FEEL THE FORCE

LESSON 8: HOW CAN WE USE LEVERS TO HELP US?

Key vocabulary:
lever, pivot, push, pull, mechanism, machine, force, fulcrum

Resources:
Everyday objects that use class one levers (for example, claw hammer, scissors, pliers, metal spoon), empty tins with inset metal lids, long-handled wooden spoons,1 litre plastic bottles filled with water to weigh 1 kg, stiff cardboard tubes approximately 3 cm diameter, modelling clay, push/pull meters up to 10 N, books (at least thick paperback size), wooden ramps to be used in Challenge 1

Key information:
A mechanism is simply a device that takes an input motion and force, and outputs a different motion and force. A lever is the simplest kind of mechanism.

LESSON SUMMARY:

This lesson introduces mechanisms – devices that change the effect of a force. Children investigate levers for moving things and increasing/decreasing a force. By the end of the lesson children know that levers can alter the size of forces required to move or balance an object.

National curriculum links:

Recognise that some mechanisms, including levers, pulleys and gears, allow a smaller force to have a greater effect

Learning intention:

To demonstrate how levers work and how they reduce the force required to move objects

Scientific enquiry type:

Carrying out simple comparative and fair tests

Working scientifically links:

Taking measurements, using a range of scientific equipment with increasing accuracy and precision, including taking repeat readings when appropriate

Success criteria:

- I can use levers to move objects.
- I can explain that when something is moved using a lever, less force is needed.
- I can label a diagram using scientific vocabulary to explain how a lever works.

EXPLORE:

Ask children what they think a mechanism is. Explain that it is a device that makes work using forces easier. Inform children they are going to use levers – a type of mechanism.

Show everyday levers: scissors, pliers and claw hammer. Explain that these levers need a moving force to make them work. Give children empty tins with inset lids. Ask them to work in pairs to open the tins. Ask if they know how to open them easily.

Give out the teaspoons and ask children to use them to open the tins.

Ask: *How did you use the spoon to open the tin?*

Emphasise that they used a force to push down on the spoon, which pivots on the edge of the tin. There is an upward force on the other end of the spoon that lifts the lid. (Put the end of the teaspoon handle, not the bowl of the spoon, under the lip of the lid.) Remind children of the arrows they used previously to show directions of forces.

Ask: *In which directions are forces working? Where is the pivot point? What playground item works like this?*

To explain the lever mechanism ask a child to hold the end of the handle of a long-handled wooden spoon. Explain that they are representing the lid of the tin. Hold the handle between your finger and thumb near the same end of the spoon. This is the fulcrum, where the lever pivots. Show what happens when a downward force is applied to the other end of the spoon as it pivots in between your finger and thumb. Ask the child what they feel happening where they are holding the handle.

Establish that the spoon is a lever and that this was the mechanism that helped to open the tin.

Explain that levers have three parts: the fulcrum, where the lever pivots; the weight arm (the part from the fulcrum to the weight to lift); and the force arm (the part from the fulcrum to where you push or pull).

Ask: *Can you name these parts in the lever you used to open the tin?*

Ask children each to draw on mini whiteboards a diagram of the tin being opened with a spoon and label it with this vocabulary.

ENQUIRE:

Explain to children that they are going to investigate how to use levers to change the force needed to move things. The challenges are differentiated by how children describe or measure the effects of levers. Children work in groups of three.

The challenges are presented on the Challenge slides to be displayed on the board, or printed out and placed in the centre of the table.

Challenge 1: Children investigate the effects of the comparative lengths of lever and weight arm on moving a load

Give each group two tins with inset lids (to act as the fulcrum), a wooden board, books and Resource sheet 1. Tell them to tape the tins together end to end, rest the board across them like a seesaw and place four books on one end. This is the weight arm.

Ask them to add books to the pile, one at a time until the weight arm lifts, and record the number of books. Ask them to repeat this twice: first making the force arm longer than the weight arm, then making both arms the same length. Encourage the children to write a sentence saying which makes it easier to move the weight: a force arm is shorter, longer than, or same length as, the weight arm.

Challenge 2: Children measure the difference a lever makes to the force needed to move an object

Explain to the children that they going to investigate the effect of changing the length of a lever. Give each group a long-handled wooden spoon, a 1 litre plastic bottle filled with water (i.e. 1 kg), a cardboard tube, modelling clay and a push/pull meter.

Provide Get things moving (Resource sheet 2). Ask the children to place the lever (spoon) under the neck of the bottle lying on its side, just below the lid, and measure and record the force (in Newtons) needed to lift the bottle with the fulcrum (cardboard tube) in four different positions: close to the bottle, and then moving it backwards towards the bowl of the spoon. Suggest that one child holds the modelling clay to stop the bottle rolling, another pushes down with the push meter and the third takes the reading from the push meter. Ask them to record these on mini whiteboards.

Challenge 3: Children measure the difference a lever makes to the force needed to move an object

Give each group a long-handled wooden spoon, a 1 litre plastic bottle filled with water (i.e. 1 kg), a cardboard tube, modelling clay and a push/pull meter. Explain to the children that they going to investigate the effect of the length of a lever.

