sheet. This activity will require that each team be given fresh sets of previously un-stretched rubber bands for experimentation.
 - c. Have the students discuss their findings as a group prior to leading a class discussion of the findings. Encourage students to use the vocabulary they have learned during this lesson during the class discussion.

TEACHER'S NOTES:

- Students will be required to make specified alterations to their K'NEX Dragster as they complete the Vehicle Performance Evaluation Student Response Sheets (i.e., number of rubber bands and changes in mass). Some students may suggest other changes they feel will improve performance; however they should be instructed to only make those changes outlined on the Vehicle Performance Evaluations Student Response Sheet.
- Students should wear protective eyewear during this activity as rubber bands have potential for breakage.
- Over-winding of the rubber bands will lead to breakage and unsafe conditions. Instruct students of the hazards of over-winding the rubber bands.
- The optimum team size for this activity is 2 to 4 students.

2. Students will complete a Newton's Dragster Challenge Design Brief. Discuss the Design Brief and the criteria for the challenge with students.
 - a. Introduce the Student Response Sheet entitled Newton's Dragster Challenge Design Brief. Review the Design Brief in detail with the students.
 - b. Introduce the Design Process Guide to students. Explain that they will use the Design Process Guide to direct their activities while working on the Newton's Dragster Challenge.
 - c. Students will demonstrate their understanding of the Newton's Dragster Challenge by completing the first page of the Design Process Guide. Review each team's responses to ensure they clearly understand the challenge and the criteria before allowing the team to continue.
 - d. Have students complete a Daily Research and Design Log sheet





TEACHER'S NOTES:

- Students should be allowed to make changes to the mass holder on their models to ensure masses stay in place (i.e., line the holder with paper or foil). Students can also choose to use either one or two rubber bands for the challenge. If students find that the wheels on their K'NEX Dragster spin at the start line, encourage them to find ways to increase the traction of the tires. For example, students may stretch small rubber bands around the tread on the rear tires.
- Students can use either graph paper or a computerized spreadsheet program to create their data charts and graphs.



Explanation

Have students complete the appropriate Student Response Sheets, data charts, graphs, and the steps outlined on the Design Process Guide as an explanation of their findings.

Student Reflection

Students will self-evaluate their challenge solutions based on the criteria provided in the rubric for this activity. Additionally, students will complete a Teamwork and Self-Assessment Form to assess their individual and team's efforts on the challenge activities.

TEACHER'S NOTES:

- Provide the students with a copy of the Newton's Dragster Assessment Rubric so they can complete a self-evaluation of their work. The rubric score and your evaluation will make up a portion of the assessment data for this lesson.
- Provide students with a Teamwork and Self-Assessment Form and review the form with students before they fill them out.



Evaluation

You may use some or all of the following to evaluate student's performance:

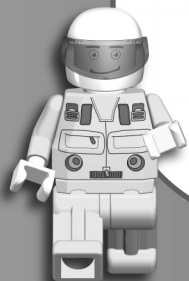
- Newton's Dragster Assessment Rubric
- Presentation of the Challenge Solution
- Daily Research and Design Logs
- Student Response Sheets
- Graphs, Charts, and Forms
- Design Journal

Extensions

1. Instruct students to research how Newton's Second Law of Motion applies to ejection seats, ejection seat simulators and other crash safety systems such as airbags.
2. Have students apply what they have learned to modify the K'NEX Rubber Band Powered Dragster to operate without a rubber band, to create a Gravity Racer, similar in nature to pine box derby racers. This will require that you create a ramp in the classroom.

Encourage students to design of their vehicles to achieve two or more of the following:

- The fastest time (speed) over a set distance.
- The longest distance traveled.
- The ability to stop at a set distance.



Understanding Newton's Second Law of Motion

Describe Newton's Second Law of Motion in your own words.

What is Newton's Second Law of Motion also known as?

Define the terms listed below. Be sure to write the definitions in your own words.

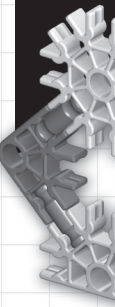
Acceleration -

Velocity -

Initial Velocity -

Force -

Newtons -



Conduct a simple experiment with your K'NEX Rubber Band Powered Dragster.

Step 1: Attach the rubber band to the rear axle of your racer and turn the axle two full rotations.

Step 2: Place your racer on the floor and measure the distance that the vehicle travels. Record the distance.

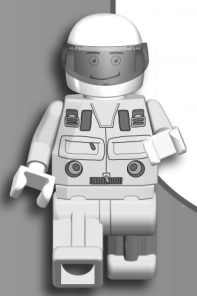
Step 3: Add a 100g mass to the mass holder on the vehicle, and repeat the previous two steps.

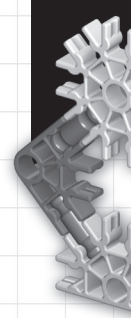
Step 4: Which vehicle traveled the greatest distance?

In the space provided below, describe how Newton's second law relates to the results you found.

Distance traveled with no added mass. _____ meters

Distance traveled with 100g of added mass. _____ meters





Vehicle Performance Evaluations

Directions:

Test your K'NEX Rubber Band Powered Dragster as you alter the independent variables (number of rubber bands, axle rotations, and mass) as directed. DO NOT wind your vehicle's rubber band in excess of the specified rotations as breakage and unsafe conditions can occur.

For each of the four activities below you will collect and record the following data in the charts provided:

- The mass of the vehicle.
- The distance the vehicle travels.
- The time it takes to travel that distance.

Once you have this information, calculate the velocity (final) and acceleration of the vehicle using the formulas below.

Velocity:	
Velocity _{Final} (m/sec) =	Distance (m)
	Time (sec)

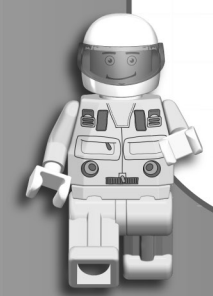
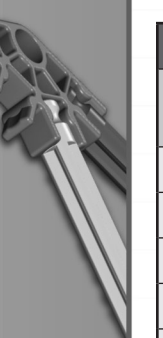
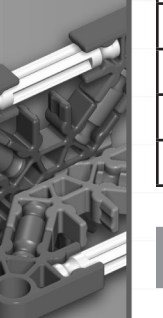
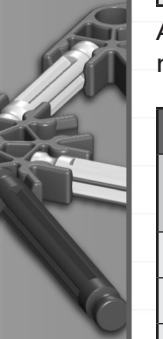
Acceleration:	
Acceleration (m/sec/sec) =	Velocity _{Final} (m/s) - Velocity _{Initial} (m/s)
	Time _{Final} (sec) - Time _{Initial} (sec)

Given that the car is not moving at the start line, the Initial Velocity and the Initial Time are both zero (0). By placing two zeros in the formula above for those values, the formula is simplified to:

Acceleration (m/sec/sec) =	Velocity _{Final} (m/s)
	Time _{Final} (sec)

Single Rubber Band & Axle Rotation Tests

- Use a fresh, un-stretched rubber band for these two activities.
- Find the mass of your dragster and enter the mass in the data table.
- Place a masking tape starting line on the floor. Wind the rubber band the specified number of rotations, and then place your dragster at the starting line.
- Let go and time the dragster and measure the distance it travels.
- Record your results in the data table.
- Compute the velocity and acceleration for each trial.



Vehicle Mass: _____ kg

# of Rotations	Distance (m)	Time _{Final} (Seconds)	Velocity _{Final} (m/sec)	Acceleration (m/sec/sec)
1				
2				
3				
4				
5				

Add a 100g mass to your K'NEX Dragster and repeat the previous activity. Remember to replace your rubber band. Record your results below.

Vehicle Mass: _____ kg

# of Rotations	Distance (m)	Time Final (Seconds)	Velocity Final (m/sec)	Acceleration (m/sec/sec)
1				
2				
3				
4				
5				

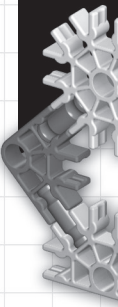
Did the vehicle perform differently with the added mass? Explain why.

Paired Rubber Bands & Axle Rotation Tests

- Remove the rubber band from your dragster and replace it with two fresh, un-stretched rubber bands,
- Follow the same directions as you did for the previous two activities.
- Record your data in the tables below.

Vehicle Mass: _____ kg

# of Rotations	Distance (m)	Time _{Final} (Seconds)	Velocity _{Final} (m/sec)	Acceleration (m/sec/sec)
1				
2				
3				
4				
5				



Add a 100g mass to your dragster and repeat the activity. Remember to replace your rubber bands.

Vehicle Mass: _____ kg				
# of Rotations	Distance (m)	Time Final (Seconds)	Velocity Final (m/sec)	Acceleration (m/sec/sec)
1				
2				
3				
4				
5				
Did the dragster perform differently with an additional rubber band? Explain why.				
Do you think the addition of a third rubber band would result in an increase or decrease in performance? Explain why.				

Calculating & Graphing Forces

Using the data collected during the activities and the formula below, calculate the force being exerted by the rear axle to power your dragster. Remember to convert your mass measurements to kilograms before completing your computations.

$$\text{Force (N)} = \text{Mass (kg)} \times \text{Acceleration (m/sec/sec)}$$

Single Rubber Band Force Results

- Calculate the forces for all ten of the trials that used a single rubber band in your Design Journal.
- Organize the data in a data table of your own design.
- Take a sheet of graph paper and place the number of rotations on the X-axis and the force in Newtons (N) on the Y-axis.
- Graph the points for the two sets of data on the same graph. (Use red data points for the empty dragster and blue for the trials with added mass.)
- Use a red line for the graph of the empty dragster data and a blue line for the graph of the data from the dragster with added mass.
- Draw a smooth curve through the points for each set of data using the proper color curve.
- Label and title the graph.

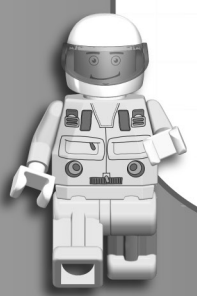
Compare the red and blue curves on the graph; describe how the force changed when the mass of the vehicle was increased.

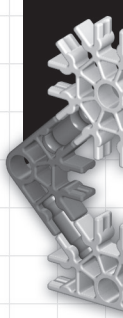
Double Rubber Band Force Results

- Follow the same directions as the single rubber band force results for this double rubber band activity. Use green points and lines for the empty dragster data and black points and lines for the dragster with added mass to make your graph.

Review the red, blue, green and black lines on your graphs. Explain any patterns, similarities and/or differences you observe based on your understanding of Newton's Second Law of Motion?

Can you predict your dragster's acceleration if you to increase or decrease the mass of your dragster by 50g? If so, explain how you would accomplish this. If not, why not?





Newton's Dragster Challenge

Design Brief

The Challenge

Your team has been hired as the pit crew for famous drag racer Ike Newton. He and his sponsors would like your team to fine-tune his dragster. The dragster must be fast on the track and have the ability to stop before it leaves the drag strip.

Your Task

- Your task is to refine Newton's dragster and its mass so that it will travel across 4 meters the fastest while still being able to stop before traveling another 3 meters and leaving the drag strip. (Simulate the end of the drag strip with a masking tape line.)

Rules & Constraints of the Challenge

- You may not change the frame of the dragster but you can change the wheels, add mass, and use either one or two rubber bands for power. You may only use materials provided by your teacher for this challenge.
- You may add a paper or foil liner to the mass holder to ensure your masses stay in the vehicle.
- Your team will compete against the other teams in the classroom and each team will be allowed two trials at race time.
- The car that is fastest to the finish line (4 meters) and able to stop before it leaves the drag strip (an additional 3 meters) will be declared the winner.

The Process

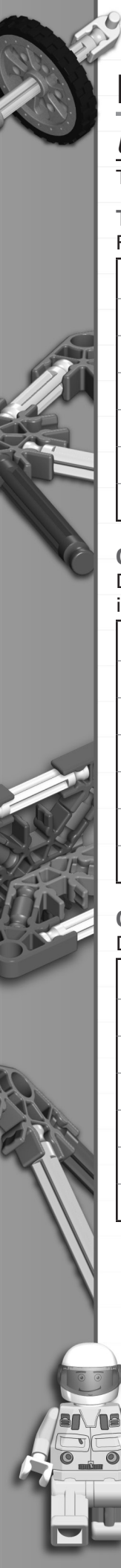
This activity will include the following phases:

- Phase 1 – Class Exploration
 - Understanding Newton's Second Law of Motion
 - Construction of the K'NEX Rubber Band Powered Dragster model
 - Vehicle Performance Evaluations Newton's Dragster Challenge Design Brief Introduction By Your Teacher

(Follow the steps on the Design Process Guide to direct your team through the remainder of the challenge.)

- Phase 2 – Independent Exploration
 - Understanding the Problem
 - Design Process Guide Student Response Sheet
 - Brainstorming & Ideation
- Phase 3 – Team Exploration
 - Explore Possibilities and Develop a Plan
 - Pro and Con Chart
 - Implement Your Plan
 - Testing and Refining the Plan
- Phase 4 – Classroom Competition
 - Taking the Challenge
- Phase 5 – Wrapping It Up
 - Reflection/Evaluation
 - Newton's Dragster Assessment Rubric
 - Teamwork and Self Assessment Student Response Sheet

Note: Complete a Daily Research and Design Log each day during this challenge.



Design Process Guide

Understanding the Problem

To demonstrate your understanding of the challenge, complete the following.

The Challenge:

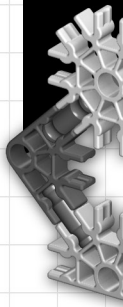
Restate the challenge, in your own words.

Criteria:

Describe what your vehicle must accomplish and any specific performance levels that it needs to meet, in your own words.

Constraints:

Describe the limitations you have been given for this challenge.



Brainstorming and Ideation

Brainstorm possible solutions to the challenge. List your individual ideas and show rough sketches in the box below and in more detail on your Daily Research and Design Log.

Ideas and Sketches

Develop an experiment that will allow you to test your solution. The experiment should enable your team to verify that any changes you have made to the dragster will allow it to travel four meters the fastest and stop before it leaves the drag strip

Exploring Possibilities and Developing a Plan

Fill out the Pro and Con Chart provided by your teacher. Describe each of the team members' ideas and list advantages and disadvantages of their devices or techniques and their experimental plans. This information should be used to develop your team's final plan.

Once evaluation of team members' ideas is complete, develop one final plan. This plan can be based on one team member's idea or a combination of elements from each of the ideas your team members offered. Put a detailed explanation of the final plan in your Design Journal along with detailed, labeled, scale drawings of the solution. Include the plan for your team's experiment and details of how your team will collect, organize and report experimental data.

Implement Your Plan

With your teacher's approval, put your team's plan into action.

Testing and Refining the Design

When the vehicle is ready, begin testing its performance and collecting data. Use masking tape to place a start line, a finish line and a line to represent the end of the drag strip on the floor.

As you experiment, continue to refine your model to improve it's performance.

Keep testing and experimenting as long as time allows. Record each of the refinements you make and the results of testing.



Taking the Challenge!

The time has come! You and your team will now complete a series of tests to see how well you did refining the operation of your vehicle. While some vehicles may outperform others, ultimately if you followed the design process you will all be winners!

The Fastest Dragster

Dragsters will be evaluated based on their times to the finish line. After all dragsters have been timed, scores will be assigned as follows: Each team may race their dragster twice and keep the results of their best race.

- **Top Dragster Class** – Fastest 1/3 of the K’NEX Dragsters
- **Super Stock Class** – Second fastest 1/3 of the K’NEX Dragsters
- **Stock Class** – Slowest 1/3 of the K’NEX Dragsters
- **Impounded** – Disqualified vehicles (Did not reach the finish line.)



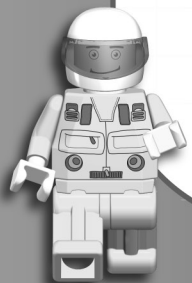
Safe Stops

Dragsters will be evaluated on their ability to stop before leaving the drag strip.

- **Stopped In Time**
- **Crashed** - Left the drag strip

The Winner

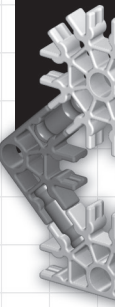
- **First Place** – Fastest dragster that stays on the drag strip.
- **Second Place** – Second fastest dragster that stays on the drag strip.
- **Third Place** – Third fastest dragster that stays on the drag strip.



Complete the Newton's Dragster Assessment Rubric to provide your teacher with your impression of how you did with this lesson.

Newton's Dragster		Assessment Rubric		
<i>Circle the scores that best represent your work.</i>	Excellent	Good	Acceptable	
Learning Journal & Worksheets	Student Response Sheets and Design Journals completed in their entirety with no spelling or grammar errors. All answers on student response sheets are accurate. 8	Student Response Sheets and Daily Journals completed in their entirety with a few (2-4) spelling and grammar errors. Most answers on student response sheets are accurate. 6	Student Response Sheets and Daily Journals completed in their entirety with many (5 or more) spelling or grammar errors. Fewer answers on student response sheets are accurate. 4	
Design & Construction	Your Dragster is very neatly constructed with crisp edges and meets the materials criteria listed in the design brief. 5	Your Dragster is neatly constructed and meets the materials criteria listed in the design brief. 4	Your Dragster is not neatly constructed, but does meet the materials criteria listed in the design brief. 3	
Teamwork/ Work Ethic	You worked well with your teammates and interacted well with others. You demonstrated excellent reliability and initiative when working on this challenge. 3	You worked well with your teammates and interacted well with others. You were reliable and demonstrated initiative when working on this challenge. 2	You usually worked well with your teammates and others. You were generally reliable and usually demonstrated initiative when working on this challenge. 1	
Vehicle Challenge Results	<i>Circle Results for each:</i>			
	Fastest	Top Dragster (3)	Super Stock (2)	Stock (1)
	Safe Stop	Stopped in time (3)	Crashed (1)	
	Winner	Fist Place (3)	Second Place (2)	Third Place (1)
Total Score	_____ /25			

Teacher Comments: _____

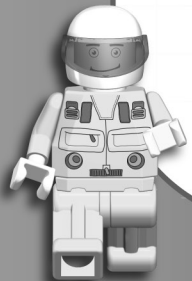


Reflection on the Activity

Now that the track is cleared and your vehicles have all been tested, complete a Teamwork and Self-Assessment Form. Use the form to reflect on your team and your contributions to your team's efforts.

Extension Activities

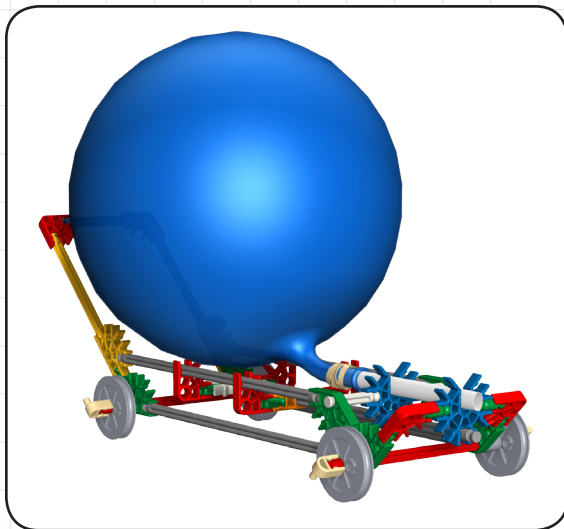
1. Using resources provided to you by your teacher, research how Newton's Second Law of Motion applies to ejection seats and ejection seat simulators such as those found at the NASTAR Center. You can also expand your research to include other crash safety systems such as airbags found in modern forms of transportation. Create a bi-fold brochure about crash safety systems, and how they use Newton's second law of motion to keep passengers and driver's safe. Be sure to include images of these systems in your brochure.
2. Apply what you have learned to modify your Newton's Dragster model to operate without a rubber band in a new race event called Newton's Gravity Racer Challenge. Your teacher will provide a ramp to test and race your vehicle on and assign you one or more performance challenges that this vehicle should be able to achieve. You should be sure to use your Design Journal to record the process used to modify your vehicle and achieve the performance goals.



LESSON #3: GOIN' FLAT OUT



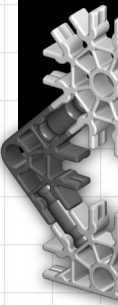
Model: K'NEX Balloon Racers



Main Concepts:

- **Science**
 - Newton's Third Law of Motion
- **Technology & Engineering**
 - Using the Engineering Design Process
- **Mathematics**
 - Measurement, Data Collection & Probability

Objectives:	Required Materials:	Optional Materials:
<p><i>Students will be able to:</i></p> <ul style="list-style-type: none"> • Demonstrate understanding that the motion of an object may be described by its speed, position, and the direction of its motion. • Demonstrate understanding that mathematics is integral to Engineering Design and Scientific Inquiry • Identify the similarities and differences between Engineering Design and Scientific Inquiry. • Demonstrate the ability to list, describe, and apply the steps of the Engineering Design Process. 	<p><i>Teacher will need:</i></p> <ul style="list-style-type: none"> • K'NEX Balloon Racer model <p><i>Students will need:</i></p> <ul style="list-style-type: none"> • Parts and building instructions for the K'NEX Balloon Racer • 9" Latex Balloons • Drinking straws of varying lengths and diameters • Tape (transparent recommended) • Rubber bands • Copies of all Student Response Sheets and forms for inclusion in students' Design Journals • Balance(s) • Stopwatches • Meter sticks or tapes 	<ul style="list-style-type: none"> • Assortment of balloons in various shapes and sizes • Variety of sizes of drinking straws. • Additional construction materials for extension activities (i.e. cardboard, balsa wood, tape, glue, etc.)





Process

Engagement

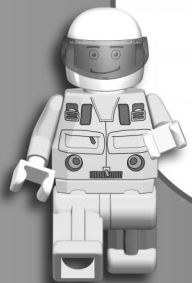
1. Review Newton's three laws of motion with the students using their textbooks or other available resources.
2. Introduce and demonstrate Newton's Third Law of Motion using the K'NEX Balloon Racer.

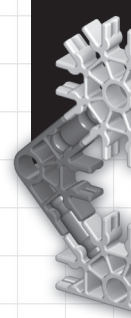
Exploration

1. Students will develop an understanding of Newton's Third Law of Motion through research and experiments using the K'NEX Balloon Racer model.
 - a. Have students complete the Understanding Newton's Third Law of Motion Student Response Sheet to demonstrate an understanding of the information and vocabulary presented in the Engagement section of this lesson and their own research. Provide each team with at least one balloon.
 - b. Have students construct the K'NEX Balloon Racer using the building instructions provided. Instruct the students to explore the operation of the model and to keep records of their observations in their Design Journals. Have students begin by using their model to demonstrate Newton's Third Law of Motion.
 - c. Instruct students to complete the series of experiments to explore the impact of various model changes on the performance of their vehicle.
 - Distribute the Vehicle Performance Evaluations Student Response Sheet and review the directions for the experiments they will complete.
 - Students will report their data and computed speeds in the tables provided. Provide a selection of different size balloons, different size straws, rubber bands, and tape for teams.
 - d. Have the students discuss their findings as a group prior to leading a class discussion of the findings, keeping in mind that not all teams tested the same variables. Encourage students to use the vocabulary they have learned during the class discussion.
2. Students will complete the Goin' Flat Out Challenge. Discuss the Design Brief and the criteria for the challenge with students.
 - a. Introduce the Student Response Sheet entitled Goin' Flat Out Challenge Design Brief to the students.
 - b. Introduce the Design Process Guide to the students. Explain that students will use the Design Process Guide to direct their activities while working on the Goin' Flat Out Challenge.
 - c. Students will demonstrate their understanding of the Goin' Flat Out Challenge by completing the first page of the Design Process Guide. Review each team's responses to ensure they understand the challenge and the criteria before allowing the team to continue.
 - d. Have students complete a Daily Research and Design Log sheet.

Explanation

1. Assign teams to design a presentation that will explain their challenge solution to the class.
The presentation should include:
 - An oral description.
 - Visual aids.
 - A demonstration of their model.



**TEACHER'S NOTES:****BALLOONS**

- Take this opportunity to review safety rules for the use of balloons and straws in the classroom.
- Balloons and straws for a team should be given to just one student.
- Once a student's lips have contacted a balloon or straw, NO OTHER STUDENT MAY TOUCH THAT BALLOON OR STRAW.
- If a balloon or straw falls on the floor or table top, it should be disposed of immediately.
- The students who use balloons and straws are responsible for their disposal based on the guidelines you provide.

STRAWS

- Students will need straws of different diameters, balloons of different sizes, rubber bands, and tape for this phase of the lesson. The tape and rubber bands are to be used to attach the balloons to the straws.
- Students will be required to make specified alterations to their K'NEX Balloon Racers as they complete the Vehicle Performance Evaluations - Student Response Sheets (i.e., diameter and/or number of straws, diameter and/or number of balloons, etc.). Some students may suggest other changes they feel will improve performance; however they should be instructed to only make those changes outlined on the Student Response Sheet. Students should be encouraged to make notes, comments, and observations about these experiments and their ideas for other vehicle alternatives in their Daily Research and Design Logs.
- Students should wear protective eyewear during this activity.
- The optimum team size for this activity is 2 to 4 students.
- Students may need multiple class periods to conduct the experiments to test the different design variables. If time is a factor, the teacher can assign each team to test one specific variable, and then all teams will demonstrate their results to the whole class.
- If additional class time is available, consider allowing students to experiment with some of their own ideas that they feel will improve the performance of the racers.

Student Reflection

Students will self-evaluate their challenge solutions based on the criteria provided in the rubric for this activity. Additionally, students will complete a Teamwork and Self-Assessment Form to assess their individual efforts and team's efforts on the challenge activities.

TEACHER'S NOTES:

- Give the Goin' Flat Out Assessment Rubric to students so they can complete a self-evaluation of their work. The rubric score and your evaluation will make up a portion of the assessment data for this lesson.
- Provide students with a Teamwork and Self-Assessment Form and review the form with students before they fill them out.



Evaluation

You may use some or all of the following to evaluate student's performance:

- Goin' Flat Out Assessment Rubric
- Presentation of the Challenge Solution
- Daily Research and Design Logs
- Student Response Sheets
- Data Tables, and Forms
- Design Journal

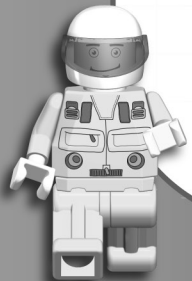
Extensions

1. Encourage students to research the history of rocketry and the basics of rocket science to prepare a presentation that includes:

- The historical impact of the invention of rockets.
- The basic science of rocket propulsion.
- Aerospace and military advances in rocketry.
- How rocket technology applies to other modern vehicles and devices.
- Important people in the development of rocketry.

Have students develop a brochure, time line, newspaper front page, or some other presentation piece to present their findings.

2. Challenge students to design their own balloon vehicle that will travel along a taut string stretched across a section of the classroom. Encourage students to conduct research online (key words: rocket balloon experiments and balloon powered cars). Students will keep complete records in their Design Journals and complete Daily Research and Design Logs during this extension activity. Students must demonstrate their final vehicle to the class.



Understanding Newton's Third Law of Motion

Describe Newton's Third Law of Motion in your own words.

