Activity Pack for Simple Machines

Teacher's Guide

LEGO education

2009689

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Introduction

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

Who Is the Material For?

This material is designed for elementary school teachers who wish to introduce their students 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 Student Worksheets supplied with the 2009689 Activity Pack for Simple Machines are suitable for students from first through third grades. Most students 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 Student Worksheets.

What Is It For?

Used together, the 9689 Simple Machines Set and this Activity Pack enable students to work as young scientists 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 students can develop skills such as creative problem-solving, communication of ideas, and teamwork. The activities lead students to make initial use of scientific method through observation, reasoning, prediction, and critical thinking.

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What Are Simple Machines?

We use simple machines every day—when we open a door, turn on a faucet, open a tin can, 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 moving dolly 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 moving dolly is one example of a compound machine. It has combined two simple machines. The handles are levers that 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 categorized 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-color 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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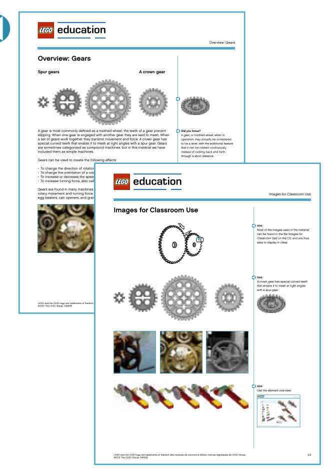
Curriculum:
This section offers a clear overview of the curriculum standards and learning goals targeted for each activity. Check which activities match your current teaching program, or use it to find inspiration for creating your own course of study.

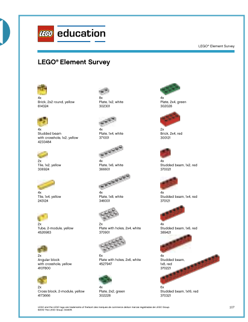
The four simple machine sections:
These sections provide information and activities for the four simple machines: gears, wheels and axles, levers, and pulleys. All four simple machine units are presented in the same way.

- 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 that can be used to support the teaching of simple machines. These images are intended to help students 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 Student 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 students 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.

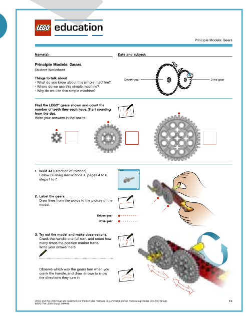
2. Provide the relevant vocabulary, e.g., by using it to talk about the simple machine in focus. See the recommended vocabulary in the **Overview** and/or see the **Glossary** for inspiration.

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 students 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 Student Worksheets.



General Comments Regarding the Material

Observations and fair tests

It is important that students 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*. Students 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.

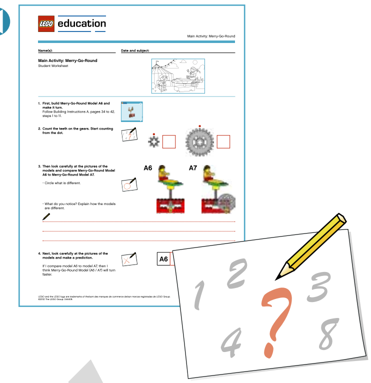
Scientific predictions

Making a scientific prediction is often based on prior observations and experiences. It is important that students attempt to state a prediction and then check to see whether their prediction was correct. The main models and the accompanying Student Worksheets will often assume that students 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 Student Worksheets, together with comments to the teacher, are written in ***blue italics*** in the Teacher's Notes.

Student Worksheets
The worksheets help students 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 Student Worksheets can be copied as required. Writing is kept to a minimum on the worksheets for the principle models—students only need to mark choices, draw lines to label illustrations, or write numbers.
On the worksheets for the main models students will be challenged to predict an outcome, which they will then investigate, and finally they will document their findings.

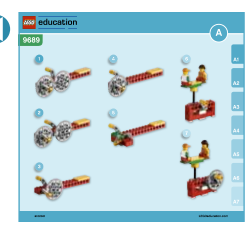


Text on the worksheets is kept to a minimum, but nevertheless early readers may need help in understanding the written instructions. Icons have been included on the worksheets to help students through the activity in focus; these symbolize, for example, that something must be marked or drawn, circled,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

The problem-solving activity
The problem-solving activity is intended to encourage students 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 organize 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 students are already experienced LEGO builders.

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

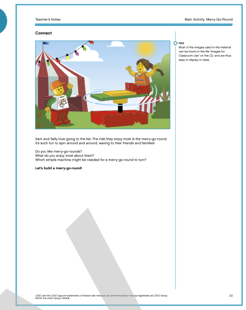
However, if you choose to continue with a main activity, then at least two more class periods will be needed, depending on the time spent on discussion, the building skills of your students, and the time you allow for experimentation. A double lesson is ideal to be able to explore, build, and investigate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

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

LEGO® Education's 4C approach

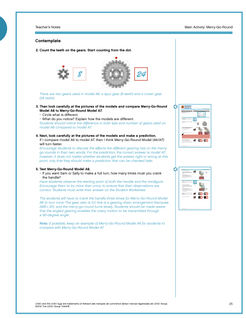
In working with the main models, in all four sections, you will be guided through LEGO® Education's 4C approach: Connect, Construct, Contemplate, and Continue, enabling your students to progress naturally through the activities.

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

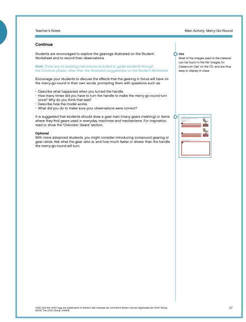


Construct
Using the building instructions, students build models covering the concepts related to the simple machine in focus. Tips are provided for testing and for making sure that each model functions as intended.

Contemplate
This stage involves students investigating the models they have constructed. Through these investigations, students 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 students' experience and understanding of the investigation. This phase provides the opportunity for you to begin evaluating learning outcomes and the progress of individual students, 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 students to change or add features to their models and to investigate further—always with the key learning area in mind. This phase encourages students to experiment and to apply their knowledge creatively.



