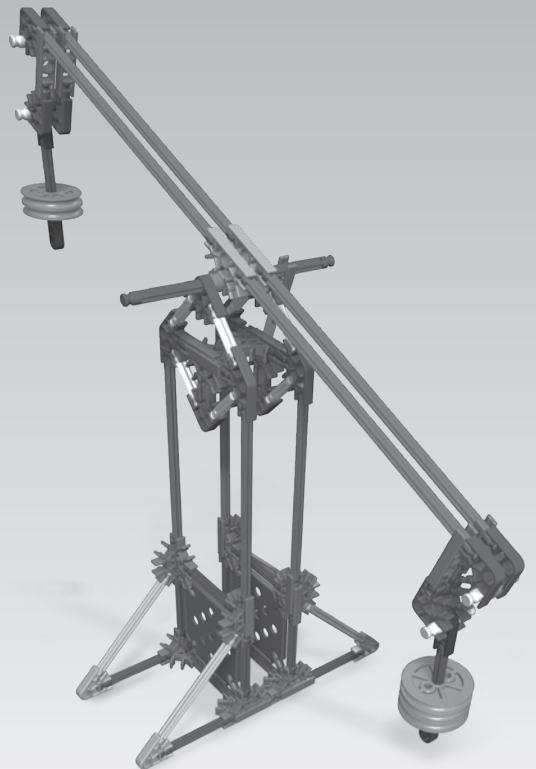
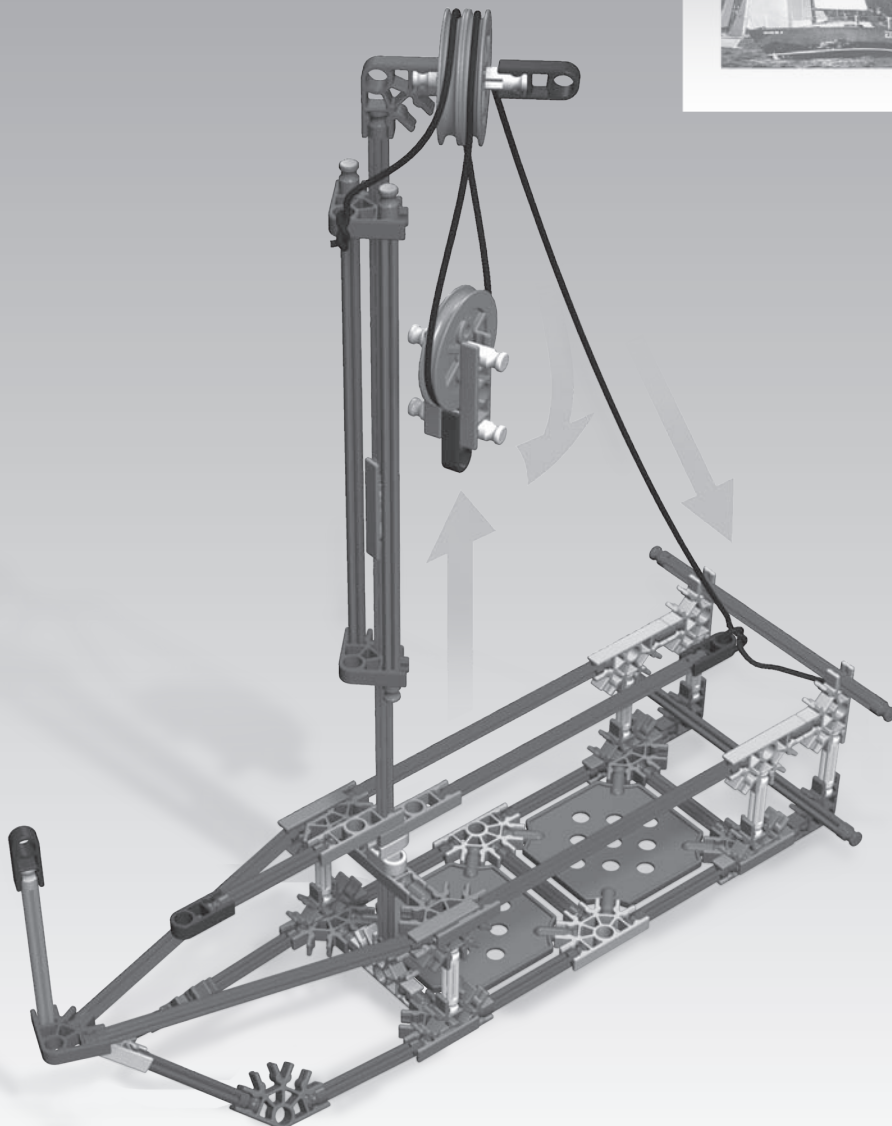
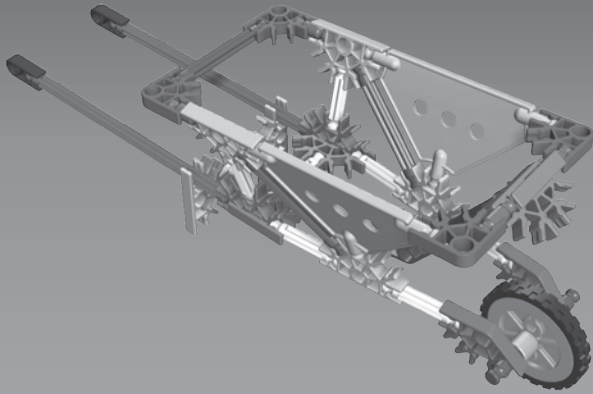


TEACHER'S GUIDE

LEVERS AND PULLEYS

UNDERSTANDING MECHANISMS



Understanding Mechanisms:

Levers and Pulleys Teacher's Guide

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

A Note About Safety

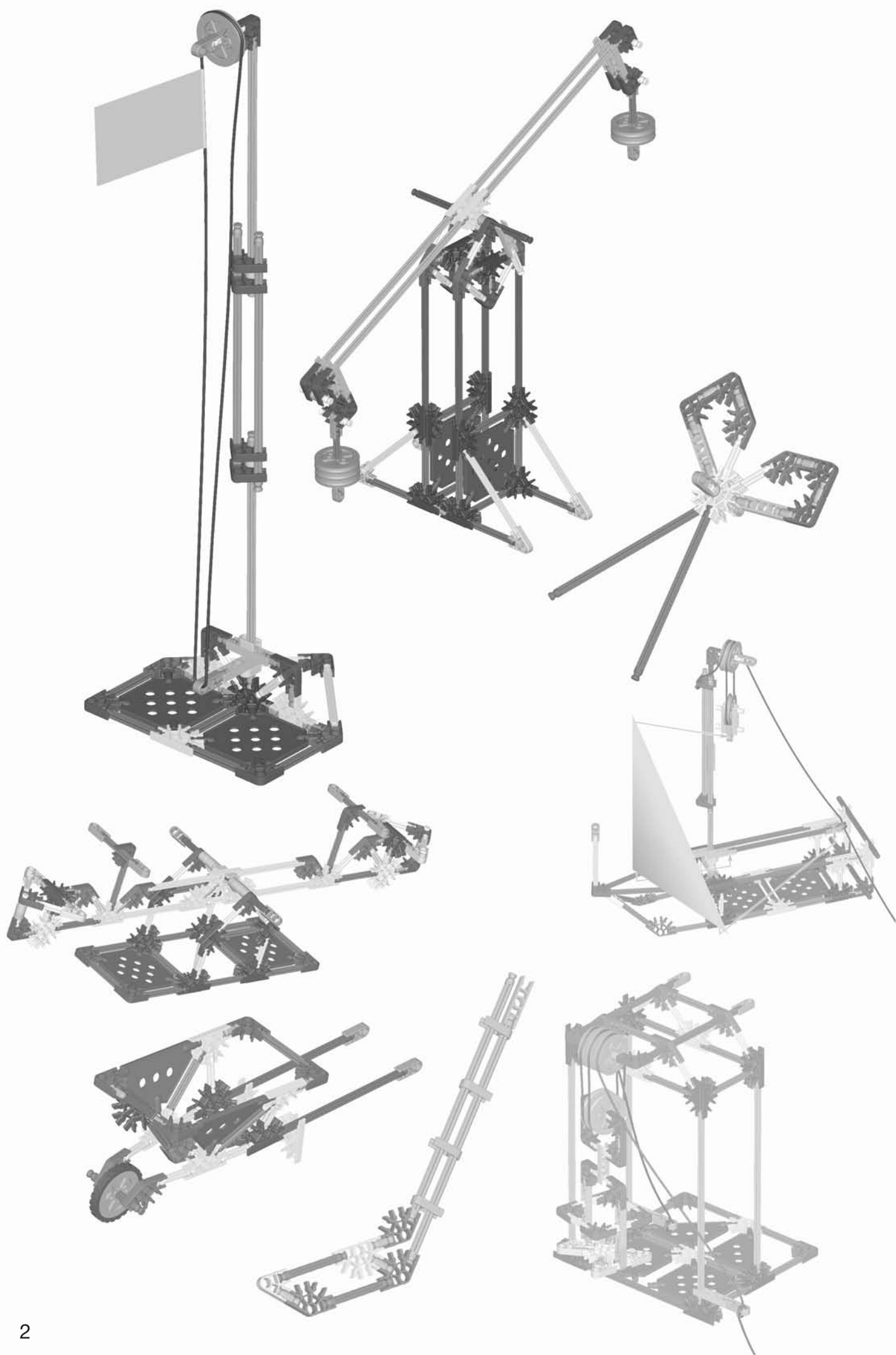
Safety is of primary concern in science and technology classrooms. It is recommended that you develop a set of rules that governs the safe, proper use of K'NEX in your classroom. Safety, as it relates to the use of the elastic bands should be specifically addressed.

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 Levers and Pulleys kit is part of a series 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: Levers and Pulleys Kit

- Developed to introduce pupils to the way levers and pulleys have been used in the design of familiar products, this construction kit also serves to make the connection between the models the pupils have built and the science that makes them work.
- Working in pairs or small collaborative groups, the kit provides opportunities for pupils to explore lifting mechanisms through the use of investigative, disassembling and evaluative activities (IDEAs) and focused practical tasks (FPTs).

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 included in the Teacher's Guide 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 each K'NEX model 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.

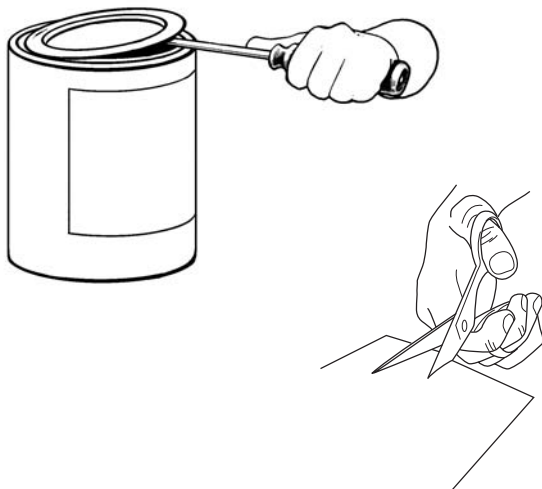
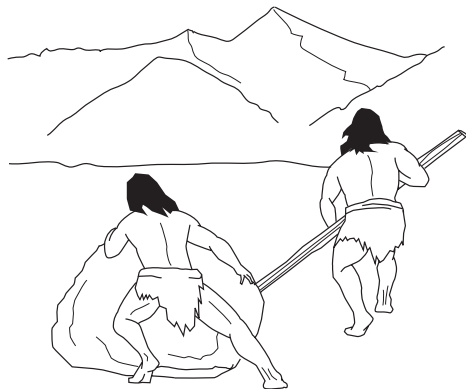
- A glossary of technical terms and scientific definitions is offered as a resource for the teacher.
- Each of the lessons can be completed in one hour but may be extended using the suggested Extension and Research Activities. Useful Internet web sites are listed to help guide the research activities. (Note: these were functioning sites at the time of going to print.)
- 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.

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A Quick Guide to Levers

It is thought that levers have been in use since prehistoric times. They were most likely used to help people lift and move heavy rocks in the Palaeolithic era, to build megalithic structures such as Stonehenge in the Neolithic period, and were the basis of the balances used by early traders and merchants to weigh gold and other valuable trade goods. Today they are found in many commonly used devices such as scissors, pliers, stapling machines, tweezers, and nutcrackers. Even cricket bats, hockey sticks, tennis racquets and JCB™ excavating machines use the principle of levers to make them work.



In the curriculum, the concept of levers may be used in designing and making activities associated with the QCA/DfEE Exemplar Scheme of Work for Design and Technology Units 1A: 'Playgrounds'; 1D: 'Moving Pictures'; 3C: 'Moving Monsters'; 4B: 'Storybooks';

5C: 'Moving Toys' and 6C: 'Fairground'; and in Science Units 1E: 'Pushes and Pulls'; 2E: 'Force and Movement'; 6E: 'Balanced and Unbalanced Forces'.

In addition, working with levers helps children relate science to the ways familiar machines work.

What is a lever?

A lever is a rigid beam, bar or rod that is able to turn or rotate about a fixed point called the fulcrum. For example:

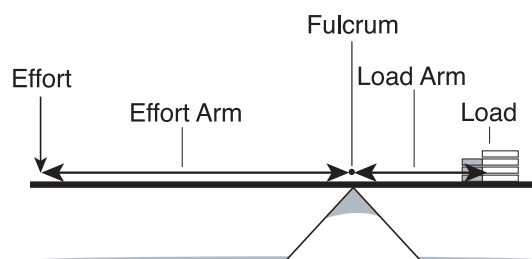


Fig. 1

The key parts of a lever are:

- **Fulcrum** - a fixed point that allows the beam to rotate around it and can occur at any point along the lever. It can be in the centre, as in a seesaw and a simple balance; off centre, as in a beam balance and claw hammer; or at one end, as in the hinge on a door, nutcrackers and tweezers.





- **Effort** - the force you apply to the lever to move an object or to overcome a resistance. The effort can be a push, pull, squeeze or lift.
- **Load** - the mass of the object you need to move or the resistance to movement that must be overcome by the lever. This object provides the force that acts against the effort. For example, the weight of a heavy object to be moved, or a piece of paper that is resisting the cutting action of the scissor blades, or friction preventing a nail from being pulled out of a piece of wood. In fact, the load can be anything that provides a resistance to your effort.

What can levers do for us?

Levers can...

