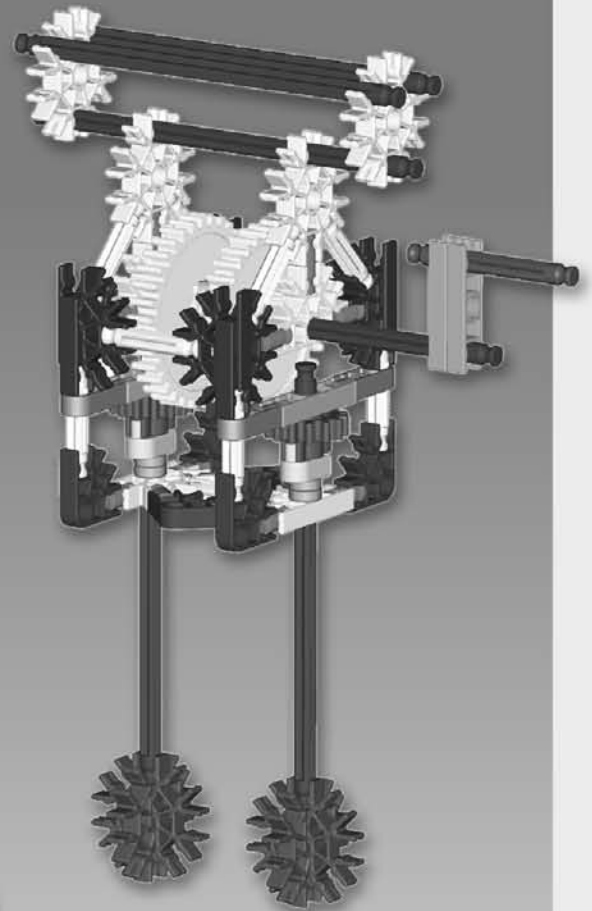
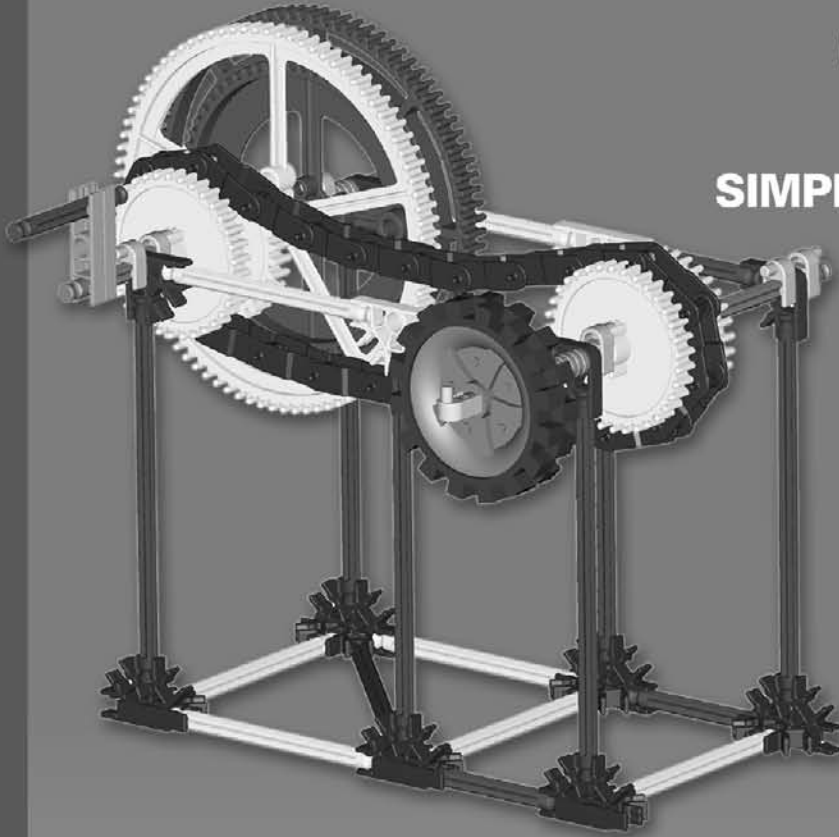


KNEX[®]

Education[™]

TEACHER'S GUIDE

SIMPLE MACHINES DELUXE[™]
GEARS



TEACHER'S GUIDE

SIMPLE MACHINES DELUXE™ GEARS

KNX 79520-V1-11/10
©2011 K'NEX Limited Partnership Group
and its licensors.

K'NEX is a trademark of K'NEX Limited Partnership Group.

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

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



WARNING:

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



AVERTISSEMENT :

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



Table of Contents

Simple Machines Deluxe Introduction	4
Standard Alignments	5
All About Gears	
What is a Gear?	8
Key Words and Definitions	8
Key Concepts	8
Student Reference Sheets	10
Spur Gears	
Lesson Plan	17
Student Activity Sheet	19
Sprocket Bicycle Gear	
Lesson Plan	20
Student Activity Sheet	22
Crown Gears	
Lesson Plan	23
Student Activity Sheet	25
Rack and Pinion Gears	
Lesson Plan	26
Student Activity Sheet	28
Worm and Worm Gear	
Lesson Plan	29
Student Activity Sheet	31
Planetary Gears	
Lesson Plan	32
Student Activity Sheet	34
Simple Transmission	
Lesson Plan	35
Student Activity Sheet	37
Car Window	
Lesson Plan	38
Student Activity Sheet	40
Lawnmower	
Lesson Plan	41
Student Activity Sheet	43
Eggbeater	
Lesson Plan	44
Student Activity Sheet	46
Food Mixer	
Lesson Plan	47
Student Activity Sheet	49
Differential	
Lesson Plan	50
Student Activity Sheet	52
Clock	
Lesson Plan	53
Student Activity Sheet	55
Part & Model List	56

Introduction:

OVERVIEW

This Teacher's Guide has been developed to support you as your students investigate the K'NEX Education Simple Machines Deluxe Set. In conjunction with the K'NEX materials and individual student journals, the information and resources here can be used to build your students' understanding of scientific concepts and channel their inquiries into active and meaningful learning experiences.

SIMPLE MACHINES DELUXE

This K'NEX Education set is designed to introduce students to the scientific concepts associated with simple machines. Students are provided with the opportunity to acquire skills using a hands-on, inquiry based approach to information and concepts. Working cooperatively, students are encouraged to interact with each other as they build, investigate, discuss and evaluate scientific principles in action.

TEACHER'S GUIDE

Designed as a resource for the teacher, this guide provides a glossary of key terms and definitions, includes an overview of the concepts associated with the different simple machines, identifies student objectives for each investigation, and offers plans and scripts to successfully present selected models and their associated activities. We have also provided Student Activity and Reference Sheets. These comprise illustrations and definitions of some of the concepts featured in the model building activities. Most lessons can be completed in 30 to 45 minutes. We recommend that teachers review their curriculum and science education standards to identify those activities that best support their academic needs.

STUDENT JOURNALS

It is expected that students will have journals available for recording information. They should be encouraged to enter initial thought at the start of an inquiry – what they “think” will happen. These initial thoughts may be amended, based upon their ongoing inquiry and analysis, until the students feel comfortable about drawing conclusions. Their journal entries will help make a connection between the models they have built, the experiments they have conducted, and how this information is applied to the real-world machines they use on a regular basis. The journals will also provide students with a place to practice making drawings and diagrams of systems. Finally, the journals will serve as a method of assessment for the Simple Machines units. Journal Checklists are also included in the Teacher's Guide for each model and its associated activities.

Alignment with National Standards Grades K-4

The National Science Education Standards

Unifying Concepts and Processes	<ul style="list-style-type: none"> • Systems, order, and organization • Evidence, models, and explanation • Change, constancy, and measurement • Form and function
Physical Science	<ul style="list-style-type: none"> • Properties of objects and materials • Position and motion of objects
Science and Technology	<ul style="list-style-type: none"> • Abilities of technological design • Understandings about science and technology

Reprinted with permission from National Science Education Standards, 2001 by the National Academy of Sciences, Courtesy of the National Academies Press, Washington, D.C.

Alignment with National Standards Grades 5 - 8

The National Science Education Standards

Unifying Concepts and Processes	<ul style="list-style-type: none"> • Systems, order, and organization • Evidence, models, and explanation • Change, constancy, and measurement • Form and function
Physical Science	<ul style="list-style-type: none"> • Motions and Forces • Transfer of Energy
Science as Inquiry	<ul style="list-style-type: none"> • Abilities necessary to do scientific inquiry • Understanding about scientific inquiry
Science and Technology	<ul style="list-style-type: none"> • Abilities of technological design • Understandings about science and technology

Reprinted with permission from National Science Education Standards, 2001 by the National Academy of Sciences, Courtesy of the National Academies Press, Washington, D.C.

Alignment with Standards for Technological Literacy Grades 3-5

Standards for Technological Literacy	
The Nature of Technology	<p>Core Concepts of Technology</p> <ul style="list-style-type: none"> • Systems • Processes • Requirements <p>Relationships among technologies</p> <ul style="list-style-type: none"> • Technologies integrated
Design	<p>The Attributes of design</p> <ul style="list-style-type: none"> • Requirements of design <p>Engineering Design</p> <ul style="list-style-type: none"> • Engineering design process • Creativity and considering all ideas • Models <p>The role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving</p> <ul style="list-style-type: none"> • Troubleshooting • Invention and innovation • Experimentation
Abilities of a Technological World	<p>Apply design process</p> <ul style="list-style-type: none"> • Collecting information • Visualize a solution • Test and evaluate solutions • Improve a design

Used with permission of ITEEA (www.iteea.org)

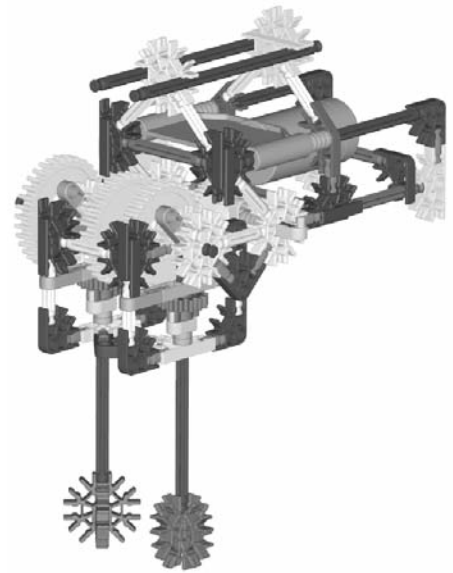
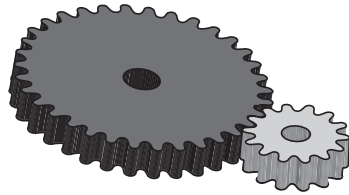
Alignment with Standards for Technological Literacy Grades 6 - 8

Standards for Technological Literacy

<p>The Nature of Technology</p>	<p>Core Concepts of Technology</p> <ul style="list-style-type: none"> • Systems • Processes • Requirements <p>Relationships among technologies</p> <ul style="list-style-type: none"> • Interaction of systems • Knowledge from other fields of study and technology
<p>Design</p>	<p>The Attributes of design</p> <ul style="list-style-type: none"> • Design leads to useful products and systems • There is no perfect design <p>Engineering Design</p> <ul style="list-style-type: none"> • Brainstorming • Modeling, testing, evaluating, and modifying <p>The role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving</p> <ul style="list-style-type: none"> • Troubleshooting • Invention and innovation • Experimentation
<p>Abilities of a Technological World</p>	<p>Apply design process</p> <ul style="list-style-type: none"> • Identify criteria and constraints • Test and evaluate • Make a product or system

Used with permission of ITEEA (www.iteea.org)

All About GEARS



What is a Gear?

- A gear is a wheel with teeth along its outer edge.
- One gear can make another gear turn when the teeth of the two gears interlock, mesh or connect.
- Gears can change the amount of force, the direction and the speed of rotation needed to do a job.

Key Words and Definitions

Effort - the force that is applied to do work; the push, pull, squeeze or lift provided to use gears to move an object

Resistance - the force provided by the object on which one is trying to do work; the object works against (pushes back) the effort

Mechanical Advantage (MA) - a mathematical calculation that reveals how many times easier a job is to do

MA greater than 1 shows that the gear system multiplied the effort force, but must move through a greater distance. MA less than 1 shows that the gear system requires greater effort force to operate but the driven gear moves more quickly

$$\text{MA} = \frac{\text{number of teeth (driven gear)}}{\text{number of teeth (drive gear)}}$$

or

$$\text{MA} = \frac{\text{diameter (driven gear)}}{\text{diameter (drive gear)}}$$

Gear ratio - a mathematical relationship that indicates the difference in the size of gears in a gear system; the rate at which one gear turns another based on the number of teeth or diameter of each gear

$$\text{Gear Ratio} = \frac{\text{number of teeth (large gear)}}{\text{number of teeth (small gear)}} : 1$$

or

$$\text{MA} = \frac{\text{diameter (large gear)}}{\text{diameter (small gear)}} : 1$$

Diameter - the distance through the center of an object; a straight line passing through the center of a circle ended at the circumference

Work - the job being done while using the gears

Load - the object (weight) lifted or moved; provides resistance to the gears

Force - any kind of push or pull applied to an object

Bevel - an angle that is not a right angle; slanted

Key Concepts

How do gears help you?

- Gears can change the force needed to make something move and the speed it moves.
- One gear affects the way another gear moves based on how the gears are configured in the system.
- Many gears, working together in different arrangements, allow a single machine to do work at both different speeds and directions.
- The Mechanical Advantage, or gear ratio, of a set of gears, is determined by ratios of: the number of teeth; the diameters; the speeds of the two gears; and the amounts of force with which they turn.

Key Concepts

How do gears affect force?

- Gears can reduce the amount of force needed to do a job.
- A small gear requires less force to turn than a big gear but must be turned many times in order to make the big gear turn once.
- When a small gear turns a big gear, the Mechanical Advantage tells how many times easier your job is.

How do gears affect speed?

- When using two gears of different sizes, the small gear turns more quickly than the big gear.
- When a big gear turns a small gear, the gear ratio tells how many times faster the job is done.

How do gears affect direction?

- When two gears are linked together, they turn in opposite directions and can make different parts of machines turn in opposite directions.
- Gears can change the angle of rotation when a gear on a vertical plane turns a gear on a horizontal plane.
- Special gear systems can change circular motion into back-and-forth motion.

What are spur gears?

- Spur gears lie in the same plane and turn in opposite directions when meshed.
- Different-sized spur gears turn at different speeds and with different amounts of force.

What are sprocket gears?

- Sprocket gears are a special type of spur gears consisting of two gears on the same plane, set apart from each other and linked by a chain.
- Sprocket gears turn in the same direction.
- Different-sized sprocket gears turn at different speeds and with different amounts of force.

What are crown gears?

- Crown gears lie in different planes (at right angles to each other) and turn in opposite directions.
- Different-sized crown gears turn at different speeds and with different amounts of force.

What are rack and pinion gears?

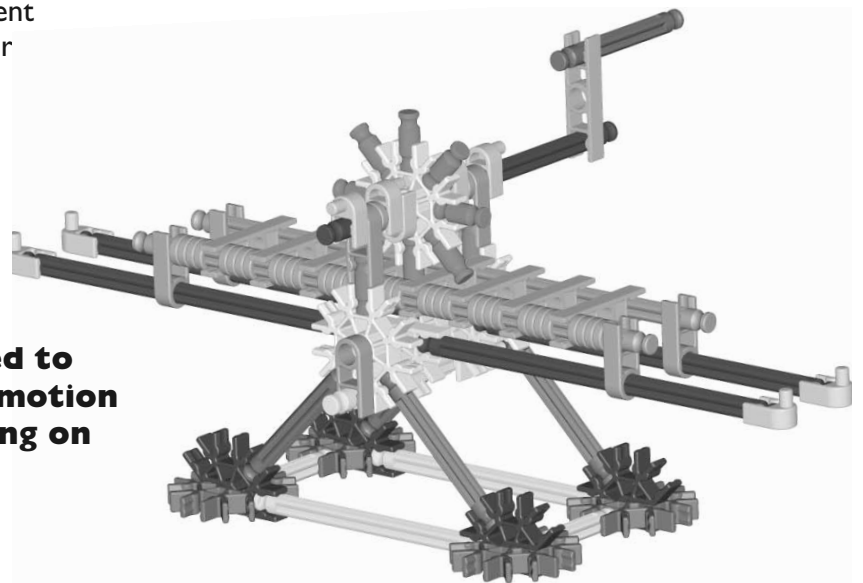
- Rack and pinion gears consist of a toothed bar and a toothed wheel.
- Rack and pinion gears change circular motion into back-and-forth motion.

What are worm gears?

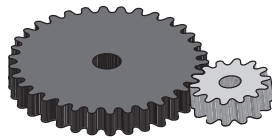
- Worm gears consist of a spiral-edged cylinder called the worm and a toothed wheel called the worm gear.
- A worm and its worm gear turn in different directions, at different speeds and with different amounts of force.
- Worm gears change fast motion into slow motion.

REMEMBER

Special types of gears can be used to change the direction of circular motion and to gear up or down depending on the need for speed.



Getting Started With Gears



What is a gear?

- A gear is a wheel with teeth along its outer edge.
- One gear can make another gear turn when the teeth of the two gears interlock, mesh or connect.
- Gears can make work easier by letting you use less force to do a job.
- Some gears let you move a gear in one direction by turning another gear in a different direction.
- Other gears help by changing the speed of the turning parts.

How do gears help you?

Gears can help you in three different ways.

Force

Gears can change the force you need to make something move. When you turn a small gear, it can make a big gear move. You have to turn it lots of times to make the big gear turn around once, but the small gear doesn't take much force to turn.

