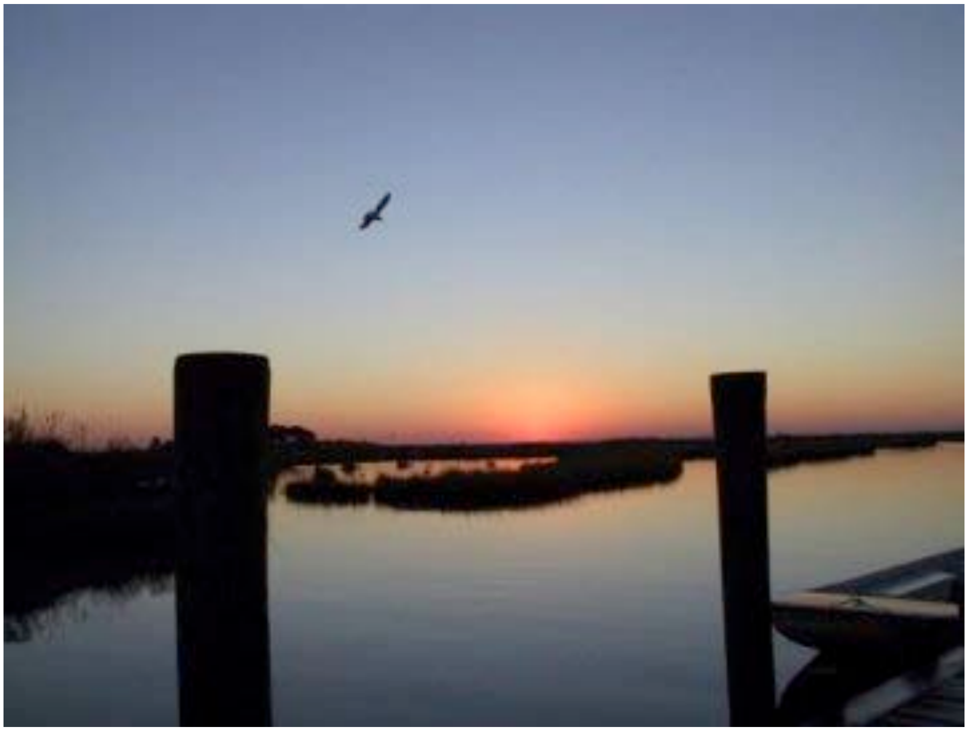

SAVE THE SEA BIRDS
STEM TEACHING KIT

An Introduction to Solar Energy, Force, and Motion

Teacher's Guide

Developed through funding from NSF ITEST award # 10-29724 and #12-47287.

This curriculum and all embedded links can be found at
www.auburn.edu/~cgs0013/ETK/SaveTheSeaBirdsETK.pdf

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Unit Overview

Introduction and Background

Students' alternative conceptions of energy, force, and motion begin at a young age and can easily persist into adulthood. We use the terms energy and force non-scientifically in everyday language such that the scientific meanings are often obscured. What comes to children's minds when they think about energy, force, and motion? Perhaps they think of a friend forcing them to do something, or perhaps having enough energy to get through a school day. In addition to the many non-scientific uses of the words, children often form their own scientific theories about the way the world works. They think that forces are necessary to keep objects in motion, that stationary objects are devoid of forces, and they do not understand that forces come in pairs. They think that when a force is used up, motion stops. Energy is often confused with force, and energy is seen as a fluid or an ingredient that flows from one place to another to make things work. They think that energy can be used up, and that it is required for motion. Without explicit interventions designed to target these alternative conceptions, chances are that they will persist into adulthood.

This STEM Teaching Kit is designed to help students with science concepts related to energy, force, and motion as well as teach them the basics of engineering design. They also come away with a sense of how engineers are people who design solutions to real-world problems.

In the case of the Save the Sea Birds, the broad context is oil pollution and its effect on sea birds. Students learn that crude oil is mined in the Middle East, West Africa, and Asia as well as here at home. It is pumped from underground on dry land as well as under fresh and salt water. Nearly 50% of crude oil is turned into gasoline for automobiles. The rest is used for heating and cooking and jet fuel. The environmental impacts of oil mining are broad. One severe impact occurs when crude oil accidentally leaks into water. Oil tankers can leak, as evidenced by the Exxon Valdez spill in 1989 off the shores of Alaska, but offshore oil rigs can explode, as evidenced by the 2010 BP Deepwater Horizon disaster in the Gulf of Mexico. The ecological impact of oil spills such as these is disastrous. Marine life is especially affected- fish, mammals, plants and sea birds as well as small creatures at the bottom of the food chain. Students are asked to consider what might reduce the chances of an oil spill happening again. Students learn about how solar energy has been used to create electricity for many things, including cars and airplanes. At this point, these cars and airplanes are for demonstration purposes, and are not effective for transporting more than one person at a time. However, engineers are working to improve the solar energy technology so that it is a feasible method of providing energy for mass transportation. When this happens, the need to drill deep under the ocean floor can be reduced, and the Sea Birds will be spared. In the Save the Sea Birds, students are tasked with the challenge of creating solar-powered transportation on a small scale.

Top 10 Oil Spills Article

http://www.circleofblue.org/waternews/2010/world/bottomless-precedent-bp-gulf-gusher-endemic-to-global-oil-problems/

Design-based science learning reflects the social constructivist theory of learning by having students work collaboratively in groups to solve problems and construct solutions, but they learn certain skills through the modeling of their teacher. When students are involved in engineering design-based activities, they are not being told what to do- they are creating and innovating, making decisions with their peers based on their underlying knowledge. The role of the teacher is to guide students through their decision-making processes and model new skills to be learned.

Through engineering design activities, students should be able to create their own knowledge of scientific principles through active manipulation and testing of materials and ideas. Students come to school with their own understandings about how the world works and their understandings may not resemble those of scientists. The teacher must provide the opportunities for students to challenge and internally modify their prior beliefs. Social constructivists see that the role of the teacher is to help learners construct their knowledge through scaffolding and coaching, and they see that learners construct meaning through active engagement, not passive listening. Learners use and apply their knowledge to carry out investigations and create artifacts that represent their understanding. Learners work within a social context as they use language to express and debate their ideas. Learners engage in authentic tasks that are relevant to them and connected with their lives outside of the school setting.

Teaching Strategies

Design-Based Science

In design-based science activities, the teacher does not tell the students what to build. Instead, the teacher steps back allowing the students to take the primary lead in their own learning. Problem solving through authentic tasks that relate to students lives should serve to increase student interest and deeper conceptual knowledge.

Whole-class demonstrations

While you may be tempted to jump into the design activity and skip over the demonstrations, please do not. The demonstrations provide the cognitive scaffolding necessary for students to link the design challenge with the complex science of energy and energy transformations. They present students with cognitive dissonance through discrepant events. They allow students the opportunity to face their conceptions of energy and refine any incorrect ones, which is imperative for the success of this STEM Teaching Kit. Without the demonstrations and discussions that surround them, students will take away a fun activity that may or may not help them understand the science, or understand what engineers do. With the demonstrations, students will gain increased conceptual understanding about solar energy, force and motion.

Cooperative Learning Groups

Ideally, students should be placed in small groups of three or four. Each student should be assigned a role in the group, such as the material collector or the light controller. Either allow students to pick their own groups, or assign them based on what you know about how your students get along and work together. Since students will be working with the same group members for the duration of this unit, it is best if the students like one another and work well together. Have students sit together with their group members from the beginning of this unit, ideally around a table where they can see and talk to one another.

Edmodo.com

This website is an educational social networking site. It is generally approved by administrators for use in schools. Students will need to make an account and you will have to give them a code to join the group (the class) in the discussion. After students have joined, you can have them complete an online storyboard. You can do this in addition to the poster-based storyboard. Some ideas for using Edmodo.com for this unit include:

- Having students find definitions of keywords or related concepts and posting them to the site for the whole class to see.
- Asking students to write questions or present ideas that they learned from the lessons.
- Posting questions to the class to gauge their understanding of the concepts being covered in each lesson (formative assessment tool).
- The possibilities for using this free website are endless!

Assessment

In the *Save the Sea Birds* STEM Teaching Kit, assessment is an integral part of instruction and consists of two types:

A. Formative assessment – embedded within the lessons, providing continual feedback to the teachers and students for improving instruction. In this unit, formative assessments include:
    - Whole-group discussions involving students' predictions of what will happen during demonstrations and feedback from students/groups following each demonstration.
    - Measuring whether or not the design was sufficiently built to transport 'sea bird eggs' to a safer location.
    - Storyboarding during each lesson. A storyboard is like a comic strip in that it tells a story through drawings and words divided up into sections that flow logically. Each time students learn a new concept, do an experiment, create a design, or test a design, it should be recorded on the storyboard for teachers and students to see and comment on. Ideally, the storyboard would be mounted on the wall for easy viewing.

B. Summative assessment – an evaluation of cumulative performance, given as written tests before and after the unit to determine students' content knowledge gains on energy concepts. Teachers should have each student complete the "Force, Motion, and Energy Evaluation" at the start of the unit, collect the assessments, score them, but do not return or discuss them with the students. The "Force, Motion, and Energy Evaluation" instrument is based on misconceptions research and has been assessed for face and content validity, construct validity, and reliability. The same evaluation will be given to each student at the end of the unit. Collect the post-tests, score them, and compare each student's pre- and post-test scores. The assessment will provide the teacher with information about students' misconceptions about force, motion, and energy. For more information about this instrument and correct answers, contact Christine Schnittka at Schnittka@auburn.edu.

Safety Considerations

Caution students not to touch heat lamps during their work with solar panels. The surface of the heat lamp and surrounding dome can cause significant skin burns if touched during or immediately after use. If you use heat lamps with clamps, consider clamping them to ring stands or other stationary devices to reduce the need for handling them.

Technology

A computer with speakers, an LCD projector and screen will be needed to show the PowerPoint presentations and videos. If laptops or tablets are available, encourage the use of the social networking educational space, Edmodo. Go to www.edmodo.com and set up an account for yourself and a "space" for your students to dialogue with each other, share ideas, photos, videos, websites, etc. It's also a good way for you to post questions and encourage students to respond.

Correlation to Standards

The *Save the Sea Birds* STEM Teaching Kit is based on standards derived from the Next Generation Science Standards, the National Science Education Standards, the Benchmarks for Science Literacy, and Standards for Technological Literacy.

STANDARD	GRADE LEVEL	RELATIONSHIP TO SAVE THE SEA BIRDS
Next Generation Science Standards	Grade 4	4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another. 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents. 4-ESS3-1. Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.
Next Generation Science Standards	Grades 6-8	MS-PS3-5. Construct, use, and present arguments to support the claim that when the motion energy of an object changes, energy is transferred to or from the object. MS-ESS3-1. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes. MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

		MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.
Next Generation Science Standards	Grades 6-8	HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. HS-PS4-5. Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
National Education Science Standards	Grades 5-8	Physical Science Content Standard B 1. The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph. 2. Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways. 3. The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth. Science and Technology Content Standard E 1. Scientific inquiry and technological design have similarities and differences. Scientists propose explanations for questions about the natural world, and engineers propose solutions relating to human problems, needs, and aspirations. Technological solutions are temporary; technologies exist

		within nature and so they cannot contravene physical or biological principles; technological solutions have side effects; and technologies cost, carry risks, and provide benefits. 2. Perfectly designed solutions do not exist. All technological solutions have trade-offs, such as safety, cost, efficiency, and appearance. Engineers often build in back-up systems to provide safety. Risk is part of living in a highly technological world. Reducing risk often results in new technology. 3. Technological designs have constraints. Some constraints are unavoidable, for example, properties of materials, or effects of weather and friction; other constraints limit choices in the design, for example, environmental protection, human safety, and aesthetics. 4. Technological solutions have intended benefits and unintended consequences. Some consequences can be predicted, others cannot. Science in Personal and Social Perspectives Content Standard F 1. Human activities also can induce hazards through resource acquisition, urban growth, land-use decisions, and waste disposal. Such activities can accelerate many natural changes.
Benchmarks for Science Literacy	Grade 6-8	Chapter 4E 1. Energy cannot be created or destroyed, but only changed from one form into another. 2. Most of what goes on in the universe... involves some form of energy being transformed into another. Chapter 4F 1. An unbalanced force acting on an object changes its speed or direction of motion, or both. Chapter 4G 1. Electrical circuits require a complete loop through which an electrical current can pass. Chapter 8C 1. Transformations and transfers of energy within a system usually result in some energy escaping into its surrounding environment. Some systems transfer less energy to their environment than others during these transformations and transfers. 2. Different ways of obtaining, transforming, and distributing energy have different environmental consequences. 3. In many instances, manufacturing and other technological activities are performed at a site close to an energy resource. Some forms of energy are transported easily, others are not. 4. Electrical energy can be generated from a variety of energy resources and can be transformed into almost any other form of energy. 5. Energy from the sun (and the wind and water energy derived from it) is available indefinitely. Because the transfer of energy from these resources is weak and variable, systems are needed to collect and concentrate the energy.
National Council of Teachers of Mathematics	Grades 6-8	1. Understand both metric and customary systems of measurement. 2. Understand relationships among units and convert from one unit to another within the same system.

Standards for Technological Literacy	Grades 6-8	Standard 8 • Design is a creative planning process that leads to useful products and systems. There is no perfect design. Requirements for a design are made up of criteria and constraints. Standard 9 • 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. Standard 10 • Troubleshooting is a problem-solving method used to identify the cause of a malfunction in a technological system. Invention is the process of turning ideas and imagination into devices and systems. Some technological problems are best solved through experimentation.