Curriculum

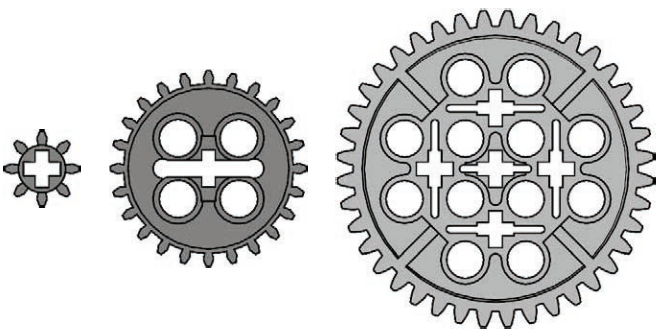
Curriculum Grid	2009689											
	Gears			Wheels and Axles			Levers			Pulleys		
	Principle Models	Main Model	Problem-Solving Model	Principle Models	Main Model	Problem-Solving Model	Principle Models	Main Model	Problem-Solving Model	Principle Models	Main Model	Problem-Solving Model
Science (NSTA)												
Science as inquiry:												
Students develop abilities necessary to do scientific inquiry.	●	●	●	●	●	●	●	●	●	●	●	●
Students plan and conduct a simple investigation.		●	●		●	●		●	●		●	●
Students employ simple equipment and tools to gather data and extend the senses.	●	●	●	●	●	●	●	●	●	●	●	●
Students use data to construct a reasonable explanation.	●	●	●	●	●	●	●	●	●	●	●	●
Students communicate investigations and explanations.		●	●		●	●		●	●		●	●
Students develop understanding about scientific inquiry.	●	●	●	●	●	●	●	●	●	●	●	●
Students know scientific investigations involve asking and answering a question and comparing the answer with what scientists already know about the world.	●	●	●	●	●	●	●	●	●	●	●	●
Students use different kinds of investigations depending on the questions they are trying to answer; types of investigations include describing objects, events, and organisms; classifying them; and doing a fair test (experimenting).	●	●	●	●	●	●	●	●	●	●	●	●
Students learn scientists develop explanations using observations (evidence) and what they already know about the world (scientific knowledge); good explanations are based on evidence from investigations.		●	●		●	●		●	●		●	●
Physical Science:												
Students develop an understanding of position and motion of objects.	●	●	●	●	●	●	●	●	●	●	●	●
Students learn the position of an object can be described by locating it relative to another object or the background.	●	●	●	●	●	●	●	●	●	●	●	●
Students identify a simple problem.	●	●	●	●	●	●	●	●	●	●	●	●
Students propose a solution.		●	●		●	●		●	●		●	●
Students implement proposed solutions.		●	●		●	●		●	●		●	●
Students evaluate a product or design.	●	●	●	●	●	●	●	●	●	●	●	●
Science and Technology:												
Students communicate a problem, design, and solution.	●	●	●	●	●	●	●	●	●	●	●	●
Students develop an understanding about science and technology.	●	●	●	●	●	●	●	●	●	●	●	●
Engineering												
Engineering Design Process:												
Students identify need or problem.		●	●		●	●		●	●		●	●
Students model in two and three dimensions.	●	●	●	●	●	●	●	●	●	●	●	●
Students test and evaluate.	●	●	●	●	●	●	●	●	●	●	●	●
Students redesign.		●	●		●	●		●	●		●	●
Students meet design constraints.	●	●	●	●	●	●	●	●	●	●	●	●
Mathematics (NCTM)												
Geometry:												
Students build and draw geometric objects.		●			●						●	
Students identify and build a three-dimensional object from two-dimensional representations of that object.	●	●		●	●		●	●		●	●	
Students identify and draw a two-dimensional representation of a three-dimensional object.		●			●						●	
Problem-Solving:												
Students predict the probability of outcomes of simple experiments and test the predictions.		●			●			●			●	
Data Analysis and Probability:												
Students collect data using observations, surveys, and experiments.	●	●		●	●		●	●		●	●	

Curriculum Highlights

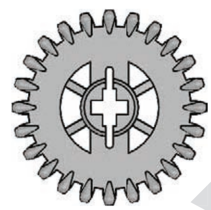
	Gears Principle & Main Models	Wheels and Axles Principle & Main Models	Levers Principle & Main Models	Pulleys Principle & Main Models
Science curriculum:				
Investigating simple machines, scientific inquiry, speed, fair testing, predicting and measuring, collecting data, and describing outcomes.	• Identify gears as either spur or crown gear. • Build a model that will gear up and increase speed of rotation. • Build a model that will gear down and decrease speed of rotation. • Arrange gears so they turn in the same direction, in opposite directions, or at 90 degrees to each other as desired. • Recognize 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. • Investigate a single fixed axle. • Investigate separate axles. • Build a wheeled model that turns a corner easily. • Build a model that can be steered. • Identify where friction might be found.	• Identify a lever as a rod or arm that tilts around a pivot to produce useful motion. • Describe the pivot, effort, and load. • Recognize that the effectiveness of a lever depends on the arrangement of the pivot point, effort, and load. • Identify first class levers.	• Identify a pulley wheel. • Build a model that will gear up and increase speed of rotation. • Build a model that will gear down and decrease speed of rotation. • Arrange pulleys so that the drive pulley turns in the same direction as the driven pulley. • Recognize that the turning ratio of one pulley to another is determined by the size of the pulleys. • Arrange pulley wheels so they turn in the same direction, in opposite directions, or at 90 degrees to each other as desired.
Technology/Engineering curriculum:				
Identifying a need or problem, building a model, and testing and evaluating.	• Build 3-dimensional models. • Follow steps of the engineering design process.	• Build 3-dimensional models. • Follow steps of the engineering design process. • Draw pictures of machines and mechanisms.	• Build 3-dimensional models. • Follow steps of the engineering design process.	• Build 3-dimensional models. • Follow steps of the engineering design process. • Draw pictures of machines and mechanisms.
Mathematics curriculum:				
Counting, drawing geometric shapes, calculating, measuring, predicting outcomes, and problem-solving.	• Predict outcomes of various trials. • Count teeth on gears and count rotations. • Draw geometric shapes.	• Predict outcomes of various trials. • Measure with standard units of measure.	• Predict outcomes of various trials. • Measure with standard units of measurement.	• Predict outcomes of various trials. • Count rotations.

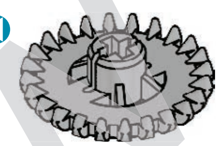
Overview: Gears

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 that enable it to mesh at right angles with a spur gear. Gears are sometimes categorized as compound machines, but in this material we have included them as simple machines.

Gears can be used to create the following effects:

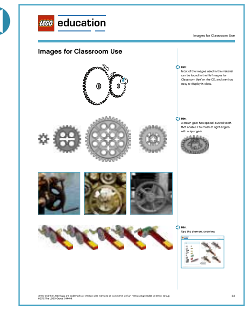
- To change the direction of rotation
- To change the orientation of a rotating movement
- To increase or decrease the speed of rotation
- To increase turning force, also called torque

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, can 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.

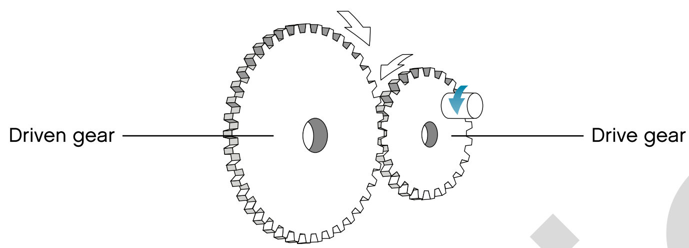
Establishing the concept

We recommend establishing the concept of the simple machine to be worked on. This could be done, for example, by showing students 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 students can name any of the objects you show them, and allow time for students to handle them.



Providing the vocabulary

Students 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*.

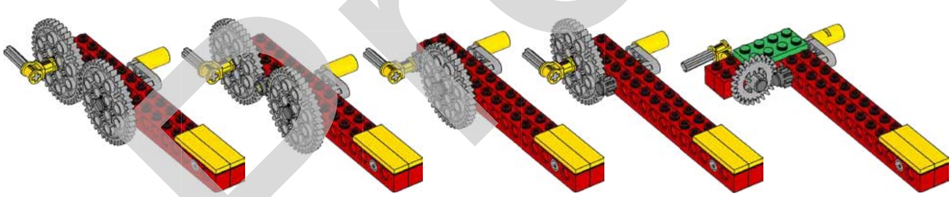


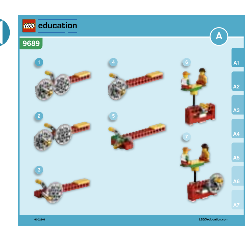
The gear that is closer to the source of power is called the drive gear and the gear that receives power from the drive gear is called the driven gear (or follower gear).

Understanding the principles

The principle models are designed to help students 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 students' understanding. The principle models can only be built one at a time from the parts in the set.





Using the principle models

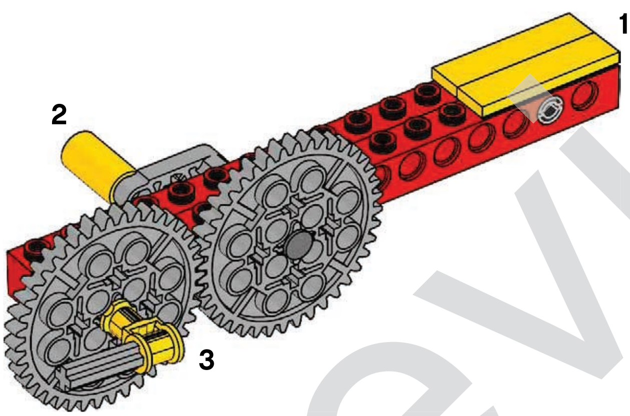
1. The yellow elements indicate where to hold, push, lift, or apply force/effort in handling the principle models. The principle models need to be held correctly for them to work properly.