- **Make jobs easier for us to do.**
Lifting or moving a heavy object requires a large amount of effort. A lever can make it easier to move the object by reducing the amount of effort force needed to do the job. It does this by **amplifying** the forces where they are needed. Consider how you would pull a nail out of a piece of wood without using a claw hammer, open a soft drink bottle without a bottle opener, or move a load of sand without a wheelbarrow. A clawhammer, bottle opener and wheelbarrow are each examples of a lever in action. In each case they help by reducing the effort that is needed to perform a specific task.

The longer the lever, the greater the amplification of the effort forces used and the easier it is to carry out the job. Archimedes is supposed to have said, "Give me a lever long enough and I can move the Earth".



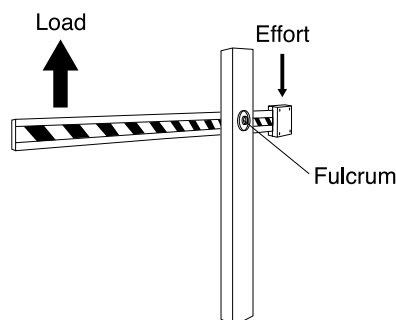
- **Change the direction of the applied force.**

A push down on one side of a seesaw, for example, results in the opposite side moving upwards.



- **Amplify or decrease the amount of output movement.**

For example, a small movement at the effort end of a car park barrier produces a large movement at the load end.



A Quick Guide to Levers

- **Increase the speed the load moves.**

This characteristic of a lever can be seen in the seige engines known as trebuchets that were used to throw large stones at castle walls in medieval times.

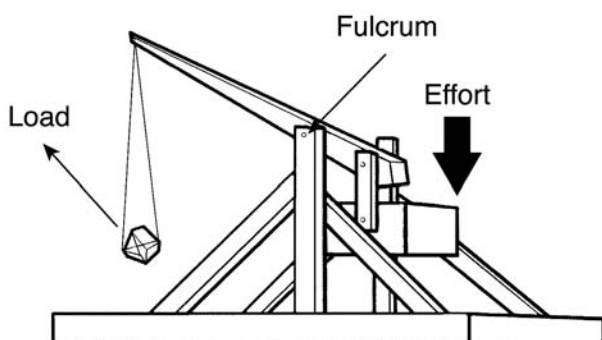


Fig. 2

Figure 2 shows a large medieval trebuchet - a giant lever in which the fulcrum is off-centre. A massive effort is applied to move a small load. The end of the long arm on the load side is made to move very quickly, accelerating the sling holding the load and propelling it forward over a long distance. Trebuchets caused enormous damage because they were able to toss objects at castle walls at speeds in excess of 160 kilometres an hour. Fishing rods and hockey sticks use the same principle.

Visit <http://www.flyingpig.co.uk/Pages/lever2.htm> to see a trebuchet in action.

Visit <http://wwwpbs.org/wbgh/nova/lostempires/trebuchet/builds.html> to see photos of the reconstruction of a trebuchet.

Are all levers the same?

There are three basic types of lever: 1st Class, 2nd Class and 3rd Class levers. They all share the common components of a rigid rod or beam, fulcrum, effort and load. They differ only in the relative positions of the fulcrum, effort and load.

1st Class Levers

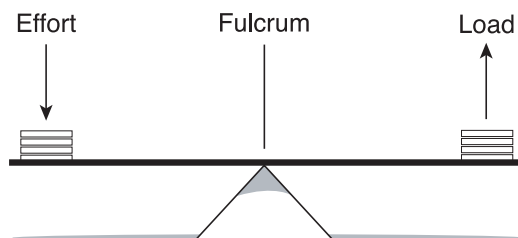
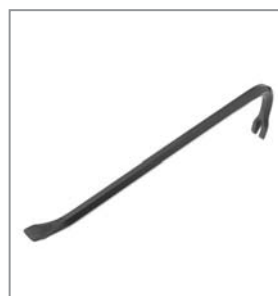
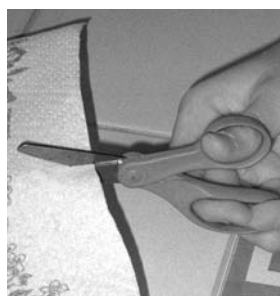


Fig. 3

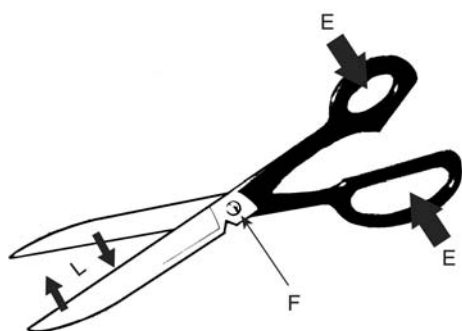


Key facts

- In a 1st Class lever the fulcrum is positioned between the effort and the load.
- The effort and load move in opposite directions. 1st Class levers, therefore, can be used to change the direction of an applied force. For example a downward push on one end of the lever can result in an upward push or pull at the other end.
- The effort force can be amplified by increasing the length of the effort arm. The longer the effort arm, the easier it is to move the load.
- The longer the load or resistance arm, the faster the load can be made to move. For example: the trebuchet.

The Principle of Levers identifies a relationship between the effort, the load and the distance of each from the fulcrum. This principle states that a lever is balanced (or in a state of equilibrium) when:

$$\begin{array}{l} \text{the effort x its distance from the fulcrum} \\ \text{on one side} \end{array} = \begin{array}{l} \text{the load x its distance from the fulcrum} \\ \text{on the opposite side} \end{array}$$



A pair of scissors is an example of two 1st Class levers working together. Squeezing the handles together produces the effort, the hinge is the fulcrum and the resistance of the card being cut is the load. The strongest cutting action is nearest the hinge.



Wire cutters have longer arms than scissors. This design modification generates a much more powerful cutting action by increasing the length of the effort arm.

2nd Class Levers

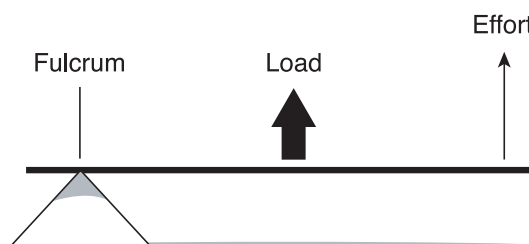
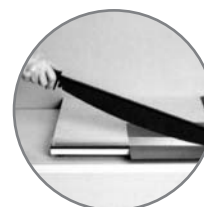
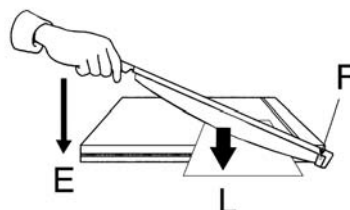
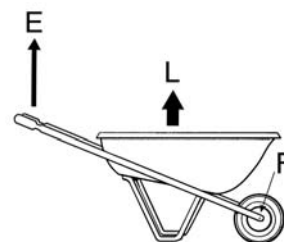
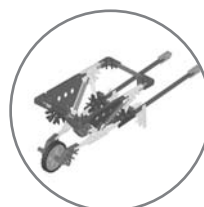
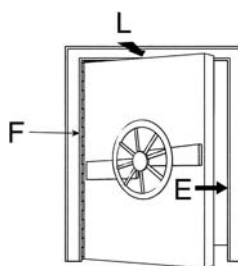


Fig. 4



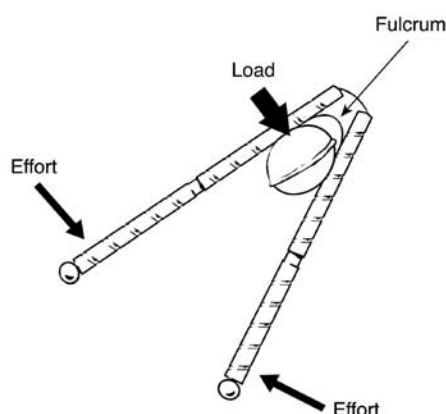
Key facts In a 2nd Class lever:

- The load is between the effort and the fulcrum.
- The effort and load move in the same direction.

A Quick Guide to Levers

- 2nd Class levers always amplify the output force. In this type of lever arrangement, the load is always closer to the fulcrum than the effort force. This means the effort arm will be longer than the load arm (see diagram). The longer the effort arm, the more the effort force is amplified where it is needed, so making it easier to move the load. With a 2nd Class lever, therefore, it is possible to move a large load with a smaller effort.

Compound 2nd Class levers.



Nutcrackers are made from two 2nd Class levers. The effort is applied to the effort arms when a hand squeezes them together, the load is the resistance of the nut's shell to cracking and the fulcrum is the hinge.

3rd Class Levers

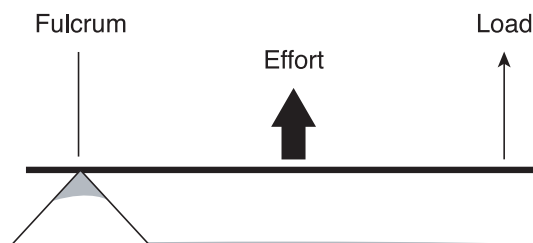


Fig. 5

Key facts

In a 3rd Class lever:

- The effort is between the fulcrum and the load.
- The effort and load move in the same direction.
- 3rd Class levers always increase the speed the load moves because the effort is always positioned closer to the fulcrum than the load. (See Fig. 5). Applying the effort close to the fulcrum requires a large input force but the effort arm only moves through a small distance. The opposite end of the lever (or load arm), however, moves through a greater distance, at a faster speed, but with less force.

In Fig. 6 the load is located twice as far from the fulcrum as the effort. In this example the load moves twice as fast as the effort, because it must move double the distance in the same amount of time.

That's the trade off. In order to get greater speed, a large effort force is needed to move a small load.

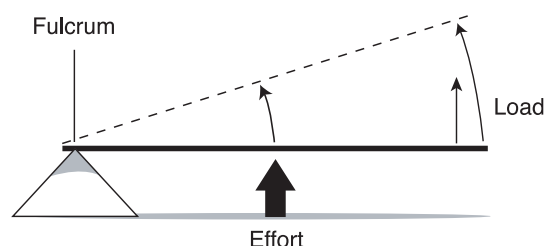
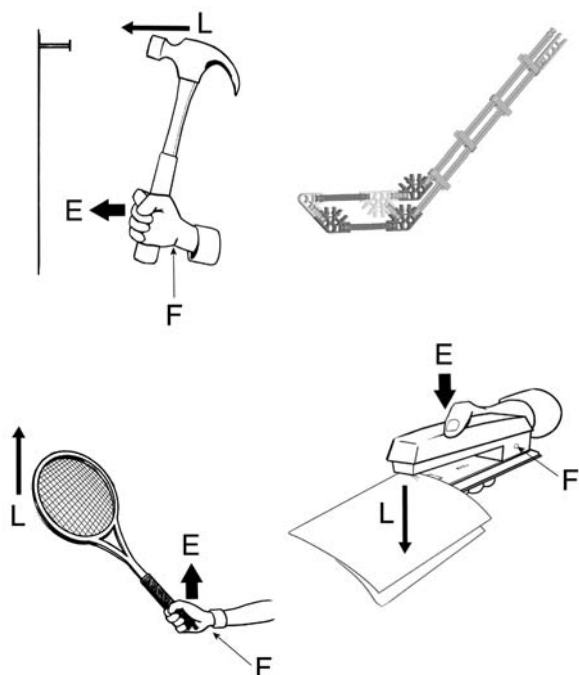
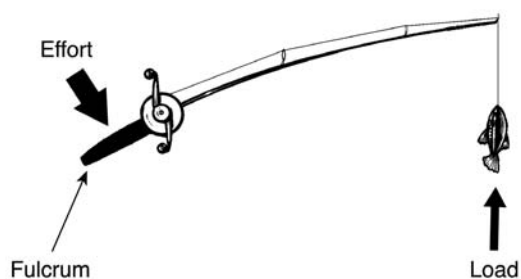


Fig. 6

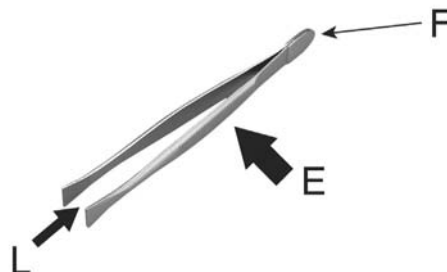


For example, raising a fish with a fishing rod actually requires more effort force than just lifting the fish using only a hand-held line. A fishing rod, however, helps by lifting the fish quickly. A small movement of your hands near the fulcrum produces a large movement at the tip of the rod, but both move in the same period of time. As a result, the tip of the rod (and the fish attached to it) actually moves more quickly than the hands and this quick action can help land the fish before it escapes.



- 3rd Class levers are not as efficient as other levers because the load is always further from the fulcrum than the effort.

Compound 3rd Class levers



A small movement of the fingers squeezing the two arms together produces a long movement at the tips of the tweezers in order to grip an object such as a hair. The load is the resistance of the hair.

Some machines use more than one type of lever in their working mechanisms.



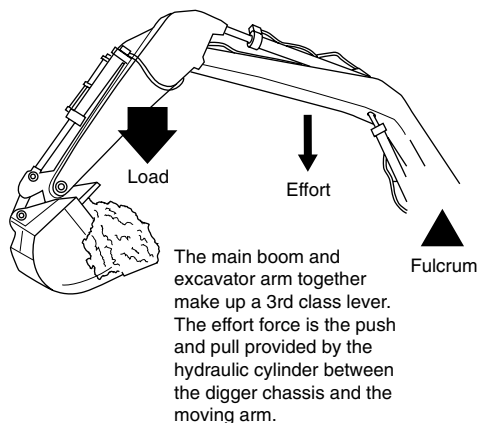
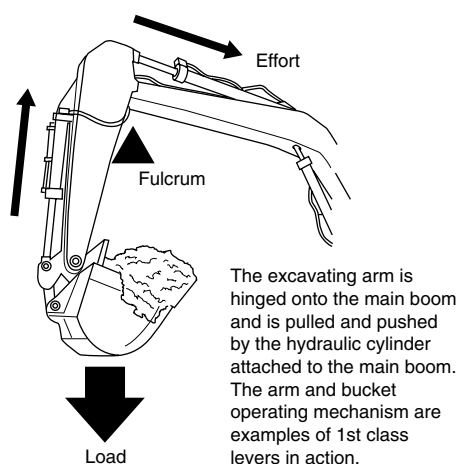
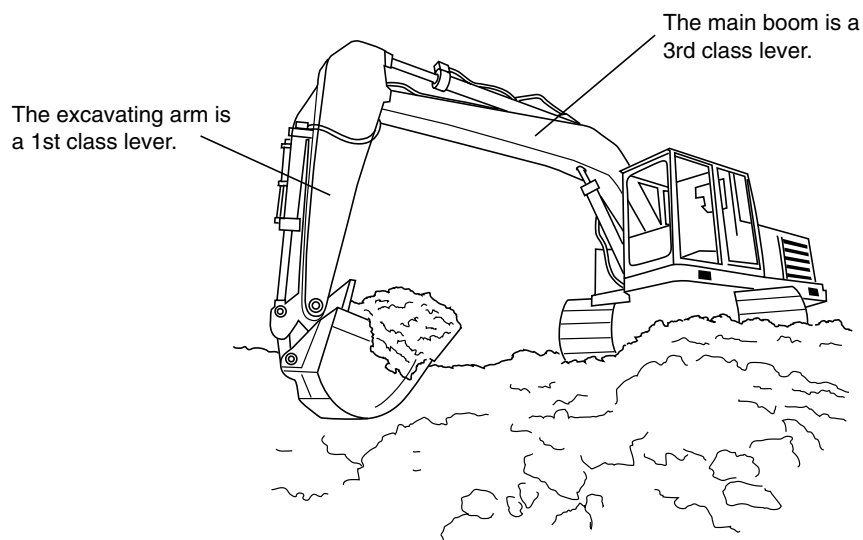
Nail clippers involve a double action - the handle presses down onto the tweezer-like action of the cutters. The handle is a 2nd Class lever while the cutter is a 3rd Class lever.