What is Newton's Third Law of Motion also known as?

Define the terms listed below. Be sure to write the definitions in your own words.

Mass -

Velocity -

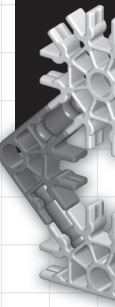
Force -

Momentum -

Gravity -

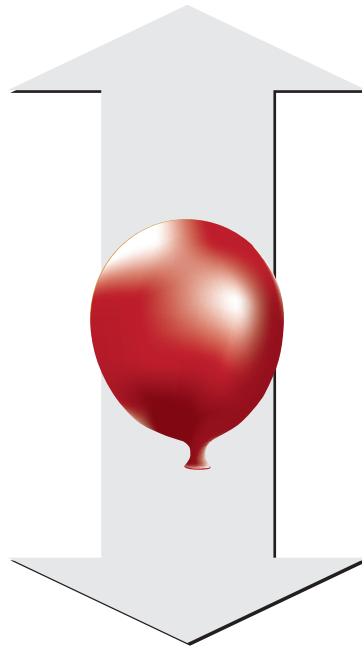
Motion -

Interaction -

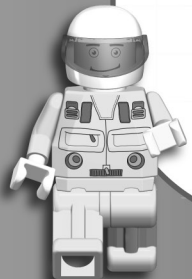
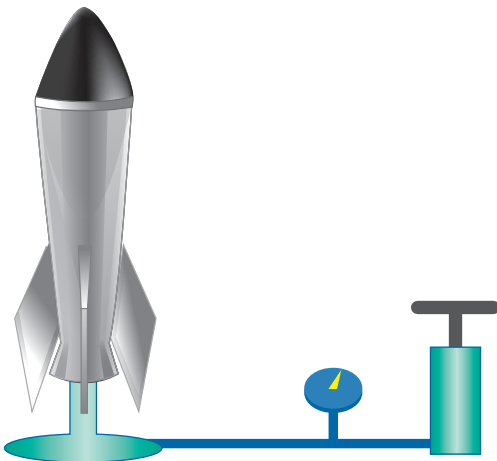


Conduct a simple experiment. Your teacher will give each team a balloon for experimentation. Complete the following:

- Step 1:** One of your team members should blow up the balloon, and be sure to hold the opening closed.
- Step 2:** Turn the balloon so that the opening is pointed towards the floor or table top.
- Step 3:** Release the balloon and observe what happens.
- Step 4:** Label arrows below based on what you observed by using the terms 'action' and 'reaction'.



Demonstrate what you have learned: draw and label action and reaction arrows on the images below.



Vehicle Performance Evaluation

Directions:

- Complete experiments to test 3 different variables designed to improve the performance of your K'NEX Balloon Racer. In the first two experiments you will select only one of the two variables to test. In the final experiment there is only one variable to test.
- Collect mass, distance, and time data for each experiment and compute the average speed of your vehicle using the formula below.

$$\text{Speed (m/sec)} = \text{Distance (m)} \div \text{Time (sec)}$$

Straw Diameter or Quantity

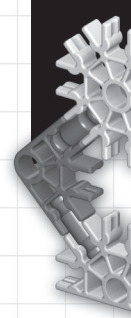
- Decide as a team if you will test the effect of straw diameter or straw quantity on the performance of your vehicle. Record your data below.
- Use masking tape to set up a starting line on the floor and collect the materials you will need to gather mass, distance, and time data. Begin your experimentation.

Trial	Variables	Mass grams (g)	Distance meters (m)	Time seconds (sec)	Calculated Speed (m/sec)
1	Size_____ or Quantity_____				
2	Size_____ or Quantity_____				
3	Size_____ or Quantity_____				
4	Size_____ or Quantity_____				

Which trial produced the greatest speed? _____

Why do you think this trial had the most impact on performance?

GOIN' FLAT OUT



Balloon Diameter or Quantity

- As a team decide if you will test the impact of the diameter of a single balloon or the number of balloons on vehicle performance.
- Follow the same experimental directions as you followed with the straws.

Trial	Variables	Mass grams (g)	Distance meters (m)	Time seconds (sec)	Calculated Speed (m/sec)
1	Size _____ or Quantity _____				
2	Size _____ or Quantity _____				
3	Size _____ or Quantity _____				
4	Size _____ or Quantity _____				

Which trial produced the greatest speed? _____

Why do you think this trial had the most impact on performance?

Wheel & Tire Combinations

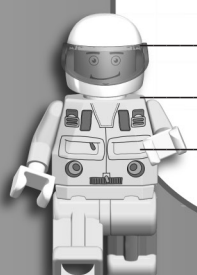
- Experiment to determine whether the vehicle performs better with or without tires. Use the results of your previous experiments determine the number and size of each you will use.
- Follow the experimental directions as you did with the straw: balloons.

Trial	Variables	Mass grams (g)	Distance meters (m)	Time seconds (sec)	Calculated Speed (m/sec)
1	Without Tires				
2	With Tires				

Which tire configuration produced the greatest speed? _____

Why do you think this configuration performed the best? _____

Review the results of your experiments. Do you see any relationship between the mass of the vehicle and its performance? If so, explain. How could you use this information to further improve your group's K'NEX Balloon Racer?



Goin' Flat Out Challenge

Design Brief

The Challenge

Your design team has been challenged to design and build a vehicle to beat the classroom land speed record! This vehicle should be based on the K'NEX Balloon Racer you have already constructed. The power source remains balloons for this challenge. Your racer will compete and be judged on three criteria. Ladies and Gentlemen, start your engines!

Your Task

- Plan, design, and refine your K'NEX Balloon Racer to be competitive in three categories: (1) speed, (2) acceleration, and (3) distance traveled.

Rules & Constraints of the Challenge

- Base your designs and decisions on the experiments you have completed.
- Plan and carry out additional experiments as you work to improve vehicle performance, Record all findings and observations on your Daily Research and Design Log.
- Use information and ideas from online resources to improve your racer. You can use any materials approved by your teacher in the redesign of your Balloon Racer.

The Process

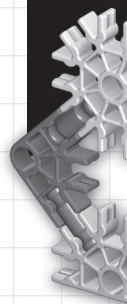
This activity will include the following phases:

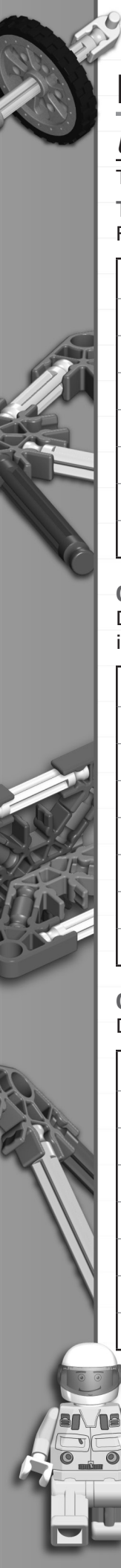
- Phase 1 – Class Exploration
 - Understanding Newton's Third Law of Motion
 - Construction of the K'NEX Balloon Racer Model.
 - Vehicle Performance Evaluation Design Challenge Introduction by Your Teacher

(Follow the steps on the Design Process Guide beginning on the next page to direct your team through the remainder of the challenge.)

- Phase 2 – Independent Exploration
 - Understanding the Problem
 - Design Process Guide Student Response Sheet
 - Brainstorming & Ideation
- Phase 3 – Team Exploration
 - Explore Possibilities and Develop a Plan
 - Pro and Con Chart
 - Implement Your Plan
 - Testing and Refining the Plan
- Phase 4 – Classroom Competition
 - Taking the Challenge
- Phase 5 – Wrapping It Up
 - Reflection/Evaluation
 - Goin' Flat Out Assessment Rubric
 - Teamwork & Self Assessment Form

Note: Complete a Daily Research and Design Log each day during this challenge.





Design Process Guide

Understanding the Problem

To demonstrate your understanding of the challenge, complete the following.

The Challenge:

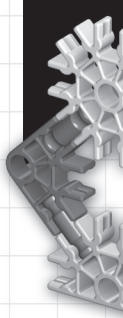
Restate the challenge, in your own words.

Criteria:

Describe what your vehicle must be able to do and any specific performance levels that it needs to meet, in your own words.

Constraints:

Describe the limitations you have been given for this challenge, in your own words.



Brainstorming and Ideation

Brainstorm possible solutions to the challenge. List your individual ideas and show rough sketches in the box below and in more detail on your Daily Research and Design Log. Be sure to list any K'NEX parts or other materials added to your K'NEX Balloon Racer.

Ideas and Sketches

Develop an experiment that will allow you to test your solution. The experiment should enable your team to verify that changes you have made to the K'NEX Balloon Racer will allow it to travel faster, with more acceleration, and/or further. Keep a record of your work in your Daily Research and Design Log.

Exploring Possibilities and Developing a Plan

Fill out the Pro and Con Chart provided by your teacher. Describe each of the team members' ideas and list advantages and disadvantages of their devices or techniques and their experimental plans. This information should be used to develop your team's final plan.

Once evaluation of team members' ideas is complete, develop one final plan. This plan can be based on one team member's idea or a combination of elements from each of the ideas your team members offered. Put a detailed explanation of the final plan in your Design Journal along with detailed, labeled, scale drawings of the solution. Include the plan for your team's experiment and details of how your team will collect, organize and report experimental data.

Implement Your Plan

With your teacher's approval, put your team's plan into action.

Testing and Refining the Design

When the vehicle is ready, begin testing its performance and collecting data. Use masking tape to place a start line on the floor.

As you experiment, continue to refine your racer to improve its performance.

Keep testing and experimenting as long as time allows. Record each of the refinements you make and the results of testing.



Taking the Challenge!

The time has come! You and your team will now complete a test to see how well you followed the design process. While some vehicles may outperform others, ultimately if you followed the design process you will all be winners!

Short Sprint

How fast your vehicle can travel over a short distance?

- Set a starting line with masking tape.
- Place a second masking tape line 2 meters from the start line.
- Time your vehicle from the starting line to the 2 meter line.
- Compute your racer's speed.

After all times are collected and speeds are calculated, racers will be ranked as follows:

- **Land Speed Record Holders** – Fastest 1/3 of racers
- **Racecar Drivers** - Middle 1/3 of racers
- **Highway Drivers** - Slowest 1/3 of racers
- **Impounded** – Disqualified drivers (racer failed to travel 2 meters)



Acceleration

Cars will be ranked based on their ability to accelerate off of the starting line.

- Use the existing starting line.
- Place a second masking tape line 1 meter from the start line.
- Time your vehicle from the starting line to the one meter line.
- Compute your racer's speed and use that speed to compute a value for acceleration.

After the acceleration values for the vehicles have been computed, racers will be ranked as follows:

- **Wheel Squealers** - Top 1/3 of acceleration values
- **Jack Rabbits** - Middle 1/3 of acceleration values
- **Responsible Drivers** - Lowest 1/3 of acceleration values
- **Impounded** – Disqualified drivers (racer failed to travel one meter)



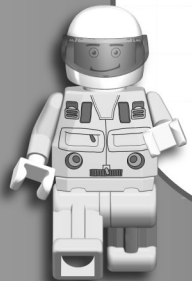
The Long Haul

How far will your car travel?

- Use the existing starting line.
- Measure the total distance traveled by the racer.

After the distances have been measured, racers will be ranked as follows:

- **International Shipping** - Top 1/3 of distances traveled
- **Cross Country Delivery** – Middle 1/3 of distances traveled.
- **Local Delivery** – Bottom 1/3 of distances traveled.
- **Return to Sender** – Disqualified drivers (racer failed to travel one meter)



Self Reflection/Evaluation

Complete the Descending to Mars Assessment Rubric to provide your impression of how you did with this lesson.

Goin' Flat Out		Assessment Rubric		
<i>Circle Responses for each:</i>	Excellent	Good	Acceptable	
Design Journal & Worksheets	Student Response Sheets and journals completed in their entirety with no spelling or grammar errors. All answers on student response sheets are accurate. 8	Student Response Sheets and journals completed in their entirety with a few (2-4) spelling and grammar errors. Most answers on student response sheets are accurate answers. 6	Student Response Sheets and journals completed in their entirety with many (5 or more) spelling or grammar errors. Some answers on student response sheets are accurate. 4	
Design & Construction	Your Balloon Racer is very neatly constructed and meets the materials criteria listed in the design brief. 5	Your Balloon Racer is neatly constructed and meets the materials criteria listed in the design brief. 4	Your Balloon Racer meets the materials criteria listed in the design brief. 3	
Teamwork/ Work Ethic	You worked well with your teammates and interacted well with others. You demonstrated excellent reliability and initiative when working on this challenge. 3	You worked well with your teammates and interacted well with others. You were reliable and demonstrated initiative when working on this challenge. 2	You usually worked well with your teammates and others. You were generally reliable and usually demonstrated initiative when working on this challenge. 1	
Vehicle Challenge Results	<i>Circle Results for each:</i>			
	Short Sprint	Land Speed (3)	Racecar (2)	Highway (1)
	Quick Start	Squealer (3)	Rabbit (2)	Responsible (1)
	Long Haul	International (3)	Cross-Country (2)	Local (1)
Total Score	_____ /25			

Teacher Comments: _____





Reflection on the Activity

1. Now that the last checkered flag has been waved and your racers have been tested, your teacher will provide you with a Teamwork and Self-Assessment Form. Use the form to reflect on your team and your contributions to your team's efforts.

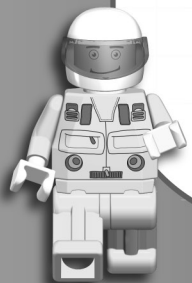
Extension Activities

1. Research the history of rocketry and the basics of rocket science and prepare a presentation that includes:

- Historical impact rockets and rocket science.
- Basic science of rocket propulsion.
- Aerospace and military advances in rocketry.
- How rocket technology applies to other modern vehicles and devices.
- Important people in the development of rocketry.

Develop a brochure, time line, newspaper front page, or some other presentation piece to present your findings.

2. Design a balloon powered vehicle that will travel along a taut string stretched across a section of the classroom. Conduct research online (use the key words: rocket balloon experiments and balloon powered cars). Keep complete records in your Design Journal and complete Daily Research and Design Logs. Prepare a presentation for the vehicle you design that will include a demonstration for your classmates.

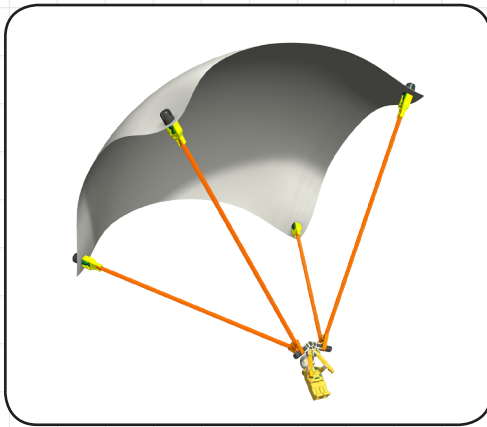


Lesson #4: Descending to Mars

x5



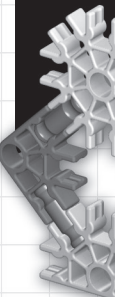
Model: K'NEX Parachutists



Main Concepts:

- **Science**
 - Gravity, Air Friction (Atmospheric Drag)
- **Technology & Engineering**
 - Engineering Design Process
- **Mathematics**
 - Geometry, Measurement

Objectives:	Required Materials:	Optional Materials:
<p><i>Students will be able to:</i></p> <ul style="list-style-type: none"> • Work effectively both independently and in collaborative teams. • Design and develop a parachute to be attached to the K'NEX parachutist to reduce rate and increase accuracy of descent. • Correctly identify a number of similarities and differences between Scientific Inquiry and Engineering Design. • Properly apply the steps of the Engineering Design Process as they relate to this activity. • Correctly describe Newton's Law of Universal Gravitation as well as Galileo's Law of Falling Bodies. • Understand that mathematics is an integral part of inquiry, experimentation, design, and development of human made items. 	<p><i>Teacher will need:</i></p> <ul style="list-style-type: none"> • Pre-built models of the Parachutists <p><i>Students will need:</i></p> <ul style="list-style-type: none"> • Parts and building instructions for the K'NEX Parachutes • Copies of all Student Response Sheets and forms for inclusion in students' Design Journals • Hole Punch (1/8 hole") • Compass • Protractor • Ruler • Scissors • Measuring Devices • Calculators • Stopwatches • Sheets of Paper: <ul style="list-style-type: none"> • Letter - 8.5" x 11" • Legal - 8.5" x 14" • Executive - 7.25" x 10.5" 	<ul style="list-style-type: none"> • Additional materials to construct parachutes: • Plastic Wrap, Wax Paper, Parchment Paper, Card Stock, Construction Paper, Transparency Film, Fabric, Etc.





Process

Engagement

1. Show students the video of parachutists in free fall and with parachutes deployed.
<http://videos.howstuffworks.com/howstuffworks/64-how-skydiving-works-video.htm>
2. Engage students in discussion concerning their prior knowledge and understanding of how parachutes work. Emphasize any important vocabulary terms that are introduced by students.
3. Introduce and explain the effects of gravity as they relate to Newton's Law of Universal Gravitation and Galileo's Law of Falling Bodies using information from students' textbooks or other resources. Demonstrate the effects of gravity on the K'NEX parachute figures by dropping them from various heights. Use and emphasize vocabulary that students must know and use during this lesson. Demonstrate the effects of air friction (atmospheric drag) by attaching parachutes made from sheets of paper to the figures and dropping them again from the same heights. Ask students to describe how circumstances changed with the addition of the parachute to the figures.

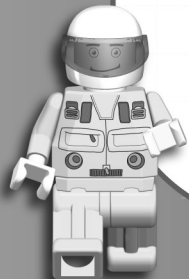
Exploration

1. Students will experiment with K'NEX Parachutist models to develop an understanding of how parachutes reduce the effects of gravity.
 - a. Students should complete the Parachutes and Falling Bodies Introduction Student Response Sheets to demonstrate an understanding of the information and vocabulary presented in the Engagement section of this lesson and their own research.
 - b. Have students construct the 3 K'NEX Parachutist models using the building instructions provided. Provide sheets of paper for students to use as they investigate and test their parachutes.
 - c. Students will complete a series of experiments to explore the effect of different parachute shapes and styles on parachute performance. Distribute the K'NEX Parachutist Performance Evaluations Student Response Sheet and review the directions for the experiments. Students will report data and calculations in the tables provided.
 - d. Have students complete a Daily Research and Design Log sheet
 - e. Have the students discuss their findings as a group prior to leading a class discussion of the findings. Encourage students to use the vocabulary they have learned during the class discussion.

TEACHER NOTES:

- Provide sheets of letter and legal size paper for the first two experiments and larger sheets for the final two experiments. Students will need scissors and tape or glue for the final two experiments.
- If you are able to locate a safe location at school where the students can drop their parachutes from higher heights, the results will be more dramatic.
- Provide students with a variety of material they can use for their parachutes. As real parachutes are generally made of fabric, include several types of fabric to the supplies students can draw from to build their parachutes.

2. Students will complete the Descending to Mars Challenge.
 - a. Introduce the Student Response Sheet entitled Descending to Mars Challenge Design Brief. Review the Design Brief in detail with the students.
 - b. Introduce the Design Process Guide to students. Explain that they will use the Design Process Guide to direct their activities while working on the Descending to Mars Challenge Design Brief.
 - c. Students will demonstrate their understanding of the Descending to Mars Challenge by completing the first page of the Design Process Guide. Review each team's responses to ensure they understand the challenge and the criteria before allowing the team to continue.
 - d. Have students complete a Daily Research and Design Log Sheet



Explanation

Assign teams to design a presentation that will explain their challenge solution to the class.

The presentation should include:

- An oral description.
- Visual aids.
- A demonstration of their model.

Student Reflection

Students will self-evaluate their challenge solutions based on the criteria provided in the rubric for this activity. Additionally, students will complete a Teamwork and Self-Assessment Form to assess their individual efforts and team's efforts on the challenge activities.

TEACHER NOTES:

- Give the Descending to Mars Assessment Rubric to students so they can complete a self-evaluation of their work.
- Collect the rubrics and review each. There is space below the rubric where you can write comments related to your evaluation of the students. The rubric score and your evaluation will make up a portion of the assessment data for this lesson.
- Provide students with a Teamwork and Self-Assessment Form and review the form with students before they fill them out.

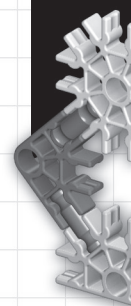
Evaluation

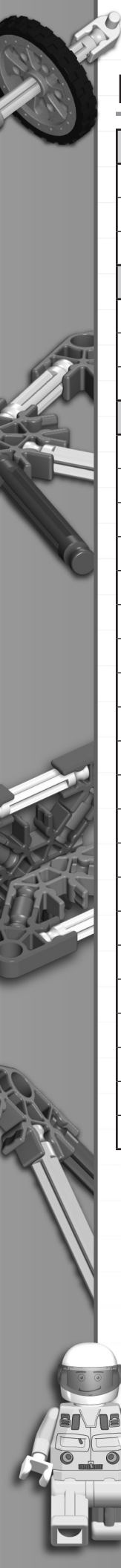
You may use some or all of the following to evaluate student's performance:

- Descending to Mars Assessment Rubric
- Presentation of the Challenge Solution
- Daily Research and Design Logs
- Student Response Sheets
- Data Tables, and Forms
- Design Journal

Extensions

1. Research Leonardo Da Vinci's parachute design and design experiments to investigate further. Students will prepare a written presentation of their research and findings in addition to their Design Journal entries for assessment.
2. Explore instances where NASA has used parachutes to bring spacecraft safely to the surface of Mars. This is an activity that will require library and online research. Students will be introduced to the fact that the force of gravity on Mars is much less than on earth and asks them whether or not that matters when designing a parachute to land a probe on the planet.





Parachutes & Falling Bodies Introduction

Describe Galileo's Law of Falling Bodies, in your own words.

Describe Newton's Law of Universal Gravitation, in your own words.

Define the terms listed below. Be sure to write the definitions in your own words.

Parachute -

Gravity -

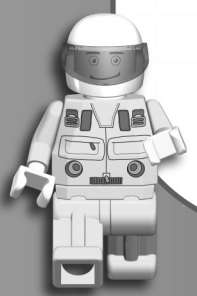
Rate of Descent -

Load -

Air Friction -

Atmospheric Drag -

Surface Area -



Use the formula $F_g = mg$ to determine the force of gravity that is attracting the bowling ball and the Apollo capsule to Earth.

- F_g = force due to gravity
- m = mass (kg)
- g = acceleration due to gravity (9.8 m/sec^2)
- The unit for force is N for Newton ($\text{kg} \cdot \text{m/sec}^2$)

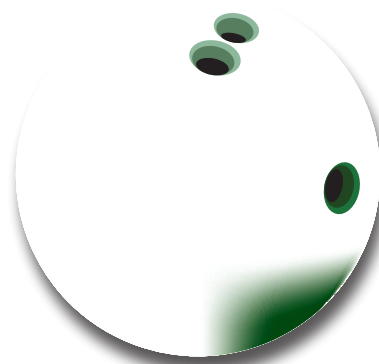
Problem 1: A Bowling Ball

Given:

Mass = 7 kilograms

Gravity = 9.8 m/s^2

$F_g = \underline{\quad} \times \underline{\quad} = \underline{\quad} \text{ N}$



Problem 2: Apollo Capsule

Given:

Mass = 4,400 kilograms

Gravity = 9.8 m/s^2

$F_g = \underline{\quad} \times \underline{\quad} = \underline{\quad} \text{ N}$



Label the parts of a simple parachute on the image below:

Draw lines from the part names below to their matching parts on the parachute.

Canopy

Lines

Risers

Harness



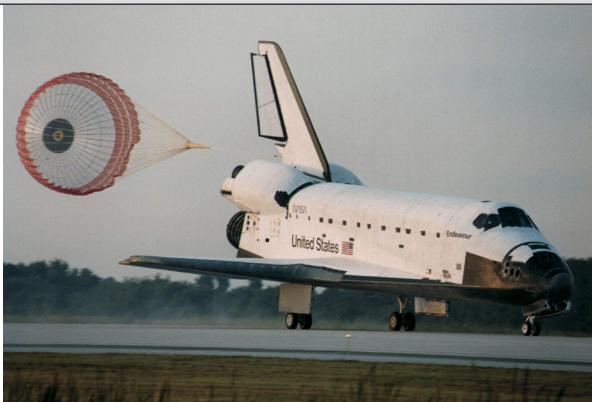
Below are images of 4 common types of parachutes. Please label each of the images with the proper parachute name from the following choices:

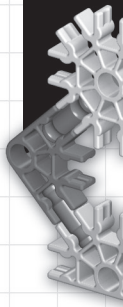
Ribbon & Ring

Ballute

Ram-air

Round





K'NEX Parachutist Performance Evaluation

Directions:

Test parachutes of different sizes and shapes to determine whether size or shape affect parachute performance.

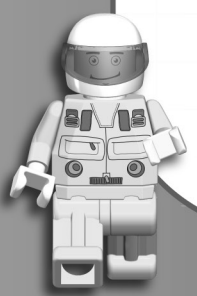
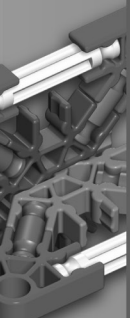
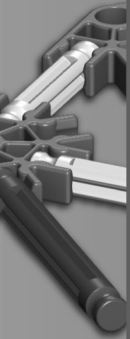
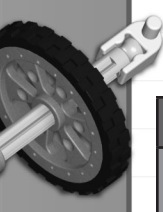
1. Drop each parachute design a total of 4 times from the same height.
 - Place a sheet of paper on the floor to act as your target
 - Measure the hang time and the distance each parachute lands from the target.
 - Calculate the rate of descent for the parachutes using the formula below.

$$\text{Rate of Descent} = \text{Drop Height (meters)} \div \text{Hang Time (seconds)}$$

- After all trials have been completed, find the average Hang Time, Distance from Target, and Rate of Descent.
- Repeat the test for each of the four parachutes and list your results below.
- Answer the questions that follow the data tables.

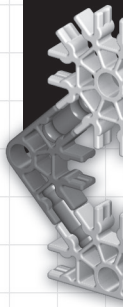
Paper Parachute #1 (8.5" x 11") Test Performance Results				
	Drop Height (m)	Hang Time (sec)	Distance from Target (m)	Calculated Rate of Descent (m/sec)
Drop 1				
Drop 2				
Drop 3				
Drop 4				
Average				

Paper Parachute #2 (8.5" x 14") Test Performance Results				
	Drop Height (m)	Hang Time (sec)	Distance from Target (m)	Calculated Rate of Descent (m/sec)
Drop 1				
Drop 2				
Drop 3				
Drop 4				
Average				



Paper Parachute #3 (8" Cone Shape) Test Performance Results				
	Drop Height (m)	Hang Time (sec)	Distance from Target (m)	Calculated Rate of Descent (m/sec)
Drop 1				
Drop 2				
Drop 3				
Drop 4				
Average				

Paper Parachute #4 (Pyramid) Test Performance Results				
	Drop Height (m)	Hang Time (sec)	Distance from Target (m)	Calculated Rate of Descent (m/sec)
Drop 1				
Drop 2				
Drop 3				
Drop 4				
Average				



Which of the parachutes best reduced the rate of descent on the K'NEX Parachutist?