Unit Summary

UNIT BIG IDEAS

- Energy exists in many forms and it is finite.
- Engineers use the engineering design process to solve real-world problems.

Learning Targets

Lesson 1-*Introduction to Engineering/Environment/Energy*

- Energy can be converted from one form to another.
- Engineers must identify the problem in order to solve it.

Lesson 2 – *Light Energy to Electrical Energy*

- Solar energy is a renewable alternative to fossil fuels, which are finite.
- A solar cell is a device that converts light energy to electrical energy.
- Different solar cells have different design advantages. For example, high voltage = high speed; high current=high torque.
- Engineers must research and understand the problems in order to solve them.

Lesson 3 – *Electrical Energy to Mechanical Energy*

- An electric motor is a device that converts electrical energy to mechanical energy.
- Gears can be utilized in different ways to provide certain design advantages.

Lesson 4 – *Friction*

- Friction can be measured and calculated.
- Friction can convert energy from useful forms into less useful heat and sound, but energy is always conserved. It is neither created nor destroyed.
- Engineers work within constraints (time, materials, space, money) and use scientific knowledge and creativity to design solutions to problems.
- Friction has constructive uses in designs.

Lesson 5 – *Engineering Design, Building and Testing*

- Engineering is an iterative process of designing and testing.
- Engineers must document their process of design and present their solution to the problem.
- Engineers redesign prototypes based upon their test data.

Each Lesson is designed for 70-80 minutes of instruction. Lessons do not necessarily correspond to a single day of instruction and may need to be adjusted depending on length of class periods.

LESSON 1

Introduction to Engineering and Energy

Learning Targets

1. Energy can be converted from one form to another.
2. Engineers must identify the problem in order to solve it.

Introductory Video

https://youtu.be/cH3ckeNMDRU

Purpose of the Lesson

1. To introduce students to the impacts that oil spills have on the environment, particularly concerning sea birds.
2. For students to form a concrete understanding of what energy is, how it is used, and how it is transformed.
3. To begin a storyboard-type poster for the unit.

Keywords

- Engineer
- Energy
- Potential Energy
- Kinetic Energy

Lesson Objectives

At the end of this lesson, students will be able to:

- Describe engineers' role in society.
- Explain why humans drill for oil.
- Explain how oil drilling has affected the environment (especially aquatic animal life).
- Brainstorm ways engineers might be able to reduce the need to drill for oil.
- Define energy as something that makes things happen or change.
- List different types of energy.
- Describe how solar energy can transform into electrical energy and then into mechanical energy.

Lesson in a Nutshell

1. Pre-assessment: Targeting prior knowledge and misconceptions. (10 minutes)
2. Introduction: What is engineering? (Discussion and/or use of PPT) (15 minutes)
3. Save the Sea birds: What is the problem? (Discussion and/or use of PPT) (15 minutes)
4. Demonstration #1- Matchbox car demonstration (10 minutes)
5. Introduce and begin storyboarding (25 minutes)
6. Wrap – up (10 minutes)

Background

Engineers are people who use science and math to solve real world problems. They can be thought of as inventors. They create designs that solve the problems of the world. A world without engineers would be difficult. There are engineers at this moment trying to solve problems such as cleaning up the ocean, improving the diagnosis and treatment of cancer, designing better cars, and even purifying water so that we could one day go to Mars! There are problems in the world that have not been solved; one of the most important problems is our dependence on fossil fuels as a source of energy.

Scientists aren't sure what energy is, they just know what it can do (Feynman, Leighton, & Sands, 1989). **Energy** is often times referred to as "the ability to do work." While this isn't incorrect, we will define energy as **something that makes things happen or change**. Humans want to take energy and put it into useable forms so that we can *do* things. All around the world we are harvesting energy and using it to make an endless number of things happen and change. One way to get this energy is to tap the world's sources of crude oil for use in combustion engines. While this is a very concentrated form of **chemical potential energy**, it is extremely dangerous and expensive to collect and transport.

In 2010, everyone watched the horrific scenes as the sea birds and marine life were threatened by the oil spill in the Gulf of Mexico. As engineers, we see this as a problem that could be prevented by implementing science and math to create designs that use cleaner, renewable energy sources, such as solar energy. The sun releases electromagnetic energy that could be used to make things happen or change. This energy can be transformed into electric energy by the use of solar cells. When photons from the sun's light travel to the Earth, they enter a solar cell and excite the electrons inside. This excitement of electrons is turning the sun's energy into **kinetic energy**, because the electrons are in motion. The energy from the moving electrons is called **electrical energy**. A discussion of these energy transformations that are taking place all around us is essential to understanding the scientific learning targets for this entire curriculum.

Crude oil is a naturally occurring source of energy found in certain geologic formations underground. It was formed over the course of millions of years as deceased organisms (plants, animals, protists, etc.) decomposed and, under the pressure and temperature of the earth above, formed a high-energy hydrocarbon called crude oil. Because oil takes millions of years to form, it is considered a finite resource. Crude oil is one of the primary forms of fossil fuels. Humans depend on fossil fuels for many daily activities including heating/cooling homes and running cars/airplanes.

Teacher Materials

- Force, Motion, and Energy Assessment for each student.
  http://www.auburn.edu/~cgs0013/ETK/Force_Motion_Evaluation.doc
- What is Engineering? PowerPoint
  http://www.auburn.edu/~cgs0013/ETK/WhatIsEngineering.ppt

- Save the Sea Birds PowerPoint
  http://www.auburn.edu/~cgs0013/ETK/Oil_Spills.ppt
- Matchbox car, miniature solar car, and shop light

Student Materials (for each group)

- ½ sheet poster board
- 1 box colored markers or pencils
- Computer access (optional)

Preparation

1. Photocopy the Force, Motion, and Energy Pre-test for students (download from Internet or see Appendix B).

2. Review the Save the Sea birds PowerPoint and What is Engineering PowerPoint? presentations.

Procedures

1. Have students complete the Force, Motion, and Energy Pre-Test.

2. Present Save the Sea Birds PowerPoint. Alternatively, have students work on their own on the Save the Sea Birds Webquest.
   http://zunal.com/webquest.php?w=181247
3. Engage students in a teacher-guided discussion using the discussion prompts in the PowerPoint as well as those listed below.
   - What do you know about engineering?
   - Do any of you have aspirations to become engineers?
   - What kinds of things do you think engineers do?
   - Do you think that engineers had a role in the 2010 oil spill?
   - What was the role of engineers in the oil spill?
   - Besides gasoline, what else could be used to move people/trains/cars/airplanes?
   - How does gasoline turn into motion in a car?
   - How has our need for energy affected animals, such as sea birds?

   "What is an Engineer?" Misconception: *A student may believe that engineers are people who work on cars. While it is true that engineers design cars, engineers also work on a vast number of projects and ideas.*

4. Distribute one blank poster board to each group and show students an example of a completed storyboard. Have groups develop a team name and write it at the top of their storyboard. Explain that each time students learn a new concept, do an experiment, create a design, or test a design it should be recorded on the storyboard for teachers and students to see and comment on.

   Teacher note: *Use of storyboards in the engineering design process provides a visual experience that helps students conceptualize each of the steps needed to understand each* *part of the entire "Save the Sea Birds" project. The storyboards allow the students to break down each important concept and provide key formative assessments throughout each of the lessons. Three points are covered in the engineering design process with the use of the storyboards: Finding Solutions, Developing an Initial Design and Presenting your Design at the end of the lesson.*

5. Show students the miniature solar car, a matchbox car, and the lamp. Then ask them the following questions:
    - What do you think will happen when we shine a light on the matchbox car?
    - What do you think will happen when we shine a light on the solar car?

6. Shine the light on the matchbox car and then the solar car. Then, ask the following:
    - Why doesn't the matchbox car move when the light is shined on it?
    - What is happening that is allowing the solar car to move?
    - What is energy?
    - What kind of energy does the lamp have?
    - When I shine the lamp light onto the car, what kind of energy will it have? During all of these conversions, solar to kinetic to electrical, was any energy lost?

    Teacher note*: *Many students have difficulty understanding how light can make one car move, and not the other one. Explain to students that the matchbox car does not have a mechanism to convert light energy into electric energy.

7. Set up a ramp on your table using a couple of textbooks and a piece of wood or another hard surface.

8. Showing students how the solar car can climb the ramp when the light is shined upon it opens up a discussion about potential energy. Ask the following:
    - Does the solar car have energy when it is at the top of the ramp, not moving?
    - Why does it have potential energy when it is at the top of the hill?
    - Can a car at the top of the ramp make something happen or change?
    - If the ramp is tilted the opposite direction, could the car roll back down and make something happen or change? Could it knock over a domino?

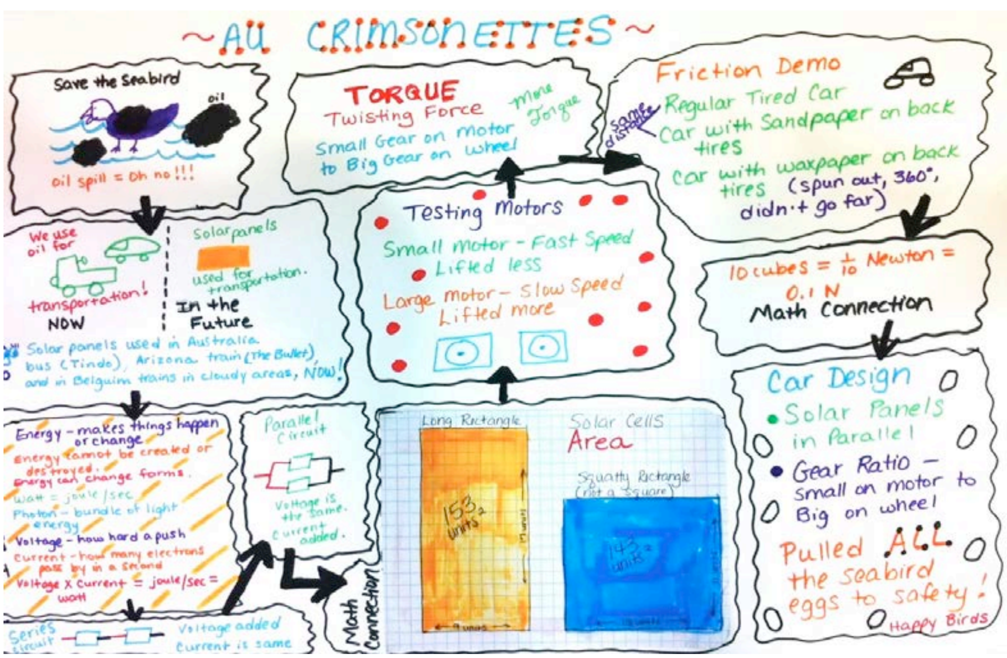
Teacher Note: *Students will have many different ideas about energy. Watts (1983) identified several alternative frameworks that children may have about energy. For instance, common alternative conceptions about energy include:*

1. *Energy is something people have, it's how they play and move around. When people are tired, they "don't have any energy."*
2. *Things that are moving have energy, while things that are still have none.*
3. *Energy is something that is made, used up, and then disappears. As in the case of heat energy, when something is no longer hot, the energy went away. They do not understand that energy is conserved. It is neither created nor destroyed.*
4. *Energy is a fluid that flows from one thing to another, spilling over from one thing to another making everything work and go.*

Several researchers have noted that children often confuse the terms, force, energy, and work, or realize they are related concepts but do not understand how. Some children confuse friction and gravity with energy, and think that potential energy is the potential to have energy (Driver et al, 1994).

Solar car traveling up ramp

9. Have students draw a box on their storyboard that shows the solar car at the top of the ramp as having potential energy and a solar car traveling down the ramp as having kinetic energy.



Storyboarding Sample

Some other options for storyboarding include:

- Illustrate “The Engineering Design Process Loop” (described in the What is Engineering? PPT).
- Draw pictures about how a combustion engine works.
- Draw pictures of energy transformations.
- Define different kinds of energy (kinetic, potential, solar, electrical, mechanical, chemical, etc.)
- Draw sea birds and the oil spill, then draw sea birds happily and healthily thriving with solar powered homes and vehicles.

Wrap-up

Ask students:

- What is energy?
- What are some devices that can convert energy?
- What happens to light energy after it leaves the lamp?
- Why do we drill for oil under the ocean?
- What do we use liquid crude oil for?
- What are some examples of engineered solutions for transportation needs?

Lesson 2

Light Energy to Electrical Energy

Learning Targets
1. Solar energy is a renewable alternative to fossil fuels, which are finite
2. A solar cell is a device that converts light energy to electrical energy.
3. Different solar cells have different design advantages. For example, high voltage = high speed; high current=high torque.
4. Engineers must research and understand the problems in order to solve them.

Purpose of the Lesson
1. Visualize electrical current and voltage.
2. Develop the ability to use multimeters and calculate the amount of electrical energy produced by solar cells.

Keywords
- Voltage
- Current
- Multimeter
- Power

Lesson Objectives
At the end of this lesson, students will be able to:

- Define voltage as a measure of the force pushing electrons in a circuit.
- Define current as a measure related to the number of electric charges passing a point in a circuit each second.
- Use a multimeter to measure the voltage and current produced by solar cells.

Lesson in a Nutshell
1. Review the context - creating solar vehicles to reduce the need for oil and gasoline, in order to positively impact pelicans and other sea birds. (10 minutes)
2. Show Energy PowerPoint and watch video showing how solar cells work. http://www.auburn.edu/~cgs0013/ETK/Day_2.ppt (5 minutes)
3. Demonstration #2 - Electric circuit with battery and motor. (10 minutes)
4. Demonstration #3 - Electric circuit with solar cell. (5 minutes)
5. Allow students to work in teams to investigate the electricity production of different solar cell configurations. (25 minutes)
6. Document learning on storyboard. (10 minutes)

Background
Voltage is a measure of the force pushing electrons in an electric circuit. When your hand touches a doorknob and it encounters static electricity, you feel a powerful shock! That is

because when the voltage is high, there is a strong force pushing electrons from the doorknob to your hand. Even though the voltage is high, there is not much energy associated with these kinds of shocks because there is a low current.