Provide Get things moving (Resource sheet 2). Ask the children to measure and record the force (in Newtons) needed to lift the bottle, and record their measurements on the Bottle lift table (Resource sheet 3). Ask them to place the lever (spoon) under the neck of the bottle (lying on its side) just below the lid, with the fulcrum as close to the bottle neck as possible, and to push down on the bowl of the spoon with a push meter. Suggest that one child holds the modelling clay to stop the bottle rolling, another pushes down with the push meter and the third takes the reading from the push meter. Ask them to repeat this but to move the fulcrum away from the bottle neck at intervals and take and record readings until they reach the bowl of the spoon.

REFLECT AND REVIEW:

Prompt children to look again at their tin opening diagrams.

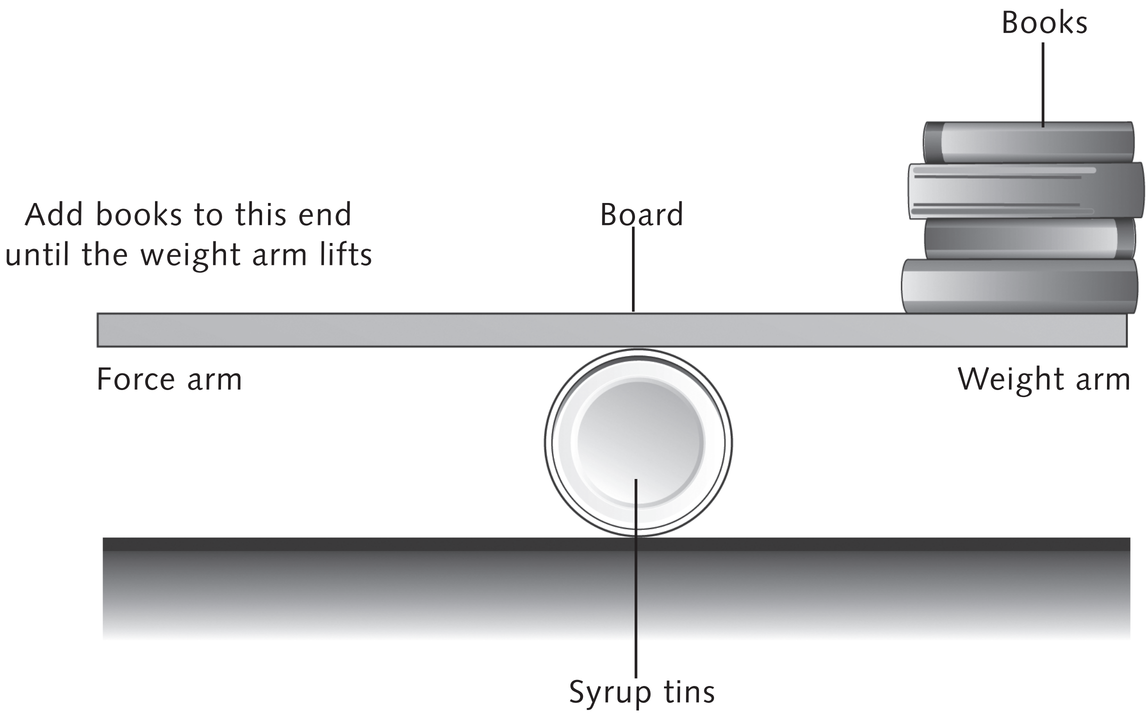
Ask: *Would it be easier to open the tin with the fulcrum further away from the lid?*

Ask Challenge 1 children how many books were needed to lift the weight at each position of the fulcrum. Ask the class if their results on lifting the bottles show that the force needed to lift the weight decreases as the fulcrum moves towards the weight.

EVIDENCE OF LEARNING:

Observe children during challenges and look at their recording. Do they use the terms ‘fulcrum’, ‘weight arm’ and ‘force arm’? Can they explain how levers work? Do they understand that the force needed to move the weight decreases the closer the fulcrum is to the weight? Do they record results accurately? Do they use results to support explanations?