The head of the claw hammer is a 3rd Class lever while the claw is a 1st class lever.

A Quick Guide to Levers

JCB excavators that use a series of hydraulically operated arms are good examples of multiple levers in action.



Useful Web Sites.

<http://www.enchantedlearning.com/physics/machines/Levers.shtml> This web site has some very simple animated drawings of the different types of levers in action.

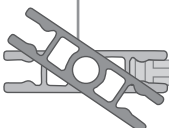
<http://www.coe.uh.edu/archive>
The University of Houston archive of lessons. Go to: Collection > Science > Lesson plans > Simple Machines.

www.flying-pig.co.uk A general site for simple machines offering useful animated drawings of mechanisms in action.

www.howstuffworks.com A library of information on different types of machines. Useful background information for teachers – you will need to use the search facility to find information.

www.mos.org/sln/Leonardo/InventorsToolbox.html A useful site covering general information on levers and other simple machines.

www.smarttown.com/sp2000/machines2000/ Simple machines made simpler. A good introduction to simple machines made by school children.





Lesson 1: Getting Started

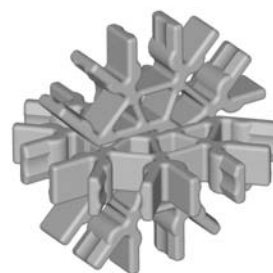


Time: 1 hour

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.
 - Identify components that can be used to make things move.

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: Levers and Pulleys 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.*



levers and pulleys

website: www.knexeducation.co.uk

- 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?

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.

Teacher's Notes

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 2.1 and 2.2: The Seesaw

1st Class Lever



Time for each lesson: 1.5 hours

Note: Lesson 2.1 is appropriate for Key Stage 1 and as an introductory activity for Key Stage 2 children. Lesson 2.2 is more appropriate for Key Stage 2.

Learning Objectives - Children should learn:

- pushes and pulls are examples of forces
- to observe and describe movements in a simple machine
- to relate science to the ways familiar machines work
- to carry out a simple investigation



Vocabulary

1st Class lever, load, effort, fulcrum, pivot, centre, off centre, beam, rigid, up, down, raise, lower, lift, opposite, direction, turns, rotates, push, pull, force, weight, force meter, simple machine

Resources

Each group of 2-3 children will need:

- 1 K'NEX Understanding Mechanisms: Levers and Pulleys kit and Building Instructions booklet
- Dot stickers or pieces of masking tape
- Felt-tipped pens
- 2 paper cups or 2 pieces of foil
- Coins, paperclips or weights to use in the cups
- 5 Newton force meter or weights
- A collection of devices that use the lever principle

Useful Internet Web Sites:

Please refer to Page 10 of A Quick Guide to Levers.

Lesson 2.1 for Key Stage 1

Possible Teaching and Learning Activities

Introduction

The activities outlined in this lesson may be used to support the QCA/ DfEE Exemplar Scheme of Work for:

Design and Technology Unit

- 1A: Playgrounds
- 1D: Moving Pictures
- 3C: Moving Monsters
- 4B: Storybooks
- 5C: Moving Toys
- 6C: Fairground

Science Units

- 1E: Pushes and Pulls
- 2C: Forces and Movement
- 6E: Balanced and Unbalanced Forces

Teacher's Notes

Key Stage 1 and 2 Activities

The suggested activities are suitable for Key Stage 1 children and provide opportunities for children to investigate and use words and phrases related to forces and movement. For example: push, pull, turn, direction, distance, force, up, down, opposite. Activities for older Key Stage 1 and Key Stage 2 children are provided on Page 17.

Lesson 2.1 and 2.2: The Seesaw

Whole Class

- Ask the children to talk about the types of moving equipment they can find in playgrounds.
- Encourage the children to describe the types of movement each piece makes. *Answers may include: up/down; back and forward; swing; rocking; round and round/rotates/circle.*
- Ask the children what they have to do to make the equipment carry out the movement. *Answers may include: push or pull to start or stop the movement.*

This introductory discussion provides an opportunity to assess children's knowledge and understanding of:

- (a) simple mechanisms and their use of technical vocabulary in describing movements,*
- (b) forces, pushes and pulls.*

Working in Groups of 2-3

- Ask the children to build the K'NEX Seesaw. You may wish to limit the K'NEX building activity to about 10-15 minutes. This will encourage the children to work cooperatively in order to complete the task within the allotted time frame. Allow them a few minutes to investigate how their model works.
- Ask, "Can the seesaw move without being pushed or pulled?"
- Ask the children to make labels with the words '**push**', '**pull**', '**push and pull**' written on them. Each group should discuss where, on their K'NEX seesaw model, they should stick the labels in order to show how they make it move.
- Ask each group to describe:
 - * **What they did to make the seesaw move.**
 - * **The movements produced by the seesaw.**
 - * **The shapes used to make the seesaw strong and rigid.**
 - * **Why they think their model has a wide base.**

* **Possible answer: We pushed one end.**

* **Possible answer: When we pushed one end down, the other end went up; when we pushed and pulled one end the opposite end went up and down.**

* **Triangles.**

* **Possible answer: It helps to make the structure stable/ stops it falling over.**

Whole Class

- Explain to the children that a seesaw is an example of a lever and that if we know what to look for we will find levers being used everywhere. Use the seesaw

model to identify the key parts of a lever - simply a rigid beam or rod that turns /rotates/ pivots about a point.

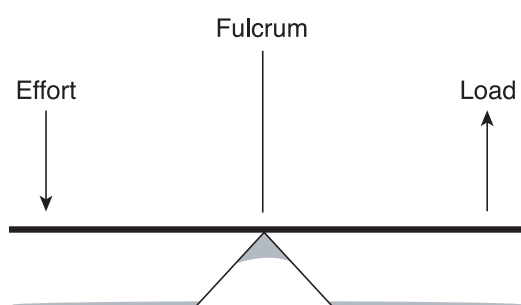
- Help the children to understand that we even have levers in our own bodies – our arms and legs are levers.
- Talk about how levers are probably one of the oldest machines known – perhaps used by people in prehistoric times to move large rocks or to help get mammoths out of pit traps.

So what do levers do?

One thing they do is to make it easier to lift things. Discuss how hard the children might find it to lift their work partner but yet how easy it is to lift them up when they use a seesaw.

You may want to ask one child to take the lid off a tin of powder paint or cocoa powder using only their fingers. Then provide a screwdriver/spoon to act as a lever to remove the lid. Ask the rest of the class to carefully observe what happened when the lever was used to remove the lid. See A Quick Guide to Levers for additional information.

- Explain to the class they will now explore how levers work.
- Use a K'NEX Seesaw model to identify and demonstrate the three main components of a lever: **effort**, **load** and **fulcrum**.
- You may want to draw a diagram on the board to reinforce the concepts.



Lesson 2.1 and 2.2: The Seesaw

Working in Groups of 2-3

- Ask each group to prepare stickers and label their seesaw model.

F - Fulcrum

L - Load

E - Effort

Each group will need 2 paper cups (or pieces of foil) and some weights (paper clips/coins/standard weights).

1. Feel the load:

- Ask one child from each group to place the back of their hand and arm on the desktop. Another member of the group then places the paper cup/foil containing the weights on the fingers of their partner's hand who then lifts the cup up from the surface of the desk. Each child tries the exercise in turn.
 - What did they feel?
 - Did the cup feel heavy?

2. Use the lever:

- Ask each group to place the weighted paper cup at one end the seesaw. What happens to the end of the seesaw with the load attached to it? Each child in turn pushes down at the opposite end and notices what happens to the load. Possible questions to ask:
 - Did it feel easier or more difficult to lift the weighted paper cup this time?
 - What was the direction moved by their push (effort)?
 - What was the direction moved by the paper cup (load)?
- Ask the children to take their labels and place them in the appropriate locations on the model to identify the fulcrum, load and effort. Ask the groups to make and add two arrow labels to their models to show the direction of movement of the effort and load forces.

Teacher's Notes

The children should be aware of the weight, or force, made by the weighted paper cup on their hand. The activity also provides an opportunity to introduce children to the idea that weight is also a force. The effect of using a weight is the same as pushing down with a finger.

*It may be useful to create a **word board** with cards that have the word on one side and a short explanation on the reverse side for children to use when needed.*

An alternative method is to wrap the weights/coins in foil and attach the foil parcels to the seat of the seesaw with an elastic band. If you use elastic bands in the classroom please review the safety guidelines, outlined at the beginning of this guide, regarding their safe use by the children.

Talk about how one end of the seesaw goes down when the weighted paper cup is placed at the load end but will not move until there is a push (an applied effort) at the opposite end. To lift the load up they must push down. In other words, the lever has helped change the direction of the movement and the applied force. The use of the directional arrows may help the children visualise what is happening as they record their observations and make labelled drawings of their model.



- Talk about how levers can be found everywhere, but they do not all look like seesaws. Other examples of levers include scissors to cut paper, a claw hammer to pull a nail out of piece of wood, a stapler, an oar used to row a boat and even their own arms and legs.

Extension Activity 1

Some children may feel it was easier to move the paper cup using the lever than without it. Discuss how they might be able to carry out a fair test to verify their ideas.

- Ask the children to describe and explain their observations in written text and/or verbally. They should include labelled drawings of their model with arrows to indicate movements and use the correct terminology to describe the different components.

Extension Activity 2

Discuss what rules the children would have to make if three of them were to use a seesaw at the same time. Where would they have to sit? How might they use their K'NEX seesaw model to test their ideas?

Lesson 2.2 for Key stage 2

Possible Teaching and Learning Activities

The following activities are more suitable for older Key Stage 1 or early Key Stage 2 children. The starting point is the K'NEX Seesaw model used in the previous lesson.

Working in Groups of 2-3

Making lifting and moving easier:

- Ask each group to modify their seesaw model so that the load is positioned closer to the fulcrum.
- Explain to the children the fulcrum is now 'off-centre', making the arms unequal in length. In the original model the fulcrum is positioned in the centre of the beam, making the arms equal in length.
- Ask the children to predict, giving their reasons, if this change will make any difference in the effort they need to use to lift the load. How will they test their predictions? Write their predictions on the board for later discussion.

Teacher's Notes

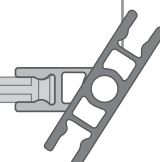
If time allows ask children to investigate levers on selected Internet web sites. For example www.enchantedlearning.com/physics/machines/levers.shtml

The children could be asked to come up with different ideas to measure the load and effort. These ideas might include using non-statutory measurements such as the number of paperclips/coins in each paper cup, or using force meters.

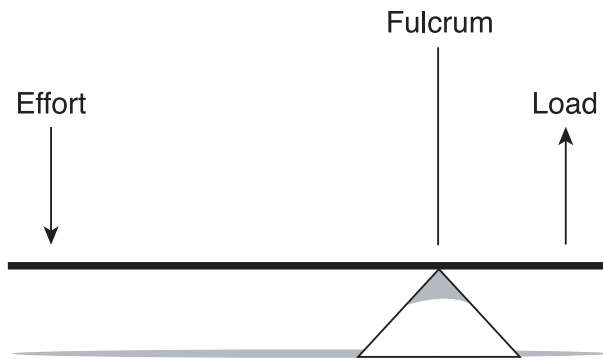
To promote the wider use and application of ICT skills and practices, the children's models and work could be recorded using a digital camera.

The children could be asked to work the modification out for themselves or they could be told to replace the yellow Rods on the load side with shorter blue or white ones.

You may wish to review what the children did in 1: 'Feel the load' and 2: 'Use the lever' described in Lesson 2.1.



Lesson 2.1 and 2.2: The Seesaw



- Try it and see. Were their predictions correct?
- Ask the children to use written text to describe and explain their observations. They should include labelled drawings of their model with arrows to indicate movements and they should use the correct terminology to describe the different components.

Whole Class

- Discuss how it now requires much less effort to lift the load when the effort is applied a greater distance from the fulcrum than the load.
- This form of lever design differs from that of the seesaw in which the load and effort are applied equidistant from the fulcrum.
- Talk about how much the 'effort' end now moves compared to the 'load'. This demonstrates another function of levers - to increase (amplify) or decrease movements depending on which end of the lever is used to apply the effort.

Teacher's Notes

The children should find that it requires a much smaller effort (a push or weighted paper cup) to lift the load. If they use the weighted paper "effort" cup from the earlier activity they will find it is too heavy.

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

*At this point you may wish to introduce the idea of **input**, **process** and **output** as applied to machines. In the case of a lever:*

- *the input is the amount and direction of the effort force*
- *the process is the lever mechanism and*
- *the output is the direction and amount of force produced at the 'load' end of the lever beam.*



- Ask the children if they think it will be harder to lift the load when it is placed a long distance from the fulcrum. Explain that they can reverse the load and effort ends of their seesaw lever model. Reposition the labelling stickers to the new arrangement and repeat the activities as before.
- Ask the children to describe and explain their observations. They should include labelled drawings of their model with arrows to indicate movements and use the correct terminology to describe the different components.

