# Activity Pack for Simple Machines
## Teacher's Guide

2009689

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# Introduction

LEGO® Education is pleased to bring you the 2009689 Activity Pack for the 9689 Simple Machines Set.

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## Who Is the Material For?

This material is designed for primary school teachers who wish to introduce their learners to the following simple machines:

- Gears
- Wheels and Axles
- Levers
- Pulleys

The LEGO models that can be made using the 9689 Simple Machines Set and the Learner Worksheets supplied with the 2009689 Activity Pack for Simple Machines are suitable for learners from years one to three. Most learners at the younger end of this age range will need to be supported and encouraged in reading and understanding the technical vocabulary and exercise descriptions used in the Learner Worksheets.

## What Is it For?

Used together, the 9689 Simple Machines Set and this Activity Pack enable learners to work as young scientists, designers and engineers, helping them to investigate and understand the operation of simple and compound machines found in everyday life. The materials promote an enjoyable but challenging classroom environment in which learners can develop skills such as creative problem-solving, communication of ideas, and teamwork. The activities lead learners to make initial use of scientific method through observation, reasoning, prediction and critical thinking.

## What Are Simple Machines?

We use simple machines every day – when we open a door, turn on a tap, open a tin, or ride a bike. Simple machines make it easy for us to do work. A force (a push or a pull effort) makes something (a mass or load) move a distance.

Simple machines have only one part to do the work and they have very few or even no moving parts. A lever is an example of such a simple machine. You can use a lever, for example a crowbar, to move a large load with a smaller effort than you would need if you did not have a machine to help you. The force applied to the lever makes the load move, but the effort needed is less than if the force was applied directly to the load. The work is thus easier to do.

The terms *load* and *effort* are used in describing how simple machines work. The load is the object that is moved, e.g. a box. The effort is the force used to do the work. In the situation illustrated, the effort is the force that someone will apply to the sack barrow to move (or lift) the load (the box).

Simple machines have very few parts; compound machines are made up of two or more simple machines. A sack barrow is one example of a compound machine. It combines two simple machines. The handles are levers which help lift the load, and the wheel and axle help move the load forward easily. The same principle applies to a wheelbarrow.

Machines help us do many things: they help us lift, pull, split, fasten, cut, carry, mix, etc. All machines are made up of simple machines. More complicated machines (compound machines) are made up of a number of simple machines that function together to help do the work. Gears are sometimes categorised as compound machines, but in this material we have regarded them as simple machines.

**Did you know?**
A crowbar is a simple machine called a lever.

**Did you know?**
A wheelbarrow is a compound machine.

## What Is in the 9689 Simple Machines Set?

The set consists of four full-colour sets of Building Instructions for the four simple machines, including instructions for both the principle models and the main models, and 204 LEGO® elements, including an element (brick) separator. The main models and the principle models described in this Activity Pack can all be built from the elements in the set, though only one at a time.

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## What Is in the 2009689 Activity Pack for Simple Machines?

This Activity Pack contains teaching suggestions and materials that will enable teachers to make effective use of the 9689 Simple Machines Set in class. The Activity Pack is divided into the following sections:

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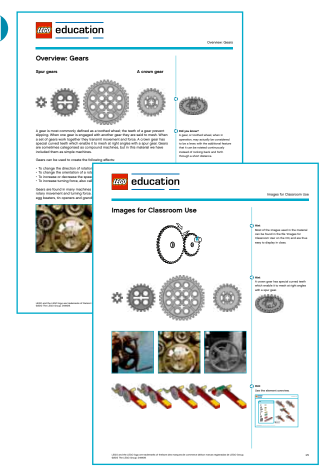
**Curriculum:**
This section offers a clear overview of the curriculum standards and learning goals targeted for each activity. Check which activities match your current teaching programme, or use it to find inspiration for creating your own course of study.

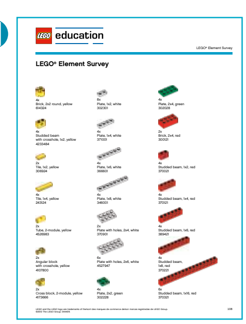
**The four simple machine sections:**
These sections provide information and activities for the four simple machines: gears, wheels and axles, levers, and pulleys. All four simple machine units are presented in the same way.

- An overview of the simple machine in focus is given. The overview starts with an introduction and with ideas for establishing the concept and providing the vocabulary relevant to the simple machine. A brief outline for using the principle models is also included.
- Following this is an overview of relevant images from Images for Classroom Use. Images for Classroom Use is a collection of photographs, pictures, drawings and illustrations, contained on the Activity Pack computer disk, which can be used to support the teaching of simple machines. These images are intended to help learners understand the links between the models they build and the real world. There is also an overview of the elements used for building both the principle models and the main models.
- Each unit then introduces the Teacher's Notes and Learner Worksheets (described later) for the principle models, the related main model, and the problem-solving activity.




**Glossary:**
The Glossary is designed as a reference for teachers. It explains most of the terms used in the materials.

**LEGO® Element Survey:**
The Element Survey illustrates and names the LEGO elements in the 9689 Simple Machines Set.



## Teaching Sequence

Though naturally teachers may well wish to vary their teaching sequence to suit their own learners and needs, we recommend the following progression:

1. Establish the concept of the simple machine in focus:
   a) Use the information from the relevant **Overview** section (Gears, Wheels and Axles, Levers, or Pulleys).
   b) Show images from **Images for Classroom Use**.
   c) Ask questions and discuss in class.

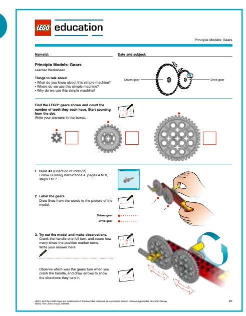
2. Provide the relevant vocabulary, e.g. by using it to talk about the simple machine in focus. See the recommended vocabulary in the **Overview** and/or see the **Glossary** for inspiration.

3. Build and investigate one or all of the principle models.

4. Build and investigate the main model and activity, but only when the related principle model activities have been carried out.

5. Try the problem-solving activity.

An alternative for older learners would be to work with all the principle models and then move directly to the problem-solving activities. As always, it is very important for teachers to be thoroughly familiar with the materials before using them in class, and therefore it is suggested that teachers should build the models themselves and try them out in conjunction with the Learner Worksheets.



## General Comments Regarding the Material

### Observations and fair tests

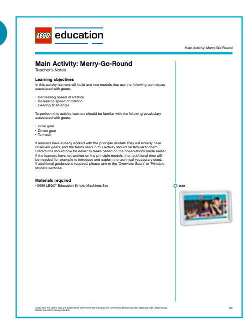
It is important that learners make their observations at least three times, since their initial observations may not be correct and will need to be checked. A minimum of three test observations is probably needed to constitute a *fair test*. Learners should be encouraged to repeat the study or activity as many times as necessary to be sure that they are getting the same answer consistently; however, note that there is only space for one final answer on the worksheet.

### Scientific predictions

Making a scientific prediction is often based on prior observations and experiences. It is important that learners attempt to state a prediction and then check to see whether their prediction was correct. The main models and the accompanying Learner Worksheets will often assume that learners have made relevant observations while working on the principle models, and therefore will be better able to predict a reasonable outcome.

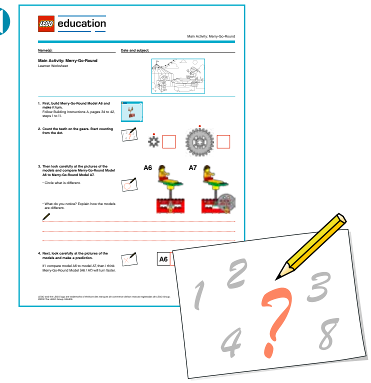
### Teacher's Notes

There are detailed Teacher's Notes for each simple machine section. In some cases, additional materials will be necessary for the activities and investigations; these are listed. The Teacher's Notes indicate key learning areas, give suggestions for carrying out each activity, provide hints, questions and vocabulary specific to the activity, and suggest further ideas for investigation. The answers to questions asked on the Learner Worksheets, together with comments to the teacher, are written in ***blue italics*** in the Teacher's Notes.



**Learner Worksheets**

The worksheets help learners to work individually, in pairs, or in groups to apply the knowledge they have acquired about the simple machine concept through building or discussion activities. The Learner Worksheets can be copied as required. Writing is kept to a minimum on the worksheets for the principle models – learners only need to mark choices, draw lines to label illustrations, or write numbers. On the worksheets for the main models learners will be challenged to predict an outcome, which they will then investigate, and finally they will document their findings.



Text on the worksheets is kept to a minimum, but nevertheless early readers may need help in understanding the written instructions. Icons have been included on the worksheets to help learners through the activity in focus; these symbolise, for example, that something must be marked or drawn, circled or joined, or that learners are asked to write in a number.

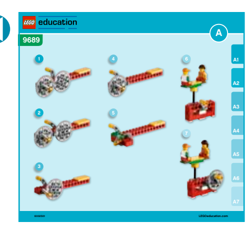
**The problem-solving activity**

The problem-solving activity is intended to encourage learners to apply the knowledge they have gained from both the different principle models and/or the main model concerning the simple machine in focus. The suggested problem-solving model solution included is only meant as a guiding principle to solving the problem posed.

## Classroom Management Tips

**How do I organise the Building Instructions?**

For easy classroom management we suggest storing the Building Instructions in binders so that they are close-at-hand and ready to use at the beginning of each lesson.



**How much time is needed?**

There are many ways to use the LEGO® 9689 Simple Machines Set in your classroom, and many different ways to plan your class schedule. Activities can be completed by individuals or by small teams or groups, depending upon the number of sets that are available to your class.

If you choose to introduce the principle models of one simple machine, 2-3 of the models can be built, investigated and explored, and the parts put away again, within a single 45-minute lesson if the learners are already experienced LEGO builders.

**Hint**

We suggest learners work together in pairs, sharing a set between them.

However, if you choose to continue with a main activity, then at least two more class periods will be needed, depending on the time spent on discussion, the building skills of your learners, and the time you allow for experimentation. A double lesson is ideal to be able to explore, build and investigate in depth most of the (optional) extension ideas built into the main activity, and especially for the learners to make any creative variations of their own.

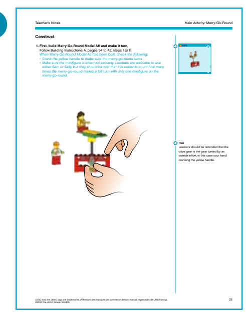
In the case of the problem-solving activities, learners should be able to tackle the challenge in a sequence of two lessons.

## LEGO® Education's 4C approach

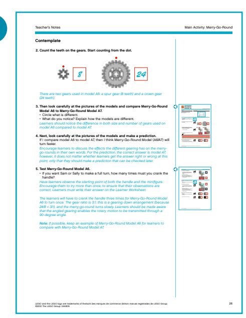
In working with the main models, in all four sections, you will be guided through LEGO® Education's 4C approach: Connect, Construct, Contemplate and Continue, enabling your learners to progress naturally through the activities.

**Connect**
The Connect story places the characters Sam and Sally in real-life surroundings, linking an object/item from the real world which most learners will recognise to the simple machine concept under consideration. This real-world object will closely resemble the LEGO models learners will work with and build. In the Connect passage the language is more child-oriented, as it is intended for you to read aloud.

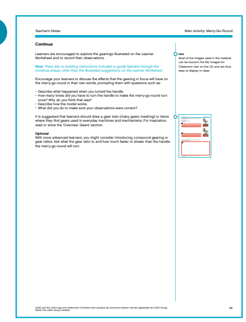
**Construct**
Using the building instructions, learners build models covering the concepts related to the simple machine in focus. Tips are provided for testing and for making sure that each model functions as intended.



**Contemplate**
This stage involves learners investigating the models they have constructed. Through these investigations, learners will learn to observe and compare results from tests that they make, and to report on their observations. They will be encouraged to describe the outcomes of their investigations. Questions are included that are designed to further deepen learners' experience and understanding of the investigation. This phase provides the opportunity for you to begin evaluating learning outcomes and the progress of individual learners, especially by looking at their worksheets and talking to them about their reflections and answers.



**Continue**
Continued learning is always more enjoyable and creative when it is sufficiently challenging. Extension ideas are therefore provided to encourage the learners to change or add features to their models and to investigate further – always with the key learning area in mind. This phase encourages learners to experiment and to apply their knowledge creatively.



**LEGO Education**

# Curriculum

| Curriculum Grid | 2009689 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Gears | | | Wheels and Axles | | | Levers | | | Pulleys | | |
| | Principle Models | Main Model | Problem-Solving Model | Principle Models | Main Model | Problem-Solving Model | Principle Models | Main Model | Problem-Solving Model | Principle Models | Main Model | Problem-Solving Model |
| **Science (English National Curriculum)** | | | | | | | | | | | | |
| **Scientific enquiry** | | | | | | | | | | | | |
| That it is important to test ideas using evidence from observation and measurement | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| Ask questions that can be investigated scientifically and decide how to find answers | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| Consider what sources of information, including first-hand experience and a range of other sources, they will use to answer questions | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| Make a fair test or comparison by changing one factor and observing or measuring the effect while keeping other factors the same | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| Use simple equipment and materials appropriately and take action to control risks | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| Make systematic observations and measurements | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| Use observations, measurements or other data to draw conclusions | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| Decide whether these conclusions agree with any prediction made and/or whether they enable further predictions to be made | | ● | ● | | ● | ● | | ● | ● | | ● | ● |
| Use their scientific knowledge and understanding to explain observations, measurements or other data or conclusions | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| **Physical processes** | | | | | | | | | | | | |
| About friction, including air resistance, as a force that slows moving objects and may prevent objects from starting to move | | | | ● | ● | ● | | | | | | |
| That when objects are pushed or pulled, an opposing pull or push can be felt | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| How to measure forces and identify the direction in which they act | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| **Design & Technology (English National Curriculum)** | | | | | | | | | | | | |
| **Developing, planning and communicating ideas** | | | | | | | | | | | | |
| Generate ideas for products after thinking about who will use them and what they will be used for, using information from a number of sources, including ICT-based sources | | | ● | | | ● | | | ● | | | ● |
| Develop ideas and explain them clearly, putting together a list of what they want their design to achieve | | | ● | | | ● | | | ● | | | ● |
| Plan what they have to do, suggesting a sequence of actions and alternatives, if needed | | | ● | | | ● | | | ● | | | ● |
| Communicate design ideas in different ways as these develop, bearing in mind aesthetic qualities, and the uses and purposes for which the product is intended | | | ● | | | ● | | | ● | | | ● |
| **Working with tools, equipment, materials and components to make quality products** | | | | | | | | | | | | |
| Measure, mark out, cut and shape a range of materials, and assemble, join and combine components and materials accurately | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| **Evaluating processes and products** | | | | | | | | | | | | |
| Reflect on the progress of their work as they design and make, identifying ways they could improve their products | | | ● | | | ● | | | ● | | | ● |
| Carry out appropriate tests before making any improvements | | | ● | | | ● | | | ● | | | ● |
| Recognise that the quality of a product depends on how well it is made and how well it meets its intended purpose | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| **Knowledge and understanding of materials and components** | | | | | | | | | | | | |
| How mechanisms can be used to make things move in different ways, using a range of equipment including an ICT control program | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |

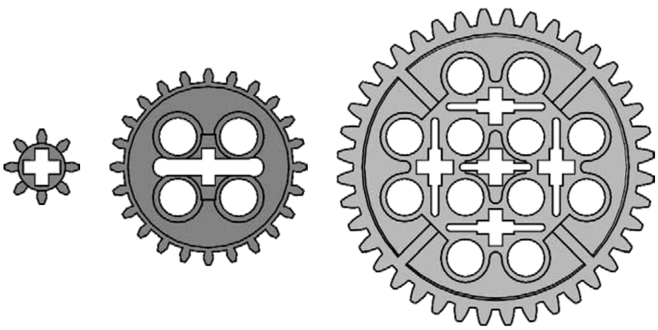
| Curriculum Grid | 2009689 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Gears | | | Wheels and Axles | | | Levers | | | Pulleys | | |
| | Principle Models | Main Model | Problem-Solving Model | Principle Models | Main Model | Problem-Solving Model | Principle Models | Main Model | Problem-Solving Model | Principle Models | Main Model | Problem-Solving Model |
| **Mathematics (English National Curriculum)** | | | | | | | | | | | | |
| **Number (Fractions, percentages and ratio)** | | | | | | | | | | | | |
| Solve simple problems involving ratio and direct proportion | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| **Number (solving numerical problems)** | | | | | | | | | | | | |
| Choose and use an appropriate way to calculate and explain their methods and reasoning | | | ● | | | ● | | | ● | | | ● |
| **Shape, space and measures (problem solving)** | | | | | | | | | | | | |
| Approach spatial problems flexibly, including trying alternative approaches to overcome difficulties | | | ● | | | ● | | | ● | | | ● |
| **Shape, space and measures (reasoning)** | | | | | | | | | | | | |
| Use mathematical reasoning to explain features of shape and space | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| **Shape, space and measures (understanding properties of shape)** | | | | | | | | | | | | |
| visualise 3-D shapes from 2-D drawings | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| **Shape, space and measures (Understanding properties of position and movement)** | | | | | | | | | | | | |
| Make and draw with increasing accuracy 2-D and 3-D shapes and patterns; recognise reflective symmetry in regular polygons; recognise their geometrical features and properties including angles, faces, pairs of parallel lines and symmetry, and use these to classify shapes and solve problems | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| Visualise and describe movements using appropriate language | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| Transform objects in practical situations; transform images using ICT; visualise and predict the position of a shape following a rotation, reflection or translation | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| **Understanding measures** | | | | | | | | | | | | |
| Recognise the need for standard units of length, mass and capacity, choose which ones are suitable for a task, and use them to make sensible estimates in everyday situations; convert one metric unit to another; know the rough metric equivalents of imperial units still in daily use | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |

## Curriculum Highlights

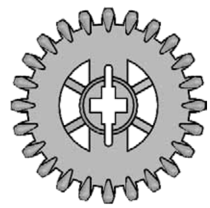
| | Gears Principle & Main Models | Wheels and Axles Principle & Main Models | Levers Principle & Main Models | Pulleys Principle & Main Models |
|---|---|---|---|---|
| **Design & Technology curriculum** | | | | |
| Making simple machines | • Identify gears as either spur or crown gear.<br>• Build a model which will gear up and increase speed of rotation.<br>• Build a model which will gear down and decrease speed of rotation.<br>• Arrange gears so they turn in the same direction, in opposite directions, or at 90 degrees to each other as desired.<br>• Recognise that how fast or how slowly one gear makes another turn depends on the number of teeth on the gears and their position. | • Identify a wheel and axle as a simple machine.<br>• Build a wheeled model which turns a corner easily.<br>• Build a model that can be steered.<br>• Identify where friction might be found. | • Identify a lever as a rod or arm that tilts around a pivot to produce useful motion.<br>• Describe the pivot, effort and load.<br>• Recognise that the effectiveness of a lever depends on the arrangement of the pivot point, effort and load.<br>• Identify first class levers. | • Identify a pulley wheel.<br>• Build a model which will gear up and increase speed of rotation.<br>• Build a model which will gear down and decrease speed of rotation.<br>• Arrange pulleys so that the drive pulley turns in the same direction as the driven pulley.<br>• Recognise that the turning ratio of one pulley to another is determined by the size of the pulleys.<br>• Arrange pulley wheels so they turn in the same direction, in opposite directions, or at 90 degrees to each other as desired. |
| Designing, making and testing simple machines | Problem solving activity – popcorn cart | Problem solving activity – wheelbarrow | Problem solving activity – railway crossing barrier | Problem solving activity – crane |
| **Science curriculum** | | | | |
| Investigating simple machines, scientific inquiry, speed, fair testing, predicting and measuring, collecting data, and describing outcomes. | • Investigate the performance of gears. | • Investigate a single fixed axle.<br>• Investigate separate axles. | • Investigate the performance of levers | • Investigate the performance of pulleys |
| **Mathematics curriculum** | | | | |
| Counting, drawing geometric shapes, calculating, measuring, predicting outcomes, and problem solving | • Predict outcomes of various trials<br>• Count teeth on gears and count rotations.<br>• Draw geometric shapes | • Predict outcomes of various trials<br>• Measure with standard units of measure | • Predict outcomes of various trials<br>• Measure with standard units of measure | • Predict outcomes of various trials<br>• Count rotations |

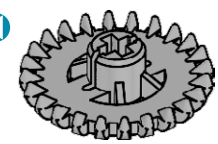
# Overview: Gears

### Spur gears



### A crown gear





A gear is most commonly defined as a toothed wheel; the teeth of a gear prevent slipping. When one gear is engaged with another gear they are said to mesh. When a set of gears work together they transmit movement and force. A crown gear has special curved teeth which enable it to mesh at right angles with a spur gear. Gears are sometimes categorised as compound machines, but in this material we have included them as simple machines.

Gears can be used to create the following effects:

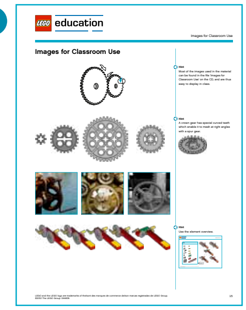
- To change the direction of rotation
- To change the orientation of a rotating movement
- To increase or decrease the speed of rotation
- To increase turning force, also called torque

Gears are found in many machines where there is a need to control the speed of rotary movement and turning force. Examples include cars, bicycles, old-fashioned egg beaters, tin openers and grandfather clocks.

**Did you know?**
A gear, or toothed wheel, when in operation, may actually be considered to be a lever, with the additional feature that it can be rotated continuously instead of rocking back and forth through a short distance.

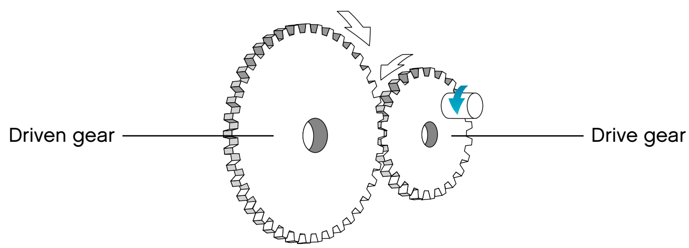
## Establishing the concept

We recommend establishing the concept of the simple machine to be worked on. This could be done, for example, by showing learners a number of exhibits from the LEGO® set to stimulate their interest. Build a principle model, or show some of the images from Images for Classroom Use, asking questions such as 'What do you know about this simple machine?' or 'Where do we use this simple machine?' See if learners can name any of the objects you show them, and allow time for learners to handle them.




## Providing the vocabulary

Learners will acquire the necessary vocabulary for the simple machine as they progress through the activities, but it may be useful to introduce certain terms at this stage. Important new vocabulary items are *drive gear* and *driven gear*.

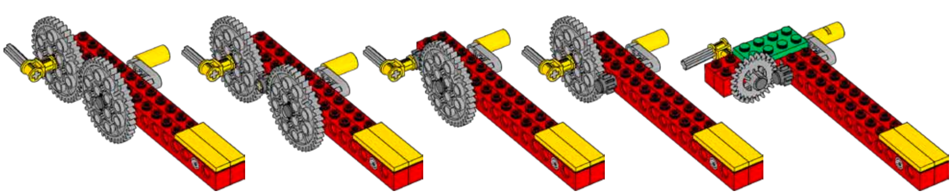


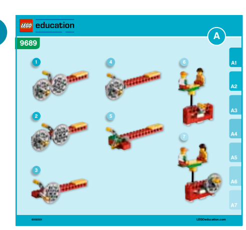

The gear that is closer to the source of power is called the drive gear and the gear that receives power from the drive gear is called the driven gear (or follower gear).

## Understanding the principles

The principle models are designed to help learners understand the principles of the simple machine in focus through hands-on experience before they move on to construct the main models.

The principle models are presented in a logical sequence that will build on learners' understanding. The principle models can only be built one at a time from the parts in the set.



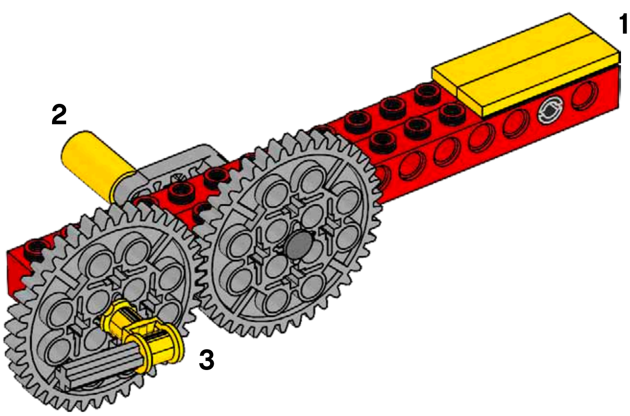


## Using the principle models

1. The yellow elements indicate where to hold, push, lift or apply force/effort in handling the principle models. The principle models need to be held correctly for them to work properly.

2. When measuring one turn of the handle, carefully observe the starting place of the handle, and be careful to stop at the same position after a full turn.

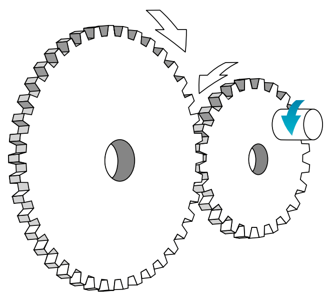
3. When measuring a full turn of the position marker, carefully observe the starting place of the position marker, and be careful to stop at the same position after a full turn. This is especially important when observing the connection between cranking the handle and the number of turns the position marker makes.



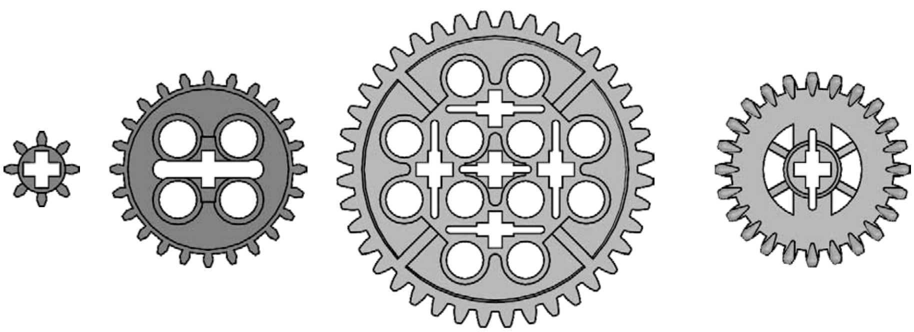

**Hint**
The principle models can be built as mirror-images for left-handed learners.

**Hint**
It is recommended that learners work in pairs; one learner can observe the position marker while the other cranks the handle a full turn.

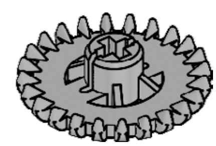
# Images for Classroom Use

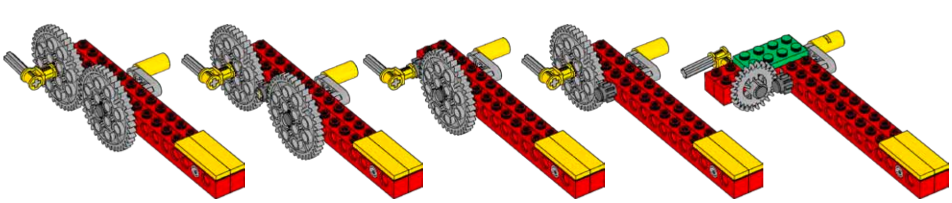


**Hint**
Most of the images used in the material can be found in the file 'Images for Classroom Use' on the CD, and are thus easy to display in class.

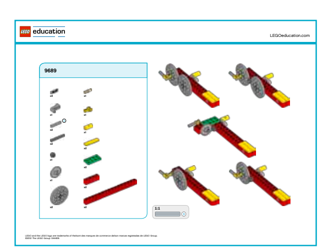


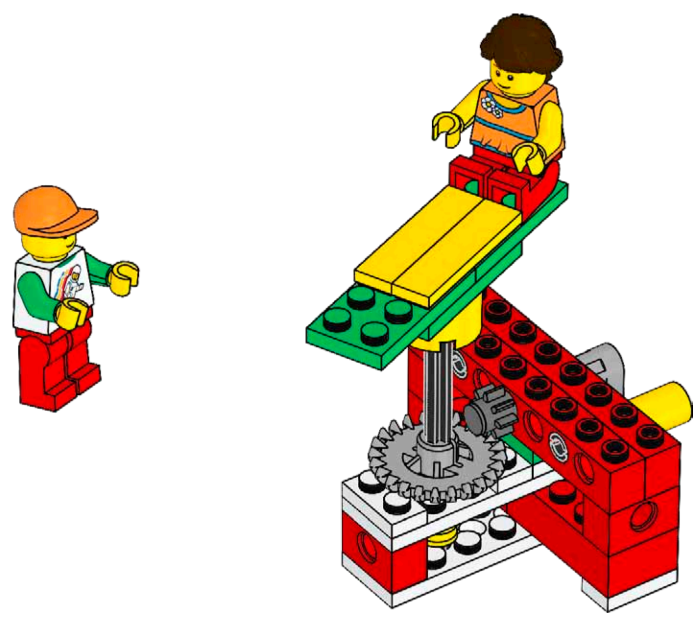
**Hint**
A crown gear has special curved teeth which enable it to mesh at right angles with a spur gear.