Speed

Gears can change the speed that a machine moves. If two gears are different sizes, the smaller gear will turn faster than the larger gear.

Many machines use gears of different sizes to make certain parts of the machine turn faster or slower than others.



Direction

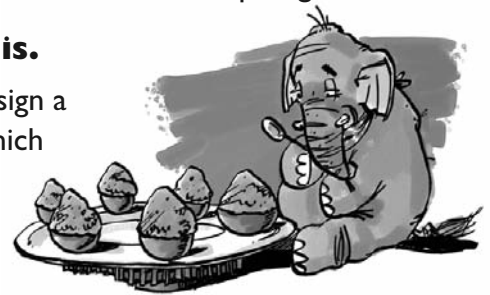
Gears can also change the direction something moves. When two gears are linked together, they turn in opposite directions and can make parts of machines turn in opposite directions too. Gears can also be set up where one gear is lying flat, but it makes an upright gear turn. Different arrangements of gears make it possible for machines to do work in many different directions.

Here's an example of how gears can help.

Imagine you work for a zoo. Your job is to build a feeder to adjust the meals for an elephant named Moe. Moe eats whatever food is put out for him so his intake must be watched closely or he'll overeat. The zoo manager asked you to find a machine to feed Moe specific amounts at the proper times. Impossible? NO! Not with the help of gears.

Picture this.

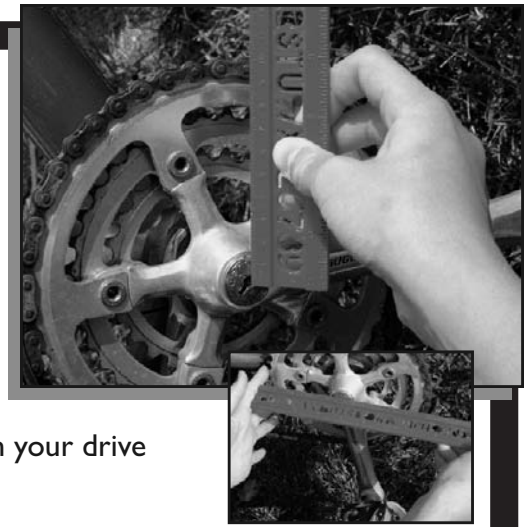
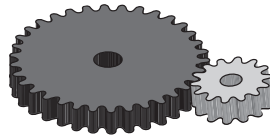
You could design a huge plate which rotates in a circle. Along the outside of the plate are large bowls with elephant-sized helpings for Moe's meals. Your design puts only one bowl in Moe's reach at a time. The speed the plate turns is controlled by a series of gears underneath the plate. This allows it to run at the right speed so Moe gets fed at the proper time without your help.



A Bright Idea!

Gears were a pretty modern invention. Conduct research to find out about the earliest use of this simple machine.

What's the Mechanical Advantage?



How much do gears help you?

Just by counting the gear's teeth and dividing a few numbers, you can find out how much gears make work easier or faster.

- 1 Count the number of teeth on your driven Gear and the number on your drive Gear.
- 2 Divide the driven number by the drive number. The answer is the **Mechanical Advantage (MA)**, which tells you how many times easier your job is.

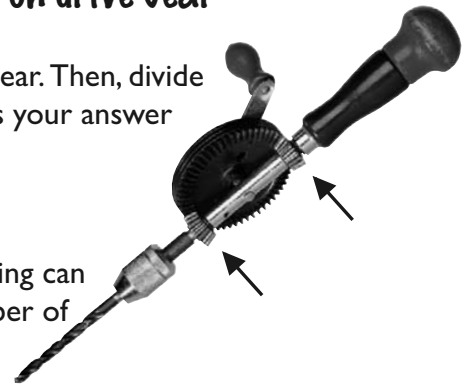
$$\text{MA} = \text{Number of teeth on driven Gear} \div \text{Number of teeth on drive Gear}$$

- 3 You can also figure out the MA by measuring the diameter of each Gear. Then, divide the diameter of the driven Gear by the diameter of the drive Gear. Is your answer about the same as your answer from Step 2?

$$\text{MA} = \text{Diameter of driven Gear} \div \text{Diameter of drive Gear}$$

- 4 You can use the gear ratio to tell you how many times faster something can move when you use a big Gear to turn a small Gear. Divide the number of teeth on the big Gear by the number of teeth on the small Gear to get this ratio.

$$\text{Gear Ratio} = \text{Number of teeth on big Gear} \div \text{Number of teeth on small Gear} : 1$$



Student Challenge

- 1 **Gears let you use less force**
Imagine you want to turn a merry-go-round. A big gear with 500 teeth is attached to the platform where people ride. A smaller gear with 20 teeth is attached to a motor.

$$\text{MA} = 500 \div 20$$

$$\text{MA} = 25$$

A Mechanical Advantage of 25 means that the motor turns the small gear 25 times for one turn of the merry-go-round, but it takes 25 times less force than it would to turn the big gear itself.

The MA shows the number of times the gear system multiplies the effort force applied to the small gear.

- 2 **Gears give you speed**
Imagine you are using a hand drill. You turn the crank on the big gear, which has 60 teeth. The small gear has 15 teeth.

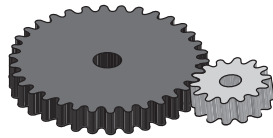
$$\text{Gear Ratio} = 60 \div 15 : 1$$

$$\text{Gear Ratio} = 4 : 1$$

The gear ratio is 4:1, which means that the drill bit turns four times faster than you turn the crank since you are using a big gear to drive a small gear. That helps you drill a hole quickly and easily.

The gear ratio shows how many times faster the small gear turns when you apply the effort force to the big gear.

What are Spur Gears?



Spur gears are sets of gears that work together by being set in the same position. The teeth on the edge of one gear mesh with the teeth on the other gear. When you turn one gear, the other gear turns in the opposite direction.

Spur gears can be the same size or different sizes. If the sizes are different, the gears will turn at different speeds and with different amounts of force.

Here's an example.

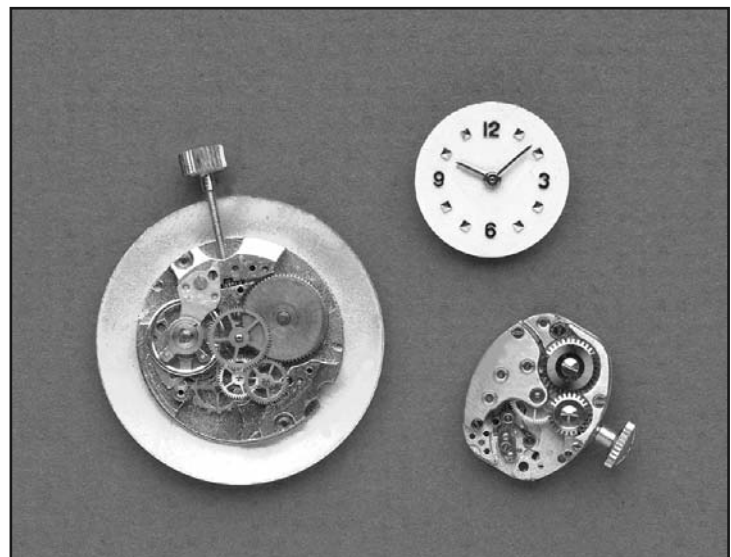
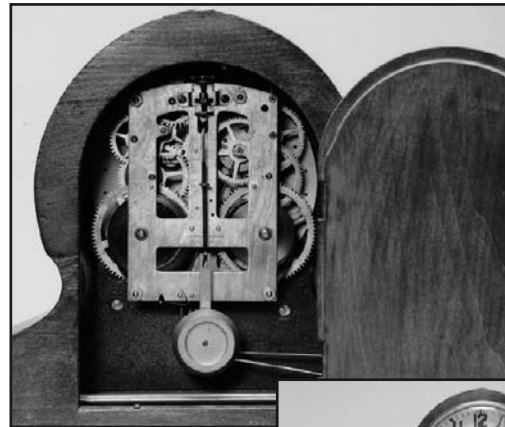
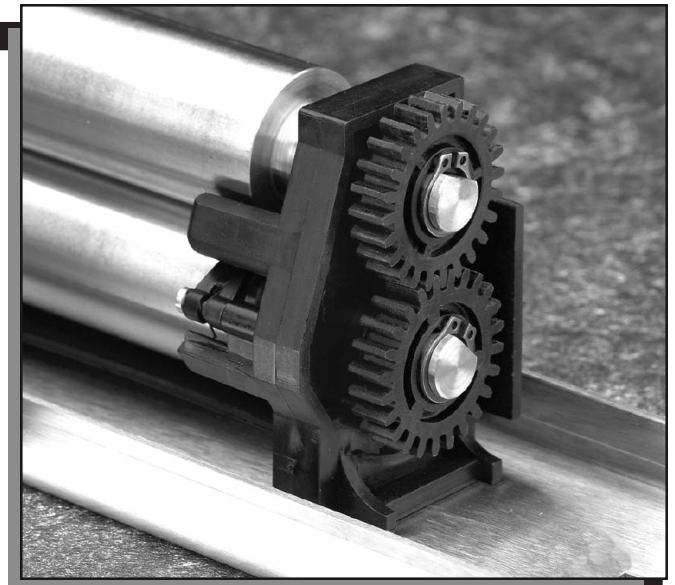
Spur gears inside a wristwatch make the hands turn. When you wind the watch, you wind up a spring that powers the gears. Small and large spur gears work together to make the hands turn at different rates, so you can tell the time.

How do spur gears help you?

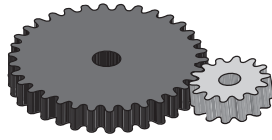
Spur gears of different sizes can help you by making parts of a machine turn at different rates. When a small gear and a large gear work together, the small gear turns faster than the large gear. Its circumference is smaller, so it doesn't have as far to go to make one complete turn.

In a wristwatch, small and large gears work together to make the second hand turn a full circle within a minute; the minute hand turn a full circle within an hour and the hour hand turn a full circle within twelve hours.

Different-sized spur gears also turn with different amounts of force. These gears can help you when you use a machine that requires extra force to do a job.



What are Worm Gears?



Worm gears have two different parts: a worm gear and a worm. The worm gear looks like most other gears, a wheel with teeth. The worm got its name because its tube-like shape resembles a worm with a ridge that wraps around it in a spiral. This ridge meshes with the teeth of the worm gear, and together, they turn. The worm and the worm gear turn at different speeds, with different amounts of force and in different directions.

Here's an example.

A crescent wrench uses worm gears. The worm is easy to recognize. It's the spiral part you turn to make the jaws of the wrench come together. The worm gear might not be so easy to identify. It has a toothed edge along the bottom of its moving jaw. (You can just imagine it's the edge of a big wheel!)

How do worm gears help you?

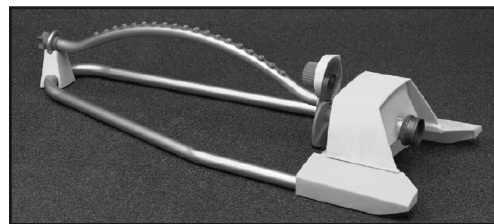
Worm gears help by letting you turn part of a machine at one speed while you make another part of the machine turn at a much slower or faster speed.

Worm gears can do this, because the worm has to make a full turn to make the worm gear move ahead by just one tooth. As a result, the worm turns much more quickly than the worm gear.

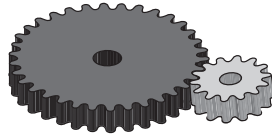
When you turn the worm on the crescent wrench, the worm gear turns slowly. It makes the movable jaw of the wrench move just a tiny bit—maybe a fraction of a millimeter. Being able to make such tiny movements lets you adjust the wrench just the right amount.

Since the worm and worm gear move at different speeds, they also move with different amounts of force. The worm gear turns with more force than the worm.

A worm and its worm gear turn in different directions. If you imagine that the worm and the worm gear each trace out a circle as they turn, the two circles are at right angles to each other.



What are Sprocket Gears?



Sprocket gears are special types of spur gears. Two sprocket gears are set in the same position, but they are placed a certain distance apart. A chain wraps around the gears. By turning one gear, you make the chain move and the chain turns the other gear. Both gears turn in the same direction. The teeth on sprocket gears are specially shaped to fit between the pegs or notches on a chain.

Here's an example.

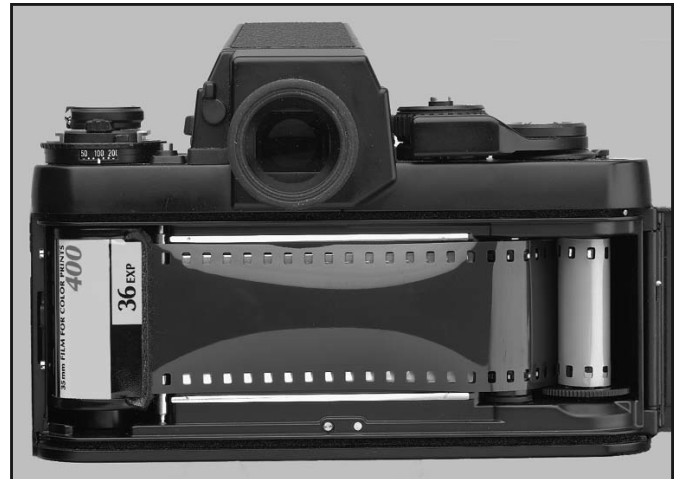
A bicycle uses sprocket gears to turn the back wheel. You push the pedals, making the pedal gear turn. The chain, which is wrapped around both gears, then makes the back gear turn. The back gear turns the wheel and off you go!

How do sprocket gears help you?

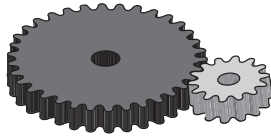
A special feature of sprocket gears is that they let you spread your turning action over a distance. You don't need to place the gears right next to each other in order for them to work together. In a bicycle, it helps to have the gears separated, so you have room for your feet to turn the pedals and to fit the big rear wheel next to the back gear.

Two sprocket gears connected by a chain move in the same direction. Both gears turn clockwise or both turn counterclockwise. That's helpful in a bicycle. Otherwise, you'd have to pedal backwards to make the bike go forward!

Sprocket gears can vary in size. Like other spur gears, they can turn at different speeds and with different amounts of force. As a result, the pedal gear turns at a different speed than the gear attached to the wheel.



What are Crown Gears?



Crown gears are gears that work together but, unlike spur gears, they are not set in the same position. Instead, a pair of crown gears lie at angles to each other – usually at right angles. One gear might be upright, while the other lays flat. Another name for crown gears is bevel gears. They are called bevel gears because the word bevel means “slanted.”

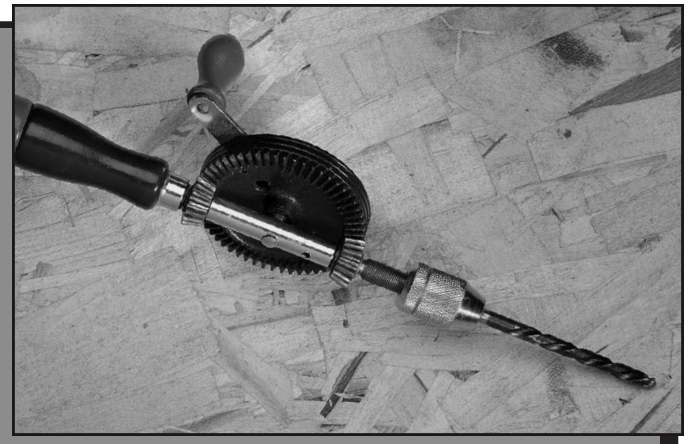
Here’s an example.

A hand drill has a crank to turn and a shaft that holds the drill bit. When you turn the crank, the drill bit spins to drill a hole. The drill’s crown gears help you drill straight down while turning the crank on the side of the drill.

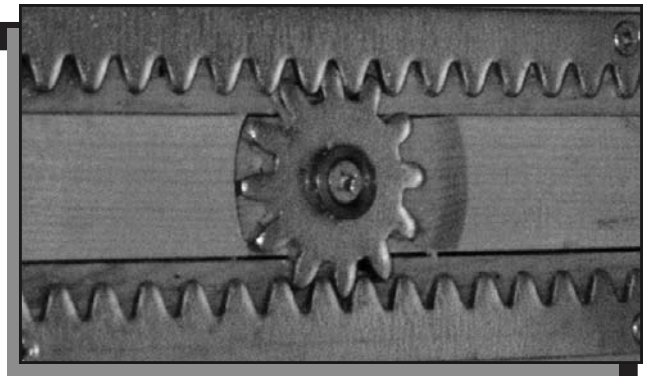
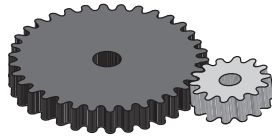
How do crown gears help you?

Crown gears make different parts of machines turn in different directions. On a hand drill, the crank is connected to an upright gear. With the crank in this position, your hand can easily turn it. If the drill had a crank that turned around the drill’s shaft, it would probably make the drill wobble as it turned and the drill would be difficult to hold.

Like spur gears, crown gears can be different sizes. Then, the crown gears will turn at different speeds and with different amounts of force, in the same way that spur gears do.



What are Rack and Pinion Gears?



Rack and pinion gears have their own special shape and their own kind of movement. The rack is a long, toothed bar which moves back and forth. The pinion is a toothed wheel which rotates.

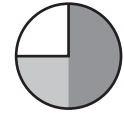
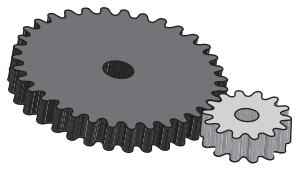
Here's an example.

