

TECHNOLOGY

Grade 9

CAPS

Teacher Guide

Revised Edition



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[Names to be supplied.]





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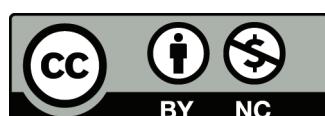
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Photocopiable grid paper





Minimum materials and tools needed for technology activities

Learners need to bring their own basic writing and drawing tools to class, as well as some waste materials that will be reused. But the school should provide all the other materials and tools listed below. Not all the materials and tools will be used in every chapter. At the start of each chapter there is a list of the specific tools and materials required for that chapter.

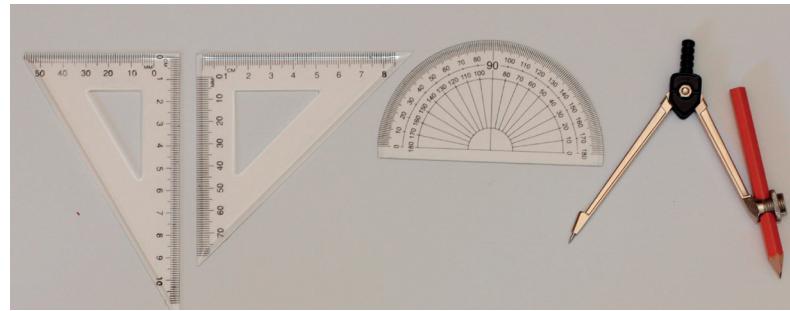
Important: The teacher should read about the required materials and tools for a chapter at least one week before that chapter starts. This will ensure that there is enough time for the teacher to put the necessary materials and tools together, and time for the learners to gather the materials they have to bring to school.

Tools to be bought by learners

(Necessary for all Technology classes)



Pen, pencil, sharpener, eraser, ruler (30 cm)



Geometry instruments: compass, protractor, set squares (30° and 45°)



Calculators

Materials to be sourced by learners

(reuse packaging materials etc.)



Left: New 180 gsm cardboard in different colours (optional, only if learners can afford it). Middle: Reused Cardboard (thick cardboard like that used for cereal boxes). Right: Corrugated cardboard (single layer)



Cardboard tubes from rolls of toilet paper, foil, etc.



Materials to be bought by schools



Big, strong scissors/ kitchen snips (buy in bulk at about R15 each). DO NOT USE SMALL CHEAP SCISSORS!



New 180 gsm cardboard in different colours (much thinner than cereal box cardboard, and easier the cut and fold)



Masking tape



Wood glue (glue stick like 'Pritt' is optional)



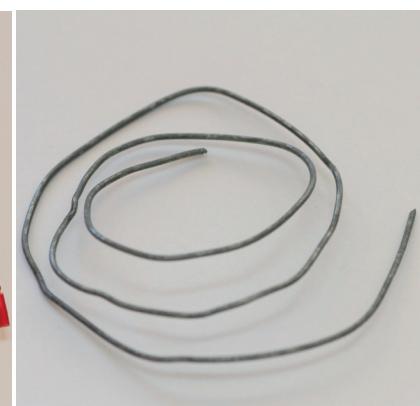
Prestik (masking tape can be used instead if this is not available)



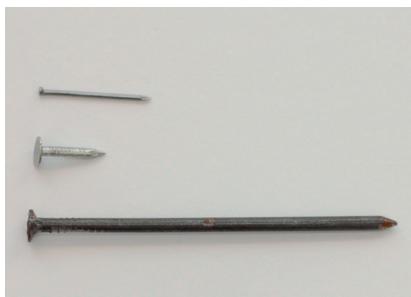
String (cotton, 2-3 mm)



Copper wire, 1 mm (this bends easily by hand and can be cut with scissors; buy from hardware store)



Galvanised steel, wire 1 mm (optional: if pliers or other tools for cutting and bending wire are available)



Nails (1 mm, 2 mm, 4 mm, and 6 mm diameters; minimum lengths between 3 cm and 8 cm)



Syringes (buy from a pharmacy, different diameters)
Pipe to use with syringes (buy from a pet shop, for fish tanks)



Paper clips



Paper fasteners (split pins, optional, may need to go to specialist stationery or art shop to buy)



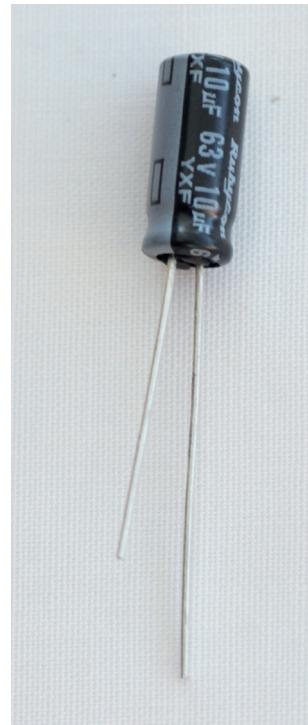
Tooth picks (buy in bulk)



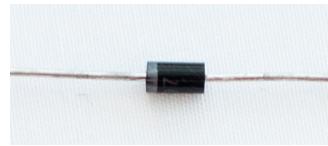
Drinking straws (buy in bulk)



Electric and electronic equipment and materials to be supplied by schools (in addition to the equipment and materials needed in Grades 7 and 8)



Capacitors



Diodes



Light dependent resistors (LDR's)



Light emitting diodes (LED's)



Push button switches



Single-pole, double-throw (SPDT) switches



Single-pole, single-throw (SPST) switches



Thermistors



Transistors



Variable resistors

X



How to use this Teacher Guide

Notes to the teacher at the start of each chapter

All the Learner Book (LB) pages are included in this Teacher Guide (TG). In addition, notes to the teacher are given before the LB pages, at the start of each chapter.

The teacher notes pages have a coloured background.

The teacher notes provide the teacher with:

- a summary of the chapter's work,
- some deeper explanations that are not in the LB, and
- a guide for how to prepare for the week's lessons.

Teachers should therefore read the teacher notes as part of their lesson planning, in addition to reading the LB pages.

Page numbers

The TG has different page numbers than the LB.

The TG page numbers are indicated in the usual position at the bottom of pages.

The LB page numbers are indicated at each place where a new LB page starts.

Answers to questions in the Learner Book

Answers to questions (shown in red) have been added to the LB pages in the TG.

When in the term to teach each chapter

The table of contents in the TG shows for each chapter the week(s) of the term in which that chapter should be done.

Teachers should also refer to CAPS as well as their subject advisors for guidance

The TG should be used in conjunction with the CAPS document.

For assessment of PATs, the TG does not provide analytical rubrics for assessment; the TG only indicates mark allocation and gives example answers. Teachers should make their own analytical rubrics, or use rubrics provided by their subject advisors, and refer to the example of an analytical rubric that is provided on p. 44 of CAPS.

Grid paper for drawing

Square and isometric grid paper are provided on the last three pages of this TG. Teachers may photocopy this for learners if required. When photocopying, please make sure that the copies are made on 100% scale.

Where to find electronic versions of the books

The DBE's Thutong website: <http://www.thutong.doe.gov.za/>

The Thutong website also contains additional learning resources.

Ukuqonda Institute: <http://ukuqonda.org.za/learning-materials/technology-grd-7-9>



Term 1: Structures

CHAPTER 1

Orthographic drawing

In Grades 7 and 8, the learners learnt the basics of drawing. So far they have covered the difference between sketches and formal drawings and have learnt how to draw oblique and perspective views. They have studied single and double vanishing point perspective drawings, and have been given a lesson on shading and colouring to provide realism in drawings.

In this chapter, the learners will initially recap a lot of these skills, then they will learn how to make drawings that show the exact sizes of parts of objects. The drawing will also show what objects look like from different viewpoints, which will give them skills necessary for drawing plans.

- 1.1 About orthographic drawings 5
1.2 Make your first orthographic drawings 8

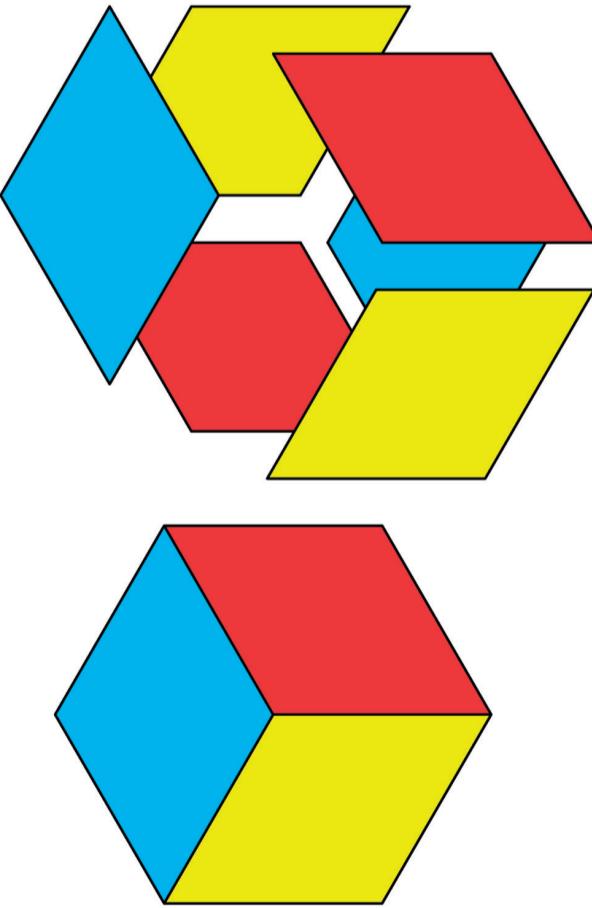


Figure 1

- Materials required for this chapter:**
pencil
eraser
coloured pencils for shading
ruler

1.1 About orthographic drawings

The learners can get an excellent idea of what they are going to learn in this chapter by looking closely at the illustrations on pages 1, 2 and 3 and answering the simple questions. On page 4 is the definition of orthographic; it is very important that the learners understand this concept so it is advised that you read through this with them. Questioning the class during and after this will be a good indicator that they understand the definition and follow the concept.

Through investigating the examples and answers that follow, the learners will be shown how orthographic drawing is used to make plans. This is a very important skill, and as this section should not take too long, it is advised that the learners observe objects around them, such as tables and chairs, and discuss which view is which. This will help them to visualise objects in section 1.2.

1.2 Make your first orthographic drawings

The learners have to be able to identify isometric views in order to draw orthographic views; Figure 15 will remind them of what an isometric projection looks like. If any learners are having difficulty visualising the three views you can use a small box to demonstrate the views; angled for isometric, and face on/side on/from above for the orthographic views.

In this section the learners will have to take note of dimensions, so you should emphasise this early on in the lesson.

Figures 18 and 19 together are very important as an aid to understanding orthographic drawings. They should be worked through carefully with the learners, ensuring that they can match the preliminary drawings with the final plan.

The learners have already learnt in Grade 8 about the different types of lines they must use in their drawings. This is covered again as a reminder in Figure 24 and the notes. Make sure that they use the correct lines when you assess their free-hand drawings on page 12.

There are not a lot of questions in this chapter, so it is important that you make sure that all the learners have grasped the concept of orthographic drawings as they will not be able to complete the work in the following chapter if they do not have this skill.



LB pages 2-3

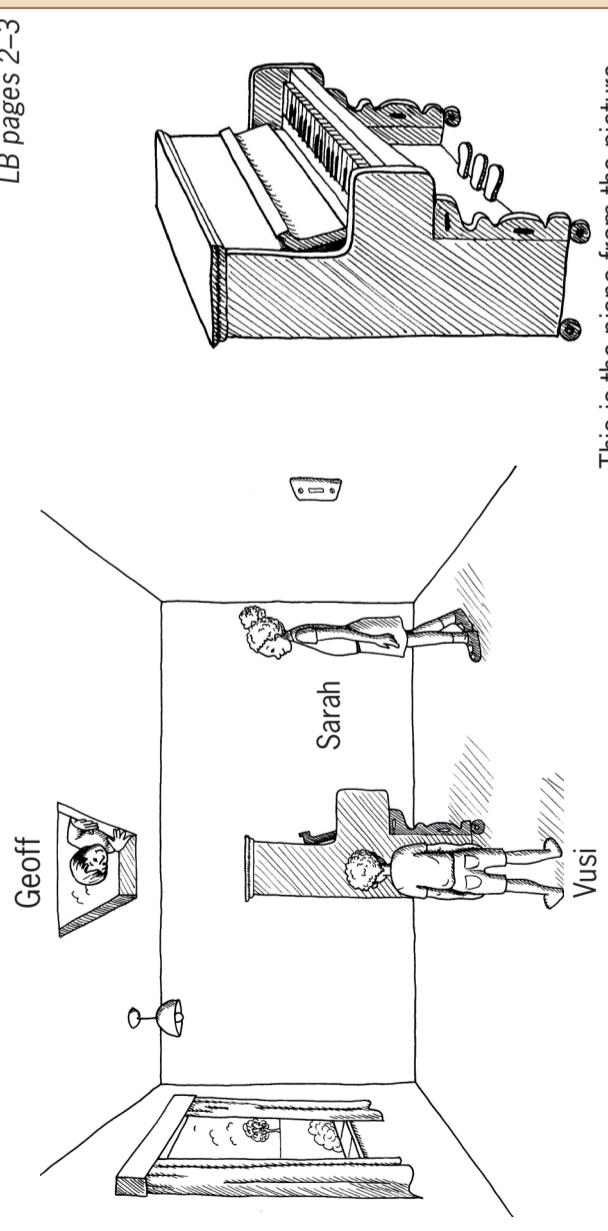


Figure 2

1.1 About orthographic drawings

In Grades 7 and 8, you learnt different ways of drawing your designs. You can quickly put your ideas on paper with sketches. Adding perspective makes drawings look more realistic. Adding shading and colour make your drawings look even better.

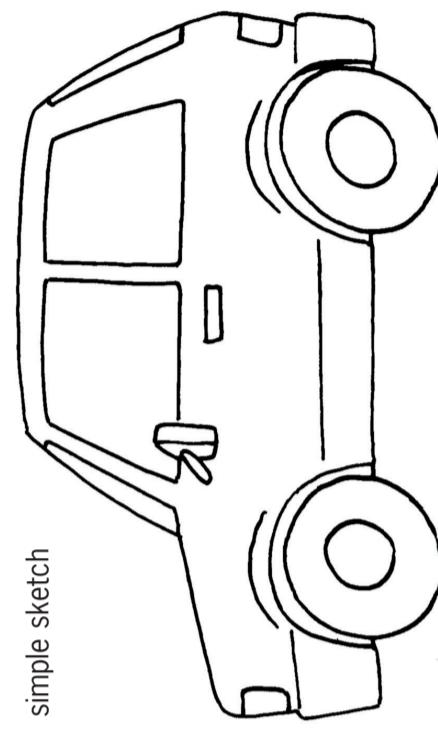


Figure 4

isometric sketch

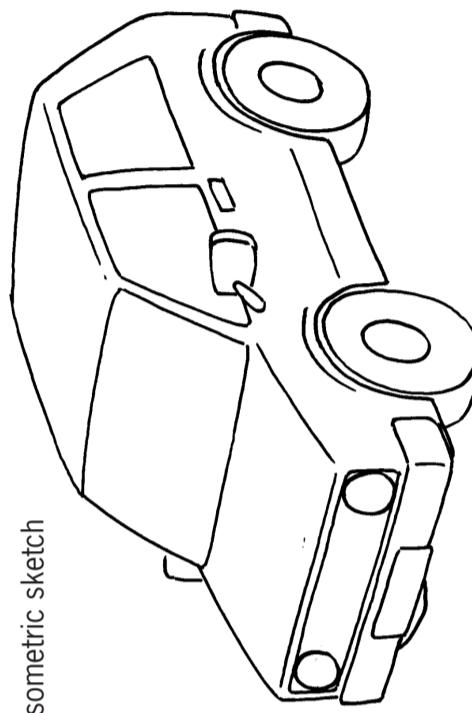


Figure 5

The word **orthographic** comes from two words. "Ortho" means looking straight at a flat face of an object. "Graphic" means a drawing.

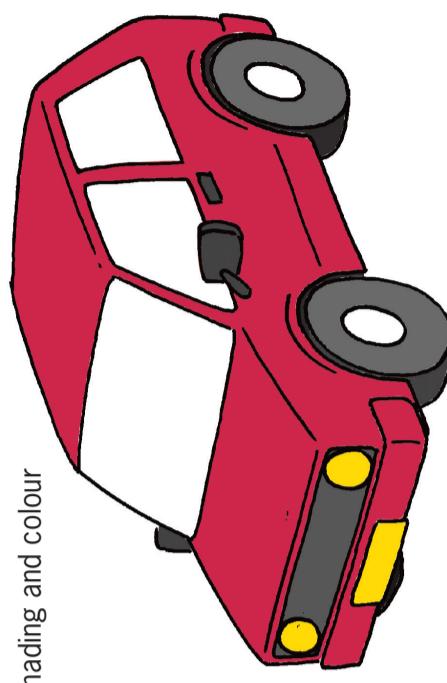


Figure 6



Orthographic drawings

You will now learn how to make **orthographic** drawings. This means you will look at an object from different sides and make separate drawings of what you see.

Look at this isometric drawing of a rectangular box. Only three faces of the box are visible.

1. How many faces of the box are not shown on this drawing?

Three faces are not shown

If you look straight down from above at the box, you will see only a blue rectangle.

This is called the **top view**.

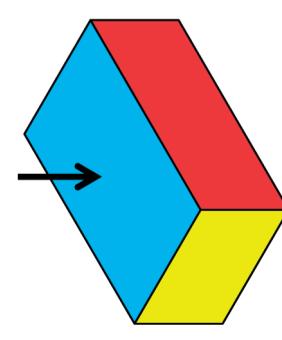


Figure 8

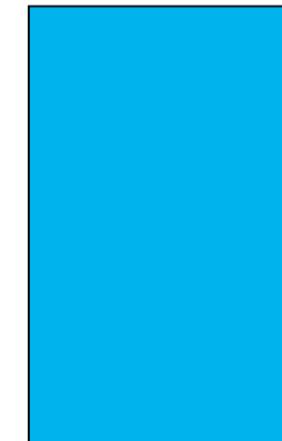


Figure 9

If you look at the box from a certain position on the left, you will see a yellow rectangle.

This is called a **side view**.

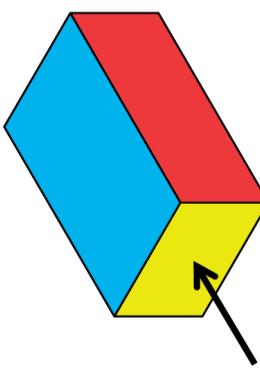


Figure 10

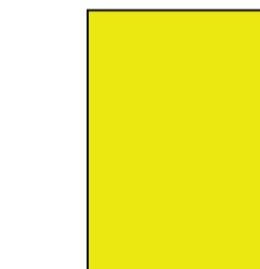


Figure 11

If you look at the box from a certain position on the right, you will see a red rectangle.

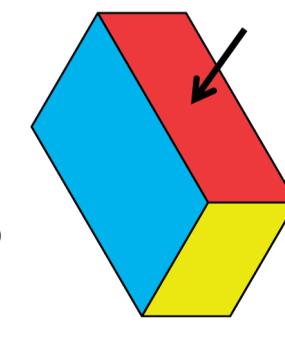


Figure 12

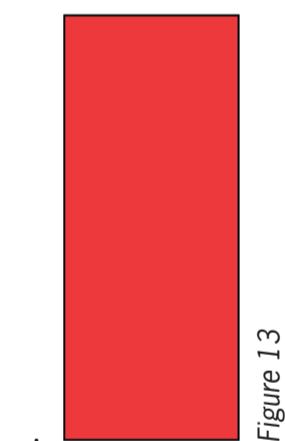


Figure 13

LB p. 5

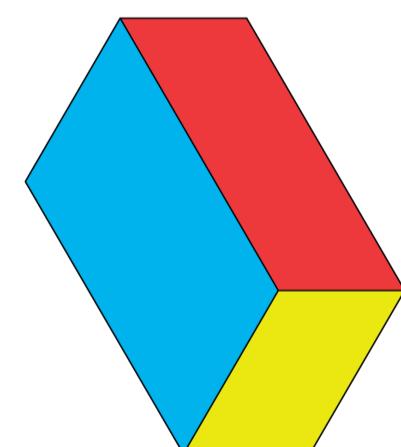


Figure 7

The front view, top view and one side view of a small house are shown below. A set of drawings like this is called **first-angle orthographic projection**.

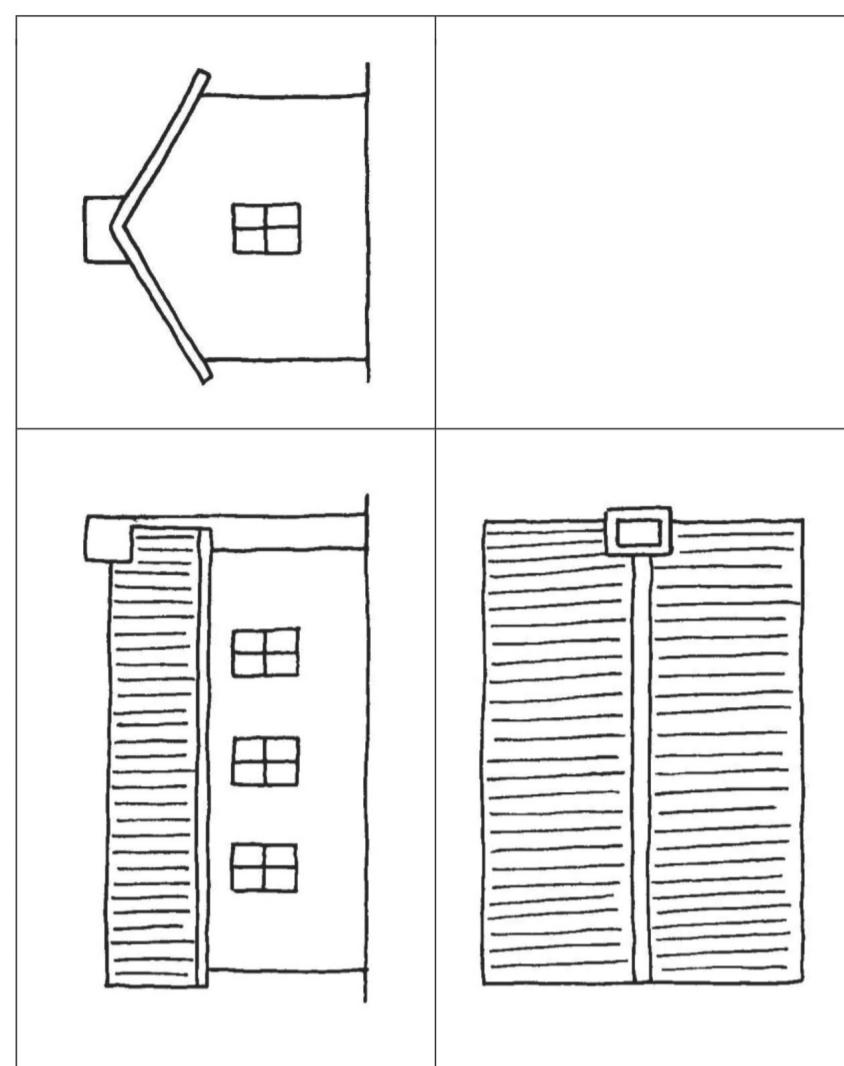
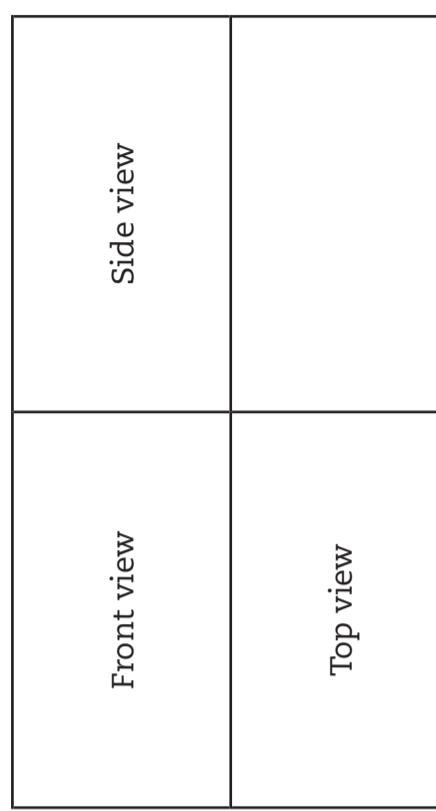


Figure 14

First angle orthographic projections are normally drawn in blocks as shown here. The front view is drawn first, in the upper left block. Construction lines are then drawn from the front view to make it easier to draw the top view and a side view. A side view can also be called an end view.



Side view

Front view

Top view



1.2 Make your first orthographic drawings

An orthographic drawing of a staircase

An isometric drawing of a mobile staircase is shown in Figure 15. The staircase is 900 mm wide. The other dimensions are shown on the side view in Figure 17 on the next page.

1. Figure 16 in the Learner Book shows a front view of the staircase. Divide a sheet of grid paper into four blocks. Copy the front view onto the top left block of your sheet of paper. Now use construction lines to draw a top view and side view in the bottom left and top right blocks.

The completed drawing in Figure 16 must look like this:

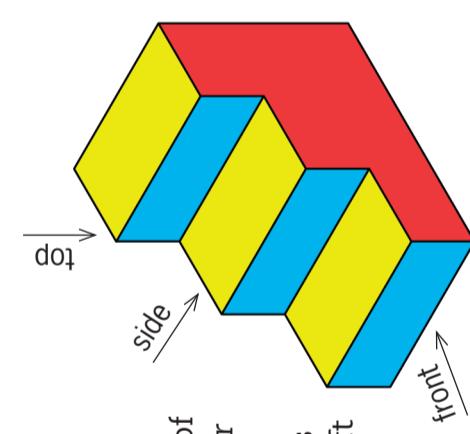


Figure 15

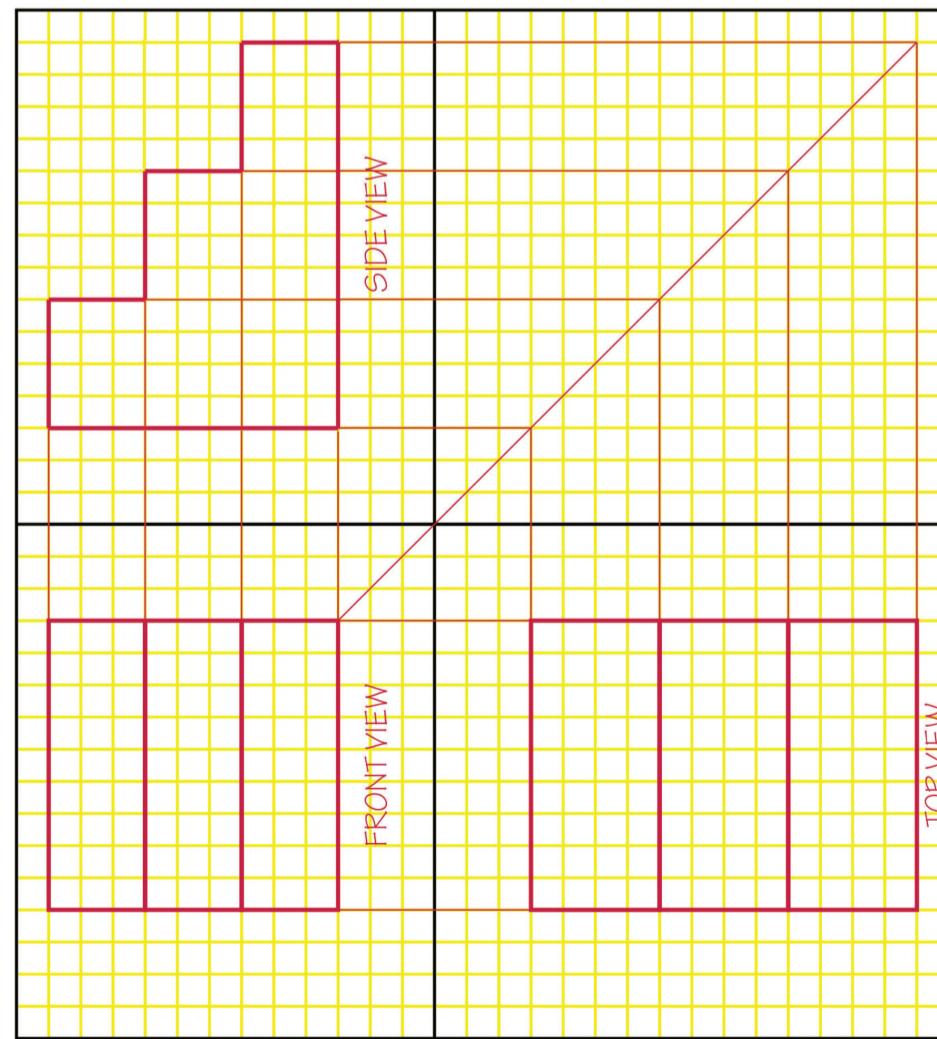


Figure 16

LB page 7

LB p. 7

LB page 8

The small lines on your ruler are 1 mm apart.

Architects use orthographic drawings of houses to tell the builder the size of the windows, how tall the walls are and how high the roof is. These are called dimensions or measurements. We usually write measurements in millimetres (mm).

Look at this side view of the staircase. You can see the measurements between the arrows.

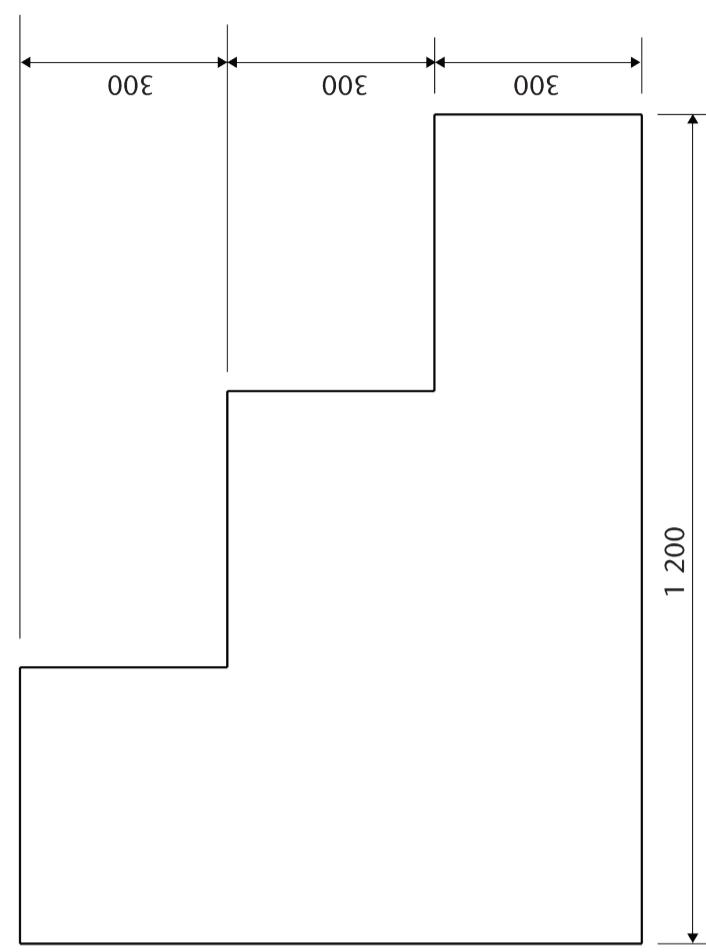
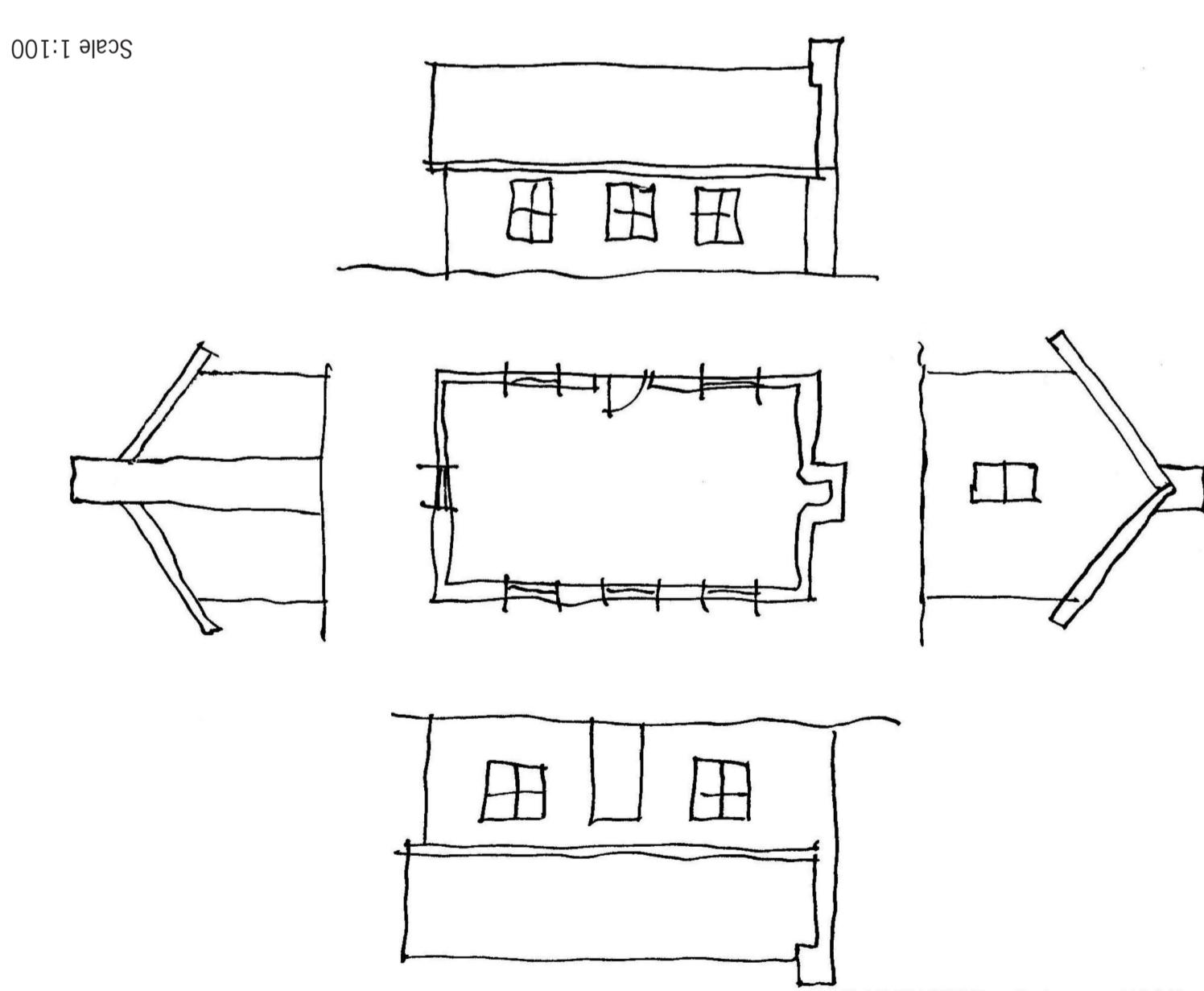


Figure 17: Side view of the staircase with measurements

Figure 18: Preliminary drawings



Have a look at the drawings below and on the next page. An architect made these while he designed a house.

LB page 9

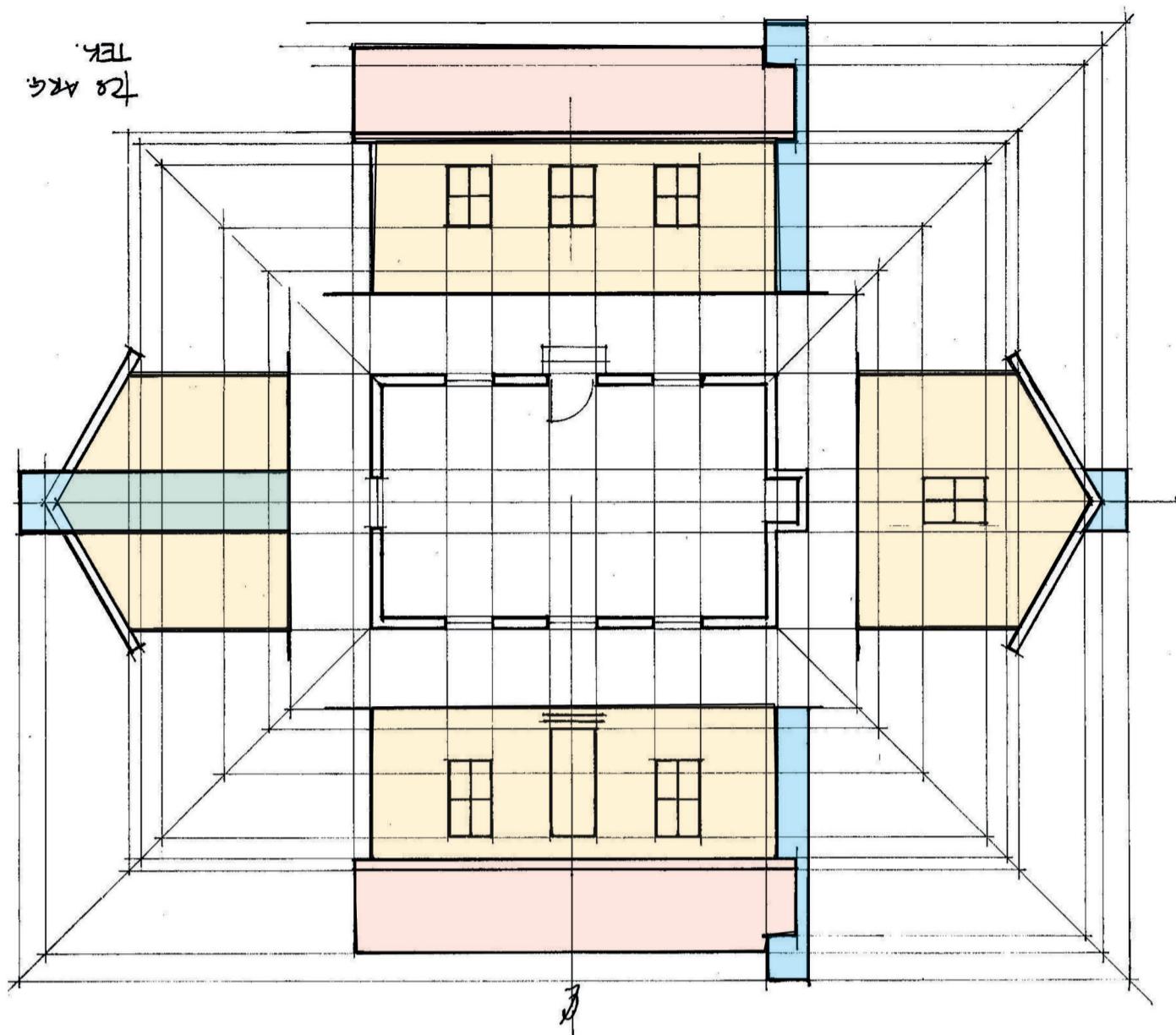


Figure 19: Final drawings



Different kinds of lines in drawings

Different kinds of lines are used in the following drawing:

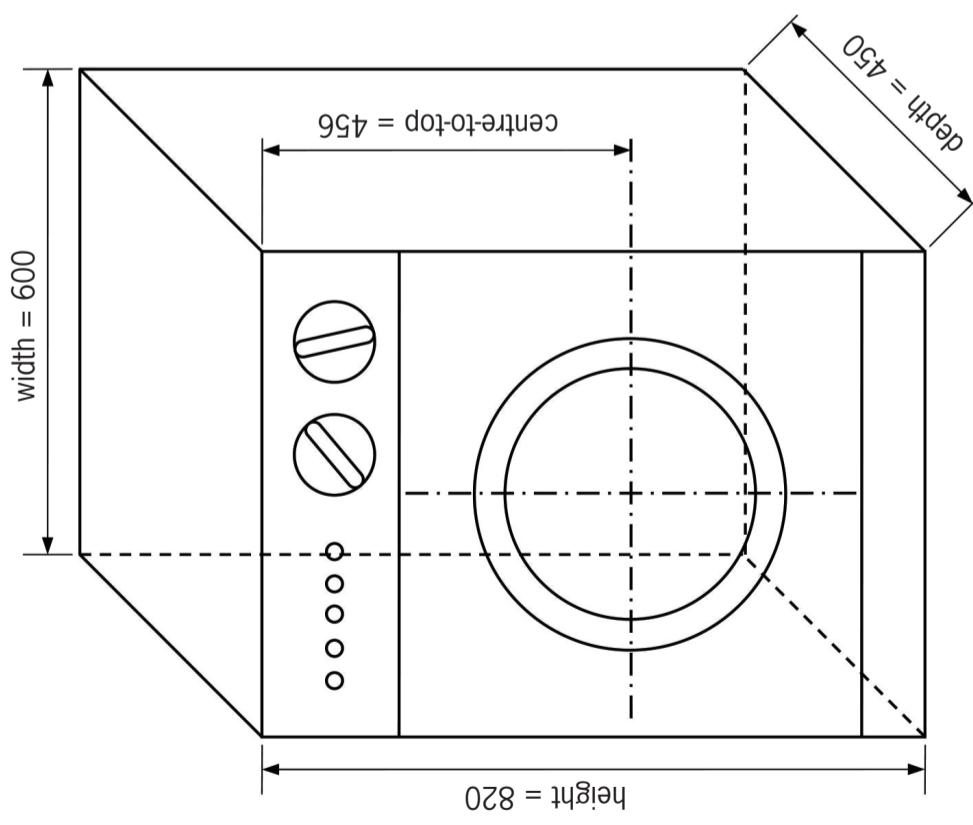


Figure 20

The following types of lines are used in the above drawing:
thick solid lines, _____
thin solid lines, _____
dashed lines, and _____
chain lines. _____

LB page 11

Use different kinds of lines

LB p. 12

Make a free-hand copy of the drawing in Figure 20. Use all of the different types of lines.

Make sure that the learners' drawings show the correct lines in their free-hand sketches of the washing machine in Figure 20.

Next week

In the next chapter you will further develop your drawing skills. You will have to make various drawings of a staircase and wheelchair ramp.

CHAPTER 2

Provide for wheelchairs

2.2 Isometric drawing

The learners are given two opportunities to practise their first isometric drawings on page 19. Both are free-hand sketches, but in the second sketch the learners should be far neater and more accurate, and make a note of dimensions. It is important that the learners only sketch the ramp in this section, as the steps are sketched in the following section.

2.3 The plan in orthographic drawings

LB page 13

In the previous chapter the learners added to their drawing skills by learning about orthographic drawing. They looked at an isometric drawing and drew an orthographic version of that drawing, taking the dimensions into account.

In this chapter the learners are going to combine orthographic and isometric skills in a practical exercise where they are asked to design a mobile staircase and ramp for wheelchair access to a stage. It is an exercise that they will be able to relate to, and this will assist with the design brief, the specifications and constraints.

- | | | |
|-----|---|----|
| 2.1 | Stairs and a ramp | 17 |
| 2.2 | Isometric drawing | 19 |
| 2.3 | The plan in orthographic drawings | 21 |

Materials required for this chapter:

- pencils
- pencil sharpener
- eraser
- ruler

2.1 Stairs and a ramp

The learners must understand exactly what they are being tasked to do to save time later on. They must revise the word specifications that they used in Grade 7 and Grade 8 projects. You will be able to monitor their understanding by assessing the rough sketches they draw of their plans for the staircase/ramp. Make sure that all the learners have entered the dimensions, as this is critical for their accurate drawings later in the lesson.

At the end of the lesson the learners must revise how isometric drawings are made: run through the paragraph on page 17 as they will need to remember this for their homework.



LB pages 14–15

2.1 Stairs and a ramp

Nelson Mandela High School has a new community hall. A staircase and wheelchair ramp is needed for the stage in the hall. The principal made a list of things that should be kept in mind when designing the staircase and wheelchair ramp.

These are called **specifications**.

The specifications for the staircase and wheelchair ramp are:

- The stairs and ramp must be made in one unit so that it can be moved.
- The unit should fit in front of the stage so that people can walk onto the stage and wheelchairs can go up and down.
- The stage is 400 mm high.
- The stairs should be wide enough for two people, about 1 200 mm.
- There should be three steps of the same size.
- The flat part of each step is 800 mm long.
- The ramp should be wide enough for one wheelchair – 1 000 mm.
- The slope of the ramp should be 2 433 mm long.
- The ramp is at a 10° slope.
- The base of the ramp should be 2 400 mm long.
- The ramp should have a handrail to prevent wheelchairs from falling off.

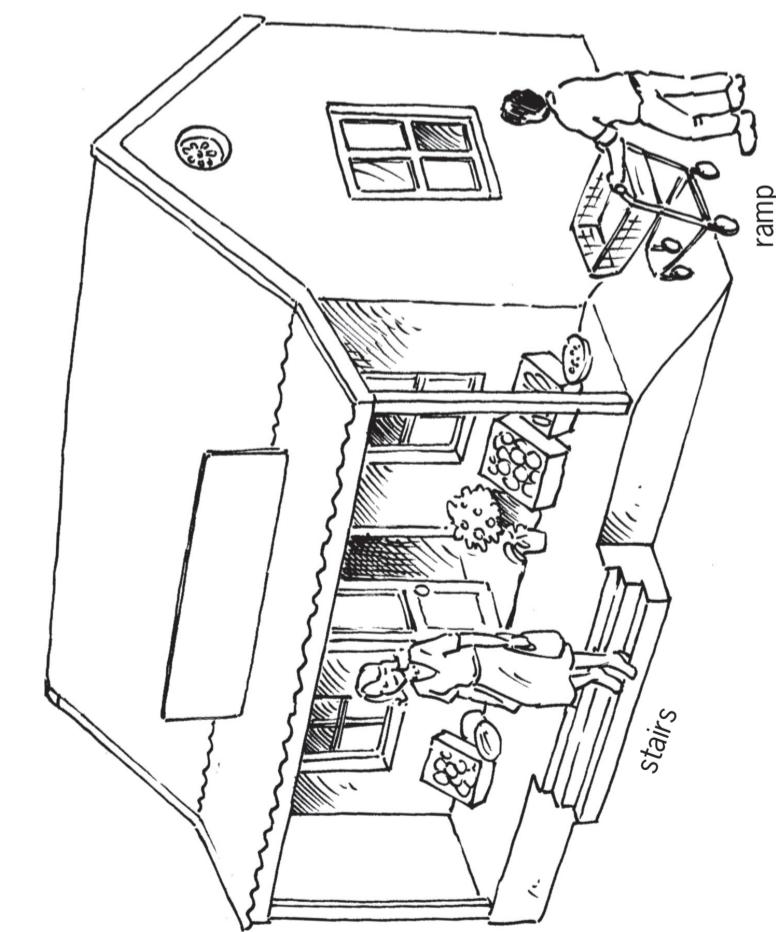


Figure 1

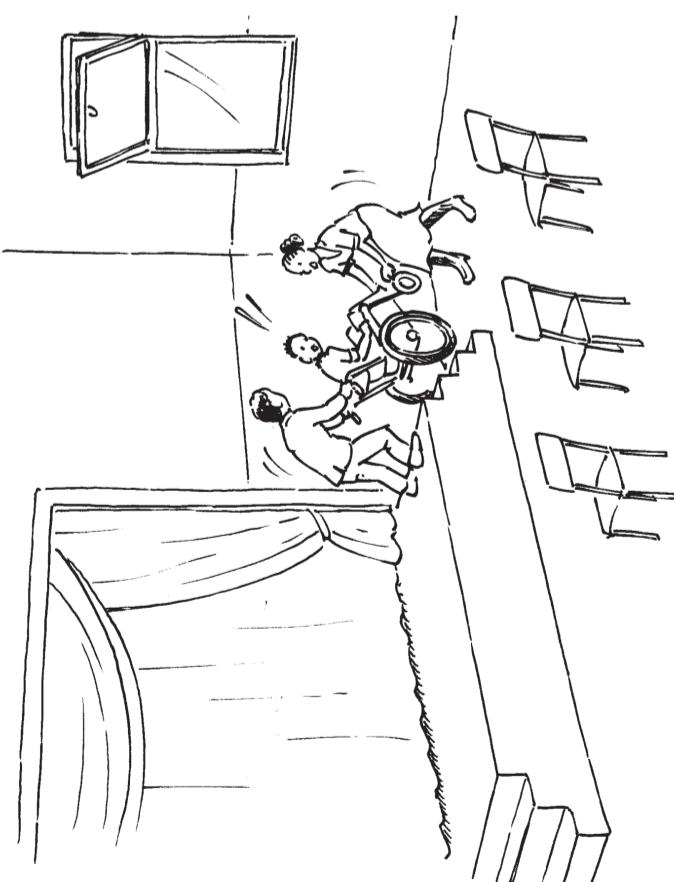


Figure 2

LB page 16

If you look at the picture on the previous page, you will see what a ramp is.

LB p. 16

To help you imagine what the combined staircase and ramp will look like, you can make a few drawings.

1. Make a rough drawing to show what you think the combined staircase and ramp should look like. Make your drawing on a clean page, and make it big enough to fill the page.
2. Dimensions are given in the above specifications. Write the dimensions in the correct places on your drawing.

Check the learners' sketches. Make sure they have followed instructions and put in the dimensions.



Isometric drawings

LB page 17

An isometric drawing can help you to see more clearly what your idea would look like when it is built. To make an isometric drawing, draw all the vertical lines of the object at 90° to the base, and all the horizontal lines at 30° to the base. You can use isometric grid paper to help you do this.

Homework: Make an isometric drawing of a cube LB p. 17

Look at the orange lines on the grid paper below. Do you see how the **vertical** line goes up through the middle of the diamond shapes? And how the **horizontal** line goes across the middle of the diamond shapes? The other lines are at 30° to the horizontal line.

Copy the drawing of the cube onto a sheet of isometric grid paper.

Check the learners' homework. Make sure the cube they have completed is correct.

2.2 Isometric drawing

LB page 18

There is an isometric drawing of a staircase in Chapter 1. What do you think an isometric drawing of the ramp would look like? It might look a bit like a slice of birthday cake!

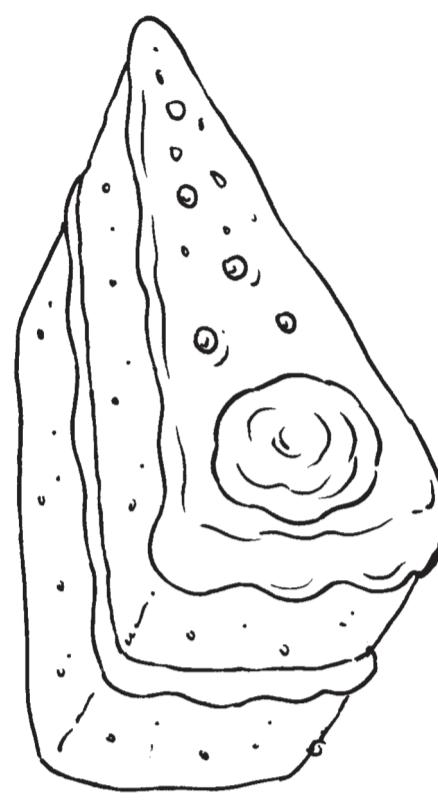


Figure 4

An isometric drawing of the wheelchair ramp LB p. 18

1. Make a sketch of the wheelchair ramp that looks like the slice of cake above, on the top part of a sheet of isometric grid paper.
2. Now make a better sketch on the bottom part of the sheet of paper.
3. Look at the list of specifications at the beginning of section 2.1. Label the following on your drawing:
 - the height of the ramp,
 - the length of the **sloping** part of the ramp, in other words the distance from A to B on the drawing on the right,
 - the length of the base,
 - the width of the ramp, and
 - the 10° angle.

A sketch is a rough drawing that helps you to quickly put your ideas onto paper. It makes it easier to think about what you are designing. You do not need to use a ruler or exact measurements.

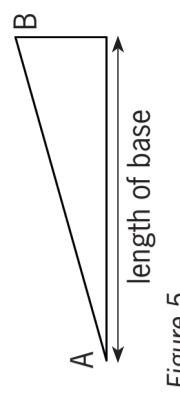


Figure 5

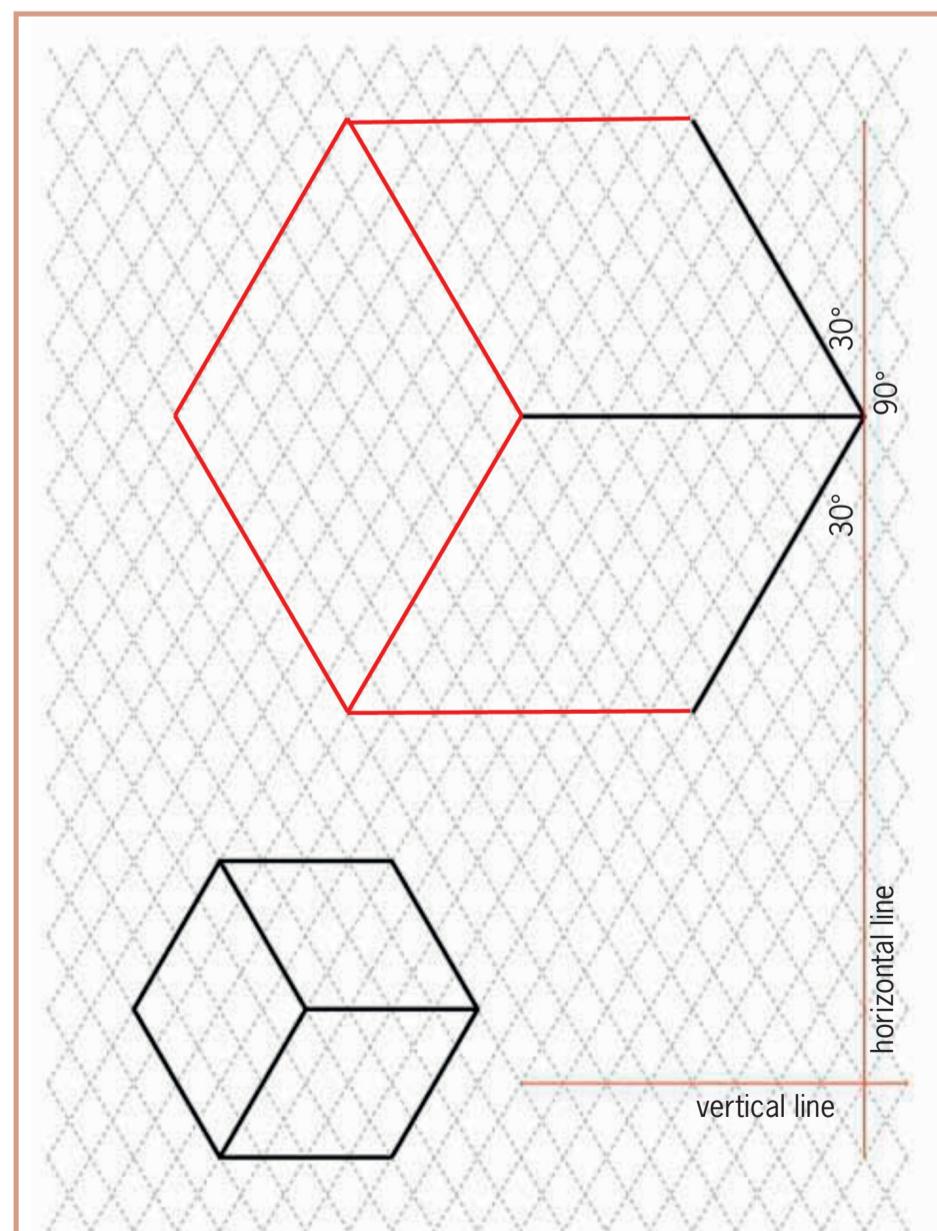


Figure 3



Check that the learners' sketches compare to this example.

LB page 19

2.3 The plan in orthographic drawings

Sketch the staircase LB p. 19

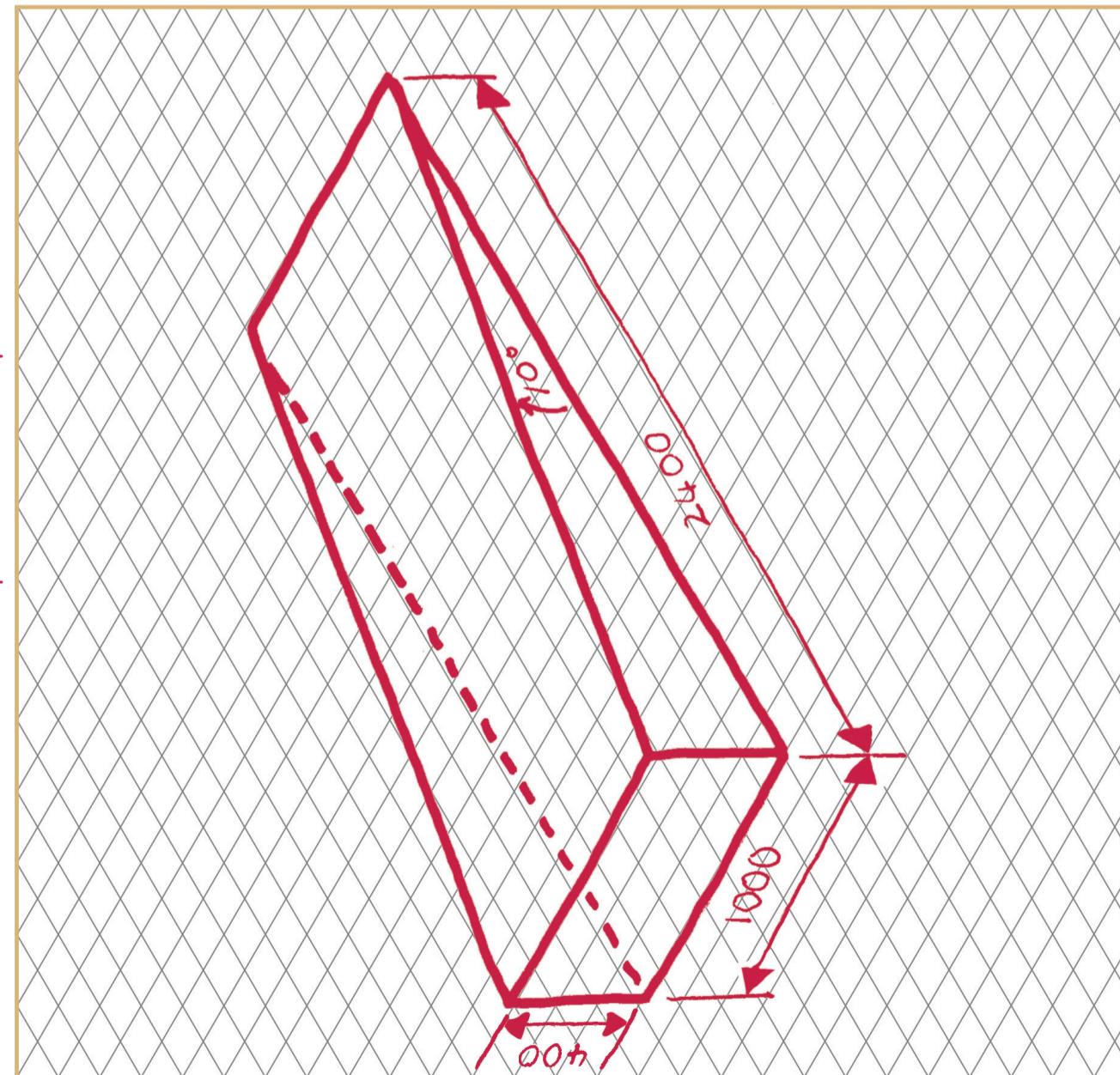
Make a sketch of the staircase on isometric grid paper.

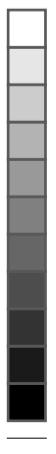
Remember it has only three steps.

Look at the list of specifications and label the following on your drawing:

- the width of the stairs,
- the height of the mobile staircase,
- the height of each step, and
- the length of the horizontal part of each step.

Check that the learners' sketches compare to the example shown on the next page.





2. Does your stair/ramp look as if it could work? Does it meet all the principal's specifications? Did you remember the handrail?
Learners' own assessment of their drawing according to the specifications.
3. If you are not satisfied with your drawing, now is the time to make changes and do it again, because it will be assessed by your teacher.

Make orthographic drawings of your design

LB p. 20

Look back at the specifications for the ramp and the staircase given on Learner Book page 16. Another student designed the ramp and staircase shown in Figure 6 below. But this learner didn't follow the specifications correctly.

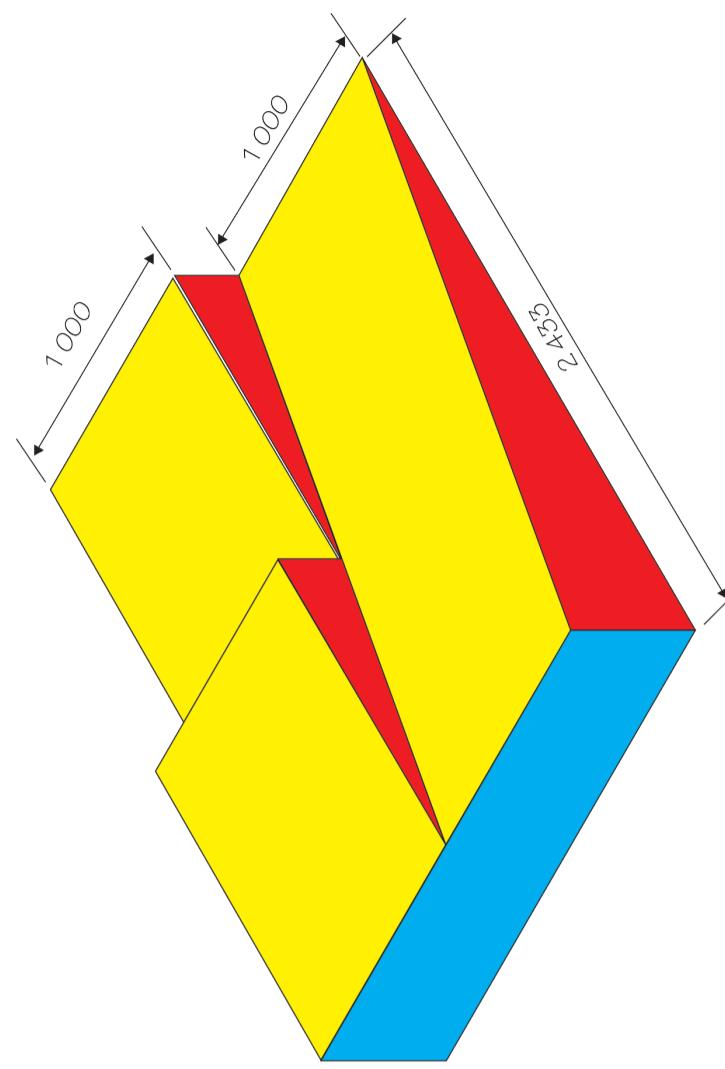
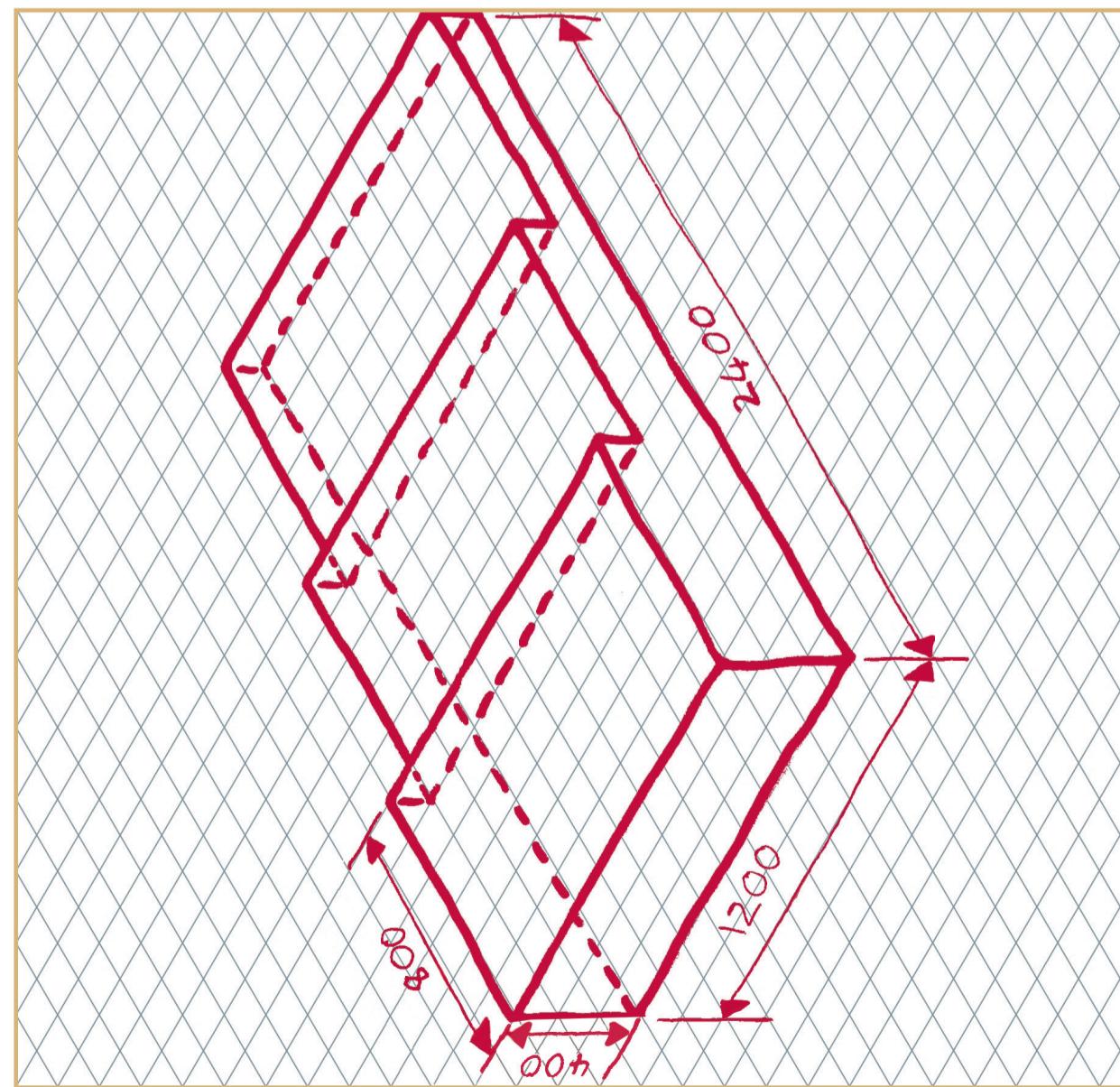


Figure 6: Is this design correct according to the specifications on page 16?

1. Compare the drawing in Figure 6 with the specifications for the ramp, given at the beginning of this chapter. Write notes to indicate any specifications that are not met.
There should be three steps instead of two. The (horizontal) length of the base should be 2 400 mm instead of 2 433 mm. The width of the stairs should be 1 200 mm instead of 1 000 mm. There should be a handrail.



Homework

LB p. 19

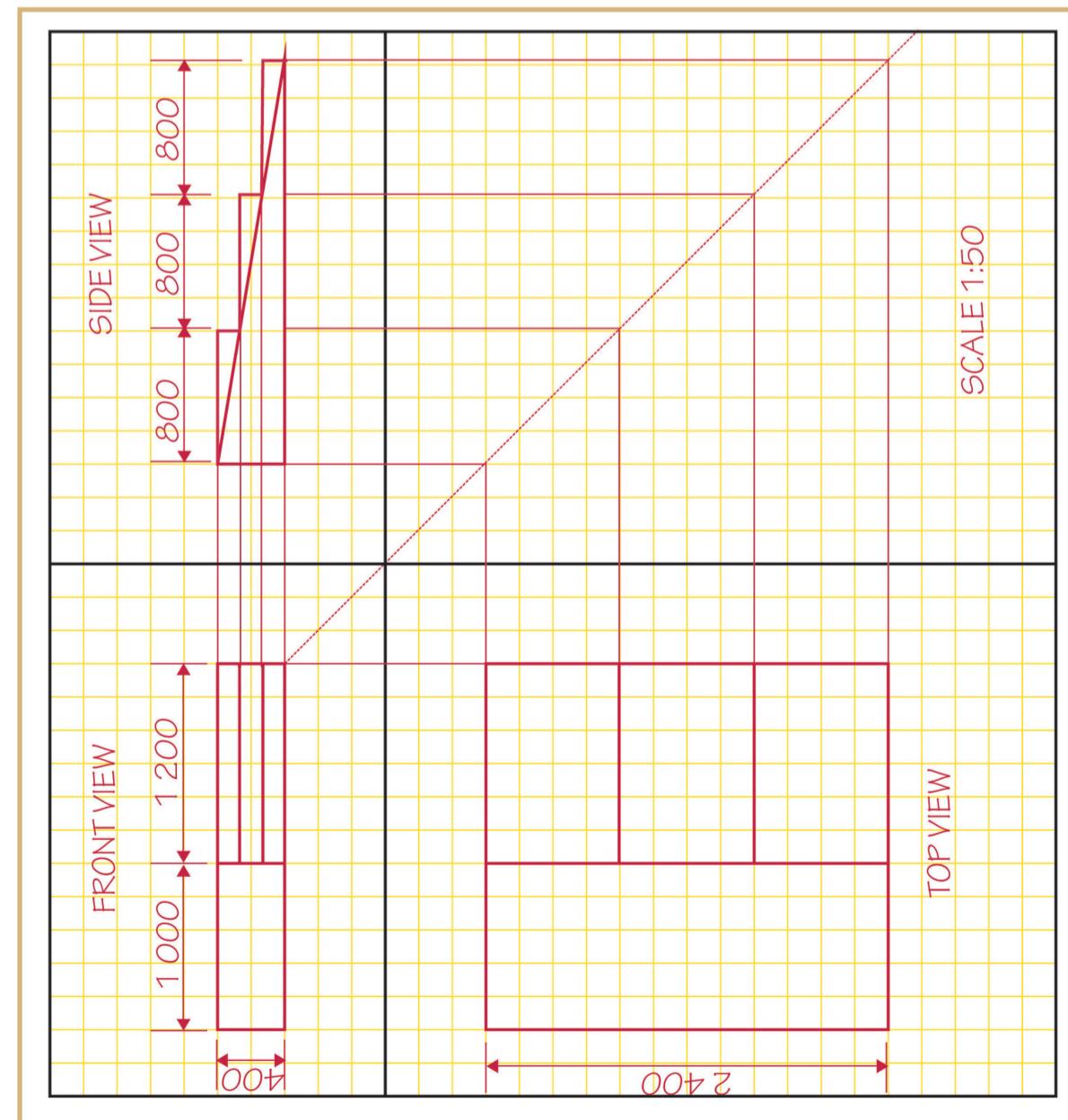
1. You already have a drawing of the staircase and a drawing of the wheelchair ramp. Sketch them together as one structure on the isometric grid below.

You must assess these drawings. The learners should have done a combination of the two previous drawings. Make sure that all unseen edges are in dashed lines. The drawing must resemble the example on page 22, but that drawing does not precisely adhere to the specifications (see the answer to question 1 on page 22). The learners' drawing, however, should precisely adhere to the specifications, except that the handrail does not need to be shown.



2. Draw a first-angle orthographic projection of your own design of the stair/ramp, according to the specifications given at the beginning of the chapter. Note that the specifications require three steps. Draw the top view, a side view from the ramp side, and a front view as a person that approaches the stairs to climb them will see the stairs or ramp. You do not have to draw the handrail as well. Make all the drawings to exact measurements, but keep in mind that if you draw them full size, they will not fit on the paper. So think of a scale that will fit on a sheet of A4 paper. Mark the real measurements on all the sides.

The illustration below is the accurate orthographic drawing according to the specifications on page 16, except that the handrail is not shown. Check the learners' drawings and make sure they have drawn all three views, that they have put all the dimensions in accurately, and that the scale is shown.



Next week

In the next chapter, you will learn more about different kinds of forces that may damage the things we build. You will also learn how materials can be made stronger, so that they can withstand forces that act on them.

CHAPTER 3

Structures, forces and materials

	LB page 21
3.1 Forces act in different places	30
3.2 Forces act in different ways	34
3.3 Different materials for different purposes	40

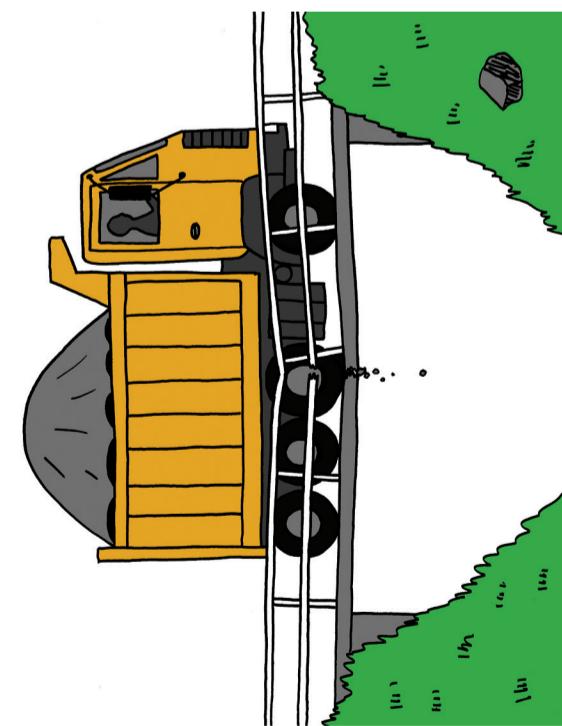


Figure 1: This bridge cannot withstand the forces acting on it.

Materials needed for this chapter:

12 sheets of unfolded, used writing paper
glue or sticky tape

Key concepts in this chapter:

- the distinction between static and dynamic loads (section 3.1)
- the distinction between even and uneven distribution of loads (section 3.1)
- different ways in which forces can act on structural elements (section 3.2)
- different properties of materials (section 3.3)

3.1 Forces act in different places

In the first lesson the materials provide a range of pictures that learners need to study closely and then answer the questions. Learners do not necessarily pay close attention to pictures, but looking closely at objects, pictures and diagrams is a very important foundational habit and skill for technological activity.

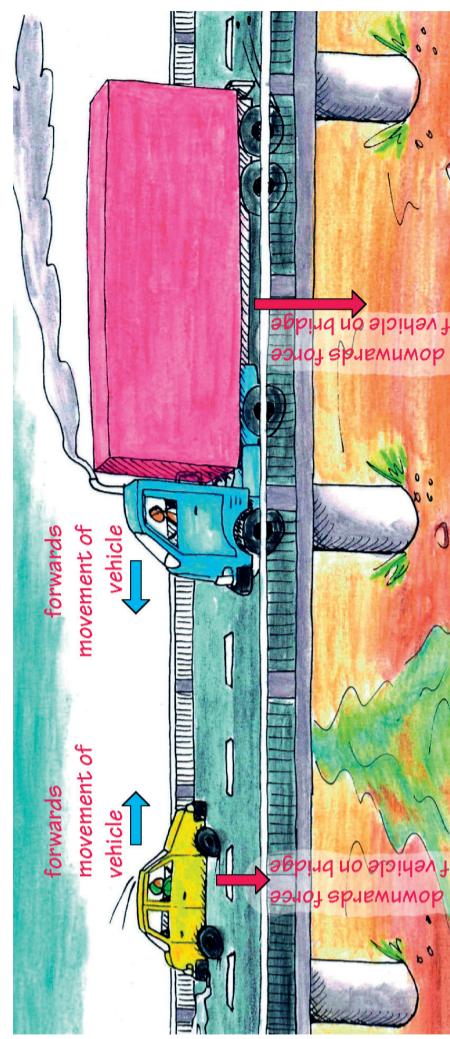
Some suggestions for additional explanations are given below.

Although we cannot see forces, we can feel them acting. For example, when the wind is blowing and you try to open the car door. A bed is a good example to use when explaining the difference between a **static force** and a **dynamic force**. A bed is strong enough to support the static force exerted by your weight as you sleep. If you jump up and down on the bed, your moving body exerts a dynamic force. Even though your body has the same weight, it exerts a greater force on the bed when you land after jumping up. As a result the bed may break. This is an example of a force that is dynamic in the sense that it acts **intermittently at the same place**. In a hammer drill, an intermittent force is used to produce a desired effect (e.g. breaking concrete).

In the learner text, Figures 5 and 7 provide examples of a different way in which a force can act dynamically, namely when the **point of impact moves around**.

Dynamic forces can cause structural failure unless they are taken into account when structures are designed. Technologists need to make their structures extra strong to resist dynamic forces.

Learners may need some support to distinguish between the direction of movement of a moving object, and the direction of the force it exerts on another object. For example, they may be asked to first draw arrows on Figure 7 to show the direction of movement of the two vehicles, and then to draw arrows to show the direction of the forces exerted by the vehicles on the bridge.



When designing structures, you need to consider the possibility of **uneven loads**. Uneven loads are demonstrated in Figure 8 (below) and Figure 9 on page 26 of the Learner Book.



LB pages 22–23

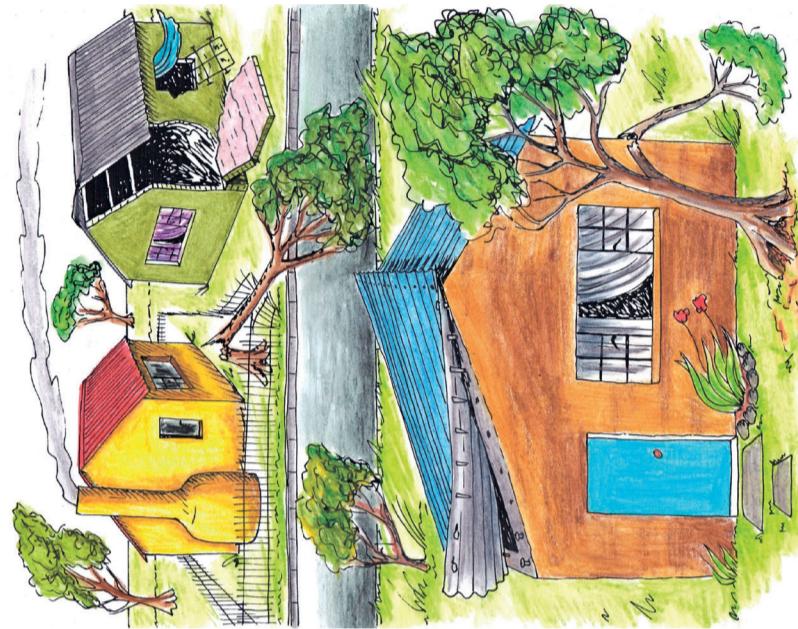


Figure 2: If the house is not strong enough, the wind may break it apart.

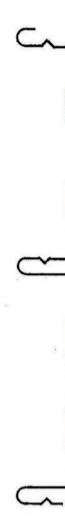
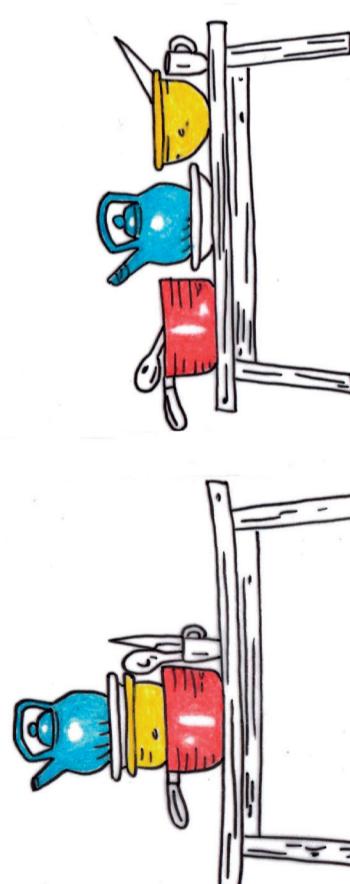


Figure 3: Roof sheets come in different shapes



3.2 Forces act in different ways

A variety of practical activities are described in the text for learners, to provide them with opportunities to experience different ways in which forces can act. We cannot see forces, but we can feel them in our body. Teachers may use the ideas below in discussions with learners.