Did the size of the parachute have any effect on the performance of the parachute? If so, what was the effect you observed?

Based on your data, do larger parachutes lower the rate of descent of the parachutist? Explain how your data supports your answer.

Based on your data, does the shape of a parachute affect its rate of descent? Explain how your data supports your answer.

Which of the four parachutes landed the parachutist closest to the target? What characteristic of that parachute do you think made that possible?

Descending to Mars Challenge

Design Brief

The Challenge

The International Space Agency (ISA) is preparing to send its next unmanned spacecraft to Mars. The ISA will send a new Robonaut (K'NEX figure) to explore the surface of the planet. The Robonaut will be controlled by computers on Earth. A few months ago, ISA successfully landed an operations base for the Robonaut on the surface of Mars. The base will be used to recharge and repair the Robonaut. Your team has been hired to develop a parachute to safely land the Robonaut on Mars near the base of operations.

Your Task

- To design, create, test, and refine a parachute that will slowly and safely bring the Robonaut to the surface of Mars near the operations base.

Rules & Constraints of the Challenge

- Base your designs on research and the experiments you have completed.
- Parachutes must be able to be attached to the current K'NEX Parachutist models without changing the models.
- Your design team can plan and carry out additional experiments as you work to improve parachute's performance, record all findings and observations on your Daily Research and Design Log.
- Only materials approved by your teacher may be used to construct your parachute.

The Process

This activity will include the following phases:

- Phase 1 – Class Exploration
 - Parachutes and Falling Bodies Student Response Sheets
 - Construction of K'NEX Parachutist Models
 - Parachutist Performance Evaluation Descending to Mars Challenge Design Brief Introduction by Your Teacher

(Follow the steps on the Design Process Guide beginning on the next page to direct your team through the remainder of the challenge.)

- Phase 2 – Independent Exploration
 - Understanding the Problem
 - Design Process Guide Student Response Sheet
 - Brainstorming & Ideation
- Phase 3 – Team Exploration
 - Explore Possibilities and Develop a Plan
 - Pro and Con Chart
 - Implement Your Plan
 - Testing and Refining the Plan
- Phase 4 – Classroom Competition
 - Taking the Challenge
- Phase 5 – Wrapping It Up
 - Reflection/Evaluation
 - Descending to Mars Assessment Rubric
 - Teamwork & Self Assessment Form – Provided by Your Teacher

Note: Complete a Daily Research and Design Log each day during this challenge.

Design Process Guide

Understanding the Problem

To demonstrate your understanding of the challenge, complete the following.

The Challenge:

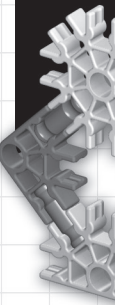
Restate the challenge, in your own words.

Criteria:

Describe what your solution needs to do and how well it needs to accomplish these tasks.

Constraints:

Describe the limitations you have been given for this challenge.





Brainstorming and Ideation

Brainstorm possible solutions to the challenge. List your individual ideas and rough sketches in the box below and in more detail on your Daily Research and Design Log. Include a list of all of the additional materials you will need to complete your parachute.

Ideas and Sketches

Develop an experiment that will allow you to test your solution. The experiment should enable your team to verify that the changes you have made to the parachute will allow it to descend more slowly and enable it to land nearer to the operations base. Keep a record of your work in your Daily Research and Design Log.

Exploring Possibilities and Developing a Plan

Fill out the Pro and Con Chart provided by your teacher. Describe each of the team members' ideas and list advantages and disadvantages of their devices or techniques and their experimental plans. This information should be used to develop your team's final plan.

Once evaluation of team members' ideas is complete, develop one final plan. This plan can be based on one team member's idea or a combination of elements from each of the ideas your team members offered. Put a detailed explanation of the final plan in your Design Journal along with detailed, labeled, scale drawings of the solution. Include the plan for your team's experiment and details of how your team will collect, organize and report experimental data.

Implement Your Plan

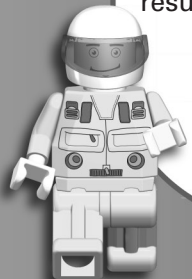
Put your team's plan into action. Once you have the approval of your teacher, begin work on modifications to your model.

Testing and Refining the Design

When the parachute is ready, begin testing its performance and collecting data. Place a sheet of paper on the floor to serve as your target.

As you experiment, refine your parachute to improve its performance.

Keep testing and experimenting as long as time allows. Record each of the refinements you make and the results of testing.



Taking the Challenge!

The time has come! You and your team will now drop your newly designed parachute 4 final times to determine its average rate of descent. Keep records of these four trials in your Design Journal. Use the rating systems below to evaluate your parachute in comparison to those designed by other teams. While some parachute designs may outperform others, ultimately if you followed the design process you will all be winners!

Rate of Descent

Testing will determine which team created the parachute with the slowest rate of descent:

- Time the descent of your parachute four times.
- Calculate the average rate of descent of your parachute.

After all times are collected and rates of descent are calculated, parachutes will be ranked as follows:

- **Soft Landing** – Slowest 1/3 of the average rates of descent.
- **Safe Landing** – Middle 1/3 of the average rates of descent.
- **Hard Landing** - Fastest 1/3 of the average rate of descent.
- **Lost in Space** – Unlaunched/undropped Robonauts.

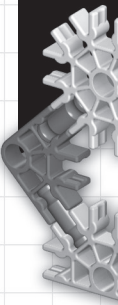
Landing Accuracy

Testing will determine which parachute landed closest to the operations base.

- Measure the distance from the operations base to the parachutist after each of four trials.
- Compute the average distance the parachutist landed from the operations base.

Parachutes will be ranked as follows:

- **Bull's Eye** - Closest 1/3 of parachutists to the operations base
- **Boundary Chaser** – Next closest 1/3 parachutists to the operations base
- **Where are We?**– Furthest 1/3 parachutists from the operations base
- **Lost in Space** – No distance traveled and/or disqualified parachutes

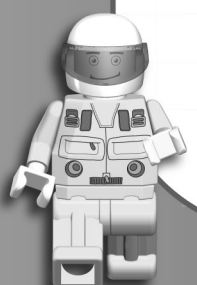


Self Reflection/Evaluation

Complete the Descending to Mars Assessment Rubric to provide your impression of how you did with this lesson.

Descending to Mars		Assessment Rubric			
Circle Responses for each:	Excellent	Good	Acceptable		
Learning Journal & Worksheets	Student Response Sheets and journals completed in their entirety with no spelling or grammar errors. All answers on Student Response Sheets are accurate. 9	Student Response Sheets and journals completed in their entirety with a few (2-4) spelling and grammar errors. Most answers on Student Response Sheets are accurate. 7	Student Response Sheets and journals completed in their entirety with many (5 or more) spelling or grammar errors. Fewer answers on Student Response Sheets are accurate. 5		
Design & Construction	Your Parachute is very neatly constructed and meets or exceeds expectations related to the criteria and constraints listed in the design brief. 6	Your Parachute is neatly constructed and meets expectations related to the criteria and constraints listed in the design brief. 5	Your Parachute has been constructed, and meets the materials criteria listed in the design brief. 4		
Teamwork/ Work Ethic	You worked well with your teammates and interacted well with others. You demonstrated excellent reliability and initiative when working on this challenge. 4	You worked well with your teammates and interacted well with others. You were reliable and demonstrated initiative when working on this challenge. 3	You usually worked well with your teammates and others. You were generally reliable and usually demonstrated initiative when working on this challenge. 2		
Challenge Tests	<i>Circle Results for each:</i>				
	Rate of Descent	Soft Landing (3)	Safe Landing (2)	Hard Landing (2)	
	Landing Accuracy	Bull's Eye (3)	Boundary Chaser (2)	Where are We? (2)	
Total Score	_____ /25				

Teacher Comments: _____



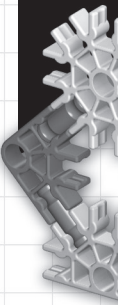
Now that the last parachute has landed and all of the Robonauts are safely in the operations base, complete the Teamwork and Self-Assessment Form. Use the form to reflect on your team and your contributions to your team's efforts.

Extension Activities

1. Research and explore the history of parachutes beginning with Leonardo Da Vinci's famous parachute design. The library and the internet will provide extensive material related to Da Vinci and his parachute. Construct a working model of his design to experiment with to see how it performs in comparison to some of the model parachutes you have worked with during this lesson. Prepare a report that highlights what you discovered during your research and the results of experiments you completed with the model you constructed.
2. NASA sent two rovers to Mars that landed in 2003 and 2004. These Rovers were named Spirit and Opportunity. They made their descent to the Martian surface with the use of specially designed and tested parachutes. Research these two famous Martian rovers with special emphasis on the systems, including parachutes, that brought them safely to the surface of Mars. As a part of your research, determine the relationship between the force of gravity on Mars and on the Earth. Prepare a multimedia presentation (i.e., PowerPoint) of your research.

Include the following:

- The role of the parachutes in slowing the descent of the rovers.
- The materials the parachutes and lines were made from.
- Other systems that assisted in slowing the descent of the rovers.
- Obstacles designers had to overcome as they designed the parachutes for the two rovers.

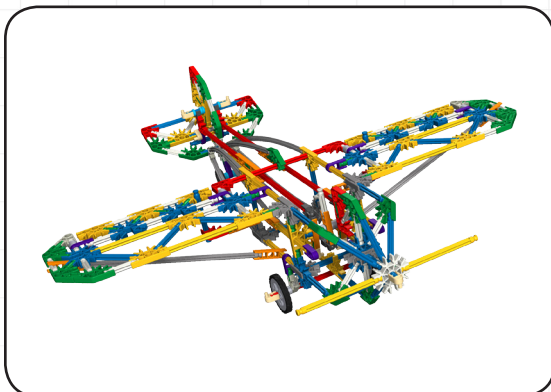


LESSON #5: MY FLYING MACHINE

x6



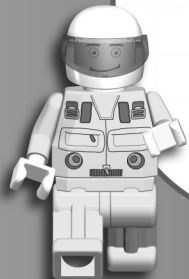
Model: K'NEX Airplane Model



Main Concepts:

- **Science**
 - Bernoulli's Principle, Forces of Flight, & Motion of an Aircraft
- **Technology & Engineering**
 - Transportation Systems
- **Mathematics**
 - Data Collection

Objectives:	Required Materials:	Optional Materials:
<p><i>Student will be able to:</i></p> <ul style="list-style-type: none"> • Work effectively both independently and in collaborative teams. • Research and create a paper airplane to meet a variety of challenges related to heavier than air flight. • Correctly identify control surfaces of an airplane as well as the movements associated with those surfaces. • Properly apply the steps of the Engineering Design Process as they relate to this activity. • Correctly describe Bernoulli's Principle. • Understand that mathematics is an integral part of inquiry, experimentation, design, and development of human made items. 	<p><i>Teacher will need:</i></p> <ul style="list-style-type: none"> • Pre-built models of the K'NEX Airplane <p><i>Students will need:</i></p> <ul style="list-style-type: none"> • Parts and building instructions for the K'NEX Parachutes • Copies of all Student Response Sheets and forms for inclusion in students' Design Journals • 8.5"x11" sheets of paper (Various weights of paper will provide more opportunities for students.) • Stopwatches • Meter sticks or tapes • Toy hoop 	<ul style="list-style-type: none"> • Copies of glider/airplane templates printed on cardstock • Glider kits pre-purchased from an outside vendor.



Process

Engagement

1. Give each of the students a sheet of paper. Have the students hold that paper up in front of them in the horizontal plane, parallel to the ground, and blow air out across the top of the paper. Ask them to describe what happened.
2. Have students explain why the paper responded like it did as the air stream passed over its surface. This is the opportunity to begin a discussion concerning lift and Bernoulli's Principle using information from textbooks or other resources.

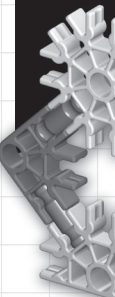
TEACHER'S NOTE:

- Instruct students to describe the activity, their observations, and notes about the discussion in their Design Journals.
- A second activity using a sheet of paper can be demonstrated for students. Make two piles of four or five books about 9 inches apart. Place a sheet of paper loosely across the opening between the piles and slip the ends of the sheet under the top two books. Maneuver the paper so it forms a small upward dome. Have students predict what they think is going to happen if someone blows a stream of air beneath the paper and between the books. The result should be that the paper is pulled downward and the dome in the page inverts. Experiment with stacks of books and paper before completing the activity with students.

3. Show students the complete K'NEX Airplane model and leave it in a prominent location as you list the four forces of flight (lift, weight, thrust and drag) on the whiteboard or chalkboard. Ask for volunteers to come to the front of the room one at a time to point out which direction they think one of these forces will act on the aircraft. Ask the rest of the class if they are in agreement. Discuss any differences in opinion.
4. Using the K'NEX Airplane model ask students to identify what part of the airplane or its surroundings produce each of the four forces. (i.e., wings produce lift; air produces drag, etc.)
5. Show students the various control surfaces on the airplane, name them, and demonstrate how each one is controlled. Lead a discussion that includes:
 - a. Vocabulary associated with flight and flight surfaces.
 - b. Each control surface as a system. (Elevators, Rudder, and Ailerons)
 - c. Linkages that connect the flight surfaces with the cockpit of the airplane.
 - d. Simple machines that are demonstrated by the various control surface linkages.

Exploration

1. Students will experiment with the three stages of the K'NEX Airplane model to develop an understanding of the principles of flight.
 - a. Have students construct the K'NEX airplane in three phases using the building instructions provided. Each phase of construction will include a new control surface system. Remind students to keep detailed notes related to flight control surfaces and the motions they produce in their Daily Research and Design Logs.
 - Phase 1: Students will build the first section of the K'NEX Airplane that will include the main fuselage of the aircraft and the elevators.
 - Have students hypothesize how the plane would respond as the elevators are moved up and down. Instruct students to put the elevators in the 'up' position. Ask how a moving plane would respond if the elevators were in this position during flight. Repeat the activity with the elevators in the 'down' position. Introduce the vocabulary term pitch to describe these motions of the plane. If necessary, demonstrate the elevator positions associated with a pitch upward and a pitch downward.

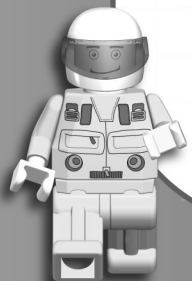


- Phase 2: Have students build the second section of the K'NEX Airplane model and add the remainder of the airplane's tail and rudder.
 - Lead a discussion similar to the one completed in Phase 1 to introduce and explore the rudder and their function.
- Phase 3: Students will build the third section of the K'NEX Airplane that will include the wings and ailerons.
 - Lead a discussion similar to the one completed in Phase 1 to introduce and explore the ailerons and their function.

- Students should complete the Principles of Flight Introduction Student Response Sheets to demonstrate an understanding of the information and vocabulary presented in the Engagement Section of this lesson, discussions during the three construction phases of the K'NEX Airplane model, and their own research.
 - Use the completed models for a variety of activities that will allow students to refine and clarify their understanding of flight control surfaces, their movements, and the movements of the plane they cause.
 - Describe the position of a control surface. Ask students to put the surface in that position on their plane and to demonstrate how the plane moves in response to that position of the control surface.
 - Repeat the above for other, single flight surfaces or combinations of two or more flight surfaces.
 - Instruct students to test their teammates using similar challenges.
 - Describe a motion of a plane and ask students to adjust the plane's control surfaces to complete such a motion. (i.e., pitch upwards, yaw right, etc.)
 - Ask students what other kinds of vehicles use control surfaces that are similar to the elevators, rudder and aileron. These vehicles can provide topics for additional student exploration.
- Have students complete the My Flying Machine Challenge Design Brief.
 - Introduce the Student Response Sheet entitled My Flying Machine Challenge Design Brief. Review the Design Brief in detail with the students.
 - Introduce the Design Process Guide to students. Explain that students will use the Design Process Guide to direct their activities while working on the My Flying Machine Challenge Design Brief.
 - Students will demonstrate their understanding of the My Flying Machine Challenge by completing the first page of the Design Process Guide. Review each team's responses to ensure they understand the challenge and the criteria before allowing the team to continue.
 - Have students complete a Daily Research and Design Log sheet
 - Have the students discuss their findings as a group prior to leading a class discussion of the findings. Encourage students use the vocabulary they have learned during the class discussion.

TEACHER'S NOTE:

- If paper airplanes will be constructed from sheets of paper, it would be advisable to have students work individually.
- If students use commercial gliders, they should work in pairs.



Explanation

1. Students should be encouraged to show their model or models to the class and share why they chose the design they used and how this choice succeeded in meeting the challenge or why they felt the design was unsuccessful. This could also be done in small groups with the instructor going from group to group to discuss what students learned through the course of this activity.
2. Assign teams to design a demonstration of their airplane and explain their challenge solution to the class. *The presentation should include:*
 - An oral portion with input from each team member.
 - A demonstration of the model.
 - A demonstration of how to make the paper airplane.

Student Reflection

Students will self-evaluate their challenge solutions based on the criteria provided in the rubric for this activity.

TEACHER'S NOTE:

- Give the My Flying Machine Assessment Rubric to students so they can complete a self-evaluation of their work. The rubric score and your evaluation will make up a portion of the assessment data for this lesson.
- Provide students with a Teamwork and Self-Assessment Form and review the form with students before they fill them out.

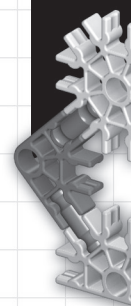
Evaluation

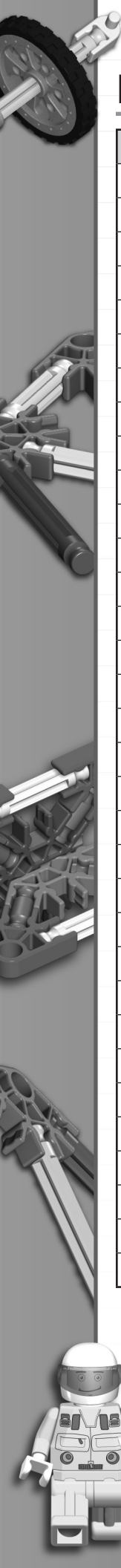
You may use some or all of the following to evaluate student's performance:

- My Flying Machine Assessment Rubric
- Presentation of the Challenge Solution
- Daily Research and Design Logs
- Student Response Sheets
- Forms
- Design Journal

Extensions

1. Research the history of flight and prepare a timeline that highlights at least 15 milestones in that history. If you have rolls of bulletin board paper they can use for their timelines the students should be able to produce some impressive results.
2. Research flight control systems and compare and contrast the various types. This activity will enable students to explore some of the most modern aircraft that are in use today. Students will be required to research at least these three flight control systems: mechanical, hydro-mechanical, and fly-by-wire.
3. Students can further their understanding of flight principles by researching kites and constructing and flying a kite.





Principles of Flight Introduction

Define the terms below. Be sure to write the definitions in your own words.

Lift -

Drag -

Weight -

Thrust -

Aileron -

Flap -

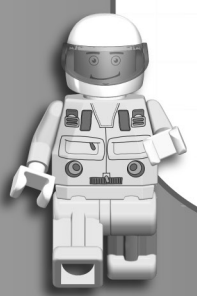
Fuselage -

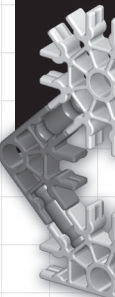
Rudder -

Wings -

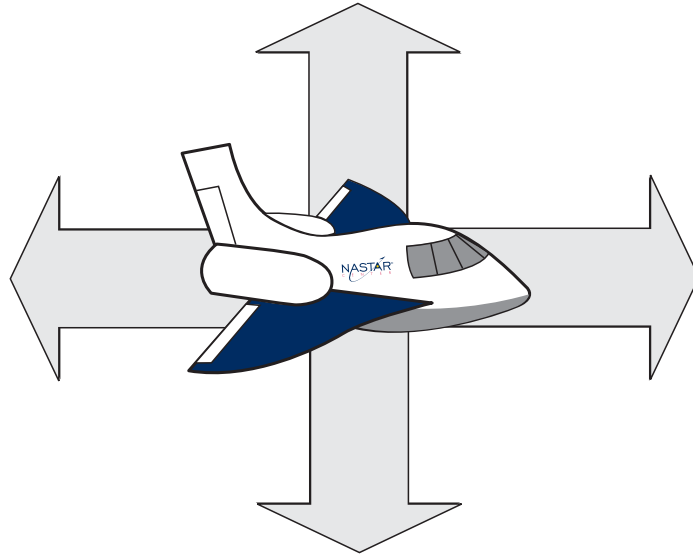
Elevons -

Angle of Attack -

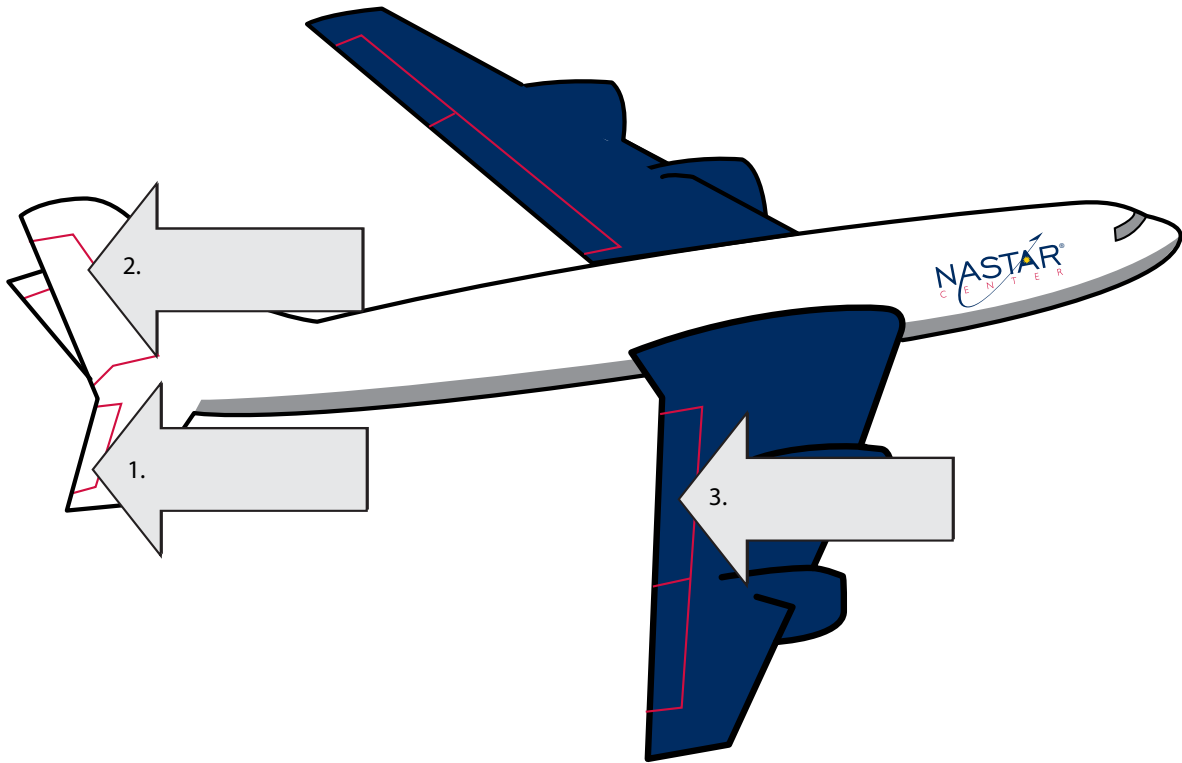




Label the four forces of flight that act on any aircraft:



Label the 3 control surfaces found on most airplanes and gliders:

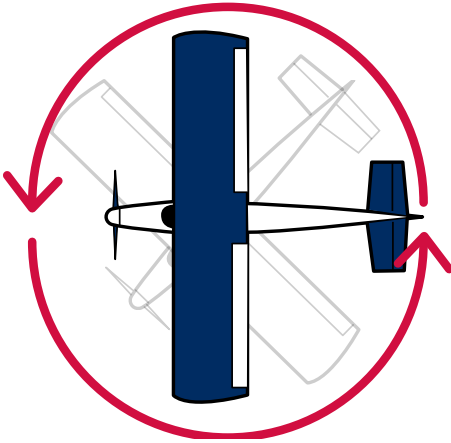


Use the following terms to describe the motion pictured in the diagrams on the right side of the page.

PITCH ROLL YAW

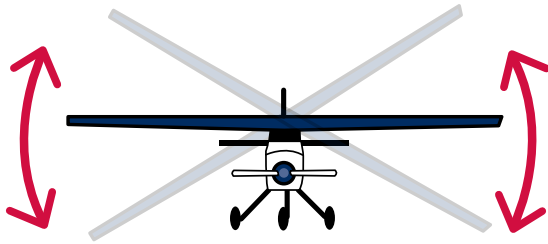
Use the following terms to describe the control surface that is responsible for the motion shown in the diagrams.

AILERONS ELEVATORS RUDDER



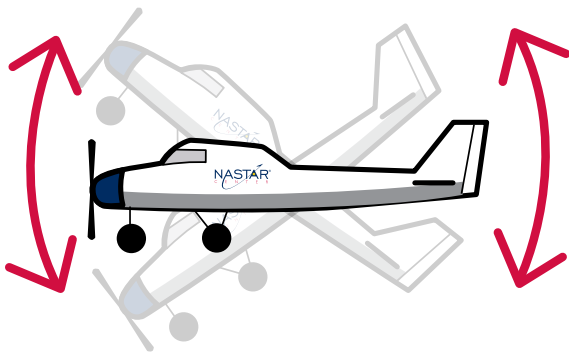
Motion illustrated:

Control surface responsible for this motion:



Motion illustrated:

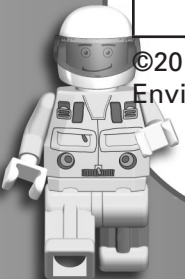
Control surface responsible for this motion:



Motion illustrated:

Control surface responsible for this motion:

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My Flying Machine Challenge

Design Brief

The Challenge

Construct your very own flying machine(s)! This flying machine(s) will not depend on a motor for propulsion, but rather use human power. You will be using paper to construct your airplanes. .

Your Task

- Build a paper airplane(s) that can compete in three competitions: fly through a large hoop, stay in the air the longest, and complete flight maneuvers.

Rules & Constraints of the Challenge

- The flying machine(s) must be constructed using a single sheet of 8 1/2" x 11" paper.
- You may use materials, such as paper clips, staples, tape, etc. approved by your teacher.
- You may not add any additional surface area to your airplane.
- You may produce three versions of your airplane for the final competitions. They can all be identical or they can be specifically designed for the three competitions. Bonus points will be awarded to students who can construct a single plane that successfully completes all challenges.
- Your flying machine(s) must have your name clearly written somewhere on the fuselage or wings.