Current is a measure indicating how many electric charges pass by a point in a circuit each second**.** Fortunately, a high voltage shock from static electricity does not contain many electrical charges. The current is low, so the shock does not damage you. In an electric wall outlet, however, the current is quite high.

For currents to flow continuously, a complete **circuit** is required. There must be a constant path from one terminal (positive or negative), through one or more devices, and back to the other terminal (positive or negative).

Read *How Stuff Works Electricity* for more explanations about current and voltage: http://science.howstuffworks.com/electricity4.htm

Power is the amount of energy flowing in an electric circuit each second and is equal to the product of the voltage and the current.

Power = Energy/second (Joules/sec) = Voltage (Volts) x Current (Amperes)

The rate of transfer of energy per second is called **power**, and the unit for power is the Watt. For example, a 60 Watt light bulb uses 60 Joules of energy each second in order to stay lit.

1 Watt = 1 Joule per second.

Teacher Materials

- 100 Watt or higher incandescent desk lamp or shop light
- Energy PowerPoint
  http://www.auburn.edu/~cgs0013/ETK/Day_2.ppt

Student Materials (for each group)

- 1 multimeter
- 2 solar cells (different types) with red and black wires that have alligator clips attached
- 1 desk lamp or shop light with at least a 100W incandescent light bulb
- Sheet of waxed paper
- Sheet of bubble wrap
- Multimeter Directions
  http://www.auburn.edu/~cgs0013/ETK/Multimeter_Directions.doc
- Solar Cells Investigations worksheet
  http://www.auburn.edu/~cgs0013/ETK/Solar_Cells_Investigation.doc

Preparation

1. Set up seven stations around the room with desk lamps.

2. Place a multimeter, two solar cells, and alligator clip wires at each station.

3. Photocopy the ***Multimeter Directions*** sheets for each station. Modify for your own multimeters if you are using a different type.

4. Photocopy the ***Solar Cells Investigation*** worksheet for students.

Procedures

1. Review the context of this unit - creating solar vehicles to reduce the need for oil and gasoline, in order to positively impact pelicans and other sea birds.

2. Review the concept of energy and introduce electrical energy as one type. Ask students:

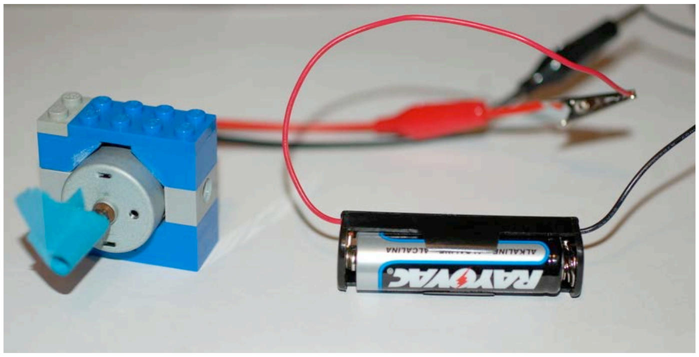
   - How do we know how much energy is present in an electric circuit?
   - How can we measure the amount of energy in an electric circuit?
   - What is electricity?

   Teacher Note*: Students should have a conceptual understanding of what electricity is and how voltage and current are two different ways of measuring electricity. They may think that more voltage = more energy, but the activities presented today will show them that both voltage and current are necessary to determine how much energy is present in a particular circuit. Even if the voltage is high, there may not be much useful energy if the current is low. Ideally, solar cells work best if they produce enough voltage and current to yield usable energy. When a motor is added to the circuit, the voltage mainly impacts speed of a motor, while the current impacts torque, or the twisting force the motor can exert.*

3. Show students the Energy PowerPoint and the video about how solar cells and combustion engines work.

4. Demonstrate for students how to create a circuit with a battery and a motor. Ask students*:*

   - How much voltage can the battery produce? (*marked on battery)*
   - How fast does the motor spin? (qualitatively)
   - Where do you see, hear, or feel energy making something happen or change?

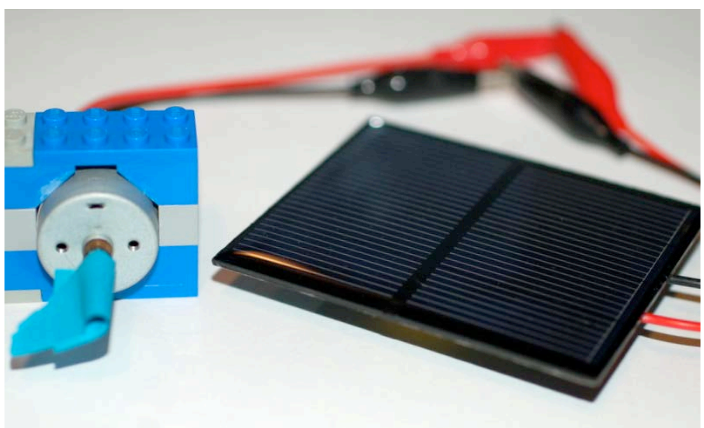


Battery and motor spinning with tape on axle

Electric Circuit With Battery and Solar Cell Demo Video
https://www.youtube.com/watch?v=M-reNoehoiU

5. Demonstrate that a circuit can also get its electric energy from a solar cell. Shine a light on the solar cell such that the motor spins. Ask students:

    - How much voltage can the solar cell produce?
    - How fast does the motor spin? (qualitatively)
    - Where is energy being transformed from light into electricity and then into motion and sound?



Solar cell and motor spinning with tape on axle

6. Explain to students the difference between voltage and current with a demonstration. Arrange 6-8 students in a circle. Give each student something to simulate an electron (ball, marble, etc.) Each student represents a copper atom, and the ball or marble represents an electron. Have one student act as the battery and "push" the electrons through the circuit by placing them forcefully in the hand of the person next to them. Note the number of "electrons" passing by each second. That is analogous to current. Note the force used to push the electrons. That is analogous to voltage. If two "electrons" are passed at a time, the current doubles.

Voltage – The driving force which pushes electrons through a circuit

Current – The flow rate of electrons through a circuit.

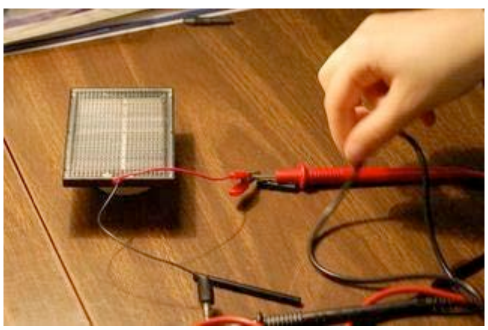
Teacher Note: *Voltage and current are both important for measuring the amount of energy produced by a solar cell. Make sure that all students understand the concept of voltage and current before proceeding to the next step.*

7. Have students complete a section of their storyboard with the definitions of electric energy, voltage, and current.

8. Activity: Pass out the Multimeter Directions sheet and the Solar Cells Investigation worksheet to each group.

9. Pass out a square solar cell, a rectangular solar cell and multimeter.

10. Have students find the voltage and the current of each solar cell and calculate the energy produced each second, recording their data and calculations on the Solar Cells Investigation worksheet.



Testing voltage and current of solar cell

11. When students have completed their data table and calculations, pose the following question:
    - While each solar cell produces a different voltage, they each produce a similar amount of energy. How can this be?

12. Have students summarize the findings of their investigation of solar cells on their storyboards.

Wrap-up

- Review the definition of electricity.
- Review how electricity is measured.
- Allow students to complete their storyboards with a picture of the two solar cells and the voltage and current produced without shading.

Ask students the following questions:

- Which one of the solar panels gives you the most power?
- What is happening inside the solar panels?
- Where is the energy coming from to power the solar panels?
- Where is the energy coming from to power the lamp?
- What are photons and where do they come from?
- What kind of energy enters the solar panels, and what kind of energy leaves?
- How might solar panels help save the seabirds?

Lesson 3

Electrical Energy to Mechanical Energy

Learning Targets
1. An electric motor is a device that converts electrical energy to mechanical energy.
2. Gears can be utilized in different ways to provide certain design advantages.

Purpose of the Lesson
1. Experiment with different motors to determine the turning force they can produce.
2. Understand that a force is a push or pull and that it can either help or hinder motion.
3. Understand that gears can be used to increase or decrease the turning force produced by a motor.

Keywords
- Motor
- Force
- Torque
- Gears
- Gear ratio
- Gear train

Lesson Objectives
At the end of this lesson, students will be able to:

- Define a force as a push or pull.
- Create a gear train that increases force output of a motor.

Lesson in a Nutshell
1. Review Lesson 2 - Electric circuits with solar cells (5 minutes)
2. Motor Activity - How can an electric motor exert a force? (10 minutes)
3. Explore spring scales to measure the turning force of different motors. (10 minutes)
4. Gear Activity: See Handout: *How Gears Help Drive the World* http://www.auburn.edu/~cgs0013/ETK/Gears.doc (25 minutes)
5. Document learning on storyboard. (10 minutes)

Background
A **motor** is a machine that converts electrical or chemical energy (such as from burning fuel) to produce useful mechanical motion. An electrical motor converts electrical energy into mechanical energy.

Force: A force is simply a push or a pull.
There has been much research into children's conceptions about force, and it is a confusing scientific concept because of how frequently the word is used in everyday language for non-

scientific purposes. For example, a child is forced to eat her vegetables; a forceful person is powerful; there are military forces overseas fighting wars; may the force be with you! Driver, Squires, Rushworth, & Wood-Robinson (1994) have consolidated the various research studies on children's conceptions of the science of force into a set of common ideas. These misconceptions are:

1. If something is moving, a force must be acting on it in the direction it is moving to keep it moving.
2. If something is not moving, then it has no forces acting on the object.
3. A moving object stops when the force acting on it is used up.
4. The more force acting on an object, the more motion it has.
5. If the force acting on a moving object stays constant, its speed will be constant.

Children do not readily understand that forces come in pairs and think of a force as a solitary thing possessed by one object. They may recognize that a book on a table puts a force on the table, but fail to recognize that the table also puts a force on the book. They do not necessarily recognize friction as a force, but rather see it as something different, for example, something that causes static electricity. The concept that force is required for motion is so widespread and tenacious that studies indicate between 82% and 85% of high school students possesses this concept, while 75% of university students also possess this concept even after instruction (Palmer & Flanagan, 1997). The "motor demonstration" that will be done in today's lesson will not address all the misconceptions students have about forces, but it will familiarize them with observing and measuring forces, and seeing that forces come in pairs.

Torque is a twisting force. You use torque to twist off the lid of the jelly jar or tighten a screw. The motors in this curriculum are used to create torque so that the wheels will have enough twisting force to pull a heavy load.

Gears are used in mechanical devices for one of four different reasons: 1) to reverse the direction of rotation, 2) to increase or decrease the speed of rotation, 3) to increase or decrease the amount of torque, and 4) to move rotational motion to a different axis. When the smaller gear is on the motor and the larger gear is the output (such as the wheel in this lesson), the output speed is slower but the output torque is higher, and you are trading slower speed to lift bigger loads. When the larger gear is on the motor and the smaller gear is the output, the output speed is faster but the output torque is smaller, and you are trading the ability to lift bigger loads to move at a faster speed. This latter scenario occurs in racing cars.

A **gear ratio** is the relationship between the number of teeth on two gears that are meshed. This relationship is expressed mathematically. For example, if one gear with 12 teeth is driven by a gear with 24 teeth, the gear ratio is 1/2, or 1:2. Gears are found in almost all types of mechanical machinery such as clocks, vehicles, farm equipment, and industrial machines. The gear ratios are used to predict the machine's performance. A **gear train** results when a number of gears are grouped into a single unit to further increase the gear ratio.

Materials

Teacher Materials

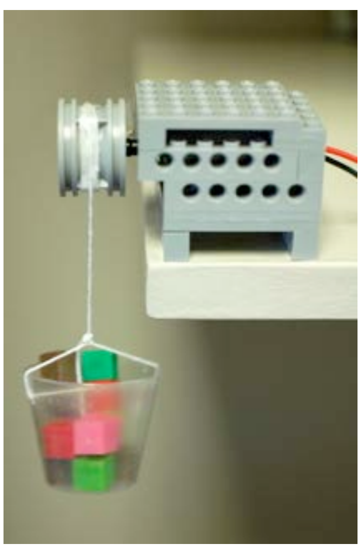
- How Gears Help Drive the World handout
  http://www.auburn.edu/~cgs0013/ETK/Gears.doc (Appendix E)
- Lamp/Bulb (optional)

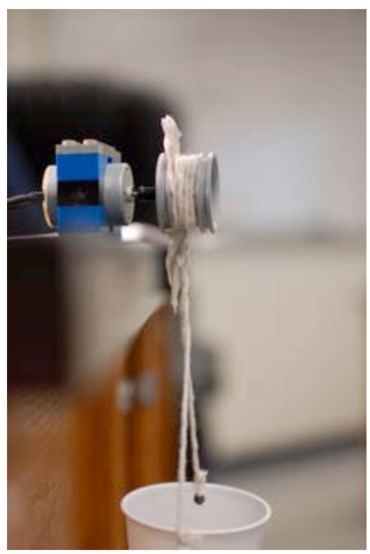
Student Materials (for each group)

- Battery
- Solar cell and light (optional)
- Motor A assembly
- Motor B assembly
- Plastic cup
- Cotton string
- 30 Rocks, Marbles or Unifix cubes
- Gears (various sizes)
- Various Lego pieces

Preparation

1. Inspect Lego kits to ensure all the pieces are in the kit. See Appendix A, Table 3 for suggested kit parts.
2. Print copies of "How Gears Help Drive the World." (1 per student)
3. Poke two holes opposite one another at the top of the plastic cup. Run the cotton string through both holes and tie in a loop as shown below.





