

**Popular mechanics**  
**Becoming a designer of machines**  
**Mechanics**  
**Energy**  
**Unit for pupils from 9-11 years**



## Introduction

This is one of ten ENGINEER primary school units developed to support science learning within the context of a wide range of engineering design challenges. Based on the successful Boston Museum of Science *Engineering is Elementary* model of inquiry-based learning, each unit features a different science area and engineering field and requires only inexpensive materials in order to support pupil-led science exploration and problem-solving design. The units have been developed to appeal to a wide range of pupils and to challenge stereotypes of engineering and engineers and so enhance both boys' and girls' participation in science, technology and engineering.

### Our pedagogic approach

Central to each unit is the engineering design cycle: ask, imagine, plan, create, improve. Emphasizing the cycle helps teachers to foster pupils' questioning and creativity, and gives space for pupils to develop their problem-solving skills including testing alternative options, interpreting results and evaluating their solutions. Tasks and challenges have been designed to be as open-ended as possible, and to avoid 'right answers'; in particular, the unit developers have aimed to avoid competition which may alienate some pupils, while retaining the motivation of wanting to solve a problem. An important goal of all of the units is to maximise opportunities for group work and to support pupils in learning to work together and communicate their ideas effectively. Students need to discuss their ideas as they explore a new problem, work out what they need to know and share their findings, design solutions, and then improvements.

### How the units are organised

Each unit begins with Lesson 0, a general preparatory lesson which is common to all ten units. Teachers choosing to use more than one unit will want to start with this lesson the first time they use the units and begin at Lesson 1 in subsequent units. Lesson 1 introduces a story context or problem which drives what happens next: Lesson 2 focuses on what exploring the science that the pupils need to solve the problem, while in Lesson 3 they design and build their design solution. Finally, Lesson 4 is an opportunity to evaluate, present, and discuss what they have done. Each unit is, however, unique, and some units are more demanding in terms of science understanding and the length of time required for the unit varies. Likely timings and age targets are indicated in each unit overview. Units have been designed to be flexible, however – teachers can choose which activities they want to include, and there are options for differentiating activities to cater for a range of abilities.

### Teacher support

Each unit guide has been written to provide appropriate science, technical and pedagogic support for teachers with a wide range of experience and expertise. Each lesson includes suggestions and tips for supporting inquiry-based learning, classroom organisation and preparation. Science and making activities are illustrated with photographs. Science pedagogy notes in the Appendix explain and discuss the science involved in the unit and how to support understanding of the central concepts for pupils in the age range. Worksheets which can be copied and answer keys are also provided.

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## Overview of the unit

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**Duration:** 6 hours and 40 minutes (400 minutes)

**Target group:** 9, 10 and 11 year old pupils

**Description:** by participating in the challenge to create mechanical machines (toys, or a counter) the pupils become engineers and learn about Mechanics with a focus on transmission and transformation of motion. During this unit, the pupils manipulate real objects to describe the simple elements of Mechanics (cams, levels, gears) and use them as tools to understand how an object works. The pupils use simple materials to test all their hypotheses and ideas and then improve them. Pupils work in groups and present and discuss their proposals. This process is seen as a way to interest pupils in science and engineering, no matter what difficulties they may face. The activities are linked with a story and pupils need to solve a challenge. The final evaluation lesson enables pupils to discuss whether they have created an object that works.

**Science curriculum:** this unit relates to the science curriculum for machines created by the human being.

**Engineering field:** this unit introduces the field of mechanical engineering.

**Objectives; in this unit the pupils will learn:**

- how to apply some key elements of basic engineering to the creation of a mechanical toy;
- to understand and appreciate the science of force and movement involved in the project;
- to apply the Engineering Design Cycle to meeting engineering challenges.

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**The lessons in this unit:**

A **Preparatory lesson** aimed at raising awareness of how engineering contributes to our daily lives in ways that are not always obvious.

**Lesson 1** introduces the engineering problem, its context and the engineering process: pupils must imagine a counter to count visitors and/or create mechanical toys to tell stories. Pupils are asked to define and analyse how a mechanical motion could be transmitted and transformed.

**In Lesson 2** the 'ask' element of the engineering process leads to an investigation of mechanical engineering. The teacher can choose to construct a counter and explore gears or alternatively mechanical toys and exploring cams. This lesson is an opportunity to gather necessary knowledge to create pupils' own mechanical object.

**Lesson 3** involves the pupils in applying the engineering design process to meet the challenge, to create mechanical objects (toys or counter). Pupils can start with a solution suggested in the teacher guide or invent one by testing different materials.

**In Lesson 4** it's time to evaluate the process of creating the mechanical toys or the counter. This is also the moment for pupils to show if they were able to meet all the criteria and to talk about how they made improvements.





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## Resources











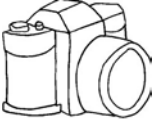



List of all the materials and quantities needed for 30 pupils.

Material	Total amount	Lesson 0	Lesson 1	Lesson 2	Lesson 3	Lesson 4
Scissors 	30		1	30	30	30
Elastic bands 	40			30	20	20
Glue sticks 	30			30	30	30
Blu-tack 	13			3	5	5
Dowels 	100			40	30	30
Straws 	100			50	30	20
Duck tape 	3			1	1	1
A glue gun 	1			1	1	1
A tendril 	5			5	5	5
Box made of polystyrene	15			15	15	
Pencils 	30		30	30	30	30

Material	Total amount	Lesson 0	Lesson 1	Lesson 2	Lesson 3	Lesson 4
String 	1				1/2	1/2
Cardboard boxes	30			15	15	
A cutter for the teacher (not essential) 	1				1	1
Corks 	20				10	10
Some cardboard	X			X	X	X
Modeling clay ("play do") 	X				X	X
Some paper				X	X	X

1. These materials are necessary for the demonstrations.







Material	Total amount	Lesson 0	Lesson 1	Lesson 2	Lesson 3	Lesson 4
A bicycle 	1		1	1		
A watch 	1		1			
A baking roller 	1		1			
A cork screw 	1		1	1		
Material	Total amount	Lesson 0	Lesson 1	Lesson 2	Lesson 3	Lesson 4
An umbrella	1		1			

						
Scissors 	1		1			
Pencils and pens 	2		2			
A compass 	4			1	4	4
A school bag 	1		1			
A mechanical toy 	1		1	1	1	1
A camera 	1		1			
A crane toy 	1		1			
A fire truck (a toy) 	1		1			
A lamp with a visible mechanism 	1		1			

The teacher can also bring non mechanical objects, like a balloon, a shoe, a book, a candle, a shirt flap, a fork, and so on.



These materials are optional. If the teacher introduces some of these, the discussion with the pupils will be more interesting.

Material	Total amount	Lesson 0	Lesson 1	Lesson 2	Lesson 3	Lesson 4
A manual typewriter 	1		1			
A microscope 	1		1			
A sewing machine 	1		1			
A centrifugal drier for salad 	1		1			
An egg beater 	1		1			
Kits of wheels (suggestion: Celda or Lego) 	10 kits			10 kits		

## Lesson 0 – Engineering an envelope

### What is engineering?

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**Duration:** teachers can choose how long to spend on this lesson depending on how much experience pupils already have. The introduction, main activities and conclusion will take up to 40 minutes; additional extension work can add a further 10-30 minutes.

#### Objectives, in this lesson pupils will learn that:

- engineers design solutions to problems using a range of technologies;
- technologies that are appropriate for a particular problem depend on the context and materials available;
- made objects have been engineered to solve problems;
- engineers can be men or women.



#### Resources (for 30 pupils)

- 8 'post-it' notes packs
- 8 sets of at least 5 different envelope types
- 8 sets of at least 5 different objects
- 8 sets of packaging examples for optional extension work
- Card, paper, glue, scissors for optional extension work



#### Preparation

- Collect together a range of different envelopes and packages
- Print copies of worksheet 1 if using
- Collect pictures for introductory activity

#### Working method

- Small groups
- Whole class discussion



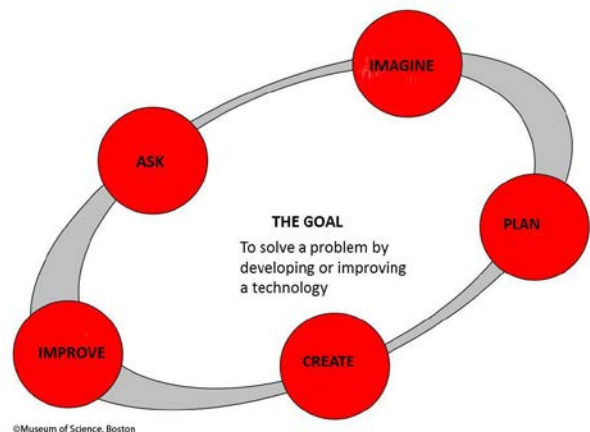
#### Context and background

*This lesson is the same in all units and is intended to encourage thinking about what technology is and to challenge stereotypes about engineers (particularly those associated with gender) and engineering.*

*It aims to develop the understanding that objects in the made world are designed for a purpose and that technology in its broadest sense refers to any object, system or process that has been designed and modified to address a particular problem or need.*

*Pupils can think about this by discussing what problem the technology of a particular artefact (in this case an envelope) is intended to solve. In this lesson, they discuss the range of technologies that are used to engineer an envelope for a particular intended purpose.*

*The lesson is also intended to avoid value judgments of 'high tech' versus 'low tech' and to encourage pupils to appreciate that it is appropriate technology in a particular context that is important: the range of available materials will determine the technology that the engineer applies to solving the problem.*



### o.1 Introduction - 10 minutes - small group and whole class discussion

Divide the class into groups of 4 and provide a packet of 'post-its' for each group. Ask the groups to discuss all the things they associate with the terms 'engineering' and 'technology'. Ensure that, as part of the discussion, each individual within the group puts at least one idea on a 'post it'.

Invite each group to place their 'post its' on to a master display sheet and briefly explain their choices to the rest of the class. Keep the whole class list for review at the end of the lesson.

#### Additional support for discussion



*This part of the lesson can be extended by providing pictures of stereotypical and unusual examples of engineering and asking pupils to group the pictures into those that they associate with engineering and those that they do not. You could use Worksheet 1 for this activity, or use the pictures there as a whole class display. Ask pupils to work in pairs to decide which of the pictures they think are related to engineering and to give their reasons why they think that some are and some are not. Each pair of pupils could share their ideas with another pair and discuss similarities and differences in ideas. You could use these ideas as a basis for a whole class discussion; encourage pupils to open up their thinking about what counts as engineering and who could be involved in it.*

### o.2 Activity 1 What is an envelope? - 5 minutes, small groups

Organise pupils into small groups to discuss what an envelope is and what counts as an envelope. To help discussion, provide a range of examples which cover and/or protect objects or materials for particular purposes (as in the pictures).



*An important part of this activity is to encourage pupils to notice that there are many interpretations of the idea of an envelope. In the pictures there are some examples that might challenge their idea of an envelope: they include a broader interpretation of what an envelope is as something that 'houses', 'protects', 'holds in place', 'covers', 'hides' or even 'reveals' a range of different objects.*

### o.3 Activity 2 Matching envelopes to objects - 15 minutes - small groups and whole class discussion

Divide the class into groups of 4 and provide a range of 'envelopes' and objects that could go in them. Ask the pupils to select which envelopes would be most suitable for the objects and to explain why.



*The objects could include: a pair of spectacles; a certificate or photograph that must not be bent; a delicate piece of jewellery; a returnable DVD; a set of confidential papers; a pair of scissors. The range of objects and envelopes can be varied according to context and what you have available.*

The following questions can help guide the discussion:

- What material is the envelope made from?
- What fixings and fastenings are used in the envelope?
- What range or types of objects could the envelope be used for?
- What other materials it could be made from?

Each group should report their ideas back to the class.



*There is an opportunity here for the teacher to lead the discussion and talk about the various technologies used in each engineered envelope including the types of structures, fixings and fastenings used (e.g. reusable or permanent fixings; reinforcement areas; internal and external materials selected; how edges are sealed.)*

*This is an evaluative activity and could be related back to the engineering design process: discussion could include thinking about the process that engineers need to be involved in when making something to solve a particular problem.*

### o.4 Extension work - optional - 10-30 minutes - small groups

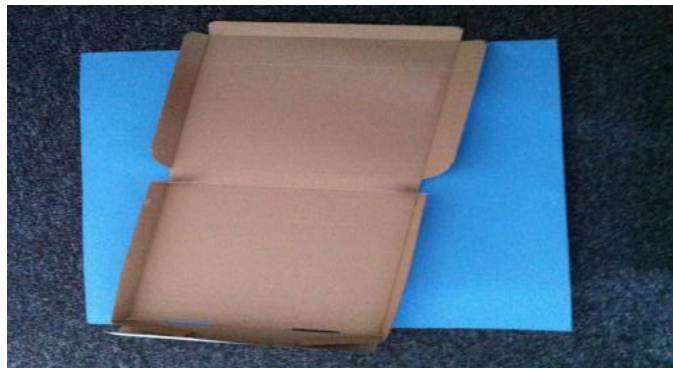
1. Present pupils with a range of envelopes and ask them to evaluate their design in terms of their fitness for purpose (see picture).



*Envelopes could be compared in terms of the types of fastenings and reinforcements used, and the mix of different materials used (e.g. bubble wrap, absorbency, strength- i.e. resistance to tearing).*

*This activity could be extended to looking at different types of packaging in relation to net folds and how these are used to reduce (or eliminate) the need for adhesives in the manufacturing process. The following 3 pictures demonstrate packaging that does not use any form of adhesive; the making involves only one type of material using cuts and folds for fastenings.*





2. Organise pupils into small groups to design and/or make an envelope in order to deliver a particular chosen object. Groups will need to draw on their understanding of materials and the design making process to produce a range of alternative designs. These could then be evaluated in whole class discussion.