The Process

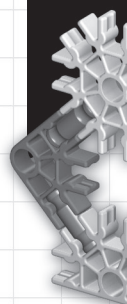
This activity will include the following phases:

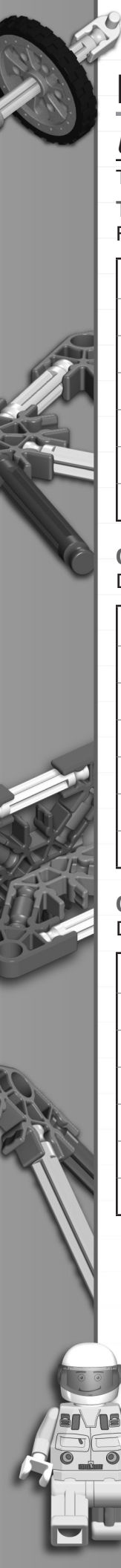
- Phase 1 – Class Exploration
 - Principles of Flight Introduction
 - Construction of K'NEX airplane in 3 phases
 - My Flying Machines Challenge Design Brief introduction by your teacher

(Follow the steps on the Design Process Guide beginning on the next page to direct your team through the remainder of the challenge.)

- Phase 2 – Independent Exploration
 - Understanding the Problem
 - Design Process Guide Student Response Sheet
 - Brainstorming & Ideation
- Phase 3 – Team Exploration
 - Explore Possibilities and Develop a Plan
 - Pro and Con Chart
 - Implement Your Plan
 - Testing and Refining the Plan
- Phase 4 – Classroom Competition
 - Taking the Challenge
- Phase 5 – Wrapping It Up
 - Reflection/Evaluation
 - Descending to Mars Assessment Rubric

Note: Complete a Daily Research and Design Log each day during this challenge.





Design Process Guide

Understanding the Problem

To demonstrate your understanding of the challenge, complete the following.

The Challenge:

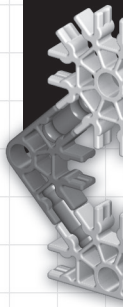
Restate the challenge, in your own words.

Criteria:

Describe what your airplane needs to do and how well it needs to accomplish these tasks.

Constraints:

Describe the limitations you have been given for this challenge.



Brainstorming and Ideation

Brainstorm possible solutions to the challenge. List your individual ideas and rough sketches in the box below and in more detail on your Daily Research and Design Log. Include a list of all of the additional materials that you will need to construct your paper airplane(s).

Ideas and Sketches

Develop a series of experiments that will allow you to test your airplane's abilities in each of the competition areas. The experiments should enable you to verify that your airplane will be competitive. Keep a record of your work in your Daily Research and Design Log.

Exploring Possibilities

Review your research to verify that you have made the right choice and finalize the plan(s) for your airplane(s). Place a detailed explanation of the final plan in your Daily Research and Design Log along with detailed, labeled, scale drawings of the solution. Include the plan for your experiments and details of how you will collect, organize and report experimental data.

Implement Your Plan

Put your plan into action. Once you have the approval of your teacher, begin building your airplane(s).

Testing and Refining the Design

When your plane(s) is ready, begin testing its performance and collecting data. Work with a classmate who will hold the large hoop at different distances for your experiments.

As you experiment, refine your airplane(s) to improve its performance.

Test and experiment as long as time allows. Record each of the refinements you make to your airplane(s) and the results of testing.



Taking the Challenge!

The time has come! You and your team will now complete a series of tests to see how well your airplane(s) is able to compete. While some airplanes may outperform others, ultimately if you followed the design process you will all be winners!

Ring Challenge

Planes must successfully be thrown through a plastic toy hoop held at the distances listed below. Use masking tape to place a pilot launch line on the floor. You will get two attempts at the eight and twelve foot distances.

- **Four Feet**
- **Eight Feet**
- **Twelve Feet**

For 3 Bonus Points, fly your plane through a hoop set at a distance of 16 feet!



Air Time

Planes will be ranked based on the length of time that they can stay in the air. At the completion of the test, students will be placed into one of four categories. Use a stopwatch to time your airplanes. You may make two attempts in this competition.

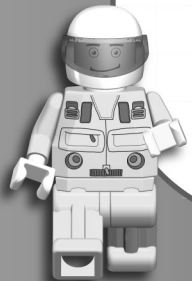
- **Air Hog** – Top 1/3 of times
- **Cruiser** – Middle 1/3 of times
- **Puddle Jumper** – Shortest 1/3 of times
- **Grounded Pilots** – Disqualified Pilots



The Hot Shot Challenge

Use the flaps on your plane(s) to accomplish up to two of the following stunts:

- **Loop Up** – Plane goes forward and does a loop up into the air.
- **Loop Down** – Plane goes forward and pitches down into a nose dive.
- **Corkscrew** – Plane does a spiral as it flies forward.
- **Hot Doggin!** – Come up with your own stunt, describe the stunt to your teacher and see what you can do.

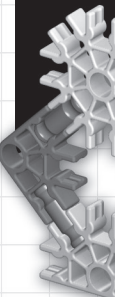


Self Reflection/Evaluation

Complete the My Flying Machine Assessment Rubric to provide your impression of how you did with this lesson.

My Flying Machine		Assessment Rubric		
<i>Circle Responses for each:</i>	Excellent	Good	Acceptable	
Design Journal & Worksheets	Your Student Response Sheets and Design Journal are complete with no spelling or grammar errors. Student Response Sheet answers are accurate. 8	Your Student Response Sheets and Design Journal are complete with few spelling or grammar errors. Most Student Response Sheet answers are accurate. 6	Your Student Response Sheets and Design Journal are complete with several spelling or grammar errors. Fewer Student Response Sheet answers are accurate. 4	
Design & Construction	Your Flying Machine is very neatly constructed with crisp edges and meets the materials criteria listed in the design brief. 5	Your Flying Machine is neatly constructed and meets the materials criteria listed in the design brief. 4	Your Flying Machine is not neatly constructed, but does meet the materials criteria listed in the design brief. 3	
Teamwork/ Work Ethic	You cooperated in group activities and interacted well with others. I have an excellent work ethic in class. 3	You cooperate in group activities and interact well with others. I have a good work ethic. 2	You usually cooperate in group activities and interact with others. I usually maintain a good work ethic. 1	
Vehicle Challenge Results	<i>Circle Results for each:</i>			
	Ring Challenge	4', 8', & 12' (3)	4' & 8' (2)	4' Only (1)
	Air Time	Air Hog (3)	Cruiser (2)	Puddle Jumper (1)
	Hot Dog	2 Successful Maneuvers (3)	1 Successful Maneuver (2)	
Score	_____/25	BONUS POINTS _____	Final Total _____	

Teacher Comments: _____





Extensions

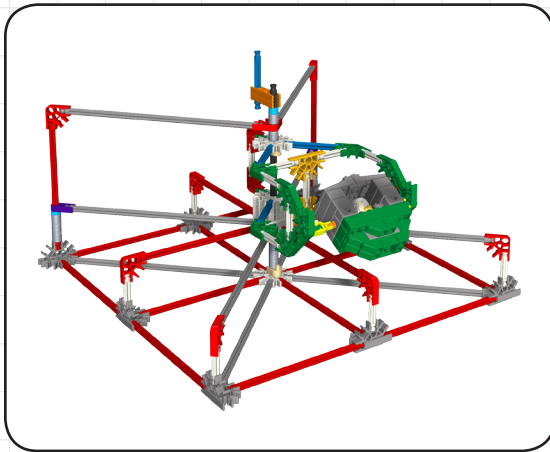
1. Use available resources to gather information concerning the history of human flight. Develop a time line that highlights important events that have led to the development of aviation as we know it today. Identify and include at least 15 important events and related images on a timeline of your own design that highlights the history of flight.
2. Airplane control systems have been improved and refined over time. Use available resources to compare and contrast basic flight control systems like those on the K'NEX Airplane model with more modern, advanced systems. Your research should include the following types of aircraft control systems: mechanical, hydro-mechanical, and fly-by-wire. Write 3-4 paragraphs to compare and contrast the various types of control systems, and make sure to point out which of these systems your K'NEX Airplane model represents.
3. Use available resources to find images of kites of all types. Identify ones that can be built using materials available at home or at school. Research how kites fly and compare their flight to the flight of paper airplanes. Select a kite that you or your team can build, share your ideas with your teacher, and gather the supplies you will need for the project. Demonstrate your kite for the class and explain how kites fly.

Lesson #6: Going for a Spin

x5



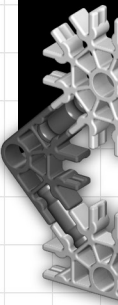
Model: Centrifuge Model



Main Concepts:

- **Science**
 - Centripetal Forces
- **Technology & Engineering**
 - Systems, Engineering Design Process
- **Mathematics**
 - Data Analysis and Probability. Measurement

Objectives:	Required Materials:	Optional Materials:
<p><i>Student will be able to:</i></p> <ul style="list-style-type: none"> • Work effectively both independently and in collaborative teams. • Design and develop a device to make accurate angle measurements. • Demonstrate an understanding of the similarities and differences between Scientific Inquiry and Engineering Design. • Properly apply the steps of the Engineering Design Process as they relate to this activity. • Correctly describe Newton's Second Law of Motion. • Understand that mathematics is an integral part of inquiry, experimentation, design, and development of human made items. 	<p><i>Teacher will need:</i></p> <ul style="list-style-type: none"> • K'NEX Centrifuge model • Nylon string • 16 oz. water or soda bottle • Food coloring <p><i>Students will need:</i></p> <ul style="list-style-type: none"> • Parts and building instructions for the K'NEX Centrifuge Model • Copies of all Student Response Sheets and forms for inclusion in student Design Journals • Sheets of 8.5"x11" printer paper • Stopwatches • Digital or analog balances • Protractors 	<p>Additional materials for construction of the challenge device at the discretion and approval of the teacher</p> <ul style="list-style-type: none"> • transparency sheets • markers • cardstock • string • small metal washers or metal nuts for weights, etc.



Process

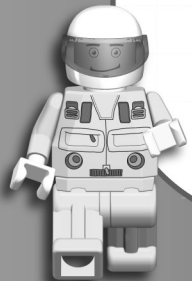
Engagement

1. Show the video from the NASTAR website that highlights their Centrifuge trainer. The video can be found at <http://www.nastarcenter.com/space/ultimate>
2. Explain how circular motion can simulate increased g-forces based on the concept of centripetal force. Refer to students' textbooks or other available resources to supplement the explanation and provide examples.
3. Demonstrate centripetal force:
 - a. Fill a soda or water bottle about one-fourth full with water and add a few drops of food coloring.
 - b. Be sure to tighten the cap.
 - c. Tie a nylon string tightly around the neck of the bottle, beneath the cap so that the string will not slip off.
 - d. Hold the bottle upside down in front of you just above your head. Ask students to record what happened to the water when you lifted and turned the bottle.

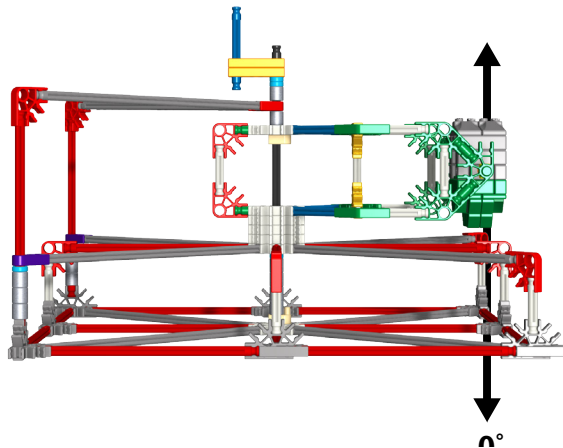
TEACHER'S NOTE:

- There will be a lot of questions the students must answer during this demonstration. The idea is to focus their attention on the water and the changes in its movements. With the answers in place, they will be better able to find an answer to why the water stays in the bottom of the bottle while the bottle is spinning on the end of a string.

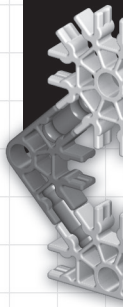
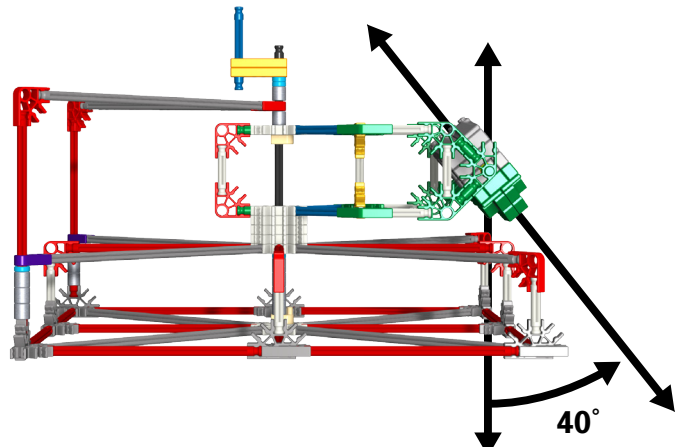
- e. Hold the bottle on its side to your right with the cap pointing toward your chest. Ask students to record what happened to the water when the bottle is held on its side. Repeat this holding the bottle to your left with the cap pointing toward your chest.
 - f. Hold the bottle straight up in front of your abdomen. Ask students to record what happened to the water when you turned the bottle upright.
 - g. Ask students to predict what will happen to the water if you swing the bottle in a circle. Remind students that the bottle will be in some of the same positions it was for your earlier demonstrations. Make a list of the students' ideas on the board.
 - h. Swing the bottle in a circle in front of you. Ask students to observe the water in the bottle and to describe what happened to the water when it was in the four positions they observed earlier. (Caution: ensure that there are no obstacles, including classroom light fixtures in the path of the bottle. Make sure there are no students to your left or right. You may wish to complete the experiment outdoors.)
 - i. Compare observations to the list of predictions.
 - j. Ask students why the water does not fall toward the cap when the bottle is upside down. Why doesn't it fall to the side of the bottle when the bottle is to the right or left of you when it is spinning. Ask them also if there is any time when the water is in the bottle just as it was in your earlier demonstrations. They should report that the water stayed in the bottom of the bottle as the bottle spun. If they are unable to explain why the water stayed in the bottom of the bottle, instruct them to find an answer on the Internet. The key word for this search is 'centripetal force experiments.'
4. Use the K'NEX Centrifuge model to demonstrate the reaction of the gondola to different spinning speeds.
 - Show students the position of the gondola when the centrifuge is stopped, when it is spun slowly and when it is spun quickly.
 - If students do not mention the fact that the angle of the gondola changes as you spin faster.
 - Point out the angle of the gondola when the centrifuge is stopped.
 - Show how the angle changes as the centrifuge is spun faster and faster.



Stationary Centrifuge



Spinning Centrifuge



- Remind students that objects spinning in a circle are constantly accelerating because they are constantly changing direction. The magnitude of the acceleration is dependent on the angular velocity of the gondola in revolutions per minute (rpm) or linear velocity in meters per second (m/s).
- Lead a discussion with students that focuses on the forces that are being exerted on the K'NEX test pilot in the gondola. As the discussion comes to a close, inform students that the walls of the gondola are exerting a force on the rider that keeps them moving in a circle. Without the walls of the gondola, the rider would fly out of the car and continue in a straight line. The force is centripetal force.

TEACHER'S NOTES:

- If vectors are a part of your science instruction, this is an excellent opportunity to discuss the direction vectors that apply to the centrifuge.
- The Centrifuge used at the NASTAR Center shown in the video includes the ability to exert 3 different force vectors on the passenger riding in the gondola.

Exploration

1. Students will develop an understanding of centripetal forces and the centrifuge through research and experiments using the K'NEX Centrifuge model.
 - Students will complete the Understanding Centripetal Force Introduction Student Response Sheet to demonstrate an understanding of the information and vocabulary presented in the Engagement section of this lesson and their own research.
2. Have students construct the K'NEX Centrifuge model following the building instructions provided. Instruct the students to explore the operation of the model and to keep records of their observations in their Design Journals.
3. Provide students with copies of the K'NEX Centrifuge Performance Tests Student Response Sheets. After the students have had a chance to read and discuss them in their small groups, answer any questions they may have regarding the experiments they will be conducting.

- Students will be computing the centripetal forces that act on the K'NEX test pilot when the centrifuge moves in a circle at different speeds. Students will use a formula derived from Newton's formula for force, $F=ma$. You may wish to visit http://www.engineeringtoolbox.com/centripetal-acceleration-d_1285.html to familiarize yourself with the formula and how it was simplified to:

$$F = 0.01097 m r n^2$$

m = mass of the K'NEX test pilot

r = radius of the centrifuge arm

n = revolutions per minute (rpm)

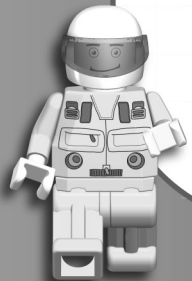
F = force which will be in Newtons

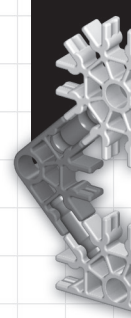
- The website has a feature that will calculate the centripetal force for the students. You may wish to allow the students to use the online calculator when they have shown their ability to complete a few of the calculations on their own.
- Provide students with balances to find the mass of the K'NEX test pilot. This value will be the same for all teams so you may choose to have one group find the value and post it on the board.
- The K'NEX Centrifuge model will produce centripetal forces that are generally less than one (1) Newton. As a result, students have been instructed to multiply the mass of the K'NEX test pilot and the radius of the centrifuge arm by 10 for each of the three experiments they will complete. This change will provide larger numbers for students to work with.
- Remind students the mass must be in kilograms and the radius must be in meters for the formula.
- Have students practice spinning the K'NEX Centrifuge at constant speeds (rpm).

TEACHER'S NOTE:

- It will take some time for students to control the rate they spin the centrifuge. With the help of a stopwatch and some practice, they will develop a strategy that works for them.
- The students will use a protractor to find the angle of the gondola at each of the four speeds. This data will be used for the challenge activity that concludes this lesson.

- When students appear to be able to control the rate at which they spin the centrifuge, instruct them to begin with a spin rate of 10 rpm and collect data. Remind students to measure the angle of the gondola at each test speed.
 - Instruct students to place their data in the tables provided on the Student Response Sheets.
 - Students should then proceed to increase the speed of the centrifuge and collect additional data.
 - Provide time for students to compute the centripetal forces that are acting on the test pilot.
 - Students will make changes to the centrifuge model to extend and shorten the length of the arm and repeat the experiments with a centrifuge that has a different radius. Students will then have three sets of data and calculations to compare and contrast. Questions are provided for students to complete as they analyze their data.
4. Students will complete the Going for a Spin Design Brief. Discuss the Design Brief and the criteria for the challenge with students.
- a. Introduce the Student Response Sheet entitled Going for a Spin Design Brief. Review the Design Brief in detail with the students.
 - b. Introduce the Design Process Guide to students. Explain that students will use the Design Process Guide to direct their activities while working on the Going for a Spin Design Brief.





- c. Students will demonstrate their understanding of the Going for a Spin Design Brief by completing the first page of the Design Process Guide. Review each team's responses to insure they understand the challenge and the criteria before continuing,
- d. Have students complete a Daily Research and Design Log sheet.
- e. The challenge activity will result in a device that will allow students to easily measure the angle of the gondola on the centrifuge as it spins. Expect that student devices will consist of cardboard or cardstock with a scale like a protractor and a weight on a string that will establish a vertical line to measure from.

Explanation

Assign teams to design a presentation that will explain their challenge solution to the class.

The presentation should include:

- An oral description.
- Visual aids.
- A demonstration of the device they designed.

Student Reflection

Students will self-evaluate their challenge solutions based on the criteria provided in the rubric for this activity. Additionally, students will complete a Teamwork and Self-Assessment Form to assess their individual efforts and team's efforts on the challenge activities.

TEACHER'S NOTE:

- Give students the Going for a Spin Assessment Rubric so they can complete a self-evaluation of their work. The rubric score and your evaluation will make up a portion of the assessment data for this lesson.
- Provide students with a Teamwork and Self-Assessment Form and review the form with students before they fill them out. Consider allowing students to complete their self-assessment as a homework assignment.

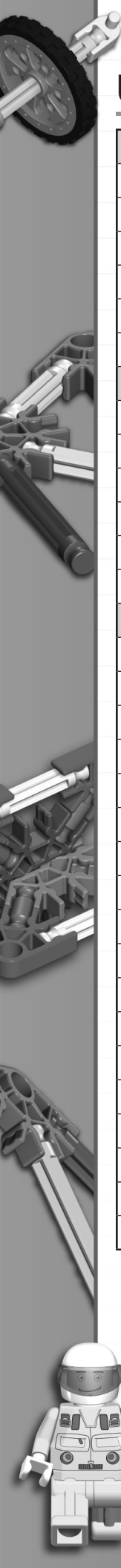
Evaluation

You may use some or all of the following to evaluate student's performance:

- Going for a Spin Assessment Rubric
- Presentation of the Challenge Solution
- Daily Research and Design Logs
- Student Response Sheets
- Data Tables and Forms
- Design Journal

Extensions

1. Have students research biomedical applications of centrifuges. Small centrifuges are a common fixture in medical and research laboratories around the world. These centrifuges use very high speeds to separate materials in all types of samples.
2. Have students research and report on how centrifuges are used by NASA. NASA carries out centrifuge experiments to find ways to counterbalance the effects of long periods of micro-gravity on astronauts. Also, NASA astronauts undergo centrifuge training as they prepare for their spaceflights.



Understanding Centripetal Force Introduction

Describe centripetal force in your own words.

Which of Newton's laws applies when dealing with centripetal forces?

Define the terms listed below. Be sure to write the definitions in your own words.

Centrifuge -

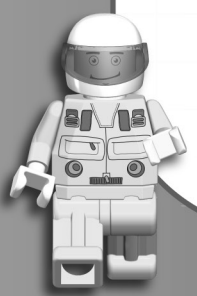
Mass -

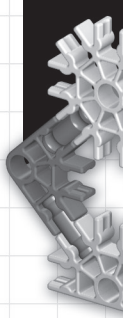
Gondola -

G-Force -

Angle -

RPM -





K'NEX Centrifuge Performance Tests

Directions: Your team will experiment with the K'NEX Centrifuge model and centripetal forces. During the experiments your team will change the radius of the centrifuge twice. You will explore how varying the length of the centrifuge arm affects the operation of the device and the forces it produces.

For each set of data below, you have been provided the:

- Rate at which you must spin the K'NEX Centrifuge model in rpm.
- Changes to make to the radius of the centrifuge arm.

Prior to starting the first test, use the balance provided by your teacher to determine the mass of the K'NEX test pilot who rides in the centrifuge. Use the formula below to calculate the centripetal force that is acting on the K'NEX test pilot at the turning speeds (rpm) shown.

The formula to determine force according to Newton's Laws of Motion is:

$$\text{Force} = \text{Mass} \times \text{Acceleration}$$

$$F = ma$$

The formula can be adapted to compute the centripetal force when the speed of the centrifuge is reported in rpm.

$$F = 0.01097 \text{ m r n}^2$$

m = mass of the K'NEX test pilot

r = radius of the centrifuge arm

n = revolutions per minute (rpm)

F = force which will be in Newtons

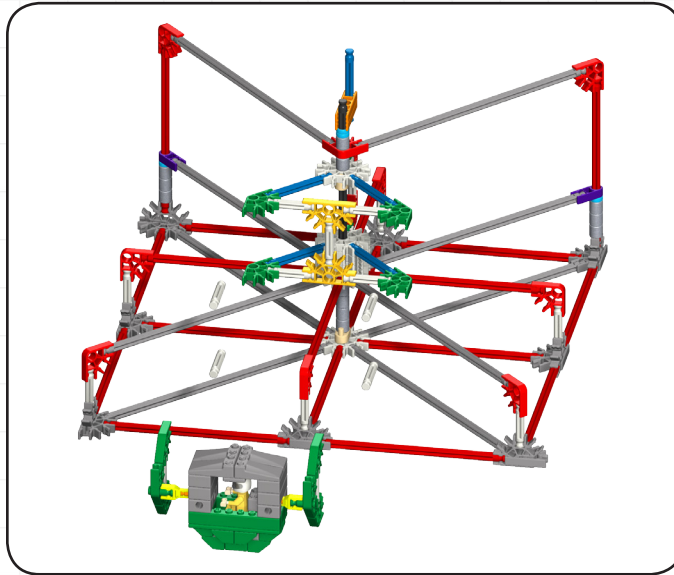
The K'NEX Centrifuge model is a small model when compared to a centrifuge used to train pilots or astronauts. The centripetal forces you calculate will be very small numbers. As a result, your team will multiply the mass of the K'NEX test pilot and the radius of the K'NEX Centrifuge arm by 10 before reporting them on the data tables.

Notice there is a data column related to the angle of the gondola. Use a protractor and design a strategy to measure this angle.

Spin the centrifuge at the appropriate revolutions per minute and measure the angle of the gondola for each trial. Use a calculator, computer or online calculator to complete your calculations.

Original Centrifuge Model				
Revolutions per minute	Mass of Gondola (kg)	Radius of Gondola Arm (m)	Force (N)	Angle of Gondola
10				
15				
20				
30				
60				

Modify the original model to increase the radius of the centrifuge arm. Replace the white Rods on the arm with blue Rods.

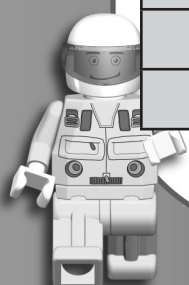


Repeat the experiment above and report your data in the next data table.

Centrifuge Model with Increased Arm Length				
<i>Increase the length of the centrifuge arm by replacing the original white Rods with blue Rods.</i>				
Revolutions per minute	Mass of Gondola (kg)	Radius of Gondola Arm (m)	Force (N)	Angle of Gondola
10				
15				
20				
30				
60				

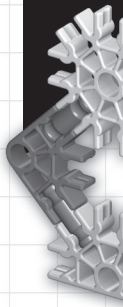
Modify the model to decrease the radius of the centrifuge arm. Replace the blue Rods added to the centrifuge arm with green Rods and repeat the experiment. Enter data and calculations in the table below.

Centrifuge Model with Decreased Arm Length				
<i>Decrease the length of the centrifuge arm by replacing the blue Rods with green Rods.</i>				
Revolutions per minute	Mass of Gondola (kg)	Radius of Gondola Arm (m)	Force (N)	Angle of Gondola
10				
15				
20				
30				
60				



Answer the following questions related to the three experiments your team just completed.

Which data chart produced the highest values for centripetal force? Explain why.
List the speed in rpm that produced the greatest centripetal force for each of the three data charts? Why did these speeds produce the greatest centripetal force?
How did the angle of the gondola change as the speed of the centrifuge increased?
How did the centripetal force change as the speed of the centrifuge increased?
Are the following statements true or false? Explain how you know and support your answer with data from your experiment.
The angle of the gondola and the speed of the centrifuge are related. The faster the centrifuge spins the smaller the angle of the gondola.
Are the following statements true or false? Explain how you know and support your answer with data from your experiment.
The angle of the gondola and centripetal force are related. The faster the centrifuge spins the larger the centripetal force it produces.





Going for a Spin

Design Brief

The Problem

Your team has been hired by the NASTAR Center to create a device that will allow visiting school students to measure the angle the gondola reaches as it spins on the centrifuge. Students must be able to use the device as they look through observation windows to the centrifuge. This is a device students will build at the center and take with them when they return to school.