Example of motors pulling objects with no gears.

Procedures

1. Go to the www.gearsket.ch website and draw gear trains. You can change the Drive and Driven gears, change the size of the Drive and Driven gear, change the direction of rotation, change the speed of the Drive gear, and even put gears on top of each other on

the same axle. It is super cool on a Smartboard and students can draw their own gear trains to see how all these factors change the direction and speed.

2. Pass out the How Gears Help Drive the World worksheet (one per student), motor assemblies, a battery in holder, a string, cup, cubes, select LEGOs and wheel hub to each group of students.

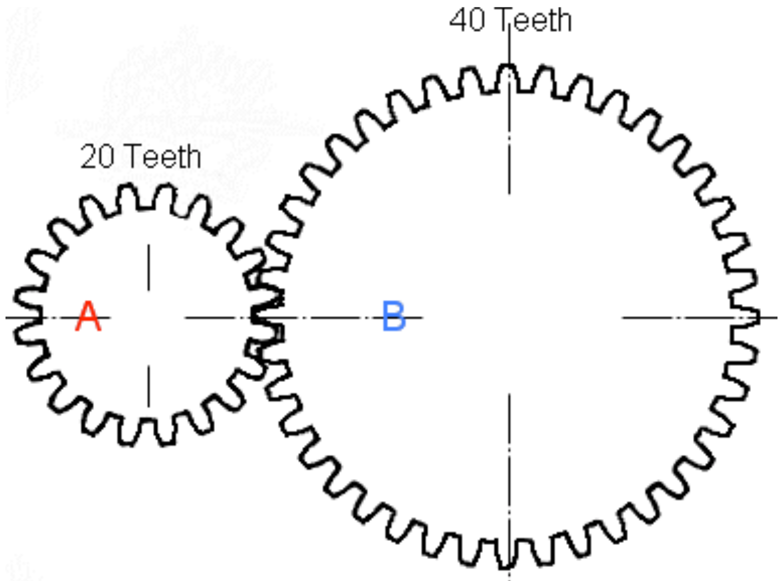
3. Model how to setup the motor activity:
   - Hold a motor on the edge of the tabletop and attach a LEGO wheel hub (without tire) to the shaft so it can wind up a string.
   - Secure the string to the wheel with a small piece of tape.
   - Attach a cup to the end of the string so the motor can lift different amounts of weight.
   - Use a battery (or solar cell with light) to make the motor turn.

4. Have students find the maximum load the motor can sustain by adding rocks, marbles, or Unifix cubes to the plastic cup until you find a load that the motor cannot raise. When this limit is reached reduce the number of cubes one at a time until the motor is capable of lifting again.

   Motor Activity Demo Video
   https://www.youtube.com/watch?v=JJATWAyEqLE

5. Provide students with a brief explanation regarding gears and gear ratios.
   - Gears are generally used for one of four different reasons:
     a. To reverse the direction of rotation
     b. To increase or decrease the speed of rotation
     c. To increase or decrease the amount of torque
     d. To move rotational motion to a different axis

$$\frac{\text{Number of teeth}_{\text{Follower}}}{\text{Number of teeth}_{\text{Driver}}} = \frac{\text{Rotational speed}_{\text{Driver}}}{\text{Rotational Speed}_{\text{Follower}}} = \frac{\text{Torque}_{\text{Follower}}}{\text{Torque}_{\text{Driver}}}$$



- Explain that when the motor is driving Gear A, Gear B will move half as fast but with twice as much torque. If the motor is driving Gear B, Gear A will move twice as fast but with half as much torque.
- Takeaways:

When the motor is driving the smaller gear and the larger gear is the follower:

a. The follower speed is slower but the follower torque is higher
b. You are trading slower speed to lift bigger loads (mechanical advantage)
c. Useful in robotic applications where torque is the main factor

When the motor is driving the larger gear and the smaller gear is the follower:

a. The follower speed is faster but the follower torque is smaller
b. You are trading the ability to lift bigger loads to move at a faster speed
c. Useful in racing applications where speed is main factor

Introduction to Gears Video
https://youtu.be/D_i3PJIYtuY

6. Have students complete the How Gears Help Drive the World handout.

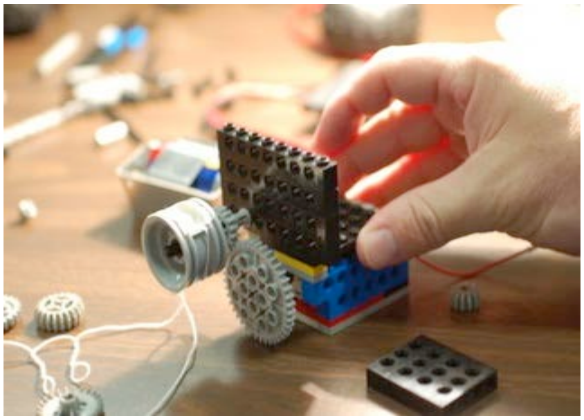
Gears Activity Demo Video
https://www.youtube.com/watch?v=H3R6XfDLAHw

7.Challenge students to figure out a way to make their motor able to exert more force or torque.

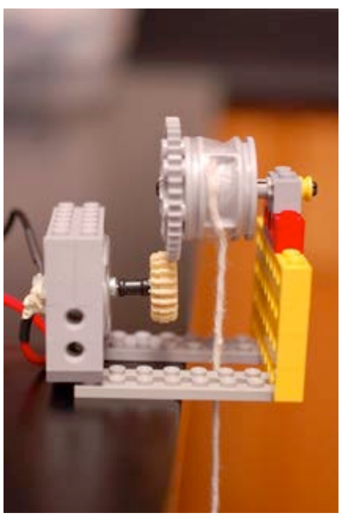
Teacher Note: *To exert more force or torque, they should create a simple gear train with a small gear on the motor and a larger gear meshed with it. The larger gear should have the wheel, string and cup assembly attached.*

8. Ask students, “How do gears increase the force output of a motor?”

    Teacher Note: *More force = less speed, so the geared-up motor spins at a slower rate and pulls the cup of rocks slower.*



Large gear on motor, small gear on spool



Small gear on motor, large gear on spool

Wrap – up

Wrap up the lesson with a review of the learning targets. Ask students:

- Have students document their activities and achievements on their storyboard and/or Edmodo.

- Ask students:

- Which motor was faster?
- Which motor produced more torque (twisting force)?
- How much force could the motor put on the string?
- What forces did the string experience?
- What forces did the cup of cubes experience?
- When the cup of cubes was raised all the way and not moving, what forces were acting on it? As the weight in the cup increased, what happened to the motion of the cup of cubes?
- What did you do to make your motor more forceful?
- What did we lose when we increased the force?
- Where do you experience gears in everyday life?

Teacher Note: *By the end of the lesson, students should be able to explain that you lose speed when you gain torque and vice versa.*

Lesson 4

Friction

Learning Targets
1. Friction can be measured and calculated.
2. Friction can convert energy from useful forms into less useful heat and sound, but energy is always conserved. It is neither created nor destroyed.
3. Engineers work within constraints (time, materials, space, money) and use scientific knowledge and creativity to design solutions to problems.
4. Friction has constructive uses in designs.

Purpose of the Lesson
1. Understand that friction is a force that helps or hinders motion.
2. Experiment with different types of friction.
3. Experiment with different tires in order to determine which tires have the most sliding friction.

Keywords
- Static friction
- Sliding friction
- Rolling friction

Lesson Objectives
At the end of this lesson, students will be able to:

- Define friction as the force between two surfaces that resists motion, but that friction is necessary for some motion (walking and cars).
- Demonstrate different types of friction.
- Explain that the heavier something is, the more sliding or rolling friction it has.
- Measure the amount of friction produced by different objects
- Explain how friction can be used to help motion (walking and cars).

Lesson in a Nutshell
1. Review Lesson 3 - Forces exerted by motors (5 minutes)
2. Demonstration #4 - Cars with different wheel materials (10 minutes)
3. Friction Activity: Build a car to measure sliding friction (10 minutes)
4. Put weights on non-rolling car and measure increase in frictional force (20 minutes)
5. Build a car body with movable wheels as a base for solar car (15 minutes)
6. Document learning on story board (10 minutes)

Background
Friction occurs whenever two surfaces are in contact with each other. The two main types of friction are **static friction** and **sliding (kinetic) friction**. Static friction is the force that must be overcome in order to set an object in motion. Sliding friction occurs between surfaces in relative

motion. There is a third type of friction called **Rolling friction.** It is a resistive force that occurs when a circular object (such as wheel or tire) rolls over a surface. It tends to slow down the motion of an object.

Many students will think of friction as something to eliminate. However, the teacher should help them see that friction helps with many types of motion. Many will not understand that friction helps people walk and cars move forward, and that the frictional force is in the direction of the motion of the person or car, but opposite the direction that the wheel or foot tends to move.

Friction is not always easily determined by the roughness of a material. Very smooth materials can have extreme amounts of friction when moved against other smooth materials. There are coefficients of friction for various material combinations. The higher the coefficient, the more friction there is.

Because it takes a greater force to put an object into motion than it does to maintain motion, static friction is typically higher than sliding friction. The amount of frictional force generated depends on the types of surfaces in contact, and the mass of the objects.

Teacher Materials

- "What is Friction" handouts
  http://www.auburn.edu/~cgs0013/ETK/WhatIsFriction.doc
- Pull-back cars (one with sandpaper, one with waxed paper, and one with nothing on the wheels)
- Pre-assembled solar car

Student Materials (for each group)

- Tires (various sizes)
- Spring scale
- Plaster-filled eggs or rocks
- LEGO pieces
- 2 textbooks

Preparation

1. Build a sample solar car with stationary tires.

2. Gather materials so that each group has a set of different tires, spring scale, plaster-filled eggs or rocks, and LEGOs to build one locked-wheel car.

3. Photocopy the "What is Friction?" hand-out.

Procedures

1. Determine student's prior conceptions about friction. Ask students the following:

   - What is friction?

- In what direction is friction acting in the pictures below?

2. Pass out the "What is Friction?" hand-out and demonstrate the spring scale setup.

Pulling books with spring scale

3. Have students work to complete Part I of the handout, "What is Friction?"

4. Show students the three pull back race cars. One has sand paper wheels, one has waxed-paper wheels, and one has rubber tire wheels. Tell students you are going to pull back the same distance on each car. Have them predict the distance each car will travel.

   Teacher note*: Results will vary depending on the surface you use. Be sure to push down hard enough so that the wheels actually wind up when you pull back on the car. Many students will predict that the sand paper car will go the farthest because the wheels have more friction. However, if you race these cars on a flat surface, this will not necessarily be the case. The sand paper tires may spin out if the surface is hard enough.*

Race cars with different wheel surfaces

Different Wheel Material Demo Video

https://www.youtube.com/watch?v=Yfs8xnxAMHg

5. After racing the cars to determine which travels the farthest, engage students in a discussion about the relationship between friction and distance traveled. Ask the following:
    - What happened when the wax paper covered wheel tried to move?
    - How would driving on snow-covered ground affect the motion of your car?
    - Why are NASCAR racecar tires smooth?
    - Why do the NASCAR drivers spin their tires before a race?
    - How can you measure the force of friction that is being exerted against the tires on your vehicle?

    Teacher note*: The car wheel has to push back on the road in order for the road to push on the wheel and cause it to move forward. In the same way, your foot has to push back on the ground for you to walk. Forces come in pairs. Your foot pushes backwards on the ground. The ground pushes forward on you. If the wheel or your foot cannot push back, if it slips and slides, the ground will not push forward on the wheel or the car. What is this force called that the ground is pushing with? Friction! Without friction, cars and people can't get moving!*

6. Pass out the three sets of tires. Have students observe the tires and determine how the tires are different from one another.

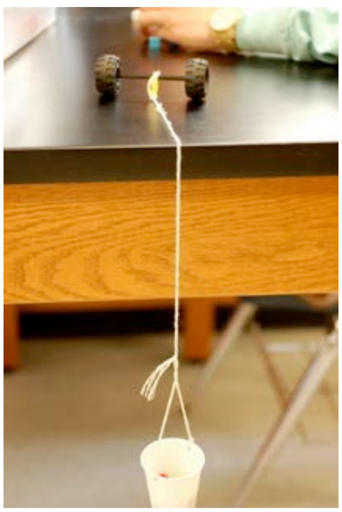
Three possible wheel types

7. Have students work in groups to measure the amount of sliding frictional force created by the different wheel types. To do this they should:

    - Put wheels on a cross axle, and thread them through a LEGO piece that does not allow the axle to turn.
    - Attach the wheel assembly with a spring scale.

- Pull on the wheel assembly with a spring scale to determine the force of sliding friction.

Testing Sliding Friction



Pull wheels that do not turn and measure friction

8. Have students work to complete Part II of the handout, “What is Friction?”

9. Describe the design challenge and allow students to begin to plan and build their cars.

Design Challenge

You are challenged to design and build a solar-powered vehicle that is able to pull a significant amount of weight. Using solar-powered mass transportation may reduce the need for gasoline, diesel fuel, and pumping crude oil out from underneath the oceans. This will decrease the possibility of oil spills affecting marine life, and save the Sea Birds from destruction. The best design is the one that pulls the most weight.