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.

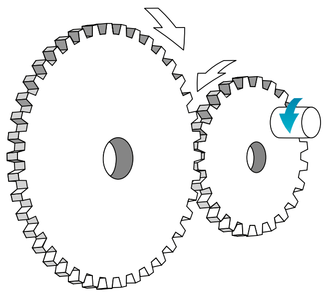
3. When measuring a full turn of the position marker, carefully observe the starting place of the position marker, and be careful to stop at the same position after a full turn. This is especially important when observing the connection between cranking the handle and the number of turns the position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

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

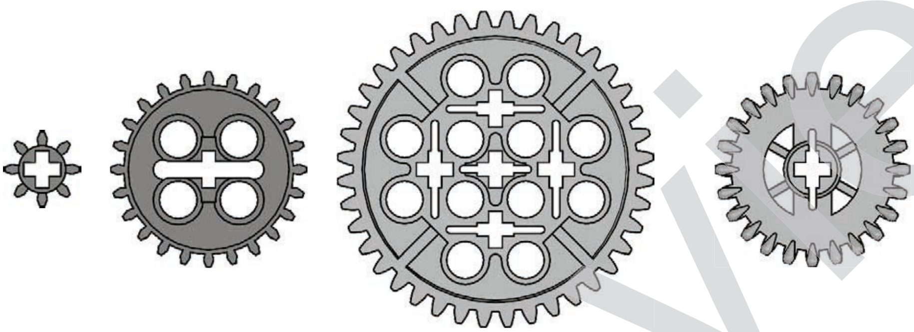
Hint
It is recommended that students work in pairs; one student can observe the position marker while the other cranks the handle a full turn.



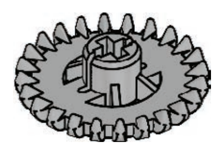
Images for Classroom Use

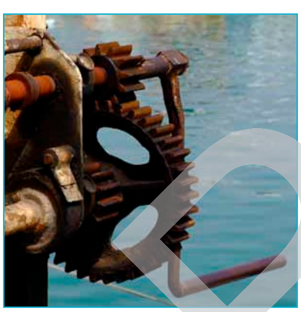


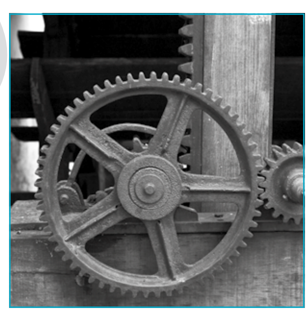
Hint
Most of the images used in the material can be found in the file "Images for Classroom Use" on the CD, and are thus easy to display in class.

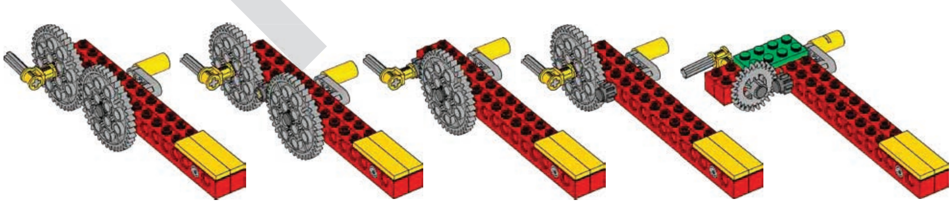


Hint
A crown gear has special curved teeth that enable it to mesh at right angles with a spur gear.

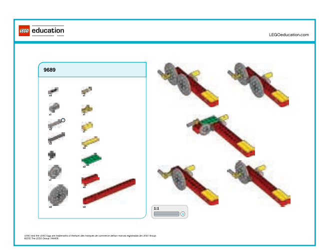


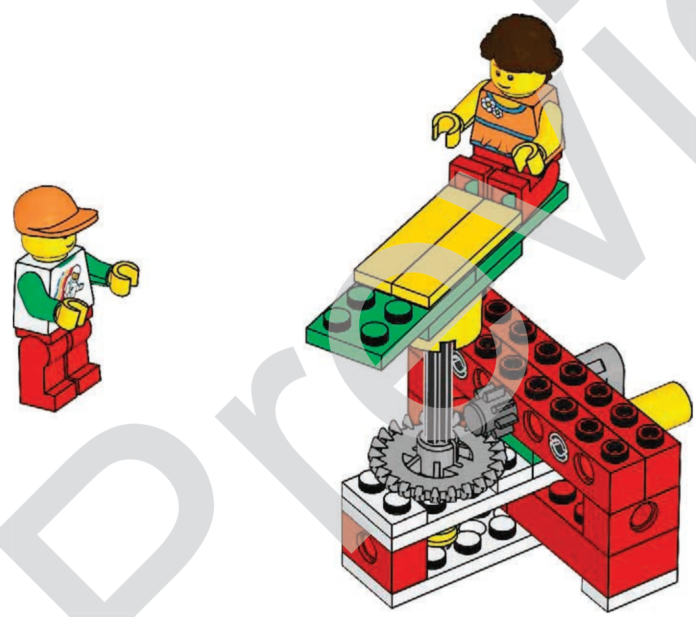




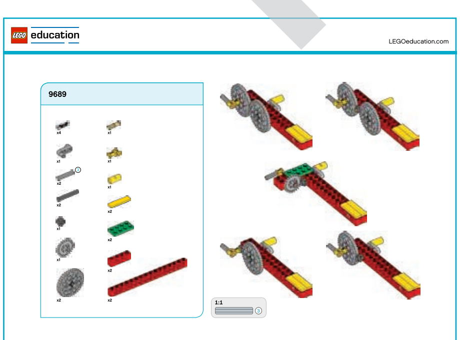


Hint
Use the element overview.





Hint
It is often 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 checklist for students to use when they are taking out and putting away their elements.

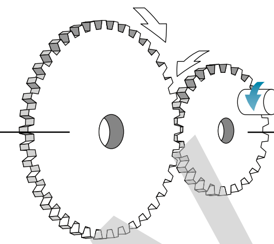
Principle Models: Gears

Teacher's Notes

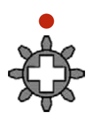
Things to talk about

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

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



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



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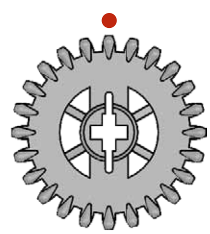

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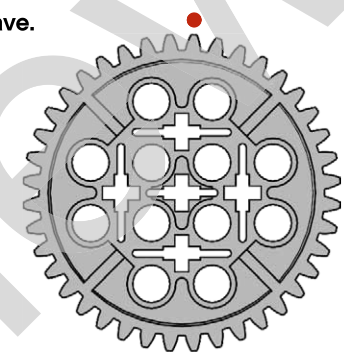
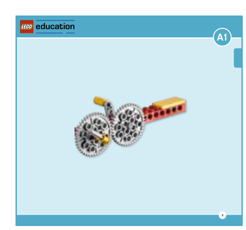
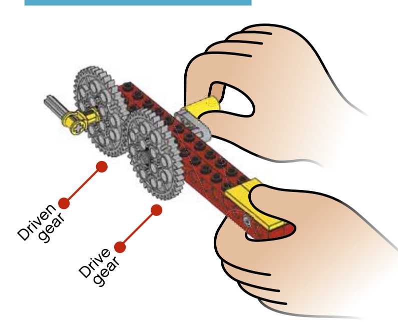


40

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.

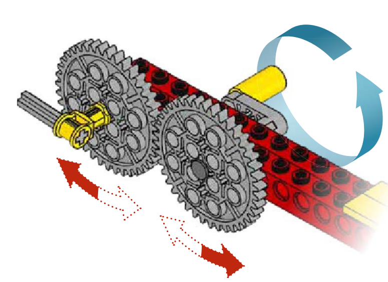


3. **Try out the model and make observations.**

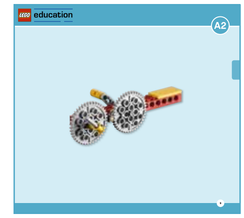
   ***Note:** It is recommended that students work in pairs; one student can observe the position marker while the other cranks the handle a full turn.*

   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 gray 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.

