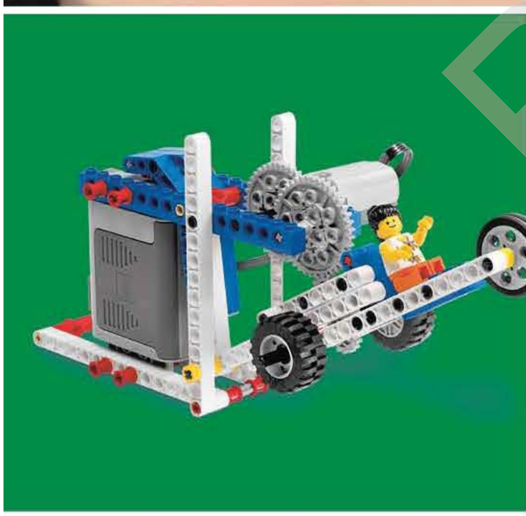
2009686

LEGO education



Investigate
Measure
Predict
Present
Record
Design & Make
Test

Teacher's Guide

LEGO education

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Introduction

LEGO® Education is pleased to bring you '2009686 Introducing Simple & Powered Machines'.

Who is it for?

The material is designed for use by non-specialist teachers of key stage 2 and lower 3. Working in pairs, children of any academic background from eight years and up can build, investigate and learn from the models.

Check the grid in the curriculum section to see which themes match your current teaching program.

What is it for?

The 'Introducing Simple & Powered Machines' activity pack enables children to work as young scientists, engineers and designers providing them with settings, tools and tasks that promote design technology, science and mathematics.

Using our activity pack children are encouraged to involve themselves in real world investigations and problem-solving. They make assumptions and predictions. They design and make models and then observe the behaviour of these models; they reflect and re-design, and then record and present their findings.

The 'Introducing Simple & Powered Machines' activity pack enables teachers to cover the following overall curriculum skills:

- Think creatively to try to explain how things work
- Establish links between cause and effect
- Design and make artefacts that fulfil specific criteria
- Try out ideas using results from observations and measurements
- Ask questions that can be investigated scientifically
- Reflect on how to find answers also imagining new possibilities
- Think about what might happen, or try things out
- Make fair tests by changing single factors and observing or measuring the effects
- Make systematic observations and measurements
- Display and communicate data using diagrams, drawings, tables, bar charts and line graphs
- Decide whether conclusions agree with any predictions made, and whether they enable further predictions
- Review work and describe its significance and limitations

What is it and how to use it?

The 9686 building set

The set has 396 elements, including a motor, and Building Instructions booklets for 14 main models and for 37 Principle Models – all in full colour. Some of the Building Instructions booklets are intended for use with other LEGO® Education activity packs.

Included is also a sorting tray and accompanying element overview showing all the different elements in the set. Everything is stored in a sturdy blue storage box with a transparent lid.

Building Instructions booklets

We have devised the Buddy Building system in which models are designed so two children can build simultaneously – also saving time. Each child (Buddy) builds his or her own subsystems using separate booklets (A and B). Working in pairs the subsystems are then built together to become one complete model.

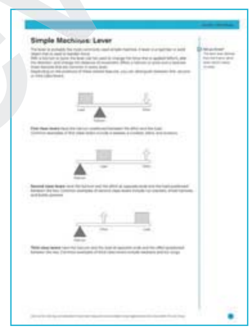
Further progression for both children is suggested in booklet B in red number sequences.

Principle Models

The Principle Models let children experience the mechanical and structural principles normally hidden away inside everyday machines and structures. The many easy-to-build models each present a hands-on demonstration of one of the concepts of simple machines, mechanisms and structures in a clear, straight-forward manner.

By progressing sequentially through the activities, using the Student Worksheets and Building Instructions, children will experience and discover the principles at work and be challenged to apply their knowledge when recording their results. In the Teacher's Notes you will find suggested answers to the questions posed in the Student Worksheets.

The Principle Models are a pathway for children to understand and integrate mechanical and structural principles applied in their own models.



Teacher's Notes

In the Teacher's Notes you will find all the information, tips and clues you need to set up a lesson. Each model the children build has specific key learning focus areas, vocabulary, questions and answers, and further ideas for investigations.

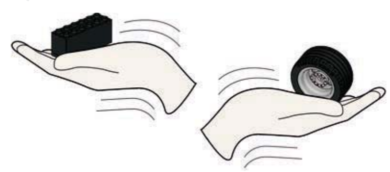
The lessons follow LEGO Education's 4C approach; Connect, Construct, Contemplate and Continue. This enables you to progress naturally through the activities.

Connect
You add to your brain's knowledge when you connect a new learning experience to those you already have or when an initial learning experience is the seed stimulating the growth of new knowledge. Ideas are provided for helping the children identify a problem and for helping Jack and Jill, our two cartoon friends who help guide us through the activities. Show the flash animation with Jack and Jill and have the children define the problem and investigate how best to come up with a solution. Another approach is to read the story in connection with the flash animation.

Please also draw on personal experience and from current events both near and far to set the scene for the children. The more easily the children identify with the situation in which Jack and Jill find themselves, the more easily they will come to grips with the technology, science, and mathematics embedded in them.

Construct
Learning is best when hands and minds are engaged. In pairs, children build models step-by-step. Two buddies each build half a model using separate booklets (A and B) to create their own subsystems and then collaborate to assemble one complete model.

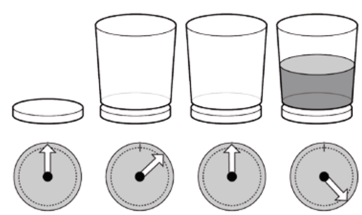
Contemplate
When you contemplate what you have done, you have the opportunity to deepen your understanding. As you reflect, you develop connections between previous knowledge and new experiences. This involves children reflecting on what they have observed or constructed, and deepening their understanding of what they have experienced. They discuss their results, reflect on and adapt ideas, and this process can be encouraged by asking relevant scientific and technical questions.



Questions are included in the material to encourage children to carry out relevant investigations, predictions and rationales, and to reflect on how to find answers – also imagining new possibilities.

This phase includes the possibility to start evaluating the learning and the progress of the individual child.

Continue
Learning is always more enjoyable and creative when it is adequately challenging. Maintaining this challenge and the pleasure of accomplishment naturally inspires the continuation of more advanced work. Therefore extension ideas are provided to encourage the children to change or add features to their models and to investigate further – always with the key learning area in mind. This phase allows the children to operate at different speeds and levels conducive to their individual capabilities.



It is OK if there is too little time to complete Continue phases within the class period. Working through the first three phases of the process covers the curriculum skills listed for any one activity. You may omit the Continue phase at your discretion, or postpone it until the next lesson.

Student Worksheets

Classroom management tips

What are the curriculum highlights?

The process of children actively building, exploring, investigating, enquiring and communicating together benefits their development in innumerable ways over and above the more traditional learning parameters. See the curriculum grid for more details. Here is an overview:

Design and technology
Making solutions to match real needs; choosing appropriate materials and processes; designing, making, testing and modifying; exploring systems and subsystems, and safety and control systems; using 2-dimensional instructions; creating 3-dimensional models; working cooperatively in a team, and more.

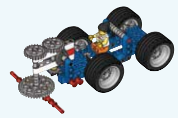
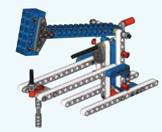
Science
Investigating, collecting, storing and transferring energy; force, speed, and the effect of friction; simple machines, calibrating and reading scales, scientific fair testing, purposeful enquiry, predicting and measuring, collating data, drawing conclusions, and more.

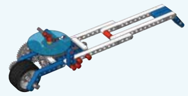
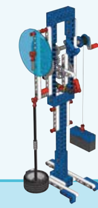
Mathematics
Maths in the service of science and technology; measuring distance, time, speed (velocity), and weight (mass); notions of accuracy in calibrating and reading scales; tabulating and interpreting data; informally calculating ratios, and more.

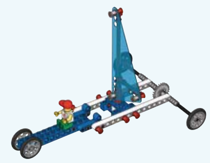
Curriculum grid
Grab a pencil and note pad and sit just for a few minutes watching and listening as a pair of your 'Buddy Builders' collaborate on any of the LEGO® activities. Note down key knowledge, skills and attitudinal outcomes as they become apparent to you.

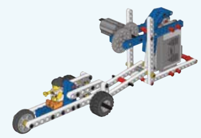
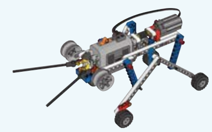
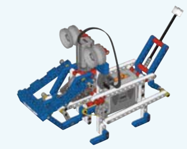
We are sure the many valuable academic, creative, problem-solving and social aspects of the activities will speak for themselves.

The major skill and knowledge outcomes most schools require for lesson planning are listed in the Curriculum grid on the following pages.

