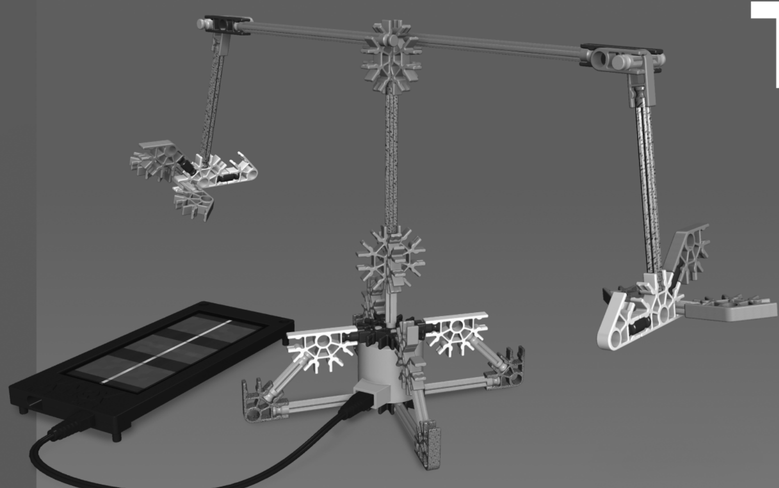
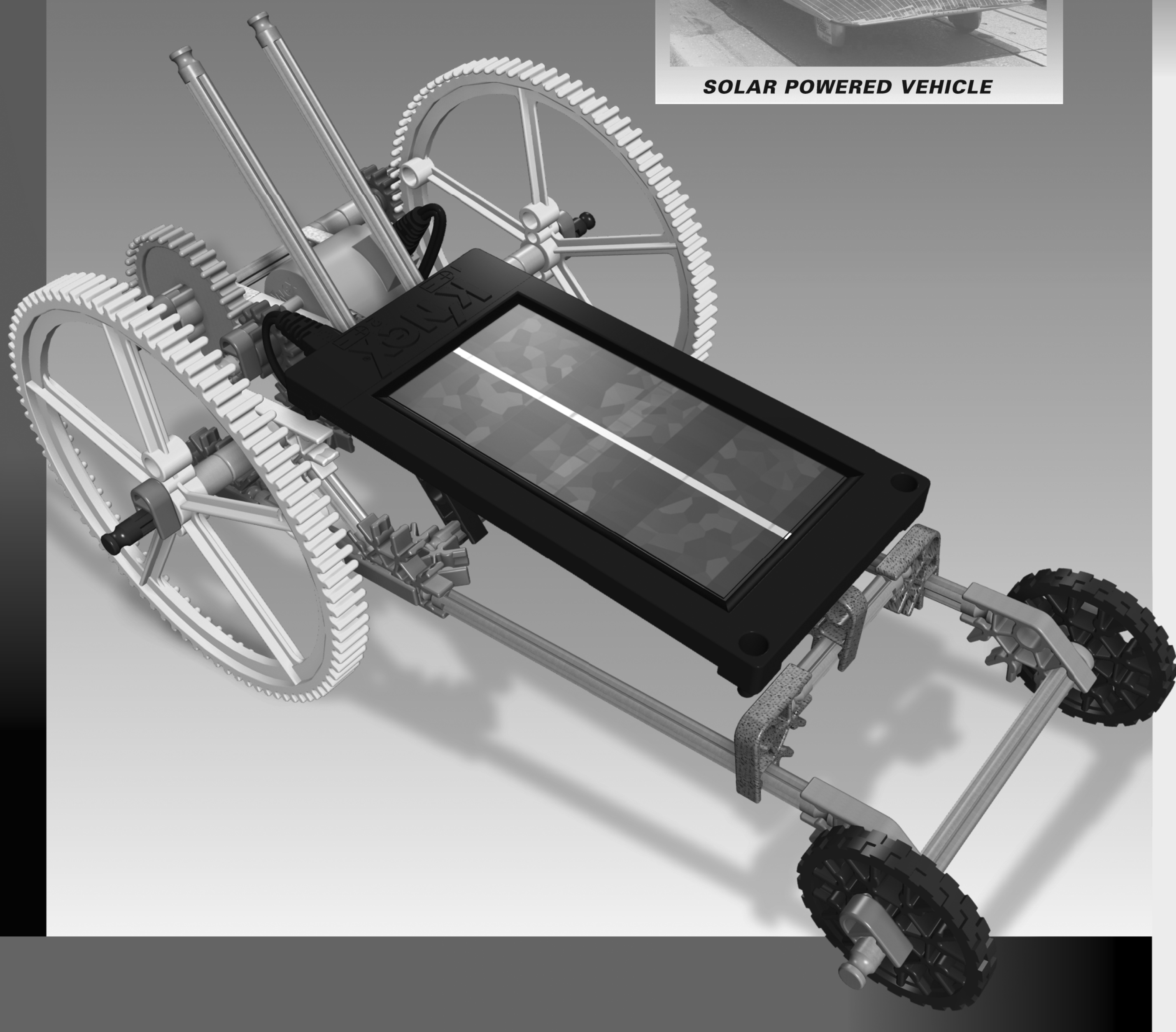
K'NEX® Education

TEACHER'S GUIDE™

SOLAR ENERGY™



SOLAR POWERED VEHICLE



Solar Energy

Teacher's Guide

KNX 96191-V2

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Conforms to ASTM Standard Consumer Safety Specification on Toy Safety, F963-07.
Manufactured under U.S. Patents 5,061,219; 5,137,486; 5,199,919; 5,238,438; 5,346,420; 5,350,331; 5,368,514; 5,421,762; 5,423,707; 5,427,559 and 5,518,435 and D389,203.
Other U.S. and foreign patents pending.

⚠ WARNING:

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

0-3

A Note About Safety

Safety is of primary concern in science and technology classrooms. It is recommended that you develop a set of rules that governs the safe, proper use of K'NEX in your classroom. Safety as it relates to the use of solar panels and light bulbs should be specifically addressed.

PARTICULAR CAUTIONS

1. **IMPORTANT:** Read all warnings and safety information before you start to build and operate the models.
2. **! WARNING:** Light bulbs can cause burns when they are lighted and hot. **NEVER TOUCH A LIT BULB.**
3. Do not use the K'NEX Solar Panel with a halogen bulb; the heat is too intense and **COULD BURN YOU OR CAUSE A FIRE.**
4. This set operates with sunlight or a 100-watt bulb (lamp sold separately). Use a gray Rod distance from the light bulb to the Solar Panel. The gray Rod measuring device will keep your Solar Panel 19cm (7.5") away from the light bulb. **DO NOT** place the Panel closer than one gray Rod distance as it may overheat and be damaged.
5. Never place the Solar Panel on top of your lamp or let it touch the bulb. You will damage (melt) the Solar Panel.
6. **NEVER EXCEED** the recommended wattage for your lamp (sold separately).
7. **Do not look directly at the sun.**
8. **CAUTION:** Keep hair, hands, face, clothing, and Power Cords away from all moving parts. Never put fingers in moving gears or other moving parts.

Table of Contents

Introduction to the K'NEX Education Solar Energy Set and Teacher's Guide

Background

The adoption of an inquiry-based approach to teaching science and related subjects is now widely recognized as a key strategy for effective learning outcomes. As the National Science Education Standards[1] explain:

> *Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in the light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (p.23)*

It is this approach that underpins the suggested activities for the **K'NEX Education Solar Energy Set.** These activities have been designed to accommodate a wide range of teacher guidance and direction in the classroom. They recognize that most students will typically progress from more structured learning environments, where the teacher uses a guided inquiry approach, to one where they are self-directed and generate their own questions.

In this way students can be encouraged, initially, to find answers to questions such as:

- How can light create movement?
- Is there a link between the amount of light striking a solar panel and the amount of electricity it generates?
- How fast does the solar car travel?

As their inquiry abilities develop, however, the teacher can adopt a more open approach by providing opportunities for students to both pose their own questions and plan and carry out their own investigations. Students are not provided with 'recipes' or sets of instructions to follow. Instead, they are helped to consider, and encouraged to discuss among themselves, how these investigations might be undertaken. For example, they may think about questions like these:

- What do we need to measure?
- How will we make the measurements?
- What equipment do we need to make the measurements?
- How many measurements do we need to take to get reliable results?
- How do we record and present our results?

By adopting this type of approach students, with teacher help, learn and develop an understanding of simple experimental and investigational techniques in a stimulating learning environment. The investigations are theirs. With ownership of the activities and investigations, the students become highly motivated, inquiring learners.

[1]National Research Council. 1996. *National Science Education Standards.* Washington, DC: National Academies Press.

Addressing Science and Technology Standards

The K'NEX Education Solar Energy Set and Teacher's Guide can be used to support science and technology curricula for Grades 6 - 9 with hands-on, inquiry-based instruction, as shown in Tables 1 and 2 below.

National Science Education Standards[1]

	LEVELS 5 - 8	LEVELS 9 - 12
Unifying Concepts and Processes	• Systems, order, and organization • Evidence, models, and explanation	
Science as Inquiry	• Abilities necessary to do scientific inquiry • Understanding about scientific inquiry	
Physical Science	• Transfer of energy • Motions and forces	
Earth and Space Science	• Earth in the solar system	• Energy in the earth system
Science and Technology	• Abilities of technological design • Understanding about science and technology	
Science in Personal and Social Perspectives	• Populations, resources, and environments • Science and technology in society	• Science and technology in local, national, and global challenges

Table 1: National Science Education Standards that can be addressed with the K'NEX Education Solar Energy Set.

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ITEA Standards for Technological Literacy[2]

STANDARDS	BENCHMARK TOPICS GRADES 6 - 8	BECHMARK TOPICS GRADES 9 - 12
The Characteristics and Scope of Technology	• Usefulness of technology	
The Core Concepts of Technology	• Systems • Resources • Processes	• Systems • Resources • Processes
Relationships Among Technologies and the Connections Between Technology and Other Fields	• Interaction of systems	• Technology transfer • Innovation and invention
The Attributes of Design	• Design leads to useful products and systems	
Engineering Design	• Brainstorming • Modeling, testing, evaluating, and modifying	
Apply Design Process	• Model a solution to a problem • Test and evaluate	
Energy and Power Technologies	• Energy can do work using many processes • Power systems	• Law of Conservation of energy • Energy sources • Renewable and non-renewable forms of energy

Table 2: ITEA Standards for Technological Literacy that can be addressed with the K'NEX Education Solar Energy Set

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[1] National Research Council. 1996. *National Science Education Standards*. Washington, DC: National Academies Press.

[2] International Technology Education Association. 2000. *Standards for Technological Literacy: Content for the Study of Technology.* Reston, VA: International Technology Education Association.

Introduction

TEACHER'S GUIDE

Intended as a resource for the teacher, the guide offers ideas for using the K'NEX Education Solar Energy Set to introduce physical science concepts associated with **energy** to students in Grades 6 - 9. **Topics** addressed in this curriculum support material include:

1. Investigating Solar Energy
2. How Well Do Solar Cells Work?
3. Storing Electricity
4. Energy To Get Moving
5. Making Energy Work For Us
6. Solar Powered Mechanisms
7. Generating Electricity

Each **lesson** comprises a number of ideas for possible teaching activities. These can help develop and reinforce students' knowledge and understanding of key energy and other physical science concepts including:

- Energy cannot be created or destroyed.
- Energy takes different forms, including solar/light and heat.
- Energy can be converted from one form into another.
- Energy can be transferred from one place to another.
- Energy can be described as kinetic or potential.
- Work and power.

LESSON	MODEL	POWER SOURCE
1. Investigating Solar Energy	Mini Shuttle Ride	Solar Panel only
2. How Well Do Solar Panels Work?	Mini Shuttle Ride	Solar Panel only
3. Storing Electricity	Crank Man	Capacitor and Solar Panel
4. Energy To Get Moving	Solar Car	Solar Panel or Capacitor
5. Making Energy Work	Spinner; Mini Shuttle Ride	Solar Panel or Capacitor
6. Solar Powered Mechanisms	Slider; Cam Operated Pump; Double pump	Solar Panel or Capacitor
7. Generating Electricity	Double pump; one other K'NEX Solar powered model	Mechanically generated electricity

Table 3: Models and Power Source(s) Used in Specific Lessons

Table 3 identifies the K'NEX Education Solar Energy **models** that are used in each lesson and the power source students will use for their investigations.

Extension ideas for each lesson are also provided. In these activities students may be asked to apply their knowledge and understanding of science concepts to solve simple technological problems.

Lists of useful **websites** are included throughout the guide to encourage further research by the students. These were active at the time of going to press.

In the event that students encounter a problem with the built model, the **troubleshooting guide** on Page 8 provides suggested solutions.

CD-ROM

The accompanying CD-ROM provides building instructions, as pdf files, for each of the K'NEX Education Solar Energy models. This allows the teacher to print additional hard copies of the instructions for groups of students, or to have them available for students to use directly from a computer screen.

Bonus Model

Included on the K'NEX Education website, www.knexeducation.com, are step-by-step instructions for using the Solar Energy Set to build an awesome, solar vehicle that actually orients itself to the sun and then moves in that direction. This model uses two solar panels and two of the motors that are included in your set. It is an ideal model to use as a culminating activity and it provides students with a complex system to investigate and describe.

Please use the following address and password to gain access to the building instructions for the K'NEX Education Solar Tracker Car: www.knexeducation.com/solar. For Bonus Model instructions enter the password: **EDINS45**.

Safety Guidelines and Operating Tips

Safety guidelines and general operating tips are provided on Page 6 - 7 of the guide. Teachers are encouraged to spend time at the start of the Solar Energy unit conveying this information to their students. They should also remind students to pay careful attention to the safety guidelines highlighted in the Building Instructions each time they build and use a new model.

Using the Solar Panels and Capacitors

It should be noted that in each K'NEX Education Solar Energy Set there are 2 Solar Panels and 2 Capacitors, which allow 4 K'NEX models to be built and operated simultaneously. Time must be allowed, however, for those using the Capacitors to fully charge their units via the Solar Panels before the start of their investigations. This will require some organization and cooperation among the various groups.

Student Journals

It is expected that students will have journals available to record information, thoughts and investigations. They should be encouraged to enter their initial thoughts as they begin each inquiry. These initial thoughts may be amended as their inquiry and analysis progresses until the student is able to draw informed conclusions. The students' journal entries will assist them as they make the connections between the behavior of their models during experiments and the real world mechanisms their models represent. In addition, their written responses will encourage the use of newly learned vocabulary associated with energy concepts, and will provide an opportunity for them to write across the curriculum. The journals also offer a place for students to practice drawing annotated diagrams of the investigations they undertake. Finally, the journals serve as an **assessment vehicle** for the Solar Energy unit. (Note: Other assessment ideas are included at the end of the lessons.)

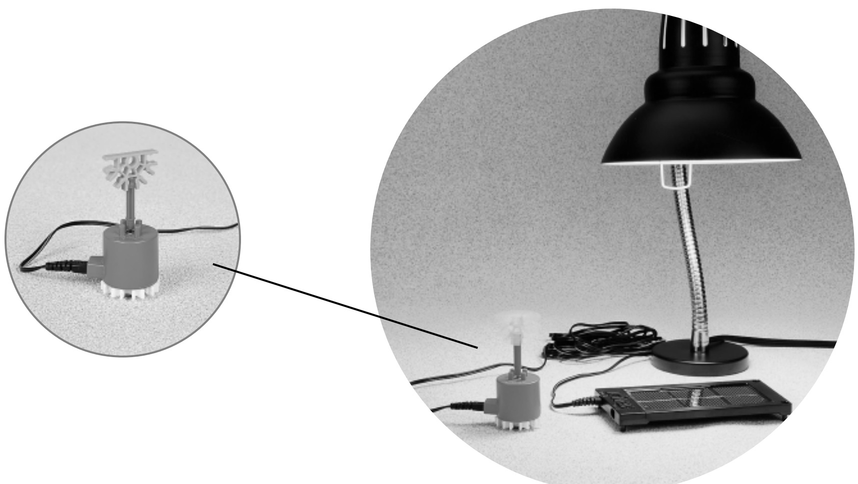
Operating Tips, Safety Guidelines, and Troubleshooting

The following information should be shared with your students before they begin to use the K’NEX Education Solar Energy Set. Ensure that the students also read the warnings and operating tips provided on Pages 2 - 3 of the accompanying Building Instructions. We encourage you to regularly remind students of these safety guidelines as they undertake the classroom activities associated with the K’NEX materials.

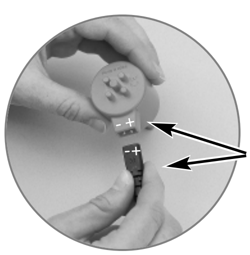
We suggest that you administer a safety assessment activity, such as a short quiz, that focuses on the safety concerns associated with this Solar Energy Set.

