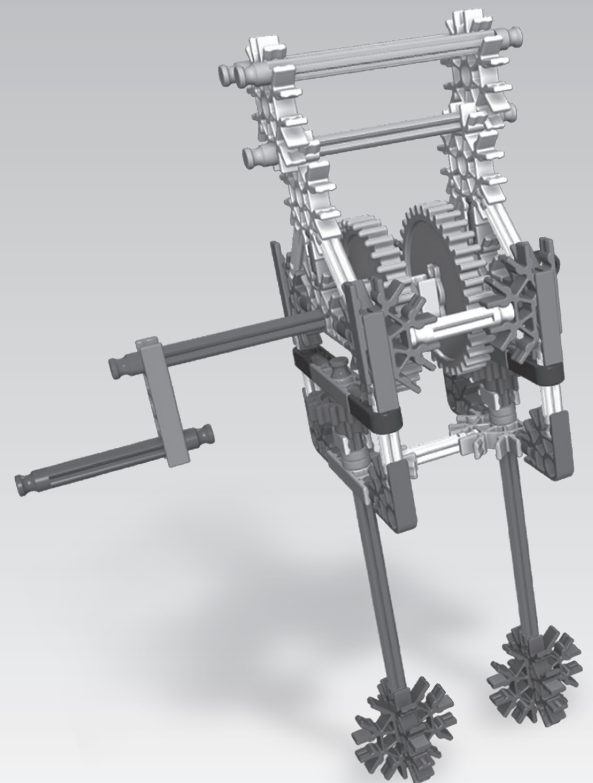


TEACHER'S GUIDE

GEARS

UNDERSTANDING MECHANISMS



Understanding Mechanisms: Gears Teacher's Guide

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Text: Dr. Alex Wright,
AW Education, Wrexham, LL12 7LR, U.K.

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

Visit our website at www.knexeducation.co.uk
or www.knexeducation.com

Email: abcknex@knex.com

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

A Note About Safety

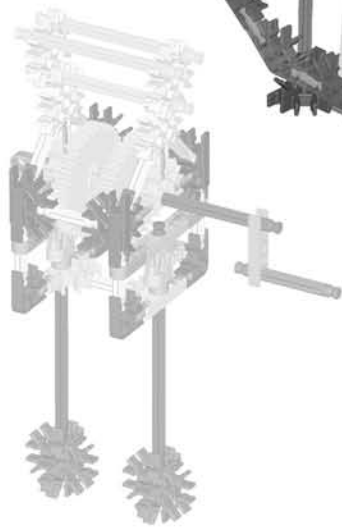
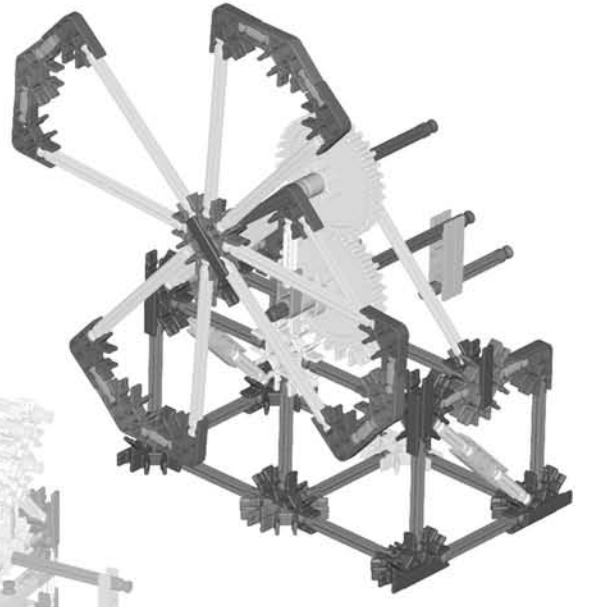
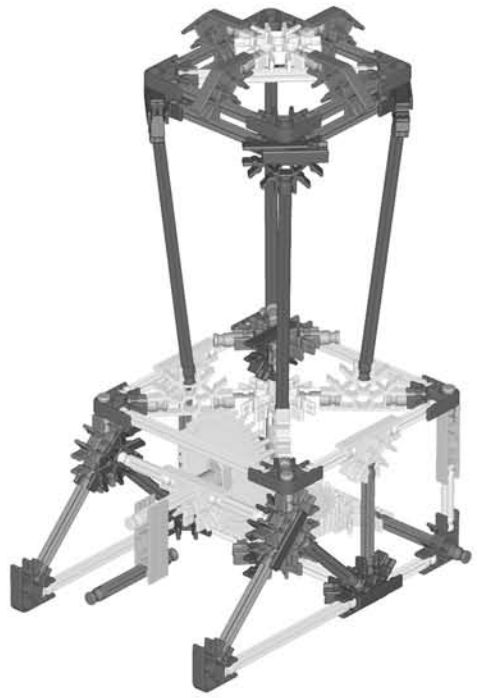
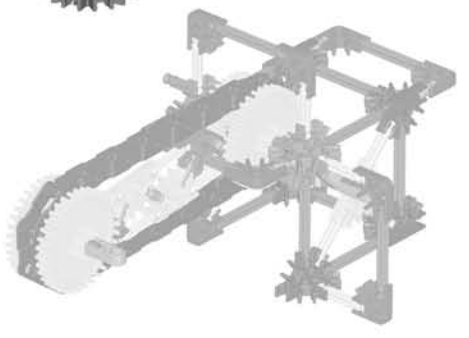
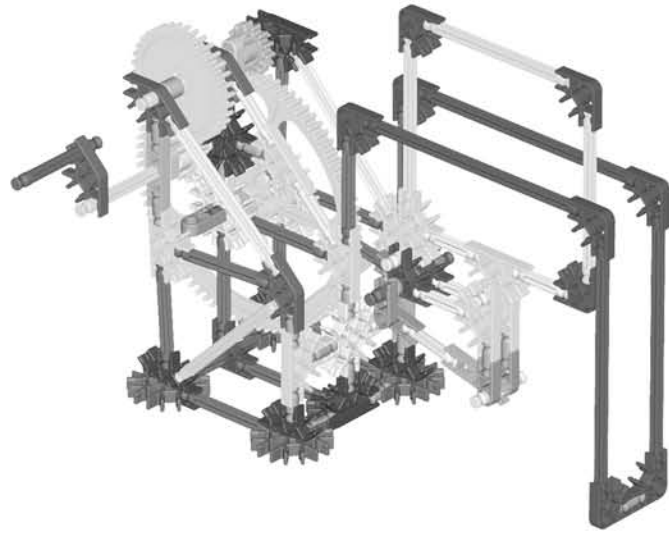
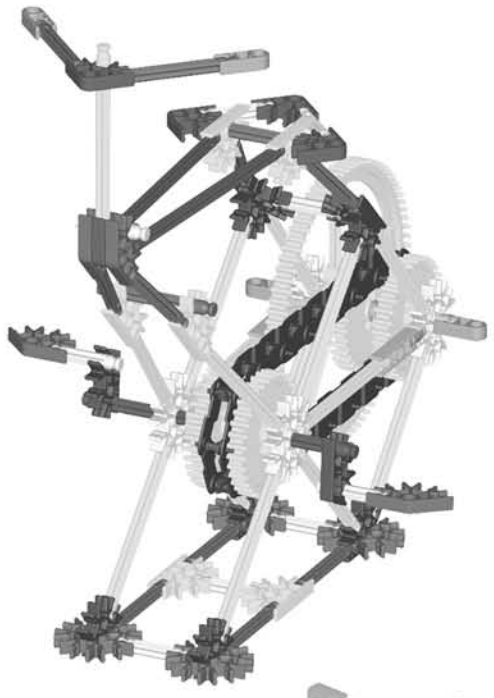
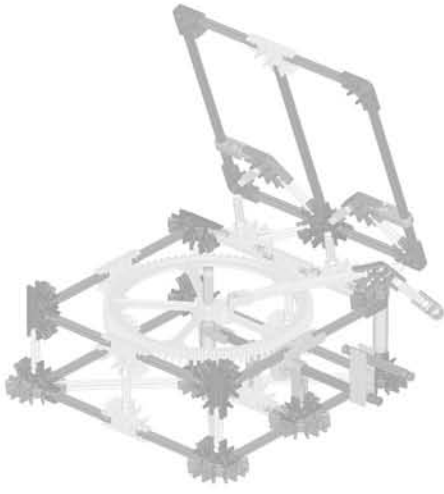
Safety is of primary concern in science and technology classrooms. It is recommended that you develop a set of rules that governs the safe, proper use of K'NEX in your classroom. Safety, as it relates to the use of the elastic bands should be specifically addressed.

PARTICULAR CAUTIONS:

Children should not overstretch or overwind their elastic bands. Overstretching and overwinding can

cause the elastic band to snap and cause personal injury. Any wear and tear or deterioration of elastic bands should be reported immediately to the teacher. Teachers and children should inspect elastic bands for deterioration before each experiment.

Caution children to keep hands and hair away from all moving parts. Never put fingers in moving gears or other moving parts.



Introduction

Your K'NEX Gears kit is part of a series of called "Understanding Mechanisms." The series has been produced to enable Key Stage 2 pupils to investigate and evaluate some familiar products, to think about how they work, and to explore the mechanisms that make them work.

Understanding Mechanisms: Gears Kit

- Developed to introduce pupils to the way gears have been used in the design of familiar products, this construction kit also serves to make the connection between the models they have built and the science that makes them work.
- Through the use of investigative, disassembling and evaluative activities (IDEAs) and focused practical tasks (FPTs), the kit provides opportunities for pupils, working in pairs or small collaborative groups, to explore how gears are used to transfer movement and forces, and to change the speed and the direction of movement.

Teacher Support Materials

- Developed initially for the non-specialist teacher, the materials included in the Teacher's Guide can also be used as a resource by more experienced teachers as they develop their own lesson plans.
- Implementing the ideas and information the Guide contains can build your pupils' knowledge and understanding of mechanisms and the ways in which they can be used to make things move.
- Key background information is provided in "A Quick Guide", while the Lesson Notes for selected K'NEX models provide more detailed information and ideas for possible teaching activities. These teaching activities have been developed primarily to support the DfEE/QCA Scheme of Work for Key Stages 1 and 2 in Design and Technology and Science, the DATA Design and Technology Primary Lesson Plans and Primary Helpsheets. The models without

accompanying Lesson Notes can be used for assessment or enrichment activities.

- A glossary of technical terms and scientific definitions is offered as a resource for the teacher.
- Each of the lessons can be completed in approximately one hour but can be extended using suggested Extension and Research Activities. Useful Internet web sites are listed to help guide the research activities. (Note: these were functioning sites at the time of going to print.)
- A selection of copymasters is provided for your classroom use. These comprise illustrations and short definitions of some of the concepts featured in the model building activities.
- The teaching activities are also intended to encourage the development of key skills by providing opportunities for whole class and group discussions, observing, evaluating and recording through the use of text and drawings, working with others to solve problems and using ICT within a design and technology context.

TABLE OF CONTENTS

A Quick Guide to Gears	4-13
Lessons 1- 5	
Lesson 1: Getting Started	14-15
Lesson 2: The Crank Fan	16-25
Lesson 3: The Car Window	26-30
Lesson 4: The Blender	31-35
Lesson 5: The Stationary Exercise Bicycle	36-40
Key Terms and Scientific Definitions	41-45
Copymasters	46-57

A Quick Guide to Gears

You may claim to know very little about gears and gearing, but if you drive a car or have ridden a bicycle, then you know how to **use** them. When driving off from a stationary position do you choose a low gear or a high gear? What is likely to happen if you try to use the highest gear in this situation? Experience tells you that your car engine will stall if you try to move off from a stationary position using the highest gear.

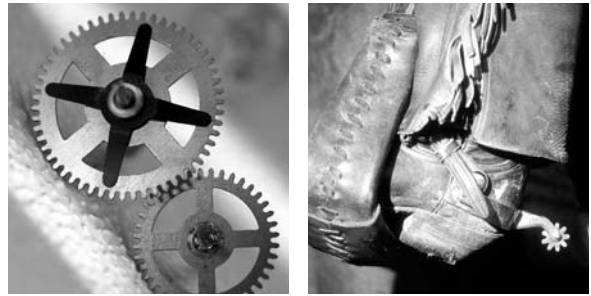
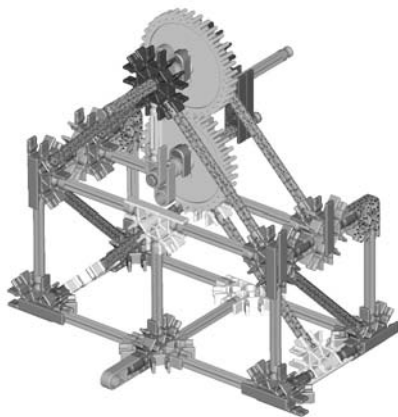
When riding a bicycle you also know that it is easier to ride up a hill using a low gear because it will require less effort on your part to turn the pedals. Using a low gear on a flat road requires very little effort, the pedals go round quickly, but the bicycle only moves slowly. To move faster you choose a higher gear. You now need to apply a little more effort to turn the pedals, but you will not need to turn them as many times as you would do when in a low gear.

Drawing on these experiences you know the following about gears:

- High gears enable you to move quickly.
- Low gears allow you to move slowly, but they also help increase pedal pushing forces (effort) when needed.

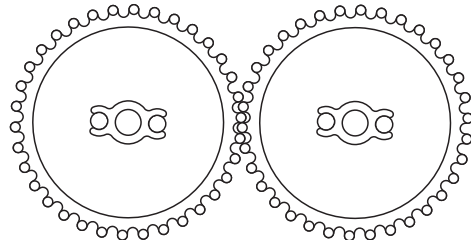
What are gears and how do they work?

Gears are wheels with teeth around their outer rim. In order to work, the teeth on gears must interlock or **mesh** so that the teeth on one gear can push against those on the other gear.



The type of gears used in the K'NEX Crank Fan model are called **spur gears** because they look like the rowels (spiked discs) on a horse rider's spurs.

Try this! Take two yellow K'NEX gear wheels and see how the teeth interlink or mesh together. Slowly turn one gear wheel against the other. Note how, as one gear wheel turns, its teeth push against those on the other gear wheel to drive it round. What do you notice about the direction(s) in which each gear turns?

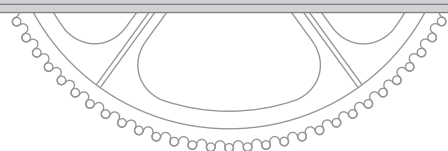


Spur gears lie in the same plane and turn in opposite directions, but only when they mesh together. Different sized spur gears turn at different speeds and with different amounts of force. Try it!

In the K'NEX Crank Fan model, gears provide the mechanism by which the rotary motion of the handle is transferred to the rotary motion produced by the fan blades.

The gears are attached to *axles* (or *shafts*) to allow them to turn.

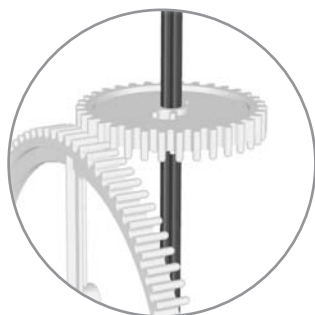
Strictly speaking, the gears provide the mechanism through which motion and forces are transferred from one axle to another.