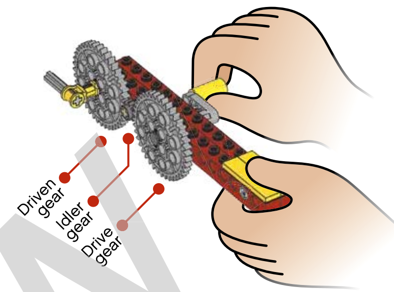
   Observe which way the gears turn when you crank the handle, and draw arrows to show the directions they turn in.
   Adjacent gears turn in opposite directions.



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

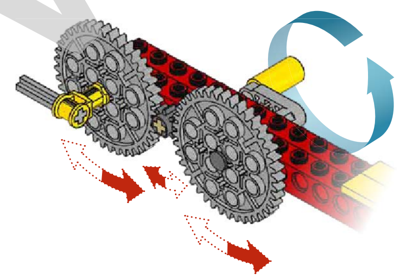


2. **Label the gears.**
   Draw lines from the words to the picture of the model.
   The small gear is an idler gear. The idler gear does not affect the relative speeds of rotation of either of the larger gears, only the direction in which the driven gear turns.



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 gray 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.



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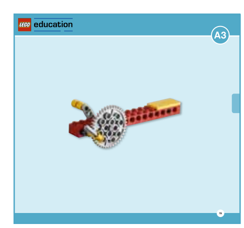
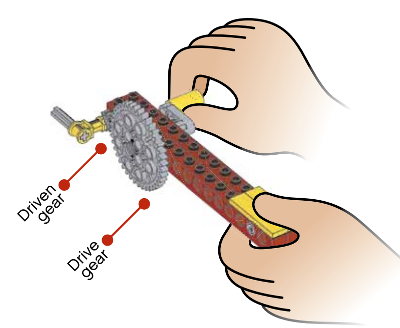
1. **Build A3** (Increasing speed of rotation).
   Follow Building Instructions A, pages 16 to 20, steps 1 to 7.

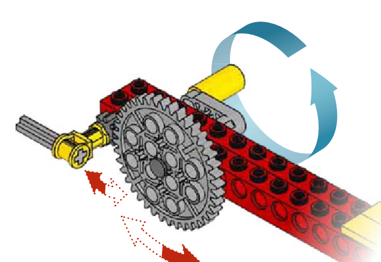


2. **Label the gears.**
   Draw lines from the words to the picture of the model.
   The drive gear is the gear that is turned by an outside effort, in this case your hand. Any gear that is turned by another gear is called a driven gear or follower.

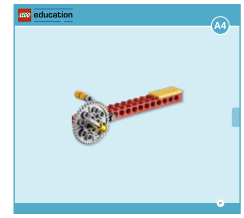


3. **Try out the model and make observations.**
   Crank the handle one full turn, and count how many times the position marker turns.
   One turn of the handle (the large drive gear) results in five turns of the smaller driven gear. This ratio of 1:5 (or 1/5) is called the gearing up ratio (8/40 = 1/5).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

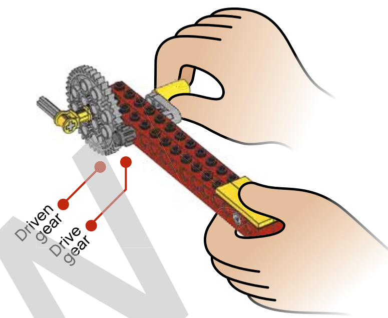
   Observe which way the gears turn when you crank the handle, and draw arrows to show the directions they turn in.
   Adjacent gears turn in opposite directions.



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

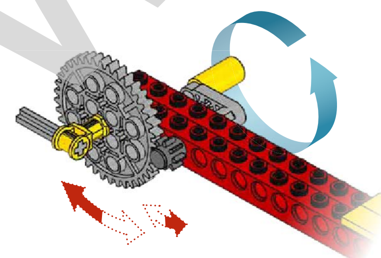


2. **Label the gears.**
   Draw lines from the words to the picture of the model.
   The drive gear is the gear that is turned by an outside effort, in this case your hand. Any gear that is turned by another gear is called a driven gear or follower.



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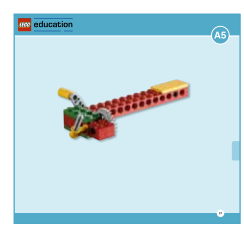
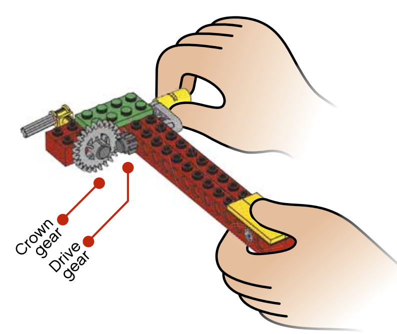
1. **Build A5** (At an angle).
   Follow Building Instructions A, pages 28 to 32, steps 1 to 8.

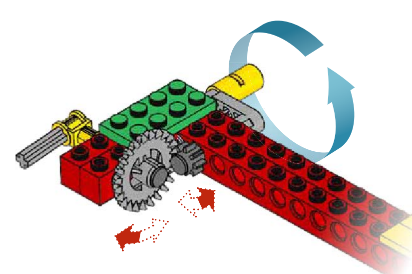


2. **Label the gears.**
   Draw lines from the words to the picture of the model.
   The 8-tooth drive spur gear moves the 24-tooth driven crown gear.



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 students give will depend on their familiarity with describing angles). The crown gear can change the rotary motion easily because it has special curved teeth that enable it to mesh at an angle/at right angles in a different direction with a spur gear.



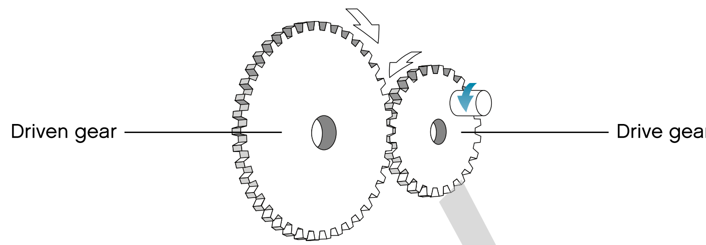
Name(s): **Date and subject:**

Principle Models: Gears

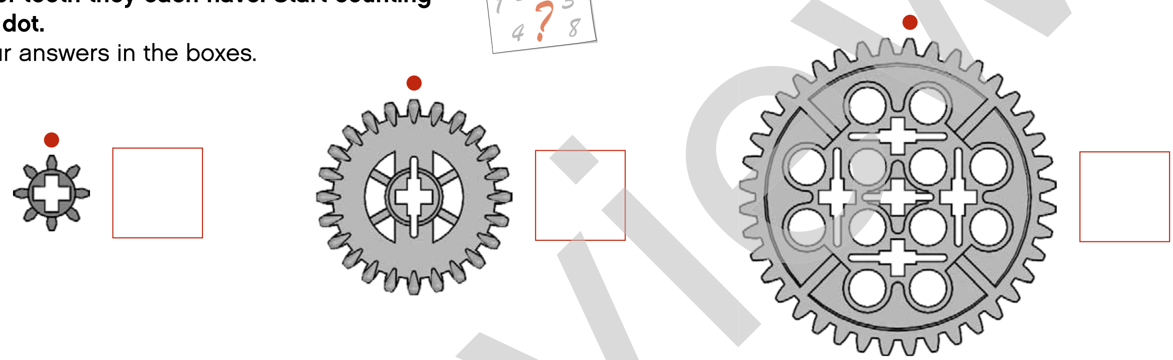
Student Worksheet

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?