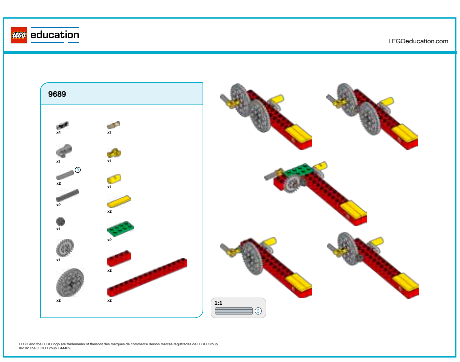


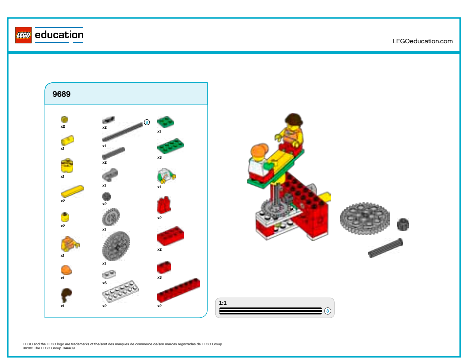
**Hint**
Use the element overview.





**Hint**
It is often more practical to sort out the elements that will be needed before starting work on the models.




**Hint**
The element overview can be printed and used as a check-list for learners to use when they are taking out and putting away their elements.

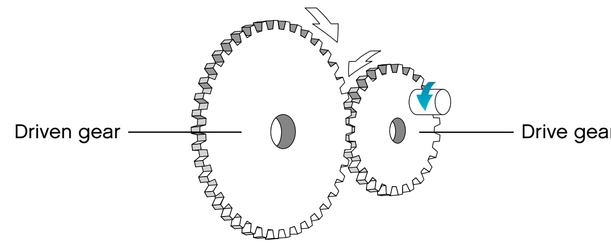
# Principle Models: Gears

Teacher's Notes

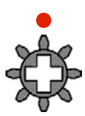
## Things to talk about

- What do you know about this simple machine?
- Where do we use this simple machine?
- Why do we use this simple machine?

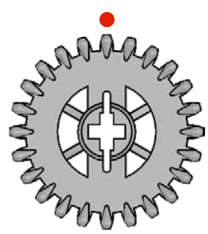
*Relate learners' answers to some of the images from Images for Classroom Use, or find ideas from the 'Overview: Gears' section to stimulate learners' interest.*



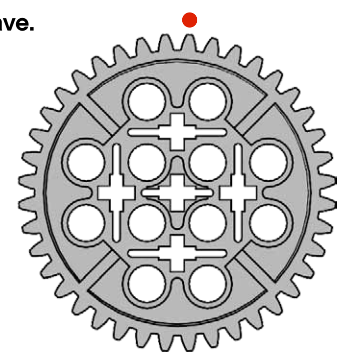

**Find the LEGO® gears shown and count the number of teeth they each have. Start counting from the dot.**



8

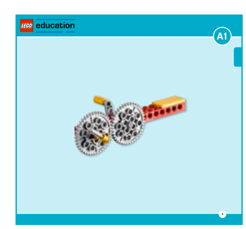


24

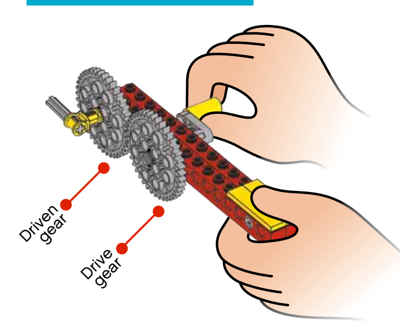


40

1. **Build A1** (Direction of rotation).
   Follow Building Instructions A, pages 4 to 8, steps 1 to 7.



2. **Label the gears.**
   Draw lines from the words to the picture of the model.
   *The drive gear is the gear that is turned by an outside effort, in this case your hand. Any gear that is turned by another gear is called the driven gear or follower.*

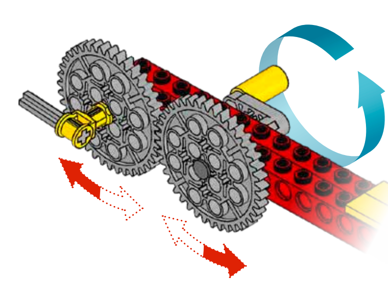



3. **Try out the model and make observations.**

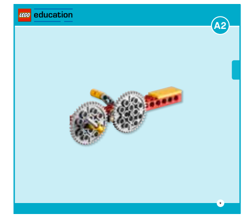
   ***Note:*** *It is recommended that learners work in pairs; one learner can observe the position marker while the other cranks the handle a full turn.*

   Crank the handle one full turn, and count how many times the position marker turns.
   *One turn of the handle results in one turn of the position marker (the grey axle). The speeds of rotation of the drive and the driven gears are the same, because they have the same number of teeth (40); this ratio is 1:1.*

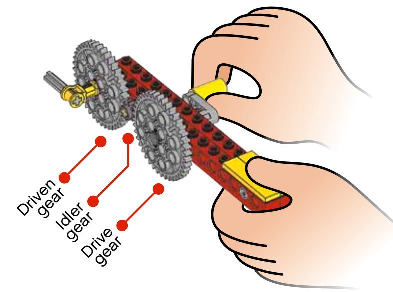
   Observe which way the gears turn when you crank the handle, and draw arrows to show the directions they turn in.
   *Adjacent gears turn in opposite directions.*



1. **Build A2** (Idler gearing).
   Follow Building Instructions A, pages 10 to 14, steps 1 to 8.

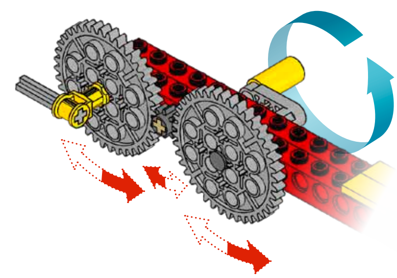



2. **Label the gears.**
   Draw lines from the words to the picture of the model.
   *The small gear is an idler gear. The idler gear does not affect the relative speeds of rotation of either of the larger gears, only the direction in which the driven gear turns.*

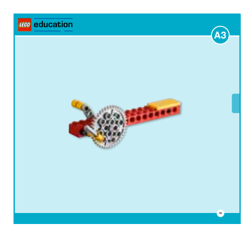



3. **Try out the model and make observations.**
   Crank the handle one full turn, and count how many times the position marker turns.
   *One turn of the handle results in one turn of the grey axle. The speeds of rotation of the drive and the driven gears are the same, because they have the same number of teeth. The gearing ratio is 1:1.*

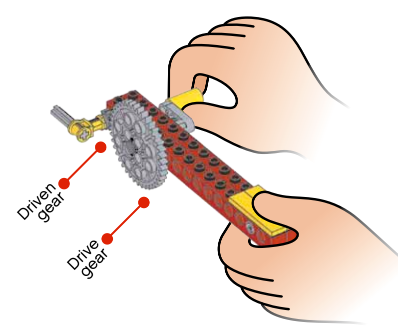
   Observe which way the gears turn when you crank the handle, and draw arrows to show the directions they turn in.
   *The 40-tooth drive gear and the 40-tooth driven gear both turn in the same direction. The idler gear rotates in the opposite direction.*



1. **Build A3** (Increasing speed of rotation).
   Follow Building Instructions A, pages 16 to 20, steps 1 to 7.

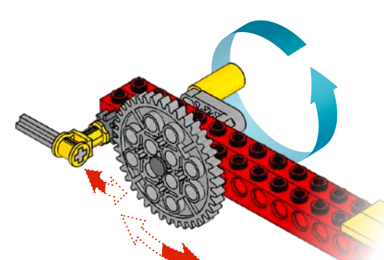



2. **Label the gears.**
   Draw lines from the words to the picture of the model.
   *The drive gear is the gear that is turned by an outside effort, in this case your hand. Any gear that is turned by another gear is called a driven gear or follower.*

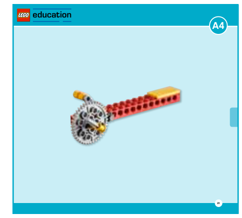



3. **Try out the model and make observations.**
   Crank the handle one full turn, and count how many times the position marker turns.
   *One turn of the handle (the large drive gear) results in five turns of the smaller driven gear. This ratio of 1:5 (or 1/5) is called the gearing up ratio (8/40 = 1/5). Increasing the gearing up ratio increases the speed of rotation of the driven gear, but decreases the force in the driven gear – the power of the gear to turn something.*

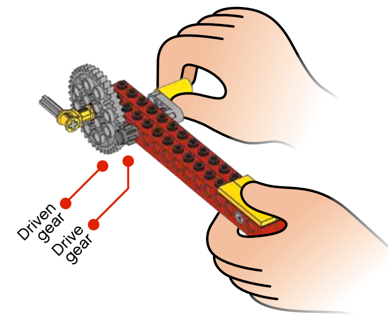
   Observe which way the gears turn when you crank the handle, and draw arrows to show the directions they turn in.
   *Adjacent gears turn in opposite directions.*



1. **Build A4** (Decreasing speed of rotation).
   Follow Building Instructions A, pages 22 to 26, steps 1 to 7.

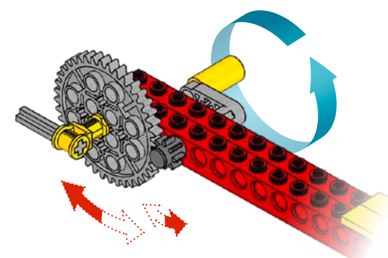



2. **Label the gears.**
   Draw lines from the words to the picture of the model.
   *The drive gear is the gear that is turned by an outside effort, in this case your hand. Any gear that is turned by another gear is called a driven gear or follower.*




3. **Try out the model and make observations.**
   Count how many times the handle has to turn for the position marker to turn once.
   *Five turns of the handle (the small drive gear) results in one turn of the large driven gear. This ratio of 5:1 (or 5/1) is called the gearing down ratio (40/8 = 5/1). Decreasing the gearing ratio decreases the speed of rotation of the driven gear, but increases the force in the driven gear – the power of the gear to turn something.*

   Observe which way the gears turn when you crank the handle, and draw arrows to show the directions they turn in.
   *Adjacent gears turn in opposite directions.*



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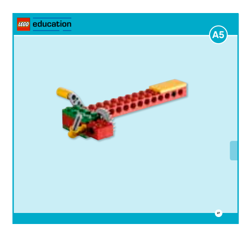
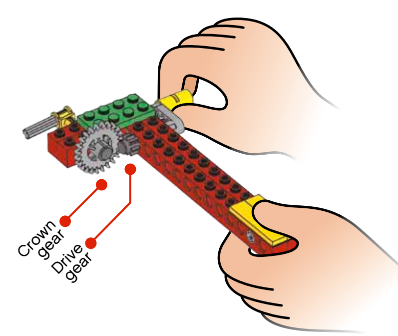
1. **Build A5** (At an angle).
   Follow Building Instructions A, pages 28 to 32, steps 1 to 8.

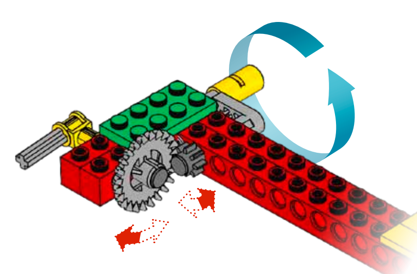



2. **Label the gears.**
   Draw lines from the words to the picture of the model.
   *The 8-tooth drive spur gear moves the 24-tooth driven crown gear.*




3. **Try out the model and make observations.**
   Count how many times the handle has to turn for the position marker to turn once.
   *Three turns of the handle (the small drive gear) results in one turn of the crown gear. This is a ratio of 3:1 (or 24/8 or 3/1).*

   Observe which way the gears turn when you crank the handle, and draw arrows to show the directions they turn in.
   *The rotary motion is changed through a 90-degree angle/turns through an angle/turns a corner (the answer your learners give will depend on their familiarity with describing angles). The crown gear can change the rotary motion easily because it has special curved teeth which enable it to mesh at an angle/at right angles in a different direction with a spur gear.*

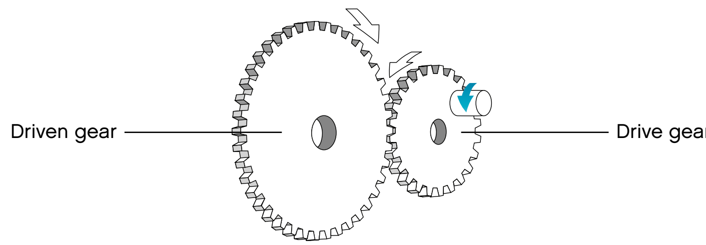


**Name(s):**

**Date and subject:**

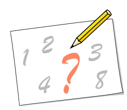
## Principle Models: Gears

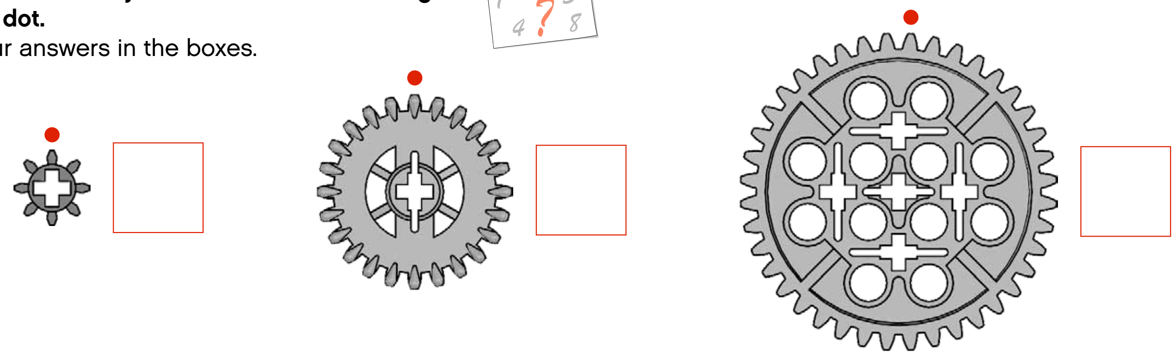
Learner Worksheet




**Things to talk about**
• What do you know about this simple machine?
• Where do we use this simple machine?
• Why do we use this simple machine?

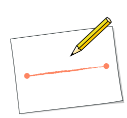
**Find the LEGO® gears shown and count the number of teeth they each have. Start counting from the dot.**
Write your answers in the boxes.



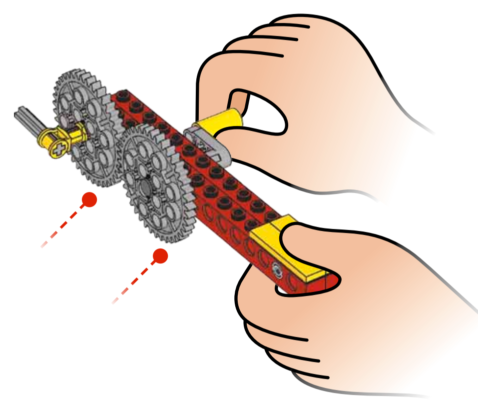
1. **Build A1** (Direction of rotation).
   Follow Building Instructions A, pages 4 to 8, steps 1 to 7.

2. **Label the gears.**
   Draw lines from the words to the picture of the model.

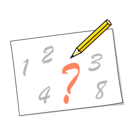


**Driven gear**

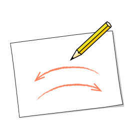
**Drive gear**

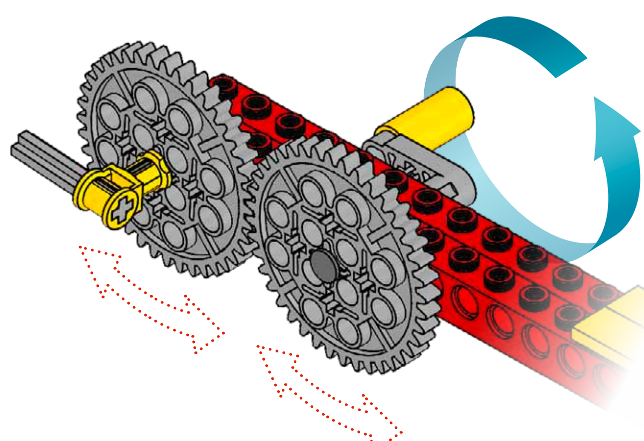


3. **Try out the model and make observations.**
   Crank the handle one full turn, and count how many times the position marker turns.
   Write your answer here:

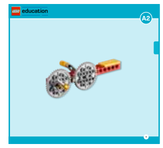


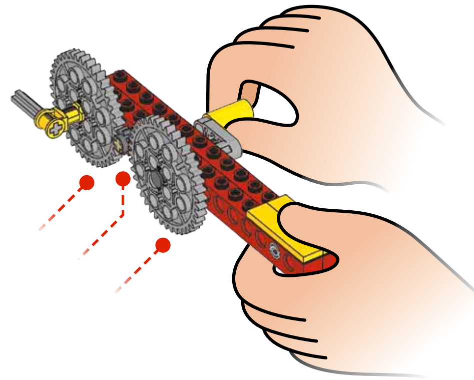

   Observe which way the gears turn when you crank the handle, and draw arrows to show the directions they turn in.





1. **Build A2** (Idler gearing).
   Follow Building Instructions A, pages 10 to 14, steps 1 to 8.





2. **Label the gears.**
   Draw lines from the words to the picture of the model.

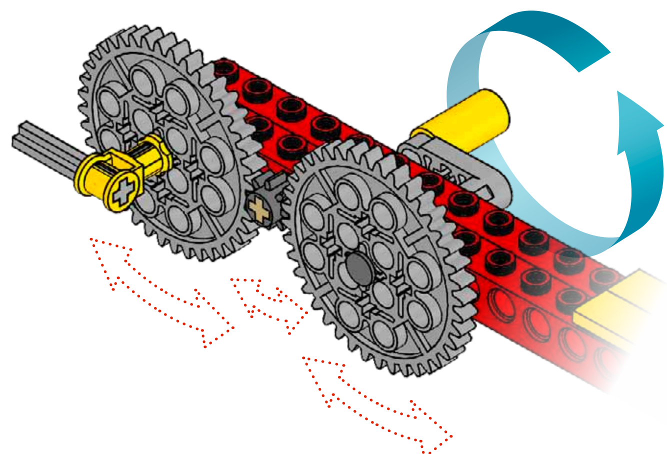
**Driven gear**

**Idler gear**

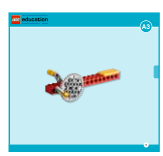
**Drive gear**

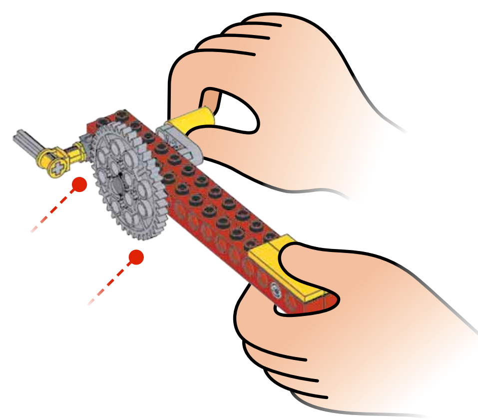
3. **Try out the model and make observations.**
   Crank the handle one full turn, and count how many times the position marker turns.
   Write your answer here:

   Observe which way the gears turn when you crank the handle, and draw arrows to show the directions they turn in.



1. **Build A3** (Increasing speed of rotation).
   Follow Building Instructions A, pages 16 to 20, steps 1 to 7.





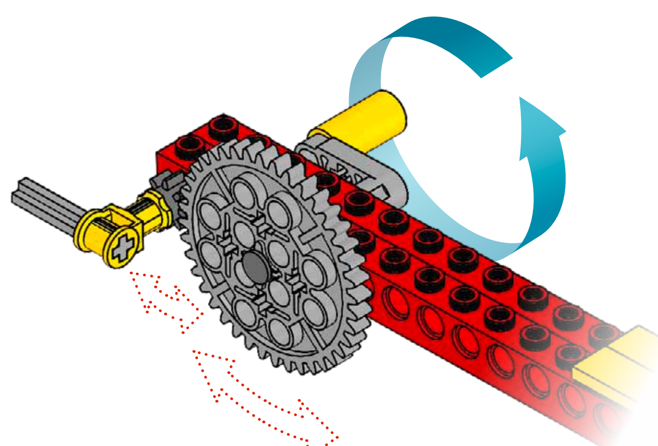
2. **Label the gears.**
   Draw lines from the words to the picture of the model.

**Driven gear**

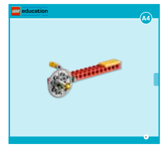
**Drive gear**

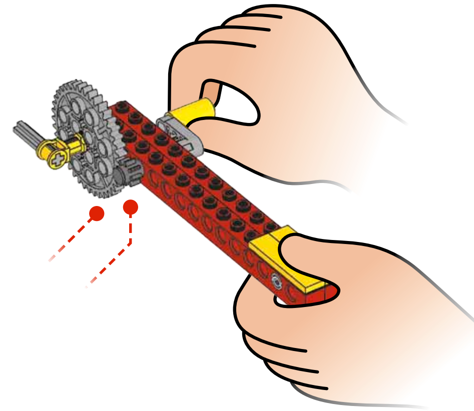
3. **Try out the model and make observations.**
   Crank the handle one full turn, and count how many times the position marker turns.
   Write your answer here:

   Observe which way the gears turn when you crank the handle, and draw arrows to show the directions they turn in.

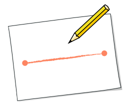


1. **Build A4** (Decreasing speed of rotation).
   Follow Building Instructions A, pages 22 to 26, steps 1 to 7.





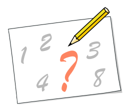
2. **Label the gears.**
   Draw lines from the words to the picture of the model.

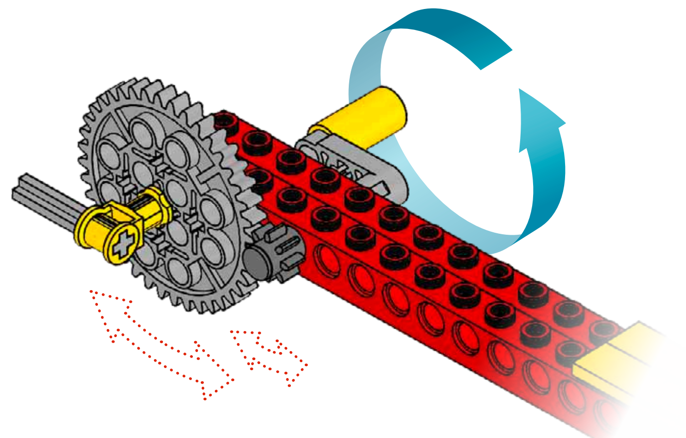


**Driven gear**

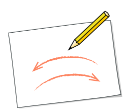
**Drive gear**

3. **Try out the model and make observations.**
   Count how many times the handle has to turn for the position marker to turn once.
   Write your answer here:

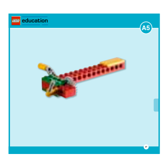


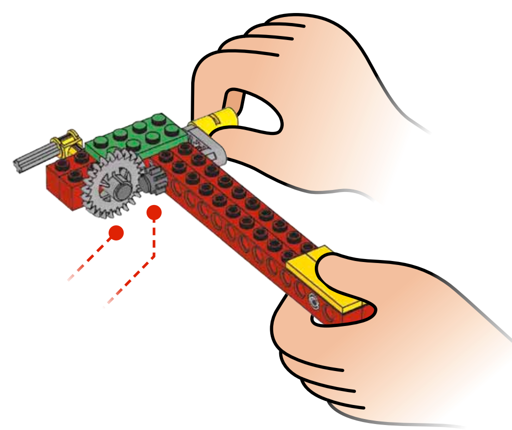


Observe which way the gears turn when you crank the handle, and draw arrows to show the directions they turn in.

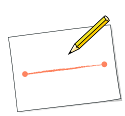


1. **Build A5** (At an angle).
   Follow Building Instructions A, pages 28 to 32, steps 1 to 8.





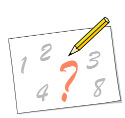
2. **Label the gears.**
   Draw lines from the words to the picture of the model.

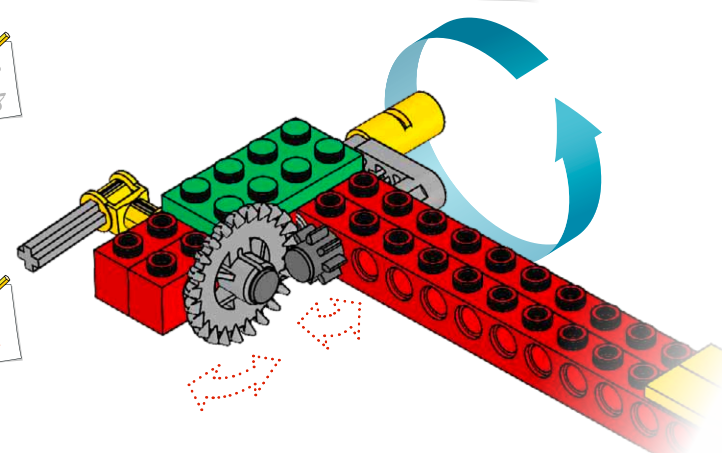


**Crown gear**

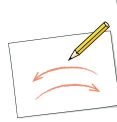
**Spur gear**

3. **Try out the model and make observations.**
   Count how many times the handle has to turn for the position marker to turn once.
   Write your answer here:





Observe which way the gears turn when you crank the handle, and draw arrows to show the directions they turn in.



# Main Activity: Merry-Go-Round

Teacher's Notes

## Learning objectives

In this activity learners will build and test models that use the following techniques associated with gears:

- Decreasing speed of rotation
- Increasing speed of rotation
- Gearing at an angle

To perform this activity, learners should be familiar with the following vocabulary associated with gears:

- Drive gear
- Driven gear
- To mesh

If learners have already worked with the principle models, they will already have observed gears, and the terms used in this activity should be familiar to them. Predictions should now be easier to make based on the observations made earlier. If the learners have not worked on the principle models, then additional time will be needed, for example to introduce and explain the technical vocabulary used. If additional guidance is required, please turn to the 'Overview: Gears' or 'Principle Models' sections.

## Materials required

• 9689 LEGO® Education Simple Machines Set

9689

## Connect

Sam and Sally love going to the fair. The ride they enjoy most is the merry-go-round. It's such fun to spin around and around, waving to their friends and families!

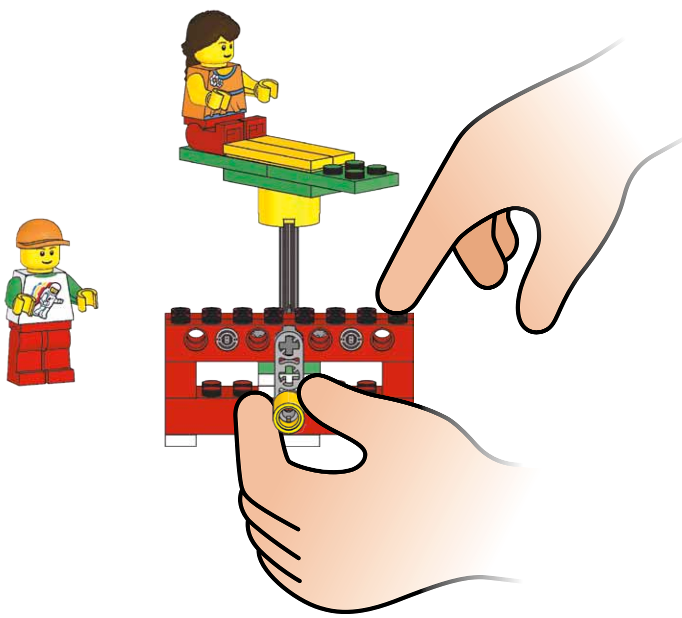
Do you like merry-go-rounds?
What do you enjoy most about them?
Which simple machine might be needed for a merry-go-round to turn?

**Let's build a merry-go-round!**

**Hint**
Most of the images used in the material can be found in the file 'Images for Classroom Use' on the CD, and are thus easy to display in class.