### 0.5 Conclusion – 10 minutes - whole class discussion

Lead a plenary discussion drawing on the original class 'post its' (and where appropriate their groupings of the 'engineering' photographs), reminding the pupils of how their original thinking might now have changed. Ask pupils to reflect on what an engineer does and what technology is.

- Emphasise that most things we use are made for a purpose and that engineers use a range of skills in finding solutions to problems.
- This involves thinking about solutions to solve problems; some of these work and some are less successful – the engineering design process includes evaluation and improvement.
- It is not 'high' tech or 'low' tech but *appropriate* technology that matters - engineers need to consider their context and resources.
- There are many types of engineering, and many different types of people from across the world, and both men and women, are engineers.



*There might be a range of equally acceptable definitions for the terms 'engineer' and 'technology'; these terms are often used interchangeably, e.g. engineering could be considered as the use of technology for problem solving. In talking about the relationship between*

*engineering, science and technology, pupils can be encouraged to think about how engineers, in the process of making objects to solve problems, use a range of technologies (including fixings and fastenings, various types of materials and different components in a range of systems) and a range of science understandings. This is an opportunity to open up discussion about how things are made and by who, and what is involved in the process of thinking about solutions to problems.*

#### **o.6 Learning outcomes - for optional assessment**

At the end of this lesson pupils should be able to:

- Recognise how a range of systems, mechanisms, structures, fixings and fastenings are used in artefacts in different ways to provide a range of solutions to solve problems
- Understand that appropriate technology is often dependent on the context and materials available
- Recognise that engineers use a wide range of skills in developing solutions to problems
- Recognise that many different types of people with different interests and skills can be engineers

# Lesson 1 – What is the engineering problem?

## Finding out about the challenge



Duration: 70 minutes

### Objectives, in this lesson the pupils will learn:

- to identify the key means by which machines transform force into movement;
- to deploy the Engineering Design Cycle has a starting point to their project;
- to work together in a collaborative and effective way.



### Resources (for 30 pupils)

- 30 x Worksheets 1

- Some objects brought by the teacher or pupils. Some are optional but could be an opportunity to lead interesting discussions.



### Preparation, the teacher has to:

- Prepare the worksheets.
- Ask pupils to bring a toy each.
- Read the story to decide whether to adapt it.
- To decide whether the counter can be used as an extension activity.

### Working method

- Plenary to set the context
- Working in teams to experiment
- Plenary to discuss results after experimenting

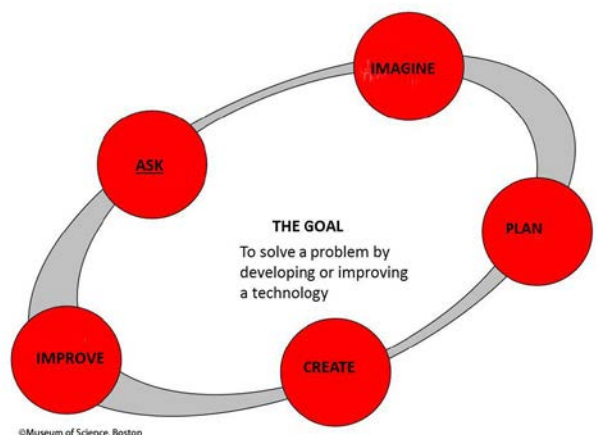


### Key ideas in this lesson

- Mechanics are present in many objects that pupils use every day.
- Pupils establish a rule themselves and together are able to define a mechanical object.
- Pupils work on a science investigation in groups.

### Context and background

The challenge, the context and the design cycle are introduced. The teacher sets the challenge by telling the story. The pupils consider what knowledge they have to know in order to meet the challenge. They need to be able to define exactly a mechanical object, helped by analysing objects brought by the teacher and/or pupils.



### 1.1 Introductory activity – set the context – class discussion - 10 minutes

The teacher reads the story to set the context (see appendix). Here is a summary: Mr Toyz is a toy seller. He receives a letter from Alfred, his son who is living away from home. Alfred asks him for help to create mechanical toys for some poor children. Unfortunately Mr Toyz has no idea how and he decides to organize something new: ask children to create toys for other children. The toys need to relate to popular stories. This venture becomes successful and Mr Toyz's shop becomes too small. In fact, he can only welcome less than ten persons. To find a solution, Mr Toyz asks older children to imagine a mechanical system which could count the people who enter in his shop and indicate when the shop is full.

The teacher emphasises that the next four lessons are going to involve building some mechanical toys for Mr Toyz. The teacher explains that the class has two jobs to do before they can begin to design their toys: first to work out what makes a mechanical toy different from any other toy; and secondly what makes it mechanical.

### 1.2 Define an object using a mechanism – working in teams – 25 minutes

Pupils will create a mechanical object in this unit. So it is important to start the project by understanding what a mechanical object is. The teacher discusses with the children the toys they have brought in to decide which of them is mechanical. He or she also brings some mechanical objects and includes them in the classroom. The children are also asked to think about what everyday objects in the classroom might be mechanical. The pupils too are asked to find them and discuss why they think that they are mechanical. We recommend the teacher to allow time for this activity: it is important for pupils to learn that they can identify mechanical objects. It is the first opportunity to identify such objects (like gears, cams, axles). They may not know the technical language at this stage but they should be encouraged to speculate on what words could be used to describe the mechanical parts of the objects they discover. The teacher can use their speculative language to introduce the more technical language of mechanics.

The class are organised into groups of 5 children, preferably gender and attainment mixed.

When the pupils find an object, they fill in the **worksheet 1 lesson 1** with a view that each group presents the object (the name, the purpose and the explanation why the object is mechanical, using the appropriate vocabulary). It gives an opportunity for the teacher to clarify the different mechanical objects.

### 1.3 Group presentations and establishing the key learning points - 25 minutes

Pupils identify common points in each mechanical object they manipulate and to try to give a description. The teacher writes the pupils' proposed description, explaining why an object is mechanical or not, on the board. This part of this activity is an occasion to establish the key teaching point by using the first stage of the engineering design cycle in that the children are beginning to ask questions about what makes mechanical objects work in the way they do.





**Key teaching point to be established by pupils and reinforced by the teacher:**

*A mechanical object is not necessarily entirely mechanical. It can be electrical with some mechanical parts. To be sure to identify mechanical objects, we need to "enter inside the object and explore it" and to understand how it functions. A mechanical part of object is a machine. The machine is composed of gears, chains (like a bicycle), cams, levers, or pulleys.*

*This machine is a connection between the hand or foot (initial motion) and the final motion. When you use a bicycle, you do not directly push the wheel, but you pedal moving a chain between the two wheels. In this way your motion is transmitted. A mechanical machine transmits the initial motion to the final place where the motion is used.*

*A mechanical object can either represent the whole object of which the mechanical machine is part (such as a bicycle where the mechanical machine is the part involving the chain and perhaps gears), or only a part of it (the dial of an old telephone).*

**1.4 Conclusion – plenary - 10 minutes**

The teacher reviews major teaching/learning points from the lesson:

- That mechanical design can be used to transmit force and transform motion
- That they are at an important point in the engineering design cycle in that they are asking questions about designing their mechanical toys
- They have learnt some important words which will help them in their task – cams and gears
- That they have worked well in their groups and are excited by the unit

## Lesson 2 – What do we need to know?

### Finding out about Mechanics

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**Duration:** 120 minutes

#### Objectives, in this lesson the pupils will learn:

- to understand forces e.g. that gears and cams can both transmit and transform motion;
- that the form of the mechanical machine (the type of cam and/or the size of the gears) influences the motion.



#### Resources (for 30 pupils)

- 30 Worksheets 1, 2 and 3
- A cork screw
- A bicycle
- Some mechanical toys

- Scotch tape

#### To explore gears

- Some kits including wheels. We suggest using Celda or Lego (see appendix).

#### To explore cams

- Cardboard
- 30 scissors
- Some elastic
- 30 glue sticks
- Some blu-tack
- Dowels
- 50 Templates of cams (see Appendix)
- 50 Straws
- Some paper

#### To construct their own toothed wheels

- plastic tops with different sizes
- a glue pistol
- some cardboard
- some cardboard sticks or nails
- 5 tendrils
- box made of polystyrene.



#### Preparation, the teacher needs to:

- test the experiments
- prepare and organize the materials
- prepare the worksheets

#### Working method

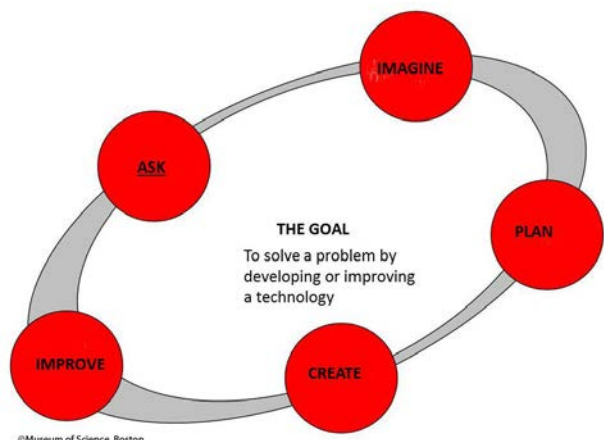
- Working in teams to explore
- Plenary to discuss the results



#### Context and background

The 'ask' element of the engineering process leads to an investigation of Mechanics. The pupils experiment and they "enter" inside mechanical machines. They discover how the size and the shape of gears and/or cams influence the transmission of the motion.

The teacher can choose the content of the lesson 2: make a counter and explore the gears, or make a mechanical toy and explore the use of cams.



### 2.1 Introductory activity – review previous lesson – whole class discussion – 15 minutes

The teacher undertakes a short review of lesson 1, reminding the pupils of the engineering problem to be solved. The teacher asks the pupils about the key teaching point established during the first lesson so as to remind pupils which objects are termed mechanical and which are not. This reminder will help them in undertaking the next activity in lesson 2.

The teacher then works through an example of a mechanical object in order to ensure that pupils can access the key vocabulary of mechanical engineering, including gears, levers and cranks. This could involve the appraisal of a fairly large object such as an anglepoise lamp with highly visible mechanics or, if the classroom has access to the internet, via the 'how stuff works' website ([www.howstuffworks.com/](http://www.howstuffworks.com/)) Pupils "enter" inside a mechanical object and discover how it works

### 2.2 What's happening inside a mechanical object? – working in groups – 20 minutes

It is suggested that the pupils work in groups of 4. The teacher distributes worksheet 1, lesson 2 one per group. Pupils examine the picture and determine the moving part of the object and colour such parts. The teacher can choose to distribute all four objects, or only some of them (the cork screw, the bicycle, or some toys). If possible, each group should also have the object itself as well as the worksheet so pupils can manipulate them and determine their operation.

At the end of the activity, each group explains the operation of each object to the others.



*For activities 2.3 and 2.4, the teacher can choose to extend the first into the second activity depending on time and the pupil's aptitudes between exploring gears or cams. Activity 2.4 describes experiments with gears. This part will enable the teacher and pupils to make a counter. Activity 2.3 is about creating a mechanical toy. Activity 2.4 is more difficult than 2.3, but it can add to the exploration of Mechanics.*

### 2.3 Discovering cams! – Working in Groups - 80 minutes

The purpose of this activity is to understand basic mechanics through the creation of a cam; the pupils' first task is to make a cam using **worksheet 2 lesson 2**. It is best if this is a teacher led activity with the pupils in groups following each stage in the creation of a basic cam.

Having created the basic cam and established the relation between turning the axle and moving the flag. The children can then experiment using different shaped cams - see

**worksheet 3 lesson 2** and **templates for cams**.

Pupils manipulate cams to understand how to transmit a motion and how to transform it. They use a simple cam mechanism to establish two rules, after solving two challenges (worksheet 2). The teacher can ask pupils to make predictions before testing them.

1. *Where is it best to place the cam according the motion chosen?*
2. *Which cam shape is appropriate for the motion chosen?*

To discover more : try the challenges!

In order to see if the pupils really understand how a cam can transmit or transform a movement, the teacher can establish challenges for the groups.

To discover and understand how cams work, pupils are asked to make a cam mechanism.

Then they use this mechanism to experiment with shapes of cams. They make a note of each result because this is needed to solve additional challenges (worksheet 3 and 4). Pupils imagine and make shapes to find one or more ways to:

- Make the follower rise the highest possible
- Make the follower rise 8 times while the cam rotates for one complete revolution
- Make the follower turn as fast as possible

Each challenge is clarified in the appendix.

#### 2.4 Extension Activity: Discovering gears! – Working in teams - 80 minutes

- To discover the operation of gears, we suggest the teacher brings a clock in to the classroom and opens the clock and shows the gears inside. The teacher can move the different parts of the clock to show the transmission of the motion.
- Pupils manipulate gears to understand how to transmit and transform a motion. They use two toothed wheels of different sizes, to establish three rules. We suggest using the worksheets to report their results.
  1. *To transmit a motion, the toothed wheels need to touch each other.*
  2. *To accelerate a motion, the final wheel has to be smaller than the initial one.*
  3. *To slow down a motion, the final wheel has to be bigger than the initial one.*

To discover more: try the challenges!

In order to see if the pupils really understand the different functions of gears (transmit, transform, accelerate or slow down the motion), the teacher can establish special challenges for the groups.

The teacher can use special kits (for example, pedagogical materials from Celda or Lego...) with simple mechanical elements. We advise the teacher to pay attention to choosing kits with different sizes of wheels. If it is possible, it is easier to explain with coloured wheels. But the teacher can also decide to make, with the pupils, their own toothed wheels. The steps are explained in the appendix.