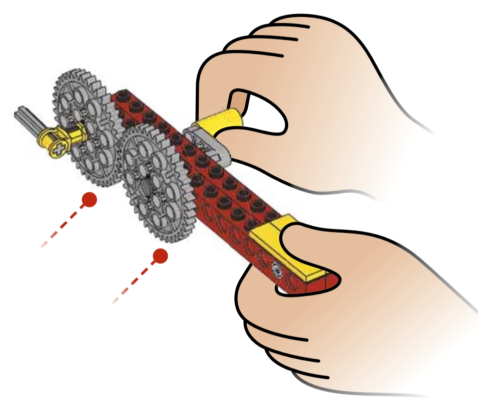


Find the LEGO® gears shown and count the number of teeth they each have. Start counting from the dot.
Write your answers in the boxes.



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.



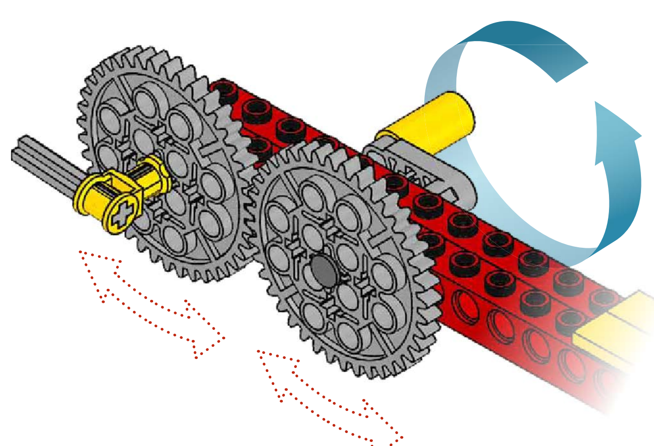
Driven gear

Drive gear

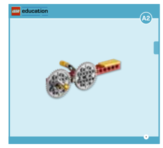
3. **Try out the model and make observations.**
   Crank the handle one full turn, and count how many times the position marker turns.
   Write your answer here:

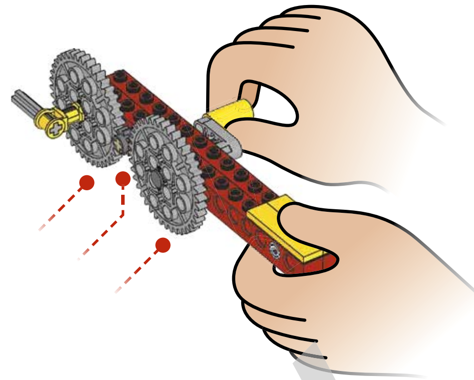
   ....

   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

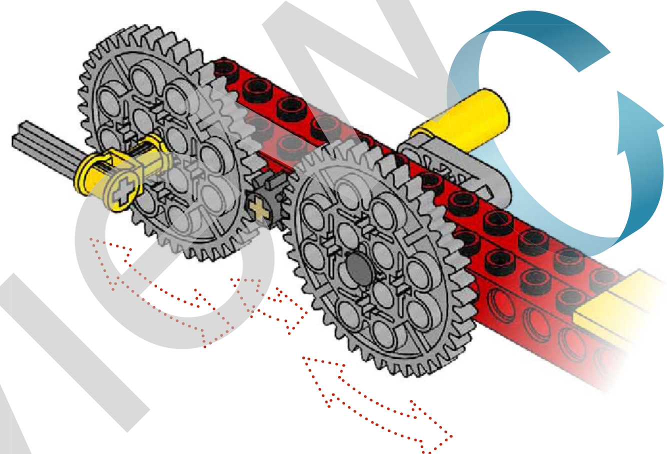
   Idler gear

   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.



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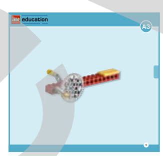
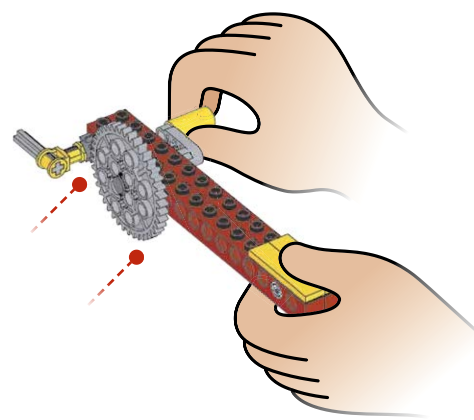
1. **Build A3** (Increasing speed of rotation).
   Follow Building Instructions A, pages 16 to 20, steps 1 to 7.





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

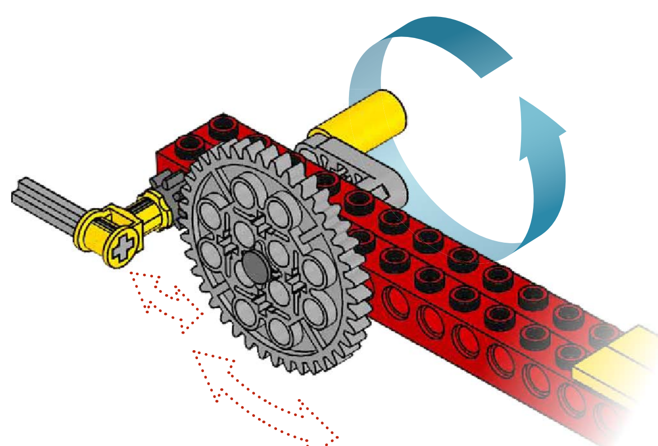
   Driven gear

   Drive gear

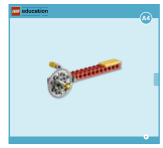
3. **Try out the model and make observations.**
   Crank the handle one full turn, and count how many times the position marker turns.
   Write your answer here:

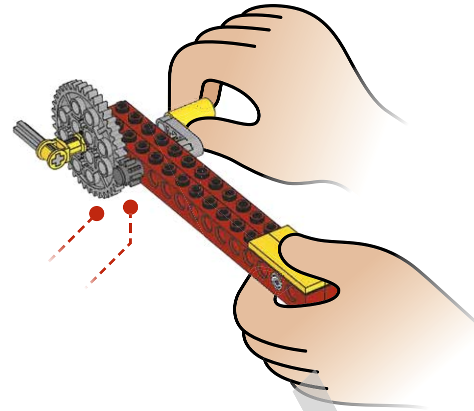
   ....

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

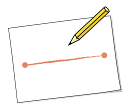


1. **Build A4** (Decreasing speed of rotation).
   Follow Building Instructions A, pages 22 to 26, steps 1 to 7.





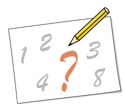
2. **Label the gears.**
   Draw lines from the words to the picture of the model.

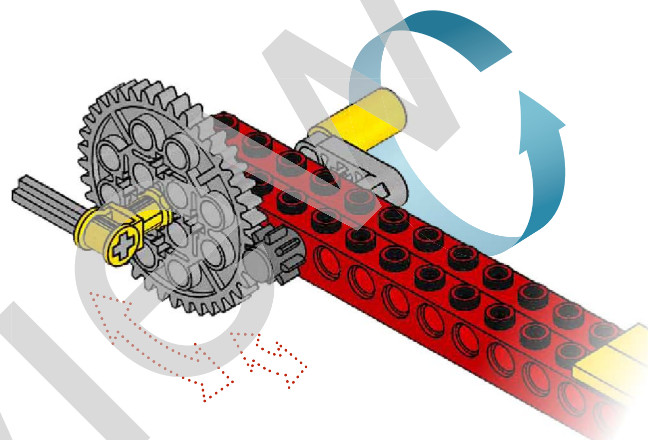


Driven gear

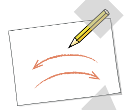
Drive gear

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.