## Construct

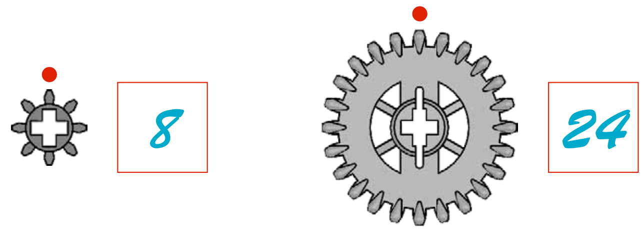
1. **First, build Merry-Go-Round Model A6 and make it turn.**
   Follow Building Instructions A, pages 34 to 42, steps 1 to 11.
   *When Merry-Go-Round Model A6 has been built, check the following:*
   - *Crank the yellow handle to make sure the merry-go-round turns.*
   - *Make sure the minifigure is attached securely. Learners are welcome to use either Sam or Sally, but they should be told that it is easier to count how many times the merry-go-round makes a full turn with only one minifigure on the merry-go-round.*

**Hint**
Learners should be reminded that the drive gear is the gear turned by an outside effort, in this case your hand cranking the yellow handle.

## Contemplate

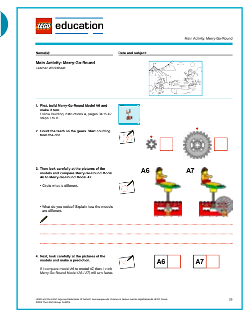
**2. Count the teeth on the gears. Start counting from the dot.**




*There are two gears used in model A6: a spur gear (8 teeth) and a crown gear (24 teeth).*

**3. Then look carefully at the pictures of the models and compare Merry-Go-Round Model A6 to Merry-Go-Round Model A7.**
- Circle what is different.
- What do you notice? Explain how the models are different.

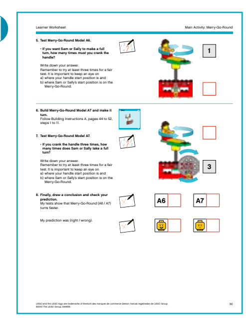
*Learners should notice the difference in both size and number of gears used on model A6 compared to model A7.*



**4. Next, look carefully at the pictures of the models and make a prediction.**
If I compare model A6 to model A7, then I think Merry-Go-Round Model (A6/A7) will turn faster.
*Encourage learners to discuss the effects the different gearing has on the merry-go-rounds in their own words. For the prediction, the correct answer is model A7; however, it does not matter whether learners get the answer right or wrong at this point, only that they should make a prediction that can be checked later.*

**5. Test Merry-Go-Round Model A6.**
- If you want Sam or Sally to make a full turn, how many times must you crank the handle?

*Have learners observe the starting point of both the handle and the minifigure. Encourage them to try more than once, to ensure that their observations are correct. Learners must write their answer on the Learner Worksheet.*



*The learners will have to crank the handle three times for Merry-Go-Round Model A6 to turn once. The gear ratio is 3:1; this is a gearing down arrangement (because 24/8 = 3/1), and the merry-go-round turns slowly. Learners should be made aware that the angled gearing enables the rotary motion to be transmitted through a 90-degree angle.*

***Note:** If possible, keep an example of Merry-Go-Round Model A6 for learners to compare with Merry-Go-Round Model A7.*

**6. Build Merry-Go-Round Model A7 and make it turn.**

Follow Building Instructions A, pages 44 to 52, steps 1 to 11.

*Encourage learners to identify the gears and count the teeth on the gears. There are four gears used in the model: two small spur gears (8 teeth), a crown gear (24 teeth), and a large spur gear (40 teeth).*


**7. Test Merry-Go-Round Model A7.**

- If you crank the handle three times, how many times does Sam or Sally make a full turn?

*Have learners pay attention to the starting positions of the handle and the minifigure as described earlier. Encourage them to try more than once, to ensure that their observations are correct.*

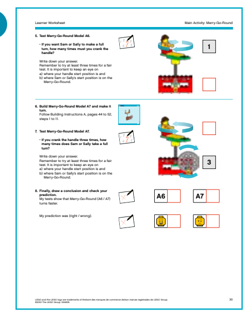
*Three turns of the 40-tooth gear produce five turns of the merry-go-round. The gear ratio is 3:5 (because 24/40 = 3/5) and the merry-go-round turns at a much faster pace.*

**Hint**

It is recommended that learners work in pairs; one learner can observe the minifigure while the other cranks the handle a full turn.

**8. Finally, draw a conclusion and check your prediction.**

*Merry-Go-Round Model A7 turns faster because of the gearing-up arrangement with the 40-tooth drive gear and the 24-tooth driven gear.*



## Continue

Learners are encouraged to explore the gearings illustrated on the Learner Worksheet and to record their observations.

***Note:** There are no building instructions included to guide learners through the Continue phase, other than the illustrated suggestions on the Learner Worksheet.*

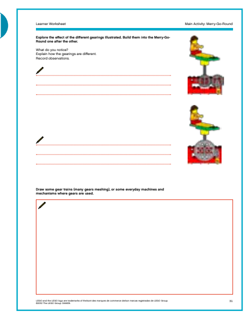
Encourage your learners to discuss the effects that the gearing in focus will have on the merry-go-round in their own words, prompting them with questions such as:

- Describe what happened when you turned the handle.
- How many times did you have to turn the handle to make the merry-go-round turn once? Why do you think that was?
- Describe how the model works.
- What did you do to make sure your observations were correct?

It is suggested that learners should draw a gear train (many gears meshing) or items where they find gears used in everyday machines and mechanisms. For inspiration, read or show the 'Overview: Gears' section.

**Optional**
With more advanced learners, you might consider introducing compound gearing or gear ratios. Ask what the gear ratio is, and how much faster or slower than the handle the merry-go-round will turn.

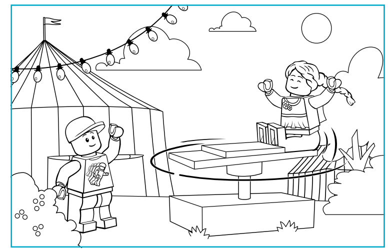
**Hint**
Most of the images used in the material can be found in the file 'Images for Classroom Use' on the CD, and are thus easy to display in class.



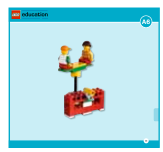
**Name(s):** **Date and subject:**

## Main Activity: Merry-Go-Round

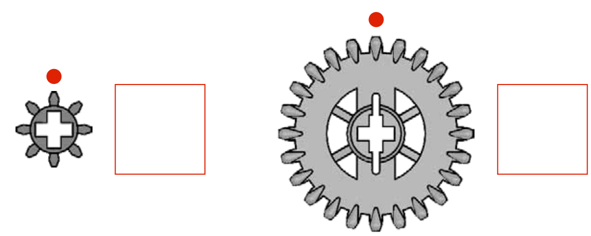
Learner Worksheet



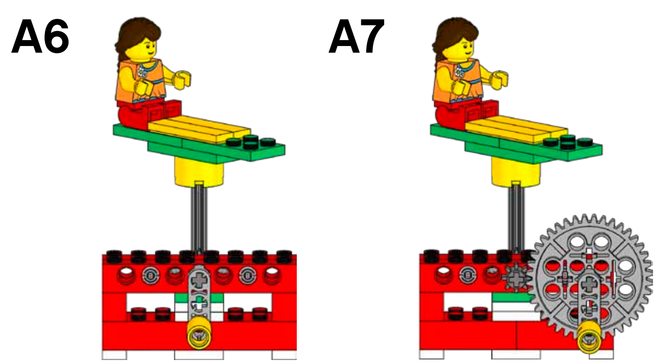
1. **First, build Merry-Go-Round Model A6 and make it turn.**
   Follow Building Instructions A, pages 34 to 42, steps 1 to 11.



2. **Count the teeth on the gears. Start counting from the dot.**



3. **Then look carefully at the pictures of the models and compare Merry-Go-Round Model A6 to Merry-Go-Round Model A7.**
   • Circle what is different.
   • What do you notice? Explain how the models are different.




4. **Next, look carefully at the pictures of the models and make a prediction.**

   If I compare model A6 to model A7, then I think Merry-Go-Round Model (A6 / A7) will turn faster.

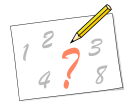
| A6 | |
|---|---|

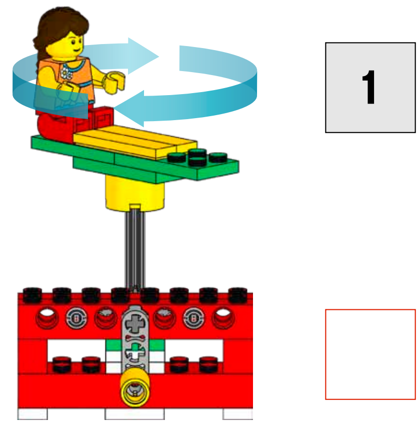
| A7 | |
|---|---|

**5. Test Merry-Go-Round Model A6.**

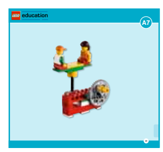
- **If you want Sam or Sally to make a full turn, how many times must you crank the handle?**

Write down your answer.
Remember to try at least three times for a fair test. It is important to keep an eye on
a) where your handle start position is and
b) where Sam or Sally's start position is on the Merry-Go-Round.



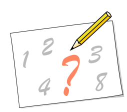

**6. Build Merry-Go-Round Model A7 and make it turn.**
Follow Building Instructions A, pages 44 to 52, steps 1 to 11.

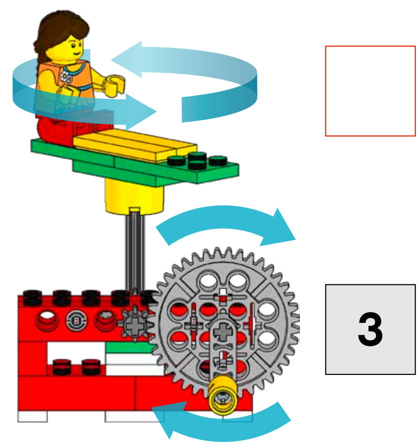


**7. Test Merry-Go-Round Model A7.**

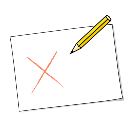
- **If you crank the handle three times, how many times does Sam or Sally take a full turn?**

Write down your answer.
Remember to try at least three times for a fair test. It is important to keep an eye on
a) where your handle start position is and
b) where Sam or Sally's start position is on the Merry-Go-Round.



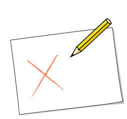



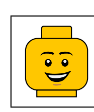

**8. Finally, draw a conclusion and check your prediction.**
My tests show that Merry-Go-Round (A6 / A7) turns faster.

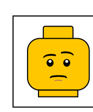


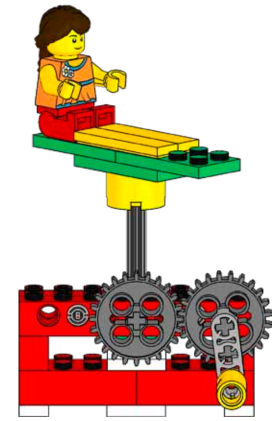
A6 A7

My prediction was (right / wrong).



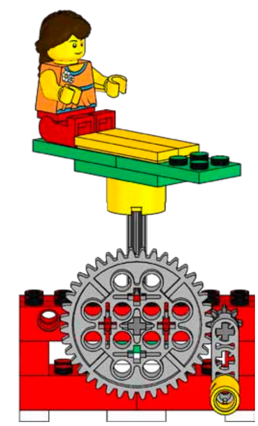






**Explore the effect of the different gearings illustrated. Build them into the Merry-Go-Round one after the other.**

What do you notice?
Explain how the gearings are different.
Record observations.



**Draw some gear trains (many gears meshing), or some everyday machines and mechanisms where gears are used.**

# Problem-Solving Activity: Popcorn Cart

Learner Worksheet

When Sam and Sally visit the fair they always buy popcorn. Sometimes it can be difficult to see where popcorn is being sold. Sam and Sally want to help the popcorn seller by building a sign for the popcorn cart that will turn and attract people's attention.

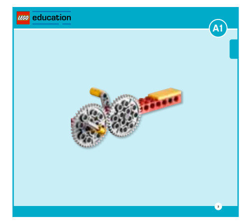
**Let's help Sam and Sally!**

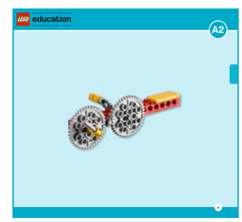
**Build a popcorn cart like the one in the picture.**

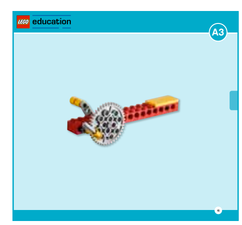
Your design brief is as follows:
• Build a popcorn cart.
• Make a sign that can turn.
• Build a mechanism that makes the sign turn when you turn a handle.

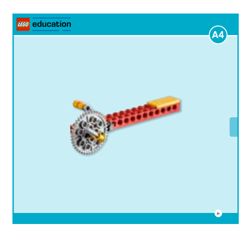
When you have finished, test your cart. Count how many times the sign spins for every five turns of the handle. Assess how easily the sign can be read at a distance. What makes it easy or difficult to read?

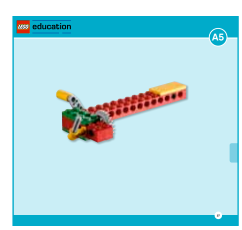
**Need help?**
Look at:



# Problem-Solving Activity: Popcorn Cart

Teacher's Notes

## Learning objectives:

Learners are encouraged to do some research related to the real-life problem they are set to solve and/or the type of simple machine that they are going to use, and to:

- Identify a need or a problem
- Develop explanations using observations
- Test, evaluate and redesign models

## Introduction

To help in the design process, instruct the learners to look at the picture on the Learner Worksheet and read the accompanying text. If time and facilities are available, have your learners conduct research, and also encourage them to generate ideas and questions by posing problems they must take into account in their design and building processes. Your learners could search the Internet to learn more about the appearance, structure and function of different sorts of carts and signs.

Learners should be reminded of the principle models that they have worked with. It might be a good idea to build principle model A5 (At an angle) to show the technique used.

Discuss in class the design problem specified in the design brief. Try to find several possible general solutions, or use the suggested solution for inspiration if necessary.

Discuss the constraints and functions your learners will have to take into account to carry out the design brief. Try to get your learners to focus on relevant issues and decisions by asking questions. These might include:

- How will your model look?
  *Maybe a popcorn handcart with wheels, handles for pushing it and a space for the popcorn, with a rotating sign on top operated by turning a handle. Or maybe simply a sign with a turning mechanism.*
- What LEGO® elements do you have available? Which wheels will you use? What can you use for a sign? How do you think you might start building?
- Should your sign turn quickly or slowly, do you think? Why?

## Optional materials

Materials for enhancing the appearance and functionality of the model: Learners can use paper, cardboard and markers to make signs. Additional LEGO elements, if available, may be used to make models more elaborate.

**When the model is finished, encourage learners to reflect on both the product that they have produced and the processes they have used by:**

- Carrying out tests to evaluate the performance of their model
- Reflecting on the design brief
- Recording their design by drawing or taking digital photos

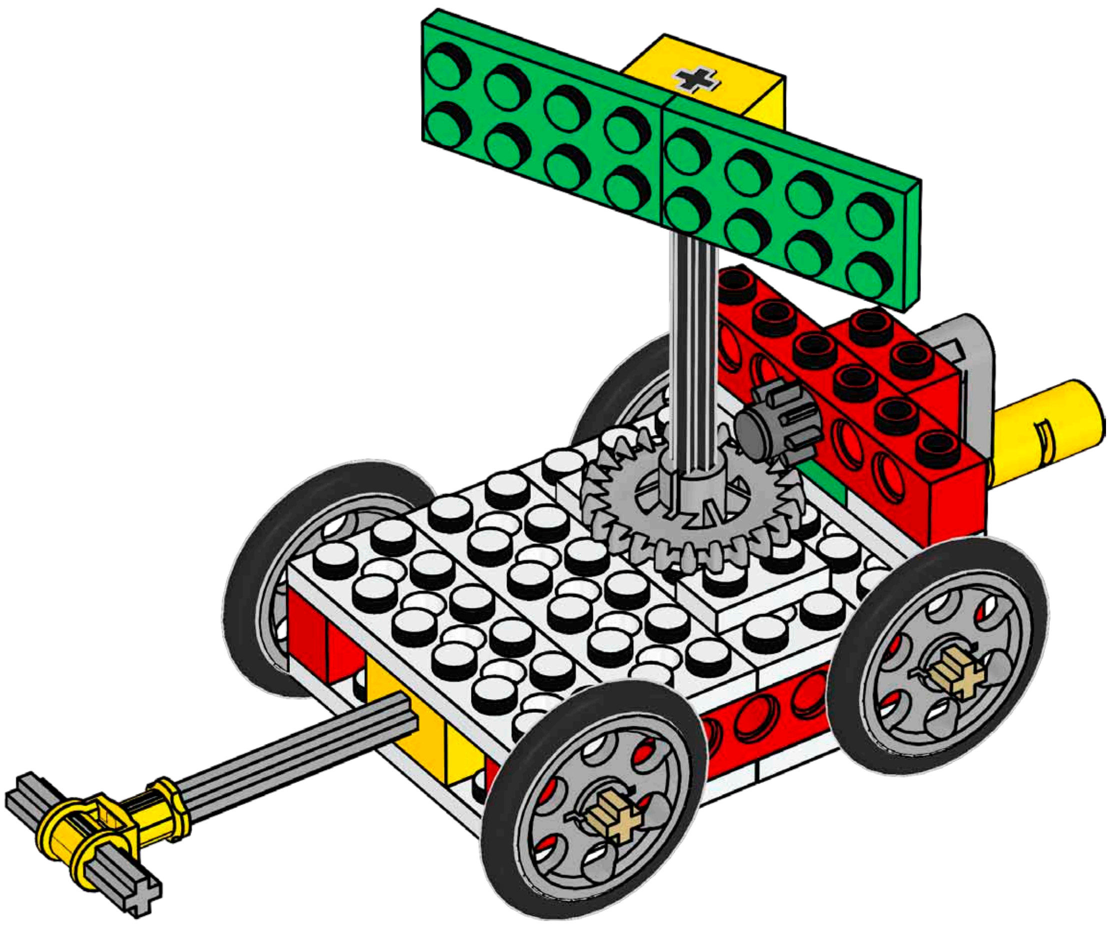
**Hint**

Most of the images used in the material can be found in the file 'Images for Classroom Use' on the CD, and are thus easy to display in class.

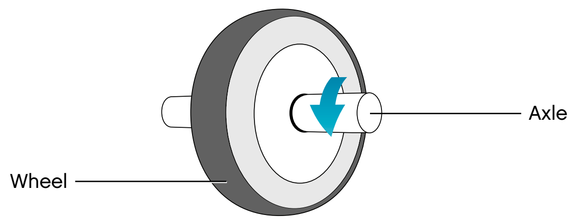
**Need help?**

Look at:

## Suggested model solution



# Overview: Wheels and Axles




A wheel is most commonly defined as a solid disc or as a circular ring with spokes, designed to turn around a smaller axle (a rod) passing through its centre. The circle traced in the air by a crank handle is also a wheel. As the crank handle goes round, the crank turns an attached axle. The wheel and attached axle both turn at the same speed. However, the force needed to turn one or the other differs, because the diameter of the wheel is larger than that of an axle. Applying a small force to turn the larger wheel produces a larger force to turn the smaller axle, as in a winch, for example.

Wheels and axles can be used to create the following effects:

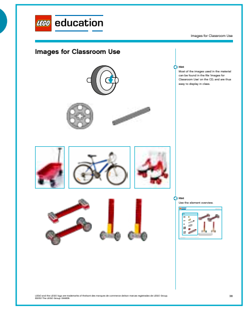
- To control the direction of movement
- To increase turning force, also called torque
- To reduce friction and to make objects easy to move

Wheels and axles are found in many machines where there is a need to control the direction of movement and turning force, such as windmills, bicycles, roller skates, vehicles, rolling pins, helicopters, fishing reels, trolleys, push-chairs and door knobs.

**Did you know?**
A disc is only a wheel when an axle runs through it.

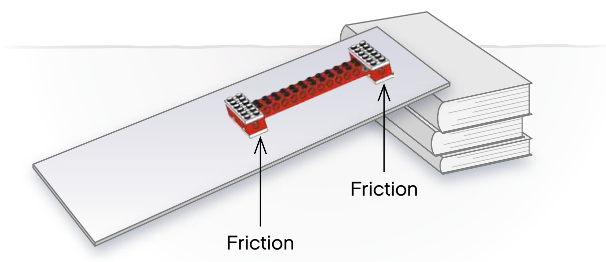
## Establishing the concept

We recommend establishing the concept of the simple machine to be worked on. This could be done, for example, by showing learners a number of exhibits from the LEGO® set to stimulate their interest. Build a principle model, or show some of the images from Images for Classroom Use, asking questions such as 'What do you know about this simple machine?' or 'Where do we use this simple machine?' See if learners can name any of the objects you show them, and allow time for learners to handle them.




## Providing the vocabulary

Learners will acquire the necessary vocabulary for the simple machine as they progress through the activities, but it may be useful to introduce one important term at this stage, namely *friction*.




Friction is the resistance met when one surface slides over another; this affects movement (see the 'Glossary' section). The effects of friction can be tested using the principle models.

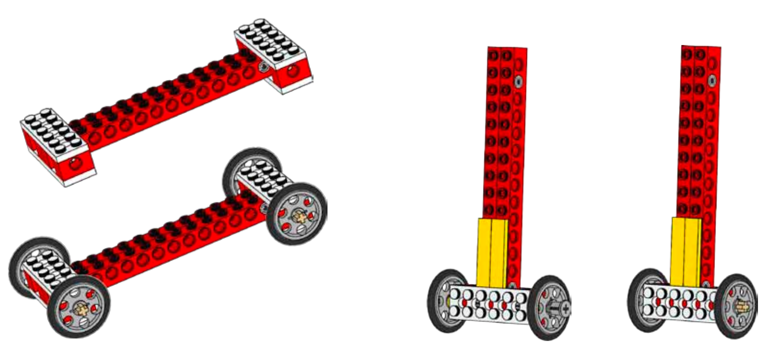
**Hint**

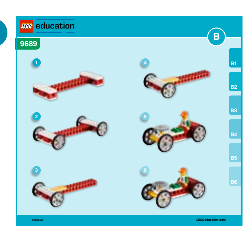
To introduce the term, it may be useful to bring some rough and smooth objects into class and show that it is harder to slide two rough objects over each other than two smooth objects.

## Understanding the principles

The principle models are designed to help learners understand the principles of the simple machine in focus through hands-on experience before they move on to construct the main models.

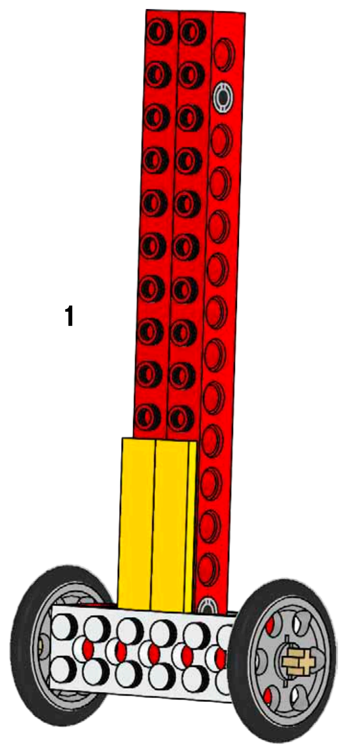
The principle models are presented in a logical sequence that will build on learners' understanding. The principle models can only be built one at a time from the parts in the set.



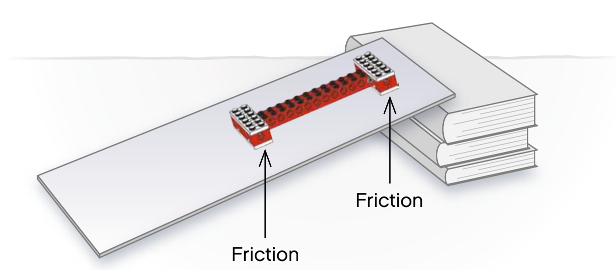


## Using the principle models

1. The yellow elements indicate where to hold, push, lift, or apply force/effort in handling the principle models. The principle models need to be held correctly for them to work properly.

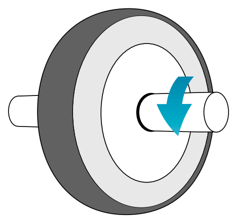


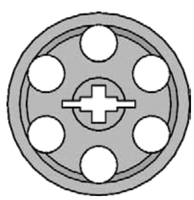

2. It is important for learners to understand what friction is before working with the wheel and axle principle models. Friction makes a moving object tend to slow down and eventually stop unless additional force is applied, e.g. when two objects move against each other.

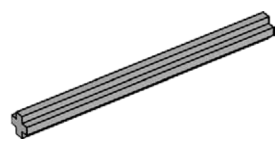


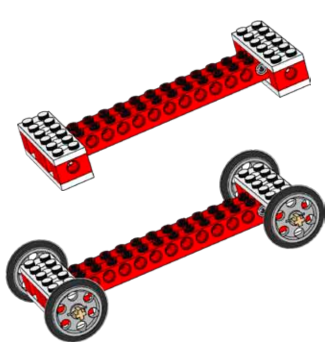

3. A ramp will be needed to test the first two principle models, B1 the sliding model and B2 the rolling model. Build a simple ramp by using books for height and a plank of wood or piece of stiff cardboard for the ramp.

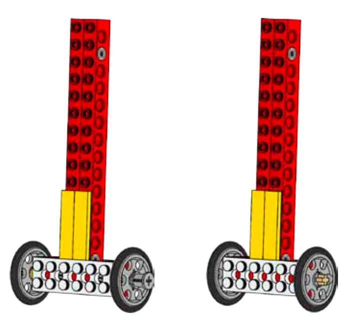
# Images for Classroom Use





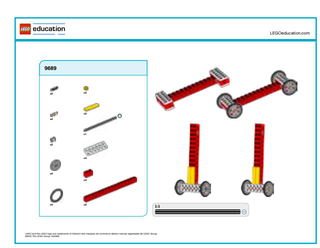


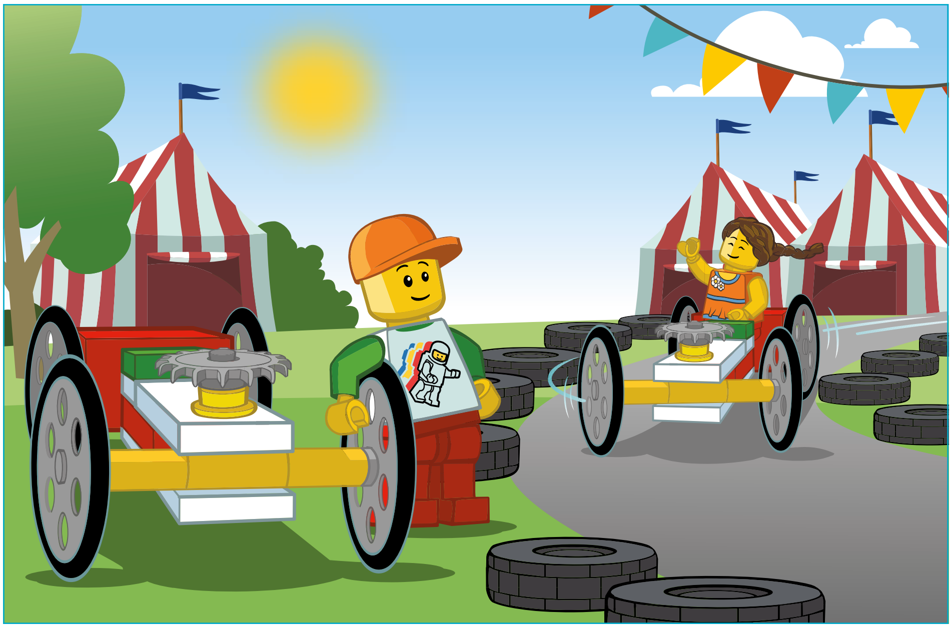


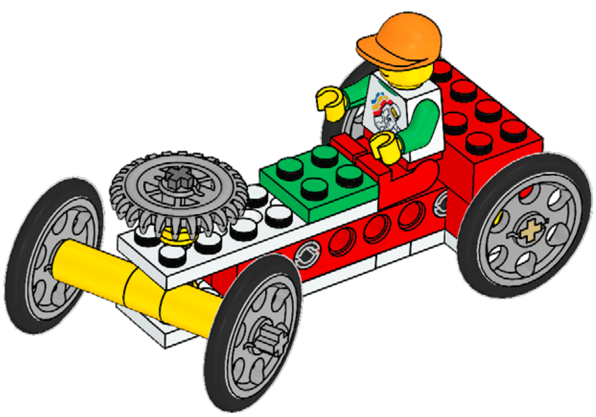


**Hint**
Most of the images used in the material can be found in the file 'Images for Classroom Use' on the CD, and are thus easy to display in class.