Official Rules:

1. Your design must be solar powered.
2. Your design must use a motor.
3. Your design must use only the materials provided.
4. The car must move.

10. Visit each team of students during the construction process. Discuss design decisions with each team and ensure that they are able to verbalize why they chose the materials they did for their design. The following questions will help you aid them in this verbalization of their creative and logical thinking:

    - How will the force created by the motor get transferred to the wheels?
    - Do you want the most voltage, current, or energy produced each second?
    - How can you increase the force that the motor can exert?
    - Do you want wheels with more friction or less friction?

11. Have students document their prototype on a story board square, drawing their design, and labeling the materials they plan to use, and indicating which tires they will use.

Wrap-up

1. Ask students:
   - What causes friction? Why?
   - What is friction?
   - Why are the soles of hiking boots different from bowling shoes?
   - Why do skateboarding shoes have special soles?
   - Should car tires have a lot of friction on the road, or as little as possible? Why?

   Teacher Note: *The amount of friction an object needs depends specifically on the function it will serve. Friction can be both good and bad for a design. Many engineers have the job of finding the right balance to meet the needs of the product. For instance, tire manufacturing companies hire engineers to design tires that have performance characteristics and use varying amounts of friction to find a good balance between longevity and performance.*

Lesson 5

Engineering Design, Building and Testing, and Redesign

Learning Targets
1. Engineering is an iterative process of design and testing.
2. Engineers must document their process of design and present their solution to the problem.
3. Engineers redesign prototypes based upon their test data.

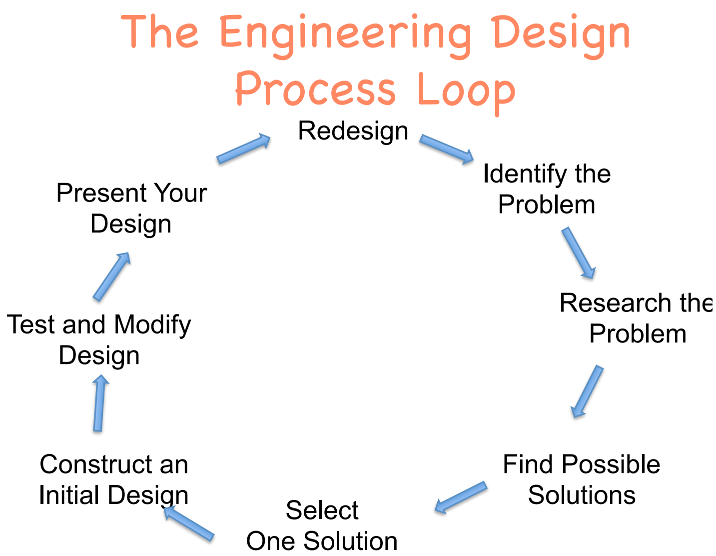
Purpose of the Lesson
1. To have students design and construct solar-powered vehicles that move.
2. For students to connect the cart to the solar car and see how many sea bird eggs it can pull.
3. For students to analyze their designs and determine which features work best and which do not.
4. To make improvements and repeat the testing process.

Lesson Objectives
At the end of this lesson, students will be able to:

- Evaluate the effectiveness of their design with regards to the solar car's ability to pull a load in a rolling cart.

Lesson in a Nutshell
1. Review Lesson 4 - Friction (5 minutes)
2. Students design and build first iteration of solar car (20 minutes)
3. Students test cars (20 minutes)
4. Revisions (20 minutes)
5. Final Testing (20 minutes)
6. Analyze and discuss results (15 minutes)
7. Document learning on story board/Wrap-up discussion (25 minutes)
8. Post-Assessment (10 minutes)

Background
The **Engineering Design Process Loop** is an iterative cycle that involves identifying a problem, brainstorming solutions, scientific research, design, testing, and re-design. There are many representations and descriptions of this process, and no one process is "right." However, the following cycle is a good model for what students are doing in this unit. Encourage cooperation, not competition. Have students share their successes and failures with each other and learn from them. The objective is to save the sea birds, not win a competition. The redesign phase is the most important. After the first testing of the car, get the student groups to talk about their designs with each other, and use the lessons learned to improve.



Teacher Materials

- Plastic eggs filled with Plaster of Paris (or smooth river rocks)
- Scale
- Shop light
- Shop light encasement

Student Materials (for each group)

- Kit of materials (See Table 5 in APPENDIX A for a list of suggested materials)
- Storyboard
- Markers or colored pencils

Preparation

1. If you do not have pre-filled eggs, fill plastic eggs with Plaster of Paris. Let them dry a few days then determine their mass and write the mass on the egg. Eggs can vary in the amount of mass they hold.

2. Photocopy the [Engineering Design Process](http://www.auburn.edu/~cgs0013/ETK/EDP.pdf) handout.
http://www.auburn.edu/~cgs0013/ETK/EDP.pdf

3. Make sure each group has a kit with all their materials in it: LEGO pieces, solar cells motor(s), connectors, gears and wheels. Provide multimeters for diagnosing problems.

Eggs filled with Plaster of Paris **Egg labeled with its mass**

4. Print the award certificate sheets so you can fill in the names of "winners" during class if you desire.

Procedures

1. Students should continue designing and constructing their prototype vehicles.

   Designing A Solar Car Video
   https://www.youtube.com/watch?v=wQGNleINASw

2. Visit each team of students during the construction process. Discuss design decisions with each team and ensure that they are able to verbalize why they chose the materials they did for their design. The following questions will help you aid them in this verbalization of their creative and logical thinking:

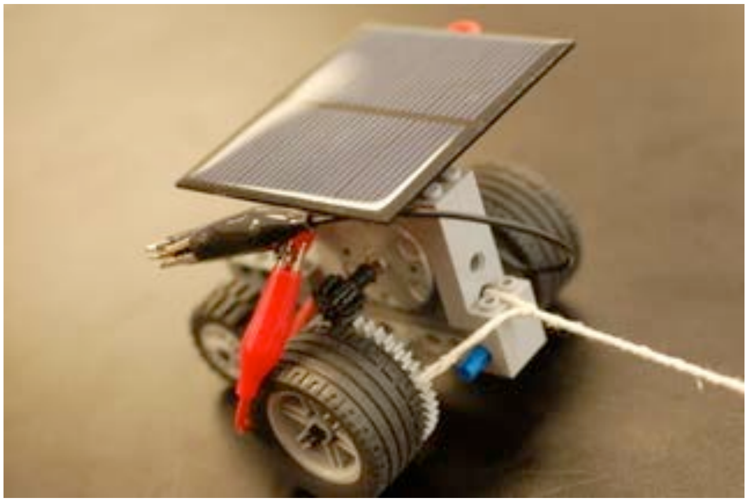
   - How will the tires you chose to use help your car?
   - How will the gears you chose help your car?
   - Which solar cell did you choose to use? Why?
   - Which motor did you choose to use? Why?

3. Students should draw all design iterations in a story-board square.

4. Have students test their designs by doing the following:

   - Turn on a shop light over the prototype to ensure it runs without a load.
   - Attach one end of the string to the cart and attach the other end to the car.
   - Turn on a shop light over the prototype attached to a cart to ensure it is capable of pulling an empty cart.
   - Add one egg at a time to the cart until the cart will no longer pull the load.

   Teacher Note: *The first designs usually cannot pull much weight. Students invariably leave out gears on the first try. Let this happen- someone will eventually remember to use gears, and everyone will jump on the bandwagon. See example in figure below.*



Sample solar vehicle with small gear on motor and large gear connected to axle

Working solar vehicle with a small gear on the motor and a larger gear connected to a gear assembly on the front axle

5. Have the class analyze the results of the test by doing the following:

    a. Analyze the vehicles that pulled the most weight
    b. Tactfully analyze the vehicles that did not perform as well and offer suggestions of what could be adjusted to improve performance.
    c. Ask students the following questions:
        - Which design features were most effective at creating force? Increasing friction? Delivering the most electrical energy to the motor?
        - Why were these design features effective at creating force? Increasing friction? Delivering the most electrical energy to the motor?

6. Have students record their ideas for design modifications on their storyboard.

7. Allow students time to re-build their cars using the design modifications from their storyboard.

8. Perform a second test to determine if the modifications improved the effectiveness of the car.

9. Have students draw their final design and their results on a storyboard square.

10. Ask students the following questions about the design of their vehicle:
    - How did your motor choice affect your vehicle's performance?
    - How did your solar cell choice affect your vehicle's performance?
    - How did your gear ratio choice affect your vehicle's performance?
    - How did your tire choice affect your vehicle's performance?

11. Ask students what they liked and disliked about this unit. Use this information to help you plan future units that combine engineering design with science.

12. Determine winning teams and distribute an award certificate to each member of the team. An award template is provided.
    http://www.auburn.edu/~cgs0013/ETK/PelicanAwards.ppt

    Teacher Note: *Below is a list of suggested awards.*
    - ***Effective Design*** – Awarded to the teams that pulled the most sea bird egg weight
      (1^{st}, 2^{nd}, and 3^{rd} place awards can be given)
    - ***Most Improved Design*** – Awarded to the team that improved the most from Test 1 to Test 2
    - ***Improved Design*** – Awarded to every team that actually improved their design and saved more sea bird egg weights during the second test
    - ***People's Choice*** – Awarded by students to the design they liked the best determined by popular vote

Sample award template

1. Have students complete the Force, Motion, and Energy Post-Test.
   http://www.auburn.edu/~cgs0013/ETK/Force_Motion_Evaluation.doc

Wrap-up

1. Ask students the following wrap – up questions:
   Engineering Prompts:
   - What process did you use to design a solution to a problem?
   - Why was this unit called "Save the Sea Birds"?
   - How does saving energy at home help animals that live so very far away?
   - What do engineers do that help people and animals?
   - What were the science concepts you had to know in order to be a good engineer in this unit?
   - What constraints did you have when you designed your solar car?
   - Why was it important to do a re-design?
   - What were some engineering practices you had to know in order to design and build the best solar car you could?

   Science Prompts:
   - What is the definition of energy?
   - What are various forms of energy?
   - How does energy seem to become lost?
   - What are amps? Volts?
   - What is friction? Is it energy, power, force, speed?

Extension Lesson

Optional

If you have time, and your students have the interest, take advantage of some of these additional activities you can use:

Activity 1:

Watch some of the following videos to give you some ideas.

1. How To Build A Solar car --- http://www.youtube.com/watch?v=h3mv8MFVtYo
2. How Solar car Works --- http://videos.howstuffworks.com/howstuffworks/178-how-solar-cars-work-video.htm
3. Solar Electric Powered Airplane --- http://www.youtube.com/watch?v=WcWSI03NKo0
4. Helios Solar Powered Airplane --- http://www.youtube.com/watch?v=1NCOPLEJOl0
5. Solar Powered Trains (in Belgium) --- http://www.youtube.com/watch?v=UC8PogeGF_w
6. Solar Powered Trains (in USA) --- http://www.youtube.com/watch?v=ddF3Aon_5Lk

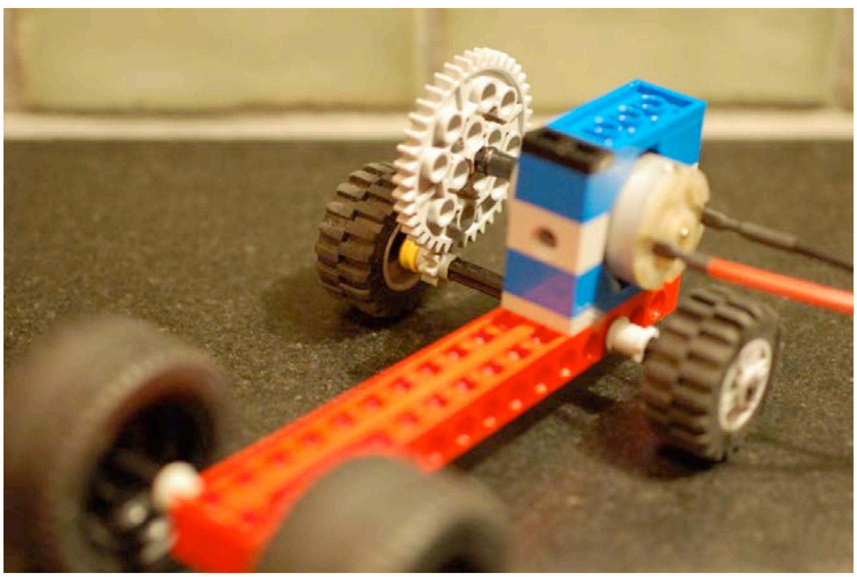
7. Solar Powered Boat (USA) --- http://www.youtube.com/watch?v=LY9_i_1lVnk

Activities:

You have designed and built a solar car for mass transportation and determined how much of a load your car can pull. However, engineers work within constraints and have additional specifications that their designs must meet. For the following three challenges, consider the specification of SPEED (it can't take forever to move Cantaloupes from California—they will spoil along the way!), the constraint of COST (this has to be affordable for the average family), and the problem of HILLS (you must cross the Rockies!)

Challenge - SPEED

Students will use gear ratios and reduce the car weight and increase aerodynamics to build the fastest car. Calculate velocity (distance/time) for each vehicle along a 1 meter long track. The gear ratio will likely be reversed with the largest gear on the motor and the smallest gear on the wheel axle. Extraneous parts should be removed. Students can test their vehicle at any time along several tracks set up around the room with stopwatches at each station.