Tension: You can feel a tension force when you link your hands together and pull.

Torsion: You can feel a torsion force if you grip the thumb of your right hand inside the palm of the left hand and twist. You will feel that the left hand is turning in one direction and the right hand is turning in the opposite direction.

Compression: You can feel a compression force when you push your hands together.

Shear: If the palms of your hands are dirty from gardening, you can clean the soil off by rubbing them together. Your hands are moving in opposite directions and exerting a shear force on your skin that scrapes off the soil.

Bending: You can feel a bending force by holding the ends of a ruler in both hands and making it curve. The forces exerted by your hands are moving in opposite directions and towards each other.

3.3 Different materials for different purposes

In this lesson, learners engage with pictures, text, practical activities and answers, to learn that different materials have different properties. These properties are: flexible/stiff; hard/soft; dense/less dense; corroding/not corroding.

Most of these properties are easy to understand, but the idea of density may be difficult for learners. Packing clothes into a suitcase is a helpful way to think about density:

Imagine there are two people going on holiday, each person has the same size suitcase. One person throws his clothes into his suitcase and then finds it difficult to get everything in! The other is a careful packer and folds everything first. She gets far more clothes in. When they are ready to go, her suitcase is much heavier than his, even though the cases are the same size. Her suitcase is denser!



3.1 Forces act in different places

Identify and analyse forces

LB page 24

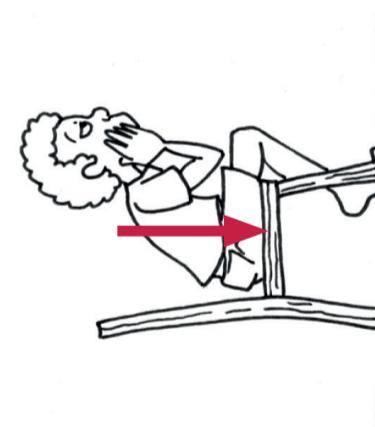


Figure 4: The boy sits still on the chair.

The weight of the boy in Figure 4 presses down on the chair as the arrow shows.

When one object pushes against another object, we say that a force is **exerted on** the object. In this case, you can say that the boy **exerts** a downward **force** on the chair, or that there is a downward **load** on the chair.

1. Work in pairs. In each of the pictures on this page and the next, show your partner how the load acts on the structure.

The red arrows in each picture show the answers.

LB page 25

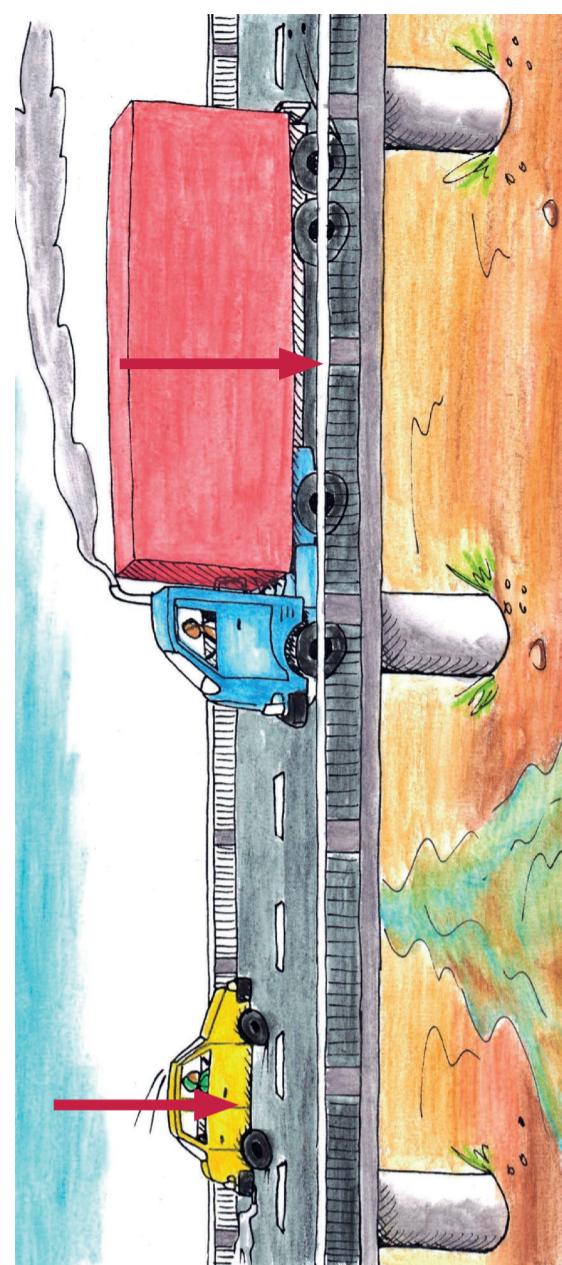


Figure 7: Vehicles passing over a bridge.

As long as a person sits still on a chair, the force on the chair remains in the same place. This is called a **stationary** or a **static force**.

3. In Figure 7 above, the truck and the car exert forces on the bridge. Can these forces also be called static? Explain why you say so.

No, because the vehicles are moving. The forces are not static.



Figure 6: A solar heating system on a roof

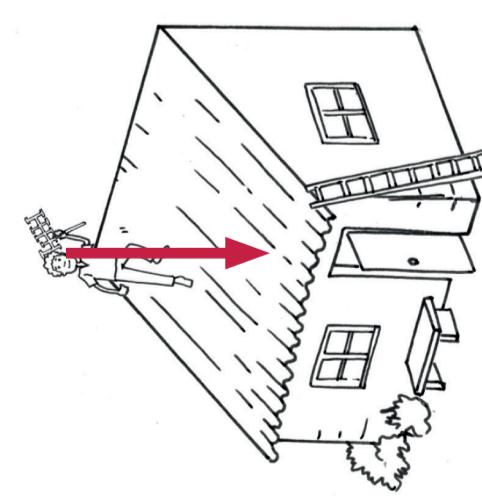


Figure 5: A man walking on a roof.

2. (a) Is the load on the roof in Figure 5 always in the same place?
Why do you say so?

No, because the man is moving around.

- (b) Is the load on the roof in Figure 6 always in the same place? Why do you say so?

Yes, because the solar heater is fixed or static.

- (c) Are the loads on the bridge in Figure 7 always in the same place? Why do you say so?

No, because the vehicles are moving.

LB page 24



Figure 7: Vehicles passing over a bridge.

As long as a person sits still on a chair, the force on the chair remains in the same place. This is called a **stationary** or a **static force**.

3. In Figure 7 above, the truck and the car exert forces on the bridge. Can these forces also be called static? Explain why you say so.

No, because the vehicles are moving. The forces are not static.

4. In each of the following cases, state whether the force exerted on the table is static or dynamic. Explain why you say so in each case.
 - (a) A pot of flowers standing on the table.

Static, because the pot is not moving.

- (b) A cat walking on the table.

Dynamic, because the cat is moving.

- (c) A boy rolling a soccer ball over the table.

Dynamic, because the ball is moving.

- (d) A man scrubbing the table.

Dynamic, because the man's hand is moving.



5. What is the difference between the loads exerted on the two tables below?

The pots are piled together on the left-hand table, so the load is in one place.
On the right-hand table, the load is spread out.

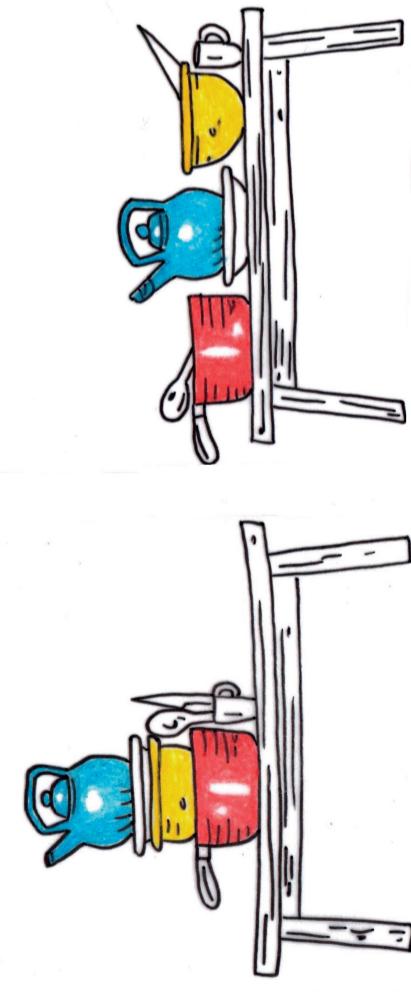


Figure 8: Different ways to place pots on a table.

A load that exerts an equal force over the whole structure that supports it, is called an **even** load.
A load that mainly exerts a force on one part of the structure that supports it, is called an **uneven load**.

A load that exerts an equal force over the whole structure that supports it, is called an **even** load.
A load that mainly exerts a force on one part of the structure that supports it, is called an **uneven load**.

6. Think of a house with a zinc roof and the forces that the sheets exert on the roof structure.

(a) Is the load even or uneven? Why do you say so?

The load is even because it is spread out all over the roof.

(b) Is the load static or dynamic? Why do you say so?

The load is static because the sheets of zinc do not move around.

7. Think of people climbing up and down wooden steps.

(a) Is the load even or uneven? Why do you say so?

The load is uneven because the person is standing on one small part of the steps each time.

(b) Is the load static or dynamic? Why do you say so?

The load is dynamic because the weight of the person is moving from one step to another.

8. You have to design two wooden tables, and you are requested to use as little wood as possible. For the one table, the design brief states that the load on the table will always be static and even. The design brief for the other table states that it has to carry the same weight as the first table, but the load will sometimes be dynamic and uneven. Describe how your designs for the two tables will differ, and explain why.

The table with a dynamic load needs to be stronger than the table with a static load, because the force of a dynamic load is greater than the force of a static load.

The same table has to support an uneven load. This means that the load may sometimes be close to the edge of the table, and the table could topple over. To stop the table from toppling over, the legs need to be as far apart as possible.

Or the legs can be built at an angle so that they point away from the table.

LB page 26

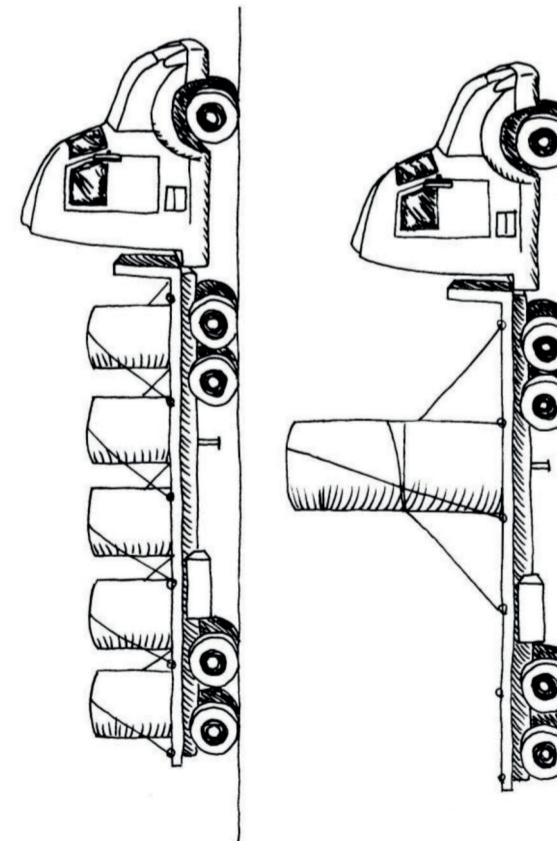


Figure 9: Different kinds of load on two trucks.



3.2 Forces act in different ways

Forces can act in the following ways on structures or parts of structures:

- tension,
 - torsion,
 - compression,
 - shear, and
 - bending.
- The different pieces of a frame structure are called **sections, elements** or **members** of the structure.

LB page 27

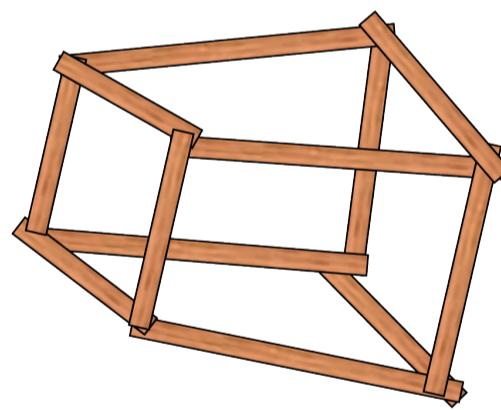


Figure 10: A frame structure made of planks.

Forces can push, pull and twist

Make six paper tubes by rolling sheets of used writing paper. Use glue or tape to prevent the tubes from unrolling.



Figure 11

1. Put your hands on both ends of a tube and push them towards each other.

When you do this, you exert **compression** forces on the tube.

2. Grab a tube at both ends and try to pull it apart. When you do this, you exert **tensile** forces on the tube. You put the tube under tension.

3. Put the ends of the tube on two books and press downwards on the middle of the tube. What happens, and what kind of force did you apply to the tube?

The tube bends because of a compression force.

4. Grab a tube at both ends and twist it as shown in this picture. When you do this, you apply **torsion**.



Figure 12

LB page 28

5. Join two tubes by putting a match or small stick through them as shown below.



Figure 13

When you try to pull the two paper tubes apart now, you will apply **shear forces** to the stick.

Find strength in shape

LB p. 28

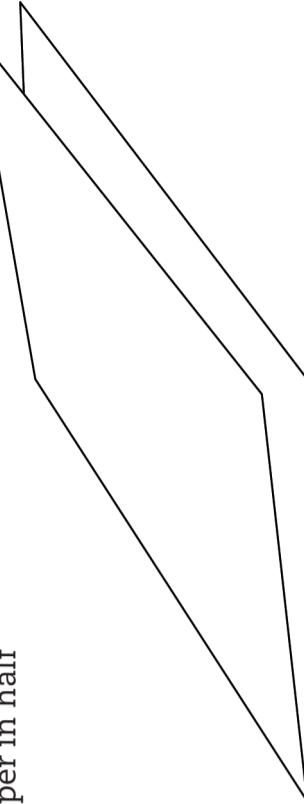


Figure 14

Fold it again:

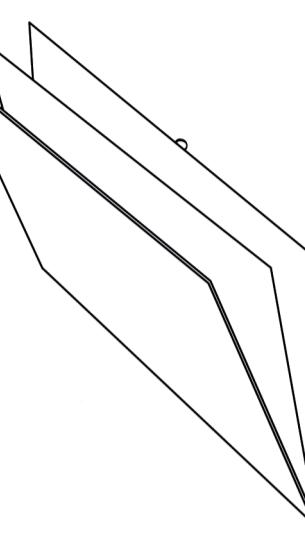


Figure 15

Fold it a third time, so that you have a flat strip that is eight layers thick.

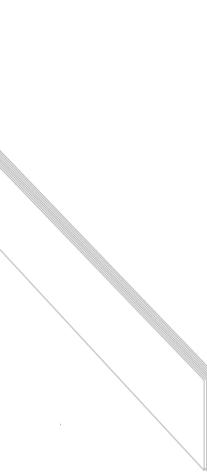


Figure 16

Make two more folded strips like this.

- LB page 29
- Put the folded strip at the edge of your desk as shown below. Hold it down on the desk with one hand and press down lightly on the outer part of the strip to bend it downwards.

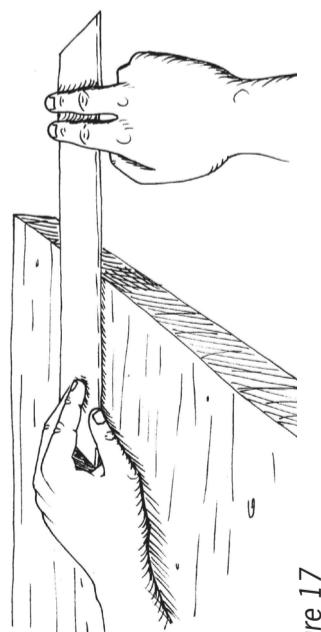


Figure 17

- Now fold your paper strip half-open again, and fold it in a new way so that you get a triangular tube as shown below.

First fold like this:

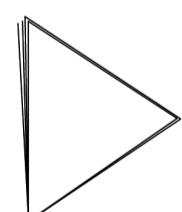


Figure 18

to make this triangular tube:



Figure 19

- Put the triangular tube at the edge of your desk as you did with the flat strip in question 2. Hold it down on the desk with one hand and press down lightly on the outer part to bend it downwards.

- What was easier to bend, the flat strip or the triangular tube?

It was easier to bend the flat strip.

This is the shape you see when you look straight at one end of your triangular tube:



Figure 21

- LB page 30
- The shape that you see when you look straight at one end of part of a structure is called the **cross-section** or **profile**.

- Make free-hand sketches of the cross-sections of a round tube, a square tube and a triangular tube.

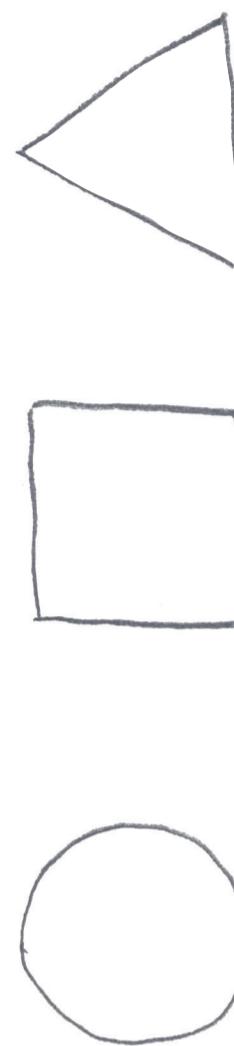


Figure 17

- Open your triangular tube and fold it again to have a T-profile as shown on the right.

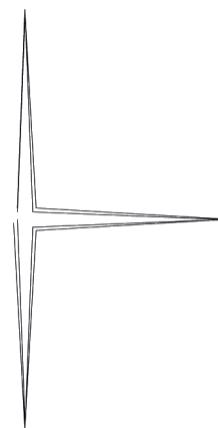


Figure 18

- Let your T-shaped section stand upright on your desk as shown here and press downwards at the top. Do not bend it now.

Take one of the flat folded sections you made in question 1. Hold it upright and press downwards at the top like you did for your strip with the T-cross section.

Which strip is stronger when you press down on its end, the flat section or the T-shaped section? Explain why.

The T-shaped section is stronger because.....
the fold that sticks out stops the strip from bending.

A T-shaped section resists compression better than a flat section that has the same length and is made of the same amount of material (paper in this case).

Figure 24

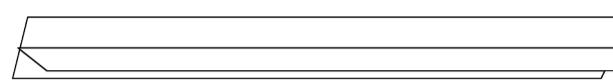


Figure 20

- Put the triangular tube at the edge of your desk as you did with the flat strip in question 2. Hold it down on the desk with one hand and press down lightly on the outer part to bend it downwards.

- What was easier to bend, the flat strip or the triangular tube?

It was easier to bend the flat strip.

This is the shape you see when you look straight at one end of your triangular tube:



Figure 21



- LB page 31
8. Compare the resistance to compression of T-shaped, square-shaped and round sections, each made from one sheet of A4 paper. Explain your answers.
- The round shape compressed first, then the square shape. The T-shape was strongest under compression. The strength comes from angles in the shape that resist bending. The T-shape has five angles; the square-shape has four angles and the round shape has none.**

Metal sections that are used to build frame structures are made in a variety of profiles. Some popular profiles are shown below.

H-profile. This profile is often used as upright supports or columns, for example in buildings. It resists compression very well, and it does not bend easily.

I-profile. This profile is used for railway tracks. The broad base provides stability.

U-profile. This is lighter than the H-profile. It is often used to provide horizontal support, for example in shelves. The chassis of a truck is normally made with U-beams.

This profile is often called angle-iron, even if it is made of metal. It has higher bending strength than flat strips. It is light and is often used for cross-bracing in pylons, towers and other structures.

Tube-profile. This is the best profile for resisting torsion.

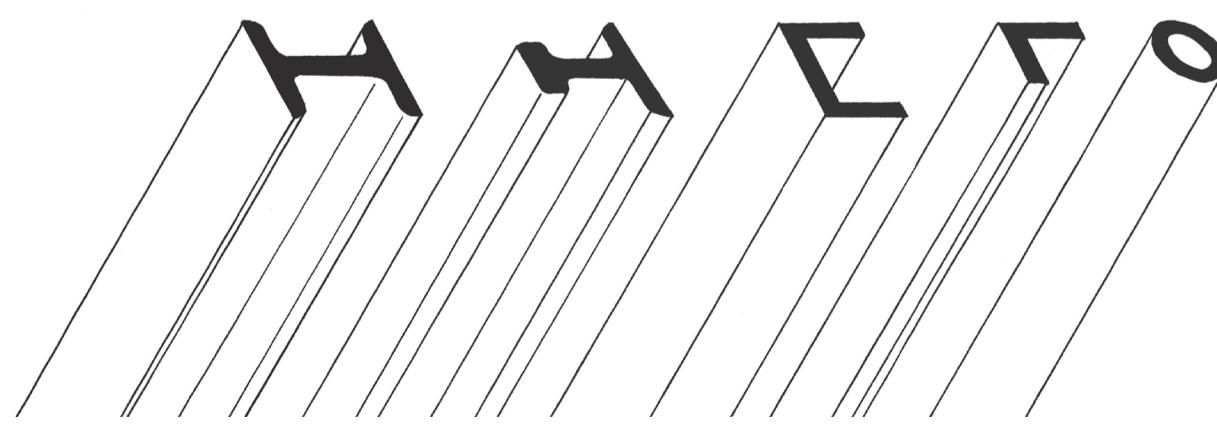


Figure 25: Metal cross-sections

Using internal cross-bracing to resist twisting

LB page 32

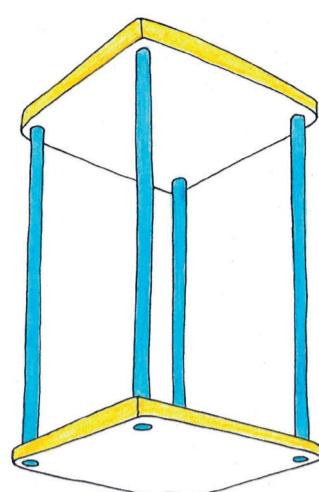


Figure 26



Figure 27

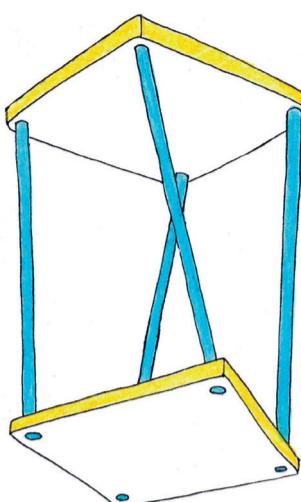


Figure 28

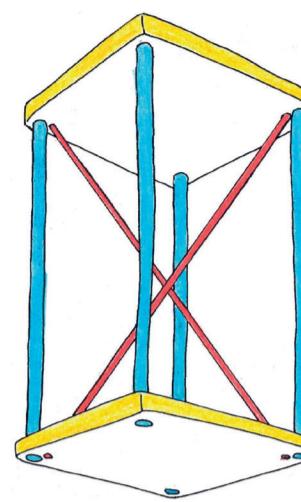


Figure 29

This is called **internal cross-bracing**.



3.3 Different materials for different purposes

How materials can differ from each other **LB p. 33**

1. What bends more easily, your pencil or a sheet of paper?

Sheet of paper

2. Put a sheet of paper flat on your desk. Pick it up with both hands and bend it. Now put it back on the desk. Is it flat again?

Yes, it is flat again, unless it was folded.

Material that bends easily, but returns to its original shape when you let go of it, is called **flexible material**. Material that is not flexible is called **stiff material**.

3. (a) Is wet clay flexible or stiff? **flexible, but does not return to its original shape**.

(b) Is the leg of a chair flexible or stiff? **stiff**

(c) Is a piece of wire flexible or stiff? **flexible**

(d) Is your shoe flexible or stiff? **flexible**

4. Press your finger against your desk. Now press your finger against your desk from when you pressed your finger against your arm?

The skin of the arm is soft. It sinks in and then pops out again. But the desk is hard and does not give way.

5. When you press your finger against a bag of sand, will it be the same as against your desk or arm?

Same as the arm, but it may not pop out again.

Some materials are hard, and some materials are soft.

Bricks are made by baking clay until it is hard.

6. (a) Think of a brick and a piece of foam plastic that is the same size as the brick (like the foam used in mattresses). Which is easier to pick up?

The foam

(b) How many bricks do you think you can carry easily if you put them in a box to carry on your shoulder?

Not more than five

(c) How many pieces of foam plastic of the same size do you think you can carry easily if you put them in a box to carry on your shoulder?

Not more than five

A brick is much heavier than a piece of foam plastic of the same size.

One difference between baked clay and foam plastic is that when you take pieces of equal size, the baked clay will be heavier than the foam plastic. It will require more effort to pick it up or to carry it.

The difference between baked clay and foam plastic can be described as follows: Baked clay has a higher **density** than the foam plastic.

LB page 34

7. (a) What material has the higher density, wood or rock?

Rock

(b) What material has the higher density, glass or plastic?

Glass

Pieces of metal that lie around outside sometimes look brown. This is called rust or corrosion. Rust is formed by chemical reactions between the metal and oxygen in the air or water. Wood and glass do not corrode. Rock that contains iron does corrode. When you walk in the veld, you can sometimes see pieces of rock that have the same shade of brown.

Corroded rock can have different colours, like those in the coloured strip at the bottom of this page. In the past, colouring for paint was obtained from corroded rock.

8. Iron is used in the construction of towers, roofs, cars and trucks and sometimes even furniture. What can you do to prevent iron from corroding?

Paint it so that air and water cannot reach the metal.



The roof structure	Wood
The roof cover	Tiles
The fence	Wood or steel
The paving around the house	Concrete

- Builders choose bricks, concrete, wood and metal because each one is useful in different ways. You can say different materials have different properties.

- Concrete is hard and it will not scratch easily, so builders use it on house floors. Concrete is also stiff, so it will not bend when we walk on it. Concrete is not damaged by water and it will not rust.

- Bricks do not bend and do not rust, so they are used to build walls.

- Wood is used in a house for doors, windows and roofs, because it is flexible. This means that when you slam a door, the wood bends a little but will not break.

- Wood can be damaged by water, wind and the heat of the sun. To protect wood against damage and to make it last longer, it should be coated with varnish, oil or some other preservative material.

- Steel is hard and strong. Steel is also flexible and it is not easy to crack with a hammer. Therefore, steel is used in security gates. However, steel is damaged by water; this is called rusting or corrosion. To prevent rusting, you have to cover steel with special paint.

LB page 36

2. Copy the table below. Fill in which materials are used for the different parts of the house in the middle column. Then fill in the reasons why you think that material is used for that part of the house in the column on the right

Part of the house	Material	Reasons for choice of material
Walls	Brick	Bricks are strong, water proof, cannot burn, and do not rust.
Window frames	Metal	Steel is strong and cheap, it keeps its shape (unlike wood which can bend when it gets wet), and it does not need to be painted as often as wood. Houses near the sea cannot use steel window frames because they rust too quickly. They have to use wood or expensive aluminium window frames.

Figure 30

LB page 35

1. Copy the table below. Different parts of the house are listed in the left-hand column. In the right-hand column, fill in the material you think that part of the house is made of.

Part of the house	Material it is made of
The walls	Bricks
The window frames	Metal or wood
The door	Wood

More about metals	
There are many different metals, such as copper, iron, aluminium, chrome, gold and platinum. Iron is cheaper than most other metals, because it is so plentiful. It is also easy to make iron into different shapes. Iron is normally mixed with a small amount of carbon to form "steel", which is much stronger than pure iron.	Unfortunately, iron corrodes or rusts easily, while other metals do not corrode as easily, if at all. For this reason, iron is often mixed with other metals, for example chrome, to make it resistant against rust. "Stainless steel" is steel that contains a large amount of chrome.

LB p. 34

Materials in a house

A house is a good example of a structure made of many different materials. To build a house like the one below, you can use bricks, concrete, wood and steel.





Door	Wood	Wood is strong, cheap and light, and easy to work with. It is a good choice in places where it will not get wet.
Roof structure	Wood	Wood is strong, cheap and light, and easy to work with. It is a good choice in places where it will not get wet.
Roof cover	Tiles	Tiles are hard and they do not bend or rust. They are heavy so the wind cannot move them
Fence	Wood	Wood poles are cheap, strong, and do not rust, but they should be treated against damage by water, insects, and fungi.
Paving around the house	Concrete	Concrete is very strong, lasts very long, and you can quickly cover a large area with concrete.

5. In the old days, wagon wheels were made of wood. Today we use rubber tyres.
Why did we change from wood to rubber?
Rubber is more flexible, cannot crack easily, grips better on a road, and is not damaged by water. Because rubber is so flexible, a rubber tyre filled with air absorbs bumps in the road so that the ride is more comfortable.
6. When builders put glass in a window frame, they push a soft sticky material called putty round the edge of the glass. The putty dries until it is hard and stops the glass from falling out. Peanut butter is also a soft sticky material and dries in the sun until it is hard. Why is it not a good idea to use peanut butter to fit glass in window frames?
Because peanut butter gets soft when hot or wet, and insects can eat it.

Next week

Next week, you will start with your practical assessment task. You will make a plan to address a need in a community.

3. Some houses have tile roofs, other houses have zinc roofs. Copy and complete a table to list the advantages and disadvantages of tile roofs.

Advantages of tile roofs	Disadvantages of tile roofs
Tiles are stiff and they do not bend or rust. They do not need painting. They last a long time. They are heavy so the wind cannot move them. They do not get too hot in summer nor too cold in winter.	They are expensive to buy and fit. They are heavy, so you need a stronger roof structure. They can easily crack if a stone falls on them.

4. What are the advantages and disadvantages of zinc roofs? Write your answers in table form.

Advantages of coated iron roofs	Disadvantages of coated iron roofs
They are cheaper to buy and fit. They are lightweight, so you can use a cheaper roof structure. They do not crack if a stone falls on them. They are coated with zinc so that they will not rust for many years.	They do not last as long as tiles. They are lightweight so the wind can damage them. They get very hot in summer and cold in winter.

CHAPTER 4 PAT

A bridge to help the community

LB page 37

Over the next six weeks, you will design and build a model of a bridge. To do this, you will work through the different stages of the design process and arrange yourselves into teams.

Week 1

Investigate Granny Margaret Thabang's problem50

Week 2

Develop rough sketches of ideas55

Week 3

Make working drawings61

Week 4

Discuss and practise making your model66

Week 5

Design an evaluation instrument67

Week 6

Present your tender to the class68

Assessment

Design:

Sketch your ideas[10]
Design brief with specifications and constraints[10]

Make:

First-angle orthographic drawing[10]
Budget[10]
Completed model[20]

Communicate:

Present the tender[10]
[Total: 70]

Materials and equipment required for this chapter:

geometry sets
big, strong scissors
corrugated cardboard from old boxes (learners should bring this to school)
cardboard of old cereal boxes (learners should bring this to school)
scrap paper for building parts of models
extra paper to draw on (the larger the paper the better)

string
masking tape

nails of different sizes to make holes, 1 mm thick and 30-40 mm long
prestik

masking tape
clay or stiff porridge to use as a model for concrete anchors

wood glue (optional)
plastic straws (optional)

pieces of wood (optional)
50

All tasks/questions are essential for the design process, even if no marks are allocated.
All tasks/questions in the PAT should be completed/answered, even the tasks/questions for which no marks are allocated for evaluation. This is because all the tasks/questions are essential parts of the design process. So, if certain tasks/questions are not done, then learners will not be able to do the subsequent tasks/questions successfully.

Week 1

Learners investigate the problem that people at a village have with crossing a river. They paraphrase (say in their own words) what the problem is and suggest different solutions. They then identify and compare the advantages and disadvantages of different types of bridges.

Week 2

Learners work individually to write the design brief, specifications and constraints for the bridge. They then make rough sketches for a possible bridge design to solve the problem. They write notes on the sketches to help explain their ideas. They team up with three or four members to start the process of preparing a tender. First, they evaluate their own and each other's rough design sketches to try to see where and how they can improve their designs. Then they make rough sketches of their improved design. Finally, the team plans the different steps from thinking of building a bridge to finally building a bridge. These steps show the lifetime of a project from being just an idea to being the real product that people benefit from. They have to think carefully about the steps of building the

bridge (planning to make), but there are also many other important steps before that, such as consulting with the community and obtaining funding. They make a flow chart to show the different steps.

Week 3

Learners work individually to make *working drawings* of their bridge designs. They will need extra paper to draw on.

Then they draw up a budget for building the bridge in reality. They are given realistic examples of the costs of some building materials. For other materials, they may have to find the costs themselves, by asking older people or at hardware stores.

Week 4

Learners work as a team to *plan to make* their models. They first individually practise making parts of the bridge out of paper. Then they build one final model of the bridge together, using cardboard, string and other materials.

Week 5

Learners work as a team to make a checklist with which they can *evaluate* their own model. They interact with other teams to get the best ideas for criteria to put on the checklist. Then each team evaluates their model with the help of the checklist.

Week 6

Each team prepares for and gives a 5-minute presentation of their tender for the project to build a bridge. Their tender presentation includes most of their previous work.

LB pages 38–39

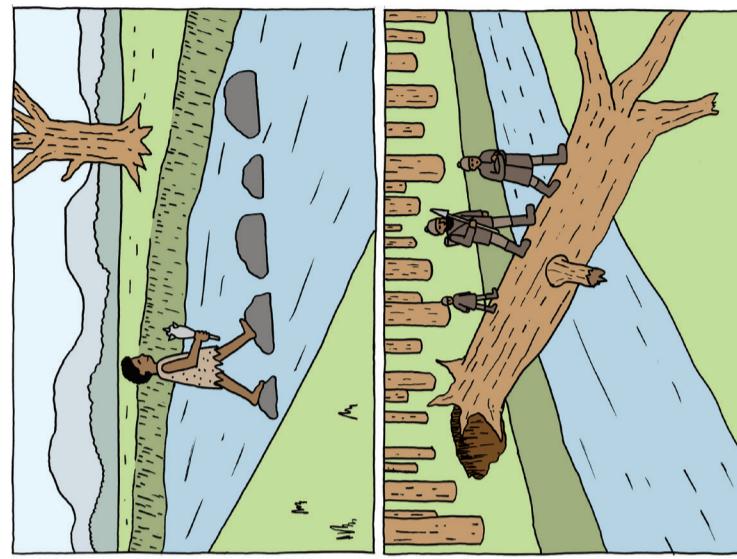


Figure 1

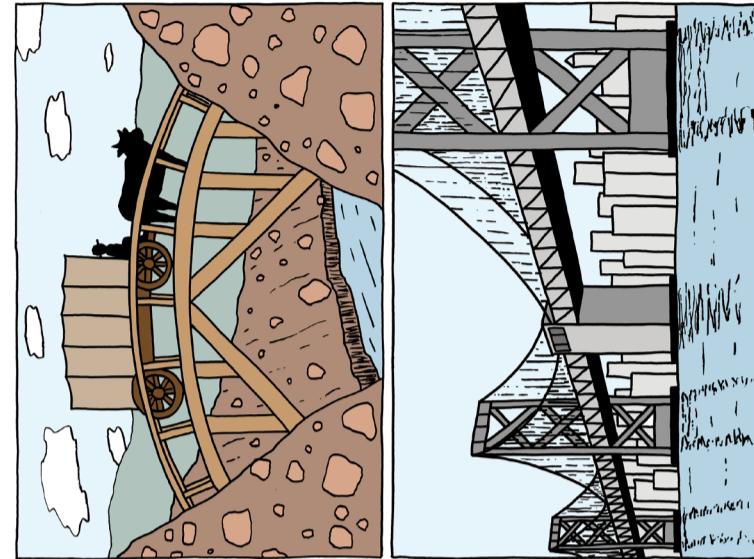


Figure 2

Week 1

Investigate Granny Margaret Thabang's problem

LB page 40
(60 minutes)

1. In your team, read through the following story.

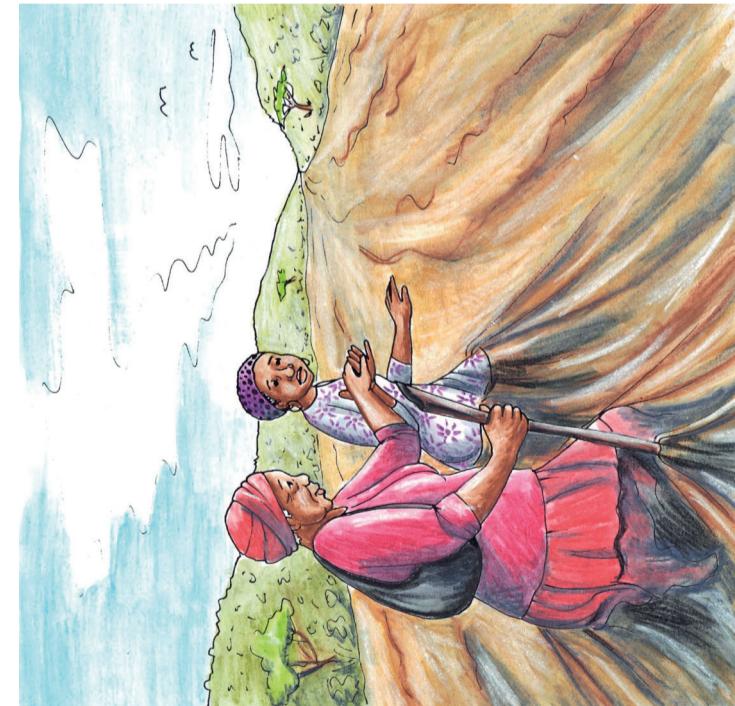


Figure 3

Rivers provide much-needed water for communities, but sometimes they can also make life difficult for people. For example, during the rainy season, people from villages on one side of a river struggle to get to the other side of the river, if there is no bridge.

Many of the people in the KwaNogau village next to the uThukela River in KwaZulu-Natal work on the other side of the river. The doctors, banks and shops that they need to visit are also on the other side. School children cross this river to get to their schools, and the elderly have to walk through it once a month to collect their government grants from the offices on the other side.

Usually, the villagers cross the river on foot, because the nearest bridge is very far away. But during the rainy season, when the river is in flood, it becomes very dangerous. The water levels are so high that it is difficult to get through it safely, and the villagers have also seen crocodiles in the river. Everyone is scared of drowning or getting attacked by the crocodiles, but they don't have a choice and have to go through the river to get to the other side.

2. Write a few sentences to explain the problem the villagers have.

- People need to cross the wide river on foot every day, but it is dangerous because of floods and crocodiles, and it takes very long to walk through the water. People in wheelchairs cannot cross the river at all.
1. In your team, read through the following story.
 3. Can you suggest a few ways to help Granny Margaret Thabang cross the river?
Build a bridge to cross the river, or use boat/ferry that is connected to a cable that spans the width of the river. The bridge is a better idea, as it would be very dangerous to cross the river on a boat when it is in flood.

uThukela Municipality

REQUEST FOR TENDER – Access Bridge for KwaNogau Village

You are hereby invited to submit a tender for the requirements of the uThukela Municipality.

Tender Number: GH038

The successful tender must provide a safe, cost-effective solution for the villagers to cross the local river. The river is 100 metres wide at the crossing point. It rises during the summer rains and there are crocodiles in the river all year round.

Closing date: 28 February

Enquiries: Mrs Leslie Oats

Figure 4: The tender request placed in a local newspaper.

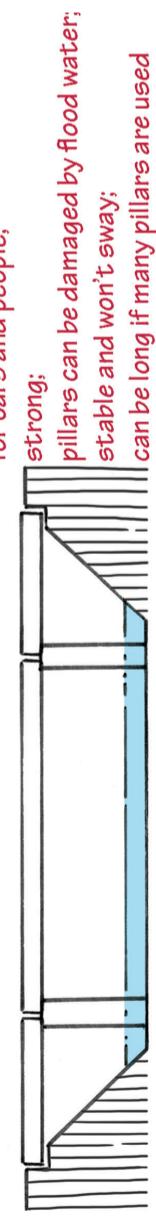
The uThukela Municipality placed a tender request in the newspaper asking contractors to submit tenders for a structure to help people safely cross the river at KwaNogau village. Municipalities are not allowed to choose a contractor without giving as many contractors as possible a chance to apply. This is to stop anyone from being favoured over others, and to prevent corruption. Each contractor writes a tender document, which is a description of their plan for the project and shows how much they will charge to complete the work. The job is given to the contractor who presents the best plan at the lowest price. You are going to build a structure to help the community. Read the story again and then investigate the different bridges below to decide which structure will be the best solution for the problem.



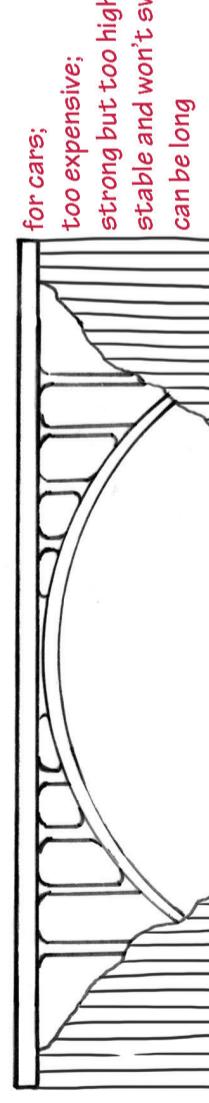
Investigate structures to solve the problem (60 minutes)

On this page and the next there are drawings of different types of bridges. You learnt about these bridges in Grade 8. Do you remember what the names mean? If you cannot remember, look at your Grade 8 book or ask your teacher to help you.

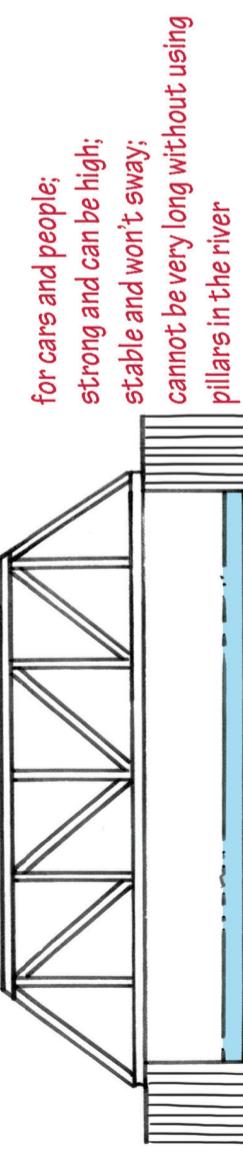
for cars and people;



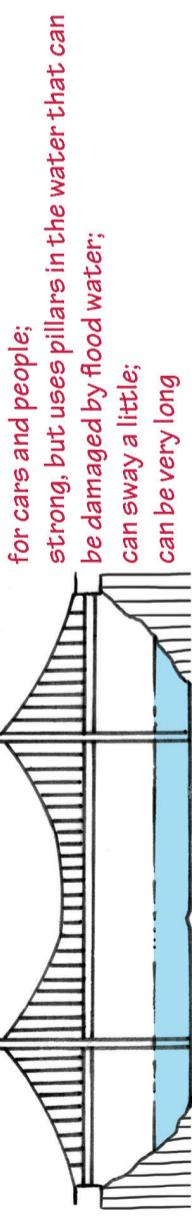
A: A beam and column bridge



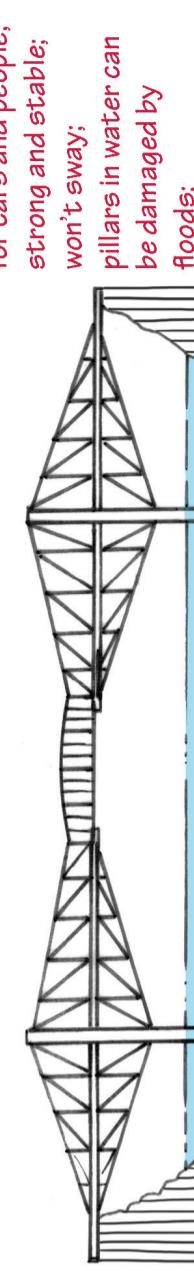
B: An arch bridge



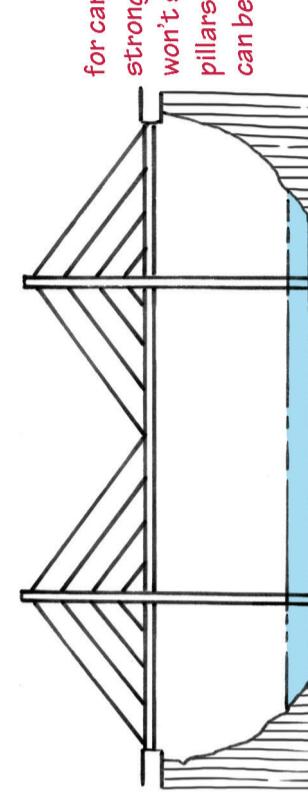
C: A truss bridge



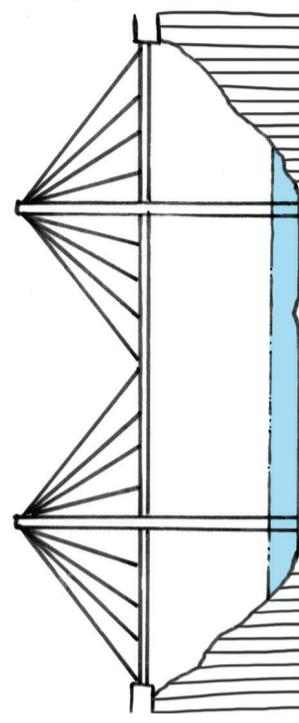
D: A suspension bridge



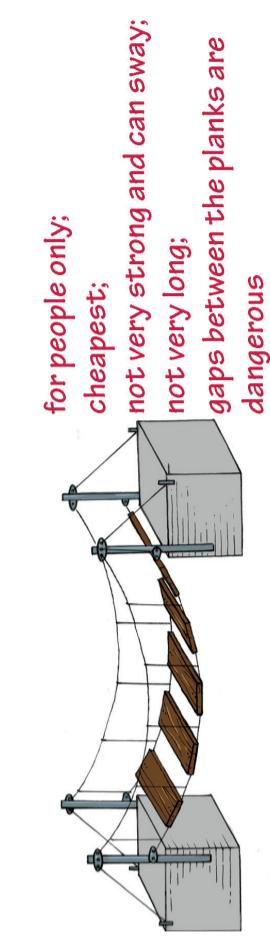
E: A cantilever bridge



F: A cable-stay bridge of the harp shape

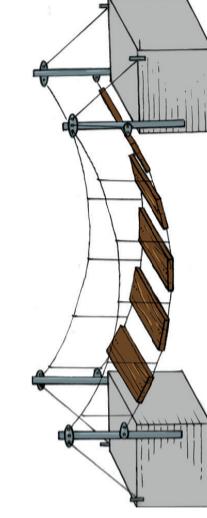


for cars and people;
strong and stable;
pillars in water can be damaged by floods;
can be long

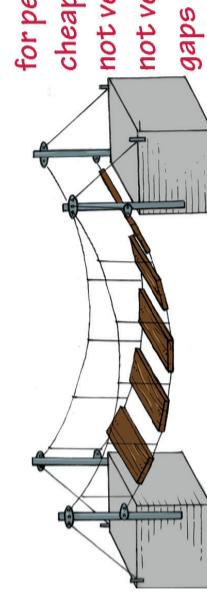


H: A small suspension bridge

for cars and people;
strong and stable;
pillars in water can be damaged by floods;
can be long



G: A cable-stay bridge of the fan shape



for people only;
cheapest;
not very strong and can sway;
not very long;
gaps between the planks are dangerous



Different types of bridges use different materials and construction methods, but they all have a similar function.

In your group, discuss some of the advantages and disadvantages of each of the bridges for the community. Think about which parts will help the community, and which parts will not help.

If the bridge is meant to carry cars, it might be too expensive for your tender. Remember that the bridge has to solve the community's problem. In technology, we call this **fit-for-purpose**. In this case, it means that your bridge has to be strong and high enough to carry people and not cars. However, your bridge has to be strong enough to withstand floods, which are common in KwaZulu-Natal. Your bridge must also be stable, so that it does not sway and cause old people and children to fall when they walk across. It should have a structure that can span a wide river.

Copy the table below and use it to help you to investigate each of the bridges in Figure 5 on the previous page. Also bring pictures of bridges to school. You can find photographs of bridges in old newspapers and magazines.

Week 2

Develop rough sketches of ideas

(30 minutes)

Draw a rough sketch of your ideas for a bridge to help the community. Use the sketching techniques that you learnt in Grades 7 and 8.

[Total: 10]

See the design sketches on page 53. This page contains notes to explain these sketches.

The bridge designed here is a combination of bridge designs D and H on the previous pages. Design H is cheap, but it is not strong enough, it sags in the middle (not good for wheelchairs), it can sway, and it has a dangerous walking surface. Design D is strong and flat and will not sway as much, but the pillars can be damaged by flood waters.

For my design I made the following choices:

- The pillars are placed far away from the water, so that they cannot be damaged by flood waters.
- Two thick I-beams are used to support the walking surface so that it remains flat and does not sag in the middle.
- These I-beams are connected by angle irons to triangulate the structure of the walkway, to prevent the bridge from swaying sideways.
- Thinner I-beams are strong enough to support the ramps, because the ramps span much shorter distances than the bridge itself.
- The ramps have a very gentle slope, so that a person in a wheelchair can get up them easily.
- The walking surfaces are made of steel plates with a rough surface (these plates are commonly used in factories for walkways), so that it will not be slippery even when it is raining hard.
- The walking surface is wide enough for two people or two wheelchairs to pass each other. If it was narrower people on the one side of the river would have to wait for people on the other side to walk over. Because the bridge is so long, they would have to wait very long.
- The bridge is made of steel, cables and concrete. The steel can be welded or bolted together. The cables can be connected with U-bolts.
- Concrete blocks are used to anchor the pillars and the end of the cables deep into the ground. The concrete blocks in which the pillars are planted lowers the centre of gravity of the pillars.
- The pillars will be moulded from concrete on the construction site, with steel reinforcement inside. This will be cheaper than transporting long steel pillars with a very long truck from a steel factory. It will also create work for people on the site.
- All the parts of the bridge can be put together on the site, so a lot of work opportunities will be created.

Note: There is something missing in this design, namely handrails.

Checklist for investigating bridges		
	Yes	No
Is the bridge for cars?		
Is the bridge for people?		
Is the bridge too expensive for the tender?		
Can the bridge be built strong and high enough so that it is not washed away by floods?		
Can the bridge be built so that it is stable and does not sway?		
Can the bridge be built long enough so that it can reach or span across the river?		
Is the bridge strong enough so that the villagers can walk safely across?		



Evaluate and adapt your rough sketches (30 minutes)

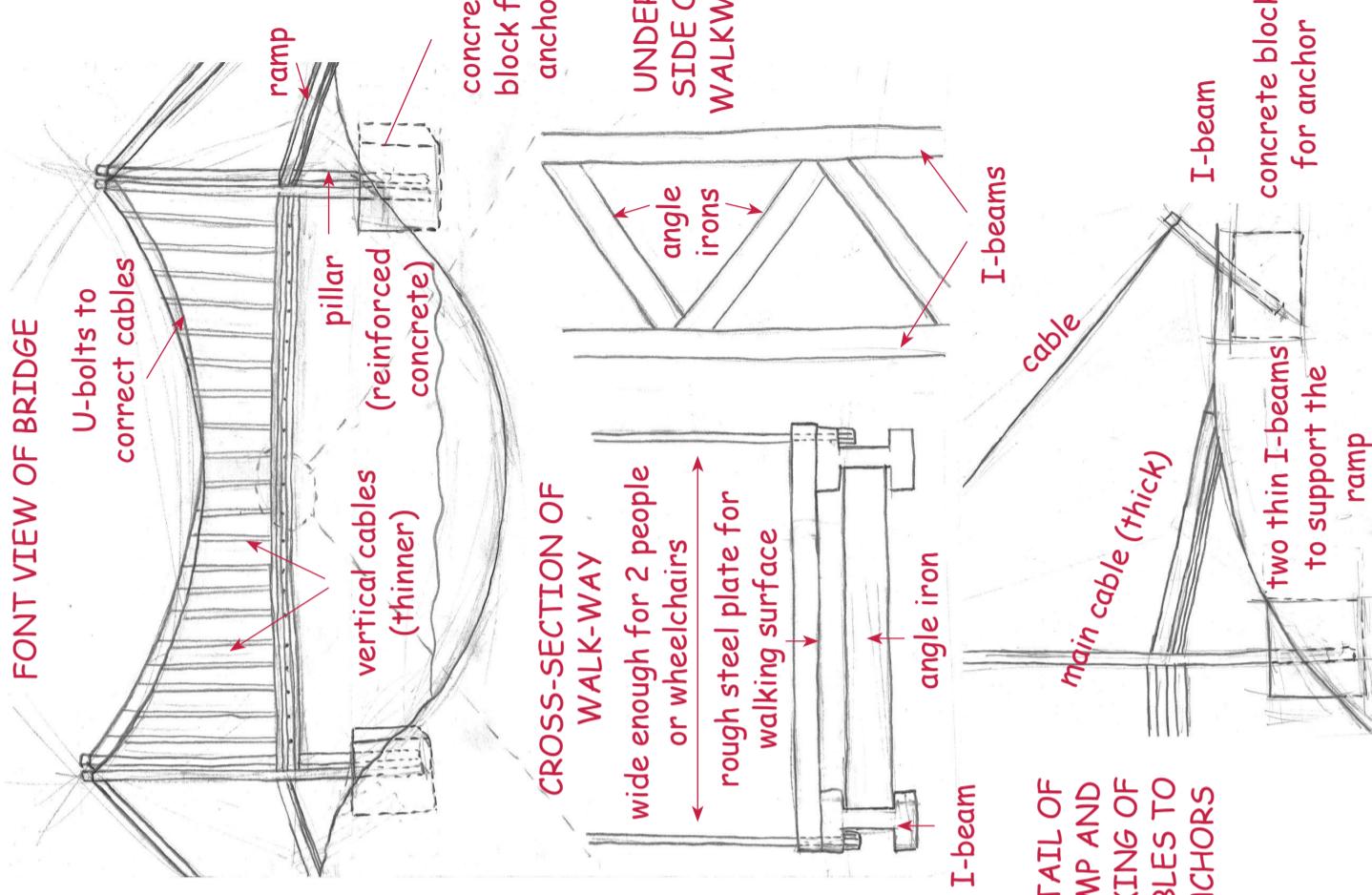
Your team will now prepare a tender. To start, choose the best design in your team. This means you need to choose one sketch from all the rough sketches. To help you choose, copy the table below and answer the following questions:

Learner's answers will depend on their designs.

Questions	Yes	No
Does the structure allow people to move across the river safely?		
Does the structure protect people from crocodiles?		
Does the structure allow a group to cross safely?		
Will the structure be safe when the river floods?		
Is the structure durable, and will it last a long time without breaking?		
Is the structure made from the right materials? Remember that the bridge could be in constant contact with water and should not rust.		
Will the structure withstand both static and dynamic forces?		
Will the structure be very expensive to build? Remember that you are building it for people, not cars.		
Will the structure be expensive to maintain?		
Does the structure damage the environment?		

If the sketches do not meet these requirements, adapt them until they do. These sketches represent your final solution and they will form the basis of your working drawing.

One possible design





Design brief with specifications and constraints (30 minutes)

LB page 46
have a gentle slope. This is so that old people, sick people and people in wheelchairs can easily get up them.

The walkway of the bridge and the ramps should have handrails for people to hold on to.

The bridge should be stable. It should not sway sideways a lot.

The bridge should last a long time.

Constraints:

The bridge should not be too expensive.

It must be possible for the local people to build most of the bridge themselves, and without using too expensive machinery. The local people may need training on the construction methods.

The bridge should be built in less than 3 months during the dry season.

(30 minutes)

Draw a flow chart

The bridge has to be completed within a certain time.

- The bridge has to be built according to budget, including all labour costs.
- The bridge has to help the community. For example, you can employ local people to work on the bridge and train them while they work on the project. That way, they will have good skills that will help them to find work when this project ends.

The bridge has to be user-friendly for disabled and older people.

Constraints could include the following:

- Time and cost constraints. For example, the building process should not take longer than a specific amount of time, and should not cost more than a certain amount.
- The bridge cannot exclude wheelchair users.
- The bridge cannot employ more than a certain number of people from another area.
- Women should not be prohibited from working on the project.

[Total: 10]

Design brief:

The bridge should allow people on foot and in wheelchairs to cross the river quickly, easily and safely, even when the river is in flood.

Specifications:

The bridge should span the full width of the river when it is in flood.

The bridge should be at least 2 metres above water.

The walkway of the bridge should be wide enough so the two people travelling in different directions can cross each other easily, even if they are both in wheelchairs.

The walkway should not be slippery even when it is raining hard.

The bridge should use ramps at the sides instead of stairs, and the ramps should

have a gentle slope. This is so that old people, sick people and people in wheelchairs can easily get up them.

The walkway of the bridge and the ramps should have handrails for people to hold on to.

The bridge should be stable. It should not sway sideways a lot.

The bridge should last a long time.

Constraints:

The bridge should not be too expensive.

It must be possible for the local people to build most of the bridge themselves, and without using too expensive machinery. The local people may need training on the construction methods.

The bridge should be built in less than 3 months during the dry season.

(30 minutes)

Draw a flow chart

Do you remember what a flow chart is? A flow chart is a summary of all the steps you have to follow to plan or make something. It is a “visual” way to show the steps in a planning or making process.

A flow chart is a summary, so use short sentences or just “keywords” to write down your steps. Then draw a box around each step and an arrow between the steps. Look at the example of a flow chart on the right. Now draw a flow chart of how you will build your bridge.

Think of the very first thing you will have to do, and start from there. For example, will you measure the river first, will you buy the materials first, will you train your staff first, or will you draw up your budget first?

You can change your flow chart later when you make the model of your bridge. Engineers and technologists often change their plans while they work on a project.

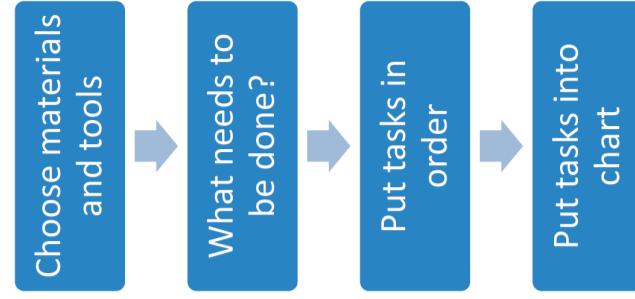


Figure 6



Week 3

Make working drawings

(60 minutes)

Measure/survey the river



Decide on best place to build the bridge. Consult the community about this.



Make a few different designs for the bridge. Consult the community about this.



Make a budget for each design.



Choose the best bridge design. Consult the community about this.



Make a proposal and get funding.



Choose building team and train them.



Build temporary workshops, store rooms and houses on the construction site.



Buy materials and buy/rent equipment.



Test bridge and fix any problems

Working drawings are guides that show us how to build a specific structure. Make a working drawing of your bridge. It should be drawn to scale and show as much detail as possible.

Each member of your team should make their own first-angle orthographic projection of the bridge, showing the front view, top view and end view.

Each of your drawings should show the measurements of the structure and the scale you have chosen. Use correct line types.

You will need the following equipment:

- 30°, 60° and 90° set square,
- a sharp pencil, and
- masking tape to attach your drawing sheet to your drawing board.

[Total: 10]

An accurate drawing of the learner's own design.

Work out a budget

(60 minutes)

All projects that cost money need a **budget**. A budget is a plan that looks at the various costs and how the money will be spent.

It is important to make sure that you have enough money before you begin any project. Otherwise, you could run out of funds halfway through the project. You also have to persuade the tender board that your bridge is cost-effective, which means that it is safe for people and the environment, and that it is not too expensive for this purpose.

When you build the bridge, think about the things that will cost money.

For example:

- materials,
- labour,
- designers and engineers,
- equipment that you hire or buy, and
- transport.

STEPS OF CONSTRUCTION:

1. Mould pillars with steel reinforcement inside.
2. Dig holes for anchors and pillars.
3. Pour concrete in holes and plant pillars.
4. Build ramps.
5. Connect main cables to anchors and tops of pillars.
6. Start from one side and add short lengths of walkway and vertical cables, about 2 meters at a time.
7. Carry on adding bits of walkway and vertical cables until the other side is reached.
8. Tighten all the cables.
9. Add handrails.



Remember that you are a contracting company and want to make a profit. Once you have worked out the other costs, add on an amount for your profit. There will be other companies who will tender for the job, so keep your costs low to make your tender attractive. However, do not compromise the safety of the bridge or allow it to become unfit for its purpose. Balance the need to make a profit with the need to build a safe bridge.

For this exercise, you have to draw up a cost sheet.
A cost sheet is a summary of all your costs.

Look at this example of a cost table for another bridge. You can use some of the material costs shown in this table when making your own cost table for your bridge design.

Your own list will be different, because it will depend on the materials you choose to use to build your bridge. If you are not certain of amounts or lengths, add on a little extra to your final figure. It is better to have a little left over than to run short.

To help you work out your costs, speak to a hardware shop owner, a building contractor, or a family member who is knowledgeable in these things. You can also look in the Yellow Pages for suppliers. They will give you information if you tell them about your project. Don't just make up the costs. You need your budget to be accurate. Apart from the items on the above list, you also have to account for VAT and insurance.

LB page 49

Labour			
Unskilled labourers	25	25 per hour	
Carpenter	2	320 per day	
Foreman	1	600 per day	
Welders	3	720 per day	
Subtotal			
Machinery/Equipment			
Bulldozer and operator	1	2 000 per day	
Road grader and operator	1	2 500 per day	
Showels and other equipment	25	10 per day	
Subtotal			
Other staff costs			
Engineer			
Architect			
Work manager			
TOTAL			

[Total: 10]

An example of a budget calculation for a bridge design is shown over the following two pages.

Example:

Item description	Quantity	Price per unit (Rands)	Total (Rands)
Materials			
Cement (80 kg bags)	50	90	10 000
Pine Planks (200 cm x 30 cm x 2 cm)	200		
Bags of nails (10 x 3 cm)	10		
Bricks	5 000		
Steel I-beam (5 m x 6 cm)	20	1 000	20 000
Subtotal			



Materials	Quantity	Price per unit including tax (Rands)	Total (Rands)
Cement	100 bags	90 per bag	9 000
Steel I-beams (5 m × 6 cm)	25	1 000	25 000
Steel I-beams (10 m × 12 cm)	4	3500	14 000
Steel I-beams (15 m × 12 cm)	4	5250	21 000
Steel angle iron (5 m × 3 cm)	30	600	18 000
Metal cable (2 cm width)	100 m	100 per metre	10 000
Metal cable (1 cm width)	100 m	50 per metre	5000
Stones for concrete foundations	2 tonnes	1 000 per tonne	2 000
Metal plate ('starred' anti-slip, 1 m × 1 m)	50	200 per plate	10 000
Bricks	5 000	2	10 000
Heavy duty bolts	500	5	2 500
U bolts to fasten cables	500	10	5 000
Subtotal materials:			131 500

Labour costs are based on 20 days work at 8 hours per day					
Labour	Quantity	Payment per day (Rands)	Total (Rands)		
Metal workers	10	500 per day	100 000		
Labourers	25	25 per hour	100 000		
Carpenters	2	320 per day	12 800		
Brick layers	5	320 per day	32 000		
Foreman	1	600 per day	12 000		
Subtotal labour			256 800		
Machinery and tools hired for ten days					
Machinery and equipment	Quantity	Rate per day (Rands)	Total (Rands)		
Bulldozer and operator	2	2 000	40 000		
Road grader and operator	1	2 500	25 000		
Winches for tightening cables	4	800	32 000		
Tools per labourer	25	10	250		
Subtotal machinery			99 500		
Design costs	Quantity	Invoice (Rands)	Total (Rands)		
Architect	1	20 000	20 000		
Engineers	2	25 000	50 000		
Subtotal design			75 000		
Total budget for bridge					
Materials			131 500		
Labour			256 800		
Machinery			99 500		
Design			45 000		
Total budget before profit			532 800		
Profit margin of 10%			53 280		
Total budget including profit			586 080		

Profit margin

What additional amount are you going to charge? Remember that you need to make a profit. This amount has to be fair to you and to the authorities who will award the contract. Total all the subtotals and then decide on a percentage for the profit. You will then have the final total, which you will submit as the cost of building your bridge.

LB page 50



Week 4

Discuss and practise making your model (60 minutes)

You will make a model of your structure. Discuss how you will do this in your group.

Think carefully about all the materials you will need to build your model. Do you need paper, glue, and/or corrugated cardboard? And what about tools? Do you need scissors or glue-guns?

Write a complete list of all the materials and tools necessary to build your model.

You need a plan to help you stay organised. Ask yourselves questions such as:

- What should we do first?
- What materials do we need for each step?

When you have decided what you will do, add it to your flow chart. Each member of your team should draw up his/her own copy of the flow chart.

The following activity will help you to make strong structures out of paper. You can use these structures to help you build your model bridge.

Make a model of your bridge (60 minutes)

Build one model for your team that looks like your working drawing. It should be built neatly, safely and to scale. You can use materials available to you such as cardboard, string, wire, pieces of wood, drinking straws, plastic and clay. You can also use glue and paint.

Be aware of safety at all times, especially when working with blades and toxic glues. (Wood glue, Prestik and Pritt are fortunately not toxic.)

Remember to follow the steps as shown in your flow chart. Everyone must be involved with making the model.

[Total: 20]

Week 5

Design an evaluation instrument (60 minutes)

LB page 51

In your team, make an assessment checklist (rubric) to see if your structure is a good solution to the community's problem. Use the specifications and your design brief from Week 1 to help you make the checklist.

Here is an example of a few items that could be in a checklist for a project:

- Is the structure stable? YES/NO
- Is the structure rigid? YES/NO
- Is the structure durable? YES/NO
- Does the structure allow for more than one person to cross it at a time? YES/NO

Now add your own items to the checklist in order to finish it.

ADDITIONAL ITEMS FOR CHECKLIST

Structure:

Are the banks of the river stable enough to hold the foundations?

Is the bridge strong enough to withstand floods?

Who will maintain the bridge and make sure it is in good condition and painted to prevent rust?

Funding:

Who will fund the costs of the bridge?

To who can the community submit the plans to ask for funding or a loan, if there isn't any funding yet?
If it takes longer to build than planned for, who will pay the additional costs?

Who should pay to maintain the bridge, the community or the government?

Local Employment:

Who will make sure that people from the local community are hired to do the work?
Does the community have the resources to build the bridge (the machinery) or must it be brought in from another town?

Plans and progress:

Has the community been part of the planning process?
Has the community accepted the bridge, its design and the possible costs?
Who will make sure that the plan the architect and engineers draw up meets the specifications?
Who will check that the builders follow the plans correctly?
Who will check costs while the bridge is being built?
When will the bridge be built: will bad weather affect the time it will take?



Evaluate your team's solution (60 minutes)

Meet with all the other teams in the class. Share your checklists among the groups and work together to choose the best criteria. This way, you will all be able to use the best criteria to make a single checklist that everyone can use.

Use the chosen checklist to assess your group's solution to the community's problem. Include this checklist in your tender documents.

LB page 52

Week 6

Present your tender to the class (120 minutes)

It is time to present your tender to the class. You have to give a 5-minute presentation to try convince the tender board that your tender is the best one. Each member of your group needs to present a part of the tender to the class.

[Total: 10]

The tender should include the following information:

- sketches and orthographic plans
- a budget
- your model
- artistic impressions of your final plan, and
- an assessment checklist.

Plan which member of the team will present which part of the tender. Someone needs to draw the artistic impression of your structure. This drawing should have colour and detail to impress the tender board.

Term 2: Mechanical systems and control

CHAPTER 5

Hydraulics and pneumatics

- LB page 53
- 5.1 Use water and air to move objects 75
 - 5.2 Narrow and wide syringes 77
 - 5.3 Change the size of forces using a hydraulic system 81

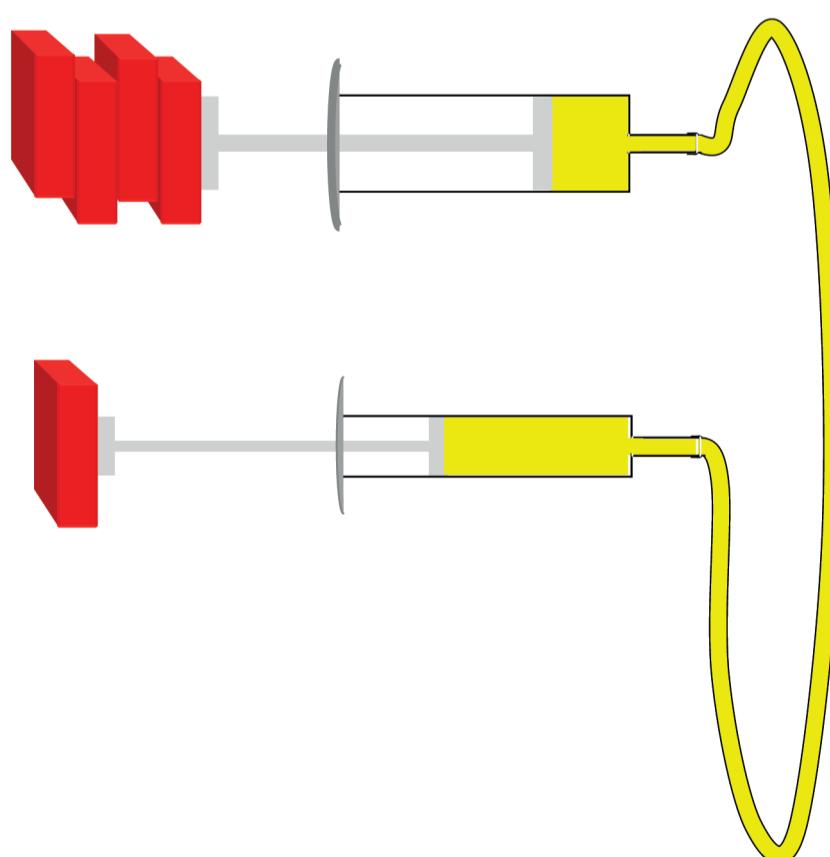
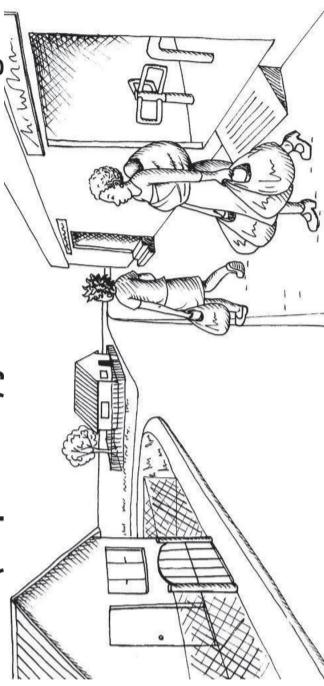


Figure 1

Materials required for this chapter

syringes of two different diameters and plastic tubing to connect them
cereal boxes
equal weights, for example matchboxes filled with sand

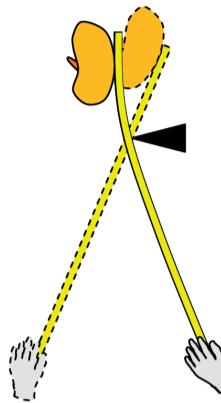
You are strongly advised to do the action research described on pages 78–80 (LB p. 59–61) and pages 81–83 (LB p. 62–64) yourself before starting with it in class.



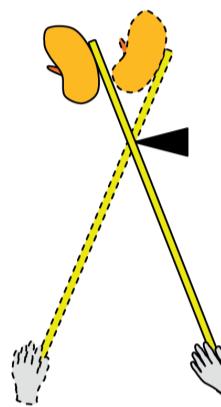
This picture appears as Figure 7 on page 58 of the Learner Book. It shows a woman carrying a heavy load to her house close by, and another woman carrying a small load for a much longer distance.

5.1 Use water and air to move objects

Learners have engaged with pneumatics and hydraulics in previous grades. In Grade 9 this should be extended into a sound understanding of the underlying principles involved. The CAPS document emphasises the difference between gases and liquids as mediums of force transfer: **Gases (like air) are compressible, liquids (like water) are incompressible**. This explains an important difference between pneumatic and hydraulic systems. In a pneumatic system, part of the work done to press in the input cylinder is absorbed by compression of the air, so the same amount of work cannot be done at the output end of the system. This is similar to what happens if a rod used as a lever is flexible. When the rod is used to lift something, part of the effort to move one end of the lever is spent on bending the lever, and is hence not available for helping to lift the load.



A somewhat flexible lever



A rigid lever



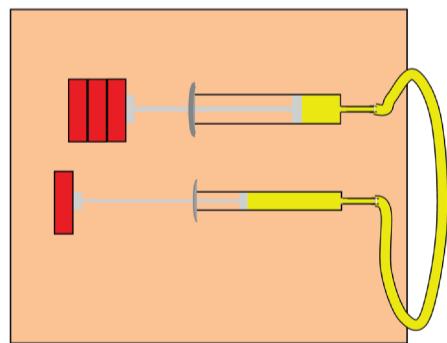
5.2 Narrow and wide syringes

Although technology is about getting things done in the real world and not chiefly about understanding it; understanding how and why things work can help to improve a person's technological skills. The idea of 'work' provides a way to achieve some understanding of how devices such as levers, gears, pulley systems and hydraulic systems provide mechanical advantage. No device can increase the amount of work done, devices can only change **the way in which work is done**.

It is understandable that to **carry a heavy pack for a short distance can be the same amount of work than carrying a light pack for a long distance**. Figure 7 and Question 1 are intended to bring make the learners grasp this. This may help them to achieve an understanding of how hydraulic systems (and other mechanisms) provide mechanical advantage.



When a first-class lever is used to lift a heavy object, all the work done by the person pressing the lever down at the input side is utilized to lift the load up at the other end (the output side). The larger output force applied over a shorter distance is the effect of the work done at the input end by applying a smaller force over a larger distance.



Consider a hydraulic cylinder consisting of an input cylinder with a small cross-sectional area and an output cylinder with a large cross-sectional area. The volume of liquid that leaves the input cylinder must be equal to the volume of liquid that enters the output cylinder. Because the output cylinder has a greater cross-sectional area, it moves a smaller distance than the input cylinder to let in this volume of liquid. And because the output cylinder moves a smaller distance, it must exert a greater force, otherwise the amount of work done by the output side would not be equal to the amount of work done on the input side.

Note that the measurements for the action research on pages 59 to 61 of the Learner Book cannot be taken on the syringes themselves, as the syringe markings indicate volume, hence the readings will be the same on the two cylinders. The action research is specifically about the differences in the distance moved by the two cylinders.

5.3 Change the size of forces using a hydraulic system

The experiment with the plastic bag filled with water is a simple and effective way of providing an experience of Pascal's principle, namely that pressure is transmitted without loss in all directions through a hydraulic system.

However, this does not mean that the force exerted by the output cylinder in a hydraulic system is equal to the force exerted on the input cylinder. These forces are only equal if the input and output cylinders have the same diameter.

At this stage learners need to begin to engage with force quantitatively. In the final activity of this chapter, the action research described on pages 78-80, learners compare the forces on the input and output cylinders by balancing a hydraulic system with weights.

LB page 54

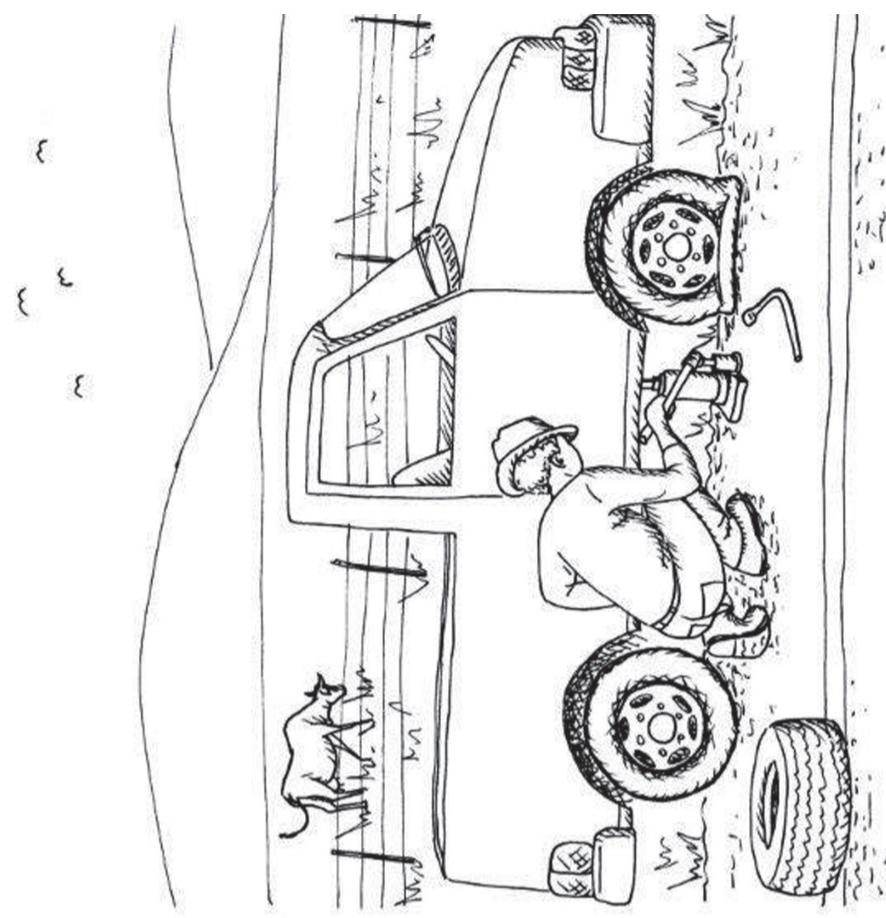


Figure 2



5.1 Use water and air to move objects

Compressible and incompressible substances LB p. 56

The blue tin contains bundled straw, the red tin contains water and the yellow tin contains sand.