Extension Activity 1

Ask the children to use a force meter to measure the effort force needed to lift the load in the three different situations outlined above. If two force meters are available per group, one force meter could be used to apply the load and the other force meter could be used to measure the effort.

Record the results on the board and discuss the results.

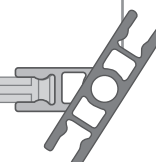
Plenary

Have a quiz on levers in which the children must use the correct technical vocabulary.

Ask the children to identify 'levers in action' from a collection of common devices used in school and at home. The names of the devices are written on cards, which are placed face down on a desk. A child selects a card naming the lever device to which they must respond. They must describe what the device is used for, how it works and be able to identify the load, fulcrum and where the effort is applied.

Teacher's Notes

Children are often surprised how much effort is needed to lift a load positioned a long way from the fulcrum, especially when effort must be applied close to the fulcrum. The other surprise comes when the load end pivots round very **quickly**, often hitting the back of their hand. To explore this further, some groups could be asked to use blue Rods and others white Rods instead of the yellow ones in the original building plans.



Lesson 3: The Balance

1st Class Lever



Time for each lesson: 1 - 1.5 hours

Learning Objectives - Children should learn:

- to observe and describe movements, direction and types of forces working in a lever mechanism
- to relate science to the ways in which familiar machines work
- to carry out a simple investigation



Vocabulary

balance, unbalanced, lever, pivot, fulcrum, beam, load, effort, direction, movement, up, down, weight, mass, level, force, Newton, friction, opposes, motion, gravity, horizontal, stationary

Resources

Each group of 2-3 children will need:

- 1 K'NEX Understanding Mechanisms: Levers and Pulleys kit and Building Instructions booklet
- Dot stickers or pieces of masking tape
- Felt-tipped pens
- Washers, paperclips (all of an equal size) or slotted gram masses to hang from the balance arms
- Ruler

Useful Internet Web Sites:

Please refer to Page 10 of A Quick Guide to Levers.

Possible Teaching and Learning Activities

Introduction

The activities outlined in this lesson may be used to support the QCA/ DfEE Exemplar Scheme of Work for:

Design and Technology Unit

- **1A: Playgrounds**
- **1D: Moving Pictures**
- **3C: Moving Monsters**
- **4B: Storybooks**
- **5C: Moving Toys**
- **6C: Fairground**

Science Units

- **1E: Pushes and Pulls**
- **2C: Forces and Movement**
- **6E: Balanced and Unbalanced Forces**

Whole Class

- Talk about how balances and other weighing devices with which the children may be familiar from other lessons, (for example: mathematics), have been used for centuries. Help the children to understand that distributing weight equally, using a form of balance, can also make it easier to carry heavy loads. Ask the children to look at the man in the photograph on Page 4 of the K'NEX Building Instructions booklet.

Teacher's Notes

The large load is split into two equal portions and evenly balanced across his shoulders.



- Ask them why it might be easier for him to carry loads in this way. What would happen if the man's load were not balanced on each side of the pole?

Working in Groups of 2-3

- Explain how the class will discover how a balance works by building and investigating a K'NEX model balance.
- Ask each group to build the K'NEX Balance model shown on Pages 4-5 of the Building Instructions booklet. Allow them time to investigate how their model works.

Whole Class

- Talk about the similarities between the K'NEX Balance model and the Seesaw model, investigated in a previous lesson.
- Discuss how the balance is an example of a lever.
- Ask the children to prepare sticky labels and use them to identify the different parts of their balance model.

F = Fulcrum **L** = Load **E** = Effort **Beam**

- (Optional) Explain how the balance and seesaw are examples of a 1st Class lever and that there are 3 different types of levers: 1st Class, 2nd Class and 3rd Class levers. Tell the children that they will be able to investigate the different lever types in other lessons.

Working in Groups 2-3

- Ask the children to remove the grey hanging trays (grey pulley wheels) from their model and push the red and orange hangers to the end of the balance arms.
- Once the two arms are stationary, ask the children to observe and describe what the model is doing, using the correct vocabulary.
- What happens when one end of the balance arm is given a small push/has a force applied?
- The children should be asked to explain their observations.
- Discuss how this activity demonstrates that an object will remain stationary until a force acts on it.

Teacher's Notes

If the load is not balanced evenly, one side will hang down lower than the other and make it difficult to carry.

Teacher's Notes

The balance model does not move because the forces acting on both arms are balanced. When a force is applied to one side it will move because the forces are now unbalanced. The arm to which the force has been applied moves in the direction of the applied force. If a weight is used, instead of a push, it will also cause the arm to move. Weight is also a force.

The balance will remain stationary, or at rest, until a weight is loaded on one side or a force is applied to one side. If that weight or force is larger than the weight or force on the opposite side then the forces acting on the balance arm will become unbalanced and the

Lesson 3: The Balance



balance arm will move in the direction of the larger force. This is a general law of physics.

Teacher's Notes

If time allows you may wish to demonstrate other examples of objects that remain stationary and have clearly identifiable and familiar forces acting on them. For example, an object suspended from a string, thread or elastic band will remain in that position. If, however, the weight of the object is increased, a point will be reached at which the string will break and the object will fall. At the point at which the string breaks, the forces acting on it are unbalanced. In other words, the weight of the object (load) is now greater than the resistance (load bearing capacity) of the string.

Talk about how mechanisms such as levers (balances) and familiar playground equipment or machines also need to have forces applied to them to make them move. All machines need a force to be applied to them to make them work.

- Ask the children to identify what other forces may have acted on the balance to stop it moving.
- * **What force slows up the arms and eventually stops them moving?**
- * **Why do the arms eventually stop in a horizontal position?**
- * **What force is acting on each arm now?**

- * **Friction in the pivot joint and air resistance.**
- * **Both arms are equal in weight and so the forces acting on each side are equal.**
- * **Gravity.**

Friction is the force that opposes movement. In the pivot joint, friction has the effect of slowing down the movement. It acts just like a brake. If both arms are of equal weight, then the force due to gravity acting on both sides will be equal and, in theory, the arms will come to rest in a horizontal position.

Exploring the K'NEX balance model

- Replace the hanging trays so that there are two pulleys on one side and one on the other side. Push both hanging trays to the end of their arms and observe, record and explain what happens.
- Pose the question, "What do you have to do to balance the forces in the model?"
- Ask the children to return to their 'unbalanced' model with two grey pulleys on one side and one on the other to find a different way to balance their model without adding or removing grey pulleys. They can slide the hanging trays along the arms.

Whole Class

- Ask the children if their results might suggest a general rule for making a balance work.
- Discuss with the class
 - How will they test their rule?
 - What will they measure?
 - How many readings do they need to take?
 - How will they record their results?

Teacher's Notes

The children should note that the heavier tray goes down while the lighter tray moves up. They should also report that this is the result of unbalanced forces in action.

The children may either add, or remove, a grey pulley to one or the other side in order to make the weights on both sides equal. The children should be encouraged to discuss their observations in terms of balanced and unbalanced forces.

The children should be able to find that by sliding the heavier hanging tray closer to the fulcrum, the balance model will again become balanced. Discuss the children's findings with those obtained in a previous investigation of the K'NEX Seesaw (Lesson 2.2: Making lifting and moving easier) in which they discovered that a small effort applied a long distance from the fulcrum can be used to lift a heavier load positioned close to the fulcrum.

If time permits, each group could work individually. Alternatively, the class could share results leading to a general class discussion on their interpretation.

You may also decide to suggest that the children use a table template, such as the one shown on Page 24, in which to record their results.

Lesson 3: The Balance

Using a template:

EFFORT SIDE		LOAD SIDE	
Number of pulleys/ washers/weights	Distance from the fulcrum	Number of pulleys/ washers/weights	Distance from the fulcrum

Younger children might use squared graph paper to record and visualise their results.

For example:

The children measure the relative distance they placed the grey K'NEX pulley hangers, the number of washers or paperclips or the value of the masses used to balance their model, in the appropriate distance measurement, as measured from the fulcrum. The blue connecting Rod on the hangers could be placed through the washers or paper clips to prevent them falling off.

Using squared graph paper:

	EFFORT SIDE										LOAD SIDE									
Distance from fulcrum in cms	10	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	10
Number of pulleys/washers/ weights									4									1		
						2														1
								2				3								
							3									2				
										9									1	

For those children who are unable to come up with their own ideas, you might suggest they keep one K'NEX pulley at one end and find the positions on the other arm to balance 2, 3 and 4 K'NEX pulleys.



- Discuss the results of their investigation in which they explored balancing the forces acting on the model. They should have found that when balanced, the forces on one side must equal the forces on the opposite side.
- Ask the children to make labelled drawings of their balance model showing the positions of the fulcrum, effort and load and the directions in which the forces are acting. They should describe and explain their observations using appropriate scientific and technological vocabulary.

Problem solving activity

Children could be set the task of applying their rule to find the weight of an unknown object using only one 10g mass.

Plenary

Ask some children to describe and explain how they solved the weighing problem.

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.

Lesson 4: The Wheelbarrow

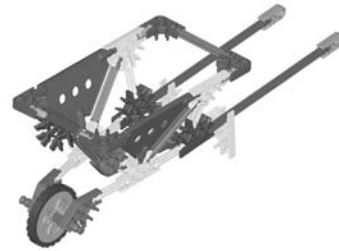
2nd Class Lever



Time: 1 - 1.5 hours

Learning Objectives - Children should learn:

- to relate science to the ways in which familiar machines work
- to carry out a simple investigation



Possible Teaching and Learning Activities

Introduction

In this lesson children investigate the science used in the design of a wheelbarrow and how knowledge and understanding of the lever principle can help them modify and improve its design for a different purpose.

Whole class

- Explain that although levers come in different forms, they all use the same basic principle: if a heavy object (load) is positioned close to the fulcrum, less force (effort) is needed to move it.
For example, a door, a paper guillotine, a stapler and nutcrackers all make use of the lever principle but they all have very different functions.
- Ask the children if it is easier to open a door by pushing close to the hinge or at the handle? Explain that the door hinge is the fulcrum, the weight of the door is the load and the effort is applied where you push. Review their findings from previous lessons – if the effort is applied a long way from the fulcrum work will be easier.

Vocabulary

lever, pivot, fulcrum, beam, handles, effort, load, lift, weight, force, Newton, heavy, object, force meter, design specification, compare, modify, 1st Class lever, 2nd Class lever, labelled drawings

Resources

Each group of 2-3 children will need:

- 1 K'NEX Introduction to Simple Machines: Levers and Pulleys kit with Building Instructions booklet
- Dot stickers or pieces of masking tape
- Felt-tipped pens
- Aluminium foil or cling film
- A pile of small washers, paper clips or plastic beads or other small objects that are awkward to carry by hand
- Force meters

Useful Internet Web Sites:

Please refer to Page 10 of A Quick Guide to Levers.

Teacher's Notes

If time is available, or as prior learning in an ICT lesson, children could use the Internet to research different uses of levers.



Whole class

- Review how, in previous lessons, the children investigated the type of lever used in a seesaw and a balance. Explain that in this lesson they will investigate a different type of lever and discover how it operates in a **wheelbarrow**. Children may be familiar with a wheelbarrow but they may not recognise it as a lever in action.

Working in Groups of 2-3

- Ask each group to build their K'NEX wheelbarrow model and investigate how it works.
- The children should line the tray of their wheelbarrow with aluminium foil or cling film. This will prevent the washers, or other small objects, from falling out as they are moved in the wheelbarrow.
- Questions to ask:
 - What are wheelbarrows used for?
 - What types of loads are normally carried in wheelbarrows?
 - How are wheelbarrows loaded and unloaded?
 - How good is the wheelbarrow design for its intended purpose?
 - How good is the wheelbarrow for lifting and moving heavy loads? (If they did not have a wheelbarrow how might they lift and move a heavy load?).
- The children should be encouraged to record, describe and explain their observations, using labelled drawings where possible.
- Ask the children to investigate the wheelbarrow as a lever and to identify and label the positions of the fulcrum, load and effort on their model using the dot stickers or masking tape labels.
- What are the design features that make a wheelbarrow a good machine for lifting and moving heavy loads?
- Review with the children how they discovered in the seesaw and balance investigations that a large weight/force close to the fulcrum could be moved by a smaller weight/force further away from the fulcrum.
- How do the positions of the effort, fulcrum and load compare to those they found in their K'NEX balance and seesaw models?

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.

Wheelbarrows are normally used to carry loose materials such as sand, soil or rubble. The wheel not only reduces friction and makes it easier to move over surfaces, but it also acts as a pivot to tip up the wheelbarrow to empty it. The tray has a sloping front end to make it easier to tip out the loose materials.

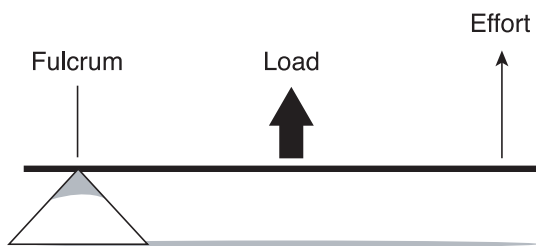
The handles used for lifting the load are placed much further from the fulcrum than is the load being carried.

Force meters could be introduced to enable the children to compare the force needed to vertically lift the wheelbarrow with its load, versus the force needed to lift the load using the handles.

In wheelbarrows the load is positioned between the lifting effort force and the fulcrum. This means that the lifting force will always be amplified. The load and the effort also move in the same direction.

Lesson 4: The Wheelbarrow

2nd Class Lever



Teacher's Notes

The wheelbarrow, although a lever in action, is a different type of lever from that found in the balance and seesaw. In those simple machines the fulcrum is between the effort and load. Talk about how both types of levers share the same features – a rigid beam that rotates about a fulcrum, effort and load.

See the 'A Quick Guide to Levers' for additional information.

Whole Class

- (Optional) Explain how levers can be classified, using the relative positions of the effort, fulcrum and load, into 1st, 2nd and 3rd Class levers.

The seesaw and balance are examples of 1st Class levers in which the fulcrum is between the effort and load. In 2nd Class levers the load is between the fulcrum and effort.

See the 'A Quick Guide to Levers' for additional information.

Working in Groups of 2-3

- What other examples of 2nd Class levers can the children find in the classroom, at home or from an Internet search?
- Identify the positions of the fulcrum, load and effort and explain how each machine works and why it is a 2nd Class lever.

If time is available, or in a prior ICT lesson, children could use the Internet to research different uses of 2nd Class levers. For example: a door, stapler, bottle opener and nutcrackers.