CHANGING THE LENGTH OF THE FORCE ARM

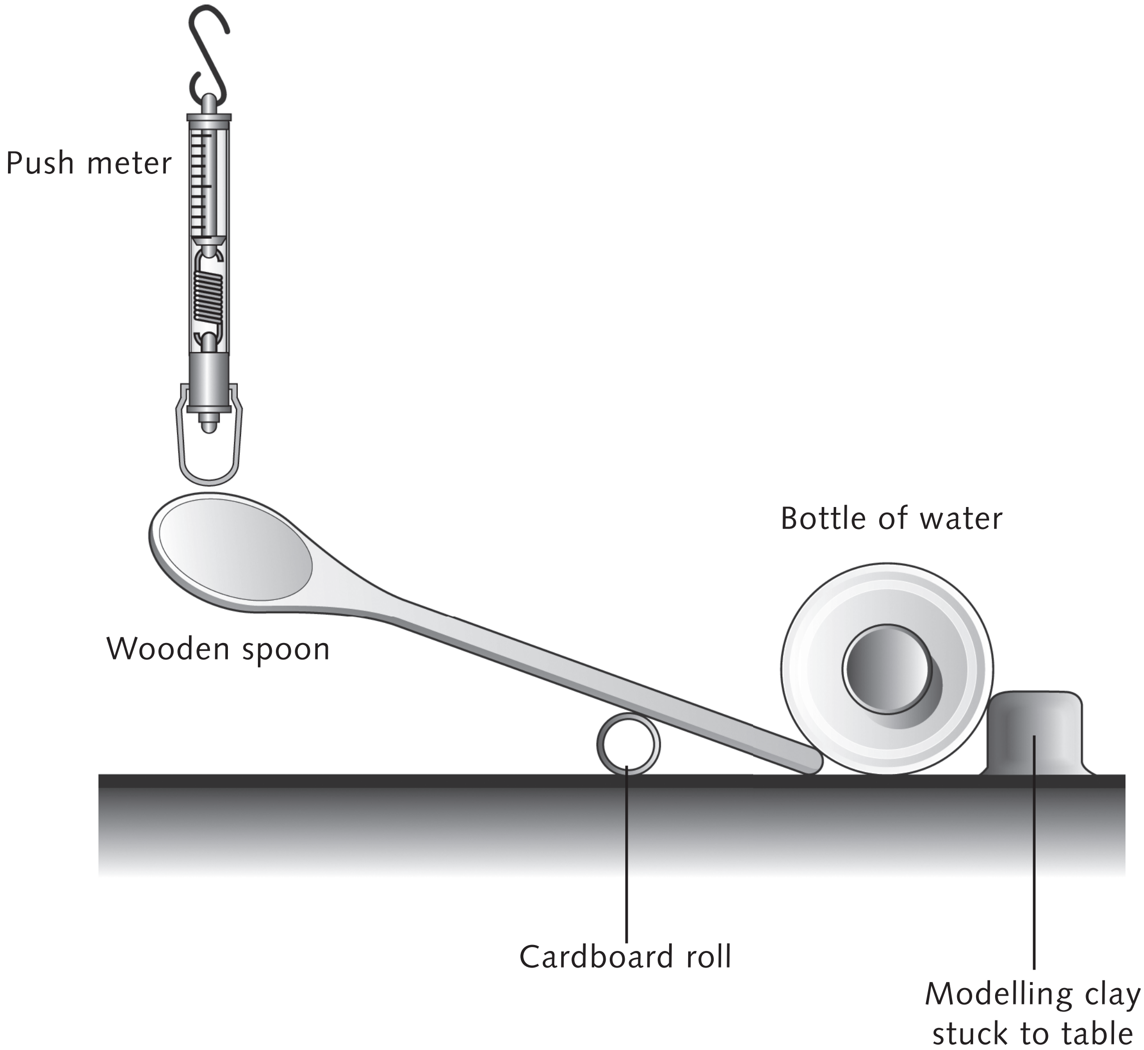


Move the syrup tins to see what happens to the number of books needed to lift the weight arm.

Write a sentence to explain what is happening.

GET THINGS MOVING

Use this diagram to help set up your lever.



BOTTLE LIFT TABLE

How does the position of the pivot affect the force needed to lift the bottle?

Distance of the pivot from the bottle (cm)	Force required to lift the bottle (N)

Draw a graph that shows what is happening. Can you predict from the graph what the force needed would be if the pivot was moved 6 cm from the bottle?

Write an "If…then…because…" sentence to say what is happening as the pivot is moved.

FEEL THE FORCE

LESSON 1: HOW CAN WE LIFT A HEAVY LOAD?

Key vocabulary:
pull, lift, force, effort, mechanism, machine, pulley

Resources:
Wooden dowel (at least 2 cm diameter) or brush handles, pulley sets or metal coat hangers and curtain rings to slide on dowel, cotton reels, string or thin rope, small bucket, sand, Newton meters, sets of slotted weights in 10 g denominations, hanging masses of 50 g, 200 g, 500 g and 1000 g

Health and safety:
Place a box of soft loose fabric or crumpled paper under objects when lifted. Ensure that pulleys are attached to a secure fixing. See Be Safe! section 13.

Key information:
Both lifts are examples of simple pulleys, but the lift over the dowel might give a higher force reading than the straight lift because of friction between string and dowel.

LESSON SUMMARY:

In this lesson children use pulleys to lift objects. By the end of the lesson they understand that pulleys make lifting easier by reducing the force needed.

Preparation required: Set up hanging points for lengths of dowel, or brush handles, from which to hang pulley sets or coat hangers. A pair of chairs would suffice if they have holes in the tops of the backrests. Weight the chairs with books on the seats or rest the dowel or brush handles between two tables and secure them with masking tape and weight them with books. Test that the string used with pulleys is strong enough to lift the objects.

National curriculum links:

Recognise that some mechanisms, including levers, pulleys and gears, allow a smaller force to have a greater effect

Learning intention:

To explain why pulleys make lifting objects easier

Scientific enquiry type:

Noticing patterns

Working scientifically links:

Reporting and presenting findings from enquiries, including conclusions, causal relationships and explanations of and degree of trust in results, in oral and written forms such a displays and other presentations

Success criteria:

- I can explain how a pulley works.
- I can plan and carry out an investigation to find out how a pulley affects the force needed to lift a load.
- I can notice a pattern between the number of pulleys used and the force needed to lift a load.

EXPLORE:

Remind children that in the last lesson they learned how levers help with lifting objects. Ask them what effect a lever has on forces.

Explain to children that they are going to investigate another type of mechanism that helps with lifting (don't use the term 'pulley' yet). Demonstrate a simple pulley: lift a small bucket of sand off the floor, using string tied to the handle. Measure the force with a Newton meter. Lift it again pulling the string over a dowel held by a child at each end. Measure the force. Finally, thread the dowel through a cotton reel and repeat the lift with the string over the cotton reel. Measure the force. Ask children if the force changed.