	Sweeper	Fishing Rod	Freewheeling	The Hammer
				
FORCES & MOTION				
Design and technology curriculum: Identifying a need and developing ideas. Working as individuals and in teams. Use materials and components as well as modular construction kits to design and make high-quality working prototypes. Use appropriate testing to identify improvements. Assembling and disassembling a range of familiar products and testing how well they meet the intended purpose.	• Investigating pulley drives for safety and gears for speed • Controlling friction and slip • Designing and making: the most efficient push along cleaning machine	• Investigating the ratchet and pawl as a safety system • Investigating automatic mechanical control of motion • Designing and making: a fishing game with easy-to-understand rules and a fair scoring system	• Investigating the effects of different wheel sizes and tyre material on vehicle efficiency (working characteristics of materials) • Wheels and axles to move loads • Designing and making: a downhill runner vehicle that rolls as far as possible	• Investigating mechanical control and timing of complex actions by cams and levers • Investigating how industries test quality of components • Designing and making: a mechanical toy with as many actions as possible
Science curriculum: Scientific enquiry including predicting and measuring the effect of variables on the performance of simple machines. Careful observation, measurement and recording.	• Balanced and unbalanced forces • Friction	• Reducing speed and increasing force using string and pulleys (block and tackle)	• Inclined planes • Friction	• Inclined planes • Friction
Mathematics' curriculum: Using and applying mathematical ideas. Calculations using all number operations. Calculate and use notions of area, averages and ratios. Measure time, distance and (force) weight to a suitable degree of accuracy. Use word equations; solve simple equations to calculate speed. Identify patterns in results; collect and handle data in tables. Communicate mathematical ideas in speech, and in written and graphic forms.	• Measuring distance • Ratios • Notions of efficiency as a percent or fraction	• Measuring distance • Estimating and comparing force, speed • Designing and evaluating fair scoring systems and fair rules for games • Ratios and fractions	• Reading and calibrating scales • Measuring distance, mass • Working with negative numbers (at bottom of hill, rolling the car backwards to zero) • Exploring limits to accuracy • Calculating averages	• Measuring number of 'impacts' per unit time • Estimating and comparing LEGO® element grip forces • Expressing relative grip forces using mathematical terms

	Trundle Wheel 	Letter Balance 	Click-Clock 	
MEASUREMENTS				
Design and technology curriculum: Identifying a need and developing ideas. Working as individuals and in teams. Use materials and components as well as modular construction kits to design and make high-quality working prototypes. Use appropriate testing to identify improvements. Assembling and disassembling a range of familiar products and testing how well they meet the intended purpose.	• Investigating gearing down and complex gearing • Designing scales that are accurate and easily readable by the user • Designing and making: the most accurate and easy-to-use distance measuring device	• Investigating lever and linkage systems • Designing scales that are accurate and easily readable • Designing and making: the most accurate and easy-to-use weighing machine	• Investigating feedback control systems (pendulum and escapement) and gearing up • Designing scales that are accurate and easily readable • Designing and making: the longest running and most accurate time measuring device	
Science curriculum: Scientific enquiry including predicting and measuring the effect of variables on the performance of simple machines. Careful observation, measurement and recording.	• Calibrating and reading scales • Measuring distance to limits of accuracy	• Balancing forces • Calibrating and reading scales • Measuring weight to limits of accuracy	• The pendulum • Calibrating and reading scales • Measuring weight to limits of accuracy	
Mathematics' curriculum: Using and applying mathematical ideas. Calculations using all number operations. Calculate and use notions of area, averages and ratios. Measure time, distance and (force) weight to a suitable degree of accuracy. Use word equations; solve simple equations to calculate speed. Identify patterns in results; collect and handle data in tables. Communicate mathematical ideas in speech, and in written and graphic forms.	• Reading and calibrating scales • Measuring distance • Counting up, counting down • Comparing accuracy of different measuring methods • Ratios and fractions • Expressing the degree of error	• Reading and calibrating scales • Measuring mass • Comparing accuracy of different measuring methods • Working with negative numbers • Expressing the degree of error	• Measuring time • Reading and calibrating scales • Comparing accuracy of different measuring methods • Expressing the degree of error	

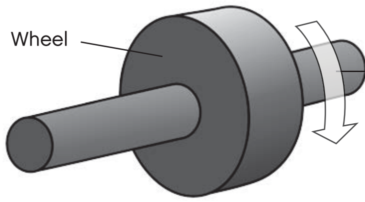
	Windmill 	**Land Yacht** 	**Flywheeler** 	
ENERGY				
Design and technology curriculum: Identifying a need and developing ideas. Working as individuals and in teams. Use materials and components as well as modular construction kits to design and make high-quality working prototypes. Use appropriate testing to identify improvements. Assembling and disassembling a range of familiar products and testing how well they meet the intended purpose.	• Investigating sail material, shape, and area for effectiveness in capturing wind energy • Investigating structures • Designing and making: the most effective energy storage and release system for a windmill	• Investigating sail shape, area and angle to wind for effectiveness in capturing wind energy • Investigating mechanisms for efficient energy for use in transport • Designing and making: the most efficient omni-directional wind powered vehicle	• Investigating the flywheel as a speed control (gearing up) and safety mechanism • Investigating the flywheel as an energy store • Using gears to increase speed • Designing and making: the smoothest running vehicle that rolls furthest using its onboard energy store	
Science curriculum: Scientific enquiry including predicting and measuring the effect of variables on the performance of simple machines. Careful observation, measurement and recording.	• Capturing wind energy to run machines • Storing and transferring energy; kinetic to potential energy transformations • Balanced and unbalanced forces	• Capturing wind energy for transport • Transforming energy by gearing down • Forces and wind resistance • Balanced and unbalanced forces	• Storing kinetic/ moving energy • Friction • Balanced and unbalanced forces	
Mathematics' curriculum: Using and applying mathematical ideas. Calculations using all number operations. Calculate and use notions of area, averages and ratios. Measure time, distance and (force) weight to a suitable degree of accuracy. Use word equations; solve simple equations to calculate speed. Identify patterns in results; collect and handle data in tables. Communicate mathematical ideas in speech, and in written and graphic forms.	• Measuring force in time and area • Estimating and comparing speed and efficiency related to sail shape and area	• Estimating and measuring distance, area, time and angle • Expressing speed and efficiency, related to the angle to wind. • Expressing speed and efficiency, related to the shape and area of the sail	• Measuring distance and time • Expressing speed and distance travelled related to the mass of the flywheels	

	Power Car	Dragster	The Walker	Dogbot
				
POWERED MACHINES				
Design and technology curriculum: Identifying a need and developing ideas. Working as individuals and in teams. Use materials and components as well as modular construction kits to design and make high-quality working prototypes. Use appropriate testing to identify improvements. Assembling and disassembling a range of familiar products and testing how well they meet the intended purpose.	• Investigating gearing down, different tyre types and wheel types to give more torque • Investigating the speed and pulling power of different arrangements of gears and wheels • Designing and making: a powered vehicle that can pull the heaviest possible load	• Investigating gearing up • Designing and making: a dragster that will travel the furthest when released from a launcher	• Investigating cranks, levers, and linkages on stability and stride distance to produce walking or reciprocating movements • Investigating ratchets to control slippage and create one-way movement • Investigating relative positions of cranks to produce a variety of life-like 'gaits' • Investigating the worm gear for extreme gearing down • Designing and making: a walker that can tackle the steepest hills and most difficult terrain	• Investigating levers, linkages, cams and cranks to produce complex timed and controlled movements • Investigating pulleys and slip for safety • Using a variety of materials to create a 'skin' for a dynamic model • Designing and making: an 'animatronic' creature that simulates dog-like behaviour
Science curriculum: Scientific enquiry including predicting and measuring the effect of variables on the performance of simple machines. Careful observation, measurement and recording.	• Investigating the effects of load on friction; reducing friction • Inclined planes and work	• Investigating the transfer of movement and energy • Investigating relationship between speed and mass; momentum and kinetic energy	• Careful observation of the way a person moves in order to compare with the way a walker actually moves	• Careful observation of the way a dog moves to compare with Dogbot's movements
Mathematics' curriculum: Using and applying mathematical ideas. Calculations using all number operations. Calculate and use notions of area, averages and ratios. Measure time, distance and (force) weight to a suitable degree of accuracy. Use word equations; solve simple equations to calculate speed. Identify patterns in results; collect and handle data in tables. Communicate mathematical ideas in speech, and in written and graphic forms.	• Measuring distance and time of travel • Measuring and expressing angle of slope • Notions and calculations of wheel diameter and circumference related to distance travelled per rotation	• Measuring distance and time of travel • Noticing patterns of distance travelled related to wheel mass	• Measuring distance, time • Calculating speed • Noticing pattern of stride length related to crank length • Measuring and expressing angle of slope	• Measuring and expressing the degree and direction of movement of 'body parts', and number of actions per unit of time • Noticing patterns of eye movements related to fulcrum position in cams • Evaluating and expressing model performance (behaviour), qualitatively and quantitatively

Pages 13 to 19 are not included in this Curriculum Preview

Simple Machines: Wheel and Axle

Wheels and axles are usually circular objects, often a big wheel and a smaller axle, rigidly secured to one another.



The wheel and axle will always rotate at the same speed. Due to the bigger circumference of the wheel, the surface of the wheel will turn at a greater speed – and with a greater distance too.

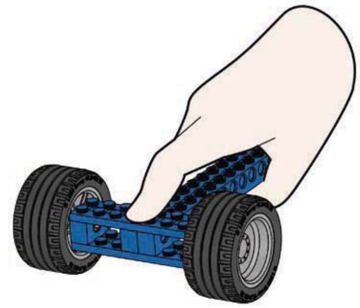
Placing a load on a wheeled vehicle almost always reduces friction compared to dragging it over the ground. Wheels in science and engineering are not always used for transport. Wheels with grooves are called pulleys and wheels with teeth are called gears.