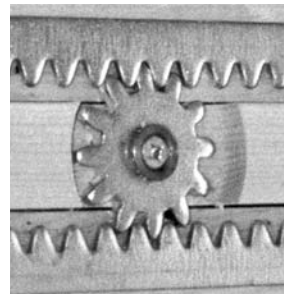


Gears can also be connected using chain links – as in a bicycle. Gears used with chains are called **sprockets**. Sprockets do not mesh with other gear wheels but with the links in the chain. When moved, they turn in the same direction. As with spur gears, different sized sprocket gears turn at different speeds and with different amounts of force. If they are the same size, they turn at the same speed and with the same force.

Crown gears are used to change the direction of rotary motion through 90-degrees. Unlike spur gears, the teeth on crown gears lie at right angles to the rim of the wheel. When they mesh with spur gears, they do so at right angles to the plane of the crown gear wheel. In many machines a large crown gear wheel is often used with a smaller spur gear called a pinion.



Another type of gear, known as a **rack and pinion**, comprises a small spur gear (a pinion) that meshes with a toothed bar (a rack) rather than another toothed wheel. This means that as the pinion is turned it pushes against the teeth of the rack making it move sideways in a straight line and produces linear motion. If the rack is moved, then the pinion can be made to rotate. The rack and pinion mechanism can be used to convert rotary to linear motion and linear to rotary motion.



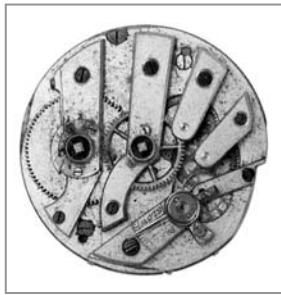
An oscillating lawn sprinkler contains yet another gear type – a **worm gear**. A worm gear is a long single tooth that spirals around a cylinder. Worm gears are usually used with a spur gear to reduce the output speed of a mechanism while, at the same time, changing the direction of rotation through 90-degrees. The mechanism can only turn if the worm gear is the driver gear and not the other way round. Because of this, a worm gear can be used as an automatic locking mechanism.



A Quick Guide to Gears

What are gears used for?

Gears are used in most machines with moving parts, from clocks and cars to egg whisks, lifting winches and hand drills. They come in different sizes and forms depending on the job they are designed to do.



Gears can be used to:

- Transfer rotary motion from one axle to another, as in a bicycle when motion is transferred from the pedals to the back wheel.
- Transmit forces from one axle to another, as in a bicycle when force is transmitted from the pedals to the back wheel.
- Amplify, or increase, output turning forces, as in changing gear to go uphill on a bicycle or in a car.
- Increase or decrease speed, as in changing gear on a bicycle or car.

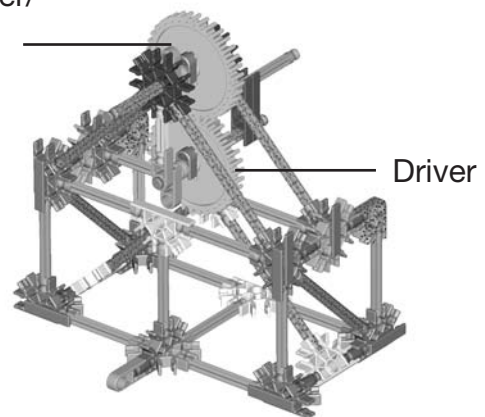
- Change the direction of motion through 90-degrees, as in an egg whisk, windmill and waterwheel.

Gear basics

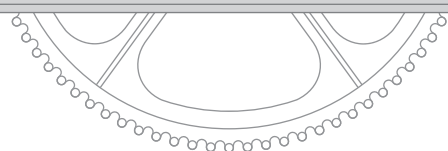
The K'NEX Crank Fan model mechanism has the simplest gear arrangement, with two meshed gears of equal size. Two or more gears that interlock, or mesh, form a **gear train**; if there is only one meshed gear on each axle, the arrangement is known as a **simple gear train**.

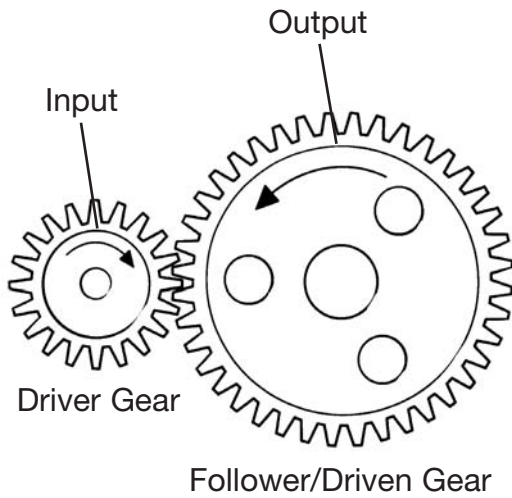


Follower/
Driven
Gear



Consider a spur gear system. The first gear wheel to be turned, and the one to which the effort force is applied, is called the driver. In the K'NEX Crank fan model, the **driver** is the gear attached to the handle axle. The driver transmits turning forces to the **follower**, or **driven**, gear causing it to rotate in the opposite direction.



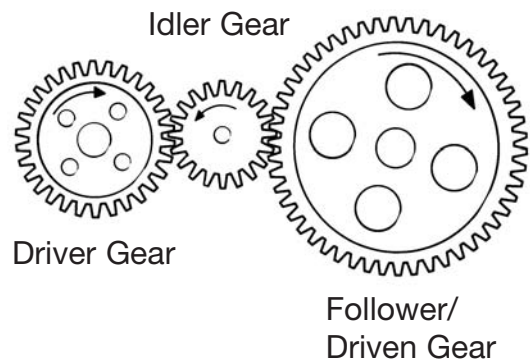


The number of turns, or the force, you apply to the driver is the **input** movement or force; what is produced by the follower is the **output** movement or force.

Key facts about simple gear trains:

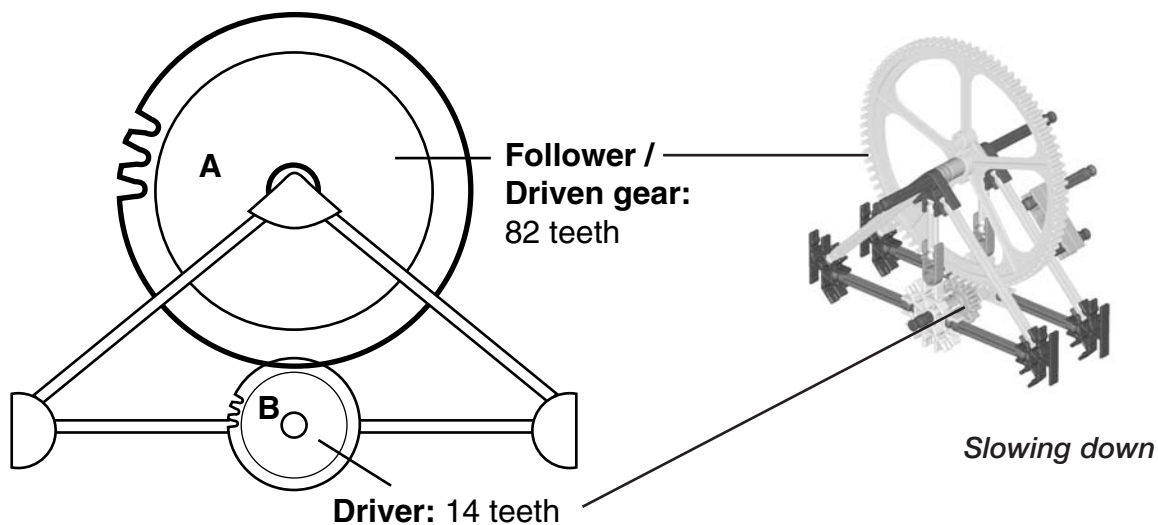
- In a simple gear train with two gears the same size, the follower turns at the same speed as the driver but in the **opposite direction**.
- Turning forces and movements input through the driver and output through the follower.

How can you make the driver and the follower gears rotate in the same direction? Add an **idler gear** between them. The addition of the idler gear will create an odd number of gears in the gear train and make the gears on either side rotate in the same direction.



Slowing down

A small gear wheel turning a large gear wheel slows the turning speed of the axle attached to the large (follower) gear. This example can be found in the K'NEX Crank Fan model (See below and on Page 3 of the Building Instructions booklet).



A Quick Guide to Gears

The small driver gear B must turn a number of times for the larger follower gear A to make one complete rotation or turn. This gear arrangement produces a slow output speed. The term used to describe this mechanism is **gearing down**.

One of the important advantages of gearing down is to increase (amplify) the output turning force available. Try this! Ask someone to try to stop you turning the handle of the Crank Fan by holding onto the fan or output axle. They will find it almost impossible to prevent you from turning the handle. By gearing down, the output turning forces have been increased six times. (A 14-tooth driver gear will make approximately 6 complete turns for every 1 turn made by an 82-tooth follower gear.)

Gearing down means you can use less effort.

On a 10-speed geared bicycle, the lowest gear is usually selected to go up very steep slopes because this is when the greatest force (pedal power) will be needed. If, however, this lowest gear is used on the flat, the pedals will go round very quickly but the bicycle will hardly move forward. To go faster, a high gear is selected but high gears need more effort to turn them and when used in a car, the engine may stall when going up even a gentle slope... that's the trade off.

Key facts about going slower

- A small driver gear turning a large follower/driven gear slows the output speed but increases the turning forces available.
- The mechanism by which this is achieved is called **gearing down**.

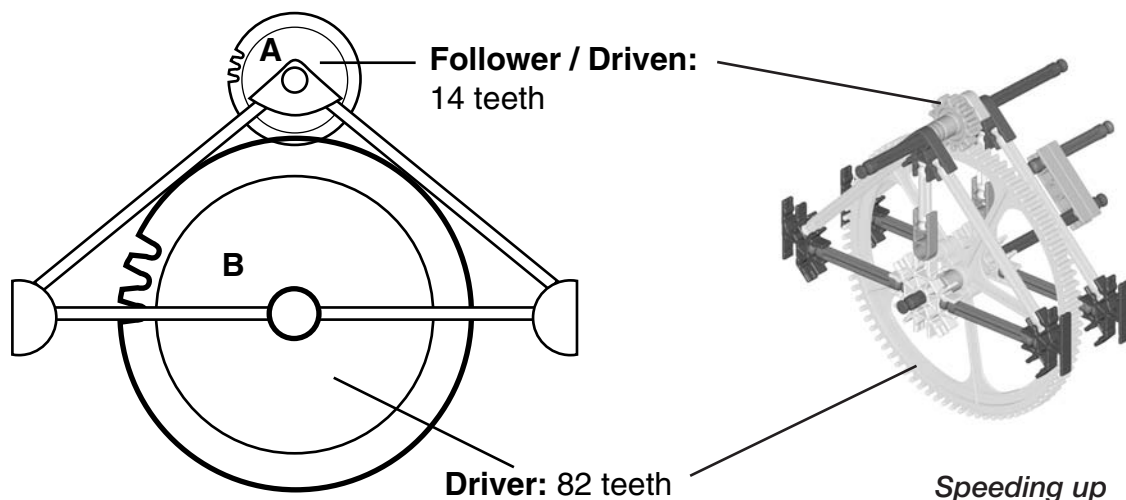
Speeding up

A large driver gear (B), turning a small follower gear (A) will increase the turning speed of the axle attached to the follower gear.

An easy modification to the K'NEX Crank Fan model gives you this gear arrangement. Try it!

The fan now turns much faster than the handle but it is slightly more difficult to turn the handle than before. The output speed is increased but more effort is needed than with the other gear arrangement. Increasing the output speed is called **gearing up**.

Ask someone to try to stop you turning the handle by holding onto the fan. This time only the lightest touch or resistance is needed for the fan to be stopped, no matter how much effort you put in.





This is exactly the same situation as trying to ride a bicycle up a hill in a high gear or trying to start to drive your car by engaging a high gear (4th or 5th gear, for example) - the bike and the engine will stall.

Key facts about speeding up

- A large driver gear turning a small follower gear increases the output speed but decreases the turning forces on the output axle.
- The mechanism by which this is achieved is called **gearing up**.

How many times faster?

Using the example of the K'NEX Crank Fan with a 14-toothed follower (A) and an 82-toothed driver (B): For every 1 complete turn made by driver B, almost 6 complete turns will be made by follower A. In other words, the ratio of input (driver) to output (follower) is approximately 1:6

Check it for yourself.

This ratio is called the **gear ratio** and may also be calculated from the number of teeth on each gear. For example:

Gear Ratio =

$$\frac{\text{Number of teeth on the follower (14)}}{\text{Number of teeth on the driver (82)}} = \frac{1}{5.85}$$

This gear ratio indicates again that for every one turn of the driver almost six turns are produced by the follower gear wheel - the output speed is approximately 6 times faster than the input speed. This is called **gearing up**.

If, on the other hand, the follower is larger than the driver we get the gear ratio of 82/14 or approximately 6:1. This gear ratio indicates that the output will be 6 times slower than the input speed. This is called **gearing down**.

Think about how, when driving your car, you go **up** through the gears to go faster and go **down** through the gears to go slower.

Changing the direction of movement through 90-degrees

Simple gear trains allow rotary motion and forces to be transferred in a straight line.

This, however, is not always useful. Windmills and waterwheel mills, for example, need to be able to change a vertical, rotary motion from the sails and the waterwheel into the horizontal, rotary motion needed by the grinding wheels to process grain. This problem was solved by positioning the teeth on one gear wheel so that they were at right angles to its face instead of around the rim. This meant that the two gear wheels could mesh at 90-degrees to each other.



Examine the two yellow gear wheels used for the mechanism in the K'NEX Blender model and see how they mesh together.

A Quick Guide to Gears

This drawing represents a crown gear wheel used to change direction of movement through 90-degrees. This type of gear is called a **crown gear** – when looked at from the side it looks rather like a crown.



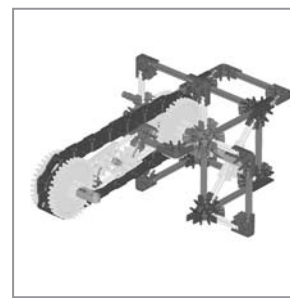
The mechanism is called a **crown gear wheel and pinion**. The pinion is simply another name for a follower gear.

Crown gears can be used in the same way as spur gears for gearing down, as in the K'NEX Phonograph model, and for gearing up, as in K'NEX Eggbeater model.