Extension Activity 1

Design problem

- A new wheelbarrow is needed to move even heavier loads. What changes should be made to their present design to enable it to move heavier loads without increasing the effort needed to lift the handles.
- How will the children test their design to ensure that it meets the new design brief?
- They should be able to describe and explain why their design will be able to lift and move heavier loads.
- The children should be encouraged to use labelled drawings wherever possible.

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.



Extension Activity 2

The wheelbarrow without a wheel

If time is available, or during an ICT lesson, children could use the Internet to research the “travois”.

Not all cultures used the wheel to help move heavy loads. Many nomadic peoples used a different method, similar in principle to the wheelbarrow, but without the wheel. For example, Native Americans on the Great Plains used the ‘travois’ to move their household belongings. This device is a frame made from a pair of long poles hitched to a dog or horse. The load is strapped across the poles, while the ends of the poles simply drag along the ground behind the animal. It is easy to assemble, to take apart when not in use, to repair and makes use of readily available materials. Discuss how the travois design compares with that of the wheelbarrow. The children might consider how they are used and how they meet the needs of the users and identify their similarities and differences.

Plenary

Share designs, features and discuss the science behind a good wheelbarrow design.



levers and pulleys

website: www.knexeducation.co.uk

Lesson 5: The Ice Hockey Stick

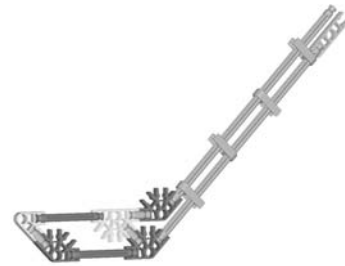
3rd Class Lever



Time: 1 - 1.5 hours

Learning Objectives - Children should learn:

- to relate science to the ways in which familiar machines work
- to carry out a simple investigation
- to carry out a problem solving activity



Vocabulary

3rd Class lever, pivot, fulcrum, effort, load, resistance, handle, weight, force, object, stationary, rest, still, design, specification, compare, labelled drawings, balanced, unbalanced, friction, air resistance, fair test

Resources

Each group of 2-3 children will need:

- 1 K'NEX Introduction to Simple Machines: Levers and Pulleys kit with Building Instructions booklet
- Dot stickers or pieces of masking tape
- Felt-tipped pens
- Measuring tape

You will need:

- Hockey stick (if possible) and other examples of sports equipment such as a cricket bat or tennis racquet

Possible Teaching and Learning Activities

Introduction

The activities in this lesson may be used to support the QCA/DfEE Exemplar Scheme of Work for Science:

- Unit 4: Friction
- Unit 6E: Balanced and Unbalanced Forces

Whole Class

- Discuss how there are a number of sports that use clubs, bats or sticks to strike balls or other objects, either over a long distance or at high speed. Examples include sticks to score goals in ice hockey, or bats to hit the ball to the boundary in cricket.

Teacher's Notes

See: A Quick Guide to Levers for additional information.



- Introduce the activity by telling the children the ice hockey player in the photograph on Page 8 of the K'NEX Building Instructions needs an improved design for his hockey stick to help him score more goals. He knows that he isn't hitting the puck fast enough but he is not sure whether he needs to buy a longer or a shorter hockey stick. The children's task is to provide evidence to help him make his decision.
- They will have available a K'NEX model of his ice hockey stick which they can use to test their ideas.
- Talk about how an ice hockey stick is yet another type of lever and that the concepts they learnt in previous lessons also apply. Review the key points about levers:
 - they all share the same basic features – a rigid beam that rotates about a fulcrum, effort and load.
 - when a heavy object (load) is positioned close to the fulcrum, less force (effort) is needed to move it.

Working in Groups of 2-3

- Ask the children to first build their K'NEX Hockey stick model, and then investigate, describe and explain how it works as a lever.
- Use the photograph on Page 8 of the Building Instructions to observe the position of the player's hands.
- Let the children try this for themselves by hitting small balls of paper with their K'NEX ice hockey stick.

* Which hand acts as the fulcrum?

* Can you identify exactly which part of that hand is the fulcrum?

* Which hand provides the effort (the force that moves the puck)?

* Where is the load?

Try this:

Working in Groups of 2-3

- Ask one child to hold their K'NEX ice hockey stick and line it up along the edge of their desktop.
- Using only their wrist, they should move the ice hockey stick backwards and forwards.

Teacher's Notes

The wrist of the hand holding the top of the ice hockey stick is the fulcrum, the lower hand provides the effort and the resistance of object being hit is the load.

The children may not realise at first that it is their wrist that is the fulcrum. Their wrist provides the point of rotation, just like a door hinge.

* The top hand.

* The wrist.

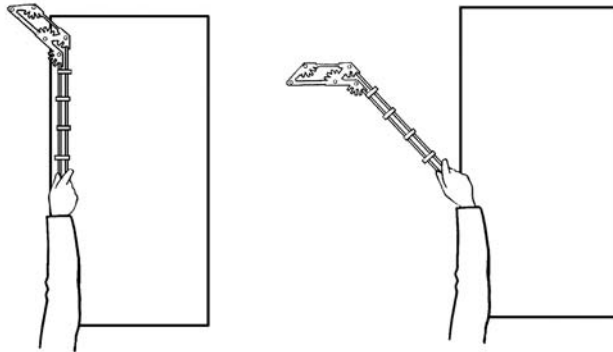
* The lower hand.

* The puck.

Depending on the flexibility of their wrists, the head of the ice hockey stick should move about 4 times the distance moved by the hand.

Lesson 5: The Ice Hockey Stick

- Their partner marks the start and stop lines and measures the distances moved by the head of the hockey stick and their partner's hand.
- Their wrist movement is essentially the same as a door opening on a hinge.



- Ask each group to use dot stickers or masking tape to label the positions of the fulcrum (F), load (L) and effort (E) as well as the direction of the forces involved (using arrows) on their model.

Whole Class (Optional Activity)

- Talk about what happens to the ball of paper or ice hockey puck before and after it is hit with the stick.
- Discuss the concept of balanced and unbalanced forces. Ask the children to describe and explain the effect of balanced and unbalanced forces in this activity.

Teacher's Notes

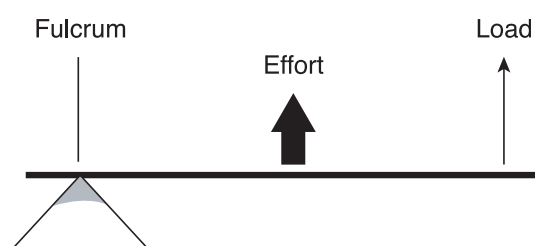
The fulcrum is the wrist, the effort is provided by the lower hand on the stick and the load is the ball of paper or ice hockey puck.

It remains at rest/stationary until it is hit with the ice hockey stick. It then moves away very quickly in the direction in which it was hit, gradually slows down and finally stops.

- *Just before the paper ball is hit, its weight will be balanced by the reaction of the floor that supports it. There are no other forces acting on the paper ball so it remains stationary until it is hit by the hockey stick.*
- *The head of the hockey stick is moving very quickly when it hits the paper ball.*
- *When a force is applied to the paper ball by the moving hockey stick, it moves off at a fast speed but then slows because of friction between it, the floor and air resistance. Friction and air resistance are forces working in the opposite direction to the movement of the ball. Why might a hockey puck move further on ice than on a floor?*

- Ask the children to describe and explain their observations. To demonstrate how a hockey stick works they should use labelled drawings, which include the positions of the fulcrum, effort and load as well as the direction of the forces that are applied.
- How do the positions of the fulcrum, effort and load compare to the other two examples of levers the children have investigated?

3rd Class Lever



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.

In 3rd Class levers the effort is positioned between the load and the fulcrum. This means that 3rd Class levers are not as efficient as the other two lever types because the load will always be further from the fulcrum than the effort. As a consequence, a much larger effort is now needed to move even a small load.

The main advantage of a 3rd Class lever is its use in making the load end move very quickly, as happens in fishing rods, cricket bats, softball bats, tennis racquets and golf clubs. See A Quick Guide to Levers for additional information on the three types of levers.

Further information is also available from the following Internet web sites:

www.howstuffworks.com;

www.enchantedlearning.com/physics/machines/levers.shtml;

www.flying-pig.co.uk

Working in Groups 2-3

- Remind the children of their design task: To provide evidence to help the hockey player in the photograph on Page 8 of the Building Instructions decide on the type of stick he needs to improve his hitting capabilities.
- Discuss the task with the children and ask them how they will set about their investigation.
 - How will they test their designs?
 - What will they test?
 - What will they measure and record?
 - How might they present their results with reference to the original design specification?
- Discuss the need to use a fair test with which to evaluate their design ideas.

If the children perform their test by hand then each test hit may be different. One possible method to eliminate the variability in the test and allow an equal strength hit on each occasion would be to attach the K'NEX ice hockey stick to a stand and allow it to swing from a measured height. The greater the height from which the ice hockey stick blade swings, the harder will be the hit on the ball.

Ask: Do the test balls all need to be the same weight? If not, how might this affect their results? How might they obtain equally weighted paper balls?

Lesson 5: The Ice Hockey Stick

Extension Activity 1

- Ask the children to investigate other 3rd Class levers used in sports, such as cricket bats, golf clubs, baseball/softball bats, tennis racquets, and fishing rods. Provide examples of these pieces of equipment for the children to examine.
- What do the players need to be able to do to meet the objectives of the game? How do the designs of the different types of sporting equipment meet the needs of the players?
- Ask the children to build a K'NEX model of the different types of sporting equipment they have identified and test their ideas.

Plenary

Share ideas about what makes a good ice hockey stick design. Ask the groups to report back to the class with their recommendation to the player. They should make comments on their designs using the correct technical and scientific language.



Teacher's Notes

A stationary puck requires the application of a great amount of effort (force) in order for it to move from rest to high speed in a very short period of time. A longer stick design makes the head of the stick move much faster than the player's hands. (Think about the radius of a circle.) A longer hockey stick, however, may make the control of the head movement more difficult. Applying the lever principle: With a longer hockey stick, the load (the puck) will be further away from the fulcrum and it will therefore need more effort (muscle power) to hit it. A shorter stick will require less effort and its movement is more easily controlled. The trade-off is that the hitting head will not move as quickly.

That is the designer's dilemma - how to make best use of the science.

Lesson 6: Scissors

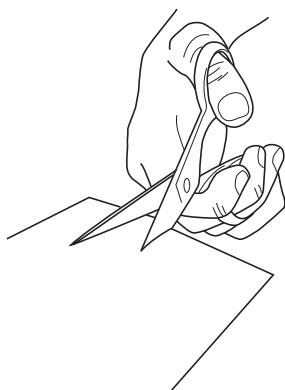
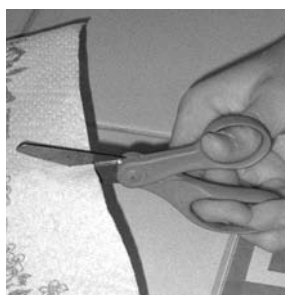
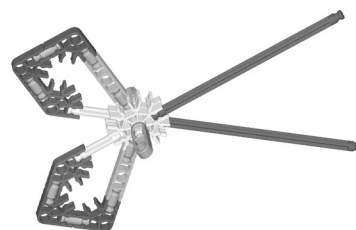
Connected 1st Class Levers



Time: 1 - 1.5 hours

Learning Objectives - Children should learn:

- to relate science to the ways in which familiar machines work
- to carry out a simple investigation



Possible Teaching and Learning Activities

Introduction

In this lesson the children investigate a familiar tool and apply their knowledge and understanding of forces when used in the design of a cutting machine – a pair of scissors.

Whole Class

Demonstrate how scissors can be safely used to cut paper and textiles.

Demonstrate how the two blades work: the blades cut across each other in a shearing action.

Vocabulary

lever, compound, connected, 1st Class levers, pivot, fulcrum, beam, handles, force, blades, wedge, object, resistance, design, specification, compare, labelled, drawings, shearing, wedges, because, evaluate, modify, modifications

Resources

Each group of 2-3 children will need:

- 1 K'NEX Understanding Mechanisms: Levers and Pulleys kit with Building Instructions booklet
- Dot stickers or pieces of masking tape
- Scissors
- Paper and card of different thickness
- Felt-tipped pens
- Modelling clay/Plasticine

You will need:

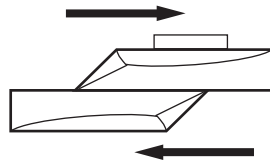
- Selection of different types of scissor-like cutting devices. For example, wire cutters, garden shears, pliers, and hair-cutting scissors.

NOTE: These items should be used for demonstration purposes only. Do not give these implements to the children.

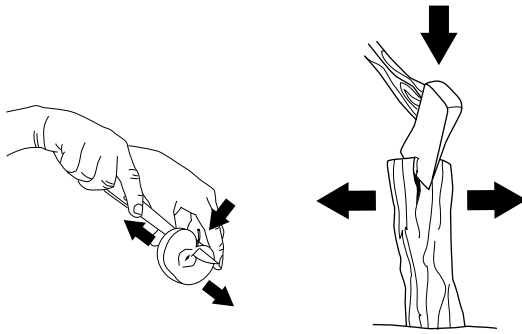
Teacher's Notes

A pair of scissors uses two simple machine concepts in its design: levers and the wedge. The cutting action itself is produced by the sharpened edges of the blades, which are in fact wedges that work in opposite directions to each other.

Lesson 6: Scissors



Cutting edges of scissors.



The sideways movement of a wedge.

Working in Groups of 2-3

Investigating how scissors work

- Allow the children time to make their K'NEX scissors model and to investigate its action.
- * **Ask them what scientific concept is being used when scissors work. You may need to provide them with a clue. Scissors have a hinge or fulcrum about which each blade rotates.**
- * **Where is the effort applied?**
- * **What acts as the load?**
- Use dot stickers or masking tape to label the parts of the scissors:
F = Fulcrum **L** = Load **E** = Effort
 Use arrows to show the direction of the applied forces.

Teacher's Notes

Use a magnifying glass to show children the shape of the cutting edge. The role of the levers is to amplify the squeezing forces from your hand.

See K'NEX Introducing Mechanisms: Wheels and Axles and Inclined Planes Teacher's Guide for further work on wedges.

The blades cut with great force into the paper and, just like all wedges, move the cut paper edges apart in a sideways direction. This action is similar to an axe splitting wood or a knife cutting an apple into two pieces.