General Operating Tips

- Always test the Motor, Power Cord and Solar Panel before building the models. Please refer your students to Page 3 of the Building Instructions for step-by-step guidelines.



- Do not drop the Solar Panel. You may crack the solar cells and this could significantly reduce the power output.
- Do not use solvents or wire wool on any part of the Solar Panel, Motor, Capacitor, or Power Cord.
- Do not leave the solar components outside as they could be damaged by moisture.
- Teachers should examine the K’NEX Solar component parts regularly for damage. The Power Cord should not be used if frayed or broken.
- Plug the Power Cord firmly into the proper jacks located in the K’NEX Solar Panel, Motor, and Capacitor.



These marks determine the direction your model will turn.

Capacitor Warnings and Information

- The Capacitor does have polarity, much like a battery. The polarity is marked on the housing. Matching polarity is important during charging, but not while discharging the Capacitor. The direction in which the motor turns, however, is dependent on the polarity.
- It is imperative that students match polarity when charging the Capacitor. Reversing polarity when charging can damage the Capacitor.
- Do not short the terminals together. This can damage the Capacitor.
- To charge the Capacitor:
  - Plug one end of the Power Cord (lead) into the silver Capacitor, making sure that you line up the polarity marks (+ to + and – to -). The other end of the Power Cord plugs into the Solar Panel. It will take approximately 2-3 minutes to recharge.
  - When charged, unplug the Power Cord from the Solar Panel and plug it into the Motor installed on your model. The Capacitor should hold its charge for at least 10-15 minutes when not in use and provide 30-60 seconds of power when working to drive the Motor of the model.

*NOTE: Lessons 3 and 4 have activities that involve students investigating the **length of time** required to charge and discharge the K'NEX Capacitor. You may not, therefore, want to share this information with your students until after they have completed their investigations.*

Solar Panel Operating Tips

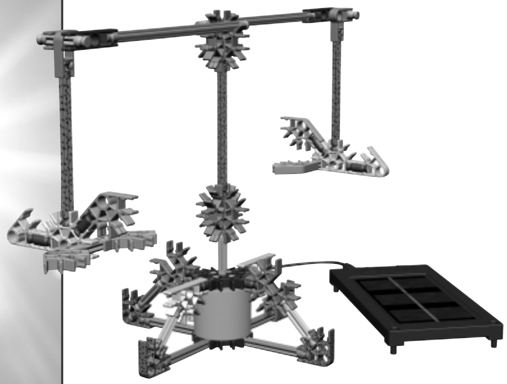
- The K'NEX Solar Panel works with:
  - The sun outdoors or through a window. (Remember: **NEVER look directly at the sun**.)
  - A standard incandescent 100-watt clear filament light bulb. (Remember: Do not exceed the wattage specified for your lamp.)
- The K'NEX Solar Panel works less effectively with:
  - Soft white and frosted light bulbs.
  - 3-way light bulbs.
- The K'NEX Solar Panel does not work with:
  - Fluorescent light bulbs.
  - Flashlights.
  - Halogen light bulbs. (The heat from this type of bulb is too intense and will melt the Solar Panel.)
- The K'NEX Solar Panel:
  - Reacts to light but not to heat. This means the more light there is available, the more effective the energy output of the Solar Panel.
  - Must be positioned at least 19cm (7.5") away from the light bulb. Make sure, however, it is not too far away as, with less light reaching the Solar cells, less power will be generated.
- Using 2 or 3 K'NEX Solar Panels together:
  - Connecting 2 or 3 Solar Panels together increases the amount of power that can be generated.
  - To connect two panels together, connect one end (plug) of the Power Cord to Jack 1 on the first Solar Panel and then connect the other end to Jack 1 on the second Solar Panel. Next, connect one end of a second Power Cord to Jack 2 (on either Panel) while the opposite end should be connected to the Motor.
  - Do not connect more than 3 Solar Panels together. This will supply more power than the Motor can handle and may cause it to be damaged.

Troubleshooting

Troubleshooting Guide

PROBLEM	SOLUTIONS
Motor shaft is not spinning.	• Check to see if both plugs are fully inserted into the jacks. • Make sure that the front of the Solar Panel is directly facing your light source. • If you are outside using natural sunlight, make sure it is a bright, sunny day with strong shadows. • If you are indoors using artificial light, make sure you are using an incandescent light bulb. Your Solar Panel **does not work** with fluorescent lights or flashlights (torches). • Make sure that your Solar Panel is not too far away from the artificial light source. The further you move the Panel from the light source, the less power it will generate and the slower the Motor will spin. Be sure, however, to position your Solar Panel at least 19cm (7.5”) from the light bulb. • Check the Motor using a different Power Cord.
The orange Rod comes off the Motor’s metal drive shaft.	• Unplug the Power Cord (lead) from the Motor, remove the Motor from the model and carefully push the Rod back onto the metal drive shaft, taking care not to bend the metal pin.
The model does not operate.	• Give your model a tap to get it started. • Recheck the instructions to make sure the model is built correctly. • If your model isn’t spinning freely, check every connection. • Check to see if the model spins freely, and that all the gears are operating and meshing. • Check to see if the tan Clip is locked into the small tan Gear on the motor shaft (orange Rod). • Make sure the black Connector is firmly on the Connector pegs of the Motor. • Move the small tan Gear and tan Clip slightly away from the black Connector. They may be attached too tightly/closely. • Test the Motor when it is not connected to the model.
The model operates backwards.	• Unplug the Power Cord from the Motor and insert the plug the opposite way. (See Page 3 of the Building Instructions.)
The model will not stop.	• Unplug the Power Cord from the Panel or Capacitor or Motor. • Position the Solar Panel away from the light source.

If you still experience problems you cannot solve please contact us at K’NEX Education:
Phone: 1-888-ABC-KNEX (Toll free), Monday – Friday, 8:30 AM – 5:00 PM Eastern time (USA and Canada only)
E-mail: abcknex@knex.com
Write: K’NEX Industries, Inc., P.O. Box 700, Hatfield, PA 19440-0700



Lesson 1: Investigating Solar Energy

Time
70-80 minutes

Learning Objectives
Students will:
- Practice & develop their observational skills.
- Apply prior knowledge in an unfamiliar situation.
- Learn & explain how energy can be transferred & converted from one form into another.
- Demonstrate how solar cells can be used to generate electricity.
- Learn & use vocabulary associated with energy & solar energy.

Materials
Each group will need:
- 1 K'NEX Mini Shuttle Ride model with Solar Panel
- 100-watt incandescent (filament) light bulb OR natural sunlight
- Cable to connect Solar Panel and Motor
- Student Journals
- Card or paper to cover Solar Panel

Overview for the Teacher

Students will investigate how light can create movement by using the **K'NEX Mini Shuttle Ride** model and a **Solar Panel**. They will trace how light energy can be converted into electrical energy, which in turn is converted into movement by an electric motor. The idea of input (light energy), outcome (electrical energy) and process/processor (Solar Panel) can be introduced.

If appropriate, class discussions based on student observations of their model's behavior could include other physical science concepts such as **Newton's Laws of Motion, momentum, centripetal forces** and **inertia.**

Teacher's Notes
*Each K'NEX Solar Energy Set contains two Solar Panels and two Capacitors, allowing 4 groups of students to work simultaneously – 2 groups using the Solar Panels as an energy source for their models and 2 groups using the Capacitors. This introductory series of activities, however, relies on the use of the **K'NEX Solar Panel only,*** making it *necessary for groups to **EITHER** double up **OR** for 2 groups, each with their own model, to share a Panel.*

Review

Your students will be more successful if they have an understanding of the following energy concepts and their associated vocabulary. For example, that energy:
- cannot be created or destroyed
- can be converted from one form of energy into another
- can be moved from place to place
- takes different forms, including light/solar, heat, movement and sound
- can be described as kinetic or potential

Lesson 1

Introduction

Explain to the students that they will use the K'NEX Mini Shuttle Ride model and a Solar Panel as they undertake a series of activities to find answers to the question: **How does light create movement?** Observations should be recorded in their journals.

Teacher's Notes
In these activities students will normally work in small groups of 2-3 to build their K'NEX Mini Shuttle Ride model or make use of a previously built model.

When time allows, student groups should be encouraged to construct their own models. This encourages cooperation and communication skills, 3-D spatial awareness and other skills related to interpreting 2-D drawings, and following a sequenced set of instructions to construct a 3-D model. In addition, constructing models enables students to familiarize themselves with a construction system they may use later as a modeling medium for their own designs.

Activity 1: What is needed to make the model move?

Process

In Groups

1. Distribute the K'NEX materials.

2. Use Pages 6-7 of the Building Instructions to construct the K'NEX Mini Shuttle Ride model. Students should not connect the Solar Panel at this time.

3. Provide a few minutes for the groups to identify the key parts of the model and what they might do.
   Electric Motor; rotating rides; Solar Panel

4. Ask (and record on the board), the following questions:
   - What is needed to make the model move?
   - What does the Motor need to enable it to drive the model?
   - Where does the electricity come from?

Whole Class

5. Review their answers. Look for responses that state the model will not move (turn) unless a **force** is applied. This force can be a push or can come from the electric motor. Electricity provides the "push" to make the motor turn.

Activity 2: What happens when light strikes the solar panel?

Process

Whole Class

1. Demonstrate/review the safety precautions for the Solar Panel. Emphasize that to avoid heat damage to the solar cells within the Panel the artificial light source should be no closer than 19 centimeters or 7.5 inches (approximately 1 gray Rod length).

Teacher's Notes
This activity can be completed in natural sunlight or using an artificial light source.

In Groups

2. Ask each group to connect their model to the Solar Panel (see Teacher's Notes above) and observe what happens to their Mini Shuttle Ride when light is shone onto the Solar Panel. Encourage them to observe very closely and explain that you expect a detailed response.

3. If using artificial light, ask the students to do the following:
   a. Move the light source further away from the panel. Observe what happens.
   b. When the panel is under the light source and the ride is moving, cover the panel with a piece of paper or card. Observe what happens.

4. Where feasible, encourage the students to compare the use of artificial light versus the use of sunlight with their Solar Panel. Can they offer an explanation for their observations.

Teacher's Notes
Observations
Many students do not see the need for careful observation. Many see something happening but do not necessarily observe the event. Rather than simply state that the model moves they should note that it starts to move slowly and gradually picks up speed. Careful observation is the key to good science. Some groups may need to give their model a small push to help it to start to move. The Mini Shuttle Ride model will move slowly at first, gather speed until it eventually rotates at a constant speed. Simultaneously, the small planes on the ride will move up and outwards.

(a) When the Solar Panel is further from the light source it slows.

(b) When the Solar Panel is covered the ride slows and stops.

The greater the intensity of the light source the greater will be the electrical energy output from the Solar Panel. The greater the amount of electrical energy generated by the Solar Panel, the faster the motor will turn. Bright sunlight will be more effective than a standard 100-watt light bulb even though the sun is almost 150,000,000 kilometers away.

Whole Class

5. Discuss with the groups how the Mini Shuttle Ride, Solar Panel, light source, cable and K'NEX Motor represent a **system**. You may ask the students to identify the components that are working together to make the ride operate.
   - Which part of the system provides the **input**? Describe that input.
   - What is the **output** in this system? Which part(s) of the system provide the output?

6. Encourage the students to think of other input/outcome systems. Discuss the concept of cause and effect, if appropriate.

7. By discussion/demonstration establish that:
   - Light energy is the input and kinetic energy (movement) is the outcome for the complete system.
   - We can trace both the energy pathway through the system and the energy conversions involved in our investigation: Using input from the students, you may want to develop diagrams of the pathways and conversions on the board. (See Page 12 for examples.) Energy transfer diagrams are also addressed in Activity 4 on Page 13.

Lesson 1

Natural Light Source (Sun)

1	Sun	→	solar panel	→	cable	→	motor	→	model
			Input				**Output**		
2	Chemical energy (potential)	→	Radiant energy	→	Electrical energy	→	Mechanical energy (kinetic)		

Artificial Light Source (Incandescent Bulb)

1	Light bulb	→	solar panel	→	cable	→	motor	→	model
			Input				**Output**		
2	Electrical energy (potential)	→	Radiant energy	→	Electrical energy	→	Mechanical energy (kinetic)		

- The sun is one of the main energy sources on Earth and that energy has been transferred from the sun into kinetic energy (movement) in the model. This allows the model to spin.
- Energy is needed to produce a force.

8. Students should keep a record of their observations and a summary of the class discussion in their journals.

Extension Activity

Ask the students to propose reasons as to why the planes rise as the ride turns.

Teacher's Notes
The reasons proposed by the students may provide an opportunity to ***discuss rotational motion, centripetal force, and acceleration.***

Activity 3: Testing a modified model

Process

In Groups

1. Ask each group to remove the planes and arms from their Mini Shuttle Ride.
2. Suggest that they feel the weight of the removed parts.
3. Explain that they will be repeating Activity 2 (above) with the modified model. Ask the students to record in their journals whether or not they expect the outcome to be the same as before and to give reasons for their answer.
4. Students undertake the activity to test their ideas and record their observations in their journals.
5. Observation guidelines:
   - Describe how the model behaved.
   - Was this different from when the planes and the arms were attached? (To refresh memories, suggest that students reattach the arms and try again.)

Teacher's Notes
With the arms detached, the outcome is that the model rotates at full speed almost immediately and when the Solar Panel is covered, it will come to a stop just as quickly.

In Activity 2 above, the turning force of the motor had to overcome the inertia (dead weight) of the ride – the same effect you might experience when trying to push a heavy object along the floor. It requires a lot of effort just to get the object moving from a resting position, but as it increases in speed it becomes easier to maintain the speed.

With the ride components removed, the mass to be moved is small compared to the original, so the motor has only a small "dead weight," or inertia, to overcome.

Whole Class

6. Discuss the class observations and what the students have learned.
   Questions to ask:
   - How were your observations of these two trials (with/without arms) different?
   - What reasons can you offer to explain your observations?

7. If appropriate you may wish to use the behavior of the model to introduce the concept of **momentum** at this point, or to reinforce prior learning in students who have already covered this topic.

8. Ask the students to summarize the class discussion in their journals.

Teacher's Notes
The complete ride model takes longer to stop because it has much greater momentum.
Momentum *is related to the mass of an object and the velocity at which it moves.*

Momentum = mass x velocity

This means an object with a large mass will have a much greater momentum than one with a smaller mass when both are traveling with the same velocity.

A large, heavy object moving at a slow speed can have a large momentum and so will be difficult to stop. For example, a loaded freight train may take up to a mile to come to a halt, while giant super tankers can require distances of several nautical miles to stop.

Activity 4: Energy Transfer

Process

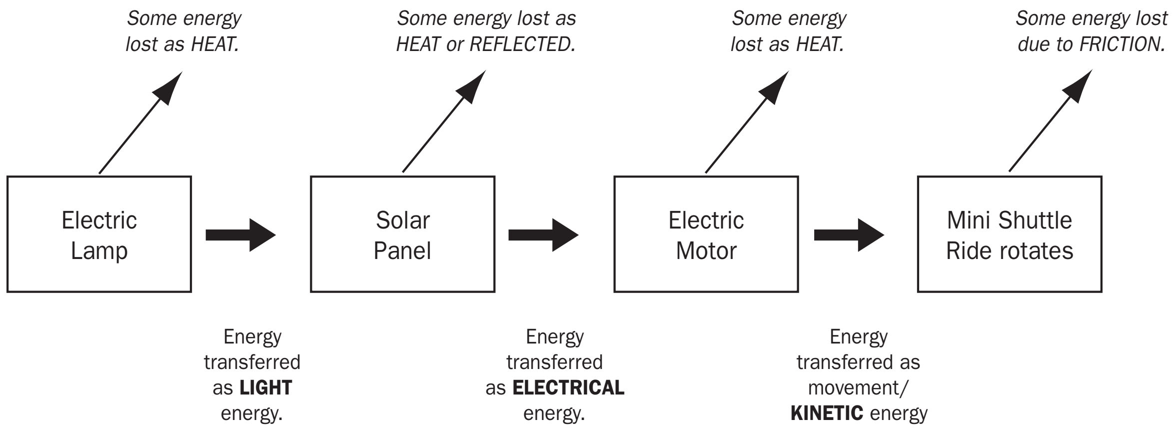
Whole Class

1. Explain that in the following activity the students will be introduced to a way of identifying and visualizing the energy transfers and conversions that have taken place in the system they have been investigating. They will use simple **energy transfer diagrams.**

2. Discuss the main forms of energy the students observed at work in their Mini Shuttle Ride models.
   Electrical energy, light energy, movement.

3. On the board, demonstrate how energy transfer diagrams can be used to show the movement of energy from place to place. (See Page 14.)