Common examples of wheels and axles are rolling pins, roller skates and pushcarts.

Did you know?
The first constructed wheel found so far was made by the Sumerians some 5,600 years ago.

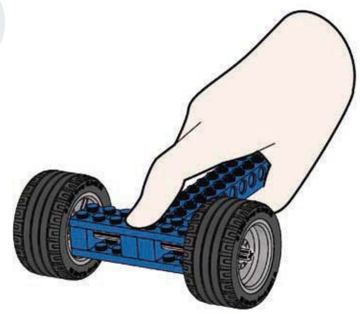
B1

Build B1 book I, pages 8 to 9
Push the model along the table in a straight line.
Describe what happens.
Now try driving it in a zigzag pattern with sharp turns.
Describe what happens.



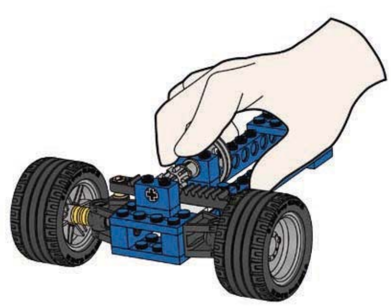
B2

Build B2 book I, pages 10 to 11
Push the model along the table in a straight line.
Describe what happens.
Now try driving it in a zigzag pattern with sharp turns.
Describe what happens and compare with the model above.



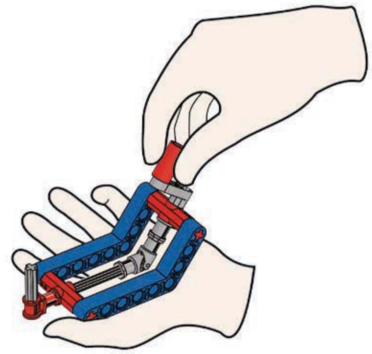
B3

Build B3 book I, pages 12 to 15
Push the model along the table in a straight line.
Describe what happens.
Now try driving it in a zigzag pattern with sharp turns.
Describe what happens and compare with the models above.



B4

Build B4 book I, pages 16 to 17
Describe what happens and the movement of the universal joint when you turn the handle.



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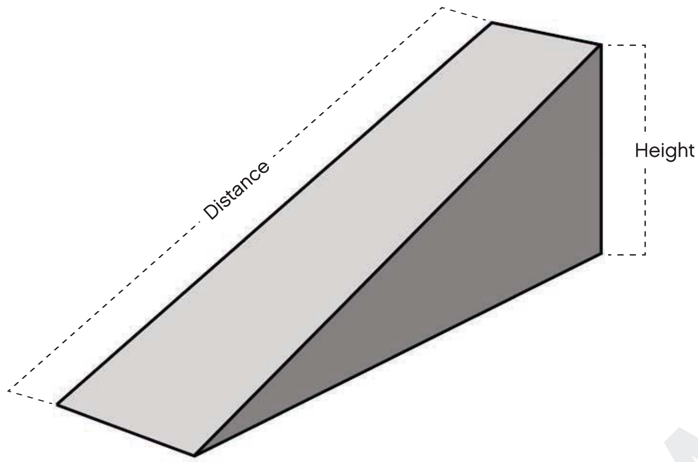
Inclined Plane

Simple Machines: Inclined Plane

An inclined plane is a slanted surface used to raise objects, e.g. a ramp.



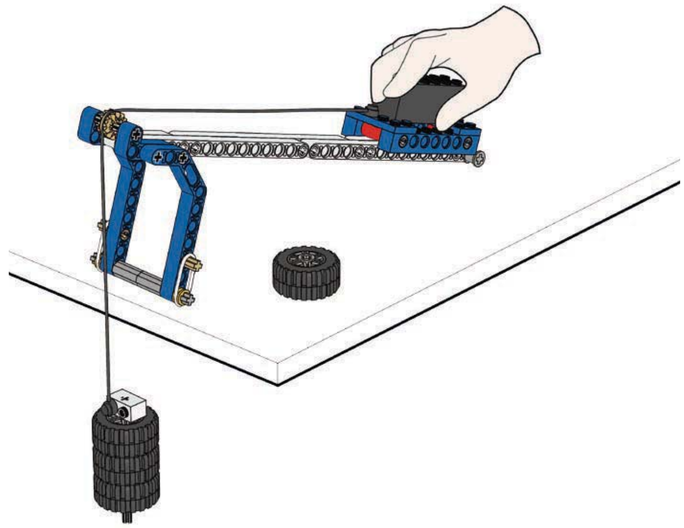
Using an inclined plane to raise an object to a given height, the object must be moved a longer distance, but with less effort needed, than if the object was to be raise straight up.
It's a trade-off either to use a lot of effort to raise a given load a short distance straight upwards or to apply much less force to raise it gradually over the longer distance of an inclined plane.

Common examples of inclined planes are ramps, ladders and stairs.

Did you know?
The advantage of using an inclined plane has been known and used for thousands of years. The ancient Egyptians used inclined planes made of earth to ease the transport of their giant stone blocks to the top of the pyramids.

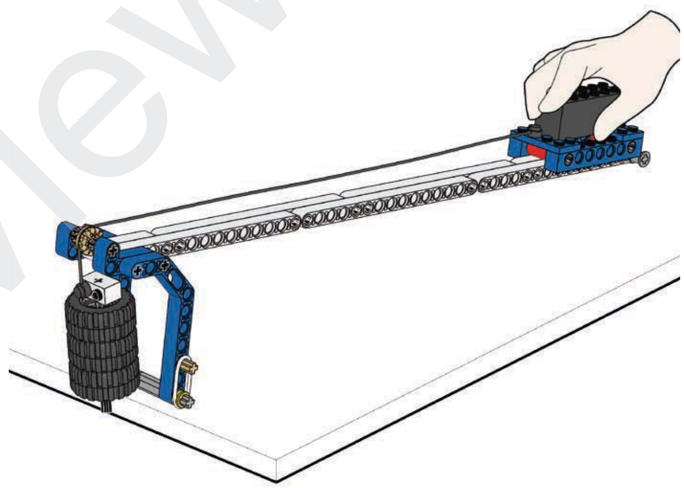
D1

Build D1 book II, pages 2 to 12
Let go of the load. Describe what happens.



D2

Build D2 book II, pages 13 to 15
Let go of the load. Describe what happens.



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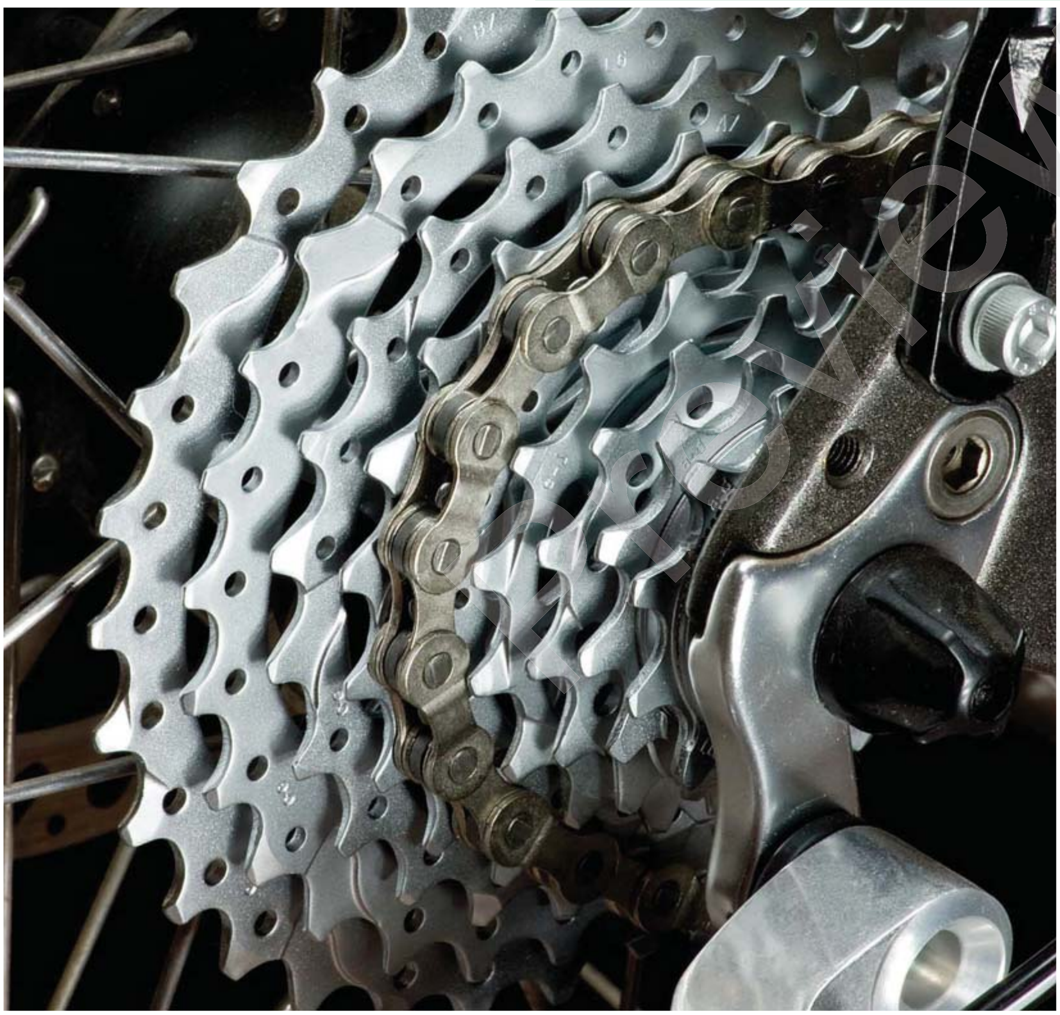
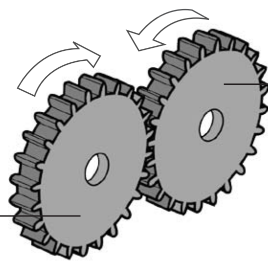


Gear

Mechanisms: Gear

Gears are wheels with teeth that mesh with each other. Because the teeth lock together, they can efficiently transfer force and motion.