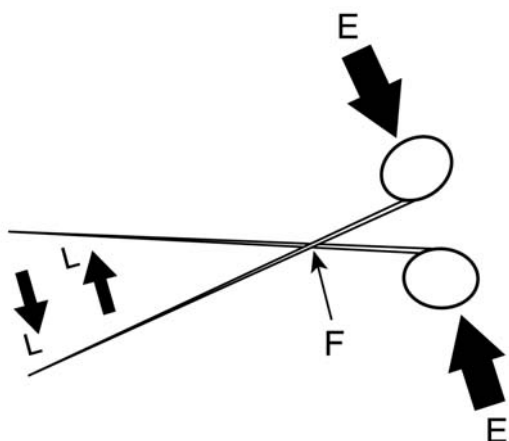
If possible demonstrate how this technology works using the K'NEX wedge model from K'NEX Introducing Mechanisms: Wheels and Axles and Inclined Planes kit.

* **At the handles.**

* **The resistance of the paper or card to the cutting blades.**

Some children may observe that they need to use two effort and load labels on their model but only one for the fulcrum. A pair of scissors makes use of two levers working in opposite directions and is an example of compound or connected 1st Class levers.

The hinge (fulcrum) is common to both levers and is positioned between the effort (handles) and the blades (load).



- Ask each group how they might test the scissors' cutting action? Fingers are NOT allowed, even with plastic.
- Where is the strongest cutting action found?
- Where is the weakest cutting action found?
- Ask the children to describe and explain verbally and in written text, how their K'NEX scissors work. They should be encouraged to use labelled drawings indicating the positions of the fulcrum, effort and load and the direction of the applied forces.

Whole Class

- Show the children a selection of other scissor-like cutting tools with which they may be familiar and which have a similar cutting action to scissors.
- Discuss how all the cutting tools have the same **basic** design but that the design has been modified to make each of them meet different needs.
 - For each cutting tool in turn ask:
 - What types of material is this tool designed to cut?
 - Would scissors be able to cut these materials? If not, why not?
 - How does the design of this cutting tool allow it to cut materials that scissors cannot?
 - Ask the children to make labelled drawings of the different types of cutting tools, indicating the position of the fulcrum, effort and load. They should make short notes to describe how the design of the cutting tool fits them for the jobs for which they are used.

Teacher's Notes

See A Quick Guide to Levers for additional information.

You may find it useful to draw a diagram on the board to illustrate this arrangement.

You might suggest using thin rolls of modelling clay/Plasticine and use the indentation made by the cutting blades as a possible measure of the cutting forces made by the blades.

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.

Cutting tools with short blades and long handles are used to cut difficult materials such as wire or thick branches. The long handles help amplify the squeezing force (effort), while the short blades mean that the load, or resistance, is near the fulcrum or hinge. This position is where the cutting forces are greatest. Remind the children about their investigations when using their K'NEX scissors to cut modelling clay.

Hair cutting scissors, on the other hand, have long blades and short handles because the main need is to make long straight cuts. You do not need a lot of cutting force to cut through hair.

Lesson 6: Scissors

Design Task

Ask the children to modify the design of their K'NEX scissors model so that it has a much stronger cutting or gripping action. With the aid of a labelled drawing of their design, they should write a description of how their design works and state how their modifications have made the cutting action stronger. They should also include the results of any tests they carried out.

Extension Activity 1

If time is available the children might be asked to transfer their design into resistant materials. You might ask them, for example, to make a pair of tongs from wood and other appropriate materials that can pick up and hold an object weighing 200g or more. What is the greatest weight their tongs can lift?

Plenary

Select some models to share with the class and ask the children to describe:

- The reasons behind their design. "We did this because..."
- Why their design works better than the original model.
- The parts of their design that please them.
- What tests they carried out to evaluate their design against the design brief.

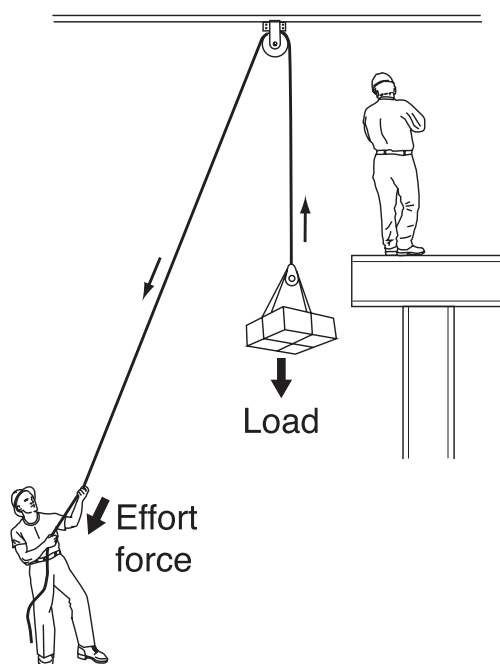
Teacher's Notes

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.



A Quick Guide to Pulleys

A pulley is a very simple type of mechanism; it has been used for thousands of years to make easier the job of lifting heavy objects. The simplest type of pulley mechanism is a single pulley.



One way of getting bricks to the top of a building is to pull them vertically upwards. This method requires a great amount of hard work. Using a single pulley mechanism, however, allows heavy objects to be lifted by pulling down on a rope from below. This is an easier and safer way to raise the load of bricks than to be on the roof pulling them up. So how does it work?

What is a pulley?

A pulley is a mechanism that can change the direction of an effort, or pulling force, applied to a rope. This means that a pull **down** may be converted into a pull **up**. Pulleys can also be used to amplify the applied effort force. Passing a rope over the rim of a revolving wheel or pulley helps to reduce the amount of friction in the system.

When a single pulley is used as a lifting device, the effort force needed to raise the load must be equal to or just greater than the load. In theory the effort needed to lift the load is the same as if the load was lifted directly from the ground without using a pulley. In practice, however, the effort force must be greater than that of the load in order to overcome the added effects of friction in the system.

Key elements of a pulley mechanism

- **Pulley** - a freely revolving wheel with a groove in its outer rim through which a rope, cable or chain can be passed.
- **Effort** - the pulling force applied to the rope to lift the load.
- **Load** - the weight of the object to be moved by the effort force.



What can pulleys be used for?

Pulleys can:

- **Change the direction of the applied effort force**
 1. A downward pull on the rope running over a single fixed pulley results in an upward movement of the load.



A Quick Guide to Pulleys

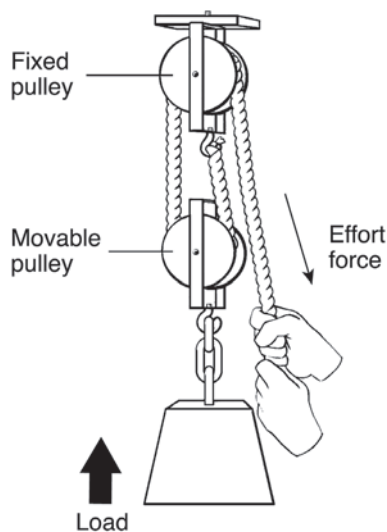
- Pulleys can also be used to move loads horizontally using a vertically applied effort force. A downward pull on a rope attached to a pulley system, can move a clothesline horizontally.



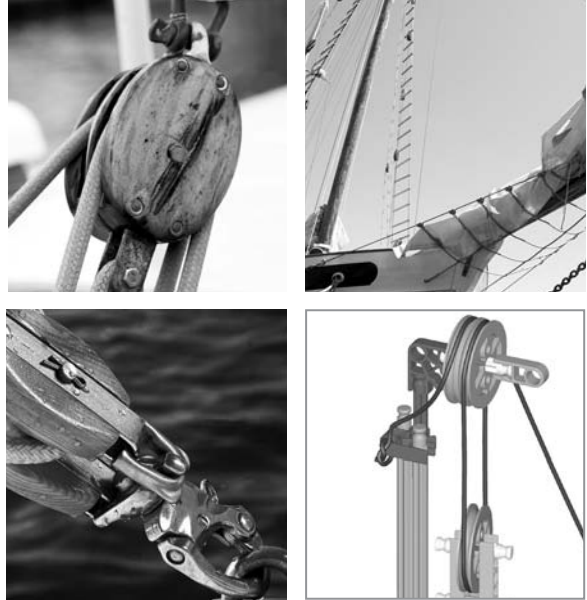
- **Amplify the applied effort force**

As more pulleys are used in a pulley system, less effort is needed to move or lift a load, but a longer amount of rope must be pulled through the system. This is the trade-off. Less effort is needed but it is applied over a longer distance.

For example, in a system composed of 2 pulleys – one upper pulley that is fixed and one lower, movable pulley – you only need apply **half** the effort force that would otherwise be needed to raise the load if pulleys were not used. The distance you must pull the rope, however, will be double the distance moved by the load.

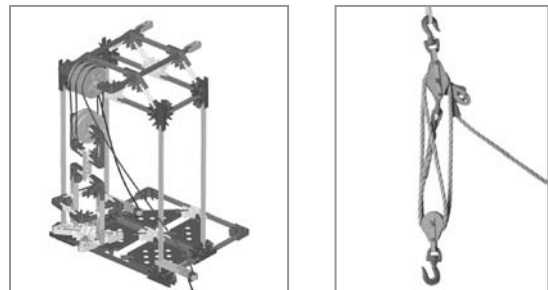


Sailboats and yachts make much use of these types of pulley systems to handle and control large heavy sails.



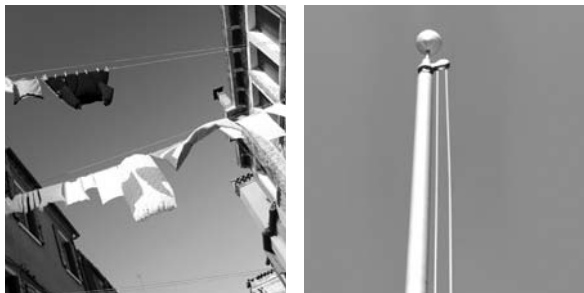
Multiple pulleys and cables are found in systems used to lift very heavy loads. A multiple or compound pulley system is called a **block and tackle**. Using multiple pulleys amplifies the effort force still further so making the job of raising the very heavy loads easier to do.

Why is it called a block and tackle? The block is the frame that holds the pulleys and the tackle is the rope or cable.



Key facts about pulleys:**Single or fixed pulley**

Examples: flagpole, clothesline, painter's platform.



A single fixed pulley must be attached to a frame and the pulley wheel can rotate freely to reduce friction.

Fixed pulleys change the direction of the applied effort force.

The load moves the same distance as the effort force.

Single fixed pulley attached to a frame.

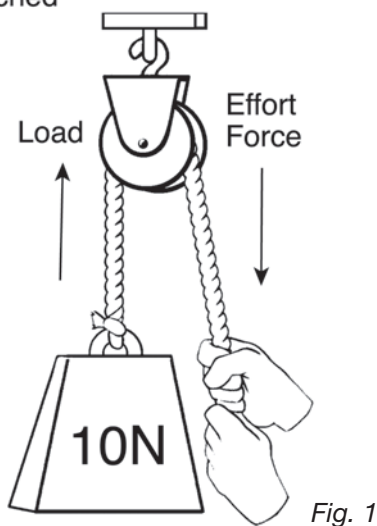


Fig. 1

The advantage of a pulley can be seen when you compare using a fixed pulley to lifting from above. When lifting from above you can only use muscle power to pull the load upwards, all the time working hard to overcome the effects of gravity.

Using a fixed pulley, however, enables you pull down and to use gravity to your advantage by allowing you to add your body weight to the effort made by your arm muscles, so making it appear to be easier to lift the load.

When a single pulley is used as a lifting device, the effort force needed to raise the load must be equal to or just greater than the load. In theory the effort needed is the same as if the load was lifted directly from the ground. In practice, however, the effort has to be greater than the load in order to overcome friction in the pulley system. Using a rotating wheel is one way of reducing friction.

Movable Pulleys

When two pulleys are used, the upper pulley must be fixed to a frame while the lower movable pulley is attached to the load it lifts. The two pulleys are connected by a single continuous rope and when the rope is pulled down, the lower pulley moves upwards taking the attached load with it.

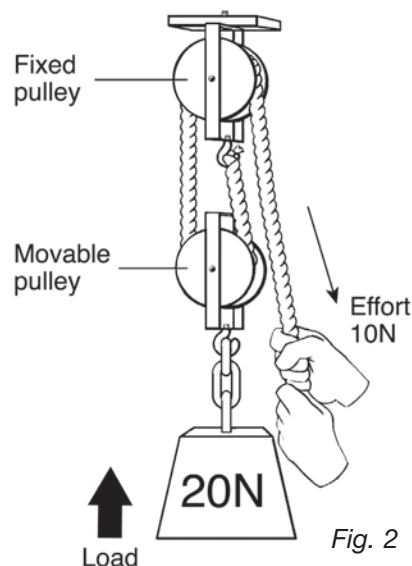


Fig. 2

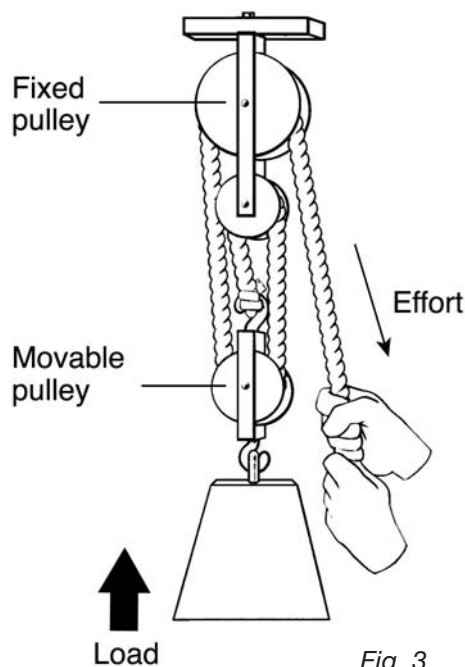
Movable pulleys amplify the applied effort force. As more pulleys are used, less effort is needed to raise the load, but the rope must be pulled through a greater distance.

A Quick Guide to Pulleys

In the example shown in Fig. 2, two pulleys are used. The weight of the load being raised is distributed equally between the two parts of the rope on either side of the movable pulley. The force needed to hold the system in balance or to raise it is now only half that of the load. The downside is that the effort force must move twice as far as the load. For example, to lift a 20N load a height of 3cm, the 10N effort force must move a distance of 6cm.