Inside a car, rack and pinion gears control the way the car turns. The car's steering wheel is connected to a pinion gear that turns round and round. It moves the rack, which turns the front wheels to the right or left, allowing the car to turn.

How do rack and pinion gears help you?

Rack and pinion gears let you change round-and-round motion into back-and-forth motion. These gears make it easy to steer a car. You can turn the wheel a little to make the car angle to the right or left, or turn it a lot to make a sharp turn. Imagine trying to steer if you didn't have rack and pinion gears. You'd have to shift the wheels in some other way - perhaps with a lever. Rack and pinion gears sure make things easier!

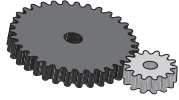




The Spur Gears Lesson Plan

Lesson Length: 30-45 minutes

Objectives



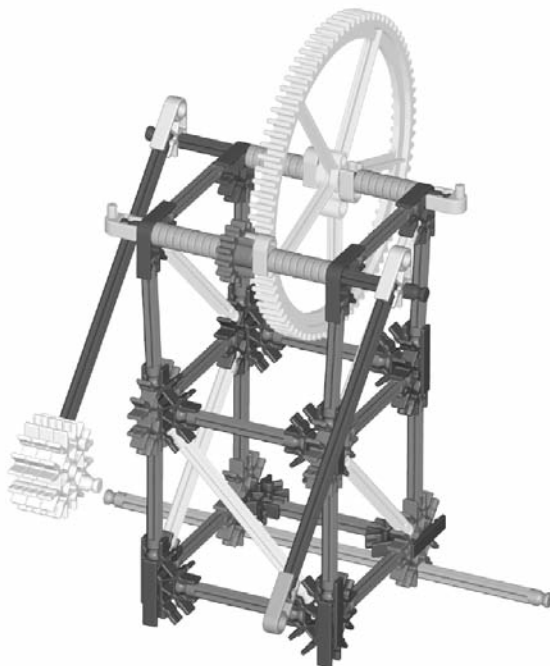
- Identify a spur gear
- Demonstrate how spur gears function
- Explain the advantage offered by spur gears of different gear ratios and their effect on force and speed
- Measure applied forces using a Rubber Band Scale and determine Mechanical Advantage
- Determine if spur gears change force, speed or direction
- Practice creative design utilizing spur gears
- Compare and contrast spur gears with other gears

Materials

- K'NEX Rubber Band Scale
- small weight, such as cup of pennies or green Rods
- string
- extra K'NEX pieces

Every wheel and axle has a job to do

A salad spinner provides a great demonstration of spur gears. Count and compare the number of turns of the salad spinner handle to the number of turns of the basket. Note that the spinner makes work easier, because the basket spins fast enough to make the water fly away from the lettuce, but you don't have to turn the crank very fast.



Journal Check

- ✓ Explanation for how spur gears function
- ✓ Explanation of 1:1 and 6:1 gear ratios based on observations
- ✓ Force measurements and comparisons for 1:1 and 6:1 gear ratios
- ✓ Explanatory paragraph for results of tests on 1:1 and 6:1 Spur Gear models
- ✓ Description of the difference between spur gear size and their functional advantage(s)
- ✓ Explanation of the relationship between spur gear arrangement and applied force

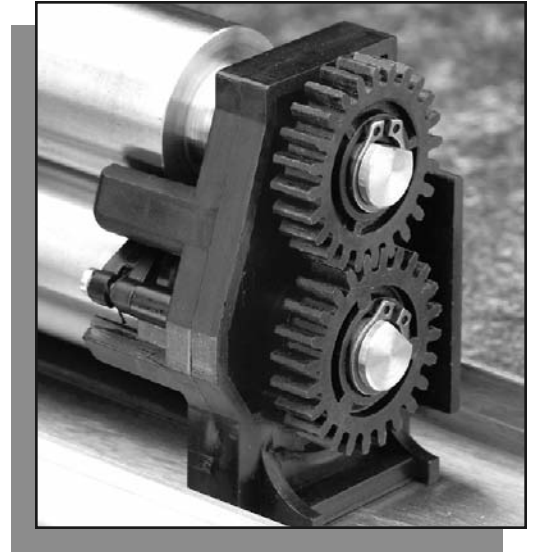
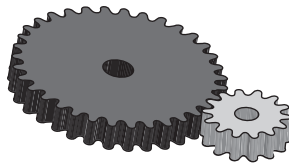
QUESTIONS

- 1 Build the 1:1 Spur Gear model. Mark each Gear near the rim with a small piece of tape. Turn the crank for the top Gear one full turn and observe the model. Which way does each Gear move? How many turns did the bottom Gear make? This Spur Gear model has a one to one (1:1) gear ratio. Based on your observation, what does this mean? (Refer to the “What’s the Mechanical Advantage” Reference Sheet for help.)
- 2
 - a. Hang a cup with small weights (green Rods, pennies, etc.) from the crank on the lower Gear. Turn the top crank to lift the weight. Feel how much force it takes to do this. Connect the K’NEX Rubber Band Scale to the end of the top Gear’s crank. Measure the amount of force used to lift the weight. Record your findings.
 - b. Next, hang the weight from the crank for the top Gear. Turn the lower crank and feel the force used to lift the weight. Do you use the same amount of force to lift the weight now? Measure the force used to lift the weight in this position. Record your findings. Compare the measurements. Did the amount of force used differ? Why or why not? Write a paragraph explaining your results.
- 3
 - a. Build the 6:1 Spur Gear model. Repeat Activity 1, turning the crank for the yellow Gear. How many turns did the blue Gear make for one turn of the yellow Gear? Based on your observation, what is the gear ratio for this model? Why would you need to use spur gears that have different ratios?
 - b. Repeat Activity 2, testing the weight on each crank. Which Gear requires less force to lift the weight? What are other benefits to using this Gear arrangement?
- 4 Using K’NEX, build a hand cranked fan that uses spur gears to turn at different speeds. Make blades for your fan from cardboard or poster board. Crank the fan and feel the cool breeze!

ANSWERS

- 1 Two adjacent spur Gears turn in opposite directions. For the 1:1 Spur Gear, the bottom Gear makes one turn as the top Gear makes a single turn. A 1:1 gear ratio means that two spur gears are the same size and they turn at the same rate.
- 2 To lift weights with the 1:1 Spur Gear, you need to apply the same force whether you attach the weight to the top or bottom Gear because the two Gears are the same size. Same size gears turn with the same amount of force.
- 3
 - a. For the 6:1 Spur Gear, the small Gear turns six times for each turn of the large Gear. When spur gears differ in size, the smaller one turns faster.
 - b. Using the 6:1 Spur Gear, you need to apply less force to the small Gear when the weight is attached to the large Gear. The large Gear turns more slowly, but with more force, so you don’t need to supply so much force yourself. This arrangement changes the direction the crank rotates.

The Spur Gears

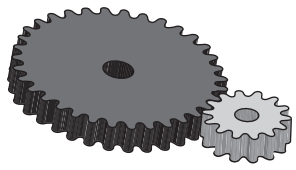


Every gear has a job to do

Spur gears lie one behind the other. By turning one spur gear, you can make another gear move. When you use a salad spinner to dry a head of lettuce, you are using spur gears. These gears are inside the lid and they connect the handle to the basket where you put the lettuce. When you turn the handle, the basket turns much faster than the handle turns. The water goes flying into the outer bowl and your lettuce is dry, thanks to spur gears!

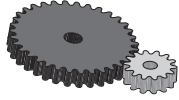
Student Challenge

- 1 Build the 1:1 Spur Gear model. Mark each Gear near the rim with a small piece of tape. Turn the crank for the top Gear one full turn and observe the model. Which way does each Gear move? How many turns did the bottom Gear make? This Spur Gear model has a one to one (1:1) gear ratio. Based on your observation, what does this mean? (Refer to the "What's the Mechanical Advantage" Reference Sheet for help.)
- 2
 - a. Hang a cup with small weights (green Rods, pennies, etc.) from the crank on the lower Gear. Turn the top crank to lift the weight. Feel how much force it takes to do this.
Connect the K'NEX Rubber Band Scale to the end of the top Gear's crank. Measure the amount of force used to lift the weight. Record your findings.
 - b. Next, hang the weight from the crank for the top Gear. Turn the lower crank and feel the force used to lift the weight. Do you use the same amount of force to lift the weight now?
- 3
 - a. Build the 6:1 Spur Gear model. Repeat Activity 1, turning the crank for the yellow Gear. How many turns did the blue Gear make for one turn of the yellow Gear? Based on your observation, what is the gear ratio for this model? Why would you need to use spur gears that have different ratios?
 - b. Repeat Activity 2, testing the weight on each crank. Which Gear requires less force to lift the weight? What are other benefits to using this Gear arrangement?
- 4 Using K'NEX, build a hand cranked fan that uses spur gears to turn at different speeds. Make blades for your fan from cardboard or poster board. Crank the fan and feel the cool breeze!



The Sprocket Bicycle Gear Lesson Plan

Objectives



- Identify a sprocket gear
- Demonstrate how sprocket gears function
- Explain the advantages offered by sprocket gears of the same and different gear ratios and their effect on force and speed
- Measure applied forces with a Rubber Band Scale and determine Mechanical Advantage
- Determine if sprocket gears change force, speed or direction
- Demonstrate the significance and advantage of gear ratios and force spread over distance
- Compare and contrast sprocket gears with other gears
- Determine the appropriateness of sprocket versus other gears used in certain machines



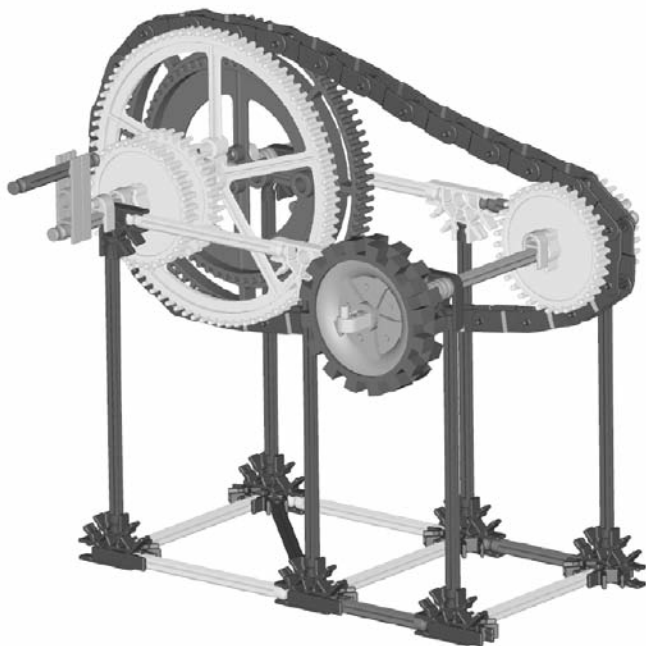
Lesson Length: 30-45 minutes

Materials

-no special materials required

Every gear has a job to do

When riding multi-speed bikes, riders need to shift gears when riding uphill, downhill or into the wind. These riding conditions affect the amount of force that must be applied to the sprocket gears in order to keep riding with a certain level of comfort and speed. (An illustration of a roller coaster's starting climb will also effectively demonstrate the use of sprocket gears.)



Journal Check

- ✓ Measurements of sprocket gear rotations and gear ratios
- ✓ Weight and force measurements
- ✓ Descriptive comparison of the feel and speed of the force required for varying sprocket gear configurations
- ✓ Explanation of how force measurements support observations
- ✓ Description of why bicycles are best served by sprocket gears
- ✓ Lists of other machines which use sprocket gears

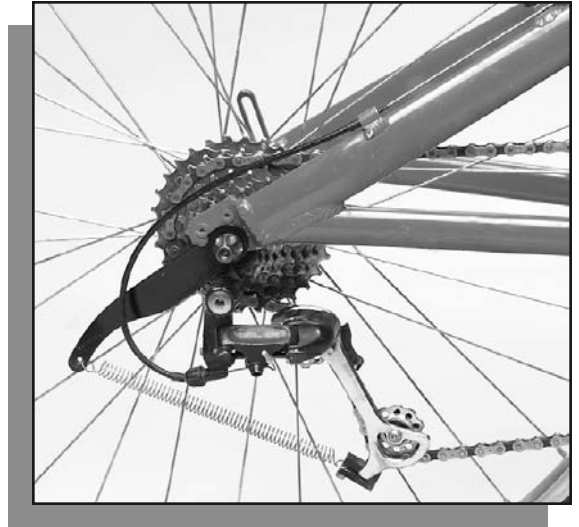
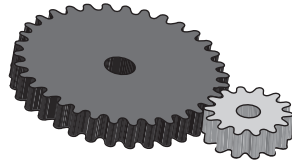
QUESTIONS

1. **a.** Set up the Sprocket Bicycle Gear model with the chain wrapped around the two sets of small yellow Gears. Turn the pedal and count the number of times the Wheel turns. Record your answer. What is the gear ratio for these Sprocket Bicycle Gears? What is the Mechanical Advantage? (Refer to the “What’s the Mechanical Advantage” Reference Sheet.)
b. Attach a cup with small weights to the gray Rod with the Wheel. Measure the force used to turn the pedals with the K’NEX Rubber Band Scale. (Snap the orange Connector at the bottom of the Scale to the blue Rod on the pedal.) Record your results.
2. **a.** Add extra links to the Chain. Wrap the Chain around the set of small Gears and big Gears. Now put the pedals on the axle with the small Gears. Put the wheel on the axle with the big Gears. How does it feel to turn the pedals?
b. Repeat the process from Activity 1. Compare these results with your previous results. Which set of Sprocket Bicycle Gears need more force to lift the weight? Why?
3. **a.** Now switch the pedals to the axle with the big Gears, and put the Wheel on the axle with the small Gears. Turn the pedals. How does it feel? Does the Wheel turn faster or slower? Why?
b. Repeat the process from Activity 1.
4. Compare all your results. Why are the gear combinations described as high and low? How do your force and speed measurements prove this? Which Gear arrangement lets you ride fast with the least force? Explain.
5. Why are sprocket gears a good choice for a bicycle? Make a list of machines that use sprocket gears. Explain why this gear system is the best choice for these machines.

ANSWERS

1. **a.** The gear ratio for the set of small Sprocket Bicycle Gears is 1:1. They turn in the same direction. The Mechanical Advantage is 1.
2. **a.** Students should find that they must turn the pedals (which are attached to the small Gears) about 2.5 turns for every turn of the wheel (which is attached to the large Gears). The pedals turn easily, but the wheel doesn’t go very fast.
b. Students will find that it takes less force to lift the weight when turning the small Gears to make the large Gears lift the weight. This arrangement has a MA of 2.5.
3. **a.** They only need to turn the pedals (which are attached to the large Gears) less than one-half a turn (about 0.4 turn) for the wheel (which is attached to the small Gears) to turn once. The pedals are harder to turn, but the wheel turns faster.
b. Students will find that it takes more force to lift the weight when turning the large Gears to make the small Gears turn but the weight is lifted faster. This arrangement has a MA of 0.4.
4. With the K’NEX model set in low gear it’s easier to pedal faster because you don’t need to apply a lot of force. However, you do not go very far because the wheel does not turn very often. With the model in high gear, you must apply more force. It will be more difficult to turn the pedals but they will turn the wheel much more often, to go farther.
The K’NEX model correlates to a real bicycle: the bicycle’s front gears are attached to the crankshaft, which the pedals turn. The back gears are attached to the back wheel, so they turn with the wheel.
5. Sprocket gears make a good choice for a bicycle because the chain makes the pedal gear turn in the same direction as the wheel gear. The chain allows the pedal gear and the wheel gear to be separated from each other so you have room for the pedals and your legs.
Students may have seen sprocket gears in chain saws, chain hoists, garage door openers, barbecue rotisseries, movie projectors and cameras (the film acts as the “chain”). These machines use sprocket gears to move the chain or to turn a gear some distance away.

The Sprocket Bicycle Gear

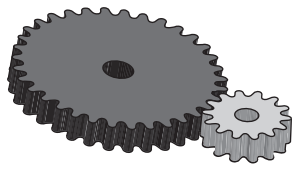


Every gear has a job to do

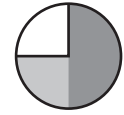
Sprocket gears are set apart from each other and are connected by a chain. Many bikes have a set of sprocket gears which help you ride at an even pace, on any kind of surface. Sprocket gears also pull roller coaster cars up the first ramp of the ride. The chain has notches or pegs that fit around the gears. When you turn one gear, the chain moves too, and it makes the gear on the other end of the chain turn. These gears let you supply the power in one place and have the power be used across a distance.

Student Challenge

1.
 - a. Set up the Sprocket Bicycle Gear model with the chain wrapped around the two sets of small yellow Gears. Turn the pedal and count the number of times the Wheel turns. Record your answer. What is the gear ratio for these Sprocket Bicycle Gears? What is the Mechanical Advantage? (Refer to the "What's the Mechanical Advantage" Reference Sheet.)
 - b. Attach a cup with small weights to the gray Rod with the Wheel. Measure the force used to turn the pedals with the K'NEX Rubber Band Scale. (Snap the orange Connector at the bottom of the Scale to the blue Rod on the pedal.) Record your results.
2.
 - a. Add extra links to the Chain. Wrap the Chain around the set of small Gears and big Gears. Now put the pedals on the axle with the small Gears. Put the wheel on the axle with the big Gears. How does it feel to turn the pedals?
 - b. Repeat the process from Activity 1. Compare these results with your previous results. Which set of Sprocket Bicycle Gears need more force to lift the weight? Why?
3.
 - a. Now switch the pedals to the axle with the big Gears, and put the Wheel on the axle with the small Gears. Turn the pedals. How does it feel? Does the Wheel turn faster or slower? Why?
 - b. Repeat the process from Activity 1.
4. Compare all your results. Why are the gear combinations described as high and low? How do your force and speed measurements prove this? Which Gear arrangement lets you ride fast with the least force? Explain.
5. Why are sprocket gears a good choice for a bicycle? Make a list of machines that use sprocket gears. Explain why this gear system is the best choice for these machines.