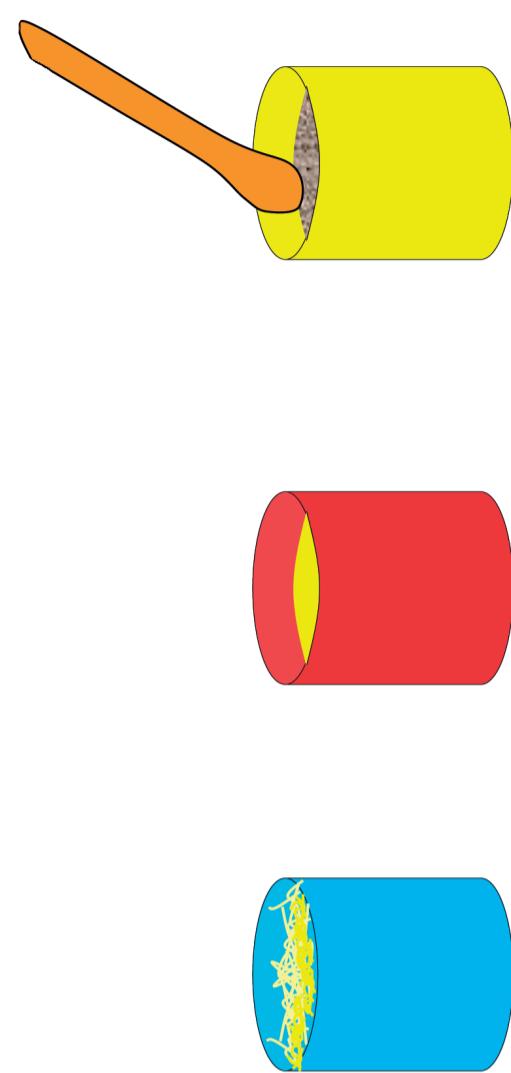


Figure 4

1. Do you think it is possible to compress the sand with the wooden spoon so that it takes less space in the yellow tin? **No**.

2. Do you think it is possible to compress the straw? **Yes**.

3. Do you think it is possible to compress the water? **No**.

Straw, grass and paper bundles are **compressible**. This means that it can be compressed to take up less space.

Sand is **incompressible**. That means it cannot be compressed to take up less space.

4. (a) Is water compressible or incompressible? **Incompressible**.
(b) Is air compressible or incompressible? **Compressible**.
(c) How can one use a syringe to investigate the compressibility of air and water?

Fill one syringe with air and the other with water. Press both while keeping a finger on the outlet tube to feel the difference.

Air is compressible, but water is incompressible.

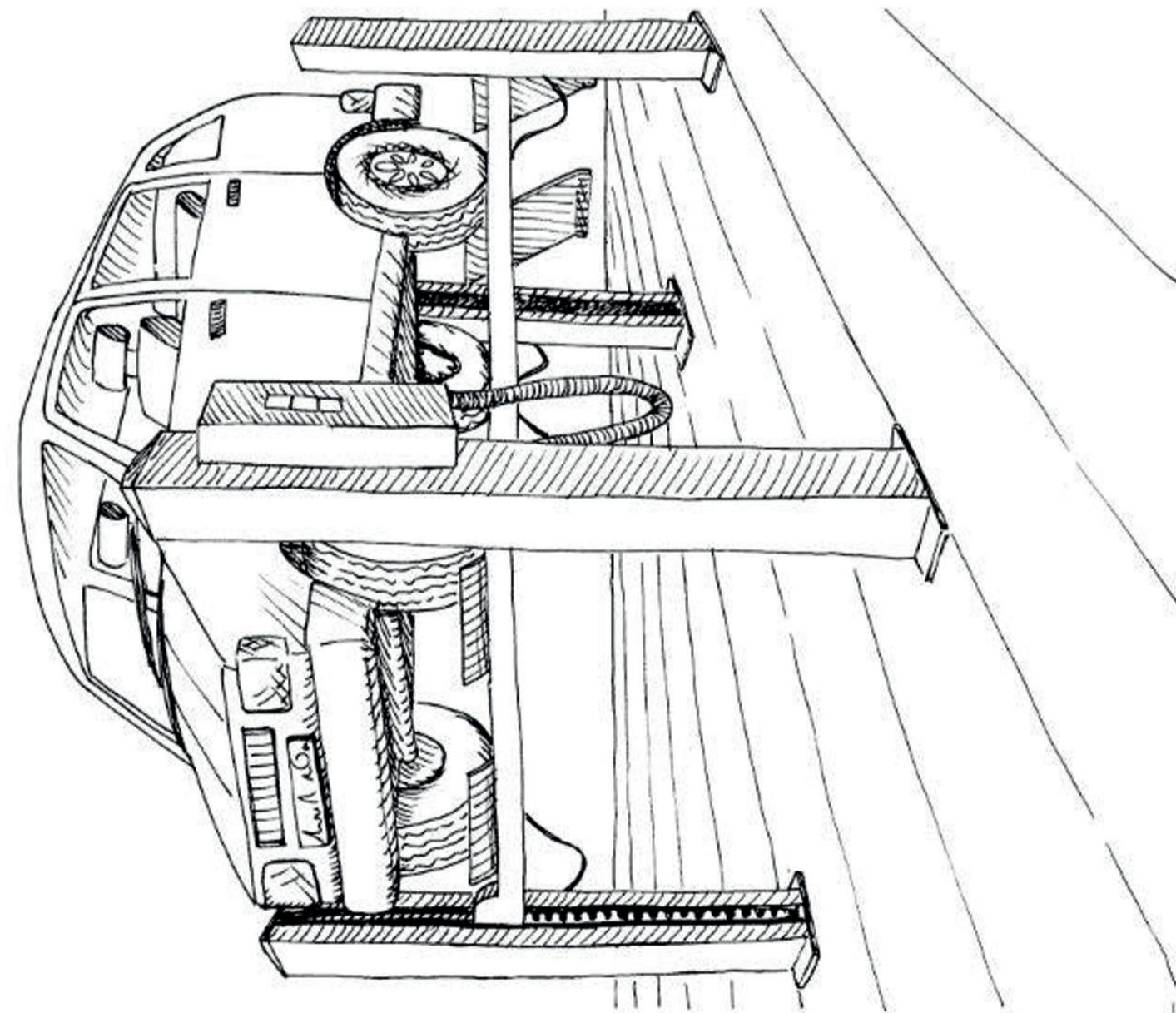


Figure 3



Two syringes that are connected with a tube can be called a **syringe system**.

If the tube and syringes are filled with air, it is called a **pneumatic system**.
If they are filled with water or oil, it is called a **hydraulic system**.

LB page 57

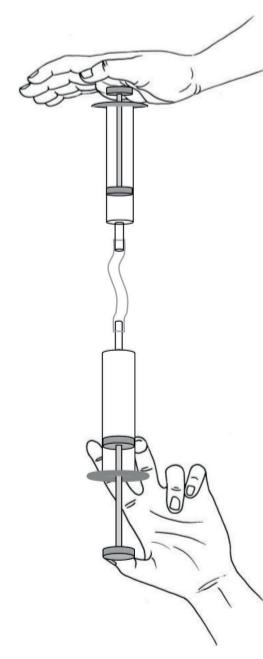


Figure 5

5. When the plunger on the left is pressed in, the plunger on the right presses against the hand. Will the pressure on the hand be the same with a pneumatic system as with a hydraulic system? Explain your answer.

The pressure on the hand will be smaller with the pneumatic system, because part of the work done to press the plunger is spent on compressing the air, and is therefore not available at the output end.

6. A pneumatic and a hydraulic system are shown below in Figure 6. In each case the two syringes are exactly the same size. Two heavy objects of the same weight are resting on plungers on the right in each case.

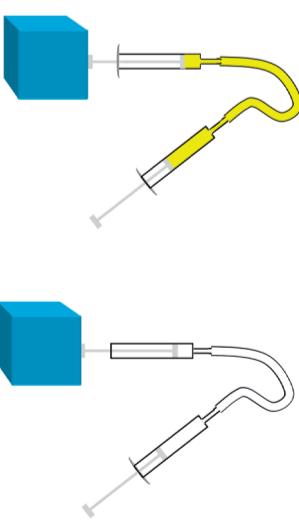


Figure 6

If the plunger on the left is pressed in by 2 cm in both systems, what will happen to the blue objects? Explain your answer.

The system of syringes and pipe on the right is filled with oil or water. Both syringes have the same diameter. When you press in the plunger on the left by 2 cm, the blue object will be lifted by exactly 2 cm.

The system of syringes and pipe on the left is filled with air. Both syringes have the same diameter. When you press in the plunger on the left by 2 cm, the blue object will be lifted by less than 2 cm, because the air will compress.

5.2 Narrow and wide syringes

Think about loads and distances

LB page 58

LB p. 58

Look at Figure 7 and then discuss the question in small groups.

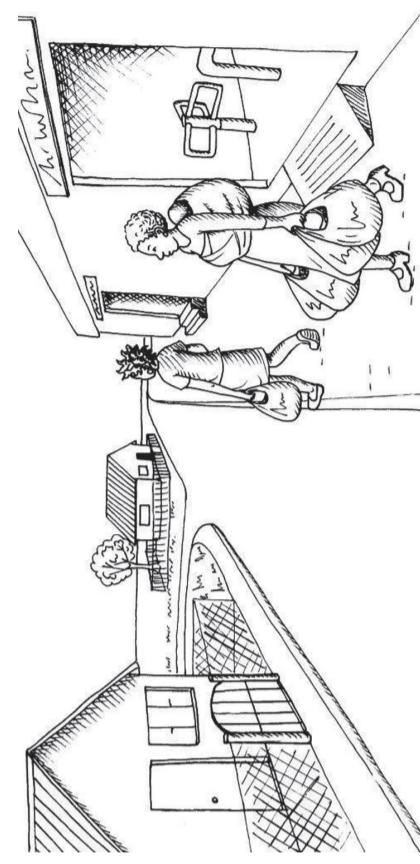


Figure 7

1. The woman carrying the big load only has to walk a short distance to her home. The woman with the small load has to walk quite far to her home. Who will be more tired when she gets home? Explain your answer.

No definite answer is possible without more information. The idea with the question is to simply inspire learners to engage with the idea that the amount of 'work' done when carrying a load depends on both the distance covered and the weight carried. It would be good if a few learners suggest that the two women do roughly the same amount of work, because that may support their thinking on mechanical advantage in hydraulic systems.

Figure 8 below shows a two-syringe system with a smaller and a bigger syringe. The system was filled with water until there were no air bubbles.

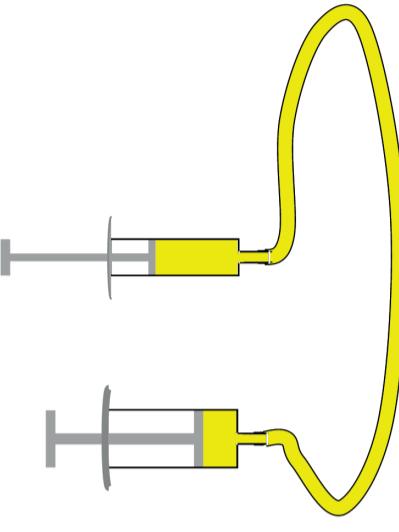


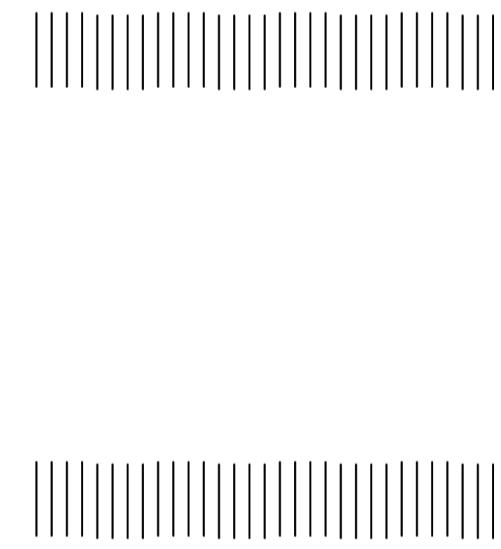
Figure 8

Action research: Input and output cylinders

You will now do more action research with two syringes. To do this, you need to make an apparatus. Copy these rulers onto a drawing and attach them to a sheet of corrugated cardboard or a cereal box. The lines are 2 mm apart.

LB p. 59

cardboard →



Attach your two-syringe system with tape to the cardboard sheet or box, as shown in Figure 9 on the next page.

If you press the plunger on the left in, the plunger on the right will move out.

The syringe on which you push the plunger in is called the **input** or **master cylinder** of the system. The syringe that is moved is called the **output** or **slave cylinder** of the system.

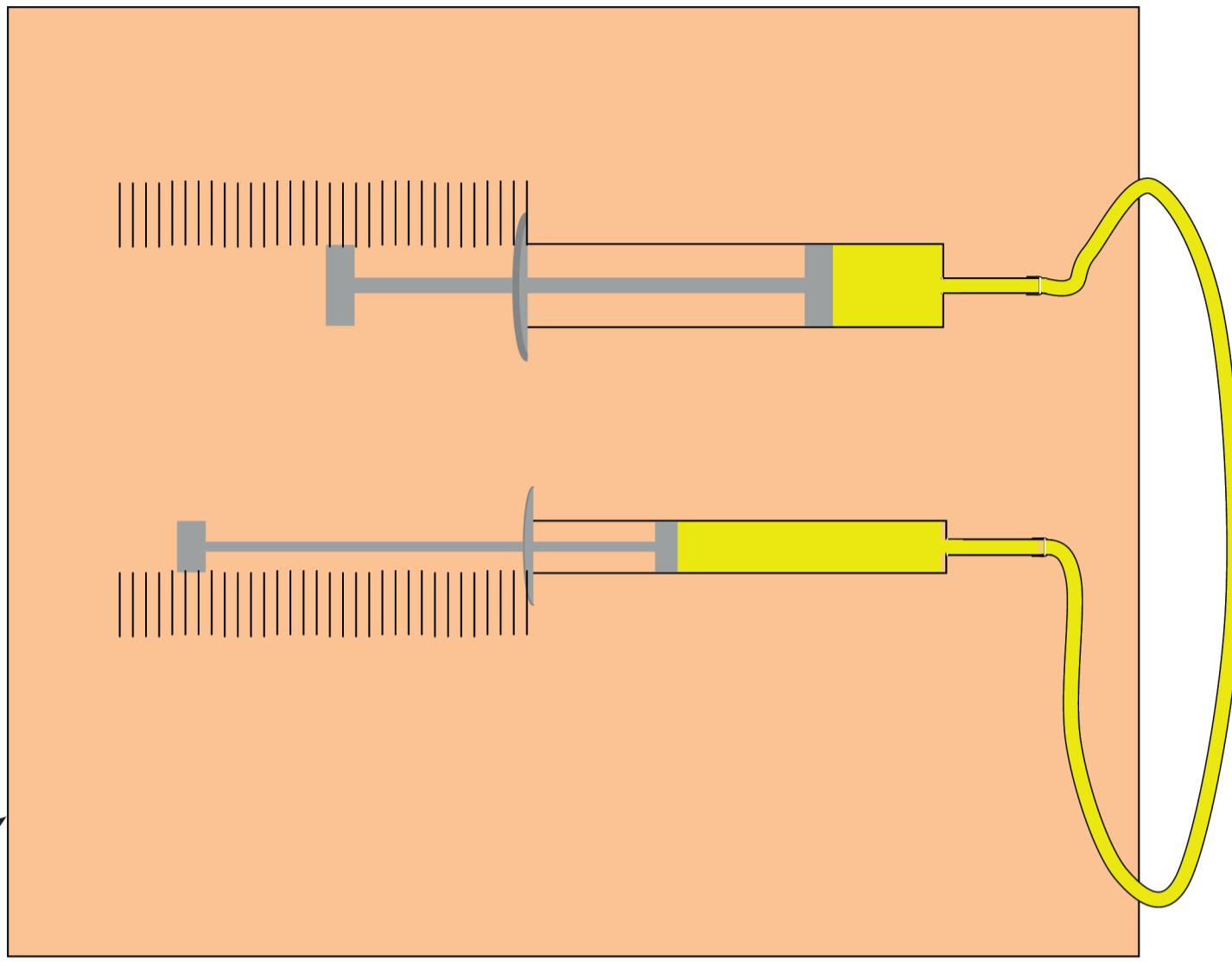
You will now do research to find out how far the output cylinder moves out when the input cylinder is pushed in for a certain distance.

1. Draw water into the input cylinder so that it is almost full, and the plunger is right next to one of the marks on the ruler.
2. Make a small mark at the top of the plunger of the output cylinder.
3. Push the input cylinder plunger in by 1 cm.
4. Measure how far the output cylinder plunger has moved.
5. Draw up a table like the one below and enter your measurement.
6. Repeat steps 1 to 4, but now push the input cylinder in by 2 cm.
7. Repeat all the steps from 1 to 4 for distances of 3 cm and 4 cm.

Input cylinder movement in cm	1	2	3	4
Output cylinder movement in cm				

The ratio between the input cylinder distance and output cylinder distance should be constant, but may slightly vary as the readings may not be precise.

Figure 9





8. Now think of the scenario where you made the wide syringe the master cylinder, and the narrow syringe the slave cylinder. How far do you think the plunger of the narrow syringe will move when you press the plunger of the wide syringe in by 1 cm?

It will be the opposite. If the wide cylinder moved $\frac{1}{4}$ cm when the narrow cylinder moved 1 cm, the narrow cylinder will move 4 cm when the wide cylinder moves 1 cm.

9. Also predict what will happen if you press the plunger of the wide cylinder in by $\frac{1}{2}$ cm, 1 cm or 2 cm. Copy the table below and fill in your predictions.

Wide master cylinder movement in cm	$\frac{1}{2}$	1	2
Narrow slave cylinder movement in cm			

The opposite of the measurements in Question 7.

10. If you still have time, do more research to check your predictions. Draw up another table to show your new predictions.

The opposite of the measurements in Question 7.

You do **work** when you press in the master cylinder. And the slave cylinder does work when it moves on the other side. The amount of work “put in” on the input side (master cylinder) must be the same as the amount of work that “comes out” on the output side (slave cylinder).

11. What do you notice? You have now investigated how the distance of movement changes when you transfer work from one syringe to another syringe with a different width. Is it only the distance of movement that change when you transfer work from one cylinder to a different cylinder?

Put a finger on the plunger of the slave cylinder when you press the plunger of the master cylinder. Do this in two ways, by using the narrow cylinder as the master cylinder and by using the wide cylinder as the master cylinder.

The force on the wider cylinder is bigger than the force on the narrow cylinder.

LB page 62

5.3 Change the size of forces using a hydraulic system

The picture shows a plastic bag filled with water.

If you put your left index finger gently against the bag and then pressed against the bag with your right index finger, what do you think you would feel with your left index finger?

When pressure is applied to a flexible container with liquid, the same pressure is felt everywhere in the container.

The pressure is “transmitted” or “transferred” through the liquid.

Note: “Pressure” is not the same as “force”, although it is related to it. A man called Blaise Pascal realised this a few centuries ago and wrote about it. It is called **Pascal’s principle**.

You will now do action research to investigate how pressure is transmitted through water. To do this, you need the same syringe system on a cardboard base that you used in the previous section. This time, put it upright and support it with books, or something else that is sturdy. You also need a few objects that are equal in weight, like small boxes filled with sand.

Figure 10

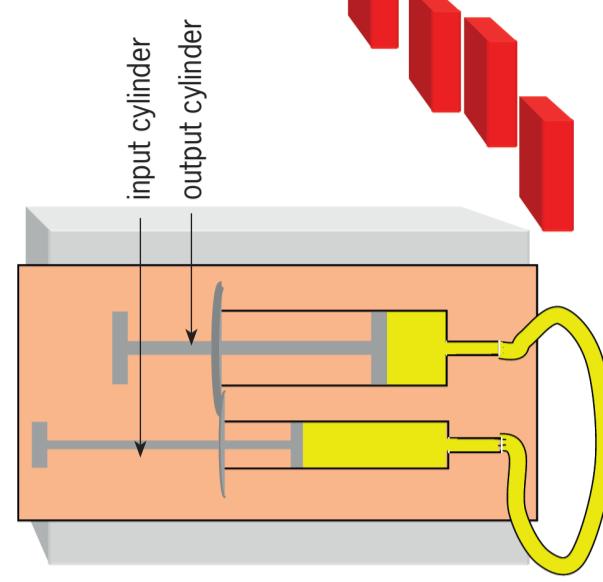


Figure 11

Action research: How is pressure transmitted through water?

1. Draw water into the wider cylinder until it is almost full. You will use this as the input cylinder.
2. Put one box on the plunger of the output cylinder. Put another box on the plunger of the input cylinder.
3. Does the plunger on the output cylinder move?

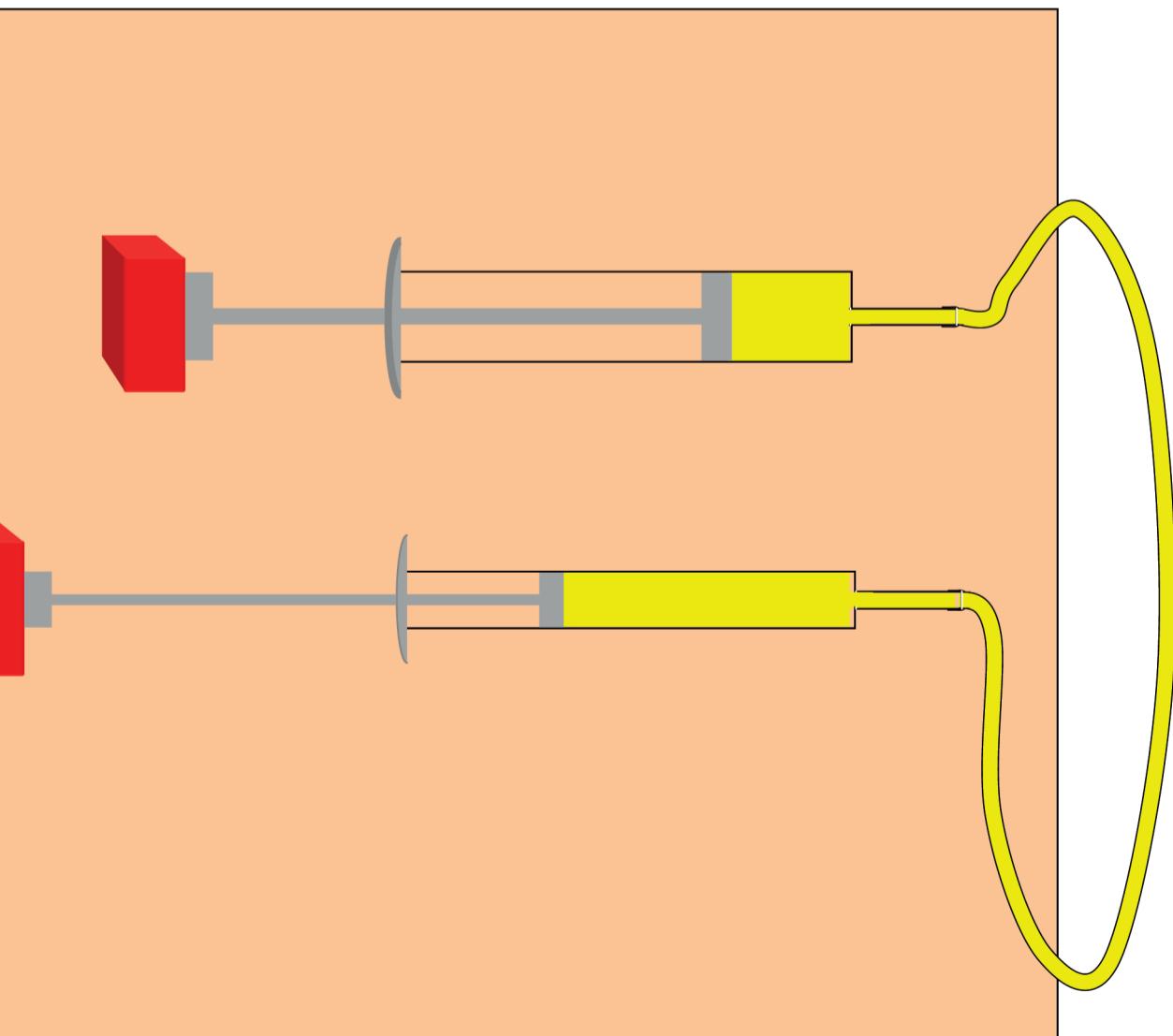
It should not move. Ask the learners to explain why not!



4. Put another box on the plunger of the input cylinder. If the plunger on the output cylinder still does not move, put more boxes on the input cylinder.

5. Think about what you have just observed. How do the boxes you have placed on the master cylinder affect the slave cylinder?
- The answer is given in the text, in the text following the question.**

LB page 64



Instead of saying "the boxes press downwards", technologists usually say "the boxes **exert** a downward force".

The boxes on the master cylinder press downwards on the plunger in the system. This force is transmitted through the water to the plunger on the slave cylinder, and it pushes the plunger of the slave cylinder upwards.

6. Did the plunger on the slave cylinder move the same distance as the plunger on the master cylinder?

No

7. Was the force exerted by the boxes you placed on the master cylinder equal to the upwards force exerted on the one box on top of the slave cylinder?

No, it was bigger.

8. Think back to the two women who walked carrying bags to their homes, in the story at the beginning of section 5.2. What does their story and this experiment have in common? Think carefully before you write down your answer.

A large force that is exerted (acts) over a small distance does the same amount of work as a small force that is exerted (acts) over a large distance.

When work is transferred from a wide cylinder to a narrow cylinder, the force exerted by the narrow cylinder is smaller than the force that is applied to the wide cylinder. That is why you had to put more than one box on the wide cylinder before it could move the one box on the narrow cylinder upwards. The pressure of the liquid is the same everywhere, on the input cylinder as well as the output cylinder. But because the input cylinder is wider, the force on the input cylinder is greater than the force on the output cylinder.

Next week

In the next chapter, you will learn how hydraulic systems are used to lift cars and other heavy objects.

CHAPTER 6

Hydraulic machines

Orientation

The work for this week involves two quite challenging topics:

- calculations about hydraulic presses, and
- the working of a hydraulic car jack.

The above topics are addressed in sections 6.2 and 6.3.

To make sense of hydraulic press calculations, learners need to clearly understand that the mechanical advantage comes from pushing a small piston a long way with a small force so that the big piston moves a short way with a big force.

Learners start to work quantitatively with the relationship between the cross-sectional area and the distance of movement. This means they need to measure quantities and do calculations with those quantities.

LB page 65	
In this chapter you will investigate how hydraulic systems are used in some practical situations.	
6.1 Using pressure to get things done	89
6.2 Calculations about hydraulic systems	92
6.3 The hydraulic car jack	95

6.1 Using pressure to get things done

The pictures and text on Learner Book pages 68–69 engage learners in two applications of hydraulic presses: metal pressing and waste compaction.

The section then continues to revise the idea of mechanical advantage in hydraulic systems. Questions 2(a) and (b) on Learner Book page 70 are critical for understanding how hydraulic systems can provide mechanical advantage. **In order to ensure that there is enough time to do and discuss these questions in class, the design and drawing task in Question 1 on Learner Book page 69 should preferably be given as homework.**

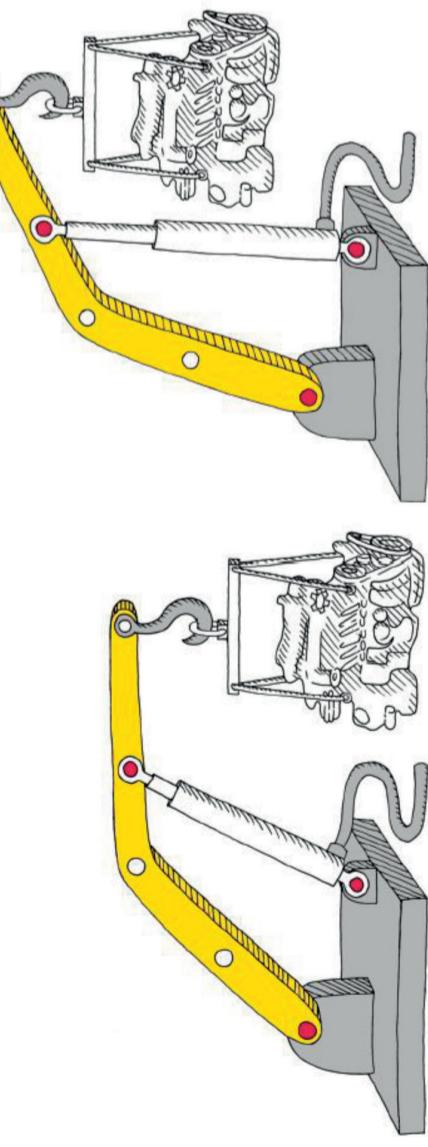


Figure 1

6.2 Calculations about hydraulic systems

Learners need to understand the following in order to make sense of calculations about hydraulic devices:

- The work done by applying a small force over a long distance is equal to the work done by applying a big force over a short distance (this was emphasized in Chapter 5 already).
- Liquid is not compressible, hence the volumetric displacement of the input cylinder is equal to the volumetric displacement of the output cylinder
- Volume = surface area of base \times height

The diagram in Figure 13 on Learner Book page 72, may help learners to grasp the above ideas.

Your learners may want to know why the pictures of hydraulic systems have rectangular cylinders. This is because it is easier to explain the concept of 'area' using a rectangle. Normally hydraulic systems have round pistons.

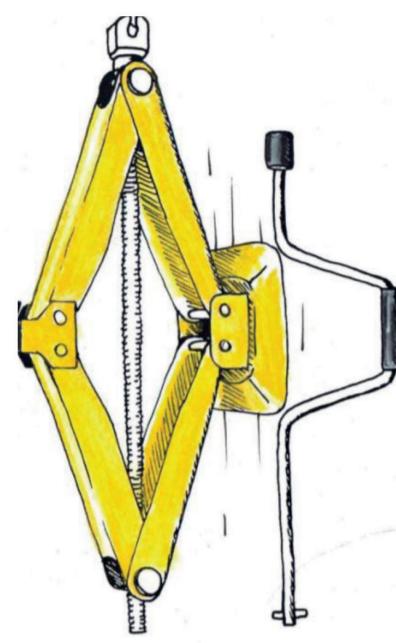


Figure 2: Mechanical jacks

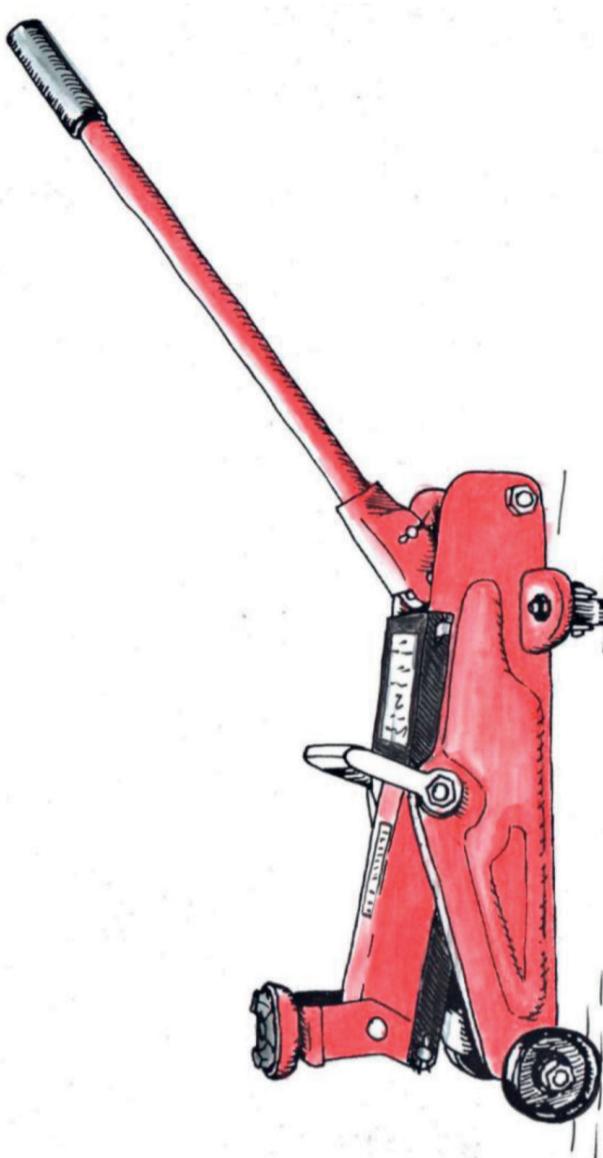


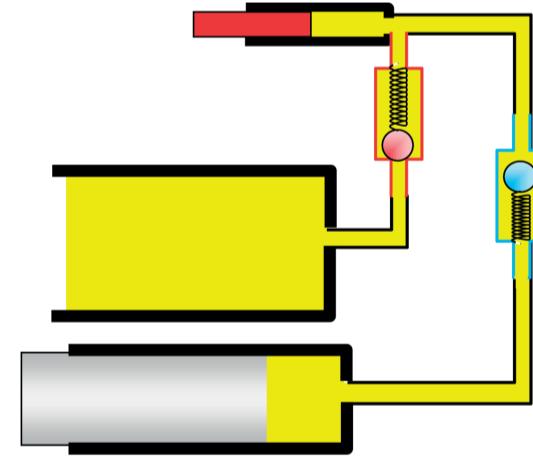
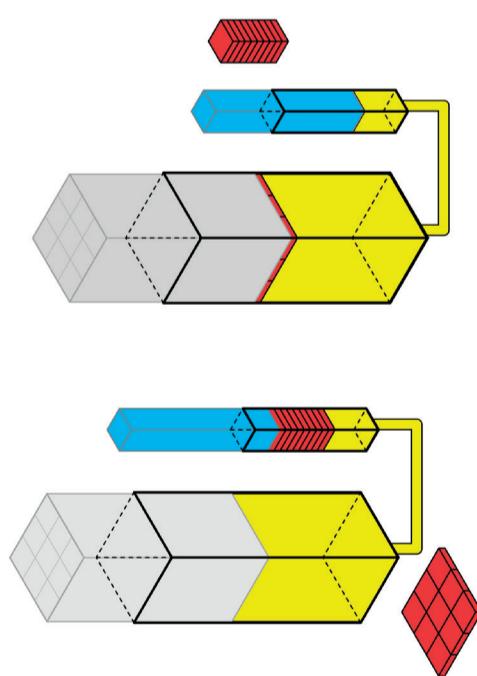
Figure 3: A hydraulic floor jack

This lesson is a series of questions using simple calculations of hydraulic systems with a mechanical advantage greater than 1. All the questions are about a small input piston (blue) and a big output piston. It is preferable that learners reason to do the calculations instead of trying to use a formula without understanding.

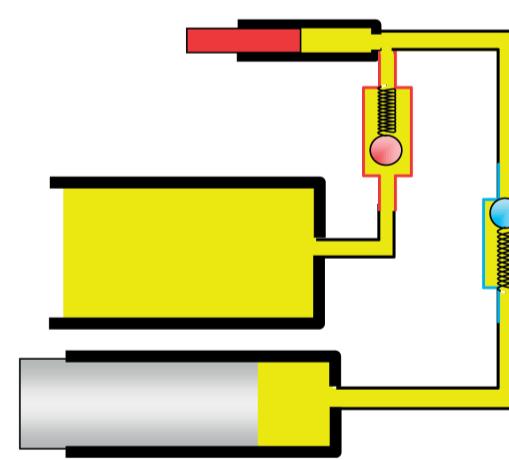
6.3 The hydraulic car jack

These diagrams appear with explanatory text on page 76 in the Learner Book (Figures 24 and 25). The questions below do not appear in the Learner Book, but may be useful in class.

What do you think will happen to the red and blue valves shown in this diagram, and to the output cylinder when the red input cylinder is pulled upwards?



What do you think will happen to the red and blue valves shown in this diagram, and to the output cylinder when the red input cylinder is pressed downwards?





LB page 67

6.1 Using pressure to get things done

LB page 68

If you press a plastic bottle down hard on a sheet of paper, you can make a perfectly round mark on that paper.

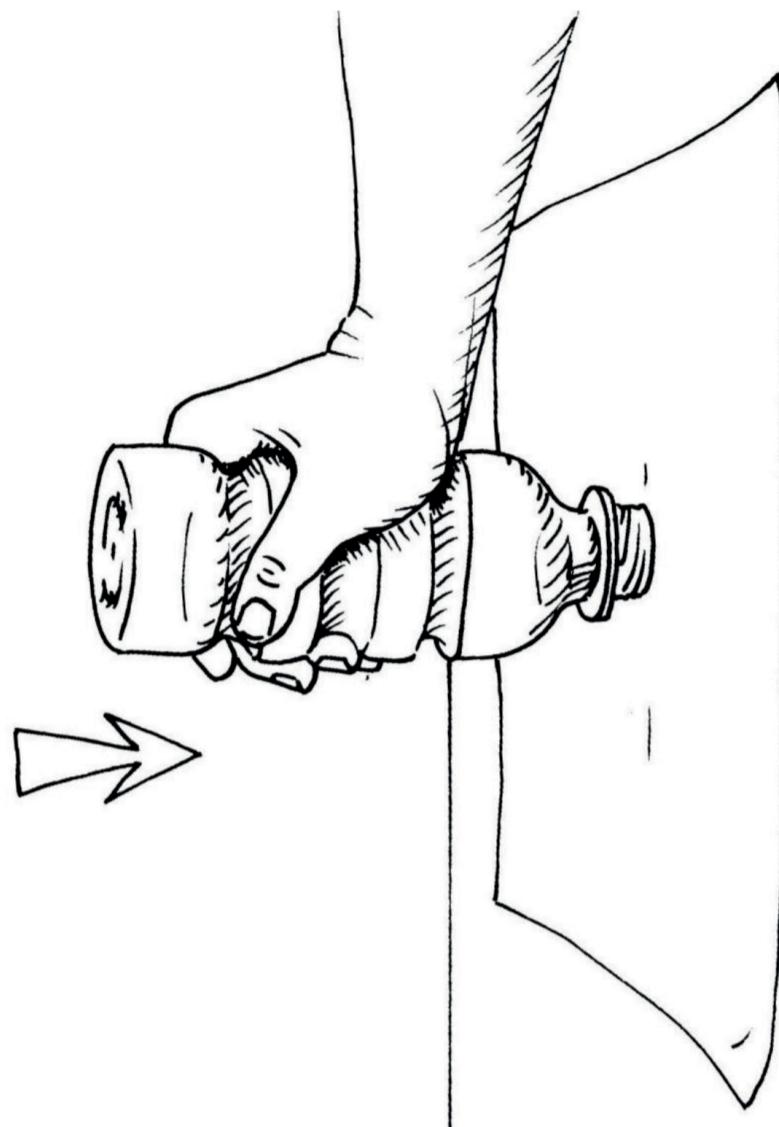


Figure 5

You can also use a bottle like this to press cookies out of a sheet of dough. Flat plastic or metal objects such as washers can be made in the same way, by pressing them out of plastic or metal sheets. With metal, you have to press down very hard.

Questions about applying pressure

LB p. 68

1. Tom wants to use two hard steel tubes with sharp edges to press washers from a sheet of iron. Can he use a type of lever to help him exert enough force to press the steel tubes through the iron sheet?

Make a sketch to show how this can be done.
The machine that you design can be called a washer-making press.

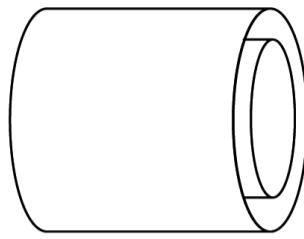


Figure 6



Many towns in South Africa use garbage trucks to collect garbage bags and other rubbish.

This truck can carry 15 cubic metres of rubbish, which is roughly 120 garbage bags. The truck has a hydraulic press with output cylinders that can compress the rubbish with a force of fifteen tons or 15 000 kg. If you want to know how big that force is, think about how heavy a full two litre bottle of cold drink feels in your hand. Now imagine you are holding 7 500 of them!

Because the truck compresses the rubbish, it can pick up about 2 000 bags before it is full.

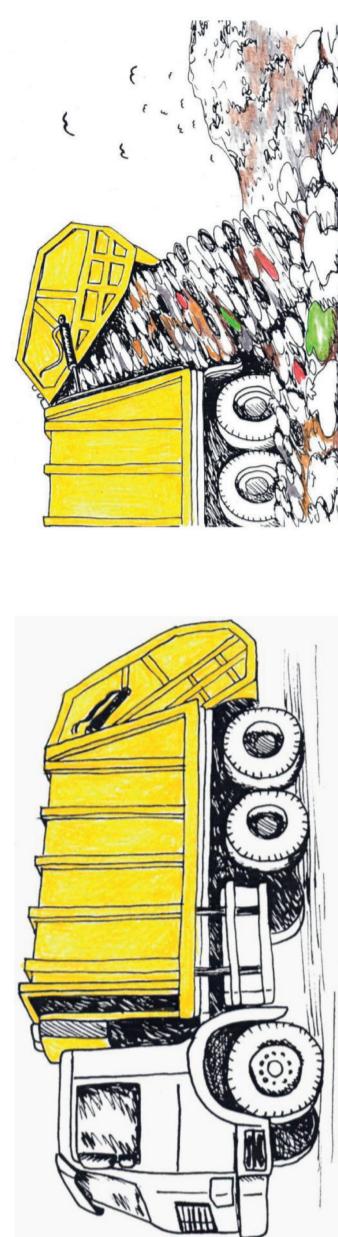


Figure 8

Learners' own design sketches.

Instead of using a lever to exert a big enough force to cut the washers, a hydraulic pushrod could be used, as shown in Figure 7.

A machine like this is called a **hydraulic press**.

The mechanical advantage gained by using an output cylinder that is wider than the input cylinder is used in a hydraulic press.

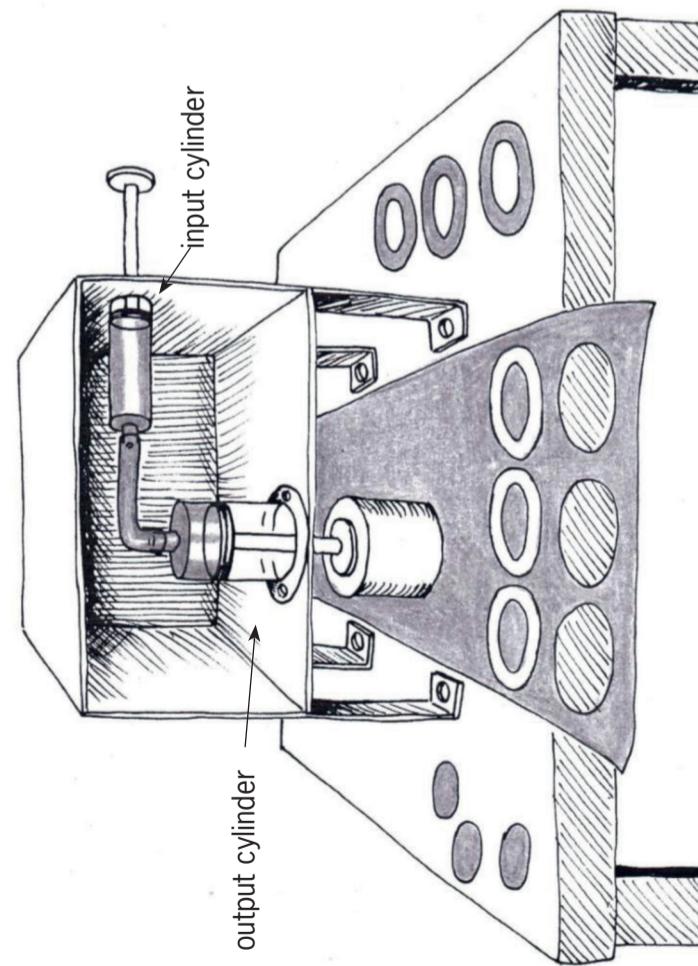


Figure 7

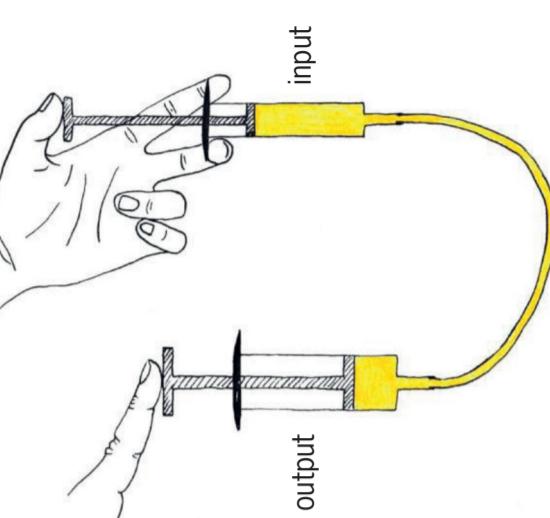


Figure 9

How does a hydraulic press work?

Look at the syringe system shown here. If you push the input plunger with your one hand, the output plunger will push up against your finger.

If the output plunger is wider than the input plunger, the output force is bigger than the input force. The mechanical advantage is bigger than 1.

If the output plunger is narrower than the input plunger, the output force is smaller than the input force. In this case, the mechanical advantage is smaller than 1.

Figure 10 shows the same type of system as Figure 9. The yellow part is water or another type of liquid. The red and blue parts are cylinders that can move up and down.

Figure 9

2. (a) Imagine a hydraulic system such as in Figure 10 that is about 50 cm high. If the blue cylinder is pushed down by 5 cm, will the red cylinder move upwards by 5 cm, by less than 5 cm or by more than 5 cm?
Less than 5 cm
- (b) Suppose a load, for example, a box with apples, is placed on top of the red cylinder. Will the upwards force on the load be the same as the downward force exerted on the blue cylinder. Or will it be bigger or smaller?
The upward force on the load will be bigger.

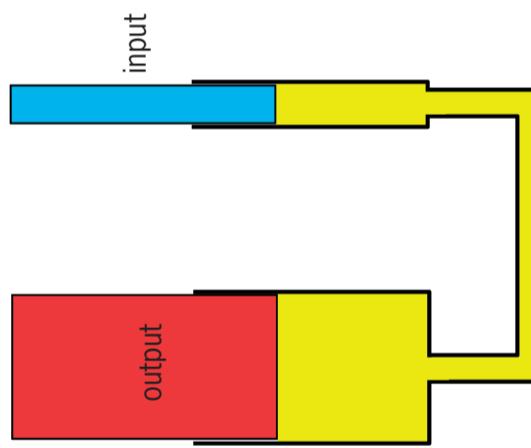


Figure 10

If the output cylinder in a simple hydraulic system is wider than the input cylinder, the output distance is smaller than the input distance, but the output force is bigger than the input force.

6.2 Calculations about hydraulic systems

A hydraulic system with rectangular cylinders is shown below. The surface area of the red cylinder top is four times bigger than the surface area of the blue cylinder top. The volume of liquid that is pushed down on the right rises up on the left and pushes the red cylinder upwards.

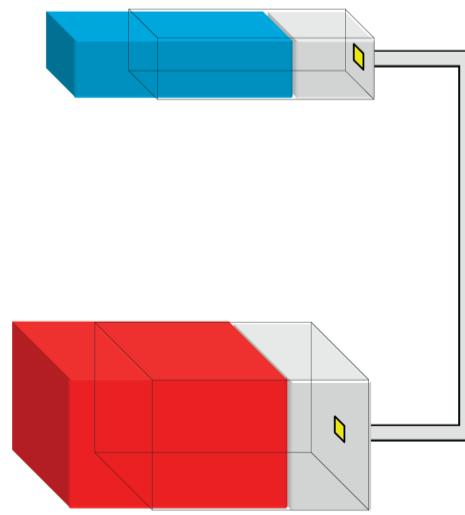


Figure 11

2. (a) The surface area of the top of a cylinder is the same as the surface area of the base of the cylinder, and it is the same as the surface area of any cut that you make at a right angle with the height of the cylinder. This is called the **cross-sectional area**.
If you struggle to understand this, imagine a roll of polony or a brick-shaped loaf of bread. Each slice that you cut from the polony or bread has exactly the same shape and size, and therefore also has the same surface area.

Calculations

LB p. 71

1. If the blue cylinder in Figure 11 moves down by 12 mm, by how much will the red cylinder move up?

By less than 12 mm, however, learners cannot be expected to give the actual answer now. The explanation is given in the text and diagram below.

Look at Figure 12.

- If the blue cylinder is pushed down through the green volume on the right, the red cylinder will move up through the green volume on the left.
 - If the surface area of the base of the output cylinder is four times the surface area of the base of the input cylinder, the output force will be four times as big as the input force. The output distance will be a $\frac{1}{4}$ of the input distance.
- In the system in Figures 11 and 12, the mechanical advantage is four, and the distance advantage is $\frac{1}{4}$.

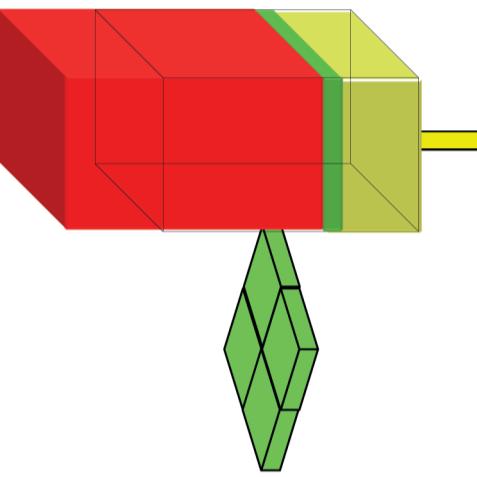
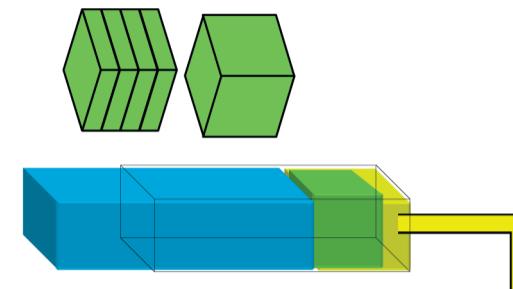


Figure 12





2. In the system shown in Figure 13, the surface area of the output cylinder top is nine times the surface area of the input cylinder top.

(a) What is the mechanical advantage of this system?

$$9 \dots$$

(b) What is the distance advantage of this system?

$$\frac{1}{9} \dots$$

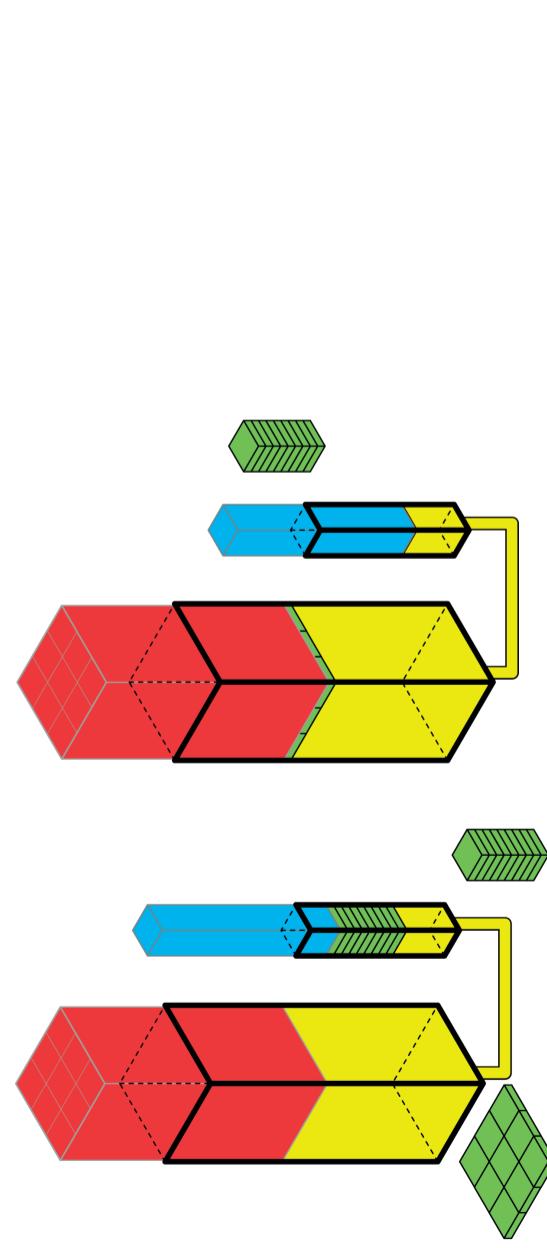


Figure 13 LB page 73

3. In a particular hydraulic press, the output cylinder moves by 2 cm when the input cylinder is moved through 10 cm. How much stronger is the output force than the input force?

Output cylinder moves through only one fifth of the distance so the force is 5 times stronger than the input force.

4. In another hydraulic press, the area of the output cylinder top is 40 cm^2 and the area of the input cylinder top is 5 cm^2 .

(a) How far will the output cylinder move if the input cylinder is moved through 16 cm?

Output cylinder moves through only one fifth of the distance so the force is 5 times stronger than the input force.

(b) How far do you need to push the input cylinder so that the output cylinder will move through 24 cm?

$$8 \times 24 = 192 \text{ cm}$$

6.3 The hydraulic car jack

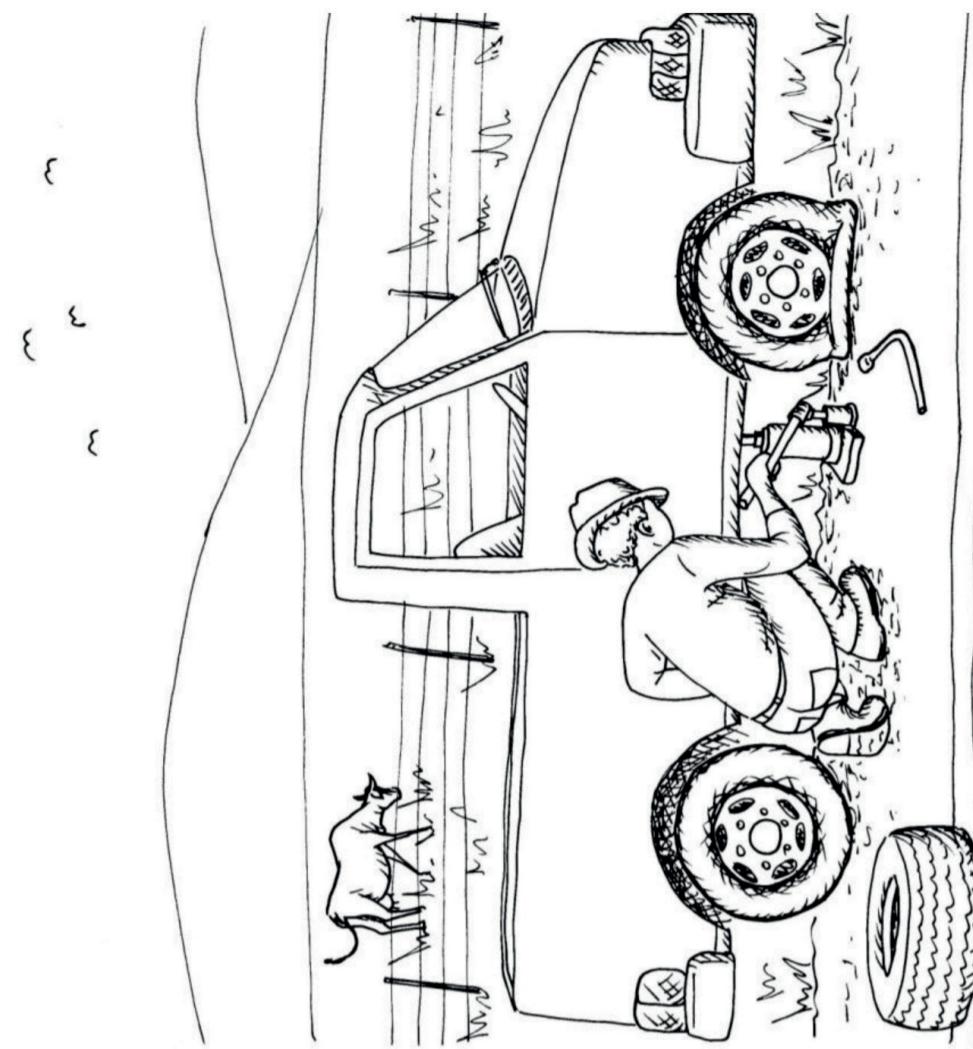


Figure 14

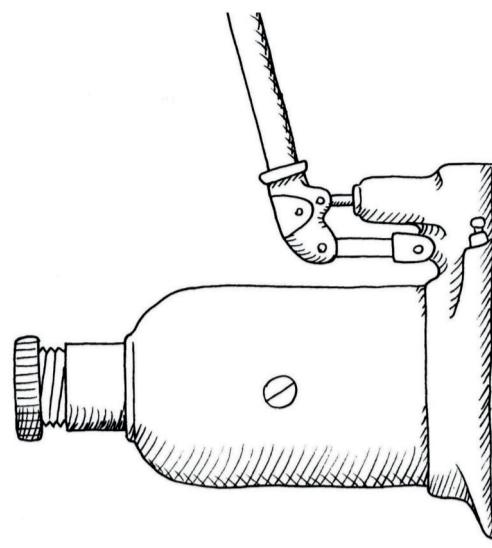


Figure 15: A hydraulic bottle jack

When a tyre goes flat, you need to lift the car up to take the wheel off and fit another wheel. Since a car is too heavy to lift with your bare hands, a device that provides a mechanical advantage is needed.

A device that is used to lift cars so that wheels can be changed is called a **jack**. A jack provides a mechanical advantage.



Look at Figure 16. A bottle jack has a hydraulic pushrod system inside, which provides a mechanical advantage. When the blue input cylinder is pushed down by some distance, the red output cylinder moves up with a bigger force, but by a much smaller distance.

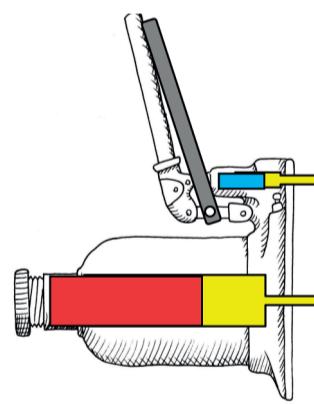


Figure 16

LB page 74

Questions about the hydraulic jack

1. Look at Figure 14 on the previous page. Do you think the car will be lifted high enough when the input cylinder is pressed down?

No, because the output cylinder will only rise a little for one push of the input cylinder.

To lift the car up high enough, the output cylinder will have to be pushed up quite a number of times. To do that, the input cylinder will have to be pulled upwards each time, so that it can be ready for a next downward push. Think of syringes to understand what will happen. You can even experiment with two syringes of different sizes again.

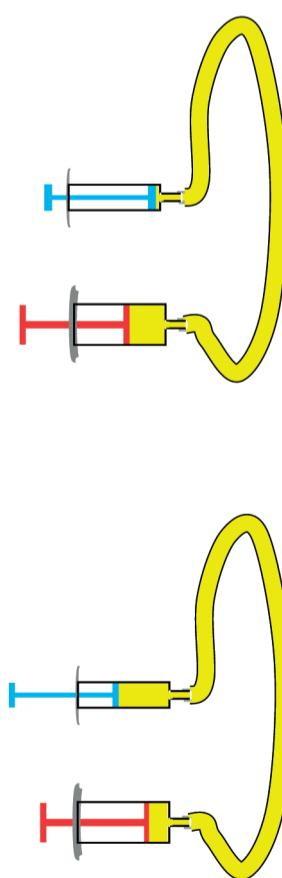


Figure 17

2. When the blue input plunger is pressed in, the red output plunger moves out. What do you think will happen if the blue input plunger is now pulled out again?

The red input plunger will be sucked down again.

If the output cylinder could remain where it is after the input cylinder has been pushed downwards, then the output cylinder could be pushed higher every time the input cylinder is pushed down.
To make this possible, more oil will be needed. A real hydraulic bottle jack has an extra container with oil, as shown in the diagram below.
To make the red cylinder stay in place each time the blue cylinder is pulled upwards, the oil should be prevented from being sucked out from underneath the red cylinder. Perhaps something like a water tap should be placed at the white box in Figure 21.

LB page 74

1. Look at Figure 14 on the previous page. Do you think the car will be lifted high enough when the input cylinder is pressed down?

No, because the output cylinder will only rise a little for one push of the input cylinder.

To lift the car up high enough, the output cylinder will have to be pushed up quite a number of times. To do that, the input cylinder will have to be pulled upwards each time, so that it can be ready for a next downward push. Think of syringes to understand what will happen. You can even experiment with two syringes of different sizes again.

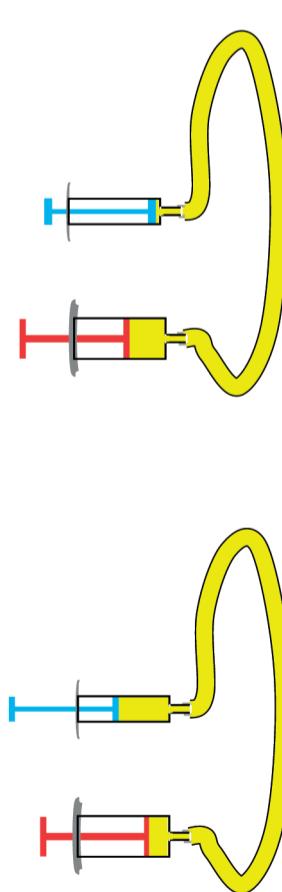


Figure 18

A ball valve such as those on the right allows liquid to flow in one direction through a tube, but not in the other direction. This ball valve consists of a ball that is connected to a spring. The spring pushes the valve against the opening, so that no liquid can flow through.
If the liquid tries to flow from the left to the right, the ball is pushed away from the opening, and the liquid can pass through.

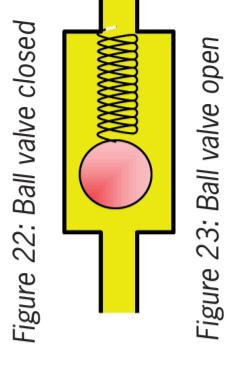


Figure 19

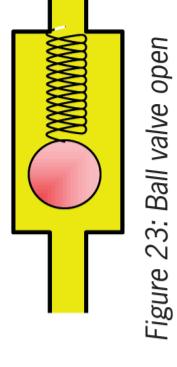


Figure 20

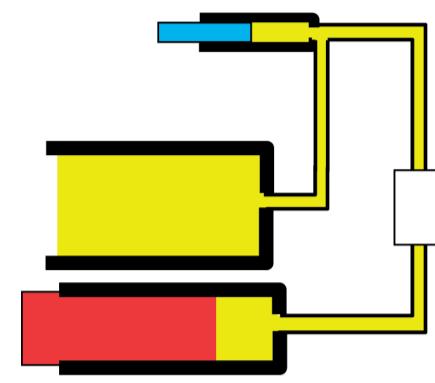


Figure 21

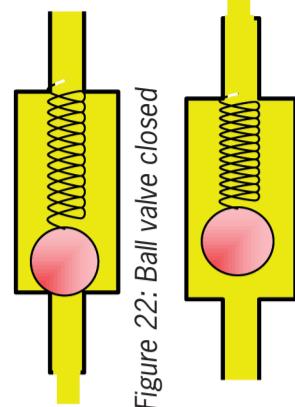


Figure 22: Ball valve closed

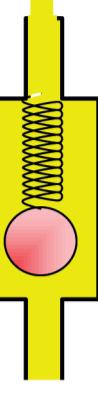


Figure 23: Ball valve open

LB page 76

The main part of a hydraulic car jack is a big output cylinder that sticks out of the top of the bottle shape. This lifts the car up when you pump the handle.

Inside the bottle is a tank with oil. The oil from this tank passes through a ball valve into the space where the input cylinder is. The ball valve does not allow the fluid to pass back.

The pump handle connects to the small input cylinder and pushes it in like the plunger in a syringe. As you pump, the input cylinder goes up and down, forcing the oil to the output cylinder through another ball valve.

The output cylinder pushes up a small distance each time the input cylinder is pushed down, but with a big force that lifts the car up.

When the input cylinder is pushed downwards, the red valve closes and the blue valve opens. The oil is then pushed past the blue valve and pushes the output cylinder upwards.

When the input cylinder is pulled upwards, the red valve opens and oil is drawn in from the tank. The blue valve closes, so that oil cannot flow back from the side of the output cylinder. As a result, the output cylinder does not move while the input cylinder is pulled upwards.

- LB page 77**
3. Make a systems diagram of how a hydraulic car jack works. The picture below can help you to think of the different things that happen between the input and output of a car jack. The systems diagram must show in different steps what happens inside the jack if you press down and pull back the lever twice. Note that the additional tank of oil in the drawing below has a hole inside it into which the output cylinder fits. This tank is also called the "oil reservoir" of the hydraulic system.

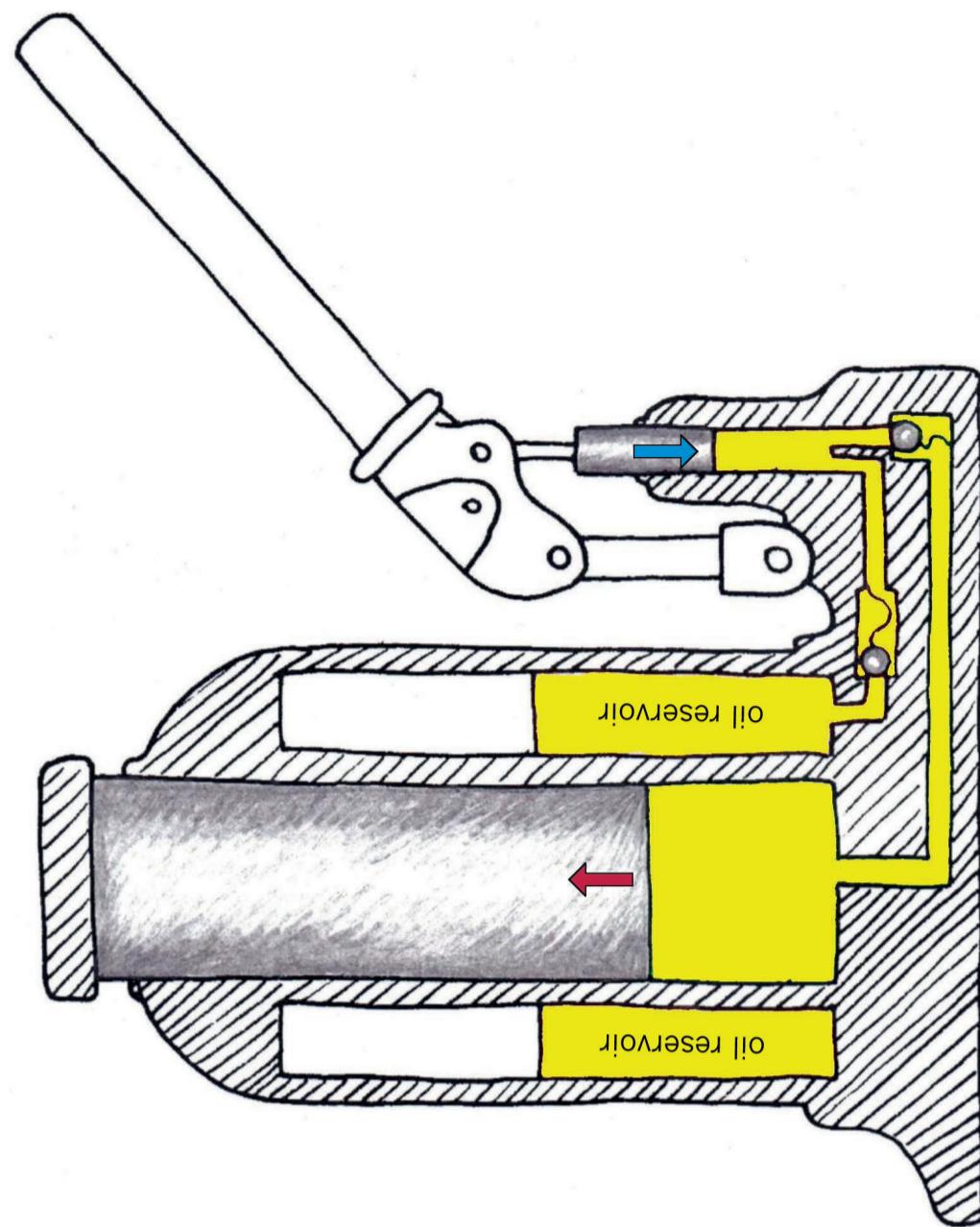


Figure 26: A few inner workings of a hydraulic car jack

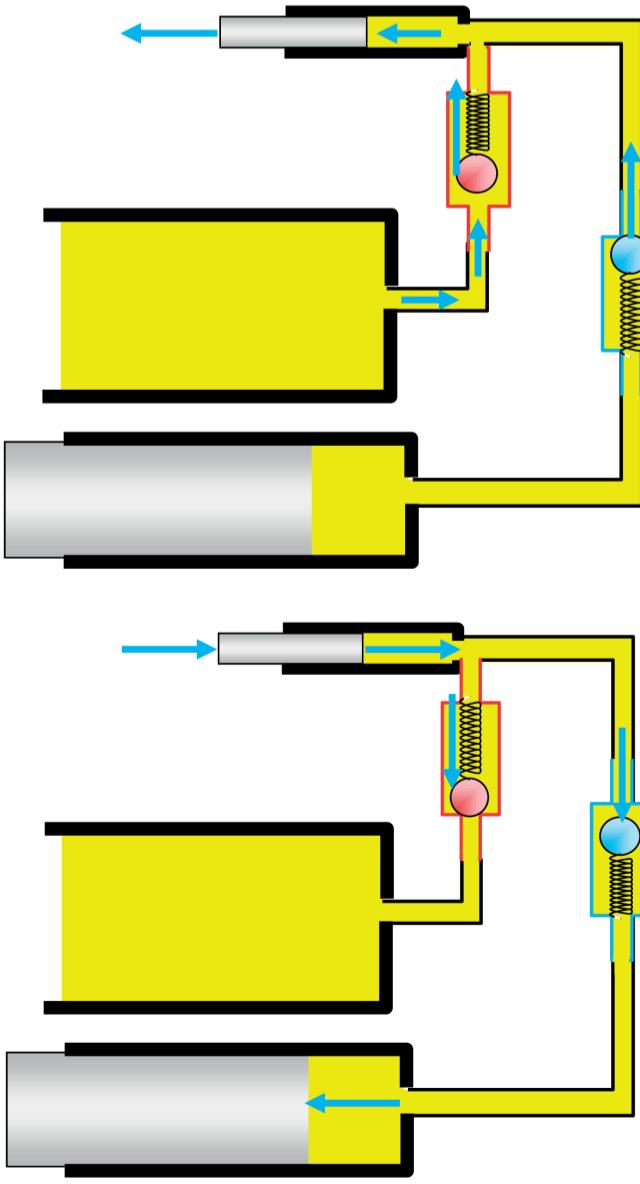


Figure 24

Figure 25



Evaluate the design of a hydraulic car jack

LB p. 78

Learners' sketches should show:

Step 1:
the lever pressed down;

- the valve to the reservoir closed and the valve to the output chamber opened;
- the output cylinder raised;

Step 2:
the lever pulled back up;

- the valve to the output chamber closed and the valve to the reservoir opened;
- oil sucked into the input cylinder chamber;

Step 3:
the lever pressed down;

- the valve to the reservoir closed and the valve to the output chamber opened;
- the output cylinder raised higher than before;

Step 4:
the lever pulled back up;

- the valve to the output chamber closed and the valve to the reservoir opened;
- oil sucked into the input cylinder chamber.

Yes, because it has non-return valves so the car can't fall.

LB page 78

An important question

What safety precautions should people take when using car jacks?

Next week

During this week, you learnt how valves can be used to control the movement of oil and of the output cylinder of a car jack. Next week, you will learn about other ways to control movement. You will also learn about pulleys and pulley systems.

CHAPTER 7

Pulleys and controllers

Materials required for this chapter

some cups or beakers with handles (see page 110)
a roll of string
HB pencils and erasers

Orientation

The first part of this chapter is about mechanisms called pulley systems, and specifically:

- single-wheel fixed pulley systems
- single-wheel moveable pulley systems
- pulley-block systems (block and tackle)

The term **pulley** is a bit misleading, since the use of pulleys have nothing to do with the ergonomic and mechanical advantages in the various mechanisms. Pulleys only serve the purpose of reducing friction in these mechanisms, and all the mechanisms can work well without pulleys.

The picture on the right, which is also in the Learner Book on page 80, shows what may be called a "single-wheel fixed pulley system" although there is no wheel or pulley. The key aspect is a support around which the rope can be pulled in a different direction than the direction in which the load is moving.

Due to the mechanics of the human body, it is easier to pull sideways and downwards on a rope to lift something up, than to pull it up directly by pulling vertically upwards. To achieve this, a rigid support is needed around which a rope or chain can be pulled. A polished surface or a pulley can be installed at the support which allows the **change of direction of pull**, to reduce friction.

Note that the change of direction of pull that is made possible by pulling round a corner (support) does not provide a mechanical advantage in any way. The full force needed to lift the load has to be applied at the input (pulling) end of the rope. A **single-wheel fixed pulley system provides no mechanical advantage**, it just provides for a change of direction pull and therefore a more convenient body position for the person who does the work.

When lifting a heavy object, a mechanical advantage can be achieved by **allowing the object to slide back** while lifting it, so that it does not move as far as the end of the rope is pulled. This technique can be easily demonstrated with a string and a cup or beaker with a handle as shown in Figure 8 on Learner Book page 84.

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7.1 Change direction with a string or rope	106
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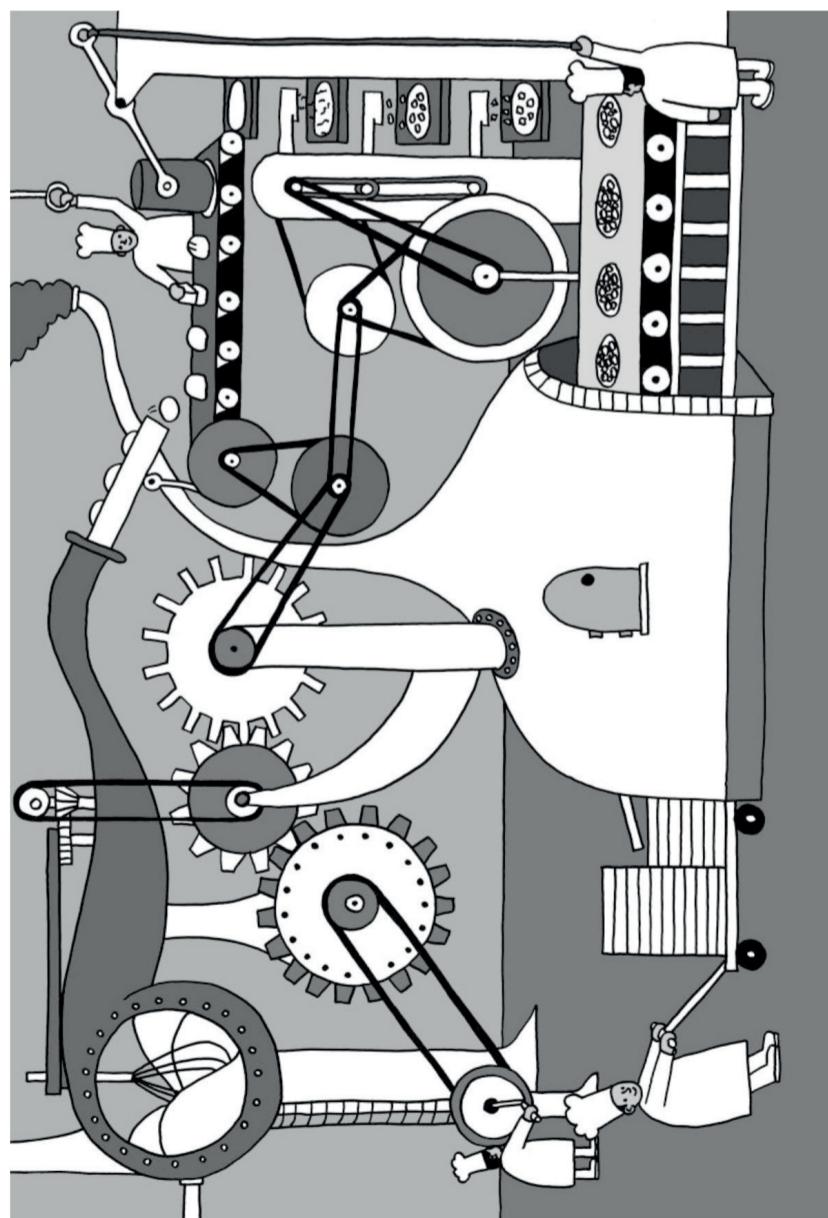
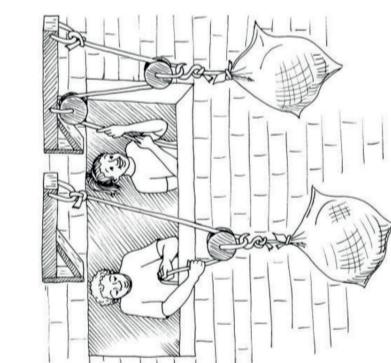


Figure 1



In both lifting systems shown on the right, moveable pulleys are used to allow the load to slide back while being lifted. The effect of a moveable pulley is that the load moves up by only half the distance through which the rope end is lifted, hence it works like a first-class lever with a mechanical advantage of 2. In the **block and tackle system** on the right, the principles of direction change and a sliding load is combined by using a moveable and a fixed pulley. Such a system provides for both a mechanical advantage and a more convenient body position.

The change of direction technique as well as the idea of one-way control mechanisms are dealt with in section 7.1. Section 7.2 is about moveable pulleys and the different kinds of simple pulley systems. Mechanical control systems forms the topic for section 7.3.

7.1 Change direction with a string or rope

The issue of friction when a rope is pulled around a supporting object is addressed first, in order to provide motivation for the focus on pulleys in this chapter. With a view to promote a more global understanding of a mechanism, this is followed by an activity on how to use a simple one-way movement control mechanism to improve the design of a simple lifting system.

7.2 Different ways to use a pulley

The simple experiment on Learner Book page 84, with a string and a cup or beaker, is critical to understand how a moveable pulley can be used to provide mechanical advantage. If this experiment was not done during the first lesson, it should be done at the start of the second lesson.

The three kinds of pulley systems that learners should master are schematically illustrated in Figures 10 A, B and C (Learner Book page 85). It may be useful to have learners look closely at these drawings and describe the differences to each other. It may also be useful to ask them to think and discuss which of the three systems may be most helpful to lift heavy loads, and why.

7.3 Mechanical control systems

This lesson describes three types of systems that control movement: calliper brakes; cam cleats; and the ratchet and pawl system. Some learners may have experienced one-way movement control devices in public places, and this may be built upon in a class discussion.