The drive gear is the gear that is turned by an outside effort, for instance your hand or an engine. Any gear that is turned by another gear is called a driven gear. The drive gear provides the input force and the driven gear delivers the output force.
Using a gear system can create change in speed, direction and force. But there are always advantages and disadvantages. For example, you can not both have more output force and an increase in speed at the same time.

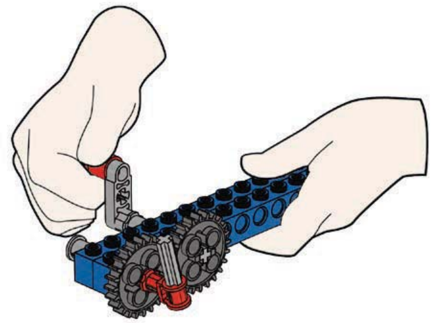
To predict the ratio of which two meshed gears will move relative to each other, divide the number of teeth on the driven gear by the number of teeth on the drive gear. This is called the gear ratio. If a driven gear with 24 teeth is meshed with a drive gear with 48 teeth, there is a 1:2 gear ratio. Meaning that the driven gear will turn twice as fast as the drive gear.

Gears are found in many machines, where there is the need to control the speed of rotary movement and turning force. Common examples include power tools, cars and egg beaters!

Did you know?
Not all gears are round. Some gears are square, triangular and even elliptical.

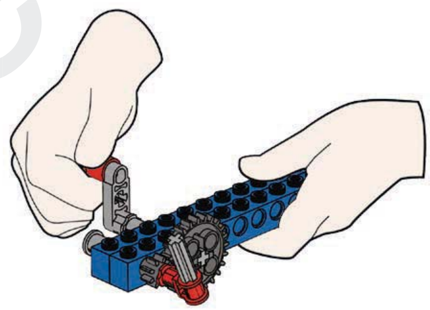
G1

Build G1 book III, page 2
Turn the handle and describe the speeds of the drive and the driven gears. Label the drive and driven gears. Use a circle to show exactly where each one is.



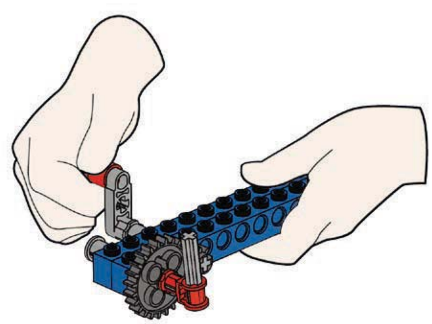
G2

Build G2 book III, page 3
Turn the handle and describe the speeds of the drive and driven gears. Label the drive and driven gears. Use a circle to show exactly where each one is.



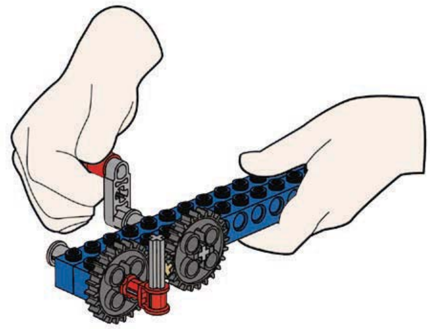
G3

Build G3 book III, page 4
Turn the handle and describe the speeds of the drive and driven gears. Label the drive and driven gears. Use a circle to show exactly where each one is.



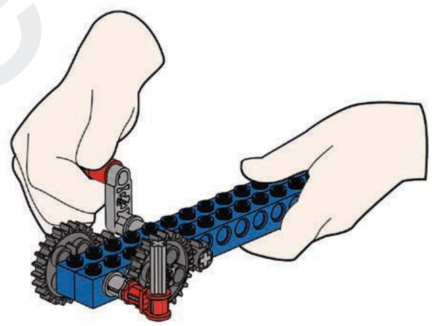
G4

Build G4 book III, pages 5 to 6
Turn the handle and describe the speed and direction of the drive and driven gears. Label the drive and driven gears. Use a circle to show exactly where each one is.



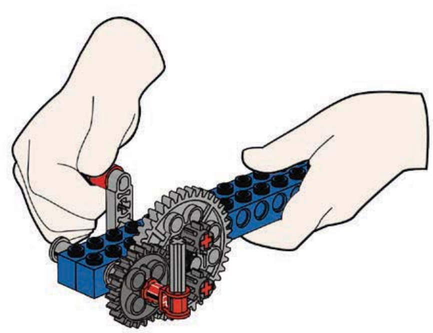
G5

Build G5 book III, pages 7 to 8
Turn the handle and describe the speed and direction of the drive and driven gears. Label the drive and driven gears. Use a circle to show exactly where each one is.



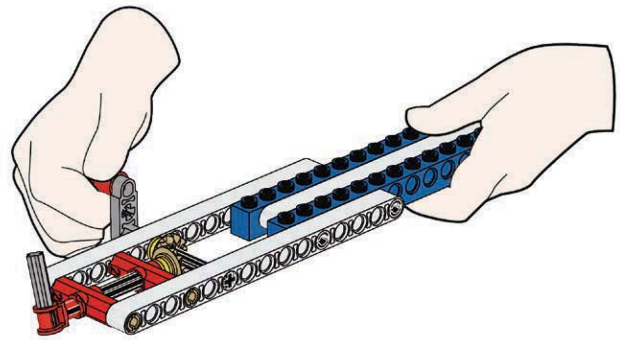
G6

Build G6 book III, pages 9 to 10
Turn the handle and describe the movement of the driven gear.



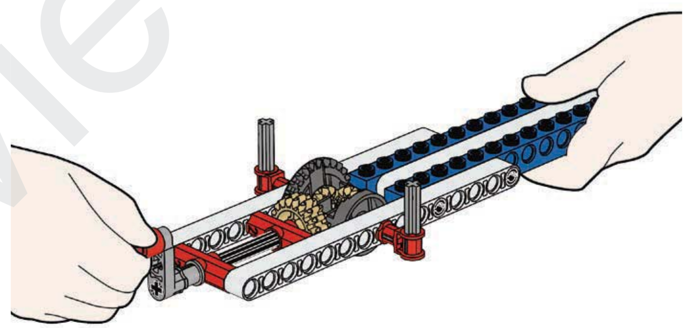
G7

Build G7 book III, pages 11 to 14
Turn the handle and describe what happens.



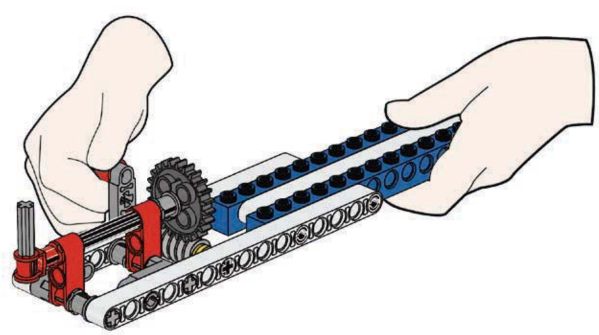
G8

Build G8 book III, pages 15 to 18
Turn the handle and describe what happens.
What happens if you stop one of the output pointers?
What happens if you stop both output pointers?



G9

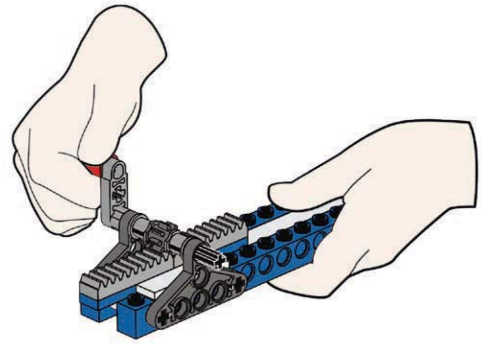
Build G9 book III, pages 19 to 22
Turn the handle and describe what happens.
What happens if you try turning the output pointer?



G10

Build G10 book III, pages 23 to 25

Turn the handle and describe what happens.