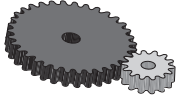


The Crown Gears Lesson Plan



Lesson Length: 30-45 minutes

Objectives



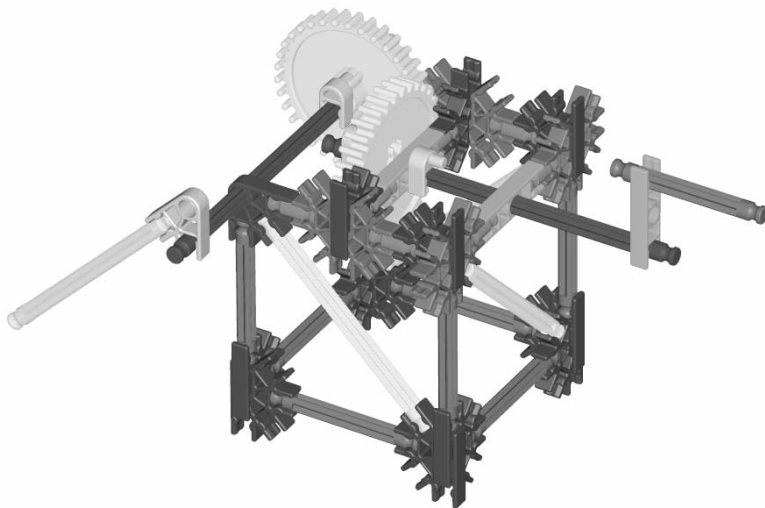
- Identify a crown gear
- Demonstrate how crown gears function
- Measure applied forces with a Rubber Band Scale and determine Mechanical Advantage
- Determine if crown gears change force, speed or direction
- Infer the significance and advantage of crown gear ratios and their effect on force and speed
- Demonstrate the significance and advantages of using crown gears
- Practice creative design to build a model which effectively utilizes crown gears
- Compare and contrast crown gears with other gears

Materials

- tape
- extra K'NEX pieces including a large Gear

Every gear has a job to do

Crown gears allow you to turn a gear in one direction, while making another gear turn at a right angle. Help students see how the arrangement of crown gears can be useful. For example, in the case of a power drill, you don't have to get your hand near the sharp drill bit to tighten the screw.



Journal Check

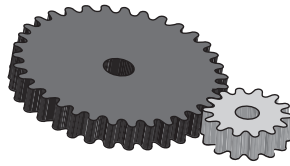
- ✓ Description of how crown gears work and the directions they turn
- ✓ Description of the difference in force and direction in various model configurations
- ✓ Force measurements for crown gear arrangements
- ✓ Gear ratios for sets of crown gears
- ✓ Description of how crown gears can do work in a newly designed potter's wheel

QUESTIONS

- 1 Turn the crank to make your K'NEX Crown Gears move. Which way does each Gear turn? How is their movement different from the movement of spur gears?
- 2 Use the K'NEX Rubber Band Scale to measure the force used to lift a small weight with the Crown Gears, like you did with the Spur Gears. Record your findings. Did the Crown Gears reduce the force needed to lift the weight? Why or why not?
- 3
 - a. Try replacing one small Gear in your Crown Gears model with a big yellow Gear. You will have to change the stand so the big Gear will fit.
 - b. Use a small piece of tape to mark the top of each Gear. Turn the large Gears one turn and see how many times the small Gear turns around.
 - c. Again, use the Rubber Band Scale to measure the force needed to lift the weight. Record your results and compare them to the previous measurement. How did this Crown Gear arrangement affect the amount of force used to do the work? Write a few sentences explaining your findings.
 - d. What is the gear ratio for this set of Crown Gears? What is the Mechanical Advantage? (Refer to the "What's the Mechanical Advantage" Reference Sheet for help.) How can crown gears help you do work?
- 4 Imagine you make clay pots and you want to build a potter's wheel that is powered by bike pedals. How might crown gears help you do this? Using K'NEX, design and build this model.

ANSWERS

- 1 When you turn the Crown Gears, one Gear turns clockwise and the other turns counter-clockwise, just as with spur gears. This may be hard to see because the two Gears lie in different planes. Look at the Crown Gears at the inside "corner" where the two Gears mesh.
- 2 Crown gears of the same size turn with the same amount of force. If the crown gears have the same gear ratio and MA as spur gears, they turn with the same amount of force.
- 3
 - b. The small yellow Gear turns about 2.5 times for each turn of the big Gear.
 - c. When turning the small Gear to lift the weight on the big Gear, the force needed to lift the weight was reduced due to the Mechanical Advantage. However, the arrangement of the Gears does not have an effect on the amount of force used.
 - d. Students will find that the big yellow Gear has 84 teeth and the small yellow Gear has 34 teeth. The equation to find the gear ratio is $84/34 = 2.47:1$. The MA will either be 2.47 or 0.4 depending upon how they set up the model. Note that this number is close to their observed results. The "What's the Mechanical Advantage?" Reference Sheet will explain more about the gear ratio.
Crown gears help do work by changing the direction of the work. You can apply the force in the direction that is easiest for you and have the work take place in a different direction.
- 4 To make a potter's wheel turn using bike pedals, you need to link a horizontal wheel with a vertical wheel. A horizontal surface is needed to put the pot on, but you have to turn the bike pedals while you're sitting up, so they must work in a vertical plane. Any other arrangement would have your pot sliding off an upright surface or you would have to pedal while lying down.

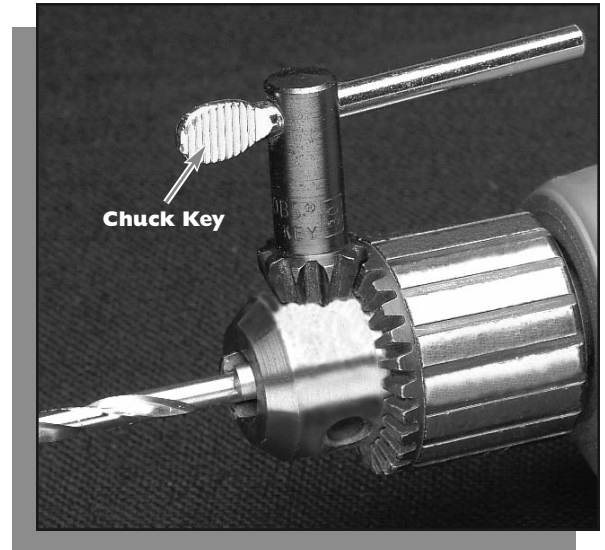


The Crown Gears

Every gear has a job to do

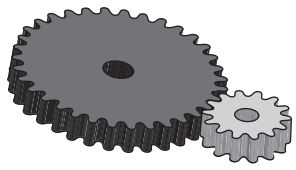
Crown gears meet at right angles, which means that one gear turns vertically (up and down) and meshes with another gear which turns horizontally (side to side).

Crown gears let you change the angle and motion you're turning. A little tool called a chuck key (pictured here at the top) uses crown gears to help you tighten a power drill bit. You turn the key and the "jaws" of the drill come together to hold the bit in place. The gears are arranged this way so the bit won't poke you when you tighten it.



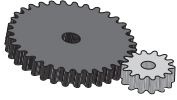
Student Challenge

- 1 Turn the crank to make your K'NEX Crown Gears move. Which way does each Gear turn? How is their movement different from the movement of spur gears?
- 2 Use the K'NEX Rubber Band Scale to measure the force used to lift a small weight with the Crown Gears, like you did with the Spur Gears. Record your findings. Did the Crown Gears reduce the force needed to lift the weight? Why or why not?
 - a. Try replacing one small Gear in your Crown Gears model with a big yellow Gear. You will have to change the stand so the big Gear will fit.
 - b. Use a small piece of tape to mark the top of each Gear. Turn the large Gears one turn and see how many times the small Gear turns around.
 - c. Again, use the Rubber Band Scale to measure the force needed to lift the weight. Record your results and compare them to the previous measurement. How did this Crown Gear arrangement affect the amount of force used to do the work? Write a few sentences explaining your findings.
 - d. What is the gear ratio for this set of Crown Gears? What is the Mechanical Advantage? (Refer to the "What's the Mechanical Advantage" Reference Sheet for help.) How can crown gears help you do work?
- 4 Imagine you make clay pots and you want to build a potter's wheel that is powered by bike pedals. How might crown gears help you do this? Using K'NEX, design and build this model.

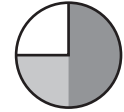


The Rack and Pinion Gears Lesson Plan

Objectives



- Identify a rack and pinion gear
- Demonstrate how rack and pinion gears function
- Explain and demonstrate the advantages offered by rack and pinion gears and their effect on force and speed
- Determine if rack and pinion gears change force, speed or direction
- Identify how rack and pinion gears are used in everyday life
- Practice creative design to build a model which utilizes rack and pinion gears
- Investigate cog railway systems and how they utilize rack and pinion gears
- Compare and contrast rack and pinion gears with other gears



Lesson Length: 30-45 minutes

Materials

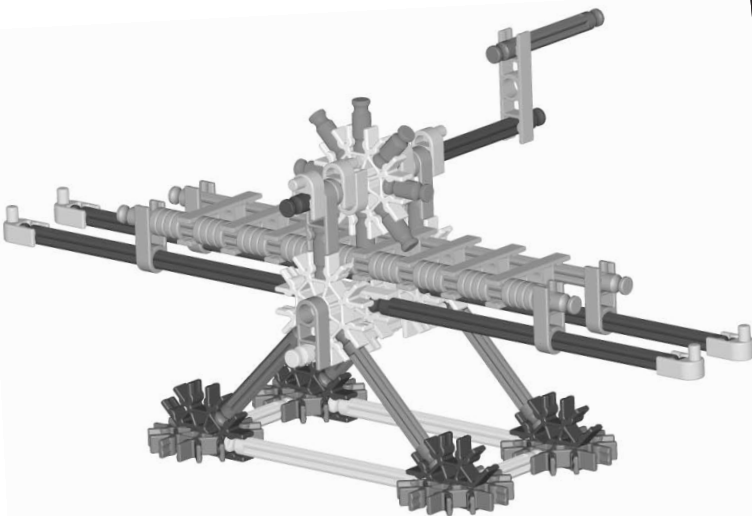
- ruler
- ping-pong ball or K'NEX ball
- extra K'NEX pieces

Every gear has a job to do

Rack and pinion gears differ from other gears because they allow you to achieve back-and-forth motion, rather than just circular motion. One common example in real-life is rack and pinion steering in cars. The steering wheel is attached to the pinion, which moves a rack connected to the front wheels. Its back-and-forth motion makes the wheels turn right or left.

Journal Check

- ✓ Explanation of how rack and pinion gears function
- ✓ Measurements for distance the rack travels
- ✓ Comparative measurements (ratios) for turning the pinion and its relationship to rack movement
- ✓ Illustration of design for rack and pinion invention
- ✓ Description of how cog railways work



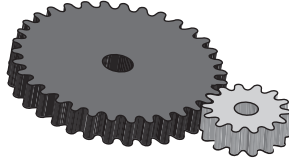
QUESTIONS

- 1 Turn the crank on your K'NEX Rack and Pinion Gears one-half turn. How far does the rack move? Use a ruler to measure the distance and record your results.
- 2 Redesign the Rack and Pinion Gears using a white Connector and eight white Rods for the pinion. Spread the teeth on your rack to fit the spacing on the pinion and lengthen the rack track.
Try turning the crank one-half turn. Measure and record how far this rack moves. Which Rack and Pinion set moves its rack farther? Which moves faster? Write a sentence describing how the size of the pinion affects the distance the rack moves.
- 3 Move the rack all the way to the left and rest a small ball on the red Rods at the right. Turn the pinion so the rack moves the ball along the Rods. Then, try moving other objects along the Rods, either horizontally or at a slant. Create a handy or a fun invention that uses rack and pinion gears. Make a drawing and write a description of your invention. For a real challenge, build it using K'NEX.
- 4
 - a. A cog railway brings train cars straight up a steep mountain slope, instead of traveling up a winding mountain path. Rack and pinion gears help keep the cog railway car from slipping down the mountain. Investigate cog railways.
 - b. Build a cog railway system out of K'NEX. How do the rack and pinion gears in a cog railway work differently from those in other rack and pinion gear systems, like a car?
- 5 Rack and pinion systems are used to connect the front wheels and the steering columns in some cars. Investigate vehicles which use this gear system and build a K'NEX vehicle of your own design with a rack and pinion steering system.

ANSWERS

- 1 Turning the crank on the Rack and Pinion Gears one-half turn causes the rack to move about 7 cms.
- 2 After the Rack and Pinion is modified, for one-half turn of the pinion, the rack moves 10 cms. The rack moves faster when the larger pinion is used. Students might express how the size of the pinion affects the distance the rack moves by stating: "The larger the pinion, the farther the rack moves for each turn of the pinion."
- 3 Students answers will vary. Everyday objects that must be moved back and forth are a good place to begin thinking of rack and pinion examples. Gears might be used to help you pass a pepper shaker across the table or to push a cassette tape into a tape player.
- 4
 - a. Cog railways are used in mountainous areas, such as the mountains of the North-east and the Rockies. The Mt. Washington Cog Railway was built in 1869 as a tourist attraction and is still used today. It uses a steam engine with two pinion gears on its underside. To move the train up the steep mountainside, the pinion gears grip the rack that lies between the rails in the center of the train track.
 - b. In a cog railway system, the car moves up because the pinions turn and grip the rack, which is stationary. The Rack and Pinion Gears model is an example of how the rack and pinion works in a car. The pinion turns while staying in one place and it causes the rack to move back and forth.

The Rack and Pinion Gears

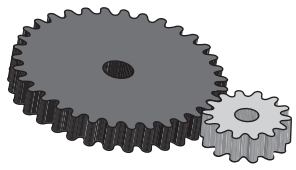


Every gear has a job to do

Rack and pinion gears have two parts: the rack, which is a bar with teeth and the pinion, which is a round gear. The rack moves back and forth and the pinion turns in circles. An ice cream scooper uses rack and pinion gears. After you've scooped up some ice cream, you push with your thumb against the rack. It slides over, turns the pinion, and out pops a round scoop of ice cream.

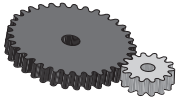
Student Challenge

- 1 Turn the crank on your K'NEX Rack and Pinion Gears one-half turn. How far does the rack move? Use a ruler to measure the distance and record your results.
- 2 Redesign the Rack and Pinion Gears using a white Connector and eight white Rods for the pinion. Spread the teeth on your rack to fit the spacing on the pinion and lengthen the rack track.
Try turning the crank one-half turn. Measure and record how far this rack moves. Which Rack and Pinion set moves its rack farther? Which moves faster? Write a sentence describing how the size of the pinion affects the distance the rack moves.
- 3 Move the rack all the way to the left and rest a small ball on the red Rods at the right. Turn the pinion so the rack moves the ball along the Rods. Then, try moving other objects along the Rods, either horizontally or at a slant. Create a handy
- 4 a. A cog railway brings train cars straight up a steep mountain slope, instead of traveling up a winding mountain path. Rack and pinion gears help keep the cog railway car from slipping down the mountain. Investigate cog railways.
b. Build a cog railway system out of K'NEX. How do the rack and pinion gears in a cog railway work differently from those in other rack and pinion gear systems, like a car?
- 5 Rack and pinion systems are used to connect the front wheels and the steering columns in some cars. Investigate vehicles which use this gear system and build a K'NEX vehicle of your own design with a rack and pinion steering system.



The Worm and Worm Gear Lesson Plan

Objectives



- Identify a worm and worm gear
- Demonstrate how a worm and worm gear function
- Explain the advantages offered by worm gears and their effect on force and speed
- Determine if worm gears change force, speed or direction
- Practice basic math skills
- Compare and contrast worm gears with other gears



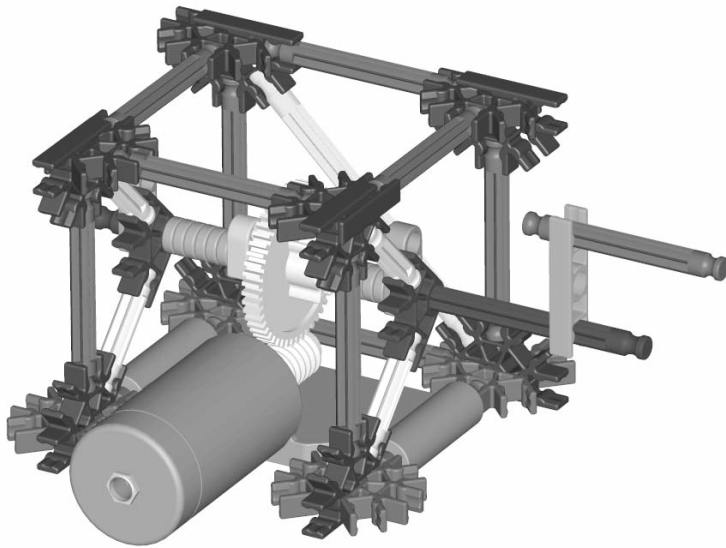
Lesson Length: 30-45 minutes

Materials

-stopwatch or clock
with second hand

Every gear has a job to do

When a garden hose is turned on full power the water comes spraying out fast. If you connect the hose to a sprinkler, you can use the power of the water to make the sprinkler move. The fast-moving water turns a small turbine inside the sprinkler, which rotates the worm. The worm turns the worm gear, which is connected to parts that move the sprinkler arm slowly back and forth.