A Simplified Energy Transfer Diagram



4. Explain that energy can be lost (dissipated) to the system in a number of different ways. For example, energy dissipated as heat as the result of friction in moving parts.

5. Ask the students the following questions:
   - Which device converted the radiant energy from the light source into electrical energy? (*The solar panel*)
   - What was used to convert the electrical energy into mechanical (kinetic) energy? (*The electric motor*)

Review

- **Discuss what the students have learned about solar energy and energy transfer.**
- **Ask the students to think of, and share with the class, other examples of systems that make use of solar energy as their primary energy source.**
  (Photosynthesis, swimming pool heaters, home electricity generation, road signs along highways.)

Extension Idea: Science and Technology

Ask the students to investigate how the Mini Shuttle Ride model behaves with 4 arms and rides attached.

- Can they predict its behavior?
- Can they explain their observations?

Teacher's Notes

As discussed above, students should have noticed how their model starts slowly and builds up to operational speed, but when the Solar Panel is covered, the ride slowly comes to a stop. With the arms removed, the motor starts at full speed, but comes to a halt very quickly when the Solar Panel is covered. Students may find that with 4 arms attached, their model may not move without a gentle push to help it on its way. This extension idea allows a further discussion of the concepts of momentum, kinetic energy and inertia.

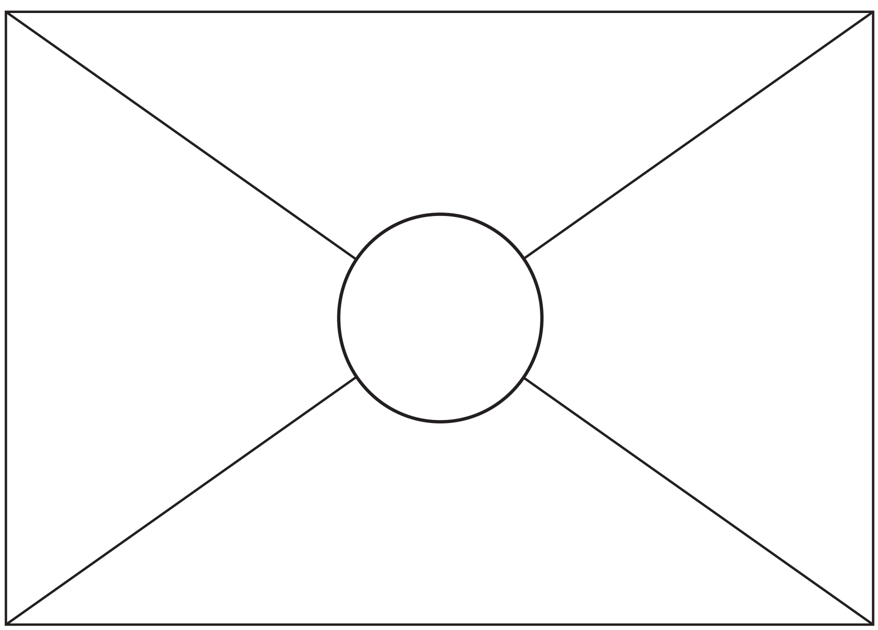
Assessment

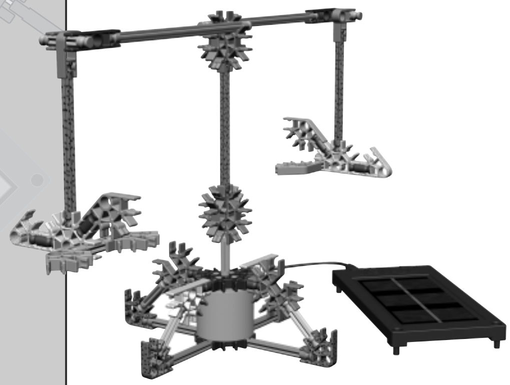
1. Journal records, with diagrams.

2. Mat Activity:
   - Ask the students to sit in groups of 4 around a table.
   - Provide each group with a sheet of chart/easel paper.
     Arrange the paper as shown so that there is a triangle-like shape in front of each student.
     They should write their name in this space.
   - Have each student list in the space what they have learned from their investigations of the Mini Shuttle Ride and the Solar Panel. They should provide as much detail as possible.
   - Ask the group to discuss what they have written and then to put information that they have agreed upon in the circular space in the center of the sheet.

The triangular area of the 'mat' offers you an understanding of what individual students learned from the activities. The circle gives a sense of changes to individual thought as a result of the discussion with the student's work group. You may wish to assign both an individual and a group grade to this activity.

Chart paper for use with assessment activity:





Lesson 2: How Well Do Solar Panels Work?

Time

Each activity requires 40-45 minutes.

Learning Objectives

Students will:

- Explain that the amount of electricity produced by a solar panel depends on the amount of light energy it receives.
- Describe and explain the advantages and disadvantages of a solar energy source for producing electricity.
- Understand and practice simple experimental investigation techniques.
- Describe how an independent variable is something that we change or that is changed in an experiment.
- Explain that experiments are used to find the links or relationships between variables.

Materials

Each group will need:

- 1 K'NEX Mini Shuttle Ride model
- 1 K'NEX Solar Panel
- 100-watt incandescent (filament) light bulb OR natural sunlight
- Stop watch or stop clock
- Ruler
- Card or paper to cover Solar Panel
- Student Journals
- Protractors (optional)
- Access to a selection of light bulbs with different wattages and finishes: (40W/60W/75W/clear/frosted etc.)

PRACTICAL NOTE: For the activities in this lesson 2 student groups will be required to **share** a Solar Panel. Alternatively, you may want to combine students into larger working groups.

Overview for the Teacher

- In this series of activities students will investigate some practical advantages and some limitations of using solar panels to generate electricity.
  These activities build on those undertaken in **Lesson 1: Investigating Solar Energy.**

- Students will develop their understanding of scientific investigative techniques as they design and carry out investigations to find answers to questions about the relationships between variables affecting the electricity generation by their K'NEX Solar Panel.

- They will plan how to carry out their investigation, what to measure, how to make and record measurements, and how to present their results as they interpret their findings.

- At this point, you may wish to introduce your students to other names commonly used for Solar Panels such as solar cells, photocells and photovoltaic cells. Explain that the K'NEX Solar Panel they will be using is made up of a number of solar cells.

Review

- Your students will be more successful if they have some understanding of, and can identify, variables in experiments.

- As a starting point, you may want to review with the class how they used their K'NEX Solar Panels in Lesson 1. Students used a commercially produced solar panel to generate electricity to operate the Mini Shuttle Ride. Energy from the sun, or an incandescent light bulb, provided radiant energy that was converted to electricity by the K'NEX Solar Panel.

- As the students move to the next activity, they should begin to ask questions about the solar panel they were using.
  - Is this the largest solar panel there is?
  - Why is a solar panel of this size put in my set?
  - Does the K'NEX Solar Panel produce more energy in the sunlight or under a bulb?
  - Will it make more energy if I use a brighter bulb?
  - How does the panel react outside on a cloudy day?
  - Will the panel make enough energy to power the model if I cover part of the surface of the panel?

- As students raise these questions and others, they will begin to develop independent variables that they can investigate and explore.

Teacher's Notes
An independent variable is something that we change, or that is changed, in an experiment. Experiments are used to find the links, or relationships, between variables. For example, the size of the kicking force used by an American football punter or place kicker determines how far the ball will travel. The kicking force is the independent variable and the distance the ball travels is called the dependent variable. When doing ***controlled*** *experiments, scientists use independent variables they can control, (100-, 75-, and 60-watt electric light bulbs, known masses,) and not ones that may change from minute to minute (natural sunlight).*

To help students as they plan, discuss what they need to measure, based on their understanding of variables, and talk about how this can be accomplished.

If your curriculum indicates that students should be able to identify and use independent and dependent variables, include these terms in your discussions.

There are several models that you could reference to aid students as they
develop their experimental strategies. (Examples: the 5E Instructional Model or the Four Question Strategy)

http://linus.chem.ukans.edu/Hewlett/fivee.html Compares the 5E Instructional Model with traditional laboratory approaches.

http://ssibroker.colorado.edu/broker/jimshort/BSCS%205E%20INSTRUCTIONAL%20MODEL.PDF An overview of the 5E Instructional Model.

Cothron, Julia H., Ronald N. Giese, and Richard J. Rezba. 1999. Students and Research: Practical Strategies for Science Classrooms and Competitions. Dubuque, IA: Kendall/Hunt Publishing Co.

For a review of this book see:

http://www.nsta.org → Select: Science Store → Enter Keywords: Students and Research Practical Strategies.

Lesson 2

Activity 1: Making Connections

Introduction

The class will undertake a series of investigations to find answers to questions about the Solar Panel and how well it works. They will use the K'NEX Mini Shuttle Ride model and a Solar Panel for these investigations.

> ***Teacher's Notes***
>
> *Students will normally work in small groups of 2 or 3 to build their K'NEX Mini Shuttle Ride model, or they will make use of a previously built model to save instructional time. For this particular activity, two student groups will **share a Solar Panel** as they test their individual models.*
>
> *Students should be instructed to keep a **journal record** of their observations and results, as well as a summary of the class discussions.*
>
> *If time allows, student groups should be allowed to construct their own models. This:*
> - *encourages cooperation and communication skills*
> - *develops 3-D spatial awareness and other skills as they follow and interpret a sequenced set of instructions using 2-D drawings to make a 3-D model*
> - *increases familiarity with a construction system that may be used later as a modeling medium for the students' own designs*

Process

In Groups

1. Distribute the K'NEX materials.

2. Use Pages 6-7 of the K'NEX Building Instructions to construct the K'NEX Mini Shuttle Ride model. Students should **NOT** connect the Solar Panel at this time.

3. Allow a few minutes for groups to become familiar with the operation of the model.

4. Explain that each group will carry out an investigation to prove or disprove their ideas on how they think Solar Panels work. They will design their own experiments.

5. Explain how they must start with a hypothesis. Discuss some possible hypotheses, for example:
   - **If** I use a stronger light source, **then** the model will move faster.

   In other words, they are hypothesizing that a strong light source will generate more electricity from the Solar Panel than weak light source.

   The hypothesis should be written in an **IF—THEN** format.

6. The class should agree on a hypothesis.

7. Ask how they might carry out an investigation to prove or disprove their hypothesis.

8. Review safety precautions. Provide time for the students to plan and then undertake their investigations. Remind them to carefully record their findings, using appropriate techniques.

9. If students need help planning their investigations, the following questions may be asked, one at a time, and recorded on the board.
   - How will you measure the amount of light striking the solar panel?
   - How will you measure the amount of electricity generated?

- What did you learn from **Lesson 1: Investigating Solar Energy** that might help you decide what to do?
- How long do you need to count rotations – 1 minute; 30 seconds; 15 seconds or less?
- Will one reading be enough, or do you need to take more than one? If more than one, how many do you need to make?
- Will taking longer time intervals to count the number of rotations make your results more accurate? Why or why not?
- How will you record your results?
- Will you need to use a table to help record your results?
- How are you going to present your results to demonstrate the link/relationship that you are hoping to discover? Will you draw a graph? What labels will you use for the axes of your graph?

Teacher's Notes
Remind students of the safety precautions that must be used when using artificial light sources with the K'NEX Solar Panel.

The questions (#9) should be set up as clues if your students are having difficulty designing their own experiments. You may want to post the questions on the board, one at a time, to spur thinking.

*You may wish to discuss/review **Lesson 1: Investigating Solar Energy** in which students should have observed how their Mini Shuttle Ride models slowed down, or may have stopped, as the light source was moved further from the Solar Panel. Some students may suggest trying frosted and clear light bulbs or bulbs with different wattages, for example 40W, 60W, 75W and 100W.*

The electric motor turns faster or slower depending on the amount of electricity generated by the Solar Panel. Measuring the speed of rotation of the Mini Shuttle Ride model will provide a measure of the amount of electricity generated.

If students are unable to come up with their own ideas, explain that they can:

- *Measure the distance from the light source to the Solar Panel and move the light source further away for successive trials.*
- *Note the wattage of the light bulb they use and vary the light bulbs.*
- *Count the number of rotations of the ride in a given time period.*

As students explore and experiment to determine the effect of the variable they have chosen, remind them that, other than for the variable they are testing, they should keep conditions for each of their trials exactly the same. For example: if they are testing the use of different wattage light bulbs, they need to be sure that the distance from the bulb to the Panel, the orientation of the Panel, etc. all remain constant. Remind students that as they seek to design and complete a "fair test," that all other aspects of the experiment must remain constant. Some experimental strategies will even require students to keep a list of the factors that they knowingly kept constant during their experiment.

Younger students may think that one experimental trial is enough. They should be encouraged to consider taking at least 3 or more recordings each time the light source distance is increased - explain that it is usual to have a small amount of "experimental variation".

Alternatively, you may wish to pool and average class results at each measurement point and discuss the possible reasons for any variations found.

Lesson 2

Whole Class

10. Discuss with the class what they learned about experimental investigation techniques. Ask individual working groups to use their results to explain any relationship they discovered. They should use correct terminology such as, **hypothesis, independent and dependent** variables.

Extension Activity

Ask each group to use their results to predict the outcome if the light is placed x cm. from their Solar Panel.

Teacher's Notes
REMINDER: The Solar Panel should not be placed closer than 19cm from a light bulb as the heat generated can damage the panel.

Activity 2

Introduction

For this and remaining activities students will use their knowledge and understanding of experimental investigation techniques gained from Activity 1 to plan and carry out other investigations, to answer simple questions, and to find out more about how solar panels work.

This activity comprises two short investigations.

Teacher's Notes
The groups will continue to use the K'NEX Mini Shuttle Ride model and Solar Panel for these activities. No additional construction time is needed.

*Two groups will need to share (take turns using) a **K'NEX Solar Panel** for these investigations.*

If sufficient teaching time is not available for each group to carry out both investigations, (each practical activity will require about 30 –35 minutes to complete,) you may wish to consider having half the class undertake Activity 2.1 and the other half Activity 2.2. Once the investigations have been completed, groups from each half of the class may first be given the opportunity to consolidate and discuss their results before reporting back to their class colleagues.

Process

In Groups

1. Demonstrate/review the safety precautions for the use of a K'NEX Solar Panel.

2. Ask each group to connect their model to the Solar Panel and observe what happens to the Mini Shuttle Ride model when they change the angle of the Solar Panel to the light source.

3. Assign the activity to the class/divide the class into two separate sets of working groups.

Group 1: Is there a link between the angle at which light strikes the solar panel and the amount of electricity it generates?

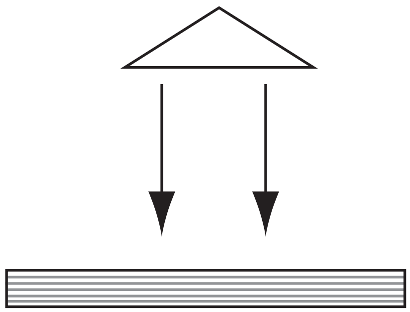


Fig. 1: Light striking vertically

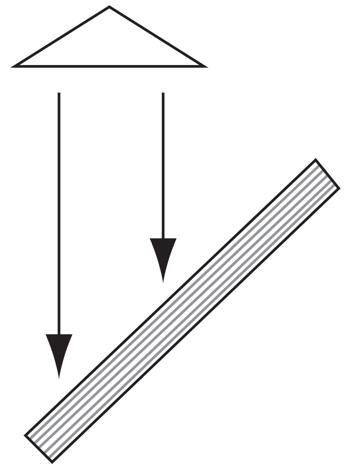


Fig. 2: Light striking at an angle

4. Groups should be asked to:
    - Identify the independent and dependent variables, and then
    - State what they think is the link between the variables.

    Record these as questions on the board.

Teacher's Notes
One possible link the students might identify: The angle of the Solar Panel to a light source may or may not have any effect on the amount of electricity generated by the Solar Panel.

5. Ask each group to plan and carry out their investigations. If necessary, ask the students to consider the following as part of their planning process:
    - How will you measure the angle of the Solar Panel to your light source?
    - How many different angle readings will you need to investigate to make the experiment valid? Two, three, or more?
    - How will you measure the amount of electricity generated by the Solar Panel? How many readings will you need to take at each Solar Panel angle?

Teacher's Notes
The questions (#5) should be set up as 'clues' if your students are having difficulty designing their own experiments. You may want to post the questions on the board, one at a time, to spur thinking.

Allow 20 minutes for this part of the activity - they may need to measure angles, complete three trials, and record and analyze their data.

Lesson 2

Group 2: Is there a link between the surface area of the K'NEX Solar Panel that is exposed to light and the amount of electricity it generates?

6. Groups should be asked to:
   - Identify the independent and dependent variables, and then
   - State what they think is the link between the variables.