Pages 63 to 100 are not included in this Curriculum Preview

Freewheeling

Design and technology
- Using mechanisms – wheels and axles
- Assembling components

Science
- Measuring distance
- Reading and calibrating scales
- Forces
- Moving energy
- Energy of position
- Friction and air resistance
- Scientific investigation

Vocabulary
- Mass
- Position
- Friction
- Efficiency

Other materials required
- 4 metres of smooth floor
- Masking tape
- Metre rule or measuring tape
- Plank of wood or shelf at least 1 metre long
- Pile of books or boxes to elevate the plank
- Spare LEGO® bricks for taking measurements
- Whiteboard marker
- Scissors

Connect

Jack and Jill are arguing as usual. They are making carts to see which one can roll the furthest down Launching Hill in their local Greenall Park.

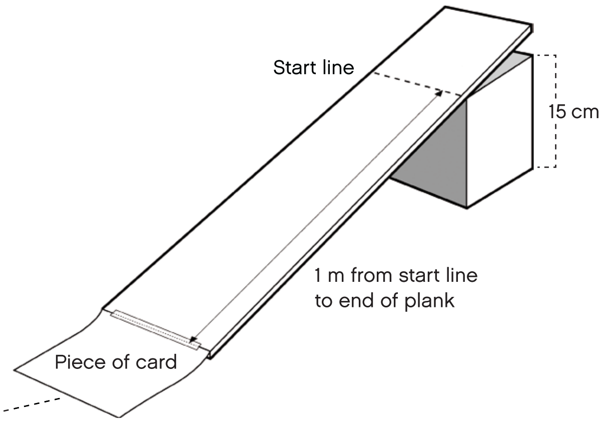
Jill says that if she puts some extra weight on her cart, she will roll further because the cart is heavier. Jack thinks that because heavy loads are hard to move, he will go further. He prefers to go for bigger wheels, but Jill is not so sure this approach will help.

Which will roll further? Heavier or lighter carts, with bigger or smaller wheels? Let's find out!

Construct

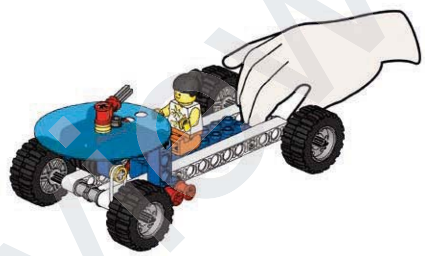
Make Launching Hill
Draw a start line, 1 metre from one end of the plank. Place a support so that the start line is 15 cm from the floor. Why do we need a start line?

We need it because then all tests are fair; all carts roll down exactly the same ramp.

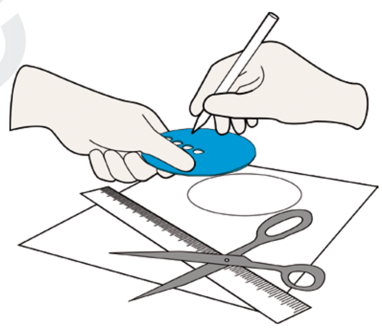


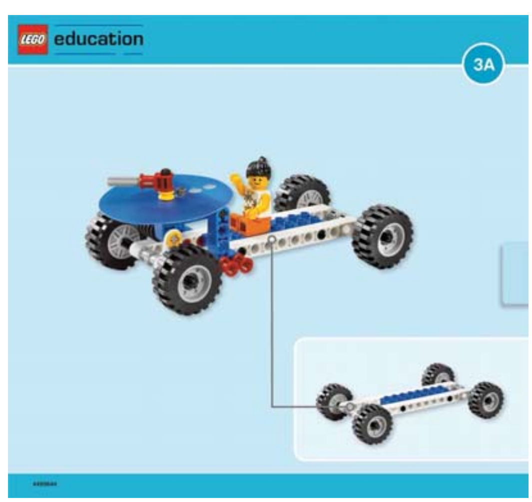
Tip:
If the thickness of the plank means that carts bump down from it onto the floor, use a piece of card to make a smooth transition from plank to floor.

Build the Freewheeler
(all of book 3A and book 3B to page 6, step 12).
- Test the Freewheeler on the ramp. Is the model running smoothly? If not, check all axles and bushings to make sure the wheels are turning smoothly. Also check that all elements are firmly linked to one another.



Trace the scale
Mark on the blue plastic disc or trace around it and cut out a paper copy. Put on scale markings and attach it on top of the blue plastic disc.



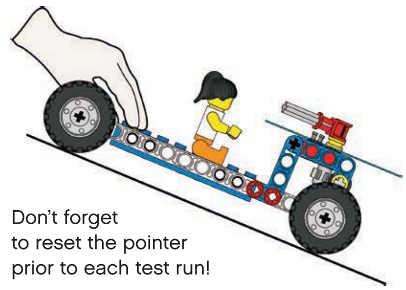


Contemplate

Measure how far the empty cart rolls. Measure with a metre rule and compare with the pointer and scale. Record the distance and use a LEGO® brick as a marker of where it stopped. Test at least 3 times to be sure you have made a scientifically correct answer.

An unloaded cart should roll about 160 cm. This is more than once around the scale. The scale is accurate to within a few centimetres.

Trace the 1 m scale divisions on the plastic scale with an erasable whiteboard marker. Let the Freewheeler go down the ramp again and see if it runs approximately 160 cm by looking at the scale and pointer (one full revolution of the disc and a little more than another half). Carry out several tests.
There is no need to use rulers or measuring tapes – just use the readings on the scale disc.



Don't forget to reset the pointer prior to each test run!

Tip:
Look at the distance the cart travels down the plank. The pointer on the plastic disc passes zero for the first time just as the cart hits the floor. It measures almost exactly 1 m in one rotation.

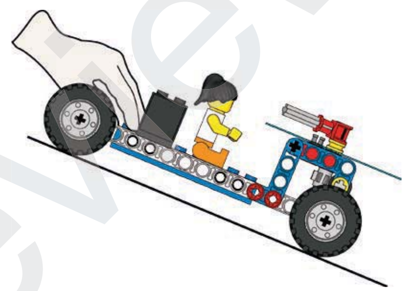
Add a weight brick to the cart (page 7, step 13). Predict how far it will roll this time by placing another marker brick along the track. Then test.

The cart will roll almost twice as far. The weight brick "falling" with the cart gives it nearly twice as much moving energy. However, note too that extra weight creates extra friction or rubbing on the axles which slows down the cart.

What do you notice about the pointer?

The pointer goes around more than once. You will need to count how many times it goes round.

Test several times to make sure your findings are consistent.

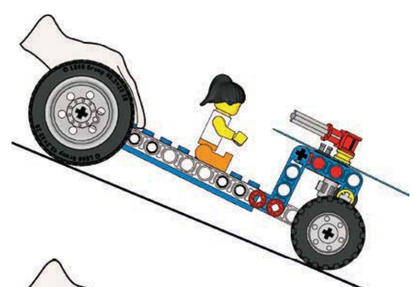


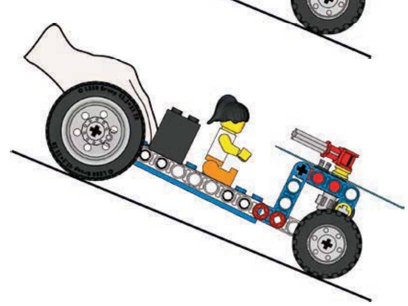
Did you know?
The empty cart weighs about 58 g. And the weight brick weighs 53 g ... almost the same!

Jack's Big Wheel Deal
Will big wheels help the cart to roll further than the smaller wheels? Fit them onto the rear axle and test on the ramp (page 7, step 14).

First test unloaded (page 7, step 14), then test loaded (page 8, step 15).

The cart usually rolls further. There are two reasons: more weight = more energy, and the rear axle turns more slowly, which means less friction.





Did you know?
The big wheels weigh about 16 g and the small wheels about 8 g.

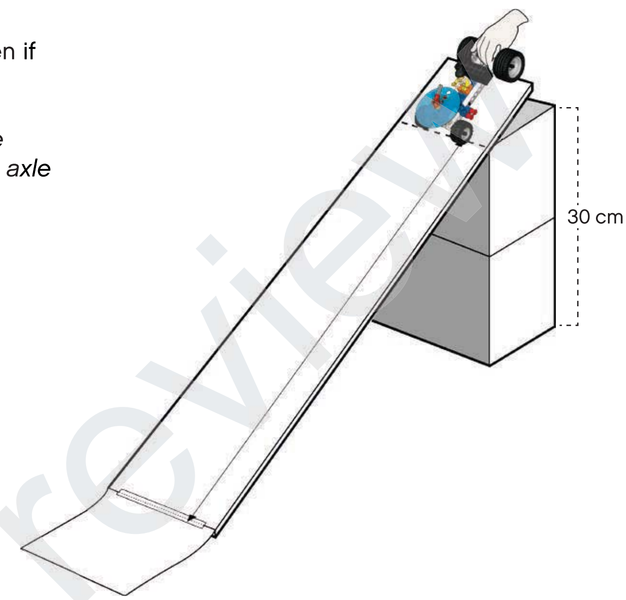
Continue

Super Scale
Build book 3B to page 12, step 12.
Replace the 8-tooth gear wheel with the 24 tooth gear. Predict and then test how far the cart will roll before the pointer completes one revolution.