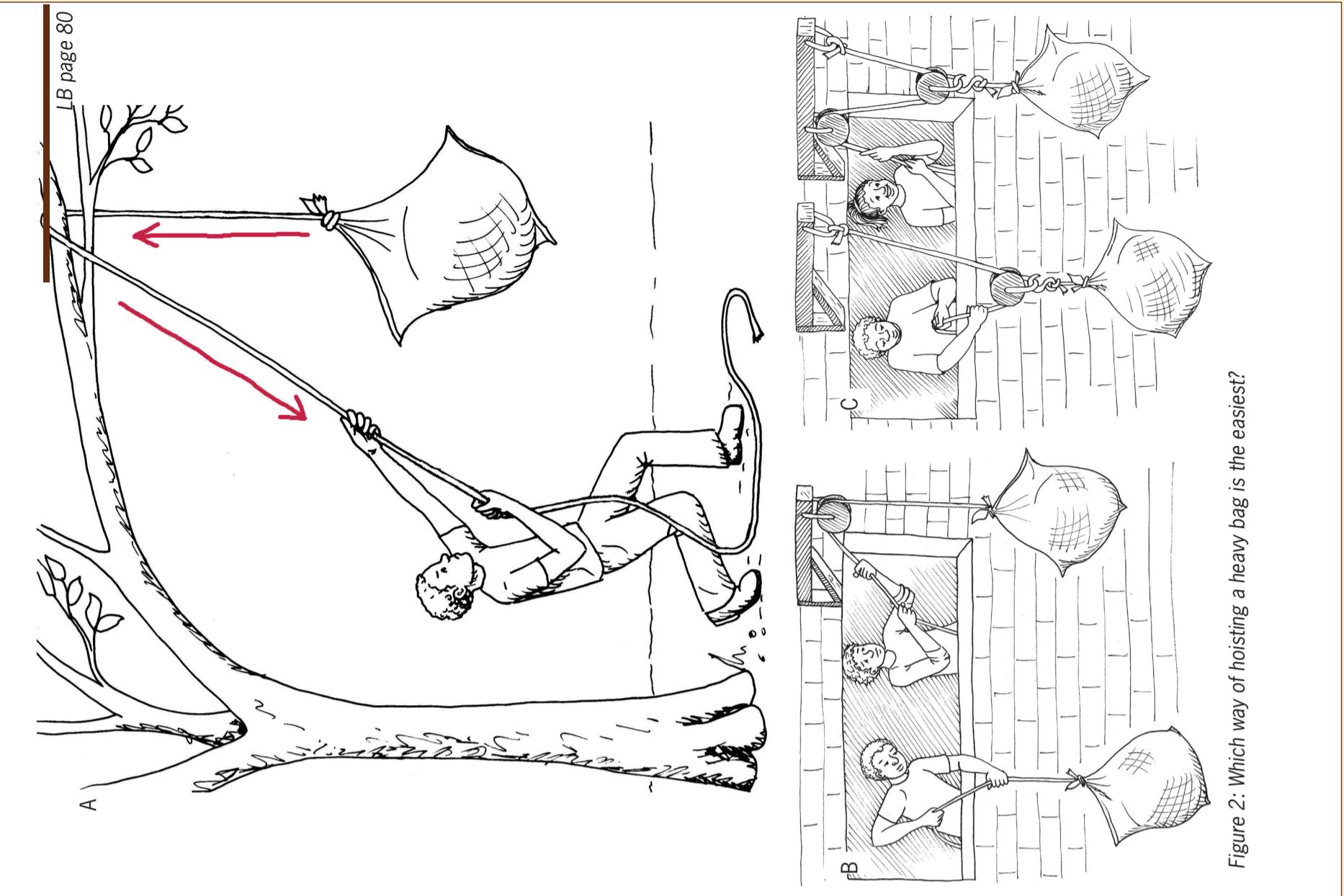


Figure 2: Which way of hoisting a heavy bag is the easiest?



LB page 81

7.1 Change direction with a string or rope

Different ways to lift something up

LB p. 81

The man in Figure 2A on the previous page wants to lift the sack with wet grain right up to the branch. He wants to fasten the sack to the branch, so that it can hang there till the wind has dried the grain out. To get the sack up, he slung a rope over the branch and fastened the one end of the rope to the sack.

1. (a) Make a rough copy of Figure 2A on the previous page. Mark the direction in which the man pulls with an arrow.
- (b) Mark the direction in which the sack will move with an arrow too.

The arrows are shown on Figure 2A on the previous page.

2. Do you think the rope will last forever if the man uses it often to pull heavy objects up around the branch?

No, the rope will eventually rub through so much that it breaks (in proper English one says 'fray' instead of 'rub through')



Figure 3: This rope has been rubbed against the edge of a brick.

If you pull heavy objects up many times with the same piece of rope or string, the rope will wear out, as you can see in the photograph. It will eventually break.

LB page 82

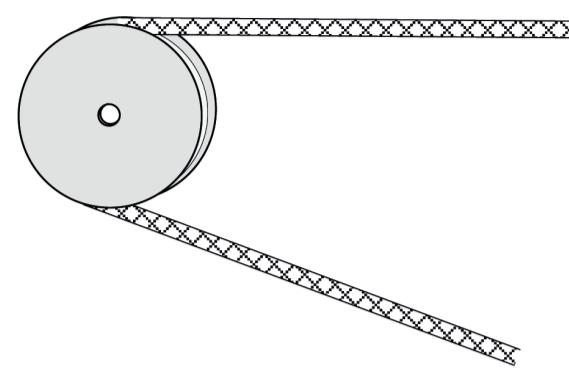


Figure 4: A pulley

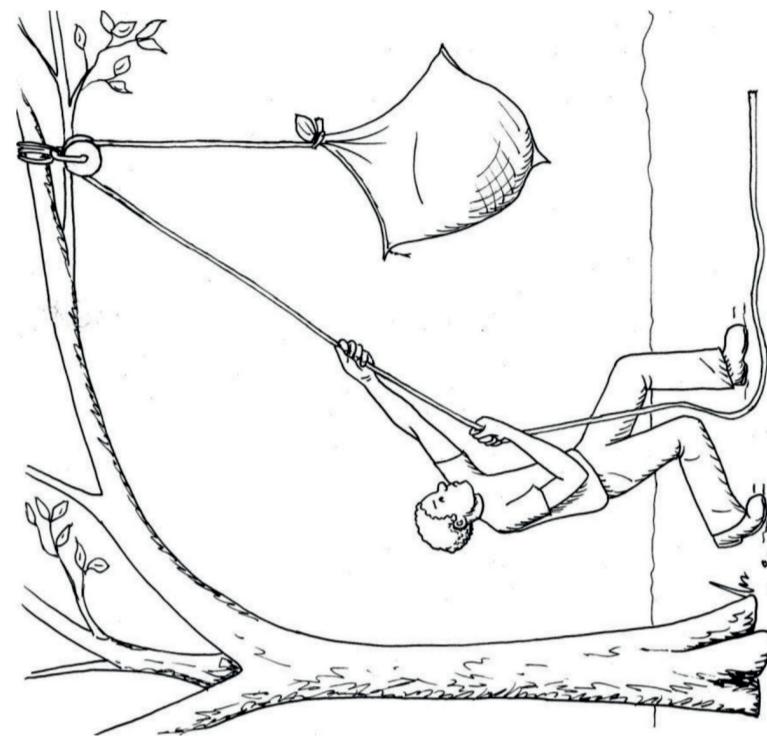
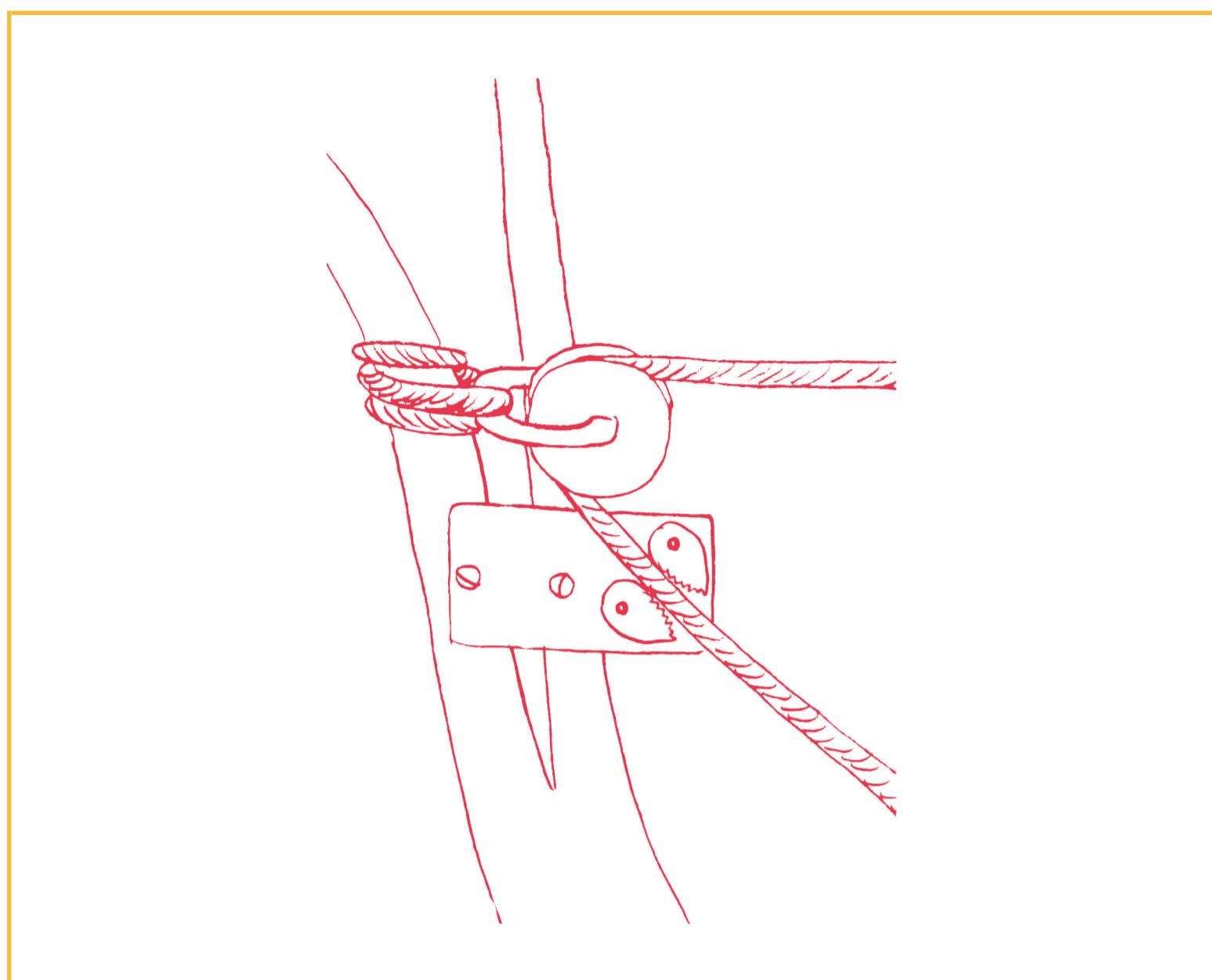


Figure 5: The man uses a pulley to lift the sack

The system that the man in Figure 5 uses is called a single wheel, fixed pulley system. Its purpose is to change the direction of pull, but it does not give a mechanical advantage.

The man cannot lift the sack from the ground up to the branch with one pull. He needs to make a plan so that the sack will not drop down again while he shifts his hands to get ready for another pull.



LB page 83

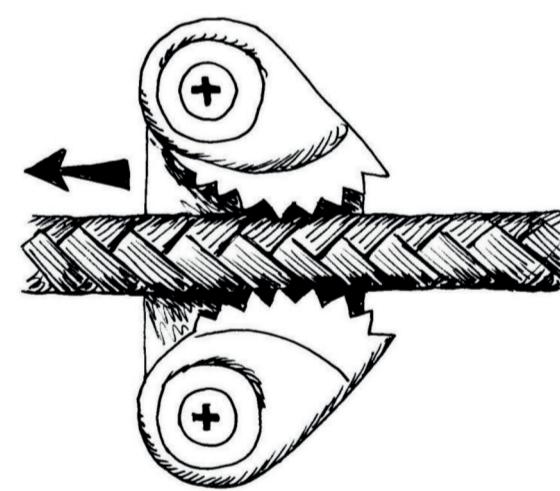


Figure 6: A cam cleat

The diagram on the right shows a device called a **cam cleat**. If you pull the rope upwards, the cams will close in on the rope and prevent it from passing through. If the rope is pulled downwards, the cams are pushed apart and the rope can pass through easily. Devices like a cleat, or the valves you learnt about in Chapter 6, allow certain movements, but prevent other movements. Devices such as these are called **control devices**.

You can experiment with a pencil between your thumb and forefinger as shown below, to experience how a cam cleat works.

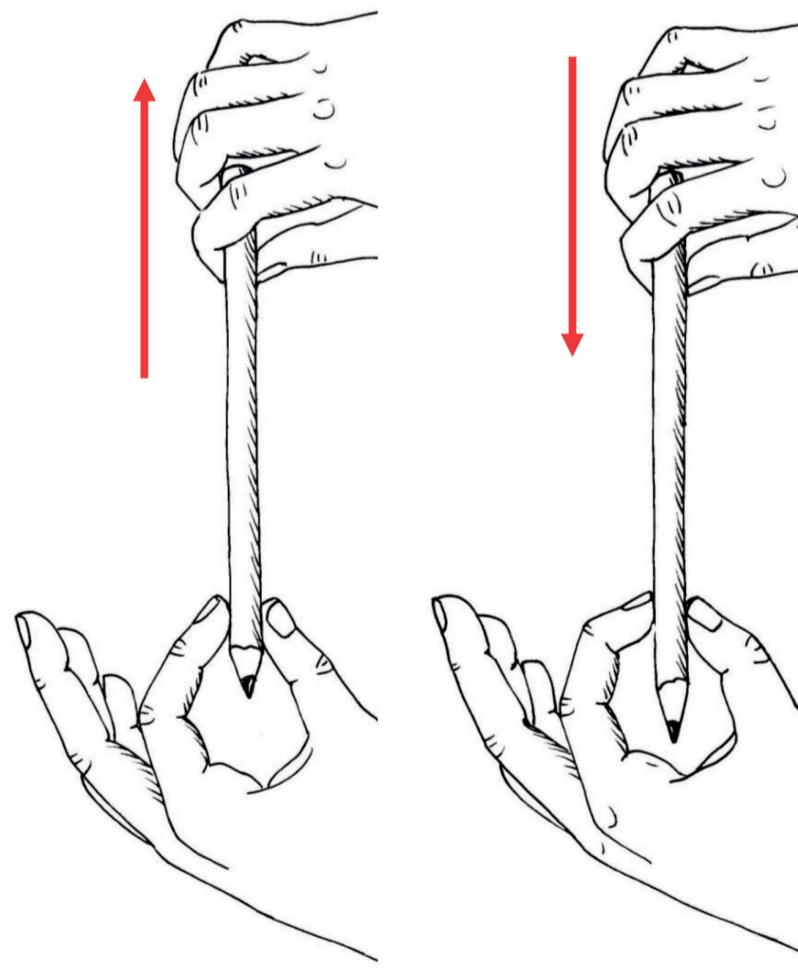


Figure 7: You can slide a pencil between your thumb and forefinger to feel how a cam cleat works.

3. Make a rough sketch to show where the man in Figure 5 can put a cam cleat to make it easier to lift the sack up to the branch.



An important experiment

LB p. 84

You need a piece of string or a shoelace, and a cup or beaker with a handle. Put the cup on your desk. Pull the string or shoelace through the handle of the cup. Hold the one end of the shoelace in the air with your left hand. Pull the other end of the string upwards with your right hand to lift the cup. Let the string slide through the handle.

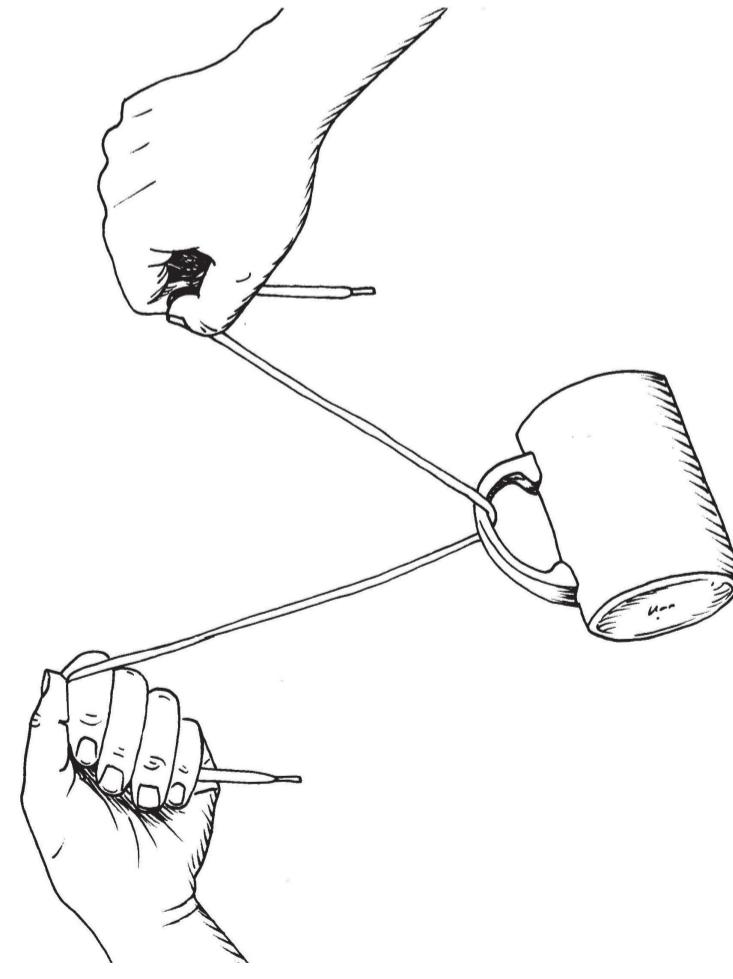


Figure 8

Is the cup raised by the same distance as you raised your right hand? Repeat the experiment and observe the movements so that you can observe the distances clearly. Try to explain your observation.

Learners will observe that the cup is not lifted by the same distance than the right hand moves up, because it slid down the string.

You will do the most work in Figure 10A, because you need to apply a larger force over the same distance (50 cm).

Or you can think of it in this way: If you pull the rope in Figure 10A 50 cm downwards, the load will move 50 cm upwards. But if you pull the rope in Figure 10C 50 cm downwards, the load will only move 25 cm upwards. You will therefore do more work on the load in Figure 10A.

LB page 85

7.2 Different ways to use a pulley

The system on the right is called a **block and tackle**.

Look carefully at the three diagrams in Figure 10, showing different ways in which pulleys can be used when lifting an object with a rope.

The red pulleys are fixed to the support structure: they can turn but they cannot move. The red pulleys are called **fixed pulleys**. The blue pulleys can move, and they are called **moveable pulleys**.

- Figure 10A shows a **single wheel, fixed pulley system**.
- Figure 10B shows a **single wheel, moveable pulley system**.
- Figure 10C shows a **pulley block system**, also called a **block and tackle**.

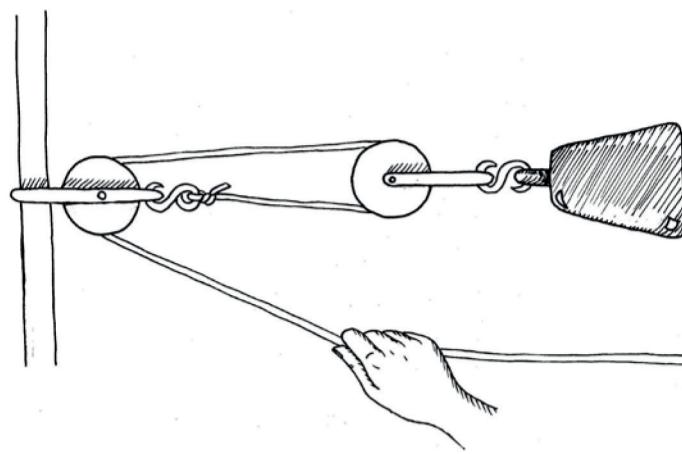


Figure 9: A block-and-tackle

Questions about pulley systems

LB p. 86

1. Look carefully at Figures 10A and 10C.
 - (a) If the rope in Figure 10A is pulled down by 50 cm, will the load (the black object) also move up by 50 cm?

Yes

- If the rope in Figure 10B is pulled up by 50 cm, will the load (the black object) also move up by 50 cm?

No, the load will only move 25 cm up.

- When will you do more work, when you pull the rope in Figure 10A down by 50 cm, or when you pull the rope in Figure 10C down by 50 cm?

You will do the most work in Figure 10A, because you need to apply a larger force over the same distance (50 cm).

Or you can think of it in this way: If you pull the rope in Figure 10A 50 cm downwards, the load will move 50 cm upwards. But if you pull the rope in Figure 10C 50 cm downwards, the load will only move 25 cm upwards. You will therefore do more work on the load in Figure 10A.

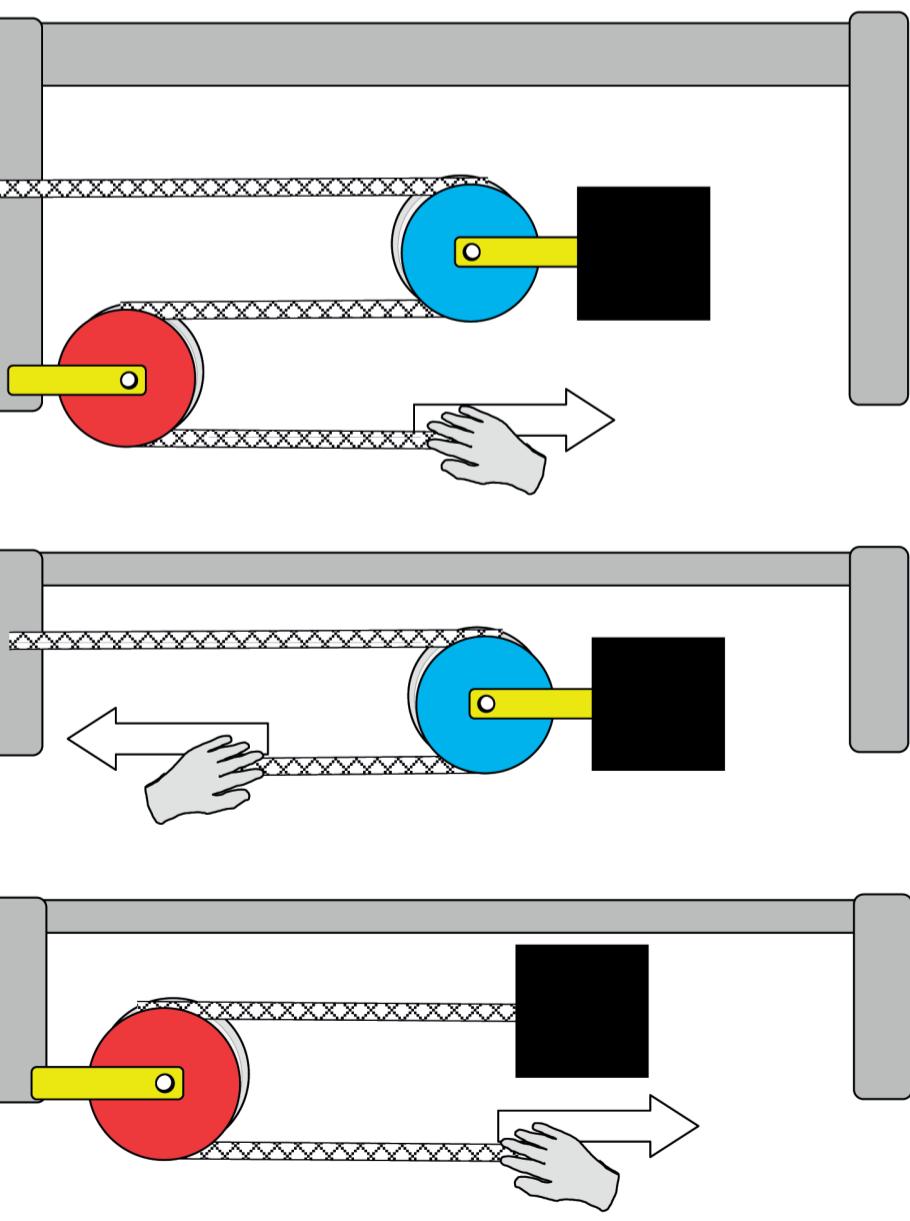


Figure 10A
Figure 10B
Figure 10C

In pulley systems such as these, the purpose of the fixed pulleys, that are shown in red, is to change the direction of the rope, so that you can pull down to lift an object up. It is easier for your body to pull a rope downwards than to pull it upwards.

2. In what way do the moveable pulleys, shown in blue, help to make it easier to lift the black object? If you have difficulty with this question, remember what you experienced when you did the experiment with the string and the cup on Learner Book page 84 (Teacher Guide page 110).

The moveable pulleys make it easier to lift the black object (load) because the object is lifted by only half the distance than the hand. This is a tough conceptual question, and the expectation should not be that the learners can give a perfect answer, but rather that the question makes them think. (It is like a first-class lever where the fulcrum is closer to the load than to the effort.)

Figure 11 could help you to better understand how a moveable pulley system works.
Suppose the load is 50 cm below the hook. To pull the load up to the level of the hook, the hand must pull up 100 cm of rope. So the hand moves up 100 cm while the load only moves up 50 cm.
Because the hand moves twice the distance of the load, the force required is the same as you would need to pick up half the load (5 kg) directly.

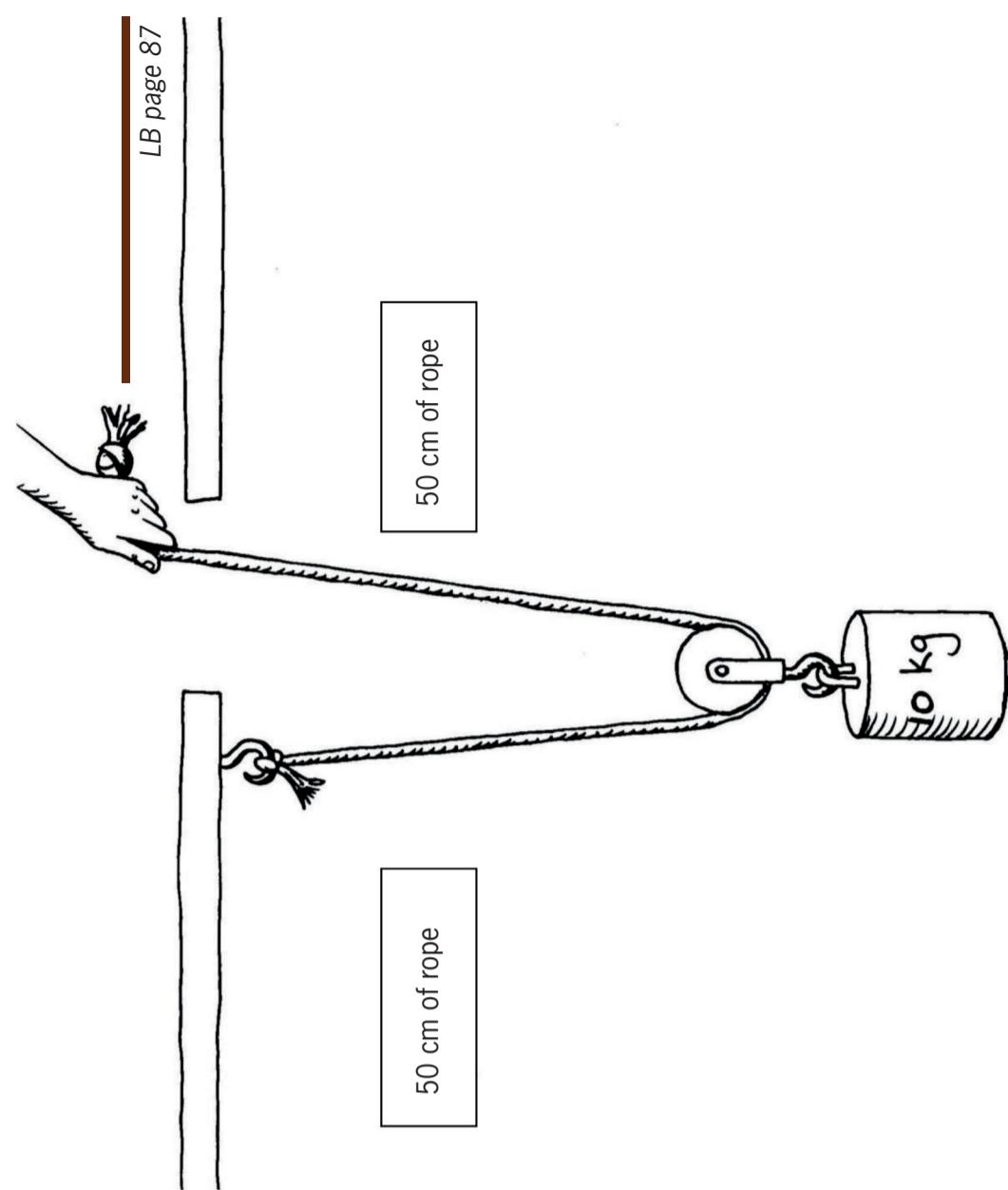


Figure 11: Single moveable-pulley system

7.3 Mechanical control systems

You can ride a bicycle very fast.

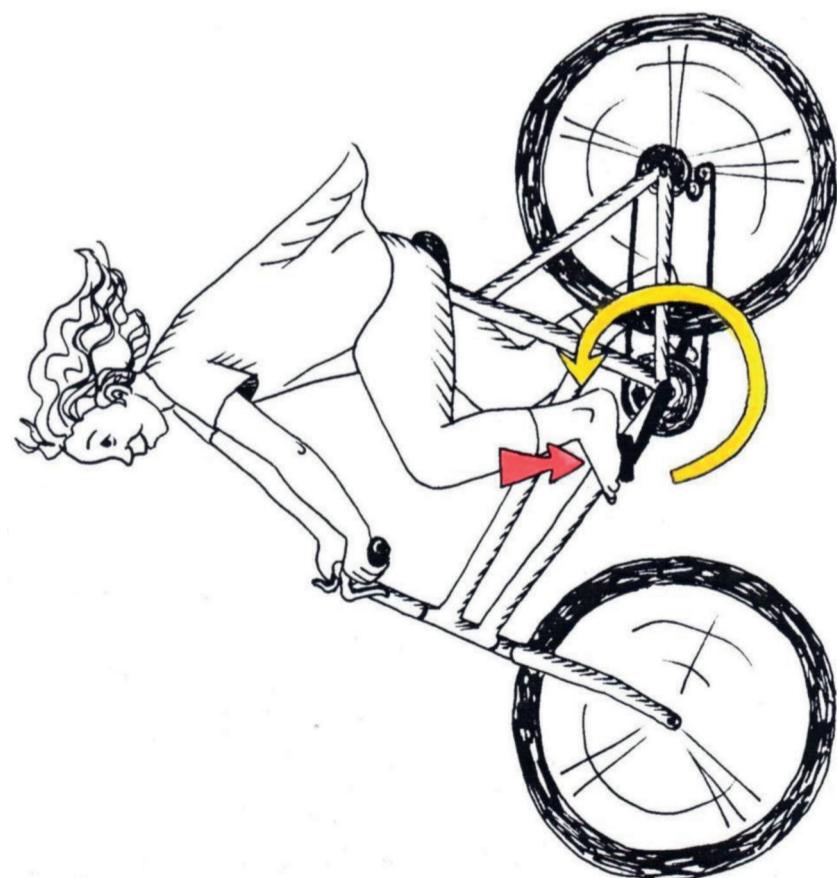


Figure 12

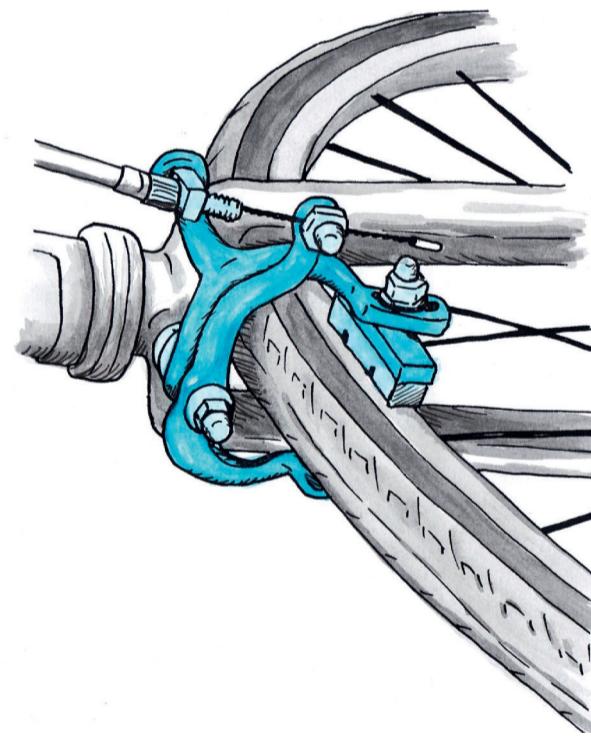


Figure 13

LB page 88

Think of a pair of scissors:

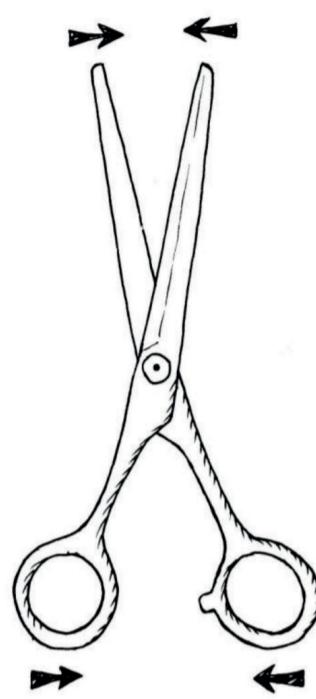


Figure 14

A pair of scissors can also be made like this:

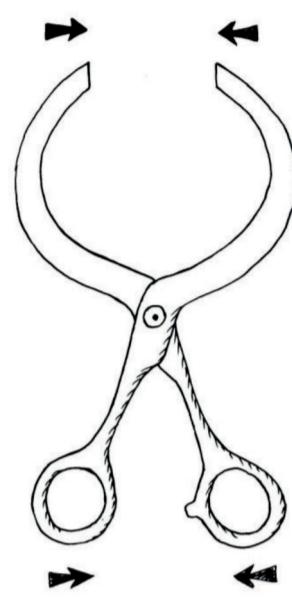


Figure 15: An instrument like this is sometimes called a **pair of callipers**.

The handles could be bent like this:

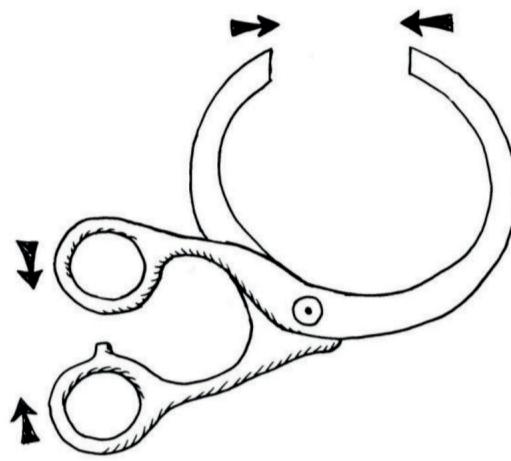


Figure 16

LB page 89

The brake system in Figure 13 is actually a pair of callipers, as you can see from Figure 17 below.

LB page 90

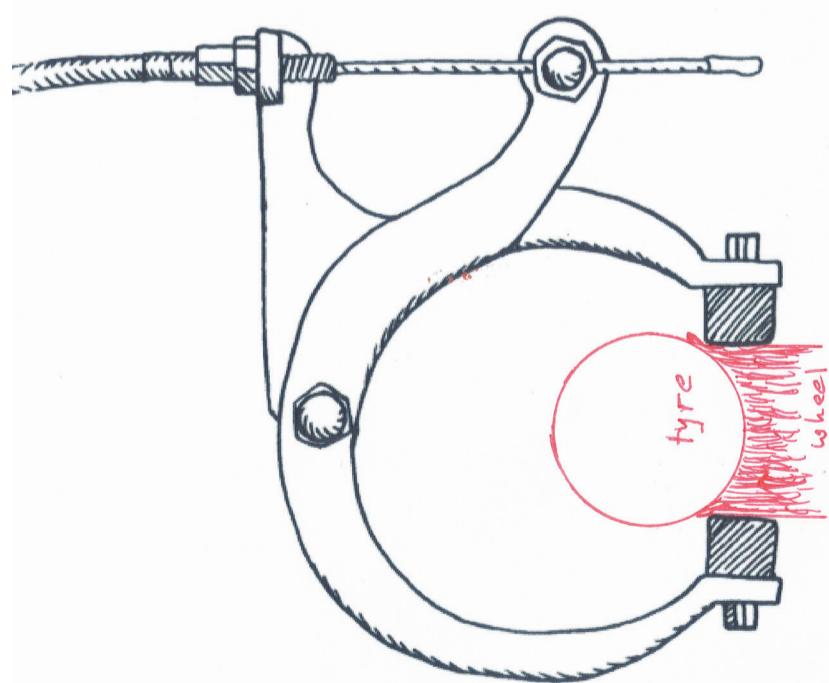


Figure 17: Calliper brake for a bicycle

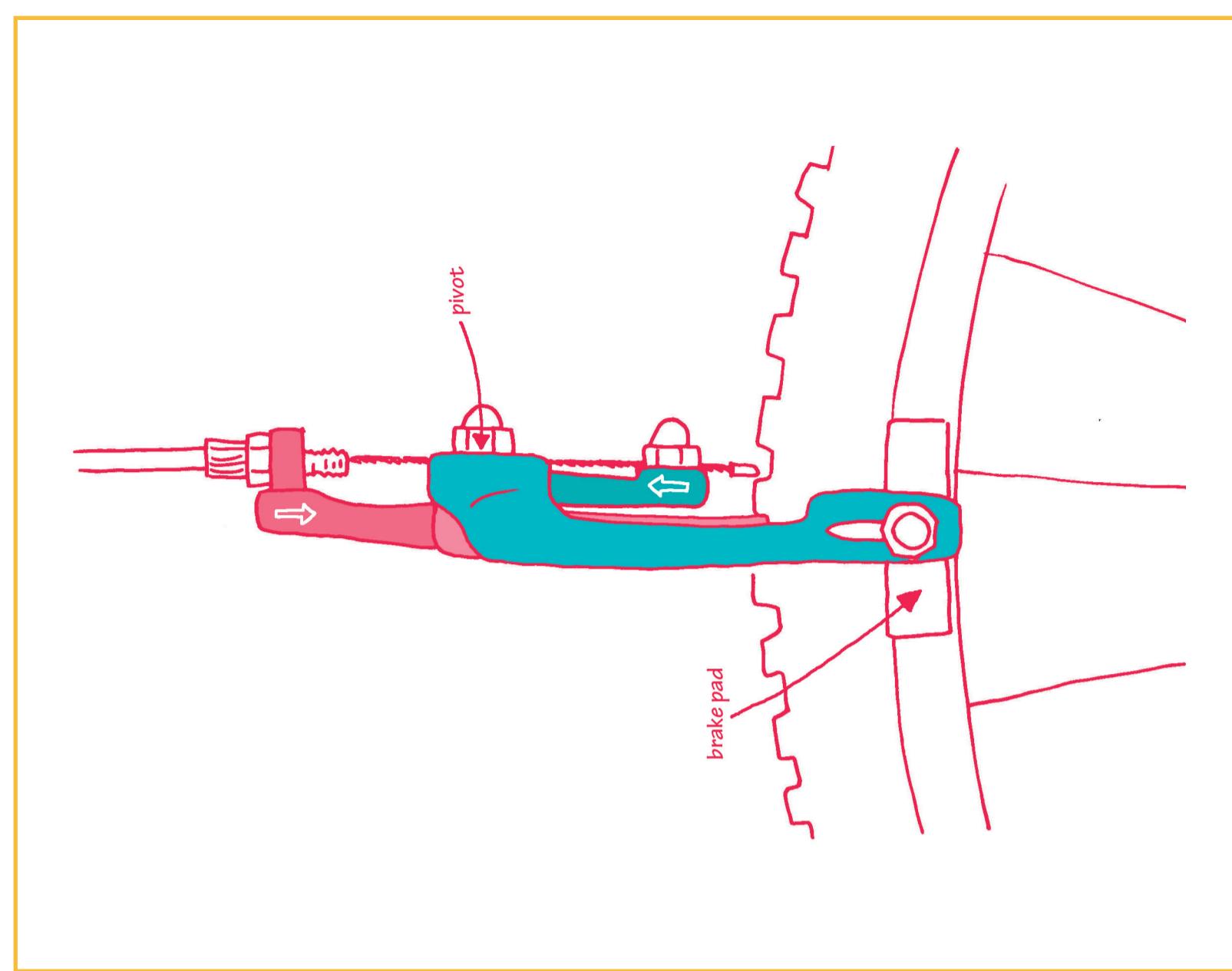
Investigate a calliper brake system

LB p. 90

- Do the following:
 - Copy the drawing of the calliper brake in Figure 17 above. On your drawing, draw the part of the bicycle wheel that fits between the brake blocks. This is the front view.

An example of a drawing is added in red to Figure 17 above.

- Draw a side view of the calliper (note that the brake blocks will look different in a side view and there will be a few hidden lines). Colour the two arms with different colours. Label the brake blocks and fulcrum. Use arrows to show how the parts move when the brake is pulled.





LB page 91
Car disc brakes also use a caliper. This caliper works in a different way to a bicycle brake. It exerts a squeezing force on a disc behind the car wheel.



Figure 18: Disc brake on a car



Figure 19: Disc brake on a motor cycle

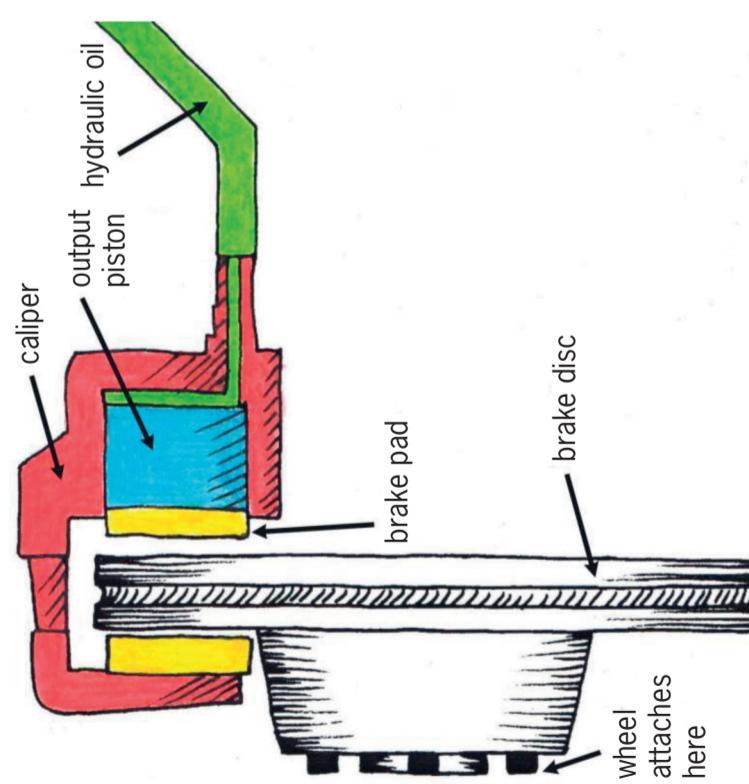


Figure 20: The parts of a car disc brake

A disc brake system consists of a brake disc, a caliper and brake pads.
When the brake pedal is pushed, it moves the input piston, which pushes hydraulic oil into the output piston.

The output piston then squeezes the brake pad against the surface of the brake disc. This contact causes friction, which forces the vehicle to slow down or stop.

One-way control systems

LB page 92

A brake system prevents movement completely. It does not allow movement in any direction.

A valve system, like that in a hydraulic car jack, only prevents flow (movement of a liquid) in one direction, but allows flow in the opposite direction. A cam cleat is like a valve, it allows movement in one direction, but not in the opposite direction.

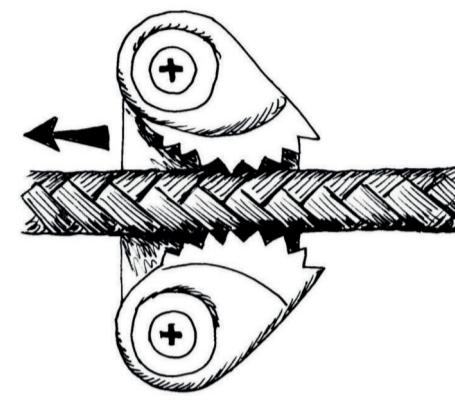


Figure 21

The device below is called a **ratchet and pawl**. The wheel with the teeth is the ratchet, and the other object is the pawl.

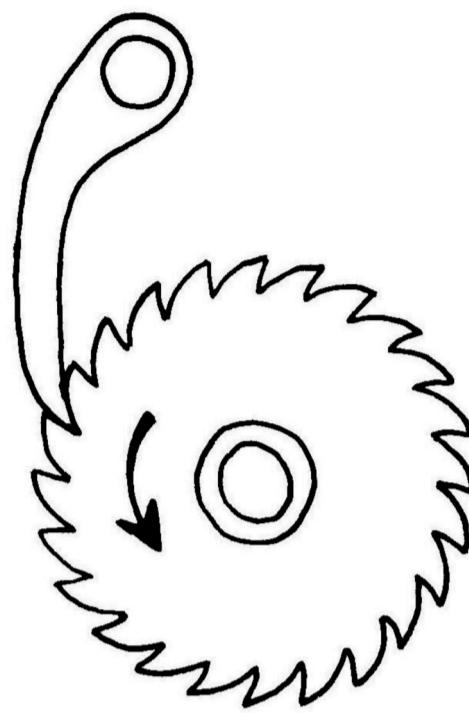


Figure 22: A ratchet and pawl



Draw a block and tackle system

LB page 94

1. Make a free-hand sketch to show how a one-way control system can be used together with a block and tackle system to lift heavy loads.

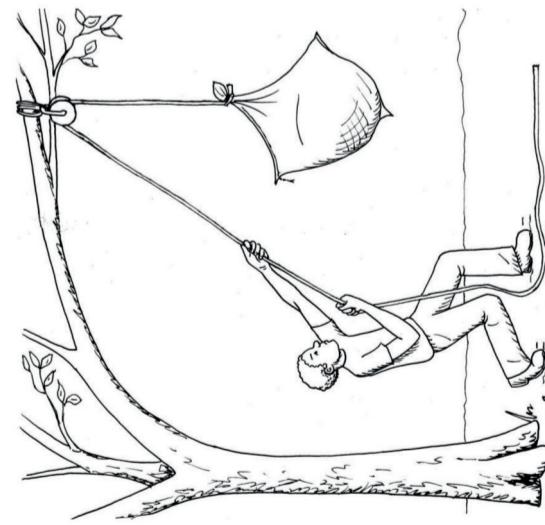
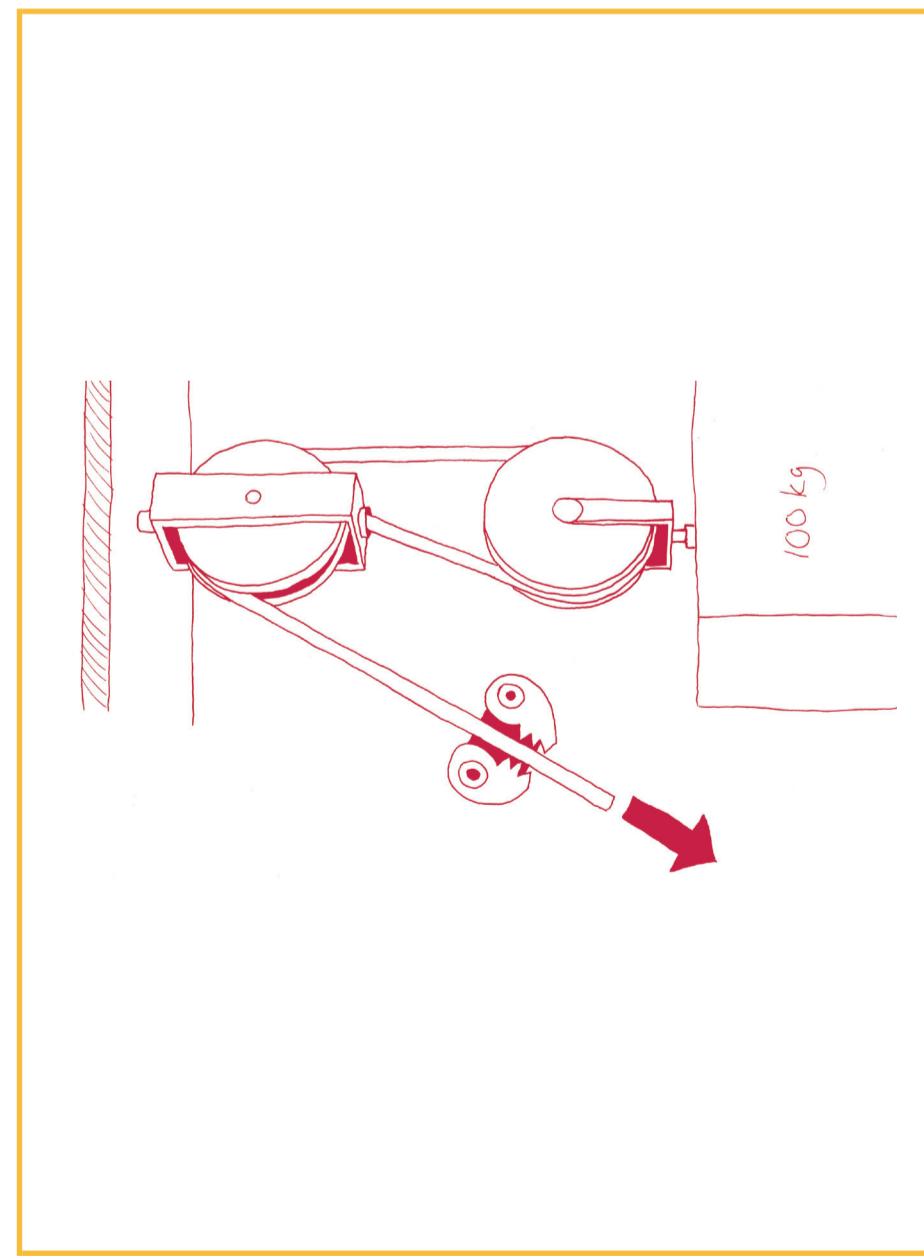


Figure 23: The man wants to lift the sack right up to the branch.



LB p. 93

- A question to make you think**
Why is it easier for the girl to get across the wall, than for the boy? Try to explain how this is similar to levers, hydraulic systems and moveable pulley systems.

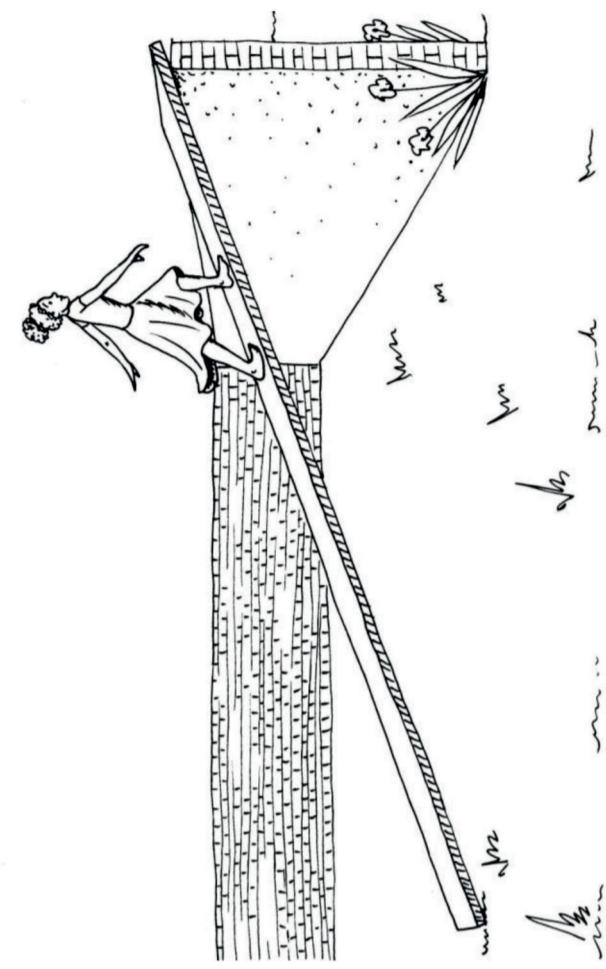


Figure 24

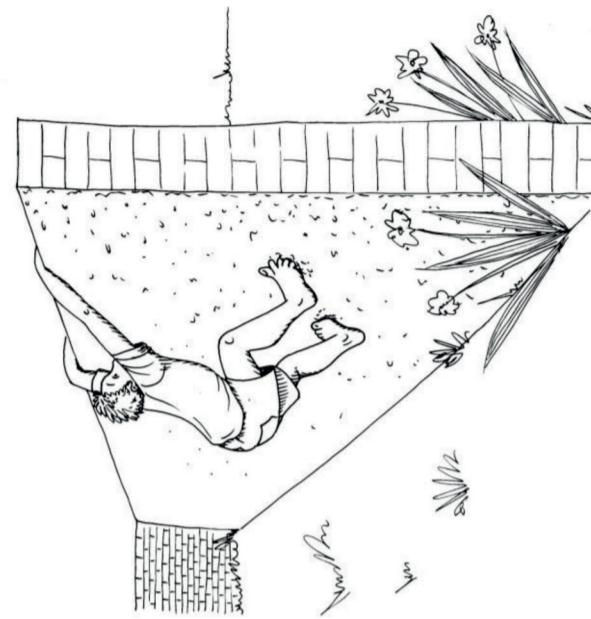


Figure 25

Next week

Next week, you will learn more about different kinds of gears and gear systems.

CHAPTER 8

Gears

In this chapter, you will revise spur gear systems and how they can be used to change the direction, speed and turning force of rotation. You will calculate the number of revolutions, rotation speeds and turning forces.

You will also look at other types of gears, namely bevel gears, rack-and-pinion gear systems, and worm gear systems. These other types of gear systems make it possible to change the direction of rotation in ways that spur gears cannot do.

- | | |
|---|-----|
| 8.1 Direction of rotation of spur gears | 126 |
| 8.2 Gear ratio, rotational speed and rotational force | 130 |
| 8.3 Other types of gears | 135 |

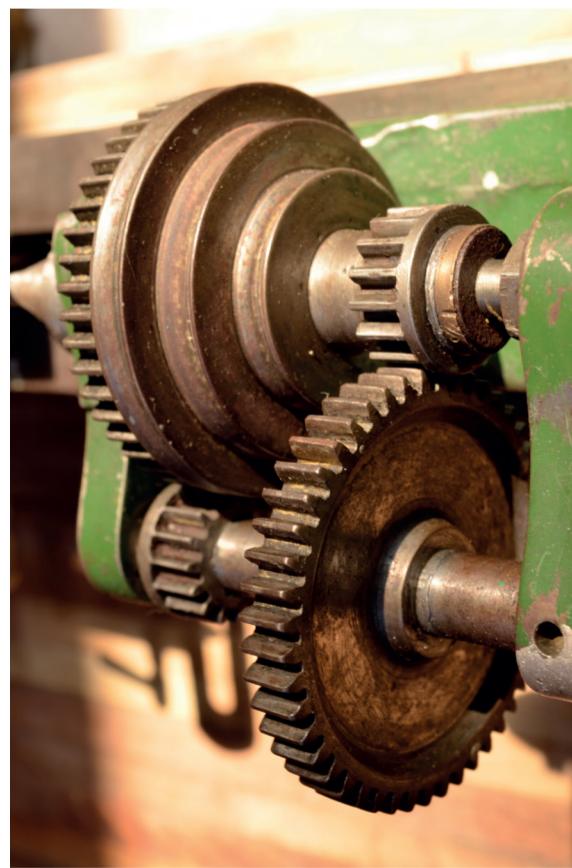


Figure 1

Materials needed for this chapter:

a calculator.

NB: As a reminder of how gear ratios are calculated, the section from the Grade 8 Chapter 5 Teacher Guide on gears is included at the end of these notes to the teacher. It is suggested you read through this again before starting this section.

8.1 Direction of rotation of spur gears

As learners have already learnt about spur gears in Grade 8, they immediately engage with a series of questions that are designed not only to test that knowledge, but to get them to visualise the movement of gears. The first few questions can be discussed in the class, but the questions on rotational speed must be answered individually. Make sure that all the learners are able to do the calculations by checking their answers.

8.2 Gear ratio, rotational speed and rotational force

This section starts with a practical context where different vehicles (a heavy vehicle and a light sports car) may need to use different gear ratios. This context gets learners thinking about the forces required to move the different vehicles.

Then the definition of gear ratio that was introduced in Grade 8 is revisited. Alternative formulas are given that express gear ratio in terms of rotational speeds of the axles, numbers of teeth of the gears, and turning forces on the axles.

In the remainder of the section learners solve problems that will develop their understanding of the relationships between rotational speeds of the axles, numbers of teeth of the gears, and turning forces on the axles. In the end, learners discover that they can use a set of gears for the same purpose as a pulley system (block-and-tackle) to make it easier to hoist a heavy load.

8.3 Other kinds of gears

Learners are shown how **bevel gears** can be used to change the direction of circular motion. They also see that bevel gears can alter the speed of rotation. The two other gear systems that learners examine are **rack-and-pinion** and **worm gear** systems. Practical examples are given which will make it easy for the learners to understand how these systems work. You can ask them to think of other practical examples where these systems could be found.



Talking about gears in everyday language, and calculating gear ratios

The definition of gear ratio is a convention, which means it is something people agreed on, like the spelling of a word. It is not an absolute truth. The people who decided on the convention for how gear ratios should be calculated were scientists and engineers. Unfortunately, they did not pay attention to the way that other people talk about gears in everyday language when this convention was formed. You have good reason to be annoyed by them for confusing you!

In everyday language you use the descriptive words "low" and "high" to talk about gears selected on a car or bicycle. In a car you use a low gear (second gear) to drive slowly up a very steep hill, and you use a high gear (fifth gear) when you drive fast on a flat road. When you cycle on a flat road, you can select either a low or a high gear. If you select a low gear, you will pedal fast but with a light force. If you select a high gear, you will pedal slowly but with a heavy force.

So, in everyday language a low gear means that the input rotational speed (of the engine or the pedals) is fast compared to the output rotational speed (of the wheel). In other words, the output rotational speed is slow compared to the input rotational speed. That means, if you divide the output rotational speed by the input rotational speed, you will get a small answer.

Unfortunately, the scientists or engineers who decided on how to calculate gear ratios defined gear ratios the other way round. They defined gear ratio as input rotational speed divided by output rotational speed:

$$\text{gear ratio} = \frac{\text{rotational speed of input axle}}{\text{rotational speed of output axle}}$$

The following table shows how the gear ratios of a motor car are shown in a motor car magazine.

Gear	1 st	2 nd	3 rd	4 th	5 th
Gear ratio	4.1	2.2	1.5	1.1	0.9

Note that the highest gear (5th) has the smallest value of the gear ratio.

A useful way to think of the definition of gear ratio is to say that it is the number of times that a car's engine or a bicycle's pedals have to rotate for the wheels to rotate once.

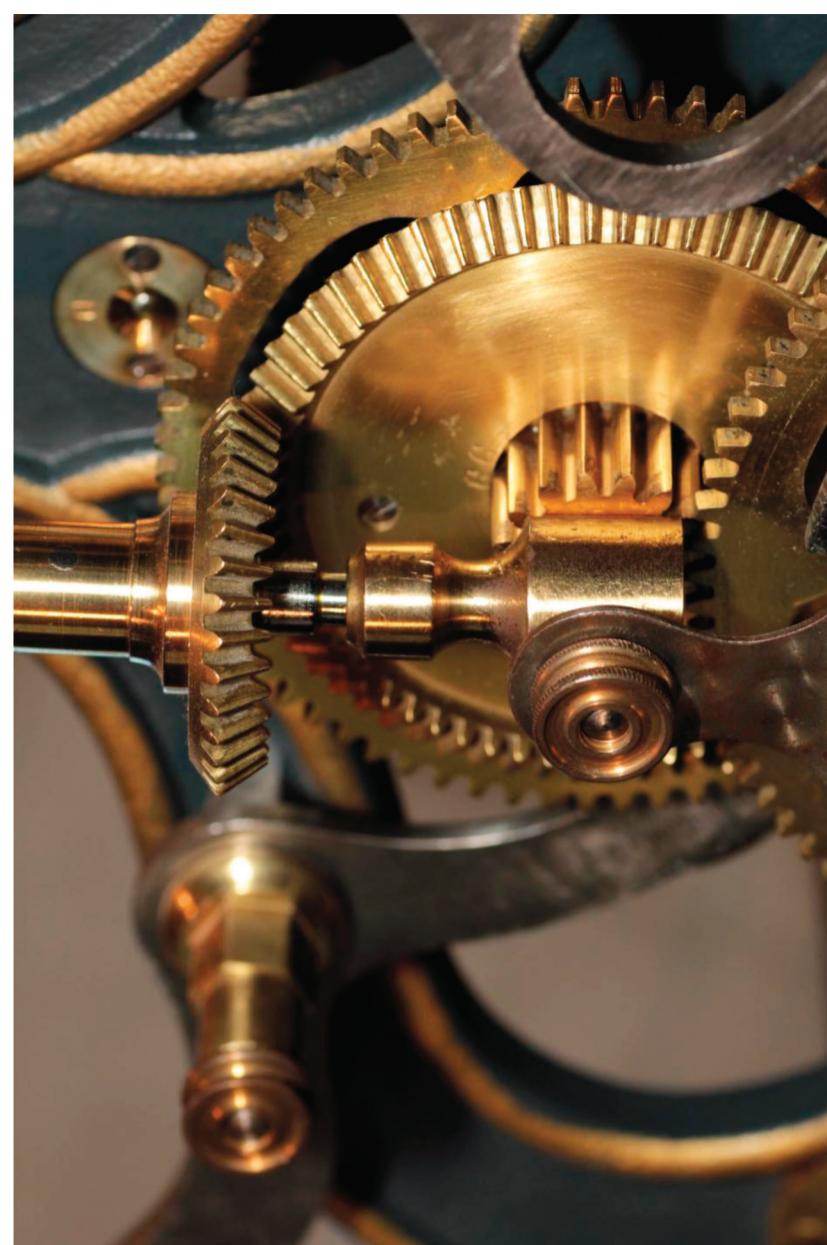
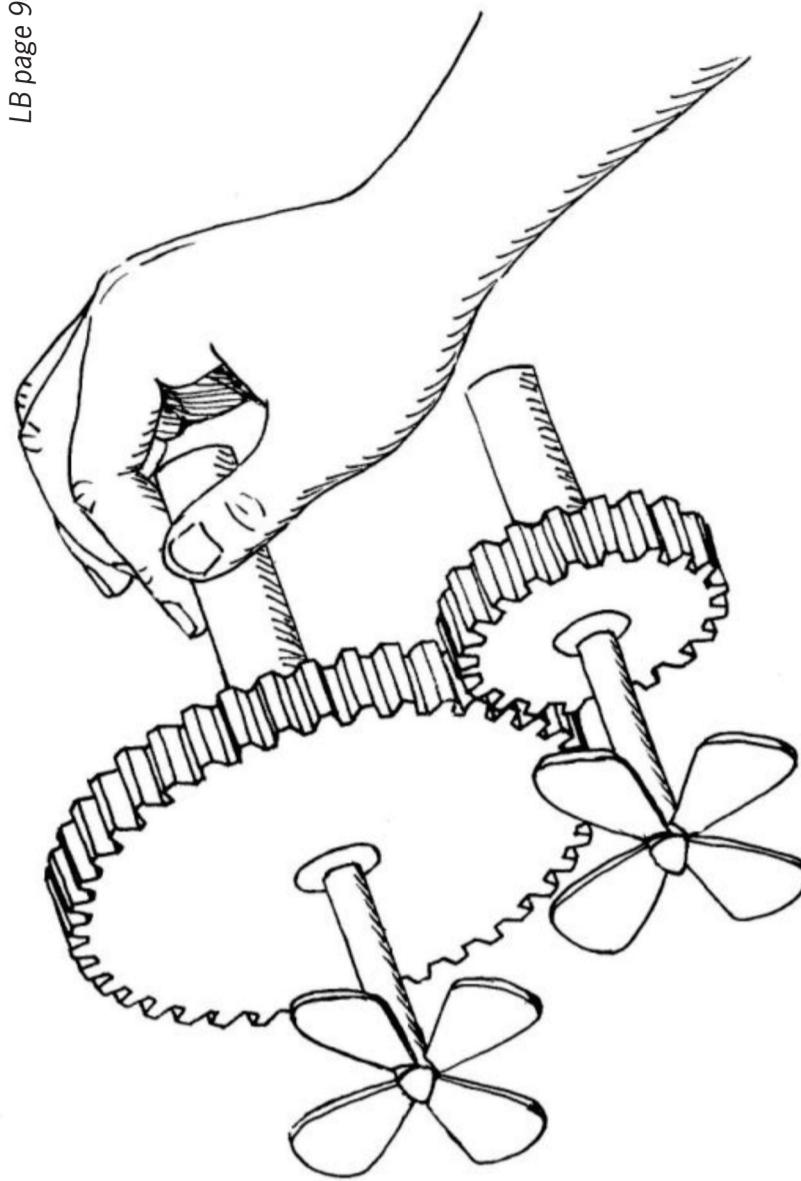


Figure 2



8.1 Direction of rotation of spur gears

Questions about counter rotation and idler gears

LB p. 97

3. If the red gear below is turned anti-clockwise, in which direction will the grey gear turn?
clockwise

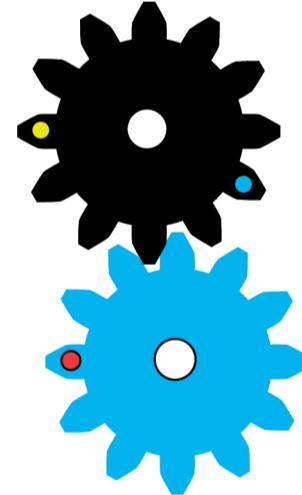


Figure 3

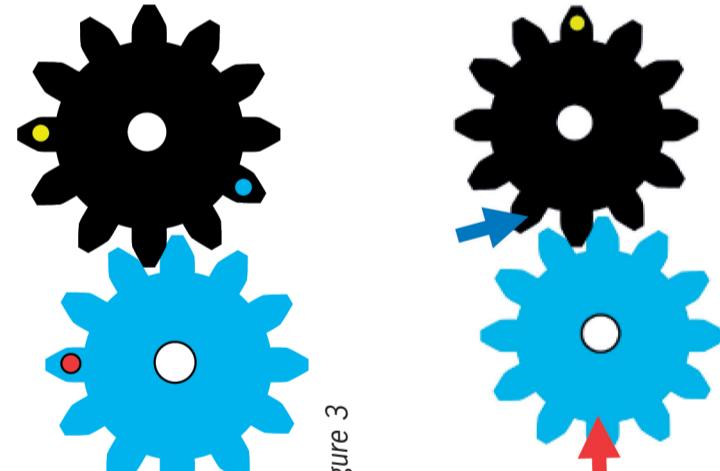


Figure 4

1. (a) How many teeth do each of these gears have?
12 and 12
- (b) The black gear is turned clockwise until the yellow dot reaches the position shown in Figure 4. Redraw Figure 4 and draw arrows to show where the blue and red dots will be.

- (c) In what direction did the blue gear turn?
anti-clockwise
- (d) Through which part of a full revolution did each gear turn?
one quarter of a revolution

- The two blue and black gears in the above situation turn in opposite directions. This can also be described by saying that the two gears **counter-rotate**.

2. The dark blue gear on the left below is turned anti-clockwise through two thirds of a full turn. Redraw Figure 5 and indicate with arrows where each of the yellow dots will be afterwards.
Each dot moves by 8 teeth.



Figure 5

3. If the red gear below is turned anti-clockwise, in which direction will the grey gear turn?
clockwise

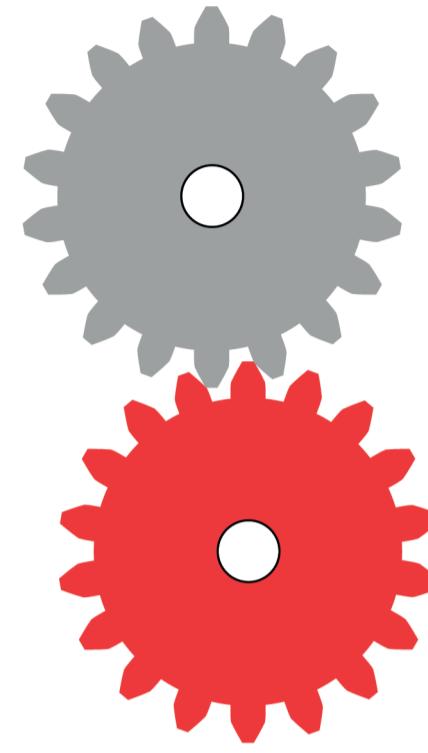


Figure 6: Counter-rotation

4. In the situation below, the red gear drives the blue gear and the blue gear then drives the grey gear. If the red gear is turned clockwise, in which direction will the grey gear turn?
clockwise

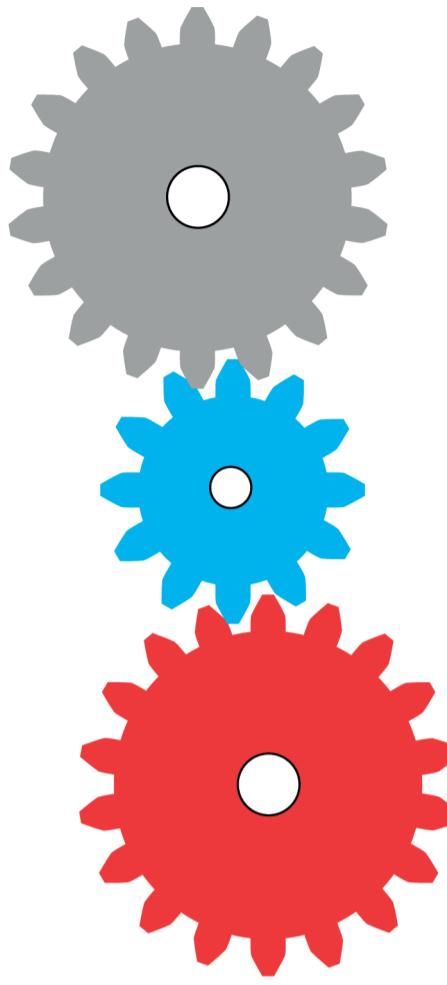


Figure 7: A blue idler gear

5. If the red gear in the above system makes one full turn, how many turns will the blue gear make, and how many turns will the grey gear make?
The blue gear makes one and a half turns and the grey gear makes one full turn.



Number or rotations of driver and driven gears

LB p. 98

Suppose the red gear in Figure 8 drives the small grey gear. The red gear has 18 teeth and the grey gear has 6 teeth. For every 1 tooth in the grey gear, there are 3 teeth in the red gear.

When a gear has made a full turn, you can say it has made one full **revolution**.

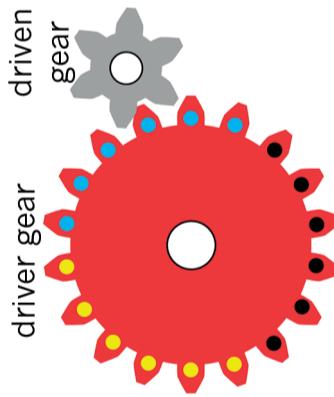


Figure 8

LB page 99

1. If the red driver gear makes one full revolution anti-clockwise, how many revolutions will the grey driven gear make, and in which direction?

The **grey gear will make three revolutions clockwise**.

2. If the red driver gear makes 8 full revolutions, how many revolutions will the grey driven gear make?

24 revolutions

3. How many revolutions should the red gear make for the grey gear to make 12 revolutions?

four revolutions

4. In a different set of gears, the driver gear has 20 teeth and the driven gear has 80 teeth. How many full revolutions will the driven gear make if the driver gear makes 20 full revolutions?

Number of times that a gear tooth of the driver gear passes the contact point between the two gears = $20 \times 20 = 400$.

This is the same as the number of times that a gear tooth of the driven gear passes the contact point between the two gears, so $400 = 80 \times (\text{number of revolutions of driven gear})$.

Re-arrange the equation: (number of revolutions of driven gear) = $400 \div 80 = 5$.

Speed of rotation of driver and driven gears

LB p. 99

Suppose the small gear in Figure 9 drives the big gear. The small gear has 20 teeth and the big gear has 40 teeth.

1. If the small driver gear makes 12 revolutions in one minute, how many revolutions will the driven gear make in the same time?

$$12 \div 2 = 6 \text{ revolutions of the driven gear}$$

Figure 9

2. If the small driver gear in Figure 9 makes 40 revolutions in one minute, how many revolutions will the driven gear make in the same time?

$$40 \div 2 = 20 \text{ revolutions of the driven gear}$$

If a gear makes 40 revolutions in one minute, we say the gear turns at a speed of **40 revolutions per minute**. The abbreviation **rpm** is often used for "revolutions per minute".

3. Look at the situation in Figure 9 again. If the driver gear with 20 teeth turns at 80 rpm, at what speed will the driven gear with 40 teeth turn?

$$80 \text{ rpm} \div 2 = 40 \text{ rpm}$$

4. If you want the driven gear in Figure 9 to turn at a speed of 120 rpm, how fast should the driver gear be turned?

$$120 \text{ rpm} \times 2 = 240 \text{ rpm}$$



8.2 Gear ratio, rotational speed and rotational force

LB page 100



Figure 10: A road roller

A road roller has a bigger engine than a sports car, but moves much slower.

To make a heavy road roller move, a large turning force needs to be applied to the wheels. If the output rotational speed of the wheels is much slower than the input rotational speed of the engine, then the output rotational force will be much bigger than the input rotational force. A road roller uses a set of gears that changes the fast rotational speed of the engine into a very slow rotational speed of the wheels, so that the rotational force at the wheels is strong enough to move the heavy road roller.

With a sports car, a much smaller rotational force is needed at the wheels, because the car is light. The set of gears used to start moving a sports car also changes the fast rotational speed of the engine into a slower rotational speed of the wheels, but not as slow as with the road roller. So with a sports car, the wheels turn faster but with a smaller turning force than the road roller.

Increase or decrease in rotational force

- Look at the set of gears in Figure 12. The driver gear has 20 teeth and the driven gear has 80 teeth.

Is this gear system increasing the rotational force or decreasing it? Explain your answer.

The big driven gear turns with a slower rotational speed than the small driver gear ($\frac{1}{4}$ times as fast). Therefore the rotational force of the driven gear will be bigger than the rotational force of the driver gear (4 times as big). That means the gear system is increasing the rotational force.

Revision of what you learnt about gears in Grade 8 LB p. 101

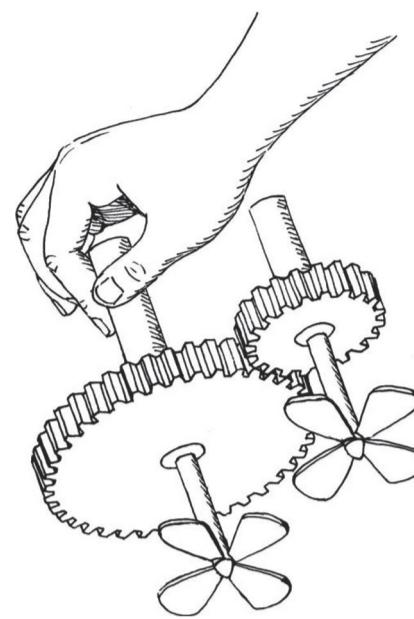


Figure 11: A sports car

Look at the set of gears on the right. The big gear is the input gear, and the small gear is the output gear. Each gear is fixed to an axle, and the axle drives a fan. The speed with which the fan turns is called the **rotational speed** of the axle.

When a gear with many teeth drives a gear with fewer teeth, the driven gear turns faster, but with a smaller turning force than the driver gear.

When a gear with few teeth drives a gear with many teeth, the driven gear turns slower, but with a bigger turning force than the driver gear.

Gear ratio is defined as follows:

$$\text{gear ratio} = \frac{\text{rotational speed of input axle}}{\text{rotational speed of output axle}} = \frac{\text{turning force on output axle}}{\text{turning force on input axle}}$$

- Calculate the gear ratio of the set of gears in Figure 12

gear ratio = (80 teeth) ÷ (20 teeth) = 4

$$\begin{aligned} &= 4:1 \\ &= 4 \text{ to } 1 \end{aligned}$$

- In Figure 12, if the input axle is rotating at 120 rpm, at what speed is the output axle rotating?

Re-arrange the formula:

$$(\text{rotational speed of output axle}) = (\text{rotational speed of input axle}) \div (\text{gear ratio})$$

$$= 120 \text{ rpm} \div 4 = 30 \text{ rpm}$$

- In Figure 12, which axle will turn with the greatest force, the driver or the driven axle?

The driven axle, because the axle that turns the slowest turns with the greatest force.

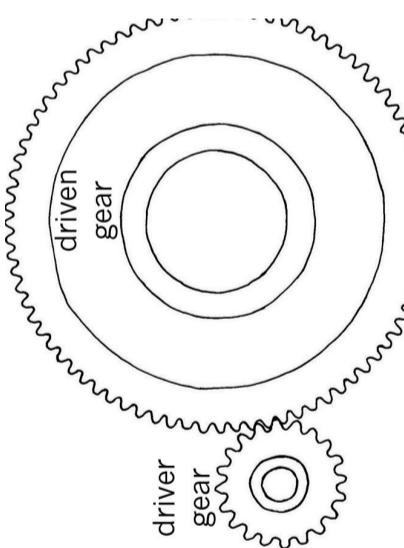


Figure 12

Comparing turning forces on the input and output axles

LB p. 102

In Chapter 7 you learnt how a system of pulleys can give you a mechanical advantage to make it easier to hoist up heavy objects. You will now investigate how a gear system can do the same, by changing a small turning force on the input axle into a big turning force on the output axle.

Look at Figure 14 below. The input (driver) gear has 9 teeth and the output (driven) gear has 18 teeth. A rope is wound around each axle.

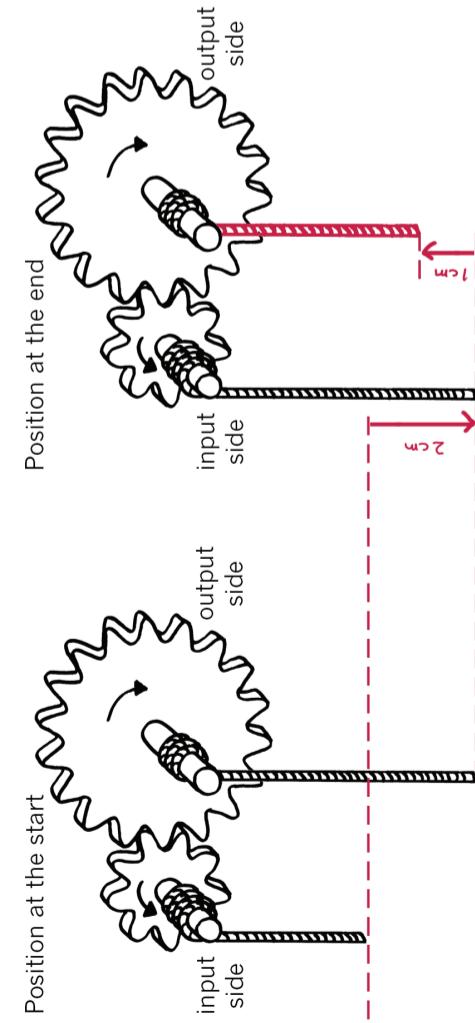


Figure 14

- What is the gear ratio?

$$\text{gear ratio} = (18 \text{ teeth}) \div (9 \text{ teeth}) = 2 : 1$$

- For one full revolution of the input gear, how many revolutions will the output gear make?

The output gear will make half a revolution.

- If you pull the input rope down by 2 cm, how far will the output rope be pulled up? Draw the vertical part of the output rope in the “position at the end” part of Figure 14 to show where the output rope will be after you pulled the input rope down by 2 cm.

The output rope is pulled up by half of the distance that the input rope is pulled down: $2 \text{ cm} \div 2 = 1 \text{ cm}$. Learners have to indicate this on the “Position at the end” in Figure 14.

- Will the force exerted by the output rope be bigger or smaller than the force applied to the input rope? How much bigger or smaller?
Hint: Think of the situation as if it was a pulley system. You already know the relationship between the input distance and the output distance.
The force exerted by the output rope will be twice as big as the force applied on the input rope.