Then, the teacher gives each group a kit and establishes rules/restrictions (use only 2 wheels, or use the biggest wheels...).

The teacher can also ask the pupils to show one or more ways to:

- Transmit a motion
- Transform a motion
- Accelerate a motion
- Slow down the motion
- Transform a regular motion into an irregular one
- Guess the direction of a wheel

Each challenge is clarified in the appendix. We suggest one solution for each challenge, but pupils may find others. The purpose is to make sure the pupils are really aware of the different functions of gears. If the teacher sees the pupils are really at ease with the first challenge, they can add a time element to complete the challenge so that it will become even more challenging for the groups. Pupils can be asked to establish rules for each challenge.

## 2.5 Conclusion – Plenary - 5 minutes

The lesson ends with a summary of what the groups have established. Each group the teacher can ask them to present their solution for a challenge to the rest of the class.

As certain rules are to be used in lesson 3, we suggest the teacher writes a summary on the board to remind the pupils:

### Concerning gears:

1. *To transmit the same motion from a first wheel to a third one, the first wheel and the final one have to be the same size.*
2. *To slow down a motion, the final wheel has to be bigger than the first one.*
3. *To transform a regular motion to an irregular one, the form of the wheel has to change. Pupils use this rule to imagine a 'jumper'. The second wheel has to turn after a turn of the first wheel.*

### Concerning cams:

1. *The follower has a constant motion, if the shape of the cam is circular.*
2. *The follower rises up and drops if the cam is pear shaped, drop or circular eccentric. The number of the "teeth" of the cam influences the motion of the follower.*
3. *To accelerate the follower, the cam must be the nearest to it.*

At the end of the lesson, the pupils will be able to:

- Connect the motion and the mechanics used.
- Choose the best mechanical elements according to the motion desired.
- Understand that the rules written on the board are important: it doesn't matter if they haven't yet understood them exactly because they can experiment during their construction (lesson 3).

## Lesson 3 – Let's build!

### Design your mechanical object (a toy or a counter)

---



**Duration:** 100 minutes (plus 80 if using the extension activity)

#### Objectives, in this lesson the pupils will learn:

- to deploy the Engineering Design Cycle to create a mechanical toy;
- to express their scientific understanding of forces and movement in an engineering project;
- to build a successful toy for subsequent evaluation.



#### Resources (for 30 pupils)

- 15 templates to create the object. We suggest constructing 1 object per group of 2 or 3 pupils

#### For the counter:

- 30 templates of the wheels
- cardboard
- wooden sticks (the axle)
- 30 scissors
- modelling clay ("play doh")
- 30 straws
- 15 box (we suggest using a polystyrene box)
- 30 pencils
- 30 glue sticks
- 5 tendrils
- some string
- and all material asked by the pupils to create their machine

#### For the mechanical toy:

- Cardboard boxes
- wooden sticks (the axes)
- some paper
- 30 glue sticks
- 30 scissors
- a glue pistol
- scotch tape
- a cutter for the teacher (not essential)
- corks
- elastic
- 5 tendrils
- straws
- templates of the shapes of cam
- blu-tack
- some cardboard
- 30 pencils



#### Preparation, the teacher needs to:

- Prepare the materials.
- Prepare some models of a counter (or a toy).

#### Working method

- Working in groups



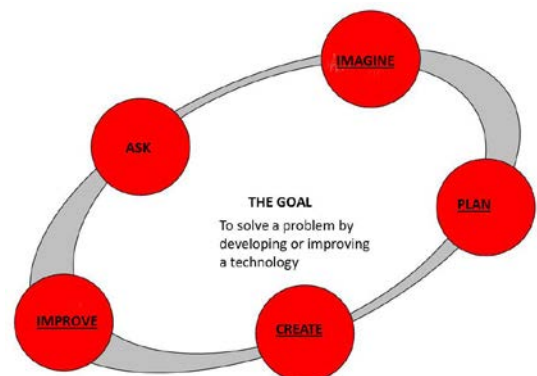
#### Key ideas in this lesson

- To be able to imagine a machine and to plan its building.
- To be able to present ideas to the other pupils.

---

#### Context and background

*In this lesson the pupils go through the steps 'imagine', 'plan', create' and 'improve'. The pupils use the science they have learned to meet the challenge.*



### 3.1 Introductory activity – review previous lesson – class discussion - 10 minutes

The teacher along with the pupils sums up what they have learned in Lesson 2 about the relationship between force and movement and the role of gears and cams in controlling movement. They discuss the rules established and formalise the challenge they have to solve. They are reminded of the engineering design process. This process is composed of 5 steps that will be used to structure the lesson:

- “Ask”: the teacher reminds pupils of the story and the challenge pupils need to solve.
- “Imagine”: pupils suggest ideas. They can draw schemes to formalise them.
- “Plan”: using their schemes, pupils gather materials they need.

In reality, these three steps can be mixed, but all must be present.

- “Create”: pupils create their prototype.

The fifth step “Improve” can be discussed during the conclusion for lesson 4.

### 3.2 Mechanical toys – working in groups - 60 minutes

#### **Step 1: Ask Explore and disassemble some toys to see the joining methods**

The teacher brings a mechanical toy to show how it works. The teacher can ask questions as “What motion can the toy show?; How does this part turn/move?; What makes it turn?” After the pupils indicate and explain their ideas, the teacher shows the inside of the toy and how it works.

#### **Step 2: Imagine Brainstorming**

The pupils are asked to give examples of stories, for example: little red Riding Hood, or Cinderella. At the end of this brainstorming, the groups or the teacher choose the story. The pupils then imagine a mechanical toy to include in the story. We suggest that 4 pupils work together. Each group has to imagine the motion they want to create for their toy and draw a design. The students are asked to list the materials they need to use to create their toy.

#### **Step 3: Creating the toy**

The teacher prepares the materials listed at the beginning of this lesson. The teacher can also add specific materials asked by the pupils. Each step to create the mechanical toy is explained in the appendix.

#### **Step 4: Presentation of the prototype**

This is an important part of the Cycle in which the pupils evaluate their engineering success

### 3.3 Extension activity - the counter – working in groups - 80 minutes

This activity is more complex. It’s a complementary activity for more able pupils, or pupils at a higher grade level.

#### **Step 1: Brainstorming**

The pupils are asked to describe a counter. They can relate to examples they find in the classroom, shops, their home, etc. They explain what they can do with a counter: add and subtract. At the end of the brainstorming session, the teacher reminds the pupils about the challenge: make a counter to count the persons inside Mr Toyz’s shop. To suggest additional ideas, this step can conclude with a visit to a technical museum.

**Step 2: Making the machine**

Each step is explained in the appendix.

**Step 3: Presentation of the prototype-****3.4 Conclusion – plenary - 30 minutes**

At the end of lesson 3, they analyse their model and notice any problems in using it. The improvements are made in lesson 4. As part of the main activity in this lesson, the planning and making are explicitly related to the engineering design process-

Each group presents their prototype toy to the class. They note carefully any suggestions for improvement which are made by their colleagues to take forward to the next lesson



## Lesson 4 – How did we do? Is the challenge met?

---



**Duration:** 100 minutes

### Objectives, in this lesson the pupils will learn:

- how to improve their object;
- to evaluate and analyse the product so as to improve it.



### Resources (for 30 pupils)

- mechanical objects built in lesson 3
- pencils
- some paper
- some glue
- scissors
- materials asked for improvement. It depends on the improvements decided by the pupils.



### Preparation, the teacher needs to::

- Gather pupils' products.
- Prepare the materials asked for by the pupils.

### Working method

- Working in groups
- Plenary

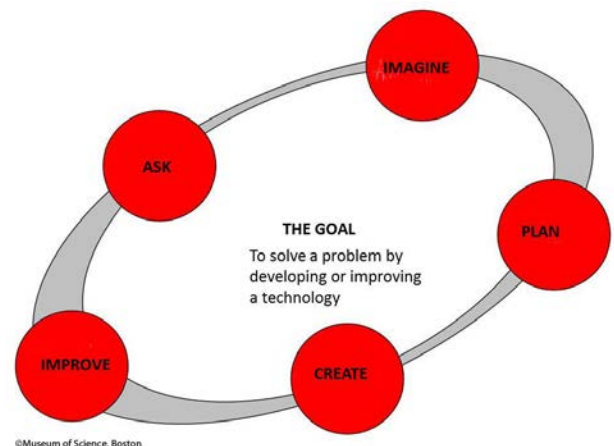


### Key ideas in this lesson

- To be able to evaluate and analyse the product so as to improve it.
  - To discuss the engineering process.
- 

### Context and background

*In this lesson the process and the product are evaluated. Is the challenge met? How did the pupils apply the science they learned and how did they work with the design cycle? This is also the moment to present their solution to the problem and be proud of what they have learned and created.*



#### 4.1 Introductory activity – class discussion - 15 minutes

The teacher along with the pupils sums up the achievements in Lesson 3.

Each group sets out their plans to improve their toy on the basis of the points made in the previous lesson.

#### 4.2 Improvements – working in teams – 60 minutes

The pupils need to make important improvements to their machines (a toy or counter). They need to indicate additional materials they need. They also need the opportunity to exchange their suggestions with the other groups and get new ideas:

For example, for the mechanical toy:

1. use thicker shapes for the cam so that it does not allow slippage off the cam;
2. use a thinner dowel in order to make it move freely within the straw;
3. use a larger box to add characters;
4. change some of the movements to test other options;
5. use another material for the cam, or, for instance, use a glue pistol instead of blu-tack to secure the cams.

For example, for the counter:

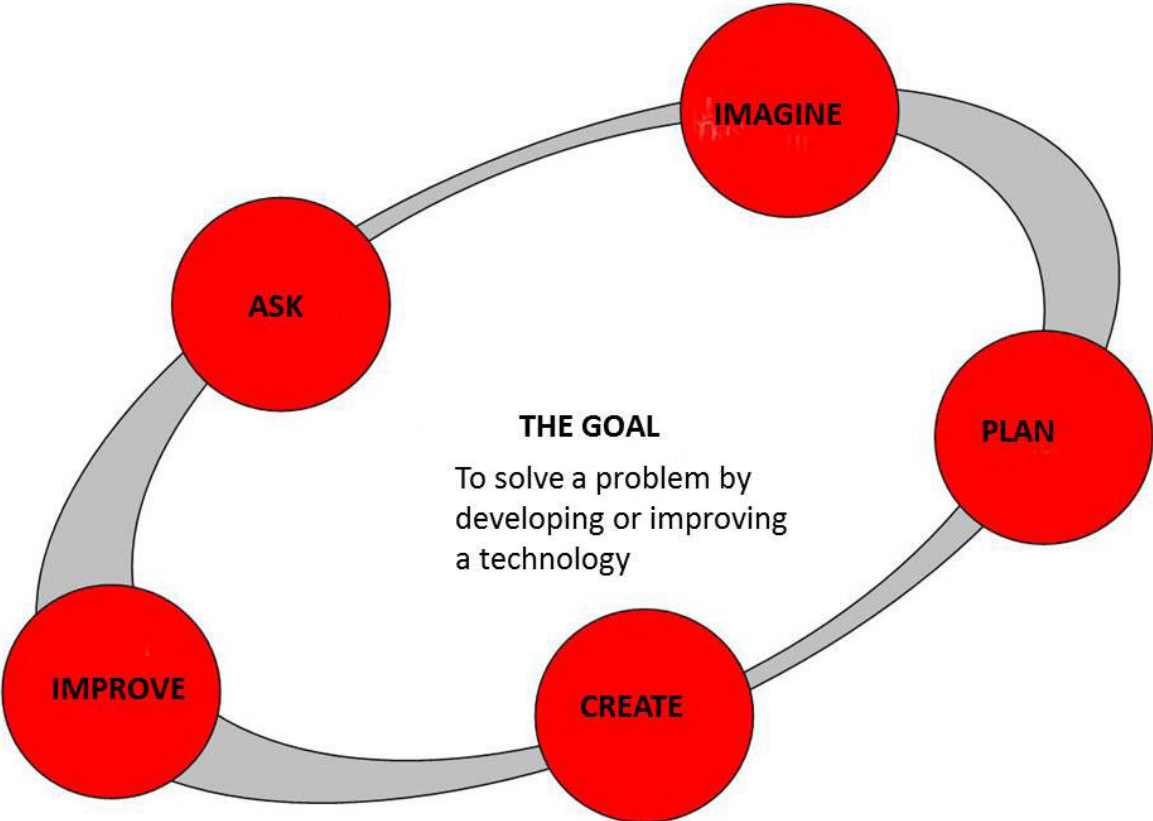
1. use larger wheels to make the connection between them better;
2. colour the wheels to make them clear;
3. write the numbers on the wheels bigger so they can be read easier;
4. use a material other than polystyrene to give better support;
5. put sticks on the inside of the cardboard teeth to make them stronger.

Each group needs to decide which ideas are to be kept. After collection of the different ideas, the groups are ready to start to build a new machine. The teacher can give them more time for constructing their new machine. The pupils will follow the steps described in lesson 3 to build their new machine and along with the construction, make their improvements.

#### 4.3 Conclusion – plenary - 25 minutes

When pupils have improved their machine; they present them to the others. At the end of this lesson, the teacher and pupils discuss what they have learned, the engineering process and the five steps: 'Ask', 'Imagine', 'Plan', 'Create' and 'Improve'.

Engineering design cycle



©Museum of Science, Boston

## Story to set the context

We are in Hagury, a little town... This town is famous for something in particular... Do you know what it is? No?! That's surprising! It's well-known, thanks to a special store! Mr Toyz's store. He has a most marvellous job. He's a toy designer. And more specially, he's the best one! In fact, his father was a toy designer too, as was his grandfather also.