It rolls 3 metres. The new gear wheel has 3 times as many teeth as the small one. The worm gear has to turn 3 times as often to get the 24-tooth gear wheel to turn once. Now you will need to calibrate the scale to measure distances accurately to 3 metres.

Super Slope
Predict first and then test what will happen if you double the height of the hill.

You double the energy of position, double the moving energy, but do not double the axle friction.



Freewheeling

Name(s): ____________________

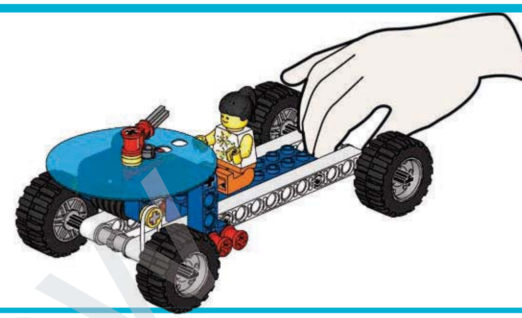
____

Which will roll furthest? Heavier or lighter carts, with bigger or smaller wheels?
Let's find out!

Build the Freewheeler

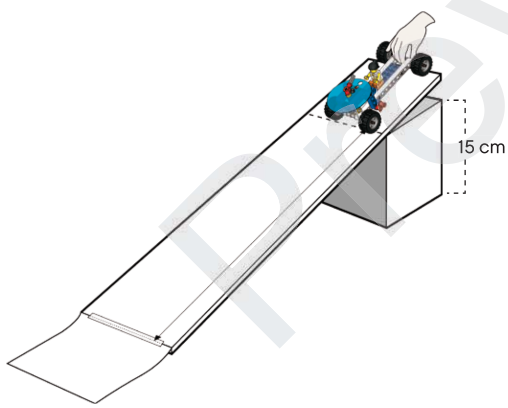
(all of book 3A and book 3B to page 6, step 12).

- Check all axles and bushings to make sure the wheels turn smoothly
- Let your Freewheeler run down the ramp



Which roll further ... heavy or light loads?

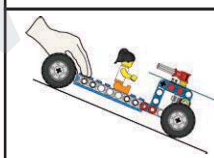
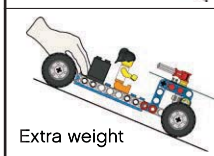
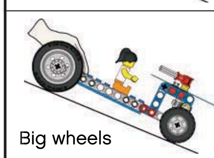
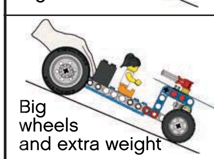
- Tip: Place a marker brick next to the track where you predict the cart will stop
- Reset the pointer on the scale after each test run



... and are big wheels better than small?

- Try using big wheels on the back axle

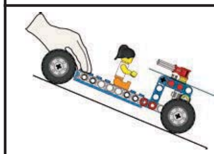
Test accordingly, following the challenges below:

	My prediction	My measurements
		
 Extra weight		
 Big wheels		
 Big wheels and extra weight		
?		

Larger scales ... and steeper hills

Build book 3B to page 12, step 12.
Change the ramp position to be 30 cm high.
Test your different types of Freewheelers.

What I found out when making the slope steeper:

	My prediction	**My measurements**
		

My Amazing Downhill Racer!

Draw your favourite Freewheeler design.
Explain how the 3 best bits work.

The Hammer

Pages 108-208 are not included in this Curriculum Pack Preview

Glossary

We have tried to make the glossary as understandable and practical as possible without resorting to difficult equations and long explanations.

A

Acceleration
The rate at which speed increases. If a car is accelerating it is moving faster.

Advantage
The ratio of the output force to the input force of a machine. Often a measure of how useful it is to us. This is sometimes called mechanical advantage.

Air resistance
The force that air creates by pushing back on a vehicle or object that is trying to push through it. A streamlined shape creates less air resistance.

Amplify
To make larger. For instance a lever can amplify the force from your arm.

Axle
A rod through the centre of a wheel, or through different parts of a cam. It transmits force, via a transmission device, from an engine to the wheel in a car or from your arm via the wheel to the axle if you are winding up a bucket on a rope.

B

Balanced force
An object is balanced and does not move when all the forces acting on it are equal and opposite.

Bearing
Part of a machine which supports moving parts. Most of the holes in LEGO® elements can work as bearings for LEGO axles. The special plastic is very low friction, so axles turn easily.

Belt
A continuous band stretched around two pulley wheels so one can turn the other. It is usually designed to slip if the follower pulley suddenly stops turning.

C

Calibrate
To set up and mark out the units on a scale for a measuring instrument. We can use known values like brass weights to mark a letter balance scale in grams or a stopwatch to mark off our new timer in seconds. This is called calibrating.

Cams
A non-circular wheel that rotates and moves a follower. It converts the rotary movement of the cam into reciprocating or oscillating the movement of the follower. Sometimes a circular wheel mounted off-centre on a shaft is used as a cam.

Compression forces
Forces in a structure that push in opposite directions, trying to squash the structure.

Control mechanism
A mechanism that regulates an action automatically. A ratchet stops an axle from turning the wrong way; an escapement stops a clock from running too fast.

Counter balance A force often provided by the weight of an object you use to reduce or remove the effects of another force. A crane uses a large concrete block on the short arm of its jib to counter the unbalancing effect of the load of the other longer arm.

Crank An arm or handle connected to a shaft (or axle) at right angles enabling the shaft to be easily turned.

D

Driven gear See Follower.

Driver The part of a machine, usually a gear, pulley, lever, crank or axle, where the force first comes into the machine.

E

Efficiency A measure of how much of the force that goes into a machine comes out as useful work. Friction often wastes a lot of energy, reducing the efficiency of a machine.

Effort The force or amount of force that you or something else puts into a machine.

Energy The capacity to do work.

Escapement A control mechanism in a timer that stops energy from, for example, a spring or falling weight escaping too quickly. Usually it ticks!

F

Fair testing Measuring the performance of a machine by comparing its performance under different conditions.

Flywheel A wheel that stores moving energy when it is spinning and releases it slowly. The heavier, wider and faster the wheel, the more energy it stores.

Follower Usually a gear, pulley or lever driven by another one. It can also be a lever driven by a cam.

Force A push or a pull.

Friction The resistance met when one surface is sliding over another, e.g. when an axle is turning in a hole or when you rub your hands together.

Fulcrum See Pivot.

G

Gear A toothed wheel or cog. The teeth of gears mesh together to transmit movement. Often called a spur gear.

Gear, crown Has teeth that stick out on one side looking like a crown. Mesh it with a regular spur gear to turn the angle of motion through 90°.

Gear, rack A flat gear with the teeth equally spaced on a straight line that converts rotational motion into linear motion when a spur gear is meshed against it.

Gear, worm A gear with one spiral tooth resembling a screw. Mesh it with a pinion to deliver large forces very slowly.

	Gear, bevel	Has teeth that are cut at a 45° angle. When two bevel gears mesh, they change the angle of their axles and movement through 90°.
	Gearing down	A small driver turns a larger follower and amplifies the force from the effort. But the follower turns more slowly.
	Gearing up	A large driver turns a smaller follower and reduces the force from the effort. But the follower turns more quickly.
	Gearing, compound	A combination of gears and axles where at least one axle has two gears of different sizes. Compound gearing results in very big changes to the speed or force of the output compared to the input.
	Grip	The grip between two surfaces depends on the amount of friction between them. Tyres grip dry road surfaces better than wet road surfaces.
I	**Idler**	A gear or pulley that is turned by a driver and then just turns another follower. It does not transform the forces in the machine.
	Inclined plane	A slanted surface or ramp generally used to raise an object with less effort than is needed to lift it directly. A cam is a special sort of continuous inclined plane.
K	**Kinetic energy**	The energy of an object that is related to its speed. The faster it travels, the more kinetic energy it has. See also potential energy.
L	**Lever**	A bar that pivots about a fixed point when an effort is applied to it.
	Lever, first class	The pivot is between the effort and the load. A long effort arm and short load arm amplifies the force at the load arm, e.g. when prying the lid off a can of paint.
	Lever, second class	The load is between the effort and the pivot. This lever amplifies the force from the effort to make lifting the load easier, e.g. in a wheelbarrow.
	Lever, third class	The effort is between the load and the pivot. This lever amplifies the speed and distance the load moves compared to the effort.
	Linkages	A mechanical linkage carries movement and forces through a series of rods or beams connected by moving pivot points. Locking pliers, a scissors lift, a sewing machine and a garage door lock all contain linkages.
	Load	Any force a structure is calculated to oppose, such as a weight or mass. It can also refer to the amount of resistance placed on a machine.
M	**Machine**	A device that makes work either easier or faster to do. It usually contains mechanisms.

Mass
Mass is the quantity of matter in an object.
On Earth, gravitational force pulling your matter makes you weigh say 70 kg.
In orbit, you feel weightless – but sadly you still have a mass of 70 kg.
Often confused with weight.

Member
The name given to individual parts of a structure, e.g. a door frame is made from two upright members and one cross member.

Mechanism
A simple arrangement of components that transforms the size or direction of a force, and the speed of its output.
For instance a lever or two gears meshing.

Momentum
The product of the velocity and mass of an object:
velocity not speed because direction is important;
mass not weight because it isn't dependant on gravity.