Ask: *Why do you think this is?*

Ask children what we call this mechanism. Prompt them to think of anywhere they have seen pulleys used. Ask what they were used for.

If the classroom has blinds demonstrate how pulleys are used to lift and lower them.

Show children the Cranes video (Video 1).

ENQUIRE:

Demonstrate lifting a 500 g hanging weight with two pulleys (Resource sheets 1, 3 and 4 give a pictorial setup). Ask a child to read the force required. Add 20 g of slotted weights to the 500 g and repeat the lift, with a child measuring the force. Ask if increasing the weight by 20 g at a time gives a meaningful reading, and if not, ask what the increase in weight should be. (You might need to suggest starting with 500 g and going up in 250 g increments.)

Explain to children that they are going to measure how pulleys make lifting loads easier. Ask them to measure accurately in Newtons.

Ask children why they should measure the force times for each weight. If necessary, remind them that taking repeat readings increases their reliability as any can ignore any that are very different from the majority.

Key information:

Challenges can be completed using curtain rings and coat hangers as in the Pulleys setup sheet (Resource sheets 1, 3 and 4), but commercially produced pulley sets are recommended. Screw cup hooks into the dowel or brush handle from which to hang pulley sets if they won't hook over large diameter dowel. For curtain rings and coat hangers hang the load from a coat hanger for comparison of results with the other two groups. Slightly bend the hanger outwards to stop the load string sliding.

The challenges are differentiated by the complexity of the mechanism, for example, the number of pulleys tested, but each group uses the same types of pulleys and string. Children work in groups of three.

The challenges are presented on the Challenge slides to be displayed on the board, or printed out and placed in the centre of the table.

Challenge 1: Children investigate lifting different weights with two pulleys

Give them the Two pulley system sheet (Resource sheet 1). Ask them to set up two pulleys and predict the force needed to lift different weights. Ask them to investigate 100 g, 250 g, 500 g, 750 g and 1000 g. Ask them to measure the force needed to lift weights from the floor to the top pulley, and the distance they pull the string. Ask them to record their results in the Pulley system results table (Resource sheet 2). Remind children to consider how to make their results as reliable as possible.

Challenge 2: Children investigate lifting different weights with three pulleys

Give them the Three pulley system sheet (Resource sheet 3). Ask them to set up three pulleys and predict the force needed to lift different weights. Ask them to investigate 100 g, 250 g, 500 g, 750 g and 1000 g. Ask them to measure the force needed to lift weights from the floor to the top pulley, and the distance they pull the string. Ask them to record results in the Pulley system results table (Resource sheet 2). Remind children to consider how to make their results as reliable as possible.

Challenge 3: Children investigate lifting different weights with four pulleys

Give them the Four pulley system sheet (Resource sheet 4). Ask them to set up four pulleys and to predict the force needed to lift different weights. Ask them to investigate 100 g, 250 g, 500 g, 750 g and 1000 g. Ask them to measure the force needed to lift weights from the floor to the top pulley, and the distance they pull the string. Ask them to record results in the Pulley system results table (Resource sheet 2). Remind children to consider how to make their results as reliable as possible.

REFLECT AND REVIEW:

Key information:

The results should produce a straight line graph. The line might curve as friction increases.

Prepare a results table on the board for each group to complete with results from their two-, three-, or four-pulley systems. Use the table in Class results sheet (Resource sheet 5) as a template.

Ask children to notice the force needed and the distance pulled for the same weights using the different pulley systems.

Ask: *What do you notice?*

Explain to them that you are going to plot all results on a line graph. Use the template in Resource sheet 3 with a different colour for each pulley system.

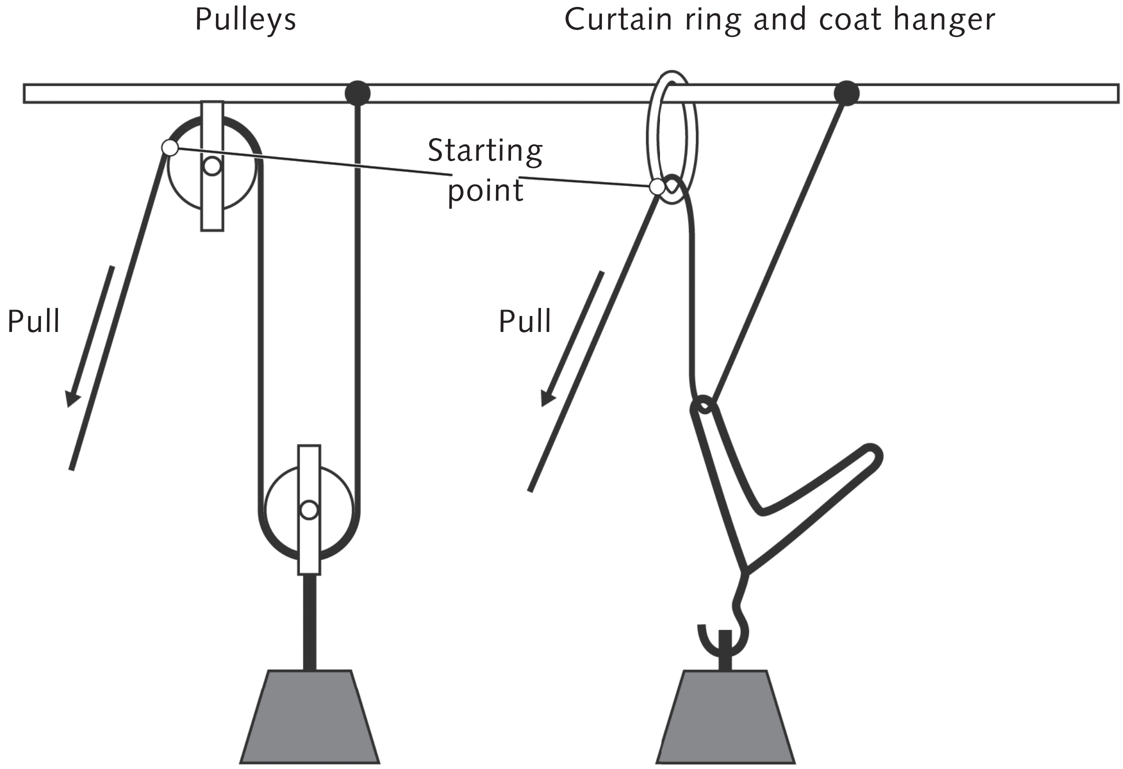
Discuss what the lines show. Ask children to use the information on the line graph to write a sentence about the number of pulleys and the force needed to lift different weights.