For each important event, Mr Toyz makes new toys. Christmas has just ended and there are just a few days to think up new toys for New Year's Eve. But there is a problem... Mr Toyz has always created his toys himself. And he is so creative that we cannot name all his inventions. But today, he has run out of ideas.

Each morning, he goes to his workshop and tries to think up new toys. But, after all those years of designing, his imagination has run out... and today...

"I've created so many toys... And now, I am a failure! I have no more inspiration". Mr Toyz is thinking when someone knocks on the door. It's the postman.

"Good morning Sir! I have some letters for you!"

Three letters arrive and one is very different from the others. Mister Toyz recognises immediately the stamp: it comes from a place faraway. His son, who has a toy shop also, has left France in order to help the children in that place and in his letter, he's asking for something special...

*"Dear Dad,*

*I've already been here for six months... It's not easy every day, as you know, but I feel lucky to be able to help people here, with the few resources I've got. I teach them everything I can, help them to build houses... But now, I want something more. I would like to make the life of the children better, or at least more fun! They have no toys here, and not enough money to buy them and they just have fun with things they find... I think you understand why I need you. Can you make some toys for the children here? You know about our conditions over there... I trust you... Thank you!*

*Alfred"*

Mr Toyz is thoughtful... "I didn't need another problem..." He stares into his coffee and thinks... And then, he has an idea!

"And if it is toys for children... why not have them design them themselves!"

Instantly, Mr Toyz thinks about a contest... Each child dreams to be like Mr Toyz and create toys! It's the first time that somebody is going to organize that in his shop. Mr Toyz hurries to make posters, notices and so on. Everything needs to be done for the following day and then he will be able to create toys for his shop and help his son too.

The next day, the shop has a new face! Each child of the town hurries to the shop window to read the poster.

"CONTEST: Create a toy to help children who don't have the chance to have any. You need to be creative. "

Children are so excited that they want to know more.

"Sir, how can we participate in this contest? What are we going to win? We won't be able to imagine such beautiful toys as yours!"

"Don't worry. The most important thing is that you have fun and other children who will have toys too! And do the best one will be displayed in my shop! "

However, there are some rules:

Rule number 1: the toys must be ecological, without any battery or any link to electricity.

Rule number 2: The toys must move..

Rule number 3: The toys must be made of recycled material - cardboard, corks, straws... So, if we sum all this up, you have to imagine mechanical toys.

But now, Mr Toyz has another problem... His toys are a real success since the beginning of the contest, more than ever before! But his shop is very small and Mr Toyz is very bothered.

"I can't have more than 10 people in here. And I can't stand in front of my shop all the day and say to the children that they have to wait... I need to find a system..."

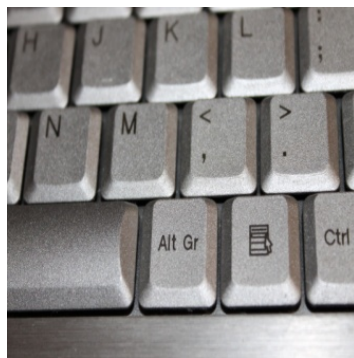
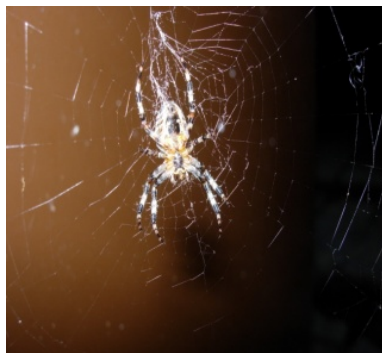
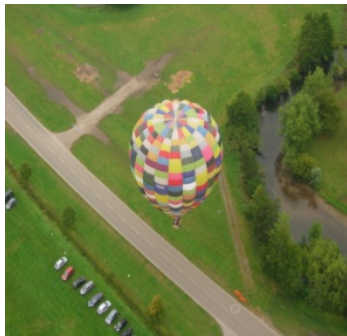
As the contest with the toys is successful, the toy seller decides to test another one...

"I can organize another contest for older children! Let's ask them to come up with a system which will enable me to know how many people are in my shop. This system needs to tell me whether my shop is full of customers or not."

And the next day, another sign appears on the shop front...now it is your turn to help Mr Toyz...

# Worksheets and answer sheets

# Worksheet 1 Lesson 0 – Engineering?



## Worksheet 1 Lesson 0 - Engineering? – Teacher notes

The pictures on the worksheet are intended to promote pupils' discussion about what engineering is, what engineers do and who could be involved in different types of engineering.

The pictures of the spider and snail present some interesting challenges. The pupils could for example, decide that the spider is 'engineering' a web and this could be related to other animal 'engineering' examples (such as a beaver building a dam). An interesting point to make is that it is more common to think of engineering in terms of the made world. We can however, learn from studying nature and the environment. For example, the material that spiders use for making a web has been copied to make a very strong material (Kevlar) that has many useful properties. Similarly, the snail has developed a useful strategy for travelling over rough surfaces to protect its soft body from being damaged. An interesting question is whether this would be useful to solve a problem in the human world (a good example is Velcro which was developed from the burrs of burdock plant).

The toys could be considered engineering since they demonstrate the application of cams but it is interesting to ask what materials they could be made from and who actually makes them. This is likely to lead to some gender issues (many of the class may think that toys are made for children by toy designers who are male).

A similar issue might arise when pupils discuss the knitted garment and the prepared meal - pupils may think that these are only made by women, and that they are not the product of engineering.

Some of the other pictures of sculptures and works of art might be perceived as not engineering and without any real practical purpose. This will raise a question about the links between engineering and art and whether or not a made object needs to have a practical purpose for it to count as being engineering.

The pictures are meant to stimulate engagement and dialogue about engineering. This could lead to a discussion about what is involved in engineering, in which you might choose to introduce the Engineering Design Cycle.



# Worksheet 1 Lesson 1 - Find a mechanical object



Name:

Date:



Do you know that mechanical objects are all around us? Your teacher has hidden mechanical objects in your classroom. Find them. Good luck!

### What do you need?

- Your observation

### To work!

1. Write the name of the object that you have found.

.....

2. Describe its function.

.....  
.....

3. Explain why you are sure that this object is mechanical.

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

## Answer sheet Worksheet 1 Lesson 1 - Find a mechanical object

Name:

Date:

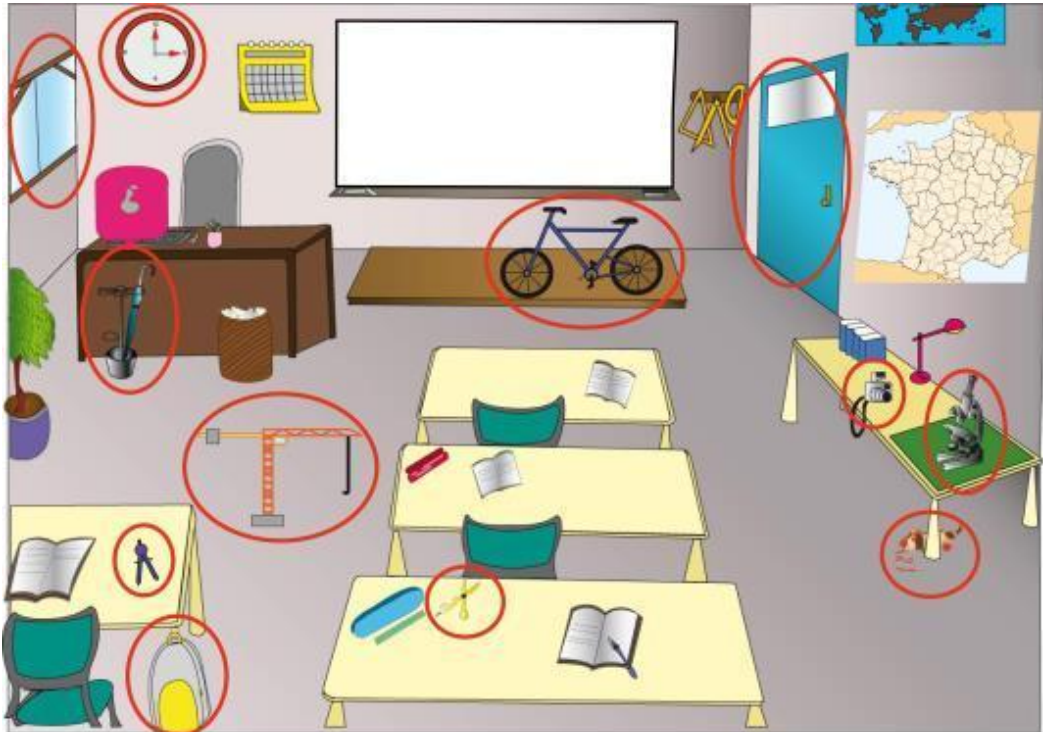


Do you know that mechanics objects are all around us? Your teacher has hidden mechanical objects in your classroom. Find them. Good luck!

### What do you need?

- Your observation

The picture is only a suggestion of ways to 'hide' mechanical objects in the classroom.



### To work!

1. Write the name of the object that you have found.

List the mechanical objects drawn in the picture.

1. the clock or a watch

2. the umbrella

3. a bicycle

4. a crane toy

5. the compass

6. the door

7. the microscope

8. the "dog" toy

9. scissors

10. the camera

11. the school bag

12. the window

## 2. Explanation of why some objects drawn in the picture are mechanical

Object	Mechanical?	Explanation
A bicycle	Yes	You push the pedal and thanks to the chain and the chain wheels, the pedal makes the wheels turn.
A watch	Yes	The hands of a clock turn, thanks to gears which are inside and also to a battery.
An umbrella	Yes	When you open the umbrella, you push a button to make it open.
A door	Yes	The door turns around an axle. And when you want to open the door, you turn the handle to unlock it.
A window	Yes	You interlock a handle to lock or unlock the window and then push the window pane.
A schoolbag	Yes	To open or to close the bag, you pull a zip.
A dog mechanical toy	Yes	There are wheels and thanks to muscular strength, the dog can move. There is transmission of motion.
Scissors	Yes	There is a transmission of the motion because the blades move thanks to the strength we transmit with our hand.
A crane toy	Yes	There is a crank and thanks to this and pulleys, the hook can go down and up.
A microscope	Yes	You turn the coarse adjustment knob to moves the stage up and down to focus.
A compass	Yes	To move the legs of a compass aside, you have to turn the little wheel in between them.
A camera	Yes	The running is mostly electronic, but the part concerning the diaphragm is mechanical.

## 3. Some others objects

Object	Mechanical?	Explanation
A typewriter	Yes	There are gears inside a typewriter.
A roller	Yes	Inside the wheels of a roller, there are ball bearings.
A mechanical whisk	Yes	When you turn the crank, this turns the whisk thanks to gears.
A corkscrew	Yes	There are two levers, one on either side of the corkscrew.
A sewing machine	Yes	Inside a sewing machine we can find cams and pulleys.
A centrifugal drier for salad	Yes	Inside the centrifuge, there are gears.
An electronic calculating machine	No	
A pen	Yes and no	For some pens, we need to push a button to make the lead come out.
A balloon	No	
Sunglasses	No	

## Worksheet 1 Lesson 2 - Define a mechanical object

Name:

Date:



Here is a mechanical object. Do not worry, there is no trap.  
Can you guess how the object operates and describe it?

### What do you need?

- An object brought by your teacher or a pupil

### To work!

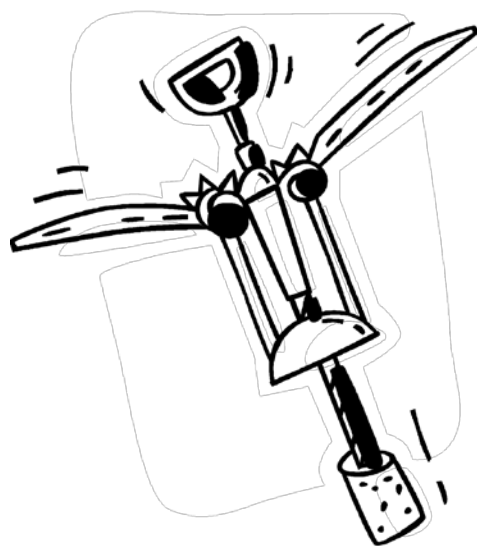
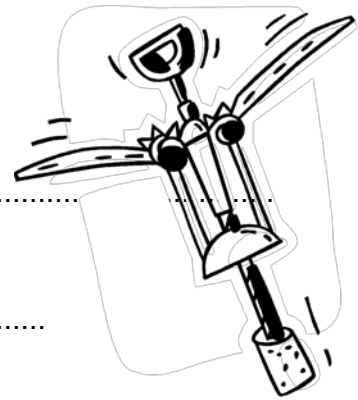
1. Write the name of the object.

.....

2. Describe its function.

.....

3. Draw the object (or only its mechanical part (s)). And let's look inside the object. Can you find mechanical parts? Yes? If so, mark then (if possible) as follows:
  - a. in red, the lever
  - b. in green, the gears
  - c. in blue, the cams :
  - d. in orange, the crank



## Worksheet 1 Lesson 2 - Define a mechanical object

Name:

Date:



Here is a mechanical object. Do not worry, there is no trap.  
Can you guess how the object operates and describe it?

### What do you need?

- An object brought by your teacher or a pupil

### To work!

1. Write the name of the object.

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2. Describe its function.

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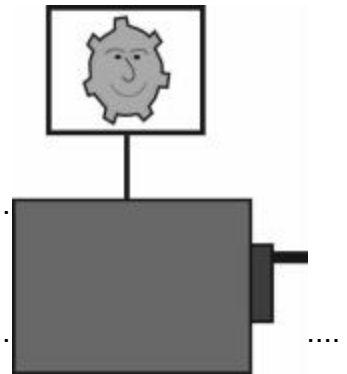
### To work!