LB page 103

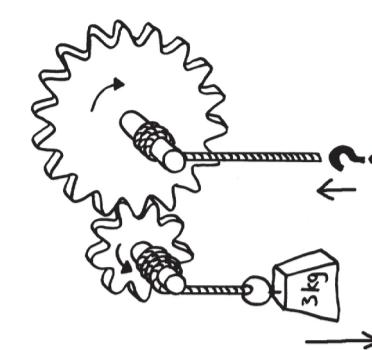


Figure 15

The 3 kg input weight in Figure 15 represents the turning force exerted on the input axle. The output weight represents the turning force exerted by the output axle. You will now check your answer to question 5 by using the formulas for gear ratio:

$$\text{gear ratio} = \frac{\text{rotational speed of input axle}}{\text{rotational speed of output axle}}$$

$$= \frac{\text{turning force on output axle}}{\text{turning force on input axle}}$$

$$= \frac{\text{number of teeth on output gear}}{\text{number of teeth on input gear}}$$

You have already used the numbers of teeth on the input and output gears to calculate that the gear ratio is 2:1. It can also be written simply as 2. If you re-arrange the blue part of the formulas, you can make the turning force on the output axle the subject of the formula:
(turning force on output axle) = (gear ratio) × (turning force on input axle)

- Use the formula above to check your answer to question 5.
turning force on output axle = $2 \times 3 \text{ kg} = 6 \text{ kg}$



7. Consider other sets of gears with ropes around the axles, as you did on the previous page:

(a) In a certain system, the input gear has 6 teeth and the output gear has 18 teeth. If you apply 4 kg of force on the input rope, what is the heaviest load that can be lifted by the output rope?

$$\text{gear ratio} = 18 \div 6 = 3$$

$$\text{output load} = 3 \times 4 \text{ kg} = 12 \text{ kg}$$

(b) In a certain system, the input gear has 12 teeth and the output gear has 30 teeth. If you want to lift a load of 75 kg on the output rope, with what force in kilograms must you pull the input rope?

$$\text{gear ratio} = 30 \div 12 = 2\frac{1}{2}$$

$$\text{input force} = 75 \text{ kg} \div 2\frac{1}{2} = 30 \text{ kg}$$

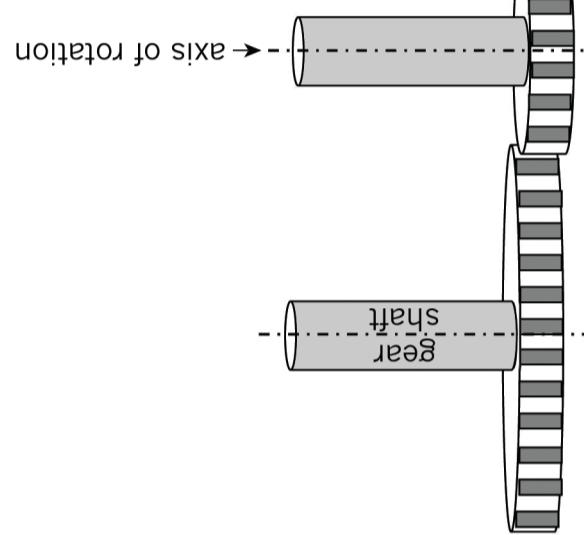
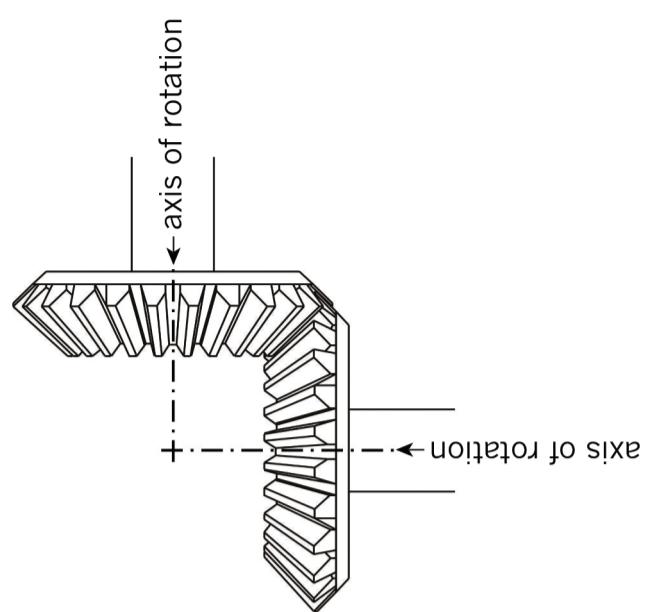
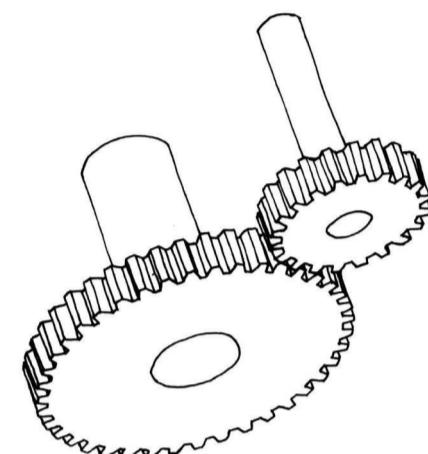
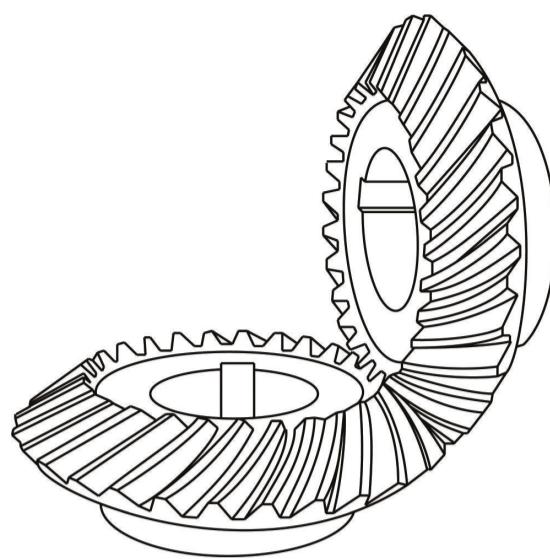
(c) A certain person can only pull with a maximum force of 25 kg. That person needs to hoist loads of up to 150 kg. Design a gear system that will allow that person to hoist the heavy loads. In other words, how many teeth should the input and the output gears have?

$$\text{gear ratio} = 150 \text{ kg} \div 25 \text{ kg} = 6 = 6:1$$

The output gear must have 6 times as many teeth as the input gear, for example 10 teeth for the input gear and 60 teeth for the output gear.

8.3 Other types of gears

Bevel gears



LB page 104

Figure 16: Two spur gears with shafts parallel to each other
Figure 17: Two bevel gears with shafts at 90° to each other

The shafts of the two spur gears in Figure 16 on the left are parallel, but the shafts of the two gears in Figure 17 on the right are at right angles to each other. The gears in Figure 17 also have a different shape to ordinary spur gears to make them work better at right angles to each other. They are called **bevel gears**.



LB page 105

Bevel gears are used to change the direction of circular motion in devices such as the hand drill in Figure 18 and the food mixer in Figure 19. We can say that the axes of rotation of the two gears are at right angles.

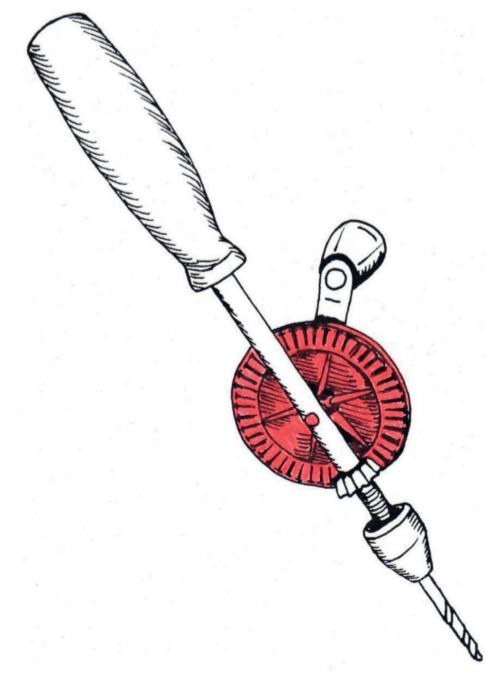


Figure 18: A hand drill

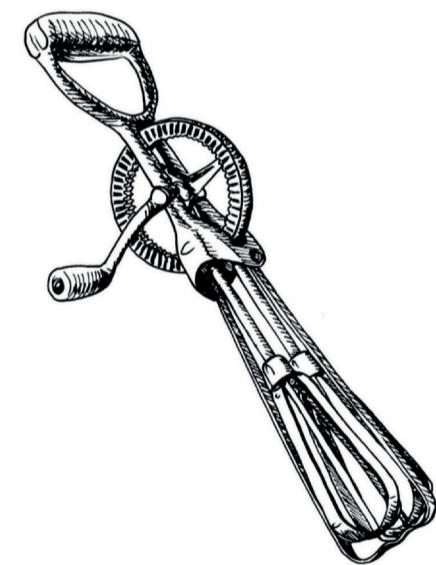


Figure 19: A food mixer

Questions about bevel gears

1. Do you think bevel gears can also be used to change the speed of rotation? Explain your answer and give examples.
Yes, if a gear system consists of two bevel gears with different number of teeth, the speed of rotation will be changed. For example, if the driver gear has many more teeth than the driven gear, then the smaller driven gear will rotate much faster.
2. Why is fast rotation needed to beat eggs properly?
Slow rotation will not break up the yolk and mix it with the egg white, and will not draw air into the mixture. You need a fast stirring action by the egg beater to do this.

3. In a particular bevel gear set, the gear ratio is 1 to 12.

(a) The driven gear in this gear set has eight teeth. How many teeth does the driver gear have?

The driven gear has 8 teeth, and the driver gear has 12 times as many teeth:

$$12 \times 8 = 96 \text{ teeth.}$$

(Learners should look at the formula on page 124 again if they get confused.)

(b) How many revolutions will the driver gear make if the driven gear makes 60 revolutions?

60 revolutions of 8 teeth divided by the 96 teeth of the driven gear:

$$60 \times 8 \div 96 = 5 \text{ revolutions.}$$

(c) How fast should the driver gear turn to make the driven gear turn at 36 rpm?

$$36 \text{ rpm} \times (1 \text{ twelfth}) = 36 \text{ rpm} \div 12 = 3 \text{ rpm}$$

4. Suppose you want to buy a food mixer to help you mix ingredients when you bake a cake. Which food mixer would require the biggest force to turn when you mix: the mixer with a ratio of 1:3 or a mixer with a gear ratio of 1:30? Explain your answer.

The gear ratio is equal to: (turning force at the output axle) \div (turning force at the input axle). If the required output turning force is fixed, then a bigger gear ratio will require a smaller input turning force. This is because the turning force is the denominator in the formula for gear ratio above. When the denominator of a fraction is smaller, the value of the fraction is bigger.

The gear ratio 1:3 is 1 third and the gear ratio 1:30 is 1 thirtieth. So 1:3 is the bigger of the two gear ratios. Therefore the mixer with a gear ratio of 1:3 will be the easiest to turn, but it will turn the slowest.



Rack-and-pinion gears

LB page 106

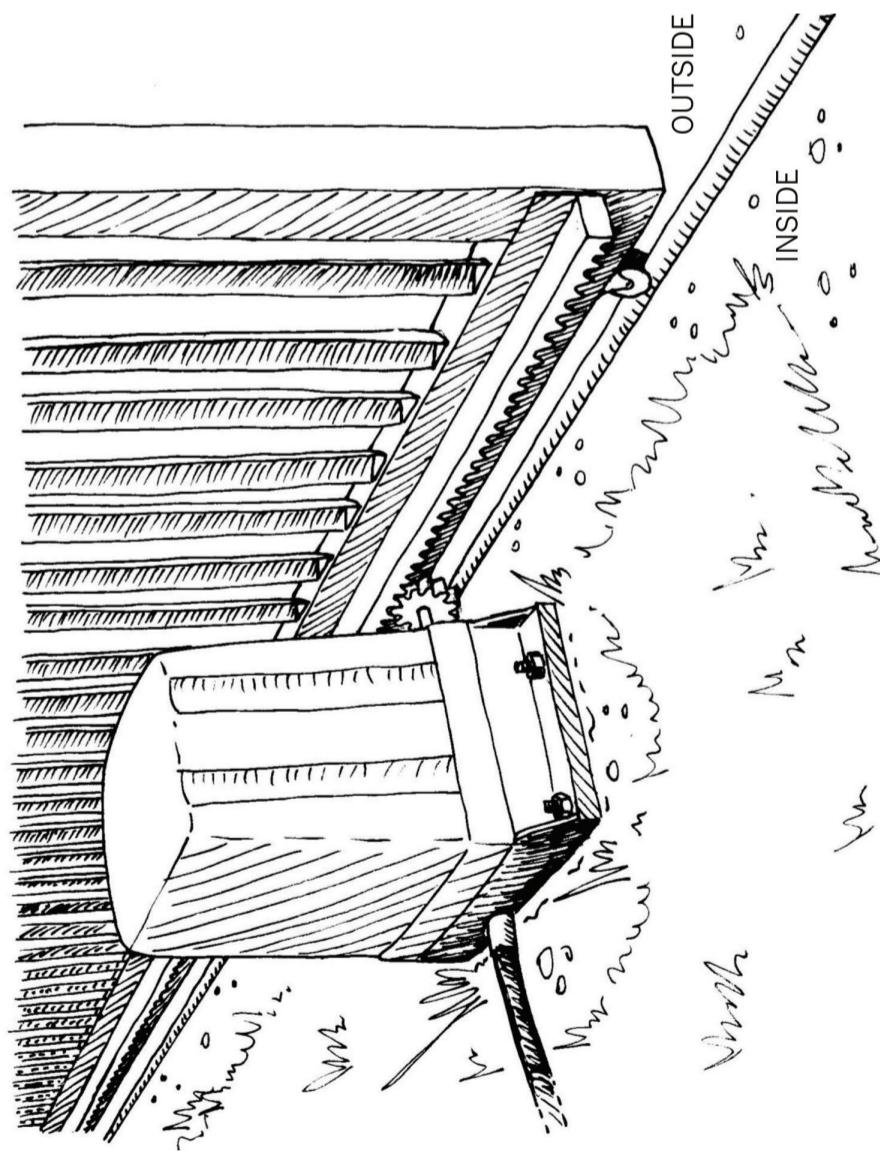


Figure 20: A rack-and-pinion gear in a security gate

Questions about rack-and-pinion gears

LB p. 106

In Figure 20, you can see a shell structure that is bolted to the ground on the inside of the gate.

1. What do you think is inside the shell structure in Figure 20, and why is it there?

There is an electric motor inside the structure. The motor turns the spur gear to open the gate.

2. In which direction will the gate move when the gear wheel is turned clockwise (as seen from inside the gate), in Figure 20?

The gate will move to the right, as seen from the inside.

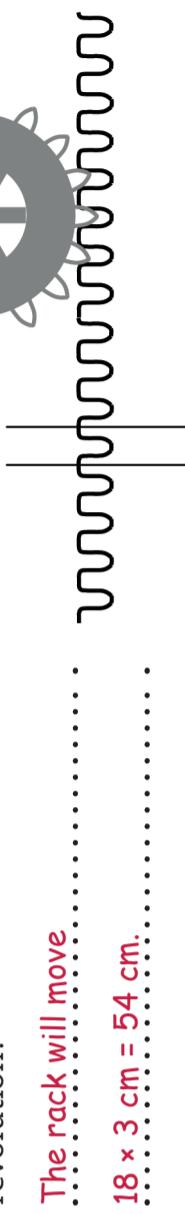
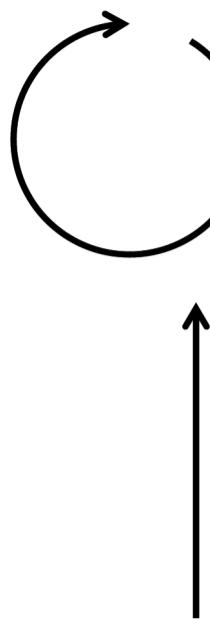


Figure 23

LB page 107



When something moves round and round, like a wheel, the movement is called a **circular motion** or **rotation**.

When something moves in a straight line, like a stone falling, the movement is called a **linear motion**.

Figure 21

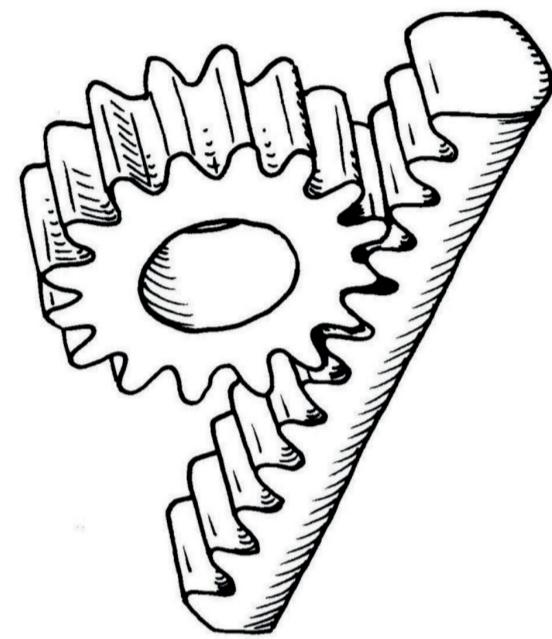


Figure 22: A rack-and-pinion gear set

3. Which part of a rack-and-pinion gear set rotates?

The pinion

4. Which part of a rack-and-pinion gear set moves in a straight line?

The rack

5. If the distance between two teeth on the rack is 3 cm, and the pinion has 18 teeth, how far will the rack move if the pinion gear makes one full revolution?

The rack will move

$$18 \times 3 \text{ cm} = 54 \text{ cm}$$

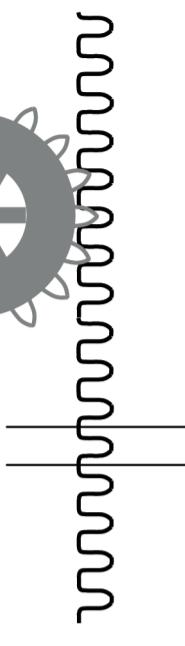


Figure 23



Some cars have steering systems that work with rack-and-pinion gears. In Figure 24, you can see that the steering wheel is connected to a pinion gear. When you turn the steering wheel, the pinion gear also rotates and moves the rack gear from side to side, a bit like an electric security gate.

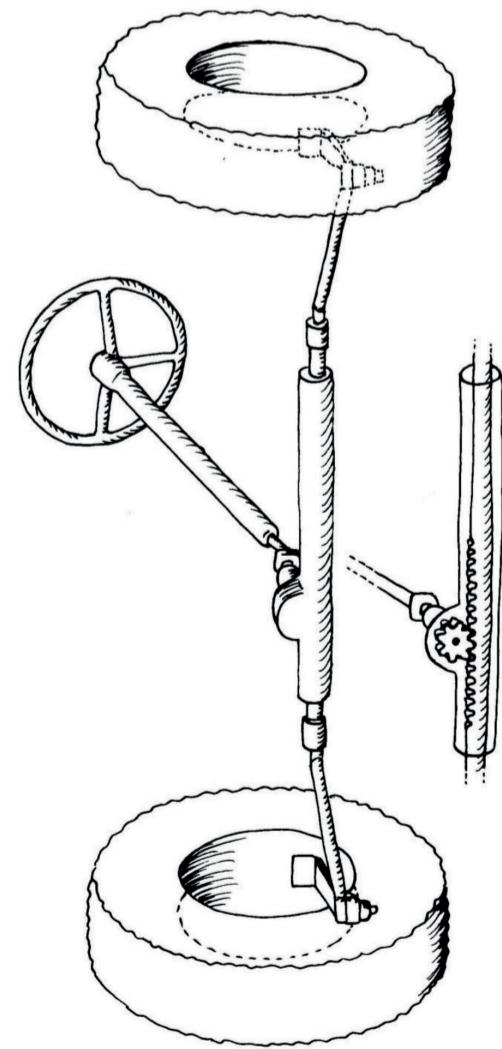


Figure 24: A rack-and-pinion car-steering system

The rack connects to the front wheels and turns them from side to side as you turn the steering wheel.

6. (a) How many teeth does the pinion gear of the steering system in Figure 24 have?

8 teeth

- (b) What difference will it make to the car driver if the pinion gear is replaced with a bigger gear that has 27 teeth?

It will be harder to turn the wheel but the driver will not have to turn the wheel as much.

Worm gears

LB page 108

Some cars have steering systems that work with rack-and-pinion gears.

In Figure 24, you can see that the steering wheel is connected to a pinion gear. When you turn the steering wheel, the pinion gear also rotates and moves the rack gear from side to side, a bit like an electric security gate.

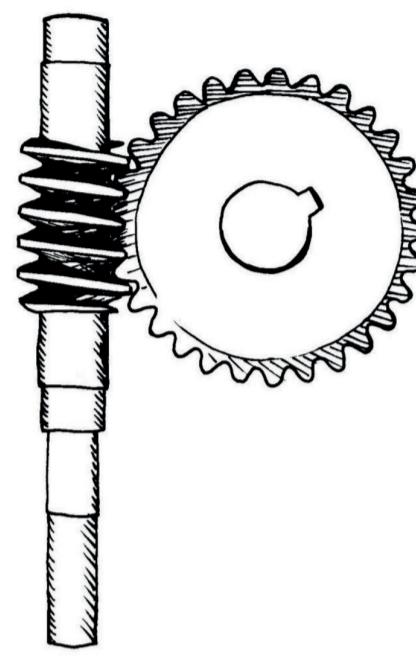


Figure 25: A worm gear set

A worm gear set consists of a worm and a worm wheel. The worm wheel is very similar to a spur gear. When the worm turns, it slowly pushes the wheel round and round. The worm is the driver gear, and the wheel is the driven gear.

LB page 109

In Figure 26 below, you can see that the worm driver touches three of the wheel's teeth. Only the red tooth on the right is actually pushed by the worm as it turns.

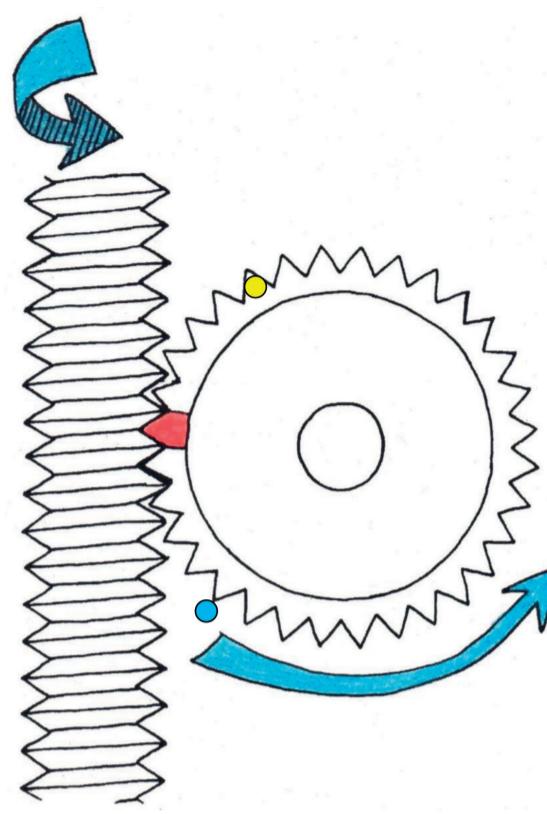


Figure 26

Worm gear sets are normally designed so that the worm pushes against a different tooth during each revolution. In other words, for each full revolution of the worm, the worm wheel rotates by one tooth.

After five revolutions of the worm, the red tooth will be at the blue dot in Figure 26, and the yellow dot will be where the red tooth was at the start.



Questions about worm gears

LB p. 109

1. If the wheel in Figure 26 has 32 teeth, how many revolutions will the worm have to make for the wheel to make one full revolution?
32.....
2. Does the toothed wheel turn faster or slower than the worm?
.....
3. If there are 18 teeth on the wheel, and the worm is turned at 6 rpm, how long will it take for the toothed wheel to make one full revolution?
minutes.....
4. If there are 18 teeth on the wheel, how fast should the worm be turned to make the wheel turn at 3 rpm?
.....

The wheel has 18 teeth so if it makes one revolution then 18 teeth move past the worm. So in 3 revolutions 54 teeth move past the worm
Each turn of the worm moves 1 tooth of the wheel so it will take 54 turns of the worm to make 3 revolutions of the wheel.
So the worm must turn at 54 rpm to make the wheel turn at 3 rpm.

The reason we use worm gears is to get a large reduction in output speed, which means a big increase in output force.
As with spur gear sets, the slower the output gear turns, the more turning force it has. As the worm rotates fast, the worm wheel rotates slowly, but with greater force. That is why worm gears are used to lift heavy objects.

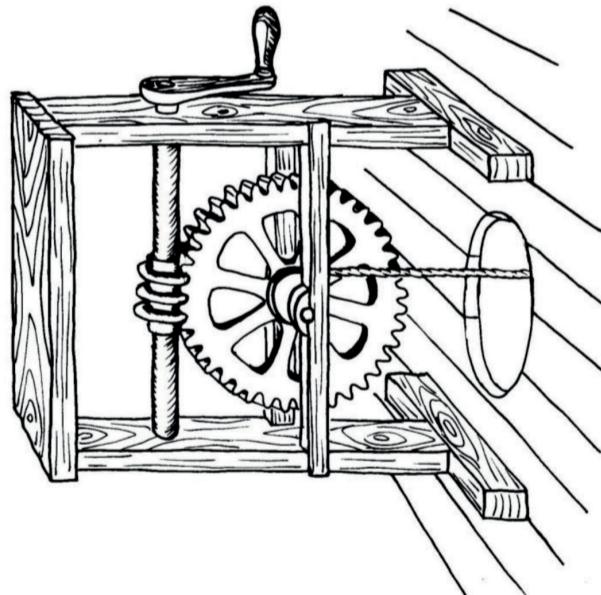


Figure 27: A worm and worm wheel used many years ago to lift heavy loads

Try to explain something, and design a jack

There is another useful thing about worm gears: the worm can turn the worm wheel, but the worm wheel cannot turn the worm. That is why worm gears are used for elevators. Imagine you are in an elevator that is lifted by an ordinary spur gear set and the power goes off. Explain what would happen and why.

The elevator will stop going upwards, because the electric motor that powers the driver gear will have stopped working. Then the weight of the elevator will make the gear that is normally the driven gear turn in the opposite direction so that the elevator will go down. The elevator is heavy enough to turn the electric motor in the direction opposite to the direction in which it should turn to lift the elevator up. It is possible that the elevator can go down very fast and the people in it can be injured when the elevator hits the ground.

You learnt about hydraulic car jacks in Chapter 6. There are also other kinds of car jacks. Make a rough sketch of how a rack-and-pinion system combined with a ratchet-and-pawl system can be used to make a car jack.

Learners' own designs.

Next week

Next week, you will look at different devices that people often use, and you will evaluate them. You will also make an artistic drawing of the inside of your classroom.

CHAPTER 9

Mechanisms at home

In previous chapters, the learners investigated the **mechanical advantage** provided by levers and gears. They have learnt how this can be used in powered machinery, and how the mechanical advantage works on large-scale tools and vehicles.

In the first section of Chapter 9, they will focus on how mechanical advantage is used in common tools; in the kitchen, the garden and around the house. The learners will evaluate and write a report on three tools they have seen used regularly at home, with the focus on understanding the mechanical advantage gained by using the tool.

The learners then follow this up by revising single-point perspective drawings through learning about the vanishing point on the horizon. They finalise the chapter by doing a drawing of the classroom from their new knowledge on this perspective.

- | | |
|--|-----|
| 9.1 Tools at home | 147 |
| 9.2 Single vanishing point perspective drawing | 152 |
| 9.3 Draw your classroom | 154 |



Figure 1: A can opener

Materials needed for this chapter:

pen	a breadknife
pencils	a garden spade or trowel
coloured pencils	a spanner
pencil sharpener	a can opener
eraser	an egg beater

Tools that will assist with teaching (any of the following will help):

a garden spade or trowel
a spanner
a can opener
an egg beater

9.1 Tools at home

The important aspect of this lesson is for the learners to explore how levers and gears are used in **all tools**, including those with which they are familiar. This is explained in the introduction. Before the learners do the exercise, they need to understand clearly how **mechanical advantage** is gained when using tools. It will help if you can demonstrate the lever principle using the knife, spanner or spade. Ask the learners to tell you which class of lever each is. (All the levers are third class.) Demonstrate the gears in the egg beater and/or the can opener. On the egg beater, ask the learners to identify the bevel gear. Count the teeth on the egg beater on both gears, and ask the class to calculate the ratio. For the exercise, the learners must evaluate three of the tools on the list. You don't want all the learners to do the same three tools, so it is recommended that you allocate three different tools to each learner. This way all the tools will be described. Make sure that the learner knows what the tool is that he or she is describing. When they have completed the exercise, the evaluation of each tool must be read out by a learner who has described that tool. They must explain why the tool has a mechanical advantage.

9.2 Single vanishing point perspective drawing

The learners move onto single vanishing point perspective drawing in this section. This is introduced through the description and definition of the **Horizon** and a **vanishing point**. Using the illustrations, then encouraging the learners to give their own examples (such as railway lines), will make the understanding much easier. The learners then take this knowledge and apply it on a smaller scale through the first exercise, the drawing of a cube in 3D vanishing point perspective. When the learners see that the principle is the same regardless of the scale of the subject – compare the drawing of the road in Figure 7 with the cube in Figure 8 – they will see that vanishing point perspective is easy to understand and draw. You can make sure that they are able to draw this perspective when they then draw the 3D shaded wooden object in the exercise **Use single vanishing point perspective** on Learner Book page 119. Tell them that they don't have to draw the plank in Figure 9; that is only there



to give them an idea of shading, texture and colouring. They can draw any wooden object; for example a piece of furniture, or any wooden shape.

9.3 Draw your classroom

In section 9.3, the learners will show that they have learnt the skill of single vanishing point perspective by drawing their classroom from the inside. Using Figure 11, you can remind them of how the points in a 'vanishing point' perspective would all eventually meet at the horizon. If they extend the lines that are in perspective, they will all meet. You can demonstrate that the classroom walls are parallel in reality, but if drawn from where the learners sit, because of vanishing point perspective, the lines would eventually meet.

Figure 12 shows how this works. On page 112, the learners must draw the room they are sitting in, using single vanishing point perspective. Ask them not to copy Figure 12. They must observe the perspective of the walls they are sitting in and draw them as they see them. Only afterwards must they compare their own drawing with Figure 12 to see if they have understood the method. The concept of the lines meeting at a vanishing point is very important.

The learners must evaluate one another's sketches and make **constructive** comments where necessary.

LB pages 112-113

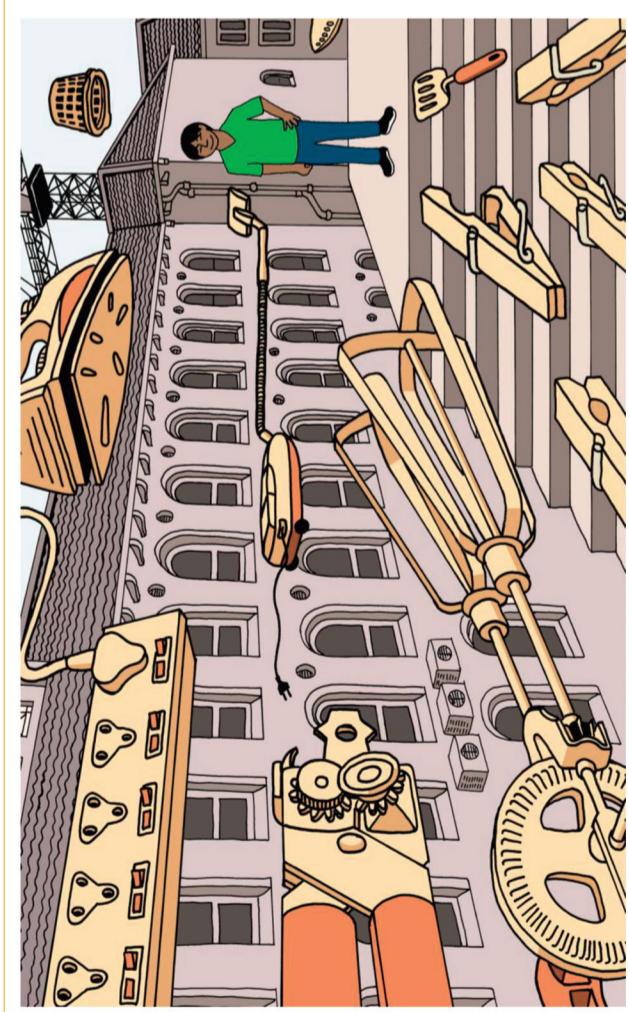


Figure 2

9.1 Tools at home

LB page 114

So far, you have learnt about levers, car jacks, pulleys and gears. These tools make life easier for us since they give us a **mechanical advantage**, which in turn gives us additional strength, grip and lift.

It is not only big machines that benefit from these advantages. At home, we have many tools that also give us a mechanical advantage. You will find them in the kitchen, the garden and the garage.

It is not always obvious that certain home tools give us a mechanical advantage. Here are some examples to show you how a mechanical advantage can sometimes be hidden.

- A bread knife is a **lever**. It works well to slice through bread because it has a long handle.
- A garden spade is also a **lever** that helps to break the surface of the soil. You provide the power (effort) with your hands, and your foot is the fulcrum. If you hold the handle with one hand and place your other hand on the shaft of the spade, your second hand is the fulcrum.
- A spanner is a **lever** that fits exactly onto a nut so that the nut can be tightened or loosened easily.
- An egg beater uses **bevel gears** to change the direction of movement. The whisk spins faster than the handle turns. The handle is attached to the driver gear, that has many teeth. Imagine that it has 36 teeth. The follower gears have fewer teeth than the driver gear. Imagine that they each have 12 teeth. For every turn of the driver gear, the follower gears will turn three times. This gives the mechanical advantage.
- Wind pumps or wind turbines spin around because the blades are **levers**. The wind pushes against the blade, acting as the force. They also use **gears** to drive pumps.
- A can opener uses **gears** and **levers** to make it easy to cut through the lid of a can.



LB pages 115-116

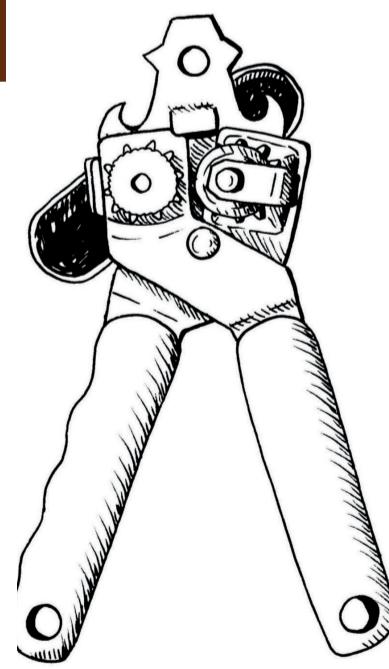


Figure 3

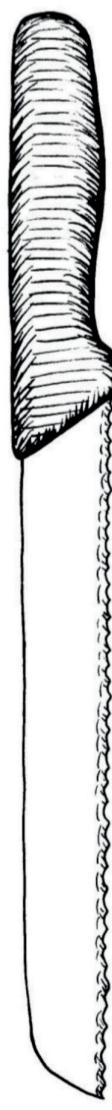


Figure 4

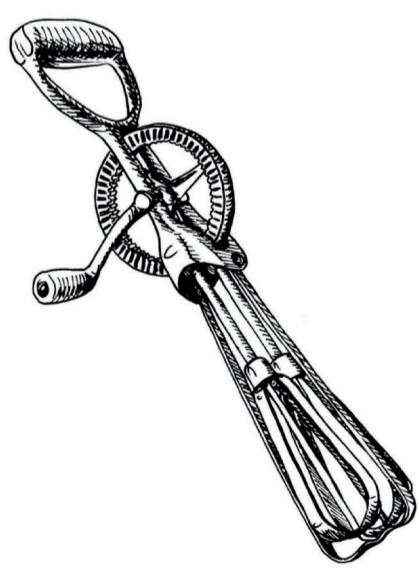


Figure 5

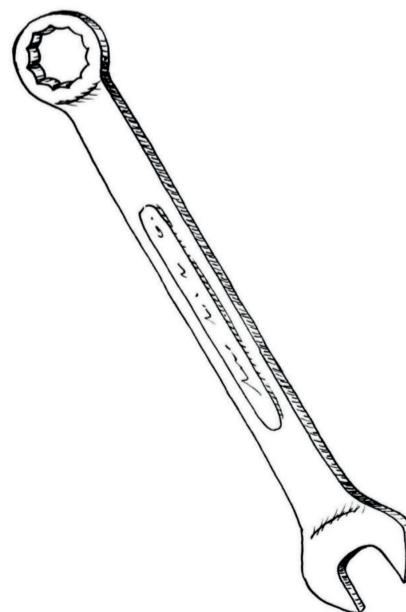


Figure 6

Evaluate household tools

LB p. 117

1. Select any three of the tools listed here and evaluate them.
 - can opener
 - egg beater
 - strap spanner for opening bottles
 - vice grip
 - wire stripper
 - ratchet spanner
 - nail scissors
 - ladder
 - secateurs
 - paper punch
 - stapler
 - tweezers
 - hammer
 - garden fork
 - pliers
 - screwdriver
2. Describe three tools that people sometimes use that are not on the list above.

If the learners may have difficulty with this ask them to think of any tools that are not on the list, as all tools will give a mechanical advantage to the user.

Some examples not listed are: crowbar, fire tongs, chisel, paint scraper, carving knife, hand drill.

The learners must complete three tables describing three tools. The most important answer is to the question: How does it give a mechanical advantage? Ensure that the learners understand the principle of mechanical advantage for each tool they describe.

Example 1

Name of the tool	Spade
Who will use it?	Gardener; builder.
What can you do with the tool; what is its purpose?	It can be used to dig; it can lift and carry loose material such as sand and cement to another place. It can be used to mix concrete.
How does it give you a mechanical advantage?	It is a 3rd class lever.



What material is it made of?	Steel; sometimes steel and wood.
Why is it made of this material?	For strength and durability.
What other materials could be used to make this tool?	Iron and strong plastic for the handle.
How much do you think you should pay for it?	Under a hundred rand.
What can go wrong when using it? How can it harm you?	You can hit your foot when digging; you can drop material.
What safety precautions should you take when you use this tool?	Wear strong shoes and gloves; watch what you are doing.

Example 2

Name of the tool	Egg beater
Who will use it?	Cook, baker, a parent or learner cooking at home.
What can you do with the tool; what is its purpose?	It stirs and mixes food quicker than you can with a spoon or fork.

How does it give you a mechanical advantage?	It has bevel gears.
What material is it made of?	Steel or aluminium and plastic.
Why is it made of this material?	For strength, to be lightweight, and to be easy and comfortable to hold.
What other materials could be used to make this tool?	Very strong plastic or hard rubber can be used instead of metal for the beaters, but won't last as long.
How much do you think you should pay for it?	Between R50 and R100 depending on what it is made of.
What can go wrong when using it? How can it harm you?	It can splash food out the bowl and make a mess. You can catch your fingers in the mixing beaters.
What safety precautions should you take when you use this tool?	Hold it firmly; don't wind the handle too fast; watch what you are doing; wear an apron.



9.2 Single vanishing point perspective drawing

Think about being in a car or taxi driving down a long, straight road. When you look straight ahead towards the **horizon**, the sides of the road seem to meet at a point far away, as in this picture.

This is called the **vanishing point**. Although the road doesn't actually get any narrower, it looks as if the straight lines meet at the horizon and the road vanishes, because of your **perspective**.

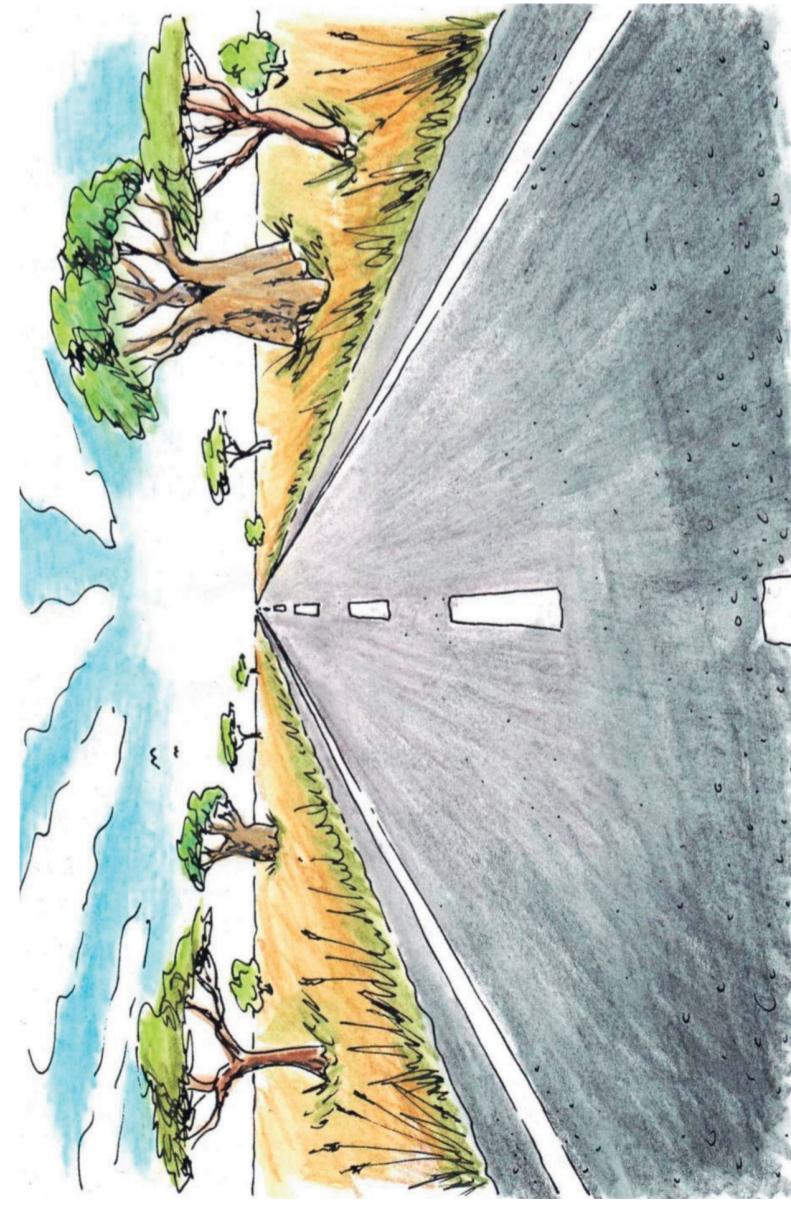


Figure 7: Vanishing point at the horizon

Drawing objects with a single vanishing point is one way to make them look as if they have three dimensions. In the drawing on the next page, you can see a rectangular box in 3D **single vanishing point perspective**.

Let the learners practise drawing the cube, following steps 1 to 4. Their cube should look like one of the examples below.

LB page 118

LB page 119

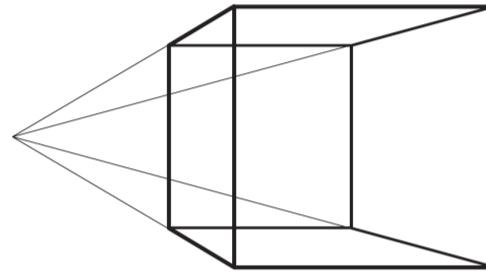


Figure 8: Drawing of a cube in 3D single vanishing point perspective

These are the steps to follow:

1. Draw one face of the cube. Select a vanishing point.
2. Draw very faint lines from each corner of the cube face to the vanishing point. These are your construction lines.
3. Draw horizontal and vertical lines for the back of the cube. The corners should connect with the construction lines.
4. Draw the shape of the cube, the outline, in darker lines.

Use single vanishing point perspective

LB p. 119

1. Draw a simple wooden object using single vanishing point perspective. Remember to use faint lines for the construction first. When you have finished, draw the shape of the object in dark lines.
2. Then make your drawing more realistic by showing the texture of the wood grain, colour and shading.

Make sure that the wooden object the learners draw has a single vanishing point. This can be in the centre, or angled as in the drawing shading and colouring has been added.

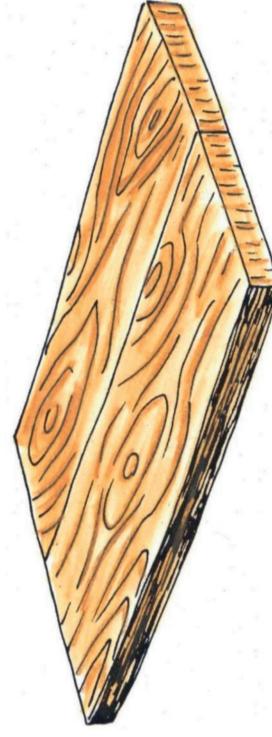


Figure 9: Adding wood grain makes things look realistic.



9.3 Draw your classroom

LB page 120

You are sitting in your classroom. Look at the walls on each side of you, at the floor and at the ceiling. Look at how all the straight lines of the room seem to angle towards each other the further away you are from them, even though you know they are actually parallel to each other. This is a bit like sitting inside a single vanishing point drawing!

The vanishing point is level with your eyes, so all the construction lines point to it.

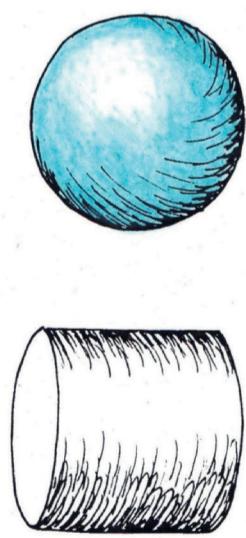


Figure 10: Shading helps to make drawings look more 3D.

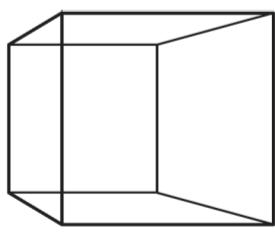


Figure 11: Making lines in front and on top darker also helps to make a drawing look more 3D.

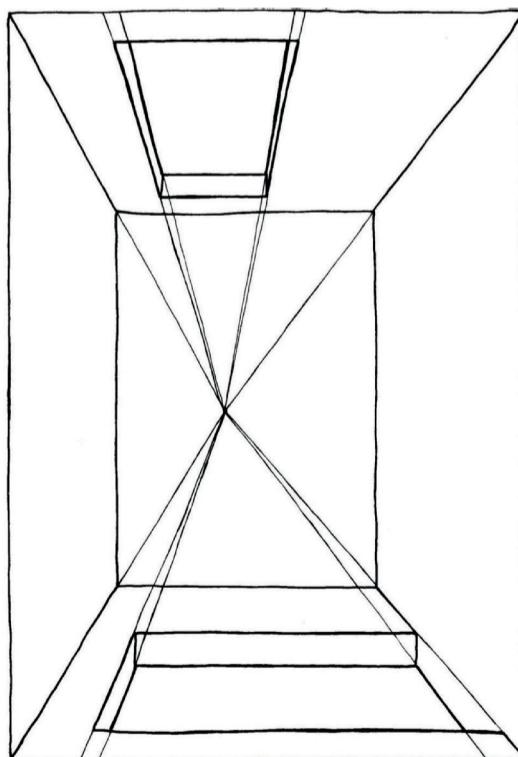


Figure 12: Single vanishing point drawing of the inside of a classroom

Single vanishing point drawing of your classroom LB p. 121

1. Make your own drawing of your classroom. Don't worry about the desks, furniture or other learners, just concentrate on the construction: the walls, floor and ceiling. It would help if you were sitting at the back of the room. If you are not at the back, ask your teacher if you can stand there for a few minutes to get an idea of how the lines move toward a point opposite your eyes. Then return to your desk and draw the sketch in the box on the following page.

Because most of the learners will not be in the centre of the classroom, you can show them that the single vanishing point can be opposite their point of view. The above two illustrations show how this happens. If necessary, draw an example of either of these two drawings on the board, and show how the vanishing point can move from left to right depending on the angle of the viewer.

LB page 122

2. Now evaluate your sketch. Compare it to Figure 12.
 - Do you think that your sketch is accurate?
 - If you continue the lines, would they meet at a vanishing point?
 - If not, what do you think you did wrong? How would you correct the sketch?
3. Show your sketch to another learner, and also evaluate their sketch using the same questions.

Understanding vanishing points and perspective drawing is very important for any drawing project. With a little practice, you can improve your drawing skills and you will find that it can help you in many subjects.

Next week

Next week, you will start with your practical assessment for this term. You will build a model of a tipper truck.

CHAPTER 10 PAT

Mechanical systems and control

LB page 123

Week 1
What is the problem? 159

Week 2
Design your tip truck 169

Week 3
Assemble the model tip truck 171

Assessment

Investigate:

How to put a door on the load bed so that it swings open by itself when the load bed tilts up (questions 1, 2, 3 (b) & 4) [10]
How to make wheels and a truck body (questions 1 & 2) [5]

Design:

Design brief with specifications and constraints [4]
How to put a door on the load bed so that it swings open by itself when the load bed tilts up (question 5) [5]
Design all the parts of the tip truck (chosen sketch) [6]

Make:

Get ready to make your parts [6]
Make your part or parts [12]
Assemble the model tip truck [12]
Orthographic first-angle projection (working drawing) [10]
[Total: 70]

Materials and equipment required for this chapter:

Materials: small cardboard boxes; corrugated cardboard; masking tape; plastic straws; wire; thin wooden dowels (2-3 mm, optional); eight plastic bottle tops of the same size; string; paper fasteners (optional); wood glue; syringes of different diameters; tubing to connect the syringes; water container to fill the syringes; two AA cells; LED; beeper; electrical conduction wire; springy material to make the normally-open switch; sand.

Tools: big strong scissors; cutting knives (optional); different size nails for making holes.

All tasks/questions are essential for the design process, even if no marks are allocated.

All tasks/questions in the PAT should be completed/answered, even the tasks/questions for which no marks are allocated for evaluation. This is because all the tasks/questions are essential parts of the design process. So, if certain tasks/questions are not done, then learners will not be able to do the subsequent tasks/questions successfully.

Week 1

Learners start by *individually* answering questions on how to start if you dream of owning your own construction company one day. They are thinking about what they need to do to start realising their dream.

After this, learners continue to work individually. They look *carefully at photos* of earth-moving equipment to see the use of hydraulic cylinders and pistons in the equipment. They write a design brief with specifications and constraints for building a model of a tip truck. Their workbooks emphasise that safety is a major concern with tip trucks, so they should take this into consideration when writing the design brief, specifications and constraints.

Lastly, learners follow instructions to practise making the different parts of a model tip truck, and answer design questions about these parts:

- They follow instructions to build a load bed with an undercarriage/chassis that can tilt.
- They have to pay special attention to hydraulics and how to choose the sizes of input and output cylinders in order to get a mechanical advantage. The teachers should remind them of what they learnt in Chapter 6 about hydraulics.

- They have to consider the position of the pivots (hinges) around which the back door swings, so that the door will automatically open when the load bed tilts up, and it will stay shut when the load bed is flat and fully laden with sand.
- They design a *normally closed switch* to be used in the circuit for the warning beeper and light.
- They follow instructions to build wheels, axles and bearings.



Week 2

Learners work in teams of three or four.

Every team member makes design sketches of all the different parts of the model. They discuss their designs with one another as they do this.

The team has a meeting to decide who will build what part of the truck. Each team member will build only one part of the truck.

Learners work individually to plan how to make the part that they decided to make. Then they make those parts, and draw additional sketches if required. The team members keep communicating about the different parts of the model they are building, to make sure that the different parts will fit together later on.

Week 3

Learners work together as a team to put all the different parts of the model tip truck together. Then they prepare to present their projects. They draw artistic 3D drawings of their models from two different directions, as well as an orthographic first angle projection drawing. Each member makes only one of these drawings.

The team uses a checklist of questions to evaluate their model together.

LB pages 124–125

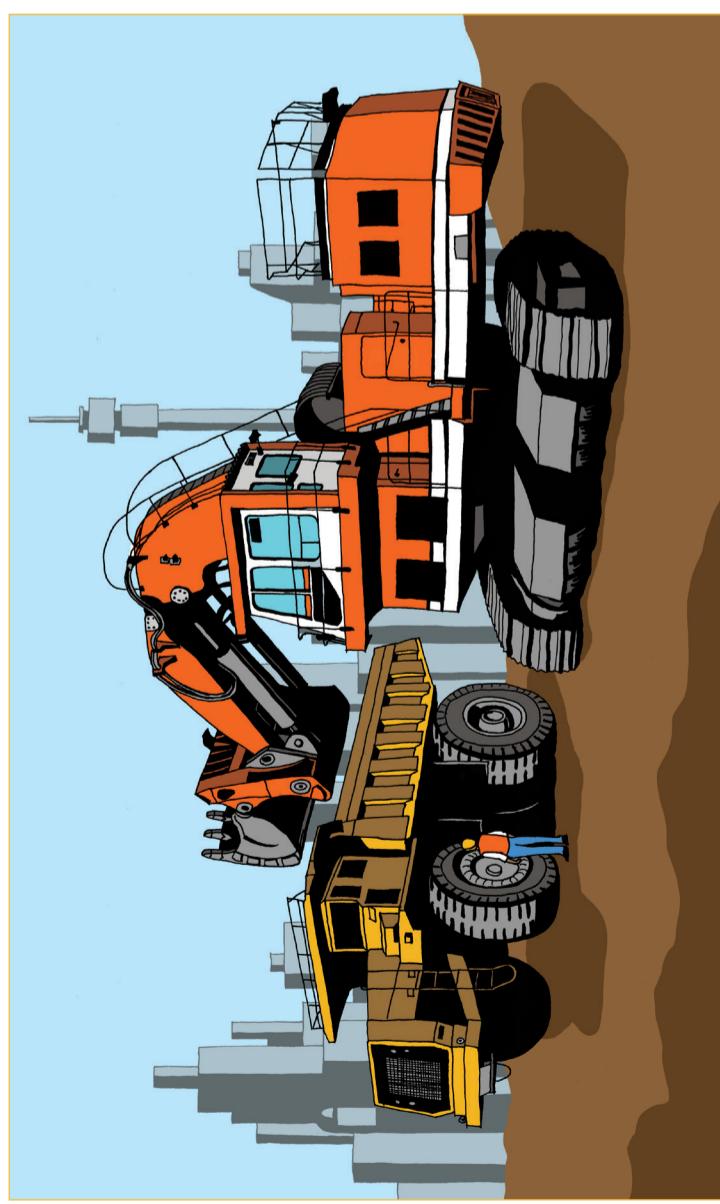


Figure 1

Week 1

What is the problem?

(30 minutes)

Maria has finished school and wants to learn about the construction industry. Eventually, she wants to own her own construction company.

Individual work

1. Who can help Maria to get started? In other words, what type of people should she meet to help her with her plans?

Other people who have done many years of construction work: companies or organisations that fund small businesses with start-up money

2. Which abilities and skills would Maria need to design and build houses?

Knowledge of construction methods and drainage.

Knowledge and skills with construction machinery.

Knowledge of safety during construction.

Skills in motivating and negotiating with people.

Financial skills such as writing proposals and keeping good financial records.

3. What kinds of equipment will her company need to build houses?

Measuring tools, such as tape measures and spirit/bubble levels.

Mechanical equipment, such as cement mixers, trucks, hydraulic lifts; cranes and pulleys.

Hand tools such as spades, saws, hammers and trowels.

Scaffolding and other structures for temporary support.

LB page 126



Machines that construction companies use

The machine in the photo below is called a mini-loader, and builders use it to move materials around a building site.



Figure 2

It has a scoop in the front, which the driver pushes into a pile of sand. Then the arms of the loader lift the load of sand into the air.

It uses diesel fuel in the engine as its source of energy. The engine turns a powerful pump that pumps hydraulic oil through hoses and pistons.

How does this mini-loader lift its arms? In other words, find the parts of this system that make the arms go up. What are the names of these parts?

A **hydraulic pump** provides oil at high pressure.

The **high pressure oil pushes the piston out of the hydraulic cylinder.**

The piston is connected to the arm of the mini-loader. This forms a lever system.

Maria is going to need a big tip truck to deliver sand to different building sites. The load must not fall off when the load back is horizontal. A big truck like that can be dangerous if it crashes into cars, it can flatten them! Also, the loads of rock, gravel or sand that tip trucks carry are usually very heavy, and when the load bed is lifted, it can start pouring out very quickly. This load can injure a person standing too close to it.

People should be trained to work safely around tip trucks. A tip truck needs to have warning lights and beepers so that everyone will know when the load bed is being lifted.

Maria needs a model of a tip truck to train her staff on how to be safe when they work around the truck.

Design brief with specifications and constraints

1. Read the previous page carefully. Write the design brief by copying this sentence and completing it:

I am going to help my group design and make a **model of a tip truck** that will **help Maria to train her truck driver and other staff on safety procedures.** [1]

Look at the photo of a tip truck on the next page. The door at the back opens by itself when the load bed lifts up. It has no bolts or locks to open and close it.

2. Write down the specifications.

The model tip truck must:

- have four strong wheels and a cab for the driver,
- a load bed that can lift up at 30° or more than 30°,
- a load bed that can carry a table spoon of sand or gravel (stones),
- a load bed that has a door at the back that can open on its own to let sand or gravel fall out,
- use a hydraulic system to raise the load bed and
- have a beeper that sounds and a red LED light that goes on when the load bed goes.

3. Write down the constraints. Remember that the constraints are the tools, materials and time that you have available to make the model.

I have two weeks to design and build the model of the tip truck.
I will use cardboard and other reusable waste materials. But I will also need tape or glue, and wire to make pivots and axles for the wheels.
I will not use any special tools other than scissors. (Some students or schools may have cutting knives and pliers available. In that case, learners can use those tools as well, after the teacher advised them about how to work safety with those tools.)

4. Form teams of four and compare your specifications.

[Total: 5]



How to make different parts of a tip truck (3 × 30 minutes = 90 minutes)

During this lesson and the next one, you will practise making different parts of a model tip truck.

Look at the photograph of a tip truck below.



Figure 3

How to use a hydraulic system to tilt up the load bed

When a tip truck unloads, the one side of the load bed lifts up, but the other side of the load bed remains at the same height. Another way to say this is that the load bed **tilts** up at an angle. The drawing on the right shows you how to make something tilt upwards by using a hydraulic system.

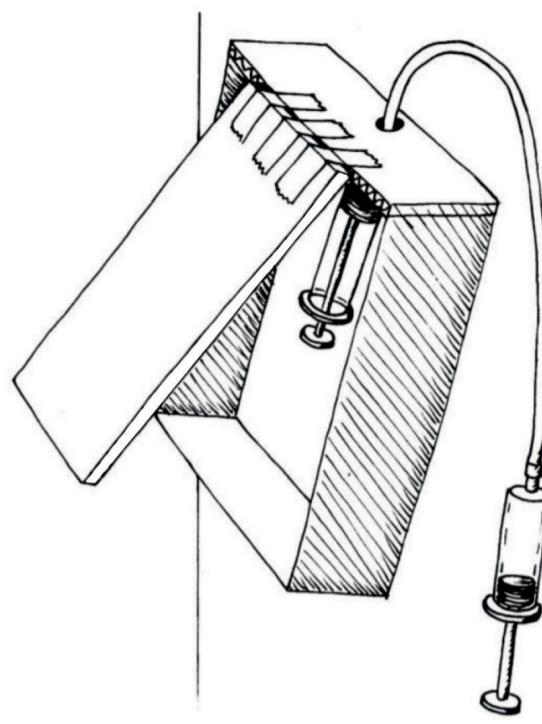


Figure 5

You need a strong box and a piece of stiff cardboard as you see in the picture above. Use strong tape to join the flat piece of cardboard to the box. Make the small hole you see in the bottom of the wall of the box. You need two syringes and some plastic tubing, like you used in Chapter 5. The syringe where the input force is applied will be called the driver piston. The syringe where the output force will be obtained will be called the driven piston.

- Now, fill the driver syringe and the tube with water. Move the driven piston to the “down” position. Push the end of the tube through the back of the box and push it onto the driven piston.
- The tube must go through the hole in the back of the box, but the driven syringe must be loose, so that it can point up or down.
- Look at Figure 6. Put a piece of Prestik under the cardboard sheet so that the slave piston can push against it.

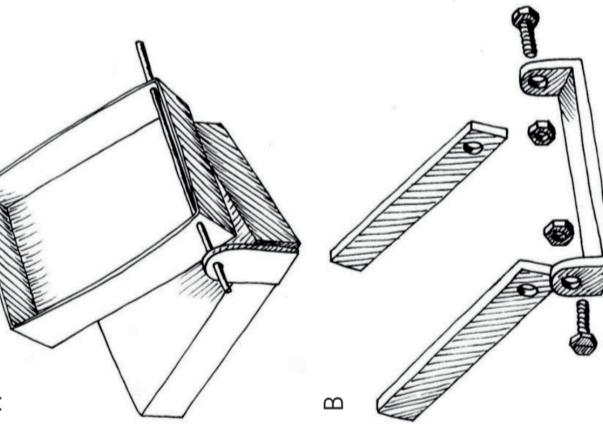


Figure 4

How to attach the load bed to the body of the truck

Sand is loaded in the load bed of the truck. The load bed and the body of the truck should be joined in such a way that the load bed can lift, as in the photo above.

You can make this out of two boxes. The drawings on the right show different ways in which this can be done. Join the top box to the bottom box with two **hinges**, so that the box can lift at one end. Doors and windows have hinges to allow them to open and close.

Take care
The cardboard must not get wet, otherwise it will become soft and weak.



- Press the driver piston so that the flat head of the slave piston pushes out and swings the cardboard sheet up. Does the cardboard sheet lift up far enough?
- Add more pieces of Prestik and find the best position to fit the flat head of the slave piston. The cardboard should tilt up to an angle of more than 30°.
- Find the best position for the Prestik and measure the distance from the hinge, so that you can remember it.

Are you getting a mechanical advantage?

Your hydraulic system has to give you a mechanical advantage. In other words, the **output force** has to be greater than the **input force**.

1. Should the driven piston under the load bed be wider than the driver piston, the same size, or narrower? Give a reason for your answer.

The **driven piston under the load bed should be wider than the driver piston** (in other words, it must have a bigger area than the driver piston). The reason is that the driven piston under the load bed must exert a bigger force than you exert on the driver piston. The driven piston has to lift a heavy load. (The teacher should point out to learners that the pistons in Figure 6 have roughly the same diameter, so they will have to change them to get a mechanical advantage.)

Now adjust your system so that the driver piston moves the driven piston. Make sure that the driven piston does not pop out of its cylinder.

2. The back of the box has to be strong and stiff. Why?

The **back of the box must be strong because** the **driven piston pushes backward just as strongly as it pushes forward to lift the load**.

3. Copy and complete the drawing on the right. The green lines show you where the driven piston is when the cardboard is down. Now draw the piston again in pencil, on this same drawing. Show its position when it has pushed the cardboard up.

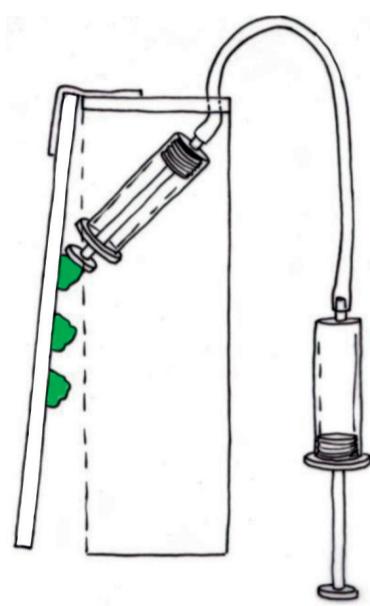


Figure 6

How to put a door on the load bed so that it swings open by itself when the load bed tilts up

Choose a box to represent the load bed. When the load bed tilts up at 30°, the sand should fall out. But when the truck is on the road, the door has to keep the sand in.

The door does not have any handles or locks to keep it shut; it should stay shut by itself. Think how you can make a door like this for the truck. Look carefully at Figure 3 again to help you. The following questions about Figure 3 will also help you.

1. Look at the position of the hinge around which the door swings. Why is the hinge placed there? Why does the door have arms that go to the front of the hinge?
The hinges are far forward from the door so that it will be very difficult or even impossible for the sand in the load bed to push the door open when the load bed is horizontal. [3]

2. Look at the chains going down from the arms of the door to the truck body. What is the purpose of these chains?

When the load bed lifts up, the back of the load bed goes down a little. But the door does not go down with it, because the chains hold the front part of each lever down while the load-bed lifts up. Because the front parts of the levers are held down by the chains, the back parts of the levers remain where they are, so that the door does not move. The floor at the back of the load bed is now lower than the door, so the sand can pour out. [3]

3. Make a drawing of what the load bed and the door will look like when the load bed is flat. In other words, what does the load bed look like when the truck is travelling and the load bed is not tilted up?

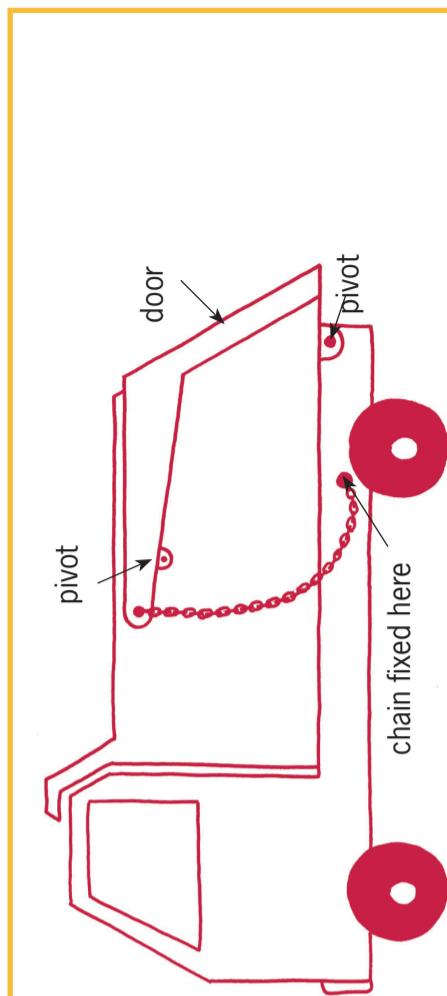


Figure 7

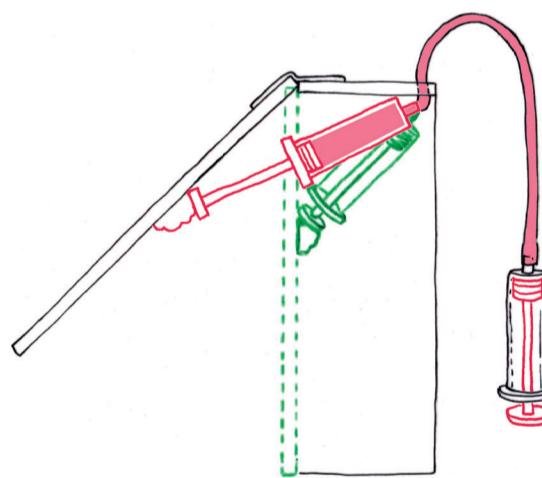


Figure 7



- Look at the picture of a tip truck in Figure 8. Pay special attention to the door at the back of the load bed.
4. Will the door of this load bed keep the sand inside when the truck is driving? Explain your answer. You can also use a drawing to explain your answer.

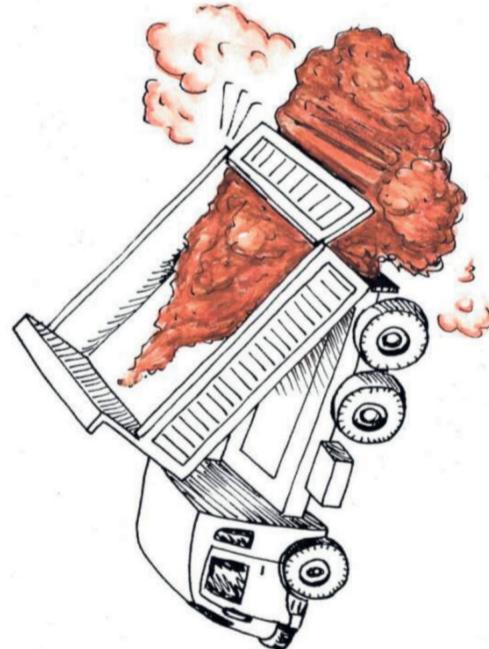
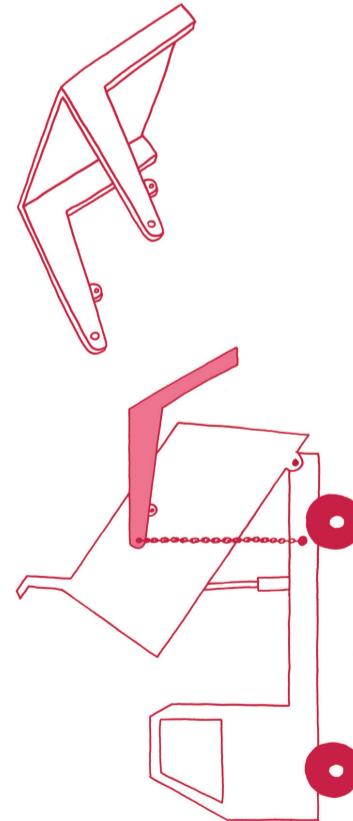


Figure 8

If the door has no latch, it will swing and let sand fall out while the truck is driving. This kind of door must have a latch. When the driver wants to tip out the sand, she or he must walk to the back and unlock the door. For the benefit of the teacher, a more comprehensive explanation of the answers to questions 1 and 4 are given here:

Imagine a scenario with two people and the door where Sipo is very strong and holds the top of the door. Tom is weaker and holds the bottom of the door. Sipo holds the door still while Tom tries to swing the door up. It will help Tom if Sipo holds the door right at the top (like the hinge in Figure 8). But if Sipo takes hold on points far away from the door, on horizontal levers attached to the top of the door (as the hinge in Figure 3), it will be very difficult for Sipo to swing the door up.

- [3] Total [9]
Total [5]
5. Make a model of the door on your box to show your design. Then make a rough sketch of your design for the door.



How to make a switch that goes "on" when the load bed tilts up

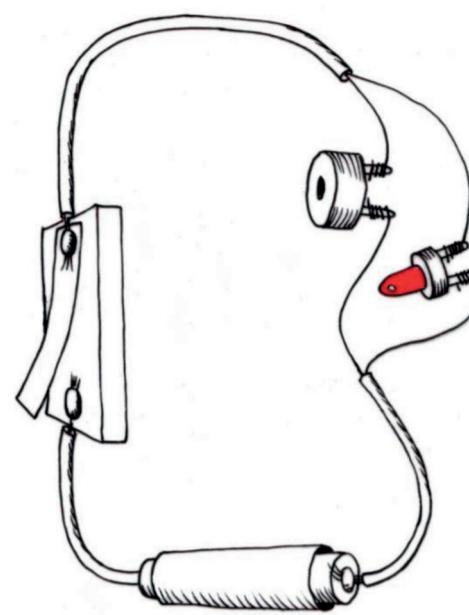
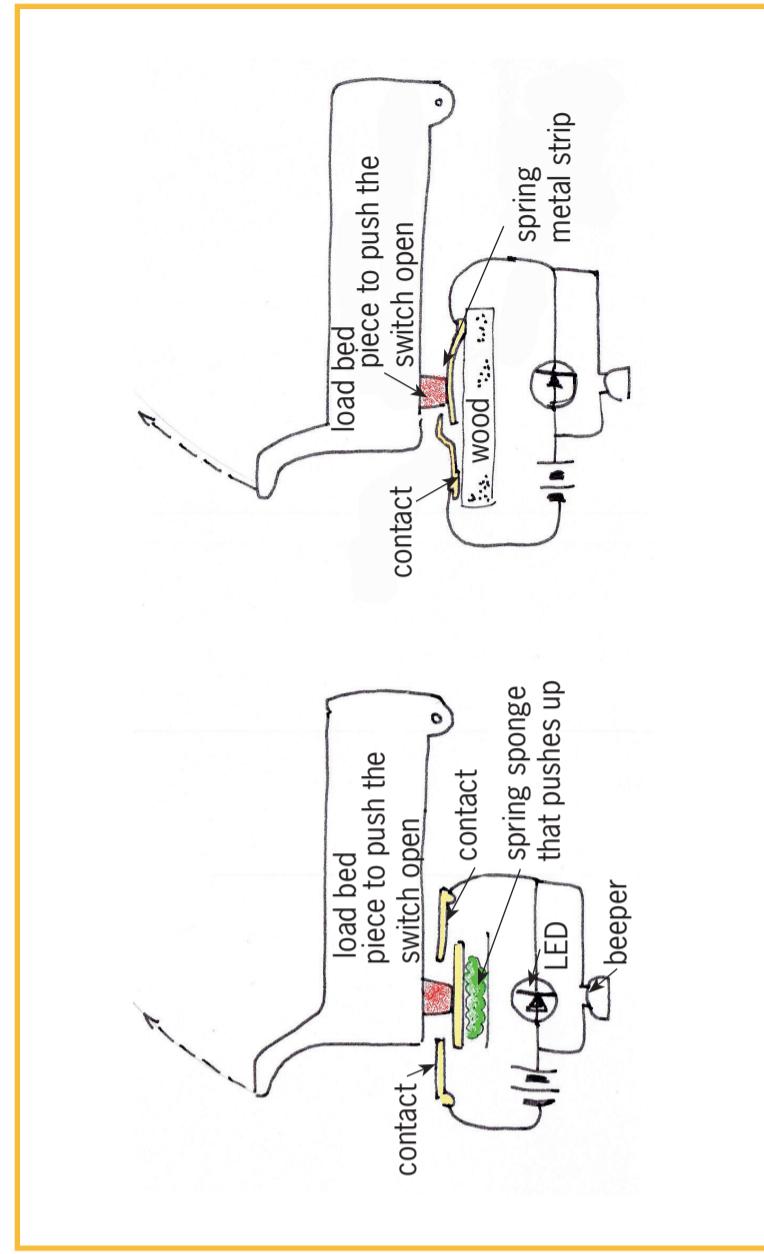


Figure 9

The truck needs a circuit that will warn the driver when the load moves. Look at the circuit on the right that is "normally open". Normally open means the switch does not complete the circuit unless something presses on the springy metal strip.

Change the design of the switch so that it is "normally closed". The weight of the truck bed should keep the switch open or "off", so that it cannot complete the circuit. When the bed lifts up, the switch must close to go "on" and complete the circuit. This will make the beeper go off and make the LED light shine.

1. Draw your idea for a normally closed switch. Show the load bed in the down-position, holding the switch open. You don't have to draw the whole truck, just the part that pushes the switch down.





How to make wheels and a truck body

The sketches below show how to make wheels from plastic bottle tops, and how to attach the wheels to the box that represents the truck body.

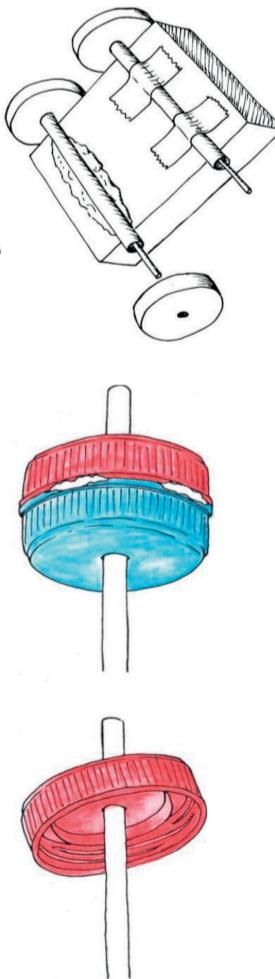


Figure 10

Remember that the back of the truck body must have enough room for the hydraulic syringe to move. The body should also have room for the hinge.

1. Look at the wheels of the truck in Figure 3. Trucks that carry heavy loads must have wheels that are strong, but also wide. Why do the tyres have to be wide?

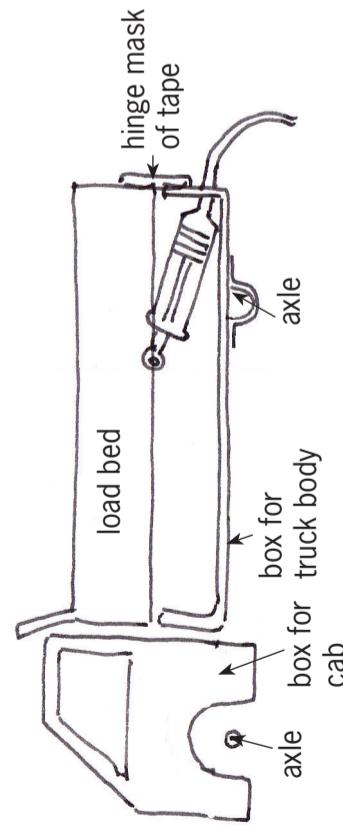
Wide tyres spread the weight of the truck over a larger area. The weight of the truck is too heavy for narrow tyres. The tyres would burst or the wheels would bend. Wide tyres also help the truck to have better grip when driving on rough terrain.

- [2]
2. How can you make sure that the wheels can turn freely?

The wheels must turn in bearings on the axle, or the axle must turn in bearings on the body of the truck. A bearing is a surface that lets a shaft turn with little friction. For the model truck, plastic straws are good bearings; an axle can be made of wire or of thin wooden dowels.

[3]

[Total: 5]
3. The truck should have enough room for the hydraulic syringe to move. It should also have room for the hinge. Make a sketch of the box you will use for the truck body, and show the syringe and the hinges on this sketch.



Week 2

Design your tip truck

(30 minutes)

You will work as a team of three or four to design and make different parts that will fit exactly together to make a model tip truck that works. Each person will make only one part.

Remind yourself why you are making this model, and look again at the specifications.

Design all the parts of the tip truck

Draw your designs on sheets of A4 paper. Give a title for each drawing, to show what the drawing is about. Also use labels to show what the different parts of the drawing are.

Use your ruler and show measurements of the parts on your drawing. The measurements are important because the part or parts you make have to fit into the parts that other people are making.

If you are making the warning circuit, draw a circuit diagram and also draw the real circuit. You have to plan your circuit so that the switch will be underneath the load bed, and you have somewhere to hide the battery.

If you get a better idea, don't throw away the first sketches. Keep all your old sketches and notes together. Your teacher will assess you on how much your ideas have improved.

[Total: 6]

Team design meeting

(30 minutes)

You will work in teams of three or four. Each person will make only certain parts of the tip truck, and in the end all the parts have to fit together.

Divide the work amongst yourselves. For example, give each person one of the following parts to make:

- the load bed and the truck body, the hinges between them, and the truck wheels and axles.
 - the door of the load bed and the cabin of the truck; or
 - the switch for the warning beeper and light, and the truck wheels and axles.
- As a team, you need to check the designs of the different parts to see if everything will fit together. Only then can you start making the different parts individually. If the parts won't fit, you will have to adapt the designs to make them fit.



Individual work: Get ready to make your parts

Rewrite and complete the following sentences:

1. I am going to make ...

Each learner can choose which parts of the team's design they will make.