Journal Check

- ✓ Explanation of how a worm and worm gear function
- ✓ Illustration of the direction worms and worm gears turn
- ✓ Number of rotations of the Worm Gear in one minute
- ✓ Number of teeth on the Worm Gear
- ✓ Number of turns of the Worm to that of the Worm Gear

QUESTIONS

- 1 Carefully, or with the help of an adult, start your Worm Gear model by plugging the cord into the gray K'NEX Motor. Watch the Worm and the Worm Gear turn. Which way do they move? Draw a picture with arrows to show the direction that each part turns.

WARNING: Important note: Be extremely careful whenever using electrical devices. Teachers should monitor student activities at all times, and should examine devices before use.

- 2
 - a. Watch the Worm turn. You can see that it spins very fast! Then, watch the Worm Gear turn and have a partner help you count the number of times it turns in 60 seconds. Mark one spot with tape or a marker so you can easily tell when the Worm Gear makes a full rotation. Divide the number of turns by 60. Your answer will be the number of turns the Worm Gear makes per second. Write down your answer.
 - b. Next, count and record the number of teeth on the Worm Gear.
 - c. Every time the Worm turns one full turn, the Worm Gear moves ahead the distance of only one small tooth. For the Worm Gear to make one full turn, the Worm has to turn the same number of times as the number of teeth on the Worm Gear. That means the Worm turns fast! To find out how fast, try this multiplication problem.

Number of turns per second \times **Number of worm gear teeth**

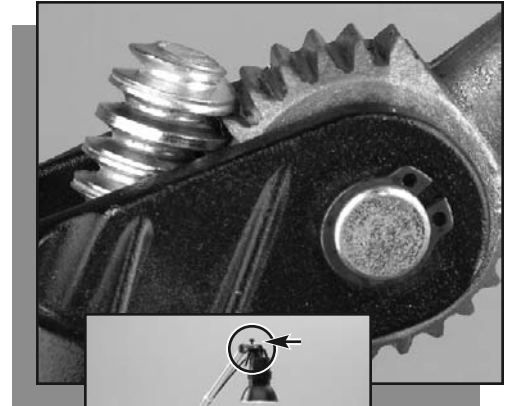
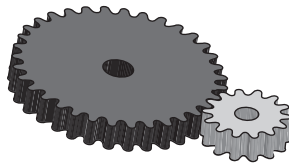
Your answer will be the number of turns the worm makes per second. That's fast!

ANSWERS

* **CAUTION:** Supervise students when they use the K'NEX Motor. Plug the transformer into the wall yourself and let them connect the small plug to the Motor. Make sure the Motor is not used near water and that students have dry hands when handling the plug.

- 1 Worm gears change the direction of motion. Like bevel or crown gears, the worm turns in one plane and the worm gear in a plane at right angles to that of the worm. To help students visualize this motion, ask them to look head on at the Worm, to see it as a wheel. Then, they should see that the two "wheels" — the Worm and the Worm Gear — are at right angles to each other. Their drawings should reflect this arrangement. They might draw axles through the wheels to better reflect the right angle.
- 2
 - a. The Worm moves so fast it's almost impossible to count the turns. However, the Worm Gear moves slowly enough that they can count how many turns it makes in a minute. Use this observation to reinforce the idea that worm gears can be used to reduce speed (or increase speed, if the worm gear makes the worm turn). Students will probably find that the Worm Gear turns about 90 times in 60 seconds or about 1.5 times per second.
 - b. The Worm Gear has 50 teeth.
 - c. The number of turns the Worm makes per second is: 1.5 turns per second \times 50 teeth per turn = 75 turns per second. Note that this speed is much faster than the 1.5 turns per second of the Worm Gear.

The Worm and Worm Gear



Every gear has a job to do

Like all gears, a worm gear is a wheel with teeth. However, unlike other gears, a worm gear is not turned by another gear. Instead, it is turned by a worm – a rod with a spiral edge that resembles a screw. Every time the worm makes one full turn, the worm gear moves ahead just a tiny distance – the width of one worm gear tooth!

When you turn the worm slowly, the worm gear turns at a much slower pace. Worm gears are used in things which need to move very slowly, like a lawn sprinkler, or in very small movements, like tightening a spotlight so it shines in precisely the right spot.

Student Challenge

- 1 Carefully, or with the help of an adult, start your Worm Gear model by plugging the cord into the gray K'NEX Motor. Watch the Worm and the Worm Gear turn. Which way do they move? Draw a picture with arrows to show the direction that each part turns.

WARNING: Important note: Be extremely careful whenever using electrical devices. Teachers should monitor student activities at all times, and should examine devices before use.

- 2 a. Watch the Worm turn. You can see that it spins very fast! Then, watch the Worm Gear turn and have a partner help you count the number of times it turns in 60 seconds. Mark one spot with tape or a marker so you can easily tell when the Worm Gear makes a full rotation. Divide the number of turns by 60. Your answer

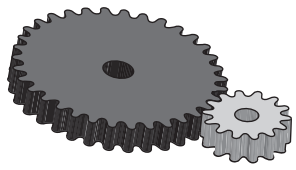
will be the number of turns the Worm Gear makes per second. Write down your answer.

b. Next, count and record the number of teeth on the Worm Gear.

c. Every time the Worm turns one full turn, the Worm Gear moves ahead the distance of only one small tooth. For the Worm Gear to make one full turn, the Worm has to turn the same number of times as the number of teeth on the Worm Gear. That means the Worm turns fast! To find out how fast, try this multiplication problem.

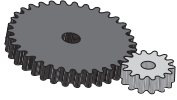
Number of turns per second \times **Number of worm gear teeth**

Your answer will be the number of turns the worm makes per second. That's fast!

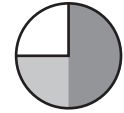


The Planetary Gears Lesson Plan

Objectives



- Identify a planetary gear and its various components
- Demonstrate how planetary gears function
- Experiment with the Planetary Gears to determine the effects on force and speed
- Measure and compare the applied forces required for different planetary gear configurations with a Rubber Band Scale
- Explain and demonstrate the advantages offered by planetary gears
- Determine if planetary gears change force, speed or direction
- Compare and contrast a planetary gear with other gears



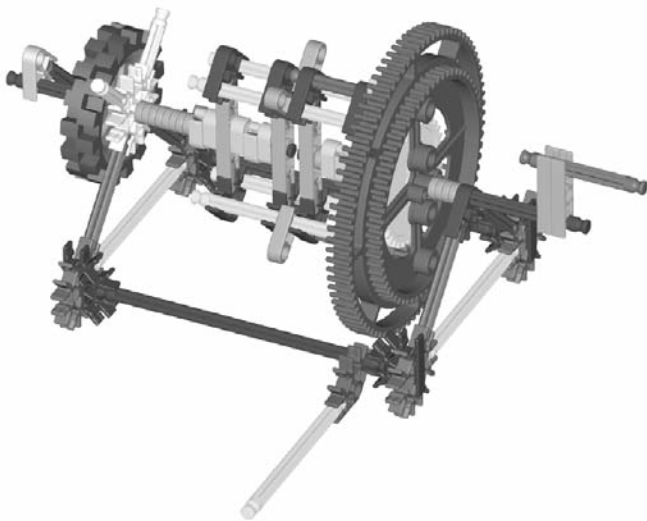
Lesson Length: 30-45 minutes

Materials

- K'NEX Rubber Band Scale
- small weight such as a cup of pennies

Every gear has a job to do

An automatic transmission in a car uses planetary gears. When you hand crank the K'NEX Planetary Gears model, you act like the motor in a car. The wheel on the model is like one of the car's wheels. Make a connection between the way the model works and the way a car works: the car motor keeps turning whether the car is moving or stopped and the car uses different gear ratios to travel at different speeds.



Journal Check

- ✓ Explanation of how the Planetary Gears function
- ✓ Description of why planetary gear components are aptly named
- ✓ Comparative measurements for the rotation of the planet and annulus gears
- ✓ Measurements with different Planetary Gear components locked in place
- ✓ Force measurements for each gear arrangement
- ✓ Explanation as to why gear arrangements affect force

QUESTIONS

- 1
 - a. Turn the crank on your Planetary Gears model. You're acting as a motor, keeping the axle turning. As you turn, watch the Gears move. Which pieces serve as the sun, planet and annulus gears? Write down the name of each Gear, and describe the size, color, location and role each plays.
 - b. Write a paragraph telling why both the sun and planet gears are suitably named.
- 2
 - a. Experiment with locking different Gears in place to see how the speed of the wheel changes. First, lock the planet and annulus gears together. Turn the crank and watch how fast the wheel turns. How many turns does the wheel make for every turn of the crank?
 - b. Now, lock the annulus gear in place by putting on the "brake" (pull up on the yellow Rod attached to the green Connector on the base). Turn the crank. How fast does the wheel spin now? How many turns does it make each time you turn the crank?
 - c. Next, release the brake on the annulus gear and hold the yellow Rods that surround the main axle. This will keep the planet gears from "orbiting" the sun gear. How fast does the wheel turn now? Which arrangement spins the wheel the fastest? Why?
- 3

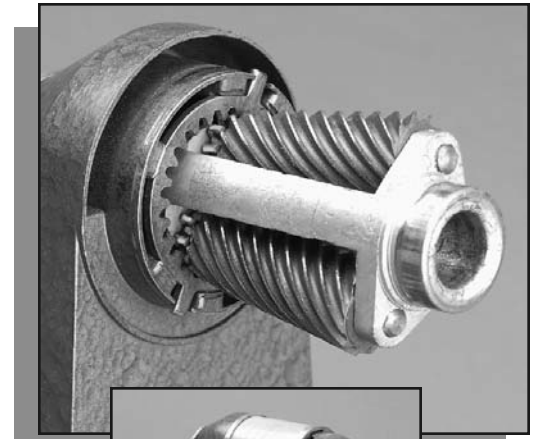
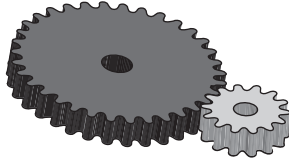
Measure the force needed to lift a weight with different arrangements of the Planetary Gears. Attach a small weight to one end of the axle for the Planetary Gears and a K'NEX Rubber Band Scale to the other. Turn the crank. Record and compare your measurements. How much force is used to lift the weight with each arrangement of the gears? Which one uses the most force? The least force? Why?

ANSWERS

- 1
 - a. Planetary Gears are more complicated than many of the other gear and simple machine models. A presentation which demonstrates that planetary gears use different gear ratios, all within a compact set of gears, will make this concept easier to grasp. The yellow Gear is the sun gear; the blue Gears are the planet gears; the green Gear is the annulus gear.
 - b. Students answers will vary but should include: the sun gear is central, like the sun in our solar system; the planet gears "orbit" or revolve around the sun gear and each planet gear also turns on its axis (axle) as planets do; annulus means ring and the annulus gear provides a ring or border around the sun and planet gears so the whole system can work together.
- 2
 - a. To lock the planet and annulus gears together, students must push one of the blue Rods that serves as an axle for a blue Gear through a hole on the green Gear. In this arrangement, all of the Gears are locked up. Everything turns only with the main axle. Since the crank and the wheel are on the same axle, they are turning at the same rate. This makes the wheel turn one full turn for every turn of the crank. The wheel turns at the same rate as the motor.
 - b. When the annulus gear is locked in place, the blue planet Gears orbit the yellow sun Gear throughout the inside of the green Gear. The entire planetary gear group (the Rods and Connectors in the middle of the models to which the blue Gears are attached) also turns. In this position, the crank must be turned about 2 times to make the wheel go around once. This gear combination makes the wheel go more slowly than the motor.
 - c. When holding the planetary gear group, the annulus gear (green Gear) turns but the wheel does not move at all. The blue Gears spin on their own axles due to the turning of the green Gear but the planetary gear group is not able to orbit the sun. When the planet gears are kept from orbiting, the wheel will not turn at all. This arrangement lets the motor "idle" — or keep running while the wheel is stopped. The crank makes about two turns for one full turn of the annulus gear.
- 3

With the arrangement from Step 2a, the machine is actually behaving like a wheel and axle since the Gears are all locked up. This arrangement uses the most force to lift the weight. The arrangement from Step 2b uses the least force to lift the weight. The arrangement from Step 2c does not lift the weight at all since the wheel does not move.

The Planetary Gears



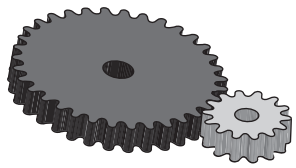
Every gear has a job to do

A set of planetary gears includes a central sun gear that connects with planet gears that are equally spaced around it. An outer *annulus* gear (“annulus” means ring) meshes with the outside edge of the planet gears. The sun gear and the annulus gear are on the same axle.

This special grouping of gears lets some of the gears turn while others are locked in place. This way, you can make different combinations of gears turn. This gives you different gear ratios and the ability to perform different tasks. Planetary gears are also useful when you want one part of a machine to turn while another part stops.

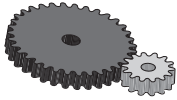
Student Challenge

1.
 - a. Turn the crank on your Planetary Gears model. You're acting as a motor, keeping the axle turning. As you turn, watch the Gears move. Which pieces serve as the sun, planet and annulus gears? Write down the name of each Gear, and describe the size, color, location and role each plays.
 - b. Write a paragraph telling why both the sun and planet gears are suitably named.
2.
 - a. Experiment with locking different Gears in place to see how the speed of the wheel changes. First, lock the planet and annulus gears together. Turn the crank and watch how fast the wheel turns. How many turns does the wheel make for every turn of the crank?
 - b. Now, lock the annulus gear in place by putting on the “brake” (pull up on the yellow Rod attached to the green Connector on the base). Turn the crank.
 - c. How fast does the wheel spin now? How many turns does it make each time you turn the crank?
 - d. Next, release the brake on the annulus gear and hold the yellow Rods that surround the main axle. This will keep the planet gears from “orbiting” the sun gear. How fast does the wheel turn now? Which arrangement spins the wheel the fastest? Why?
3. Measure the force needed to lift a weight with different arrangements of the Planetary Gears. Attach a small weight to one end of the axle for the Planetary Gears and a K'NEX Rubber Band Scale to the other. Turn the crank. Record and compare your measurements. How much force is used to lift the weight with each arrangement of the gears? Which one uses the most force? The least force? Why?

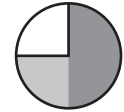


The Simple Transmission Lesson Plan

Objectives



- Identify a simple transmission and its components
- Demonstrate how a simple transmission functions
- Explain how work is done by gears within a simple transmission
- Determine if the gears within a transmission change force, speed or direction
- Infer uses of a transmission in other machines
- Modify the Simple Transmission to create an invention which utilizes the different transmission settings



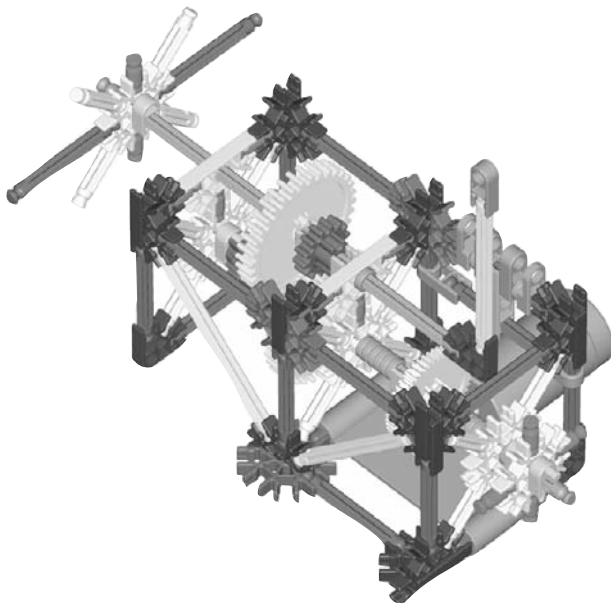
Lesson Length: 30-45 minutes

Materials

-no special materials required

Every gear has a job to do

The K'NEX Simple Transmission model illustrates, in a simplified way, how a manual transmission works. (An automatic transmission works on a different system.) A description of cars with manual gearshifts will yield information about how the transmission allows the car to be driven forward or in reverse and how the driver moves the gearshift to make the car change gears. The sounds the car makes when gears are shifted—a slower or faster whirring sound as the engine changes speeds—may prove to be helpful.



Journal Check

- ✓ Description of how the Simple Transmission works and how the Gears link up
- ✓ Explanation of which gearshift placement turns faster and why
- ✓ Identification and explanation of the three different gear positions and their proper names
- ✓ Description of what happens when gearing is switched quickly
- ✓ List of other machines which use a transmission
- ✓ Description of what the modified K'NEX model does

QUESTIONS

- 1 Carefully, or with the help of an adult, plug the cord into the gray K'NEX Motor of your Transmission model. The yellow Rod is the gearshift. Start with the gearshift in the middle position and then move it to the right or left so the different Gears link up. Write down what you observe.

WARNING: Important note: Be extremely careful whenever using electrical devices. Teachers should monitor student activities at all times, and should examine devices before use.