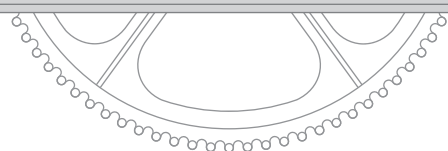
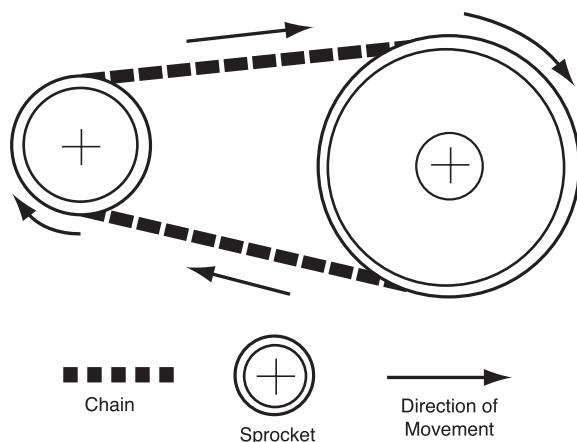


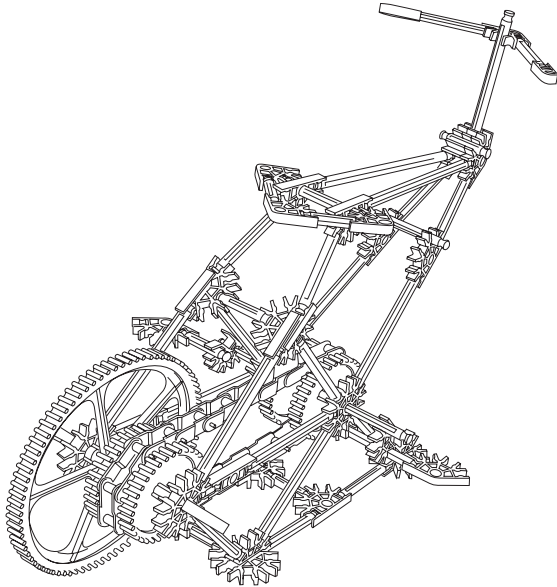
A chain and sprocket system

Chain and sprocket systems use a chain to transfer rotary motion from a driver's axle to a follower's axle. We are perhaps most familiar with the chain and sprocket system used in bicycles. This gear arrangement can be seen in the K'NEX Stationary Bike model.



Sprockets are toothed wheels on which a chain runs. The drawing shown below represents a chain and sprocket system as used in the K'NEX Stationary Bike model.





Chain and sprocket systems can be used to:

- Transfer rotary motion and forces
- Amplify forces
- Increase or decrease speed

They share these features with simple gear trains.

They **differ** from simple gear trains, however, in that:

- The driver and follower sprockets rotate in the same direction.
- They can be used to convert rotary motion into linear motion as, for example, in a chainsaw (see the K'NEX Chainsaw model), in conveyor belts used on production lines, and on the lifting mechanisms of fork lift trucks.
- Chain and sprocket systems are adjustable. To increase or decrease the distance between the two axles simply lengthen or shorten the chain.

Key facts about chain and sprocket systems:

Chain drive systems use a chain and sprocket to transfer motion from the driver axle to the follower axle. The same rules apply to both simple gear trains and chain and sprocket systems:

- With two sprockets the same size the input speed is the same as the output speed.
- A small driver sprocket makes a large follower sprocket turn slowly but increases the turning forces on the output axle.
- A large driver sprocket makes a small follower sprocket turn faster but decreases the turning forces on the output axle.

Recording: making drawings

It is important for children to record what they have observed and discovered in their investigations. The use of labelled drawings is a valuable communication skill that needs to be learnt.

Yet, if asked to make a drawing of a K'NEX gear or other mechanism, the children's first reaction may well be, "I can't do that!" Others, who accept the challenge, may spend the next 20 minutes making sure they have drawn every tooth on every gear wheel.

Children's drawings do not need to look exactly like the K'NEX, or any other, machine they are investigating. What is important, however, is to demonstrate how the machine works. To achieve this, children could be encouraged to make drawings that show, for example, the way in which the moving parts connect to each other. Drawing also helps to focus the children's attention on the working parts.

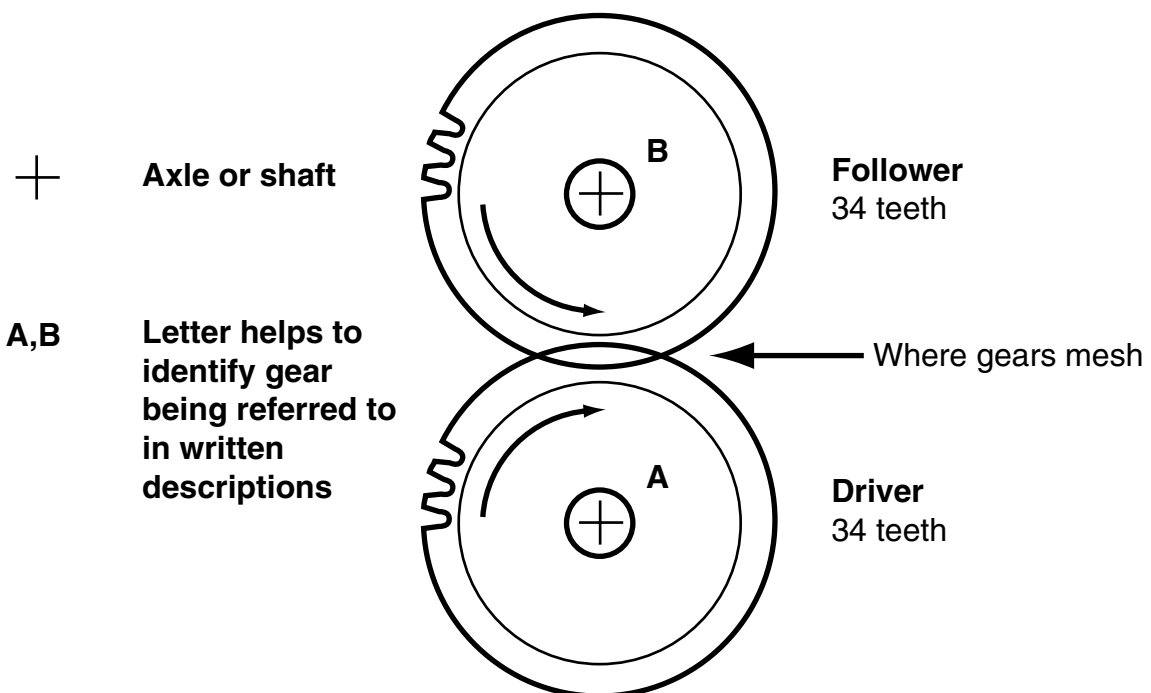
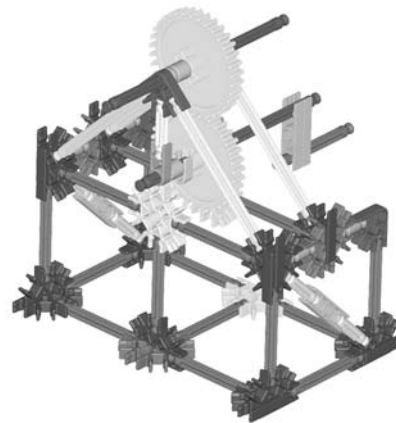
A Quick Guide to Gears

Children may be encouraged to think about and discuss what they are doing through facilitating questions such as:

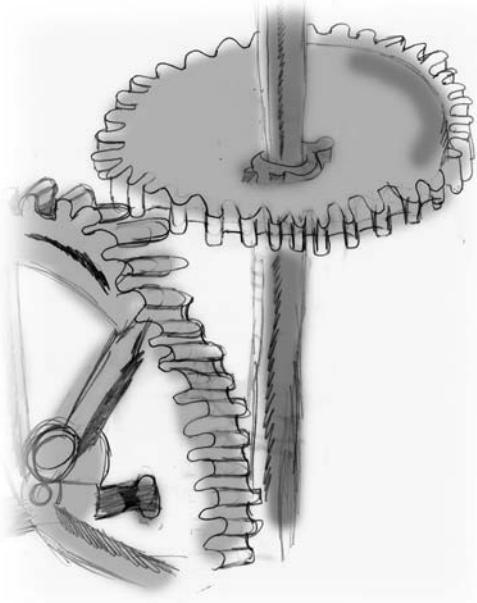
- What does the machine do?
- What are the functions of the moving parts?
- How are the moving parts connected? How do they make other parts move?
- What are the moving parts called?
- What types of movements do the moving parts make?

The use of graphic symbols is a simple technique that can be used to help the children focus on interpreting the key parts of the mechanism.

For example, the simple gear train used in the K'NEX Crank Fan model could be represented by the use of symbols and careful labelling, as shown in the diagram at the bottom of this page.



Some children, however, may want to produce more realistic drawings, such as this one showing the arrangement of a crown gear, or use photographs, taken with a digital camera, to record their observations.



Useful Internet Web Sites

www.coe.uh.edu/archive/

The University of Houston archive of lessons. Search >Collections > Science >Lesson plans >Simple Machines.

www.flying-pig.co.uk

A general site for simple machines. It includes some simple animated drawings of mechanisms in action.

www.howstuffworks.com

A library of information on different types of machines. Useful background information for teachers. Use the search facility to find information.

www.mos.org/sln/Leonardo/InventorsToolbox.html

A site that includes some helpful illustrations of different types of gears.

www.smartown.com/sp2000/machines2000/

Simple machines made simpler. A good introduction to simple machines made by primary school children.

Lesson 1: Getting Started

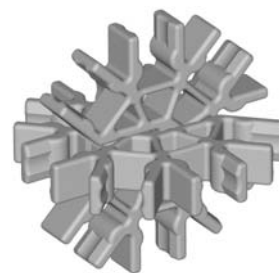


Time: 1 hour

NOTE: This lesson, which introduces children to the K'NEX materials and building techniques, is included in each of the Understanding Mechanisms Teacher's Guides. If your class is already familiar with the K'NEX Understanding Mechanisms kits you may omit it and begin with Lesson 2.

Learning Objectives - Children should learn:

- to assemble, join and combine materials and components
- that construction material can be used to try out ideas
- to recognise shapes and their application in structures
- to draw and label designs



Possible Teaching and Learning Activities

Introduction

This lesson provides children with the opportunity to investigate how K'NEX construction materials may be used to create different 2D and 3D shapes. It could also contribute to cross-curricular activities, including:

- Mathematics: shape and space, movement and angles.
- Literacy: speaking and listening, describing observations.

Working in Groups of 2-3

- Ask the children to use the K'NEX materials in their kit to make and name different:
 - 2D shapes
 - 3D shapes – e.g. cubes, cuboids and cylinders
 - Symmetrical shapes/mirror images
- Ask the children what sorts of shapes might be used to make stable structures.
- Ask the children to look at their K'NEX components and:
 - Identify those that contain an angle of:
 - 90-degrees
 - less than 90-degrees
 - more than 90-degrees
 - What sort of shapes can they make with these components?
 - Identify Connectors that allow them to build shapes containing right angles.
 - Identify Connectors that can be used to make rigid and flexible joints.

Vocabulary

dimensional, 2D, 3D, cubes, cuboids, cylinders, symmetrical, Rods, Flexi-rods, Connectors, Spacers, Hubs, Tyres, components, right angles, stable, rigid, flexible, functions

Resources

Each group of 2-3 children will need:

- 1 K'NEX Understanding Mechanisms: Gears Kit with Building Instructions booklet

Teacher's Notes

For many children, this may be their first opportunity to explore, experience and experiment with the K'NEX materials they will be using in their classroom activities. This includes learning the names of the different components and their functions.

Note: K'NEX Rods, Flexi-rods, Connectors, Spacers, Hubs and Tyres are always capitalized.

*The Building Instructions booklet provided in each set includes a **building tips page**, which offers guidelines for connecting the individual pieces. You may want to provide time for the children to practice connecting the different components. It is crucial that they grasp the building concept at this stage so that frustrations are avoided later.*

- Identify components that can be used to make things move.
- Ask the children to:
 - Make a tall, stable structure.
 - Make a model with moving parts.
- Ask the children to make drawings of their models and to label them showing:
 - How and where they made the structure stable.
 - How their model works and the movements the model makes.
- Children may be encouraged to think about and discuss what they are doing through facilitating questions such as:
 - What does the machine do?
 - What are the functions of the moving parts?
 - How are the moving parts connected or how do they make other parts move?
 - What are the moving parts called?
 - What types of movements do the moving parts make?

Plenary Session

- Choose a range of models that may be shared with the class.
- Possible questions to ask:
 - How did you make this?
 - Were any parts of the model difficult to make?
 - What parts of your model are you pleased with and why?
 - What shapes did you use in your model? Why?
 - How stable is your model? How did you test your model?
 - What movements were you trying to make and how did you make them work?
 - What components did you use to make the movements?
 - What other types of machines have you seen in which these components were used and what did the machines do?
 - What would you do differently next time?

Teacher's Notes

Provide some basic guidelines for maintaining all the pieces in the set for future use. At least 5 minutes will be needed at the end of each lesson for cleaning up the materials.

Using labelled drawings is an important communication skill that needs to be learnt. Emphasize to the children that it is not important for their drawing to look exactly like the K'NEX or any other machine they are investigating. It is more important for their drawing to show how the machine works. For example, they should show how the moving parts connect to each other.

Interpreting 2D drawings to construct 3D models is an important skill to be learnt and from the outset children should be asked to say what movements/functions their model will perform before they build and investigate the actual mechanisms.



Lesson 2: The Crank Fan

How to transfer rotary motion using a simple gear train

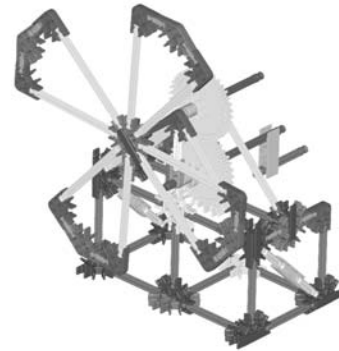


Time: 1 hour + 1.5 hours

The crank fan lesson is in two parts; the first part can be used with Key Stage 1 children using a limited vocabulary while both parts allow Key Stage 2 children to progressively investigate how gears work using a more expansive terminology.

Learning Objectives - Children should learn:

- to investigate and disassemble products in order to learn how they work
- how to transfer rotary motion using gears
- how gears may be used to increase and decrease speed
- to communicate information about products and mechanisms through labelled drawings



KEY STAGE 1

Possible Teaching and Learning Activities

Introduction

The Crank Fan model from the K'NEX Understanding Mechanisms: Gears kit may be used to support the QCA/ DfEE scheme of work Exemplar Materials for Design and Technology **Unit 2C: Winding up** by replacing the fan with a string and lifting attachment. Using the K'NEX Crank Fan model in this way demonstrates to children that similar mechanisms can be used in different ways. It may also be used to support Science **Unit 2C: Forces and Movement** – 'Explain how to make familiar objects move faster or slower.'

Younger Key Stage 1 children are not expected to construct the K'NEX Crank Fan model themselves but a pre-built model could be made available for their investigations. In addition, children may not be familiar with following step-by-step instructions and interpreting 2D plans. Extra time and support may be needed if this is the first time children have been asked to make K'NEX models from 2D plans.

Whole Class

Demonstrate how an electric fan works. It may be useful to have a partly dismantled electric fan on display. Use the K'NEX Crank Fan model to show how that fan works.