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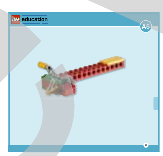
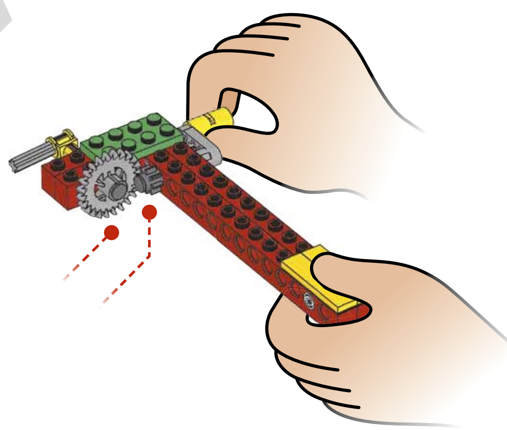
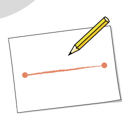
1. **Build A5** (At an angle).
   Follow Building Instructions A, pages 28 to 32, steps 1 to 8.





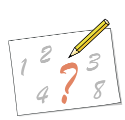
2. **Label the gears.**
   Draw lines from the words to the picture of the model.

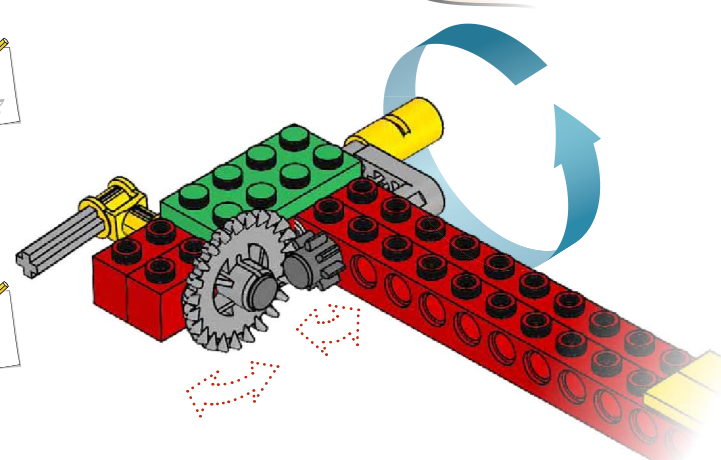


Crown gear

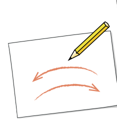
Spur gear

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 students 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, students should be familiar with the following vocabulary associated with gears:

- Drive gear
- Driven gear
- To mesh

If students 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 students 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!

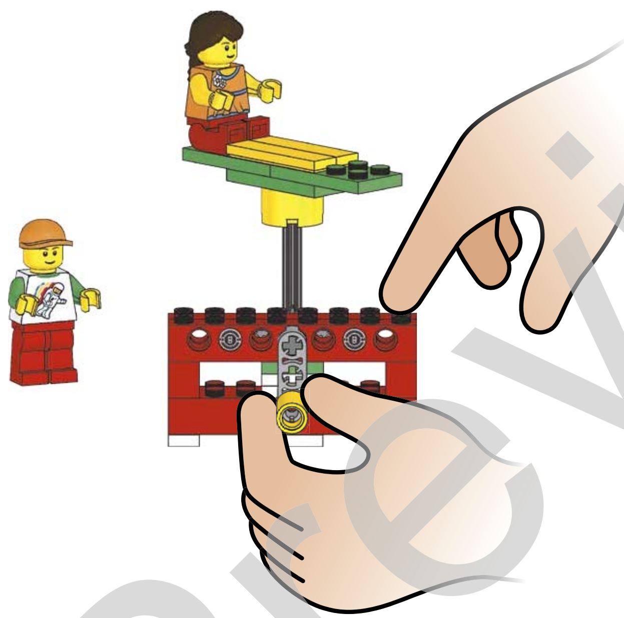
Do you like merry-go-rounds?
What do you enjoy most about them?
Which simple machine might be needed for a merry-go-round to turn?

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

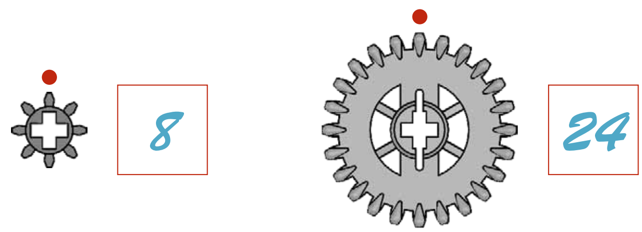
1. First, build Merry-Go-Round Model A6 and make it turn.
Follow Building Instructions A, pages 34 to 42, steps 1 to 11.
When Merry-Go-Round Model A6 has been built, check the following:
- *Crank the yellow handle to make sure the merry-go-round turns.*
- *Make sure the minifigure is attached securely. Students 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.*



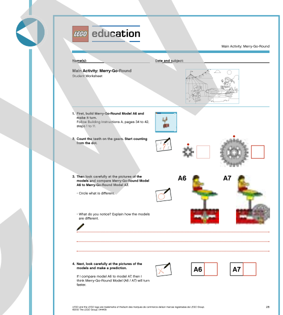
Hint
Students should be reminded that the drive gear is the gear turned by an outside effort, in this case your hand cranking the yellow handle.

Contemplate

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



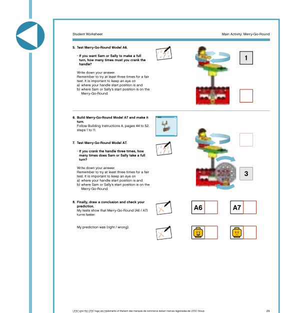
There are two gears used in model A6: a spur gear (8 teeth) and a crown gear (24 teeth).



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.

Students 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 students 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 students 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 students 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. Students must write their answer on the Student Worksheet.

The students 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. Students 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 students 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 students 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 students 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.

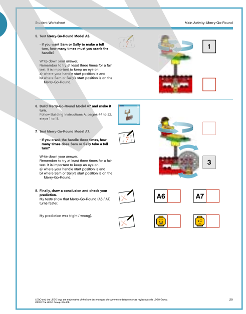
Three turns of the 40-tooth gear produce five turns of the merry-go-round. The gear ratio is 3:5 (because 24/40 = 3/5), and the merry-go-round turns at a much faster pace.

Hint

It is recommended that students work in pairs; one student 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

Students are encouraged to explore the gearings illustrated on the Student Worksheet and to record their observations.

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

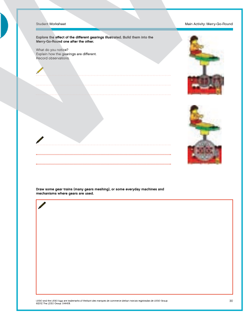
Encourage your students to discuss the effects that the gearing in focus will have on the merry-go-round in their own words, prompting them with questions such as:

- 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 students 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 students, 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.

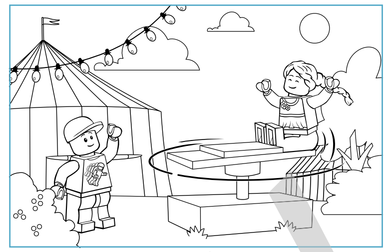
Hint
Most of the images used in the material can be found in the file "Images for Classroom Use" on the CD, and are thus easy to display in class.



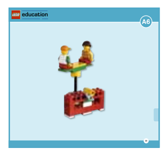
Name(s): ______________________ **Date and subject:** ______________________

Main Activity: Merry-Go-Round

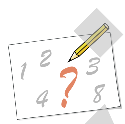
Student Worksheet

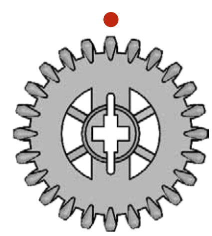


1. **First, build Merry-Go-Round Model A6 and make it turn.**
   Follow Building Instructions A, pages 34 to 42, steps 1 to 11.



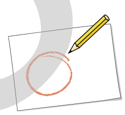
2. **Count the teeth on the gears. Start counting from the dot.**





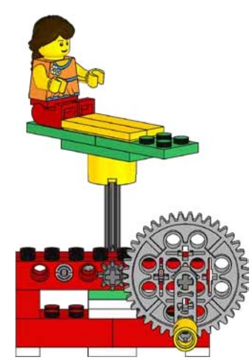
3. **Then look carefully at the pictures of the models and compare Merry-Go-Round Model A6 to Merry-Go-Round Model A7.**

   • Circle what is different.