Compound Pulleys

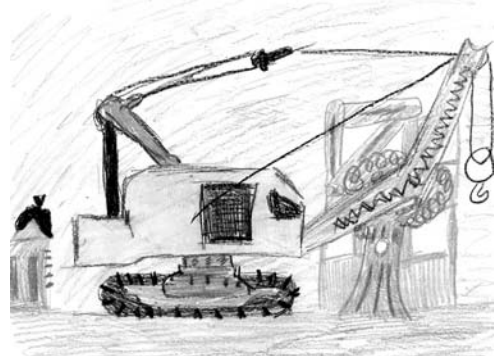
Compound pulleys are made from two or more sets of pulleys connected by the same rope. The upper set is made from fixed pulleys attached to a frame, while the lower set is made from movable pulleys. Effort is applied by pulling down on the rope or chain. Compound pulleys not only change the direction of the applied force but they also increase the force applied to the load.



As more pulleys are used, less and less effort is needed to lift heavy loads. In Fig. 3, the K'NEX block and tackle model has 4 strings supporting the two lower movable pulleys. The number of supporting strings equals the number of times the pulley system multiplies the effort force.

If the load to be lifted by the K'NEX block and tackle model is 4N, then the effort force required to lift it will be 1N. This is because the load is divided between four parts of the rope, each part carrying a quarter of the load.

If the load is raised 1cm, the cumulative effect on the distance moved by the effort will be $4 \times 1\text{cm}$. In this example the effort will move 4 times the distance moved by the load.





Lesson 7: The Flagpole

A Fixed Pulley System



Time: 1 - 1.5 hours

Learning Objectives - Children should learn:

- pulleys are wheels with grooves around their outer rim
- pulleys can be used to lift objects and change the direction of movement
- to relate science to the ways in which familiar machines work
- to carry out a simple investigation



Possible Teaching and Learning Activities

Introduction

The activities in this lesson may be used to support the QCA/DfEE Exemplar Scheme of Work for:

Design and Technology Unit

- **2C: Winding Up**

Science Units

- **1E: Pushes and Pulls**
- **2C: Forces and Movement**
- **6E: Balanced and Unbalanced Forces**

Whole Class/Demonstration:

- Review with the children how many of the simple machines they have investigated make it easier to lift heavy objects.
- Ask for a volunteer(s) to bend, face down, over a table/desk, next to one edge, and reach down on the side of the table/desk to lift a bucket or basket filled with heavy objects. (Children should not extend an arm over the front of the desk).
- Ask the volunteer to describe how difficult (or easy) this was for them.
- Secure a rope to the bucket and ask them to pull it up using the rope.
- Encourage the children to consider ways in which this could be done more easily. For example: place a broom handle across two desks and loop the rope over the handle. The volunteer can now pull down on the rope instead of pulling up. Does this arrangement make it easier or more difficult to lift the load? Record their suggestions/answers on the board for later reference and discussion.
- Explain that their task is to build a model that will demonstrate the use of a simple machine called a pulley that can make the job of raising an object easier.

Vocabulary

pulley, wheel, groove, rim, fixed, pull, force, lift, raise, lower, gravity, rotary, motion, linear, load, effort, Newtons, measurement, opposite, direction

Resources

Each group of 2-3 children will need:

- 1 K'NEX Understanding Mechanisms: Levers and Pulleys kit with Building Instructions booklet
- Dot stickers or pieces of masking tape
- Felt-tipped pens
- Measuring tape or rulers
- Coloured paper or cloth
- Coloured crayons or pencils
- Scissors
- Stapler, glue or tape
- 200g slotted weights
- 1 small bucket or basket filled with heavy objects
- String/rope
- Broom handle

Lesson 7: The Flagpole

Working in Groups of 2-3

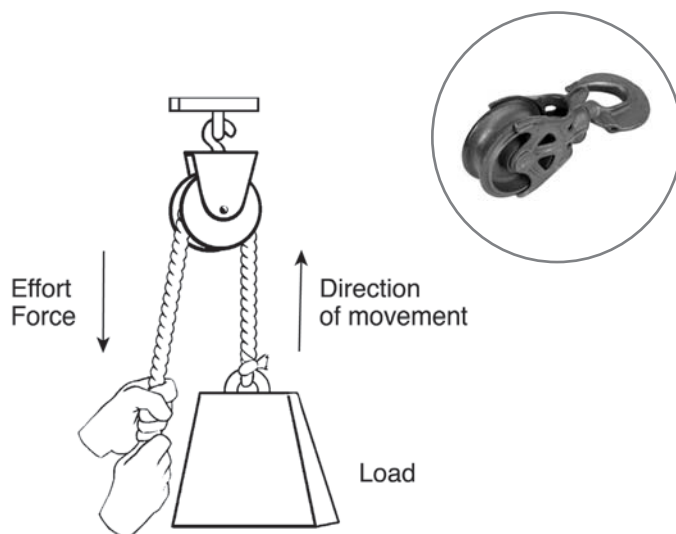
- Ask the children to build the K'NEX Flagpole model, (Pages 10-11 of the Building Instructions booklet), and allow them time to investigate how it works and what it does.
- With the help of a labelled diagram drawn on the board, discuss how a pulley wheel works and how the rope fits into the groove in the rim of the wheel.

Whole Class

- Explain how their K'NEX Flagpole model provides an example of a FIXED pulley. This is a pulley that does not move when the rope is pulled, although the wheel may spin in place.
- Ask the children why they think flagpoles make use of pulleys to raise and lower a flag.
- How would they get a flag to the top of the pole if they did not use a pulley?
- Where have the children seen other examples of this type of pulley being used?

How many different types of machines do the children know about that use pulleys in their mechanisms?

What do these machines do?



Teacher's Notes

The children should not cut the string in this model. A long string will be needed for subsequent pulley building activities.

See: *A Quick Guide to Pulleys and Key Technical Terms and Scientific Definitions* for additional information.

It is easier and safer to pull down on a rope to raise a flag than it is to climb a tall ladder to secure the flag to the top of the pole.

Possibly on cranes, washing lines, on equipment in the school gym, or classrooms.

Free photographs of pulleys in action on cranes can be obtained from www.freefoto.com

A pulley is a wheel with a groove around its outside edge into which a rope or belt can fit. By pulling down on one end of the rope a load on the other end can be lifted. Pulleys can be used to change the direction of movement and can make it easier to lift heavy objects. Children will be able to explore different types of pulley systems during the next few lessons.

*For additional information please refer to *A Quick Guide to Pulleys and Key Technical Terms and Scientific Definitions*.*

Internet Web site on pulleys: www.howstuffworks.com and search 'pulleys'.

Some examples you may want to discuss with the children include:

- * **lifting heavy objects, as in cranes or running a flag up a flagpole.**
- * **transferring movement and forces in sewing machines and vacuum cleaners.**
- * **moving equipment in the gym or even opening and closing curtains.**

Working in Groups of 2-3

(If the children have added the string to their flagpole, ask them to remove it before beginning this next activity.)

- Ask the children to complete the following:

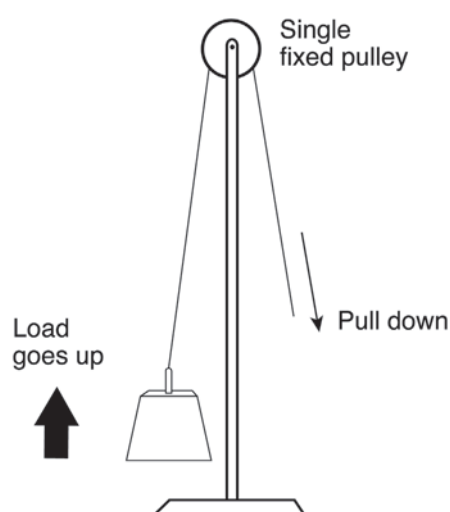
Step 1: Attach a slotted mass to one end of the string and simply lift it vertically by hand. Ask them to feel how much force or effort is needed to lift the mass. What happens when they let go of the string?

Step 2: Pass the string over the pulley. Lift the mass by pulling the string. Feel how much force is now needed to lift the mass.

NOTE: Care should be taken when pulling down on the string so it does not slip. The string should be grasped just below the pulley and pulled down **SLOWLY**.

- Does the pulley make lifting the mass easier?
- * **What types of movement are produced by pulley systems?**
- Ask the children to use stickers to label the fixed pulley and the directions of movements of the effort and load.

- * **Amplifying forces to help lift heavy objects using little effort.**
- * **The circular motion of a motor is transferred to wheels or cylinders.**
- * **Changing the direction of movement.**



- * **(i) Linear: by the moving load and the pulling force.**
- * **(ii) Rotary: by the pulley wheel.**

The pulling force is the effort, while the mass being lifted is the load. This is the same as in levers. When using the fixed pulley the children pull down on the string to raise the mass. It is easier to pull down on the string using a pulley because "body" weight can also be used to help the pulling forces. (Ask them to remember the demonstration at the beginning of the lesson when a pupil reached down to lift up a heavy load.) When pulling directly upwards only "muscle" power can be used. In fact, the same amount of effort is used in both cases.

Lesson 7: The Flagpole

- How might the children measure the forces needed?

Step 3: Ask the children to repeat Step 2 but only this time they should measure the distances moved by their hand (the effort) when pulling on the string and the distance moved by the mass (the load). One child should grip the string just below the pulley and pull down slowly to lift the load. Another child then measures:

- (i) how far the string has been pulled
- (ii) how far the load has been raised above the desktop.

- What do their measurements tell them about how a fixed pulley works?

- Ask each group to record and explain their findings and observations by writing and making labelled drawings. They should indicate the direction of the applied forces, the direction of movement of the pulling force and the object being raised. The children should be encouraged to use the correct scientific vocabulary.

Optional Activity for Step 3

- Ask the children to describe what they have observed in terms of balanced and unbalanced forces.

Teacher's Notes

A force meter could also be used for these activities to enable the children to take direct measurements. If you have not already done so, demonstrate how a force meter is used to measure forces and explain that the unit of measurement is Newtons (N).

To lift a load the children would have to pull on the rope with at least as much force as the weight of the load. They might test this by connecting a force meter to either end of the pulley rope, pulling each force meter and recording the reading.

The distance moved by the effort and the load is the same. If force meters have been used then, in theory, the values obtained for the effort force and load should also be the same. In reality, however, the effort force is likely to be larger because of the additional effect of friction in the pulley system. Fixed pulleys only change the direction of movement or the applied force; they do not amplify the force.

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.

Teacher's Notes

When the load is pulled upwards, the pulling force is greater than the weight of the object – the forces are unbalanced. When the object is held still, the forces are balanced – it is not moving. The force applied on the rope end equals that of the weight on the other end. When released it falls because there is now no upward pulling force but only the force of gravity pulling it downwards.

Extension Activity 1**Working in Groups of 2-3**

- Ask the children to design a flag for their flagpole using coloured paper or cloth, felt-tipped pens or crayons.
- How are they going to attach their flag to the string so that it is also easy to remove?
- How can they make sure the flag can open in a breeze?

OR**Alternative activity****Working in Groups of 2-3**

Design a flag code message system to be used to send and receive short secret messages to and from another group.

Plenary

Discuss what the children have learnt about pulleys and how they are used, using vocabulary that relates to the science and technology they discovered.

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.

If possible, retain a flagpole model, with its fixed pulley, so that the children can compare it with the compound pulley system used in the sailboat model.

Lesson 8: The Sailboat

A Compound Pulley System



Time: 1 - 1.5 hours

Learning Objectives - Children should learn:

- to relate science to the ways in which familiar machines work
- to carry out a simple investigation



Vocabulary

pulleys, fixed, movable, force, effort, load, double pulley system, single pulley system, compound, compare, doubled, amplify, because, trade-off, pull, force meter, prototype, Newton, friction, lift, lower, raise

Resources

Each group of 2-3 children will need:

- 1 K'NEX Introduction to Simple Machines: Levers and Pulleys kit with Building Instructions booklet
- Dot stickers or pieces of masking tape
- Felt-tipped pens
- Measuring tape or rulers
- Coloured paper or cloth
- Coloured crayons or pencils
- Scissors
- Stapler, glue or tape
- 200g slotted masses or 5 Newton force meter
- Large paperclips

You will need:

- The K'NEX flagpole model
- Pictures of sailboats and sailing ships available for the children to view
- Additional lengths of string for Extension Activity 2 (optional)

Possible Teaching and Learning Activities

Introduction

Whole class

- Review with the children how the use of a pulley system helps make the job of raising a flag to the top of a pole easier. In this case, the pulley is used to change the direction of the effort force – it is easier to pull down on a rope than to pull up on one. Using a pulley system also means that you do not have to climb a ladder to reach the top of the pole.

Teacher's Notes

More information on pulleys is available from A Quick Guide to Pulleys and the Internet web site www.howstuffworks.com

- Ask the children to look at the pictures of different sailing boats. Talk about how, regardless of the size of the sailboat, sailors have always been faced with the same problem: how to lower and raise heavy sails safely. In days of large sailing ships sailors had to climb the masts and literally pull up large, heavy sails by hand – it was very dangerous work. Modern sailboats use pulley systems that allow the crew to raise and lower sails quickly without leaving the (relative) safety of the deck.
- This lesson investigates how pulleys can be used to lift heavy objects.
- Ask the children to collect/find pictures of lifting machines from books or from research using the Internet.
- Discuss how pulleys can be used in a number of situations.
- Allow the children time to investigate photographs or illustrations of lifting machines that use pulleys.
- What are these machines used for?
- How heavy are the loads they lift?
- Is there any connection between the size of the loads and the number of pulleys and ropes/cables they use?

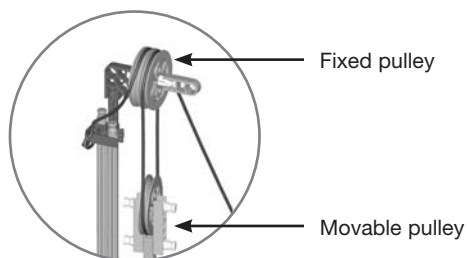
Working in Groups of 2-3

- Ask the children to construct the K'NEX Sailboat model shown on Pages 12-13 of the Building Instructions booklet.

Building Tip: Building Steps 6 – 8 will require cooperation between the members of the group. This applies particularly to Step 7 when string is attached to the pulleys. Make sure that one child holds the movable pulley (built in Step 6) while another carefully threads the string around the pulley wheels.

Remind the children that they should NOT cut the string. They will need a long string for several other pulley activities.

- Allow time for the children to investigate how the sail mechanism works by lifting a mass attached to the lower pulley. An opened, large paperclip could be used as a hook.