   Record these as questions on the board.

Teacher's Notes
Possible links the students might identify:
1. *The amount of electricity generated by the Solar Panel (dependent variable) may or may not be related to the surface area of the Solar Panel (independent variable) exposed to sunlight/incandescent light.*

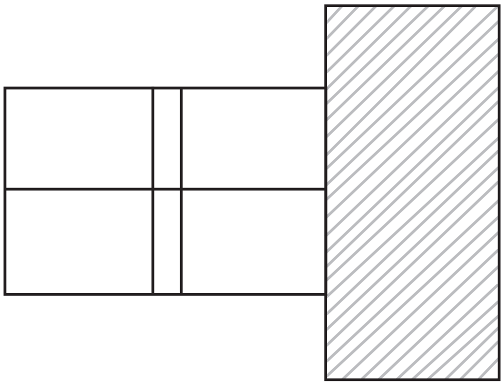
2: *The amount of electricity generated by the Solar Panel may or may not be related to the amount of the Solar Panel that is covered i.e. horizontally or vertically.*

If the class is unable to identify the variables and the links, you may wish to record the above examples on the board.

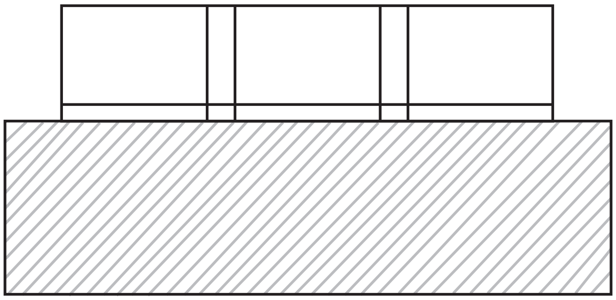
This activity may be carried out in either natural sunlight or using an artificial light source.

Students should be asked to first look at the structure of the Solar Panel and to consider if this may have any effect on the possible outcomes.

Can they relate the structure of the K'NEX Solar Panel to how it works? There appear to be three vertical panels, divided in half, horizontally, by a silver metallic strip. How might this structure affect the amount of electricity produced by the Solar Panel when it is partly covered?



(a) Vertical strip covering one-third of the Solar Panel



(b) Horizontal strip covering one-half of the Solar Panel

> ***Teacher's Notes***
> *Students should discover that covering one-third with a **vertical** strip (a) results in **no output movement** in the model, whereas covering one-half **horizontally** (b) still allows movement even though a large surface area is covered.*
>
> *Older students might be able to use a multi-meter to measure voltage and current output to confirm the information on the Solar Panel i.e. 1.38volts and 500mA.*

7. Ask each group to plan and carry out their investigation. If necessary, ask each group to consider the following as part of their planning process:
   - How will you measure the area covered?
   - How many different areas do you need to investigate to make the experiment valid? For example 1/3; 1/2; 2/3; 1 (the whole Solar Panel).
   - How will you measure the amount of electricity generated by the Solar Panel? How many readings do you need to take for each area?

> ***Teacher's Notes***
> *The questions (#5) should be set up as a series of 'clues' if your students are having difficulty designing their own experiments. You may want to post the questions on the board, one at a time, to spur thinking.*
>
> *Allow 20 minutes for this part of the activity. Remind students to record their observations in their journals.*

Whole Class

8. Ask what the class has learned about the way in which solar panels work and the implications their findings may have on their practical application as an alternative source of electrical energy for use in the home or workplace.

> ***Teacher's Notes***
> *If time is available you may wish to broaden the class discussion to test the students' understanding and the implications of their findings on the practical application of using solar panels as a source of electrical energy.*
>
> *Where have they seen solar panels being used? What types of buildings or workplaces make use of electricity produced by solar panels?*
>
> *What are the potential advantages and disadvantages of using solar panels as a source of electrical energy?*
> *In which countries would solar panels offer a very practical solution for electrical energy needs? Why?*
> *Where would solar panels not be very practical? Why not?*
>
> *If they were incorporating solar panels into the design of a home/building as a way to reduce energy costs, where, and in which direction, would they place the solar panels to obtain the maximum amount of electricity? They should assume the building is located in the Northern Hemisphere. Students should be able to support their answers using evidence obtained from their investigations and research.*

Lesson 2

Teacher's Notes
Some useful web sites that may help students with further study and research on Solar Panels and renewable energy:

http://www.bigfrogmountain.com/phototour.cfm A commercial site but in the gallery sidebar on the home page there is a display of photographs showing different and varied uses of solar panels.

http://www.ases.org/ The American Solar Energy Society (ASES) is a national organization dedicated to advancing the use of solar energy for the benefit of U.S. citizens and the global environment. ASES promotes the widespread near- and long-term use of solar energy.

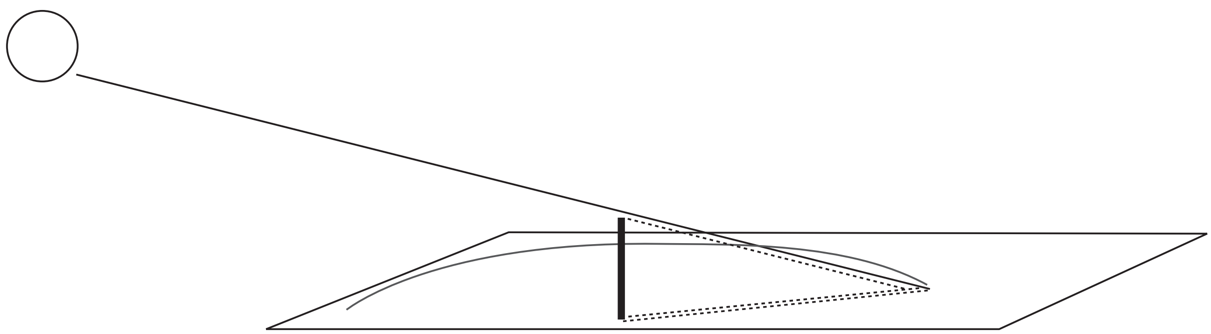
http://www.solar4power.com/solar-power-education-links.html A commercial site but it offers extensive data sources for educational purposes including global maps of average real sun hours, US insolation charts (by state),and links to other solar resource sites.

http://www.nrel.gov/clean_energy/solar.html The National Renewable Energy Laboratory website. Follow a link to Photovoltaic cells for an explanation as to how they work.

http://www.eere.energy.gov/solar/multimedia.html U.S. Department of Energy - Energy Efficiency and Renewable Energy site. A useful site for students to explore.

Extension Activities

1. Students carry out a simple experiment to track the passage of the sun across the horizon and measure the angle of the sun to the horizon.



Teacher's Notes
This simple method of measuring the angle of the sun to the horizon is based on the sundial or ***gnomon****.*
The students trace the passage of the shadow of the upright pointer as it passes across the card during the day.
The angle (dotted lines) produced from the top of the pointer to the trace gives the desired reading.

2. Science and Technology

Use K'NEX and/or other appropriate materials to make a frame to hold the Solar Panels in the optimal position for use in all other investigations.

- What are the critical features/decisions that will influence your design?
- Use information from your earlier investigations to help make critical design decisions.

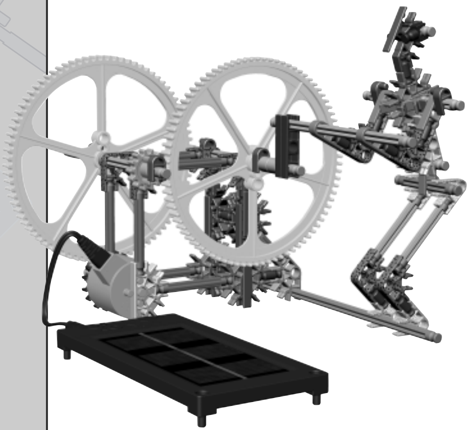
3. Technology: Design and make challenge

In the developing world, schools may not have access to a power source to operate fans for cooling and ventilating hot, stuffy classrooms. Use your K'NEX Solar Energy kit and other appropriate materials to design and make a **solar powered fan** for safe use in a classroom used by young children.

- Indicate in your plans where the fan and Solar Panel will be placed.
- What are the critical features/decisions that will influence your design?
  For example:
  - Safety issues - consider the ages of the children who may be in the classroom.
  - What factors will affect the positioning of the Solar Panel?
  - What factors will affect the positioning of the fan to enable it to meet the design brief?

Assessment

Student should be expected to maintain journals that include detailed notes and, where appropriate, annotated diagrams of their investigations.



LESSON 3: Storing Electricity - Using The K'NEX Capacitor

LESSON 3

Time
75-80 minutes for each of Activities 1 & 2.

Learning Objectives
Students will:
- Understand and explain how capacitors can be used to store and transport energy.
- Understand that stored energy is potential energy.
- Practice and develop their observational skills.
- Practice simple experimental investigation techniques.

Materials
Each group will need:
- 1 K'NEX Crank Man model
- 1 K'NEX Solar Panel
- 1 K'NEX Capacitor
- 100-watt incandescent (filament) light bulb
- Stop watch or stop clock
- Ruler
- Tape measure
- Student Journals

For class demonstration (optional) you will need:
- 1 spring
- 1 large rubber band
- An object such as a book
- 1 small, empty milk carton

OVERVIEW FOR THE TEACHER
Using a K'NEX Capacitor the class will investigate how electrical energy can "be saved" and stored for later use.

REVIEW
Students will have more success with interpreting their later investigations if they first explore the K'NEX Capacitor. This will help them understand its operation, benefits, and limitations as an energy storage unit.

Review how energy can be stored in many different forms before being transferred and used somewhere else. An object with stored energy has the potential to do something - the energy it contains is called **potential energy.**

You may want to complete three demonstrations to reinforce students' understanding of stored energy:
- **Stretch a spring.** Ask the students if the spring has any energy. They should respond that the spring has energy because it can recoil and snap your hand. The energy is stored in the spring until it is released. This type of stored energy is termed **potential energy.**

- **Stretch a rubber band.** Ask the students if the rubber band has any energy. They should respond as in the previous demonstration.

- **Hold an object** (book) at shoulder height. Ask the students if the book has any energy. They should respond that the book has energy because it can be dropped. If someone is unsure if it has energy, drop the book on an empty lunchroom milk carton and observe what happens to the carton. It is crushed due to the energy from the book. The book held at shoulder height has potential energy because of the force of gravity that will make it fall to the floor when the book is released. This type of potential energy is called **gravitational potential energy**.

Explain that charged batteries or electric capacitors also have potential energy – potential "electrical" energy. The stored or **potential energy** is only converted into **kinetic energy** when the tension in the spring or elastic band is released, or when the object is dropped. Similarly, **potential energy** is only converted into **electrical energy** when the battery or capacitor is connected to an output device.

Teacher's Notes
*The possible teaching activities outlined below make use of a **K'NEX Capacitor.** You may need to briefly explain what a capacitor is and what it does. Students are familiar with batteries; capacitors and rechargeable batteries can perform essentially similar functions in that they can "store electricity," be discharged, and be charged several times. If needed, you will find more detailed information about capacitors outlined below.*

Introduction

Discuss the results of student investigations in which they will have recognized some of the limitations, as well as the advantages, of using solar energy and solar cells to generate electricity. In a solar powered home, for example, where is the electricity to come from to run all the electrical devices at night? (Solar cells can operate when it is cloudy, albeit at a reduced output, using diffused light.)
Explain to the class that they will use the K'NEX Crank Man model and a Solar Panel to undertake a series of activities to find possible answers to this question.

The class will investigate how electrical energy can "be saved" and stored for later use.

Teacher's Notes
From their investigations, students should appreciate that in cases where solar energy is used as the main source of electricity in a home or elsewhere, there also needs to be some way of "storing" the electricity that is generated, making it available when there is no light.

Electrical Energy Stored in a Capacitor
*An electric capacitor has the **capacity** to store charge. It is made from two metal plates separated by a thin layer of insulating material known as a **dielectric**. Capacitors work by storing electric charge. A positive (+) charge is stored on one plate and a negative (-) charge on the other. Charging up the capacitor involves transferring electrons from the positive plate to the negative one. Once fully charged, there is a potential difference between the plates, i.e. there will be a voltage between them. The potential difference is a measure of the amount of work that a charge moving from one plate to the other can perform.*

When the stored electricity is used, the negatively charged electrons flow through an electrical device, such as the K'NEX Motor, to the positive plate. The capacitor is discharged in the process. When 'uncharged' each metal plate contains as many electrons as protons, (they are essentially in equilibrium,) so there will be no potential difference between the plates.

*Capacitors resemble rechargeable batteries in that they can be discharged and charged multiple times. In a battery, however, chemical energy is converted into electrical energy whereas a capacitor simply uses its plates to **store** electric charge.*

Lesson 3

Activity 1: Investigating the K'NEX Capacitor and how to use it

Process

Whole Class

1. Ask the class how many students have used solar powered calculators or watches? What other solar powered devices do they know or use?

2. How do these devices work when there is no light?

3. Discuss how sometimes these and similar devices need more electrical energy than they can immediately obtain from their solar cells. In such situations it is important to have available a readily accessible electrical energy supply. From where is this supply to come?

Teacher's Notes
In many solar powered devices some of the electricity generated is stored in rechargeable batteries for later use. The students may also have seen solar panels used for highway signs, streetlights, speed restriction signs and telephones, especially in remote areas.

Many electronic devices, however, only need a small store of electricity. In such cases ***capacitors*** *are used to help even out the electrical supply.*

In Groups

4. Distribute the K'NEX materials. Remind students to keep detailed journal notes of their investigations.

5. Ask each group to identify and examine their gray K'NEX Capacitor.

Teacher's Notes
The K'NEX Capacitor looks similar to a K'NEX Motor but without the drive shaft. One important feature for the students to note is the polarity marked on the Capacitor's connection jack.

6. Ask students to comment on why they think it may be important to use the correct polarity when connecting their K'NEX Capacitor to the Solar Panel? They should consider how capacitors work.

Teacher's Notes
Explain that it is very important to observe the correct polarity when connecting K'NEX Capacitors to their K'NEX Solar Panels for charging: positive to positive and negative to negative.

7. Students should connect their Capacitor to the K'NEX Motor to ensure it is fully discharged before starting any investigations.

Teacher's Notes
If any Capacitors have residual charge, ask the students to keep the model running until it stops. Explain that all Capacitors are now discharged and this will be the starting point for the class investigations. This provides all groups with an even starting point for all investigations. In this way they can help to ensure that any testing they do would be considered a 'fair test.'

8. Use Pages 18-19 from the Building Instructions to construct the K'NEX Crank Man model.

9. Once the Solar Panel has been connected to the Crank Man model, students can turn on their light and spend a few minutes observing how the model works, identifying its key parts, and their role in its mechanism. (*Electric motor; gears used to slow speed of rotation.*)

Teacher's Notes
*A more detailed study of the Crank Man mechanism is included as a later activity. (See: **Extension Activity 1.**)*

10. Ask the students to either turn off the light or disconnect the Solar Panel from the K'NEX model to remove the primary energy source.

11. Ask (and record on the board), the following questions:
    - Why does the Crank Man model stop working?
    - Without a light energy source, from where will the electrical energy needed to run the model come?

Teacher's Notes
Each group will have previously ensured their Capacitor has been fully discharged. They will now use the Capacitor to store electrical energy produced by the Solar Panel.

12. Each group should connect their Solar Panel to their K'NEX Capacitor **making sure the correct polarity is observed.** Before turning on their light, each group member should check that the polarity of their connection is correct.

13. Once checked, ask each group to charge their Capacitor for one minute. At the end of one minute they should turn off their light and disconnect their Capacitor from the Solar Panel.

14. Next, have one group member watch the clock and direct their partners to connect the Capacitor to the model so they can time how long it operates using the stored electricity from the Capacitor. When the model is operating, the members of the group that are not timing should determine how many complete rotations are made by the arms of the Crank Man in one minute.

Teacher's Notes
In this instance it is not important that the polarity of the connection between the Capacitor and the motor is +ve to +ve; -ve to –ve. The motor will simply turn in the opposite direction. The polarity of the connection is important when charging the Capacitor. In this initial test, the model may not run long enough for the students to time rotations for a full minute. Can students think of a way to overcome this dilemma?

15. Ask (and record on the board), the following questions to help the students with their investigation:
    - If the Capacitor is charged for one minute, will you get one minute of running time?
    - Is one reading enough to get accurate results? Why or why not?
    - How many repeat readings should you make to get reliable results? Why?
    - What do you think might happen if you used an unloaded motor?