1. Write the name of the object.

.....

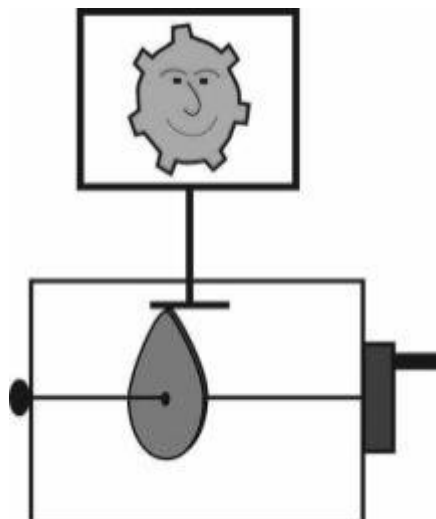
2. Describe its function.

.....



3. Draw the object (or only its mechanical part (s)). And let's look inside the object. Can you find mechanical parts? Yes? If so, mark then (if possible) as follows:

- a. in red, the lever
- b. in green, the gears
- c. in blue, the cams :
- d. in orange, the crank



## Worksheet 1 Lesson 2 - Define a mechanical object

Name:

Date:



Hello! Here is a mechanical object. Do not worry, there is no trap.  
Can you guess how the object operates and describe it?

### What do you need?

- An object brought by your teacher or a pupil

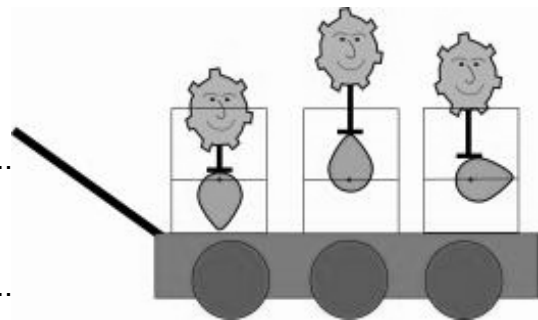
### To work!

1. Write the name of the object.

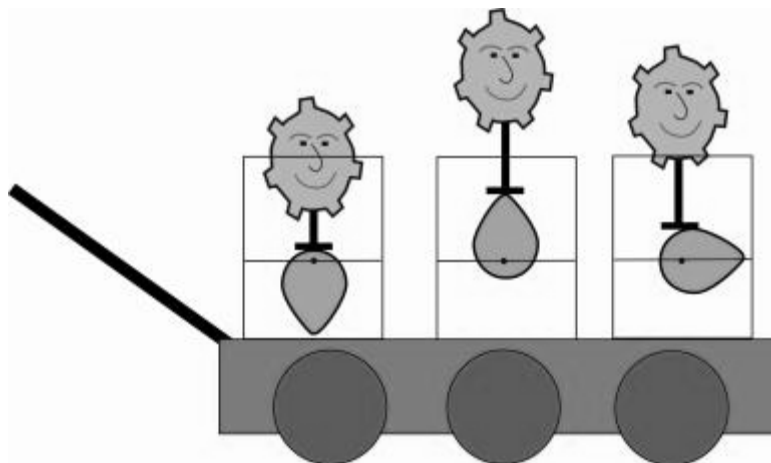
.....

2. Describe its function.

.....



3. Draw the object (or only its mechanical part (s)). And let's look inside the object. Can you find mechanical parts? Yes? If so, mark then (if possible) as follows:
  - a. in red, the lever
  - b. in green, the gears
  - c. in blue, the cams :
  - d. in orange, the crank



## Answer sheet Worksheet 1 Lesson 2 - Define a mechanical object

Name:

Date:



Here is a mechanical object. Do not worry, there is no trap.  
Can you guess how the object operates and describe it?

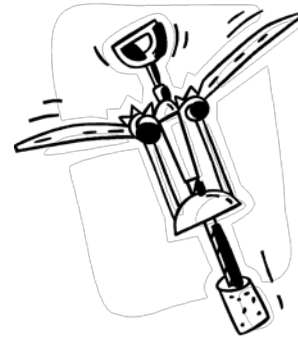
### What do you need?

- An object brought by your teacher or a pupil

### To work!

1. Write the name of the object

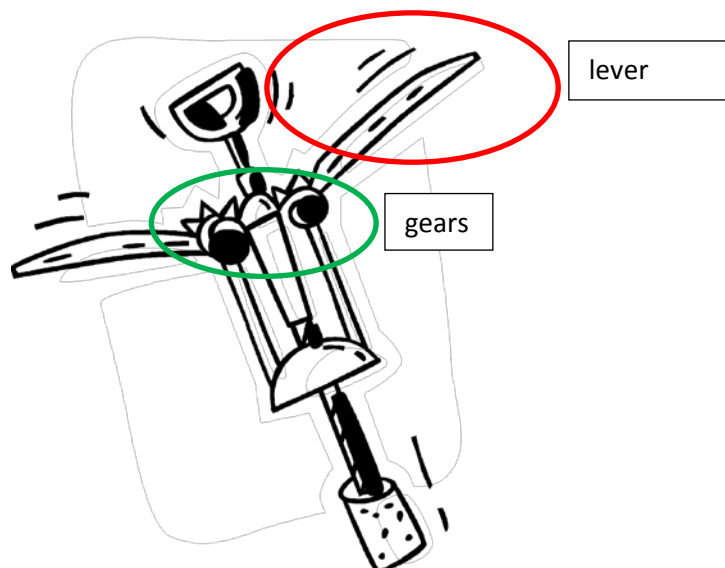
**A cork screw**



2. Describe its function.

**The cork screw is used to remove corks from bottles.**

3. Draw the object (or only its mechanical part (s)). And let's look inside the object. Can you find mechanical parts? Yes? If so, mark then (if possible) as follows:
  - in red, the lever
  - in green, the gears
  - in blue, the cams : **there is no cam**
  - in orange, the crank : **there is no crank**





## Answer sheet Worksheet 1 Lesson 2 - Define a mechanical object

Name:

Date:



Here is a mechanical object. Do not worry, there is no trap.  
Can you guess how the object operates and describe it?

### What do you need?

- An object brought by your teacher or a pupil

### To work!

1. Write the name of the object

**A bicycle**

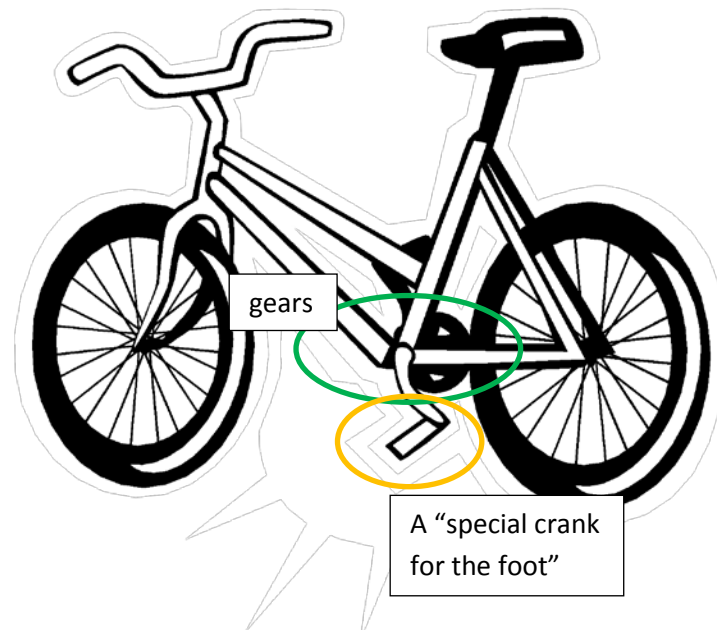


2. Describe its function.

**The bicycle is used to move.**

3. Draw the object (or only its mechanical part (s)). And let's look inside the object. Can you find mechanical parts? Yes? If so, mark them (if possible) as follows:

- in red, the lever: **there is no lever**
- in green, the gears
- in blue, the cams : **there is no cam**
- in orange, the crank



## Answer sheet Worksheet 1 Lesson 2 - Define a mechanical object

Name:

Date:



Here is a mechanical object. Do not worry, there is no trap.  
Can you guess how the object operates and describe it?

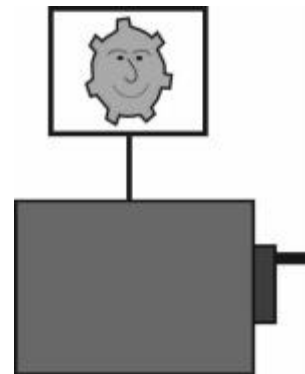
### What do you need?

- An object brought by your teacher or a pupil

### To work!

1. Write the name of the object

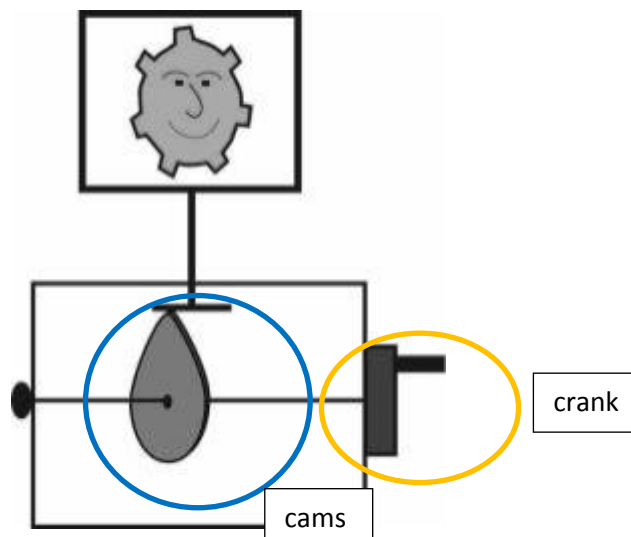
**A toy**



2. Describe its function.

**Its function is to play : when we turn the crank, the picture goes up and down.**

3. Draw the object (or only its mechanical part (s)). And let's look inside the object. Can you find mechanical parts? Yes ? If so, mark them (if possible) as follows:
  - in red, the lever: **there is no lever**
  - in green, the gears: **there is no gear**
  - in blue, the cams
  - in orange, the crank



## Answer sheet Worksheet 1 Lesson 2 - Define a mechanical object

Name:

Date:



Hello! Here is a mechanical object. Do not worry, there is no trap.  
Can you guess how the object operates and describe it?

### What do you need?

- An object brought by your teacher or a pupil

### To work!

1. Write the name of the object

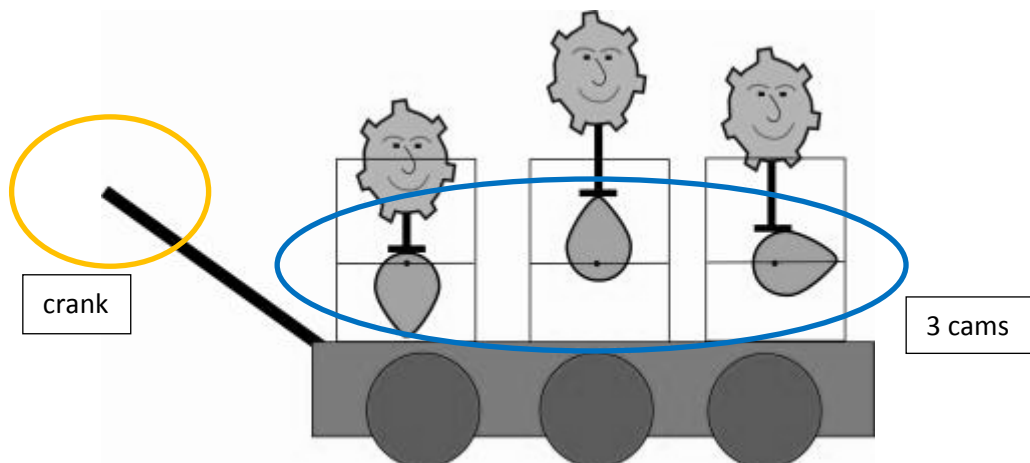
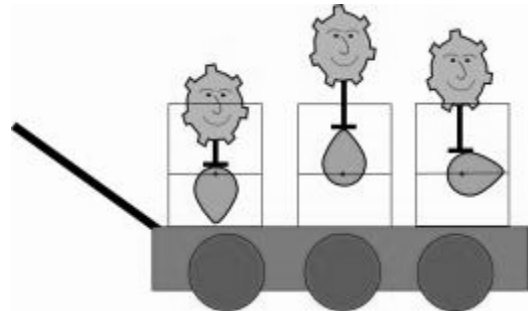
**A toy**

2. Describe its function:

**Its function is to play: when we push the toy, the drawn toothed wheels go up and down.**

3. Draw the object (or only its mechanical part (s)). And let's look inside the object. Can you find mechanical parts? Yes? If so, mark them (if possible) as follows:

- in red, the lever: **there is no lever**
- in green, the gears: **there is no gear**
- in blue, the cams
- in yellow, the crank



## Worksheet 2 Lesson 2 - Let's play with cams! (1/3)

Name:

Date:



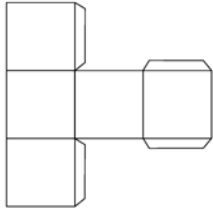
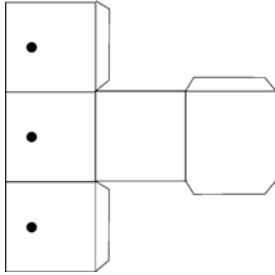


Many mechanical toys are composed of cams. I am sure you know them; when you push them some parts of the toy go up and down. Let's examine cams to understand how they work!