Vocabulary

gear wheels, axle, handle, crank, winder, gears, teeth, rim, opposite, direction, clockwise, anticlockwise, faster, slower, rotate, rotary, linear, movement, motion, mechanism, smaller, larger, input, output, driver, follower, gear ratio, gearing up, gearing down, friction, lubricant

Resources

Each group of 2-3 children will need:

- 1 K'NEX Understanding Mechanisms: Gears kit with Building Instructions booklet
- Dot stickers or pieces of masking tape
- Felt-tipped pens

You will need:

- An electric fan
- A collection of devices and toys that use gears
- A built model of the K'NEX Crank Fan

Useful Internet Web Sites

Please refer to Page 13 of A Quick Guide to Gears.

Teacher's Notes

Use caution when displaying the dismantled electric fan. Children should not touch the parts.

Children may be encouraged to think about and discuss what they are investigating through the use of facilitating questions such as:

- * **What does the machine do?**
- * **What happens when they turn the handle?**
- * **What are the functions of the moving parts?**
- * **Will the fan turn if one of the gear wheels is removed?**
- * **How are the moving parts connected or how do they make other parts move?**
- * **What are the moving parts called?**
- * **What types of movements do the moving parts make?**

Working in Groups of 2-3

- If a collection of devices that use gears is available, allow the children time to investigate/demonstrate these and to talk about and discuss their observations.

Whole Class

- Ask the children to talk about the ways in which gears are used to make the toys and devices they have examined work. Explain that in this lesson they will investigate how gears work by investigating a K'NEX model.

Working in Groups of 2-3

- Distribute 2 gears from the K'NEX Understanding Mechanisms: Gears kit to each group. Encourage them to think about how they would describe a gear and to explore how gears fit together. You may choose to accept their operational definition for how gears work, or formalize the terms they use in describing gears and how they fit together. (For example, *mesh*.)
- Distribute pieces of tape or dot stickers and ask the children to place a small piece of tape on each of the two K'NEX gears so that they can observe the

Teacher's Notes

- * **Answers will vary but expect them to respond that the fan blades turn.**
- * **Answers will vary, but children should identify that one gear wheel causes the other to turn and this drives the fan blades.**
- * **Look at how the teeth on the gear wheels mesh together.**
- * **Gear wheels, winder, handle...**
- * **The handle, gears and fan all move in circles.**

This activity will allow you to establish the children's level of understanding of gears. It may also help establish that gears, in some form, are used in the majority of machines that have moving parts - from cars to clocks, from toys to computer printers.

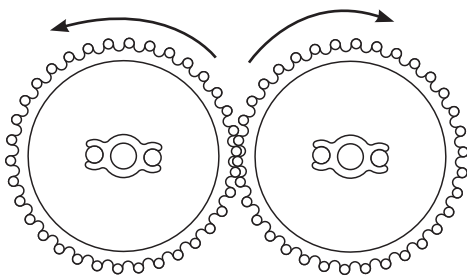
Gears are wheels with teeth around their outer rims. As one gear wheel turns, its teeth push against the teeth on the other gear wheel, pushing it around. If the first gear wheel is turning clockwise, then it will push the second gear wheel in the opposite direction i.e. anticlockwise.

This activity provides an opportunity to introduce formal terms that the

Lesson 2: The Crank Fan

direction(s) in which the gears move. The children should lay the gears on a piece of paper on their desk so that they mesh. Suggest that one child insert a pencil point into the central hole of each gear to hold them in place, while the other child turns ONE gear.

- Ask them to notice what happens.
 - Do both gears move?
 - Do both gears move in the same direction?
- Encourage them to add arrows to the gears to show the direction of movement.



Whole Class

- Using a K'NEX Crank fan model continue to introduce/reinforce the new technical vocabulary and terminology the children will use as they undertake their investigation. For example, **gear wheels, axle, handle, winder and rotary movement.**

Working in Groups of 2-3

Before the children build their K'NEX models and explore real mechanisms, explain that they may find it helpful to use a process, such as the one outlined here, for their investigations. This might involve:

- Identifying the parts of the model from 2D drawings
 - Naming the parts
 - Stating their functions in the model
 - Identifying the movements the parts will make
 - Building the model
 - Investigating
 - Determining whether or not their initial ideas were right
-
- Ask each group to build the K'NEX Crank Fan model and allow them time to investigate how their model works. Ask them if they know why it is called a **crank fan**.

children should use during their investigations with gears.

Teacher's Notes

*You may find it useful to create a **word wall** showing the range of words and terminology the children may need when (a) discussing their investigations and findings, (b) making labelled drawings and (c) writing descriptions. Words could be written on cards, possibly with simple descriptors on the reverse side.*

See A Quick Guide to Gears and Key Terms and Scientific Definitions for additional information.

Interpreting 2D drawings to construct 3D models is an important skill for children to learn.

Undertaking this type of process will help the children's skill development.

*The handle, or **crank**, behaves as if it is a rotating lever mechanism. The axle is the fulcrum and the arm or crank is the lever. As when using a lever, a longer crank is*



- Other facilitating questions to ask the children might include:
 - * **What are the names of the parts that make the fan/lifting device turn/rotate?**
 - * **What is the mechanism, used to turn the fan/lifting device, called?**
 - * **How would they make the fan/lifting device turn faster/slower?**
 - * **Describe the type of movement made by the fan/lifting device?**
 - * **What is the direction of movement made by the handle and fan?**
 - * **Do the two gear wheels turn in the same direction?**
 - * **Will the mechanism be easier to turn without the handle?**
- Ask the children to prepare and stick labels on their model to identify the key moving parts of the mechanism. They should add arrows to show directions of movement. This may help them later when they describe their observations and findings.

Extension Activity 1

Using the fan model, you may wish to ask the children to observe that the blades of the fan make one complete turn or rotation for every complete turn of the handle. This happens because the gear wheels are the same size. They can check this by marking both gear wheels with dot stickers at the point where the two gear wheels mesh and see what

easier to turn than a short one – it needs less effort force. Attempting to turn the axle itself will require a large effort force. You can test this for yourself by turning the crank fan model with and without the handle.

Teacher's Notes

- * **Possible answer: Gear wheels, axles, handle.**
- * **Possible answer: Winder, handle, crank.**
- * **Possible answer: Turn the handle faster/more slowly.**
- * **Possible answer: Rotary/linear motion.**
- * **Possible answer: Clockwise/anticlockwise.**
- * **Possible answer: In different directions: clockwise/anticlockwise.**
- * **Possible answer: No.**

Lesson 2: The Crank Fan

happens when they turn the handle slowly through one complete turn. The stickers will rotate in opposite directions and will come together again in time with the handle and fan.

Whole Class

- Talk about the children's observations. Encourage them to use their K'NEX models to demonstrate their explanations through the use of correct technical vocabulary.

Extension Activity 2

Working in groups of 4-6 (using 2 building kits)

- Ask one half of the group to use their K'NEX kit to rebuild the crank fan so that a large gear drives a small gear; ask the other half of the group to rebuild their crank fan so that a small gear drives a large one.

- Ask the groups to investigate what happens to the fan/lifting device when:

- * **the large gear drives the smaller gear wheel?**

- * **the smaller gear drives the larger gear wheel?**

- * **the gear wheels do not mesh together?**

- Before they begin each investigation ask the children to speculate what they think will happen; then they should try it out. Were they correct?

KEY STAGE 2

Possible Teaching and Learning Activities

Introduction

Children at Key Stage 2 are expected to develop their knowledge and understanding as to how mechanisms can be used to make things move in different ways. Investigations and vocabulary can be developed in greater depth, building on the activities from Key Stage 1. If this is the first time children are using the kit, start with the Key Stage 1 activities.

Teacher's Notes

The following series of investigations require the children to rebuild their models using different sized gears. Guidelines are provided on the right hand side of Page 3 of the Building Instructions booklet. We suggest that two groups work together, with one group building the model with the large gear as the driver, while the second group uses a small gear as the driver. Having both models available will make comparisons easier.

- * **The smaller gear wheel turns faster.**

- * **The larger gear wheel turns more slowly.**

- * **The fan/lifting device will not work when the handle is turned.**

Whole Class

Demonstrate how an electric fan works. It may be useful to have a partly dismantled electric fan on display. Use the K'NEX Crank Fan model to show how that fan works.

Children could be encouraged to think about and discuss what they are investigating through the use of facilitating questions, such as:

- What does the machine do?
- What are the functions of the moving parts?
- How are the moving parts connected?
- How do they make other parts move?
- What are the moving parts called?
- What types of movements do the moving parts make?

Working in Groups of 2-3:

If a collection of devices that use gears is available, allow the children time to investigate these and to talk about and discuss their observations.

Ask the children to describe familiar machines that use gears. On the board, make a list of these machines and what they do.

Whole Class

Using a K'NEX Crank fan model introduce the technical vocabulary and terminology the children will need. For example: **gears, input and output, mechanism, driver, follower and gear train.**

Using a K'NEX Crank Fan model as an example, demonstrate on the board how to make simple labelled drawings, using arrows to show the direction of movement. The diagram on Page 22, for example, is a symbolic representation of gears in a simple gear train.

Teacher's Notes

Use caution when displaying the dismantled electric fan. Children should not touch the parts.

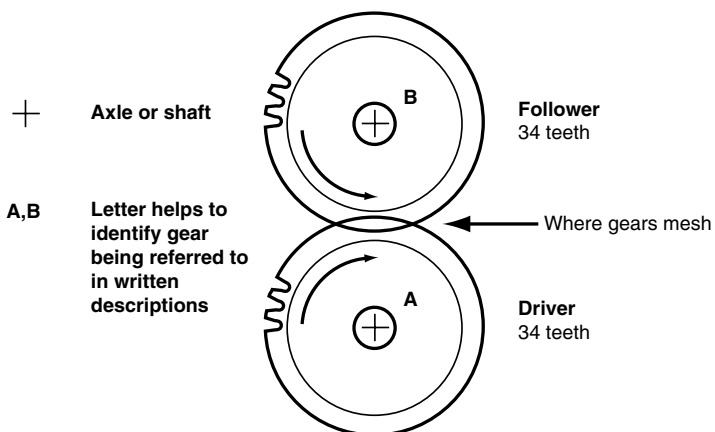
These activities will allow you to establish/review the children's understanding of the use of gears. They may also help establish that gears, in some form, are used in the majority of machines that have moving parts - from cars to clocks, from toys to computer printers.

*You may find it useful to create a **word wall** showing the range of words and terminology the children may need when (a) discussing their investigations and findings, (b) making labelled drawings and (c) writing descriptions. Words could be written on cards, possibly with simple descriptors on the reverse side.*

See A Quick Guide to Gears and Key Terms and Scientific Definitions for additional information.

It is not necessary to draw every K'NEX building component used in the model - simply the key ones used in the mechanism. Explain to the children that it is not important for their drawing to look exactly like the K'NEX, or any other, machine they are investigating. Help to

Lesson 2: The Crank Fan



develop the children's observational skills by focusing their attention on the way in which the machine works. Ask, for example, how the moving parts connect to each other. Their drawings should reflect these connections.

Some children may want to draw the teeth on each gear wheel as they may feel that this is a more accurate representation of the mechanism they have been investigating. Older children may count the number of teeth on each gear wheel to indicate the different sizes. Either method is acceptable.

Working in Groups of 2-3

- Ask each pair to build the K'NEX Crank Fan model and provide time for them to investigate how it works? You may want to use the following to guide their inquiry:
 - Identify the parts that move and how they are connected to each other.
 - How many different moving parts does the model have?
 - What types of movement are used and produced?
 - Identify the input and output movement and the type of movement made by each.
 - How can the speed of the output movement be controlled?
- Ask the children to prepare and stick labels on their model to identify the key moving parts of the mechanism. They should also add arrows to show directions of movement. This may help them later when they describe their observations and findings.
- Ask the children what they think might happen to the speed of the fan if, instead of two equal sized gear wheels, their model had:
 - (a) a large gear driving a smaller gear wheel.
 - (b) a smaller gear driving a larger gear wheel.
- Invite the children to investigate and see if their suggestions were correct.

Fan turns faster than the handle.

Fan turns slower than the handle.

Teacher's Notes

When introducing the extended investigation the class should be



Whole Class

Discuss the effect of changing the size of the driver and follower gear wheels.

What other mechanisms can produce the same effect?

Ask those children who have bicycles with gears what they do when they want to go faster. They change into a higher gear: the chain connects the large “gear wheel” attached to the pedals to the smallest gear on the back wheel. It is harder to push the pedals in this situation but you do not have to push them round so frequently and you move forward faster on your bike. To go more slowly, or to ride up slopes, a low gear is selected i.e. the largest gear wheel on the back wheel is selected. It is easier to push, but the pedals go round more times than they would do if using the higher gear to travel at the same speed. Their bicycles are examples of the use of a chain and sprocket mechanism.

Ask the children to record their observations and results. They should use labelled drawings and written notes, and should apply the correct vocabulary and terminology to show what happens in the following situations:

* **The driver and follower gear wheels are the same size.**

referred back to the K’NEX Crank Fan Building Instructions, (see the diagrams on the right hand side of Page 3), to show them how to modify their models. If time is a concern, half the class could build one version and the other half the alternative version. The models could be exchanged when observations are completed.

Teacher’s Notes

Chain and sprocket mechanisms (see K’NEX Stationary Bike and Chainsaw: Lessons 7 and 8), and belt drive mechanisms can also be used to produce similar outcomes.

It may be helpful to have a bicycle with gears in the classroom for demonstration purposes. You may wish to introduce additional technical vocabulary at this point; this vocabulary may make it easier for the children to describe what is happening.

*In a simple gear train mechanism comprising two gears, the **driver** gear is the one that drives the mechanism. The driver gear is where the input force/movement is applied. All the other gears that are turned or driven by the action of this gear are called **driven** or **follower** gears. The force/movement produced by the last driven or follower gear is the **output** of the mechanism.*

* **Both driver and follower gears turn at the same speed but in opposite directions.**

Lesson 2: The Crank Fan

* The driver is larger than the follower.

* The driver is smaller than the follower.

- They should use arrows to show the direction of movement.

Extension Activity 1

- Ask the children how they might estimate the speed of movement of each gear wheel. (Strictly speaking, this is the axle speed.)
- What would the children measure to estimate by how much the input and output speeds differ?
- Help the children to understand that the simplest way is to mark each gear wheel, then count and compare the number of input and output turns. For example: Counting how many output turns are produced for one input turn will give a simple '**gear ratio**'.
- A more accurate approach is to compare the number of teeth on each gear wheel. You can write the formula for the **gear ratio** on the board:

For an 84-toothed driver turning a 14-toothed follower gear...

$$\text{Gear Ratio} = \frac{\text{Number of teeth on the follower (14)}}{\text{Number of teeth on the driver (84)}} = \frac{1}{6}$$

e.g. 14 / 84 gives a gear ratio of 1:6

- Help the children to understand how this works out: The circumference of the driver gear (measured by the number of teeth) is 6 times greater than that of the follower. Therefore:
 84×1 (turn of driver) = 14×6 (turns of the follower)
or 1:6

* The smaller follower gear wheel turns faster than the driver.

* The larger follower gear wheel turns more slowly than the driver.

Teacher's Notes

If available, a digital camera could be used to record children's models and be included with other ICT applications when creating reports.

See **A Quick Guide to Gears** for additional information.

To answer the question on speed you may wish to introduce the idea of **gear ratios** at this point.

NOTE: The K'NEX Crank Fan model uses an **82**-toothed gear and a 14-toothed gear.