EVIDENCE OF LEARNING:

Listen to children during the challenges and as they interpret their results. Do they make predictions about forces needed to lift weights? Do they measure the force and the distance the string has travelled accurately? Do they repeat readings? Do they understand that as the number of pulleys increases so does the distance they pull the string, but the force used decreases? Can they interpret data to identify a pattern between the force required to lift a weight and the number of pulleys?

TWO PULLEY SYSTEM: CHALLENGE 1

Mark a starting point on the string before pulling. When the pull is complete then measure the distance from the mark back to the pulley. Make sure you pull the string downwards in order to avoid the pulleys or curtain rings be pulled along the dowel.



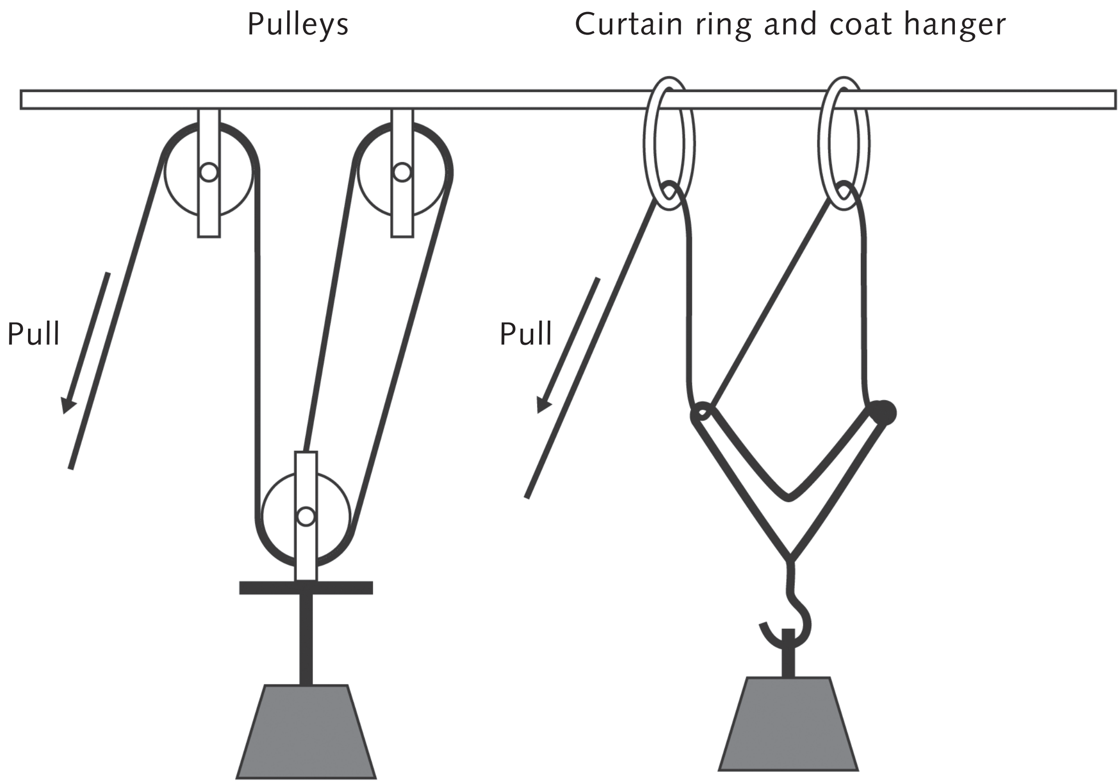
PULLEY SYSTEMS: RESULTS TABLE

Should you be taking repeat readings? You may want to extend the table.