Your Task

- Develop a device to determine the angle the centrifuge gondola reaches as it spins at a constant speed.

Criteria & Rules of the Challenge

- Use the original K'NEX Centrifuge model to demonstrate your team's device.
- Review the data you collected previously during this lesson.
- Once the device has been created, run tests to determine if the device is giving dependable angle measurements.
- You may use a protractor and the materials provided by your teacher.
- The Design Process Guide will lead you through this challenge.

The Process

This activity will include the following phases:

- Phase 1 – Class Exploration
 - Understanding Centripetal Force Introduction
 - Construction of the K'NEX Centrifuge Model
 - K'NEX Centrifuge Performance Tests Going for a Spin Design Brief Introduction by teacher

(Follow the steps on the Design Process Guide beginning on the next page to direct your team through the remainder of the challenge.)

- Phase 2 – Independent Exploration
 - Understanding the Problem
 - Design Process Guide Student Response Sheet
 - Brainstorming & Ideation
- Phase 3 – Team Exploration
 - Explore Possibilities and Develop a Plan
 - Pro and Con Chart
 - Implement Your Plan
 - Testing and Refining the Plan
- Phase 4 – Classroom Competition
 - Taking the Challenge
- Phase 5 – Wrapping It Up
 - Reflection/Evaluation
 - Going for a Spin Assessment Rubric
 - Teamwork & Self Assessment Form

Note: Complete a Daily Research and Design Log each day during this challenge.

Design Process Guide

Understanding the Problem

To demonstrate your understanding of the challenge, complete the following:

The Challenge:

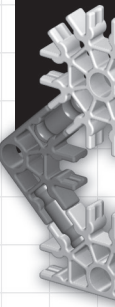
Restate the challenge, in your own words.

Criteria:

In your own words, describe what your solution needs to accomplish and any specific performance levels that it needs to meet.

Constraints:

Describe the limitations you have been given for this activity.



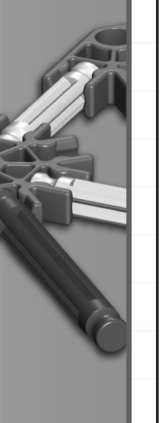


Brainstorming and Ideation

Brainstorm possible solutions to the challenge. List your individual ideas and rough sketches in the box below and in more detail on your Daily Research and Design Log. Include a list of all of the additional materials you will need to complete your measurement device.

Gondola Angle Measuring Device

Rough Sketch



Develop an experiment that will allow you to test your solution. The experiment should enable your team to verify that the device can measure the angle of the K'NEX Centrifuge model. Keep a record of your work in your Daily Research and Design Log.

Explore Possibilities and Developing a Plan

Fill out the **Pro and Con Chart** provided by your teacher. Describe each of the team members' ideas and list advantages and disadvantages of their designs and experimental plans. This information should be used to develop your team's final plan.

Once evaluation of team members' ideas is complete, develop one final plan. This plan can be based on one team member's idea or a combination of elements from each of the ideas your team members offered. Put a detailed explanation of the final plan in your Design Journal along with detailed, labeled, scale drawings of the solution. Include the plan for your team's experiment and details of how your team will collect, organize and report experimental data.

Implement Your Plan

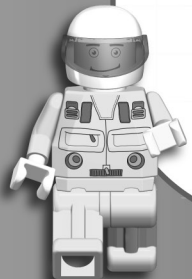
With your teacher's approval, put your team's plan into action.

Testing and Refining the design

When the device is ready, begin testing its performance and collecting data.

As you experiment, refine the device to improve its performance.

Keep testing and experimenting as long as time allows. Record each of the refinements you make and the results of testing.



The Challenge!

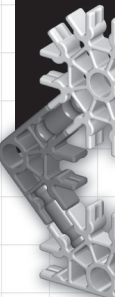
The time has come! You and your team should now use the device you created to measure the angle of the Gondola at speeds of 10, 30, and 50 rpm. Keep records of the angles the gondola reaches in your Design Journal. As a final test, give your device to your teacher and allow them to use it to measure an angle while one team member spins the centrifuge.

Reflection on the Activity

Complete the Going for a Spin Assessment Rubric to provide your impression of how you did with this lesson.

Going for a Spin		Assessment Rubric	
<i>Circle Responses for each:</i>	Excellent	Good	Acceptable
Learning Journal & Worksheets	Student Response Sheets and Design Journals completed with no spelling or grammar errors. All answers on Student Response Sheets are accurate. 10	Student Response Sheets and Design Journals completed with few spelling and grammar errors. Most answers on Student Response Sheets are accurate. 8	Student Response Sheets and Design Journals completed with many spelling or grammar errors. Fewer answers on Student Response Sheets are accurate. 6
Design & Construction	Your device is very neatly constructed, easy to use, and meets or exceeds expectations outlined in the Design Brief. 10	Your device is neatly constructed, easy to use, and meets expectations outlined in the Design Brief. 8	Your device has been constructed, is in useable form, and meets the materials criteria listed in the Design Brief. 6
Teamwork/ Work Ethic	You worked well with your teammates and interacted well with others. You demonstrated excellent reliability and initiative when working on this challenge. 5	You worked well with your teammates and interacted well with others. You were reliable and demonstrated initiative when working on this challenge. 3	You usually worked well with your teammates and others. You were generally reliable and usually demonstrated initiative when working on this challenge. 1
Total Score	_____ /25		

Teacher Comments: _____


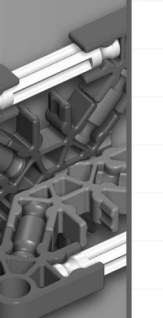



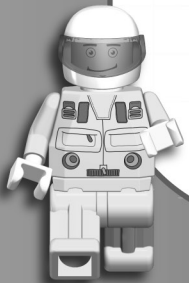


Reflection on the Activity

Now that the centrifuge has stopped for the day and your angle measurement device works perfectly, your teacher will provide you with a Teamwork and Self-Assessment Form. Use the form to reflect on your team and your contributions to your team's efforts.

Extension Activities

1. Small centrifuges are a common fixture in medical and research laboratories around the world. Research how centrifuge technology is used in a variety of biomedical applications. Identify at least two ways centrifuges are used and the benefits they provide doctors and biomedical researchers. Write a 1 to 2 page report that describes what you discovered and include images of one or more biomedical centrifuges.
 2. Research and report how centrifuges are used by NASA. For example, NASA carries out centrifuge experiments to discover ways to counterbalance the effects of long periods of micro-gravity on astronauts. Additionally, NASA astronauts undergo centrifuge training as they prepare for their spaceflights. Gather information on these and other ways NASA uses centrifuges. Prepare a Centripetal Forces and Space Exploration poster with text and images for the bulletin board in your classroom.
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- 
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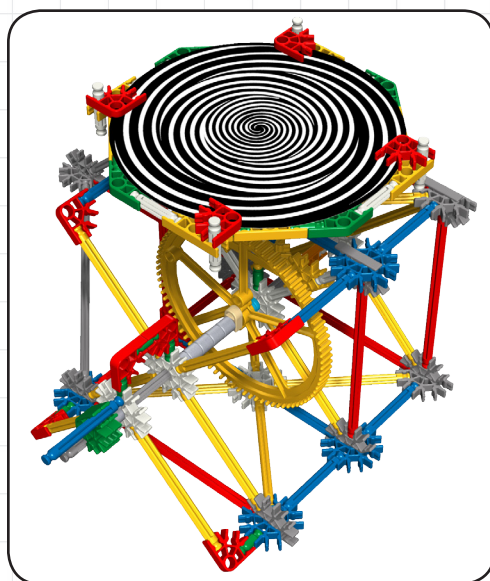


LESSON #7: VISUAL DISORIENTATION STATION

x4



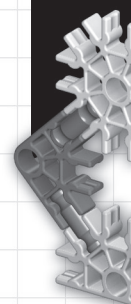
Model: K'NEX Stroboscope



Main Concepts:

- **Science**
 - Motion Aftereffect, Color Illusions
- **Technology & Engineering**
 - Mechanical Systems
- **Mathematics**
 - Measurement

Objectives:	Required Materials:	Optional Materials:
<p><i>Student will be able to:</i></p> <ul style="list-style-type: none"> • Work effectively both independently and in collaborative teams. • Design and develop disks for an optical illusion experiment. • Correctly describe how the eye detects motion related to color and depth perception. • Understand that mathematics is an integral part of inquiry, experimentation, design, and development of human made items. 	<p><i>Teacher will need:</i></p> <ul style="list-style-type: none"> • Pre-built model of the K'NEX Stroboscope • Pre-printed copies of spiral-pattern disk. <p><i>Students will need:</i></p> <ul style="list-style-type: none"> • Parts and building instructions for the K'NEX Stroboscope model • Stopwatches or clocks with second hands • Paper for disk creation • Cardstock or standard printer paper. • Copies of all Student Response Sheets and forms for inclusion in students' Design Journals 	<ul style="list-style-type: none"> • Colored pencils, markers, or crayons





Process

Engagement

1. Using the K'NEX Stroboscope Model with a spiral-pattern disk (template included) to demonstrate the concept of motion aftereffect.
 - Rotate the disk clockwise using the hand crank. Begin to spin the disk at a rate of about 5-10 revolutions per minute and have students to stare at the center of the disk for about 20-30 seconds.
 - Ask students to look at the person next to them and describe what they see.
 - Ask students to why they believe this phenomenon occurred.
 - Conduct the same experiment this time spinning the disk counter-clockwise at the same speed for another 20-30 seconds. Have students to look at the person next to them and describe what they see. Was there any change from their previous observations? (Students may mention that the motion is in the opposite direction of what they observed earlier.)

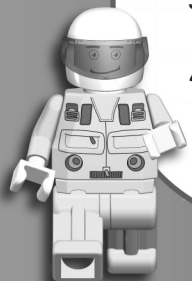
TEACHER'S NOTES:

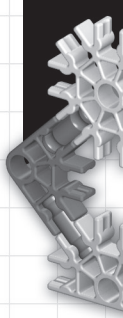
- Depending on the size of the class, this activity may have to be presented to small groups of students individually. This particular effect is best seen when the K'NEX Stroboscope is turned slowly.
- Students should describe that they have the sense that the person sitting next to them seems to be moving. They may describe the motion as rushing toward them or away from them, or that they are expanding and contracting.

2. Discuss how the human eye works, and that human eyes are sensitive to motion (in this activity, inward and outward motion). Discuss how optical nerve cells, located in the visual cortex, perceive motion. Some of these nerve cells react and fire more frequently when the objects you are viewing move outward from the center of your field of vision. In other cases, nerve cells fire more frequently when the objects you are viewing are moving inward. In the case of objects standing still, the inward and outward nerve cells operate in balance (equilibrium) with one another. When continuous motion is observed for 20 – 30 seconds and then the subject looks at a stationary object, the stationary object appears to move in the opposite direction. There are many theories to explain this illusion from nerve cell fatigue to visual adaptation. (Students can research the motion aftereffect in more detail by searching online using the key words: motion aftereffect, spiral aftereffect, or waterfall aftereffect.)
3. Instruct students to conduct basic research on motion aftereffects using resources in the library or on the Internet. Review their findings as part of a class discussion.
4. Use the K'NEX Stroboscope model to demonstrate how fatigue or visual adaptation can lead to different optical illusions. Explain to students that airplane pilots and astronauts can experience a variety of visual and other sensory illusions that can impact their ability to fly or work. In the case of astronauts, the illusions can lead to motion sickness that can take up to a few days to overcome.

Exploration

1. Students will experiment with the K'NEX Stroboscope model to develop an understanding of optical illusions and motion aftereffects.
 - a. Students should complete the Optical Illusion and Motion Aftereffect Introduction Student Response Sheet based on the information and vocabulary presented in the Engagement section of this lesson and their own research.
 - b. Have students construct the K'NEX Stroboscope model using the building instructions provided. Provide copies of the spiral image template for use with their model.
2. Students will complete the Visual Disorientation Station Challenge Design Brief.
3. Introduce the Student Response Sheet entitled Visual Disorientation Station Challenge Design Brief. Review the Design Brief in detail with the students.
4. Introduce the Design Process Guide to students. Explain that students will use the Design Process Guide to direct their activities while working on the Visual Disorientation Station Challenge.





5. Students will demonstrate their understanding of the Visual Disorientation Station Challenge Design Brief by completing the Design Process Guide. Review each team's responses to ensure they understand the challenge and the criteria before continuing
6. Inform students that they will complete a Daily Research and Design Log each day they work on the challenge.
7. Provide direction to students as they choose and prepare their disk designs. Each team should make a C. E. Benham's color illusion disk for one of their illusions. Samples and templates can be found on the Internet using the key words provided in the Visual Disorientation Station Challenge Design Brief or you can gather a collection of templates for the students to choose from. Provide students with a collection of blank disks to make their own designs for experimentation. A template for blank disks can be found at the end of this lesson.

TEACHER'S NOTES:

- There are a number of different kinds of disks made by Benham and G. Sarcone. You can either assign the students to a specific design or allow them to create on their disk. For the Wagon Wheel Effect, students can choose from wagon wheels, bicycles wheels or car wheels.
- Cardstock is the recommended disk material.

Explanation

Assign teams to design a presentation that will explain their challenge solution to the class.

The presentation should include:

- An oral description.
- A demonstration of the C. E. Benham color illusion
- A demonstration of other disks the team designed

Student Reflection

Students will self-evaluate their challenge solutions based on the criteria provided in the rubric for this activity. Additionally, students will complete a Teamwork and Self-Assessment Form to assess their individual efforts and team's efforts on the challenge activities.

TEACHER'S NOTES:

- Give the Visual Disorientation Station Challenge Rubric to students so they can complete a self-evaluation of their work.
- Collect the rubrics and review each. The rubric score and your evaluation will make up a portion of the assessment data for this lesson.

Evaluation

You may use some or all of the following to evaluate student performance:

- Visual Disorientation Station Assessment Rubric
- Presentation of the Challenge Solution
- Daily Research and Design Logs
- Student Response Sheets
- Forms
- Design Journal

Extensions

Have students to research the work done by James Clerk Maxwell and Ogden Rood related to the mixing of color. Their work has had a lasting impact on art, color photography, and television. Students will prepare a set of Maxwell Color Wheels to demonstrate how a spinning color wheel can show color mixing. The students will prepare a report and demonstration for their classmates.

Optical Illusion and Motion Aftereffect Introduction

Describe motion aftereffect in your own words.

How does the concept of a motion aftereffect relate to the optical illusion you witnessed in class?

Define the terms listed below. Be sure to write the definitions in your own words.

Sensory Receptors -

Optical -

Illusion -

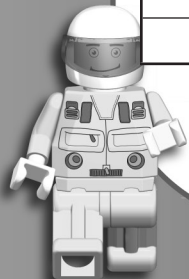
Optical Illusion -

Optic Nerve -

Visual Cortex -

Fatigue -

RPM -



Visual Disorientation Station Challenge

Design Brief

The Challenge

The International Space Agency (ISA) is preparing to send another crew of astronauts into space. Your team has been hired to develop a series of illusion disks to help the astronauts to recognize optical illusions and their effects.

Your Task

- Design, create, and test disks to demonstrate optical illusions.
- Describe a theory to explain motion aftereffects and another to explain Benham's color wheel.
- Present your work and findings to the ISA Board of Directors (your classmates).

Rules & Constraints of the Challenge

- Base your designs on your research of optical illusions. Use the following key words to direct your research: Benham Disks, Sarcone Disks, Spiral Illusions, Wagon Wheel Effect
- Use the card stock or paper provided by your teacher to create your disks.
- Use and follow the directions found in the Design Process Guide as you design and create your disks.

The Process

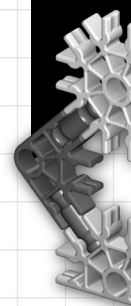
This activity will include the following phases:

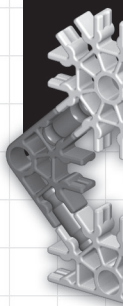
- Phase 1 – Class Exploration
 - Optical Illusion and Motion Aftereffect Introduction
 - Construction of the K'NEX Stroboscope
 - Spinning Disk Experimentation
 - Visual Disorientation Station Design Challenge introduction by teacher

(Follow the steps on the Design Process Guide beginning on the next page to direct your team through the remainder of the challenge.)

- Phase 2 – Independent Exploration
 - Understanding the Problem
 - Design Process Guide Student Response Sheet
 - Brainstorming & Ideation
- Phase 3 – Team Exploration
 - Explore Possibilities and Develop a Plan
 - Pro and Con Chart
 - Implement Your Plan
 - Testing and Refining the Plan
- Phase 4 – Classroom Presentations
 - Team Stroboscope Disk Demonstrations
- Phase 5 – Wrapping It Up
 - Reflection/Evaluation
 - Visual Disorientation Station Assessment Rubric
 - Teamwork & Self Assessment Form

Note: Complete a Daily Research and Design Log each day during this challenge.





Brainstorming and Ideation

Brainstorm possible solutions to the challenge. List your individual ideas and rough sketches with labels in the box below and in more detail on your Daily Research and Design Log. Include a list of all of the additional materials you will need to complete your disks.

Draw a thumbnail sketch of your disks and list any additional materials you will need.

Develop an experiment that will allow you to test the disks you will create. The experiment should enable your team to verify that the disks effectively demonstrate an illusion. Keep a record of your work in your Daily Research and Design Log.

Exploring Possibilities and Developing a Plan

Fill out the Pro and Con Chart provided by your teacher. Describe each of the team members' ideas and list advantages and disadvantages of their designs and experimental plans. This information should be used to develop your team's final plan

Once evaluation of team members' ideas is complete, develop a final list of the disks your team will create and a plan to test the designs. This plan can be based on one team member's idea or a combination of elements from each of the ideas your team offered. Include a detailed explanation of the final plan in your Design Journal.

Implement Your Plan

Use blank disks and begin transferring designs to the disks or create designs of your own. Ensure that your team prepares a Benham's color disk. Attach a completed disk to the K'NEX Stroboscope model and begin your experimentation.

Testing and Refining the Design

Keep careful records of your findings as your team experiments. Remember, some illusions may be more apparent at slow speeds while others may appear at higher speeds. Make sure that all of the team members are able to experience the optical illusions. If you are experiencing problems, be sure to check the accuracy of the pattern that you placed on the disk, refine your disk or make a new one if necessary.



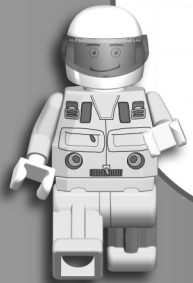
Stroboscope Presentation

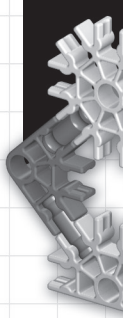
The time has come! You and your team will now present your illusion to the class.

Include:

- Website(s) where you found the disk patterns.
- Disks that the team created based on research.
- Disks your team designed on its own.
- Demonstrations of each disk.
- Explain causes of motion aftereffects and the colors seen with Benham's disk.

Keep records of how many of your classmates were able to see each of the illusions in your Design Journal.





Self Reflection/Evaluation

Complete the Visual Disorientation Station Assessment Rubric to provide your impression of how you did with this lesson.

Visual Disorientation Station		Assessment Rubric		
<i>Circle Responses for each:</i>	Excellent	Good	Acceptable	
Design Journal & Worksheets	Student Response Sheets and Design Journals completed in their entirety with no spelling or grammar errors. 8	Student Response Sheets and Design Journals completed in their entirety with a few (2-4) spelling and grammar errors. 6	Student Response Sheets and Design Journals completed in their entirety with many (5 or more) spelling or grammar errors. 4	
Design & Construction	Your spinning disks are neatly designed, flat, and drawn with crisp lines. They allowed most students to experience the expected illusions. 6	Your spinning disks are neatly designed and drawn. Many students were able to experience the expected illusions. 5	Your spinning disks were completed as required. Many students were unable to experience the expected illusions. 4	
Teamwork/ Work Ethic	You worked well with your teammates and interacted well with others. You demonstrated excellent reliability and initiative when working on this challenge. 3	You worked well with your teammates and interacted well with others. You were reliable and demonstrated initiative when working on this challenge. 2	You usually worked well with your teammates and others. You were generally reliable and usually demonstrated initiative when working on this challenge. 1	
	<i>Circle Results for each:</i>			
Total Score	_____ /25			

Teacher Comments: _____

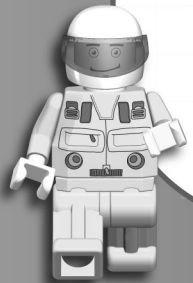
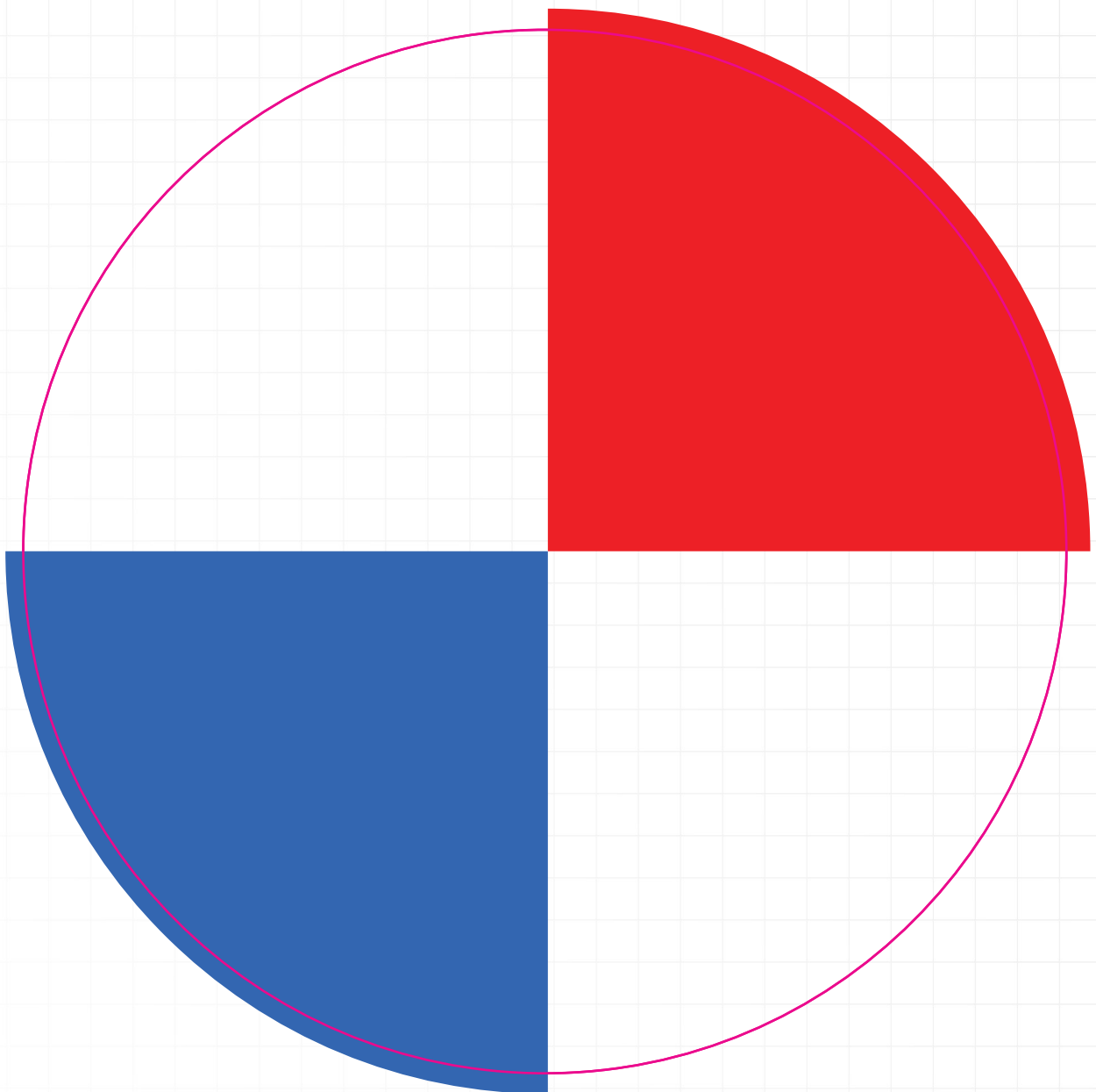
Reflection on the Activity

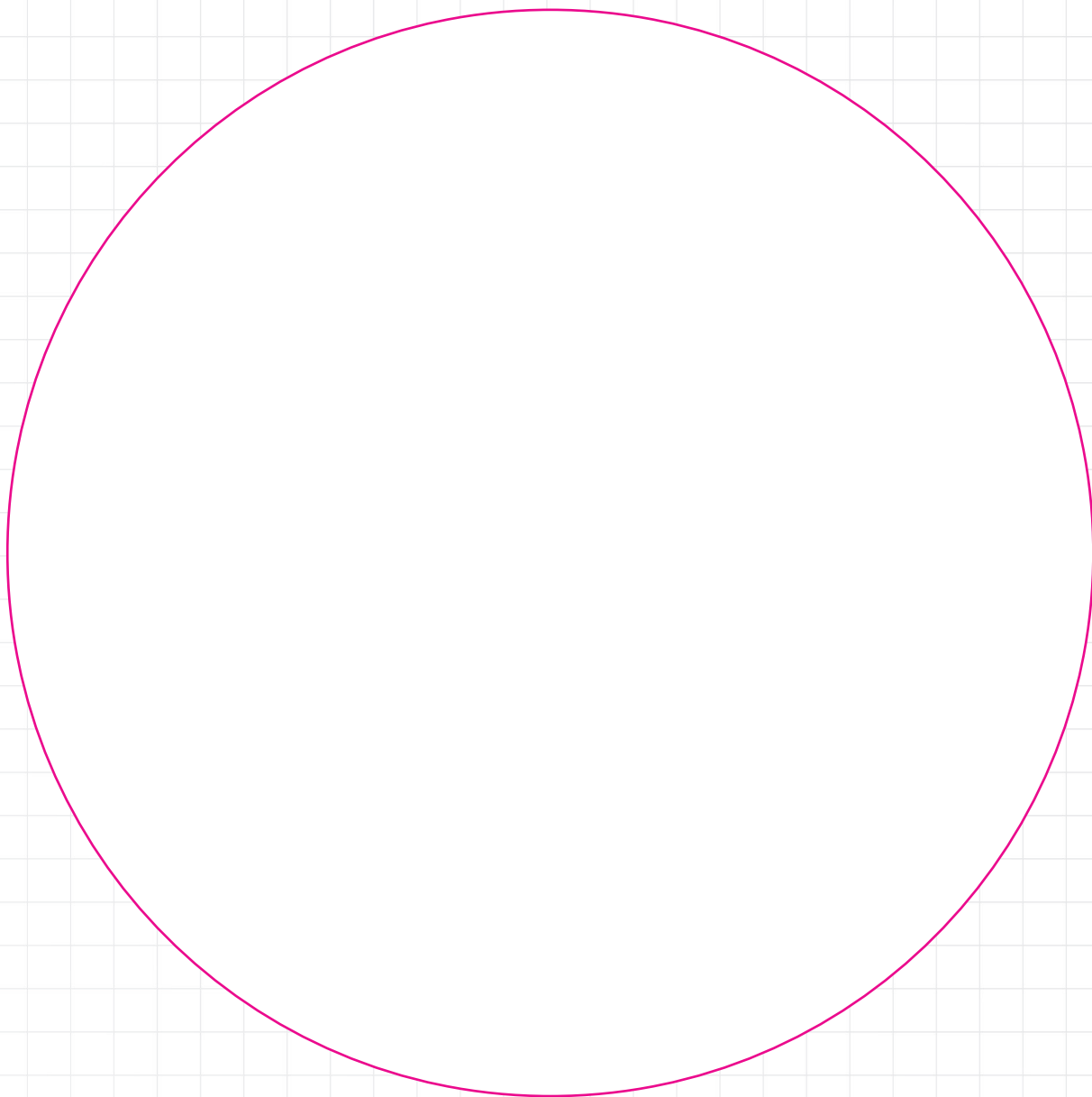
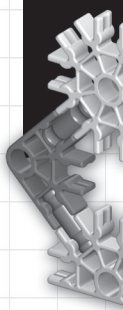
Now that the last illusions have been completed and your presentation has been a success, your teacher will provide you with a Teamwork and Self-Assessment Form. Use the form to reflect on your team and your contributions to your team's efforts.