- The gear ratio 1:6 indicates that for every one turn of the driver gear, six turns are produced by the follower gear wheel. Or, said another way, the output speed is six times faster than the input speed. This is called **gearing up**.
- On the other hand, if a 14-toothed driver turns an 84-toothed follower gear we obtain a gear ratio of 84/14 or 6:1.
- This gear ratio indicates that the output will be 6 times slower than the input speed. This is called **gearing down**.

Extension Activity 2

Science: Unit 4E Friction

When the handle is turned and released the fan quickly stops rotating. If one gear wheel is removed and the fan spun, it will keep turning freely for a longer time.

- Ask the children to explain these observations.
- How might friction be reduced in machines?
- What is used in bicycles and in car engines to reduce friction?

Note: Oil cannot be used with plastic construction kits but liquid soap can act as a good lubricant and can be easily washed off later.

Plenary Session

Ask the children to describe and explain the movements and the function of the mechanism they have investigated.

Teacher's Notes

*You may want the children to think about when they have travelled in a car. The driver goes **up** through the gears to go faster (1,2,3,4,5) and goes **down** through the gears, to go slower (5,4,3,2,1).*

Lesson 3: The Car Window

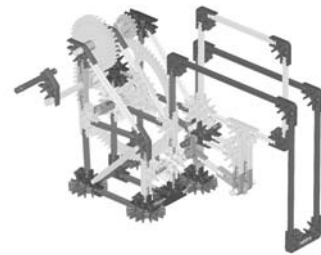
How to convert rotary motion into linear motion



Time: 1 hour

Learning Objectives - Children should learn:

- to investigate and disassemble products in order to learn how they work
- how to convert rotary motion into linear motion
- to communicate information about products and mechanisms through labelled drawings



Possible Teaching and Learning Activities

Whole Class

Introduction

Children are familiar with the action of opening and closing car windows - they turn a handle or press a button and the window goes up or down.

- But how does the window actually go up and down?
- What happens inside the door?

This lesson is about finding out how the mechanism operates.

Ask the children to look at the photograph on Page 4 of the K'NEX Introduction to Simple Machines: Gears Building Instructions booklet. Discuss the actions taking place in the opening of the car window. The children cannot see the mechanism in the photograph but encourage them to describe how they think it might work. You may find the following types of questions helpful.

- * **What types of movement are involved in this mechanism?**
- * **Can you identify the input and output movements.**
- * **How are the movements of the window controlled?**

Vocabulary

gear wheels, axle, handle, winder, gears, opposite, direction, clockwise, anticlockwise, faster, slower, rotate, rotary, linear, movement, motion, mechanism, input, output, driver, follower, gear ratio, gear train.

Resources

Each group of 2-3 children will need:

- 1 K'NEX Understanding Mechanisms: Gears Kit with Building Instructions booklet
- Dot stickers or pieces of masking tape
- Felt-tipped pens

You will need:

- A collection of devices and toys that use gears

Useful Internet Web Sites:

Please refer to Page 13 of A Quick Guide to Gears.

Teacher's Notes

- * **(i) Rotary motion when turning the handle/using the electric motor and (ii) linear motion by the window moving up or down.**
- * **The input movement is rotary motion by the handle and the output is linear motion by the window.**
- * **By turning the handle clockwise or anticlockwise; turning the handle fast or slow; reversing the switch.**

Possible Teaching and Learning Activities

Ask the children to talk about other examples of lifting and lowering mechanisms with which they may be familiar or which they have investigated in previous lessons. These may include: QCA DfEE Exemplar Scheme of Work for Design & Technology Units: 1A Moving Pictures; 2C Winding Up; 4B Story Books; 5C Moving Toys.

Would any of the mechanisms they have identified work in a car window mechanism? Ask them to explain the reasons for their suggestions.

Working in Groups of 2-3

Before the children build their K'NEX models and explore real mechanisms, explain that they may find it helpful to use a process, such as the one outlined here, for their investigations. This might involve:

- Identifying the parts of the model from 2D drawings
 - Naming the parts
 - Stating their functions in the model
 - Identifying the movements the parts will make
 - Building the model
 - Investigating
 - Determining whether or not their initial ideas were right
-
- Provide time for the children to make their K'NEX Car Window (Pages 4-5, Building Instructions booklet) and to investigate how it works.

- Ask each group to investigate:

* **The parts that move and how they are connected.**

* **Identify and name the input and output movements.**

Teacher's Notes

Interpreting 2D drawings to construct 3D models is an important skill for children to learn.

Undertaking this type of process will help the children's skill development.

Building Tips:

1. In Step 3 ask the children to pay careful attention to the placement of the blue Rod (with a free end) within the white Connector.

2. Joining Step 4 to the section built in Steps 1-3 may require more than one pair of hands.

You may want to write these questions/directions on the board. This will help focus the subsequent discussion concerning the children's findings.

* **Gear wheels that mesh together.**

* **Rotary and linear.**

Lesson 3: The Car Window

- * Why a small gear wheel is used as the driver to turn a large follower.
- * How they can control the speed of the output movement.
- * Why the handle turns many times but the window only rises very slowly.
- * Whether or not the mechanism will be easier to turn without the handle.
- * Ask the children to provide the technical name (other than handle) for the mechanism used to open and close the window.

Whole Class

- Use a K'NEX Car Window model to demonstrate how the model works/review the children's observations. This will provide an opportunity for you to reinforce existing terms and to introduce additional technical vocabulary and terminology.
- Ask the children to prepare and stick labels on their models to identify the key moving parts of the mechanism and the directions of movement. This activity may be of help later when they describe their observations and findings.
- As a review, you could ask for volunteers to take turns to describe, step-by-step, what occurs from the point where effort is applied to the handle, to the point where the window is raised. Use the following to start the explanation:
"Turning the crank handle anticlockwise causes the tan gear wheel to..."

Teacher's Notes

- * To slow the movement of the window and to increase the output force.
- * Turn the handle faster.
- * The mechanism is gearing down: the handle is attached to a small gear wheel that turns a large gear wheel.
- * Not easier – the long handle works in a similar way to a lever.
- * A crank.

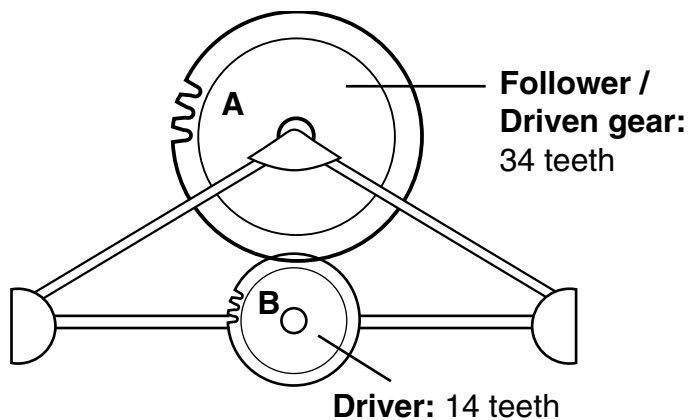
See: **A Quick Guide to Gears** and Teacher's Notes for Lesson 2: Crank Fan for additional information.

*As part of the demonstration and discussion you may find it useful to add any new terms that arise to the class **word wall**. These will help the children as they create labels, discuss their investigations, make labelled drawings and write descriptions.*

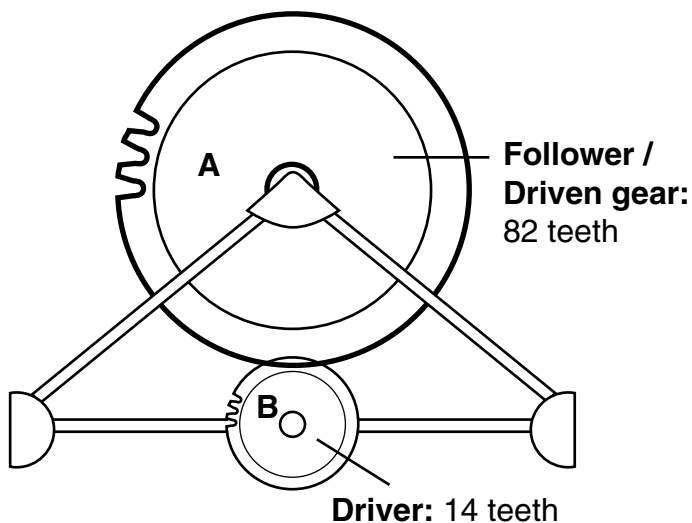
Words could also be written on cards, possibly with simple descriptors on the reverse side.

*The window is operated by a simple crank system (the handle), which turns the first of two **simple gear trains** inside the door. These gearing mechanisms are designed to slow up the final output movement of the window.*

Gear Train 1



Gear Train 2



- Ask the children to investigate how the window is moved by the second gear train.
- How is the motion of the window different from the motion of the handle/winder and the gears?

This slowing is called *gearing down*. In the first gear train, a small (tan) driver gear (14-teeth) drives a larger (yellow) follower gear (34-teeth), while in the second gear train another 14-tooth gear drives a large 82-toothed gear. This twofold slowing down process causes the large 82-toothed gear to move very slowly. A consequence of this slowing or gearing down is to increase the turning forces available to lift the heavy glass window.

As a **possible extension activity** you might ask the children to observe how many times the 14-toothed tan driver gear wheel must be turned to make the 34-toothed yellow follower gear wheel turn once – approximately two and a half turns. This number gives an approximate measure of the gear ratio of this part of the mechanism. In this case the gear ratio is 2.5:1, which indicates that the input speed is two and a half times faster than the output speed. Put another way, the output speed is two and a half times slower than the input speed.

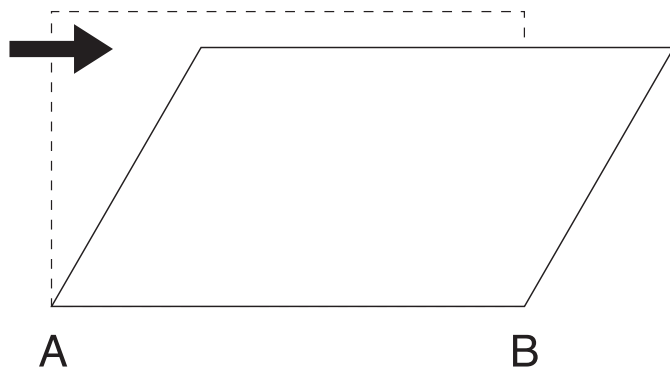
In the second gear train, the small tan driver gear would have to turn approximately 6 times to turn the very large yellow follower gear once. In this case the gear ratio will be 6:1. The window opening mechanism, however, will not allow one complete turn of the large yellow follower gear wheel to be made.

See: **A Quick Guide to Gears** and Lesson 2: Crank Fan for additional information.

Teacher's Notes

The window is raised using a lever arm connected to the axle of the largest yellow gear wheel. As the yellow gear wheel turns, the

Lesson 3: The Car Window



Principle of Parallel Linkage

- Ask the children to record their observations and results using labelled drawings and notes. They should make use of the correct vocabulary and terminology to show how the window opening mechanism works. They should use arrows to show the direction of movement.

Extension Activity 1

- Ask the children to discuss why it is important for a car window to move slowly.
- Would the children allow the K'NEX model design for a car opening mechanism to be used in a car? They should explain their reasons.
- Ask the children to consider how using thicker glass would affect the design of the car window mechanism.
- Many modern cars have electric windows. What important safety features should be included in the design of the window opening mechanism? Think about who might be using the car, where they might be sitting and whether or not they are able to operate the window controls.

Plenary Session

Ask the children to discuss and explain the movements and the function of the mechanism they have investigated.

window arm moves up and down. The movement of the arm raises and lowers the window. Notice how the vertical part of the window raising mechanism always stays vertical. Its motion is linear while the handle and gears rotate.

This mechanism is an example of a linkage. A linkage is an important control system because it allows forces and movements to be transferred. It also changes the direction of a force or makes things move in a particular way. Calliper brakes on bicycles, treadle sewing machines and toolbox drawers that stay level when opened are examples of linkages.

Linkages based on a parallelogram can be used to make two sides move together or stay parallel to each other as the linkage moves. See diagram opposite.

Teacher's Notes

Using thicker glass means that the window will be heavier. The gear mechanisms may need to be modified to produce a greater output force.

To promote the wider use and application of ICT skills and practices, the children's models and work can be recorded using a digital camera.



Lesson 4: Blender

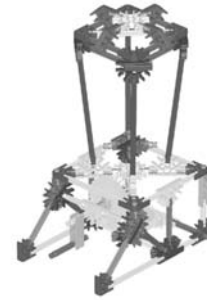
How to change the direction of rotary motion through 90-degrees



Time: 1 hour

Learning Objectives - Children should learn:

- to investigate and disassemble products in order to learn how they work
- how to change the direction of rotary motion through 90-degrees
- to communicate information about products and mechanisms through labelled drawings.



Vocabulary

gear wheels, axle, handle, winder, gears, clockwise, anticlockwise, faster, slower, rotate, rotary, crown gear, right angle, 90-degrees, vertical, horizontal, spur gear, mechanism, input, output, driver, follower, gear ratio, gear train

Resources

Each group of 2-3 children will need:

- 1 K'NEX Understanding Mechanisms: Gears Kit with Building Instructions booklet
- Dot stickers or pieces of masking tape
- Felt-tipped pens

You will need

- Food blender
- Ingredients for blending

Useful Internet Web Sites:

Please refer to **A Quick Guide to Gears**, Page 13.

Possible Teaching and Learning Activities

Introduction

Whole Class

- Talk about how, in the preparation of food, some ingredients may need to be chopped up into small pieces. Demonstrate the process using a knife and using a blender and discuss the needs, advantages and disadvantages of both processes.
- Demonstrate how a real blender works and talk about:
 - The different uses of blenders and how different materials are used in the blender for different purposes. For example: metal blades for cutting, plastic or glass for the container and plastic for the body of the blender (to cover the electrical components).

Teacher's Notes

This activity may also provide an opportunity to talk about the aesthetics and functionality of the blender design.

- What do the children like or dislike about the design? Shape? Colour? Noise? Can they provide reasons for their opinions?
- What important safety issues must be considered in the design of equipment that handles food?

Lesson 4: Blender

- How some blenders use different speed settings in order to chop, beat or homogenize the food.
- Explain to the children how they will investigate one possible mechanism to operate the cutting blades of a blender. Their blender will be hand operated.
- Review with the children the way in which the spur gear system in their K'NEX Crank Fan could either change the output **speed** or change the output **force**. Explain that a spur gear is just one type of gear arrangement. In the blender they will encounter a different arrangement that carries out a different job.

Working in Groups of 2-3

Before the children build their K'NEX models and explore real mechanisms, remind them that they may find it helpful to use a process, such as the one outlined here, for their investigations. This might involve:

- Identifying the parts of the model from the 2D drawings
- Naming the parts
- Stating their functions in the model
- Identifying the movements the parts will make
- Building the model
- Investigating
- Determining whether or not their initial ideas were right



Ask the children to build their K'NEX Blender model (Pages 6-7, Building Instructions booklet) and provide them with some time to investigate, record and discuss how the mechanism works.

- To help the children see the directions of movement of each gear wheel they might place a dot sticker or piece of masking tape on each one and an arrow to show the direction of movement.