How much force do you use? **Number of pulleys: __________**				
Weight being lifted (g)	**Estimated force (N)**	**Estimated distance (cm)**	**Actual force (N)**	**Actual distance (cm)**

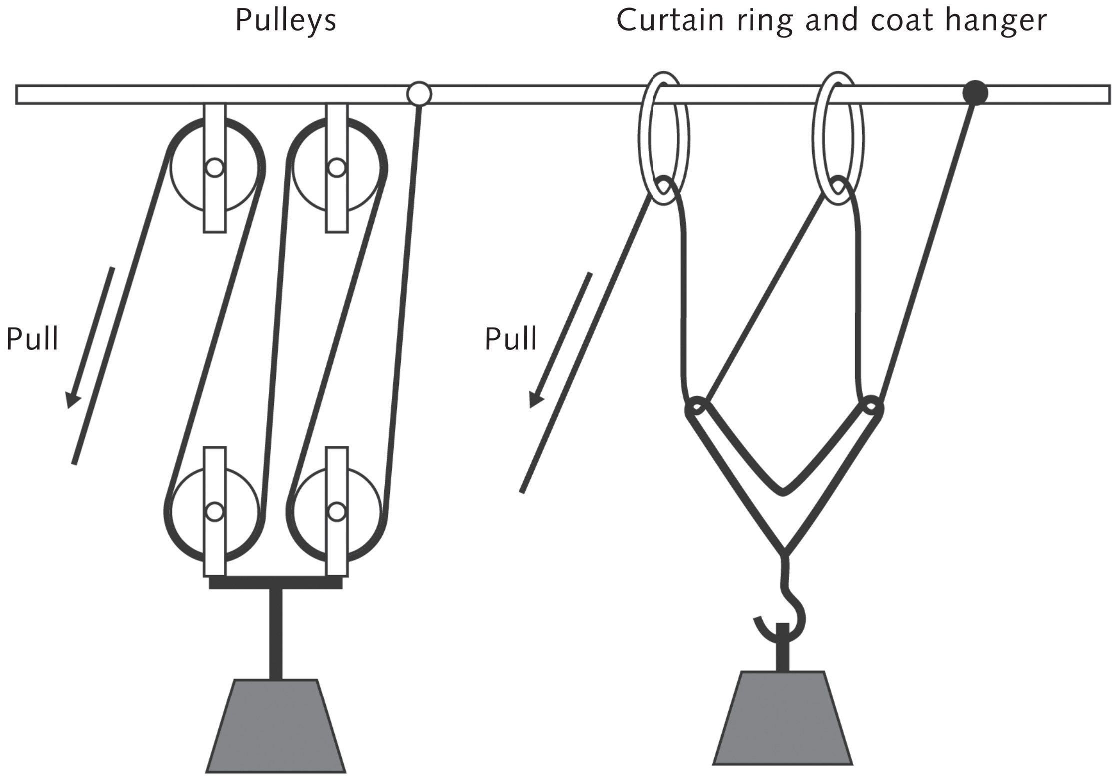
THREE PULLEY SYSTEM: CHALLENGE 2

Mark a starting point on the string before pulling. When the pull is complete then measure the distance from the mark back to the pulley. Make sure you pull the string downwards in order to avoid the pulleys or curtain rings be pulled along the dowel.



FOUR PULLEY SYSTEM: CHALLENGE 3

Mark a starting point on the string before pulling. When the pull is complete then measure the distance from the mark back to the pulley. Make sure you pull the string downwards in order to avoid the pulleys or curtain rings be pulled along the dowel.