2. I will need the following materials:

Examples of materials (learners have to think ahead, aided by their design drawings): cardboard boxes of the right size for the load bed; stiff cardboard; tape; straws for bearings; wire or wooden dowels for axles; bottle tops for wheels; string for chains to hold the door-arms down; wire or paper fasteners for hinges (pivots); wood glue; syringes of different diameters; plastic tubing to connect the syringes; water container to fill the syringes; two AA cells; LED; beeper/buzzer; electrical conduction wire for the circuit; springy material to make the normally-open switch; sand to put in the load bed of the model truck.

3. I will need the following tools:

Examples of tools: big strong scissors; cutting/craft knives (optional); different size nails for making different size holes; pliers (optional).

[3]

[Total: 6]

There are constraints on the tools that you can use. You can only use tools that you can find, and that are safe for you to work with.

[Total: 12]

Week 3

Assemble the model tip truck

(2 × 30 min = 60 minutes)

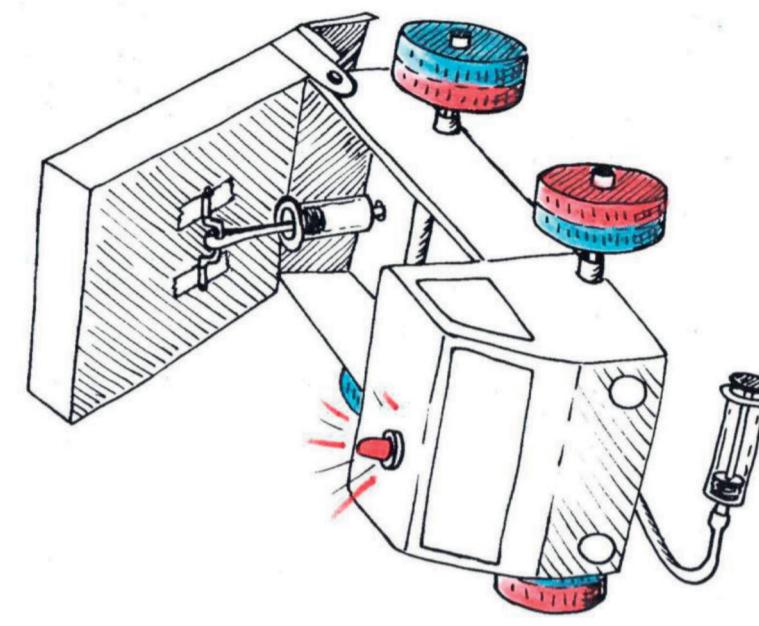


Figure 12

Now bring all the parts together to make the whole truck. Be careful when you assemble the truck. Some parts might not fit exactly. Don't force them together as this could break both parts. It will be easier to simply alter a part that doesn't fit by cutting it carefully, or adding a small piece with glue.

The picture on the right is an example of a tip truck someone made. Your model will look different to this and could work better than this one.

[Total: 12]

(2 × 30 min = 60 minutes)

Presenting your project

Each team will have five minutes to explain their design and show their drawings to the rest of the class.

Each team member should present the best sketches they have made of a part, or parts.

Three new drawings should also be made of the completed truck. You need to decide as a group who is going to make each of these drawings:

- An artistic three-dimensional drawing showing the completed tip truck from the front, with the load bed tilted up.
- An artistic three-dimensional drawing showing the completed tip truck from the back, with the load bed tilted up.
- An orthographic drawing showing the front, top and side views of the completed tip truck. This is called an **orthographic first-angle projection**.



The illustration below shows how the model is projected onto the paper, in order to draw an "orthographic first-angle projection".

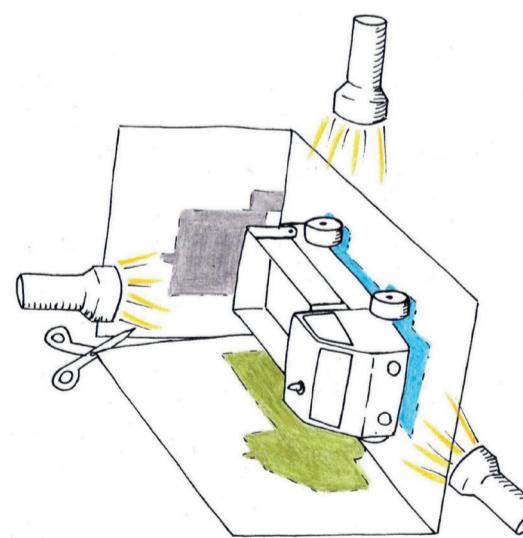


Figure 13

Look at the scissors in the figure. If you cut the box open, the sides will fall down and lie flat on the table. Then you will have the orthographic first-angle projection.

Now you need to complete an orthographic first-angle projection of the truck.

The side view has been drawn for you. Use the red projection lines to complete the top view of the truck. Then use the blue lines to complete the front view.

Finally add the labels for "front view", "top view" and "side view" to your drawing.
[Total: 10]

Evaluate your model

When you evaluate a model, you ask questions about it. Most of the questions relate to the specifications. Turn back and read the specifications again.

- Does the truck have four wheels that look wide enough to carry a heavy load?
- Does the truck have a cabin for the driver?
- Can the truck carry a tablespoon of sand?
- Does the load bed lift up with a hydraulic system? What is the highest angle it can reach?
- Does the load slide out of a gate at the back of the load bed?
- Does a beeper sound or does an LED come on when the load bed goes up?
- Does the hydraulic system give you a mechanical advantage?
- In theory, what is the mechanical advantage of the system? The syringes have a lot of friction in them and so the real mechanical advantage is less than the theoretical advantage.

Next week

Enjoy your winter holidays! After the holidays, you will learn more about electrical circuits and parts that can be used in them.

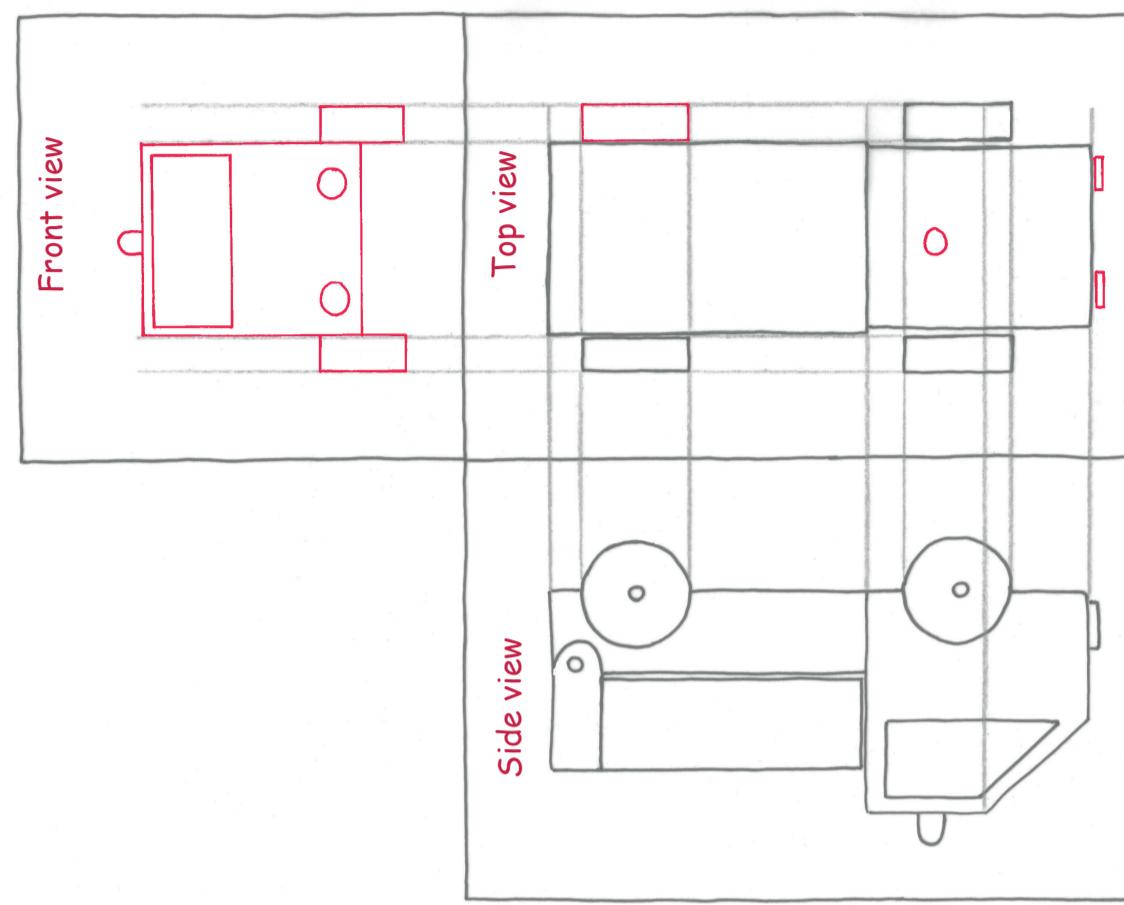
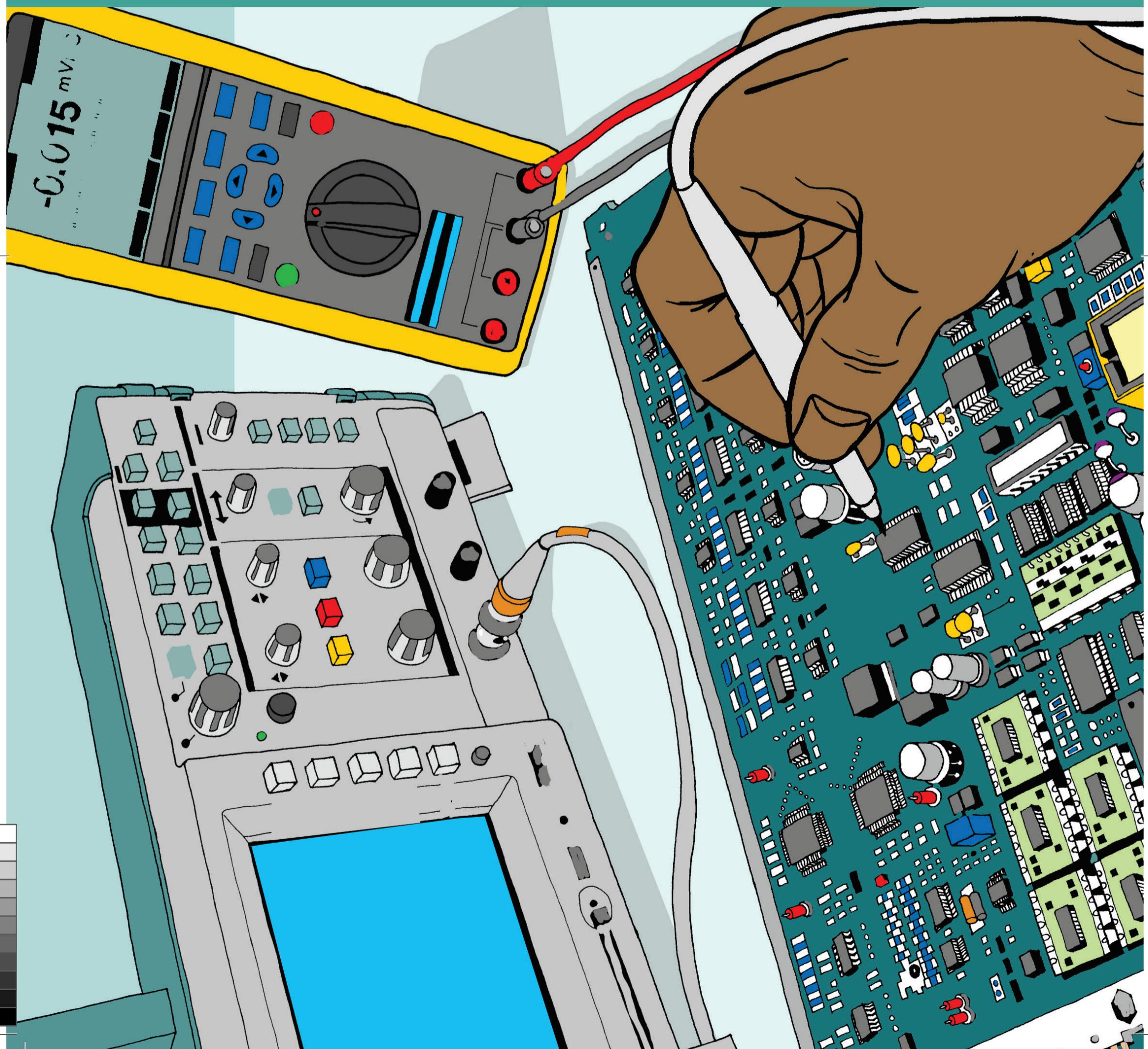


Figure 14

Terms 3 and 4



Term 3: Electrical | Electronic systems

CHAPTER 11 Component symbols and simple circuits

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In this chapter, you will revise the work you did on electrical systems and control in Grade 8. You will revise simple circuits, circuit diagrams and connecting cells and light bulbs in series and parallel. You will also revise switches in series and parallel. You will then do action research on the effects of changing the voltage in a circuit.

- 11.1 Revision 1: Component symbols 178
- 11.2 Revision 2: Simple circuits 186
- 11.3 Testing voltage and current in circuits (Ohm's Law) 188



Figure 1: A torch

11.1 Revision 1: Component symbols

In this section, learners first revise what they learned in Grade 8 about circuits and components, and draw simple circuit diagrams. They do not build and test circuits, but rely instead on what they learned before. They compare circuits with cells in series and in parallel. They also compare circuits with light bulbs in series and in parallel, and answer questions about the voltage across and the current through the light bulbs. They complete truth tables for circuits with switches in series and circuits with switches in parallel.

In these notes, the words "lamp", "light bulb" and "bulb" all mean the same.

Cells in series

The easiest description of a series circuit is that there is only one path for the current.

Cells in parallel

Learners may wonder what the advantage is of connecting cells in parallel since the arrangement does not increase the voltage and does not make the bulb brighter. However, in some situations, cells in parallel will be able to produce a bigger current than the same number of cells in series. The reason is that the internal resistances of the cells in parallel are also in parallel, giving a battery with a lower internal resistance. With cells in series, their internal resistances are in series and add together.

Lamps in series

You may have to explain the term "voltage drop across the lamp". It means the same as "the voltage across the lamp" and the "potential difference across the lamp". The word "drop" is used because the flowing charges transfer (give away) some of their energy to the lamp filament as they flow through. We know they give away energy because the filament gets white-hot. Therefore, the charges have less energy on the other side of the lamp and we say there has been a drop or decrease in the voltage across the lamp.

Lamps in parallel

Why can we say each lamp in parallel gets the same voltage drop across it? The answer is that the positive terminal of the battery is connected to both lamps by copper wires, which are very good conductors. These copper wires are the long straight lines in the diagram. Because the conductors are so good, there is no voltage drop across those conductors. It is as if we have connected each lamp straight onto the terminal of the battery and the wires were not there.



Question 5 (b) and Figure 9 might hold a surprise for learners. Usually, we give them the same kind of torch bulbs or lamps to work with. Therefore, they might expect that the current through L1 and L2 should be the same. Prompt them with a question: "Do you think the lamps are of the same kind?"

Now, some of them might think (and this is more of a worry for a teacher): "Oh well, I can't understand this stuff, and there's no way of telling what the currents are in each lamp. If the book says the currents are different, that's how it is". You should therefore explain that the currents can be different because lamps are made with different filaments. If you look closely at light bulbs/lamps, you may find some printing on the screw-contact. It might say "0.3W" or "6V 3W" or "3.8V". These numbers are the power rating in watts or the maximum voltage for which the filament is designed.

Some manufacturers colour-code their bulbs to show the rating. If you look inside the bulb, you may see a little plastic bead that holds the conducting wires apart. The bead may be white, blue, green or yellow. The colour tells you the voltage that will make that bulb very bright. The Eveready Company used to make torch bulbs with the colour codes as follows: white meant 1,1 volts, blue meant 2,4 volts, and green meant 3,8 volts. (Remember that your bulbs might come from China and have other colour codes.)

We usually put 1,5 volts across a bulb rated for 1,1 volts and it will be bright and not burn out. Similarly, we can put 3 volts across a bulb rated for 2,4 volts and 4,5 volts across a bulb rated for 3,8 volts.

Switches in series and parallel

This recaps what you did in Grade 8 on logic gates, the bell system in the bus, and the alarm system for Mr Abdulla's shop.

11.2 Revision 2: Simple circuits

The learners have to make circuits, following the instructions in their book. Each time they make a circuit, they must also draw a circuit diagram of it.

11.3 Testing voltage and current in circuits

The learners use multi-meters to measure resistance, voltage and current in real circuits, and use their measurements to construct a graph of the relationship between current and voltage.

Different ranges of measurement on a multimeter

You will have to teach learners how to read the multi-meters. The manufacturers do not consider learners when they print the face of the meter! On the DCV scale, "DCV" means "Direct Current, Volts". **200m** means 200 millivolts; on this range, you can measure up to 200×0.001 volts, that is to say, up to 0,2 volts. If the voltage you are trying to measure is greater than 0,2 volts, the display will put a 1 on the left-hand end. The "1" means, "the meter is working but you should select a higher range".

So, you need to switch to the **2000m** range. "2000m" means 2 000 millivolts, which is 2 volts, and 2 volts is the biggest voltage it can measure. If you measure again and still see a 1 on the display, the voltage is greater than 2 volts, so switch to the range that is labelled **20**. Of course, this means 20 volts. Now you might see a number such as 1,52 in the display. If you switch to the **200** range, you should still see 1,5 in the display. The last digit does not display because the 200-volt range is not as accurate as the 20-volt range.

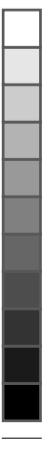
You can buy multi-meters from hardware stores, and sometimes even from supermarkets. They are relatively cheap.

An alternative to multi-meters is ammeters and voltmeters. Each meter does just one job: it shows voltage or it shows current. For school use, choose voltmeters that read up to 10 volts and ammeters that read up to 3 amperes.

The red and black wires must be connected the correct way around on the terminals of the meters: if you connect the wrong way around, the needle will try to move to the left.

The advantage of a multi-meter is that you can measure resistance directly. The multi-meter has its own battery inside, and when you connect across a resistor, the multi-meter passes a small current through the resistor, compares the voltage and the current, and displays the result as a resistance value.

The teacher should print copies of the graph paper in the Learner Books for learners to draw the graph in Figure 24.



11.1 Revision 1: Component symbols

Components are the parts that we connect in an electric circuit.

Do you remember the symbols for cells, lamps and switches?

Do you remember the difference between joining components in series and in parallel? Let's see what you can remember.

You have already learnt that an electric circuit is a closed path in which a current flows.

The simplest circuit has:

- a power source such as a cell,
- a conductor, and
- a load that provides resistance, such as a lamp.

Cells in series

Two or more cells can be connected **in series** to increase the voltage in the circuit. Figure 2 below shows two cells connected in series in a circuit. The positive terminal of cell A is connected to the lamp. The negative terminal of cell B is connected to the other terminal of the lamp.

1. Draw a circuit diagram of the circuit in Figure 2.

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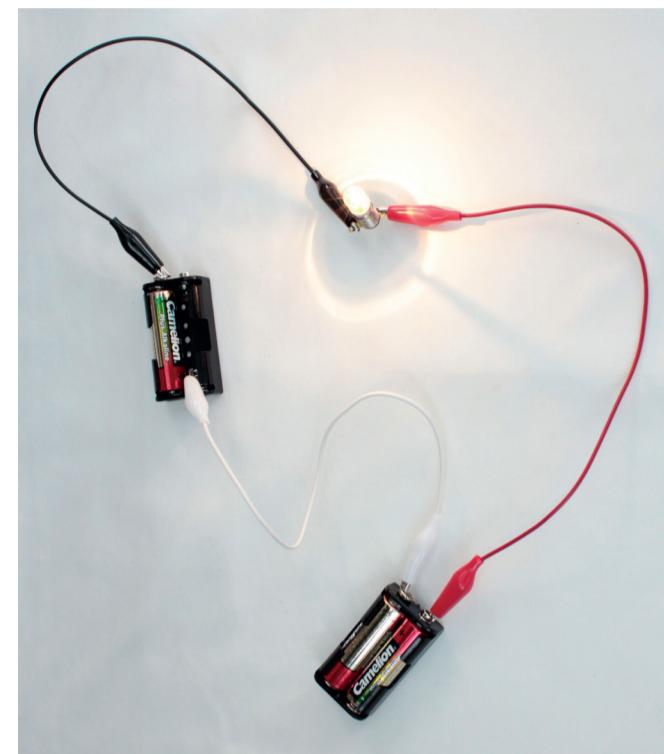
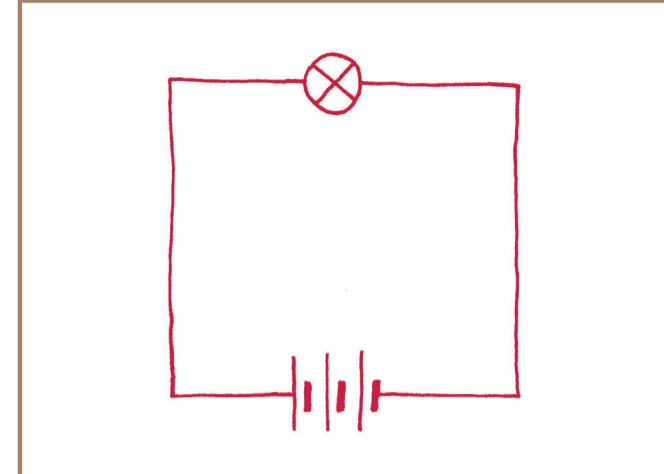
In series means the cells are connected end-to-end, and the current flows through each cell in turn.

The positive terminal of cell A is connected to the positive terminal of cell B, and the negative terminal of cell B is connected to the other terminal of the lamp.

When cells are connected in series, their total voltage is the sum of the voltages of the three cells:
 $1,5\text{ V} + 1,5\text{ V} + 1,5\text{ V} = 4,5\text{ V}$

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2. Figure 3 below shows three cells connected in series in a circuit. Draw a circuit diagram of the circuit.



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Two or more cells can also be connected **in parallel**. A parallel circuit has two or more different paths for the current to travel along.

Figure 4 shows three cells connected in parallel in a circuit. The positive terminals of all three cells are connected to one another and to the lamp. The negative terminals of all three cells are connected to one another and to the other terminal of the lamp.

1. Draw a circuit diagram of the circuit in Figure 4.

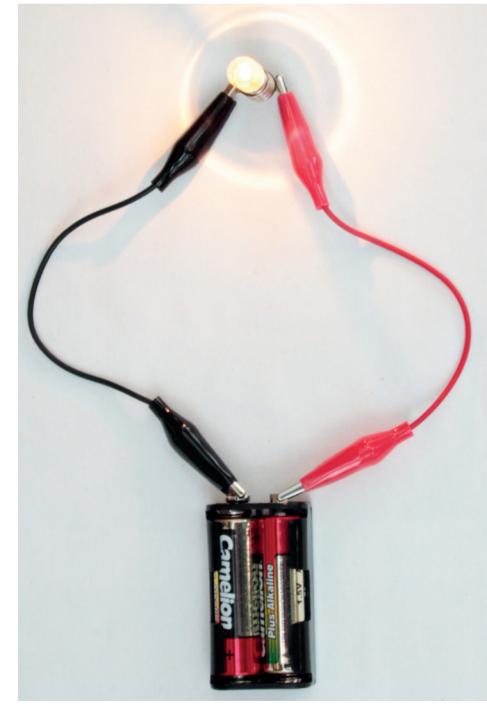
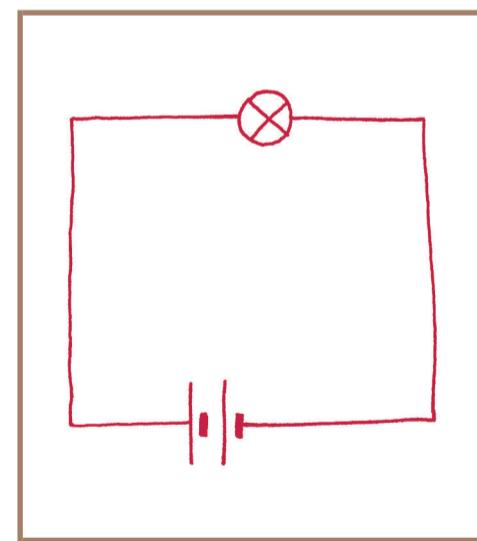


Figure 2: Two cells in series connected to a lamp

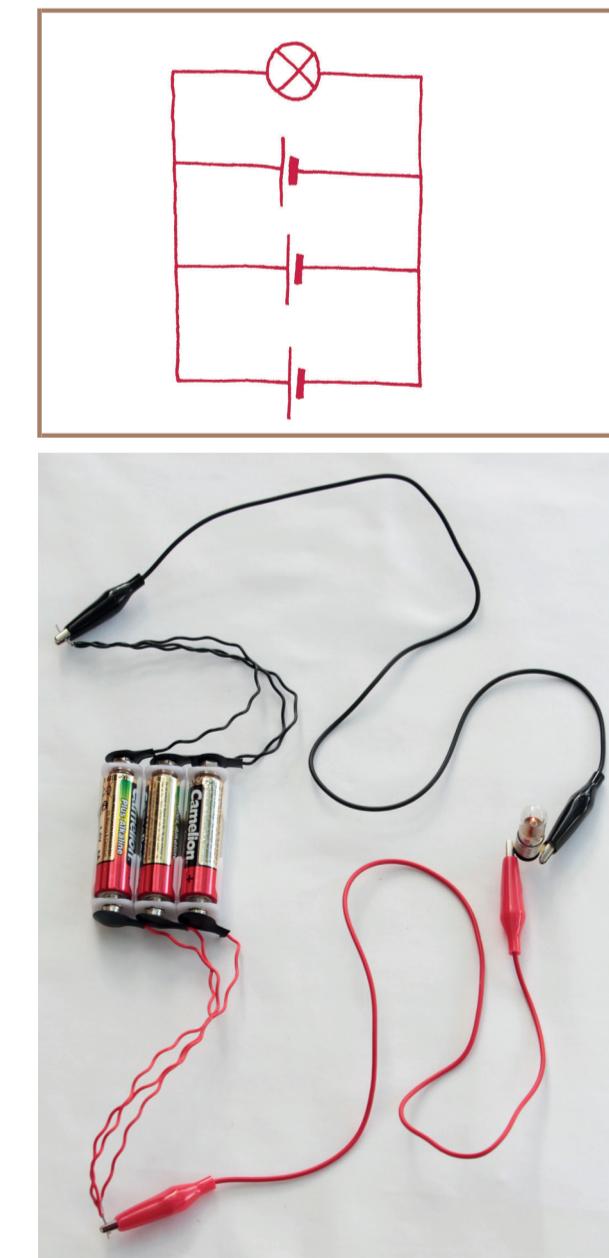


Figure 4: Three cells in parallel connected to a lamp

When cells are connected in parallel, the total voltage of the cells is the same as that of a single cell (1,5 volts).

Lamps in series

Two or more lamps can also be connected in series. The pictures below show circuit diagrams of two and three lamps connected in series with the battery. The positive terminal of the battery ($B+$) is connected to lamp 1, the other side of lamp 1 is connected to lamp 2, the other side of lamp 2 is connected to the negative terminal ($B-$) of the battery, and so forth.

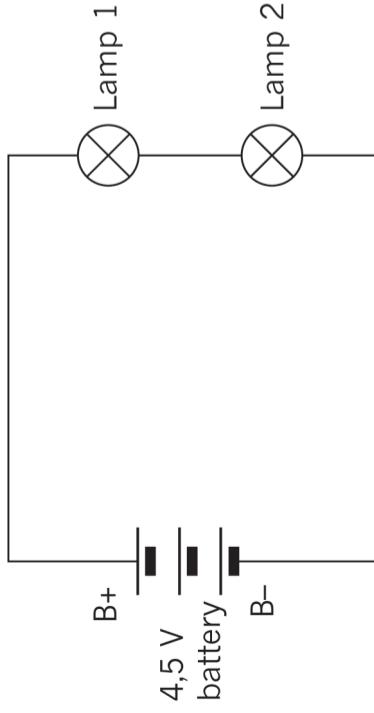


Figure 5: Two lamps in series

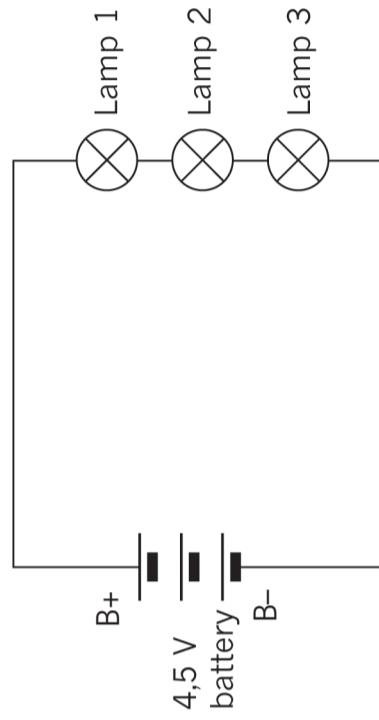


Figure 6: Three lamps in series

- How does increasing the number of lamps in series change the current and voltage in the circuit?
The overall voltage drop across the lamps remains the same, but the current decreases.

If all the lamps have the same resistance, the voltage drop across each lamp will be equal to 1,5 V. When the voltage drops of all the lamps are added, the total battery voltage of 4,5 V is obtained.
The current is the same through each lamp.

Lamps in parallel

LB p. 143
Two or more lamps can also be connected to the battery in parallel, as shown in the pictures below. The positive terminal of the battery is directly connected to one side of each lamp and the negative terminal to the other side of each lamp.

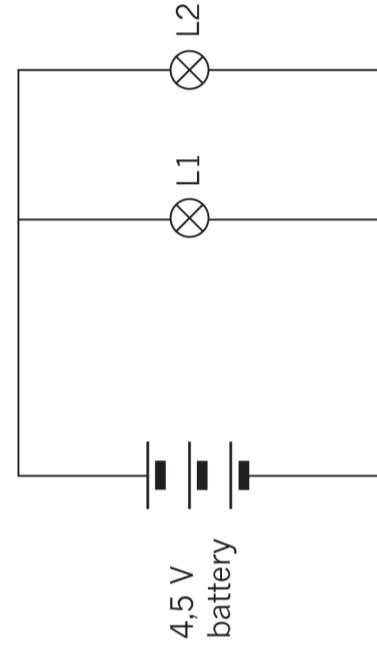


Figure 7: Circuit diagram of two lamps in parallel

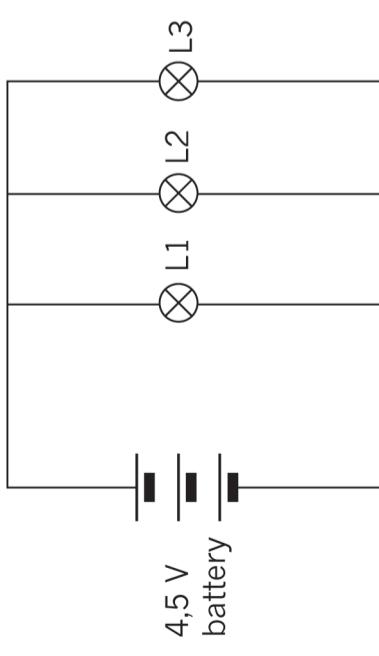


Figure 8: Circuit diagram of three lamps in parallel

The applied voltage is the same across each lamp.

The current splits so that some current goes through each lamp. If we add the three currents in the lamps we find the total current from the battery: $I_t = I_1 + I_2 + I_3$

1. Look at the circuit diagram in Figure 9 and answer the following questions:

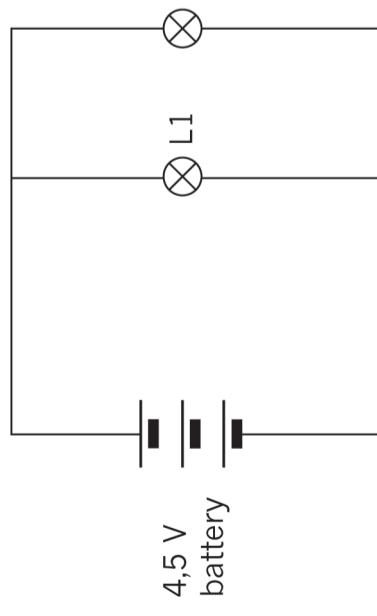


Figure 9

(a) What is the voltage drop across lamps 1 and 2?

The voltage drop across each lamp is 4.5 V. (It will actually be slightly less than that because of the internal resistance of the battery.)

(b) The total current in the circuit is 10 A. If lamp 1 has a current of 4 A flowing through it, what will the current be through lamp 2?

$$10 \text{ A} - 4 \text{ A} = 6 \text{ A}$$

Switches in series and parallel

In a circuit with one switch, the switch controls whether the current flows through the circuit or not. If the switch is open, no current flows, as the circuit is not completed. The closed switch allows the current to flow.



Figure 10: Symbols for an open switch and a closed switch

We can use two or more switches to control components in a circuit in more complex ways.

In a logic circuit, an open switch is regarded as having a value of 0, and a closed switch as having a value of 1.

The switches are the inputs that control the final state of the circuit.

If the circuit is not completed, the output is in the OFF state and has a value of 0.

If the circuit is completed, the output is in the ON state and has a value of 1.

Switches in series

In the circuit below, there are two switches in series. This gives us four different switch combinations. They are:

- switch A and B both open,
- switch A open and B closed,
- switch A closed and B open, and
- both switches closed.

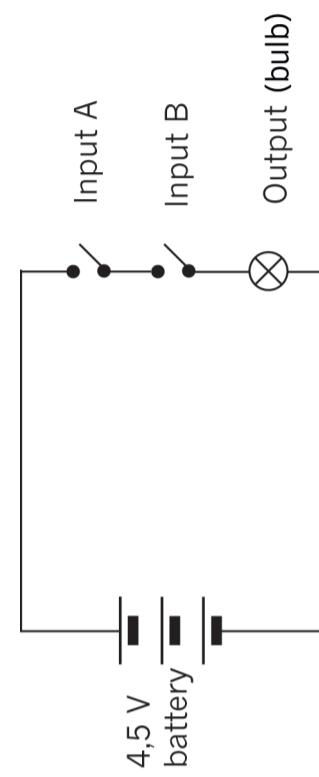


Figure 11: Circuit with two switches in series

Do you see that the current cannot flow through the circuit if either switch A or switch B is open? Both of them must be closed for the lamp to glow.



LB page 145

- In the table below, “0” means off or open, and “1” means on or closed. Copy and complete the table to show all the different combinations possible in the circuit in Figure 11. To help you, the first two rows of the table have already been completed. Make sure you understand those two rows before you complete the table.

Input A	Input B	Output
0	0	0
0	1	0
1	0	0
1	1	1

The table showing these combinations is called a **truth table**. Both switch A and switch B must be closed for the circuit to be completed (an output of 1).

So we can see that switches connected in series give us an **AND** function.

Switches in parallel

In the circuit below, there are two switches in parallel. This also gives us four different switch combinations.

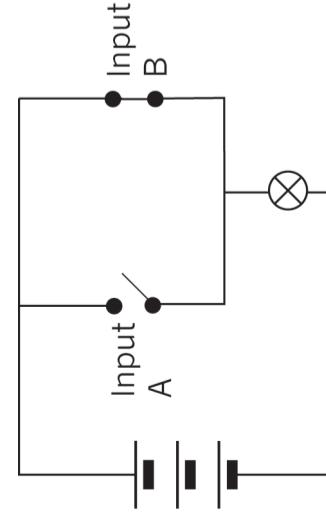


Figure 12: Circuit with two switches in parallel

Do you see that the current can go through the closed switch, even if the other switch is open?

- Complete the truth table below for the circuit in Figure 12.

Input A	Input B	Output
0	0	0
0	1	0
1	0	0
1	1	1

- Complete the truth table below for the circuit in Figure 12.

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The truth table shows that when switch A or switch B is closed, the output will be 1 (the lamp will be on). We call switches in parallel an **OR** function.

Questions for homework

- Would the lamp glow in each of these circuits? Explain your answer.
 - Figure 13:

Yes.

Explanation 1: When either one or both parallel switches are closed, the circuit is closed.
Explanation 2: The lamp is part of a complete circuit that includes the battery.

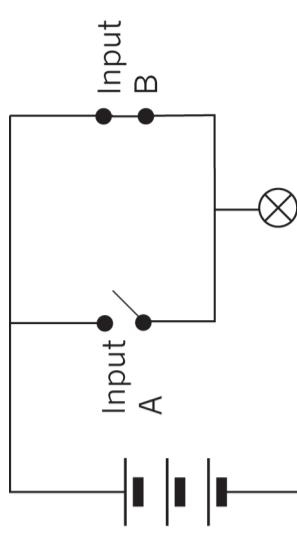


Figure 13

(b) Figure 14:



Figure 14

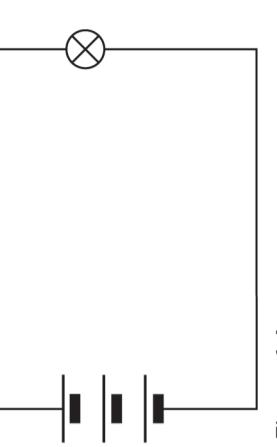


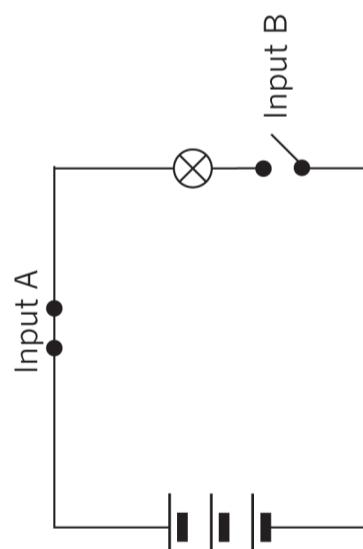
Figure 14

No.
Explanation 1: For series switches, both switches need to be closed for the circuit to be closed.
Explanation 2: The input A is open, so the circuit is not closed.



(c) Figure 15:

No.
This is the same as for question (b), except that switch A is now closed and switch B is now open.



2. A kettle must be switched on at the wall plug first and then at the kettle itself.
(a) Copy the truth table below. Fill it in to show all the possible combinations.

Wall plug switch	Kettle switch	Output
0	0	0
0	1	0
1	0	0
1	1	1

- (b) Is this an AND function or an OR function? Explain your answer.

It is an AND function. Both switches have to be closed for the kettle to work. If one is off, the kettle will not work.

11.2 Revision 2: Simple circuits

In this lesson, you will set up simple circuits, revising what you learnt about setting up circuits in Grade 8.

Set up circuits

You will need the following for this activity:

- two AA cells in cell holders,
- connecting wires,
- a switch, and
- two lamps.

Note that you can use a homemade switch and a cell holder made of insulation tape for this activity.

1. Look at the circuit below.

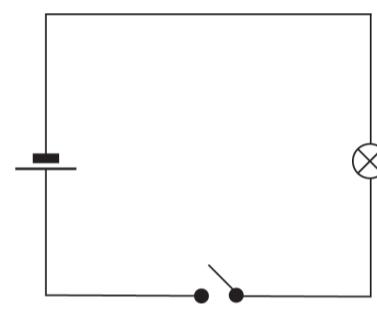


Figure 15

Set up this circuit and check that it works by closing the switch.

- (a) Does the lamp glow?

Yes, it does glow.

When you have the circuit working correctly, move on to question 2.

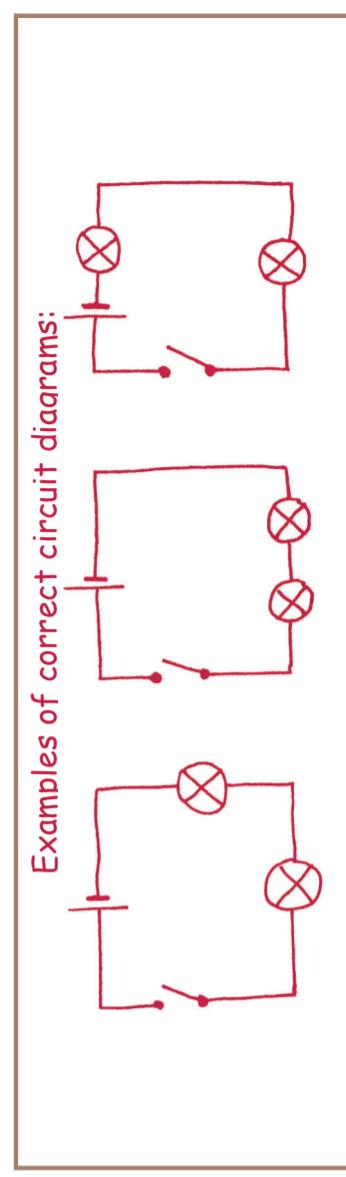
If you need to, you can troubleshoot your circuit by looking at the following:

- If the lamp doesn't light up, but the wires get hot, you may have a short circuit. This means that the lamp is not connected correctly in the circuit, or that it is faulty. Check that the lamp is connected correctly in the circuit.
- If the lamp still doesn't light up, check each component and connecting wire by replacing them, one by one. You can identify which one is faulty this way.

LB page 147

2. Add another lamp to the circuit in series with the first one.
(a) Draw a circuit diagram for this circuit.

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Examples of correct circuit diagrams:

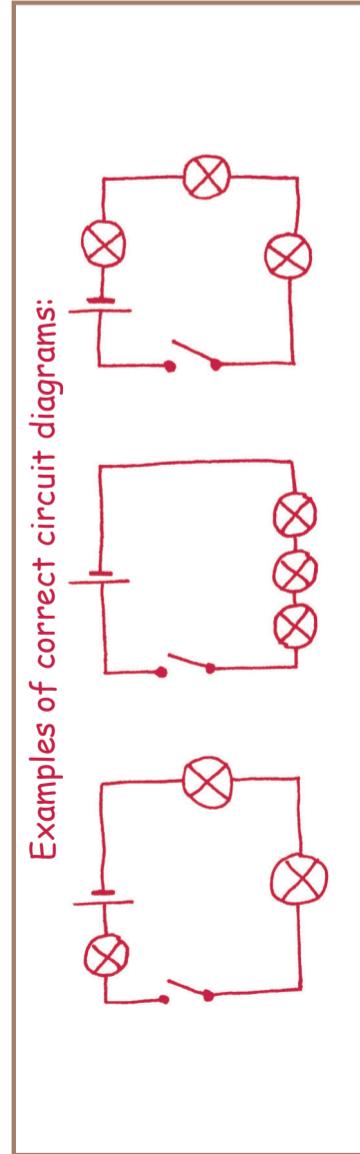
Note the third example of a correct circuit diagram. It looks like the lamps are in parallel, but electrically they are in series. It is important that learners do not confuse what a circuit looks like with how it works electrically. It would be a good idea to draw the third example on the board, and ask the learners if the lamps are in series or in parallel.

(b) What do you notice about the brightness of the lamps?

Both bulbs glow less brightly than the one that was originally on its own.

3. Set up the same circuit, but add another bulb in series with the first bulb.

(a) Draw a circuit diagram for this new circuit.



(b) Write what you notice about the lamps in this circuit.
All three lamps glow less brightly than the two lamps in the previous circuit.

4. Write down your conclusions about changing the number of cells and the number of lamps in the circuit.

Adding an extra lamp in series to a circuit that already has one or more lamps connected in series, results in all the lamps glowing less brightly (more dimly) than before. Explanation: The electrical energy is being shared between the three lamps, so each lamp gets less electrical energy.

11.3 Testing voltage and current in circuits (Ohm's Law)

LB page 148

In this lesson, you will investigate the relationship between the values of the voltage and the current in a circuit. You will need to use a multi-meter that can be set to measure the voltage, resistance or the current in a circuit.

Begin by reading the text below on how to use a multi-meter correctly.

Measuring resistance

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Identify the section labelled “ Ω ” on the multi-meter dial.

- Connect the red test lead to the “V Ω mA” terminal, and the black test lead to the “COM” terminal.
- Adjust the function selector switch to the highest range in the section labelled “ Ω ”. There are different resistance ranges on a multi-meter, such as $200\ \Omega$, $2\ k\Omega$, $200\ k\Omega$ and $2\ M\Omega$.
- Connect the ends of the test leads across the unknown resistor as shown.
- Ensure that the resistor is isolated from any other component or power supply.
- Read the resistance value from the display. If the displayed value is zero or very small, for example 0,001, then switch the function selector switch to a lower resistance range. Keep on switching to lower resistance ranges until the displayed value is larger than 1. Remember that the displayed value is for the units of measurement indicated by the range you selected. It may be Ω , $k\Omega$ or $M\Omega$.

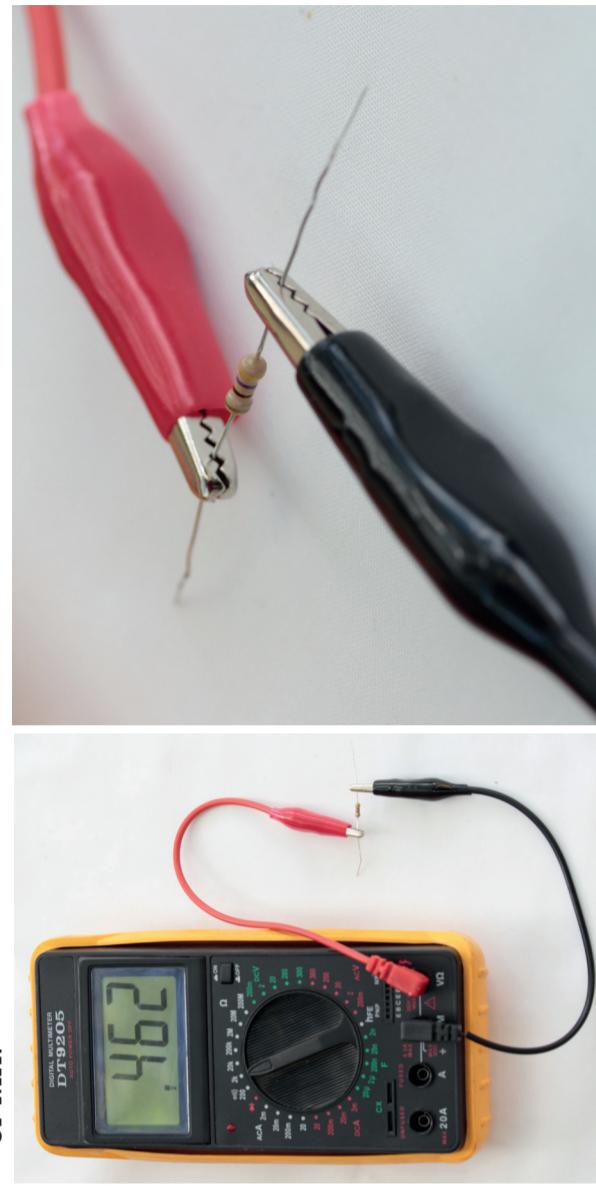


Figure 17: Multi-meter set and connected to measure resistance



Measuring voltage

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Identify the section labelled “DCV” on the multi-meter dial.

- Connect the red test lead to the “V Ω mA” terminal, and the black test lead to the “COM” terminal.
- Adjust the range selector to the “DCV”.
- Set the meter on the highest range.
- Connect the other ends of the test leads parallel across the part of the circuit where the voltage is to be measured; red test lead to positive (+), and black test lead to negative (-).
- Read the voltage from the display. You may need to adjust the function selector to choose a different voltage range, so that the reading is displayed properly and accurately.



Figure 18: Multi-meter set and connected to measure current

Measuring current

LB p. 149

Identify the section labelled “DCA” on the multi-meter dial.

- Connect the red test lead to the “V Ω mA” terminal and the black test lead to the “COM” terminal. If the current to be measured is between 200 mA and 10 A, connect the red test lead to the “10 A” terminal.
- Adjust the function selector to the “A” (ampere) region. If you are measuring an unknown current, start from the highest range, then adjust to a proper lower range for the best accuracy.
- Connect the other ends of the test leads in series with the part of the circuit where the current is to be measured. (Disconnect the circuit and place the meter in series.)
- Read the current value from the display.

Action research

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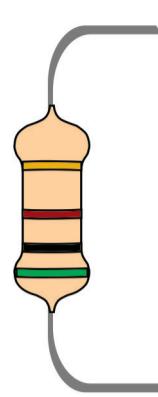
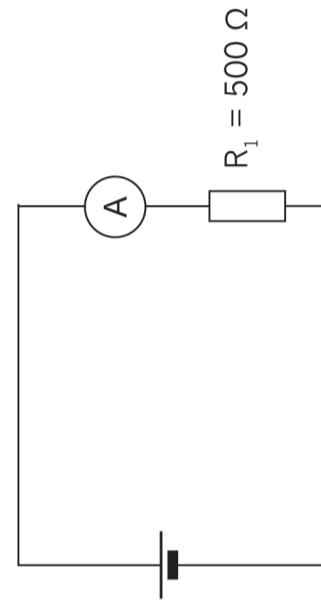


Figure 19: A 500 ohm resistor

You will need the following for this activity:

- three penlight cells (AA) in holders,
 - a 500 ohm resistor, with the colour bands exactly as in Figure 19, and
 - two multi-meters, or an ammeter and a voltmeter.
1. Set up the circuit as shown in Figure 20 below, using a cell, resistor and ammeter. If you use a multi-meter instead of an ammeter, set it on the amps scale.



- Figure 20: Circuit with one cell, resistor and ammeter
2. Now connect a voltmeter across the resistor, as shown in Figure 21. If you use a multi-meter instead of a voltmeter, set it on the volts scale.

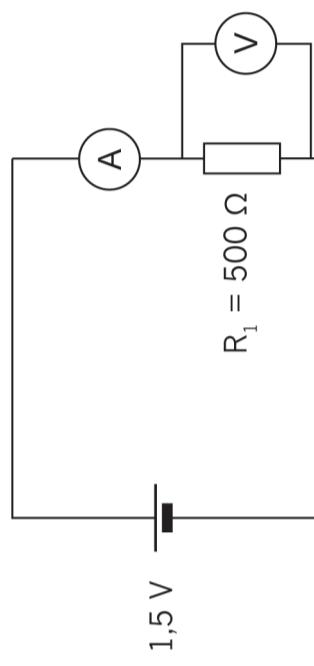


Figure 21: Circuit with one cell, resistor, ammeter and voltmeter across resistor

Record the readings.

V = 1,5 V or slightly less
I = 3,0 mA (milliamperes) or slightly less



3. Now connect a second cell in series as shown in the circuit diagram below:

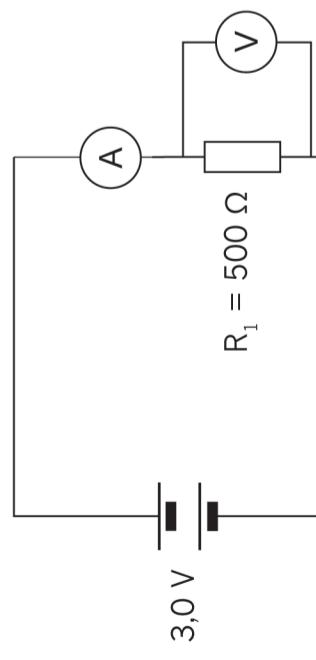


Figure 22: Circuit with two cells in series, resistor, ammeter and voltmeter across resistor

Record the readings.

V = 3,0 V or slightly less

I = 6,0 mA (milliamps) or slightly less

4. Now connect a third cell in series as shown in Figure 23.

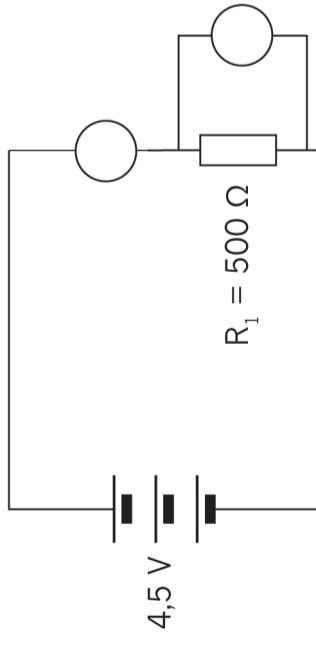


Figure 23

Record the readings.

V = 4,5 V or slightly less

I = 9,0 mA (milliamps) or slightly less

5. Copy the table below and fill in your readings.

	With one cell	With two cells	With three cells
Voltage	1,5 V	3,0 V	4,5 V
Current	3,0 mA	6,0 mA	9,0 mA

6. Copy the set of axes below onto graph paper. Plot the graph.

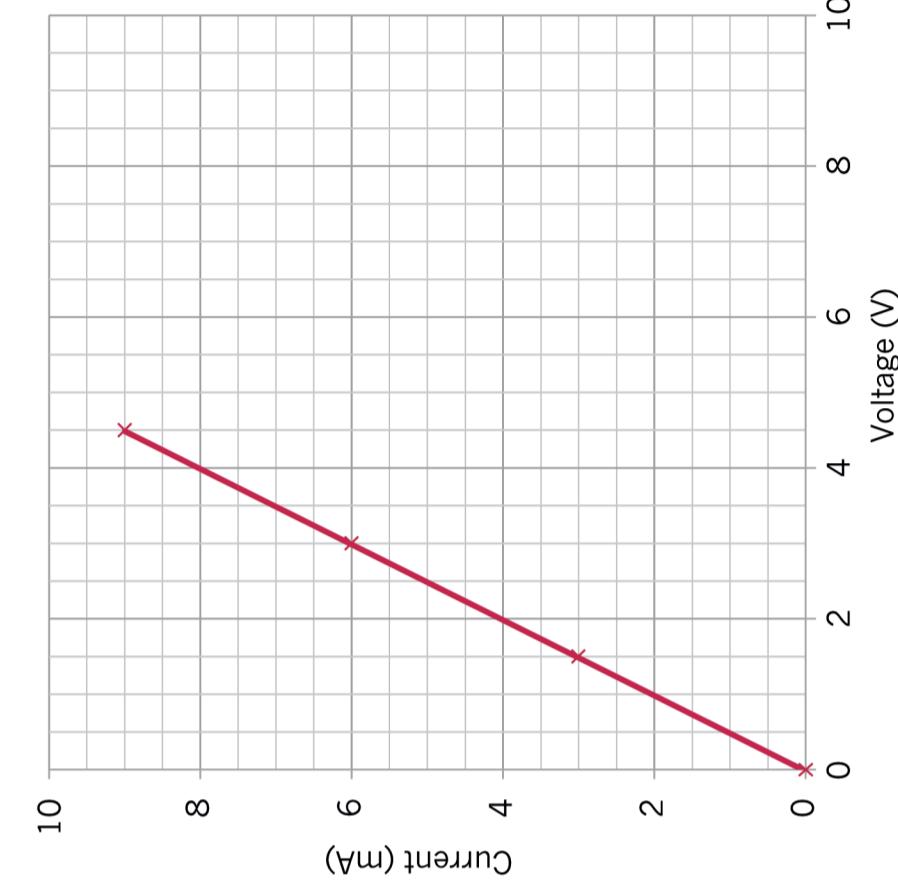


Figure 22: Graph of the relationship between potential difference and current

7. Describe the relationship between voltage and current for a 500 Ω resistor.

The co-ordinates lie in a straight line. The origin is on this line.

- Did you notice that as the voltage is increased the current increases?
- Is your graph in a straight line?

There is a **directly proportional relationship** between voltage and current. As the voltage is doubled, the current will double; and as the voltage is tripled, the current will triple.

Next week

Next week, you will look at different kinds of resistors used in circuits. You will also practise doing calculations using the formulas in Ohm's Law.

CHAPTER 12

Resistor colour codes and Ohm's Law

LB page 153

In this chapter, you will learn how to use resistors in electric circuits to control a current. You will discover that there are different kinds of resistors for different purposes, and you will learn how to read the amount of resistance on a resistor. You will also learn about Ohm's Law, which relates the quantities of voltage, current and resistance, and you will use formulas to calculate the values of voltage, current and resistance.

- 12.1 Resistors and their identification codes 197
12.2 Ohm's Law 200
12.3 Calculations using Ohm's Law 202

Note to the teacher:

If learners have coloured pencils, they should bring them to class for lesson 2.1

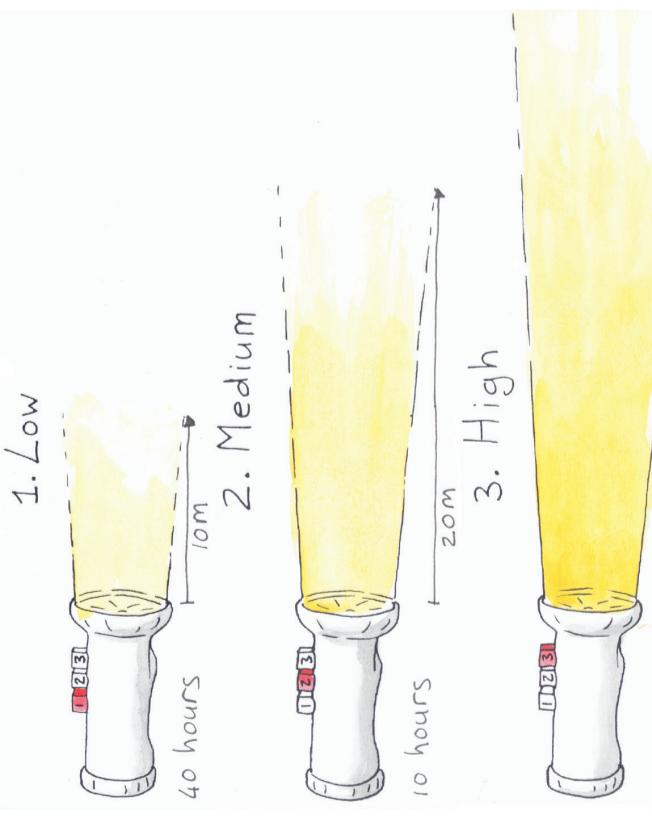


Figure 1: You can change the brightness of the light on some torches. The brighter the light you choose, the faster the battery will run out.

12.1 Resistors and their identification codes

Learners must make the connection between the concept of resistance and the concepts they have met already, namely voltage and current. They learn to read the colour codes representing the resistance values of resistors. They have to master the units of resistance, such as ohm, kilo-ohm and mega-ohm.

You can give your learners real resistors to "read" and find the resistance values. Most electrical equipment has some control circuit in it, and you will see circuit boards like the ones in the Learners Book.

Let learners take apart an old desktop computer – they will find plenty of circuit boards with resistors on them. Chargers and transformers for cell phones and laptop computers have control circuits in them, and there too learners will find resistors (along with many other interesting components they should learn about).

12.2 Ohm's Law

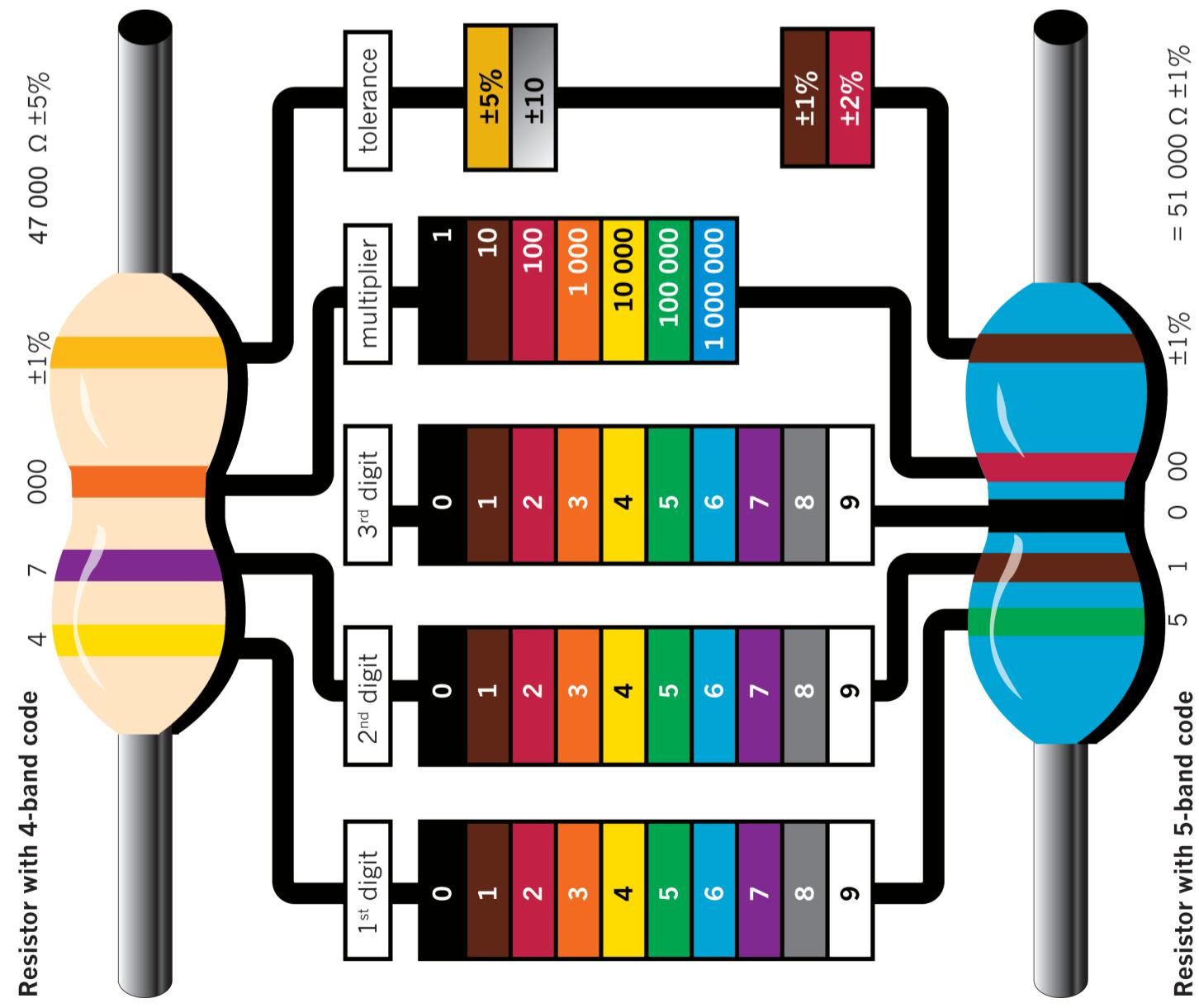
Learners meet the mathematical form of the relationship between voltage, current and resistance, $V = I \times R$, and they practise changing the subject of that formula.

12.3 Calculations using Ohm's Law

The learners follow example calculations using the Ohm's Law relationship. They then calculate currents, voltages and resistances for nine questions.



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12.1 Resistors and their identification codes

What is resistance?

Electricity flows far more easily through copper wire than through plastic wire, string or grass. Copper wire has a low resistance to electricity flow, whereas plastic wire has a high **resistance**. Because electricity flows easily through copper wire, copper is a good **conductor** of electricity.

The resistance that an object, for example a piece of wire, offers to the flow of electricity can be measured. Resistance is measured in ohms. We use the symbol Ω .

To **resist** something means to try prevent it. If you sit in a tree and the wind blows hard, you can resist falling down by clinging to the branches.

To **conduct** means to allow something to pass through.

When electricity flows through a conductor, heat is generated. Some metals, such as nickel and chrome, resist the flow of electricity quite strongly, and heat up when even a small electric current is forced to flow through it. The heating elements of stoves and kettles are normally made of a mixture of nickel and chrome. When some metals get extremely hot, they **emit** light.

If the resistance in a circuit is very low, for example when the terminals of a cell are connected with a piece of thick copper wire, the current will flow very strongly. This is called a “short circuit”. It can result in so much heat being generated that damage is caused to the cell and other parts of the circuit, the conducting wires can melt and a fire can start.

By adding more resistance to a circuit, you can control how great the current is that flows through the circuit. In this way, you can protect the components in a circuit from too much current flowing through them. Increasing the resistance also means the cell or battery powering the circuit will last longer. You can add precise amounts of resistance by using resistors with the required resistance value.

Figure 2: How to read the colour bands on a resistor to find out what its resistance is. (You will only work with resistors with four-colour bands, such as the one at the top.)



What is a resistor?

A resistor is a specially designed component that is normally used in a circuit to limit the current. Resistors are made of materials with a high resistance to electricity flow, and come in the form of thin wires or films. Resistors also have precise resistance values that don't change much in different environmental conditions.

The most commonly used resistors look like tubes, with two wires to connect it to the circuit. The symbol to show a resistor in a circuit diagram is an open rectangle or a zigzag line.



Figure 3: A typical resistor

Low-value resistors often have their resistance value printed on them in numbers, while high-value resistors are coded, using coloured bands. The first three bands give the value of the resistor in ohms. The colour-code chart on the second page of this chapter will help you to work out the resistance value in ohms. Resistors are the most commonly used components in electronics, as they are useful to control current. You will see how they are used in the following weeks.

Units of measurement: ohms, kilo-ohms and mega-ohms

- $1 \text{ k}\Omega = 1000 \Omega = 10^3 \Omega$
- $1 \text{ M}\Omega = 1000 \text{ k}\Omega = 1000000 \Omega = 10^6 \Omega$

The fourth band on a resistor shows the accuracy rating as a percentage. This is also called the "tolerance". The band is gold or silver, depending on the tolerance. For the circuits you will be building, this is not important.

Kilo means multiply by a thousand, for example $1 \text{ km} = 1000 \times 1 \text{ m}$.
Mega means multiply by a million.

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The resistance of resistors

1. Work out and write down the resistance of each of these resistors:

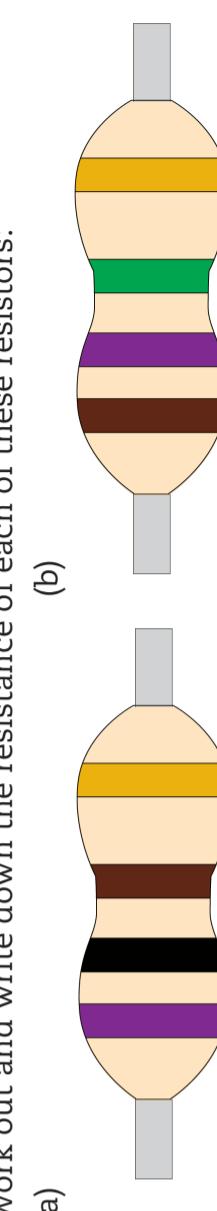


Figure 5

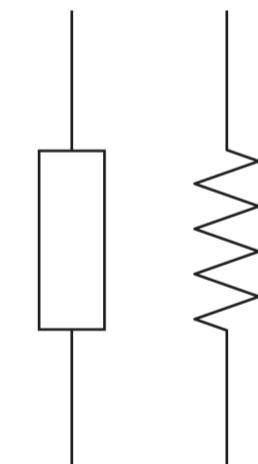


Figure 4: Circuit symbols for resistors

LB p. 157

The resistance of resistors

1. Work out and write down the resistance of each of these resistors:

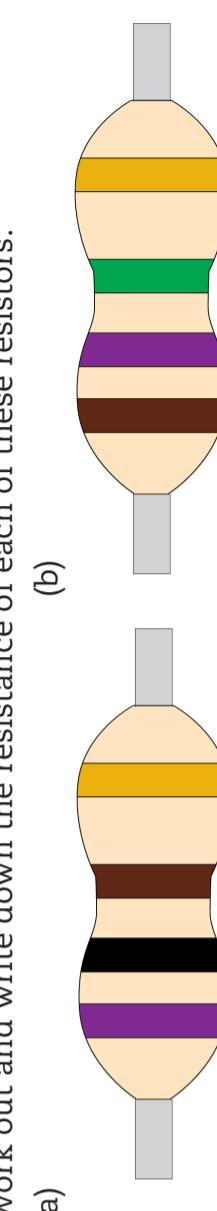


Figure 6

700 Ω

1700 $k\Omega$

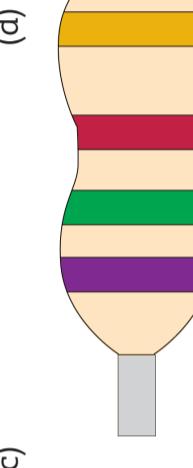


Figure 7

7.5 $k\Omega$

43 $M\Omega$

2. Copy blank resistors with the bands into your books. Fill in the colour codes to show the given resistance. If you don't have coloured pencils or pens, write the colour of each band above it.

(a) $200 \text{ k}\Omega$

red, black, yellow

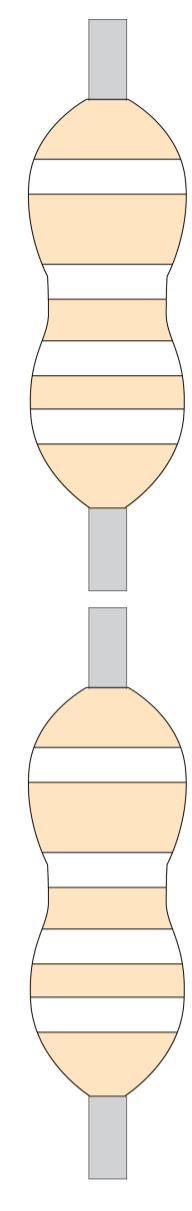


Figure 8

Figure 9

Figure 9

3. Describe the function of a resistor as a component in an electrical circuit.

It reduces the current through the circuit, and reduces the voltage drop across other circuit components that are in series with the resistor.

Figure 10

CHAPTER 12: RESISTOR COLOUR CODES AND OHM'S LAW



12.2 Ohm's Law

There is a special relationship between the voltage, current, and resistance in any circuit. You can control any one of these three **variables** by changing the other two variables.

Ohm's Law states that as voltage increases, the current increases if the resistance is **constant**.

In the formula for Ohm's Law:

- **V** is the **potential** or **voltage difference** measured in volts,
- **I** is **current** measured in amps, and
- **R** is **resistance** measured in ohms.

Figure 11 shows this relationship in a formula triangle.

When the voltage and current are known, the resistance can be calculated with:

$$R = \frac{V}{I}$$

When the resistance and current are known, the voltage can be calculated with:

$$V = I \times R$$

When the resistance and voltage are known, the current can be calculated with:

$$I = \frac{V}{R}$$

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A **variable** is a quantity that can have different values, for example the amount of water in a tank. A **constant** is a quantity that always has the same value, for example gravitational acceleration. Sometimes we call a quantity a constant because we decide to keep it constant.

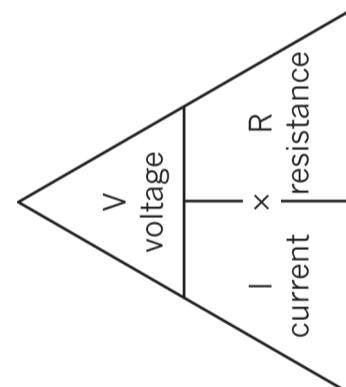


Figure 11

2. How will the current change if the voltage supplied by the battery of cells is kept constant but the resistor is replaced by another resistor with a lower resistance?
The current will increase.

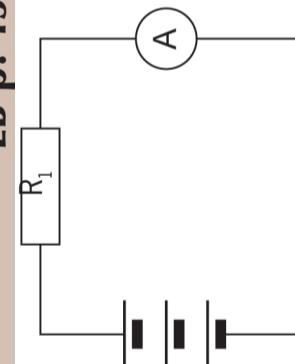
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3. How would you describe the relationship between the current and the voltage in a circuit?
They are in direct proportion to each other: when one changes by a factor the other one changes by the same factor (for example, if one is increased to five and a half times its value the other will also increase five and a half times. If one is made a third of its value, the other will decrease to a third of its previous value).

4. Which of these changes will cause the current through an electrical circuit to decrease? Write down all the letters of the statements that are correct.
(a) a decrease in the voltage
(b) a decrease in the resistance
(c) an increase in the voltage
(d) an increase in the resistance
(a) and (d)

5. An electrical circuit has three 1.5 V cells in series that is connected to a lamp and a resistor in series. Which of the following things would cause the lamp to shine less brightly? Write down all the letters of the statements that are correct.
(a) an increase in the voltage of the battery (add another cell)
(b) a decrease in the voltage of the battery (remove a cell)
(c) a decrease in the resistance of the resistor
(d) an increase in the resistance of the resistor
(b) and (d)

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1. What does Ohm's Law say will change in a circuit when the resistance is kept constant but the number of cells in series is increased?

The current will increase in direct proportion to the number of cells.

Figure 12

Questions

Consider the following circuit in Figure 12 on the right:



12.3 Calculations using Ohm's Law

In the previous lesson, you learnt how Ohm's Law can be used to predict what will happen when you change one or two of the following variables: current, voltage or resistance. You will now use the formulas of Ohm's Law to make predictions. Remember to use the correct units in the formula!

Example 1

Calculate the value of the resistance in the diagram below if the voltage across the resistor is 12 V and the current through the resistor is 2 A.

$$R = \frac{V}{I}$$

$$= \frac{12 \text{ V}}{2 \text{ A}}$$

$$= 6 \Omega$$

Figure 13

Example 2

Calculate the value of the voltage supply in the circuit below if the resistor has a value of 4 Ω and the current through the resistor is 2,5 A.

$$V = I \times R$$

$$= 2,5 \text{ A} \times 4 \Omega$$

$$= 10 \text{ V}$$

Figure 14

Example 3

Calculate the value of the current in the circuit below if the resistor has a value of 3 Ω and the voltage across the resistor is 12 V.

$$I = \frac{V}{R}$$

$$= \frac{12 \text{ V}}{3 \Omega}$$

$$= 4 \text{ A}$$

Figure 15

Questions

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- What will the potential difference be if the current in a circuit is 10 A and the total resistance is 1 000 Ω?

$$V = I \times R, \text{ so } V = (10 \text{ A}) \times (1 000 \Omega) = 10 000 \text{ V}$$

- Given V = 10V and R = 1 kΩ, what will the value of the current be in a circuit?

$$V = I \times R, \text{ so } I = V \div R = (10 \text{ V}) \div (1 000 \Omega) = 0,010 \text{ A}$$

- Given V = 20V and R = 5 kΩ, solve for the current.

$$V = I \times R, \text{ so } I = V \div R = (20 \text{ V}) \div (5 000 \Omega) = 0,004 \text{ A}$$

- A tumble dryer in a laundry service uses a 220 V power source. The coils of the heater provide an average resistance of 12 Ω. What is the current flowing through the heating coils?

$$V = I \times R, \text{ so } I = V \div R = (220 \text{ V}) \div (12 \Omega) = 18,3 \text{ A}$$

- A 9 V battery maintains a current of 3 A through a radio. What is the resistance in the circuit?

$$V = I \times R, \text{ so } R = V \div I = (9 \text{ V}) \div (3 \text{ A}) = 3 \Omega$$

- If the voltage across a circuit is increased four times, what would you expect to happen to the current through the circuit?

It will increase four times as well.



7. (a) In the circuit below, calculate the resistance value of the resistor.

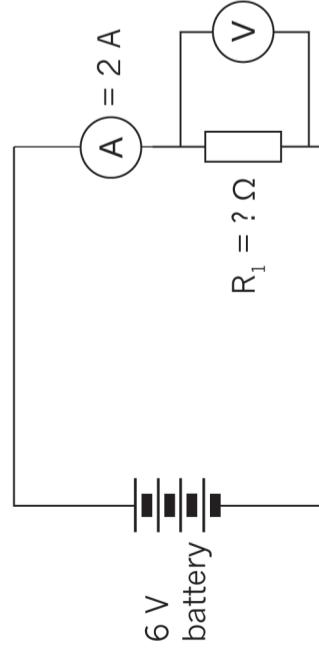


Figure 16

$$V = I \times R, \text{ so } R = V \div I = (6 \text{ V}) \div (2 \text{ A}) = 3 \Omega$$

- (b) If two more cells are added to the circuit, will the current increase or decrease? Check your prediction using the formula.

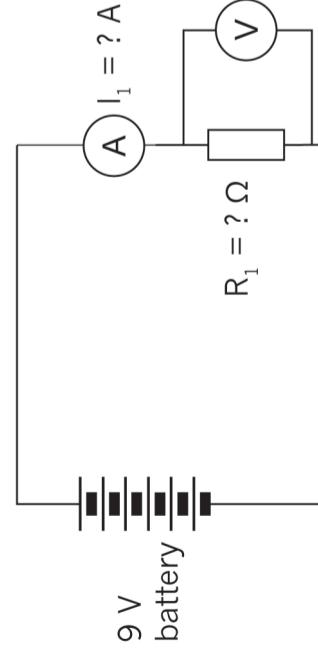


Figure 17

Increase by two cells means $2 \times 1.5 \text{ V} = 3 \text{ V extra}$
 $V = I \times R, \text{ so } I = V \div R = (9 \text{ V}) \div (3 \Omega) = 3 \text{ A}, \text{ which is bigger than } 2 \text{ A.}$

8. Calculate the battery voltage for the circuit below:

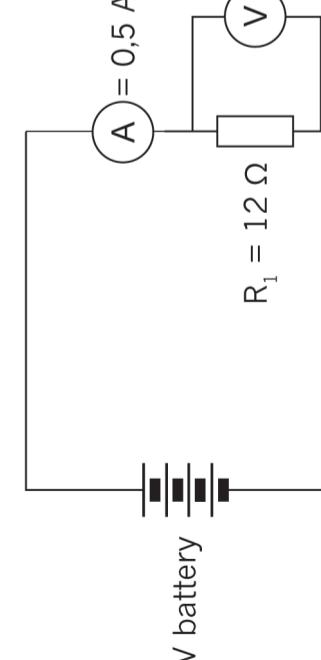


Figure 18

$$V = I \times R, \text{ so } V = (0.5 \text{ A}) \times (12 \Omega) = 6 \text{ V}$$

9. Look at the circuit below:

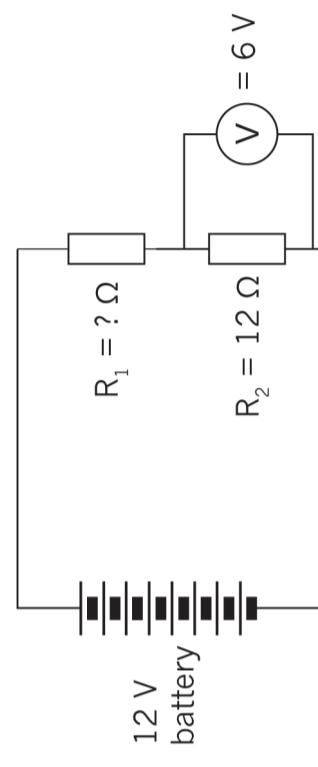


Figure 19

- (a) Calculate the current through R_1 .

$$V = I \times R, \text{ so } I = V \div R = (6 \text{ V}) \div (12 \Omega) = 0.5 \text{ A}$$

- (b) What will the current be through R_1 ?
0.5 A. The resistors are in series, so the same current flows through each resistor.

- (c) What will the voltage drop across R_1 be?

$$V = 12 \text{ V} - 6 \text{ V} = 6 \text{ V}$$

- (d) What will the resistance value of R_2 be?
12 Ω. It has the same voltage drop across it as R_1 .

Next week

In the next chapter, you will learn about components commonly used in electronic systems and their special functions.

CHAPTER 13

Electronic components 1

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In this chapter, you will learn about electronic systems and about components in electronic circuits. You will also learn about the following control devices: switches, diodes and transistors. Finally, you will make a simple transistor circuit.