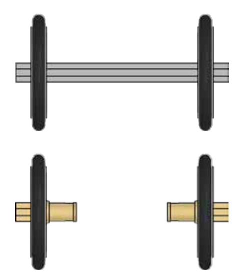
**Hint**
Use the element overview.

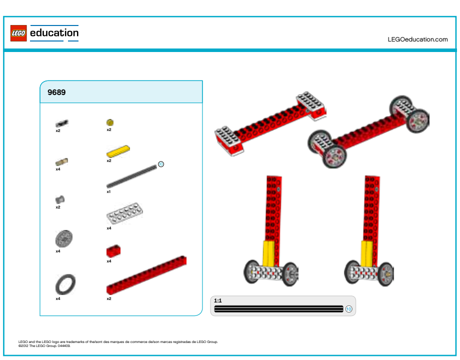


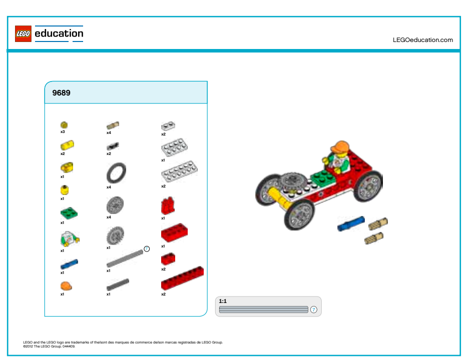




**Hint**
It is often more practical to sort out the elements that will be needed before starting work on the models.






**Hint**
The element overview can be printed and used as a check-list for learners to use when they are taking out and putting away their elements.

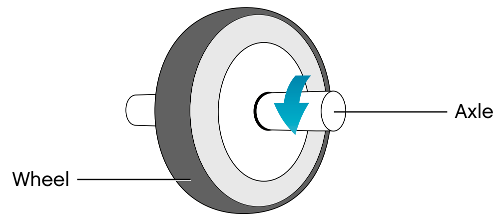
# Principle Models: Wheels and Axles

Teacher's Notes

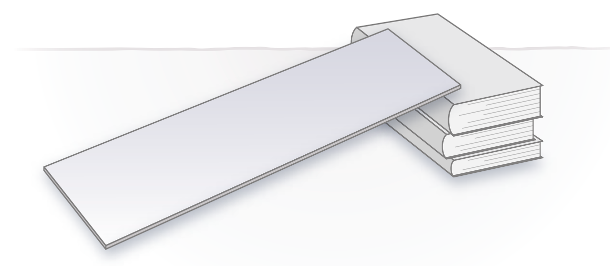
## Things to talk about

- What do you know about this simple machine?
- Where do we use this simple machine?
- Why do we use this simple machine?

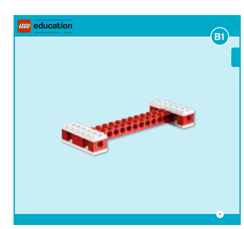
*Relate learners' answers to some of the images from Images for Classroom Use, or find ideas from the 'Overview: Wheels and Axles' section to stimulate learners' interest.*




**Build a ramp to test the first two principle models B1, B2.**
*Build a simple ramp by using books for height and a plank of wood or piece of stiff cardboard. Models are tested by holding them at the top of the ramp and releasing them.*

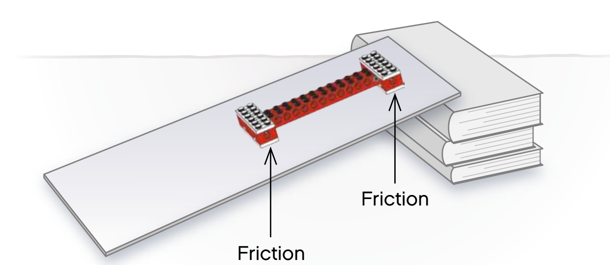


1. **Build B1** (Sliding model).
   Follow Building Instructions B, pages 4 to 6, steps 1 to 5.

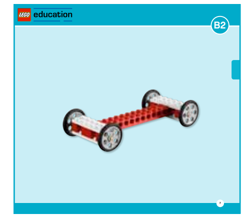


2. **Try out the model and make observations.**
   Find friction. Mark with an arrow where you think there is friction when you let the model slide down the ramp.
   *Learners should be made aware that there is a lot of friction when one surface slides over another.*

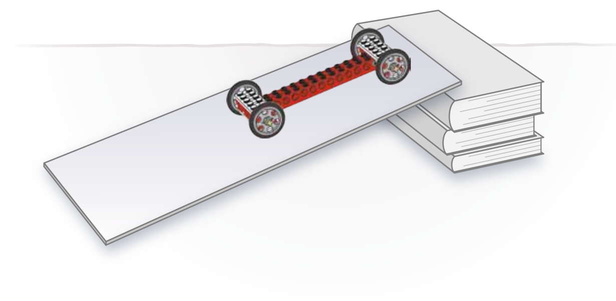
   **Measure how far the model travels.**
   *Just how far the sliding model B1 will move will vary, depending on such variables as the surface and angle of the test ramp, and any effort used to push the model. Learners will notice that the model is difficult to move. There is a lot of friction, and the sliding model, B1, won't travel far beyond the bottom of the ramp, if it slides down the ramp at all.*



1. **Build B2** (Rolling model).
   Follow Building Instructions B, page 8, step 1.



2. **Try out the model and make observations.**
   Friction is a force that slows down motion when two surfaces move against each other.

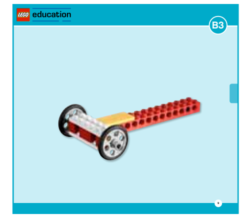


Is this model affected by friction?
*Learners might reasonably mark either answer! There is no significant friction between the tyres and the surface of the ramp. New sections of the tyre come into contact with the ramp surface as the wheel turns. On the other hand, there is friction in the axles where they are in contact with the surface of the holes through which they pass, and this does slow down the model.*

Measure how far the model travels.
*Learners will notice that the effects of friction have been greatly reduced by the use of wheels. Learners will not have to push the rolling model B2 very hard for it to move in the direction the wheels are facing, even on a flat surface; it will roll down the ramp easily when released, and the rolling model B2 travels further than the sliding model B1.*

3. **Compare model B1 to model B2.**
   How easy or difficult was it to make model B1 move compared to model B2?
   Mark each model.
   *Learners will notice that the rolling model B2 is much easier to move. The friction is greatly reduced by the wheels and axles, and the rolling model B2 will travel further than the sliding model B1.*

1. **Build B3** (Single, fixed axle model).
   Follow Building Instructions B, pages 10 to 14, steps 1 to 9.



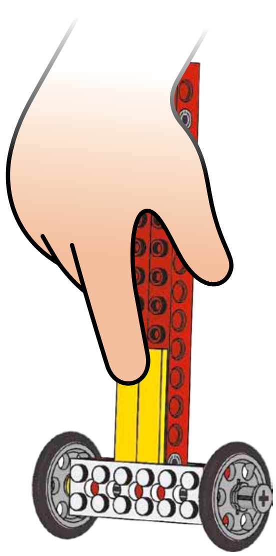

   **This model must be tested on a flat surface.**

2. **Try out the model and make observations.**
   Mark which type of axle is used in the model.

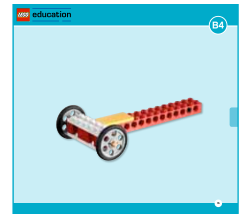

   *Model B3 is built with a single, fixed axle.*

   Test your model moving in a straight line.
   Mark how easy or difficult it is to steer your model in a straight line.
   *Learners will notice that model B3, with its single axle, is very easy to steer in a straight line.*

   Test your model turning a corner.
   Mark how easy or difficult it is to steer your model round a corner.
   *Answers will vary depending on many variables such as the surface of the test track and the effort used to move the model. Learners should notice, though, that model B3, with its single axle, is hard to steer through a sharp turn. When turning a corner sharply, one wheel will always skid. The wheels cannot turn at different speeds.*

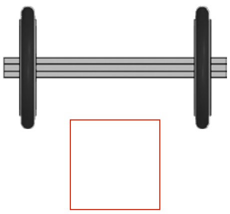


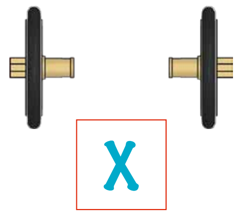
1. **Build B4** (Separate axles model).
   Follow Building Instructions B, pages 16 to 20, steps 1 to 7.




   **This model must be tested on a flat surface.**

2. **Try out the model and make observations.**
   Mark which type of axle is used in the model.



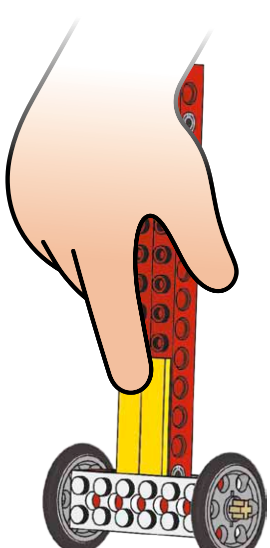



   *Model B4 is built with separate axles.*

   Test your model moving in a straight line.
   Mark how easy or difficult it is to steer your model in a straight line.
   *Learners will notice that model B4, with its separate axles, is very easy to steer in a straight line.*

   Test your model turning a corner.
   Mark how easy or difficult it is to steer your model round a corner.
   *Learners will notice that the model B4, with separate axles, is very easy to steer both in a straight line and when following zigzag patterns involving sharp turns. The separate axles allow the wheels to turn at different speeds.*

3. **Compare model B3 to model B4.**
   How easy or difficult was B3 to steer compared to B4?
   *Learners will notice that model B4, with its separate axles, is easier to steer round corners than model B3, with its single axle.*



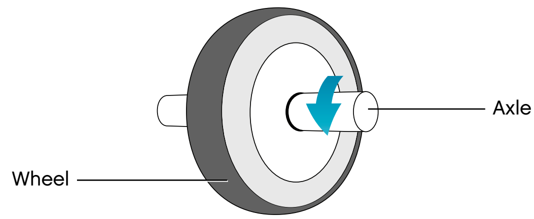
**Name(s):** **Date and subject:**

## Principle Models: Wheels and Axles

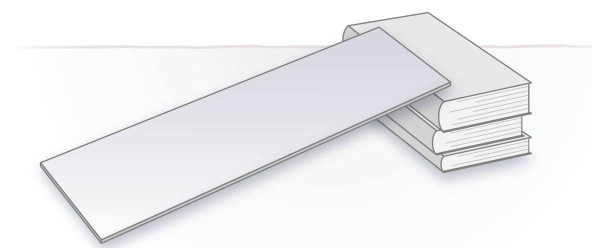
Learner Worksheet

**Things to talk about**

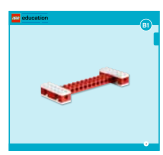
- What do you know about this simple machine?
- Where do we use this simple machine?
- Why do we use this simple machine?



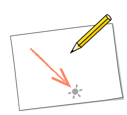

**Build a ramp to test the first two principle models B1, B2.**
Books for height and a plank of wood or piece of stiff cardboard should be effective.
When your ramp is ready, then build and test the models, one at a time!



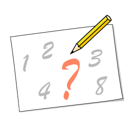
1. **Build B1** (Sliding model).
   Follow Building Instructions B, pages 4 to 6, steps 1 to 5.

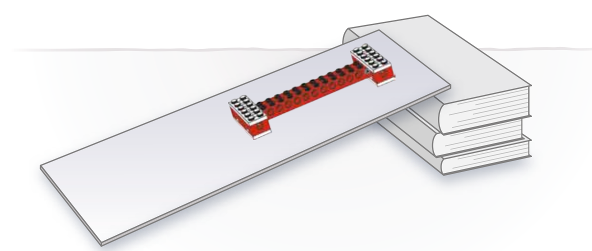


2. **Try out the model and make observations.**
   Find friction. Mark with an arrow where you think there is friction when you let the model slide down the ramp.



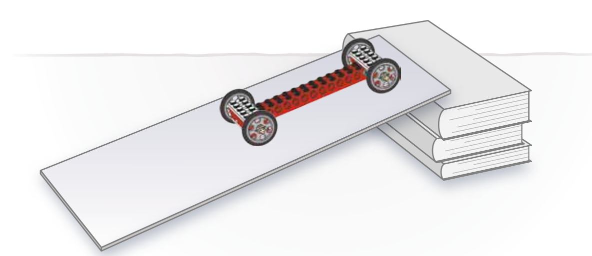
   Measure how far the model travels.
   Write your answer here:



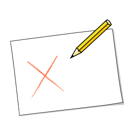


1. **Build B2** (Rolling model).
   Follow Building Instructions B page 8, step 1.

2. **Try out the model and make observations.**
   Friction is a force which slows down motion when two surfaces move against each other.

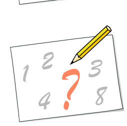


   Is this model affected by friction? YES / NO

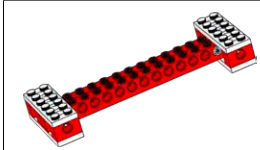
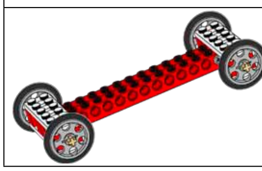


| YES | | NO | |
|---|---|---|---|

   Measure how far the model travels.
   Write your answer here:



**3. Compare model B1 to model B2.**
How easy or difficult was it to make model B1 move compared to model B2?
Mark each model.

| | Easy | Difficult |
|---|---|---|
|  | | |
|  | | |

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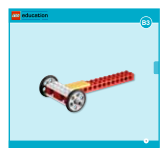
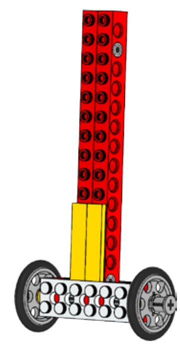
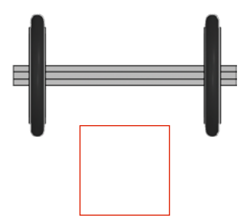
**1. Build B3** (Single, fixed axle model).
Follow Building Instructions B, pages 10 to 14, steps 1 to 9.

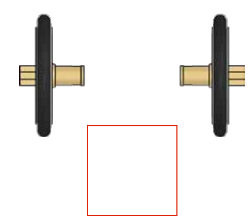


**This model must be tested on a flat surface.**



**2. Try out the model and make observations.**
Mark which type of axle is used in the model.





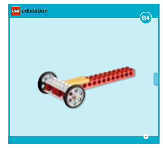
Test your model moving in a straight line.
Mark how easy or difficult it is to steer your model in a straight line.

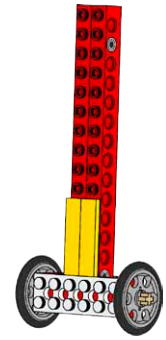
| | Easy | Difficult |
|---|---|---|
|  | | |

Test your model turning a corner.
Mark how easy or difficult it is to steer your model round a corner.

| | Easy | Difficult |
|---|---|---|
|  | | |

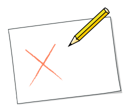
1. **Build B4** (Separate axles model).
   Follow Building Instructions B, pages 16 to 20, steps 1 to 7.

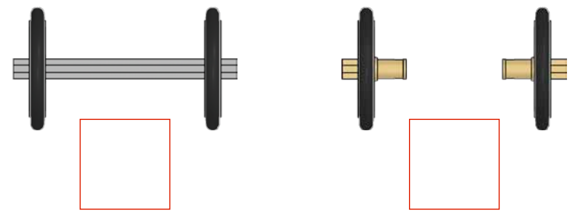




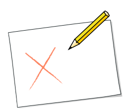
**This model must be tested on a flat surface.**

2. **Try out the model and make observations.**
   Mark which type of axle is used in the model.



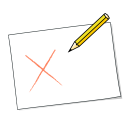


Test your model moving in a straight line.
Mark how easy or difficult it is to steer your model in a straight line.



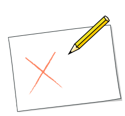
| | Easy | Difficult |
|---|---|---|
|  | | |

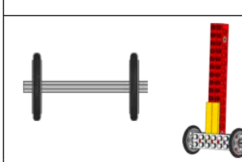
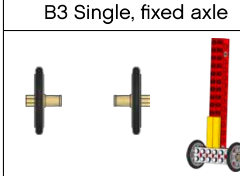
Test your model turning a corner.
Mark how easy or difficult it is to steer your model round a corner.



| | Easy | Difficult |
|---|---|---|
|  | | |

3. **Compare model B3 to model B4.**
   How easy or difficult was B3 to steer compared to B4?
   Mark your answer.



| | Easy | Difficult |
|---|---|---|
|  B3 Single, fixed axle | | |
|  B4 Separate axles | | |

# Main Activity: Go-Cart

Teacher's Notes

## Learning objectives

In this activity learners will build and test models that use the following structures:

- A single, fixed axle
- Separate axles

To perform this activity, learners should be familiar with the following vocabulary associated with wheels and axles:

- Friction
- Separate axles
- Single, fixed axle
- To skid
- To steer

If learners have already worked with the principle models, they will already have observed wheels and axles, and the terms used in this activity should be familiar to them. Predictions should now be easier to make based on the observations made earlier. If the learners have not worked on the principle models, then additional time will be needed, for example to introduce and explain the technical vocabulary used. If additional guidance is required, please turn to the 'Overview: Wheels and Axles' or 'Principle Models' sections.

## Materials required

- 9689 LEGO® Education Simple Machines Set

### Other materials required

- A flat surface or test track where the models can drive in a straight direction, turn corners, and drive in a zigzag pattern

9689

## Connect

Sam and Sally love going to the fair. They enjoy racing on the go-cart track. It's also fun just to drive around, waving to their friends and families, but they have to keep a careful eye on the track – not all go-carts are that easy to steer.

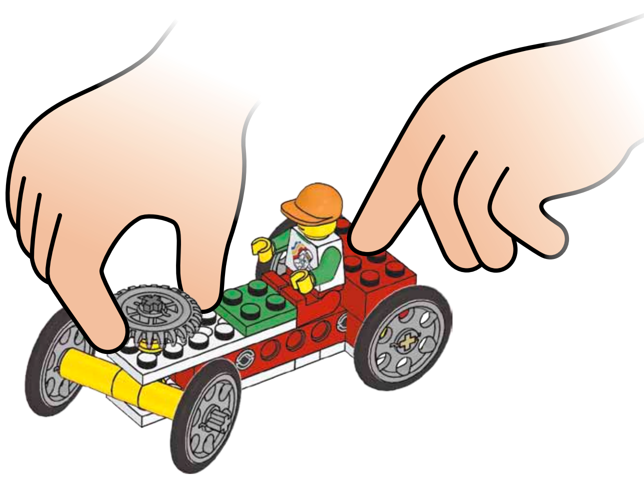
Have you tried steering a go-cart?
What do you enjoy most about go-carts?
Which simple machine is needed for a go-cart to move and turn?

**Let's build a go-cart!**

Hint
Most of the images used in the material can be found in the file 'Images for Classroom Use' on the CD, and are thus easy to display in class.

## Construct

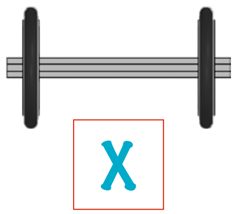
1. **First, build Go-Cart Model B5 and steer it around.**
   Follow Building Instructions B, pages 22 to 30, steps 1 to 13.
   *When Go-Cart Model B5 has been built, check the following:*
   - *If necessary, learners should be made aware of how friction (see 'Glossary' section) can affect movement. If the wheels are pushed in too far towards the body of the model they cannot turn freely.*
   - *Make sure Sam or Sally is attached securely.*

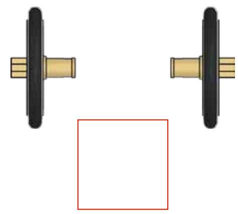


**Hint**
When testing the go-cart, use both hands to keep all four wheels on the track. Place one hand on the back of the cart and the other on the steering wheel.

## Contemplate

**2. Mark which type of axle is used for the front set of wheels.**

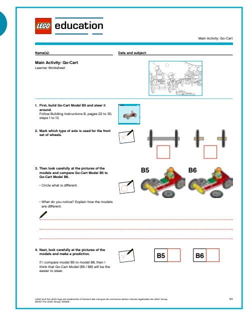


*Model B5 uses a single, fixed axle.*

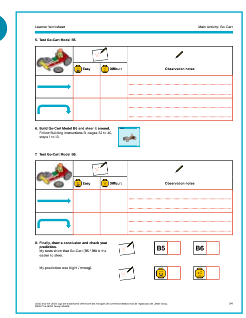
**3. Then look carefully at the pictures of the models and compare Go-Cart Model B5 to Go-Cart Model B6.**
- Circle what is different.
- What do you notice? Explain how the models are different.

*Learners should notice the difference in the axles used for the front set of wheels. Model B5 uses a single axle, while model B6 uses separate axles.*



**4. Next, look carefully at the pictures of the models and make a prediction.**
If I compare model B5 to model B6, then I think that Go-Cart Model (B5/B6) will be the easier to steer.
*Encourage learners to discuss the effects the different axles will have on the go-carts in their own words. For the prediction, the correct answer is model B6; however it does not matter whether learners get the answer right or wrong at this point, only that they should make a prediction that can be checked later.*

**5. Test Go-Cart Model B5.**
*Learners observe and test the degree of ease with which they can steer the model in a straight line and around a sharp corner. Encourage them to try more than once to ensure that their observations are correct.*



*The learners will notice that Go-Cart Model B5 is very easy to steer when driving in a straight line. However, they will also notice that it is hard to steer through sharp turns or in a zigzag pattern, as the wheels cannot turn at different speeds. One wheel will always skid when turning corners. Learners must write their answers in the chart.*

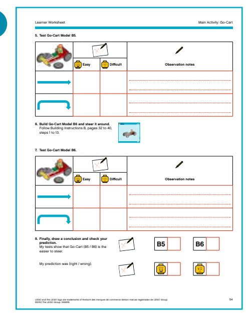
***Note:** If possible, keep an example of Go-Cart Model B5 for learners to compare with Go-Cart Model B6.*

**6. Build Go-Cart Model B6 and steer it around.**
Follow Building Instructions B, pages 32 to 40, steps 1 to 13.
*Encourage learners to identify parts while they are trying out the model.*


**7. Test Go-Cart Model B6.**
*Learners observe and test the degree of ease with which they can steer the model in a straight line and around a sharp corner. Encourage them to try more than once to ensure that their observations are correct.*

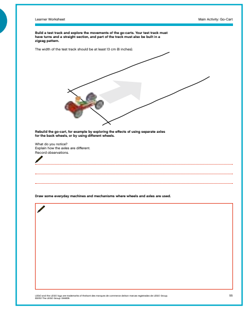
*The learners will notice that Go-Cart Model B6 is very easy to steer, both when driving in a straight line and when following zigzag patterns involving sharp turns. The separate axles allow the wheels to turn at different speeds. Learners must write their answers in the chart.*

**8. Finally, draw a conclusion and check your prediction.**
*Go-Cart Model B6 turns more easily because of the use of separate axles.*



## Continue

Learners are asked to build a test track and to explore the movements of the go-carts. Learner are also encouraged to rebuild the go-cart by, for example, exploring the effect of using separate axles for the back set of wheels, or by using different wheels. They must write down their observations.

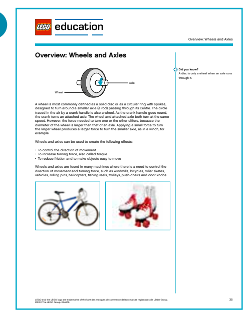


***Note:** There are no building instructions included to guide learners through the Continue phase.*

Encourage learners to discuss the effects the different wheels and axles will have on the go-carts in their own words, prompting them with questions such as:

- Describe what happened when you tried steering the go-cart.
- How easy/difficult was it to steer around the test track? Why do you think that was?
- Describe how the model works.
- What did you do to make sure your observations were correct?

It is suggested that learners should draw different items where they find wheels and axles used in everyday machines and mechanisms. For inspiration, read or show the 'Overview: Wheels and Axles' section.

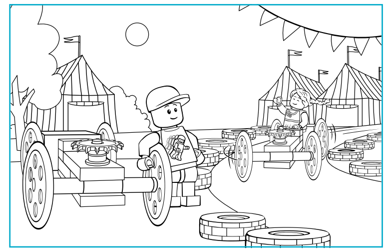



**Optional**
With more advanced learners, you might consider introducing wheels as rollers or exploring the wheel and axle as a winch. Wheels do not have to roll on the ground to be effective; roller conveyors use wheels to move objects easily. In a winch, the wheel is the circular path traced in the air by the crank handle.

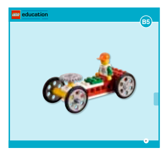
**Name(s):** **Date and subject:**

## Main Activity: Go-Cart

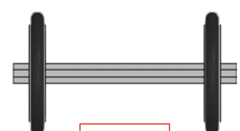
Learner Worksheet



1. **First, build Go-Cart Model B5 and steer it around.**
   Follow Building Instructions B, pages 22 to 30, steps 1 to 13.



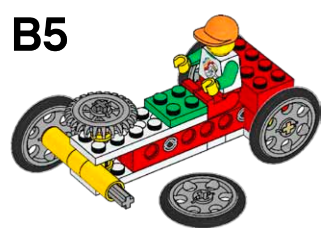
2. **Mark which type of axle is used for the front set of wheels.**



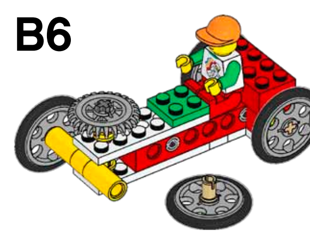
3. **Then look carefully at the pictures of the models and compare Go-Cart Model B5 to Go-Cart Model B6.**

   • Circle what is different.

B5



B6



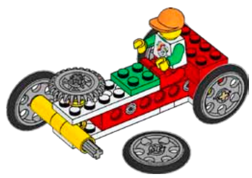
   • What do you notice? Explain how the models are different.

4. **Next, look carefully at the pictures of the models and make a prediction.**

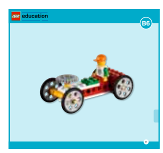
   If I compare model B5 to model B6, then I think that Go-Cart Model (B5 / B6) will be the easier to steer.

B5 B6

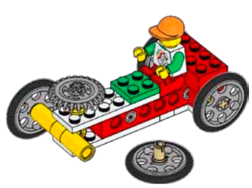
**5. Test Go-Cart Model B5.**

|  | Easy | Difficult | Observation notes |
|---|---|---|---|
| | | | |
| | | | |

**6. Build Go-Cart Model B6 and steer it around.**
Follow Building Instructions B, pages 32 to 40, steps 1 to 13.



**7. Test Go-Cart Model B6.**

|  | Easy | Difficult | Observation notes |
|---|---|---|---|
| | | | |
| | | | |

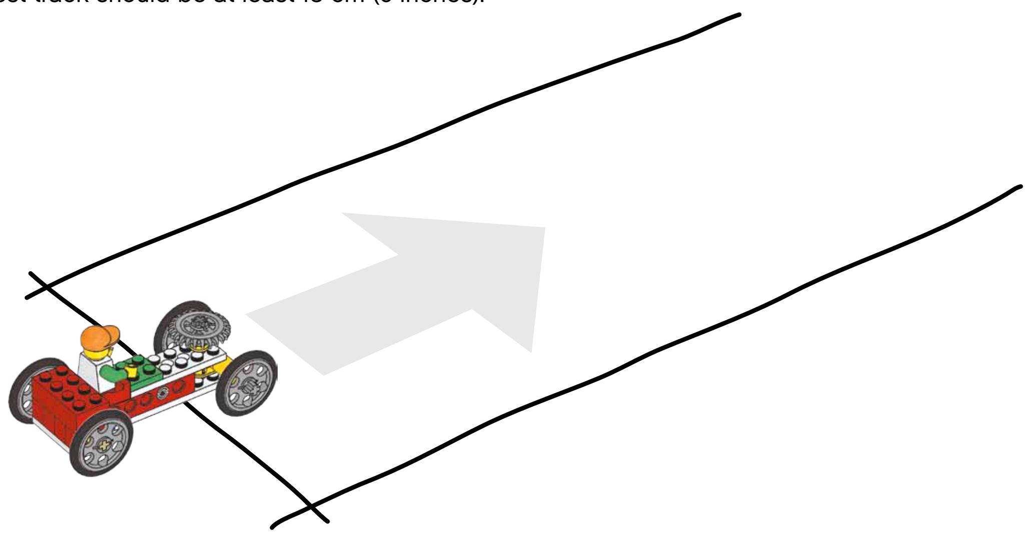
**8. Finally, draw a conclusion and check your prediction.**
My tests show that Go-Cart (B5 / B6) is the easier to steer.