> ***Teacher's Notes***
> *An unloaded motor is one to which nothing is attached. This can be easily achieved by disengaging the large yellow gear wheel from the small tan gear wheel on the motor drive shaft.*
>
> *The unloaded motor will run for almost a full minute on a one-minute charge. Charge a Capacitor for one minute and demonstrate for the class how long the unloaded motor will run from a one-minute charge.*

16. Review and discuss the class results and conclusions:
    - Why did the Crank Man model run for less time than the unloaded motor?
    - Where did the "missing" energy go?
    - Can you explain the difference in the results for the running time of the loaded and unloaded motor?
    - What are the key things you should consider?
    - What conditions were different in the two tests? Why is this difference important?
      In one test the motor was loaded and in the other unloaded.
    - What conditions were the same? *The charge time and the motor used.*
    - How will this difference affect how much energy is needed to drive the motor when loaded and unloaded?
    - Did the K'NEX piece on the unloaded motor spin faster than the arms of the Crank Man?
      The K'NEX piece spins so fast that the rotations cannot be counted, whereas the arms of the Crank Man move slowly enough to be counted.

> ***Teacher's Notes***
> *Review the fact that energy can be neither created nor destroyed but may be changed from one form to another. In the activity, energy has been changed from light (solar) energy into electrical energy and then into kinetic energy. The loaded motor has to drive the model's mechanism and in so doing, some energy will be changed into heat, some will be used to move the heavier Crank Man model, and some to overcome resistance due to friction between the moving parts. The unloaded motor, however, has no such mechanism to drive and so most of the energy is available to simply drive the motor.*
>
> *The unloaded motor also has internal moving parts so that some energy will be dissipated as heat and overcoming friction.*
>
> *In both tests, the total energy at the start and end is the same; it has just been changed into different forms.*

Extension Activity 1: Crank Man - how does he work?

Mechanics/Technology (More suitable for older students)

Time 35 – 40 minutes.

Introduction

Invite the students to investigate the mechanical systems that create the movements produced by the K'NEX Crank Man model.

In Groups

1. Having constructed their model (see Activity 1), students can connect it to the Solar Panel, turn on their light and observe how it works.

2. Ask (and record on the board), the following questions to help focus the students' observations and activities. All observations and findings should be recorded in their journals.
   - The model looks as though the Crank Man is turning the gear mechanism, but where is the actual input?
     For the mechanism – the electric motor; for the whole model – the Solar Panel.
   - What is the actual outcome?
     The Crank Man moves back and forwards – he oscillates.
   - Why is the model called the "Crank Man"?
     Because his movement is created by a mechanism called a crank.
   - What is a crank? Where is it in the model?
     The crank is the "handle" being turned by the Crank Man.
   - What is the effect of the gear mechanism on the output speed of the motor?
     The fast output speed of the motor is slowed and the force is increased.
   - By how much is the output slowed? How can this information be found?
     There are two ways this can be done:
     (1) By counting input and output turns; (2) By calculating the gear ratio.
   - How easy is it to turn the motor drive shaft compared to the one connected to the crank? Explain your observation.

Teacher's Notes
*A small driver gear wheel turning a large driven gear wheel results in gearing down. Another outcome is that less effort is required if a small gear wheel is used as the driver rather than if a larger driver gear wheel in used. Such a mechanism is a **force multiplier**.*

*Force multipliers are machines that allow a small effort to move a large load. The number of times that the load moved is greater than the effort used is called the **mechanical advantage** (MA).*

Force multipliers have an MA >1.

MA = Force/effort

The reverse situation applies when a large driver is used to turn a small driven gear. A large effort is needed to move a small load. Here the MA <1.

Is the K'NEX Crank Man model a force multiplier machine? Ask students to explain their answers.

Activity 2:
How long does it take to fully charge a K'NEX Capacitor?

Introduction

Review Activity 1, in which students charged their K'NEX Capacitor for one minute and used that charge to carry out a simple investigation. Ask the following questions:

- Was your Capacitor fully charged when you undertook the investigations in Activity 1?
- How can you tell when your Capacitor is fully charged? There is no light or anything else on the Capacitor that gives this information.
- How long will it take for the Solar Panel to fully charge the Capacitor?

Process

Whole Class

1. Explain to the class they will design and carry out an investigation that will enable them to answer the question, "How long will it take for the Solar Panel to fully charge the Capacitor?"

> ***Teacher's Notes***
> *Using a standard 100W light bulb placed no closer than 19cm or 7.5 inches, the Capacitor will be fully charged after about 3 minutes; continuing to charge after that time will not add significantly to the charge. You may suggest a maximum charging time of 4 or 5 minutes to help keep student plans realistic.*

In Groups

2. Groups use the Crank Man model from Activity 1.

3. Ask (and record on the board), the following questions to help the groups plan their investigation:
   - What investigative techniques can you use from your previous investigations into how the Solar Panel worked?
   - How might the amount of electricity generated by the Solar Panel affect the time it takes for the Capacitor to fully charge?
     How did the amount of electricity generated by the Solar Panel affect how fast the Mini Shuttle Ride model turned?
   - What conditions can affect the amount of electricity generated by the Solar Panel?
     The strength of the light source striking the Solar Panel; the distance of the light source from Solar Panel; the angle of the Solar Panel to the light source.
   - How can the light energy source be kept constant (the same) throughout the investigation?
     By standardizing the process. For example, always using 100W bulb placed 19cm (7.5 inches) from the Solar Panel.
   - What are the input and outcome variables you need to measure?
     Charging time and Capacitor charge.
   - How can the amount of charge in the Capacitor be measured/estimated?
     How long the model runs until it stops will be dependant on the amount of charge in the Capacitor.
   - Will you use a loaded or unloaded motor? Does it matter which is used?
     A loaded motor will discharge the Capacitor faster than an unloaded motor.
   - What range of charging times do you need to cover?
     For example every 30 seconds up to…x minutes?
   - How many readings will you need to take at each step?
     If time is at a premium, agree through class discussion on the range of charging times to be investigated. Class results for each charging time can then be pooled for analysis and interpretation.
   - How will you record and present your results? Is a graph better than a table of results? Why or why not?
   - What resources/equipment will you need to carry out your investigation? Make a list.
   - How long do you estimate your investigation will take?

4. Allow the class 10 to 15 minutes planning time. Before the students begin their investigations, select a small number of groups to present their ideas about how they will set up and carry out their investigation, record their observations, and present their results.

Teacher's Notes
It is good experimental technique to encourage students to plot their results in a graphical form as they actually undertake their investigation. If they adopt this approach, they can immediately see trends as they happen.

They may also see if additional measurements need to be taken, or if they already have sufficient information to interpret their findings.

The graph for charging a Capacitor is not a straight line but is exponential and will level off from 3 minutes onwards. Students may be more familiar with straight-line graphs and may not have come across exponential curves before. Some explanation may be needed.

Whole Class

5. Once the investigations have been completed, discuss the class results in relation to the question:
   "How long will it take for the Solar Panel to fully charge the Capacitor?"
   - Did all the groups get similar results?
   - What explanations can students offer for any observed variations?

6. Review what the students learned about designing and carrying out an experimental investigation.

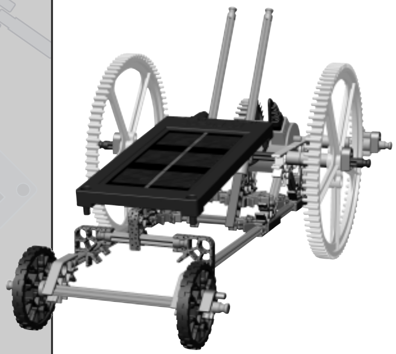
Extension Activity 2: How long does it take for the K'NEX Capacitor to fully discharge?

The students have just carried out an investigation to find the time needed to fully charge up their K'NEX Capacitor. If they have drawn graphs, they will have discovered that their Capacitor charges exponentially. Does the Capacitor discharge in the same way or does it discharge at a constant rate?

- Ask the students to design and carry out an investigation to find an answer to this question.

Assessment

Students should use their journals to record detailed notes of their investigation and findings.
They should include graphs and annotated diagrams.



Lesson 4: Energy To Get Moving - Solar Powered Vehicles

Time
70-80 minutes for EACH of Activities 1-3.
35-40 minutes for Activity 4

Learning Objectives
Students will:
- Investigate the advantages and disadvantages of using solar cell technology for land transport in the future.
- Use the formula:
  Speed = Distance/Time
  in experimental contexts.
- Apply and practice experimental techniques.
- Apply and practice problem-solving techniques.

Materials
Each group will need:
- 1 K'NEX Solar Car
- 1 K'NEX Solar Panel or Capacitor
- Stop watch or stop clock
- Measuring tape
- Pan balance (electronic or standard)
- 50g and 100g masses
- Student Journals

Teacher's Notes
- *The activities outlined below are best tried in natural sunlight.*
- *1 K'NEX Solar Energy Set supports 2 student groups using Solar Panels and 2 student groups using Capacitors to power their vehicles. If both groups are working outside they should work in concert so that time is made available for the Capacitors to be charged from the Solar Panels.*
- *If students must undertake investigations in a classroom, please note that we **do not** advise allowing students to follow their solar car with electrical cords and light fixtures. Instead, the Capacitors can be used to power the cars with light energy collected from an incandescent light fixture.*

Overview for the Teacher
Where does the electricity come from to power space satellites? Without solar panels, space exploration as we know it would not be possible. Back on earth, engineers are trying to find an effective and efficient way of using solar cell technology to power, among other things, cars and other land vehicles. They hope that this technology can be used as an alternative power source to fossil fuels, which have such damaging effects environmentally.

Students will investigate how light energy can be converted into a form of energy that can be used to drive a vehicle – a K'NEX Solar Car. Students should be able to recognize that in the process, **light energy** is converted into **mechanical kinetic energy.**

Teacher's Notes
As an introductory/preparatory activity students could be asked to carry out an Internet investigation of solar cars. Some suggested web sites to help students get started:

http://inventors.about.com/library/inventors/blsolarcar.htm Provides an historical perspective on the development of solar power. Helpful information about how solar panels work.

http://campus.umr.edu/solar1/ Contains helpful visuals (photo gallery) to show how a solar racing car chassis is designed.

http://www.formulasun.org/education/seles9.html This site gives an interesting insight into the design of solar powered racing cars.

There are three main investigations in this section.

1. How fast does the K'NEX Solar Car travel?

2. Is there a link between the weight of the Solar Car and its speed?

3. How can the speed of the Solar Car be improved?

The first activity is intended to further develop students' investigation skills. These skills can then be applied to the investigative procedures that may be used in the other two activities. Each activity includes a series of questions designed to stimulate student thinking and reflection. The intention is for students to gain some basic knowledge and understanding of simple vehicle design; for example, the importance of balancing the power available to the weight of their vehicle, gearing and wheel size. Modeling a vehicle using the K'NEX Solar Energy construction kit provides experiential knowledge that could subsequently be applied to designing and making solar powered vehicles using other materials and electrical components.

Teacher's Notes
When working on their investigations, students will normally work in pairs or small groups of 2 or 3 to first build their K'NEX Solar Cars, (or make use of a previously built model), and then carry out the activities outlined below.

Students should be instructed to keep a record of their observations and results in their journals, as well as a summary of the class discussions.

Review

Your students will be more successful if they have an understanding of the concept of speed. You may want to review/reinforce this concept by discussing:

- Speed is a measure of distance traveled in a given time.

- Use of the formula:
  $\text{Speed} = \frac{\text{Distance}}{\text{Time}}$

- The difference between speed and velocity.

- How speed is measured – miles per hour; feet per second; meters per second.

- The SI units for speed.

Lesson 4

Activity 1: How fast is the K'NEX Solar Powered Car?

Introduction

Explain to the students that planning and carrying out a series of simple investigations to provide answers to questions about their K'NEX Solar Car will help them to develop their experimental techniques.

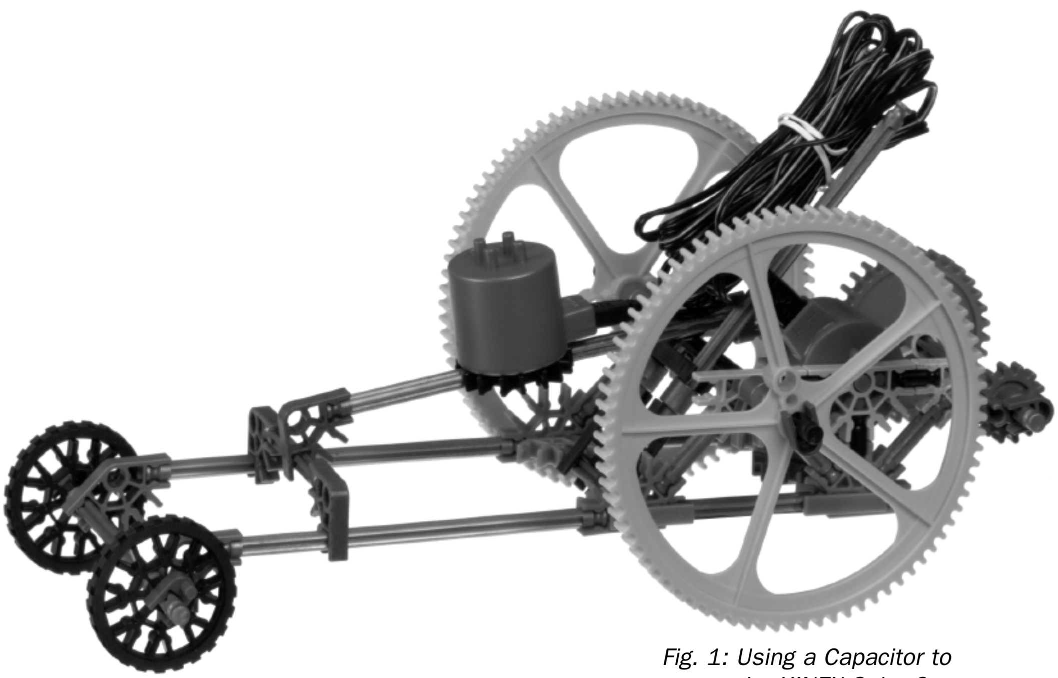


Fig. 1: Using a Capacitor to power the K'NEX Solar Car

Process

In Groups

1. Distribute the K'NEX and other materials.

2. Use Pages 12-14 of the Building Instructions booklet to construct the K'NEX Solar Car model.

3. Allow the students a few minutes to identify the key parts of their model, (*electric motor, gear box, power source*), before testing their solar powered cars.

4. Ask (and record on the board), the following questions:
   - How fast do you think your car can travel? Record this estimate in your journal.
   - How can you check your estimate?
   - What data do you need to collect in order to calculate the actual speed of your solar car?

5. Explain that they will have 10-15 minutes to plan what they must do in order to measure how fast their vehicle will travel.

6. If students appear to be having difficulty, you may wish to provide some 'prompts' to help spur their thinking. These can be recorded on the board, one at a time. For example:
   - What variables have you identified?
     - Which variable is independent?
     - Which variable is dependent?
     - What conditions will remain constant?
     - How will you measure the variables you have identified?

- Over what distance will you need to time your moving solar car in order to obtain accurate results? 1m, 2m… 10m?
  - You may want to think about how far a fast-moving car might travel in a short time and how far a slow-moving car might travel in the same time. Into which category does your solar car fall – fast or slow?
- How far might you expect your car to travel in 10, 15, or 30 seconds?
- How many times will you need to repeat your time measurements to get reliable results?
- How you will record and present your results?

7. Ideally, groups should set up their investigations outside, in natural sunlight. Explain how those working with Capacitors will need to charge their units between trials – this will require those groups using Solar Panels to work cooperatively with the Capacitor groups. Allow 30 minutes for them to carry out their investigations.

Teacher's Notes
Students are often surprised by the fact that measurements/readings differ slightly from trial to trial and that experimental variation is the norm.

The review for this activity might include a discussion on how and why experimental variation occurs. For example, the conditions under which the different trials took place may have changed – the sun may not have been shining as brightly as it was for other tests; during the building process, wheels might have been accidentally pushed more tightly against the car chassis, causing greater friction; the Solar Panel may not have been at the same angle to the light source.

Remember, Capacitor groups will need to charge their Capacitors between the trials of the direct sunlight users. You may wish to compare the results of the two groups.

Whole Class

8. Record all the class results on the board and review the results.
   - How close were the students' estimates to the actual speeds recorded? Can the students display the differences in graph form?
   - How much variation was there among the results? Can students devise a graphic way to demonstrate the observed variation?
   - What explanations can the class put forward for the variation in results?
   - Were all the models exactly the same?
   - Were the test conditions exactly the same?

Extension Idea: Friction

Ask each group to investigate the effect of different types of surfaces on the speed performance of their solar cars and explain their results. (Sidewalk vs. blacktop, or other outdoor surfaces.)

How might they improve the performance of their solar car on a smooth surface?
Attach rubber bands to the outer rim of the drive wheels to increase the grip between the wheel and the surface.

Activity 2: Is there a link between the weight of the K'NEX solar car and its speed?