- | | |
|------------------------|-----|
| 13.1 Switches | 208 |
| 13.2 Diodes | 214 |
| 13.3 Transistors | 217 |

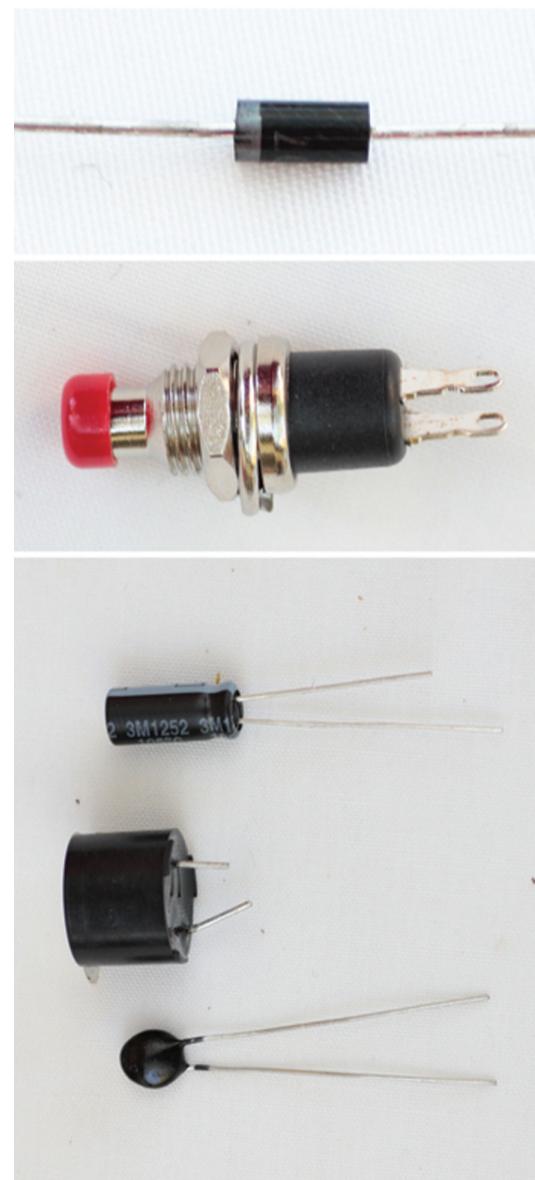


Figure 1: A few examples of electronic components that we will deal with in this chapter

13.1 Switches

The learners have to study circuit diagrams and explain how each circuit works. They have to complete nine such tasks.

13.2 Diodes

Learners read an explanation of what a diode does, and interpret the explanation by explaining, themselves, the differences in the use of a normal diode and a light-emitting diode.

13.3 Transistors

Learners read an explanation of what a transistor does and apply their knowledge to explain how a transistor can act as a very sensitive switch. It is very important that learners interpret the photo of the circuit in Figure 19 to understand that it is electrically the same circuit as the one shown by the circuit diagram in Figure 18. Learners need to practise this kind of “translation” between how a circuit looks on a circuit diagram, and how it looks in real life, for them to be able to build circuits for given circuit diagrams later on.

The teacher should therefore listen to individual learners explaining how the circuit works. Learners will need to point to parts of the circuit on the diagram and the photo while they are explaining.

The teacher can also ask learners to explain the circuit to each other in groups of two or three learners. The purpose of such group work is for each learner to get an opportunity to say what they are thinking about the circuit. It may be easier for them to say it than to write it, and they may find it easier to first say it in their home language.



13.1 Switches

A switch controls the electric current by closing or opening the circuit. There are various types of switches that control the circuit in different ways. In this lesson, you will learn about manual switches that a user can turn on or off.

List different switches

1. Think about different switches that you use daily and make a list of as many of them as you can.
 - light switches
 - plug switches
 - switches on appliances such as kettles, toasters, lamps and ovens
 - switches on electronic devices such as remote controls and cell phones

Push button switch

Push button switches are often used for doorbell circuits, as in Figure 2. This simple doorbell circuit consists of cells in series, a push button and a buzzer, all connected by conducting wire. A person visiting the house presses the button for a short time and then releases it.



Figure 2: A simple doorbell circuit

A doorbell circuit

1. Draw the circuit diagram of the doorbell circuit in Figure 2. Use the correct circuit diagram symbols. Note that the cells are in series.

When the push button is pressed in, the circuit is cor makes a sound. The buzzer makes a sound for as long as the push button is pressed in.

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Single-pole, single-throw switch (SPST)
Switches are named using the words “pole” and “throw”. Pole refers to the number of circuits the switch controls, and throw refers to how many contacts the switch can make.

Single-pole, single-throw switches (SPST) control one input circuit and make one contact with the output circuit.



Figure 3: The symbol for an SPST switch

An example of an SPST is a lighting circuit. Below is a typical lighting circuit. When the switch is closed, the current will flow from the positive terminal (+) of the battery through the switch, through the lamp and back to the negative (-) terminal of the battery.

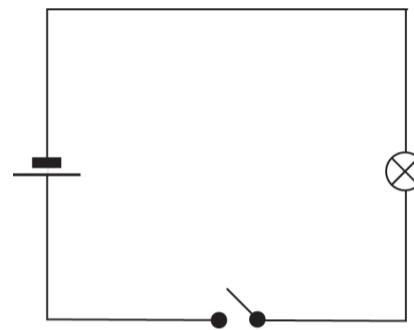


Figure 4: A typical light circuit with an energy source, switch and lamp

Single-pole, double-throw switches (SPDT)

Single-pole, double-throw switches control one circuit, but they make two contacts so that they can control two devices. They turn on device 1 in one position and device 2 in the other position. There is no “off” position for this switch.

An example of an SPDT is a switch that turns on a red lamp in one position and a green lamp in the other position.



Figure 5: The symbol for an SPDT switch



A lighting circuit

The circuit diagram below shows a two-way lighting circuit.

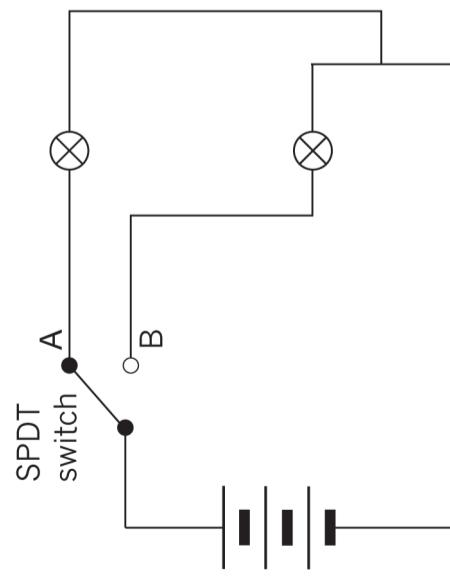


Figure 6: A circuit with a battery, two lamps and an SPDT switch controlling two outputs

1. Explain in your own words how this circuit works.

The explanation must mention that at any given time one of the lamps is on and the other is off.

2. Think about how you can use an SPDT switch. You can make up an example, as long as it makes sense.

A few examples could be:

- green and red lights to show whether a door is open or closed,
- a heat-sensitive switch to show if a plate on a stove is hot or cold,
- lights to show if the water level in a tank is low or high (switch connected to a floating lever device),
- to show if a train is arriving at a level crossing or not, and
- a TV that shows a green light when it's on, a red light when it's off but it is supplied with electrical energy, and no light when it's not being supplied with electrical energy (for instance if the plug is pulled out, or the wall switch is off, or there's a power failure).

3. Look at Figure 6 again. An SPDT switch controls two possible outputs. They cannot both be ON, nor can they both be OFF. Is this an example of OR logic or AND logic? Explain your answer.

It is an example of OR logic since one throw is always 1 while the other is 0.
In other words, only the 1-0 and 0-1 inputs are possible with an SPDT switch.

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It's impossible to give a 0-0 or a 1-1 input.

As long as the circuit is supplied with electrical energy, it's impossible to get a 0 output.

4. Look at the circuit diagram below. It shows how one light can be controlled by two different switches.

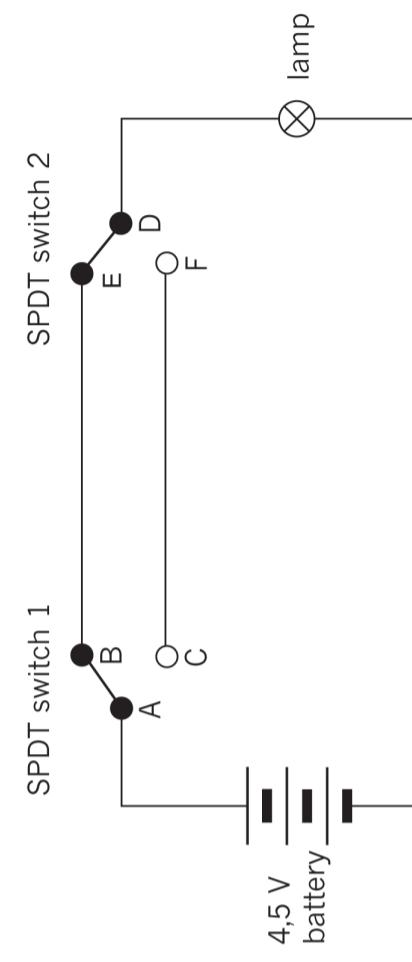


Figure 7: A circuit with two SPDT switches is often used to control a lamp with one switch at each end of a long passage. It is also used to control a lamp with one switch at the bottom of a staircase, and the other switch at the top of the staircase.

- (a) Will the lamp turn on if A connects to C and D connects to F? **yes**
(b) Will the lamp turn on if A connects to C and D connects to E? **no**

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(c) Will the lamp turn on if AB and ED are closed? **yes**
(d) Will the lamp turn on if DF and AB are closed? **no**
(e) Explain why the type of circuit in Figure 7 is useful for controlling the lamp in a long passage.

If you want to walk down a long passage at night, you want to switch the lamp on when you enter the passage on the one side, and switch it off when you exit the passage on the other side. If you could not switch off the lamp on the other side, the lamp would remain on, and you would be wasting electrical energy.



Double-pole, double-throw switches (DPDT)

A double-pole, double-throw switch (DPDT) is like two SPDT switches with their switch levers attached to each other. There are two input circuits, and for each input circuit, there are two possible output circuits.

In the symbol below, the dotted line shows that the switches operate together.

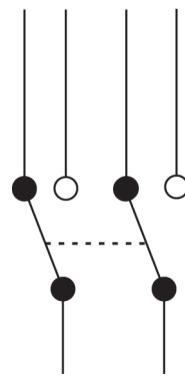


Figure 8

Consider an automatic car gate powered by an electric motor. To open the gate, the motor should turn in one direction. To close the gate, the motor should turn in the opposite direction. How can the direction in which the motor turns be changed? The way to do this is to change the direction of the current through the electric motor. Double-pole, double-throw switches can be used to reverse the direction of current through a circuit, so they are useful in applications such as automatic car gates. The circuit diagram below shows how a DPDT switch can change the direction of current through an electric motor.

When the DPDT switch is moved to the other position than in Figure 9, the current will flow through the circuit in the following order:

- from the positive terminal of the battery,
- through the ON/OFF switch to 1,
- through the top part of the DPDT switch from 1 to 5,
- through the motor from M2 to M1,
- to 6,
- through the bottom part of the DPDT switch from 6 to 2, and
- to the negative terminal of the battery.

A gate motor circuit

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1. Explain in your own words how this circuit works.

Learners' own formulation. The answer must mention that both terminals of the motor are connected to the two poles of the battery at any time when the switch is in one of its two positions, and that flipping the switch only changes which terminals are connected to which poles.

2. Explain the difference between an SPDT and a DPDT switch.

An SPDT switch has one pole which allows you to choose between two possible output sides to which the circuit will be connected. A DPDT switch has two poles, and each of these poles has two possible output sides.

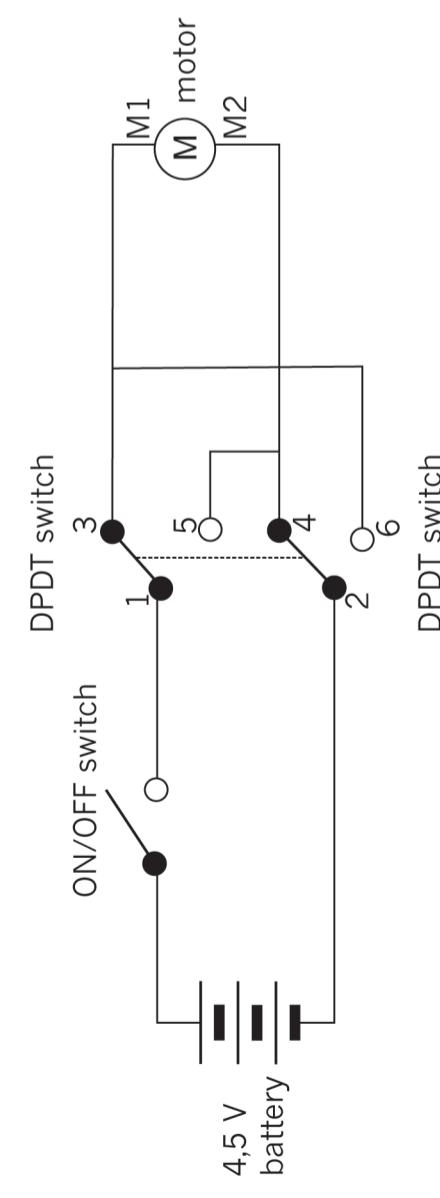


Figure 9: A circuit where a DPDT switch controls the direction in which an electric motor turns

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The motor shaft will rotate in one direction when the current passes through it from terminal M1 to M2, but the motor shaft will rotate in the opposite direction when the current passes through it from terminal M2 to M1.

When the ON/OFF switch is switched ON, with the DPDT switch in the position indicated in the diagram above, the current will flow from the positive of the battery, through the ON/OFF switch to 1, to 3, through the motor from M1, to M2, to 4, to 2 and back to the negative of the battery.



13.2 Diodes

A diode is a component with two terminals that can be connected in a circuit. The function of a diode in a circuit is to allow an electric current to flow in the forward direction and to block current in the opposite direction.

If the anode is connected to a higher voltage than the cathode, the current will flow from the anode to the cathode. This is called "forward bias". If the diode is put in the circuit back to front, so that the voltage at the cathode is higher than the voltage at the anode, the diode will not conduct electricity. This is called "reverse bias".

Diodes are normally used to prevent damage to other components in circuits. For example, some components have positive and negative terminals and will be damaged if a current goes through them in the wrong direction. A diode can protect against a current flowing the wrong way if a battery was put in incorrectly to power the components. If you put batteries into a radio incorrectly, a diode will prevent damage to the radio.

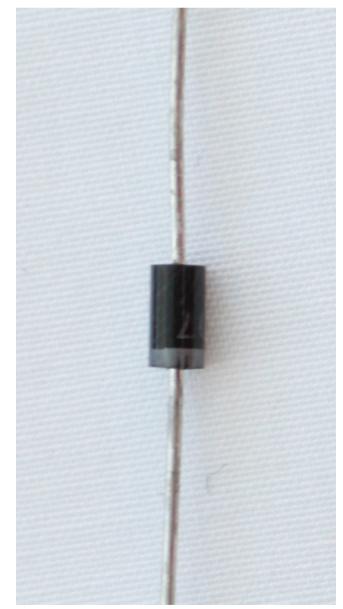


Figure 10: A diode

Diodes vary considerably in size, current-carrying capacity, and reverse blocking voltage. They range from small diodes that can only handle 20 mA with a reverse blockage of 30 V, to large industrial diodes that can carry hundreds of amps and block up to thousands of volts. You can use a multimeter or a simple tester (battery, resistor and LED) to check in which direction a diode conducts.

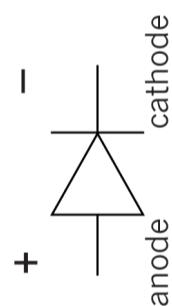


Figure 11: Circuit symbol of a diode. The current flow in a diode is in the direction of the arrow head.

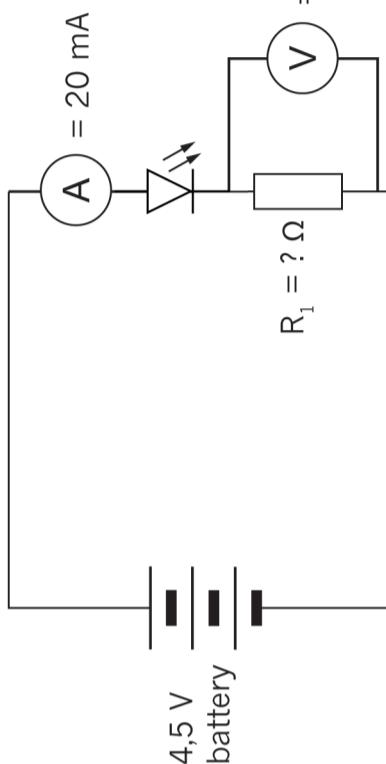


Figure 14: LED circuit with a current-limiting resistor.

Light-emitting diodes (LED)

A light-emitting diode (LED) is a special kind of diode that glows when electricity passes through it. LEDs produce light of specific colours, based on the materials they are made from. For example, they can produce red, amber, yellow, green, blue, violet and white. The most common colour is red.

LEDs are often used to show if a circuit is working. Think about the small red light glowing on the front of a TV set that can sometimes change from red to amber.

LEDs are used as indicators in many devices, including calculator screens and digital clocks.

The LED will only allow current to pass in one direction. The cathode is normally indicated by a flat side on the casing and the anode is normally indicated by a slightly longer leg. The current required to power an LED is usually around 20 mA.

The arrow symbol for an LED tells you in which direction the current flows.

Nowadays, LEDs are used in many cases where normal light bulbs were used. For example, household lighting is being replaced by LEDs. They are replacing light bulbs because they are more efficient and use much less electric energy. They also last for a long time.

To protect an LED from too much current, a resistor has to be added to the circuit, as in the diagram below.

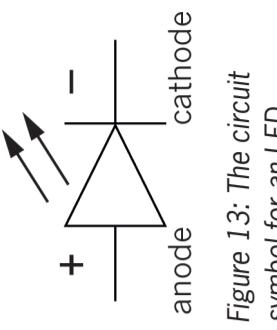


Figure 12: An LED. The longer of the two wires coming out of the LED should be connected to the positive terminal, and the shorter wire to the negative terminal.

Figure 13: The circuit symbol for an LED.



Questions

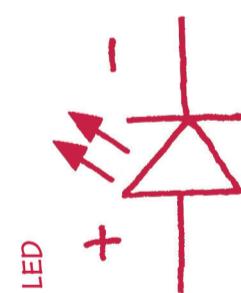
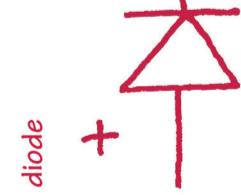
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1. Describe the function of a diode in your own words.
A diode allows current to flow in one direction, but not in the opposite direction.
2. List at least four places where LEDs are used. Don't use the examples already given.
A few examples:
 - a cell phone light
 - LED computer and TV screens (only on more modern screens)
 - to show if an appliance (for example a printer or air conditioner) is active or on standby
 - to show if a multi-plug adapter is switched on at the wall socket
 - modern torches
 - modern traffic lights (robots)
 - "daytime running lights" on some new cars

3. How can you make sure that a diode is connected correctly?

The longer leg should be connected to the positive terminal, and the shorter leg to the negative terminal. To check in which direction current can flow through a diode, you can also use a multimeter on its resistance setting. In the one direction the resistance will be very big (no conduction), and in the other direction the resistance will be very small (good conduction).

4. Draw the circuit symbols for a diode and for an LED.



13.3 Transistors

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Transistors are very important building blocks of modern electronic devices. They enable us to design smaller and cheaper electronic devices.

A transistor is a semiconductor device that consists of three layers. Each layer has its own connection point with a specific name: **collector, base and emitter**.

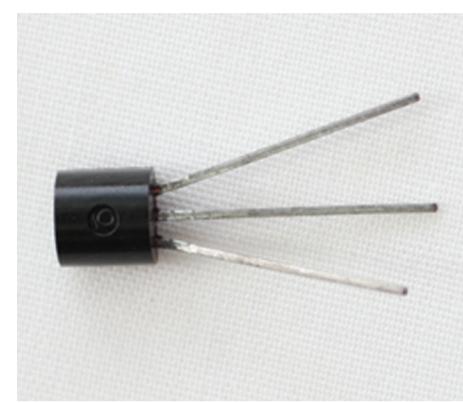


Figure 15: One type of transistor

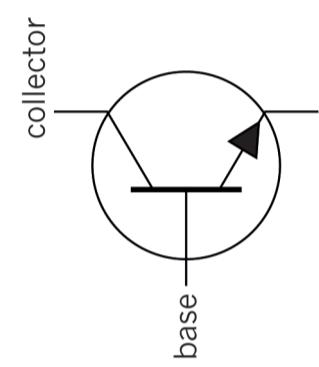


Figure 16: The circuit symbol for an npn transistor

A transistor works as a type of switch to turn current on and off. It can also amplify a current.

An **npn** transistor acts as if there is a switch between the collector and the emitter. When the voltage drop between the base and the emitter is smaller than 0,6 V, the resistance between the collector and the emitter is very high, so only a very small current passes through. When the voltage drop between the base and the emitter goes higher than 0,6 V, the resistance between collector and emitter suddenly decreases by a large amount, and then a strong current flows through the transistor. The transistor works like a switch because a tiny current through the base, going to the emitter, switches on a much larger current through the collector. So it is an electrically controlled switch.

Transistor is short for "trans-resistor" and this explains how it works. With a relatively small base current, the resistance between the collector and the emitter is changed. As the base current increases, the collector emitter resistance decreases.

In Chapter 14, you will learn about the applications of transistors.

There are other types of transistors, for example pnp transistors that work a bit differently from npn transistors. But you will only work with npn transistors in this term.



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Suppose you want to make a switch that is ON or closed when you touch its two terminals with your finger, and OFF or open when you don't touch it. Look at the circuit diagram in Figure 17 for a touch switch such as the one described. The purpose of this circuit is to light up the LED when you touch the touch switch with your finger.

Unfortunately, this circuit won't work well, since your finger is a very weak conductor. In other words, it has a very high resistance. So the current will be very small when you touch the switch. Therefore, the LED will only emit a dim light.

By using a transistor, you can build a circuit that uses the very small current through your finger to switch on a larger current that passes through the LED, which will then emit a bright light.

Figure 18 shows a circuit that uses a transistor for this purpose. In this circuit, the touch switch is an "input device," the npn transistor is a "control device," and the LED is the "output device".

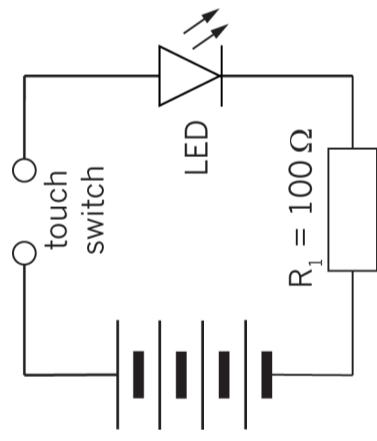


Figure 17: A simple touch switch circuit that will not work well

A transistor uses a small current circuit to switch on a larger current circuit. This is why transistors are also used in music equipment to "amplify" the sound.

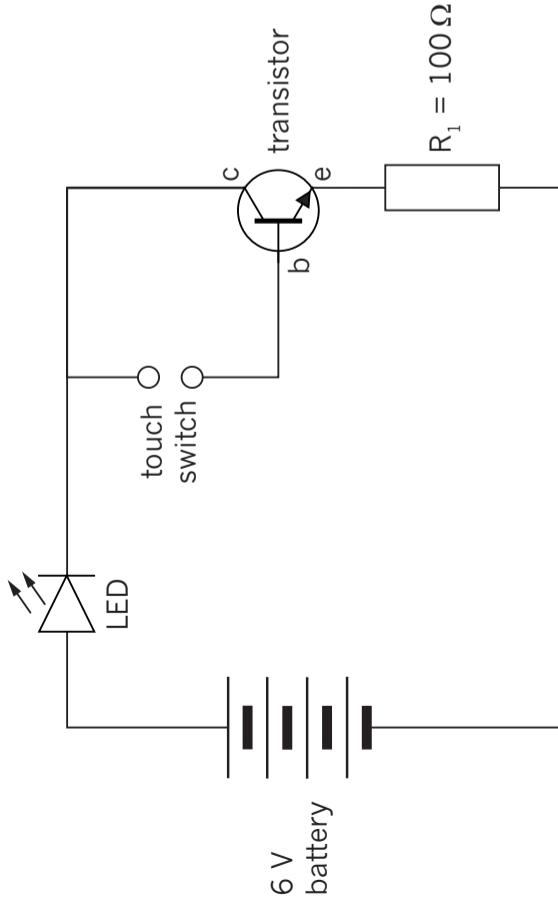


Figure 18: Circuit using a transistor as an electronic switch

1. The photograph below shows a circuit built according to the circuit diagram in Figure 18. Look at the photograph and identify each component in the circuit. Redraw the photograph and write labels for the different components and draw arrows pointing from the labels to the components.

Next week

Next week, you will learn more about electronic systems and components in electronic circuits. You will also learn about capacitors, and various kinds of input devices such as sensors.

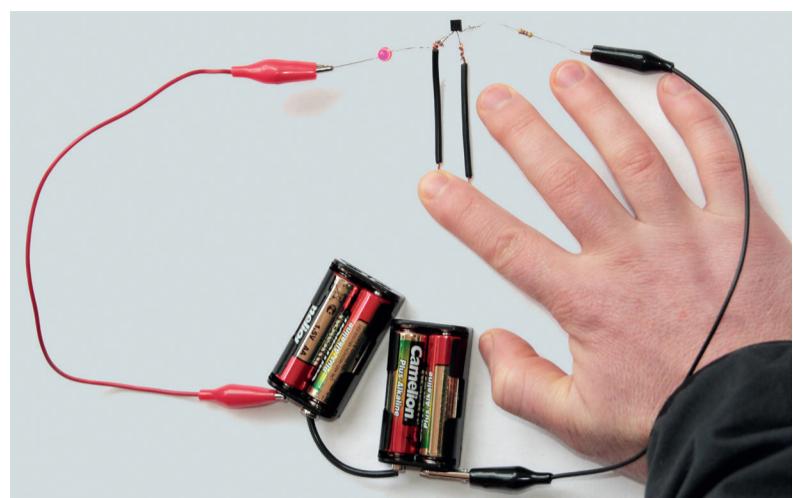


Figure 19: The construction of a touch switch circuit with a transistor and an LED.

2. Explain how the different parts of the transistor are connected in this circuit.

The collector is connected to the LED, the emitter is connected to the resistor, and the base is connected to the bottom one of the two horizontal wires that form the touch switch.
3. Explain what you expect to see when the touch switch is activated.

The LED will light up (assuming its terminals are connected correctly to the battery, and that the finger has sufficient moisture to conduct a small current).
4. Touch the two terminals of the touch switch with one finger. Describe what happens.

The LED lights up.

CHAPTER 14

Electronic components 2

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In this chapter, you will learn more about electronic systems and components in electronic circuits. You will learn about various kinds of sensors that act as input devices. A touch switch is a sensor that works with the moisture on your skin. This is a very sensitive device that produces a small current. A transistor is required to make the current big enough to have an effect. This week, you will learn about other kinds of sensors and how they are used in devices.

You will also learn about capacitors.

- 14.1 Light-dependent resistors (LDR) 224
- 14.2 Thermistors (temperature-sensitive resistors) 226
- 14.3 Capacitors 229

Somehow, you'll have to get these components. Many companies will send components by post or courier. Delivery is not free, unless your order is quite large. However, you can put together a large order by going through your district office, or organising it in your school cluster, or by organising it with teachers from other schools at a meeting of a teacher association, such as the SA Association of Science and Technology Educators (SAASTE). Contact details for companies that sell electronic components, as well as for SAASTE, are given at the end of these teacher notes.

The teacher should build the circuits in Figures 6, 9 and 12, so that learners can see how these components work. Build them on a "breadboard" such as you see at the end of the teacher notes to Chapter 15.

14.1 Light-dependent resistors (LDR)

Learners read the information about an LDR and apply it to describe how a day-night switching circuit operates.

Learners do not have to understand why the LDR is connected in the position where it is in the transistor circuit for a day/night light switch (Figure 6). And they do not have to understand the purposes of the other resistors in this circuit. (They also do not have to understand how the circuit of the fire alarm in the next section works.) That is quite difficult to understand. But learners should know the purpose of the circuit. And they should describe in words how the transistor and the LDR is connected in the circuit. To describe this, they will have to read the circuit diagram carefully. Reading circuit diagrams is good exercise for when learners will later build a transistor circuit, so that they will connect the different components in the correct way.

An explanation of how the day/night switch transistor circuit works:

Learners do not have to understand this, but some clever learners may ask the teacher about it. So below is a more complete explanation of how the circuit works. But even the explanation below is not a complete explanation.

As it gets darker, the resistance of the LDR increases. The LDR is in series with R1 and R2, so the total potential difference is shared between R2, R3 and the LDR. The amount of voltage drop across each one of these three resistors in series depends on its resistance. The higher the resistance, compared to the other resistors in series, the larger part of the total voltage drop will occur across that resistor. So when the resistance of the LDR increases, the voltage drop across it also increases.

The LDR is in parallel with the loop of the circuit from point "a" to point "e". So the voltage drop across point "a" to point "e" is the same as the voltage drop across the LDR. The loop of the circuit from point "a" to point "e" includes the path from the base of the transistor (point "b") to the emitter of the transistor (point "e"). So when the voltage drop across points "a" and "e" increases, the voltage drop across points "b" and "e" also increases. When this voltage drop becomes larger than 0,6 V, the resistance between the collector and the emitter of the transistor suddenly decreases by a large amount, so that enough current can pass through to light up the LED.

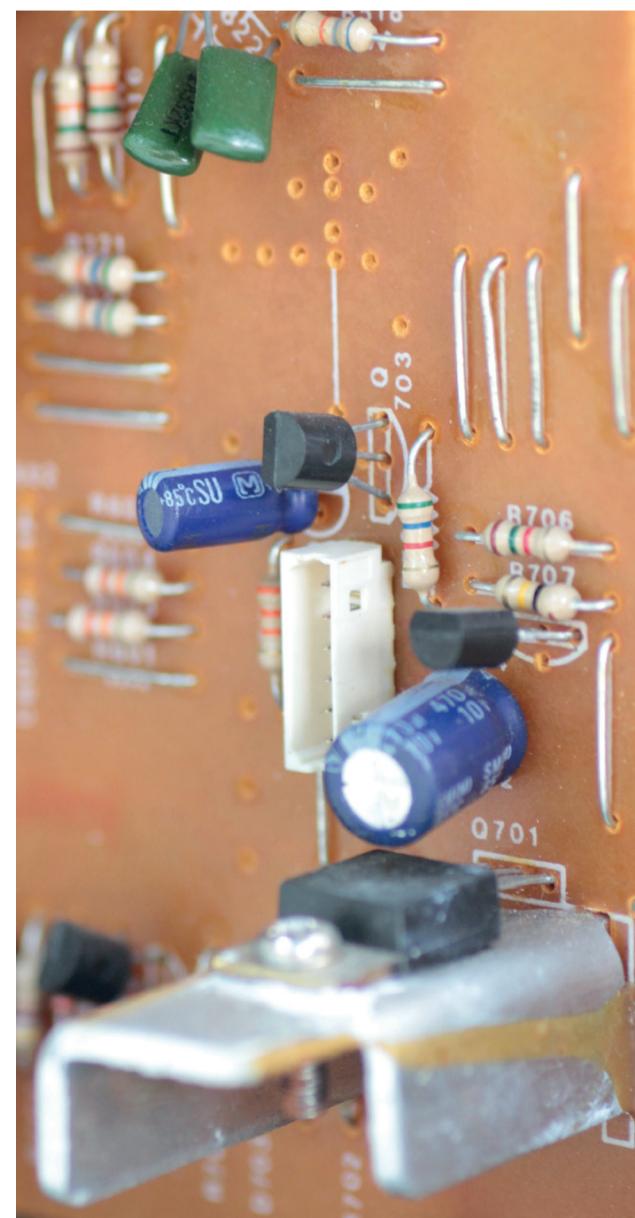


Figure 1: Components connected on a printed circuit board



14.2 Thermistors (temperature-sensitive resistors)

Learners think of applications for a thermistor, use a multi-meter to actually measure the resistance of a thermistor, and see how the resistance changes as it heats up. The learners also analyse a circuit diagram of a heat-activated switch and describe what the thermistor and transistor do in the circuit. They then draw the circuit diagram for a different circuit that will switch on a heater when it has cooled down below a certain temperature.

14.3 Capacitors

Learners read information about capacitors and the concept of capacitance. They then apply this knowledge to explain what happens in a circuit that has a capacitor.

You can order components from the companies listed below. There are still more companies that you can find if you search on Google, using the search phrase “electronic component suppliers South Africa”.

When you get to a website, you will always find a tab called Contact us or Contact or Home or About us. Click on one of those and you will find a telephone number or email address to use.

Hi-Q Electronics: <http://www.hi-q.co.za/online.asp>

Hobbytronics: <http://www.hobbytronics.co.za/>

Mantech Electronics: <http://www.mantech.co.za/> (Johannesburg area)

DIY Electronics: <http://diyelectronics.co.za> (Durban area)

Electronics 1-2-3: <http://www.electronics123.co.za/> (This company offers workshops in electronics for adults and children. They are in the Pretoria area.)

Netram Technologies: <https://netram.co.za/>

Rabtron: <http://www.shop.rabtron.co.za>

ouser Electronics: <http://www.ouser.co.za> (Cape Town area)

Yebo Electronics: <http://www.fort777.co.za>

If there is an active school cluster or a SAASTE branch in your area, its members who teach Grade 9 Technology could get together and place a bulk order for electronic components from a company that sells such components. The order would have to be large enough for one of the suppliers to mail it to the address of one of the schools or the branch. Or someone goes to fetch it. Costs would be shared between participating schools.

When you have received the components, organise a cluster or branch workshop on Grade 9 electronics for teachers, as most teachers will be unfamiliar with this topic.

The list below gives contact details of SAASTE executive committee members in different provinces:

NAME	POSITION	CONTACT NO	EMAIL ADDRESS	PROVINCE
Mr Thabo Sithole	President	071 914 3238	thabofrance@gmail.com	FS
Mr Sealanyane Molahlehi	Deputy President	072 998 6775	molaseal@gmail.com	FS
Ms Buthile Titise	Secretary	079 921 2317	buthiletite@gmail.com	FS
Ms Keitumetsе Mokwele	Treasurer	076 591 6404	keitumets7@gmail.com	NW
Mr Phumzile Mashalaba	Project Coordinator	082 931 9730	pmashalaba@yahoo.com	EC

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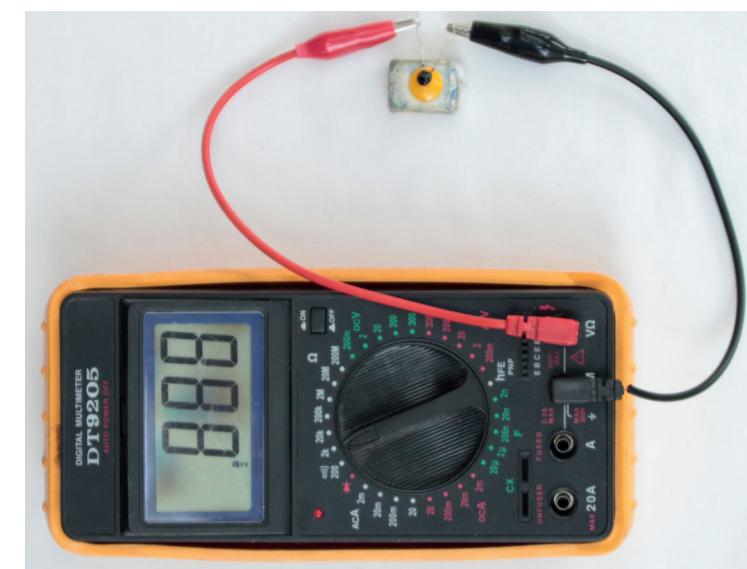


Figure 3: Measuring the resistance of a thermistor while heating it with a hot object. You can heat a metal thumb tack by pressing it into an eraser, and then rubbing it hard against a piece of wood or plastic for one minute. **Safety warning:** The thumb tack can get very hot and burn your skin, which can cause a wound.

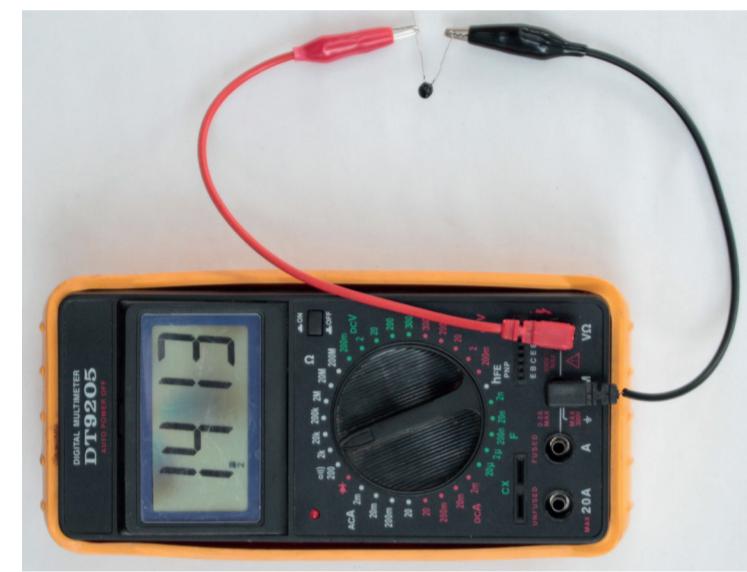


Figure 2: Measuring the resistance of a thermistor at room temperature.



14.1 Light-dependent resistors (LDR)

A light-dependent resistor, also called an **LDR**, is a resistor of which the resistance decreases when it is exposed to light of a higher intensity. It can therefore be used to detect light and trigger warning devices in cases where light may cause problems.

- When an LDR is in the dark, its resistance value will be very high, around $1\text{ M}\Omega$.
- When an LDR is exposed to a light of high intensity, the resistance value will decrease. It could drop from $1\text{ M}\Omega$ to $2\text{ k}\Omega$.

An LDR has two terminals that can be connected to a circuit in either direction.

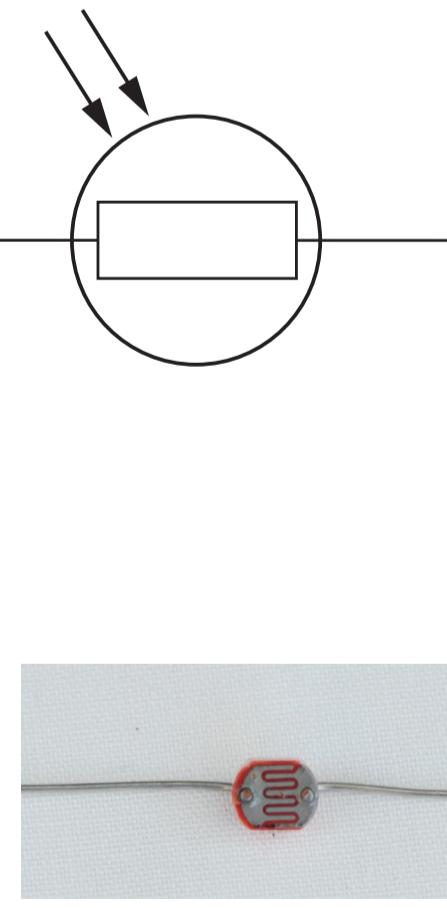


Figure 4: A light-dependent resistor

Figure 5: The circuit symbol for a light-dependent resistor

Circuit of a day/night switch

Day/night switches are often used to turn on street and outside lights once it gets dark. It has an advantage above time switches, since the time settings can go wrong, and the amount of daylight does not remain constant during different weather conditions.

In this example, a light-dependent resistor (LDR) is the input device, an *n-p-n* transistor is the control device, and an LED is the output device.

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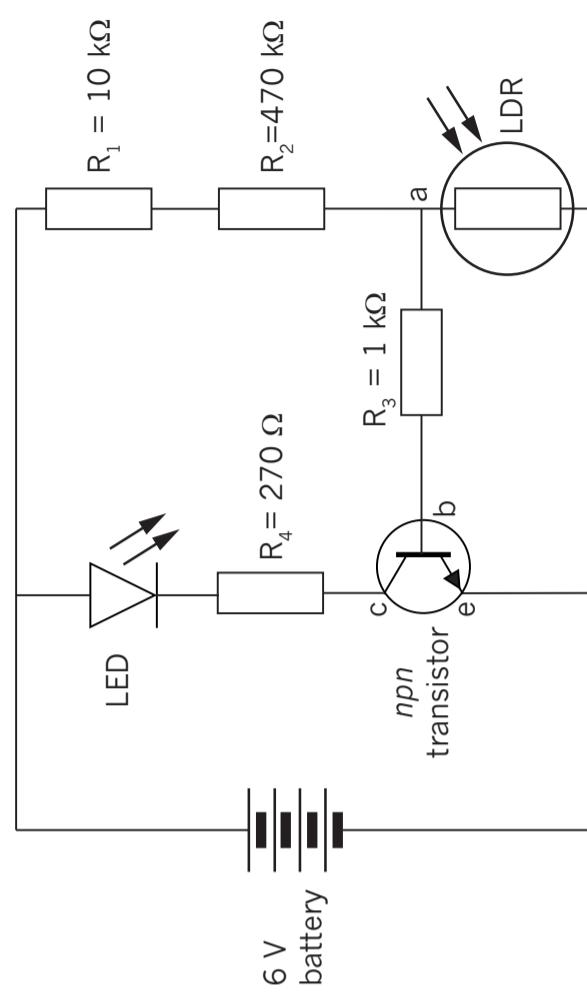


Figure 6: Circuit diagram of a day/night switch

1. Write four examples of when it would be useful to have a device that detects the amount of light, and does something in response to it.

A few examples:

- Safety lights that switch on when the ambient light intensity drops below a certain level.
- Detect if something has moved past a point where a beam of light is shone on a circuit with an LDR
- Car lights that automatically switch on when it gets darks, and switch off when it is light.
- An alarm clock that wakes you up when the ambient light becomes higher than a certain intensity.

LB p. 178



2. What is the role of the LDR in the circuit?

When the amount of light decreases, the resistance of the LDR increases.

When the resistance of the LDR increases enough, it results in the transistor allowing current through between the collector and the emitter, so the LED lights up.

Optional further explanation that some learners might give: When the resistance of the LDR increases, the voltage drop between the base and the emitter of the transistor also increases. When that voltage drop becomes high enough, the transistor allows a big enough current to flow from the collector to the emitter, so the LED lights up.

3. Describe how the transistor is connected to the circuit.

The LED is in the loop containing the collector and emitter. The loop containing the base is connected in parallel with the LDR.

4. What is the role of the transistor in this circuit?

It switches the LED on or off depending on the positive potential at the base.

14.2 Thermistors (temperature-sensitive resistors)

The resistance value of this resistor depends on the temperature it is exposed to.

There are two types of thermistors:

- A “negative-temperature coefficient” type thermistor, where the resistance value decreases with an increase in temperature.
This is also called an “NTC” or “-T” thermistor.
- A “positive-temperature coefficient” type thermistor, where the resistance value increases with an increase in temperature.
This is also called a “PTC” or “+T” thermistor.



Figure 7: A thermistor

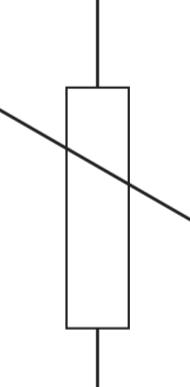


Figure 8: The circuit symbol for a thermistor

Uses of thermistors LB p. 179

1. Write four examples of situations in which electronic devices that use a thermistor of either type would be useful.

A few examples:

- *Switching a kettle off automatically when the water boils.*
- *Switching on fans or extra fans in an appliance when its temperature becomes too high, for example to prevent a computer from overheating and being damaged by the heat.*
- *Switching an air conditioner or a fridge on or off automatically.*
- *Setting off a fire alarm.*

Measuring the resistance of a thermistor LB p. 179

Figures 2 and 3 on Learner Book page 176 show the resistance of a thermistor measured at room temperature, and when heated by placing it on a hot object. At room temperature, the resistance is 1 413 Ω. When the thermistor is heated with a hot object, the resistance decreases to 888 Ω.

1. Was the thermistor a PTC or an NTC?

NTC

2. Give reasons for your answer.
When the temperature of the thermistor is raised, its electrical resistance is lowered.



Heat-activated switch

A thermistor can be used in a heat-controlled switch for a fire alarm. When the thermistor is heated up, its resistance is decreased and the transistor starts conducting a current, switching on the LED.

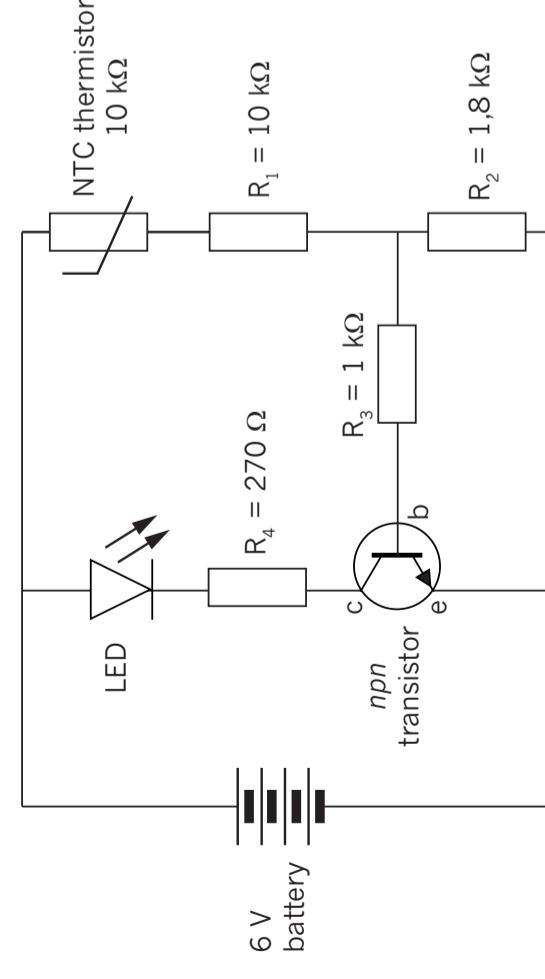


Figure 9: Diagram of a simple fire alarm with an NTC thermistor

- What is the role of the thermistor in the circuit?

When it becomes hot due to a fire, its resistance decreases, and this causes the LED to light up.

- Describe how the transistor is connected to the circuit.

The LED is in the loop containing the collector and emitter. The NTC thermistor is in the loop of the circuit that is parallel with the LED.

- Draw a simplified circuit diagram for an indicator light to show when a heater has dropped below a certain temperature and starts heating up again.

The same as Figure 9, but this time with a PTC thermistor instead of an NTC thermistor.

The LED will switch off again when the temperature increases and the resistance of the PTC is high enough.

14.3 Capacitors

The main function of a capacitor is to store electric charge. A capacitor consists of two metal plates separated by an insulator called a dielectric. The ability of a capacitor to store electric charge is called its capacitance.

Capacitance is measured in farad. The symbol "C" is used for capacitance. Because the farad is such a large unit, practical values usually have the prefixes m (milli-), μ (micro-), n (nano-) or p (pico-).

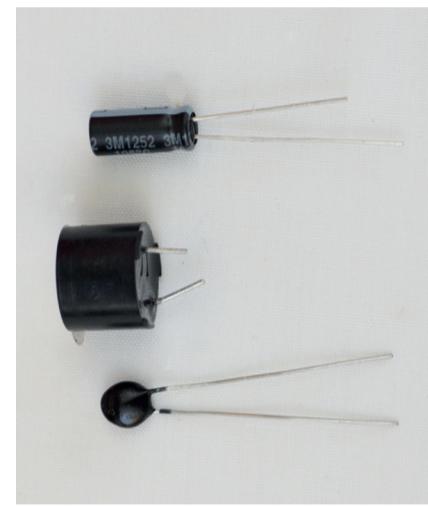


Figure 10: Different types of capacitors

Figure 11: The circuit symbol for a capacitor

When capacitors are connected in parallel, the total area of the metal plates on each side is increased, so the total capacitance is increased.

When capacitors are connected in series, the distance between the opposite plates is increased. And because capacitance is inversely proportional to the distance between the plates, the total capacitance is reduced to less than that of the smallest capacitor.

Charge and discharge of a capacitor

The charging and discharging of a capacitor can be observed by building the circuit in the diagram below. When the switch is switched to position A, the current will flow from the + of the battery, through LED₁, through the switch to one plate of the capacitor. The negative of the battery is connected to the other plate of the capacitor through the resistor R₁. While the capacitor is charging, LED₁ will be ON.

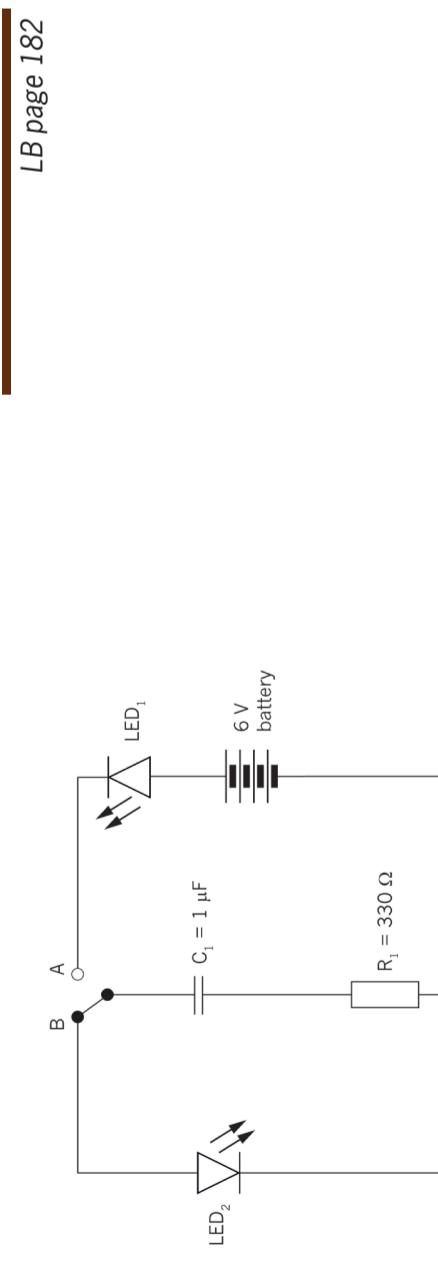


Figure 12: Capacitor charging and discharging circuit

After the capacitor has been charged and the switch is switched to position B, a current will now flow from the + plate of the capacitor through LED₂, and through the resistor R₁ to the negative plate of the capacitor. While the capacitor is discharging, LED₂ will be ON.

Capacitors are often used in electronic devices that need a carefully controlled time delay, such as timers and traffic lights. The exact kind of capacitor can be chosen to get the exact time delay that is needed. Increasing the value of the capacitor increases the length of the time delay.

Questions about components

- Copy the table on the next two pages, without the photographs. Name the component in the picture and draw the correct circuit symbol next to the name. Write a brief description of the main uses of the component.

Name of component	Picture	Symbol	Use
light-dependent resistor (LDR)			Changes its resistance depending on the intensity of light it absorbs.
capacitor			Stores electric charge.
thermistor			Changes its resistance depending on the temperature.

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Next week
Next week, you will draw circuit diagrams and build simple circuits.

Name of component	Picture	Symbol	Use
LED			Ensures that current can only flow in one direction, and produces light from electrical energy.
transistor			Acts as a switch or amplifier that is electrically controlled.

CHAPTER 15

Build and draw electronic circuits

In this chapter, you will draw circuit diagrams and assemble four electronic circuits, using the components you have learnt about in Chapters 3 and 4.

15.1 Simple electronic circuits	236
15.2 A control circuit and a time-delay circuit	238
15.3 Build a fire-alarm circuit.....	241

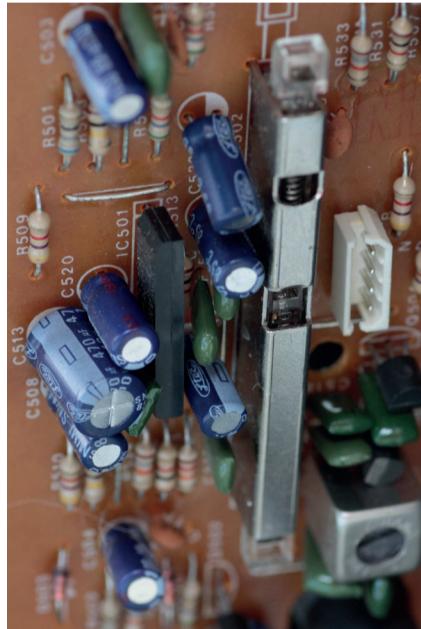
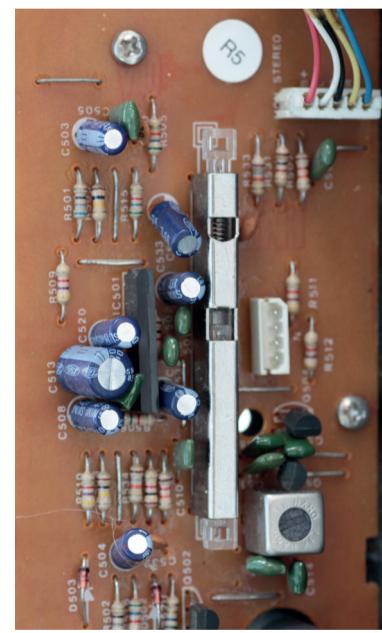


Figure 1: A part of the circuit for a radio

15.1 Simple electronic circuits

In this section, the learners will build several circuits using electronic components. You will have to organise the components and other equipment.

A circuit with an LED

The learners make this simple circuit and investigate the effect of connecting the LED in two ways: first with its long leg towards the positive terminal, and then with the short leg towards the positive terminal.

A circuit with an LDR

The learners will work with a real circuit to observe the effect of shining light on the LDR or shading it.

15.2 A control circuit and a time-delay circuit

A fire alarm: A circuit with a sensor and a transistor

The learners read about the general properties of a simple control circuit. They identify the input sensor and output device in a circuit diagram of the control circuit. They identify the input and output parts of the circuit by using a system diagram.

They do not have to understand the purposes of the different resistors in the control circuit, as that is too advanced for them.

They redraw the control circuit for a fire alarm that was given in Chapter 14 Figure 9, but with few small changes:

- They change the output device from an LED to a buzzer.
- They change resistor 1 to a variable resistor. They will see the reason for that in the next section, when they build and test the circuit.
- They draw the input part of the circuit on the left-hand side and the output part on the right-hand side. This is the other way round from the way it is drawn in Chapter 14 Figure 9. The purpose of asking them to do it in this way, is for them to think about whether that will change the way the circuit works, or whether the two circuit diagrams are electrically equivalent. When they follow the paths of current (lines) for the different loops in the circuit with their fingers, they will come to understand that the two ways of drawing the circuit are indeed electrically equivalent – they merely look different. This visual thinking exercise is good preparation for when they will build the circuit, because a real circuit usually looks very different from its circuit diagram, and more messy! You need to follow the wires to check that the circuit you build is electrically equivalent to the circuit diagram.
- They leave out the resistor that is in series with the output device (resistor 4). The reason for this is explained below.

Some output devices such as LED's, have very small resistances, and they may be damaged by too large a current. So for such output devices, a resistor needs to be added in series with the output device, to prevent the current through the output device from becoming too large. That is the purpose of resistor 4 in the circuit in Chapter 14 Figure 9. But other devices do not need a resistor in series. Then a resistor should not be added in series, because it will "use up" some

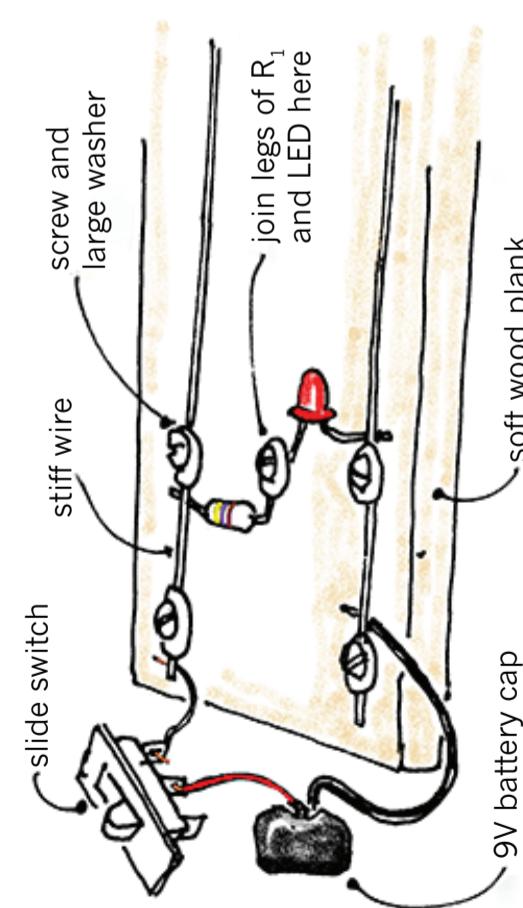
of the potential difference offered by the battery. In the case of the circuit for the fire alarm, a buzzer rated for 3 V to 6 V should be used without a resistor in series with it.

15.3 Build a fire alarm circuit

Learners actually *build* the fire alarm circuit, applying the knowledge they have gained from the previous section.

You cannot treat this as theory – the learners must have working circuits because they are going to use the circuits to control the kettle switch that they must make for the PAT in Chapter 16.

The learners can make their circuits on “breadboards” if you have them. If you don’t have breadboards, you can give the learners soft planks, screws and washers, as you see in the figure on the opposite page.



An alternative to a commercial breadboard

The stiff wires at the top and bottom of the board press against the wood because the screws hold them down. You can lift the wires just enough to push the lead of a battery, resistor or other component underneath.

The circuit in the drawing above shows a connector for a 9 V battery, but learners will build a circuit with a 6 V battery (four 1.5 V cells in a cell holder). This is because the buzzer of the fire alarm is only rated for a maximum of 6 V. It may break if you apply a higher voltage across it. After learners built the circuit they will test it. It will probably not work at first, so they need to do some troubleshooting.

They will need to adjust the variable resistor so that the alarm is activated at the correct temperature, not too early (at too low a temperature) but also not too late (at too high a temperature).

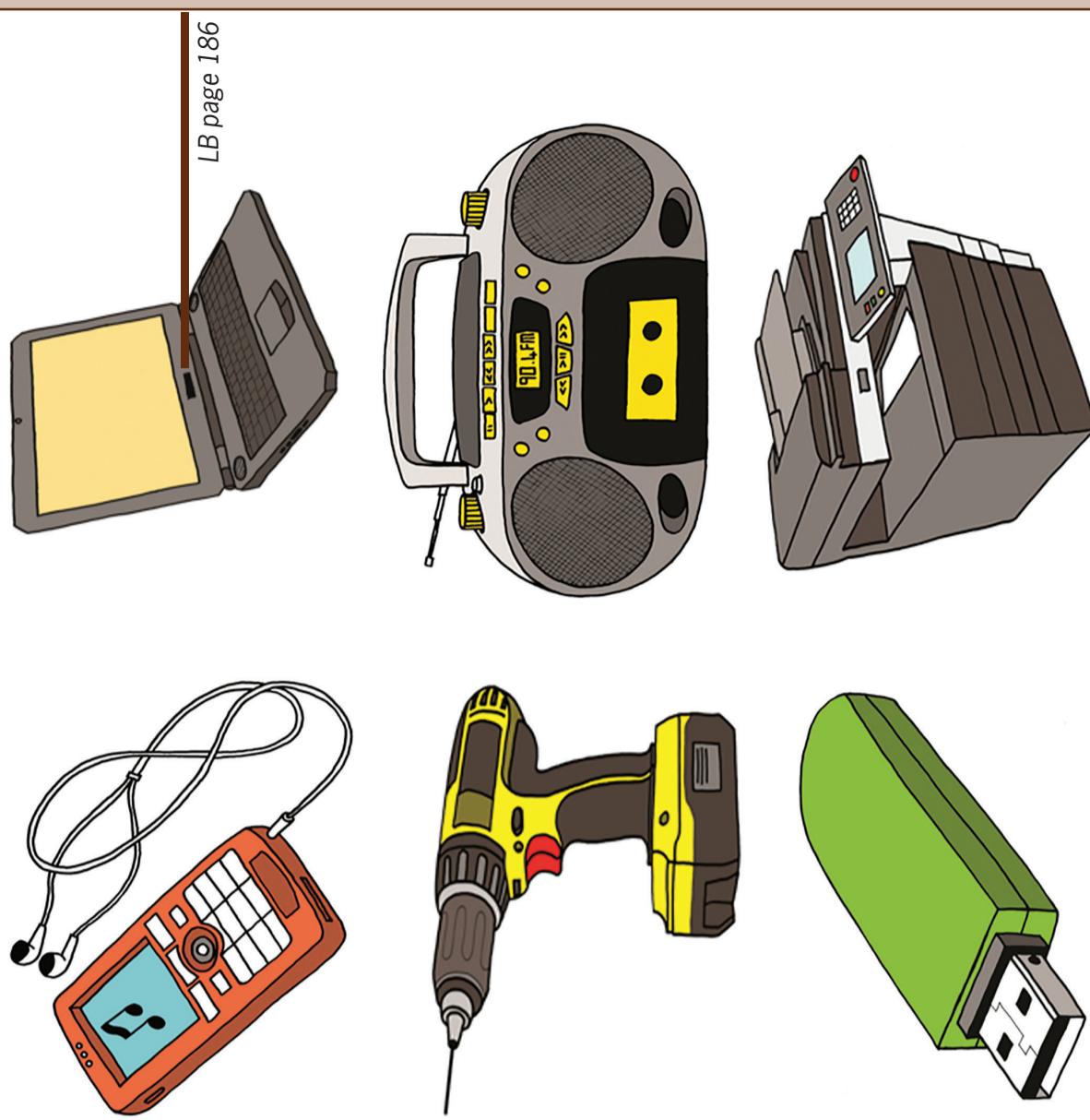


Figure 2: All of these appliances contain electronic circuits.



15.1 Simple electronic circuits

A circuit with an LED

In this lesson, you need to assemble a simple LED circuit. You will draw the circuit diagram on your own and then work in pairs to assemble it.

You will need:

- an LED,
- a $470\ \Omega$ resistor,
- a switch,
- four 1,5 V cells in series, or a 9 V battery, and
- electric conducting wire with crocodile clips for connections.

The photograph below shows the circuit you need to build.

1. Draw a circuit diagram for Figure 3.

The photograph below shows the circuit you need to build.

1. Draw a circuit diagram for Figure 3.

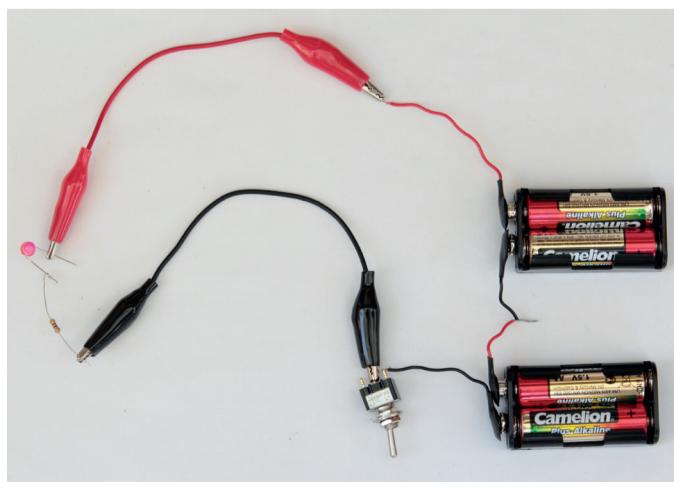


Figure 3: A circuit with an LED, a battery, a switch, a resistor and an LED.

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A circuit with an LDR

Now you will build a circuit where an LDR regulates the current.

You will need:

- an LDR,
- four 1,5 V cells in a cell holder, and
- a buzzer.

The photograph on the right shows a circuit where an LDR regulates the current through the circuit.

1. Work individually to draw a circuit diagram of Figure 4.
2. Work in pairs to build the circuit.
3. Predict what will happen when:

- (a) The LDR is covered

The buzzer will make a very soft noise or no noise at all.

- (b) The LDR is in bright sunlight

The buzzer will make a loud noise.

4. Is the buzzer affected by different sources of light, such as light from an electric lamp, light from a cell phone screen or light from a torch? Do a practical investigation and write down your findings.

The brighter the light, the louder the buzzer sounds.

LB p. 188

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The brighter the light, the louder the buzzer sounds.

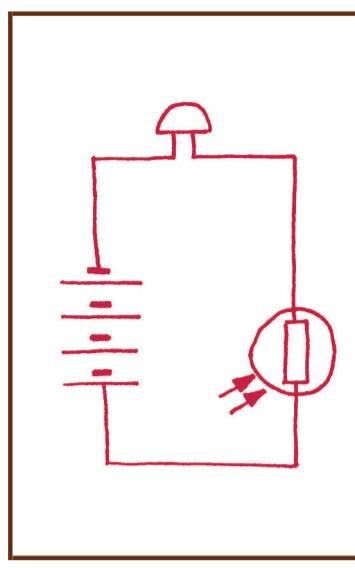


Figure 4: A circuit where the current is regulated by a light-dependent resistor



15.2 A control circuit and a time-delay circuit

A fire alarm: A circuit with a sensor and a transistor

In the next lesson, you will build the electronic circuit for a fire alarm. In the next chapter, you will use the same circuit but for a different purpose, as part of an automatic kettle switch. It is very important that you complete the circuit and that it works, as you will use it in the PAT in the weeks that follow.

The type of circuit you will build is used very often to switch an output device on and off without using a switch. Instead of a switch controlled by hand, this type of circuit uses an input sensor in combination with a transistor to switch the output device on or off automatically, depending on the measurement of something by the input sensor.

This type of circuit is called a control circuit since one circuit controls another circuit. In the case where a transistor is used with a sensor such as an LDR, the base-emitter current controls the larger collector-emitter current.

Note that resistor 2 and the input sensor may have to change places depending on the relationship between the resistance of the input sensor and the required output:

- If a decrease in resistance of the input sensor should switch on the output device, then resistor 2 and the input sensor should be arranged as in Figure 5. Look back at the circuit for a heat-activated switch using a negative temperature coefficient (NTC) thermistor, on page 180.
- If an increase in resistance of the input sensor should switch on the output device, then resistor 2 and the input sensor should be arranged the other way around to Figure 5. Look back at the circuit for a day/night switch using a light-dependent resistor (LDR), on page 178.

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It is easier to understand the circuit if you think about a systems diagram. Look at Figure 6. The yellow part is the output side of the diagram.

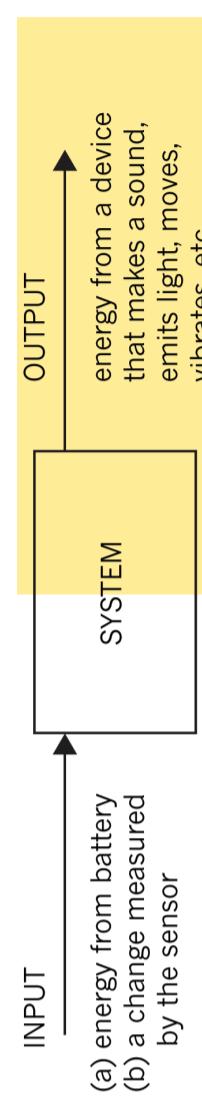


Figure 6 shows how the circuit in Figure 5 is the same as the systems diagram.

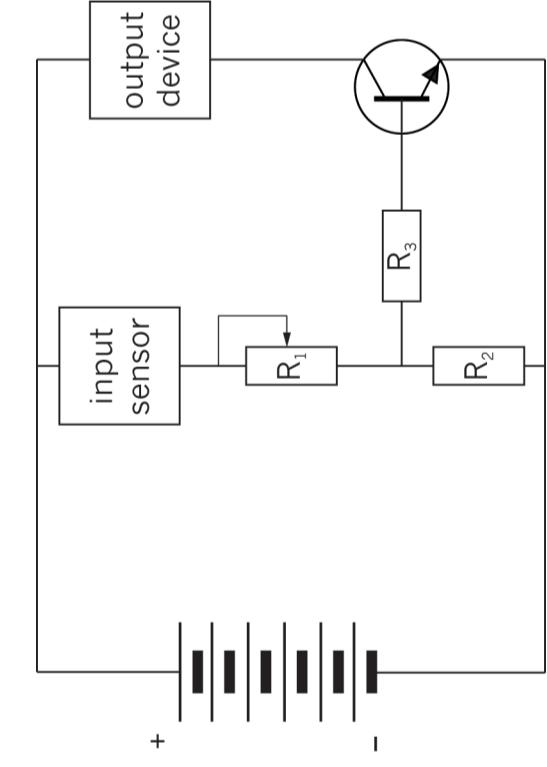
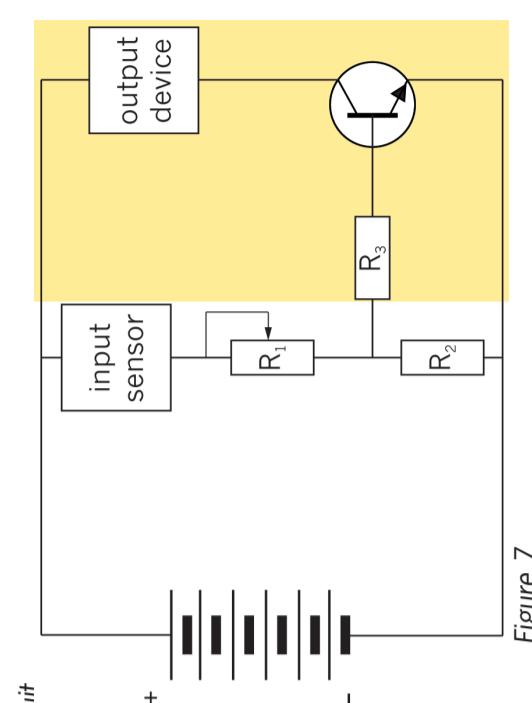


Figure 5: The circuit diagram for the control circuit

LB page 190

It is easier to understand the circuit if you think about a systems diagram. Look at Figure 6. The yellow part is the output side of the diagram.



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Identify the different components and draw the circuit

The circuit for the fire alarm contains the following components:

- a battery consisting of 4 cells in series,
- an input sensor to measure the temperature,
- a variable resistor to set the temperature at which the alarm should go off,
- an output device to make noise when it gets too hot, and
- a transistor to switch the output device on when it gets too hot.

1. What type of electronic component will you use as the input sensor?
a thermometer
2. What type of device will you use as the output device?
a buzzer / beeper / speaker
3. What voltage does the battery supply to the circuit?
4 x 1,5 V = 6 V



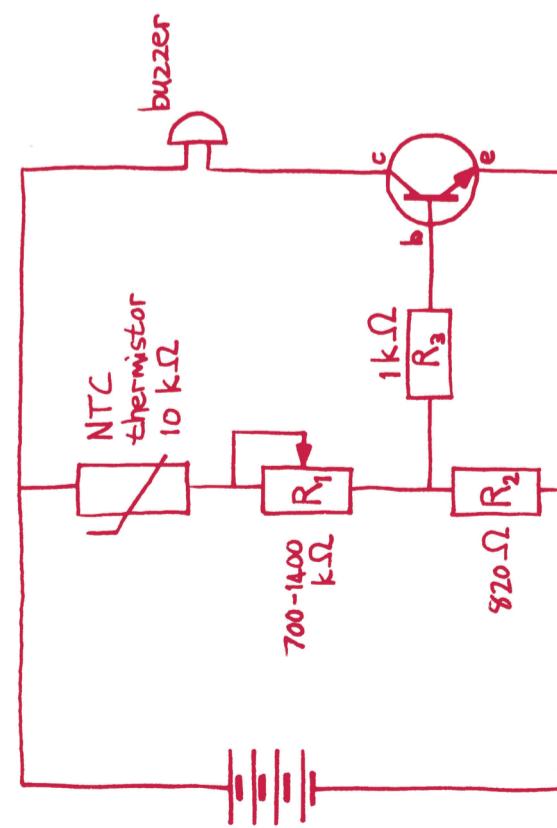
4. Draw a circuit diagram for a fire alarm:
 - (a) Show the correct symbols for the components you will use as the input and the output sensors.
 - (b) Show the voltage of the battery.
 - (c) Show the emitter ("e"), base ("b") and collector ("c") of the transistor. Look back on what you learnt about transistors in Chapter 13.

15.3 Build a fire-alarm circuit

Build a circuit and test it

LB p. 192

4. Draw a circuit diagram for a fire alarm:
 - (a) Show the correct symbols for the components you will use as the input and the output sensors.
 - (b) Show the voltage of the battery.
 - (c) Show the emitter ("e"), base ("b") and collector ("c") of the transistor. Look back on what you learnt about transistors in Chapter 13.



A circuit diagram showing the different components in a fire alarm

The purpose of resistors 1 to 3 in the control circuit is hard to explain. It has to do with the minimum current to the base of the transistor that is needed to allow current through from the collector to the emitter of the transistor. If you choose to study more electronics in FET or at university, you will learn about the purpose of these resistors, and how to calculate their resistances.

Someone has already done the calculations of the resistances of different components that should be used for the fire alarm to work. These are called the specifications for the resistances of components.

- $R_1 = 700 \text{ to } 1400 \text{ k}\Omega$ (variable resistor)
- $R_2 = 820 \Omega$
- $R_3 = 1 \text{ k}\Omega$
- input sensor: $10 \text{ k}\Omega$

5. Show the specified resistances of the components on your circuit diagram.

You need the following materials to build the circuit:

- four 1,5 V cells in series, in a cell holder,
 - conduction wires with crocodile clips,
 - a 10 kΩ NTC thermistor,
 - a 700 to 1 400 kΩ variable resistor,
 - a 820 Ω and a 1 kΩ resistor,
 - an npn transistor, and
 - a buzzer, that is specified to be used with between 3 V and 6 V across it.
1. Now build the circuit. Set the variable resistor to its lowest resistance.
 2. Once your circuit is complete, check that all your connections are good.
 3. Then connect the battery to the circuit.
 4. To test the fire alarm, warm up a thumb tack by pressing it into an eraser, and rubbing it hard against a piece of wood or plastic for a minute. Then press it against the thermistor.

Troubleshooting

If the fire alarm does not work, then:

- test whether the battery is flat or not,
 - test all your connections again,
 - follow the flow of the current on your board with your finger, to check whether you connected the components the right way, and
 - check that you connected the transistor the right way round.
- If the fire alarm makes a sound even when the thermistor is not heated, then increase the resistance of the variable resistor until the alarm stops making a sound. Do not increase the resistance of the variable resistor more than is necessary, because then the fire alarm will not make a sound when it is heated.



If you have time: Build a time-delay circuit LB p. 193

Capacitors are often used in time-delay circuits.

You will need:

- four 1,5 V cells in series, or a 9 V battery,
- two LEDs,
- a $470\ \Omega$ resistor,
- a $1\ 000\ \mu F$ capacitor, and
- an SPDT switch.

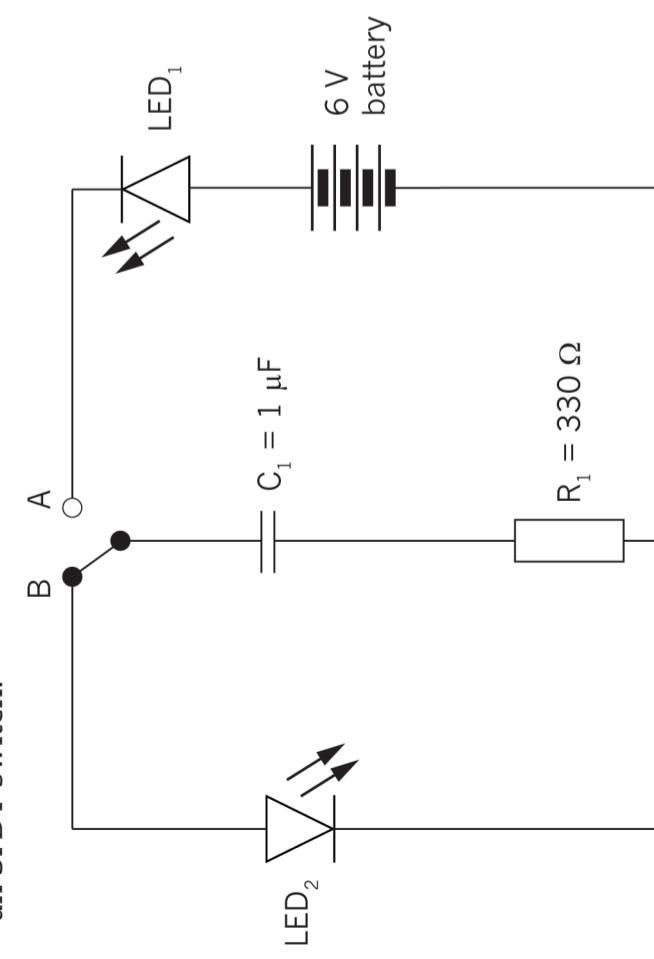


Figure 8: A time-delay circuit

- Build the circuit. Put the switch to A and observe the LEDs.
Describe what happens and explain it in detail.

When you switch the SPDT switch to position A, LED₁ will initially be bright, but then grow dimmer and dimmer until it does not glow at all.
The reason for this is that the capacitor is initially discharged, so current can flow through the circuit on the right while the capacitor is charging. But the more the capacitor charges, the less charge it can accept, so the current flows slower and slower until the capacitor is fully charged.
When you switch the SPDT switch to position B, LED₂ will initially be bright as the capacitor discharges through the circuit on the left. LED₂ will grow dimmer and dimmer until it stops glowing altogether since the charge on the capacitor will get smaller as it discharges, until it has no charge left.

Further reading: Boards on which more complicated circuits are built

If you try to build a more complicated circuit by connecting components using conducting wire and crocodile clips, many wires will cross one another and the circuit will be messy, looking like a tangled bunch of ropes.

To make a complicated circuit in a neater and smaller way, most circuits are built on boards such as "bread boards", "strip boards", or "printed circuit boards" (PCBs).



Figure 9: A simple LED circuit built on a strip board

Figure 9 below shows a simple LED circuit, such as the one you built in section 15.1, but here it is built on a strip board. Notice that there are no connecting wires used to build this circuit! This is because at the bottom of the strip board there are parallel copper strips connecting the holes in each column. This makes it possible to construct a circuit without using wire.

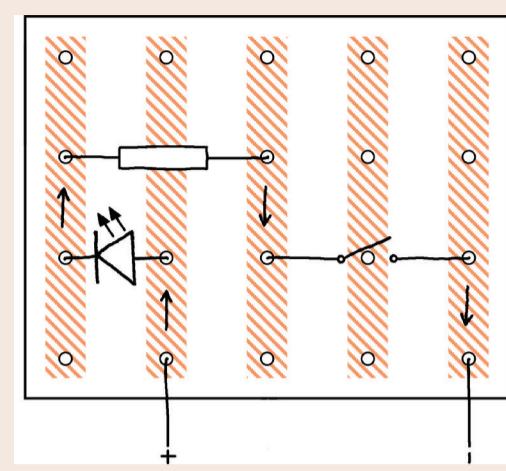


Figure 10: One possible layout of the simple LED circuit on a strip board

Figure 9 shows one possible plan of how to arrange the simple LED circuit on a strip board. The copper strips are at the bottom of a strip board, and not visible from the top. Therefore, the copper strips on the drawing of the layout were drawn with hatching, to show that you cannot really see them from the top.