A6

A7



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

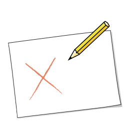
....

....

....

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.



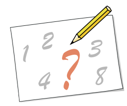
A6	

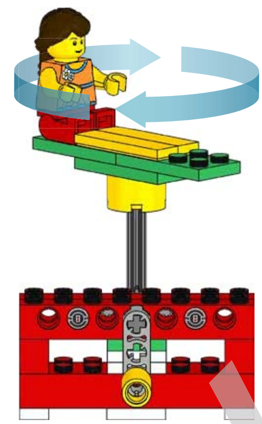
A7	

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?**

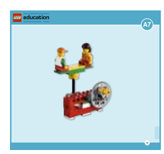
Write down your answer.
Remember to try at least three times for a fair test. It is important to keep an eye on
a) where your handle start position is and
b) where Sam or Sally's start position is on the Merry-Go-Round.





1

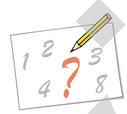
6. Build Merry-Go-Round Model A7 and make it turn.
Follow Building Instructions A, pages 44 to 52, steps 1 to 11.

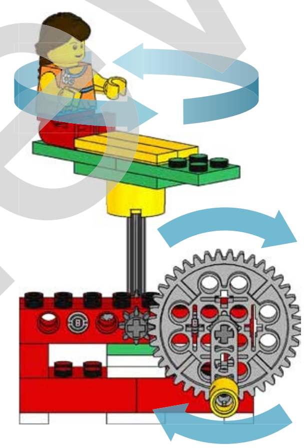


7. Test Merry-Go-Round Model A7.

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

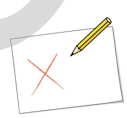
Write down your answer.
Remember to try at least three times for a fair test. It is important to keep an eye on
a) where your handle start position is and
b) where Sam or Sally's start position is on the Merry-Go-Round.





3

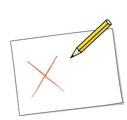
8. Finally, draw a conclusion and check your prediction.
My tests show that Merry-Go-Round (A6 / A7) turns faster.

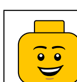


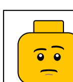
A6

A7

My prediction was (right / wrong).

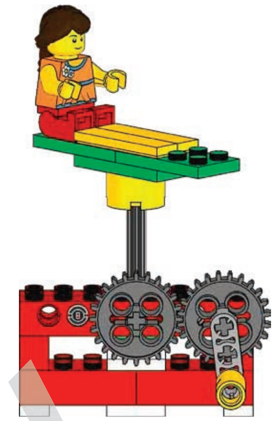


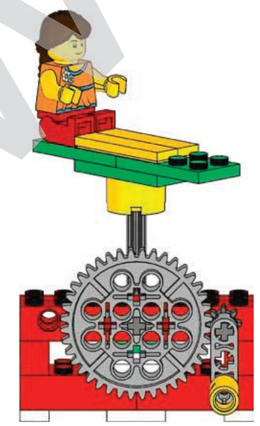




Explore the effect of the different gearings illustrated. Build them into the Merry-Go-Round one after the other.

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

Student 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.

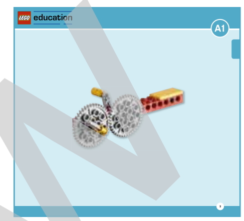
Let's help Sam and Sally!

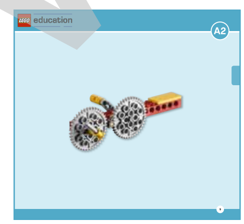
Build a popcorn cart like the one in the picture.

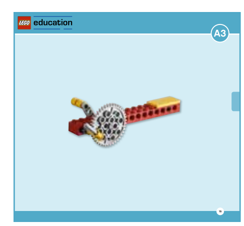
Your design brief is as follows:
- Build a popcorn cart.
- Make a sign that can turn.
- Build a mechanism that makes the sign turn when you turn a handle.

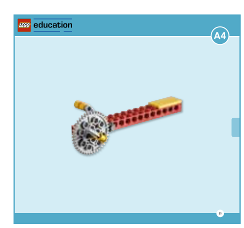
When you have finished, test your cart. Count how many times the sign spins for every five turns of the handle. Assess how easily the sign can be read at a distance. What makes it easy or difficult to read?

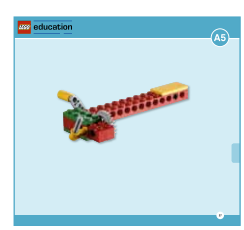
Need help?
Look at:











Problem-Solving Activity: Popcorn Cart

Teacher's Notes

Learning objectives:

Students 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 students to look at the picture on the Student Worksheet and read the accompanying text. If time and facilities are available, have your students 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 students could search the Internet to learn more about the appearance, structure, and function of different sorts of carts and signs.

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

Discuss the constraints and functions your students will have to take into account to carry out the design brief. Try to get your students 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

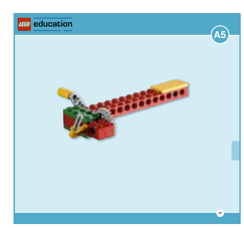
Materials for enhancing the appearance and functionality of the model: Students can use paper, cardboard, and markers to make signs. Additional LEGO elements, if available, may be used to make models more elaborate.

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

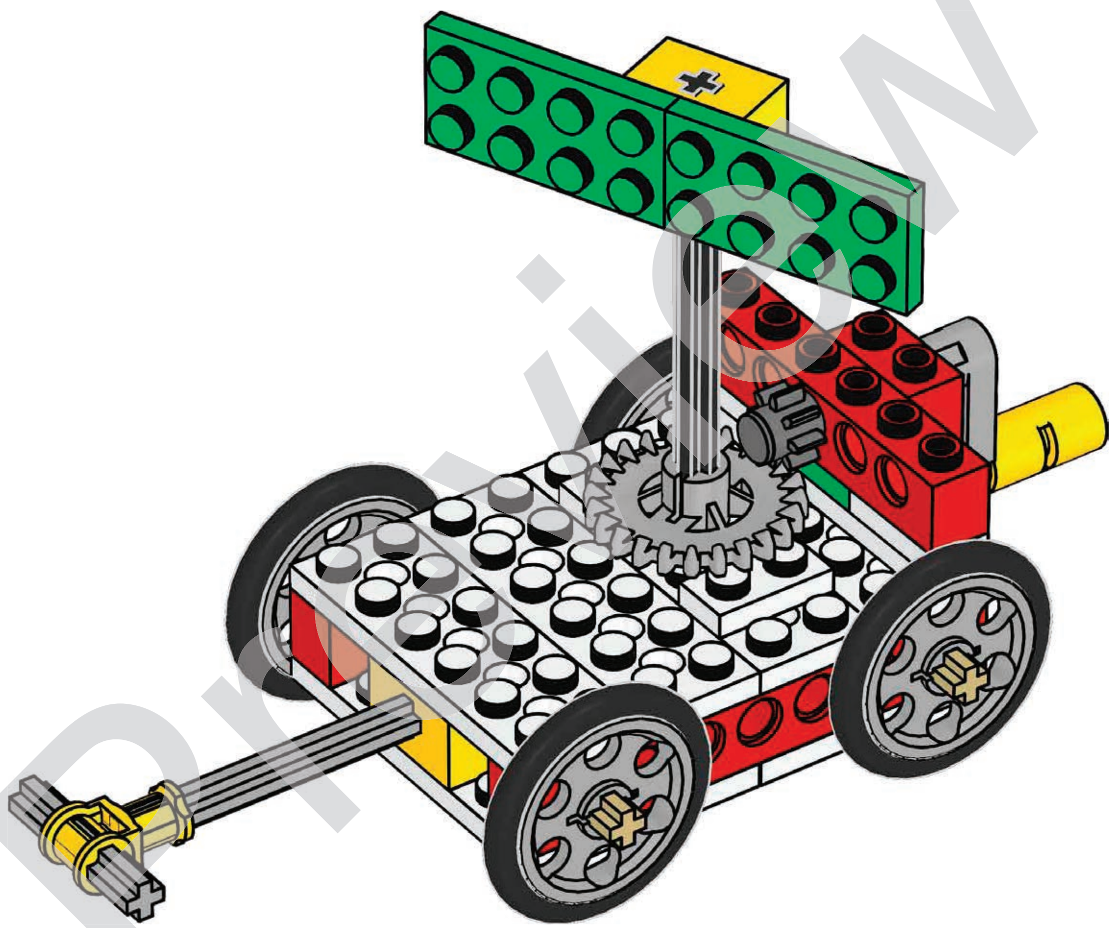
- Carrying out tests to evaluate the performance of their model
- Reflecting on the design brief
- Recording their design by drawing or taking digital photos

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

Establishing the concept

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 space between two lines or planes that intersect; the inclination of one line to another. Measured in degrees or radians.