- *What important safety issues are there for the user?
Electrical precautions?
Sharp cutting tools?
Precautions required if operated by children?*

Teacher's Notes

Interpreting 2D drawings to construct 3D models is an important skill for children to learn.

Undertaking this type of process will help the children's skill development.

You may want to write the following questions/directions on the board. This will also help focus the subsequent discussion concerning the children's findings.



- Children may be encouraged to think about and discuss what they are doing through facilitating questions such as:

- * Identify and describe the parts that move and explain what they do.
- * Identify the parts that move in a vertical plane and those that move in a horizontal plane.
- * How are the moving parts connected so that they create the change in direction of movement?
- * Identify and name the input and output movements.
- * Where does the output motion take place?
- * Identify the driver and follower gears.
- * What is the direction of rotation of the driver and follower gears?
- * How is the speed of the output movement controlled?
- * Why does the handle rotate at the same speed as the cutting blades?
- * Will the mechanism be easier to turn without the handle?
- * Does this gear system change speed, force or direction of motion?

Teacher's Notes

- * Gear wheels move. They transfer rotary movement and force.
- * Crank: vertical; 1st gear: vertical; 2nd gear: horizontal; blades: vertical.
- * The crown gear wheel meshes at right angles to another smaller spur gear; this changes the direction of motion so that one gear turns vertically and the other horizontally.
- * Rotary in and rotary out.
- * It occurs at the chopping blades.
- * The driver gear is attached to the handle and the follower gear moves the cutting blades.
- * Clockwise /anticlockwise.
- * By turning the handle faster.
- * The gear wheels are the same size.
- * No.
- * It changes the direction of motion.

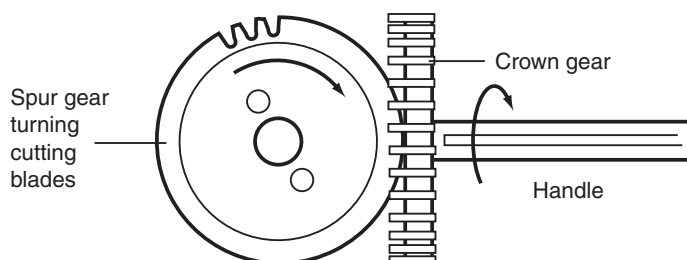
Lesson 4: Blender

Whole Class

- Using a K'NEX Blender model, demonstrate and introduce/reinforce the vocabulary the children should use when describing the working of their model. For example: **input and output, mechanism, driver, follower and crown gear wheel mechanism.**
- Explain to the children that they have been exploring a **crown gear system**. This gear system is used to change the direction of motion. Ask them to take one of the spare gear wheels from the kit and suggest a reason why the name “crown” is used.



Using the K'NEX Blender model as an example, demonstrate on the board how to make simple labelled drawings, using arrows to show the direction of movement. For example:



Teacher's Notes

You may need to demonstrate how the yellow gears have “teeth” that are set at 90-degrees to the surface of the gear wheel.

Looked at from its side the gear wheel looks like a crown – hence its name: **crown gear wheel**.

These teeth, at right angles to the surface of the wheel, mesh with those on the rim of a second gear wheel to give the 90-degree change in direction.

The follower or driven gear is sometimes called a pinion and the mechanism is called a crown gear wheel and pinion.

Other gear wheels, whose teeth are around the rim, are called **spur gears** – because they look like the rowels on a horse rider's spurs.

As part of the demonstration and discussion you may find it useful to add new terms to the class word wall to help the children when they create labels, when discussing their investigations and when making labelled drawings and writing descriptions.

Words could be written on cards, possibly with simple descriptors on the reverse side.

See: **A Quick Guide to Gears** for additional information.

Working in Groups of 2-3

Ask the children to record their observations and results using labelled drawings and notes. They should employ the correct vocabulary and terminology to show how the mechanism works. Their drawings should have arrows to show the direction of movement.

Whole Class

Talk about how the model is constructed and how the components are joined together to create a stable structure.

- Why is it important for the blender to have a stable structure?
- How is this achieved in the real life example?
- Where is heaviest part of the blender to be found?

Extension Activity

Talk about other familiar mechanisms that can produce a similar change in direction and the types of machines that make use of them. For example:

- Egg whisks have a large central gear wheel that is used to produce two outputs. The whisks have to turn very fast to make an effective whisking action. Hand drills often use **bevel** gears, while adjustable spanners use worm gears. Bevel gears have their rims bevelled to an angle of 45-degrees so that when the gear teeth mesh they form a 90-degree angle. Hand drills have a slow output movement to enable the cutting action of the drill to be controlled. Compare this type of movement with that of the egg whisk mechanism.



- Pulley wheels also change the direction of movement – a pull down results in a pull up.
- Round belts twisted through 90-degrees are used in some vacuum cleaners where the motor and brushes are at 90-degrees to each other.

Plenary Session

Ask the children to explain the movements and the function of the mechanism they have investigated.

Teacher's Notes

To promote the wider use and application of ICT skills and practices, the children's models and work might be recorded using a digital camera.

*Building instructions for a K'NEX model of an **egg whisk** are provided on Pages 10-11 of the Building Instructions booklet. You may want to use this model as an enrichment activity.*

Lesson 5: The Stationary Exercise Bicycle

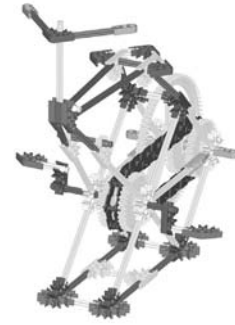
How to transfer motion and forces using a chain and sprocket mechanism



Time: 1 - 1.5 hours

Learning Objectives - Children should learn:

- to investigate and disassemble products in order to learn how they work
- how to transfer motion and forces using a chain and sprocket mechanism
- to communicate information about products and mechanisms through labelled drawings



Possible Teaching and Learning Activities

Introduction

Whole Class

- Review with the children the ways in which gears are connected and how motion and forces are transmitted through a gear system.
- Talk about the differences they have identified between spur gears and crown gears. The spur gear system changed the output speed or amplified the output force. The crown gear system changed the direction of motion through 90-degrees. In both cases, however, the gears meshed or touched each other.
- Explain that in this lesson they will explore another type of gear system, one in which the gears do not touch each other. This gear arrangement is the system that is used in bicycles. Explain that they will examine how it operates in a **stationary exercise bicycle**.
- Talk about how people need to exercise to keep fit and healthy.
 - What sort of activities do the children take part in to keep themselves fit?
- Many people use fitness clubs with specially designed machines.
 - Ask the children to identify different types of exercise machines.
 - What parts of the body are the exercise machines designed to exercise?
 - How do they meet this need?
- Cycling is a healthy and very popular activity, but until the development of the stationary exercise bicycle it was not possible to do it indoors.
- Discuss how the stationary exercise bike design is based on a 2-wheeled bicycle.

Vocabulary

axle, handle, crank, gears, sprocket, chain, chain drive, rim, opposite, clockwise, anticlockwise, faster, slower, rotary, movement, motion, mechanism, input, output, driver, follower, gear ratio, gearing up, gearing down, speed, modify

Resources

Each group of 2-3 children will need:

- 1 K'NEX Understanding Mechanisms: Gears Kit with Building Instructions booklet
- Dot stickers or pieces of masking tape
- Felt-tipped pens

You will need

- Stationary exercise bicycle (or the K'NEX model) and/or a bicycle

Useful Internet Web Sites:

Please refer to **A Quick Guide to Gears**, Page 13.

- If possible, provide an example of an exercise bike (you could use the K'NEX model) or a bicycle for the children to investigate. Alternatively, ask the children to look at the photograph on Page 12 of the Building Instructions booklet to interpret how they think the mechanism works.
- Children may be encouraged to think about and discuss what they are doing through facilitating questions such as:
 - What does the machine do?
 - How well does it do the job it is designed to do?
 - What are the functions of the moving parts?
 - How are the moving parts connected? How do they make other parts move?
 - What are the moving parts called?
 - What stops the bike from falling over?
 - Where does the power come from to drive the bicycle?
 - How is the power transferred to the drive wheel?
 - When riding a bicycle, in which gear is it hardest to push the pedals round?
- As they describe its workings, encourage the children to use terms they already know that are associated with a bicycle's gear system.

Working in Groups of 2-3

- Ask each group to build and investigate their K'NEX Stationary Bike model (Pages 12-13 of the Building Instructions booklet) and provide time for them to investigate their model.

Whole Class

- Using a stationary bike model/bicycle, demonstrate and explain the **input and output movements, pedal, sprocket, chain drive mechanism, links, driver, follower/driven gear, and axle.**

Teacher's Notes

Write the questions you want the children to investigate on the board for reference and post activity discussions.

Foot power, via the pedals

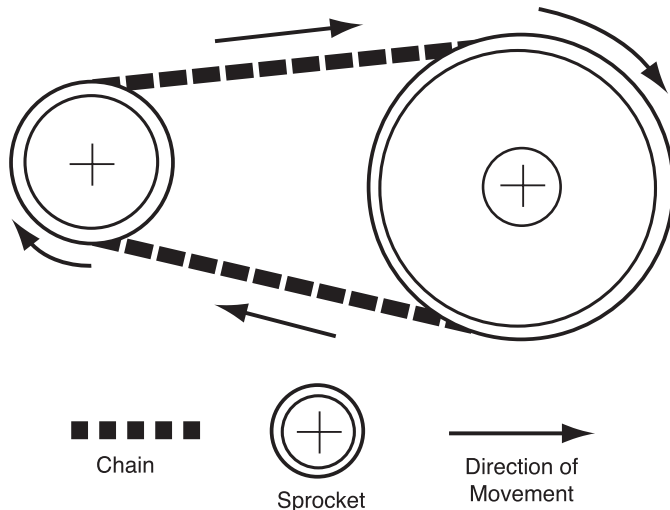
By a chain and sprocket mechanism.

The highest gear.

As part of the demonstration and discussion you may find it useful to add new terms to the class word wall to help the children as they create labels, discuss their investigations, make labelled drawings and write descriptions. Words could be written on cards, possibly with simple descriptors on the reverse side.

Lesson 5: The Stationary Exercise Bicycle

- With the model as an example, demonstrate on the board how to make simple labelled drawings, using arrows to show the direction of movement. The diagram below, for example, could be used as a symbolic representation of a chain and sprocket drive system.



The chain and sprocket drive system uses a chain to transmit rotary motion from a driver axle to a follower or driven axle. Sprockets are toothed wheels on which a chain runs. The sprockets are placed a certain distance apart and the chain links mesh with the teeth on the sprocket so that turning the driver sprocket moves the chain and thus turns the driven or follower sprocket.

Spur gears must mesh to transmit movement but with a chain drive mechanism the distance between sprockets can be adjusted by shortening or lengthening the chain.

See **A Quick Guide to Gears** for additional information.

- Encourage the children to record their observations through the use of labelled drawings and notes. They should employ the correct vocabulary and terminology to show how the chain and sprocket drive mechanism works. They should use arrows to show the direction of movement and indicate the speeds of movement of each sprocket.
- Children should:
 - Describe the parts that move and their function.
 - Show how the gears are connected to transfer the drive force from the pedals to the rear wheel.
 - Identify and name the input and output movements.
 - Identify the direction of rotation of the pedals and rear wheels. Use the terms clockwise/anticlockwise.
- Ask the children to respond to the following questions using the word, "because..."

- * **Do the pedals rotate at the same speed as the rear wheel?**
- * **Do the pedals and rear wheel turn in the same direction?**

To help the children see the directions of movement of each moving part they might place a dot sticker or piece of masking tape on each sprocket and one on the chain.

The teeth on the sprockets mesh with the chain links and push it along when they turn. The chain connects the two sprockets.

- * **Yes, because the sprockets are the same size.**
- * **Yes.**

* **Will the mechanism be easier or more difficult to turn without the pedals?**

Whole Class

- Discuss how the pedals on a bicycle are similar to the handle (crank) in a winding mechanism and in the other K'NEX models they have made, such as the crank fan, blender and record player.
- Would longer pedal cranks be easier to turn?
- Would it be a good idea to have longer pedals on a bicycle? If not...why not?
- Talk about the differences and similarities between sprocket and chain drive mechanisms and simple gear trains.
- Ask the children if they can think of one reason why a bicycle uses a chain and sprocket system and not a spur gear system.



* **More difficult because a pedal functions just like a crank handle in a winding mechanism. It helps to amplify turning forces.**

Teacher's Notes

Bicycle pedals are another example of a crank, identical in practice to the handle operating the K'NEX Crank Fan model. Cranks work as if they are rotating levers. Remember that long levers allow you to create large turning forces.

You may find it useful to have a K'NEX Crank Fan model available to compare with the children's K'NEX Stationary Bike models. Both models use the same sized driver and follower gears. In both cases the number of input turns by the pedal crank will equal the number of output turns produced by the wheel. In other words the gear ratio in both drive systems is 1 to 1.

The main differences are:

(a) The direction of rotation. In the stationary bike's chain and sprocket mechanism, both driver and follower rotate in the same direction, whereas in the K'NEX crank fan model – a simple gear train using spur gears – the gears rotate in opposite directions. If a spur gear system were used on a bicycle you would need to pedal backward in order to move forward.

(b) In the chain and sprocket mechanism the rotary motion is transmitted over a longer distance, determined by the length of the chain, whereas spur gears must mesh.

Lesson 5: The Stationary Exercise Bicycle

- Ask for volunteers, taking turns, to summarize the way in which motion is transferred through the stationary bike system. The first volunteer should start the description at the pedals and the last volunteer describes what happens at the rear wheel.

- Discuss how they might modify their stationary bike's drive mechanism to make it harder to push the pedals. This would make the person exercising on the bike work harder. They should be prepared to explain the reasons for their proposed modifications.
- Refer the children to:
 - The photograph on Page 12. Do the sizes of the wheel casings give them a clue?
 - The outcomes of their investigations using the K'NEX Crank Fan model.

Extension Activity 1

If time is available, ask the children to modify their bike models to meet the new specification.

Plenary Session

Ask the children to explain the movements and the function of the mechanism they have investigated.

What would they do to improve the stationary exercise bike design?

Teacher's Notes

Turning the pedals transfers motion and energy through the driver axle to the sprocket at the front of the bike (driver sprocket). As the front sprocket turns, motion is transferred to the chain. The chain transfers motion and energy to the rear sprocket (follower sprocket). The turning of the follower sprocket turns the rear wheel.

(i) One possible way is to make the driver sprocket larger. This will cause the back wheel to turn much faster but it will need more effort to turn the pedals – just like using a high gear on a bicycle.

(ii) A second way might be to make the pedal cranks shorter. Because a crank acts like a rotating lever, a short lever will not be able to amplify forces as much as a long lever. More effort, therefore, will be needed to turn the pedals.

There are not enough K'NEX components in one kit to do this activity. Two groups of children will have to work together.

At the end of the lesson ensure that the parts are returned to the kits from which they were taken and that the children check the contents of each kit.