B5 B6

My prediction was (right / wrong).

**Build a test track and explore the movements of the go-carts. Your test track must have turns and a straight section, and part of the track must also be built in a zigzag pattern.**

The width of the test track should be at least 13 cm (6 inches).



**Rebuild the go-cart, for example by exploring the effects of using separate axles for the back wheels, or by using different wheels.**

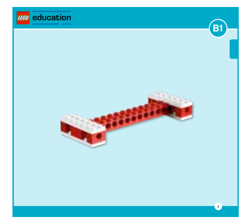
What do you notice?
Explain how the axles are different.
Record observations.

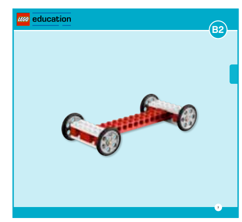
**Draw some everyday machines and mechanisms where wheels and axles are used.**

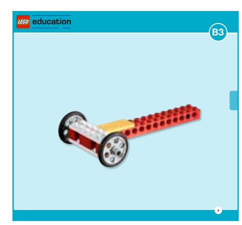
# Problem-Solving Activity: Wheelbarrow

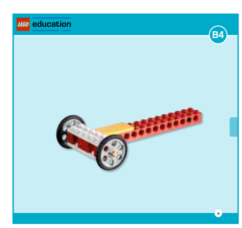
Learner Worksheet

**Need help?**
Look at:




When Sam and Sally visit the fair they always remark on how tidy the area is kept. Although not everybody remembers to throw their litter in the bin! Having so many people in one place at one time means that a lot of people working at the fair have to spend time picking up litter. Sam and Sally want to help the people working at the fair to carry the many the bags of litter that have been gathered.

**Let's help Sam and Sally!**

**Build a wheelbarrow like the one in the picture.**

Your design brief is as follows:
- Build a wheelbarrow.
- Give your wheelbarrow handles, and legs to support it while standing.
- Your wheelbarrow must be able to carry the LEGO® weight.

When you have finished, test the wheelbarrow. Push it along with the LEGO weight in it, and check to see if it is well balanced. Assess how easily the wheelbarrow can be moved in a straight direction and turned. What makes it easy or difficult to steer?

# Problem-Solving Activity: Wheelbarrow

Teacher's Notes

## Learning objectives:

Learners are encouraged do some research related to the real-life problem they are set to solve and/or the type of simple machine that they are going to use, and to:

- Identify a need or a problem
- Develop explanations using observations
- Test, evaluate and redesign models

## Introduction

To help in the design process, instruct the learners to look at the picture on the Learner Worksheet and read the accompanying text. If time and facilities are available, have your learners conduct research, and also encourage them to generate ideas and questions by posing problems they must take into account in their design and building process. Your learners could search the Internet to learn more about the appearance, structure and function of different sorts of litter carts and wheelbarrows.

Learners should be reminded of the principle models that they have worked with. It might be a good idea to build principle models B3 and B4 to show the different structures.

Discuss in class the design problem specified in the design brief. Try to find several possible general solutions, or use the suggested solution for inspiration if necessary.

Discuss the constraints and functions your learners will have to take into account to carry out the design brief. Try to get your learners to focus on relevant issues and decisions by asking questions. These might include:

- How will your model look?
  *Maybe a handcart with wheels, and perhaps handles for pushing it and a space for the load. Or maybe simply a wheelbarrow like the one shown in the drawing.*
- What LEGO® elements do you have available? Should you use big wheels or small wheels for the wheelbarrow, and how will your wheelbarrow stand on the ground? What can you use as legs to support the wheelbarrow?
- How do you think you might start building?

## Optional materials

Materials for enhancing the appearance and functionality of the model: Learners can use paper, cardboard and markers to make the bin element of the wheelbarrow or to make bags of litter. Additional LEGO elements, if available, may be used.

**When the model is finished, encourage learners to reflect on both the product that they have produced and the processes they have used by:**

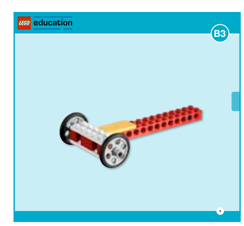
- Carrying out tests to evaluate the performance of their model
- Reflecting on the design brief
- Recording their design by drawing or taking digital photos

**Hint**

Most of the images used in the material can be found in the file 'Images for Classroom Use' on the CD, and are thus easy to display in class.

**Need help?**

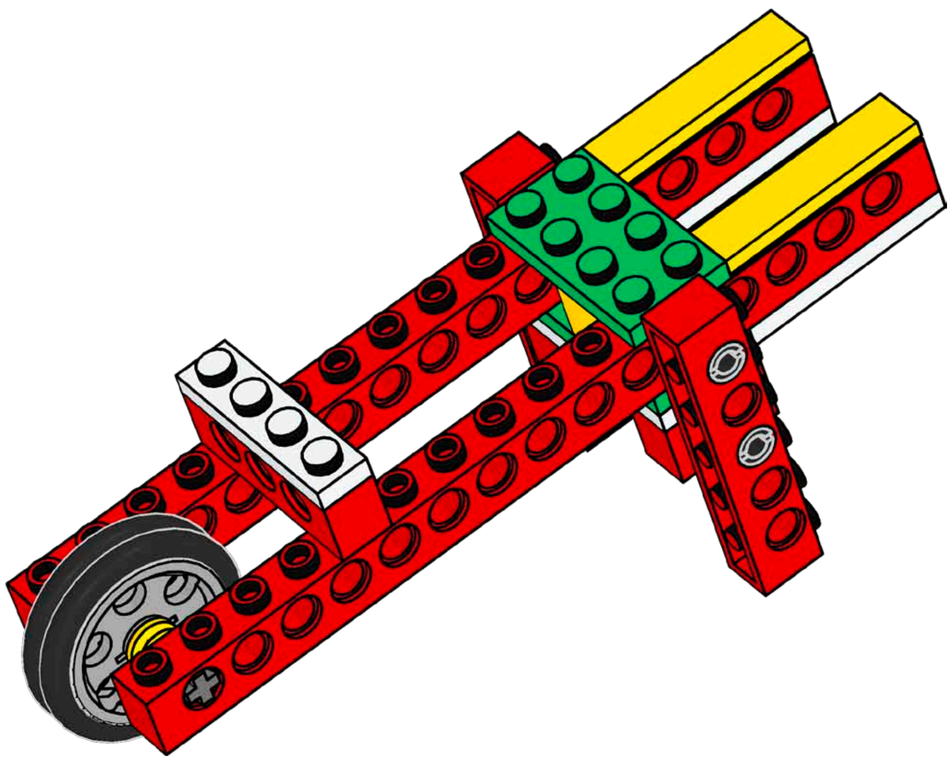
Look at:



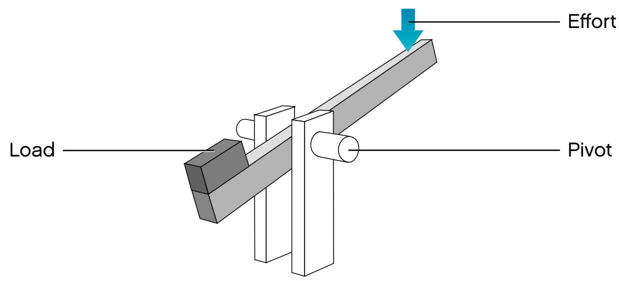

**Did you know?**

The LEGO weight element weighs approximately 53 g (1.8 oz.).

## Suggested model solution



# Overview: Levers




A lever is most commonly defined as a rod or arm that tilts around a pivot, also called a fulcrum, to produce useful motion. The load is moved by the effort (a push or pull) used to make the lever tilt about the pivot. With a lever arm or lever beam, a load can be lifted with the least effort by placing it as close to the pivot as possible, or by applying the effort as far from the pivot as possible.

There are three main arrangements of the pivot, load and effort, creating three types or classes of levers. A first class lever has the pivot between the effort and load, and is used to do work and to produce useful movement. A second class lever has the load between the effort and pivot, and is used mainly to do work. A third class lever has the effort between the pivot and load, and is used mainly to amplify movement.

Levers can be used to create the following effects:

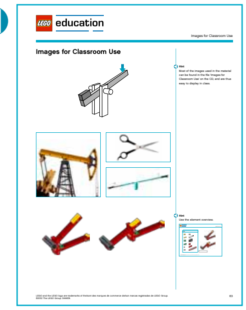
- To apply a force at a distance
- To change the direction of a force
- To increase force
- To increase movement

Levers are found in many machines, such as wheelbarrows, oars, rakes, nutcrackers, tweezers, screwdrivers, snow shovels, hammers, bottle openers, light switches, staplers, crowbars, scissors and see-saws.

**Did you know?**
Levers make work easier by amplifying motion or force, or by changing the direction of a force.

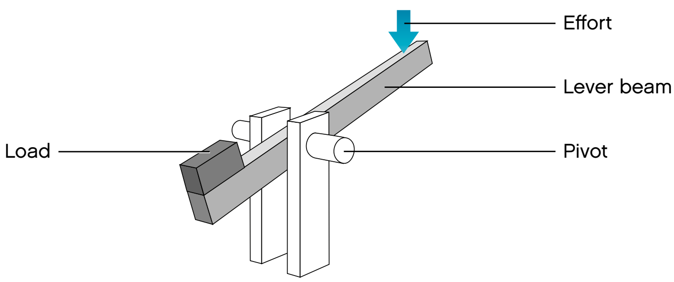
## Establishing the concept

We recommend establishing the concept of the simple machine to be worked on. This could be done, for example, by showing learners a number of exhibits from the LEGO® set to stimulate their interest. Build a principle model, or show some of the images from Images for Classroom Use, asking questions such as 'What do you know about this simple machine?' or 'Where do we use this simple machine?' See if learners can name any of the objects you show them, and allow time for learners to handle them.




## Providing the vocabulary

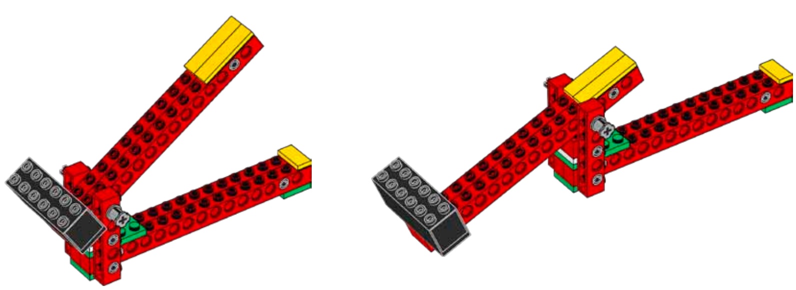
Learners will acquire the necessary vocabulary for the simple machine as they progress through the activities, but it may be useful to introduce certain terms at this stage. Important new vocabulary items are *effort, load, pivot and lever beam*.

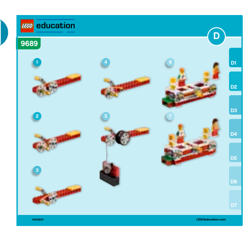



## Understanding the principles

The principle models are designed to help learners understand the principles of the simple machine in focus through hands-on experience before they move on to construct the main models.

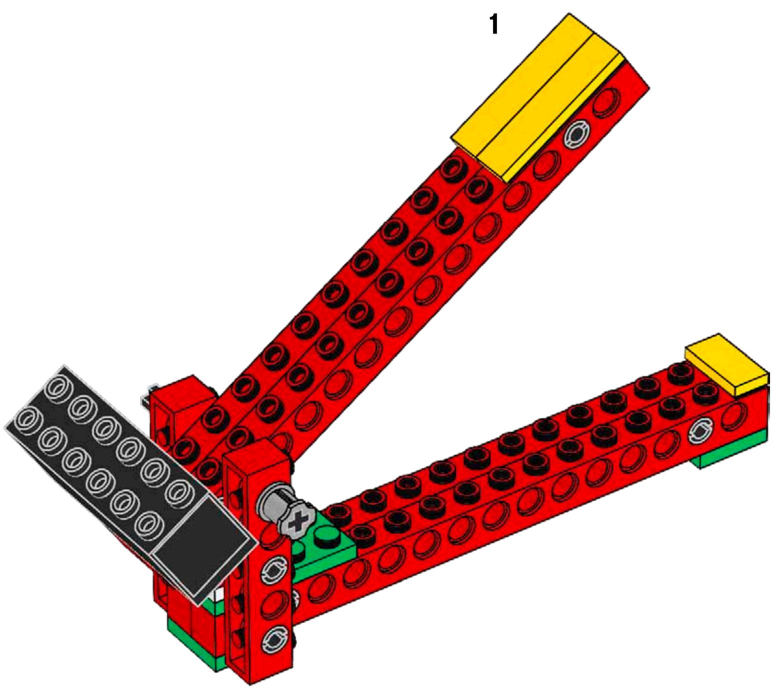
The principle models are presented in a logical sequence that will build on learners' understanding. The principle models can only be built one at a time from the parts in the set.





## Using the principle models

1. The yellow elements indicate where to hold, push, lift, or apply force/effort in handling the principle models. The principle models need to be held correctly if they are to work properly.



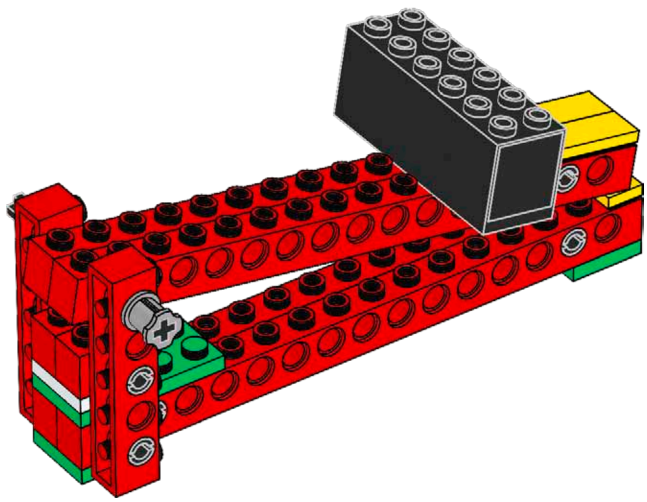

### First class lever

A first class lever has the pivot placed between the effort and the load. This type of lever changes the direction of the effort force and can change the amount of effort needed to lift or move a load. A see-saw is an example of a first class lever.

**Hint**
It is possible to introduce second and third class levers simply by rebuilding the model. See next page.

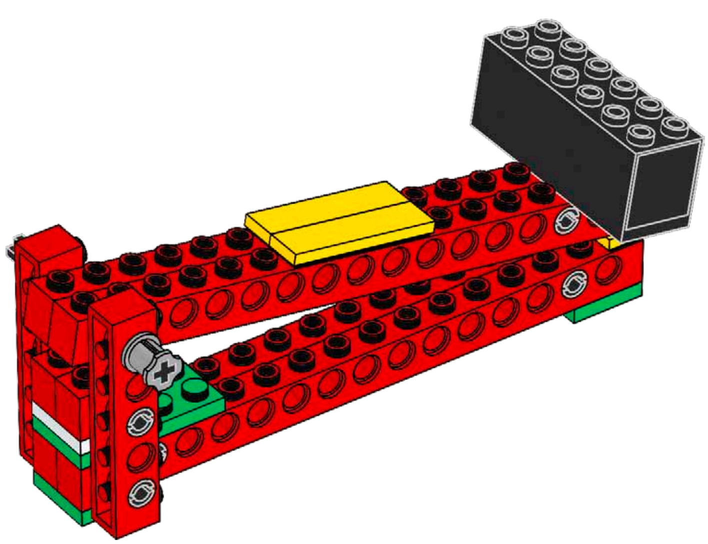
## Second class lever

A second class lever has the load placed between the effort and the pivot. This type of lever does not change the direction of the effort force, but can reduce the amount of effort needed to lift a load. A wheelbarrow is an example of a second class lever.



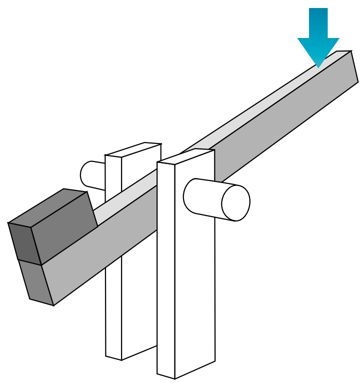
## Third class lever

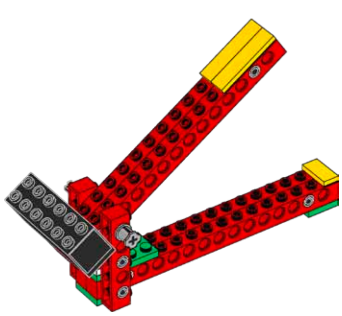
A third class lever has the effort between the load and the pivot. This type of lever does not change the direction of the effort force, but can increase the distance the effort moves a load. A broom is an example of a third class lever.

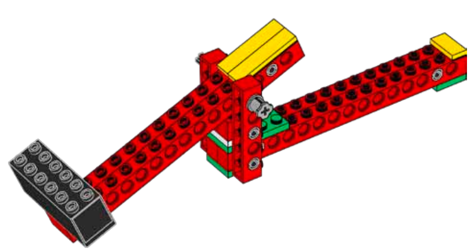


**Did you know?**
Levers can be connected together through a common pivot to produce useful tools and mechanisms; scissors, nutcrackers and tweezers are all connected levers.

# Images for Classroom Use

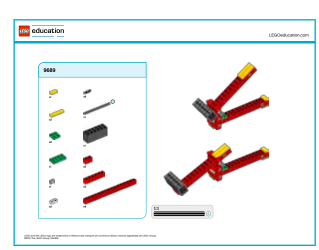


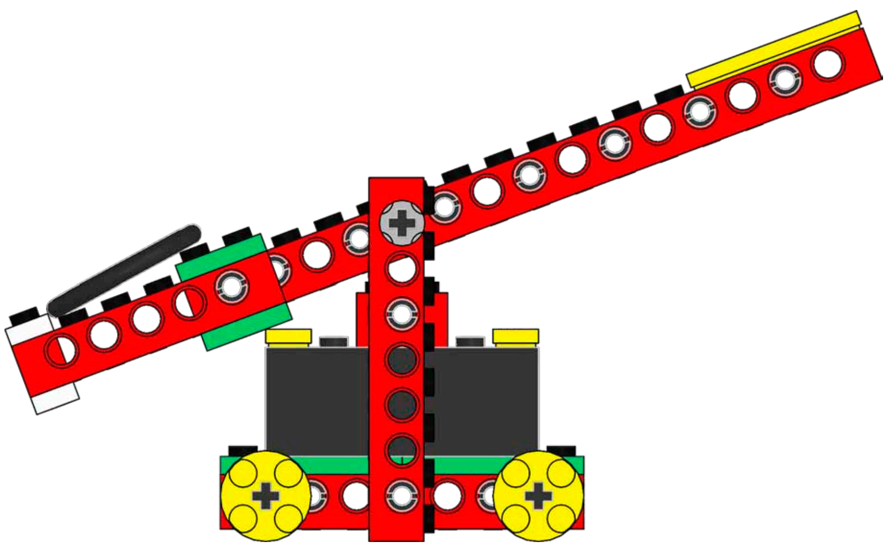




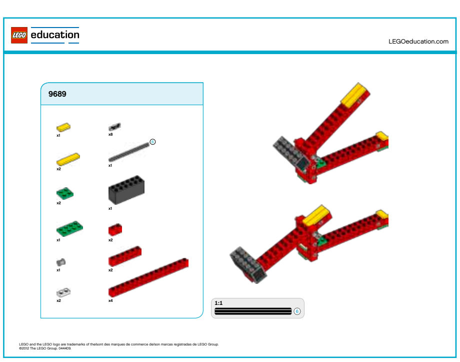
**Hint**
Most of the images used in the material can be found in the file 'Images for Classroom Use' on the CD, and are thus easy to display in class.

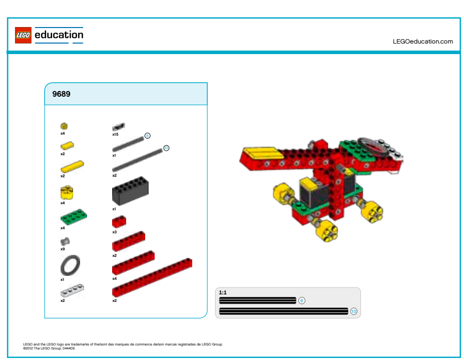
**Hint**
Use the element overview.





**Hint**
It is often more practical to sort out the elements that will be needed before starting work on the models.




**Hint**
The element overview can be printed and used as a check-list for learners to use when they are taking out and putting away their elements.

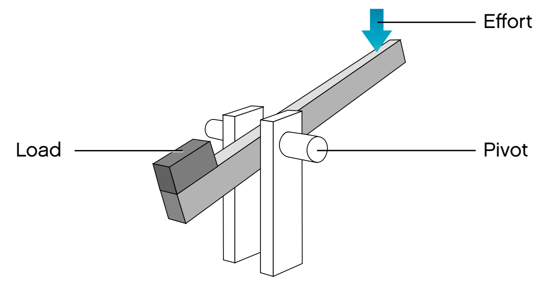
# Principle Models: Levers

Teacher's Notes

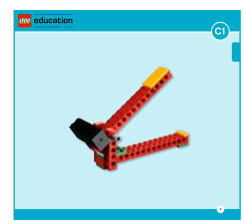
### Things to talk about

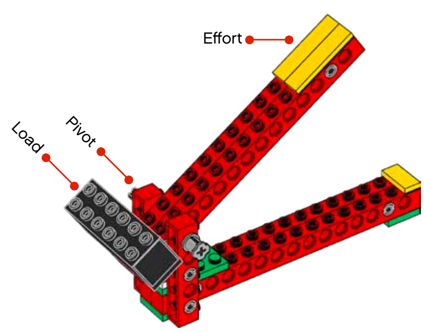
- What do you know about this simple machine?
- Where do we use this simple machine?
- Why do we use this simple machine?

*Relate learners' answers to some of the images from Images for Classroom Use, or find ideas from the 'Overview: Levers' section to stimulate learners' interest.*




**1. Build C1** (First class lever C1).
Follow Building Instructions C, pages 4 to 12, steps 1 to 10.




**2. Label the lever.**
Draw lines from the words to the picture of the model.
*First class levers have the pivot positioned between the effort and the load.*

**3. Classify an item.**
Which real life item is a first class lever?
*A crowbar is a first class lever.*

a) Crowbar

b) Nutcracker

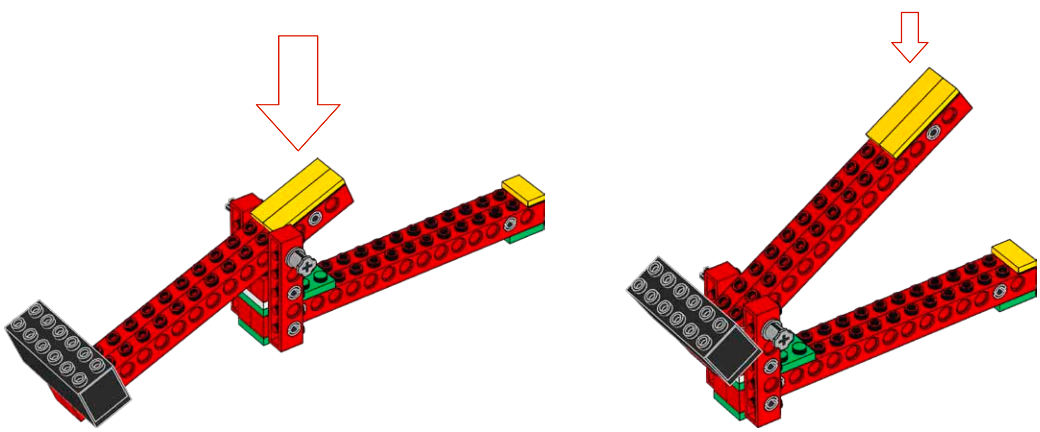
c) Tweezers

**4. Try out the model and make observations.**
Try out lever C1. Assess and make a note about the amount of effort needed to move the load.

1. **Build C2** (First class lever C2).
   Follow Building Instructions C, page 14, step 1.

2. **Try out the model and make observations.**
   Try out lever C2. Assess and make a note about the amount of effort needed to move the load. Observe how the difference in length from the pivot to the load affects the amount of effort needed to move the load.

   After testing both levers, compare your observations and explain, either by writing your answer or by drawing with different sized arrows, how much effort is needed with each lever.
   *Lever C1 needs the least amount of effort (the smallest arrow) to move the load, because it has the shortest distance from the pivot to the load compared to lever C2.*



**Name(s):** 

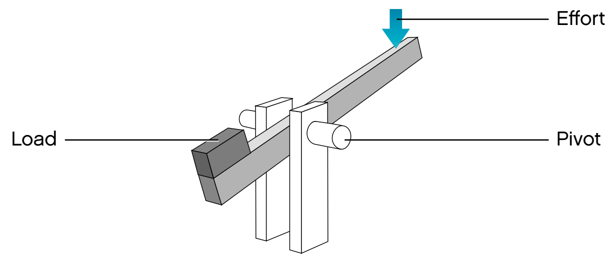
**Date and subject:** 

## Principle Models: Levers

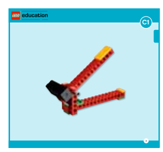
Learner Worksheet

### Things to talk about

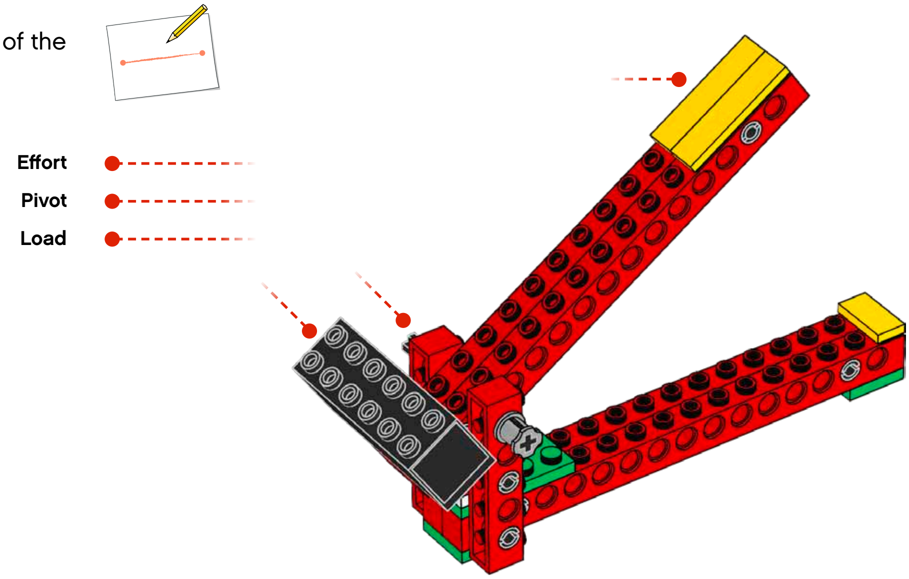
- What do you know about this simple machine?
- Where do we use this simple machine?
- Why do we use this simple machine?




1. **Build C1** (First class lever C1).
   Follow Building Instructions C, pages 4 to 12, steps 1 to 10.



2. **Label the lever.**
   Draw lines from the words to the picture of the model.

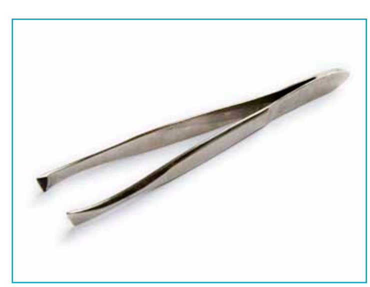



3. **Classify an item.**
   Which real life item is a first class lever?
   Circle the item or write your answer here:

.......................................................................................

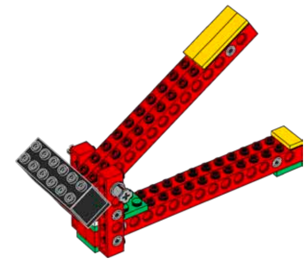
a) Crowbar

b) Nutcracker



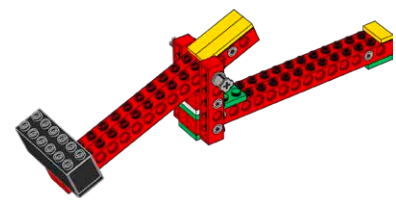
c) Tweezers

4. **Try out the model and make observations.**
   Try out lever C1. Assess and make a note about the amount of effort needed to move the load.