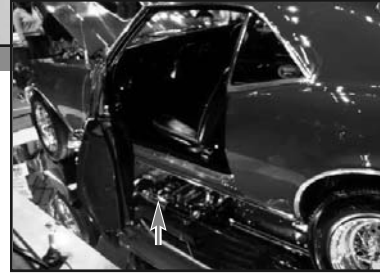
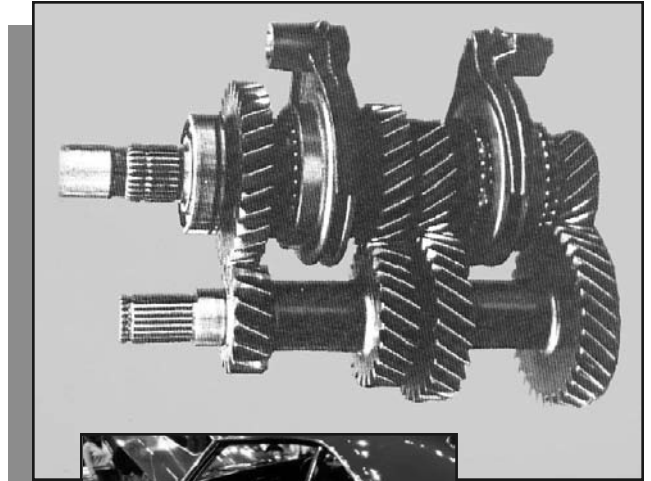
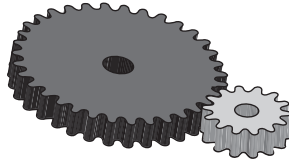
- b. Which makes the shaft turn faster – shifting the Gears to the right or to the left? Explain why.
 - c. This Simple Transmission has three positions: first gear, second gear and neutral. These are also referred to as high gear, low gear and neutral. Match the gear names to each other. Then match those to the actual K'NEX Simple Transmission model. Which do you think is which and why? What does the Transmission do when it is in neutral?
- 2 Try switching fast from neutral into high gear. What happens? How is this like what happens in a car, when the driver accidentally switches from the lowest gear to the highest gear or vice versa?
- 3 Besides cars, what other machines do you think might use a transmission? Alter your model to create an invention that uses all three transmission settings. What does your creation do?

ANSWERS

* **CAUTION:** Supervise students when they use the K'NEX Motor. Plug the transformer into the wall yourself and let them connect the small plug to the Motor. Make sure the Motor is not used near water and that students have dry hands when handling the plug.

- 1
 - a. The center gearshift position leaves the upper shaft in “neutral” — the Motor is still running, but it isn't driving anything. Shifting to the right makes the upper shaft turn at low speed, while shifting to the left makes it turn at high speed.
 - b. With the gray Motor in front of you, shifting to the left makes the shaft turn faster. This is because a large Gear turns a small Gear. The small Gear can turn several times for each turn of the large Gear, so it moves at a faster speed.
 - c. A manual transmission in a car has more gear combinations than the K'NEX Simple Transmission. In a car, the gears for slow driving are called first gear or low gear. Second gear, third gear, and fourth gear are used for medium, fast, and very fast driving. When the Transmission is in neutral, the Motor continues to run but it is not driving anything; the upper shaft does not turn at all.
- 2 When you switch the Simple Transmission from neutral to high gear, the Gears may grind together, because the top Gear has to catch up with the lower Gear that is already moving. This is similar to what happens in a car when shifting from neutral or low gear into the highest gear. A car's gears will make the same grinding noise as the K'NEX model.
- 3 Students might build attachments on the upper shaft of the Transmission model to make a multi-speed fan, blender or another invention.

The Simple Transmission



Every gear has a job to do

A car can creep along at a low speed or it can zoom down the road. If you could see inside the car's engine while you were driving, you would see that the engine doesn't have a wide range of speeds. Actually, it just turns fast all the time. Gears are what help the engine move the car at different speeds. A system of gears, working together, make up the car's transmission, which drives the car's engine.

Student Challenge

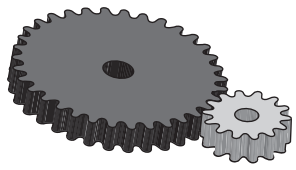
- 1 a. Carefully, or with the help of an adult, plug the cord into the gray K'NEX Motor of your Transmission model. The yellow Rod is the gearshift. Start with the gearshift in the middle position and then move it to the right or left so the different Gears link up. Write down what you observe.

WARNING: Important note: Be extremely careful whenever using electrical devices. Teachers should monitor student activities at all times, and should examine devices before use.

- b. Which makes the shaft turn faster – shifting the Gears to the right or to the left? Explain why.
- c. This Simple Transmission has three positions: first gear, second gear and neutral. These are also referred to as high

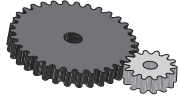
gear, low gear and neutral. Match the gear names to each other. Then match those to the actual K'NEX Simple Transmission model. Which do you think is which and why? What does the Transmission do when it is in neutral?

- 2 Try switching fast from neutral into high gear. What happens? How is this like what happens in a car, when the driver accidentally switches from the lowest gear to the highest gear or vice versa?
- 3 Besides cars, what other machines do you think might use a transmission? Alter your model to create an invention that uses all three transmission settings. What does your creation do?

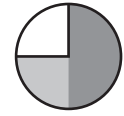


The Car Window Lesson Plan

Objectives



- Identify the type(s) of gear in a car window
- Demonstrate how a car window functions
- Calculate and explain the Mechanical Advantage of the gears in the Car Window and their effect on force and speed
- Compare and contrast gear revolutions
- Infer rationale for gear configurations
- Determine if the gears in a car window change force, speed or direction
- Apply knowledge of rack and pinion gear systems and determine if this system would work for a car window
- Design and build a model which utilizes rack and pinion gears



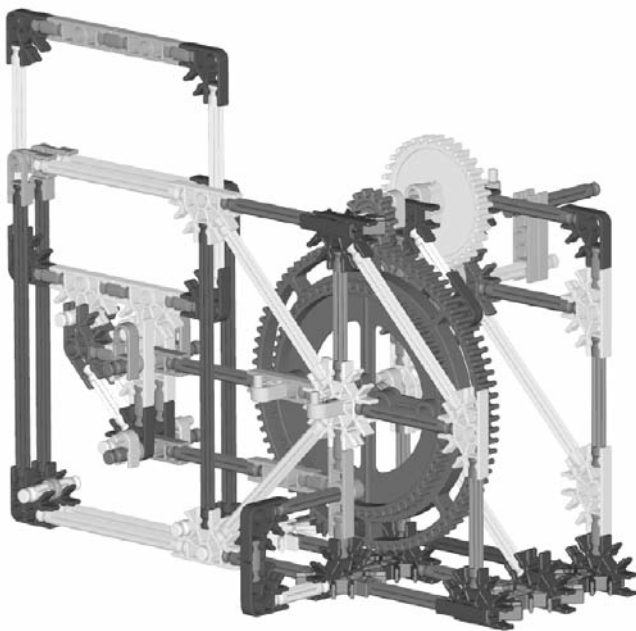
Lesson Length: 30-45 minutes

Materials

- tape
- extra K'NEX pieces

Every gear has a job to do

When opening and closing the window on a car, the mechanisms that do the work are contained inside the car door. It may be difficult to picture the movement of the gears inside the door—but it would resemble the K'NEX Car Window. The gears are configured somewhat differently, but the window works in basically the same way. The K'NEX Car Window operates by hand crank and most windows today are electric and use a switch lever to open and close.



Journal Check

- ✓ Identification of gear type used in Car Window
- ✓ Revolutions of different Gears and resulting gear ratios and MAs
- ✓ Calculations of gear ratios
- ✓ Comparison of Gears and ratio function
- ✓ Description of Gear function if Gear configuration was reversed
- ✓ Assessment of rack and pinion gear configuration in the Car Window

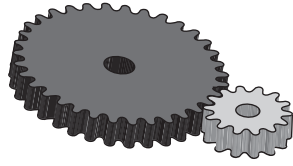
QUESTIONS

- 1 What kind of gears does the K'NEX Car Window use: spur, crown, rack and pinion, worm or sprocket gears?
- 2
 - a. Lower the Car Window all the way and then turn the crank one full turn to raise the window. When you turn the crank one full turn, how much does the blue Gear turn? [Note: Be careful not to overwind the window or the blue Rod will pop off!] How much does the yellow Gear turn? What is the Mechanical Advantage for this gear system?
 - b. Now turn the crank one full turn again and watch the blue Gear on the top axle (the Rod with the yellow Gear). How much of a turn does it make? How does this compare to the yellow Gear?
 - c. Turn the crank fully again and watch the green Gear. How much does it turn? What is the ratio between the blue and green Gears? What is the MA?
 - d. Why does the Car Window have this arrangement of Gears? What would happen to the Car Window if the arrangement was reversed? Explain.
- 3 The K'NEX Car Window uses circular motion to make the window go up and down. Turn the handle and observe how the Gears and the arm that holds the window work together. Would rack and pinion gears work well to raise and lower a car window? Make a drawing to show how it might work. Then, build a K'NEX car window using rack and pinion gears.

ANSWERS

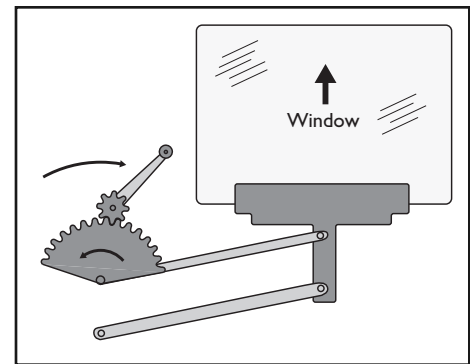
- 1 The Car Window uses two pairs of spur gears. Note that the Gears in each pair lie in the same plane.
- 2
 - a. Since this blue Gear is on the same axle as the crank, it turns once for one turn of the crank. The yellow Gear makes a little less than one-half turn. The Mechanical Advantage for these Gears is 2.43.
 - b. The blue Gear on the top axle turns a little less than half a turn when the crank turns a full turn. It turns the same amount as the yellow Gear. Help students see that even though the blue and yellow Gears are different sizes, they turn the same amount because they are on the same axle. The gear ratio is not a factor.
 - c. The green Gear only turns a very short distance for a full turn of the crank. The gear ratio is 6:1. The MA is 6. In this case, the small Gear turns without needing to use a lot of force, but the big Gear can only cover a short distance. This works out fine since the Car Window only has a short distance to move.
 - d. The gear ratio and MA greatly affect how the Gears work together. Help students see that the combination of all these Gears makes it possible for you to move the window just a little without having to be very precise in your turning action or providing a lot of effort. If the gear configuration was reversed, it would take more effort to turn the crank and the window would move so quickly that you would have to take great care when turning or you could damage the window.
- 3 When designing a car window using rack and pinion gears, students will probably design a vertical rack that pushes the window up. As they build, they might discover advantages or disadvantages to using rack and pinion gears. They will need to consider where the window crank will be positioned on the door (preferably in a place where it could easily be reached!) and where the rack will move as the window goes up (possibly under the window or along the side).

The Car Window



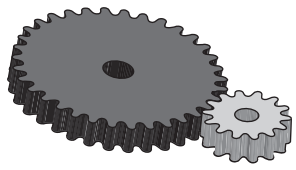
Every gear has a job to do

Most cars today have automatic windows with levers which you push to open and close the car's windows. Some cars still have manual windows which operate by cranking a wheel and axle on the inside of the car door. Regardless of which system is used, the window moves up and down. How does this happen? Gears are the answer. A system of gears inside the door shift an arm, which make the window move up or down.

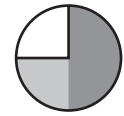


Student Challenge

- 1 What kind of gears does the K'NEX Car Window use: spur, crown, rack and pinion, worm or sprocket gears?
- 2
 - a. Lower the Car Window all the way and then turn the crank one full turn to raise the window. When you turn the crank one full turn, how much does the blue Gear turn? (Note: Be careful not to overwind the window or the blue Rod will pop off!) How much does the yellow Gear turn? What is the Mechanical Advantage for this gear system?
 - b. Now turn the crank one full turn again and watch the blue Gear on the top axle (the Rod with the yellow Gear). How much of a turn does it make? How does this compare to the yellow Gear?
 - c. Turn the crank fully again and watch the green Gear. How much does it turn? What is the ratio between the blue and green Gears? What is the MA?
 - d. Why does the Car Window have this arrangement of Gears? What would happen to the Car Window if the arrangement was reversed? Explain.
- 3 The K'NEX Car Window uses circular motion to make the window go up and down. Turn the handle and observe how the Gears and the arm that holds the window work together. Would rack and pinion gears work well to raise and lower a car window? Make a drawing to show how it might work. Then, build a K'NEX car window using rack and pinion gears.

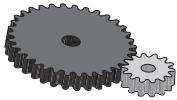


The Lawnmower Lesson Plan



Lesson Length: 30-45 minutes

Objectives



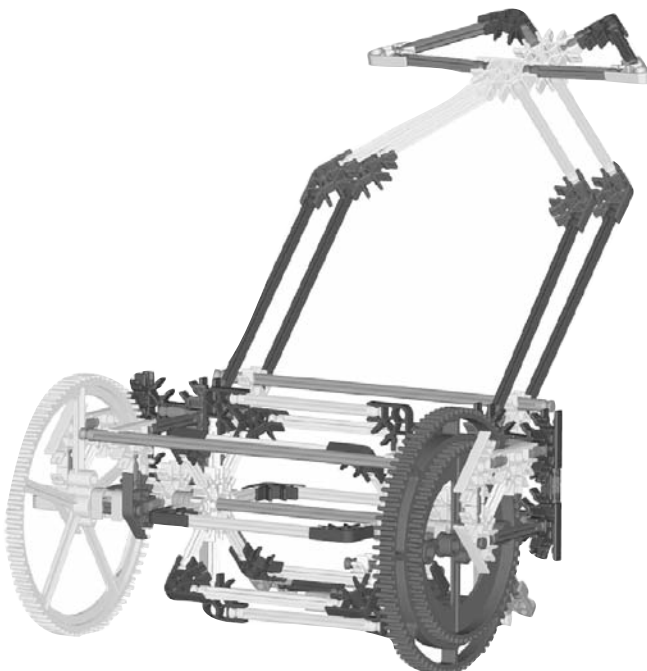
- Identify the type(s) of gear used in a lawnmower
- Demonstrate how a lawnmower functions
- Explain the advantages offered by spur gears and their effect on force and speed
- Determine if the spur gears in the Lawnmower change force, speed or direction
- Calculate and demonstrate the significance and advantage of gear ratios

Materials

- green tissue paper
- scissors
- tape
- extra K'NEX pieces

Every gear has a job to do

This type of lawnmower is not used much anymore but surprisingly, most kids are familiar with it. The gears in a real push mower are not visible from the outside, which is typical of spur gears but they work in the same way as the Gears in the K'NEX Lawnmower. The different speeds of the wheels and the rotating blades give a clue that gears are used.

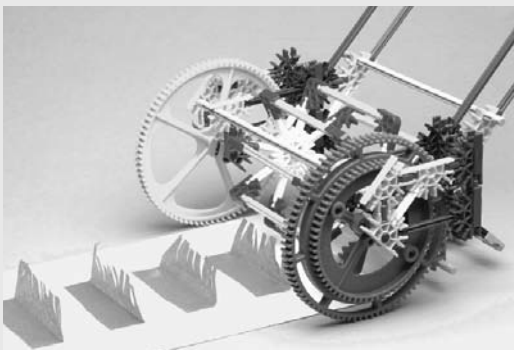


Journal Check

- ✓ Identification of the type of gears in the Lawnmower
- ✓ Explanation of how the spur gears function
- ✓ Calculations of gear ratios
- ✓ Comparison of the different gear configurations and ratios
- ✓ Assessment of which gear arrangements would be most effective and why
- ✓ Description of the scissor action of the Lawnmower

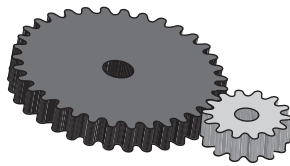
QUESTIONS

- 1 a. Push your K'NEX Lawnmower across your desk and watch how the wheels and blades turn. Which moves faster?
b. Count the number of teeth on the large and small Gears that make the wheels turn. (Be sure to count the inside ring of teeth on the green Gear, not the outside ring!) Then figure out the gear ratio by dividing the large number by the small number. This ratio tells you how much faster one gear turns compared to the other when a large gear drives a small gear.
- 2 What kind of gears does the Lawnmower use: spur, crown, rack and pinion, worm or sprocket gears? How does the arrangement of Gears in the Lawnmower differ from other gear systems? Can you think of a different arrangement which would work better? If you can, build it. If not, use reference materials to learn more about lawnmowers and explain why this is the best set up for these gears.
- 3 Make some "grass" for your Lawnmower to mow. You can do this by cutting strips of tissue paper about 50 x 100 cm. Then, make short cuts into one of the long sides of each strip. Fold and tape the strips to a piece of paper so that the grass stands up. Then, mow the lawn! Your Lawnmower may not cut, but watch the way the blades of grass get swept past the cutting blade. Can you see the scissor action? Write a paragraph describing this.