Key Technical Terms and Scientific Definitions



*This list of key terms is intended as background information. While we recognize that some of these terms are not fundamental to National Curriculum requirements for Key Stage 2 Design and Technology and Science, we have nevertheless included them here to help you better understand some of the concepts investigated in the **K'NEX Understanding Mechanisms** kits.*

SIMPLE MACHINE

A simple tool used to make jobs easier to do. For example, a lever allows you to apply a small force to move a much larger load. Try pulling a nail out of a piece of wood without a claw hammer. A claw hammer uses the lever principle in its design. Other examples of simple machines are wheels and axles, pulleys, inclined planes or ramps, wedges, and screws.

Simple machines can be used to increase forces or change the direction of a force needed to make an object move. They are simple because they transfer energy in a single movement. Simple machines make it easier for you to do jobs by changing the **way** in which jobs can be done; they cannot change the job to be done. For example, you can load a heavy object onto the back of a lorry by lifting it the short vertical distance – a process that will require a lot of effort. Alternatively, you can take the longer but easier route up a ramp with the object. Either way, the job is done.

In science, when an object is moved by a force **work** is said to have been done. Simple machines make it easier for you to do work. Some simple machines allow a small force to move a large load and are called **force amplifiers**. For example: crowbars and wheelbarrows. Other simple machines can be used to convert small, slow movements into large, faster movements. Such machines are **distance or speed amplifiers**. A fishing rod used to cast a hook, or a mediaeval throwing machine, such as a trebuchet, are examples of this application.

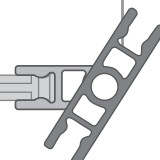
COMPOUND MACHINES

These have two or more simple machines working together in their mechanism. For example, two 1st Class levers make up a pair of scissors, or pliers, while a complex car engine may be made from several hundred mechanisms.

WORK

Work is a scientific concept and is only done when a force moves an object in the same direction as the applied force.

If you push against an object and it does not move then, from a scientific point of view, you will not have done any work. For example, no matter how hard you push in an attempt to move a car while its brakes are on, you will have not done any work if it has not moved. Once, however, the brakes have been released and the car starts to move, then you will be doing work. The amount of work you do depends on the magnitude of the force you apply and the distance you move the object.



gears

website: www.knexeducation.co.uk

Key Technical Terms and Scientific Definitions

$$\text{Work} = \text{Force} \times \text{Distance moved by the object in the direction of the force}$$

or

$$W = F \times d$$

If the force is measured in **newtons** (symbol **N**) and the distance is in **metres** (**m**) then the **work done** (**W**) is measured in **newton metres** (**Nm**).

The SI unit of work is the **joule** (**J**) and **1 joule = 1 newton metre**.

FORCE

A force is a push or a pull which, when applied to an object, can make it change shape, move faster or slower, or change direction. You cannot see forces but you can feel or see their effects.

A force has both size and direction. The size of a force is measured in **newtons** (**N**) and can be measured using spring balances called **force meters** or **Newton meters**.

EFFORT

The force you apply to move one part of a simple machine, i.e. the **input force** that is applied to a simple machine, or mechanism, to make it do work. With a wheel and axle simple machine, the effort force can be applied to either the wheel, or the axle, in order to make the other part move. Think of a waterwheel being turned by a millstream or a car axle driving the road wheels. The function of a simple machine, or mechanism, is to transfer the force both to the location and in the direction in which it is needed to move the **load**.

LOAD

The **weight** of an object to be moved or the **resistance** that must be overcome before an object can be moved.

The resistance can be the **frictional forces** in a mechanism itself or simply the **friction** between two surfaces.

RESISTANCE

The force that works against the effort. It could be either the weight of the object to be moved and/or frictional forces.

FRICTION

The force that occurs when two surfaces rub against each other. Friction tends to slow things down, which means it can be both beneficial and unhelpful. For example: friction is beneficial in the case of brakes applied to the wheels of cars and bicycles to slow them down, but friction between surfaces can also cause wear - tyres wear out. Rough surfaces increase friction, while smooth surfaces reduce it.

Friction also generates heat. You can feel this when you rub your hands together quickly.

MECHANICAL ADVANTAGE

Most machines are designed to make jobs easier to do. For example, a wheelbarrow that allows you to move a heavy load of soil or a winch used to lift a heavy object. When a machine enables you to use a small effort to move a large load, that machine has given you a “mechanical advantage” you would not otherwise have had. How large or small a mechanical advantage a machine provides can be measured by comparing the load you can move with the effort you used to move it.

The calculation used is:

$$\text{Mechanical Advantage (MA)} = \frac{\text{Load}}{\text{Effort}}$$

The mathematical calculation indicates how many times the machine multiplies the effort force.

For example, if a machine allowed you to move a load of 300N using a 100N effort force, the mechanical advantage of the machine will be 3:1 or simply 3.

If the value of the MA is greater than 1 then your machine allows you to move a large load using an effort force less than that of the load. Does this mean you can get something for nothing? Can you get more from less? Unfortunately this is not the case. While a high MA value means you can use less effort force than that of the load to be moved, the distance moved by the effort will be much greater than that moved by the load. This is the trade-off.

Remember, simple machines and mechanisms can make it easier to do a job by changing the way in which the job is done; they do not change the actual job to be done. The work needed to be done will always remain the same, so that to move a load, you can use a large effort applied over a short distance, or a small effort applied over a longer distance. It all balances out in the end.

MECHANISMS

Although designed and made to do different jobs and make jobs easier to do, all mechanisms share some common features.

- They are made from simple machines, either used singly or in combination.
- They involve some form of motion.
- They need an input force to make them work.
- They produce an output force and motion of some kind.

Key Technical Terms and Scientific Definitions

TYPES OF MOTION

4 basic forms of motion are used in mechanisms:



- **Rotary:** This can be seen in the movement of car, bicycle and gear wheels and in Ferris wheels or carousels as they go round and round on an axis. It is the most commonly occurring type of motion in a mechanism.



- **Oscillating:** This is an alternating, or swinging to and fro, type of motion. It can be observed in car windscreen wipers, children's swings or in pendulums as they move backwards and forwards in an arc.



- **Linear:** This is motion occurring in a straight line, in one direction. Examples include the linear movement of a paper trimmer, a sliding lock, or a conveyor belt.

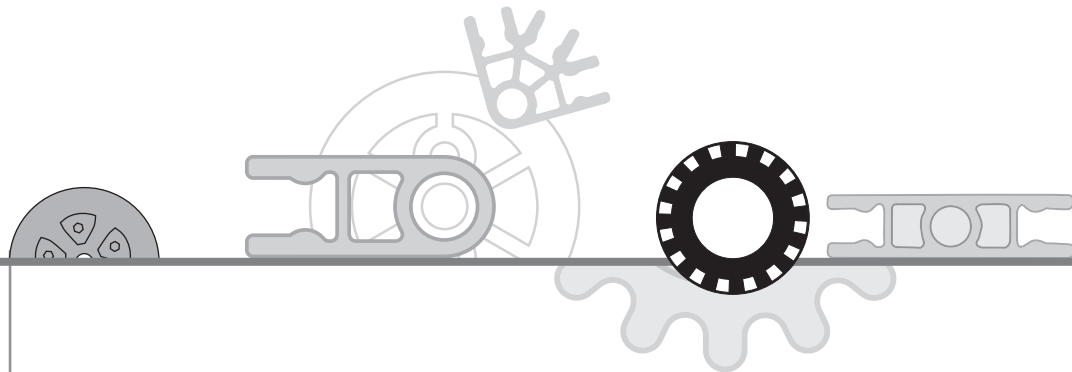


- **Reciprocating:** This involves an alternate backward and forward motion, in a straight line, as in the movement of a sewing machine needle or the pistons of a car engine.

One form of motion (**input**) can be converted into another (**output**) through the use of a **mechanism (process)**.

TYPES OF SIMPLE MACHINES

- **Lever:** A rigid beam, bar or rod that turns, or rotates, about a fixed point called the fulcrum. For example: a child's seesaw.
- **Wheel and axle:** A round disk (wheel) with a rod (axle) rigidly connected through the centre of the wheel so that they both turn together. A wheel can be used to turn an axle or an axle can be used to turn a wheel. For example: a winch raising a bucket from a well. The wheel can be a solid, circular disk, such as a car wheel, but it can also be the circular path made by a handle that turns, such as a lever rotating around a fixed point.
- **Gear:** This is not a simple machine but it could be thought of as a wheel with teeth around its outer rim. Gears are used to transfer motion and force from one location to another, change the direction of rotational motion and amplify the force applied to do a job.



• **Pulley:** A wheel with a groove in its outer rim that spins freely on an axle. A rope, cable, or chain runs in the wheel's groove and may be attached to a load. As the wheel turns, the rope moves in either direction so that a pull down on one side will raise an object on the opposite side of the wheel.

• **Fixed Pulley:** A pulley attached to a solid surface; it does not move when the rope is pulled, other than to turn in place. Fixed pulleys change the direction of an applied force.

• **Movable Pulleys:** A pulley attached directly to the load being lifted; it moves when the rope is pulled.

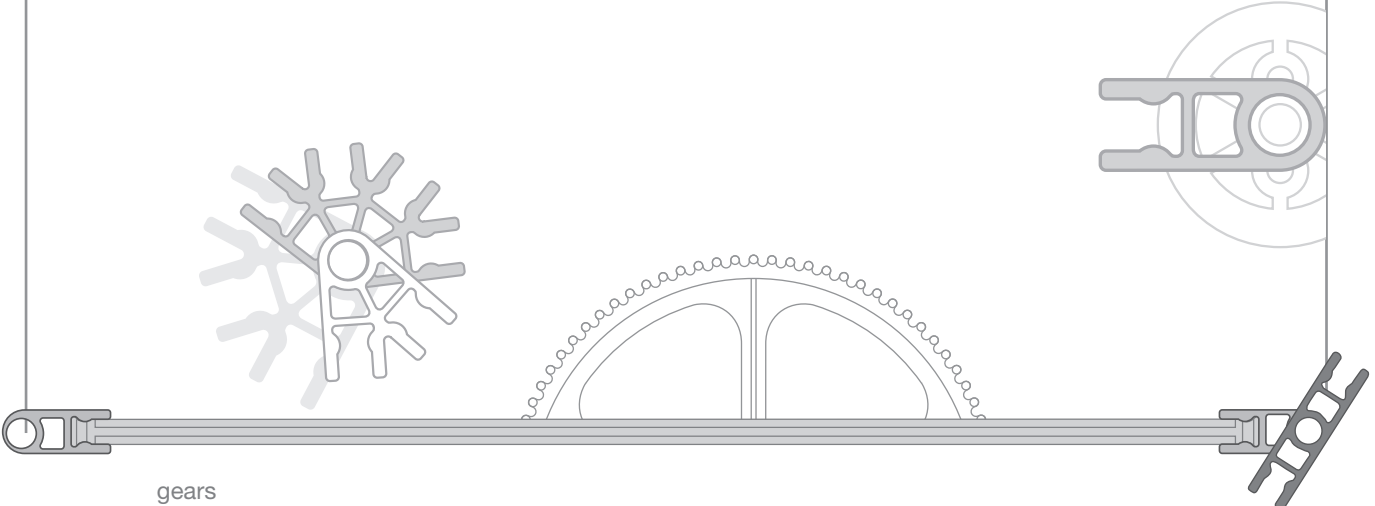
• **Combination Pulleys:** A series of fixed and movable pulleys used together to gain the advantages of both in doing the work.

• **Block and Tackle:** A specific combination of fixed and movable pulleys used to lift very heavy objects; the block is the frame holding the pulleys; the tackle is the rope or cable.

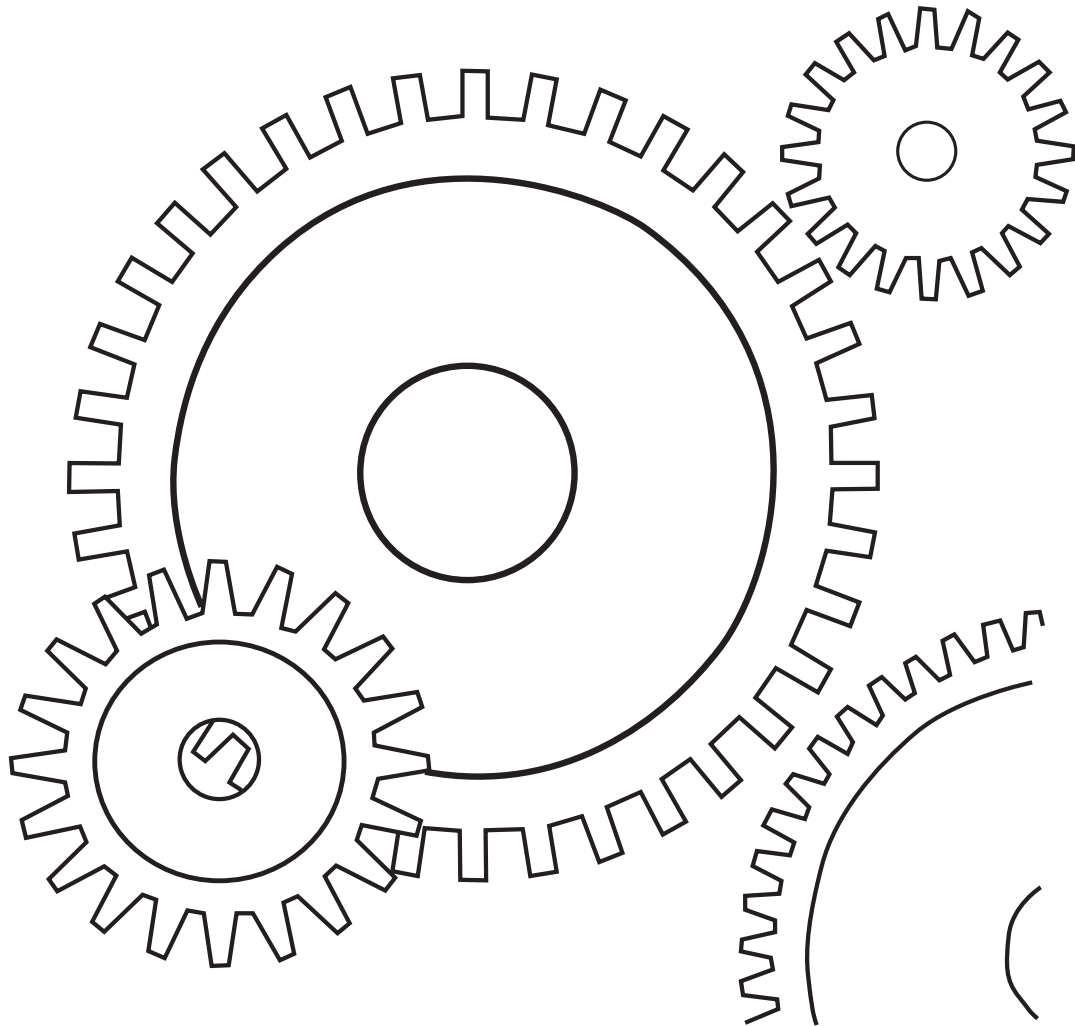
• **Inclined Plane:** A flat surface with one end higher than the other. The most recognisable form of an inclined plane is a **ramp**. Ramps make it easier to move from one height to another.

• **Screw:** A shaft (body) that has an inclined plane spiralling around it. The inclined plane forms ridges (threads) around the shaft to become another simple machine: the screw. It can be used to lift objects or fasten two things together.