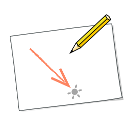


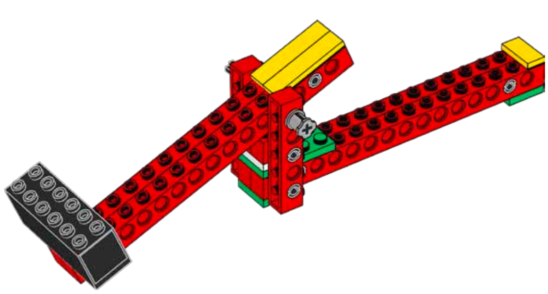
1. **Build C2** (First class lever C2).
   Follow Building Instructions C, page 14, step 1.

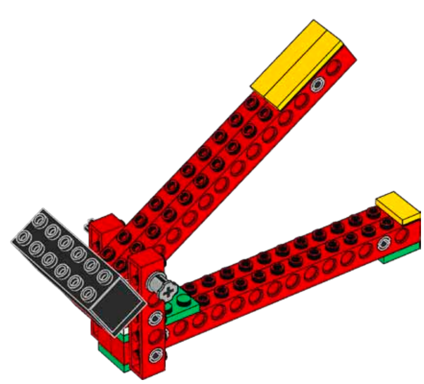
2. **Try out the model and make observations.**
   Try out lever C2. Assess and make a note about the amount of effort needed to move the load. Observe how the difference in length from the pivot to the load affects the amount of effort needed to move the load.



After testing both levers, compare your observations and explain, either by writing your answer or by drawing with different sized arrows, how much effort is needed with each lever.







# Main Activity: Catapult

Teacher's Notes

## Learning objectives

In this activity learners will build and test models that use the following structures:

- First class levers

To perform this activity, learners should be familiar with the following vocabulary associated with levers:

- Pivot
- Load
- Effort

If learners have already worked with the principle models, they will already have observed levers, and the terms used in this activity should be familiar. Predictions should now be easier to make based on their observations made earlier. If the learners have not worked on the principle models, then additional time will be needed, for example to introduce and explain the technical vocabulary used. If additional guidance is required, please turn to the 'Overview: Levers' or 'Principle Models' sections.

## Materials required

- 9689 LEGO® Education Simple Machines Set

9689

## Connect

Sam and Sally love going to the fair. There is a catapult game, where players shoot at a goal to win prizes by scoring most points. Sam and Sally love competing against their friends and families!

Do you like playing games where you have to aim at a goal?
What do you enjoy most about them?
Which simple machine is needed for a catapult to work?

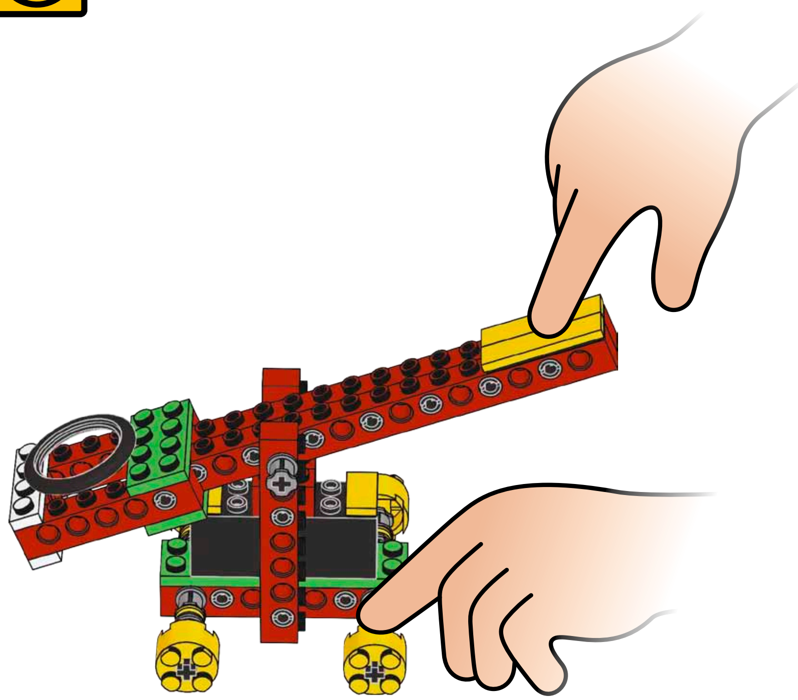
**Let's build a catapult!**

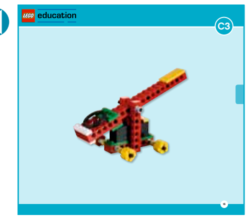
**Hint**
Most of the images used in the material can be found in the file 'Images for Classroom Use' on the CD, and are thus easy to display in class.

## Construct

**1. First, build Catapult Model C3 and try it out.**
Follow Building Instructions C, pages 16 to 30, steps 1 to 16.

***Note:*** *Be careful not to let learners point the catapult towards anybody’s face when catapulting the rubber tyre.*

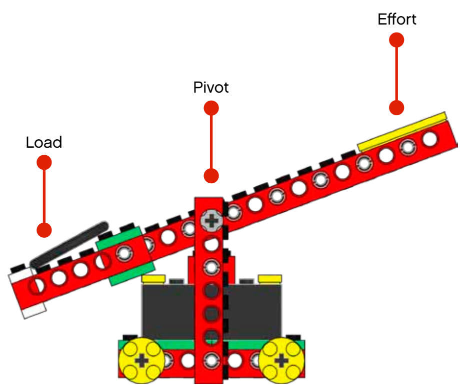





**Hint**
Place one hand on the side of the catapult when catapulting the rubber tyre. To avoid any risk of learners getting hit, make sure all the class know which direction the catapult is to be fired in.

## Contemplate

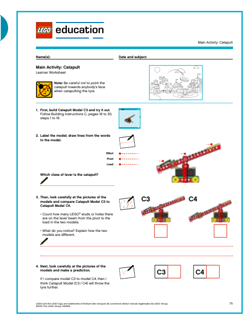
**2. Label the model; draw lines from the words to the model.**




**Which class of lever is the catapult?**
*The catapult is a first class lever, which has the pivot positioned between the effort and the load.*

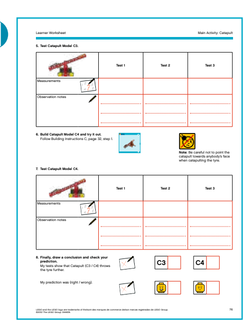
**3. Then, look carefully at the pictures of the models and compare Catapult Model C3 to Catapult Model C4.**
- Count how many LEGO® studs or holes there are on the lever beam from the pivot to the load in the two models.
- What do you notice? Explain how the two models are different.

*Learners should notice that even though both catapults are first class levers, the lengths from the load to the pivot differ in model C3 and model C4.*



**4. Next, look carefully at the pictures of the models and make a prediction.**
If I compare model C3 to model C4, then I think Catapult Model (C3/C4) will throw the tyre further.
*Encourage learners to discuss the effects the different lengths between the load and the pivot will have on the catapults in their own words. For the prediction, the correct answer is model C4; however, it does not matter whether learners get the answer right or wrong at this point, only that they should make a prediction that can be checked later. Even though many variables will affect the catapult – especially the amount of effort used – model C4 should still throw further than C3, because the beam is longer from the load to the pivot in model C4.*

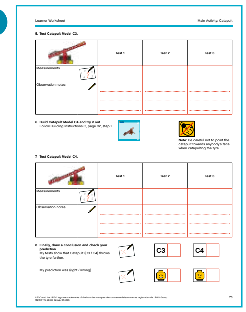
**5. Test Catapult Model C3.**
*Have learners observe the starting place of the lever, including the lever beam, the pivot and the load on the catapult. Encourage them to try more than once, to ensure that their observations are correct. Learners must write their measurements on the Learner Worksheet.*



***Note:** If possible, keep an example of Catapult Model C3 for learners to compare with Catapult Model C4.*

**6. Build Catapult Model C4 and try it out.**
Follow Building Instructions C, page 32, step 1.
*Encourage learners to identify parts while they are trying the model. Learners should be asked to count how many LEGO® studs there are from the pivot to the load.*

**7. Test Catapult Model C4.**
*Encourage learners to try more than once, to ensure that their observations are correct. Learners must write their measurements on the Learner Worksheet.*

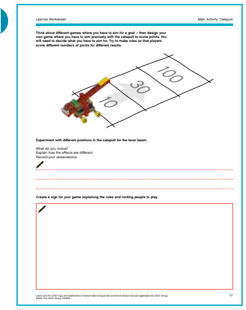


**8. Finally, draw a conclusion and check your prediction.**
*Catapult Model C4 throws the furthest because of the distance between the pivot and the load.*

## Continue

Learners are encouraged to make a game with rules that they can play using the catapult.

*__Note:__ There are no building instructions included to guide learners through the Continue phase, other than the illustrated suggestions on the Learner Worksheet.*




Encourage your learners to discuss the importance of agreeing on rules for the game before playing, prompting them with questions such as:

- What is the aim of the game?
- Describe what happens if you miss.
- How many times are you allowed to try?
- Describe how you can win the game.
- How will you make sure your rules are followed?

It is suggested that learners create a sign explaining the rules and inviting people to play the game.

**Optional**
It is suggested that learners should draw different items where they find levers used in everyday machines and mechanisms. For inspiration, read or show the 'Overview: Levers' section.

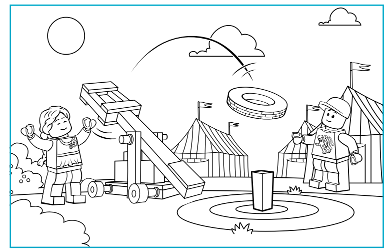
**Hint**
Most of the images used in the material can be found in the file 'Images for Classroom Use' on the CD, and are thus easy to display in class.

**Name(s):** **Date and subject:**

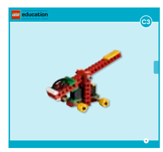
## Main Activity: Catapult

Learner Worksheet

**Note:** Be careful not to point the catapult towards anybody's face when catapulting the tyre.



1. **First, build Catapult Model C3 and try it out.** Follow Building Instructions C, pages 16 to 30, steps 1 to 16.

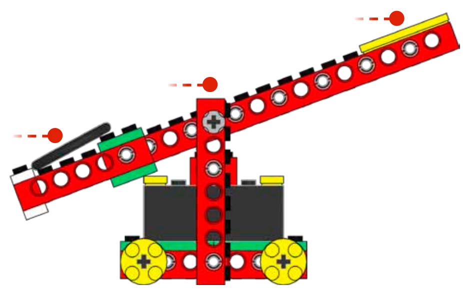


2. **Label the model; draw lines from the words to the model.**

Effort

Pivot

Load

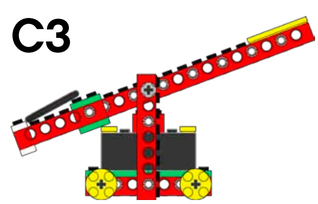


**Which class of lever is the catapult?**

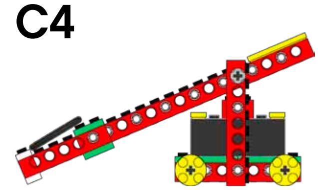
..........................................................................................

3. **Then, look carefully at the pictures of the models and compare Catapult Model C3 to Catapult Model C4.**
   - Count how many LEGO® studs or holes there are on the lever beam from the pivot to the load in the two models.
   - What do you notice? Explain how the two models are different.

C3



C4



..........................................................................................

..........................................................................................

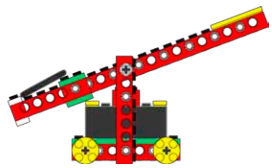
4. **Next, look carefully at the pictures of the models and make a prediction.**

   If I compare model C3 to model C4, then I think Catapult Model (C3 / C4) will throw the tyre further.

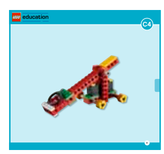
| C3 | |
|---|---|

| C4 | |
|---|---|

**5. Test Catapult Model C3.**

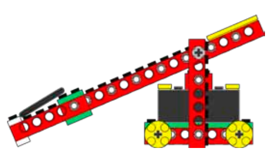
|  | Test 1 | Test 2 | Test 3 |
|---|---|---|---|
| Measurements | | | |
| Observation notes | | | |

**6. Build Catapult Model C4 and try it out.**
Follow Building Instructions C, page 32, step 1.



**Note:** Be careful not to point the catapult towards anybody's face when catapulting the tyre.

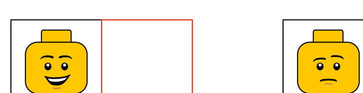
**7. Test Catapult Model C4.**

|  | Test 1 | Test 2 | Test 3 |
|---|---|---|---|
| Measurements | | | |
| Observation notes | | | |

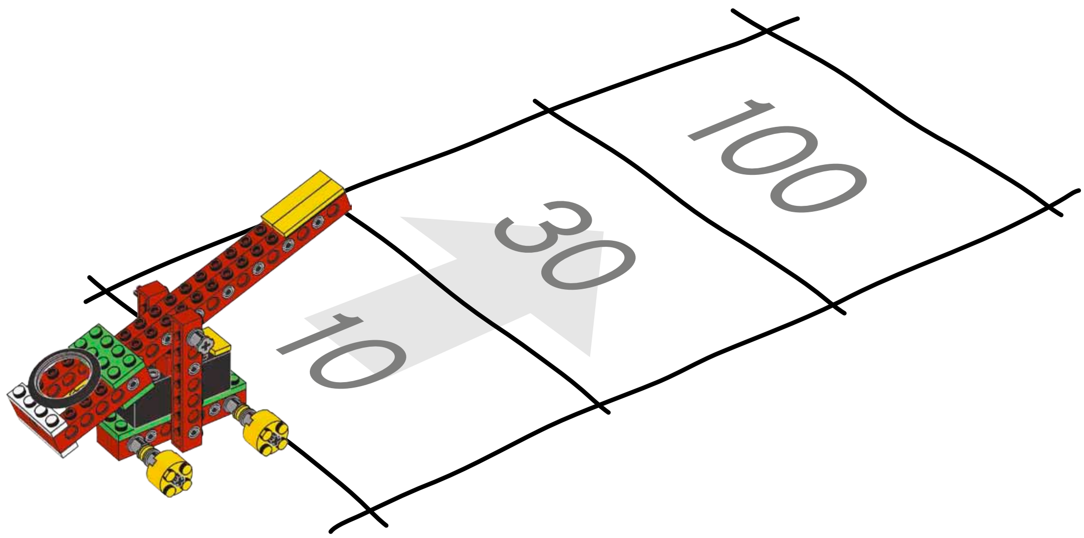
**8. Finally, draw a conclusion and check your prediction.**
My tests show that Catapult (C3 / C4) throws the tyre further.

| C3 | | C4 | |
|---|---|---|---|

My prediction was (right / wrong).



**Think about different games where you have to aim for a goal – then design your own game where you have to aim precisely with the catapult to score points. You will need to decide what you have to aim for. Try to make rules so that players score different numbers of points for different results.**




**Experiment with different positions in the catapult for the lever beam.**

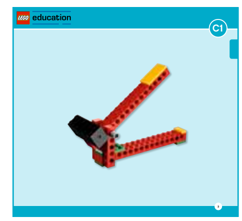
What do you notice?
Explain how the effects are different.
Record your observations.

**Create a sign for your game explaining the rules and inviting people to play.**

# Problem-Solving Activity: Railway Crossing Barrier

Learner Worksheet

**Need help?**
Look at:





When Sam and Sally visit the fair, certain paths have railway crossing barriers. This is because you can take a train ride around the different areas of the fairground, but you have to be careful crossing the railway tracks. On their way to the train ride, Sam and Sally notice that the railway crossing barrier is broken. They want to try to fix it before the train comes.

**Let's help Sam and Sally!**

**Build a railway crossing barrier like the one in the picture.**

Your design brief is as follows:
- Build a railway crossing barrier longer than 15 cm (6 inches).
- Build a single stand for the barrier to balance on.
- Find a way to make it easy to open and close the barrier.

When you have finished, measure the length of your railway crossing barrier, and assess how easy it is to open and close. Assess how well balanced the railway crossing barrier is. What makes it stable?

# Problem-Solving Activity: Railway Crossing Barrier

Teacher's Notes

**Learning objectives:**

Learners are encouraged to do some research related to the real-life problem they are set to solve and/or the type of simple machine that they are going to use, and to:

- Identify a need or a problem
- Develop explanations using observations
- Test, evaluate and redesign models

## Introduction

To help in the design process, instruct the learners to look at the picture on the Learner Worksheet and read the accompanying text. If time and facilities are available, have your learners conduct research, and also encourage them to generate ideas and questions by posing problems they must take into account in their design and building processes. Your learners could search the Internet to learn more about the appearance, structure and function of different sorts of barriers, gates and railway crossings.

Learners should be reminded of the principle models that they have worked with. It might be a good idea to build principle model C1, a first class lever, to show the technique used.

Discuss in class the design problem specified in the design brief. Try to find several possible general solutions, or use the suggested solution for inspiration if necessary.

Discuss the constraints and functions your learners will have to take into account to carry out the design brief. Try to get your learners to focus on relevant issues and decisions by asking questions. These might include:

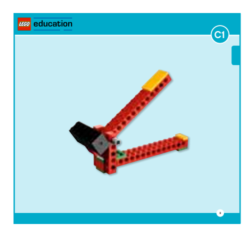
- How will your model look?
  *Maybe a railway crossing barrier with a lock function, and perhaps a handle for opening and closing it.*
- What LEGO® elements do you have available? How can you make the barrier balance with only one leg? What could be used as a counterbalance? How will your railway crossing barrier stand on the ground? How long a beam can you use? How do you think you might start building?
- Do you think your railway crossing barrier should open quickly or slowly? Why?

**Hint**

Most of the images used in the material can be found in the file 'Images for Classroom Use' on the CD, and are thus easy to display in class.

**Need help?**

Look at:



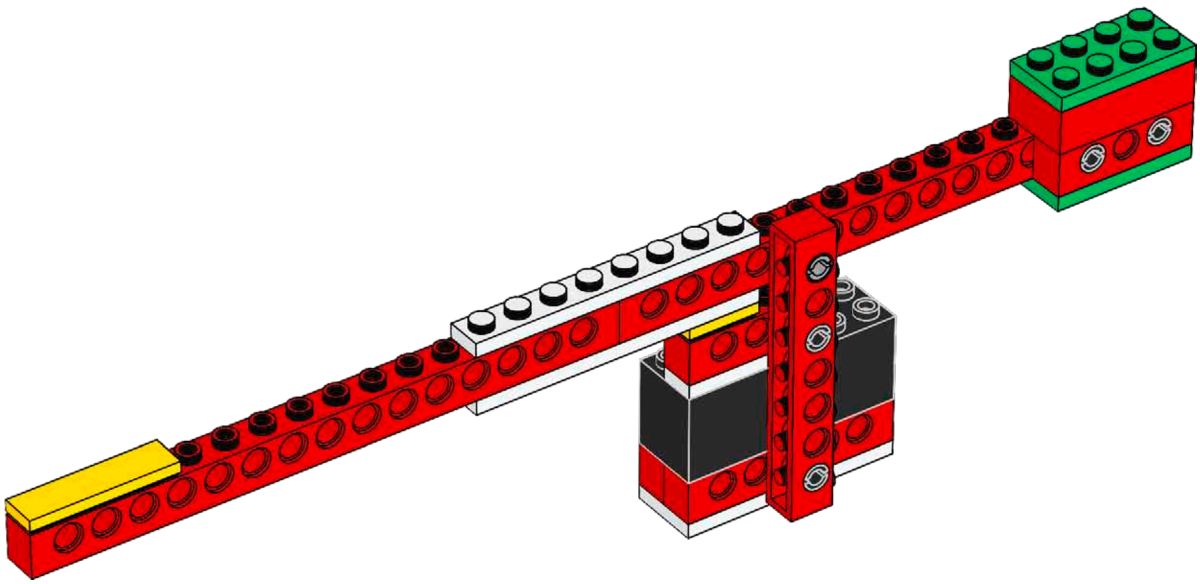

## Optional materials

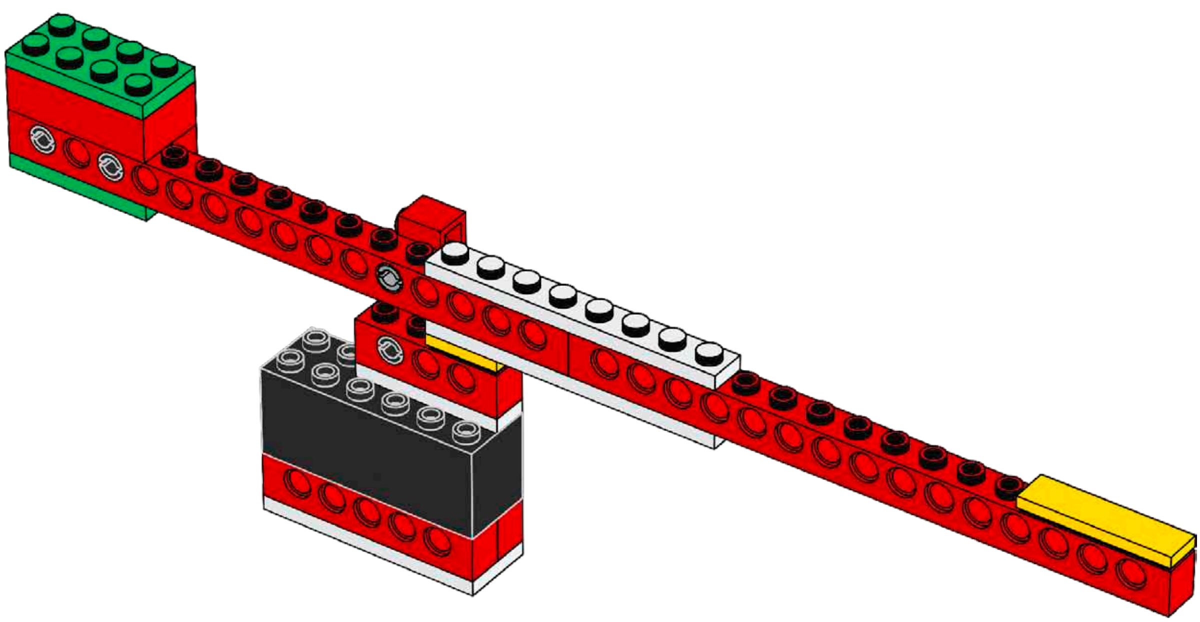
Materials for enhancing the appearance and functionality of the model: Learners can use paper, cardboard and markers to make the railway crossing barrier look more realistic. Additional LEGO elements, if available, may be used to make models more elaborate.

**When the model is finished, encourage learners to reflect on both the product that they have produced and the processes they have used by:**

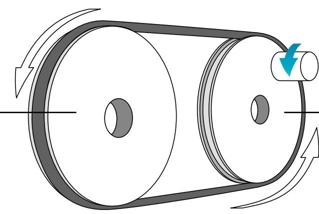
- Carrying out tests to evaluate the performance of their model
- Reflecting on the design brief
- Recording their design by drawing or taking digital photos

## Suggested model solution





# Overview: Pulleys




A pulley is most commonly defined as a wheel with a grooved rim for a belt or rope. A belt connecting pulleys can 'slip', meaning that the effort is not being used efficiently. This can happen either when the pulley belt is too loose, or if the pulley wheels differ in size. On the other hand, if the pulley belt is too tight, the belt will create wasteful friction forces on the pulley.

Pulleys can be used to create the following effects:

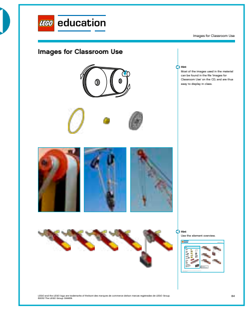
- To change the orientation of a pulling force
- To change the direction of rotation
- To change the orientation of a rotating movement
- To increase a pulling force
- To increase or decrease the speed of rotation
- To increase turning force, also called torque

Pulleys are found in many machines, such as fan belts, elevators, steam shovels, flagpoles, clothesline pulleys, cranes, old-fashioned wells, blocks and tackle, winches, wire stretchers and Venetian blinds.

**Did you know?**
Pulleys connected by a belt have a trade-off between turning force and turning speed. In general terms, you lose in turning force what you gain in turning speed, and vice versa.

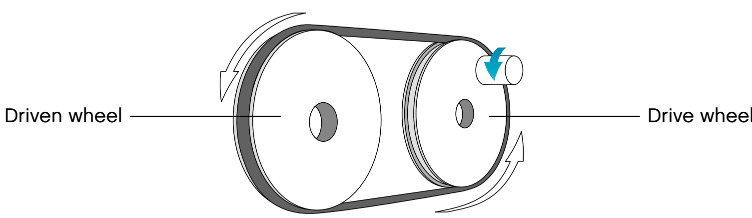
## Establishing the concept

We recommend establishing the concept of the simple machine to be worked on. This could be done, for example, by showing learners a number of exhibits from the LEGO® set to stimulate their interest. Build a principle model, or show some of the images from Images for Classroom Use, asking questions such as 'What do you know about this simple machine?' or 'Where do we use this simple machine?' See if learners can name any of the objects you show them, and allow time for learners to handle them.



## Providing the vocabulary

Learners will acquire the necessary vocabulary for the simple machine as they progress through the activities, but it may be useful to introduce certain terms at this stage. Important new vocabulary items are *drive wheel* and *driven wheel*.

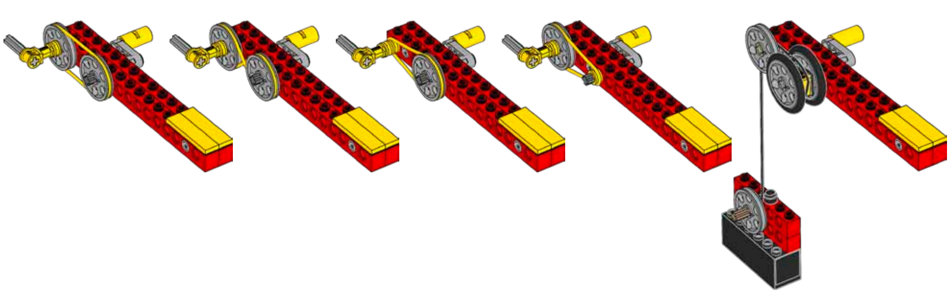


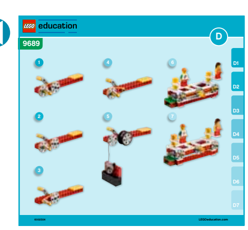

The pulley that is turned by an outside force, such as that from a motor or from a person turning a handle, is called a drive or the drive wheel. When this turns at least one other pulley by a belt, the next pulley is called the driven wheel (or follower).

## Understanding the principles

The principle models are designed to help learners understand the principles of the simple machine in focus through hands-on experience before they move on to construct the main models.

The principle models are presented in a logical sequence that will build on learners' understanding. The principle models can only be built one at a time from the parts in the set.



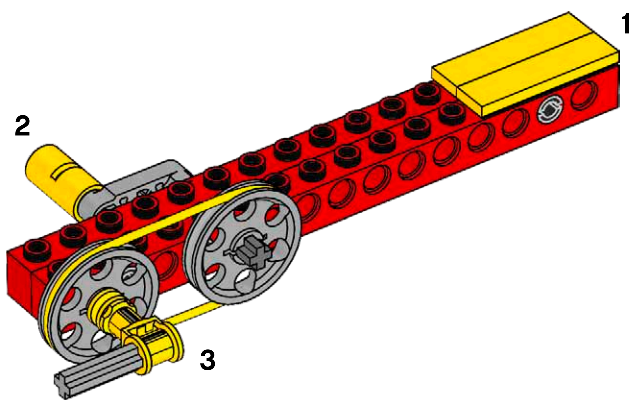


## Using the principle models

1. The yellow elements indicate where to hold, push, lift, or apply force/effort in handling the principle models. The principle models need to be held correctly for them to work properly.

2. When measuring one turn of the handle, carefully observe the starting place of the handle, and be careful to stop at the same position after a full turn.

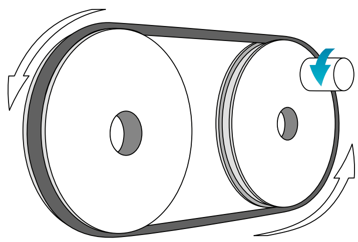
3. When measuring a full turn of the position marker, carefully observe the starting place of the position marker, and be careful to stop at the same position after a full turn. This is especially important when observing the connection between cranking the handle and the number of turns the position marker makes.