Introduction

Students will investigate the effect of a vehicle's weight on its performance.

Teacher's Notes
Many students are aware of the fact that high performance racing cars have very powerful engines and light body weights. In fact, racing car designers try to increase the engine power and reduce car weight. Aircraft designers attempt to do the same.

*If you are addressing technology education standards, you may wish to introduce the concept of **power-to-weight ratio** during this activity. For example, a car with a very powerful engine but a light chassis weight will travel much faster than one with a less powerful engine and a much heavier chassis. Compare the speed performance of a racing car, NASCAR racer, or dragster with a heavy truck.*

Process

Whole Class

1. Write this question on the board:

   Is there a link between the weight of the K'NEX Solar Car and its performance?

   Ask the class what they think the relationship between weight and performance might be. Explain that the students will design and carry out their own investigations to answer this question.

In Groups

2. Distribute the K'NEX materials for groups to build their own models, or groups may make use of previously made models.

3. Ask each group to spend 10 - 15 minutes planning an investigation that will enable them to test their vehicles. If the students need help, you may wish to ask (and record on the board), questions such as:
   - What are the two variables you will need to investigate? *Weight and speed.*
   - Which is the independent variable and which the dependent variable? *Weight / Speed*.
   - How do you think reducing/increasing the weight of the solar car chassis will affect its speed?
   - What reasons can you give for your answers?
     *The independent variable will be the **weight** of the K'NEX Solar Car and the dependent variable will be its **speed.** The power produced by the electric Motor will remain constant, provided the amount of light striking the Solar Panel does not increase or decrease.*
   - What will you measure and how will you take your measurements?
   - How many readings should you take at each weight in order to obtain a reliable set of results?
   - How will you record and present your data?
   - What equipment will you need to use?
   - What help can you get from similar investigations carried out previously?

4. Provide sufficient time, (30 - 40 minutes,) for the students to complete their investigations.

Teacher's Notes
You may wish to explain/discuss the fact that experiments are not only carried out to prove or disprove a hypothesis or theory, but also to enable scientists to predict how things will behave under certain conditions. Can they, for example, use their results to predict how fast a solar car powered by a single solar panel and a given weight will travel?

Students may choose to add small masses incrementally to the solar car chassis.

*To complete this activity, the teams might ask to use their results from Activity 1 for comparative purposes. Ask if such a comparison may be valid or invalid (fair or unfair). Why or why not? Discuss some circumstances under which a comparison of the two sets of results might be "**unfair**." For example, the first activity was carried out in bright sunlight while the second was carried out when it was cloudy, or the surfaces over which their solar cars traveled were different. Explain that, for a valid comparison to be made, the conditions under which the two investigations were carried out must be identical.*

Whole Class

5. Review the class results and discuss their findings about the relationship between the weight and speed of their Solar Cars.
   - What did the class learn about planning and carrying out investigations?
   - Did student groups represent their results the same way? Which representations were the most informative?

Activity 3: How can the speed of the K'NEX solar car be improved?

[Design and Technology]

Introduction

The main objective is for students to apply their previous learning to solve a simple technological problem – how to make their solar car travel faster.

For this activity two groups will work together to optimize the use of the available resources and to help develop team collaboration and communication skills.

Process

Whole Class

1. Distribute the K'NEX materials for students to build their models from Pages 12-14 of the K'NEX Building Instructions, or groups may make use of previously made models.

2. Explain that the class will be divided into design teams. Each team will attempt to develop a solution to the question:

   How can the speed of the K'NEX Solar Car be improved?

3. Design teams will compete against each other, over a 2m course, in order to find the fastest solar car.

Lesson 4

Teacher's Notes
The K'NEX Solar Car, (see Page 12 of the Building Instructions), has been designed with a rear wheel drive in which the electric Motor drives the two large yellow drive wheels.

Other car designs have a four wheel drive system. In such vehicles, one Solar Panel may be used to power the front wheel and one to power the rear wheels.

Will four drive wheels be faster than two? What will be the effect of the additional weight of the second Solar Panel on the car's performance?

In Groups

4. Divide the class, (free choice or teacher assigned,) into two-wheel drive and four-wheel drive design teams.

5. Allow 30 – 60 minutes for planning, construction, and testing.

6. Ask the design teams to discuss among themselves their options for increasing the speed of the Solar Car.

Teacher's Notes
Some approaches for the students to consider:

- *Front-wheel instead of rear-wheel drive.*
- *Increasing the traction (grip) of the drive wheels.*
- *Decreasing the weight and increasing the power output from their electric Motor.*
- *Increasing the electrical power output to the motor by connecting two Solar Panels together.*

Help students to realize that adding a second Panel and Motor also adds weight to their model.

7. Ask students to record their ideas in their journals using text and drawings. They should include any ideas that were rejected and the reasons for their decisions.

Two-wheel drive solar car groups

8. You may want to ask (and record on the board), the following questions to help student groups make critical design and planning decisions:
   - How do you think it may be possible to increase the electrical power output to the K'NEX Motor to run your solar car? Will connecting two Solar Panels together increase the power output of your electric Motor?
   - Will the advantage of increased output from two Solar Panels overcome the disadvantage of their additional weight?
   - How will the extra weight of an additional Solar Panel affect your solar car's performance?
   - Front-wheel drive or rear-wheel drive?
   - How can you get extra "grip" between the wheels and the test surface?
   - How can you fit both Solar Panels to optimize their electrical energy output?
   - Will the chassis need to be redesigned to allow it to carry both Solar Panels at the same time?

Teacher's Notes
Connecting Solar Panels together increases the power output. To connect two Panels together, connect jack 1 on Panel 1 to jack 1 on Panel 2. Connect the model's electric Motor to the free jack 2 on either Panel. For safety reasons, do not connect more than 3 K'NEX Solar Panels.

Four-wheel drive solar car groups

9. You may want to ask (and record on the board), the following questions to help student groups make critical design and planning decisions:
   - Can you make use of the existing two-wheel drive transmission system design to drive the front wheels?
   - How can you make the four drive wheels turn in the same direction?
   - Must all four drive wheels be the same size?
   - How can you get extra “grip” between the wheels and the test surface?
   - How can you fit both Solar Panels to optimize their electrical energy output?
   - Will the chassis need to be redesigned to allow it to carry both Solar Panels at the same time?
   - Will the advantage of increased output from two Solar Panels overcome the disadvantage of their additional weight?

Teacher's Notes
Some groups may not realize that to make a four-wheel drive solar car, one Solar Panel must drive the front wheels while another Panel drives the rear wheels. It is important that the front and rear wheels turn in the same direction. This may seem obvious, but some groups may find they need to reverse the polarity of the electrical connections to one or other Motor in order to achieve this.

Whole Class

10. Allow 10 –15 minutes for groups to race their models.

11. Review and discuss the outcomes of the races. What design features contributed to the success of the fastest vehicle? What lessons did the students learn?

Teacher's Notes
As a follow-up activity discuss the possible outcomes of their findings for designing solar and other modes of transport. Discuss how solutions to design problems are often compromises. In this instance, the additional weight of the second Solar Panel may counteract the potential advantages of the additional power they give. Ideally, a better solution might be a much lighter Solar Panel with a higher electrical energy output. This technology, however, is not available here so other solutions may need to be found.

You may want your students to review the designs of solar vehicles participating in the American Solar Challenge race. This event, whose main sponsor is the U.S. Department of Energy, involves teams of students from universities in the U.S.A and Canada. They design, build and then race their vehicles from Texas to Alberta.
www.americansolarchallenge.org Go to: History.

Activity 4: How far will the K'NEX solar car travel on a full Capacitor charge?

Introduction

Students will apply what they have learned in this and previous lessons to solve a design problem.

PROBLEM: To design and make a vehicle that will travel more than 8m carrying its own electrical power source.

- The only electrical power supply available is a K'NEX Capacitor.
- Only one measured test run will be allowed for each group's vehicle.

Teacher's Notes
On a hard, level surface the solar car can travel approximately 10m before coming to a stop.

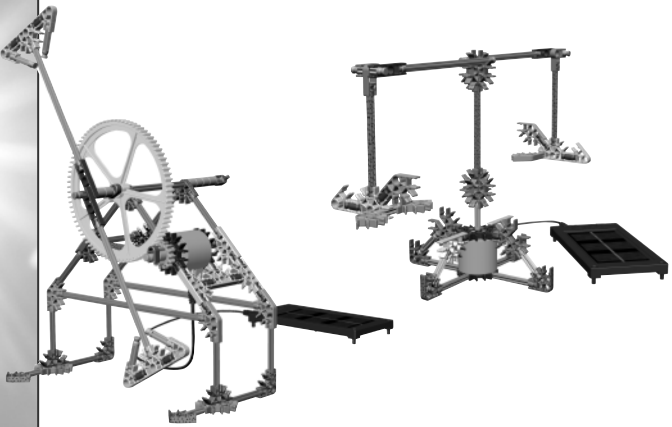
Process

In Groups

1. Four students will make up one design team. They have a total time of one hour to plan, design, make, and test their vehicles.
2. Distribute the K'NEX materials.
3. To help the students design and plan, you may want to discuss some design considerations that might be taken into account:
   - The possible effect of weight on the car's performance.
   - How can the effects of friction on moving parts be reduced?
   - Three wheels or four wheels?
   - What is the best power drive arrangement – rear wheel, front wheel, or in the middle?
4. Allow student teams a few minutes to fully charge their Capacitors.
   Each group sets up and runs their car along the test track. The distance is measured.

Whole Class

5. Ask the class to discuss the question:
   Why was the design of the vehicle that traveled the furthest successful?
   - What were its best features?
   - What was not taken into consideration in the other designs?
   - How did it make the best use of the energy available?
   - How did it reduce energy "wastage"?
6. Encourage each group to talk about what they learned from the activity and what they would do differently next time.



Lesson 5: Making Energy Work

Time
70-80 minutes for each of Activities 1 & 2.
35-40 minutes for Activity 3.

Learning Objectives
Students will:
- Demonstrate and explain that energy can be transferred and converted from one form to another.
- Demonstrate and explain that energy can be dissipated (lost) to a system because of friction.
- Demonstrate and explain that solar cells convert light energy into electrical energy and that electrical energy can be transferred to an electrical motor to exert force.
- Recognize and identify input, process and output when applied to a simple system.
- Demonstrate and explain that gearing down amplifies output forces.

Materials
Each group will need:
- 1 K'NEX Spinner model
- 1 K'NEX Mini Shuttle Ride model
- 1 K'NEX Solar Panel or Capacitor
- 100-watt incandescent (filament) light bulb OR natural sunlight
- Additional copies of relevant pages from Building Instructions (optional)
- Stop watch or stop clock
- Card or stiff paper
- Tape
- Student Journals

These items may be required for Activity 4:
- Selection of slotted masses: 50g; 100g; 200g; or non-conventional masses such as pennies; paper cup to hold masses; string; meter ruler

Overview for the Teacher
The possible teaching ideas outlined are intended to help reinforce students' analytical and observational skills. This can be achieved through investigation and by identifying the effects of inputs, processes and the outcomes produced. The investigations can be carried out from a scientific perspective (energy transfer and conversion) and/or from a technological perspective (types of motion and forces; systems and subsystems).

Teacher's Notes
1 K'NEX Solar Energy Set supports 2 student groups using Solar Panels and 2 student groups using Capacitors to power their models. These groups should work in concert and time, (2-3 minutes,) should be made available for the Capacitors to be charged using the Solar Panels.

Lesson 5

Review

It will be helpful if students are familiar with the concepts of:

- Energy transfer and conversion.
- Gearing up and gearing down.
- Gear or velocity ratios.
- The mechanical advantage conferred on a system by gearing down.
- Systems and subsystems.

Teacher's Notes
In Lesson 2, students investigated the Mini Shuttle Ride model. That model was an example of a direct drive system. The motor moved the model directly without gears, belts, or other subsystems. In Lesson 4, the students investigated the Solar Car model, which used a series of gears to increase the power of the motor so it could move the car. Gear systems generally provide one of two benefits to a mechanical system. They can 'gear up' a mechanism, providing higher speeds to complete certain tasks, or they can 'gear down' a mechanism, providing higher power. There is a trade-off in each case. When gearing up, more power is needed to reach higher speeds. In other words, speed is gained at the expense of power. When gearing down, power is gained at the expense of speed.

Machines use transmission systems to transfer rotary movement from its source (input) to where it is needed and in the form it is needed (output). The form in which it is needed can be a fast or a slow output speed. Many machines use gear wheels in their transmission systems, (e.g. gearboxes), to speed up (gear up) or slow down (gear down) the output speed of rotation. A gearbox is the process/processor by which a fast input speed is converted into a slow output speed, and vice versa.

Activity 1: Structure and function

Introduction

Explain to the students that this activity provides an opportunity to review their existing knowledge of energy transfer and conversion, as well as gears and gearing used in simple mechanical systems.

Teacher's Notes
In these activities students will normally work in small groups of 2 or 3 to build their K'NEX models. Alternatively, they may make use of previously built models from earlier lessons.

In all activities students should be instructed to keep a journal record of their observations and results, as well as a summary of the class discussions.

For this Activity you may want to combine 2 small groups into a larger one of 4-6 students. This allows each larger group to have access to 1 Spinner model, 1 Mini Shuttle Ride model, 1 Solar Panel and 1 Capacitor. All will need to gather data. One group of 3 can be collecting data while the other is working on setting up the other model for the experiment. Also, if the two groups observe and record separately, they can discuss and review inconsistencies.

Process

In Groups

1. Distribute the K'NEX materials.

2. Organize the class into larger working groups of 4-6 students. Half of the group will construct the Mini Shuttle Ride model and half the Spinner model.

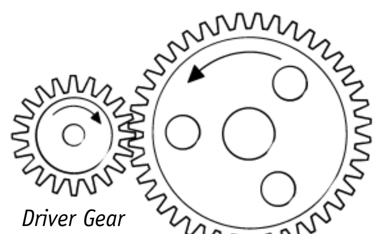
3. Use Pages 6-7 from the Building Instructions to construct the K'NEX Mini Shuttle Ride model and Pages 8-9 for the K'NEX Spinner model. If this is the first time that these models have been built you may need to provide additional copies of the Building Instructions. Previously built models from earlier lessons may also be used. **Students should not connect the Solar Panel at this time.**

4. Allow students a few minutes to explore how their models work and the movements they make. They should identify the key parts of each model and their function. *Electric motor, gears.*

5. To investigate these differences one group observes one model and the other the second model and then they switch. Then they can discuss their findings. To help students in their investigation, ask (and record on the board), the following questions:
   - What differences do you notice between the K'NEX Spinner model and the Mini Shuttle Ride model? What additional components are used in the Spinner model?
     Small and large gearwheels – the K'NEX Motor is connected to the Spinner by a small gear wheel and that turns a large gear wheel.

   - What is the function of these additional components?
     To transfer rotational motion from the motor to the Spinner mechanism; to produce a slow, powerful rotational output speed from a fast, low power input speed. Additionally, the gear system provides more power to move the Spinner.

Teacher's Notes
The simplest gears – like those used in the K'NEX system - are called spur gears because they look like the rowels on spurs. You may wish allocate a little time for the students to explore how gears work.



By observing the gear mechanism while the Spinner is slowly turned by hand, students can observe how one tooth pushes against its neighbor on the other gear wheel. The gear wheel attached to the power source providing the input movement is called the ***driver*** *and the one being turned is called the* ***follower,*** *or* ***driven*** *gear. A large driver turning a small driven gear wheel produces a fast output speed, while a small driver turning a large driven gear produces a slow output speed.*

The Spinner mechanism is a very simple gearbox and transmission system and is the process by which a fast input speed is slowed down. Calculating gear ratios will enable students to work out by how much the input speed is slowed down and by how much the input power is multiplied.

6. Ask each group to connect their K'NEX Solar Panel to their Spinner model, place in a light source, observe, and record their observations in their journals.