### What do you need?

- a piece of card (40 cm x 50 cm) or a cardboard box
- cardboard
- glue
- scissors
- pieces of dowel
- blu-tack
- elastic

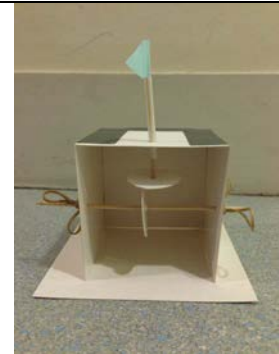
### To work!

#### 1. Making a cam mechanism

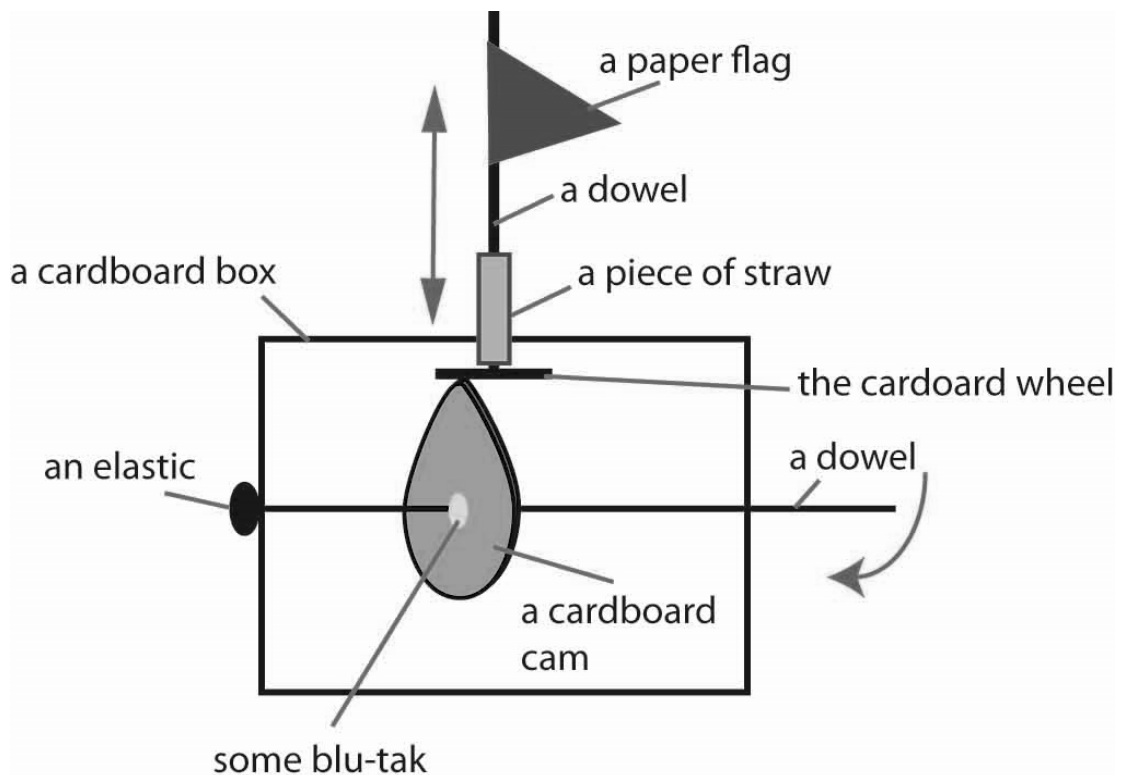
<p>Use a cardboard box or draw out a template on a piece of card to make an open cube with 10 cm sides. Cut it out and score the folds.</p>	
<p>Measure and mark three holes at 5 cm from a side and 2 cm from the other. Here is the scheme.</p>	
<p>Make the cube, sticking the tabs with glue. You can use paperclips if necessary.</p>	
<p>Draw a wheel of 2 cm of diameter and cut it out. Stick the wheel on to the bottom of a piece of dowel rod: this will be your follower.</p>	

Thread a cam onto the thicker dowel and thread this through the holes in the frame, securing it in place with blu-tack so that the cam turns with the axle, not by itself.

Thread the follower through the hole in the top of the frame so that the wheel is resting on the cam. To be sure to obtain the correct motion, we suggest using a straw.



Here is our realization.



### Test a shape for the cam

To be sure that the mechanism is correct, test a circular shape for the cam

## Worksheet 3 Lesson 2 - Let's play with cams! (2/3)

Name:

Date:



As you discover cams, let's test different shapes of cam.

### What do you need?

- a piece of card (40 cm x 50 cm) or a cardboard box
- cardboard
- glue
- scissors
- pieces of dowel
- blu-tack
- elastic

### To work!

Observe the motion according to the shape of the cam. Test different shapes and note your results.

What's happening with...	Draw your cam	And the result is...
A circular cam		
A circular cam, but eccentric		
A pear shaped cam		
An elliptic cam		
A drop cam		
A star cam		
Your cam!		

## Answer sheet Worksheet 3 Lesson 2 - Let's play with cams! (2/3)

Name:

Date:

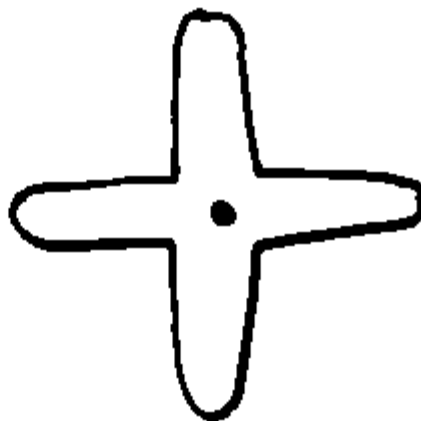
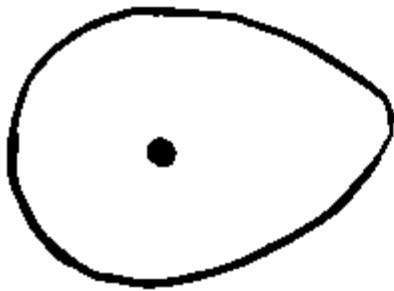
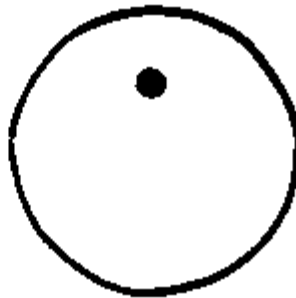
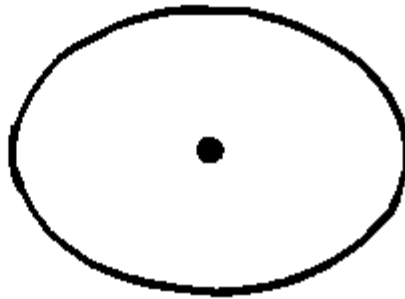
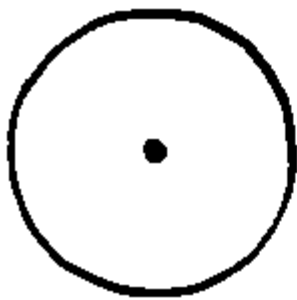


As you discover the cams, let's test different shapes of cam.

Test different shapes and note your results

What's happening with...	Draw your cam	And the result is...
A circular cam		The flag turns but does not rise nor drop.
A circular eccentric cam		The flag turns. As the cam rotates, the flag rises then drops. The movement is smooth and at a constant speed.
A pear shaped cam		The flag turns and rises twice when the cam rotates for one complete revolution. The movement is smooth, the speed is not constant.
An elliptic cam		The flag turns and rises twice when the cam rotates for one complete revolution. The movement is smooth.
A drop cam		The flag turns, then rises slowly and suddenly drops when the follower passes the peak.
A star cam		The flag turns and rises four times when the cam rotates for one complete revolution. It drops suddenly each time.
Your cam!		

## Templates for cams



These sizes of the templates are for a box with sides 10 cm.



## Worksheet 4 Lesson 2 - Let's play with cams! (3/3)

Name:

Date:



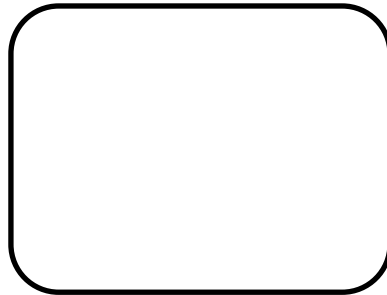
You have now finished your cam mechanism. Let's experiment now to solve the challenges!

### What do you need?

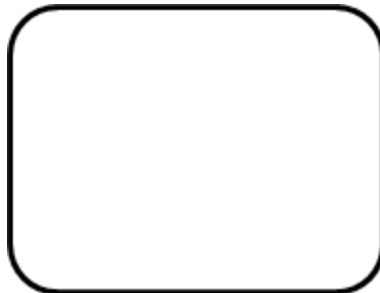
- Your mechanism built during worksheet 2
- cardboard
- glue
- scissors
- pieces of dowel
- suggested shape for cams
- blu-tack
- elastic

### To work!

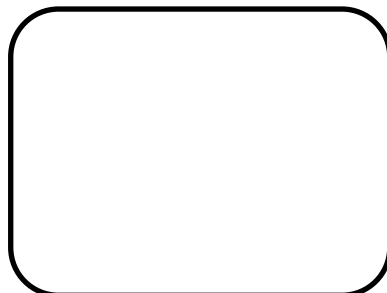
1. Imagine a shape for your cam so that your follower rises the highest possible. Draw your cam.



2. Imagine a shape for your cam so that your follower rises 8 times while the cam rotates for one complete revolution. Draw your cam.



3. Imagine a system to make the flag turn the fastest possible! Draw your cam



# Answer sheet Worksheet 4 Lesson 2 - Let's play with cams! (3/3)

Name:

Date:

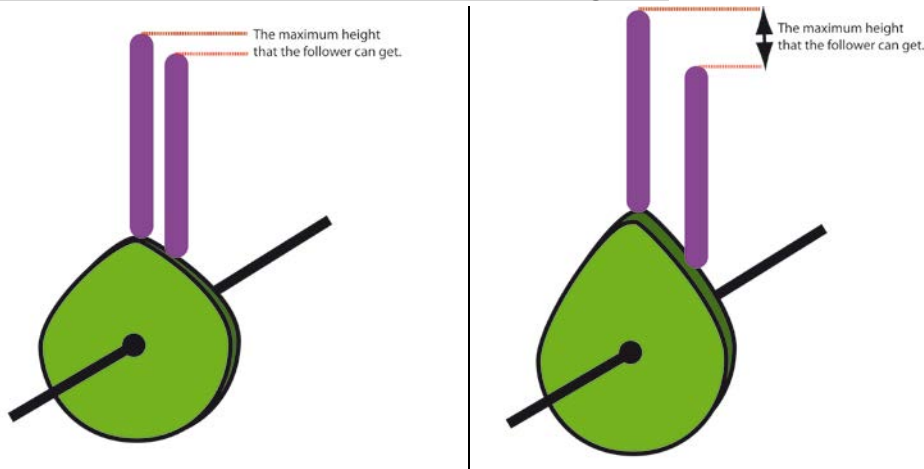


You have now finished your cam mechanisms. Let's experiment now to solve the challenges!

## To work!

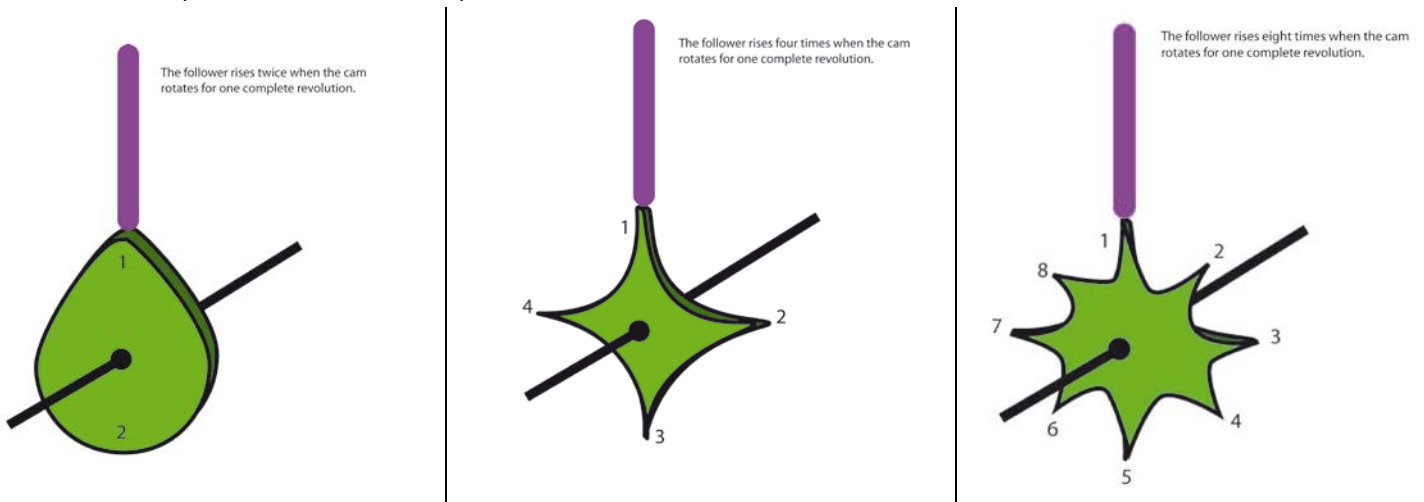
1. Imagine a shape for your cam so that your follower rises the highest possible. Draw your cam.

**The cam has to have one side larger than the other. The second picture shows how to transform the cam's shape to make the follower rise the highest.**



Note: both diagrams seem to be the same

2. Imagine a shape for your cam so that your follower rises 8 times while the cam rotates for one complete revolution. Draw your cam.