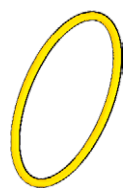


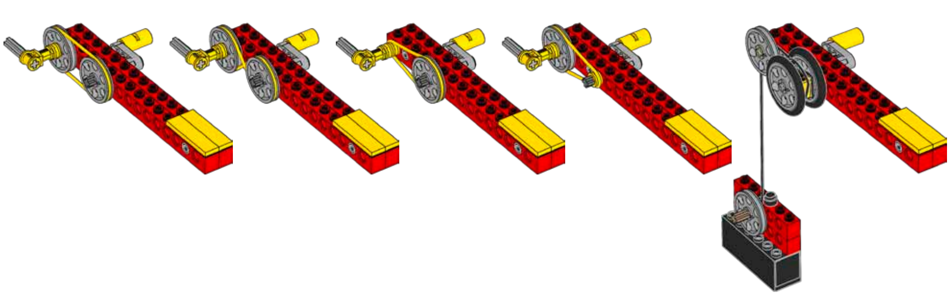

**Hint**
The principle models can be built as mirror-images for left-handed learners.

**Hint**
It is recommended that learners work in pairs; one learner can observe the position marker while the other cranks the handle a full turn.

# Images for Classroom Use

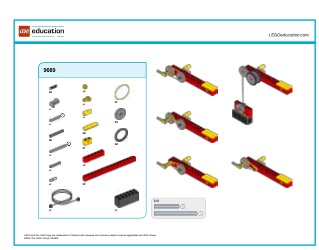


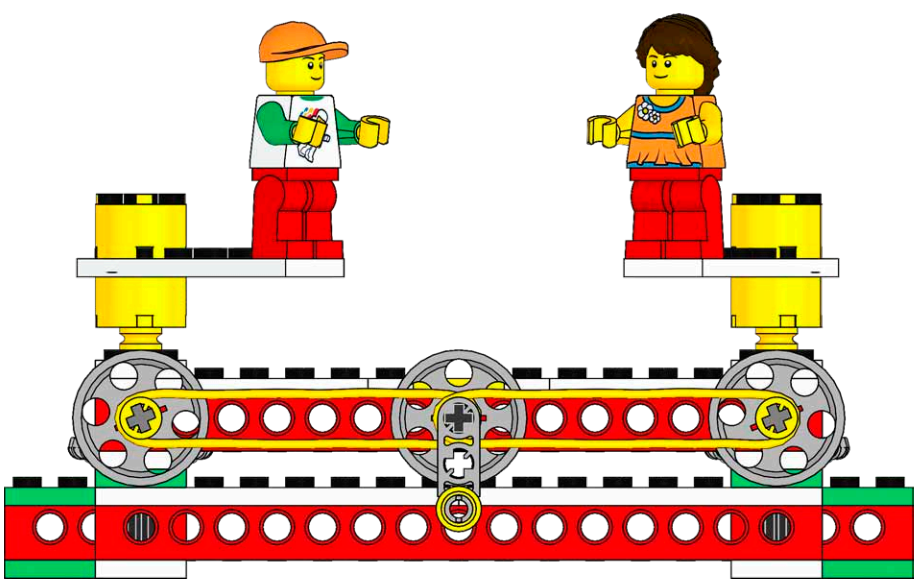




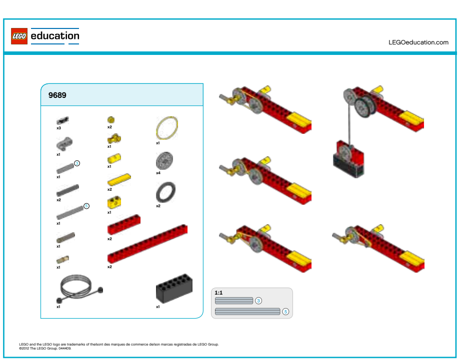
**Hint**
Most of the images used in the material can be found in the file 'Images for Classroom Use' on the CD, and are thus easy to display in class.

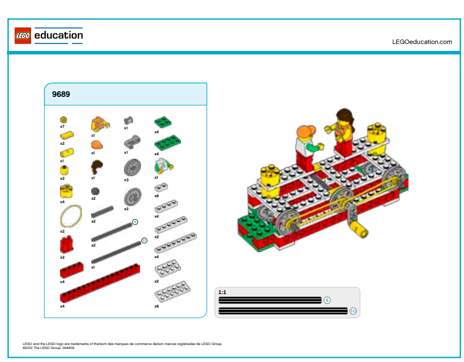
**Hint**
Use the element overview.





**Hint**
It is often more practical to sort out the elements that will be needed before starting work on the models.





**Hint**
The element overview can be printed and used as a check-list for learners to use when they are taking out and putting away their elements.

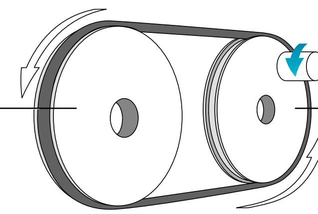
# Principle Models: Pulleys

Teacher's Notes

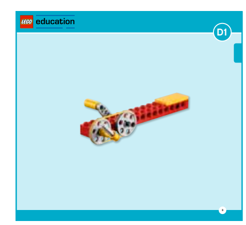
## Things to talk about

- What do you know about this simple machine?
- Where do we use this simple machine?
- Why do we use this simple machine?

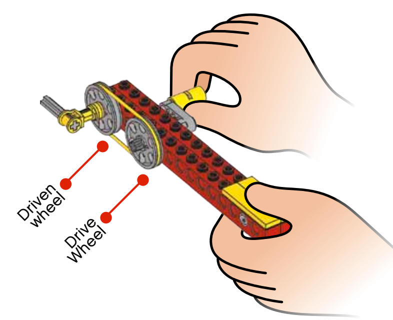
*Relate learners' answers to some of the images from Images for Classroom Use, or find ideas from the 'Overview: Pulleys' section to stimulate learners' interest.*




1. **Build D1** (Direction of rotation).
   Follow Building Instructions D, pages 4 to 8, steps 1 to 8.



2. **Label the pulleys.**
   Draw lines from the words to the picture of the model.
   *The drive wheel is the pulley that is turned by an outside effort, in this case your hand. Any pulley that is turned by another pulley is called the driven wheel or follower.*

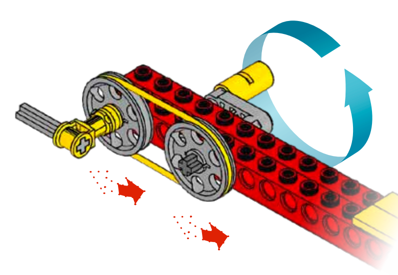



3. **Try out the model and make observations.**

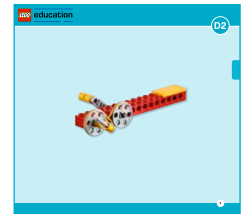
   ***Note:*** *It is recommended that learners work in pairs; one learner can observe the position marker while the other cranks the handle a full turn.*

   Crank the handle one full turn, and count how many times the position marker turns.
   *One turn of the handle results in one turn of the position marker (the grey axle). The speed of the rotations of the drive and the driven pulleys are the same, because the wheels have the same diameters.*

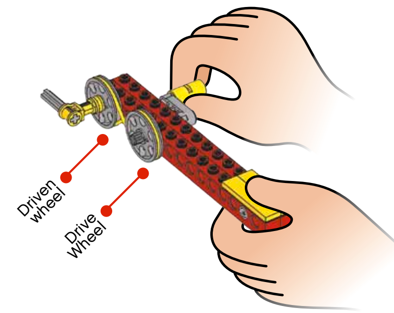
   Observe which way the pulleys turn when you crank the handle, and draw arrows to show the directions they turn in.
   *The pulley wheels turn in the same direction.*



1. **Build D2** (Changing direction of rotation).
   Follow Building Instructions D, page 10, step 1.

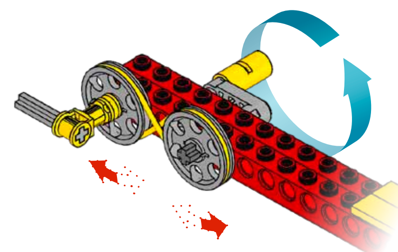


2. **Label the pulleys.**
   Draw lines from the words to the picture of the model.
   *The drive wheel is the pulley that is turned by an outside effort, in this case your hand.*
   *Any pulley that is turned by another pulley is called the driven wheel or follower.*




3. **Try out the model and make observations.**
   Crank the handle one full turn, and count how many times the position marker turns.
   *One turn of the handle results in one turn of the position marker (the grey axle).*
   *The speed of the rotations of the drive and the driven wheels are the same, because the wheels have the same diameters.*

   Observe which way the pulleys turn when you crank the handle, and draw arrows to show the directions they turn in.
   *The pulley wheels turn in opposite directions, because the pulley belt is twisted.*



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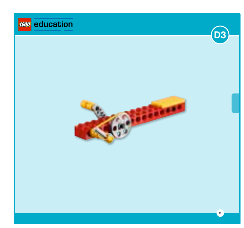
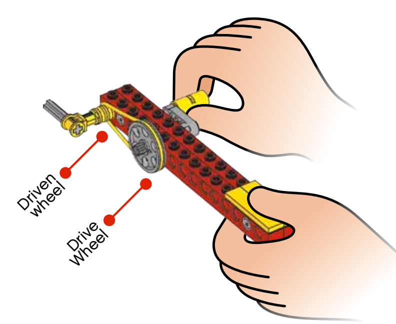
1. **Build D3** (Increasing speed of rotation).
   Follow Building Instructions D, pages 12 to 16, steps 1 to 7.

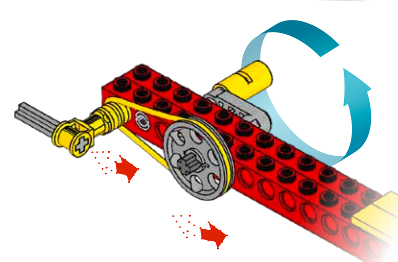


2. **Label the pulleys.**
   Draw lines from the words to the picture of the model.
   *The drive wheel is the pulley that is turned by an outside effort, in this case your hand.*
   *Any pulley that is turned by another pulley is called the driven wheel or follower.*

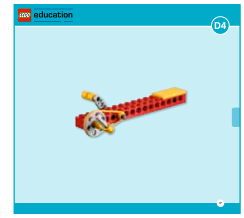



3. **Try out the model and make observations.**
   Crank the handle one full turn, and count how many times the position marker turns.
   *One turn of the handle (the large drive wheel) results in three turns of the smaller driven wheel. This ratio of 1:3 (or 1/3) is called the gearing up ratio. Increasing speed increases the speed of rotation but decreases the force, and the belt can slip.*

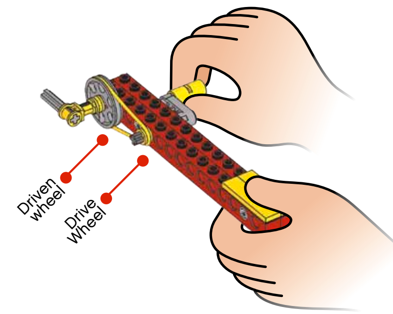
   Observe which way the pulleys turn when you crank the handle, and draw arrows to show the directions they turn in.
   *The pulley wheels turn in the same direction.*



1. **Build D4** (Decreasing speed of rotation).
   Follow Building Instructions D, pages 18 to 22, steps 1 to 8.

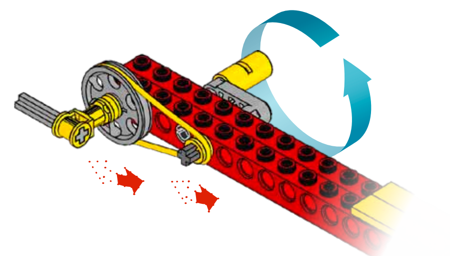



2. **Label the pulleys.**
   Draw lines from the words to the picture of the model.
   *The drive wheel is the pulley that is turned by an outside effort, in this case your hand. Any pulley that is turned by another pulley is called the driven wheel or follower.*

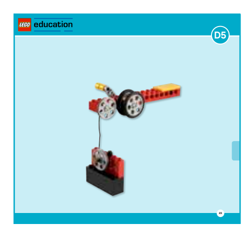



3. **Try out the model and make observations.**
   Count how many times the handle has to turn for the position marker to turn once.
   *Three turns of the handle (the small driver) results in one turn of the large driven wheel. This ratio of 3:1 (or 3/1) is called the gearing down ratio. Decreasing speed decreases the speed of rotation but increases the force, and the belt can slip.*

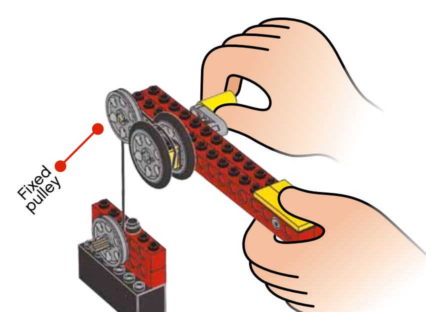
   Observe which way the pulleys turn when you crank the handle, and draw arrows to show the directions they turn in.
   *The pulley wheels turn in the same direction.*



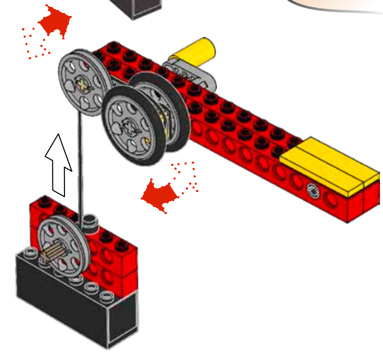
1. **Build D5** (Fixed pulley).
   Follow Building Instructions D, pages 24 to 32, steps 1 to 10.




2. **Label the pulley.**
   Draw a line from the word to the picture of the model.
   *A fixed pulley is made rigid or fastened so that it cannot be moved.*




3. **Try out the model and make observations.**
   Observe the directions of movement in the line when the model is used to lift a load. Mark the direction of movement of the line with arrows, from the load to the fixed pulley and from the fixed pulley to the winch. Continue from where the first arrow is drawn on the model.
   *This model shows a single fixed pulley. This merely changes the direction of motion, which learners will notice if the arrows are drawn correctly.*

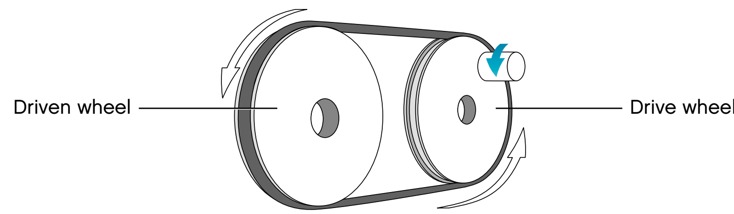


**Name(s):** 

**Date and subject:** 

## Principle Models: Pulleys

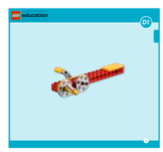
Learner Worksheet



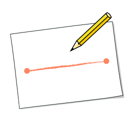

**Things to talk about**

- What do you know about this simple machine?
- Where do we use this simple machine?
- Why do we use this simple machine?

1. **Build D1** (Direction of rotation).
   Follow Building Instructions D, pages 4 to 8, steps 1 to 8.

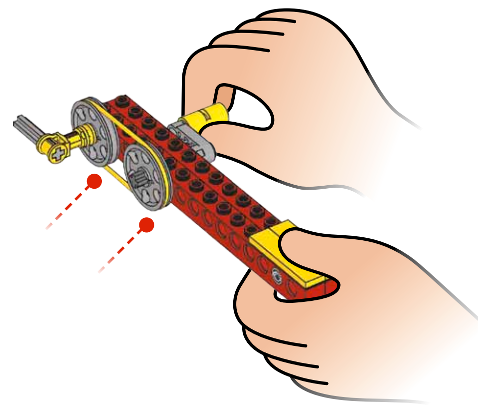


2. **Label the pulleys.**
   Draw lines from the words to the picture of the model.

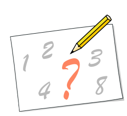


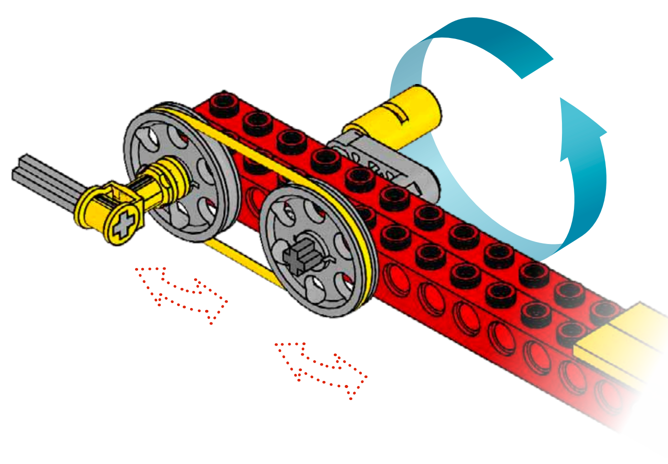
**Driven wheel**

**Drive wheel**

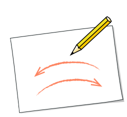


3. **Try out the model and make observations.**
   Crank the handle one full turn, and count how many times the position marker turns.
   Write your answer here:

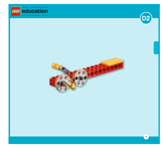


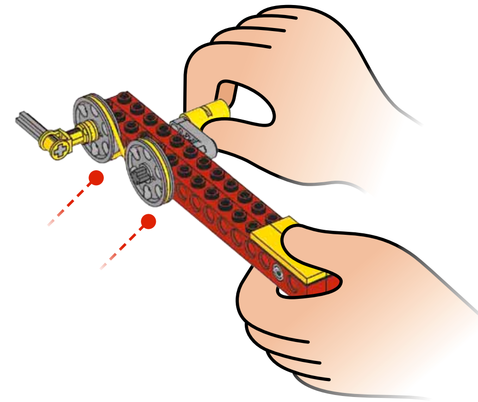



Observe which way the pulleys turn when you crank the handle, and draw arrows to show the directions they turn in.

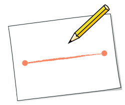


1. **Build D2** (Changing direction of rotation).
   Follow Building Instructions D, page 10, step 1.





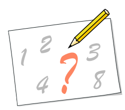
2. **Label the pulleys.**
   Draw lines from the words to the picture of the model.

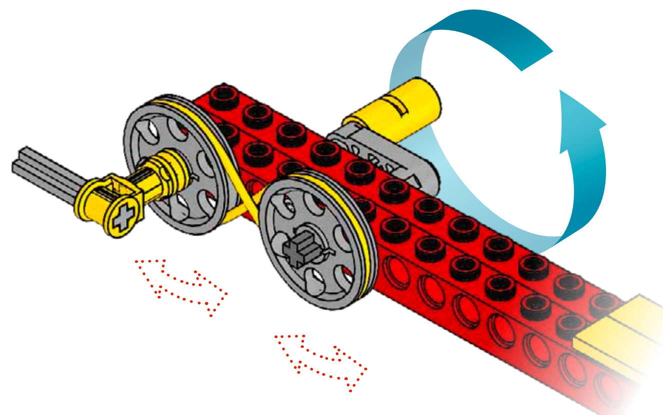


**Driven wheel**

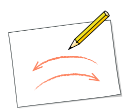
**Drive wheel**

3. **Try out the model and make observations.**
   Crank the handle one full turn, and count how many times the position marker turns.
   Write your answer here:





Observe which way the pulleys turn when you crank the handle, and draw arrows to show the directions they turn in.



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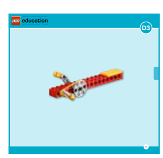
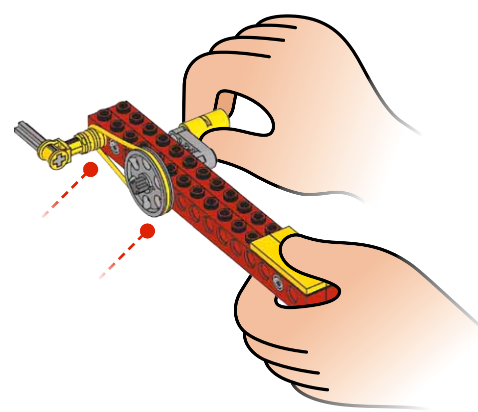
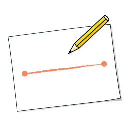
1. **Build D3** (Increasing speed of rotation).
   Follow Building Instructions D, pages 12 to 16, steps 1 to 7.





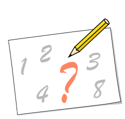
2. **Label the pulleys.**
   Draw lines from the words to the picture of the model.

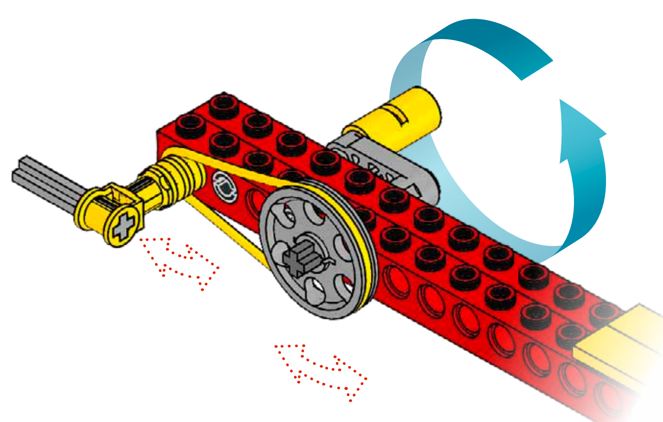


**Driven wheel**

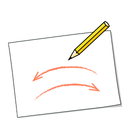
**Drive wheel**

3. **Try out the model and make observations.**
   Crank the handle one full turn, and count how many times the position marker turns.
   Write your answer here:

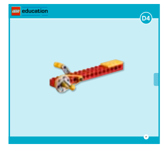




Observe which way the pulleys turn when you crank the handle, and draw arrows to show the directions they turn in.



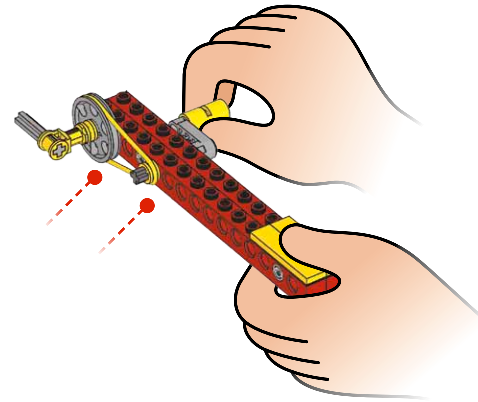
1. **Build D4** (Decreasing speed of rotation).
   Follow Building Instructions D, pages 18 to 22, steps 1 to 8.



2. **Label the pulleys.**
   Draw lines from the words to the picture of the model.

**Driven wheel**

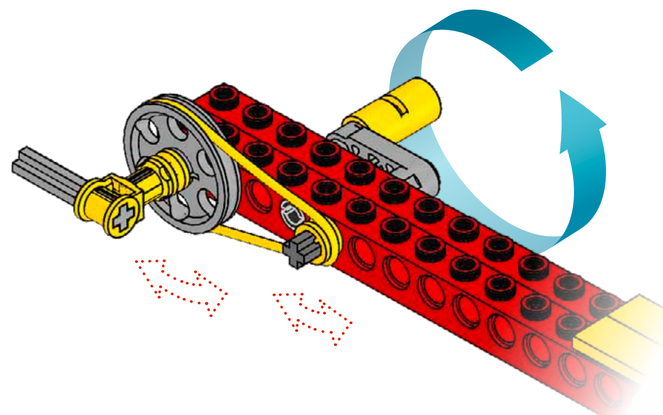
**Drive wheel**



3. **Try out the model and make observations.**
   Count how many times the handle has to turn for the position marker to turn once.
   Write your answer here:

   ..............................................................................................

   Observe which way the pulleys turn when you crank the handle, and draw arrows to show the directions they turn in.



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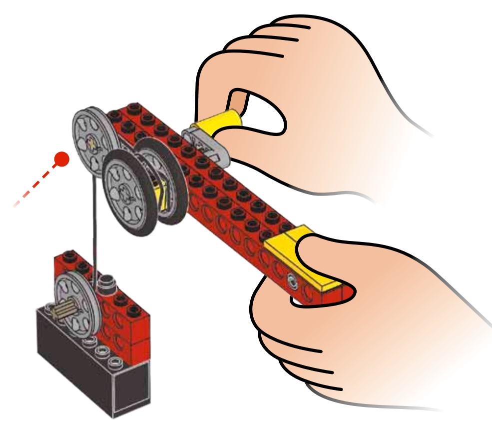
1. **Build D5** (Fixed pulley).
   Follow Building Instructions D, pages 24 to 32, steps 1 to 10.

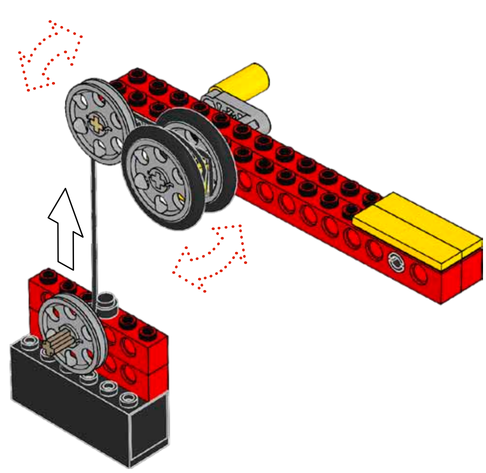
2. **Label the pulley.**
   Draw a line from the word to the picture of the model.

**Fixed pulley**



3. **Try out the model and make observations.**
   Observe the directions of movement in the line when the model is used to lift a load.

   Mark the direction of movement of the line with arrows, from the load to the fixed pulley and from the fixed pulley to the winch. Continue from where the first arrow is drawn on the model.



# Main Activity: Crazy Floors

Teacher's Notes

## Learning objectives

In this activity learners will build and test models that use the following techniques associated with pulleys:

- Decreasing speed of rotation
- Increasing speed of rotation
- Direction of rotation
- Changing direction of rotation

To perform this activity, learners should be familiar with the following vocabulary associated with pulleys:

- Drive wheel
- Driven wheel
- Slip

If learners have already worked with the principle models, they will already have observed pulleys, and the terms used in this activity should be familiar. Predictions should now be easier to make based on the observations made earlier. If the learners have not worked on the principle models, then additional time will be needed, for example to introduce and explain the technical vocabulary used. If additional guidance is required, please turn to the 'Overview: Pulleys' or 'Principle Models' sections.

## Materials required

- 9689 LEGO® Education Simple Machines Set

9689

## Connect

Sam and Sally love going to the fair. There is a fun attraction where you have to have good balance. The floors are crazy! They move at different speeds of rotation and in different directions. It is fun turning and trying not to get dizzy or fall down.

Are you good at keeping your balance?
Have you ever seen floors move?
Which simple machine is needed for Crazy Floors to turn?

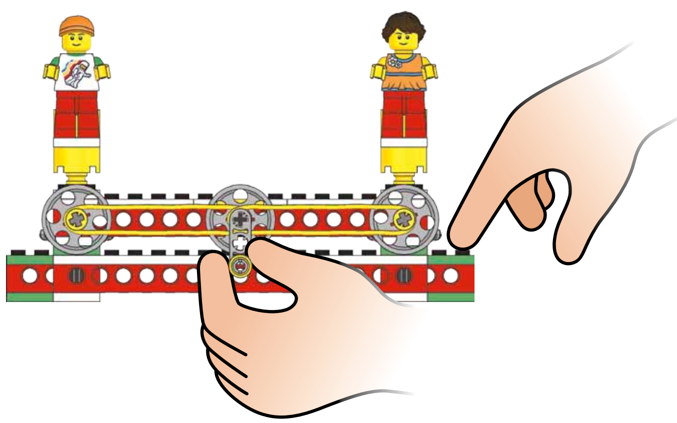
**Let’s build Crazy Floors!**

**Hint**
Most of the images used in the material can be found in the file 'Images for Classroom Use’ on the CD, and are thus easy to display in class.

## Construct

1. **First, build Crazy Floors Model D6 and make it turn.**
   Follow Building Instructions D, pages 34 to 54, steps 1 to 22.
   *When Crazy Floors Model D6 has been built, check the following:*
   - *Crank the yellow handle to make the crazy floors turn.*
   - *Make sure Sam and Sally are attached securely.*

   ***Note:*** *Make sure Sam and Sally are placed as shown on the model.*



**Hint**
Learners should be reminded that the drive wheel is the pulley turned by an outside effort, in this case your hand cranking the yellow handle.