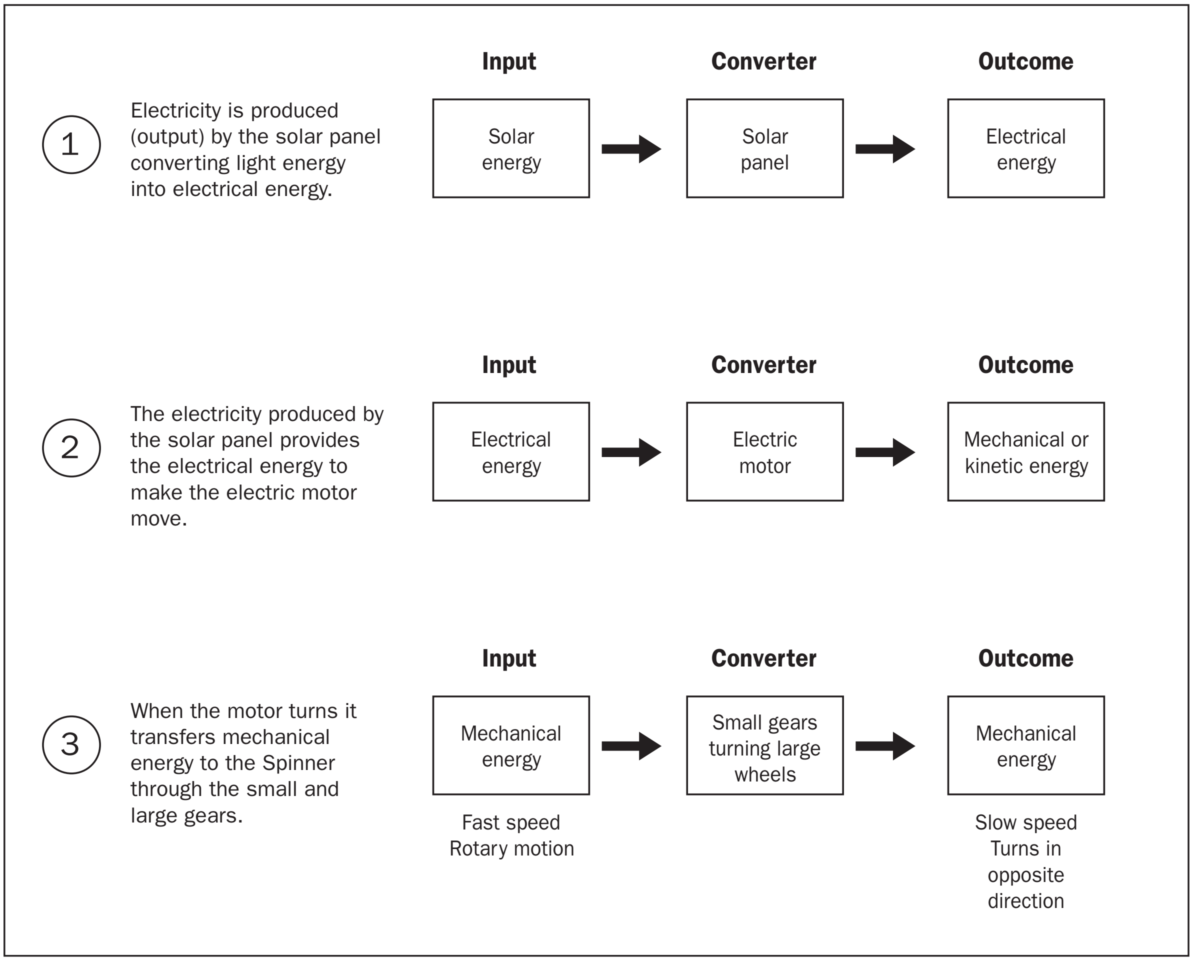
Teacher's Notes
Explain to the students the essential safety rules they must follow to avoid heat damage to the Solar Panels. They must position their Solar Panels at least 19cm from an artificial light source. This activity may also be completed in natural sunlight.

7. To help students in their investigation ask, (and record on the board,) the following questions:
   - What happens to the solar/light energy after it hits the Solar Panel?
     It is converted into electrical energy.
   - What other types of energy can be found in action in your working model?
     Electrical and mechanical.
   - If light energy is the **input**, what type of energy is the **output**?
     Mechanical or kinetic energy
   - What is the sequence of energy transfer and conversion in the model?
     (See below.)
   - Where may energy be dissipated (lost to the system)?
     Friction between moving parts, producing heat and sound.
   - How many sub-systems are present when the Solar Panel is used to power the Spinner model?
     There are three main subsystems:
     1: Light energy (input) is converted into electrical energy (output) by the Solar Panel (converter).
     2: Electrical energy (input) is converted into movement energy (output) by the electric motor (converter).
     3: The fast input speed (input) of the motor is slowed by a small gear wheel on the motor axle turning a large gear wheel on the Spinner axle (the converter) to produce the slow Spinner speed (output).
   - Explain how the outcome from one subsystem can be used as the input for a separate subsystem.

Whole Class

Review the class results.
By discussion establish that:

- Overall light energy is the **input** and mechanical energy (rotary movement) is the **output.**
- When energy is moved from place to place it is said to be **transferred.**
- Energy transferred by electricity is called **electrical energy.**
- Energy transferred by movement is called **kinetic energy.**
- The complete solar powered Spinner system can be sub-divided into three subsystems to make it easier to understand. (This is demonstrated on Page 47.)



Activity 2: How can we find out how fast the motor spins?

Introduction

In Lesson 2 students learned how to estimate the output speed of a rotating model by counting the number of rotations it makes in a given time.

Explain that this activity challenges the students to find out how fast their K’NEX Motor axle rotates.

Review

Students need prior understanding of gear ratios and how they are calculated from the number of teeth in the driver and driven gear wheels.

That the gear ratio, (or velocity ratio: **VR**,) is calculated using the formula:

$$\text{Gear ratio} = \frac{\text{Number of teeth on DRIVEN gear}}{\text{Number of teeth on DRIVER gear}}$$

Teacher's Notes
In the Spinner model the large gear wheel that is being driven has 84 teeth. The small driver gear wheel, (connected to the motor that provides the power source), has 14 teeth. If we substitute these into our formula:

$$\text{Gear ratio} = \frac{\text{Driven}}{\text{Driver}}$$

$$\text{Gear ratio} = \frac{84}{14} = \frac{42}{7} = \frac{6}{1}$$

therefore, the ***Gear Ratio = 6:1***

In other words 6 input rotations are needed to produce 1 output rotation.
By estimating the output speed in rpm and knowing the gear ratio of the system, the input speed of the motor can be calculated.

For example, if the Spinner rotates at 20 rpm and the gear ratio of the spinner gearbox is 6:1 then the motor speed must be 6 x 20 = ***120 rpm.***

Process

Whole Class

1. Use a K'NEX electric Motor connected to a Solar Panel to demonstrate how fast its axle turns and to introduce the problem to be solved to the class. **"How can you measure something that turns too fast to count?"**

2. Ask the class for suggestions as to how they may approach solving the problem.

Teacher's Notes
An unloaded motor rotates too quickly to be able to count the number of turns it makes in any given time. It must, therefore, be slowed down. A solution is readily available - the Spinner model uses a simple transmission system, or gearbox, that slows the input speed considerably. The students may have observed this fact from the previous activity, but can they recognize its use as a potential solution to solving their problem?

In Groups

3. Distribute the K'NEX materials.

4. Use Pages 8-9 from the Building Instructions to construct K'NEX Spinner models. Alternatively, pre-built models from previous activities may be used.

5. Remind students to keep a detailed record of their investigation in their journals.

6. Ask the students to connect the Solar Panel/charged Capacitor to their model. Allow them a few minutes to explore how their model works and the movements it makes, including the identification of key parts and their function in its mechanism. (*Electric motor, gears.*)

7. Suggest the students consider how their observations in Activity 1 can help them find how fast the K'NEX electric Motor turns.

8. If necessary, ask (and record on the board), the following questions to help the groups come up with their solutions. These can be provided as 'clues' and posted on the board, one at a time, to spur thinking.
   - Do the arms on the Spinner turn faster or slower than the Motor?
   - What effect do the gears (gearbox) have on how fast the Spinner turns?
   - How can you determine the impact of the gearbox on the speed of the Motor?
   - What information does the gear ratio of the gearbox provide that will be useful to your calculations?

9. Once their investigations are complete, ask each group to record their results in a table on the board and then calculate the average (mean) figure for the class.
   Ask them to note the highest and lowest result (range). How much do these results vary from the class average?

Whole Class

10. Review with different groups how they solved the problem.

11. Review and discuss the class results.

12. Ask why they think there is variation in results across the class.

Teacher's Notes
*It is important to explain to the class that they should **expect** there to be variations in the results, even if the experiment and the associated mathematical calculations have been undertaken correctly. It would be very unusual to get the same result time after time, even from the same group. It is the norm that results do vary simply because it is very difficult to replicate exactly the conditions under which experiments are carried out. There will always be some high and low figures with most of the results grouped around the mean. It is the size of the spread (range) of the results around the mean that determines their degree of reliability.*

What may be the causes of the variation in the results?
Although all models were made from an identical set of plans, it does not mean that all the models are themselves identical.
- *There will be slight variations in how different groups put their models together, especially in the assembly of the moving parts. Some parts may fit more tightly in some models, producing frictional effects.*
- *Models may not all be placed the same distance from the light source.*
- *Human error may also come into play when counting rotations and taking time measurements.*

Activity 3: Assessing the effects of friction

Introduction

Explain to the students that in this short activity they will be able to investigate the effects of friction on the output of their K'NEX Spinner model. Through discussion, develop a question to investigate, such as: **How does friction affect the output performance of a mechanism with moving parts?** Record the question on the board.

Review

Friction is a force that opposes motion. Friction is produced when one surface rubs against another (e.g. rubbing hands together), or from water resistance or even air resistance.

Lesson 5

Teacher's Notes
Friction and resistance to movement do not only involve solid surfaces. Ask the students to think about what happens to them when they try to walk against high winds; why cars, boats and aircraft are streamlined; how parachutes work; what happens to a machine when its moving parts are connected too tightly?

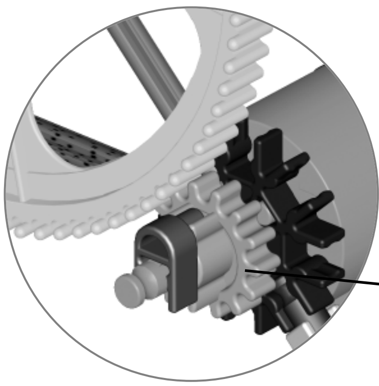
Process

In Groups

1. Distribute the K'NEX materials.

2. If necessary, use Pages 8-9 from the Building Instructions to construct the K'NEX Spinner model.

3. Ask the students to remove the small blue gear wheel from the electric motor axle so the Spinner can turn freely. (See enlarged section shown on Page 9 of the Building Instructions.)



   They should take turns spinning the Spinner by hand and then record and explain their observations in their journals.
   Students do not need the Solar Panel/Capacitor for this activity.

4. Ask the students to consider, and discuss in their groups, the following questions:
   - How might you increase frictional effects in your Spinner model? What effect will this action have on your model's performance?
   - How will increasing the amount of friction affect the amount of energy needed to move the Spinner?

Teacher's Notes
Students can use a simple push by hand and observe the number of complete rotations made by the Spinner under different conditions.

The more two surfaces press together, the greater will be the amount of energy expended to overcome the effects of friction. In other words, the harder the students will need to push. Although not a directly measurable value, students can "feel" the different push force needed to rotate the Spinner. With increased friction or resistance in its mechanism, the Spinner will not complete as many rotations as before.

Students can simulate some effects of friction by rubbing their hands together. When they do this, heat is generated. Heat is a form of energy and is lost (dissipated) in machines when two surfaces move against each other. It can be reduced by lubrication – try a little liquid soap on the hands and see what happens when you rub them together. Help students understand that friction does not only apply to two solid surfaces rubbing against each other. Talk about how much more difficult it is to ride a bicycle, walk or run into a strong wind.

5. Ask the students to carry out a simple experiment to demonstrate the effects of friction/air resistance on their model's performance?

6. If students have difficulty getting started, ask (and record on the board), the following questions, one at a time, to spur their thinking:
   - What are the independent and dependent variables you need to measure?
     The only variables that can be directly measured are the number of rotations and surface area of spinner arms. Others may be simply assigned descriptor values to indicate their condition e.g. loose/tight.
   - How will you make your measurements?
   - How can you report your data?
   - What comparisons do you need to make?

Teacher's Notes

- *Tightening the K'NEX connections on the moving parts by pushing them closer together will increase friction between moving surfaces.*
- *Rotating the 'blades' (the white Rods and light grey Connectors) at the ends of the Spinner arms through 90-degrees will increase air resistance. The performance of this model setting can then be compared with the setting shown in the original design in the Building Instructions.*
- *Index card stock, or similar stiff materials, may be added to the blades to block the air spaces between the K'NEX parts and/or to increase the surface area of the blade.*
- *Additional Spinner arms may also be added.*
- *If time allows students could investigate the effect of altering the blade angle.*

Whole Class

7. Review the class results. Make sure that every group has an opportunity to present their ideas and findings because the investigations may have been approached differently.

8. Discuss how:
   - Increased friction and air resistance tend to slow down moving objects and increase energy consumption.
   - The effects of friction may be minimized - for example, by streamlining, lubrication, bearings, etc.

Activity 4

Introduction

- Explain that this activity provides students with an opportunity to be creative and innovative. Their challenge is to redesign a K'NEX Solar Energy model so that it can undertake a completely different task from the one originally intended. Students may chose, for example, to have their new model wind up string to pull an object across the table, or something similar. Let their imagination be their guide.

- Upon completion of the challenge, the students will then design an experiment to answer a question they have about the new function the model is performing – for example, "How far can the model pull the mass in 30-seconds?"

Lesson 5

Teacher's Notes
Students should be asked to design an experiment that includes the question they are going to investigate, their hypothesis, the procedure they will follow, the materials they will use, the measurements they will make, how they will collect and organize their data, and how they will present their results.

You may want students to make a poster of their investigation that includes a drawing of their model in action, their hypothesis, data, and findings.

*This is an excellent **assessment project** that will enable students with varied learning styles to participate.*

Process

Whole Class

You may want to use the following script to introduce the challenge to the whole class:

1. "Class, you have used several models from the K'NEX Education Solar Energy Set. Each of these models has a specific mechanical system and they have all performed a meaningful task (spinning Rides, operating the Crank Man, or powering the Solar Car). Your challenge is to redesign one of those models, or use the Spinner model, so that it can perform some other meaningful task that is different from its original use. This is your chance to use your imagination and creativity as you plan, design, and build. Working in teams you will be able to draw upon the resources of the group for suggestions and ideas that you, as an individual, may not have thought of on your own."

In Groups

2. Suggest that the teams take some time to review the models that they have used in previous investigations and decide together which model they would like to redesign.

3. Ask the students to construct the model using the Building Instructions.

4. When constructed, you may want to ask the students to discuss and undertake the following:
   - How are you going to change/adapt this model?
   - How will your team enable the *new* model to complete a meaningful task?
   - Will you need any additional materials?
   - When you have answered the three questions above, ask your teacher to review your ideas and to determine if the extra materials you need are available.
   - Complete the model and test to see if it works as you expected.

5. Explain to the students that the next step is to design an experiment that they can complete in class and that will answer a question that they would like to know about their newly designed model.

Teacher's Notes
You may need to provide examples of questions, such as how fast the model completes a task, how much force the model is able to exert, how many turns of the gears are required to complete the chosen task etc.

6. Provide the following guidelines for the students:
   - Once you have chosen a question, please work as a team to write a hypothesis that indicates what you expect the results of your experiment to show.
   - As you design your experiment, you should plan and write your materials list, and describe the procedure you will use, including how you will collect, organize and present data.
   - Verify with your teacher that you have met all of the required components of your investigation and then proceed.

Whole Class

7. Provide time for each team to (a) demonstrate their model, noting the modifications that were made to the original, and (b) present their investigation and findings. If they have produced posters of their activities, they can be discussed at this time and then used to form a display with the models.

Assessment

1. Journal records, with diagrams.

2. Posters.

Lesson 6: Solar Powered Mechanisms

Time
70-80 minutes

Learning Objectives
Students will:
- Understand and demonstrate how one form of motion can be changed into another.
- Understand and demonstrate that more than one output can be produced from a single input.
- Understand and use technical vocabulary associated with simple mechanical systems.
- Practice and develop their observational skills.

Materials
Each group will need:
- 1 K'NEX Cam Operated Pump or Slider model
- 1 K'NEX Double Pump model (Activity 2)
- 1 K'NEX Solar Panel or Capacitor
- Connecting cable for Solar Panel or Capacitor
- 100-watt incandescent (filament) light bulb OR natural sunlight
- Student Journals

Overview for the Teacher

Students will work in small groups to investigate some simple mechanisms that enable the electrical energy produced by solar panels to be utilized in practical ways. They can trace how electrical energy is used to power an electric motor, the output of which is rotational motion.

They will identify and investigate how rotational motion can be converted into a variety of different forms of mechanical movement.

Teacher's Notes
- *The K'NEX Solar Energy Set supports 4 groups of students working simultaneously, with 2 groups using Solar Panels and 2 groups using Capacitors. Students using a Solar Panel will need to make it available to charge a Capacitor when it is not in active use. This requires good cooperation between groups.*
- *2 K'NEX Cam Operated Pump and Slider models can be built simultaneously allowing groups to exchange built models.*

Review

To help students interpret and explain their observations they should understand that while mechanisms are designed to do different tasks, they also share some important features. For example, they:
- all involve some form of motion
- need a force to enable them to move
- need an input to enable them to do work
- produce an output
- make tasks easier to do

Four basic forms of motion are used in mechanisms:

- Linear – motion occurring in a straight line, as seen in a paper trimmer, sliding lock or conveyor belt.