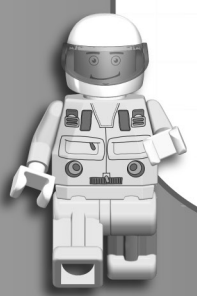
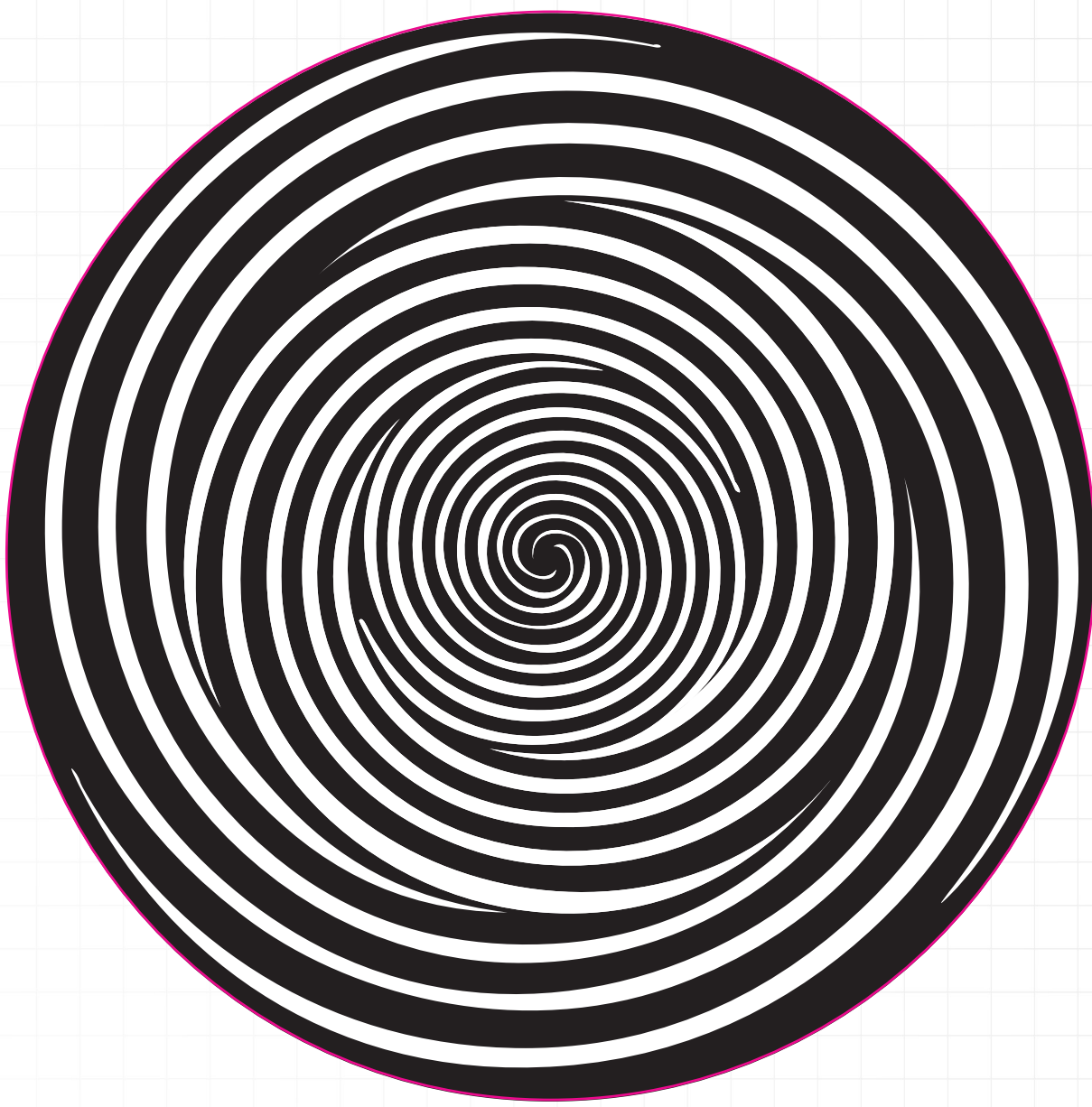
Extension Activity

Color Effects Using Spinning Wheels

Conduct research on the work done by James Clerk Maxwell and Ogden Rood as they used spinning color wheels and tops to complete color mixing experiments. Take a collection of blank disks and recreate some of the scientists' color wheels or designs of your own. Describe the colors that were produced when you spun your color wheels on the K'NEX Stroboscope model. Write a brief 2-3 paragraph report outlining the work of Maxwell and Rood in addition to your own work and discoveries. Diagram the various color wheels you produced and list the colors they produced on the K'NEX Stroboscope model. Demonstrate your color wheel disks for the class.



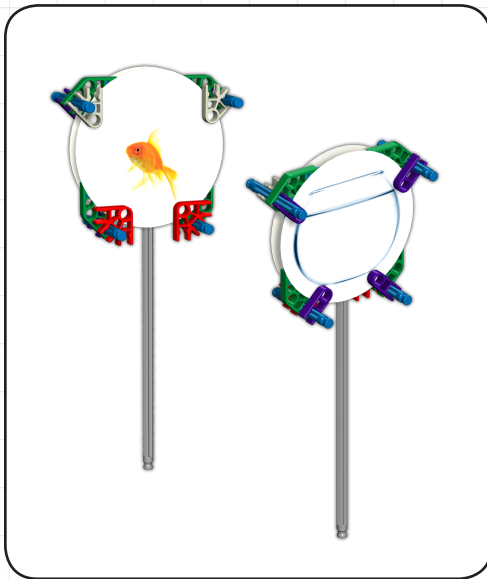




Lesson #8: Flipping Out



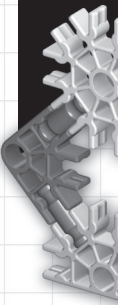
Model: K'NEX Thaumatrope Model



Main Concepts:

- **Science**
 - Vision, Persistence of Vision, Retinal Retention
- **Technology & Engineering**
 - Engineering Design, Construction
- **Mathematics**
 - Measurement

Objectives	Required Materials:	Optional Materials:
<p><i>Student will be able to:</i></p> <ul style="list-style-type: none"> • Work effectively both independently and on collaborative teams. • Describe how the eye detects and retains an image. • Define and understand persistence of vision or retinal retention. • Design and develop a thaumatrope to produce a desired optical illusion. • Understand that mathematics is an integral part of inquiry, experimentation, design, and development of human made items. 	<p><i>Teacher will need:</i></p> <ul style="list-style-type: none"> • K'NEX Thaumatrope model • Pre-printed copies of bird cage illusion inserts for the thaumatrope. <p><i>Students will need:</i></p> <ul style="list-style-type: none"> • Parts and building instructions for the K'NEX Thaumatrope model • Compasses • Pre-printed copies of the bird and cage illusion and blank disks • Colored pencils, markers, or crayons • Drawing tools such as rulers, triangles, etc. • Additional craft materials for model construction. • Straws, craft sticks, string, and other materials at the teacher's discretion. 	<ul style="list-style-type: none"> • Multimedia presentation software • Materials for creation of visual aids such as various sizes of poster board, foam board, etc.





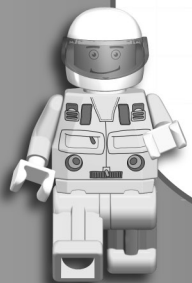
Process

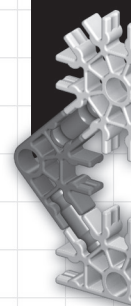
Engagement

1. Use the K'NEX Thaumatrope model, with the bird and cage disks to demonstrate the illusion that results when the thaumatrope is spun.
2. Place the thaumatrope between the palms of your hands and rotate the device back and forth. Spin the device as fast as you can for the illusion to be most effective. This illusion works best when students are within 4-8 feet of the device, you may need to conduct this demonstration in small groups.
 - a. Engage students in a class discussion of the K'NEX Thaumatrope and ask them to hypothesize why the observed phenomenon occurred. Some may draw upon what they learned during the last activity while others may come up with ideas of their own. Assign students to research the thaumatrope for additional ideas. Instruct students to keep a record of what they learned in their Design Journals.
 - b. Review how a human eye works and make a point to reference what students learned during the previous lesson.
 - c. Discuss the theory that the retina of a human eye retains an image for a brief period after the object is removed.
 - This theory is known as Retinal Retention or Persistence of Vision.
 - Ask students how Persistence of Vision or Retinal Retention relates to the phenomenon they witnessed during the thaumatrope demonstration. They may suggest the first image remains for a moment due to Retinal Retention and then the second image comes into view and the two images blend together to make one or something similar. List students' ideas on the board.
 - Persistence of Vision is the phrase that is usually used to describe the effect that is demonstrated by the thaumatrope. The image of the first disk remains visible for about 1/25th of a second after the disk spins away. During that 1/25th of a second, the second disk replaces the first and the two images appear as one.

TEACHER'S NOTE:

- In addition to explaining the illusion shown by the thaumatrope, the theory of Persistence of Vision has long been considered an explanation for the eyes' ability to see smooth motion when the single frames of a film are projected on a screen. Some research has shown that the ability to observe smooth motion while observing single frames of film may be much more complicated and not a result of Persistence of Vision at all. As students research, they may locate resources that present one theory or the other. If students report finding conflicting information, this would provide an excellent opportunity to discuss the fact that science is always experimenting and trying to improve the theories that explain the world around us.





Exploration

1. Students will explore a 'motion toy' that was first popular in the 1800s. They will construct the K'NEX Thaumatrope model and experiment to determine how the device works and how it creates illusions.
 - a. Students should complete the Persistence of Vision Introduction Student Response Sheet to demonstrate an understanding of the information and vocabulary presented in the Engagement section of this lesson and their own research.
 - b. Have students construct the K'NEX Thaumatrope models using the building instructions provided. Provide copies of the bird and cage disks for students to attach to their models.
 - c. Allow students to complete a series of experiments to determine:
 - Does the distance an observer stands in front of the thaumatrope affect the clarity of the image?
 - Does the speed the thaumatrope is spun effect the clarity and visibility of the image?
 - Can you see a four letter word using the thaumatrope if there are only two letters on each disk?
 - Produce thaumatrope disks of their own design that will show a single image illusion when spun?
 - How does the background color of disks affect the images they produce? Do pairs of disks with the same color background perform as well as, better, or worse than pairs of disks that have contrasting color backgrounds? Explain your results.
 - Remind students to complete Daily Research and Design Logs entries as they experiment.
2. Students will complete the Flipping Out Challenge Design Brief. Discuss the Design Brief and the criteria for the challenge with students.
 - a. Introduce the Student Response Sheet entitled Flipping Out Challenge Design Brief. Review the Design Brief in detail with the students.
 - b. Introduce the Design Process Guide to the students. Explain that they will use the Design Process Guide to direct their activities while working on the Flipping Out Challenge Design Brief.
 - c. Students will demonstrate their understanding of the Flipping Out Challenge by completing the first page of the Design Process Guide. Review each team's responses to ensure they understand the challenge and the criteria before continuing.
 - d. Have students complete a Daily Research and Design Log.

TEACHER'S NOTES:

- Teams will be building thaumatropes using materials that you provide as one of the tasks in this challenge. Generally, the thaumatrope projects on the Internet require string, blank disks, wire, soda straws, cardboard, etc.
- This would be an excellent opportunity to allow students to share what they have learned with their families. Do not be surprised if students take home the thaumatropes they make and return the next day with disks that family members have designed at home.

Explanation

Assign teams to design a presentation and demonstration that will explain their challenge solution to the class.

The presentation should include:

- An oral description of how they designed and constructed their thaumatropes
- Visual aids
- A demonstration of their thaumatrope
- A set of directions that other students can use to construct the models



Student Reflection

Students will self-evaluate their challenge solutions based on the criteria provided in the rubric for this activity. Additionally, students will complete a Teamwork and Self-Assessment Form to assess their individual efforts and team's efforts on the challenge activities.

TEACHER'S NOTE:

- Give the Flipping Out Assessment Rubric to students so they can complete a self-evaluation of their work. The rubric score and your evaluation will make up a portion of the assessment data for this lesson.
- Provide students with a Teamwork and Self-Assessment Form and review the form with students before they fill them out.

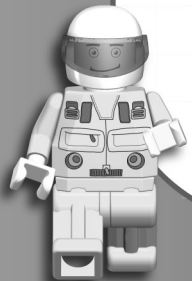
Evaluation

You may use some or all of the following to assess student's performance:

- Flipping Out Assessment Rubric
- Persistence of Vision Introduction
- Presentation of the Flipping Out Challenge Solution
- Daily Research and Design Logs
- Student Response Sheets
- Disks Prepared by Students
- Design Journal

Extensions

Students should investigate the impact of visual illusions and Persistence of Vision on pilots, astronauts, and other individuals who undergo similar physical stressors such as increased g-forces and atmospheric pressure changes? Students may also develop a further understanding of how the phenomenon of Persistence of Vision helped lead to the development of the Animation industry. Students will research animation history to create a timeline that highlights important individuals, technologies, as well as discoveries that have led to modern film animation.



Persistence of Vision Introduction

Describe Persistence of Vision in your own words.
How does Persistence of Vision relate to the optical illusion that you witnessed in class?
Define the terms listed below. Be sure to write the definitions in your own words.
Thaumatrope -
Retina -
Retinal Retention -
Contrast -
Motion Toy -



Flipping Out Challenge

Design Brief

The Challenge

Each year, school students visit the NASTAR Center as part of a science field trip. During the visit to NASTAR, students learn about the effect of optical illusions on pilots and astronauts. Your team has been hired by the NASTAR Center to design and create a thaumatrope model that students can easily construct when they visit NASTAR to demonstrate an optical illusion.

Your Task

- Design, create, and test a thaumatrope and at least two pairs of thaumatrope disks.
- Develop a set of step-by-step directions to build a thaumatrope.

Rules & Constraints of the Challenge

- Research thaumatropes on the Internet to find ways to construct simple thaumatrope models with common craft materials.
- Design and create a thaumatrope using the materials provided by your teacher.
- Design and prepare at least two pairs of thaumatrope disks that can be used in both the newly built thaumatrope and the K'NEX thaumatrope.
- Create step-by-step directions and diagrams so that others can create the same device.
- Follow the directions found in the Design Process Guide as you solve this challenge.

The Process

This activity will include the following phases:

Note: Complete a Daily Research and Design Log each day during this challenge.

- Phase 1 – Class Exploration
 - Persistence of Vision Introduction – Construction of K'NEX Thaumatrope Models
 - Experimentation
 - Flipping Out Challenge – Introduced by Your Teacher

(Follow the steps on the Design Process Guide beginning on the next page to direct your team through the remainder of the challenge.)

- Phase 2 – Independent Exploration
 - Understanding the Problem
 - Design Process Guide Student Response Sheet
 - Brainstorming & Ideation
- Phase 3 – Team Exploration
 - Explore Possibilities and Develop a Plan
 - Pro and Con Chart
 - Implement Your Plan
 - Testing and Refining the Plan
- Phase 4 – Classroom Presentations
 - Team Thaumatrope Disk Demonstrations
- Phase 5 – Wrapping It Up
 - Reflection/Evaluation
 - Flipping Out Challenge Assessment Rubric
 - Teamwork & Self Assessment Form

Design Process Guide

Understanding the Problem

To demonstrate your understanding of the challenge, complete the following.

The Challenge:

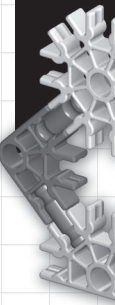
Restate the challenge, in your own words.

Criteria:

Describe what your solution needs to accomplish and any specific performance levels that it needs to meet, in your own words.

Constraints:

Please describe the limitations you have been given for this challenge.



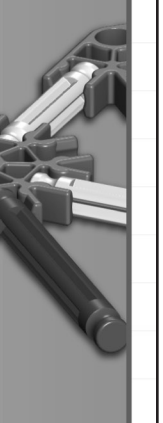


Brainstorming and Ideation

Brainstorm possible solutions to the challenge. List your individual ideas and rough sketches with labels in the box below and in more detail on your Daily Research and Design Log. Include a list of all of the additional materials you will need to complete your thaumatrope and disks.

Using the space provided below, draw a rough sketch of the idea you have for the new thaumatrope and the disks that you are suggesting. Include labels for the materials that will be used to construct the model.

Rough Sketch Area



Develop an experiment that will allow you to test your thaumatrope and disks. The experiment should allow your team to verify the new thaumatrope is working properly with the disks the team has developed. Suggest a plan to write the step-by-step directions to build the thaumatrope model. Keep a record of your work in your Daily Research and Design Log.

Exploring Possibilities and Developing a Plan

Fill out the Pro and Con Chart provided by your teacher. Describe each of the team members' ideas and list advantages and disadvantages of their designs, experimental plans, and strategy to develop a set of building instructions. This information should be used to develop your team's final plan.

Once evaluation of team members' ideas is complete, develop one final plan. This plan can be based on one team member's idea or a combination of elements from each of the ideas your team offered. Put a detailed explanation of the final plan in your Design Journal along with detailed, labeled, scale drawings of the solution. Include the plan for your team's experiment.

Implement Your Plan

With your teacher's approval, put your team's plan into action. Construct a working prototype of your new thaumatrope. You may only use the materials approved by your teacher.

Testing and Refining the design

When the thaumatrope and disks are ready, begin testing their performance and collecting data. As you experiment, refine your thaumatrope to improve its performance. Refine the disks as needed or produce new disks if the illusions are not crisp and clear.

Keep testing and experimenting as long as time allows. Record each of the refinements you make and the results of testing.

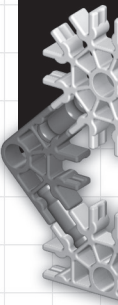


Thraumatrope Presentation

The time has come! You and your team will now present your thaumatrope and disks to the class.

Include:

- Website(s) where you found the directions to build the thaumatrope.
- Website(s) where you found designs you used for disks.
- Disks your team designed.
- Demonstrations of the thaumatrope and disks.
- Description of what makes the illusion caused by the thaumatrope possible.
- A copy of the step-by-step directions your team developed to build the thaumatrope.

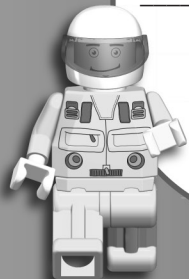


Self Reflection/Evaluation

Complete the Flipping Out Challenge Assessment Rubric to provide your impression of how you did with this lesson.

Flipping Out Challenge		Assessment Rubric	
<i>Circle Responses for each:</i>	Excellent	Good	Acceptable
Learning Journal	Student Journal entries completed in their entirety with no spelling or grammar errors. 8	Student Journal entries completed in their entirety with a few (2-4) spelling and grammar errors. 6	Student Journal entries completed in their entirety with many (5 or more) spelling or grammar errors. 4
Design & Construction	Your thaumatrope is very well built and the disks are clearly drawn. The thaumatrope produces a clear and crisp illusion. 6	Your thaumatrope is neatly constructed and the disks are drawn carefully. The thaumatrope produces a clear illusion. 5	Your thaumatrope is operational. The disks would produce a clearer illusion if more attention had been paid to drawing clear images. 4
Step-by-step Directions	Step-by-Step Directions written with no spelling or grammar errors. Directions are written clearly and concisely, and include neatly drawn diagrams for each stage of the directions. 8	Step-by-Step Directions written with a few (2-4) spelling and grammar errors. Directions are written clearly and concisely, and include diagrams drawn for each stage of the directions. 6	Step-by-Step Directions written with a many (5+) spelling and grammar errors. Directions are written clearly, and include diagrams drawn for each stage of the directions. 4
Teamwork/ Work Ethic	You worked well with your teammates and interacted well with others. You demonstrated excellent reliability and initiative when working on this challenge. 3	You worked well with your teammates and interacted well with others. You were reliable and demonstrated initiative when working on this challenge. 2	You usually worked well with your teammates and others. You were generally reliable and usually demonstrated initiative when working on this challenge. 1
Total Score	_____ /25		

Teacher Comments: _____

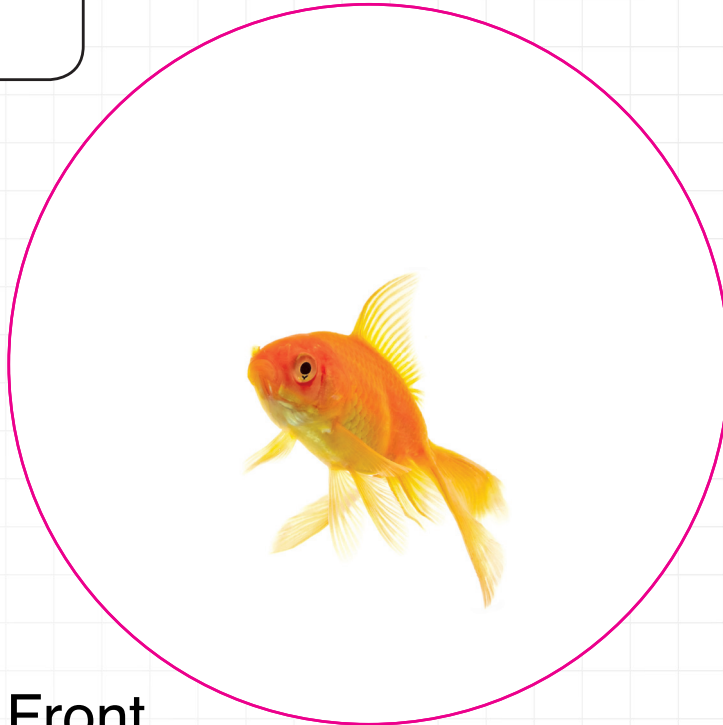
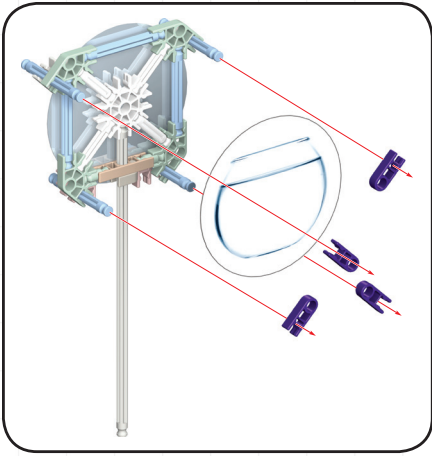


Reflection on the Activity

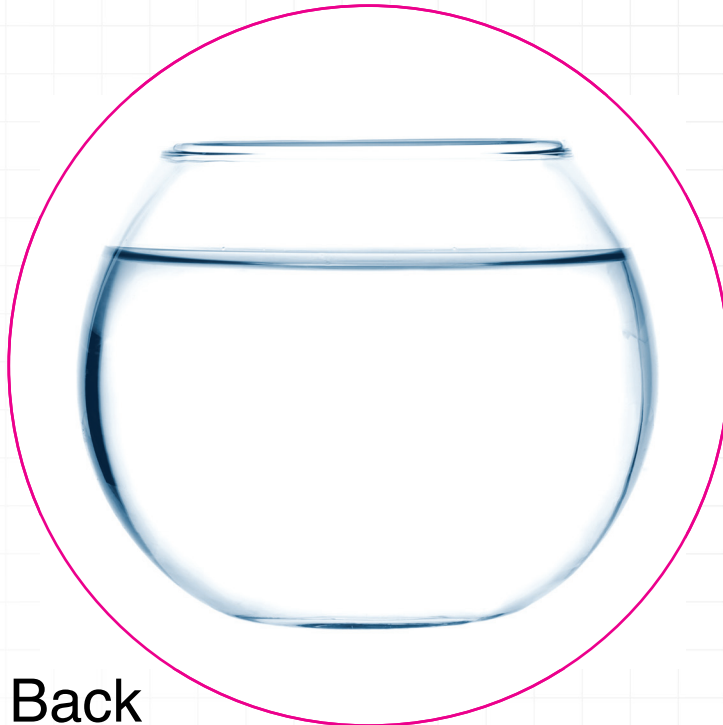
Now that the last illusions have been completed and your presentation has been a success, your teacher will provide you with a Teamwork and Self-Assessment Form. Use the form to reflect on your team and your contributions to your team's efforts.

Extension Activities

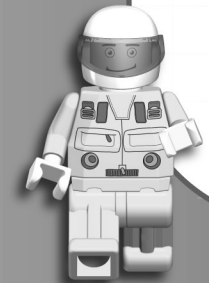
1. Investigate the impact of visual illusions on pilots, astronauts, and other individuals who undergo physical stressors such as increased g-forces and atmospheric pressure changes while doing their jobs. Your research may extend to others whose jobs can be impacted by optical illusions. NASA often deals with space sickness problems experienced by astronauts who enter weightless environments. Disorientation, visual illusions, etc. affect many astronauts for a day or two as they deal with spatial orientation issues in a weightless environment. Create a multimedia presentation or a two-page report to share what you have learned about these impacts.
2. Research the early history of animation, the technologies that made it possible, as well as the people involved in the early years of animation. Create a timeline of important events in the history of Animation from the early 1800's to today. This timeline should include the names of pioneers in the field, events, important technological developments as well as images where appropriate. Include 1 or 2 paragraphs that describe how it is possible for humans to view a series of still frames and see smooth motion.