## Contemplate

**2. Count the number of pulley wheels on the model.**

 4  3

*There are seven pulley wheels built into the model; three large grey pulley wheels and four small yellow pulley wheels.*

**3. Then look carefully at the pictures of the models and compare Crazy Floors Model D6 to Crazy Floors Model D7.**

- Circle what is different.
- What do you notice? Explain how the models are different.

*Learners should notice the difference in the way the pulleys are arranged on model D6 compared to model D7.*

**4. Next, look carefully at the pictures of the models and make a prediction.**
If I compare model D6 to model D7, then I think Crazy Floors Model (D6/D7) will show the larger difference in turning (speed of rotations) between Sam's side and Sally's side.
*Encourage learners to discuss the effects the different pulley arrangements have on the crazy floors in their own words. For the prediction, the correct answer is model D7, as it will show a difference in the speed of rotation of the crazy floors on each side of the model. Model D6 has a ratio of 1:1 and both sides of the model will move (turn) at the same speed. However, it does not matter whether learners get the answer right or wrong at this point, only that they should make a prediction that can be checked later.*

**5. Test Crazy Floors Model D6.**

- If you want Sam or Sally to make a full turn, how many times must you crank the handle?

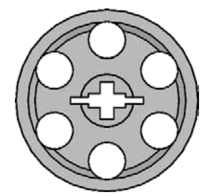
*Have learners observe the starting point of the handle and both Sam's and Sally's starting positions on the crazy floors. Encourage them to try more than once, to ensure that their observations are correct. Learners must write their answer in the blank box beside the handle.*

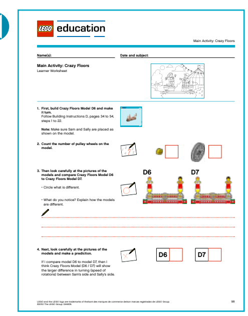
*The learners will have to crank the handle approximately four times for Crazy Floors Model D6 to turn once, but due to slip answers may vary. If learners have worked with the principle models for gears, they should be made aware that the angled gearing below the crazy floors enables the rotary motion to be transmitted through a 90-degree angle.*

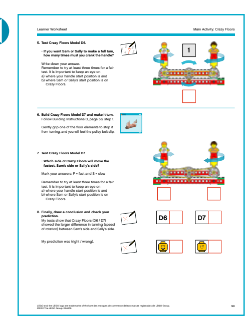
***Note:** If possible, keep an example of Crazy Floors Model D6 for learners to compare with Crazy Floors Model D7.*

**Did you know?**
The inside diameter of a small pulley wheel is 5.8 mm (≈ 0.22 in.).

The inside diameter of a large pulley wheel is 22 mm (≈ 0.8 in.).



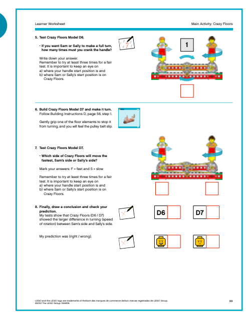




**6. Build Crazy Floors Model D7 and make it turn.**
Follow Building Instructions D, page 56, step 1.
Gently grip one of the floor elements to stop it from turning, and you will feel the pulley belt slip.
*Encourage learners to identify parts while they are testing the model. Learners can be made aware of 'slip' (see Glossary) by gently gripping the floor element to prevent it from turning, as this causes the attached pulley belt to slip.*


**7. Test Crazy Floors Model D7.**
• Which side of Crazy Floors will move the fastest, Sam's side or Sally's side?
*Have learners pay attention to the starting positions of both the handle and the minifigures. Encourage them to try more than once, to ensure that their observations are correct. Learners must write an F for fast and an S for slow.*
*The different pulley arrangements produce different speeds of rotation for Sam and Sally. The drive wheel is attached to the handle, and there is thus a gearing up pulley arrangement to the side where Sam stands. Sam turns at a much faster pace (= F, for fast) than the gearing down pulley arrangement on the side where Sally stands, which turns at a much slower (= S, for slow) pace.*

**8. Finally, draw a conclusion and check your prediction.**
*Crazy Floors Model D7 has the larger difference in the speed of rotation of the crazy floors because of the different pulley arrangements.*



## Continue

Learners are encouraged to explore the pulley arrangements illustrated on the Learner Worksheet and to record their observations.

***Note:** There are no building instructions included to guide learners through the Continue phase, other than the illustrated suggestions on the Learner Worksheet.*

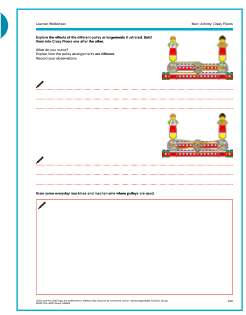
Encourage your learners to discuss the effects the pulley arrangement will have on Crazy Floors in their own words, prompting them with questions such as:

- Describe what happened when you turned the handle.
- How many times did you have to turn the handle to make the crazy floors turn once? Why do you think that was?
- Describe how the model works.
- What did you do to make sure your observations were correct?

It is suggested that learners should draw items where they find pulleys used in everyday machines and mechanisms. For inspiration read or show the 'Overview: Pulleys’ section.

**Optional**
With more advanced learners, you might consider introducing compound belt drives. Pulley wheels of two different sizes on the same axle can be connected to other pulley wheels to build more extensive gearing down (and gearing up) arrangements.

**Hint**
Most of the images used in the material can be found in the file 'Images for Classroom Use’ on the CD, and are thus easy to display in class.

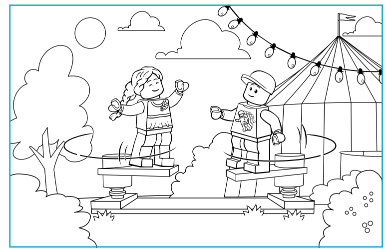


**Name(s):** 

**Date and subject:**

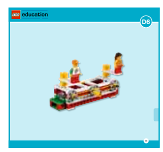
# Main Activity: Crazy Floors

Learner Worksheet

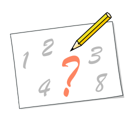


1. **First, build Crazy Floors Model D6 and make it turn.**
   Follow Building Instructions D, pages 34 to 54, steps 1 to 22.

   **Note:** Make sure Sam and Sally are placed as shown on the model.



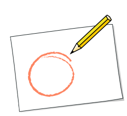
2. **Count the number of pulley wheels on the model.**



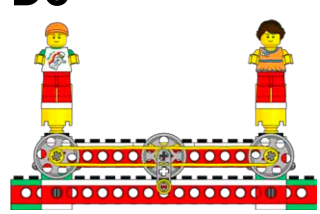
3. **Then look carefully at the pictures of the models and compare Crazy Floors Model D6 to Crazy Floors Model D7.**

   • Circle what is different.

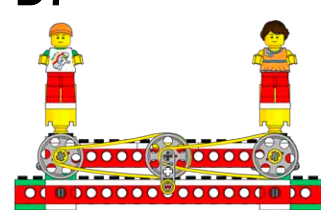
   • What do you notice? Explain how the models are different.



D6

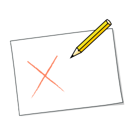


D7



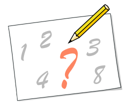
4. **Next, look carefully at the pictures of the models and make a prediction.**

   If I compare model D6 to model D7, then I think Crazy Floors Model (D6 / D7) will show the larger difference in turning (speed of rotations) between Sam's side and Sally's side.



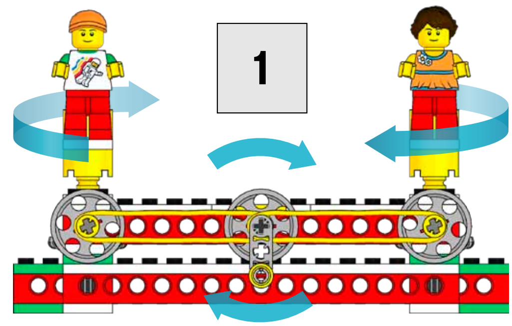
| D6 | | D7 | |
|---|---|---|---|

**5. Test Crazy Floors Model D6.**



- **If you want Sam or Sally to make a full turn, how many times must you crank the handle?**

Write down your answer.
Remember to try at least three times for a fair test. It is important to keep an eye on
a) where your handle start position is and
b) where Sam or Sally’s start position is on Crazy Floors.




**6. Build Crazy Floors Model D7 and make it turn.**
Follow Building Instructions D, page 56, step 1.

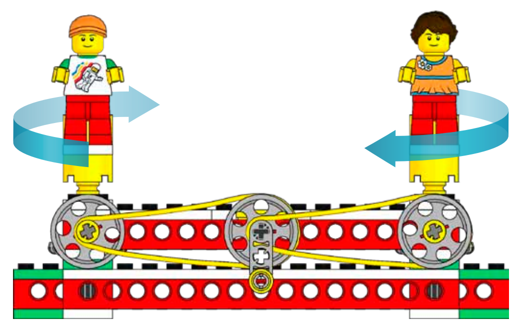
Gently grip one of the floor elements to stop it from turning, and you will feel the pulley belt slip.

**7. Test Crazy Floors Model D7.**

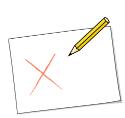
- **Which side of Crazy Floors will move the fastest, Sam’s side or Sally’s side?**

Mark your answers: F = fast and S = slow

Remember to try at least three times for a fair test. It is important to keep an eye on
a) where your handle start position is and
b) where Sam or Sally’s start position is on Crazy Floors.

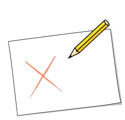


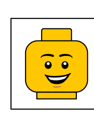
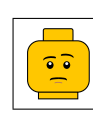
**8. Finally, draw a conclusion and check your prediction.**
My tests show that Crazy Floors (D6 / D7) showed the larger difference in turning (speed of rotation) between Sam’s side and Sally’s side.



D6 D7

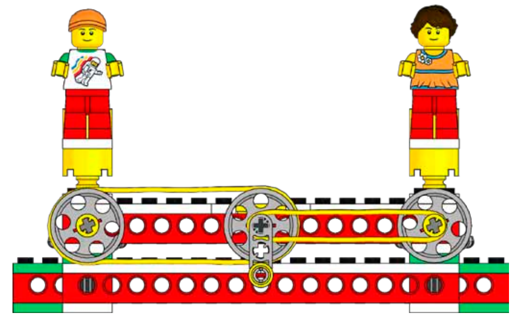
My prediction was (right / wrong).

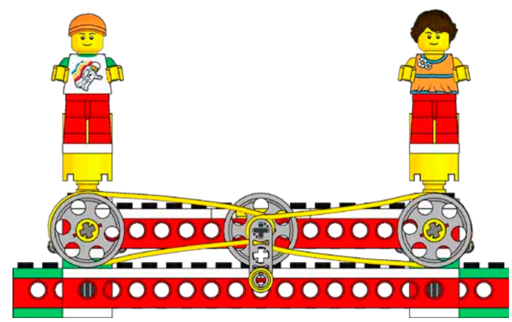


**Explore the effects of the different pulley arrangements illustrated. Build them into Crazy Floors one after the other.**

What do you notice?
Explain how the pulley arrangements are different.
Record your observations.





**Draw some everyday machines and mechanisms where pulleys are used.**

# Problem-Solving Activity: Crane

Learner Worksheet

When the fair is packing up to leave town, Sam and Sally enjoy watching a large crane lifting some of the heavy attractions. Sam and Sally want to try to build a crane and pretend they are part of the working crew at the fair.

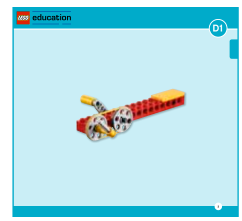
**Let's help Sam and Sally!**

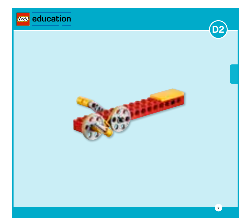
**Build a crane like the one in the picture.**

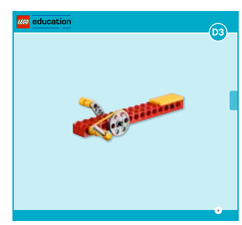
Your design brief is as follows:
• Build a crane that balances well.
• Use a fixed pulley on the crane.
• Build a mechanism that makes the winding mechanism stay locked.

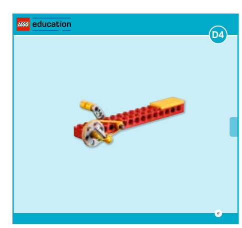
When you have finished, test your crane. How well does your lock system work? How much of a load can your crane lift? Assess how easily the crane can move the load and how well it stays stable. What makes the load easy or difficult to move?

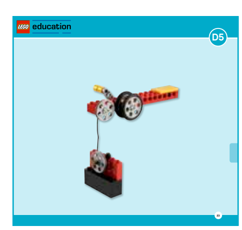
**Need help?**
Look at:



# Problem-Solving Activity: Crane

Teacher's Notes

## Learning objectives:

Learners are encouraged to do some research related to the real-life problem they are set to solve and/or the type of simple machine that they are going to use, and to:

- Identify a need or a problem
- Develop explanations using observations
- Test, evaluate and redesign models

## Introduction

To help in the design process, instruct the learners to look at the picture on the Learner Worksheet and read the accompanying text. If time and facilities are available, have your learners conduct research, and also encourage them to generate ideas and questions by posing problems they must take into account in their design and building process. Your learners could search the Internet to learn more about the appearance, structure and function of different sorts of cranes, and about how a block and tackle can be used as a lock mechanism.

Learners should be reminded of the principle models that they have worked with. It might be a good idea to build principle model D5 (Fixed pulley) to show the technique used.

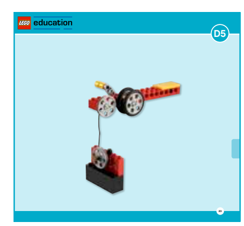
Discuss in class the design problem specified in the design brief. Try to find several possible general solutions, or use the suggested solution for inspiration if necessary.

Discuss the constraints and functions your learners will have to take into account to carry out the design brief. Try to get your learners to focus on relevant issues and decisions by asking questions. These might include:

- How will your model look?
  *Maybe a crane, shaped like a tower, and perhaps a handle for lifting the load, with lock mechanism operated by another handle. Or maybe simply a pawl and ratchet mechanism.*
- What LEGO® elements do you have available? How can you balance your crane? What could be used as a counterbalance? What can you use for a fixed pulley? How do you think you might start building?
- Should your crane lift quickly or slowly, do you think? Why?

**Hint**
Most of the images used in the material can be found in the file 'Images for Classroom Use' on the CD, and are thus easy to display in class.

**Need help?**
Look at:



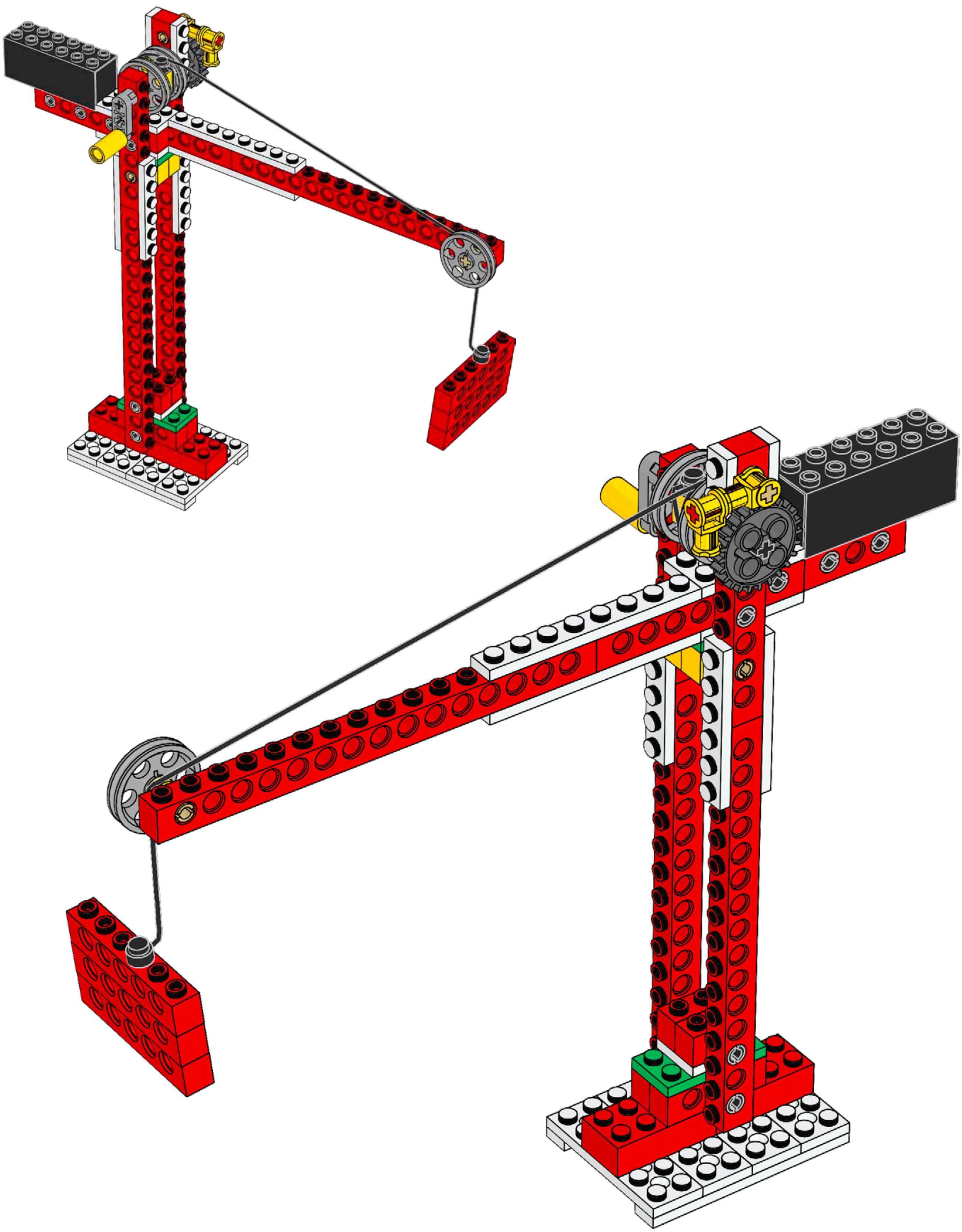

## Optional materials

Materials for enhancing the appearance and functionality of the model. Additional LEGO elements, if available, may be used to make models more elaborate.

**When the model is finished, encourage learners to reflect on both the product that they have produced and the processes they have used by:**

- Carrying out tests to evaluate the performance of their model
- Reflecting on the design brief
- Recording their design by drawing or taking digital photos

## Suggested model solution



# Glossary

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

A

**Angle** The inclination of two straight lines or planes that intersect, measured in degrees or radians.

**Axle** A rod through the centre of a wheel. An axle provides support for a wheel. If the axle is fastened to the wheel, it can transmit force to the wheel (as an engine makes the wheels of a car move).

B

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

C

**Compound gearing** 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.

**Counterbalance** A force often provided by the weight of an object used 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 turned easily.

D

**Drive gear/pulley** A gear or pulley that is turned by an applied force. In a machine, usually the part (a gear, pulley, lever, crank or axle) where the force first comes into the machine.

**Driven gear/pulley** Usually a gear wheel or pulley that is turned by another gear wheel or pulley. Also called a follower.

E

**Effort** The force or amount of force that is put into a machine.

## F

**Fair testing** Measuring the performance of a machine or model by testing and comparing its performance more than once.

**First class lever** (see Lever, first class)

**Fixed pulley** (see Pulley, fixed)

**Follower** (see Driven gear/pulley)

**Force** A push or a pull.

**Friction** A force that resists the movement of one object in contact with another. Also the resistance met by an object when moving over or turning against another object. Friction makes a moving object tend to slow down and eventually stop unless additional force is applied, e.g. when a sledge is pulled across snow. Friction produces heat which often wastes a lot of energy, reducing the efficiency of a machine.

**Fulcrum** Another word for a pivot (see Pivot).

## G

**Gear** A gear is a toothed wheel. A way to classify gears is by the number of teeth they have, e.g. an 8-tooth gear or a 40-tooth gear. Gears can be used to transfer force, to increase or reduce speed of rotation, and to change the direction of rotary motion. The teeth of gears mesh together to transmit movement.

**Gear, at an angle** (see Gear, crown)

**Gear, crown** A crown gear is a specialised gear wheel with teeth protruding to one side (looking like a crown). Because of its special teeth, a crown gear can mesh with an ordinary gear at a 90-degree angle.

**Gearing down** An arrangement in which a small drive gear turns a larger driven gear, resulting in a slowing down of the turning. Gearing down produces a more powerful turning force.

**Gearing up** An arrangement in which a large drive gear turns a small driven gear, resulting in a speeding up of the turning. Gearing up reduces the turning force.

**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 wheel that is turned by a drive gear and which turns another driven gear. It does not transform the forces in the machine, but affects direction of rotation of the driven gear.

L

**Lever** — A bar that pivots or rotates about a fixed point when a force (effort) is applied.

**Lever, first class** — A lever in which the pivot is between the effort and the load. This lever changes the direction of the effort force, and can change the amount of effort needed to lift a load. A long effort arm and short load arm amplify the force at the load arm, e.g. when prying the lid off a can of paint.

**Lever, second class** — A lever in which the load is between the effort and the pivot. This lever does not change the direction of the effort force, but can reduce the amount of effort needed to lift a load, e.g. in a wheelbarrow.

**Lever, third class** — A lever in which the effort is between the load and the pivot. This lever does not change the direction of the effort force, but can increase the distance the effort moves a load, e.g. in sweeping with a broom.

**Load** — An object to be raised or moved. The load is sometimes called the resistance.

M

**Machine and/ or Mechanism** — A device that makes work either easier or faster to do by changing the size or the direction of effort (force) needed, or by changing the distance through which the effort must move. However, a machine or mechanism cannot increase the amount of work done; if it reduces the effort needed, at the same time it increases the distance the effort has to move. A machine usually contains mechanisms. A mechanism is a simple arrangement of components that transforms the size or direction of a force, and the speed of its output. For example, a lever or two gears meshing are mechanisms.

**Mesh** — To fit together or to be engaged. The teeth of two gear wheels can mesh if they have the same spacing, and if the gear wheels are brought into contact with each other.

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.

**Pivot** — The point around which something turns or rotates, such as the pivot of a lever. The axle or rod supporting the middle of a see-saw is an example of a pivot. The pivot does not always have to be in the middle of the lever. In some types or classes of levers, the pivot point may be at one end, as in a wheelbarrow. See also Fulcrum.

**Pulley** — A pulley is a simple machine which usually consists of a grooved wheel round which a rope, belt, cable or chain is placed. A pulley is used to transfer force, alter speed of rotation, or to turn another wheel.

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

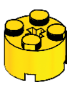
S

**Slip or slippage** A belt or rope slipping, usually on a pulley wheel as a safety feature.

T

**Torque** Turning force, for example from an axle.

# LEGO® Element Survey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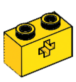
614324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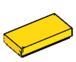
Studded beam
with crosshole, 1x2, yellow
4233484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Tile, 1x2, yellow
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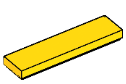
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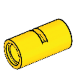
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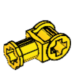
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Angular block
with crosshole, yellow
4107800


2x
Cross block, 2-module, yellow
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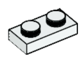
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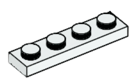
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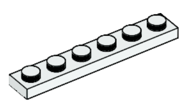
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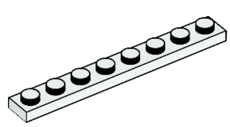
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Plate, 1x8, white
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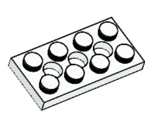
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Plate with holes, 2x4, white
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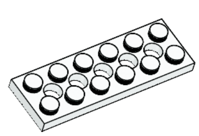
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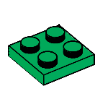
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Plate, 2x2, green
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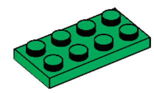
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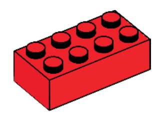
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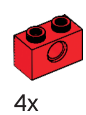
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Studded beam, 1x2, red
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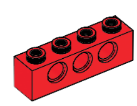
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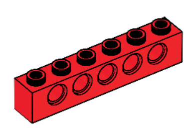
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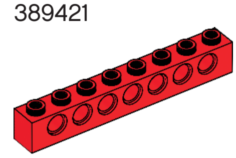
4x
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1x8, red
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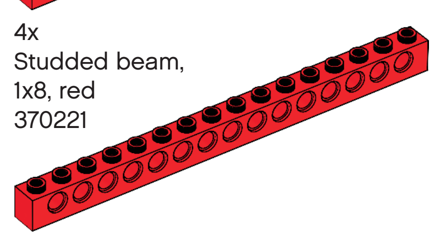
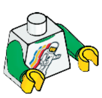
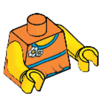

6x
Studded beam, 1x16, red
370321

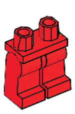

1x
Minifigure, cap, orange
4583147

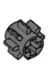

2x
Minifigure, head, yellow
4651441


1x
Minifigure, wig, dark brown
4581313

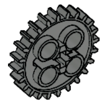

1x
Minifigure, body, white
4549942

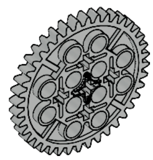

1x
Minifigure, body, orange
4580475

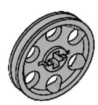

2x
Minifigure, legs, red
9342


4x
Gear, 8-tooth, dark grey
4514559


2x
Gear, 24-tooth crown, grey
4211434

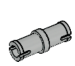

2x
Gear, 24-tooth, dark grey
4514558


2x
Gear, 40-tooth, grey
4285634

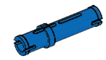

4x
Hub, 24x4, grey
4494222

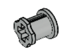

4x
tyre, 30, 4x4, black
281526


16x
Connector peg
with friction, black
4121715

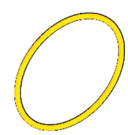

10x
Connector peg, grey
4211807

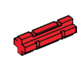

10x
Connector peg with axle, beige
4666579

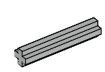

2x
Connector peg
with friction, 3-module, blue
4514553

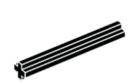

16x
Bushing, grey
4211622

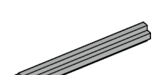

16x
Bushing, ½-module, yellow
4239601


2x
Belt, 33 mm, yellow
4544151

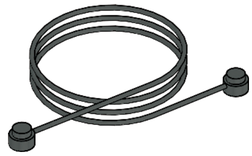

4x
Axle, 2-module, red
4142865


2x
Axle, 3-module, grey
4211815

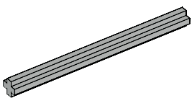

2x
Axle, 4-module, black
370526


2x
Axle, 5-module, grey
4211639

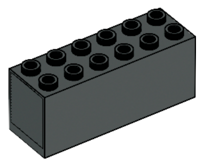
2x
Axle, 6-module, black
370626



1x
String, 40-module with knobs, black
4528334

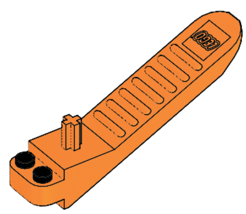


2x
Axle, 7-module, grey
4211805

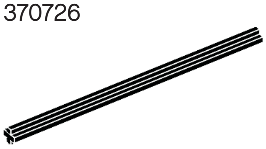


1x
Weight element, black
73843

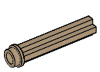
2x
Axle, 8-module, black
370726



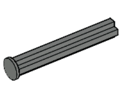
1x
Element separator, orange
4654448



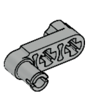
2x
Axle, 10-module, black
373726



2x
Axle with knob,
3-module, dark sand
4566927

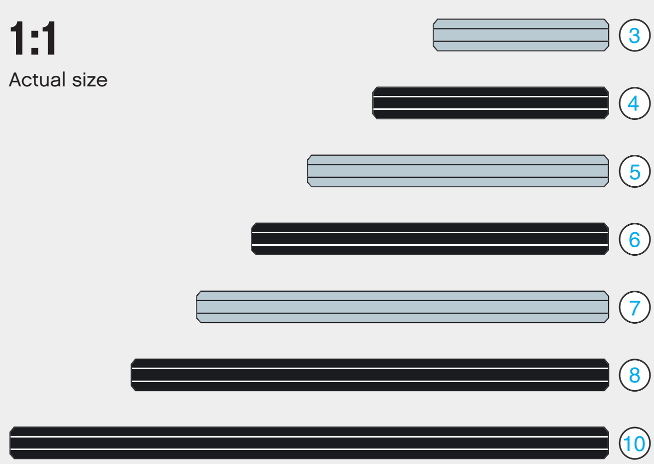


2x
Axle with stop,
4-module, dark grey
4560177



1x
Connector peg, handle, grey
4563045

**1:1**
Actual size



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