ANSWERS

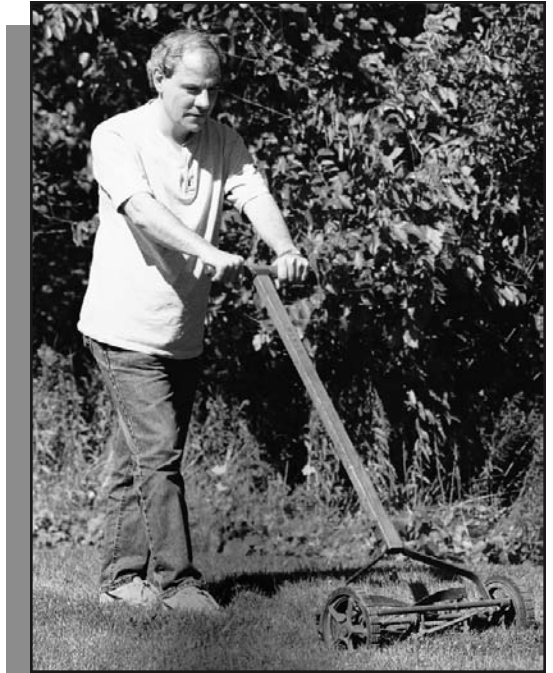
- 1 a. The Lawnmower blades turn faster than the wheels.
b. Make sure to count the inner circle of teeth on the large green Gear; it has 62 teeth. The small Gear has 14 teeth. The gear ratio is about 4.4:1. You apply the effort to push the Lawnmower but the green Gear turns the blue Gear fast so that the blades can turn quickly to cut the grass. Note that the large yellow Gear just serves as the Lawnmower's other wheel; it doesn't connect to any other Gear.
- 2 The Lawnmower uses spur gears. The Gears are arranged so that the small Gear runs on the inner edge of the big Gear instead of the outer edge. Help students see that even though the arrangement is slightly different from other spur gears they know, these gears still lie in the same plane, which is a characteristic of spur gears.
Students answers will vary but should include logical reasons to back up their ideas. They will likely determine that this is the most effective gear arrangement. It is convenient to line the gears up in the same plane and easier to perform the work in this plane also. You are using the spur gears to apply your force over a greater distance with more speed.
- 3 The best way to see how the Lawnmower works is by watching from the back of the mower. The rotating blades sweep the grass to make it stand up and then the grass is caught between a rotating blade and the fixed blade. The fixed blade actually does the cutting. Since the rotating blade is angled, it moves across the fixed blade in the same way two scissor blades meet.



The Lawnmower

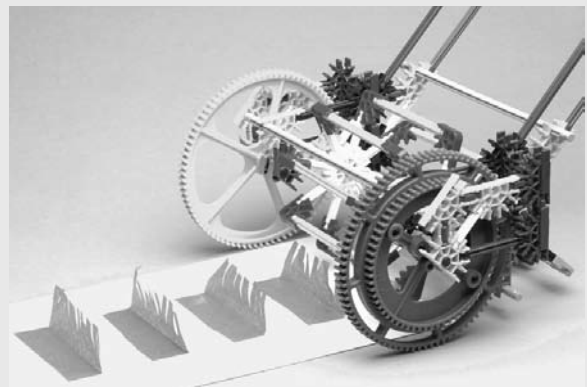
Every gear has a job to do

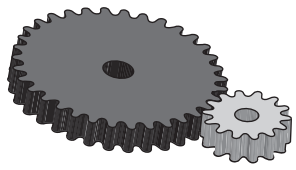
An old-fashioned lawnmower uses spinning blades to cut the grass. As the blades whirl around, they catch the long grass against a sharp blade that stays in one place at the back of the mower. The moving and fixed blades act like a scissors to cut the grass. Inside the wheels, gears make the blades turn at the right speed.



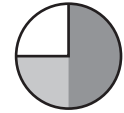
Student Challenge

- 1 a. Push your K'NEX Lawnmower across your desk and watch how the wheels and blades turn. Which moves faster?
 b. Count the number of teeth on the large and small Gears that make the wheels turn. (Be sure to count the inside ring of teeth on the green Gear, not the outside ring!) Then figure out the gear ratio by dividing the large number by the small number. This ratio tells you how much faster one gear turns compared to the other when a large gear drives a small gear.
- 2 What kind of gears does the Lawnmower use: spur, crown, rack and pinion, worm or sprocket gears? How does the arrangement of Gears in the Lawnmower differ from other gear systems? Can you think of a different arrangement which would work better? If you can, build it. If not, use reference materials to learn more about lawnmowers and explain why this is the best set up for these gears.
- 3 Make some "grass" for your Lawnmower to mow. You can do this by cutting strips of tissue paper about 50 x 100 cm. Then, make short cuts into one of the long sides of each strip. Fold and tape the strips to a piece of paper so that the grass stands up. Then, mow the lawn! Your Lawnmower may not cut, but watch the way the blades of grass get swept past the cutting blade. Can you see the scissor action? Write a paragraph describing this.



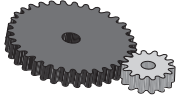


The Eggbeater Lesson Plan



Lesson Length: 30-45 minutes

Objectives



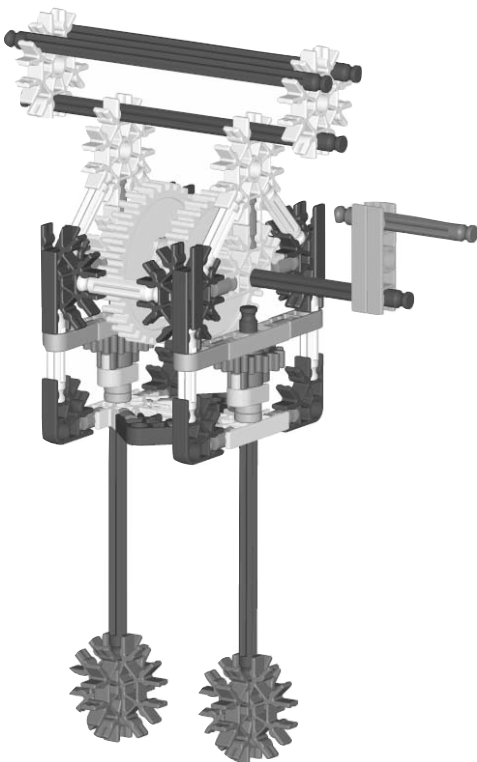
- Identify the type(s) of gear used in an eggbeater
- Demonstrate how an eggbeater functions
- Explain the advantages offered by crown gears and their effect on force and speed
- Determine if the crown gears in the Eggbeater change force, speed or direction
- Experiment with the way the crown gears drive the Eggbeater
- Determine if the Eggbeater could be designed differently to be more effective
- Design, write and illustrate an advertisement for the Eggbeater

Materials

- bowl or laundry tub
- water
- dish soap
- spoon
- colored markers
- magazines and catalogs

Every gear has a job to do

Beating an egg with a fork in a bowl until it's white and frothy is hard work. An eggbeater works much better than the fork and makes the work much easier. The gears in a real eggbeater correspond with the gears in the K'NEX model. The gears let you apply less force and beat the eggs in no time.



Journal Check

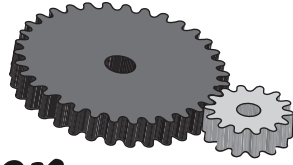
- ✓ Explanation and assessment of how crown gears function in the Eggbeater
- ✓ Timing for bubble generation with a spoon and Eggbeater
- ✓ Assessment of the best tool for the work
- ✓ Observation of the direction the beaters turn and how this affects their work
- ✓ Explanation of the best arrangement for beaters
- ✓ Written and illustrated advertisement for the Eggbeater

QUESTIONS

- 1 As you turn the crank on your Eggbeater, look at the direction the Gears turn. Would this tool work as well if it used spur gears? Explain.
- 2
 - a. Fill a bowl or laundry tub about 6 centimeters deep with water. Then, add a small amount of dish soap. Use a spoon to stir the mixture. Time how long it takes to cover the surface of the water with bubbles.
 - b. Now, start over with new water and soap. Try stirring the mixture with your Eggbeater. How long does it take to cover the water surface with bubbles when you use the Eggbeater? Which tool is best for the job? Why?
- 3 Observe the rotating motion of the beaters when you turn the crank. Do the beaters turn in the same or opposite directions? If the beaters turned differently, do you think they would work better? Why or why not? Explain your answer.
- 4 Write an ad describing this handy, time-saving tool. Then illustrate and design an advertisement for your Eggbeater.

ANSWERS

- 1 The arrangement of the crown gears (vertical and horizontal) and the two pairs of Gears make the beaters turn in opposite directions. Using spur gears would probably not work as well because then you would have to do your turning in a horizontal plane, at the top of the Eggbeater where you hold it, which would be awkward.
- 2 The Eggbeater should allow students to whip up soap bubbles much faster than they could using a spoon. One reason for this is because the large Gears attached to the crank make the small Gears turn the beaters very fast. Also, the two beaters turning in opposite directions make the soapy water churn and mix well.
- 3 The beaters turn in opposite directions. If the beaters turned in the same direction, the Eggbeater would still work but having them turn differently makes mixing faster and easier. Encourage students to experiment with the Eggbeater to determine how they could make the beaters turn in the same direction to see how effective they are.
- 4 Have magazines or catalogs accessible to students so they can each get ideas about how to write advertisements for their Eggbeaters. Their ads might include illustrations, recipes, quotes from “satisfied customers” or even impressive technical jargon. Encourage them to be creative and think of other uses for the Eggbeater.



The Eggbeater

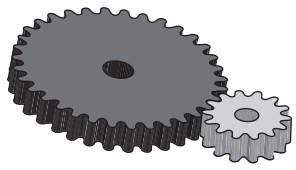
Every gear has a job to do

Have you ever tried to beat egg whites or pancake mix with a fork? It takes a lot of time and energy to turn the egg whites into fluffy foam and beat the lumps out of the pancake batter. Gears can make these jobs easier and faster. An eggbeater and a manual hand mixer both use crown gears. The upright gears make it easy for you to turn the crank. The other gears lay flat, so they can turn the beaters around and around in the bowl.



Student Challenge

- 1 As you turn the crank on your Eggbeater, look at the direction the Gears turn. Would this tool work as well if it used spur gears? Explain.
- 2
 - a. Fill a bowl or laundry tub about 6 centimeters deep with water. Then, add a small amount of dish soap. Use a spoon to stir the mixture. Time how long it takes to cover the surface of the water with bubbles.
 - b. Now, start over with new water and soap. Try stirring the mixture with your Eggbeater. How long does it take to cover
- 3 the water surface with bubbles when you use the Eggbeater? Which tool is best for the job? Why?
- 4 Observe the rotating motion of the beaters when you turn the crank. Do the beaters turn in the same or opposite directions? If the beaters turned differently, do you think they would work better? Why or why not? Explain your answer.
- 5 Write an ad describing this handy, time-saving tool. Then illustrate and design an advertisement for your Eggbeater.

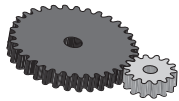


The Food Mixer Lesson Plan



Lesson Length: 30-45 minutes

Objectives



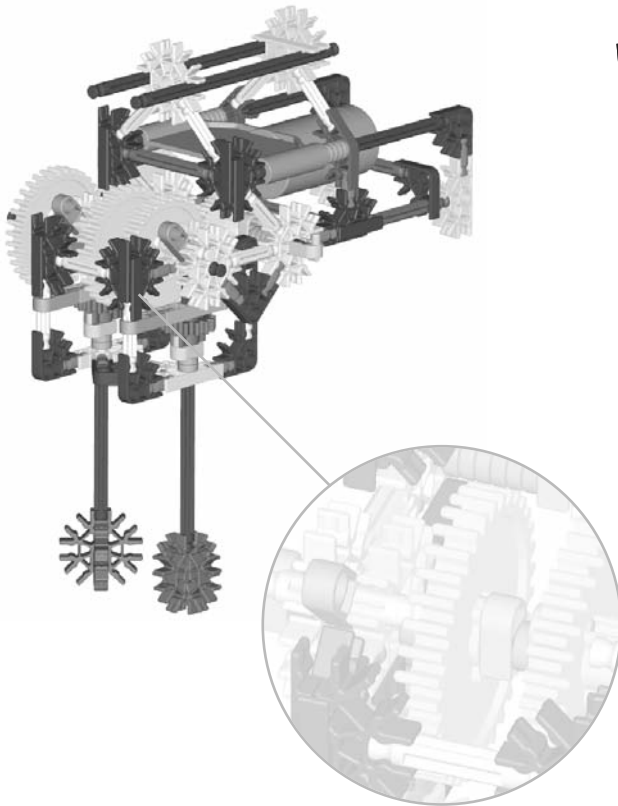
- Identify the type(s) of gears in a food mixer
- Demonstrate how a food mixer functions
- Explain the advantage offered by worm gears and their effect on force and speed
- Determine if the worm gears in the Food Mixer change force, speed or direction
- Compare and contrast machines which perform the same function but use different types of gears

Materials

- bowl
- jellybeans, two different colors

Every gear has a job to do

A real electric mixer turns its beaters very quickly in opposite directions. It can also work at different speeds. When compared with an eggbeater, the two function in the same way but the electric mixer has more power.



Journal Check

- ✓ Explanation of how the Worm and Worm Gear do work
- ✓ Comparison of the Food Mixer and the Eggbeater
- ✓ Prediction and support regarding the speed of the beaters if gear sizes were changed
- ✓ Explanation of why two beaters are required in the mixer as opposed to one
- ✓ Assessment of the effectiveness of the beaters if they both turned in the same direction

QUESTIONS

- 1 With the help of an adult, start your Food Mixer by plugging the cord into the gray K'NEX Motor. How are the Gears in this model different from the Gears in the K'NEX Eggbeater model? Describe the difference in writing.

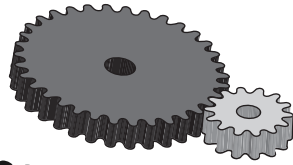
WARNING: Important note: Be extremely careful whenever using electrical devices. Teachers should monitor student activities at all times, and should examine devices before use.

- 2 If you changed the blue Gears on the shafts of the beaters to larger Gears, would the beaters turn faster, slower or at the same speed? Predict what would happen. Write down your prediction and then experiment to find out.
- 3 Try using your Food Mixer to stir up a bowl of jelly beans. Put jelly beans of two different colors in a bowl, with the colors separated on each side of the bowl. Watch how the two beaters turn in opposite directions and mix the colors together. Then, remove one beater and try mixing with a single beater. Which way works better – using one or two beaters? Why? Explain your answer. If the beaters turned in the same direction, would the Food Mixer mix the jelly beans as well? Experiment with the Mixer design and function to find out.

ANSWERS

* **CAUTION:** Supervise students when they use the K'NEX Motor. Plug the transformer into the wall yourself and let them connect the small plug to the Motor. Make sure the Motor is not used near water and that students have dry hands when handling the plug.

- 1 In the Food Mixer, a Worm Gear turns the axle that holds the upright Gears; in the Eggbeater, you turn the crank to turn the upright gear axle. The horizontal Gears (on the shafts of the beaters) turn the same way in both models.
- 2 If you increase the diameter of the Gears at the top of the beater shafts, the beaters will turn more slowly. Encourage students to think about the problem and make a prediction before they experiment to find out the answer. Refer them to the “What’s the Mechanical Advantage?” Reference Sheet.
- 3 When students try mixing jellybeans, use two or more colors to really bring out the mixing process. Have several students in a group watch as the colors mix together. Encourage them to see how the beaters turning in opposite directions really churn up the jellybeans and mix them better than a single beater does.



The Food Mixer

Every gear has a job to do

When you make cookies, some ingredients make the batter thick and hard to stir. An electric mixer makes stirring easier because its motor gives you extra power. But you wouldn't want the mixer's beaters to turn as fast as the motor turns. Then you'd have cookie batter splattering out of the bowl and all over the kitchen! Worm gears make the mixer's beaters turn at a slower speed than the motor — just the right speed for mixing.



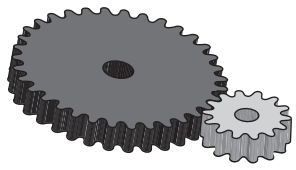
Student Challenge

- 1 With the help of an adult, start your Food Mixer by plugging the cord into the gray K'NEX Motor. How are the Gears in this model different from the Gears in the K'NEX Eggbeater model? Describe the difference in writing.

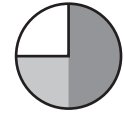
WARNING: Important note: Be extremely careful whenever using electrical devices. Teachers should monitor student activities at all times, and should examine devices before use.

- 2 If you changed the blue Gears on the shafts of the beaters to larger Gears, would the beaters turn faster, slower or at the same speed? Predict what would happen. Write down your prediction and then experiment to find out.

- 3 Try using your Food Mixer to stir up a bowl of jelly beans. Put jelly beans of two different colors in a bowl, with the colors separated on each side of the bowl. Watch how the two beaters turn in opposite directions and mix the colors together. Then, remove one beater and try mixing with a single beater. Which way works better — using one or two beaters? Why? Explain your answer. If the beaters turned in the same direction, would the Food Mixer mix the jelly beans as well? Experiment with the Mixer design and function to find out.

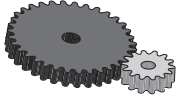


The Differential Lesson Plan



Lesson Length: 30-45 minutes

Objectives



- Identify the type(s) of gear used in a differential
- Demonstrate how a differential functions
- Compare and contrast models with and without a differential
- Understand the necessity of a differential in a vehicle
- Demonstrate how the planetary gears within a differential work
- Explain the advantage offered by these planetary gears and their effect on force and speed
- Determine what other machines could benefit from a differential

Materials

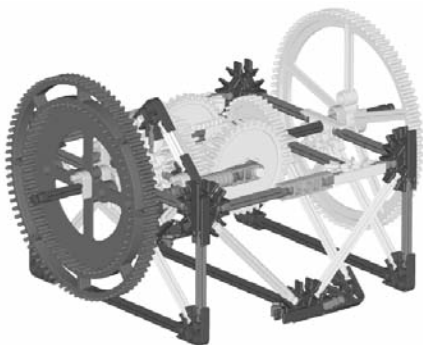
-carpet, towel or other rough surface

Every gear has a job to do

A good way to visualize the need for a differential is to imagine a marching band making a turn. The marchers on the inside of the curve don't have far to go, so they take small steps and move slowly. The marchers on the outside of the curve must move faster to keep the rows of marchers lined up. In a front-wheel drive car, both front wheels are fixed to the axle, which is turned by the engine.