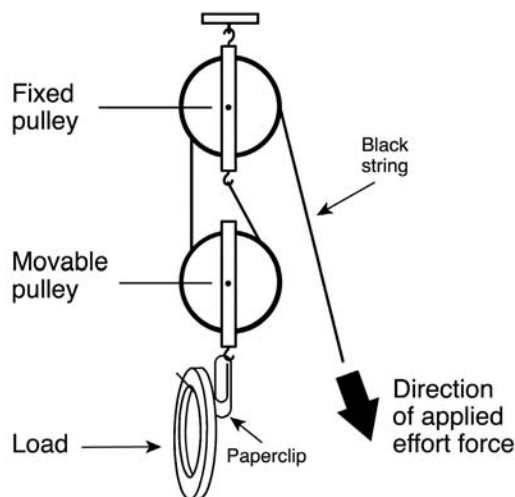
Teacher's Notes

Free photographs can be obtained from www.freefoto.com and <http://pics.tech4learning.com/>

Talk about how machines that are used to lift heavy weights usually have numerous pulleys in the lifting mechanisms. The greater the number of pulleys that are used, the easier it becomes to lift heavy loads.

In this model pulley system there are two pulleys, an upper fixed pulley and a lower movable pulley. Two ropes are attached to the lower movable pulley. This arrangement is called a double, or compound, pulley system.

Lesson 8: The Sailboat



- Ask the children to consider how the lower pulley differs from the pulley wheels at the top of the mast. Talk about the concept of movable pulleys.
- What do they notice about the distances moved by the lower pulley wheel and the end of the rope? Are they the same as in the flagpole model, or different? If possible, have the flagpole model available for comparison.
- What do they notice about the effort forces needed to pull the string to raise the load? How do their findings compare with what they found using the flagpole model?
- Use stickers to identify and label the **fixed** and **movable** pulleys and the directions of movement observed.
- Ask the children how they might test how well their pulley system works? Discuss how they might measure the forces used? How many measurements do they need to take?
- Ask each group to record and explain their findings and observations through writing and labelled drawings. They should indicate the direction of the applied forces, the direction of movement of the pulling force and the object being raised. The children should be encouraged to use correct scientific vocabulary.

Teacher's Notes

The distance moved by the effort or pulling force - the child's hand pulling the string - is twice that moved by the load but the pulling force needed to move the load is halved.

This is the trade-off. The pulling force (effort) needed is halved but the distance it has to move is doubled.

It may be necessary to review that forces are measured in Newtons (N) and if weights are used, how their values can be converted into Newtons. Alternatively, two force meters may be used - one to measure the downward pulling force and the other the force that is to be overcome.

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.



Extension Activity 1

Working in Groups of 2-3

If time is available, ask the children to design a sail for their sailboat using appropriate materials. The children could use photographs of sailboats to research ideas for sail designs and shapes.

- How will the sail be attached to their mechanism for raising and lowering?
- How will the sail be 'fixed' in position when it has been raised?

Extension Activity 2

Design Task - Working in Groups of 2-3

Their sailboat needs to be rigged for use by a crew with physical disabilities. The task is to design a sail handling system to raise and lower two sails, one fore and one aft, which can be operated from the deck.

They can only use the contents of the kit to make their prototype.

Allow the children time to select, measure and make a sail from suitable textiles.

- How will they attach the sail to
 - (i) the raising mechanism
 - (ii) the sail boom?
- How do real sailboats do this?
- Can they make use of the "flagpole" mechanism?

The children should be encouraged to draw plans for their design, indicating how they think it will work.

On completion ask:

- What changes did you make during the testing of your design?
- What were the most difficult parts to make?
- How did you solve the problems?

Plenary

Review what the children have learnt about movable and fixed pulleys and how, when fixed and movable pulleys work together, they form a compound pulley system.

Note: The "rope" that comes with the kit should not be cut, so an alternative will be necessary.

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.

Lesson 9: The Block and Tackle

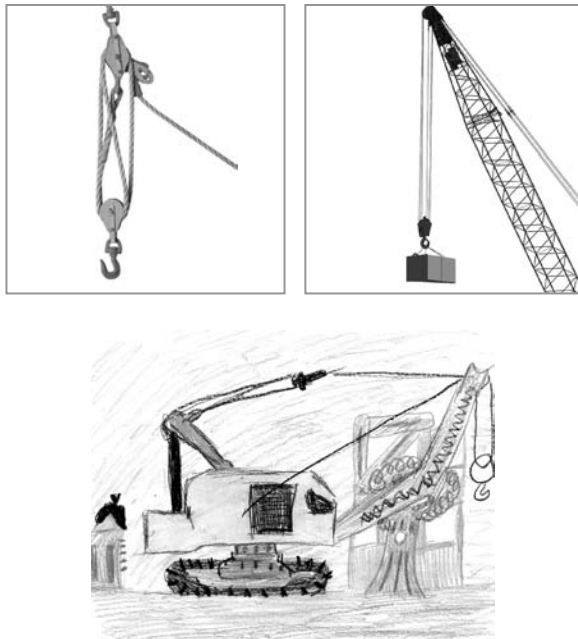
A Compound Pulley System



Time: 1 - 1.5 hours

Learning Objectives - Children should learn:

- to observe and describe movements in a simple machine
- to relate science to the ways in which familiar machines work
- to carry out a simple investigation



Vocabulary

block and tackle, pull, pulley, fixed, movable, force, effort, load, counterbalance, counterweight, balanced, unbalanced, lever, modify, evaluate, amplify, trade-off, topple, unstable, stability, compare, because

Resources

Each group of 2-3 children will need:

- 1 K'NEX Introduction to Simple Machines: Levers and Pulleys kit with Building Instructions booklet
- Dot stickers or pieces of masking tape
- Felt-tipped pens
- Measuring tape or rulers
- Paper cup
- 200g slotted masses
- Large paperclips
- 2 x 5 Newton force meters (optional)

Possible Teaching and Learning Activities

Introduction

Whole class

- Discuss and/or review the children's previous experiences in which they discovered a connection between the number of pulleys used in a pulley system and the amplification of the pulling force – the greater the number of pulleys used, the easier becomes the lifting job.
- Show, or ask the children to find, photographs and pictures of cranes at work.
- Ask them to describe the pulleys systems they use and the jobs they have to do?
- How do they think these pulleys systems make it easier to lift heavy loads?

Teacher's Notes

Photographs of cranes can be obtained from www.freefoto.com and <http://pics.tech4learning.com/>

www.freefoto.com has some good photographs of a giant floating crane pulling the Gateshead Millennium Bridge in place.

Internet research:
www.howstuffworks.com.

For additional information on pulleys see A Quick Guide to Pulleys.



Whole class

- Introduce the activities by explaining how the cranes use 'block and tackle' mechanisms to lift very heavy loads and how a block and tackle can make the job of lifting heavy objects easier.
- Before building their K'NEX Block and Tackle model ask the children to look at the plans for their model on Page 15 of the Building Instructions booklet.
- Explain how the block and tackle is constructed by winding the rope around a number of fixed and movable pulley wheels.
- How many times do they think the lifting force will be increased by this pulley system?

Working in Groups of 2-3

Let's Investigate

- Ask the children to construct their K'NEX Block and Tackle model and allow them some time to investigate how it works.
- Ask each group to identify and label the fixed and movable pulleys in their model.
- How do the children think using a number of fixed and movable pulleys in a lifting mechanism will affect its ability to lift a load?
- Ask each child in turn to place a paper cup containing one or more 200g masses on the palm of his or her hand and to raise and lower it. This will allow them to gain some impression of the load being lifted by their model and the forces needed to raise it.
- Suggest the children try lifting the paper cup using the K'NEX Block and Tackle model.
 - Ask what happened to their model when they first tried to lift the weighted paper cup?
 - Ask the children to explain their observations.
 - What other science concept is working here?
 - How might they solve the problem?

Teacher's Notes

The correct answer is 4 times.

The multiplication can be found by counting the number of lengths of rope supporting the movable pulleys. In this example there are 2 movable pulleys, each with two supporting ropes = 4. (The three pulleys at the top of the structure are fixed pulleys.)

See: A Quick Guide to Pulleys.

Force meters could be used to record the actual forces needed to lift the weighted paper cup vertically. These can then be compared with those needed when using the block and tackle.

The K'NEX Block and Tackle model becomes unstable and will topple forwards as the weighted paper cup is lifted. When the load is lifted off the desktop the structure acts like a lever that pivots around its front edge. The front edge becomes the fulcrum and if the weight of the load is greater than the weight of the model, the model will topple in the direction of the load. The forces in the system have become unbalanced.

A counterweight is needed to balance the weight of the load being lifted. The folder shown in the photograph on Page 15 of the Building Instructions booklet is acting as the counterweight.

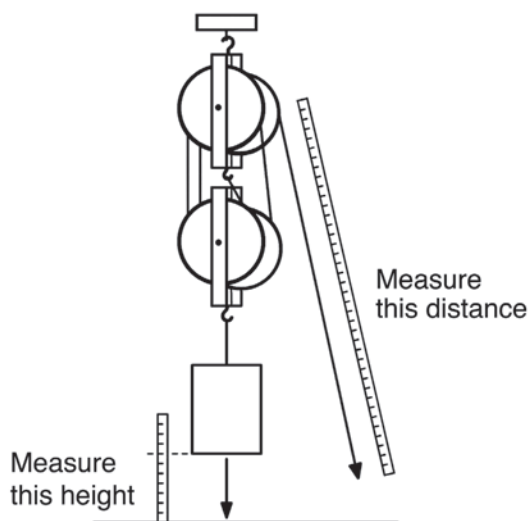
Lesson 9: The Block and Tackle

Investigating Further

- Explain that as they use the block and tackle model to lift a load the children should try to discover answers to the following questions:
- What did they find out about the amount of effort needed to lift the load?
- How does the lifting 'power' of this model compare to the other pulley models?
- How does the pulley system in this model differ from the other pulley models they have investigated?

(a) Planning their own tests

- Ask the children how will they test their ideas.
- Encourage them to plan and explain their tests before carrying them out.
- What measurements do they need to make?
How will they take their measurements?
- How will they record their results? In a table?
- Refer them back to what they did in earlier lessons on pulleys.



(b) Directed investigation

- Ask the children to place the weighted cup in the basket and pull on the string to lift it.

In cranes the counterweight is very heavy because it must be placed close to the fulcrum. Ask the children to identify the positions of the counterweights in the photographs of cranes they have found.

Teacher's notes:

Investigating Further

There are two approaches you might consider using:

a) Building on earlier lessons, ask the children to plan their own tests, including measurements to be taken and data logging techniques. Children could use rulers and measuring tapes to measure the distance moved by the effort and load. Force meters could be used to record the effort force.

b) Direct the children as to what they should do.



- Feel the force needed to lift the weighted paper cup.
- How does lifting the weighted paper cup with the block and tackle compare to lifting it directly by hand?
- Count the number of strings supporting the lower movable pulleys. What might this information tell you about how much this block and tackle system helps you to lift the load?
- Using the block and tackle, raise the cup about 5cm. Measure how far the string must be pulled to allow the paper cup to reach this height?

For either approach:

- Ask the children to describe and explain their observations, to make labelled drawings of their model and use arrows to indicate movements. They should be encouraged to use the correct terminology to describe the different components.

Extension Activity 1

Design Task

Working in Groups of 2-3

The present lifting mechanism is not safe when in use. Modify the design so that it will not topple when lifting heavy objects.

The children should be encouraged to

- draw plans for their design
- explain how they will evaluate it
- write a description of how they think it will work.

On completion ask:

- What changes did you make during the testing of your design?
- What were the most difficult parts to make?
- How did you solve the problems?

Extension Activity 2

Design Task

Working in Groups of 2-3

Your mother is a physical therapist working with people who have been injured and have to use wheelchairs. It is often difficult for your mother to lift the patients out of their wheelchairs to use the machines for their exercises. Using K'NEX and other appropriate materials, design and make a portable pulley system that can lift patients out of their wheel chairs and transport them to the different exercise machines. Explain how your machine operates and how it uses pulleys to accomplish the task.

Teacher's Notes

Force meters could be used to compare the actual forces needed to lift the weighted paper cup vertically with those needed when using the K'NEX block and tackle model.

An alternative approach could be to use two force meters - one representing the pulling force, or effort, and the other the load to be overcome by the effort.

The children should notice a significant reduction in the effort needed to lift the weighted cup when using the block and tackle. They should also observe that there are 4 strings supporting the two lower movable pulleys. This system makes it 4 times easier to lift the weighted paper cup load, but the 'trade-off' is they have to pull the string 4 times the distance moved by the load.

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.

Lesson 9: The Block and Tackle

Plenary

Discuss what the children have learnt in the lesson using the words relating to the science and technology they discovered.

Ask them what they think the effect of adding more pulleys to their block and tackle might be on its lifting ability.

Talk about patterns that may be arising in their results from this and other lessons. You may want to discuss, for example, how simple machines help to make jobs easier to do by increasing/amplifying applied forces, but note that there is a trade-off. Using a simple machine can mean that they expend less effort BUT they have to apply the effort over a longer distance.

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

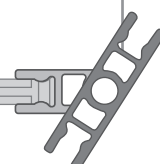
Work is a scientific concept and is only done when a force moves an object in the same direction as the applied force.

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.



levers and pulleys

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.

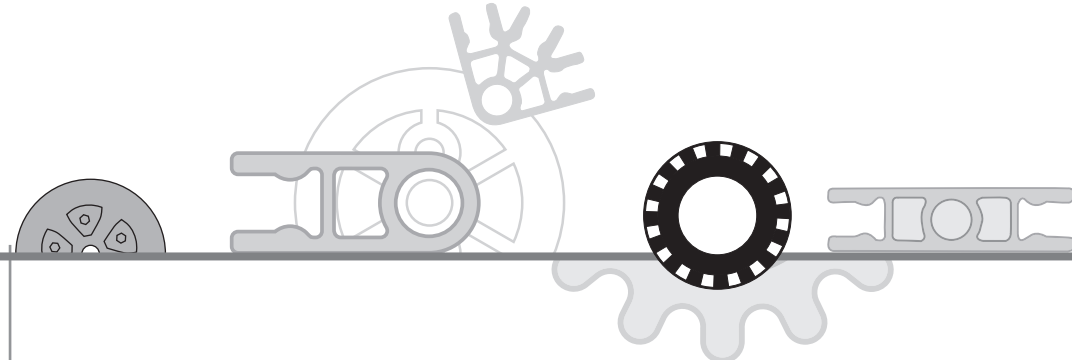


- **Reciprocating:** This involves an alternate backward and forward motion, in a straight line, as in the movement of a sewing machine needle or the pistons of a car engine.

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.