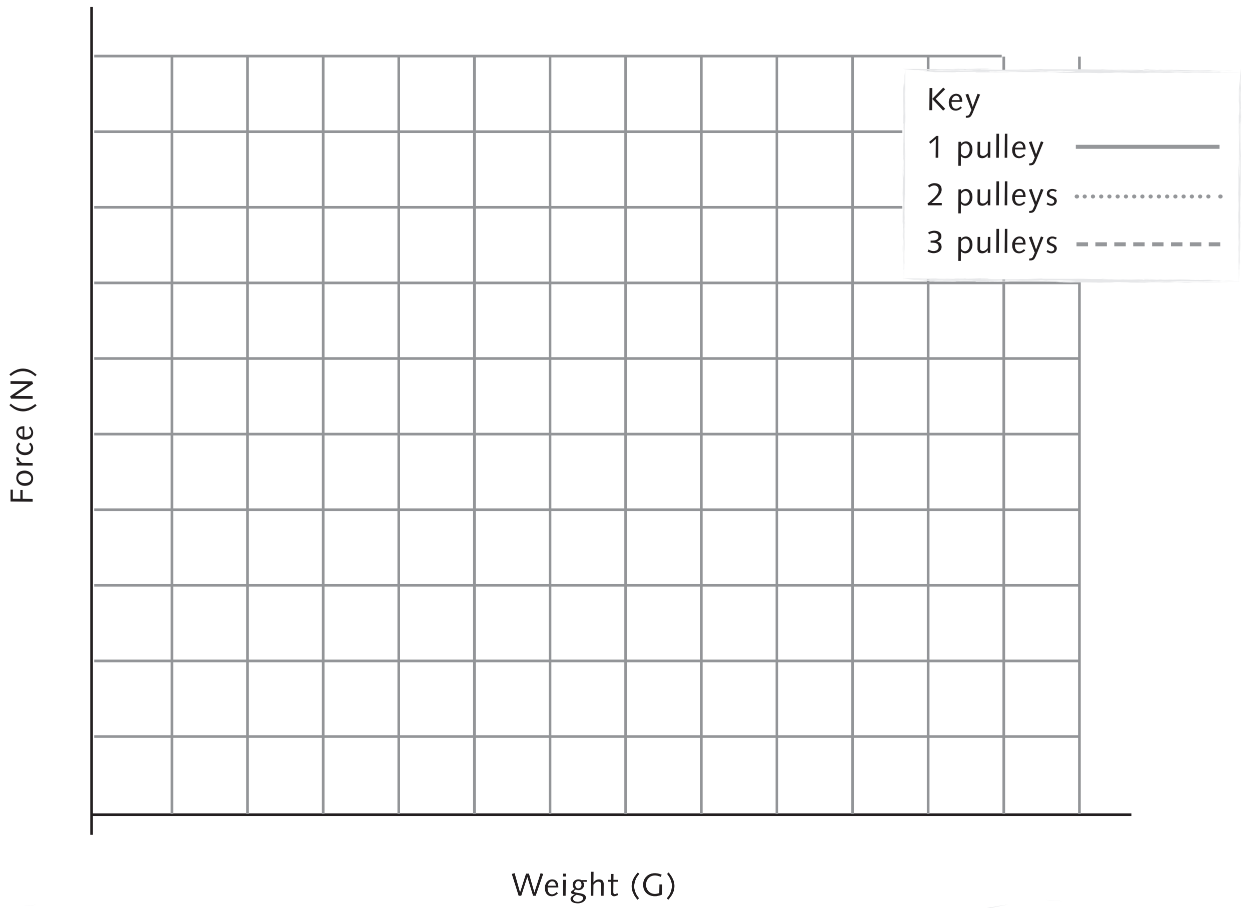


CLASS RESULTS

Draw the table on the board to use in the Reflect and review section.

	Two pulleys		Three pulleys		Four pulleys	
Weight lifted	**Force (N)**	**Distance (cm)**	**Force (N)**	**Distance (cm)**	**Force (N)**	**Distance (cm)**

Graph of the force required to lift weights with 2, 3 and 4 pulleys



FEEL THE FORCE

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LESSON 10: CAN A WHEEL WITH TEETH MAKE WORK EASIER?

Key vocabulary:
gears, forces, cogs, wheels, teeth

Resources:
Balloon whisk, rotary whisk, 2 bowls and 2 egg whites, cheap clock with removable back, commercially produced plastic gear wheels, plastic bricks, axles, plastic brick bases

Health and safety:
Children should work with the equipment under supervision. Remind children to be careful with the kitchen items. Ensure children do not use sharp items without supervision.

Key information:
Gears are an example of a mechanism. A gear is a wheel with teeth. The teeth are also called cogs and gears are sometimes called cog wheels. One gear on its own is not any use; you need to have at least two gears working together. Because the teeth fit together, when one wheel is turned the other one also turns, but in the opposite direction. Gears can increase the amount of work accomplished, for example, if you have a big gear attached to a small gear, when the big wheel is turned slowly the small gear turns quickly. This means gears can be used to reduce the amount of effort needed. Most children will have seen or heard about gears in their bikes.

LESSON SUMMARY:

In this lesson children learn about gears, a third type of mechanism that helps us to do things by changing the effect of forces. Children identify where gears are used in everyday life. By the end of the lesson they understand how gears are used to transfer movement from one place to another and how they can change the speed and direction of movement, and convert a small force into a bigger action.

National curriculum links:

Recognise that some mechanisms, including levers, pulleys and gears, allow a smaller force to have a greater effect

Learning intention:

To explain how gears allow a smaller force to have a greater effect

Scientific enquiry type:

Noticing patterns

Working scientifically links:

Recording data and results of increasing complexity using scientific diagrams and labels, classification keys, tables, scatter graphs and bar and line graphs

Success criteria:

- I can identify gears in a range of everyday items.
- I can make simple gears and explain how they work.
- I can explain how gears convert a force.

EXPLORE:

Ask children if they have heard of the terms ‘cogs’ or ‘gears’.

Ask: *What are they and how do they work? Have you used gears in Design and Technology? Do you have a bike with gears? How do the gears help you to cycle?*

Explain that a gear is just a circle with teeth called cogs. Show children a rotary egg whisk and a balloon hand whisk. Can they see the gears and cogs in the rotary whisk?

Ask them how many gears there are in the rotary whisk and prompt them to think about which way the gears move and what happens to all the gears when the handle is turned.

Ask two children to each whisk an egg white, one using a balloon hand whisk and one using a rotary whisk. Explain to them that they are going to do this for 20 seconds and then swap whisks. Ask them which whisk was easier to use to beat the egg white and how the machine (the rotary whisk) made it easier.

Explain to children that gears make some things easier to do by changing the force needed to make something move. Remind them about the other mechanisms that they have learned about in the module that help us to do things.

Ask: *How are gears different from levers and pulleys?*

Show the video of the cyclist (Video 1). Ask children to watch how the speed of the pedalling changes when he is cycling along a flat road, up a hill and in a time trial. Explain to them that increasing the size of one gear, where the pedals are attached, makes the smaller gears on the back wheel work faster.

ENQUIRE:

Explain to children that they are going to investigate how gears work in different combinations. Introduce them to the idea that the number of teeth and the size of the gear affect how many times the gear rotates when it is meshed with another gear of a different size. Inform children that they need to make careful observations to count the number of teeth on the different gears and the number of turns, and the changes to the direction of movement that occur when the gears are combined. The challenges are differentiated by the way children are required to record the changes to the movement that they observe and the complexity of the mechanisms that they construct and describe. Children work in groups of two or three.

The challenges are presented on the Challenge slides to be displayed on the board, or printed out and placed in the centre of the table.