(The rear wheels receive the power in a rear-wheel drive car.)

The axle makes the wheels turn. Since both wheels must be fixed to the axle, they must use a differential to be able to turn at different speeds.



Journal Check

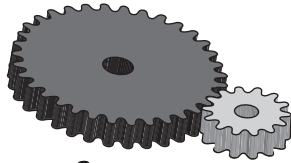
- ✓ Description of how the Axle model works and why
- ✓ Description of how the Axle with Differential works and why
- ✓ Explanation of the movement of the Gears in the Differential
- ✓ Description of the action of turning with the Differential
- ✓ List of other machines that might benefit from a differential

QUESTIONS

- 1 Build the Axle model, as shown in Figure A in the instructions, and test it. Push it straight over a rough surface, like a carpet. Explain what happens. Push the model around a sharp turn. What do you notice? Describe what happens when this model makes a turn. Why does this happen?
- 2
 - a. Now, build the Axle with Differential, as shown in figure B in the instructions. Roll the Axle with Differential straight over a rough surface. Observe the cluster of Gears that make up the Differential. Which Gears turn and which Gears don't? Record your observations.
 - b. Continue to roll the Axle with Differential along and have it make a sharp turn. Watch the cluster of Gears move as you make a turn with the Axle with Differential. What do you notice about how the model turns now? Which Gears are working? How does the cluster of Gears affect the turning? Describe the action of turning a corner with the use of the Differential.
- 3 A differential is a complicated, yet very clever gearing machine. What machines, other than a car, could benefit from the use of a differential gearing system? Work with a partner to brainstorm a list of machines.

ANSWERS

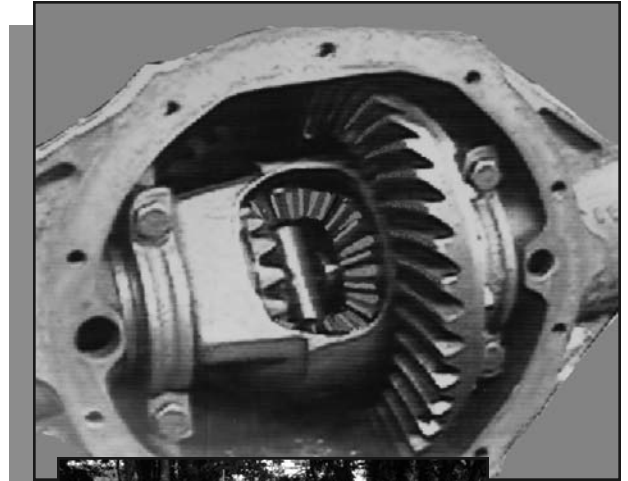
- 1 Students should see that the two big Gears just serve as wheels in this model. Try to provide a carpeted surface on which to run the models. If a carpet is not available, a towel can make a good substitute. When students try to make a turn using the Axle model, they should feel a strain as one wheel lags behind the other. They may notice that the wheel on the outside of the turn may slip to keep up with the inner wheel. In describing what happens, they may just say that it's hard to make a tight turn.
- 2
 - a. Make it clear that the cluster of Gears in the center of the model make up the Differential. This gear system uses planetary gears with crown gears. The two yellow Gears parallel to the wheels are the sun gears. The two yellow Gears at right angles to the sun gears are the planet gears. You may want to put markings on the two sets of gears in order to differentiate between them. Again, the two big Gears are not functioning as gears but only as wheels.
When students use the Axle with Differential model to travel in a straight line, they should notice that the sun gears turn on their axes, but the planet gears don't turn on their axes (although they do move as part of the Differential unit).
 - b. Explain that the Differential helps each wheel turn independently at the right speed. Turning is much easier, one wheel travels at a different speed than the other and you can make very tight turns with this model, compared to the Axle model.
When the wheels turn, the planet gears in the Differential also turn — in opposite directions. The sun gears move at the same rate as the wheels. One sun gear may turn slowly or hold still while the other sun gear turns quickly.
- 3 Students answers will vary.



The Differential

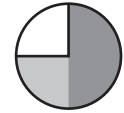
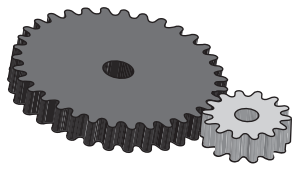
Every gear has a job to do

When a car makes a right turn around a corner, the wheels on the right side of the vehicle make a small curve near the curb, but the wheels on the left travel in a big curve. The left wheels have to travel farther than the right wheels, but all of the wheels do this action in the same period of time. That means that the left wheels actually have to go faster than the right. But how can they go faster when the left and right wheels are attached to the same axle? A differential is a set of gears that lets the left and right wheels turn at different speeds.



Student Challenge

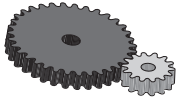
- 1 Build the Axle model, as shown in Figure A in the instructions, and test it. Push it straight over a rough surface, like a carpet. Explain what happens. Push the model around a sharp turn. What do you notice? Describe what happens when this model makes a turn. Why does this happen?
- 2
 - a. Now, build the Axle with Differential, as shown in figure B in the instructions. Roll the Axle with Differential straight over a rough surface. Observe the cluster of Gears that make up the Differential. Which Gears turn and which Gears don't? Record your observations.
 - b. Continue to roll the Axle with Differential along and have it make a sharp turn. Watch the cluster of Gears move as you make a turn with the Axle with Differential. What do you notice about how the model turns now? Which Gears are working? How does the cluster of Gears affect the turning? Describe the action of turning a corner with the use of the Differential.
- 3 A differential is a complicated, yet very clever gearing machine. What machines, other than a car, could benefit from the use of a differential gearing system? Work with a partner to brainstorm a list of machines.



The Clock Lesson Plan

Lesson Length: 30-45 minutes

Objectives



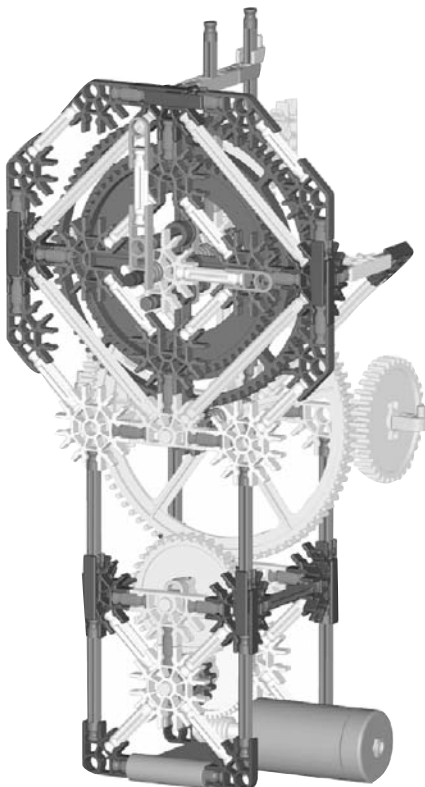
- Identify the type(s) of gear used in a clock
- Demonstrate how a clock functions
- Compare the functioning of the K'NEX Clock with a real clock
- Design a clock face for telling time and assess time telling features
- Determine how to tell time based on this Clock's system mechanisms
- Modify the Clock to determine the effects of changing gear configurations
- Write a creative story about the effects of the Clock's timing system

Materials

- lightweight cardboard
- scissors
- masking tape
- colored markers
- extra K'NEX pieces including Gears

Every gear has a job to do

Mechanical clocks have a complex arrangements of gears. Some clocks also have complicated gear systems which mark the date or phases of the moon as well as the time. Clockmakers have a highly skilled job which requires precision work to make sure the gears run correctly to read the correct time, all the time.



Journal Check

- ✓ Number of times minute hand turns in a full turn of hour hand
- ✓ Explanation of how the K'NEX Clock differs from a normal clock
- ✓ Explanation of how the gear configurations affect the function of the Clock
- ✓ Description and effects of modifications made to gear configurations
- ✓ Creative story about the Clock

QUESTIONS

- 1 Carefully, or with the help of an adult, plug the cord into the K'NEX Clock's gray K'NEX Motor and let the Clock run. Watch how the Clock hands turn. How many times does the minute hand turn for each full turn of the hour hand? How is this Clock different from a normal clock? (Hint: A normal clock is a twelve-hour clock. What would you call this one?)

WARNING: Important note: Be extremely careful whenever using electrical devices. Teachers should monitor student activities at all times, and should examine devices before use.

- 2
 - a. Make a face for your Clock, with markings to show the hours. Remember, it won't be like a normal clock face! To do this, run your Clock until both hands are pointing straight up. Then, start your Clock, stopping it each time the minute hand points straight up. Make a mark where the hour hand points. Keep going until you have marked the whole face.
 - b. Start your Clock and then pull the Motor plug out to stop it. Try telling what time your Clock shows. Remember, one turn of the hour hand still stands for 60 minutes. Take turns with a friend running the clock and guessing the time.
- 3 Try changing the Gear configurations that are at work inside the Clock. How do the different Gear combinations affect the speed and direction of the hands on the Clock. Describe the changes you made to the Clock and how these changes altered the way the Clock works.
- 4 Write a story about your unusual Clock. You might imagine that in a far off land, people use a different system for telling time or that you had a dream in which time sped up. Share your story with the class.

ANSWERS

* **CAUTION:** Supervise students when they use the K'NEX Motor. Plug the transformer into the wall yourself and let them connect the small plug to the Motor. Make sure the Motor is not used near water and that students have dry hands when handling the plug.

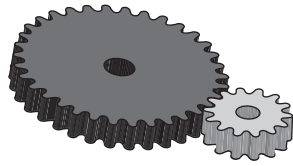
Use the Clock as a culminating activity. Review what students have learned about gears and assess their understanding by seeing if they can identify the various gear systems within this model.

- 1 The minute hand on the K'NEX Clock turns 36 times for every single turn of the hour hand, compared with 12 times for the minute hand of a normal clock. This could be called a 36-hour clock.
- 2
 - a. To make a clock face, students could cut out a 12-centimeter cardboard circle with a 5-centimeter hole in the center. The circle should then be fitted over the clock's hands to go behind them. A little masking tape will help keep the face in place. To mark the clock face, students could mark numerals 1 through 36 or they could repeat 1 through 12 three times.
 - b. To tell time with the K'NEX Clock, read the hour markings to tell the hour. Determine the minutes after the hour just as you would with a normal clock. For example, when the minute hand points straight down, it's 30 minutes past the hour.

Students may need assistance positioning their gears so the hands point straight up to begin marking the Clock's face. Try disengaging the Clock's Gears by pushing the yellow Gears away from their blue Gears, so the hands can spin freely.

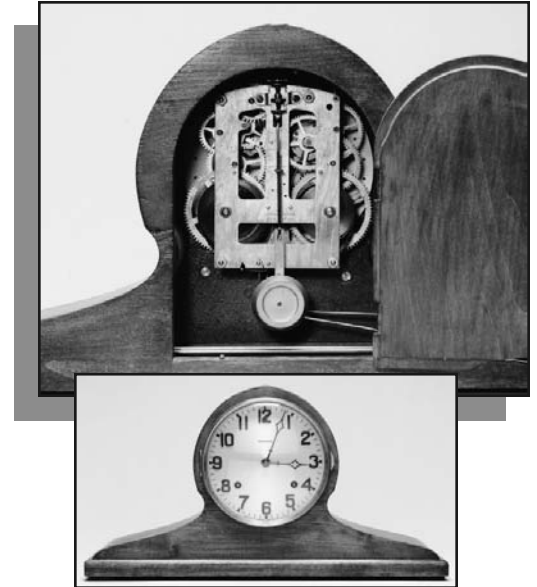
- 3 Students answers will vary depending upon how they reconfigure the Gears. All answers should reflect knowledge of the basic facts of each gear system that they utilize and their reasons for using a particular gear system.
- 4 To get started writing stories, students might think of situations where time is important, such as running a race or waiting for a special occasion. Their stories could put a twist on an everyday situation by having time run at a different rate or by having a different way to tell time.

The Clock



Every gear has a job to do

Face clocks – the kind of clocks with hands and a face with numbers – have lots of gears which turn at different rates. The special combination of gears makes the minute, hour and second hands rotate at the right speeds. Many types of gears all work together in a clock to make sure you are always on time!



Student Challenge

- 1 Carefully, or with the help of an adult, plug the cord into the K'NEX Clock's gray K'NEX Motor and let the Clock run. Watch how the Clock hands turn. How many times does the minute hand turn for each full turn of the hour hand? How is this Clock different from a normal clock? (*Hint: A normal clock is a twelve-hour clock. What would you call this one?*)

WARNING: Important note: Be extremely careful whenever using electrical devices. Teachers should monitor student activities at all times, and should examine devices before use.

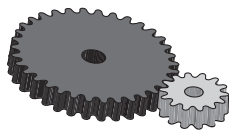
- 2
 - a. Make a face for your Clock, with markings to show the hours. Remember, it won't be like a normal clock face! To do this, run your Clock until both hands are pointing straight up. Then, start your Clock, stopping it each time the minute hand points straight up. Make a mark where the hour hand points. Keep going until you have marked the whole face.

- b. Start your Clock and then pull the Motor plug out to stop it. Try telling what time your Clock shows. Remember, one turn of the hour hand still stands for 60 minutes. Take turns with a friend running the clock and guessing the time.

- 3 Try changing the Gear configurations that are at work inside the Clock. How do the different Gear combinations affect the speed and direction of the hands on the Clock. Describe the changes you made to the Clock and how these changes altered the way the Clock works.
- 4 Write a story about your unusual Clock. You might imagine that in a far off land, people use a different system for telling time or that you had a dream in which time sped up. Share your story with the class.

GEARS

Part & Model List



		SPUR GEARS	SPROCKET BICYCLE GEAR	CROWN GEARS	RACK & PINION GEARS	WORM & WORM GEAR	PLANETARY GEARS	SIMPLE TRANSMISSION	CAR WINDOW	LAWN MOWER	EGG BEATER	FOOD MIXER	DIFFERENTIAL	CLOCK	TOTAL PARTS IN GEARS SET
	Tan Connector	5	10	4	10	1	11	13	11	11	4	11	12	9	27
	Gray Connector	1	0	0	8	2	4	5	6	0	4	6	2	8	10
	Orange Connector	0	4	3	9	1	6	1	2	3	4	2	2	6	14
	Lt Gray Connector	4	0	1	0	0	1	0	0	2	0	0	0	0	4
	Red Connector	4	4	2	0	2	9	5	17	18	6	13	10	6	18
	Green Connector	0	0	0	0	0	1	0	3	6	0	2	0	7	6
	Yellow Connector	4	2	0	2	0	0	2	11	13	4	8	8	11	13
	Blue Connector	8	0	4	4	4	4	3	3	4	4	4	0	4	8
	White Connector	3	0	0	3	0	1	5	1	5	4	5	1	4	5
	Purple Connector	16	12	12	4	12	4	13	11	12	8	12	12	14	16
	Yel/Grn Female Hinge	0	0	0	0	0	0	0	2	2	0	0	0	0	2
	Lt. Blue Male Hinge	0	0	0	0	0	0	2	2	2	0	0	0	2	2
	Green Rod	6	0	8	10	0	8	12	25	26	18	24	10	28	28
	White Rod	4	0	0	2	4	2	16	12	22	11	16	6	20	22
	Blue Rod	20	6	9	5	12	8	18	19	16	1	5	15	19	21
	Yellow Rod	7	7	4	3	1	7	3	13	14	0	0	10	10	14
	Red Rod	4	7	2	5	1	4	0	5	5	6	8	5	1	8
	Gray Rod	1	2	0	2	0	0	2	0	3	0	0	0	0	6
	Med. Tire	0	1	0	0	0	1	0	0	0	0	0	0	0	1
	Lge. Pulley	0	1	0	0	0	1	0	0	0	0	0	0	0	1
	Motor Assembly	0	0	0	0	1	0	1	0	0	0	1	0	1	1
	Adapter	0	0	0	0	1	0	1	0	0	0	1	0	1	1
	Natural Worm Gear	0	0	0	0	1	0	1	0	0	0	1	0	1	1
	Sm. Blue Gear (14)	1	0	0	0	0	2	2	2	1	2	2	0	2	2
	Black Chain Link	0	28	0	0	0	0	0	0	0	0	0	0	0	28
	Sm. Gray Gear (14)	0	0	0	0	0	0	0	0	0	0	0	0	3	3
	Med. Yellow Gear (34)	2	4	2	0	0	1	2	1	0	2	4	4	4	4
	Lt. Blue Spacer	34	28	0	42	12	14	22	12	11	7	30	27	42	42
	Green Gear (84)	0	1	0	0	0	1	0	1	1	0	0	1	1	1
	Lge. Yellow Gear (84)	1	1	0	0	0	0	0	0	1	0	0	1	1	1
	Rubber Band #18	0	0	0	0	0	0	0	0	0	0	0	0	0	3
	TOTALS PER MODEL	125	118	51	109	55	90	129	159	178	85	155	126	205	311