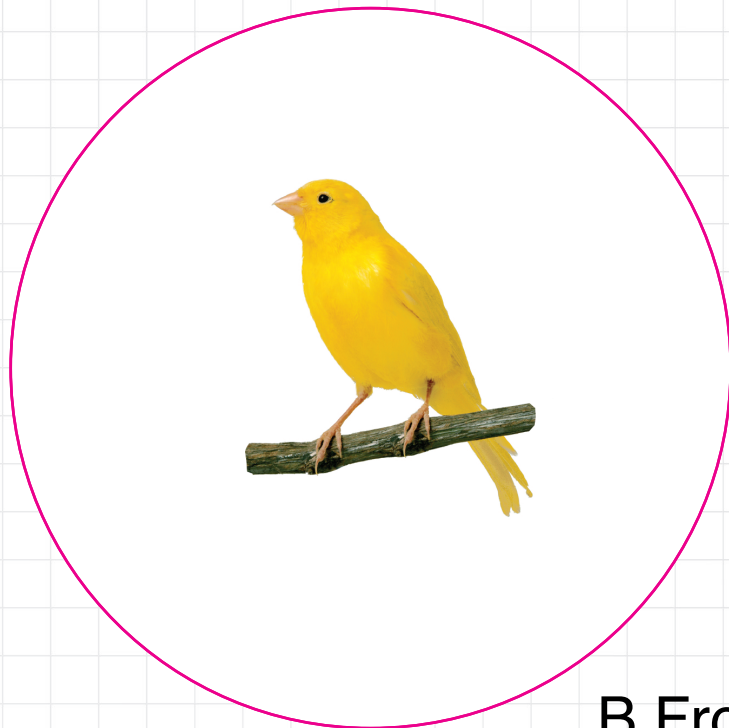


A Front

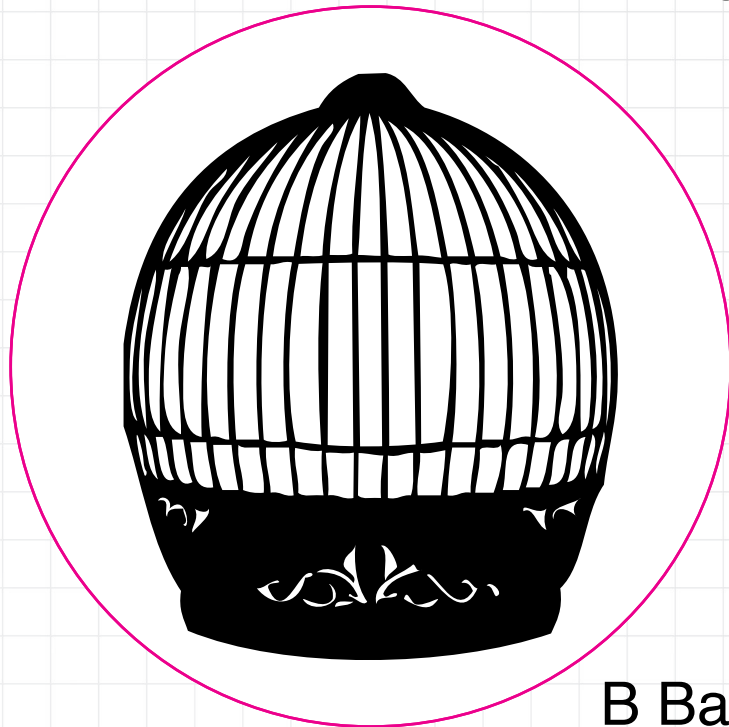


A Back

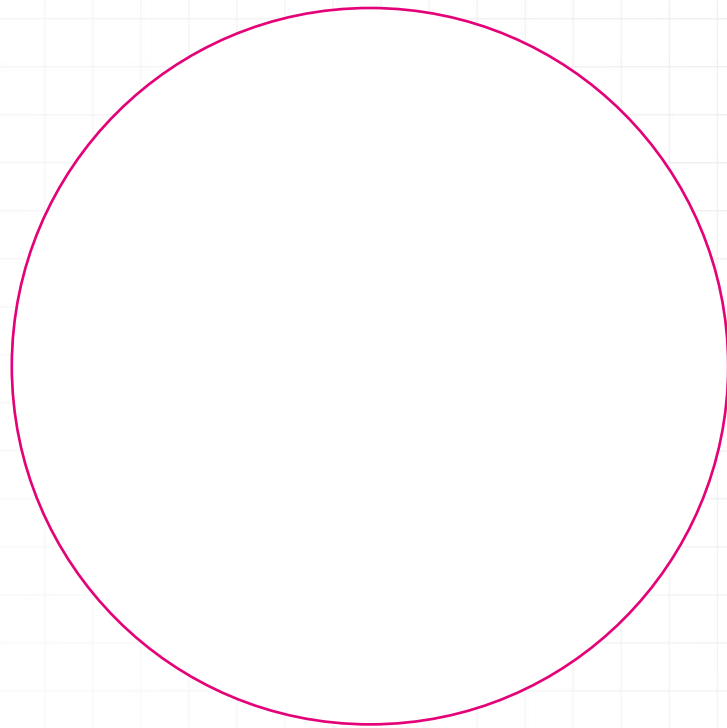
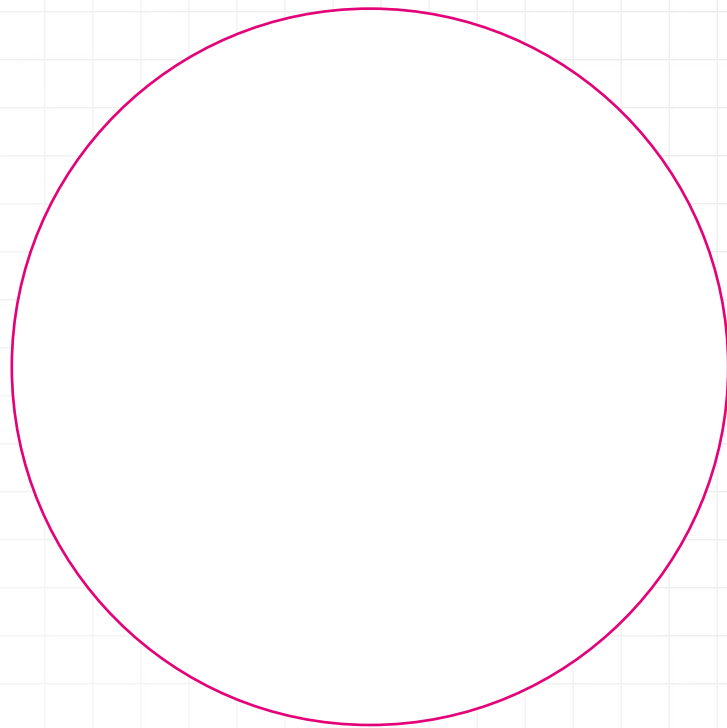
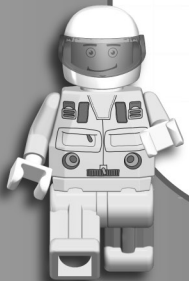
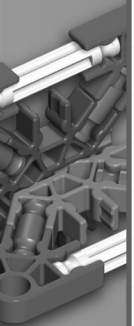




B Front



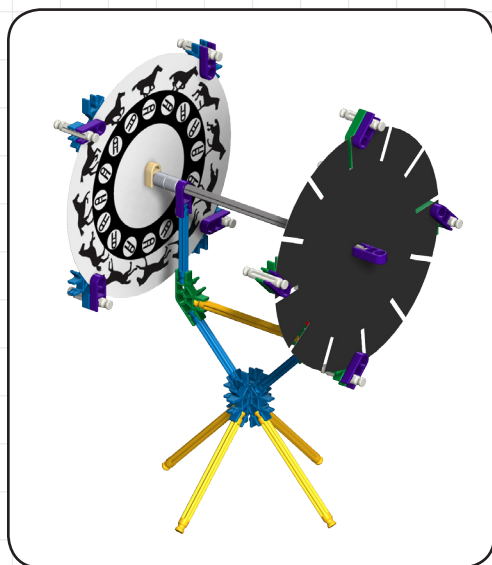
B Back



Lesson #9: Spinning Yarns



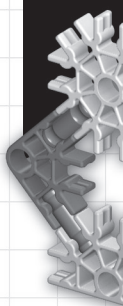
Model: K'NEX Phenakistoscope



Main Concepts:

- **Science**
 - Stroboscopic Effect, Visual Perception
- **Technology & Engineering**
 - Engineering Design
- **Mathematics**
 - Measurement, Scale

Objectives:	Required Materials:	Optional Materials:
<p><i>Student will be able to:</i></p> <ul style="list-style-type: none"> • Work effectively both independently and collaboratively in teams. • Describe how the eye detects and retains an image. • Define and understand Kinestasis (stop motion). • Design and develop a phenakistoscope disc to animate a learned concept. • Understand that good planning is an important part of inquiry, experimentation, design, and development of human made items. 	<p><i>Teacher will need:</i></p> <ul style="list-style-type: none"> • K'NEX Phenakistoscope model • Pre-printed copies of the fish and bird illusion disks. <p><i>Students will need:</i></p> <ul style="list-style-type: none"> • Parts and building instructions for the K'NEX Phenakistoscope • Soft, Rubber Bouncing Ball (1" minimum diameter) • Drawing tools • Pencils, colored pencils, rulers, etc. • Pre-Printed templates. • Copies of all Student Response Sheets and forms for inclusion in students' Design Journals 	<p><i>Materials for stop motion models:</i></p> <ul style="list-style-type: none"> • K'NEX Figures • Modeling clay • Colored Paper • Other materials at the discretion of the teacher. • Paper and drawing tools for flip book creation. (Extension)





Process

Engagement

1. Use the pre-built model of the K'NEX Phenakistoscope, with the discs that illustrate a person walking and a horse running.
 - a. Ensure that students sit within visual range of the K'NEX Phenakistoscope and that they can see through the apertures on the front disk of the model.
 - b. Demonstrate the model for a small group of students by spinning the device in a clockwise direction at a rate of about 20 – 30 revolutions per minute. The illusion works best when students are within 1-2 feet of the device. Ask students to describe what they see. In addition to the motion, students may realize the image's depth of field changes. This change is dependent on the distance they are from the device and the perspective of individual students (whether they are directly in front of the device or not).
 - c. Challenge students to explain why this phenomenon occurred. They should be able to access prior knowledge from their experiences with the Spinning Disks and Thaumatrope to help with their explanations.
 - d. Inform students that this model demonstrates how a series of individual images can produce the illusion of motion by a process called stop action animation. The principle behind this motion toy of the 1800s is considered to be one of the precursors of animation and the film industry. The sequence of images on the phenakistoscope is replaced by a series of frames that are found on film.
2. Lead a discussion to introduce animation and determine students' prior knowledge of animation. Ask students to tell you what animation is. What types of things have they seen that are animated? They may mention cartoons, films, TV commercials, etc. Ask them what makes the items they have listed animated. They may describe animation as a series of drawings that are seen so quickly that the items on the screen move.

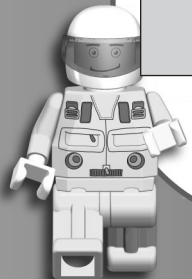
Students may also mention seeing animations of simple figures or clay animals that move as if they were alive. These are examples of stop action animations. A rigid, but jointed figure or clay model is photographed over and over again in a variety of positions as it completes movements. When the images are sequenced and played back on film, the figure or clay models appear to move and complete tasks. These animations require exacting camera work and a great deal of patience. A series of actions could include hundreds if not thousands of individual images to produce the illusion of smooth motion.

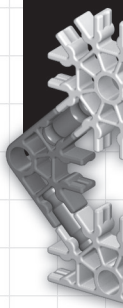
Listen to student's responses, ask questions for clarification of their ideas, and clarify their understanding of animation with information you present.

3. Introduce animation as much more than a series of drawings or stop action images.
 - a. First is the concept for the animation. Will it be a cartoon with a theme, a commercial for new blue jeans, or a public service announcement to encourage recycling? This is the conceptualization phase of the animation process. The concept will drive the rest of the animation process.
 - b. Storyboarding is a natural next step in the animation process. This is the opportunity to lay out the sequence of events that will make up a scene of the animation. The storyboard is a carefully planned series of rough sketches that portray the concept for the animation. In some sense, the story board looks like a rough draft of a comic book. Individual frames with rough sketches and lots of notes.

TEACHER'S NOTE:

- Additional information related to animation and storyboards can be found on the Internet. Use keywords: animation, animation storyboards, etc. This site provides basic information and examples of storyboards: <http://accad.osu.edu/womenandtech/Storyboard%20Resource/>.





4. Assign students to explore vocabulary related to animation. They should familiarize themselves with the terms: inbetweens, freeze frames, stretching and squashing as they relate to animation.
 - **Inbetweens:** the frames that are designed between two slides of an animation to ensure the final animation shows smooth motion. These inbetweens usually show intermediate steps in the motion being shown.
 - **Freeze Frames:** several identical frames together in an animation to emphasize that an object has stopped moving.
 - **Stretch and squash:** In real life pliable things (i.e., people, animals, rubber items, etc.) stretch and squash as they move, fall, or hit the floor. In order to make animations realistic, the animator must stretch items some of the time and squash them at other times. For example, a rubber ball's shape should be stretched slightly as it falls, squashed when it hits the floor, and stretched again as it bounces upward.

As students search for information they should include the word animation in their key words: animation inbetweens, animation stretch and squash, etc.

Exploration

1. Students will complete the Introduction to Simple Animation Student Response Sheets based on the information and vocabulary presented in the Engagement section of this lesson and their own research.
 - The Introduction to Simple Animation Student Response Sheet allows students to demonstrate their knowledge of vocabulary and basic concepts.
 - Understanding the Squash and Stretch Animation Technique Student Response Sheet includes an experiment students will complete to compare squash and stretch animation techniques with reality. Students will need soft rubber balls for this experiment.
 - Storybook Practice SRS provides students with a set of 8 empty storyboard frames and another set of randomly sequenced images of a K'NEX Figure that were taken as it was making a forward roll. Students will cut out the images of the K'NEX Figure and sequence them on the storyboard correctly to demonstrate a forward roll.
2. Students will construct the K'NEX Phenakistoscope model using the building instructions provided. When the model is completed, have students experiment with the walking person and running horse disks. Instruct students to record their observations on their Daily Research and Design Log.
3. Allow students to share their experiences as part of a class discussion. Was their phenakistoscope a success? How close were they to the model when they saw the clearest animation? What did they learn about animation as they observed their disks?
4. Students will complete the Spinning Yarns Animation Challenge Design Brief. Discuss the Design Brief and the criteria for the challenge with students.
 - Introduce the Student Response Sheet entitled Spinning Yarns Challenge Design Brief. Review the Design Brief in detail with the students.
 - Introduce the Design Process Guide to students. Explain that students will use the Design Process Guide to direct their activities while working on the Spinning Yarns Challenge.
 - Students will demonstrate their understanding of the Spinning Yarns Challenge by completing the first page of the Design Process Guide. Review each team's responses to ensure they understand the challenge and the criteria before allowing the team to continue.
 - Inform students that they will complete a Daily Research and Design Log sheet.
5. The most difficult task for students will be the selection of a concept they will use as they develop their phenakistoscope disk. They may choose:
 - To create a disk to present something they learned during their work with the K'NEX Education Energy, Motion and Aeronautics Set.
 - A concept from one of their other classes.
 - An action they complete in math, science, or technology. An insect landing on a flower and departing, a math problem being solved, a saw cutting a board, a robot walking, etc.

TEACHER'S NOTE:

This activity can be completed in a variety of ways depending on the resources available in your classroom.

- Simple drawing techniques
- Digital Cameras: if the technology exists in your classroom, students can use physical models or claymation to produce a sequence of stop action photos that can be cut out and attached to a phenakistoscope disk.

6. After completing the storyboard stage of design, students will transfer the storyboard images to the Student Response Sheet that includes the storyboard template.
7. Students should attach their completed disk or disks to the Phenakistoscope, and test to ensure that the disk produces the anticipated animation effect. If not, students should refine their designs to make sure the disk works properly.

Explanation

Assign teams to design a presentation and demonstration that will explain their challenge solution to the class. *The presentation should include:*

- An oral description of how they designed and constructed their disk(s)
- Visual aids
- A demonstration of their disk(s)

Student Reflection

Students will self-evaluate their challenge solutions based on the criteria provided in the rubric for this activity. Additionally, students will complete a Teamwork and Self-Assessment Form to assess their individual efforts and team's efforts on the challenge activities.

TEACHER'S NOTES:

- Give the Spinning Yarns Assessment Rubric to students so they can complete a self-evaluation of their work.
- Collect the rubrics and review each. The rubric score and your evaluation will make up a portion of the assessment data for this lesson.
- Provide students with a Teamwork and Self-Assessment Form and review the form with students before they fill them out.

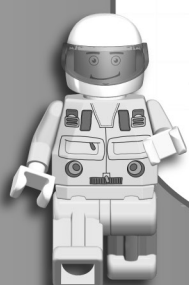
Evaluation

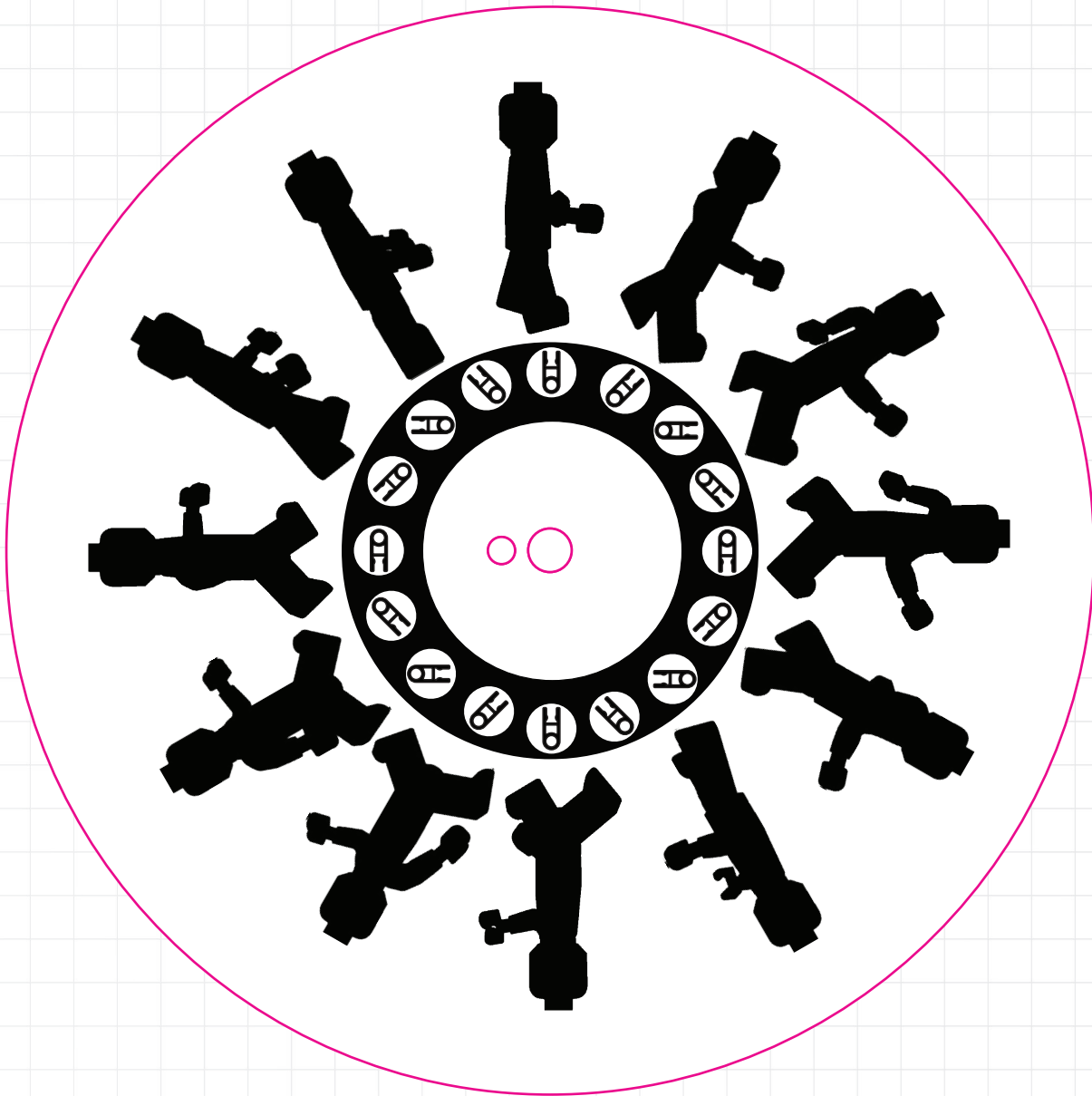
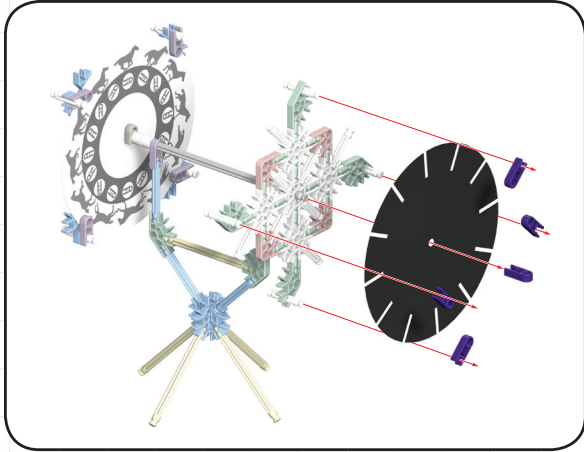
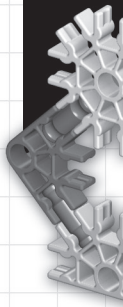
You may use some or all of the following to evaluate student's performance:

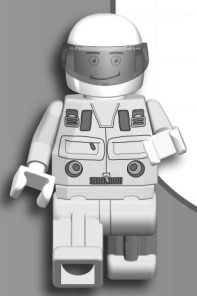
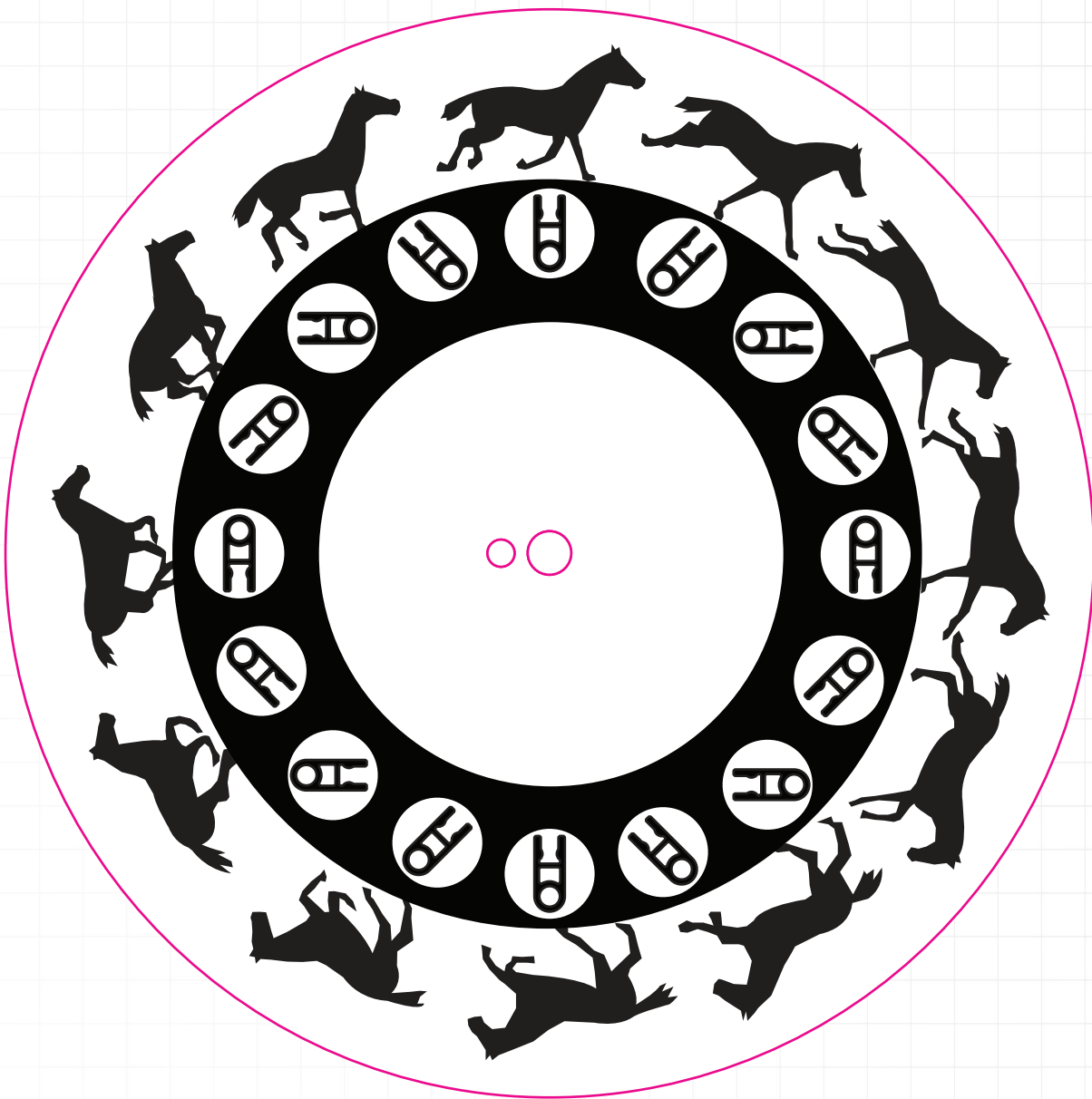
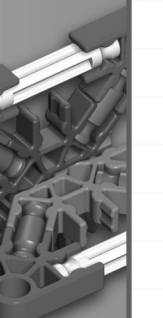
- Spinning Yarns Assessment Rubric
- Introduction to Simple Animation Student Response Sheets
- Presentation of the Spinning Yarns Animation Challenge Solution
- Daily Research and Design Logs
- Storyboard Disks Prepared by Students
- Design Journal