3. Imagine a system to make the flag turn the fastest possible! Draw the cam.

**It depends on the position of the cam and the follower; the nearer the cam to the follower, the faster the flag turns.**

## Worksheet 5 Lesson 2 - Let's play with gears!



Name:

Date:



To turn each wheel, we need an engine, which means we need some energy. And to transform the motion, we need to use wheels of the right size. Let's make gears!

### What do you need?

- A kit of toothed wheels with different colors and sizes.

### To work!

1. Choose a wheel and fix it.
2. Compare the speed of different wheels and note your results in the table.

The fixed wheel is ...	Draw your experiment	Which wheel turns faster?
The smaller one		
The smallest one		
Same size of wheel		
The bigger one		

## Answer sheet Worksheet 5 Lesson 2 - Let's play with gears!

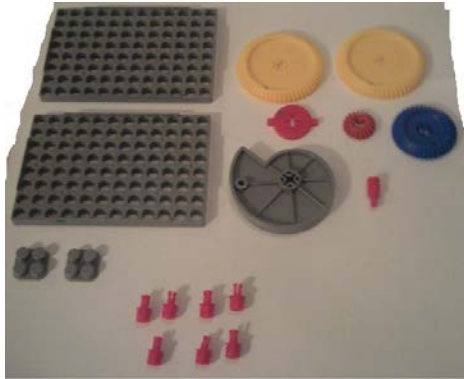
Name:

Date:



To turn each wheel, we need an engine, which means we need some energy. And to transform the motion, we need to use wheels of the right size. Let's make gears!

1. We suggest using the material 'CELDA' or 'Lego', with toothed wheels of different colours and sizes. The teacher can use other industrial materials or make them with the pupils.



### Contents of a kit:

- 1 pink wheel with its axle
- 2 grey platforms and 2 grey pieces to assemble them
- 1 red crank
- 1 small red wheel
- 1 blue wheel
- 2 yellow wheels
- 7 axes

The fixed wheel is...	Draw your experiment		Which wheel turns faster?
The smaller one			The smaller wheel turns faster than the fixed one.
The smallest one			The smallest wheel turns faster than the fixed one.
The same size of wheel			Two same sized wheels turn at the same speed.
The bigger one			The bigger wheel turns slower than the fixed one.

**The pupils need to observe that:**

**The bigger wheel turns slower than the other one. The size of a wheel is important for the speed. If it is bigger, there are more teeth and the wheel turns slower. It is the contrary, if the wheel is smaller.**

2. If the teacher prefers to make the toothed wheels, here is how.

Part 1: gather the material



**What do you need?**

- cardboard
- scissors
- a box made in polystyrene
- some plastic tops with different sizes
- a glue pistol
- a tendril
- sticks

Part 2: making the toothed wheel

- Take off a layer of the cardboard to get the "tooth".
- Make a hole in the plastic top with the tendril
- Use the glue pistol to stick the cardboard around the plastic top

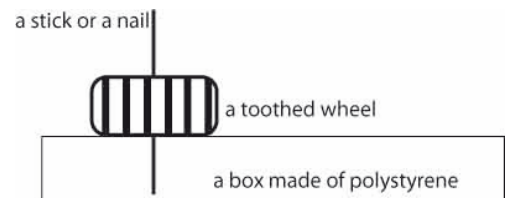
The toothed wheel is ready! Pupils can use others plastic tops to make wheels of different sizes.



Part 3: fix the first wheel

A/ classify the wheels regarding their size: from smaller to bigger.

B/ choose a wheel with size in the middle. Fix it on a box made from polystyrene with a stick or a nail. This wheel will be the analogous to the yellow wheel in the kit.



Part 4: make a gear

The aim of this part is to examine the speed of each wheel. We suggest beginning the experiments with the bigger wheels.

Fix two wheels next each other, in order to transmit the motion. Draw the experiment and indicate the result you observed in the table.

Here is an example of a gear that pupils are asked to make.



Top view



Side view

## Suggestions for constructing mechanical objects

### How to build a mechanical toy

The teacher needs to prepare the materials for the pupils. The teacher can also ask the pupils to bring some of the materials from their homes (straws, modelling clay such as play-do, cardboard but the teacher needs to define the type of cardboard they are going to use; different cardboard boxes). The teacher can make the choice to either let every group build their own toy, or simply decide to allow each group to build only one toy.

The toy can be made in different ways. Our proposal is only one suggestion. The teacher does not need to use it. But we suggest to the teacher reads the suggestions to help pupils to make their own (advice, idea...).

### What do you need?

- a box (such as a shoe box)
- some cardboard in order to make the box if you don't have one and for the cams
- some straws
- some dowels
- a scotch
- 2 elastics
- A glue pistol
- some blu-tack

### Step 1: Which story and which characters?

- First, the pupils and the teacher need to choose a story for the toy. We remember that the aim of Mister Toyz is to ask pupils to imagine toys for telling stories.
- Then, pupils define a main character and draw it on cardboard. They can also print it out and then stick it on cardboard.

*In our case, we chose Timon from the Lion King (©Walt Disney Pictures).*



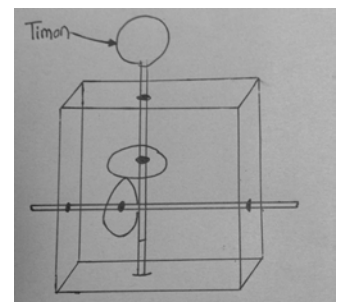
### Step 2: Define the mechanic motion

After they chose the characters, pupils define its motion. That means that they have to use the knowledge discovered in lesson 2, so as to define the shape of the cam they need. They need to make it: of course, they will improve it after their first try

*In our case, we decided that Timon is going to jump once when the cam rotates for one complete revolution and spin around. So we chose the pear shaped cam.*

### Step 3: Assemble and organise the ideas

For better organisation, we suggest pupils draw a scheme in order to decide where exactly they are going to fix the characters on the box and where the



mechanism will be. As they work in groups, this will make it easier to list the materials.

#### **Step 4: Create the toy**

Now it is time to make the toy.

1. The first thing to prepare is the box. You can take a shoebox and cut it in half. And if you don't have one, you can take 4 pieces of cardboard of sides 10cm and make a box with them.
2. The character needs to be fixed on a wooden stick.

*We used some scotch tape, but you can use a glue pistol to fix your character better.*



3. Mark the place for the character on the box.
4. Check its mechanism.
5. Hole the box on each side in order to fix the 'principal' axis.
6. Draw the cam chosen during step 2. Cut it and fix it on the axis.  
*In our case, we chose a pear shaped one.*



7. Place the character inside the box and check it's well fixed.  
*We put a straw inside the stick in order to be sure our character is straight. And it was stuck on the bottom of the box using the glue pistol.*



8. Fix the follower with blu-tack or the glue pistol. But be careful! It has to be in touch with the cam in order to transmit the motion.



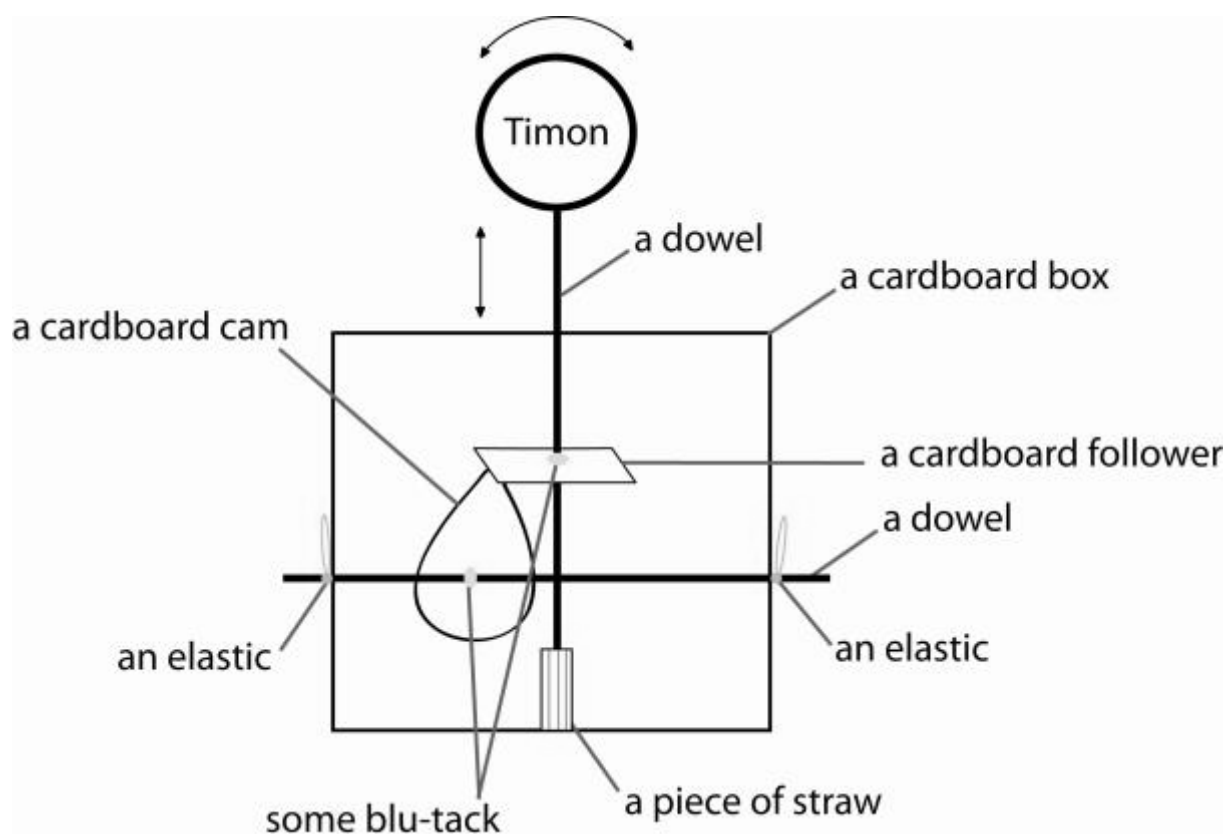
**Step 5: Test and improve**

Now, pupils test their toy and check that the motion is correct when the axis rotates. They can make adjustments, if this is necessary. If everything is correct, we suggest securing the mechanism (the cam, the axis and the follower).

*We suggest securing them with elastic bands or cardboard.*







When everything is correct, pupils can work on a second character! They use the same process.

**Step 6: Decorate the toy**

If pupils have enough space in their box, they could add a background.

*In our case, we decided to add one around the box.*



## How to build the counter?

The teacher needs to prepare the materials for the pupils. The teacher can also ask the pupils to bring some of the materials from their home (straws, modelling clay such as play-do, cardboard, but the teacher needs to define the type of cardboard they are going to use, a box made of polystyrene). The teacher could make the choice to either let each group build their own counter, or simply decide to build the same machine per group

The machine can be made in different ways. We explain two ways. The teacher does not need to use both ways with the pupils. But we suggest the teacher uses them to help the pupils make their machines (advise, idea...).

### 1. First possibility

#### What do you need?

- 2 template wheels
- 2 cardboard sticks
- 1 straw
- pieces of modelling clay (in order to help the cardboard stick to stay horizontal)
- small pieces of cardboard to make the jumper
- a box made of polystyrene
- some PATAFIX (or "blu-tack")

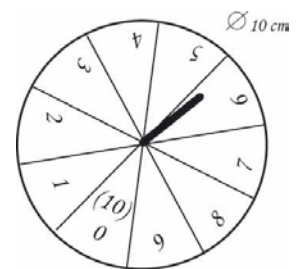
The construction can be undertaken in 3 steps. We describe them.

#### Step 1: Making the wheels

The teacher distributes cardboard and a template for the wheels.

Pupils:

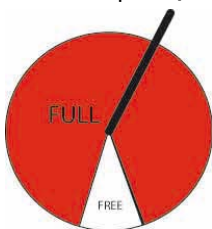
1. stick two 'paper' wheels on cardboard
2. cut the wheels
3. make a small hole, in the centre of 2 wheels. The hole needs to be large enough to insert the cardboard stick but not too wide so the wheel is held tightly.
4. write the numbers from 0(10) to 9 one of the wheels
5. fix the wheel on the polystyrene box.



This machine is made with 2 wheels the same size. The teacher can increase the number of templates and change the size to let pupils choose the size of wheel they want to use.

#### Step 2: The wheel to count the number of the participants

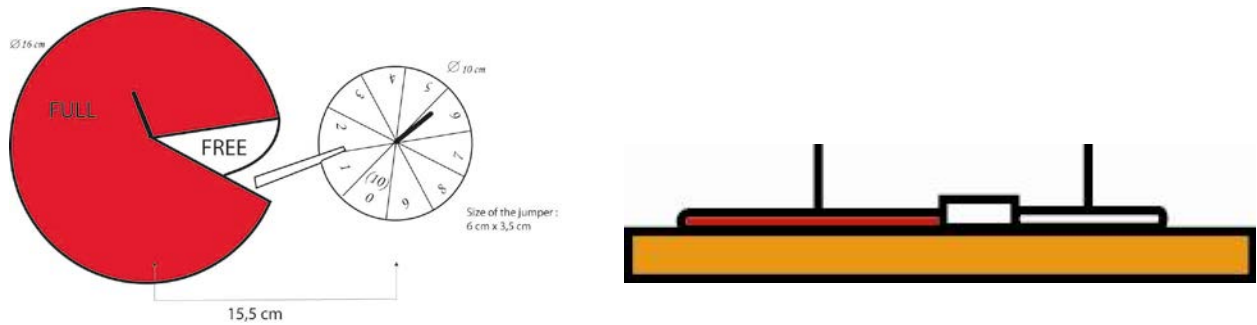
The group = chooses another wheel and designs it to write 'Full and 'Free'. Different shapes can be used: a square, a triangle or a circle, or any other shape...We have chosen to use a wheel.