Challenge 1: Children investigate how gears move

Give each group commercially produced plastic gears of different sizes. Ask them to see if they can construct a mechanism that uses at least three different sized gears with different numbers of cogs. Challenge the children to count the number of turns of the individual gears and the direction of movement. Ask them to think about how the number of cogs and the size of the gear affect how many times one gear rotates when meshed with another gear of a different size.

Ask the children to record what they do in diagrams with arrows and labels, and ask them to write an 'If…then…because…' sentence about the size of the cog and its rotation.

Challenge 2: Children investigate how gears speed up or slow down motion

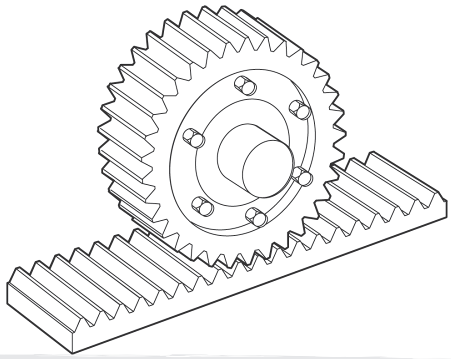
Give each group commercially produced plastic gears of different sizes. Explain that their challenge is to use different sized gears to work out the relationship between the size of gear and the number of turns. Ask the children to set up connecting gears (gear trains) that show that when one gear (the driving gear) is turned through one rotation, the final gear (the driven gear) in the sequence turns three times. Explain that this is a ratio of 1:3.

Ask the children to record what they do in labelled diagrams showing the number of rotations of each gear, with arrows to indicate the direction in which each gear turns. Ask them to write two 'If…then…because…' sentences about what they have done.

Challenge 3: Children use different types of gears to change the speed and direction of the motion

Give each group commercially produced plastic gears of different sizes. Explain that their challenge is to use at least four gears to generate a gear train for which the speed of the final cog should be half the speed of the first cog, and the final cog should turn in a different plane to that of the first cog.

Ask the children to record the gear ratios by counting the number of cogs on the gears and to draw labelled diagrams showing the number and direction of turns. Ask them to write two 'If…then…because…' sentences about what they have done.



Key information:

Gear ratios are dependent on the number of cogs (teeth) on a gear. If a driving gear has 10 teeth and the driven gear has 20 teeth then the driving gear turns twice for one turn of the driven gear – a gear ratio of 2:1. Adding larger gears slows down the motion and smaller gears speed it up.

Key information:

If the driving gear is set up vertically then the final driven gear must be horizontal and vice versa.

REFLECT AND REVIEW:

At the end of the Challenge section give children a few minutes to have a look at other children's mechanisms. Ask them to identify three ways that gears affect motion and to write them in their books. Bring the children back together to share their findings.

Establish that gears can make things move faster; can change the direction of movement; and can reduce the amount of force that is needed.

Give children a variety of everyday items that use gears, for example, a tin opener, a clock and the rotary egg whisk.

Ask: *How many gears can you see? In what way do these gears change the movement of the object?*

Show children the Clock video (Video 2) and ask them to watch how the gears move. Extend this into a homework activity for children to identify an item in their home that has gears and decide how they work.

EVIDENCE OF LEARNING:

Watch and listen to children in their groups as they carry out the challenges. Review the diagrams and the 'If…then…because…' sentences as evidence of children's understanding of how gears change speed and direction. Do children understand that the size of gears affects the speed of other gears and how gears change the direction of movement? Do they understand that a large gear makes a smaller one rotate much faster, and vice versa? Can they identify gears that are used in everyday life?

CROSS-CURRICULAR OPPORTUNITIES:

This lesson links to D&T as children can use their understanding of cogs and gears to create a model that moves.

SNAPSHOT ASSESSMENT: ANNOTATING MECHANISMS

Year group: 5 | Module 7: Feel the Force. Lessons 8, 9, 10

Curriculum statement:
Recognise that some mechanisms, including levers, pulleys and gears, allow a smaller force to have a greater effect.

Resources
Set of labels per child or group
Felt pens
Glue sticks

Activity instructions
Use the diagrams to structure a conversation with individual children or small groups. Give the children the labels with the names of the different mechanisms. Ask them to stick them below the correct mechanism.
Encourage children to talk about how the different mechanisms work. Ensure that they notice the human (hand) that provides the force to start the mechanism moving. Ask them to draw an arrow in blue on the diagram of the lever to show the direction in which the human moves the mechanism. Ask them to draw a red arrow to show the direction of movement that results from the human effort. Ask them to describe how the direction has changed. Give them a small force label and a heavy load label. Ask them where they should go.
Ask the children where they have seen examples of each mechanism in everyday life.

Questions to check understanding
How does a lever or pulley make lifting a heavy load easier? What does a gear do? (All increase the effect of a small force.)

Curriculum statement is achieved if the child:
Can identify correctly a lever, pulley and gear. Can identify how the movement and force is changed. Can give an example of each mechanism in everyday life.

gears	lever	pulley
heavy load	heavy load	heavy load
small force	small force	small force

gears	lever	pulley
heavy load	heavy load	heavy load
small force	small force	small force

gears	lever	pulley
heavy load	heavy load	heavy load
small force	small force	small force

SNAPSHOT ASSESSMENT: ANNOTATING MECHANISMS

Year group: 5 | Module 7: Feel the Force. Lessons 8, 9, 10