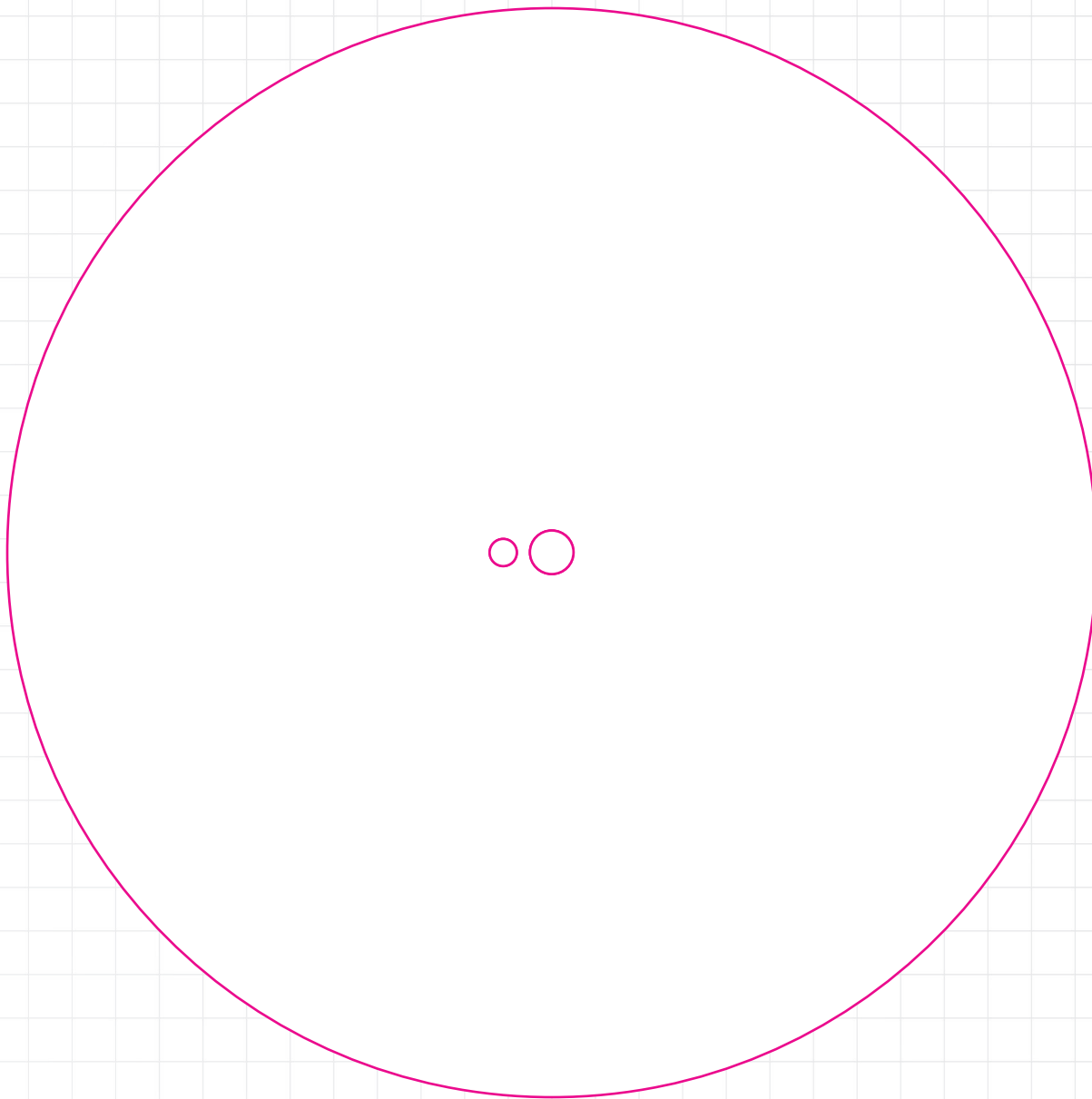
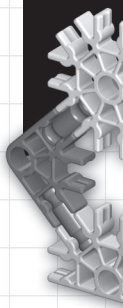
Extensions

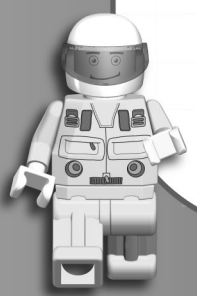
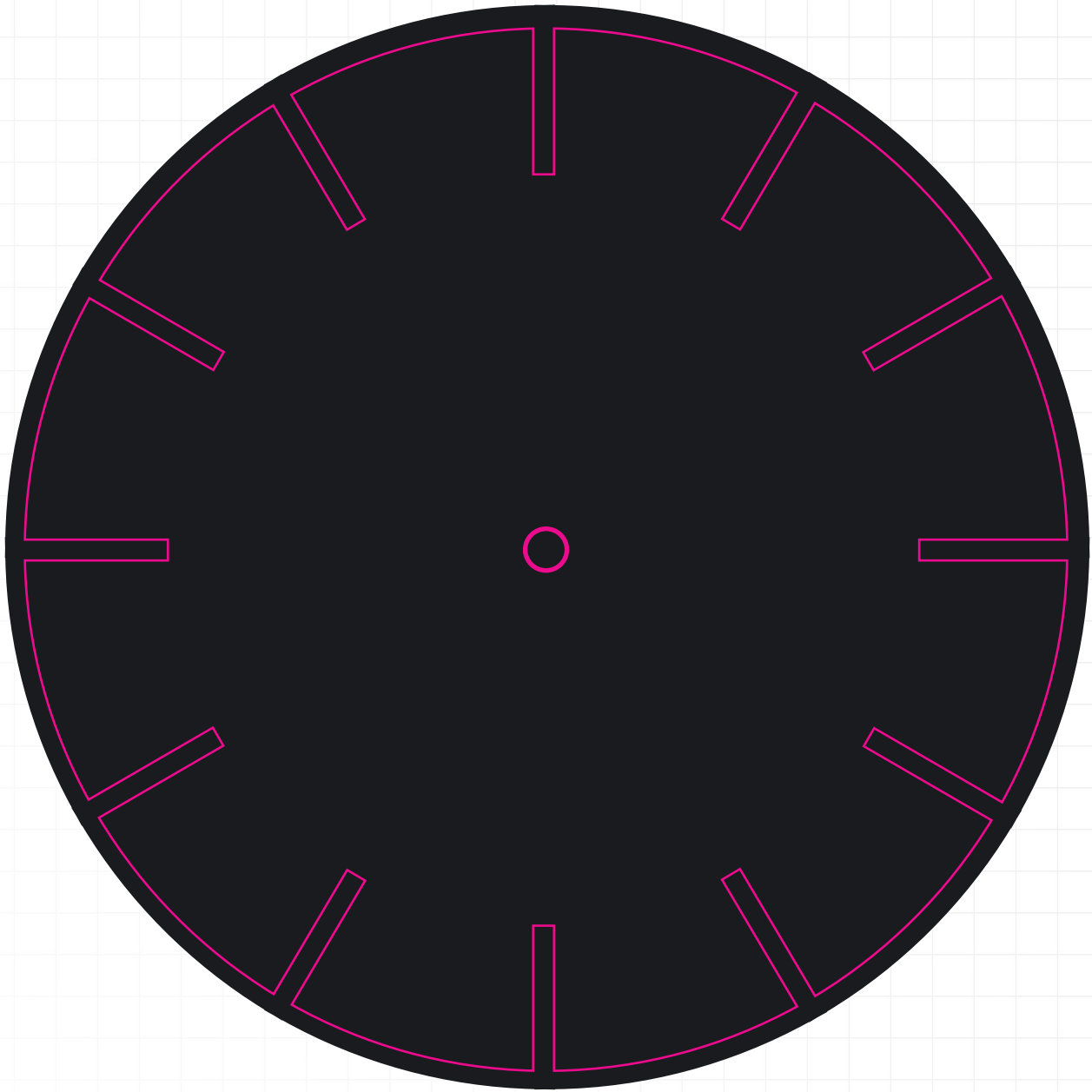
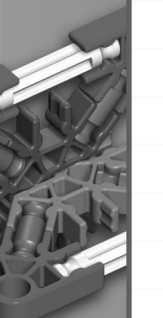
1. Investigate the early history of animation by researching zoetropes and designing and developing a working zoetrope model and strip of images. Students must document their work in their Design Journal.
2. Develop a further understanding of basic animation, illusions, and film making through the creation of a flipbook. They will follow the process of conceptualizing an idea, building a storyboard and completing the flip book. Encourage students to design flip books that can be shared with younger students. Students must document their work in their Design Journals.











Introduction to Simple Animation

Describe stop motion animation in your own words.

How does stop motion animation relate to the optical illusion you witnessed using the phenakistoscope?

Define the terms listed below. Be sure to write the definitions in your own words.

Kinestasis -

Frame -

Frame Rate -

Scene -

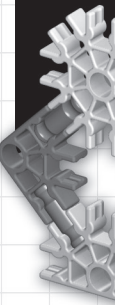
Aperture -

Depth of Field -

Storyboard -

Squash and Stretch -

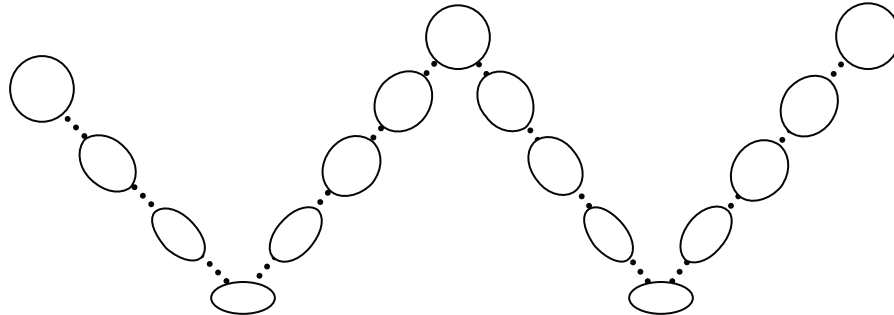
Inbetweens -



Understanding the Squash and Stretch Animation Technique

Squash and stretch are techniques used in animation to make an animated sequence more realistic. Squashing and stretching exaggerate the movement of the object in the animation.

Squashed & Stretched Bouncing Ball Example



To see how this is different from the way a real object bounces, do an experiment using a small rubber ball. Observe the ball as you bounce it on the floor. Carefully observe ball's path and the shape of the ball as it falls, hits the floor, bounces, and then rebounds into the air. In the space below, draw what you observed as the ball makes a single bounce.

Real Bouncing Ball Observation

Was there a difference between what occurs in the animated squashed and stretched example and what you observed with an actual rubber ball? If so, describe the difference?






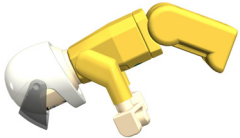
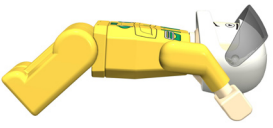

If you were to use this technique to animate a person jumping into the air, describe how you would draw a person as they prepared to jump into the air, and what they would look like after leaving the ground.

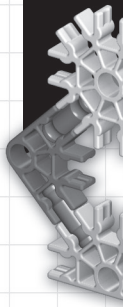
Storyboard Practice

Cut out the images or 'frames' (of the figure) and arrange them in the proper order on the storyboard to illustrate the K'NEX Figure completing a forward roll. In the space provided below each frame of the storyboard, label what is taking place in the frame. Identify which frames are: start frame, end frame, inbetweens, and freeze frames.

Frame 1 _____	Frame 2 _____	Frame 3 _____	Frame 4 _____
Frame 5 _____	Frame 6 _____	Frame 7 _____	Frame 8 _____

Carefully cut out the frame images below. Arrange them in the correct order on the storyboard before gluing them down.



Spinning Yarns Animation Challenge

Design Brief

The Challenge

Your team has been hired by a local educational animation company, EDUCANI, to create a short animated scene of a scientific, mathematical, or technological principle.

Your Task

- To design and create a disk for use in your phenakistoscope to demonstrate something you have learned during the course of this school year.

Rules & Constraints of the Challenge

- Create your disk using the skills and processes learned during this lesson.
- Phenakistoscope disks must be created to fit properly onto your K'NEX model.
- Use the paper or cardstock provided by your teacher.
- Conceptualize an idea and create a storyboard to present the scene.
- Use and follow the directions found in the Design Process Guide as you design and create your disc.

The Process

This activity will include the following phases:

- Phase 1 – Class Exploration
 - Introduction to Simple Animation Student Response Sheet
 - Construction of K'NEX Phenakistoscope Model
 - Experimentation Using Pre-Printed Disks
 - Spinning Yarns Animation Challenge Design Brief introduction by Teacher

(Follow the steps on the Design Process Guide beginning on the next page to direct your team through the remainder of the challenge.)

- Phase 2 – Independent Exploration
 - Understanding the Problem
 - Design Process Guide Student Response Sheet
 - Brainstorming & Ideation
- Phase 3 – Team Exploration
 - Explore Possibilities and Develop a Plan
 - Pro and Con Chart
 - Implement Your Plan
 - Testing and Refining the Plan
- Phase 4 – Classroom Presentations
 - Team Phenakistoscope Disk Demonstrations
- Phase 5 – Wrapping It Up
 - Reflection/Evaluation
 - Spinning Yarns Assessment Rubric
 - Teamwork & Self Assessment Forms

Note: Complete a Daily Research and Design Log each day during this challenge.

Design Process Guide

Understanding the Problem

To demonstrate your understanding of the challenge, complete the following.

The Challenge:

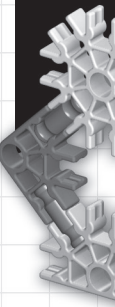
Restate the challenge, in your own words.

Criteria:

Describe what your solution needs to do and any specific performance levels that it needs to meet, in your own words.

Constraints:

Please describe the limitations you have been given for this challenge.





Brainstorming and Ideation

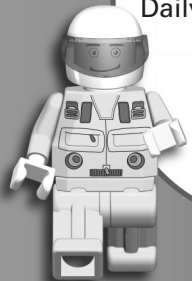
Brainstorm possible concepts that can be used to solve the challenge and use the storyboard template to draw a rough sketch of the images you would like to include on the new disk.

Concepts: _____

Story Board Template

Frame 1 _____	Frame 2 _____	Frame 3 _____	Frame 4 _____
Frame 5 _____	Frame 6 _____	Frame 7 _____	Frame 8 _____
Frame 9 _____	Frame 10 _____	Frame 11 _____	Frame 12 _____

Develop an experiment that will allow you to test the disk when it is complete. The experiment should allow your team to verify the new disk presents the desired illusion. Keep a record of your work in your Daily Research and Design Log.



Exploring Possibilities and Developing a Plan

Fill out the Pro and Con Chart provided by your teacher. Describe each of the team members' concepts and storyboard ideas. List advantages and disadvantages of their concepts, storyboard ideas, and experimental plans in the space provided. This information should be used to develop your team's final plan.

Once evaluation of team members' ideas is complete, develop one final plan. This plan can be based on one team member's idea or a combination of elements from each of the ideas your team offered. Put a detailed explanation of the final plan in your Design Journal. Include the plan for your team's experiment. Your team should then develop one final, complete storyboard that will be the basis of your disk.

Implement Your Plan

With your teacher's approval, put your team's plan into action.

Testing and Refining the Design

When the disk is ready, begin testing its performance and collecting data. As you experiment, refine your Phenakistoscope to improve its performance. Refine the disk as needed or produce a new disk if the illusions are not crisp and clear.

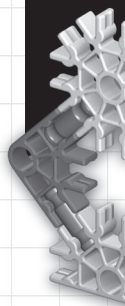
Team Presentation

Your team will present and demonstrate the disk to the class.

Include:

- Demonstrations of the phenakistoscope with the disk the team created.
- Describe what makes the illusion caused by the phenakistoscope possible.

Collect feedback from your classmates on the animation that you created. Can they identify the principle or concept that has been animated? Is the animation crisp and clear to the observers? Record their feedback on your Daily Design and Research Log, and include your thoughts on other models you observed as well.

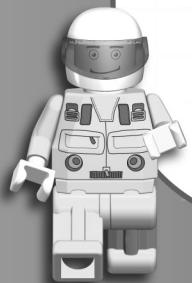


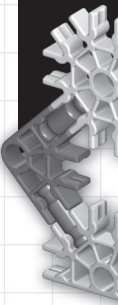
Self Reflection/Evaluation

Complete the Spinning Yarns Assessment Rubric to provide your impression of how you did with this lesson.

Spinning Yarns		Assessment Rubric		
Circle Responses for each:	Excellent	Good	Acceptable	
Learning Journal	Student Response Sheets and journals completed in their entirety with no spelling or grammar errors. 8	Student Response Sheets and journals completed in their entirety with a few (2-4) spelling and grammar errors. 6	Student Response Sheets and journals completed in their entirety with many (5 or more) spelling or grammar errors. 4	
Design & Construction	Your disk is very neatly designed and drawn. The disk meets or exceeds expectations related to the criteria and constraints listed in the design brief. 6	Your disk is neatly designed and drawn. It meets expectations related to the criteria and constraints listed in the design brief. 5	Your disk is designed and drawn and meets criteria listed in the design brief. 4	
Story-boarding	Storyboard completed very neatly with all appropriate information provided to explain what is taking place in each frame of the scene. 8	Storyboard completed neatly with appropriate information provided to explain what is taking place in most frames of the scene. 6	Storyboard completed with all appropriate information provided to explain what is taking place in some frames of the scene. 4	
Teamwork/ Work Ethic	Cooperates and interacts well with others and uses excellent work ethics in class. 3	Cooperates and interacts well with others and uses good work ethics in class. 2	Usually interacts well with others and usually maintain good work ethics in class. 1	
Total Score	_____ /25			

Teacher Comments: _____





Reflection on the Activity

Now that the last illusions have been demonstrated and your presentation has been a success, your teacher will provide you with a Teamwork and Self-Assessment Form. Use the form to reflect on your team and your contributions to your team's efforts.

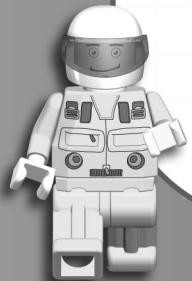
Extension Activities

1. Learn about other early animation mechanisms and motion toys by constructing a zoetrope. Research the zoetrope and investigate ways to construct a working model. The best strategy would be to use one of the previous models from this set as the foundation for your zoetrope. You may use pieces from your K'NEX Set along with card stock, cardboard, and other materials with the approval of your teacher. You may use the animation storyboard you just created to prepare the strip of images for the zoetrope or create an entirely new one of your own choosing. Demonstrate your model to your teacher and classmates.
2. Research how flip books can be used to create a stop action animated sequence. Create your own flipbook based on something from your own imagination or a book that you have recently read. Follow the same process used to create your phenakistoscope disk: conceptualize an idea, build a storyboard, and complete the flip book. Demonstrate your flip book to your teacher and classmates.



Glossary of Terms

- Acceleration** – Occurs when there is an increase in the speed/velocity of a moving object or a change in its direction of travel (i.e., circular motion).
- Aileron** – An adjustable control surface found on the trailing edge of an aircraft wing used to control the air stream for banking, rolling, and balancing an airplane.
- Airfoil** – Refers to any part of an aircraft that acts to create or provide lift or control.
- Air Friction** – The force that air exerts on an object that is moving through it.
- Angle** – The difference in direction between two lines or surfaces measured in degrees.
- Angle of Attack** – Refers to the angle of a wing to the air flowing over that wing or its aileron.
- Apogee** – Refers to the point at which a projectile is the is farthest from horizontal plane from which it was launched. This is also the point where the projectile ceases to move in an upward direction and begins its downward motion.
- Aperture** – A fixed or adjustable opening or hole that allows light to pass through an object.
- Ascent** – Refers to the movement of any object in an upward direction.
- Atmospheric Drag** – Refers to the force or forces that oppose the motion of an object through a liquid or gas.
- Ballistics** – The science that investigates the motion of projectiles as they are propelled through the air.
- Bernoulli's Principle** – The scientific principle developed by Daniel Bernoulli to explain what occurs as air travels faster across a surface, which reduces the air pressure against that surface to produce lift.
- Centrifuge** – A mechanical device that rotates rapidly to simulate the effects of gravity or acceleration on humans, which can also be used to separate substances of different densities.
- Centrifugal Force** – An apparent or fictitious force that seems to pull a rotating object away from the center of rotation.
- Centripetal Force** – Refers to the real force that tends to move or pull an object toward the center of rotation.
- Contrast** – The effect created by arranging colors, shades, or textures that differ from one another next to each other or opposite each other to emphasize each or light and dark areas.
- Depth of Field** – Refers to the range of space from a viewing aperture to the target object or image.
- Depth Perception** – The ability to observe the distance to objects in 3-dimensional space and to see the environment in 3 dimensions.
- Descent** – Refers to the movement of an object in a downward direction from a higher position.
- Drag** – The resistance caused by friction experienced by a moving object as it travels through air or fluids.
- Elevators** – Horizontal, adjustable control surface or surfaces found on the tailplane of an aircraft. They are used to control the up-and-down movement or pitch of the aircraft.



- Elevons** – An adjustable control surface(s) of an aircraft that functions as both an elevator and an aileron, typically found on the wing or wings of an aircraft without a tailplane.
- Fatigue** – Any temporary decrease in the capability of body parts, such as the eye, to operate in a normal way usually due to continuous or excessive activity or stimulation.
- Flap** – Horizontal, adjustable control surface or surfaces found on the trailing edge of a wing or airfoil used to create lift or drag typically used to assist take-off and landing.
- Force** – A push or pull that alters the position of an object.
- Frame** – A single picture or image that is used in the production of motion pictures or animated sequences.
- Frame Rate** – The number of individual images or frames displayed in a given time period to produce an animated or motion picture sequence.
- Freeze Frame** – A repeated image or picture in a moving picture that gives the illusion of a no movement for a brief or extended period of time.
- Fuselage** – The main body of an airplane, often containing a cockpit and seating areas, to which the wings, tailplane, etc are attached.
- Fusion** – The blending or combining of two or more materials, images, or ideas to create a single material, image, or idea.
- Galileo's Law of Falling Bodies** – This law states that a falling body will increase in acceleration due to gravity at a rate of 9.8 meters per second during each second that it falls until it reaches its terminal velocity.
- G-Force** – A measure of the force caused by acceleration. A force of 1 g is equal to the force of gravity. An amusement park ride may produce a 3 g force due to its acceleration which is three times the force of gravity.
- Gondola** – A moving compartment suspended from a mechanical or transportation device for carrying passengers or instruments, often found on an airship, balloon, ski lift, or centrifuge.
- Gravity** – A force of attraction exerted by objects on one another. Massive objects like planets, suns, etc. have sufficient gravity to noticeably affect one another and objects near their surface.
- Illusion** – Physiological stimulus that creates a false impression that misleads the mind or the senses, typically the visual senses, into believing something that is not real is taking place or exists.
- Inbetweens** – The intermediate frames of a motion picture or animated sequence that are between two images causing it to appear that first image in the sequence is evolving or moving smoothly into the second image.
- Inertia** – The tendency for an object to remain at rest if it is not moving and to remain in motion if it is moving unless they are acted upon by some outside force.
- Initial Velocity** – Refers to the rate of speed of an object prior to being acted upon by an outside directional force.
- Interaction** – The combined effect that occurs when two or more objects that influence one another, often causing an action or reaction.
- Kinestasis** – The name for a stop motion film or animated sequence that contains rapidly moving scenes or images often set to music.
- Lift** – The forces that oppose weight, causing an aircraft to leave the ground, stay in the air and increase in altitude.



Load – The total measure of force (weight) exerted upon an object.

Mass – The measurable property of an object created by the amount of matter they contain combined with the influence of gravity on that matter.

Momentum – The measure of a moving object's ability to exert a force on something in its path. The momentum (p) of a moving object is equal to its mass times its velocity ($p = mv$). (Note: to design and layout: The letters of the formula must be lower case.)

Motion – The movements of an object that result in a real or perceive change of position.

Motion Toy – A device, relying on the stroboscopic effect, used to demonstrate the existence of persistence of vision, often for the purpose of visual entertainment.

Newton – The unit of force that measures the force required to accelerate an object weighing one kilogram to a speed of one meter per second per second.

Newton's Law of Universal Gravitation – The scientific law developed by Sir Isaac Newton that states that there is a force of attraction between two or more objects that is proportional to the combined masses of the objects as well as inversely proportional to the square of the distance between those objects.

Newton's Laws of Motion – The set of three laws developed by Sir Isaac Newton that define the relationship between force, motion, acceleration, mass, and inertia as they relate to any object in the universe.

Newton's First Law of Motion – Also known as the Law of Inertia, it states that an object at rest will remain at rest and that a body in motion will remain in motion unless acted upon by an outside force.

Newton's Second Law of Motion – This law states that any force acting on an object is equal to the acceleration of the object times its mass ($F=ma$).

Newton's Third Law of Motion – This law states that for every action there is an equal and opposite reaction.

Optic Nerve – The cluster of nerve fibers that transmit visual light signals from retina to the brain's visual cortex.

Optical – Related to the science of optics, it refers to the ability to sense or produce light that is in the visible range.

Optical Fusion – Refers to the process where images from each eye combine to form a single visible image of our surroundings.

Optical illusion – Refers to a visual phenomena where the eye perceives an images that differ from reality.

Parachute – A device used to reduce the velocity of a person or object in motion allowing that person or object to come to a safe landing or stop.

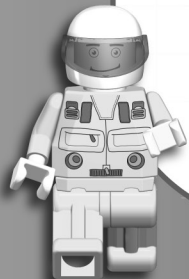
Parabolic arc – Refers to the path that a projectile travels which typically has the overall shape of a parabola.

Perception – A physiological process using one or more of the senses to detect and interpret information about the surrounding environment.


Persistence of Vision – The illusion of movement that occurs when viewing motion pictures due to retinal retention.

Pitch – The rotational movement of an aircraft where one end of the aircraft rises up, front or rear; this motion is controlled by the elevators.

Projectile – Any object that is capable of being propelled forward, typically through the air, when acted upon by an outside force.



- Range** – The farthest distance to which an object can effectively be propelled based on a given force and direction.
- Rate of Descent** – Sometimes referred to as, sink rate, the rate of descent is the speed or velocity that an object decreases in altitude.
- Retina** – The light-sensitive membrane in the back of the eye that receives an image from the lens. It sends this image through the optic nerve to the brain.
- Retinal Retention** – The result of the retina of the eye retaining an image of some form of visual stimulus for a brief moment after the stimulus moves from its original position.
- Roll** – Refers to the motion of an aircraft where one wing rises while the other wing falls, controlled by a set of control surfaces called ailerons.
- RPM (Revolutions Per Minute)** – This is a measurement of the rotational speed of an object or device taking place over a period of 60 seconds.
- Rudder** – A vertical, adjustable control surface used to control the left-to-right or right-to-left motion of any form of transportation. On an aircraft, the rudder is typically located on the vertical stabilizer, which is a part of the aircraft's tailplane.
- Scene** – The sequence of action that is typically made of a series of frames related to motion pictures and animation.
- Sensory Receptors** – The part of an organism's sensory system that responds to a stimulus by sending signals to the brain.
- Shade** – Refers to the lightness or darkness of a color.
- Spatial Relations** – A term used to specify where an object is located within a space, or the way in which two or more objects who occupy the same space relate to one another.
- Squash and Stretch** – Refers to a common animation technique that makes the actions taking place appear to be more realistic by exaggerating the movements of the object.
- Stop Motion Animation** – Also known as frame-by-frame animation, Refers to an animation technique where an object is drawn or photographed with slight changes in position or movement one frame at a time. When a viewer sees the frames switched quickly, one after another, they observe the illusion of movement.
- Storyboard** – Refers to a set of drawings or photographs arranged in sequence that outlines or summarizes the actions that will take place in a movie or animated sequence.
- Stroboscopic Effect** – Refers to a visual phenomenon caused by persistence of vision that makes a series of objects in continuous motion appear to be slow moving, or even stationary.
- Surface Area** – Refers to the area of the surface on a two-dimensional object that is determined by multiplying length x width. When referring to a three-dimensional object it is the total of the combined areas of all surfaces of the object.
- Terminal Velocity** – The constant velocity a falling body reaches when air resistance equals the force of gravity pulling on the object.
- Thaumatrope** – A device used to create the illusion that two separate images on opposite sides of the device become one single image when rotated rapidly.
- Thrust** – Refers to the force needed to move an object in the desired direction of travel.



Trajectory – Refers to the curved path that a projectile takes through the air or space after a force propels the projectile in a specific direction.

Velocity – Refers rate of change in position of an object that is in motion, usually described in meters per second.

Visual Cortex – The specific part of the brain responsible for receiving and processing nerve impulses sent from the eye.

Weight – The force acting on an object that must be overcome in order to produce lift.

Wing – The lift producing part of an aircraft typically attached to the fuselage.

Yaw – Refers to the rotational motion of an aircraft caused by changes in the position of the rudder.