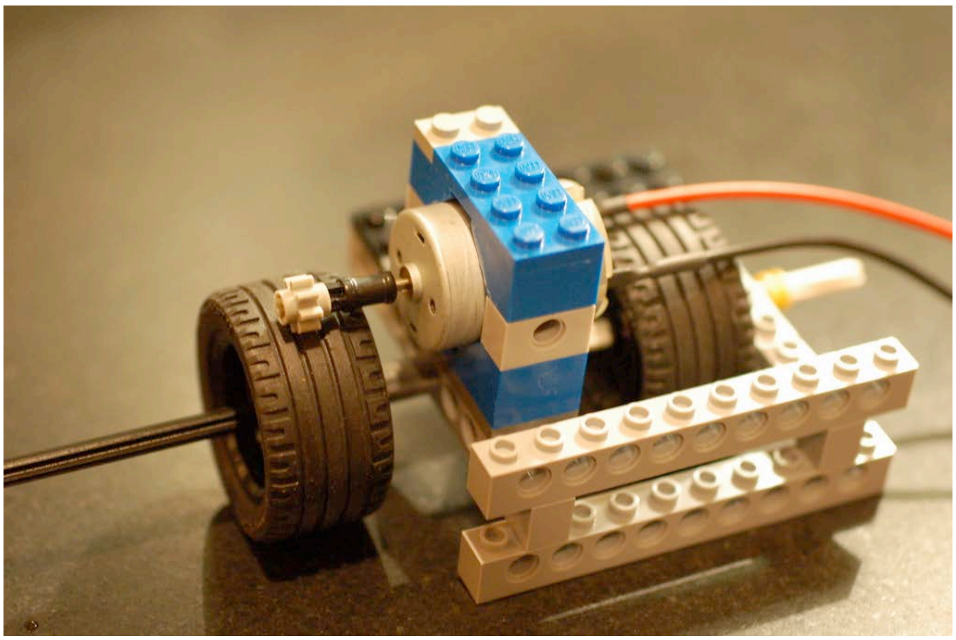
Here you see a simple car frame with two axles and four wheels, one motor, two gears, and some bushes to keep axles from moving.

Challenge- COST

Students will use the following price sheet to optimize the cost of their car. The objective is to minimize cost while maximizing pulling capability. The ratio of $$/Newtons will be used. If the car parts cost $100 and the car can pull 100 grams (100 grams = 1 Newton) then the ratio is 100 $/N

Price Sheet at the SOLAR ZONE

LEGOs by the piece (10 cents per piece)
Gears ($1 per gear)
Wheels (50 cents per wheel)
Solar panels ($5 each)
Motors ($5 each)

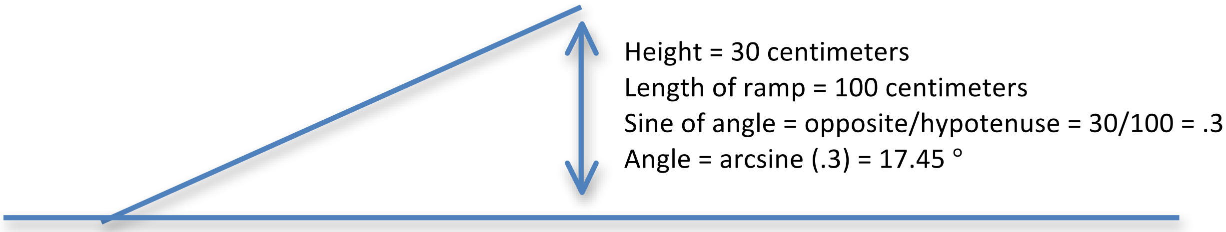


This vehicle only has two wheels and one gear. It actually works! The small gear presses on the wheel and the friction between the two is enough to drive the axle. The cost for this vehicle is $13 since there are 10 LEGO pieces, 1 gear, 2 wheels, 1 solar panel, and one motor.

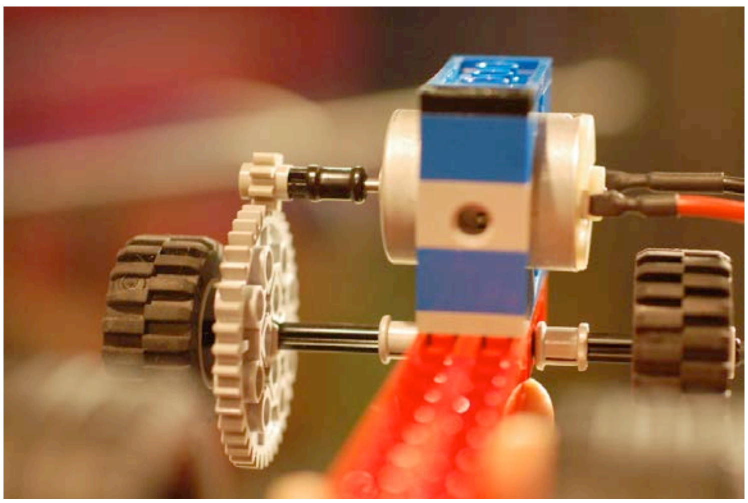
Challenge- HILLS

It's one thing to ride a bike along a flat sidewalk, but have you tried going up hills? You need a lot more force! You need a lot more energy! To maximize your hill potential, think about gearing down (small gear on the motor) and about wheel size and stability so you don't flip backwards. Create a sturdy hill out of the kit lid. Prop the lid up on books and measure the angle of the hill. The angle can be measured with a compass, or with math.

http://www.rapidtables.com/calc/math/Arcsin_Calculator.htm



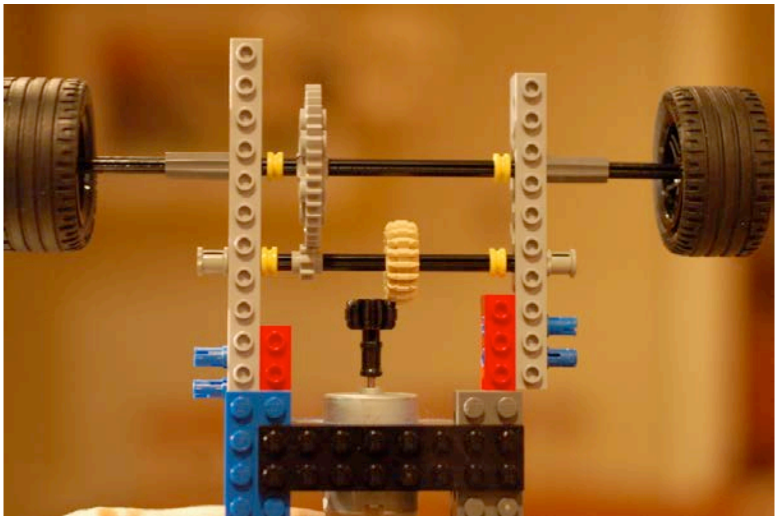
Challenge- Gear Train



To increase torque, have a small gear drive a larger one. The large gear is on the same axle as the wheels. They will go slowly, but have more torque. Note here that I mounted the motor upside down to align the gears better. A gear train would provide even more torque.

The gear ratio here is 8 teeth to 40, reduced to 1:5. This means that the small gear turns 5 times for one rotation of the large gear. This decreases the speed 5 times and increases the torque 5 times.

A gear train uses several gears to increase the gear ratio even more.



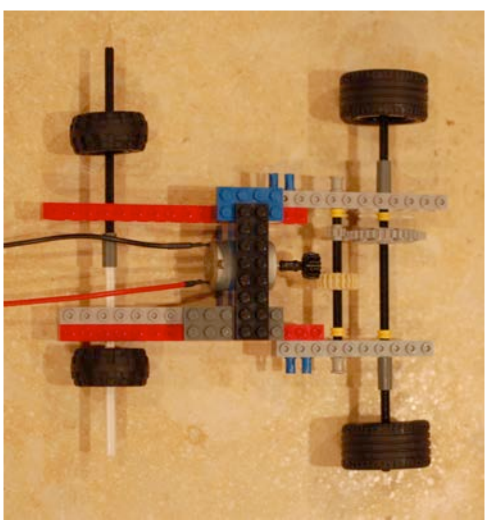
Black gear—12 teeth
Yellow gear- 20 teeth
Small gray gear- 8 teeth
Large gray gear- 40 teeth

Follow the gears from the motor to the wheels. See here that the first ratio is 12:20 which reduces to 3:5. The second gear ratio is 8:40 which reduces to 1:5

We multiply the two gear ratios to find out the final ratio. Will this gear train have a larger gear ratio than the original 1:5?

$$\frac{3}{5} \text{ x } \frac{1}{5} = \frac{3}{25}$$

Is 3:25 a larger ratio than 1:5? For every three turns of the black gear, the wheel turns 25 times. So, for every one turn of the black gear the wheel turns 25/3 times or 8.33 times. So, yes, this gear train increases the torque of the motor by over 8 times.



Algebra/Physical Science Connection

Have students calculate the velocity of their car.

v = d/t   (m/s)

d = displacement

t = time

Mark off a meter-long length on the floor and provide timers. As students add weight (people) to the trolley, have them calculate the velocity again. Having data like this gives your students the opportunity to graph different variables and look for linear relationships. Is there a relationship between the weight of the load and the velocity? This might provide the opportunity to discuss slope and linear equations and the value of interpolating and extrapolating data points.

	Mass (*kg*)	**Displacement (*m*)**	**Time (*s*)**	**Velocity (*m/s*)**
Trial 1				
Trial 2				
Trial 3				

Appendices

APPENDIX A

MATERIALS AND SUPPLIES

Supplies:
The materials listed in Table 1 are needed by the teacher regardless of how many classes he or she teaches. They can be used for each class. The materials listed in Table 2 are "per student group." So, if a teacher has four classes with 7 student groups in each class, 28 student kits will supply one teacher with enough supplies. Some materials can be purchased from a grocery store, hardware store, craft store, or large shopping mart but many will have to be mail ordered. Suggested sites are provided below where necessary. The entire kit can also be purchased from www.stemteachingkits.com

Table 1
Basic Teacher Supplies needed for *Save the Sea Birds* ETK

Quantity	Item
1	Mini solar race car Steve Spangler Part# WROB-200
7	Desk lamp
7	Light Bulbs, 100W
7	Multimeters
7	Calculators
1	Tote bin to hold and store all supplies. Size depends on number of classes
1	Small pull cart with wheels for holding plaster-filled sea bird eggs. Can be made with Legos. See Table 8 and Figure 4
3kg	Assorted plaster-filled sea bird eggs. See Figure 5
7	Edmund Scientifics Part# 3001000 Spring Scale, 250 g/2.5 N
7	Plastic Cups
1	Roll of cotton string
3	Pull-back toy race cars http://www.arborsci.com/pull-back-car plus sand paper and waxed paper for wheels.
7	Solar cell A assemblies (these can be used with each class) See Table 6
7	Solar cell B assemblies (these can be used with each class) See Table 7
14	AA batteries
7	Battery holders for two AA batteries
2	Super glue bottles
3 packs	Heat Shrink tubing from Radio Shack (Cat # 278-1611)

Table 2

Student supplies for each student group

Part Description	Source	Quantity
Plastic shoe box for storage	Home Depot	1
Motor A assembly	See Table 3	1
Motor B assembly	See Table 4	1
Lego box assembly	See Table 5	1

Table 3

Motor A Assembly

Component	Mfg	Part Number	Description	Color	Qty
7100 RPM motor assy	Lego	3020	Plate 2X4	Black	2
	Lego	3700	Technic Brick 1x2 with hole	Black	2
	Lego	3023	Plate 1x2	Black	2
	Lego	3039	Roof Tile 2x2, 45 deg	Black	2
	Lego	3660	Roof Tile 2x2, 45 deg, inv	Black	2
	Kysan	RE-280SA-2865	Motor, DC, 23.8 mm, 1.5-4.5V, 7100 RPM, 0.16A		1
	Radio Shack	278-1156	Wire with Covered Alligator Clip	Black	1
	Radio Shack	278-1156	Wire with Covered Alligator Clip	Red	1
	Pololu	1001	Cross Adaptor for 2mm Shaft	Grey	1
					14

Table 4

Motor B Assembly

Component	Mfg	Part Number	Description	Color	Qty
3100 RPM motor assy	Lego	3307	Brick with Bow, 1x6x2	Grey	2
	Lego	3700	Technic Brick 1x2 with hole	Grey	4
	Lego	3795	Plate 2x6	Grey	1
	Kysan	RF-500TB-1445	Motor, DC, 32 mm, 1-9V, 3100 RPM, 0.026A	Grey	1
	Pololu	1001	Cross Adaptor for 2mm Shaft	Grey	1
	Radio Shack	278-1156	Wire with Covered Alligator Clip	Black	1
	Radio Shack	278-1156	Wire with Covered Alligator Clip	Red	1
					11

Table 5

Suggested Parts for Each Set of Legos per Group of Students

Qty	Item
1	Lego, 8-tooth gear
1	Lego, 40-tooth gear
1	Lego, 24 Tooth Crown Gear
1	Lego, Double Conical Wheel Z12 1m
1	Lego, Double Conical Wheel Z20 1m
8	Lego, Technic Bush for cross axle
8	Lego, Technic 1/2 Bush
8	Lego, Connector Peg
4	Lego, Connector Peg, 3M with Stop Bush
4	Lego, Cross Axle 6M
4	Lego, Cross Axle 8M
4	Lego, Cross axle 12M
4	Lego, Cross Axle, Extension 2M
4	Lego, Technic Brick 1x2 with hole
4	Lego, Technic Brick 1x4 with holes
4	Lego, Technic Brick 1x6 with holes
4	Lego, Technic Brick 1x10 with holes
2	Lego, Technic Brick 1x16 with holes