• **Wedge:** A device made of two inclined planes arranged back-to-back. Instead of moving up the slope, wedges themselves move to push things apart. Wedges are inclined planes that move pointed-end first and are used in many cutting tools such as axes, knives and chisels.



Gears: Changing direction, speed, and force...

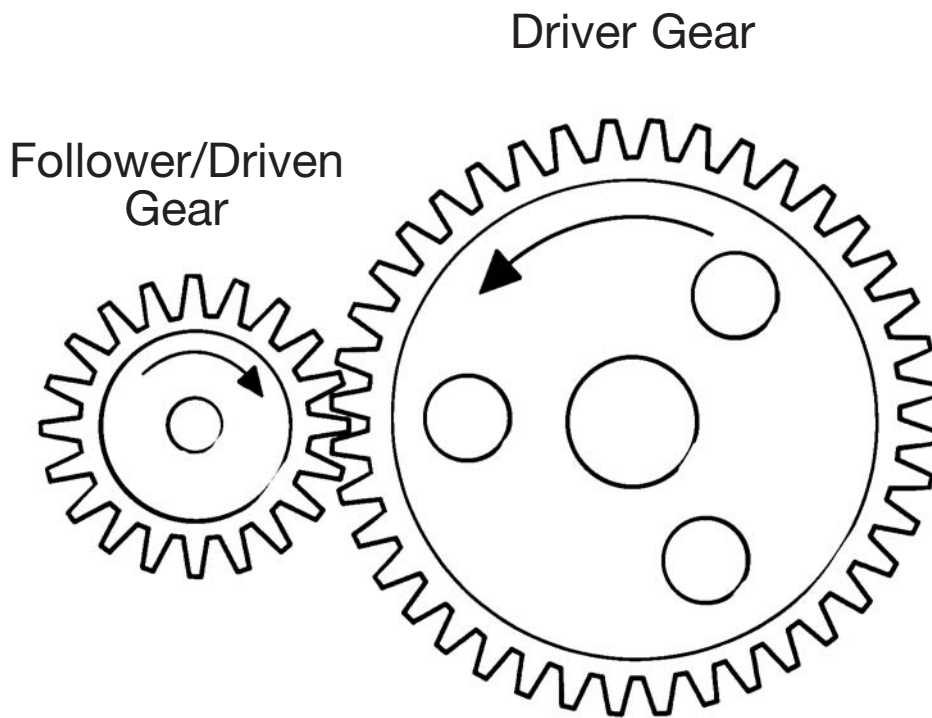


A gear is a wheel with teeth along its outer rim.

Gears can:

- Change the **DIRECTION** in which something moves.
- Change the **SPEED** at which something moves.
- Change the **FORCE** needed to make something move.

Gears: On the move



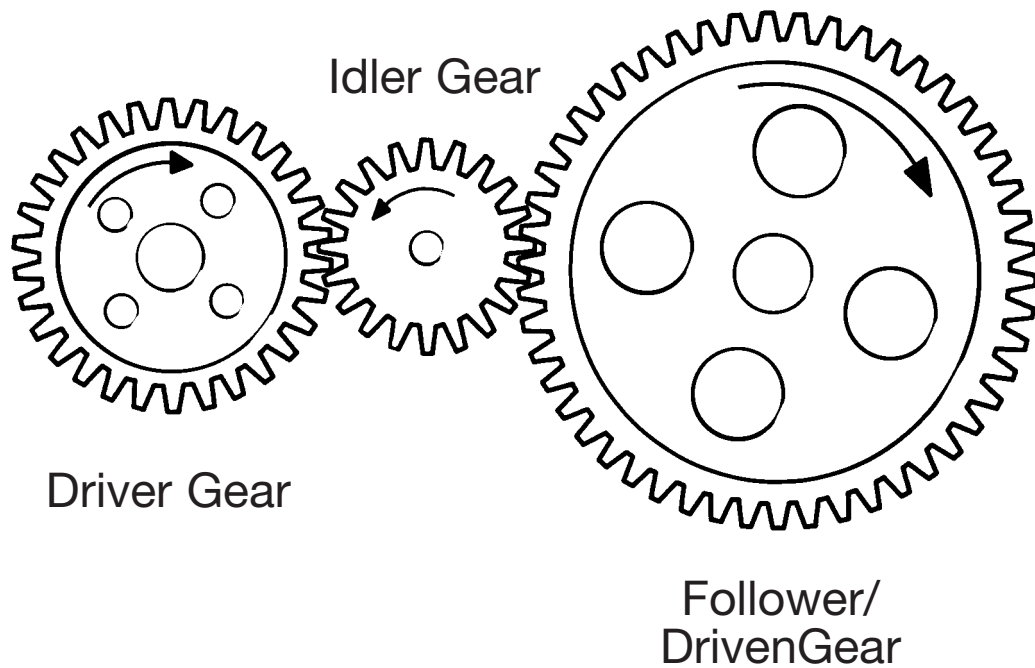
DRIVER GEAR:

The gear to which the effort force is applied.

FOLLOWER/DRIVEN GEAR:

The gear connected (meshed) to the driver gear.

GEAR TRAINS: Changing the direction of rotation...

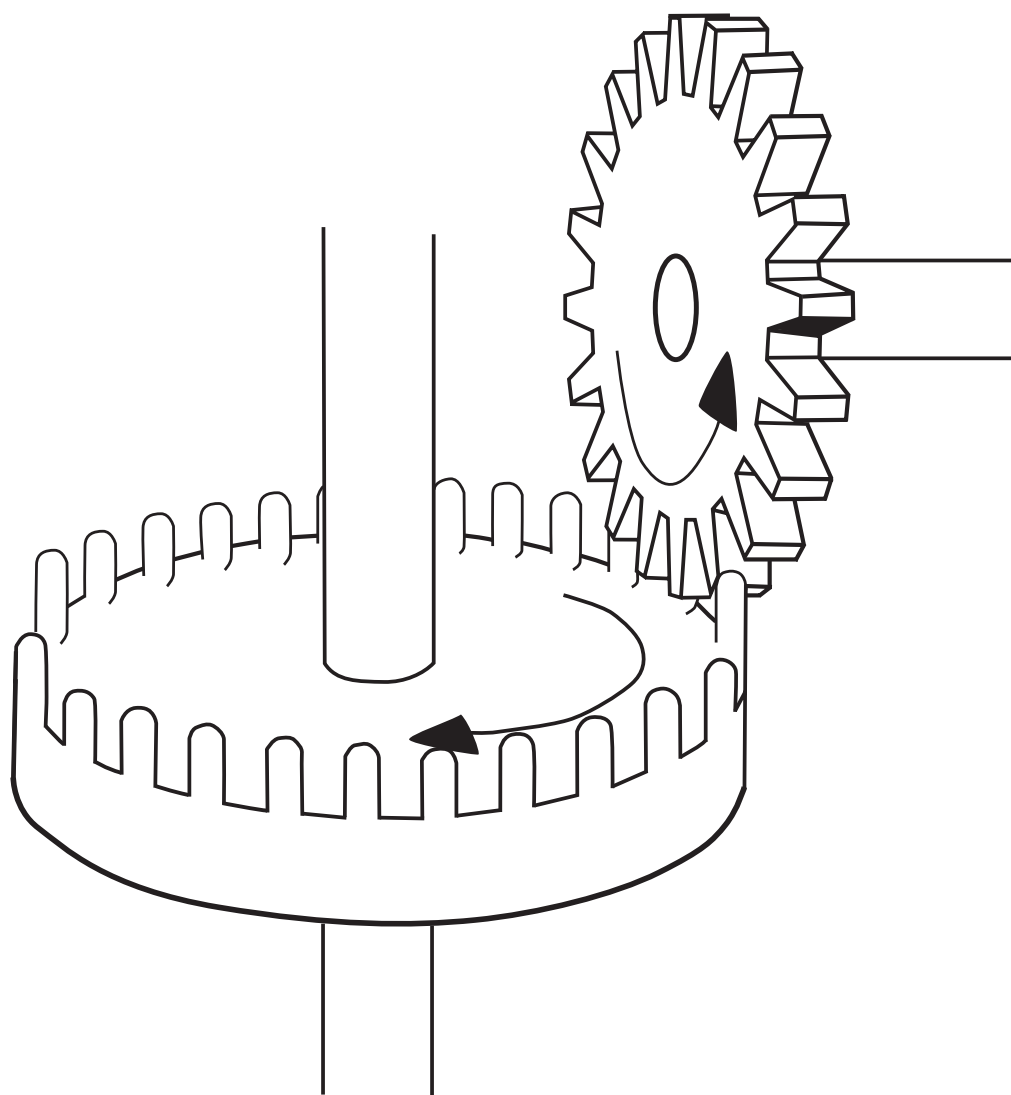


Two or more gears meshed together make up a gear train.

Meshed gears turn in opposite directions.

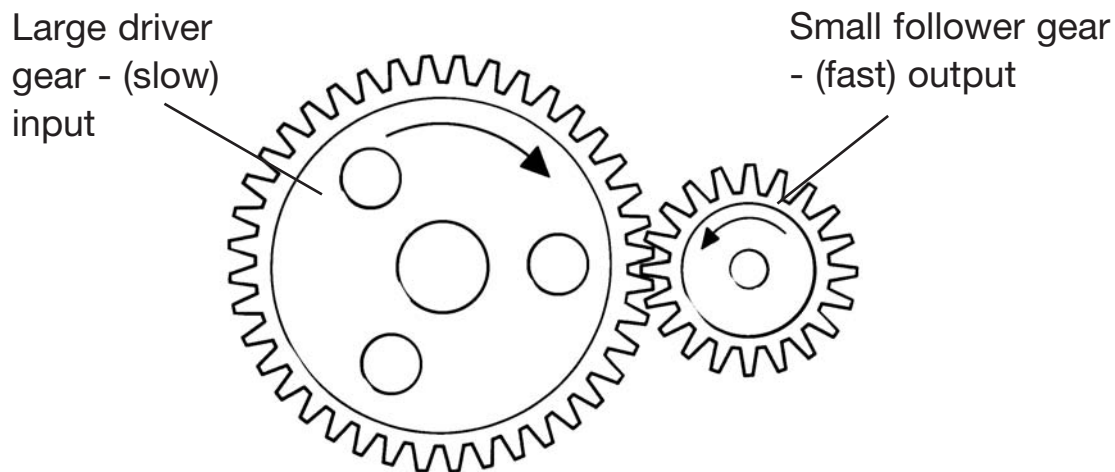
An idler gear makes the gears on either side of it turn in the same direction.

CROWN GEARS: Changing planes...



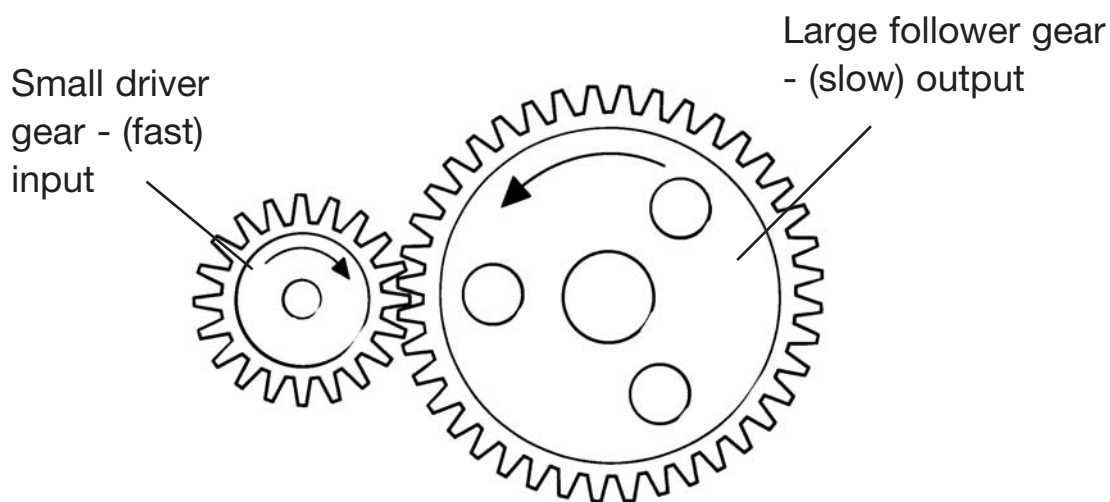
A crown gear meshes at right angles (90-degrees) to another gear and changes the direction of motion. One gear turns vertically (up and down), while the other turns horizontally (side to side).

GEAR TRAINS: Changing speed and force



SPEEDING UP/GEARING UP:

A large driver gear makes a small follower gear turn faster. This increases turning speed, but reduces turning force.



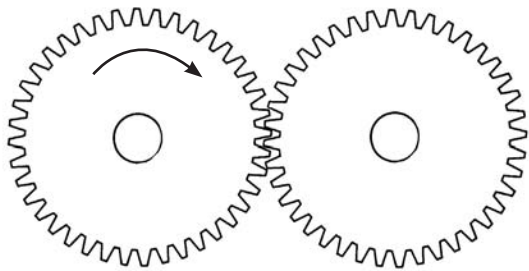
SPEEDING DOWN/GEARING DOWN:

A small driver gear makes a large follower gear turn more slowly. This reduces turning speed, but increases turning force.

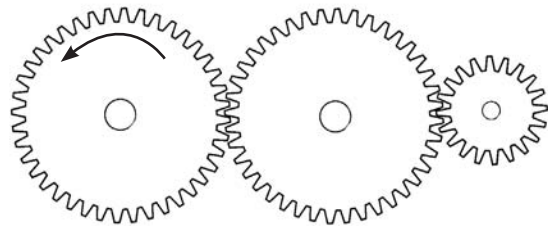
GEARS: Try This ...

Which way will these gears turn?

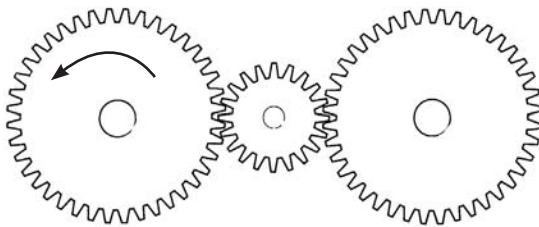
a)



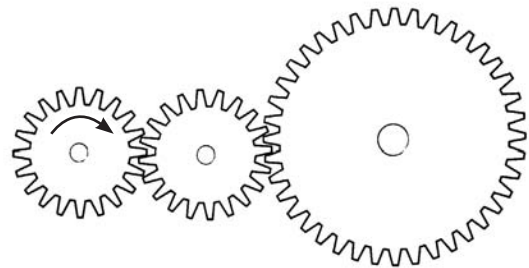
d)



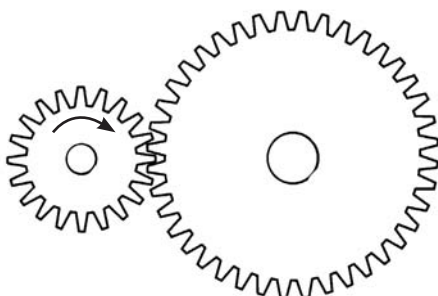
b)



e)



c)



f)