N

Net weight
The weight of a substance after the weight of its container has been taken away.

P

Pawl and ratchet
An arrangement of a block or wedge (pawl) and a gear wheel (ratchet) that lets the gear turn in one direction only.

Pendulum
A weight hung from a fixed point so that it can swing freely back and forth under the influence of gravity.

Period of swing
The time it takes for a pendulum to complete one swing.
For our pendulum, lowering the weight lengthens the pendulum and lengthens the time or period of swing and vice versa.

Pinion
Another name for a gear that meshes with a gear rack or worm gear.

Pitch
The distance moved by a screw when the screw is turned through one complete turn (360°).

Pivot
The point around which something turns or rotates, such as the pivot of a lever.

Potential energy
The energy of an object that is related to its position. The higher up it is, the more potential energy it has.
See also Kinetic energy.

Power
The rate at which a machine does work (work divided by time).
See also Work.

Pulley
A wheel with a grooved rim used with a belt, chain or rope.

Pulley, fixed
Changes the direction of the applied force.
A fixed pulley does not move with the load.

Pulley, movable
Changes the amount of applied force needed to lift the load.
A movable pulley moves with the load.

Pulley block
One or more pulleys in a movable frame with ropes or (block and tackle) chains running around them to one or more fixed pulleys.
The pulley block moves with the load and reduces the applied force needed to lift the load.

R

Rack (gear rack)	A specialized gear in the shape of a flat bar with teeth.
Renewable energy	Energy from a renewable source such as sunlight, wind or flowing water.
Resetting	Turning a pointer on a scale back to zero again.
Rigid	A rigid material does not easily stretch or bend and does not deform under load.
RPM	Revolutions or turns per minute. This is usually the measure of speed of a motor. The LEGO® motor turns at about 400 rpm unloaded (when it is not driving a machine).

S

Sequencing	Setting up actions to happen in the right order and at the correct time intervals. Cams are often used for this purpose.
Sheave	A pulley wheel with a grooved rim. The groove is used to hold a rope, belt or cable so that it does not slip off the wheel.
Slip	A belt or rope slipping, usually on a pulley wheel as a safety feature.
Speed	See Velocity.
Strut	A member of a structure that is in compression. Struts prevent parts of structures from moving towards each other.

T

Tensile forces	Forces in a structure that pull in opposite directions trying to stretch the structure.
Tie	A member of a structure that is in tension. Ties prevent parts of structures from moving apart, i.e. they 'tie' them together.
Torque	The turning force coming from an axle.
Transmission	A system of gears or pulleys with an input and one or more outputs. A gearbox contains a transmission, and so does a clock.

U

Unbalanced force	A force that is not opposed by an equal and opposite force. An object feeling an unbalanced force must begin to move in some way.

V

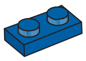
Velocity	The speed in a particular direction. To calculate the speed of a vehicle, we divide the distance travelled by the time taken.

W

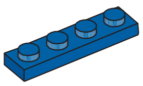
Weight	See Mass.
Wind resistance	See Air resistance.
Work	We calculate the work done by multiplying the force needed to move an object by the distance it is moved (force x distance). See also Power.

LEGO education

LEGO® Element Survey



8x
Plate, 1x2, blue
302323



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Plate, 1x4, blue
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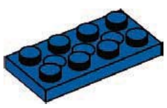

6x
Plate with holes, 2x4, blue
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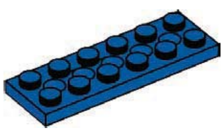
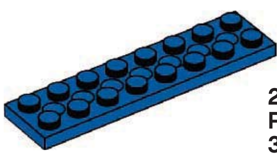
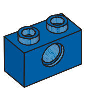


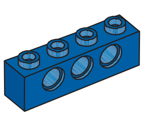
8x
Plate with holes, 2x6, blue
4114027



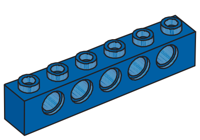
2x
Plate with holes, 2x8, blue
373823



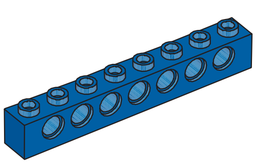
4x
Studded beam, 1x2, blue
370023



4x
Studded beam, 1x4, blue
370123

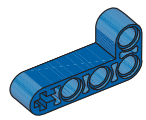


4x
Studded beam, 1x6, blue
389423

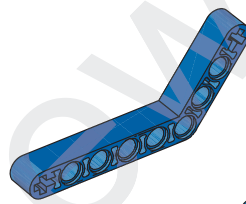


4x
Studded beam, 1x8, blue
370223

10x
Connector peg with friction, 3-module, blue
4514553



8x
Angular beam, 4x2-module, blue
4168114



4x
Angular beam, 4x6-module, blue
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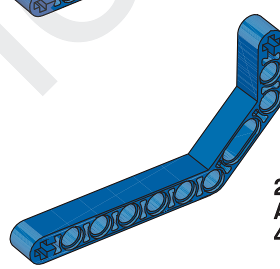

2x
Angular beam, 3x7-module, blue
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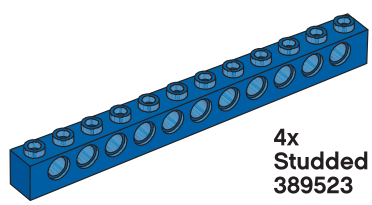

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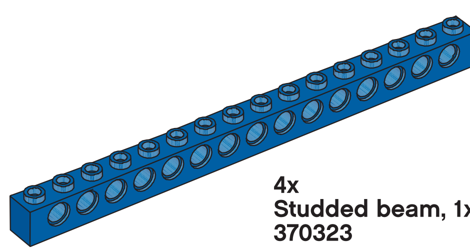
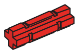
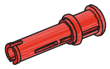
Studded beam, 1x12, blue
389523



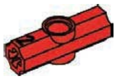
4x
Studded beam, 1x16, blue
370323

2 

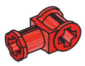
14x
Axle, 2-module, red
4142865



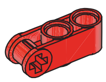
14x
Connector peg with bushing, red
4140806



4x
Angular block, 2 (180°), red
4234429

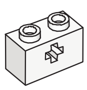


10x
Angular block with crosshole, red
4118897

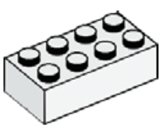


4x
Cross block, 3-module, red
4175442

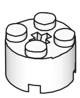
2x
Tube, 2-module, red
4526984



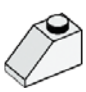
4x
Studded beam, 1x2 with crosshole, white
4233486



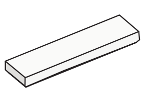
2x
Brick, 2x4, white
300101



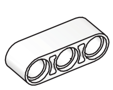
2x
Brick, 2x2 round, white
614301



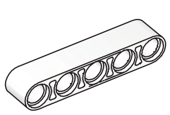
4x
Roof brick, 1x2/45°, white
4121932



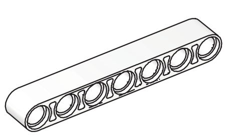
2x
Tile, 1x4, white
243101



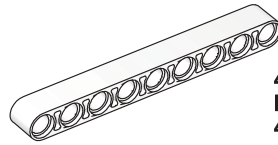
2x
Beam, 3-module, white
4208160



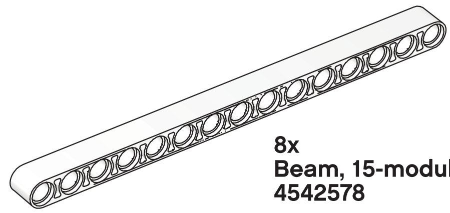
2x
Beam, 5-module, white
4249021



2x
Beam, 7-module, white
4495927



4x
Beam, 9-module, white
4156341



8x
Beam, 15-module, white
4542578

2x
Steering arm, black
4114670

2x
Bearing for steering arm, black
4114671

4x
Angular block, 1 (0°), dark grey
4210658

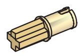
4x
Angular block, 3 (157,5°), black
4107082

28x
Connector peg with friction, black
4121715

4x
Tyre, 30,4x4, black
281526

4x
Tyre, 30,4x14, black
4140670

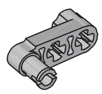
4x
Tyre, 43,2x22, black
4184286



12x
Connector peg with axle, beige
4186017

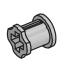
4x
Connector peg, 3-module, beige
4514554

16x
Bushing, ½-module, yellow
4239601



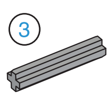
4x
Connector peg, handle, grey
4211688

8x
Connector peg, grey
4211807

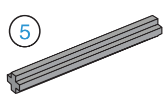


16x
Bushing, grey
4211622

8x
Axle extender, 2-module, grey
4512360

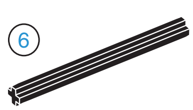


8x
Axle, 3-module, grey
4211815

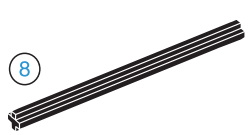


4x
Axle, 5-module, grey
4211639

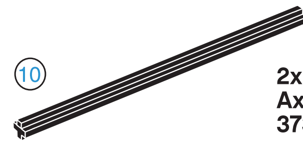
8x
Axle, 4-module, black
370526



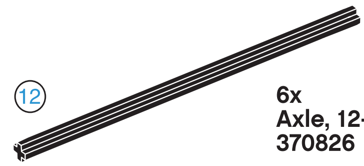
2x
Axle, 6-module, black
370626



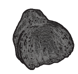
2x
Axle, 8-module, black
370726



2x
Axle, 10-module, black
373726



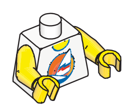
6x
Axle, 12-module, black
370826



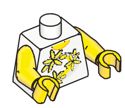
1x
Minifigure, ponytail wig, black
609326