2	Lego, Plate 2x4
2	Lego, Plate 2x6
2	Lego, Plate 2x8
1	Lego, Technic Lever 3M
2	Lego, Rim Wide with cross 30/20
4	Lego, Wheel with Split Axle hole
2	Lego, Tire, Offset Tread, 24 x 8
2	Lego, Tire, Balloon 43 x 26
4	Lego, Tire, Offset Tread, 30 x 10.5
1	7100 RPM, 23.8mm Motor Assembly
1	3100 RPM, 32mm Motor Assembly

Table 6

Solar Cell A Assembly

Component	Mfg	Part Number	Description	Color	Qty
0.82W Solar Cell Assembly			2V/410mA Solar cell , 82x70mm		1
	Lego	3001	Brick 2x4	White	1
	Radio Shack	278-1156	Wire with Covered Alligator Clip	Black	1
	Radio Shack	278-1156	Wire with Covered Alligator Clip	Red	1
					4

Table 7

Solar Cell B Assembly

Component	Mfg	Part Number	Description	Color	Qty
0.735W Solar Cell Assembly			3.5V/210mA Solar cell, 110x56 mm		1
	Lego	3001	Brick 2x4	White	1
	Radio Shack	278-1156	Wire with Covered Alligator Clip	Black	1
	Radio Shack	278-1156	Wire with Covered Alligator Clip	Red	1
					4

Table 8

Parts List for Cart (1 per teacher)

Component	Mfg	Part Number	Description	Qty
Pull Cart	Lego	4512363	Cross Axle, Extension 2M	4
	Lego	370726	Cross Axle 8M	4
	Lego	4211622	Bushing for cross axle	12
	Lego	4184286	Tyre, Normal Wide, 43.2x22	4
	Lego	4297210	Rim, Wide with Cross 30/20	4
	Grocery		Glad Plastic Storage Container	1

Steve Spangler Science http://www.stevespanglerscience.com
Edmund Scientifics http://scientificsonline.com
Kysan Electronics http://store.kysanelectronics.com
Jameco www.jameco.com
Pololu www.pololu.com
Kelvin www.kelvin.com
Lego Pick a Brick http://shop.lego.com/en-US/Pick-A-Brick-ByTheme
Brick Link http://www.bricklink.com
Radio Shack www.radioshack.com

Preparations of Materials:

Solar Cell Assemblies
Prepare the solar cells by attaching little alligator clips to the end of each wire. Pull back the plastic insulation and feed the wire through the little hole. Twist tight, and then slide the plastic insulation back into place. There is no need to solder. If the solar cells have no wires, then solder half a test lead with alligator clip onto each terminal.

Glue Lego pieces to the backs of the solar cells. You could first sand off the Lego bumps prior to gluing but it is not necessary. See Figure 1. In order to glue the brick securely, super glue works, or E6000 Jewelry adhesive works well and can be ordered online from www.DickBlick.com.

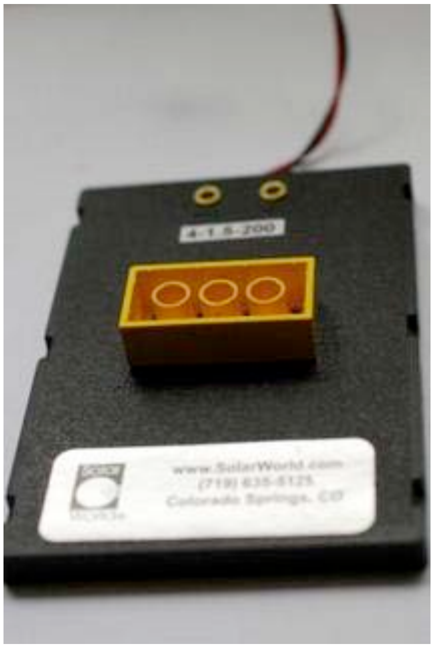


Figure 1. Solar cell with sanded-down Lego pieces glued to back.

Motor Assemblies

Prepare the motors by super gluing Lego pieces to each motor to create a motor mount. Feed shrink tubing onto each half of a test lead, then solder test leads with alligator clips to the terminals on each motor. Blowdry the shrink tubing so it shrinks around the soldered joint. See Figure 2.

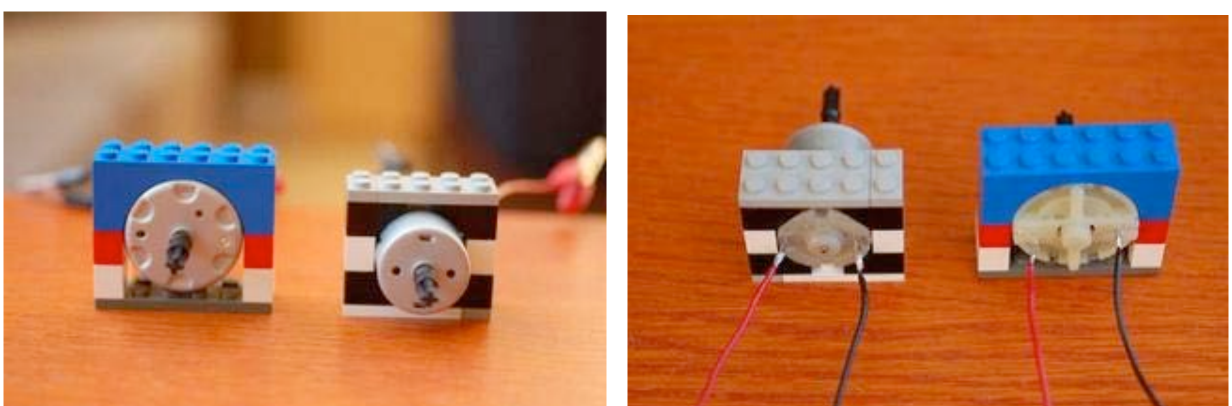


Figure 2. Solar cells and motors with connectors

Lego Parts Assemblies
Sort Lego pieces so that each group has sufficient supplies to build one car. See Figure 3 for picture of suggested supplies listed in Table 5.

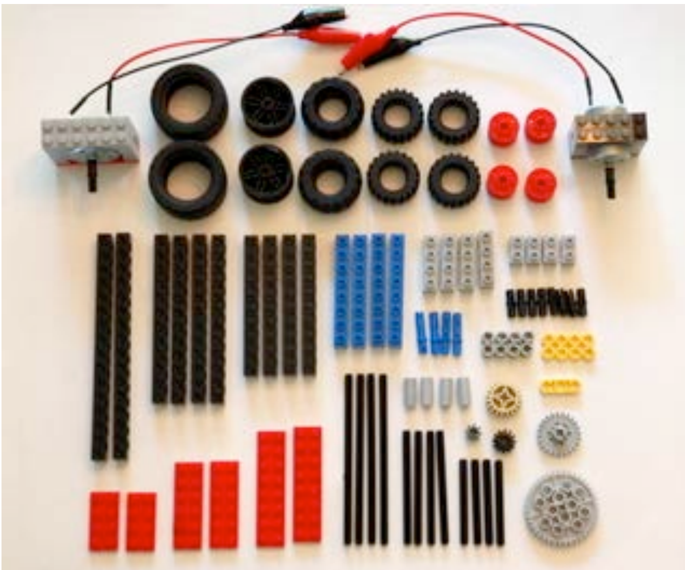
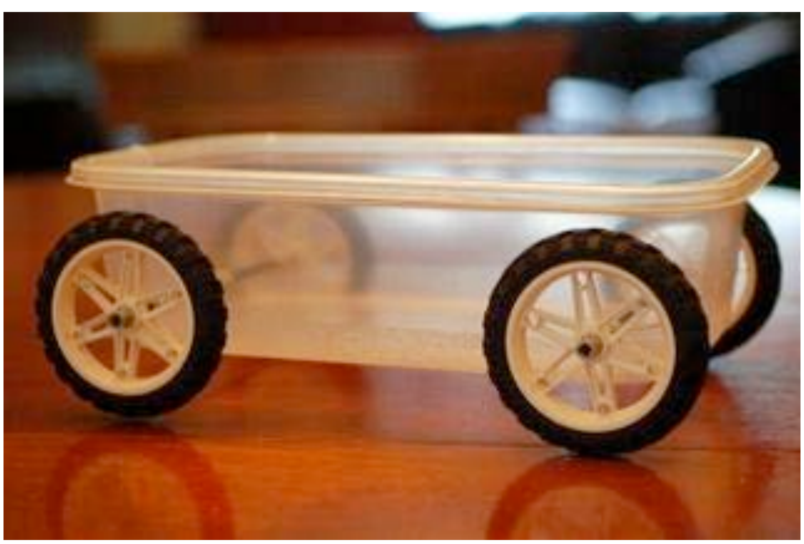


Figure 3. Suggested Legos for each solar car

Cart Assembly
You will also need to build a cart that the solar vehicle will pull. The cart will be loaded with plaster-filled sea bird eggs, so it needs a sufficient surface area. See Figure 4 for an example of what kind of cart you can build, and Figure 5 for a picture of plastic eggs filled with Plaster of Paris.



Cart for pulling rocks

Eggs

APPENDIX B

Name: ______________________________Date: _________________ AMSTI Site: ________________________

Force, Motion, and Energy Evaluation

- This questionnaire is about your understandings of force, motion, and energy.
- For each question circle the answer that is closest to your understanding.
- Be sure to read all the choices before selecting one.

1. **What is the best definition of energy?**
   a. Energy is a natural resource.
   b. Energy is the ability to make things go, change, or happen.
   c. Energy is the ability to do work quickly.
   d. Energy is the substance required to make electricity.

2. **What happens to the electric energy used to operate a hair dryer while it is on?**
   a. The energy transforms into kinetic and thermal energy.
   b. The energy returns to the electric company.
   c. The energy gradually disappears until none of it remains anywhere.
   d. The energy becomes potential energy.

3. **When designing a car tire, it is important to consider the friction the tire will have on the road. Why?**
   a. The tire needs to have friction with the road or the car will not move.
   b. Friction slows down motion, therefore the driving tires should have as little as possible.
   c. Friction makes things heat up, and hot tires perform better on wet roads.
   d. Some tires should be smooth to reduce friction, like on a race track.

4. **How does a solar cell work?**
   a. Heat activates the electrons in the silicon dioxide layers.
   b. Batteries are used to power the solar cells.
   c. Light pushes electrons from one silicon layer to the next.
   d. Water in small tubes is heated, and circulated through generators.

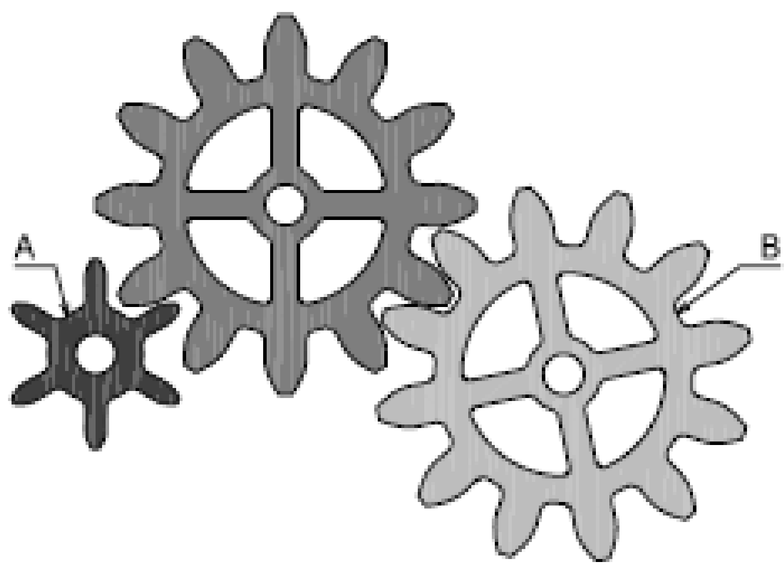
5. **What is the best definition of "force"?**
   a. A force is a push on an object.
   b. A force can either be a push or a pull on an object.
   c. Force is a property of matter.
   d. A force is the energy required to move something.

6. **Where do gasoline and oil get their chemical energy?**
    a. They get energy from the decay of radioisotopes.
    b. They get energy because the substances are stored in the ground.
    c. They get energy from living things that decayed long ago.
    d. They get their chemical energy only when they burn.

7. **The primary purpose of a solar cell is to convert…**
    a. thermal energy to electric energy
    b. light energy to mechanical energy
    c. thermal energy to mechanical energy
    d. light energy to electric energy

8. **Would a solar cell be useful in a cold, cloudy place?**
    a. No, because solar cells need warmth to work.
    b. No, because solar cells need clear skies to work.
    c. Yes, because solar cells can be powered by batteries.
    d. Yes, because photons can pass through clouds.

9. If Gear A turns clockwise. What direction and speed does Gear B rotate?



a. Gear B rotates clockwise just as fast as Gear A
b. Gear B rotates counterclockwise just as fast as Gear A
c. Gear B rotates clockwise faster than Gear A
d. Gear B rotates clockwise slower than Gear A

10. The primary purpose of an electric motor is to convert…

a. electric energy to thermal energy
b. electric energy to mechanical energy
c. mechanical energy to thermal energy
d. mechanical energy to electric energy

11. How does gasoline make a car engine run?

a. Gasoline is burned, creating electricity, which creates motion in the motor.
b. Gasoline is ignited with spark plugs and it is the heat from the spark plugs that drives the motor.
c. Gasoline is mixed with air and burned, which causes the burning gases to expand and create a force on the pistons.
d. Gasoline is burned and this creates exhaust, which is forced out the back of the car, creating propulsion.