Axle A rod through the center 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 an automobile 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.

Counter-balance 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 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 specialized 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. Tires grip dry road surfaces better than wet road surfaces.

I

Idler A gear wheel that is turned by a drive gear and that 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 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 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 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.

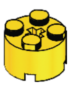
Slip or slippage A belt or rope slipping, usually on a pulley wheel as a safety feature.

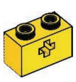
S

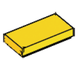
Torque Turning force, for example from an axle.

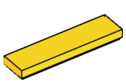
T

LEGO® Element Survey


4x
Brick, 2x2 round, yellow
614324


4x
Studded beam
with crosshole, 1x2, yellow
4233484


2x
Tile, 1x2, yellow
306924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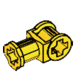
Tile, 1x4, yellow
243124


2x
Tube, 2-module, yellow
4526983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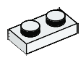
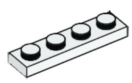
Angular block
with crosshole, yellow
4107800


2x
Cross block, 2-module, yellow
4173666


8x
Plate, 1x2, white
302301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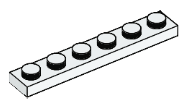
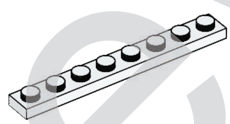

4x
Plate, 1x6, white
366601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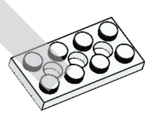
Plate, 1x8, white
346001


2x
Plate with holes, 2x4, white
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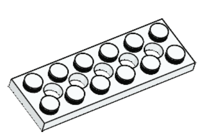
6x
Plate with holes, 2x6, white
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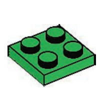
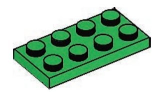

4x
Plate, 2x2, green
302228


4x
Plate, 2x4, green
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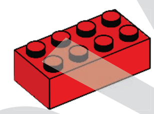
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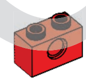
Brick, 2x4, red
300121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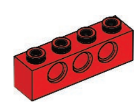
Studded beam, 1x2, red
370021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Studded beam, 1x4, red
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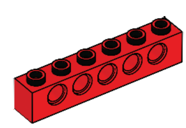
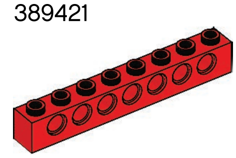
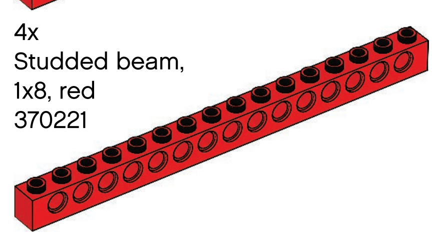

4x
Studded beam, 1x6, red
389421


4x
Studded beam,
1x8, red
370221


6x
Studded beam, 1x16, red
370321

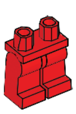

1x
Minifigure, cap, orange
4583147

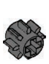

2x
Minifigure, head, yellow
4651441


1x
Minifigure, wig, dark brown
4581313

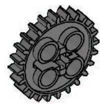

1x
Minifigure, body, white
4549942

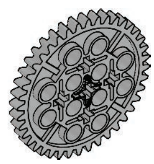

1x
Minifigure, body, orange
4580475


2x
Minifigure, legs, red
9342


4x
Gear, 8-tooth, dark gray
4514559


2x
Gear, 24-tooth crown, gray
4211434

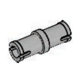

2x
Gear, 24-tooth, dark gray
4514558

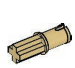

2x
Gear, 40-tooth, gray
4285634

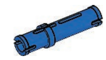

4x
Hub, 24x4, gray
4494222

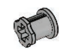

4x
Tire, 30, 4x4, black
281526


16x
Connector peg
with friction, black
4121715

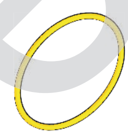

10x
Connector peg, gray
4211807

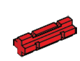

10x
Connector peg with axle, beige
4666579

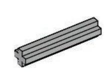

2x
Connector peg
with friction, 3-module, blue
4514553


16x
Bushing, gray
4211622

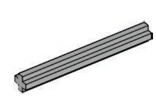

16x
Bushing, ½-module, yellow
4239601


2x
Belt, 33 mm, yellow
4544151

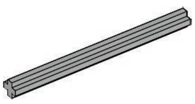

4x
Axle, 2-module, red
4142865


2x
Axle, 3-module, gray
4211815


2x
Axle, 4-module, black
370526

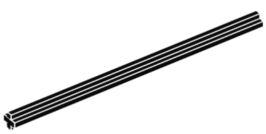

2x
Axle, 5-module, gray
4211639

2x
Axle, 6-module, black
370626

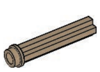


2x
Axle, 7-module, gray
4211805

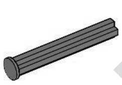
2x
Axle, 8-module, black
370726



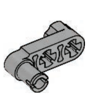
2x
Axle, 10-module, black
373726



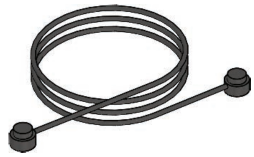
2x
Axle with knob,
3-module, dark sand
4566927



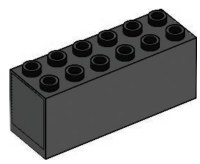
2x
Axle with stop,
4-module, dark gray
4560177



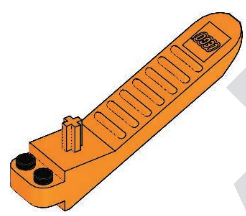
1x
Connector peg, handle, gray
4563045



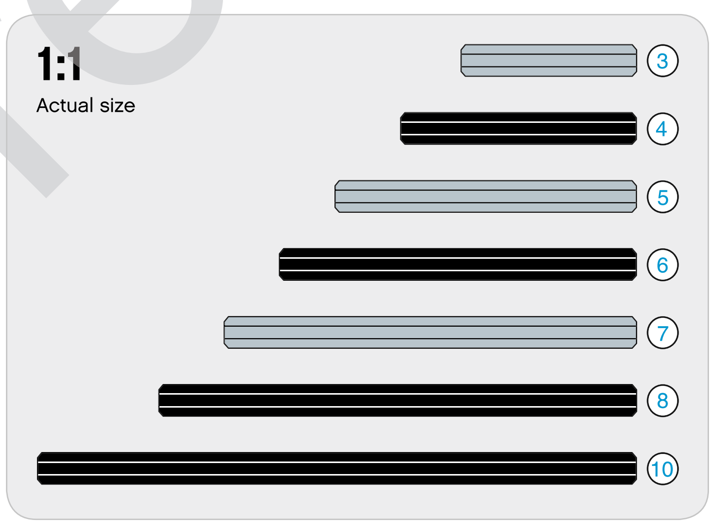
1x
String, 40-module with knobs, black
4528334



1x
Weight element, black
73843



1x
Element separator, orange
4654448



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