1x
Minifigure, cap, red
448521

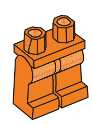
2x
Minifigure, head, yellow
9336



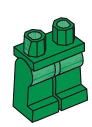
1x
Minifigure, body, white with surfer
4275606



1x
Minifigure, body, white with flowers
4275536

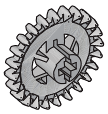


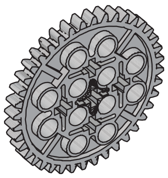
1x
Minifigure, legs, orange
4120158

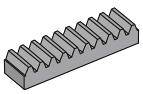


1x
Minifigure, legs, green
74040


2x
Gear, 16-tooth, grey
4211563


4x
Gear, 24-tooth crown, grey
4211434


2x
Gear, 40-tooth, grey
4285634


2x
Gear, 10-tooth rack, grey
4211450

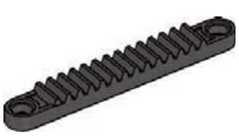

2x
Worm gear, grey
4211510


1x
Differential, 28-tooth, dark grey
4525184


4x
Gear, 24-tooth, dark grey
4514558


6x
Gear, 8-tooth, dark grey
4514559

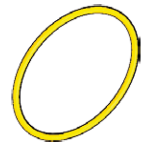

2x
Gear, 12-tooth double bevel, black
4177431

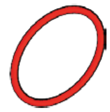

1x
Gear, 14-tooth rack, black
4275503


6x
Gear, 12-tooth bevel, beige
4514556

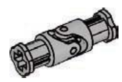

2x
Gear, 20-tooth bevel, beige
4514557

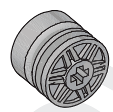

2x
Gear, 20-tooth double bevel, beige
4514555

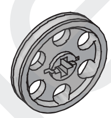

2x
Belt, 33 mm, yellow
4544151

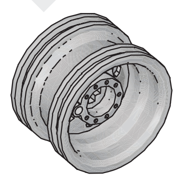

2x
Belt, 24 mm, red
4544143

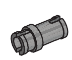

2x
Belt, 15 mm, white
4544140

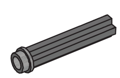

1x
Universal joint, 3-module, grey
4525904


4x
Hub, 18x14, grey
4490127

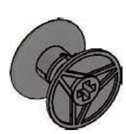

4x
Hub, 24x4, grey
4494222

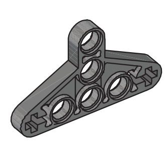

4x
Hub, 30x20, grey
4297210

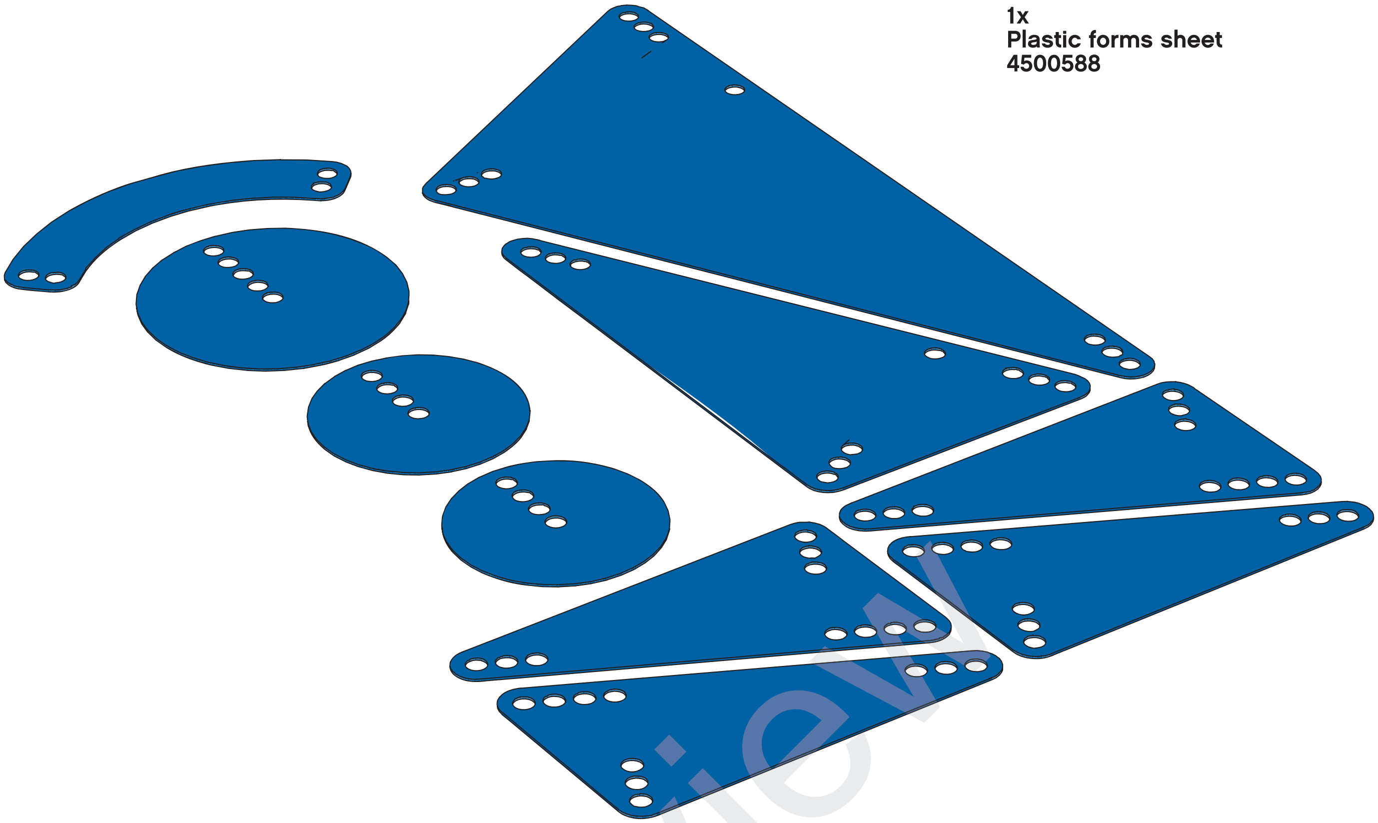

6x
Connector peg, 1½-module, dark grey
4211050


4x
Axle with knob, 3-module, dark grey
4211086

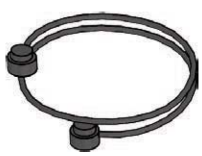

4x
Cam wheel, dark grey
4210759


1x
Bobbin, dark grey
4239891

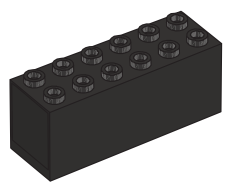

2x
½ beam, triangle, dark grey
4210689



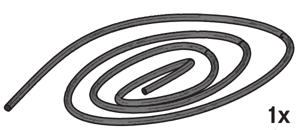
1x
Plastic forms sheet
4500588



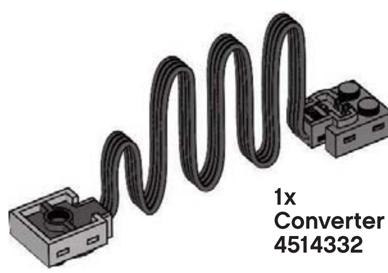
2x
String, 40-module with knobs, black
4528334



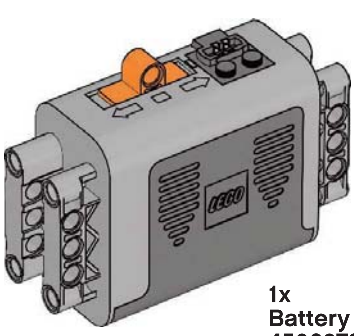
1x
Weight element, black
73843



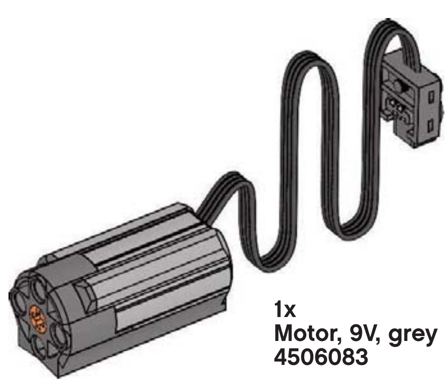
1x
String, 2 m, black
4276325



1x
Converter cable, black
4514332



1x
Battery box, 9V, grey
4506078



1x
Motor, 9V, grey
4506083

UK source file, including curriculum objectives, has been developed in cooperation with David Barlex.
Localisation, translation & DTP: EICOM ApS, Denmark

LEGO education