12. A car with a full tank of gasoline is driven until it runs out of gas. What happened to the gasoline's energy?

a. It was only used to move the car.
b. It moved the car, while the battery powered the stereo, lights and air conditioning.
c. It moved the car, ran the car's equipment, heated the engine, and created noise.
d. Some energy moved the car, some ran the car's equipment, some heated the engine, and some created noise. However, some energy was destroyed.

13. A heavy block with a string attached is placed on a table. You pull on the string to the right with a force of 7.5 Newtons. However, the block does not move. A spring scale, attached to the string, reads 7.5 N. Which force acting on the block is also equal to 7.5 N?

a. The weight of the block
b. A force exerted by atmosphere
c. The upward force exerted by table
d. The force exerted by static friction

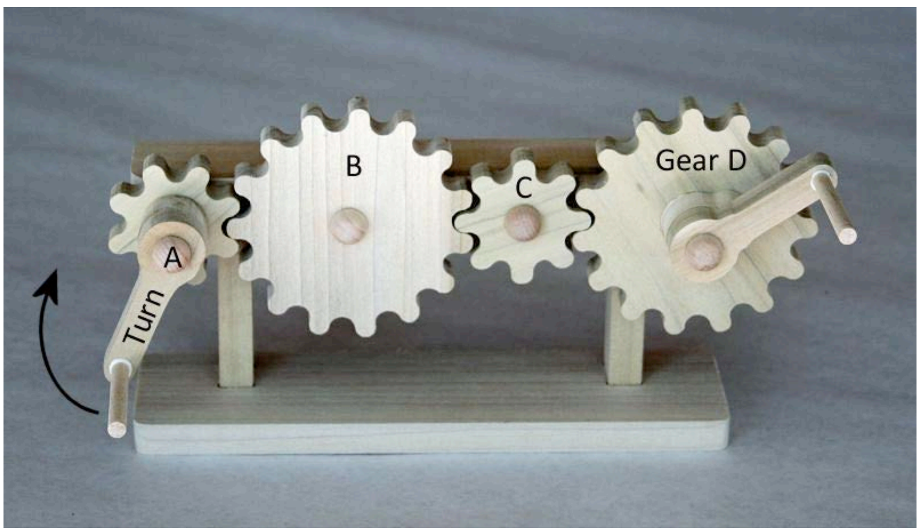
14. What is the purpose of having gears in a machine?

a. To reverse the direction of the motion.
b. To increase or decrease torque.
c. To increase or decrease rotational speed.
d. All of the above.

15. **What happens to most of the crude oil pumped out of the Earth?**
    a. It becomes fuel oil to heat our homes
    b. It becomes gasoline for transportation
    c. It is used in power plants to create electricity
    d. It is used to make plastics

16. **Another word for a twisting force is…**
    a. momentum
    b. crank
    c. inertia
    d. torque

17. **When you turn a gear train as seen in the picture, what effect does it have on Gear D?**



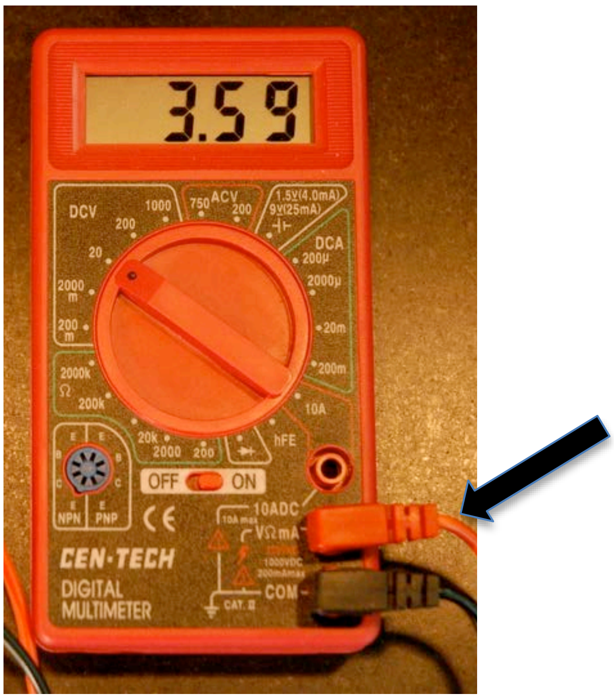
    a. Gear D turns faster with more torque than Gear A
    b. Gear D turns slower with less torque than Gear A
    c. Gear D turns faster with less torque than Gear A
    d. Gear D turns slower with more torque than Gear A

APPENDIX C

Multimeter Directions

Multimeters measure multiple things!
(Multi = multiple, meter = measure)

To measure electric VOLTAGE in a circuit turn the dial here:



DCV means Direct Current Voltage, the type of voltage created by a battery or a solar cell. The number 20 means the maximum voltage measured is 20 Volts.

To measure electrical CURRENT in a circuit turn the dial here:

DCA means Direct Current Amps, the type of current created by a battery or solar cell. The number 10A means that the maximum current measured is 10 Amps.

Move the red wire to the 10ADC plug when measuring current.

APPENDIX D

Name__________________________ Date_________________Block/Period___________

Solar Cells Investigation

A solar cell is very similar to a plant leaf. A plant leaf uses photosynthesis to convert sunlight to useful energy. Solar cells use a similar process to convert light energy to electrical energy. Closely examine the two types of solar cells carefully. What do you see? How are they different? How are they similar?

Background:

Energy per second = Volts x Amps
1 Watt = 1 Joule per second
Light source = 100W lamp
Two types of solar cells labeled A and B

Investigation Question: How much electrical energy per second can each solar cell produce?

Procedure:

1. Use the alligator clips to attach one solar cell to the multimeter.
2. Configure the multimeter to measure Voltage.
3. Hold light source approximately 12 inches directly above the solar cell.
4. Read the value for Voltage in volts and record in the data table below.
5. Configure the multimeter to measure Current.
6. Hold light source approximately 12 inches directly above the solar cell.
7. Read the value for Current in amperes, or amps for short, and record in the data table below.
8. Repeat the above steps for both solar cells.
9. Multiply the voltage (V) and current (A) to find energy per second (Joules per second).
10. Shade the solar cell with waxed paper and bubble wrap in different amounts. How does this change the amount of energy the solar cells produce?

Results:

Solar Cells	**Voltage** *(Volts)*	**Current** *(Amps)*	**Energy/second** *(Joules/sec)*	**Power** *(Watts)*
Solar Cell A Without shading				
Solar Cell B Without shading				
Solar Cell A With shading				
Solar Cell B With shading				

APPENDIX E

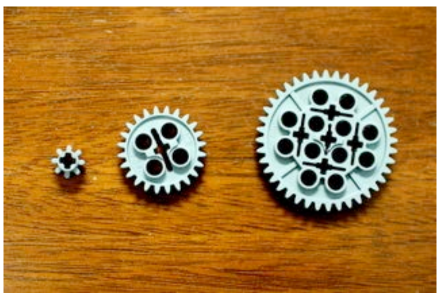
Name__________________________ Date_________________Block/Period__________

How Gears Help Drive the World

Gears and gear trains (multiple gears working together) are used everywhere around us to help the machines we use everyday work better. In this investigation we will look at how gears can slow down or speed up motion and how they can make a small motor do a big job.

Activity 1- Examine the gears

Look at each of the gears in your kit: You may find three gears with 8, 24, and 40 teeth. Each of these is a special type of gear called a spur gear.



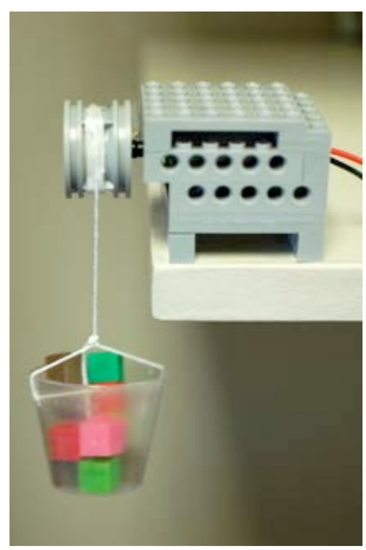
What about each gear is similar?

What is different?

Activity 2- The Motor

Objective: How much weight are your motors capable of lifting without the help of gears?

Procedure:



1. Secure the first motor firmly to a table top and attach a LEGO wheel (without a tire) to the shaft to act as a spool.
2. Tape some string to the wheel so that it can be wound around the spool. The other end of the string should be attached to a cup used to lift various weights.
3. Connect the motor to a battery or to a solar cell and shine the light on it.
4. Find the maximum load the motor can sustain by adding rocks, marbles, or Unifix cubes to the plastic cup until you find a load that the motor cannot raise.
5. Record the maximum number of cubes lifted by each motor below.

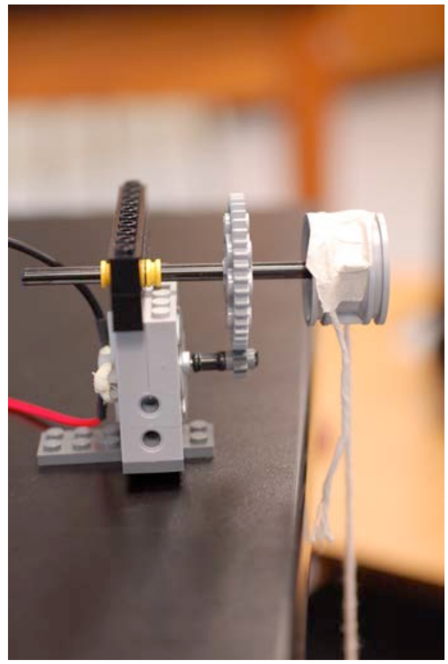
My big motor could lift _________ unifix cubes.
My smaller motor could lift __________ unifix cubes

Activity 3- Bring in the Gears

Objective: Will adding gears allow the motors to lift more weight?

Procedure:

1. Choose the motor that was the strongest. Using the pieces in your kit connect **the small gear to the motor** and **the medium gear to the wheel** holding the string.



2. Connect the motor to the battery (or shine the light on the solar cell).

3. How many unifix cubes can your motor lift now?

4. Record the results below.

   With the smaller gear on the motor, my stronger motor could lift _________ unifix cubes.

5. Now, switch the gears so that the large gear is on the motor and the small gear is on the wheel holding the string.

6. Connect the motor to the battery.

7. How many unifix cubes can your motor lift now?

8. Record the results below.

With the large gear on the motor, my stronger motor could lift ____________ unifix cubes.

APPENDIX F

Name__________________________ Date__________________Block/Period___________

What is Friction?

Why is ice so slippery? Why is it so difficult to push or pull a heavy box across the carpet?

It's the friction that makes the box hard to push or the lack of friction that makes ice slippery. Friction is a force between two surfaces that resists motion. But friction is necessary for walking and for vehicles to move! Friction comes in many forms:

Static Friction – the force that prevents a stationary object from moving.

Sliding Friction – the force that hinders the motion of an object after it has overcome static friction and is sliding on the surface.

Rolling Friction – the friction that a rolling object experiences against a surface. For example, when a car is moving, the tires experience rolling friction. Rolling friction can be 100 to 1000 times less than static or kinetic friction.

Understanding Friction: Part 1

Objective: To understand how friction and weight are related.

Prediction: Which do you think will have more sliding friction, one book or two?

Procedure:

1. Tie a string around a textbook. Hang the textbook from a spring scale. How heavy is it? ________Newtons
2. Holding the spring scale, pull the textbook and record the force that you have to apply to get the book to start moving (the reading on the spring scale in Newtons). This force is equal to the force of static friction.
3. What is the frictional force when the book is moving? This is the force of sliding friction.
4. Now, repeat steps 1-2 with two textbooks instead of one.
5. Record all results in the table below.

Results:

Number of Books	Weight (N)	Static Friction Force (N)	Sliding Friction Force (N)
1			
2			

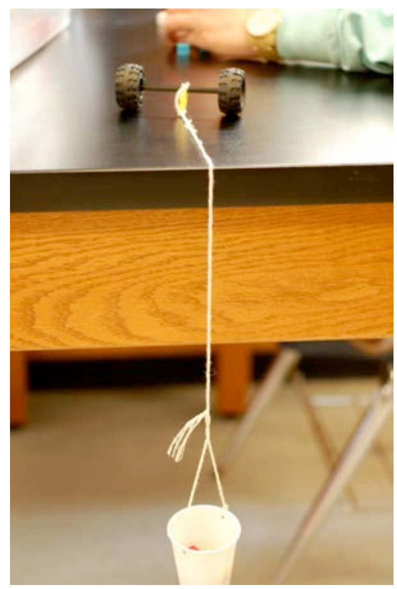
Discussion:

How do your results compare to your prediction?

How does an object's weight affect the friction force?

Understanding Friction: Part 2

Objective: To understand that different materials have different frictional properties.



Prediction: Which tires have the most sliding friction? (Hint: You need sliding friction to keep from sliding!)

Procedure:

1. You have three sets of tires and each set is different from the other. How are these tires different? Using the little Lego with the cross hatch opening, connect two tires so that the tires do not roll.
2. Hang the plastic cup on a string from the axle of the two tires.
3. Drop Unifix cubes into the cup to see how much force is necessary to get the tires to start moving Remember, 10 cubes = 10 grams = 0.1 Newtons.
4. Determine which set of tires has the greatest frictional force. Remember, without sliding friction, your car will slide!
5. If you want to build a solar car that can transport many people, what kind of tires do you think you need? Do you want tires with very little sliding friction, or tires with more?

Results:

Set of tires	Number of cubes	Weight in cup (N)	Friction Force (N)
small			
medium			
large			

APPENDIX G

Engineering Design Process