- Rotational or circular – the most common form of motion, as seen in the movement of wheels or gears.

- Oscillatory – an alternating, or swinging back and forward type of motion, as seen in a pendulum, children's swings, and windshield wipers.

- Reciprocating – an alternate backward and forward, or up and down motion, in a straight line, as seen in the movement of a sewing machine needle, or the pistons of a car engine.

Activity 1: From round and round to up and down

Introduction

Explain to the class that they will use (i) the K'NEX Cam Operated Pump and (ii) the K'NEX Slider models to undertake activities investigating how rotational motion can be changed to other forms of motion.

> ***Teacher's Notes***
> *Students will normally be expected to work in small groups of 2 or 3 to either build their K'NEX model or to make use of previously made models. Remind students that they will not only exchange models during the course of their investigations, but that they will also need to cooperate as they share the Solar Panels to charge the Capacitors.*

Process

In Groups

1. Distribute the K'NEX materials.

2. Use Pages 15-17 of the Building Instructions to build the K'NEX Cam Operated Pump model and Pages 10-11 to build the K'NEX Slider model. Students should not connect the Solar Panel or Capacitor at this time.

> ***Teacher's Notes***
> *Groups that are using Capacitors to power their models should charge them during the building process.*

3. Remind students that observations should be recorded in journals using labeled drawings and written text. Make certain those using Capacitors know how to attach them to their models.

4. Remind the students that the purpose of this activity is to investigate how one type of motion can be converted into another type. Students should now connect their models to their power source and make their observations. You may want to ask the following series of questions and record them on the board to help students focus their observations. Possible answers are provided.
   - A force is needed to make your model move. Where does this force come from?
     The electric current produced by the Solar Panel is used to power the electric Motor.
   - What is the input movement?
     Rotational motion.
   - How is the input movement created?
     By the electric Motor.
   - What type of output movement is produced?
     In the case of both models – reciprocating motion.
   - How is the output movement created?
     For the Cam model – circular or eccentric cam and follower mechanism; for the Slider model – crank and slider mechanism.
   - In what ways are the Cam and Slider models similar and in what ways are they different? Look at the inputs and outputs and how the output movement is produced.
     In both models the input motion and output movement produced are the same. What is different is how the input is converted into the output.

5. Once groups have completed observations of their model they should swap with another group and repeat the above steps with their new model.

Teacher's Notes
Some technological vocabulary will be required by the students to make accurate descriptions of mechanisms. To help introduce new terms to the students you may consider providing a vocabulary list or word web.

If students experience difficulty in remembering the names of key mechanical components, you may want to use constructed models to demonstrate/show and name key parts of the mechanism. They will have come across a rotating handle or crank when using the K'NEX Crank Man model (Lesson 3). In the K'NEX Slider model the crank is combined with a slider to produce a crank and slider mechanism.

Whole Class

6. Review each of the questions above based on the observations the students have made of the two models.

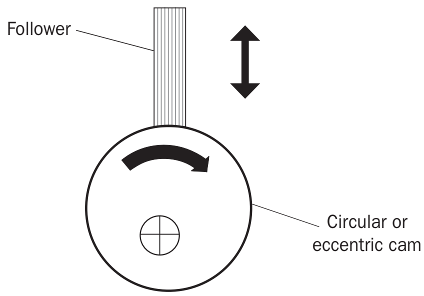
   When reviewing the question **"In what ways are the Cam and Slider models similar and in what ways are they different?"** demonstrate how, in the **Slider model**, the crank and slider mechanism can work in either direction:
   - It can be used to convert rotational movement into reciprocating motion as found, for example, in powered saws, compressors and pumps.
   - If the input and outputs are reversed, the model can be used to convert reciprocating motion into rotational motion as found, for example, in the pistons in a car engine turning the crank shaft.

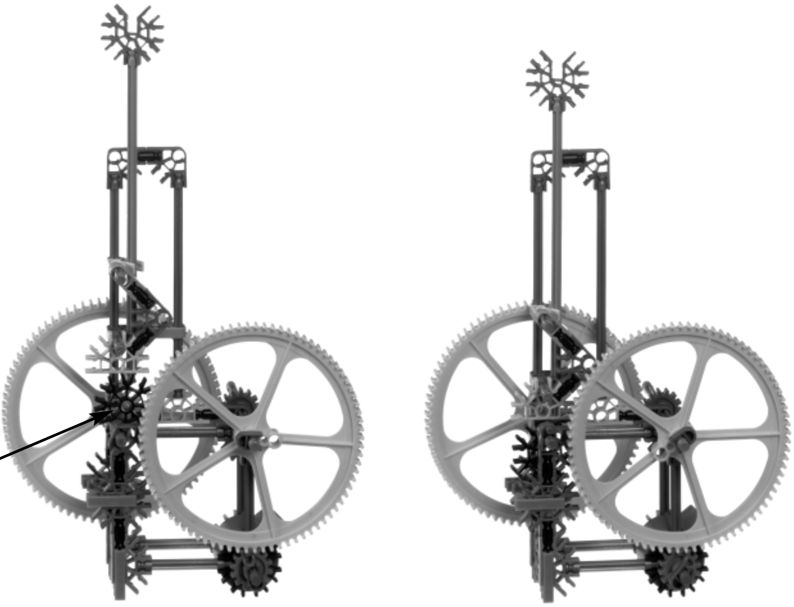
   On the other hand, the **Cam model** can work in one way only – if the cam itself is turned.

7. Explain that there are often many different ways for one form of motion to be converted into another. The mechanism chosen by design engineers will depend on the job that has to be done.

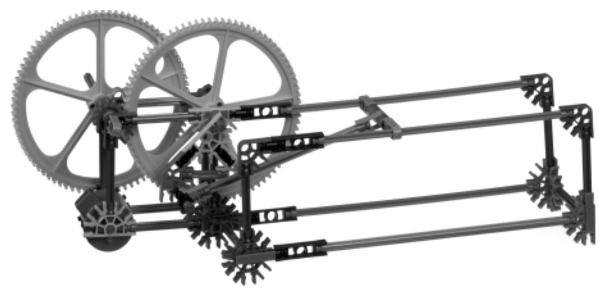
Teacher's Notes

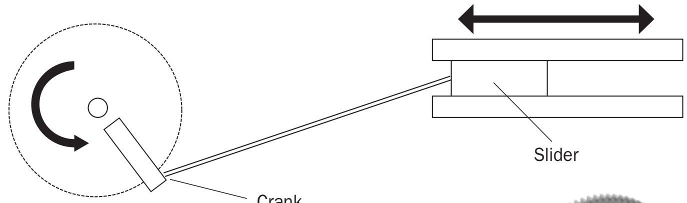
*Cams are simply shaped pieces of metal or plastic fitted to a rotating axle or shaft. The simplest form of rotary cam is called a **circular or eccentric cam**, like the one used in the K'NEX Cam Operated Pump model. It is called 'eccentric' because it is fitted off-center on the axle. A follower is held against the cam, in this model by its own weight, and as the cam turns, the follower moves.*

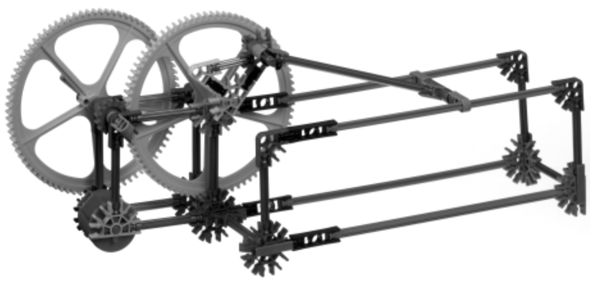




In crank and slider mechanisms, the crank (rotating handle) rotates and the slider reciprocates. The distance the slider moves depends on the length of the crank. A long crank will move the slider a greater distance than a short crank.







Extension Activity: Investigating the effects on the mechanism of using different cams

The K'NEX Cam Operated Pump model has seven different cams (K'NEX pieces) that can be attached to the mechanism in order to alter the output of the system. Each cam will cause the shaft of the model to respond in a different way.

- Have students try each of the K'NEX cams on the model in turn, observe the action of the model, and record the motion that they see.
- For each new cam added to the model, ask the students to draw a free-hand graph that approximates the action of the end of the shaft.

> ***Teacher's Notes***
> *Students may need some practice to master this free-hand skill.*

- Design investigations that will enable them to determine if the model operates at the same speed with each of the cams.
- Design investigations that will enable them to determine the operating speed of the Slider model. Repeat with different wattage bulbs, etc.

Activity 2: How to get two outputs from one input

Process

In Groups

1. Distribute the K'NEX Materials.

2. Students should use Pages 21-23 of the Building Instructions to build the K'NEX Double Pump model. Ask them to explore the operation of their model once the Solar Panel or Capacitor has been connected.

> ***Teacher's Notes***
> *Groups that are using Capacitors to power their models should charge them during the building process.*

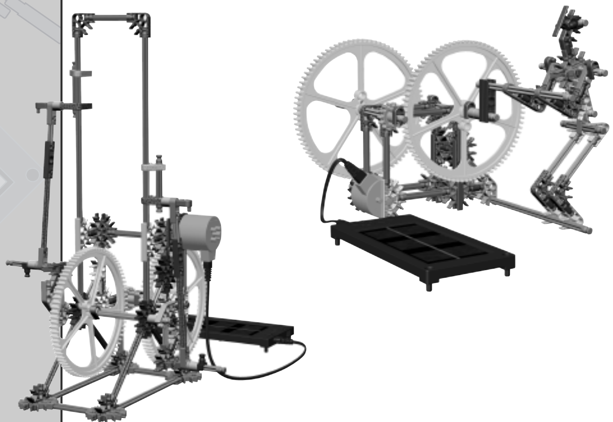
3. Ask (and record on the board), the following questions to help focus student observations. Observations should be recorded in journals using labeled drawings and written text. Possible answers are provided.
   - What is the input movement?
     Rotational motion.
   - What type of output movement is produced?
     There are two output movements produced – both movements are reciprocating motion.
   - How is the output movement created?
     By using two crank and slider mechanisms attached to the ends of the final drive shaft.

Whole Class

Discuss class observations, noting how a single output drive shaft can be used as the input for two separate outputs. Explain that having multiple outputs from a single input is a common feature of machine design, as found, for example, in a modern car engine.

Assessment

Students should maintain journals that include detailed notes and annotated drawings of their investigations.



LESSON 7: Generating Electricity

Time
35-40 minutes

Learning Objectives
Students will:
- Learn that electric motors can be used as electric generators.

Materials
Each group will need:
- 1 K'NEX Double Pump model
- 1 other K'NEX solar powered model – free choice
- Student Journals
- Chart/easel paper (for optional assessment activity)

LESSON 7

OVERVIEW FOR THE TEACHER
The activities outlined here can be used as the basis of a simple class demonstration to show that electricity can be generated in ways other than with solar panels. Comparisons can be made with the factors that affect the amount of electricity produced by the solar panel and the motor as a generator. In demonstration and group activities, the K'NEX Double Pump model is used as an electricity generator. These activities do not require you, or your students, to have a detailed knowledge of how an electric motor or generator works.

Teacher's Notes
When an electric current flows through a wire coil it creates a magnetic field around the coil and behaves in a similar way to a bar magnet. This is the principle behind the operation of an electric motor.

On the other hand, when a wire moves through a magnetic field an electric current can be produced in the wire; the size of the current depends on how quickly the wire moves. This is the principle behind the operation of an electric generator.

Introduction
How can an electric motor, which needs electricity to run, be used to **generate** electricity? In Lesson 6 students learned that a **crank and slider mechanism** can be operated in two ways by reversing the input and output. Can the same idea be applied to an electric motor? Explain to the class that they will use the K'NEX Double Pump model to undertake a series of activities to find answers to this question.

Teacher's Notes
Students normally work in small groups of 2 or 3 either to build their K'NEX models or to make use of previously made models, but because two K'NEX models will be needed per group you may consider joining two small groups for these activities.

Activity 1: From Electric motor to electric generator

Process

In Groups

1. Distribute the K'NEX materials.

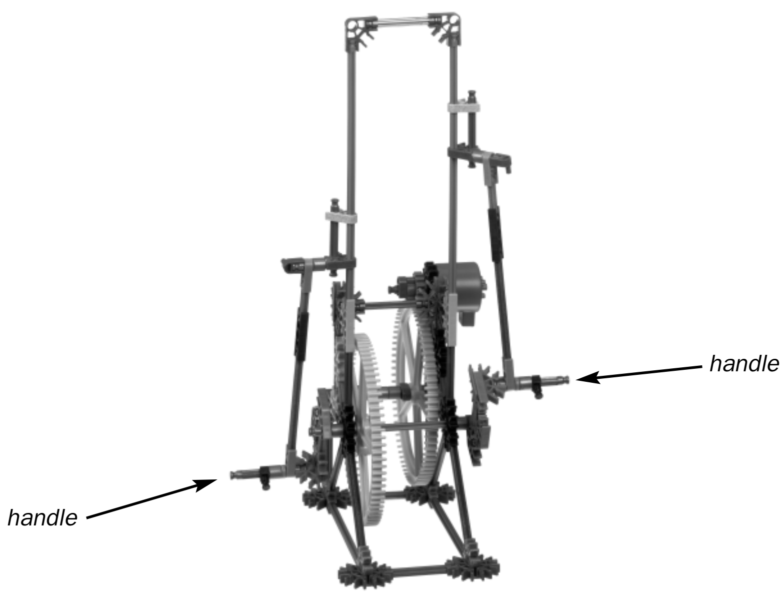
2. Use Pages 21-23 of the Building Instructions to construct the K'NEX Double Pump model and appropriate pages for each group's choice of a second K'NEX model.

3. Using the Power Cord (lead) that would normally connect the Solar Panel and the Motor, connect the Double Pump Motor to the Motor on the other K'NEX model.

4. You may want to focus the students' investigations by asking the following questions, or writing them on the board to facilitate discussion:
   - What happens to the second model when one of the cranks (handles) of the Double Pump are turned slowly at first and then steadily increased in speed?

> ***Teacher's Notes***
> *Turning too vigorously could detach one of the handles. The model will work better if the base is held firmly on the desk surface.*

   - Can you explain what must be happening to enable the motion you observe?
   - What will happen if the crank handles are turned in the opposite direction?
   - What will happen if the polarity of one end of the cable connection is reversed?
   - What effect does the gearing mechanism have on the output speed of the second model?
     This question may not apply if the students have selected a second model to operate which does not have a gear system.



5. Ask the groups to design and complete a series of activities that will enable them to clearly and completely answer the questions posed above. Students should maintain careful records of the activities they design, the reasoning they employed, and the results they found.

Whole Class

6. Review and discuss the activities each group undertook and their observations.
   Did the students maintain careful notes and drawings in their journals as they were investigating?
   Possible student observations might include:
   - As we started the Double Pump moving, the second model begins moving almost immediately. As we turned the Double Pump faster, the second model moved faster.
   - Somehow, electricity must be moving from the Double Pump to the second model. Since we are not using a Solar Panel or a Capacitor, the only logical explanation is that the motor is somehow making electricity.
   - If the Double Pump model is moved in the opposite direction, the other model moves in the opposite direction.
   - Reversing the polarity of the system by reversing the plug on either one, (but not both), of the motors, causes the second model to move in the opposite direction.
   - We turned the Double Pump, which had a large gear driving a small gear. This arrangement of gears geared up the system and allowed us to turn the motor's shaft six times faster that we turned the large gear. Without the gears, we probably would not have been able to turn the motor fast enough to power the second model.

> ***Teacher's Notes***
> *The polarity can be reversed at either the generator (Double Pump's Motor) or at the second model's Motor.*
> *This activity provides an excellent opportunity for further instruction related to generators based either on student interest or curriculum requirements.*

Summarizing

In this activity:
- The Double Pump motor now behaves as an electricity generator.
- The direction in which the second model turns depends on the direction in which the model being used as the generator turns. Reverse the direction and the other model moves in the opposite direction also. A similar effect will occur when the polarity of the connecting cables is reversed.

> ***Teacher's Notes***
> *In the class discussion you may wish to refer to the similarities in the amount of electricity generated by the K'NEX Solar Panel under strong and weak light conditions.*
>
> *Electrical current produced in this way is direct current (dc), similar to that obtained from batteries and capacitors.*

Assessment

1. Student Journals.

2. Mat Activity (See Page 15 for guidelines on administering this assessment).