### Step 3: How connect the two wheels?

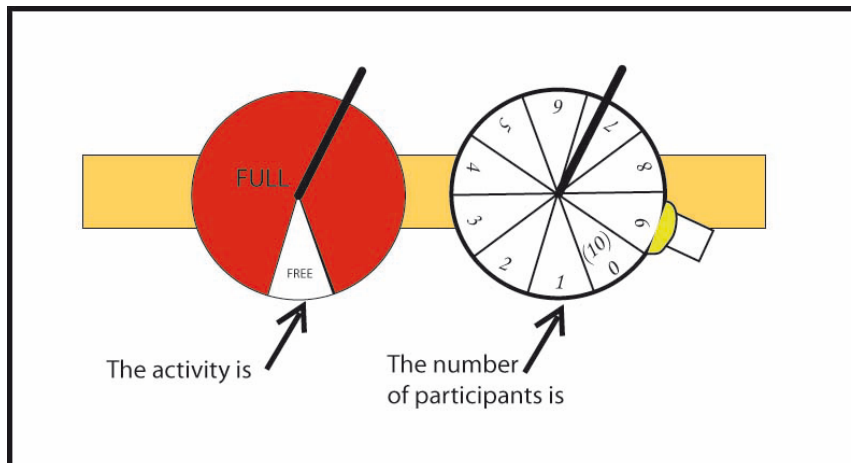
At first, pupils try to imagine a way to connect the two wheels. Then, they adapt the position of the jumper for the second wheel to move only when the first one passes from 9 to 10. If pupils solve the challenge easily, they can be asked to imagine a jumper to allow adding and also subtracting.

First possibility to connect the two wheels:



Then, the counter is finished!

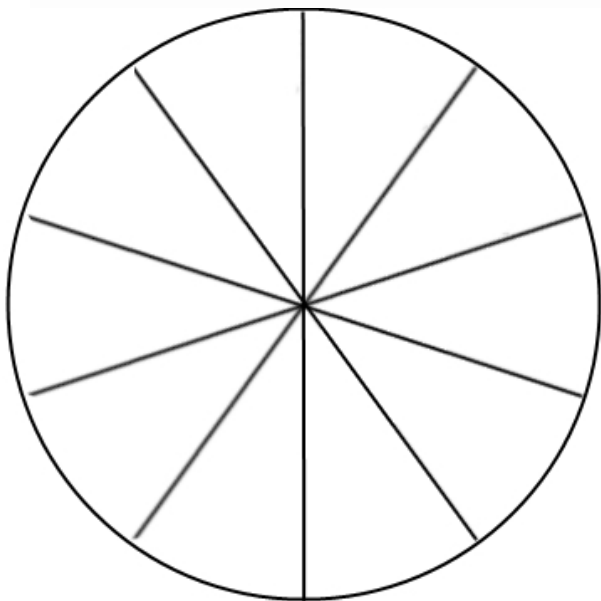
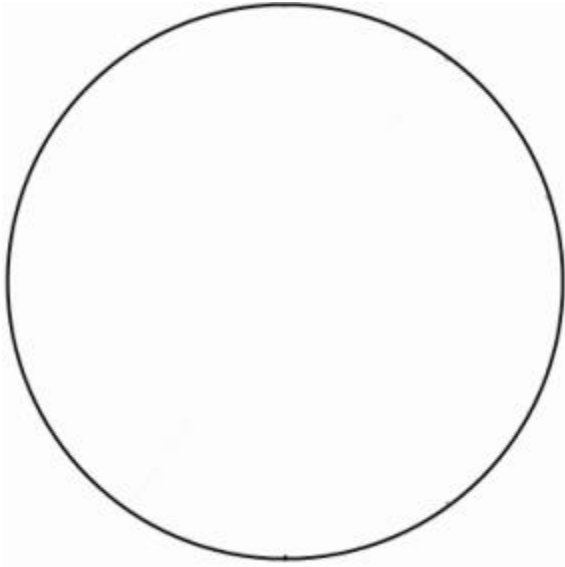
Second possibility to connect the two wheels:



We do not suggest making the two forms of machines. However, we think that it is important for the teacher to analyse them in order this is helpful for the pupils to give advice or to suggest ideas.

## Template for the 'unit' wheel

The teacher can change the size for this wheel if preferred.



## Science notes for teachers about mechanics

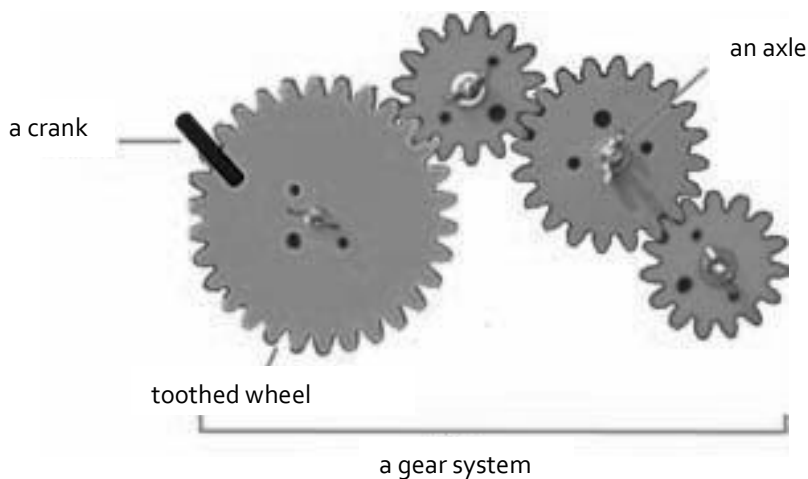
### Some key science concepts involved in Lesson 2

- Forces can be transmitted from one place to another in objects that are moving and in stationary objects
- Forces can change the speed\* of an object (accelerate it or slow it down)
- Forces can change the direction of an object

\*Scientifically speaking this would be termed velocity

In Lesson 2, pupils explore how simple machines can be used to transmit a motion, transform a motion, accelerate a motion (speed it up) or slow a motion down. It is important that pupils have tactile experience of applying forces in different contexts and have opportunity to predict outcomes and discuss their findings.

**Figure 1.** Using gears to transmit motion



### Transmitting motion

In the above diagram the force applied to the crank turns the wheel and this force is transmitted through the gear system. It is useful to get the pupils to predict the direction (clockwise or anticlockwise) each gear will turn when a force is applied to the crank handle. If the crank gear is turned anticlockwise, in which direction will the other gears turn?

### Changing the speed of the transmitted motion

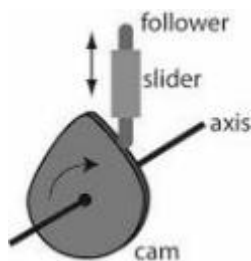
The gears above are different sizes. Turning the crank gear through one complete revolution will result in the smaller gears turning through more than one revolution. If the crank gear turns at a constant rate, the other smaller gears in the system will turn more quickly and the motion will be speeded up. It would be a useful challenge for the pupils to consider how the motion could be slowed down in the same system. This would require the smaller gear to be the crank gear. In this situation the relationship between the number of turns is reversed. Therefore, turning the smaller gear one complete revolution results in the larger gear turning a partial revolution. If the smaller gear is turned at a constant rate, the other gears in the system will turn more slowly and the motion will be slowed. Pupils can investigate different gear systems and make predictions about how the system will either speed up or slow the motion.

**Figure 2.** Using gears to transform motion



There are different ways in which gears in simple machines can be used to transform motion. In the example (Figure 2) the gear system is transforming rotational motion into linear motion. As the circular toothed gear rotates, the straight toothed gear bar move from right to left depending on whether the circular gear is moving clockwise or anticlockwise. Gear systems of this type can be used in different ways to move both horizontally and vertically. The bar could for example, be fixed to the horizontal top of a sliding gate for opening and closing. Alternatively, the bar could be fixed vertically to a sluice gate to control water levels (as in a canal lock paddle gate).

**Figure 3.** Using cams to transmit and transform motion



Cams are easier to make and can be effective mechanisms for transmitting and transforming motion. This unit allows pupils the opportunity to be creative in the use and application of cams by exploring the effect that different cams have on transmitting and transforming motion. In the example above, when the cam turns, the follower goes up and down following the cam's profile. The slider allows the follower to move freely. The follower's motion depends on the cam's profile. Pupils will experiment with this in Lesson 2. Similar to the gear mechanism in Figure 2, the rotary input motion of the cam is transformed to a linear one for the follower and slider.

## Some pupils' ideas about mechanics science concepts

Children's thinking about the natural world comes from their everyday experiences. They may not represent the established current scientific view but they usually contain sensible reasoning based on observation and interaction. Offering opportunities for children to challenge their thinking through activity is more likely to shift their perceptions than telling them facts. However, this presents a significant pedagogical task. It is extremely demanding for learners at all levels and ages to accommodate new ideas about a particular phenomenon, especially when these seem to contradict common sense reasoning. Although through research we have some insight into the ideas pupils are likely to have in particular conceptual domains in science, often, pupils have difficulty in articulating their thinking so there is a need to exercise some caution in making assumptions about their reasoning. This highlights the importance of providing opportunity for children to discuss their thinking.

The engineering process developed in this unit provides pupils with opportunities to imagine creative solutions to solve the engineering challenge. They are encouraged to present and discuss their approach and critically evaluate, in positive ways through making suggestions for improvement, creations by others pupils.

In learning about mechanics in this way, pupils can develop their understanding of forces. Pupils often find difficulty in explaining what forces *are* but can more easily recognise what forces *do* to objects. They know from experience that forces can make objects move and that this can involve both speeding up and slowing down. They know that to move a stationary object that they need to apply a force. Stationary objects and moving objects present their own challenges in understanding of forces.

### **Balanced forces: Stationary structures**

Pupils could reason that there are no forces acting on objects that are stationary and not recognise that forces are needed to keep the object in a stationary position. This idea can be explored in a number of ways but where possible, it is useful to get pupils to have tactile experience of forces acting on objects that are not moving. Investigating balance in a range of objects and shifting their own balance to feel forces is helpful in this regard, as is feeling the buoyancy force when pushing down on a balloon floating in a tank of water. The key idea here is that in order for an object to be stationary, it's not that there are no forces acting on it, rather, it is that the forces acting on it are balanced. We can experience this directly in a game of tug-of-war when despite each side exerting a force and pulling, there is no movement in either direction if the forces are equal and balanced. It is also difficult to recognise that forces in stationary structures can be transmitted within the structure itself. The reason for this is that the transmission is difficult to visualise in something that is static. Again where possible, it is important to let pupils feel or see the forces acting in stationary structures. Exploring creative ways of supporting weights in model structures (including but not limited to bridges) is a useful way of doing this.

### **Balanced forces: moving objects**

Using a force to move a stationary object can lead to pupils thinking that if they apply a force to an object to get it moving, that it will keep moving until the force they have applied runs out. If they throw a ball into the air for example, they could reason that the force they have given the ball stays with it until it runs out (that is, the force gets *used up* by the motion of the object as opposed to *acts on* the object). This is eminently sensible and intuitive but at odds with scientific explanation. Forces don't belong to objects they act on them. The forces acting on an object that is moving in a straight line and neither speeding up or slowing down are balanced. This is difficult to comprehend because it is sometimes difficult to recognise which forces are acting on the moving object and whether or not the object is travelling at the same speed, slowing down or speeding up. Where the forces acting on a moving object are not balanced, the object is either speeding up, slowing down or changing direction. It is supportive to pupils if the teacher is able to draw on their life experience to

recognise where this happens. Pupils know for example, that in descending a steep hill on a bicycle, it is necessary to use the breaks to constantly apply a frictional force to slow down the bicycle. This is an important idea; that to slow down a moving object, a force must be applied all the time (constantly). This also applies to an object that is speeding up; there must be force acting on it all the time. In cycling on a flat surface, for example, it is necessary to constantly apply a force to the pedals in order to keep accelerating. For an object that is free falling, the force of gravity acts on it all the time to accelerate it towards the earth. This means that the object would keep going faster and faster until it reached the ground. This does not happen because another force, air resistance, balances out the effect of gravitational pull. Investigating the journey of a free fall parachutist exemplifies this.

The unit offers pupils a range of experiences to explore some of their ideas about forces in a different context. It can be used as an opportunity to extend their awareness of how engineers use their knowledge of forces to design and make simple machines to perform particular tasks. In undertaking the challenge, the pupils can extend their thinking about different ways in which forces can be transmitted, how simple machines can transform motion for particular purposes and how mechanisms can speed up or slow down movement. In most instances, through making their models, pupils will have tactile and visual experiences of where forces are acting.



## Partners

Bloomfield science Museum Jerusalem  
 The National Museum of Science and Technology "Leonardo da Vinci"  
 Science Centre NEMO  
 Teknikens hus  
 Techmania Science Center  
 Experimentarium  
 The Eugenides foundation  
 Condervatoire National des Art et Métiers- muse des arts et métiers  
 Science Oxford  
 The Deutsches Museum Bonn  
 Boston's Museum of Science

Netiv Zvulun – School  
 Istituto Comprensivo Copernico  
 Daltonschool Neptunus  
 Gränsskolan School  
 The 21st Elementary School  
 Maglegårdsskolen  
 The Moraitis school  
 EE. PU. CHAPTAL  
 Pegasus Primary School  
 KGS Donatusschule

ECSITE – European Network of Science Centres and Museums  
 ICASE – International Council of Associations for Science Education  
 ARTTIC  
 Manchester Metropolitan University  
 University of the West of England

Er zijn 10 lessenseries beschikbaar in deze talen:



The units are available on [www.engineer-project.eu](http://www.engineer-project.eu) till 2015 and on [www.scientix.eu](http://www.scientix.eu)