Soldering is done with lead, because lead is a good electrical conductor and has a low melting point, so it is easy and quick to melt it with a soldering iron. Bread boards and printed circuit boards are other types of boards used to build complicated circuits. They also have copper connections at the back, but these connections are arranged in a different way than on a strip board.

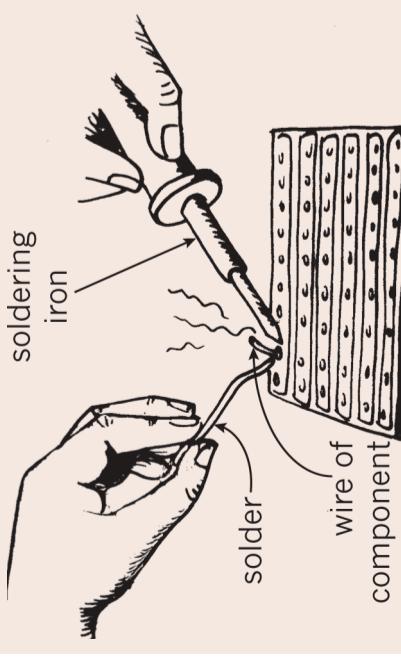


Figure 11: Soldering components onto the back of a strip board

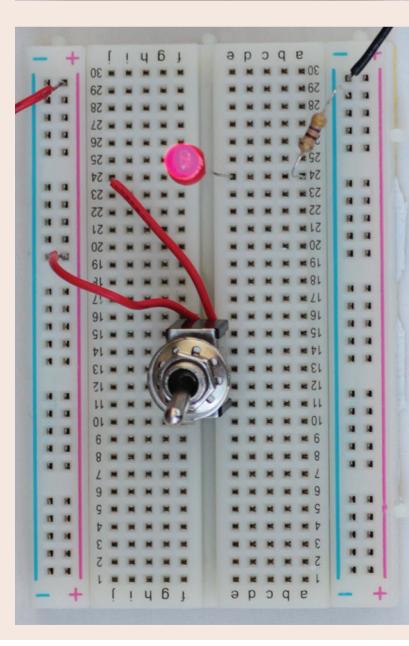


Figure 12: The front and back of a bread board

With a breadboard it is not necessary to solder connections, since each hole in the breadboard has a spring that grips the wire tightly to make proper electrical contact.

Almost all manufactured electronic devices use printed circuit boards, where the copper connections at the back can be made in any pattern. This makes it possible to make complicated circuits that are very small.

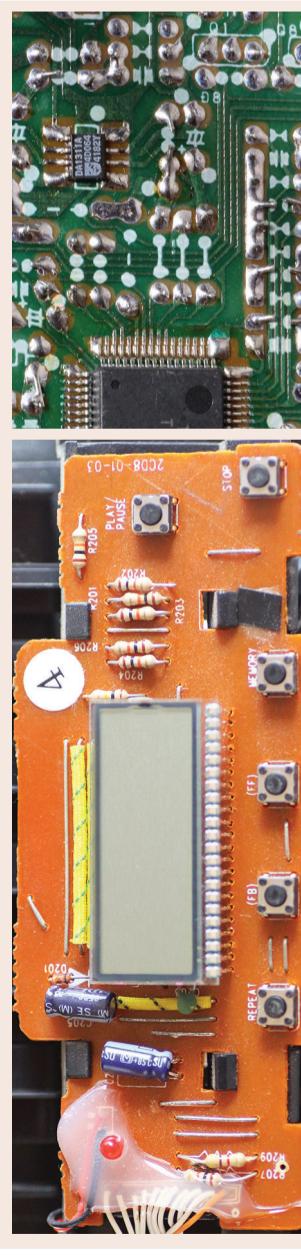


Figure 13: The front and back of a printed circuit board

Next week

The next chapter is your PAT for this term. You will learn how an electronic circuit can be used to control another circuit with a much bigger current. You will build a device using both circuits and then test it.

CHAPTER 16 PAT

Electronic systems and control

LB page 197

In this PAT, you will first study where electronic circuits, using very small currents, are used to control electric circuits with much bigger currents. You will then design and build your own electric circuit that will be controlled by an electronic circuit.

Week 1 72

Investigate: Situations where electronic control circuits are needed

Investigate: A circuit with an input sensor, control knob, transistor and output device

Design brief and initial sketches

Week 2 80

Evaluate: Team meeting to choose best combination of design ideas

Design: Improve your design as a team

Plan to make: Orthographic and 3D drawings of the design

Week 3 85

Make the switch

Connect the switch to the electronic circuit and test it

Week 4 89

Communicate: Prepare a team presentation

Communicate: Give team presentation, and listen to other teams' presentations

Assessment

Situations where electronic systems control electric circuits (individual work)	[5]
Design brief and sketches (individual work)	[12]
Evaluate and improve the design (team work)	[8]
Final drawings of the design (individual work)	[15]
Make the switch (individual work)	[25]
Presentation (team work)	[5]
	[Total: 70]

Tools required for this chapter:
long-nose pliers with wire-cutting jaws
tin snips or kitchen shears that can cut cold
drink cans
hole-makers (brad awls)
screwdrivers to match screws you have

Materials required for this chapter:

contact glue
sticky-tape
clear package tape
thin wire for making springs
very thin insulated copper wire to wind around a straw, to make an electromagnet:
at least 6 m per learner (Get this wire from old chargers, transformers or ballast coils for neon lights.)
straws
large nails that fit inside the straws
soft planks
screws

cold drink cans (The material is tin-plated steel or aluminium. It is coated with a plastic layer – sandpaper the plastic coating off the places that must conduct electricity.)
cells – 1,5 volt
cell holders
bulbs and bulb-holders
insulated wire and wire with crocodile clips
strong, hard cardboard boxes
wood glue to use on cardboard
stiff plastic such as the kind used for margarine tubs

All tasks/questions are essential for the design process, even if no marks are allocated.
All tasks/questions in the PAT should be completed/answered, even the tasks/questions for which no marks are allocated for evaluation. This is because all the tasks/questions are essential parts of the design process. So, if certain tasks/questions are not done, then learners will not be able to do the subsequent tasks/questions successfully.

Week 1

Situations where electronic circuits control electric circuits (30 minutes)

Learners read information and perhaps handle real circuit breakers that are not connected to the mains.

The scenario for the PAT is on page 203. The task requires learners to design a switch to turn off a kettle automatically when the water reaches a certain temperature.

Go straight to page 203 and show the learners what the task will be. Discuss the problem without going into much detail – you will deal with details next week. Once they know why they are investigating control circuits, then the investigations will make more sense to them.



Try to have a kettle with a temperature-controlled switch in the room, boil water in it, and show how it switches itself off.

Then tell learners to go back to page 201, and answer questions 1 to 3 individually. Afterwards, discuss the answers to these questions with them.

Investigate: A circuit with an input sensor, control knob, transistor and output device (15 minutes)

Learners must end this section by giving appropriate examples of input, output and control components. They must explain how each one works.

Important concepts here are control device and sensor device. All sensor devices are control devices, but there are control devices (for example switches) that are not sensors. In other words, there are many control devices but only some of them are sensors.

The circuit that will be used for the kettle switch is the same as the fire-alarm circuit that was built in Section 15.3, with one important difference: instead of a buzzer, the output device will be an electromagnet.

Design brief and initial sketches (75 minutes)

Design brief

Spend some time on this, letting the learners put the brief into their own words.

Specifications, constraints, planning to make, and design sketches

Let the learners look at the picture of the kettle on page 203, as a stimulus for their ideas. Better still, give them a kettle to handle and look at. You may have to feed in the idea of an electromagnet when question 5 is being done.

Consider an alternative sequence of activities if learners are struggling

This activity might be very hard for many learners, and they might not produce useful answers and designs sketches working individually. If that is the case, you should consider sequencing activities differently from the way it is sequenced in the learner book.

It is questions 4 to 10 on pages 204-205 that are hard. So if learners are struggling a lot with these, you could ask learners to work on this in teams, as is shown in the learner book for Week 2: "Evaluate as a team". It would then be useful to ask each team to give feedback to the whole class. Let learners come and draw their ideas on the board as a stimulus for other learners to come up with more ideas.

If you change the sequence like this, each learner should still write down the answers to the questions and make the design sketches. Those answers and sketches will be assessed for each learner individually.

Week 2

Evaluate as a team: Learn from one another's designs to make a better design together (60 minutes)

For this teamwork, the following strategy helps for thinking creatively about how to solve a problem, and for considering many different ideas for a solution.

1. Generating new ideas:

- At the start, learners will have no ideas for how to solve the problem. So they should first create some ideas. People's minds struggle to think creatively when they feel their ideas are being judged, by themselves or by others. Therefore, as a first step, learners should not judge any ideas negatively or "give up" on them too early.
 - First "add some flesh" to the idea: make a sketch of it, make some notes, and tell others about it, without judging the idea.
2. Refining designs ideas, and choosing one idea from many ideas:
- Once a team has created and discussed many design ideas, they should now start to think critically about these design ideas.
- How exactly will this design work?
 - Is there something else that is needed to make it work?
 - Do you need to change something to the design to make it work?
 - Can the design be simplified so that it will be easier and quicker to make it?
 - What is the most useful idea or ideas in this design?
 - Will it be useful to combine ideas from different team members' individual designs, in order to make the final design?
 - Only right at the end, the team may have to choose between different designs.

Make individually: 2D Working drawing and 3D drawings of your design (60 minutes)

It is unlikely that learners will draw a design and then make their product like in the drawing. While they are working with real objects, they get new ideas. Their design evolves from their attempts to make the parts work together. In other words, the final product will not look like the drawings, and that is normal. However, drawings are important because they are tools that help you think, by visualising.

Learners may want to change their drawings or make new drawings after they have made their models. Especially in this PAT, they will need to make many changes to their designs while they are building their models. It will actually be easier for them to make the drawings afterwards, because they will then be able to see what they are drawing.

Consider an alternative sequence of activities

The activities to make the model in week 3 will be very time-consuming. It is important that learners complete their model and test it, so that they get the satisfaction of experiencing



how their design solved the problem. You may therefore choose to postpone the making of 2D working drawings and 3D drawings until after the models are completed. If you choose to do that, then the learners should start with the making of the models right now, in the remaining 60 minutes of week 2.

Homework: Planning to make and gathering materials

Learners should start collecting materials in the first week of the PAT, as soon as they have a vague idea of what they are going to make. The list below is just some suggestions. Look at the pictures below to see where these will be used.

- very thin insulated copper wire to wind around a straw, to make an electromagnet: at least 6 m per learner. (Get this wire from old chargers, transformers or ballast coils for neon lights.)
- straws
- large nails that fit inside the straws
- cold drink cans (The material is tin-plated steel or aluminium. It is coated with a plastic layer – sandpaper the plastic coating off the places that must conduct electricity.)
- strong, hard cardboard boxes
- soft planks
- screws
- stiff plastic such as the kind used for margarine tubs

Week 3

Make and test your prototype of the switch

(120 minutes)

Question 3 on page 208 is the focus of the PAT. If learners have made their electro-mechanical switch for a kettle, they have succeeded. Using this switch together with an electronic control circuit is not essential for completing this PAT.

Ideally, the heat-sensitive control circuit will activate the electromagnet when the water is hot enough. However, if learners do not have working electronic control circuits, they can instead activate the electromagnet by hand, by using a second battery that passes a current through the electromagnet.

Figures B and C give you two ideas of how the automatic switch could work. You should make one of the designs yourself, to understand the various adjustments that it needs.

How does a solenoid actuator work?

In Grade 7 Chapter 16, learners made an electromagnet by winding insulated wire around an iron nail or bolt. When you pass a current through the coil of wire, you set up a magnetic field inside the coil. This field magnetises the iron, and this makes the field even stronger.

Look at Figure A. What happens if you place the iron nail a little outside the solenoid? The solenoid induces (creates) a magnetic field inside itself, and it also induces a field inside the iron. The two magnetic fields attract each other and the iron nail is pulled into the solenoid. We say it is actuated – the solenoid made it move.

This motion of the actuator will be the output from the electro-mechanical switch. It is called “electro-mechanical” because it consists of electrical parts and mechanical parts that work together.

Figure B shows the parts of a possible design of the switch, as well as how it works. The switch is off. The kettle is not heating water.

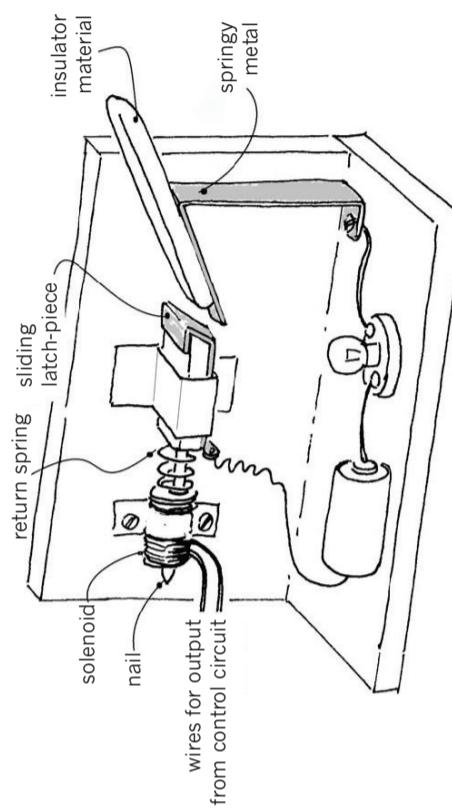


Figure A: The electromagnet – also called a solenoid actuator

If you search on YouTube for “solenoids relays ScienceOnline”, you will find a 5-minute video that gives a good explanation of solenoids and how to make them.

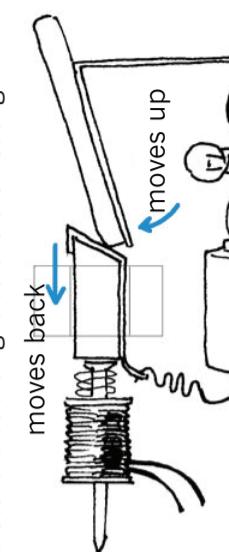


Figure C: The lever pushes the latch-piece back against the spring.

Figure B: The switch is off. The circuit is open. We will pretend that the light bulb is the heating element and that the cell is mains power to the kettle.

Look at Figure C. Now you want to heat water, so you push down the lever on the top right. (This is the only part of the switch that you see on the outside of the kettle.) When the lever is pressed down on the right-hand side, then the left-hand side of the lever moves up.



Look at Figure D. The lever has a conducting surface. The latch-piece is also a conductor. They are touching each other and passing current. So the heating element in the kettle gets hot.

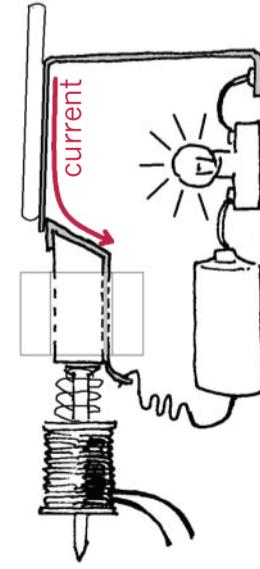


Figure D: When you press the lever far enough, the latch-piece jumps back to its normal position and holds the lever there.

Look at Figure E. After some time, the thermistor (in the electronic control circuit) senses that the water has reached the pre-set temperature. This causes the transistor to let a current though the output device (a buzzer in the case of the fire alarm, and a solenoid in the case of the kettle switch). The solenoid pulls the nail in, the left-hand side of the lever is pulled down by the springy metal, and the circuit is broken. The kettle element is now off, and it stops heating the water. It cannot switch on again until you decide to move the lever to switch it on.

(If you want to learn more about how the control circuit does the above, there is an explanation at the end of these teacher notes.)

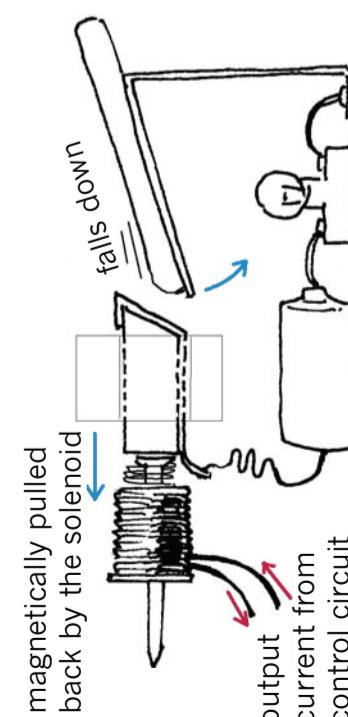


Figure E: The solenoid pulls the nail in, the nail pulls the latch-piece in, and the lever falls.

How to make the model

You can make the latch-piece out of Styrofoam or out of a strip of plastic about 1 cm wide and about 9 cm long. Fold it like a trapezium, as you see in Figure F. The conducting strip under the latch-piece can be made from heavy-duty aluminium cooking foil or from a strip of aluminium cold drink can.

The spring strip under the lever can also be made from cold drink can aluminium. Don't choose very stiff material, or the solenoid won't be able to pull strongly enough to move the latch-piece away.

You can make the return spring from very thin wire, bent into a spiral, or you can make the spring as you see in Figure G. The ends of the spring push outward: one end pushes against the

solenoid and the other end pushes against the head of the nail. The job of the return spring is to return the latch-piece to its position when the solenoid is not pulling it.

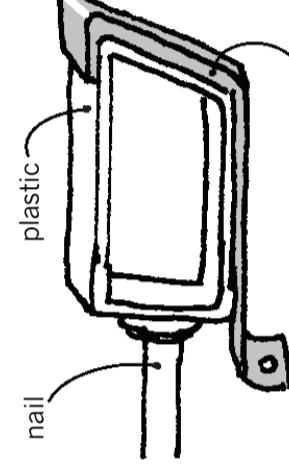


Figure F: The latch-piece can be made from a strip of plastic. Glue the nail onto the end. Glue the conducting foil or thin metal onto the bottom of the latch-piece.

Adjustments you might have to do, to make this model work

The latch-piece rubs against the carrier it slides in, and so it does not slide freely. Also, the latch-piece can't move completely freely because there is a wire attached to the conducting foil. The solenoid has to move the nail with enough force to overcome both these forces.

The return spring must push the latch-piece back into position but this might mean that the spring is too stiff for the solenoid to pull against. You can adjust the stiffness of the spring in Figure G by bending the wire or by cutting the plastic strip to make it narrower.

These problems with friction and stiffness can be overcome by using a bigger battery and much larger current in the solenoid, to pull the nail in with more force, but then you need a "power transistor" in the control circuit to carry that larger current. There is a way around this problem. You can add a "relay" to the system. A relay is a switch that closes when a small current passes through it: when the contacts in the relay close, they can pass a large current. The small current will be the collector current through the transistor. When this current flows, it powers a small electromagnet inside the relay, and the electromagnet closes the contacts that can carry a much larger current. That larger current then goes through the solenoid.

However, adding a relay is making the project more complicated. You might want to set such a task as a challenge to a few learners to solve for the national Science Expo. The alternative design below gives another way around the problem of friction.

Ideas for alternative designs

You need some ideas to suggest to the learners as they design alternative solutions to parts of this system.

Figure H shows you an alternative design. In this design, friction is less, so the model could work without the need for a power transistor or a relay. Use the nail as one of the conductors. When the thermistor "tells" the solenoid to pull the nail

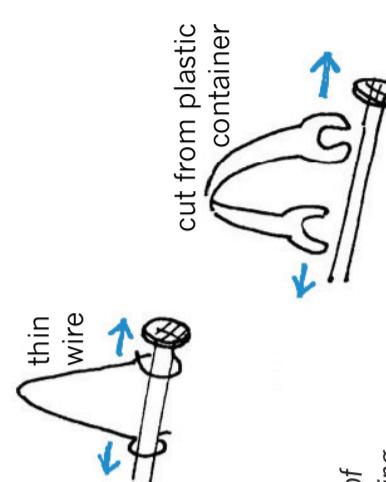
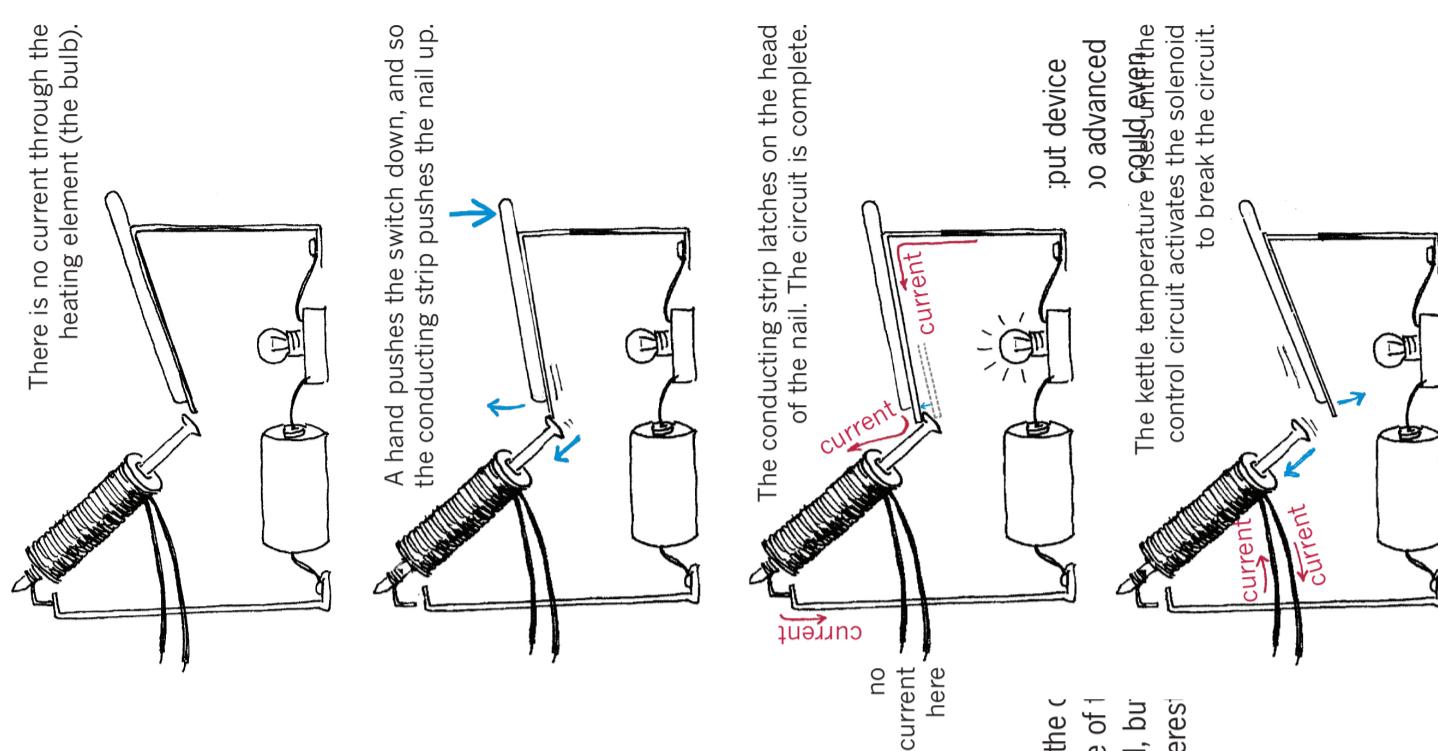


Figure G: A return spring can be made like this, from thin wire or a strip of plastic.

Figure I: What happens when a hand presses the switch down?



Below is an explanation of how the (solenoid) when the temperature of [for most learners to understand, but understand it. Also, it will be interesting] put device to advanced the control circuit activates the solenoid to break the circuit.

up, the head of the nail drops the metal strip and the circuit is broken. The circuit cannot be switched on again until your hand moves the metal strip up and into contact with the nail. The drawings and notes in Figure I explain this in more detail.

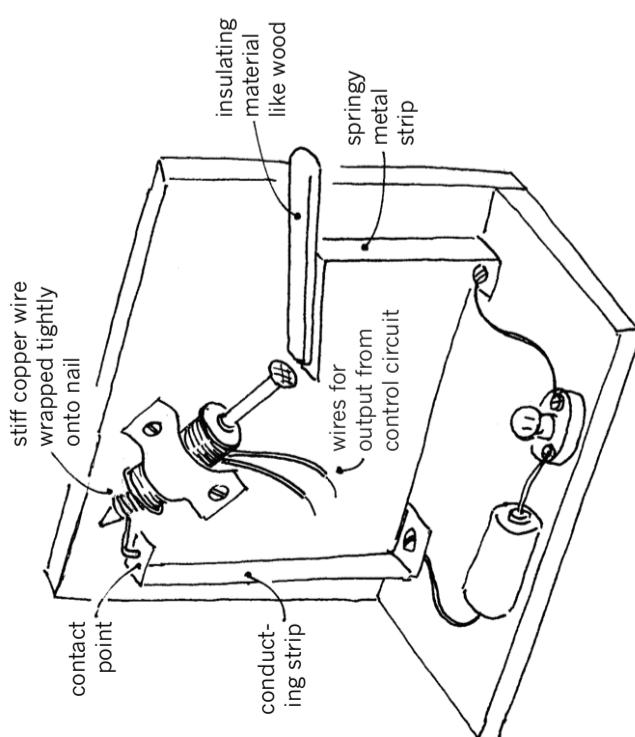


Figure H: A variation on the design idea in Figure B. Again, we pretend that the bulb is the heating element in the kettle.



Look at the circuit diagram for the fire alarm on page 191 (this answer drawing is only shown in the Teacher Guide). This circuit diagram is printed again on the right.

The NTC thermistor's resistance decreases as it heats up, and so the potential difference across it decreases as well. As you know, the potential differences across a chain of resistors in series add up to the potential difference across the ends of the chain. So if the potential difference across the thermistor decreases, then the potential differences across each of the other resistors in the chain, namely R_1 and R_2 , increases.

The potential difference across R_2 is the same as the potential difference between the points "a" and "e" on the circuit diagram, because they are parallel parts of the circuit. So if the potential difference across R_2 increases, then the potential difference between "b" (the base of the transistor) and "e" (the emitter of the transistor) also increases. That means that the current between "b" and "e" increases. When the current between the transistor's collector ("c") and emitter ("e") suddenly decreases by a large amount. Then a strong enough current can flow through the output component – the solenoid (in Figure J, the output device is a buzzer rather than a solenoid).

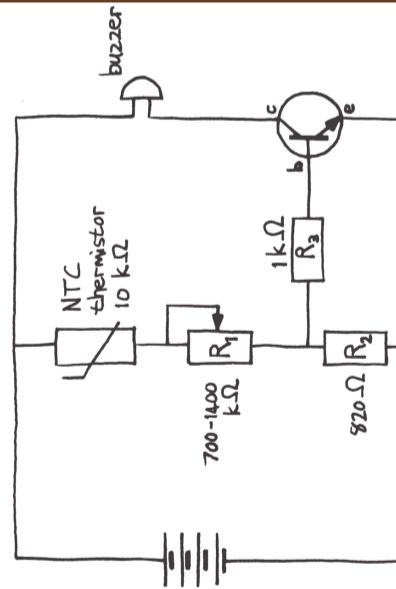


Figure J: A circuit diagram showing the different components in a fire alarm

LB pages 198–199

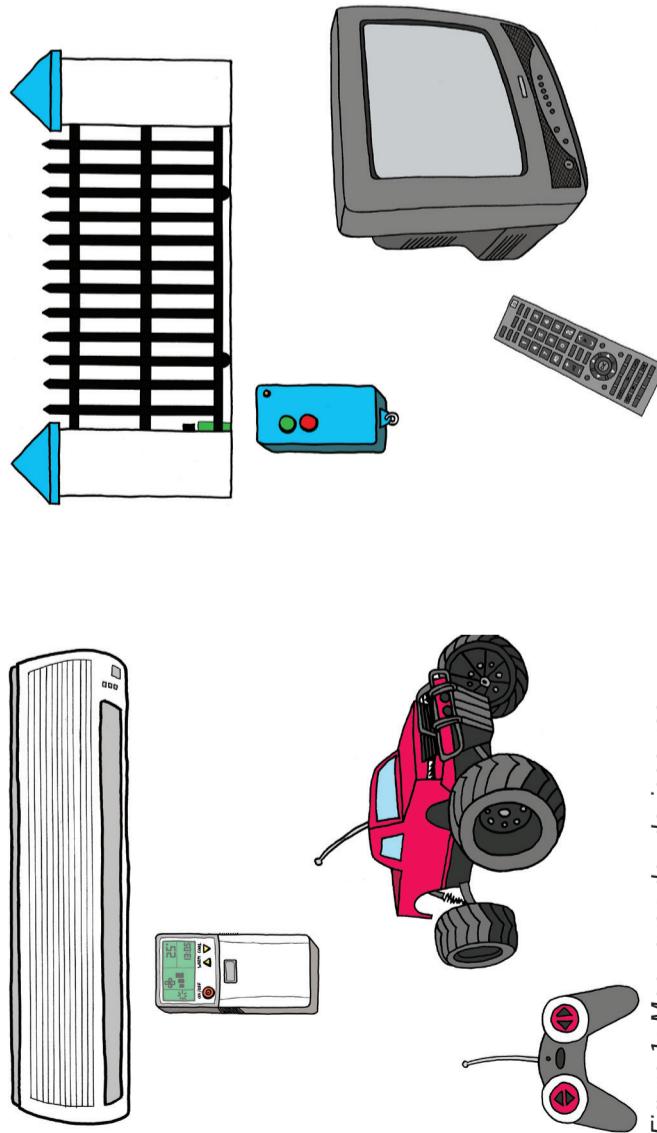


Figure 1: Many everyday devices use electronic control circuits.

Week 1

Situations where electronic circuits control electric circuits (30 minutes)

There are many household appliances that use **electronic circuits** to control electric circuits with bigger currents.

The following two devices are used inside the electric switchboard (or distribution board) of every building that is connected with electricity in a safe way.

- **Ordinary circuit breakers:**

Shuts off a circuit (for example, the circuit supplying all the lights in a house) when the current becomes too big (if the current is too big for the thickness of wire used, the wire will overheat).

- **Residual-current circuit breakers:**

Switches off the main power supply if it detects a leakage of power, such as when a person accidentally touches a "live" electrical wire or contact and the electricity is then conducted through his or her body. This device has to cut the current very quickly, otherwise the person can die due to electric shock. Therefore, it switches off the power even when it detects only a small amount of leakage of electrical current.



Figure 2: An electrical distribution board with circuit breakers

LB page 200



The following household appliances use electronic circuits to control them:

- **ovens:** to control the temperature,
- **radios and other music appliances:** to control the volume of the speakers,
- **some energy-saving lights:** to switch off automatically when there is enough natural light, and
- **kettles:** to switch off when the water boils.

1. Give two examples of situations or applications where electrical circuits are used. [1]

A few examples:

stove plates; electrical heaters and hair dryers; fans and air-conditioners;
lights; hot-water tanks (geysers); starter motor of a car; spark plugs of a car
engine, etc.

2. Give two examples of situations or applications where electronic circuits are used. [1]

A few examples:

calculator; remote control; computer; cell phone

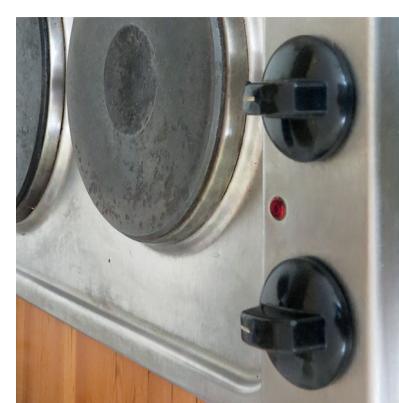
3. Give three examples of situations or applications where electronic circuits and electric circuits are used together. [3]

A few examples:

cell phone charger; automatic car gate; residual-current circuit breaker

[Total: 5]

Investigate: A circuit with an input sensor, control knob, transistor and output device (15 minutes)



A sensor is a control device that can have a variable effect. A switch can only be open (infinite large resistance) or closed (zero resistance), so a switch is not a sensor. Devices such as thermistors and LDRs can have different resistances, depending on the temperature or amount of light. They can therefore be used as sensors. A device that can generate a voltage, such as a photovoltaic cell, can also be used as a sensor. A sensor “senses” something such as temperature, or light, just as your body’s senses do. A variable resistor is also a control device, but it is not a sensor, because it is a device for which the user can set the resistance.

The circuit for the fire alarm that you built in Chapter 15 can be used for different applications where a small input current from an input sensor has to switch on a circuit with a larger current for an output device. There is also a variable resistor so that the user can determine at what level of light or temperature (for example) the output device should be switched on or off.

Figure 3: The control knob of a stove plate is connected to a variable resistor. This controls the current through the heating element. The bigger the current, the hotter the plate will be.

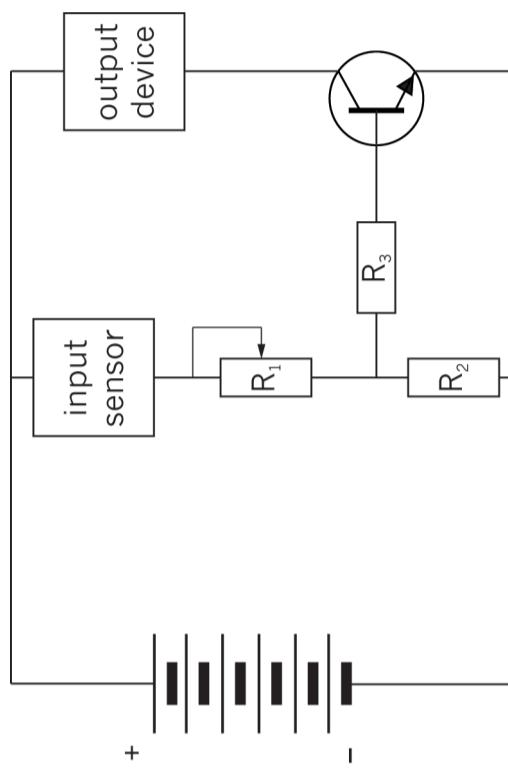


Figure 4: The control circuit that you built in Chapter 15 for a fire alarm

- **ovens:** to control the temperature,
- **radios and other music appliances:** to control the volume of the speakers,
- **some energy-saving lights:** to switch off automatically when there is enough natural light, and
- **kettles:** to switch off when the water boils.

1. Give two examples of situations or applications where electrical circuits are used. [1]

A few examples:

stove plates; electrical heaters and hair dryers; fans and air-conditioners;
lights; hot-water tanks (geysers); starter motor of a car; spark plugs of a car
engine, etc.

2. Give two examples of situations or applications where electronic circuits are used. [1]

A few examples:

calculator; remote control; computer; cell phone

3. Give three examples of situations or applications where electronic circuits and electric circuits are used together. [3]

A few examples:

cell phone charger; automatic car gate; residual-current circuit breaker

[Total: 5]



1. Name three input components that you know of.
a switch; NTC or PTC thermistor; LDR; variable resistor
2. Name three output devices that you know of.
a lamp/LED; buzzer/beeper; electric motor
3. Name a device that uses a control knob to set the level of something.
A radio has a control knob to set the volume.

Design brief and initial sketches (75 minutes)

The scenario for the PAT

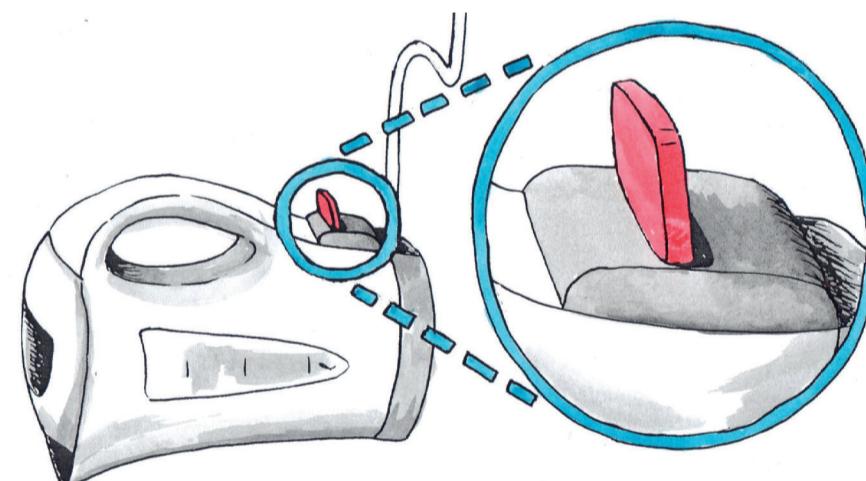
A kettle uses electricity at a rate 30 times higher than a normal light bulb. A lot of electricity can be saved if a kettle is used more effectively.

If a kettle keeps boiling without being switched off, it uses electricity unnecessarily. This leads to a waste of electricity.

If you drink your tea or coffee without cold milk, you do not want boiling hot water (100°C), since it will burn you. So it is a waste of electricity and time to bring the water to boiling point (100°C). Most of the time, a kettle only needs to heat water to a temperature of about 75°C . If the kettle keeps heating the water to a temperature of 100°C , it is a waste of electricity.

You will design and make an “energy-saving switch” for a kettle. The switch will be controlled by an electronic circuit so that the kettle will automatically switch off when the water reaches the required temperature. The electronic circuit will have a variable resistor so that the temperature at which the kettle will automatically switch off can be set by the user.

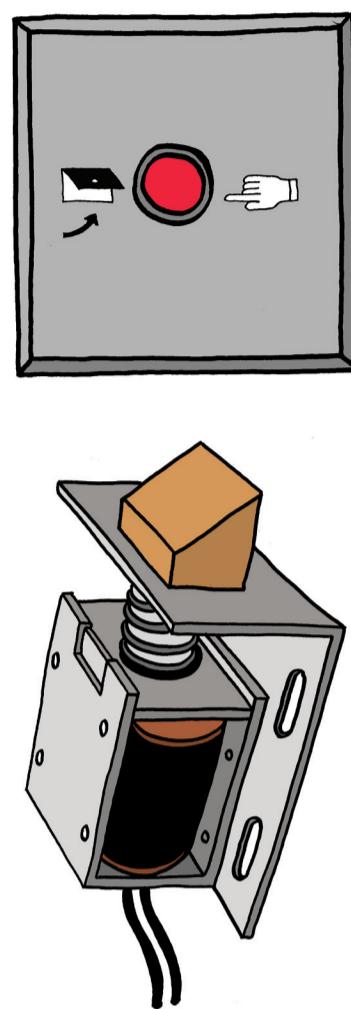
Figure 5



Design brief

LB page 203

The drawings below show how an electric door lock works. This may give you useful ideas for your design of an energy-saving kettle switch.



LB page 204

Look at the brown part on the right-hand side of the lock mechanism above. This is the part that moves in or out to open or lock the door. This part is called a “latch”.

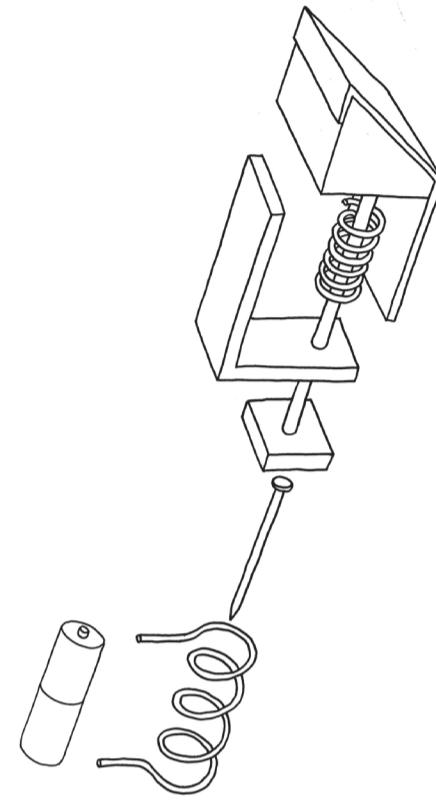


Figure 7: A 3D assembly drawing of the parts inside an electric door lock

Design brief

1. What is the purpose of the switch you will be designing?

Hint: Think about how easy it is for people to do things, the impact on the environment, and costs involved.

The switch should make it possible for people to heat water in a kettle without having to switch off the kettle themselves.

The switch should automatically switch off when the required temperature is reached, so that no electrical energy is wasted unnecessarily. This will mean less electricity needs to be generated, so there will be less negative environmental effects from power stations and coal mines. Also, people will save money, as they will not have to pay for the extra electricity.



Specifications

2. What parts should the device have where the user must press or turn something by hand? [1]

The switch should have a lever that you press down to turn the kettle on. The switch should have a spring against which you must press to turn the kettle off. The kettle should also have a knob where you can set the temperature of the water at which the switch will automatically turn the kettle off.

3. Are there part(s) of the device that would sometimes be moved by the user, and other times be moved automatically? [1]

Yes. The switch lever will be moved down by the user to switch the kettle on, but it will be moved up automatically by something inside the switch to switch the kettle off when the water reaches the required temperature.

4. How should the moving parts of your switch work? For example, what should cause it to move one way, and what should cause it to move the other way? Use names for the different moving parts, as well as for the other parts that will make the moving parts move or stop them from moving. [2]

Note to the teacher: Learners will not be able to explain this easily. They actually need to finalise their design before they can explain it fully. All that is necessary for this question is that they give names to the switch lever, the spring, the latch, the electromagnet, and the electrical contact. But a full explanation is given below.

Full explanation: When you press the switch lever down, it will press the lever against a spring that tries to press it back up. But once you have pressed the lever down far enough, a latch catches the lever so that it cannot move up any more. When the lever is caught by the latch, an electrical contact is made so that the circuit to the heating element of the kettle is closed, and the kettle is switched on. The latch works similarly to a door latch.

When the water reaches the required temperature, the control circuit will allow electrical current to flow through an electromagnet. The electromagnet will pull the metal latch back so that it doesn't stop the lever from moving up. The spring will then press the lever up again. When the lever is up, there will be no electrical contact to close the circuit containing the heating element, so the kettle will be off.

5. What type of electrical component can generate the automatic movement that your device has to perform? This component will be the output device in the control circuit on page 202. [1]
- an electromagnet**
6. Does your device need a container or supporting structure to keep all the parts together? What type of container or structure do you think will work well?
The device needs a container with strong attachment points for all the moving parts. A closed plastic container will work well. (But learners can use cardboard instead for the models of their designs.)

Constraints

7. What property should the container of the device have, for safety reasons? Give the reason(s) as well.
The container should not allow water to come into the device, because that could cause a short circuit. A short circuit could damage the device and even start a fire. (Learners have to identify this constraint, but they don't have the time and materials to make a waterproof container.)

8. Make a time schedule showing how much time you have to design and make the product.
**• 2 hours to design and draw (Week 2)
• 2 hours to build and test (Week 3)**

Planning to make

9. Make a list of all the materials you will need.
**• a long wooden bar for the switch lever
• a nail to put through the middle of the switch lever as a pivot
• a springy metal plate for the spring, as well as a metal plate to be on one side of the electrical contact
• a wooden or cardboard block in the shape of a latch
• thin metal plate (or thick strong foil) to cover the latch with, for the other side of the electrical contact
• a coil spring for the latch, or thin wire from which you can make a coil spring by wrapping it around a pen
• an electromagnet made from insulated copper wire wrapped around a thick iron nail
• a thick piece of metal to attach to the back of the latch, so that this can be attracted by the electromagnet**



- corrugated cardboard shaped to make a container in which the latch can slide, and also a place where the pivot for the switch lever can be attached

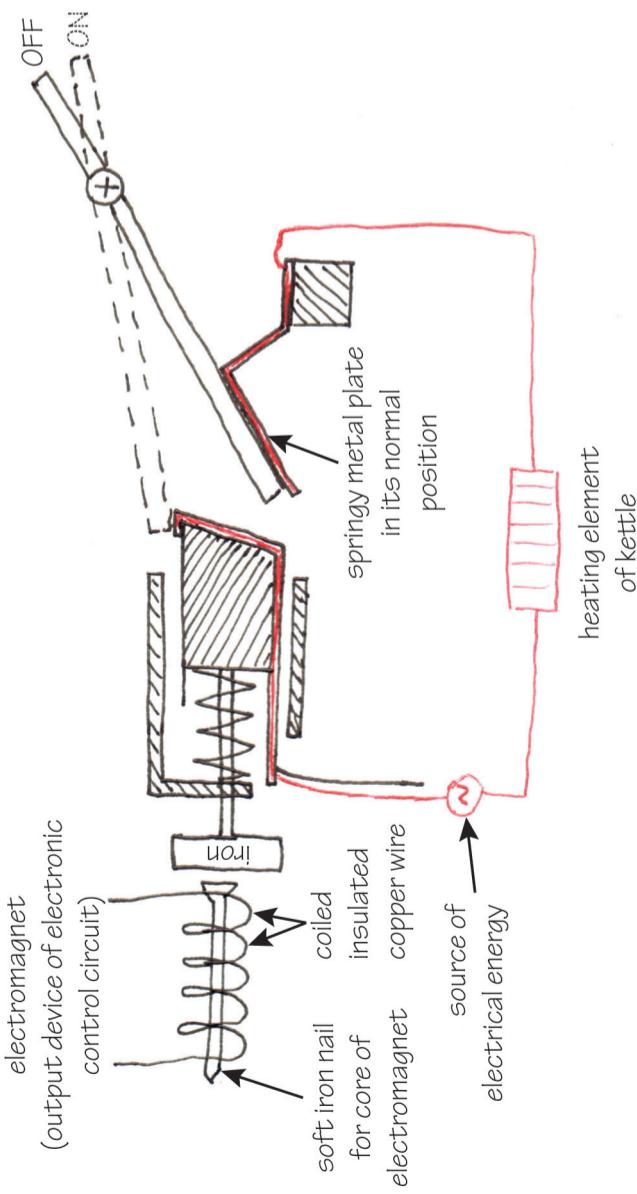
10. Make a list of all the tools you will need.

- scissors
- ruler
- wire cutter

Design sketches

11. Make at least two rough sketches of your design. Use labels and notes to explain your design. If your second sketch is an improvement on your first sketch, keep the first sketch, but simply label the second sketch as "improved design". [5]

Learners' own ideas. They should sketch at least two different design ideas. A sketch of one possible design is shown below. Note that learners will have two more opportunities to improve and sketch designs. So their design here does not need to be as good or as complete as the example given below.



Week 2

Evaluate as a team: Learn from one another's designs to make a better design together (60 minutes)

LB page 206

1. Each team member should explain his or her design to the rest of the team, and the others should ask questions if they don't understand something.
2. After everyone has explained their designs, you should make a list of the advantages and disadvantages of all the designs.

This depends on the particular designs.

You should check that learners listed advantages and disadvantages for every design.

Learn from the different designs that different people made

Don't throw an idea away too quickly even if there is a problem with it. First sketch and explain it to the others. This idea can lead to another better idea. If everyone throws their ideas away too quickly, there will be no ideas on the table to work with. Design teams work well when they separate the work into two stages:

- First generate ideas, sketch and explain them, without anyone saying anything negative about the ideas.

If someone makes a negative remark at this stage, you should say "Red flag! No negative remarks at this stage."

There is no such thing as a perfect design! For example, you can make a complicated design that will work very well, but that will be expensive and difficult to build. Or you can make a simple and cheap design that works, but is not strong enough.

Saying "Mary made a bad design" or "Sipho's is much better", for example, will hurt someone's feelings or make others feel proud or arrogant. If someone says "Mary's design ...", you should say "Red flag! We call that Design C."

[2]

3. Now combine different ideas from different designs into one better design. Your team will only succeed at this if you talk and sketch together “creatively”. Being creative means “playing with ideas”.
- To communicate well and to be creative, you have to make many rough sketches. Include labels and notes to help explain the sketches. [4]

Learners' own ideas.

They should make at least two rough sketches showing different aspects of the design.

The design sketches do not need to be final yet, so learners can make sketches of design aspects that are still problematic, and change it later.

They should include labels and notes to explain their sketches.

4. Now each person should make their own sketches of the improved design that the team made together. Once again, show labels and notes to explain the sketches. Make at least two sketches, so that both the whole design and hidden detail can be seen. You might want to draw the design from different view points, or draw a few parts on their own. [4]

Learners' own ideas.

They should make at least two sketches to show different parts of the team's design, or to show the design viewed from different angles.

These sketches should be neater than the rough sketches on the previous page, to show the final design clearly.

They should also make notes and give names to different parts.

[Total: 8]

Make individually: 2D Working drawing and 3D drawings of your design (60 minutes)

- Look back at Chapter 1 page 7 for an explanation of first-angle orthographic projections.
1. Make a 2D working drawing of your design in first-angle orthographic projection. It should be drawn to scale and show as much detail as possible. Show dimensions and the scale. Show all hidden details. [8]

Drawing of learners' own designs.



2. Make an isometric drawing of your design to scale. Do not show the container or structural support for the inner parts of your design. Only show the inner parts. Do not show any hidden details, but choose your view point so that as much detail as possible is shown. Show the scale, but do not show the dimensions.

Drawing of learners' own designs.

Learners need to use drawing triangles to draw lines that are at a 30° angle to the horizontal.

[7]

Homework: Planning to make and gathering materials

Make lists of the materials and tools you will need to build a model of your automatic kettle switch next week. You need to include the materials you will need to build the output device for the control circuit that you will later connect to your model of the switch. (Look back at your answer to question 5 on page 204.)

If there are any materials on your list that are not available at school, gather waste materials that you can use instead and bring it to school next week. If you do not do this, you won't be able to build a model of your design.

- You used the list to fix or improve your model.
 - You tested your model again, writing down the problems, and going back and fixing or improving your model until it worked, at least one more time.
 - Your model worked, or you wrote a good explanation and made sketches of what you still need to change on your model to make it work.
- [Total: 25]
- Week 3**
- Make and test your prototype of the switch (120 minutes)**
- You should work only individually in this section, with your own model. There is one exception, namely question 4.(a). For that question, you should work as a team to test the control circuit before you connect it to your model. After that you should return to working individually.
1. Work alone to build a model of your design for the switch. A model of a new design is called a **prototype**.
 2. Work alone to build the output device for the control circuit that you will later connect to your switch.
- Designers and engineers usually make many **prototypes** before the design is good enough to start manufacturing and selling it. Each prototype is an attempt to improve on the previous one.

3. Test your model with a simple circuit consisting of a battery and the electric output device that you made.
4. Test your model by connecting it to the control circuit that you made in Chapter 15, but this time connect a 9 V battery to the circuit, instead of the 6 V battery you used in Chapter 15. The output device needs a bigger potential difference than the buzzer in Chapter 15 did.

- (a) Before you connect the control circuit to any model, your team should test the control circuit as you did before (see page 192), because some of the connections may have come loose.
- (b) To test your automatic kettle switch, you can use a thumb tack pressed into an eraser that you heat by rubbing it on a piece of wood or plastic for a minute.
- (c) If you were not able to build a control circuit successfully in Chapter 15, you can use the simple circuit discussed in question 3 above to test your model of the switch.

5. You will probably find that your model does not work the first time you test it. This is normal! Most new things that people design don't work the first time they test it. Try to find out what's wrong, and then go back and fix it before you test it again.

LB page 209

- Your teacher will give you marks for the following:
- You brought all the materials needed to make a model of your design. [2]
 - You accurately made the model according to your design drawings. [8]
 - You successfully built the electric output device. [2]
 - You connected your model to the simple circuit with the output device, and used a good method to test it. [1]
 - After you tested your model for the first time, you made a list of all the possible reasons that your model is not working or why it is not working well. [2]
 - You used the list to fix or improve your model. [2]
 - You tested your model again, writing down the problems, and going back and fixing or improving your model until it worked, at least one more time. [4]
 - Your model worked, or you wrote a good explanation and made sketches of what you still need to change on your model to make it work. [4]
- [Total: 25]

You need to keep a record of all your testing and improvements on your model, otherwise you will not get marks for that work.



Week 4

Present your design process and final prototypes

Your team will give a presentation of your project later this week. The presentation should be between three and five minutes long. Each member of your team should do a part of the presentation. The other learners in the class may ask you questions after your presentation.

Your presentation should be mostly about the design process that you followed to design, make and improve your prototypes.

Team meeting: Prepare your presentations

- (30 minutes)
- Decide which part of the presentation each of you will do. Write it down. [1]
 - Decide in what order you will give the different parts of the presentation. Who will talk first, and who will talk next?

Write the parts of the presentation in the order that you will do them, and write who will do which part.

- For homework, you should practise your part of the presentation. [1]

[Total: 2]

Giving the presentations

Your teacher will look at the following to give you marks for your part of your team's presentation:

- You were well prepared for your presentation. [2]
- You explained how you made progress during the design process. [2]
- You looked at your audience and spoke clearly. [1]

[Total: 5]

LB page 210

An alternative to the kettle switch project: Designing and building a circuit continuity tester

Your teacher may decide to let you do the following project instead of designing and building an automatic kettle switch. Often when people have to connect wires in electric circuits, there are so many wires that it is difficult to know which two wire ends are of the same wire. It would help to have a device that shows whether two wire ends are connected or not. This is what a "circuit continuity tester" does.

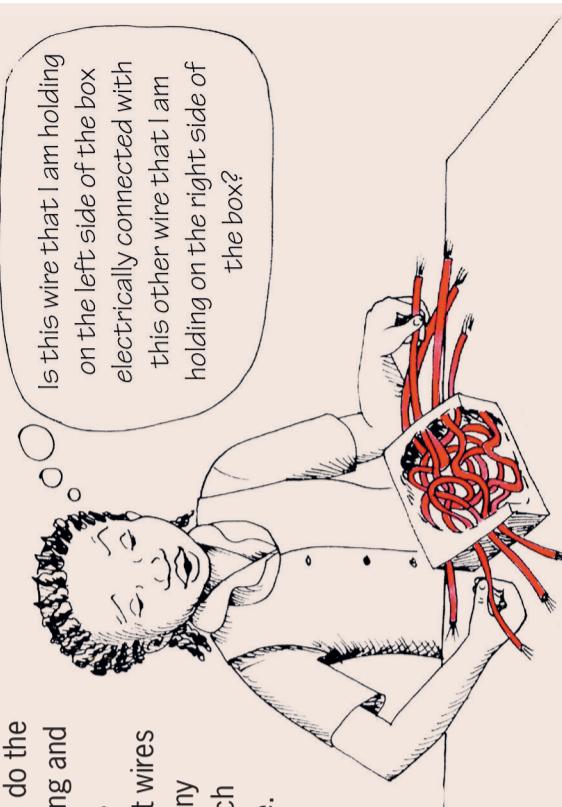


Figure 8

A circuit continuity tester is actually an open circuit. The circuit can only be closed by the two wire ends that you are testing. Use the two test leads of the circuit continuity tester to touch the two wire ends that you want to test. If there is a path for current to be conducted between the two wire ends, this will complete the circuit and a light or a buzzer on the circuit continuity tester will be activated.

Note that a circuit continuity tester cannot tell you whether the two wire ends are of the same wire. It can only tell you whether there is a path for current to be conducted between the two wire ends, in other words whether the two wire ends are electrically connected. But if you know that there are no splitting or joining of wires in between the two wire ends, then the wire ends can only be electrically connected if they are of the same wire.

If you design and build a circuit continuity tester as your project, think about the following:

- It should be easy to let the test leads of the circuit continuity tester make proper electrical contact with the wire ends.
- The tester should be small.
- The tester should be protected from shocks, for example if it gets dropped.
- The tester should be protected from water, since water can cause a short circuit.

A few ideas for building a circuit continuity tester are shown in the photos below.



Figure 9



Figure 10

Term 4: Processing

CHAPTER 17

Preserving metals

In Grades 7 and 8, you learnt how to classify metals into **ferrous** and **non-ferrous** metals. In this chapter, you will revise this skill of classifying metals. You will learn how to make metal products last longer by painting, galvanising and electroplating. If we can use materials and equipment longer before they are broken and need to be replaced, then we won't have to buy new materials and equipment so often. That means that less metal will need to be mined to make new materials and equipment. Less mining means less negative impact on the environment because of mining.

LB page 213

Ferrous refers to the presence of the element iron in a metal such as steel. This generally makes the metal more prone to react with oxygen (oxidisation). **Non-ferrous** metals don't contain iron molecules. Examples are aluminium, copper, zinc and gold. They are generally more expensive than ferrous metals.

17.1 Painting metals	284
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Materials required for this chapter:

- 10 or more samples of corroded metal
- wire brush
- sandpaper
- paint and primer for learners to see
- two big glasses or beakers
- electrodes (a length of copper wire and a brass or iron key)
- a power supply (a 1,5V "D" cell with battery holder)
- two crocodile clip leads

copper sulphate solution (NB: This is poisonous and so must be stored in a safe place.)

20 galvanised metal items (such as a galvanised nails or bolts, or pieces of corrugated iron). The items can all be the same. Pieces of corrugated iron roof sheet will work very well, but you should first cut it into smaller pieces so that it will be small enough to fit into plastic bottles or jars. You should use a pairs of snips or shears (like scissors, but stronger so that it can cut metal) to cut the sheet into smaller pieces.

a packet of table salt

10 or more nails

10 or more plastic bottles or jars with lids (can be old cold drink bottles)

a permanent marking pen for writing groups' names on the plastic bottles

In this chapter, learners are introduced to three common ways of preventing the corrosion of ferrous metals.

The teacher should let learners read and do practical work on the part on "Work in a group to investigate corrosion" (p. 223 in the Learner Book) before they start learning about painting and other methods of preserving metals (17.1). This is so that learners understand the purpose of preserving metals before they learn about the different methods with which metals can be preserved.

Ideally learners should do a corrosion experiment themselves, in groups. If there is not sufficient time for this, then the teacher should demonstrate the experiment to the class. The teacher will need to start the experiment already in the previous week, because corrosion takes a long time. The experimental instructions are given below.

Materials and equipment:

- a transparent plastic container – for example, a plastic water bottle of which the top has been cut open,
- a teaspoon of table salt, and
- two galvanised objects. Make sure that the objects are small enough to fit into the container.

Method:

- Remove some of the galvanised coating from one of the galvanised objects – possibly by rubbing it against the edge of a brick or with sand paper. This is too expose the steel underneath the zinc coating.



- b) Pour water into the container (but not too much water, as the objects should not be fully submerged in the water).
- c) Dissolve the salt in the water.
- d) Now insert the two objects into the salt water. A part of each object should be in the water, but another part should be outside the water.
- e) Store the container in safe place.
- f) Observe the container every two days to see how the corrosion progresses. Compare the object of which some galvanising has been removed with the object that is still fully galvanised.

17.1 Painting metals

Place samples of corroded metal on selected desks in the classroom. Use these as a starting point for discussion about:

- the nature of oxidation in ferrous metals,
 - the problems this creates when buildings and other objects are made of these materials,
 - the role of paint as an agent in slowing down corrosion, and
 - the process to be followed when repairing and painting a corroded piece of metal.
- For homework, learners review the chapter and complete the exercise on "Preserve metals by painting."

17.2 Galvanising

Collect the Section 17.1 homework assignments.

Give learners 10 minutes to read the content of Section 17.2.

Then ask learners questions to make sure that they have understood:

- the difference between the two forms of galvanisation described in this section,
- why zinc provides an effective protection for ferrous metals, and
- the strengths and weaknesses of "hot dip" as opposed to "electroplated" galvanising.

For homework, learners review the chapter and complete the "What have you learnt?" at the end of this section.

An additional way in which zinc protects ferrous metal (too advanced for learners)

Below is a simplified explanation of how zinc provides "galvanic cathodic protection" to ferrous metals:

When zinc is in electrical contact with iron, it forms a weak electrochemical cell, similar to the electrochemical cell learners made with a zinc-coated washer and a copper coin in Grade 8 Section 19.1. The zinc "donates" electrons to the iron. So it loses electrons itself, which is a different way of saying that it oxidises. The iron receives the electrons. This prevents the iron from oxidising itself, because oxidation of a metal occurs when the metal loses electrons. Sometimes ships have big blocks of zinc on them, which are connected to the steel of the

- b) ship with conducting material to form a closed electrical circuit. Because the zinc-iron electrochemical cell provides the iron with electrons, it is only after all the zinc have oxidised that the iron will start to oxidise. People also say that the zinc blocks are "sacrificial anodes".

17.3 Electroplating

Collect the Section 17.2 homework ("What have you learnt?").

In section 17.3, learners will first read about electroplating, and then do electroplating themselves, in groups, as a practical activity. The most important thing for learners in this section is to gain practical experience.

The teacher notes below first discuss the practical/experimental instructions.

Thereafter, it tries to answer the question "How does electroplating work?"

Instructions for the practical activity

Materials and equipment needed (for 10 groups):

- 10 glass beakers or jam jars made of glass or clear plastic (150 to 200 ml)
- 10 cells in good condition, with cellholders or some way to connect wires to the terminals (e.g. sticky-tape to wrap around from positive to negative terminals)
- 10 pairs of conducting wires, one red-covered and one black-covered. If these have crocodile clips on their ends, that is best, but clips are not essential. The colours of the wires help learners to remember which side is positive and which negative. If only white wire is available, that will also work.

10 copper pieces. This can be a copper strip, a piece of clean copper pipe, or a coil of bare copper wire. This will be the copper electrode.

a roll of paper towel

2 litres of hot water in a large glass container, to prepare the copper sulfate solution

1 large plastic spoon or stirrer, for dissolving the copper sulfate

Each group needs at least one metal object for plating.

10 lumps of steel wool for cleaning the object before plating

a bottle of methylated spirits, for cleaning the objects before plating

10 small bowls, in which the teacher will pour small amounts of methylated spirits to be used by the learners

white toothpaste, also for cleaning the objects

The following should be prepared by learners before the lesson:

Each learner should bring a small metal object to class a week before the lesson. This could be a key, a ring, a safety pin, a pencil-sharpener or a belt-buckle. It must be small enough to fit inside a jam jar.

The following should be prepared by the teacher before the lesson:

The teacher should prepare a strong solution of copper sulfate before the start of the lesson.



Prepare enough solution for 10 groups, by dissolving about 20 teaspoons of copper sulfate in 2 litres of hot water. At the start, add only 10 teaspoons of copper sulfate, and stir until it is all dissolved. Then add more teaspoons and stir again. Keep adding copper sulfate until some solid copper sulfate remains on the bottom of the container, that does not dissolve with further stirring. Now you know now that you have a saturated solution. That is to say, the water, at that temperature, cannot hold more copper sulfate.

These 2 litres should be enough for 10 jars the learners will use. If you worry about the cost of the copper sulfate, remember that you will collect the solution from the learners at the end of the lesson, and you can store it for the next class (and for next year).

You should do the experiment yourself before the lesson: Connect the circuit and plate a key or something else with copper. Note the instructions about first cleaning the metal object, given below.

The teacher (maybe with the support of the Natural Sciences teacher) can before the lesson make drawings on the board, to help learners to visualise on the sub-microscopic level what will be happening during the copper-plating experiment. The section at the end of these teacher notes ("Explanation of electroplating by referring to ions") suggests how this can be done.

Suggestion of how the teacher can manage the lesson:

Let the learners read section 17.3 for themselves, while you set out the equipment for group leaders to collect.

Check that they have understood words like corrosion, solution and electrolyte.

Let each group leader come to collect the following from you:

- a jar of copper sulfate solution,
- a cell,
- a copper electrode (the copper strip, rod, pipe or coil of wire), and
- a black and a red conducting wire.

On the tools table, place materials that will be used to clean the objects:

- lumps of steel wool,
- small bowls of methylated spirits (the smaller the bowls, the better, since spirits is flammable and poisonous),
- dabs of toothpaste on pieces of plastic, and
- squares of paper towel for rubbing the toothpaste onto the object, and for cleaning up afterwards.

Step 1 for learners:

Clean the object to be electroplated

- Steel wool will be used to remove rust or paint or other coatings on the object.
- Methylated spirits dissolves grease on the object that came from people's fingers.
- Toothpaste is a cleaning compound that contains a very fine abrasive (particles like sand, but much smaller) that polishes the surface.

Step 2 for learners: Learners should now read and follow the instructions at the bottom of page 221 in the Learner Book.

Step 3 for learners: Electroplate the object

Each group will need 3 to 5 minutes to coat an object with copper.

Things that the teacher should check about each group's experimental setup:

- The copper electrode is connected to the positive terminal of the cell (they should use a red wire for the connection).
- The object to be coated is connected to the negative terminal of the cell (they should use a black wire for the connection).
- The crocodile clips are not in the solution because they will be corroded by the reaction.
- The copper electrode and the metal object are far apart and not touching each other.

Troubleshooting

If the electrolyte solution is too weak (dilute), then the copper deposit will be a bit black and thin. If the copper deposit rubs off easily, ask the learners whether they cleaned the surface well. Human fingers always have some grease on them, so the learners should not touch the object in places that will go into the solution.

Safety warnings:

Copper sulfate, like many other chemicals and substances we use in the home, is poisonous, so remind the learners not to touch their mouths and eyes, and to wash their hands after the activity.

Methylated spirits is also poisonous, and learners should take the same precautions with it as for copper sulfate. It is a volatile and flammable liquid, and therefore the following precautions should also be taken:

- Avoid breathing in the fumes of the spirits.
- Keep the spirits away from any sources of flames (e.g. sparks) or heat, so that it does not start burning.
- Keep the bottle of methylated spirits away from the learners. By giving them only small amounts of spirits (in small bowls), the safety risks are minimised.

A YouTube video with good experimental instructions:

"Home Science Tools" shows a 1-minute video of the whole copper plating activity on YouTube. (Search on YouTube for: *home science tools electro-plating copper plate a key.*)

How does electroplating work?

Useful revision that is not included in the Learner Book

To understand electroplating, learners will have to think back to things that they have already learnt in Natural Sciences. It is suggested that the Technology and Natural Sciences teachers plan together how and when this revision can be done. And that you also ask the FET Physical Sciences teacher for input on this.

1. When a small amount of salt or sugar is mixed well with water, it dissolves, and there are no solid grains left. The mixture of water and salt, or water and sugar, is a liquid. We call a liquid that is such a mix of substances a **solution**. Some substances can dissolve in water; others cannot.



2. A solution that can conduct electricity is called an **electrolyte**.
3. When two or more atoms are **chemically bonded**, they form a **molecule**. We cannot see a molecule, because it is too small, but we can see a substance that consists of billions of molecules of exactly the same kind. Some molecules consist of two or more **different kinds of atoms** – we call a pure substance that consists of such molecules a **compound**.

Copper sulfate is an example of a compound: A copper sulfate molecule consists of a copper atom and a sulfate group of atoms that are chemically bonded (CuSO_4).

4. In Natural Sciences Grade 8 Terms 2 and 3, learners learnt that copper(II) chloride (CuCl_2) solution can be decomposed (broken down) into the elements that compose it with the use of electricity, to form solid copper and chlorine gas. Such decomposition of a compound by using electricity is called **electrolysis**. One of the results of the electrolysis of CuCl_2 is that the one electrode is coated with copper. This is a way of **electroplating** with copper.
5. In Natural Sciences Grade 8 Terms 2 and 3, learners learnt that **rust** is a compound consisting of iron and oxygen. They also learnt that steel can be coated with a thin layer of chromium or zinc to protect it against rust, and that electroplating is one technique by which this coating can be done. (**Corrosion** is the term that is used generally for the oxidisation or other reactions of any metal with non-metals. The term rust is used only for the oxidisation of metals that contain iron, such as steel.)

Ions: This is only studied in FET Physical Science, but it is needed to understand how electroplating works

Learning about ions is not in the curricula for Grades 7 to 9 Natural Sciences or Technology. However, the Learner Book provides a brief introduction to what ions are, because one can only understand why an electrolytic solution can conduct electricity, and how solid copper forms out of the solution, if one understands that there are ions in the solution. It is optional for learners to read this introduction to ions, and it is therefore also optional for them to understand how electroplating works.

You can remind learners that they already used an electrolytic solution in Grade 8 section 19.1. There they made a copper-zinc cell by putting a cloth wet with salty water between a piece of copper and a piece of zinc. The salt water was also an electrolyte, because it also conducted electricity. More about this is explained below.

Explanation of electroplating by referring to ions:

The teacher can help learners to visualise what is happening at the sub-microscopic level while they see the copper building up on the object.

The teacher can draw a sketch on the board, showing a molecule (which is neutral), and then show the molecule as two separate ions, one positive and the other negative. Let us use table salt (sodium chloride or NaCl) as an example:
Solid table salt is $(\text{Na}^+ \text{Cl}^-)$, but when it dissolves in water, it becomes Na^+ ions and Cl^- ions separately.

The two ions have opposite charges. They can move around separately in the solution (electrolyte), and move in between the water molecules.

Similarly, copper sulfate also “breaks up” (dissociates) into ions when dissolved in water:
solid CuSO_4 dissolve in water $\xrightarrow{\hspace{1cm}}$ Cu^{2+} and SO_4^{2-}

In the copper plating experiment, the following then happens because of the electrical energy provided by the cell:

- The negative side of the cell attracts the positive copper ions (Cu^{2+}) in the electrolyte, and pulls them onto the object. When they touch the object, they are given electrons by the electrical current and become neutral copper atoms (Cu).
- The positive side of the cell attracts electrons, and takes them away from some of the copper atoms on the piece of copper. This changes those neutral copper atoms (Cu) into positively charged copper ions (Cu^{2+}).
- Overall, there is a movement of copper ions from the positive terminal, through the solution, to the negative terminal.

This is all illustrated in the figure below. The SO_4^{2-} (sulfate) ions that are also in the solution (electrolyte) are not shown on this illustration, to keep the illustration simple. This illustration is a modified version of the simpler illustration in the Learner Book (Figure 9).

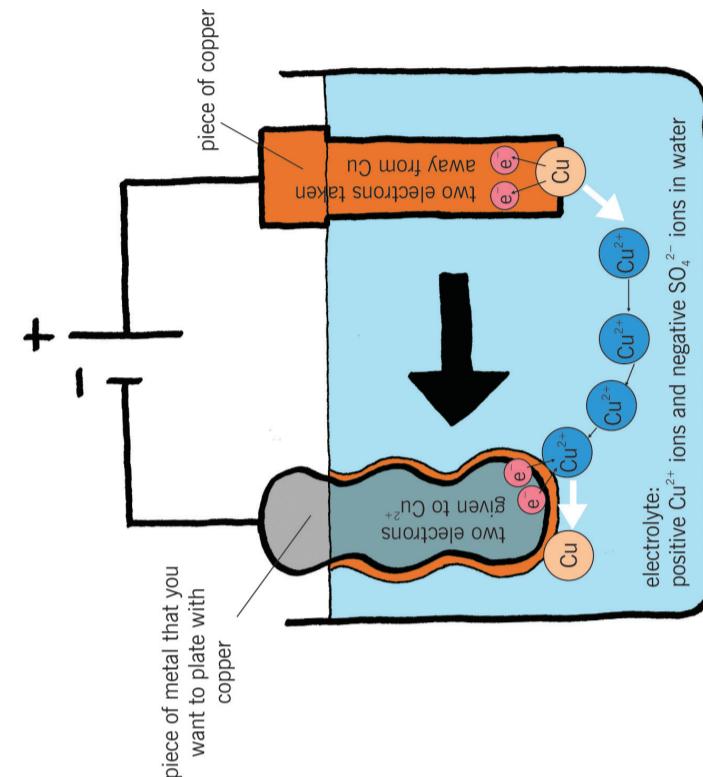


Figure a: A visual explanation of how copper plating works

A YouTube video with a good explanation of how electroplating works:

For a deeper (and more advanced) explanation of electroplating, watch Tyler DeWitt's video on YouTube. (Search on YouTube for: tyler dewitt electroplating.) This video shows how silver (expensive) is electroplated onto copper (cheap).



Figure 1: Examples of metal corrosion or rust



17.1 Painting metals

LB page 216

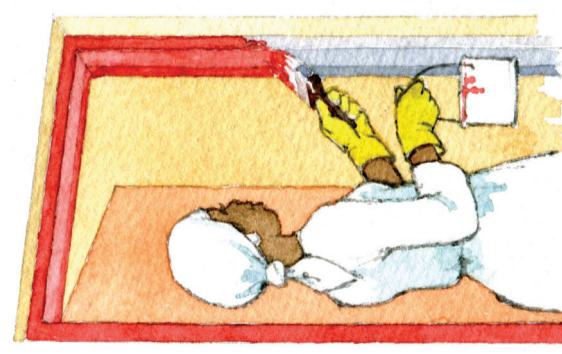


Figure 2: A woman painting a door frame

Although metals, as we usually perceive them, are generally very tough, they do break down over time. Rust is one of the most common ways that metals can deteriorate. Plants and animals die, become compost and return to the earth. When metals rust, they break down into smaller particles and also return to the earth. As you know by now, metals come from the earth originally and humans extract metals by mining.

But what causes metals to rust? For many metals, a slow chemical reaction spontaneously occurs between the surface of the metal and oxygen, when the metal is in contact with water or with moisture in the air. This is called oxidisation or corrosion. Corrosion can only occur if the metal is in contact with water or moisture in the air. Ferrous metals are not resistant to corrosion. When a ferrous metal corrodes, it is called rust.

Corrosion happens much faster when there are salts or acids dissolved in the water or the moisture in the air. For example, close to the sea, metals corrode much quicker than inland. Figure 3 shows an example of this.

However, there are ways of protecting metals against oxidisation. The cheapest way of preserving ferrous metals is by painting the exposed surface.

If it is a brand-new, smooth piece of metal that has never been painted before, it is best to first roughen the surface a bit. It is difficult for paint to stick to a very smooth surface. To roughen the surface, you can use wire brush such as the one shown in Figure 4 or sandpaper as shown in Figure 5. Make sure that there is no dust on the surface. You can wipe it with a clean cloth to get rid of dust. Then you must apply one, or preferably two, coats of primer. Primer protects the metal and makes it easier for the top coat of paint to stick to the metal's surface. Finally, you can apply the top coat of paint.

Painting a rusted piece of metal is a bit more difficult. First, you need to get rid of as much rust as possible. If there is old, flaky paint, you must remove that as well. A wire brush and sandpaper work well for this. It is hard to get rid of all the rust, therefore you need to apply a special primer to stop the oxidisation. If you don't



Figure 3: A rusted car by the coast

How do you paint metal? That depends on whether it is a brand new piece of metal or a piece of metal that has already rusted.

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Figure 5: Sandpaper



Figure 4: Wire brush



use a special primer, the metal will keep rusting underneath the paint, which will make the paint come off after a while.

Certain types of primers meant to stop rusting still require another primer to be painted on top of it, before you can apply the final coat of paint.

You have to read the instructions for the specific product carefully before buying or using it. When you've applied all the relevant primers, you can apply your top coat of paint. Now you know how to fix rusted things and make them beautiful again, instead of just throwing them away!

Important things to keep in mind when you paint:

1. Always wait till the paint you've applied is completely dry before you apply another coat.
2. Always make sure that the surface is clean before you paint it. There must be no dust, water or oil on it. Dust, water and oil prevent paint from sticking to the surface.

Preserve metals by painting

LB p. 218

Answer the questions below:

1. What materials do you need to use when painting metals?

Wire brush, sandpaper, primer paint, paint brushes and paint for final coat.

2. Write a brief outline explaining why it is important to use a primer coat when painting metals.

Applying a primer underneath the top coat of paint will protect the metal better than a coat of paint alone. The final coat of paint will stick (adhere) better to the primer than to the bare metal. The primer acts as a glue between the bare metal and the final coat of paint. Without a primer, the paint could peel or flake off. If it is old metal that had previously rusted, application of a special anti-rust primer is needed to prevent further rusting.

3. In your own words, briefly explain why boats and ships have to be painted on a regular basis.

Boats and ships are in contact with water most of the time, so corrosion can occur all the time. Also, if they are in the sea, there are salts dissolved in sea water, and this makes the corrosion happen much quicker. Regular painting will slow down the corrosion, because it will prevent metal from being in contact with water and air.

4. Study the numbered steps below. They give the process of painting metals, but the steps in the process are not in the correct order. Write down the numbers of the steps in the order that they should be done.

1. **Double coat with primer.** When some metals are exposed to oxygen, it results in rust or oxidisation. Primer helps the top coat of paint to stick to the surface. It also prevents oxidisation, or at least slows it down.
2. **Sand down your metal.** Scrape or sand the surface of your metal to ensure an even longer lasting and more durable coat of paint. When the surface of the metal is rough, the paint will stick to it better.
3. **Apply a zinc-chromate primer if you are working with rusted metal.** Scrape all the loose rust and residual dust off first, then coat it with this special primer.
4. **Clean off all loose paint, dirt, grease and grime from the surface of your metal.** If you miss this step, you will end up with a coat of paint that won't stick to the metal and peels off easily. Even oils on the surface that may not be visible will affect your paint job, so give your metal a thorough rub down even if you don't think it is necessary.
5. **Paint.** Acrylic latex paint is usually the best paint to use for metal. A cheap paint that is not made especially for coating metal will probably rub off. This will result in the metal requiring a new coat of paint a lot sooner. Work carefully and apply your paint evenly on the surface.
6. **Read the labels.** Make sure your primer and your coat of paint are compatible. If they are not, your paint will not stick to the primer. Check the drying time, so that you give enough time for the primer to dry before you put the next layer of paint on. Planning ahead is always important when painting.

The correct order of the steps is: 6; 4; 2; 3; 1; 5



17.2 Galvanising

LB page 219

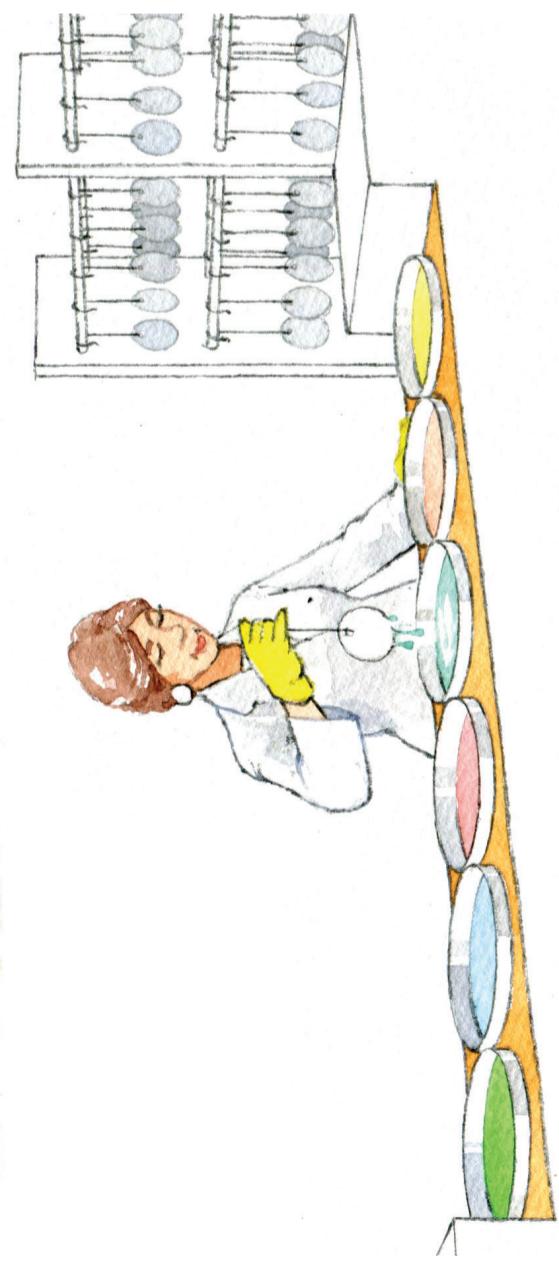


Figure 6

Apart from painting, we can also protect ferrous metals from corrosion by applying a thin coat of zinc. This process is called **galvanisation**. Zinc also corrodes, but the zinc reacts with the oxygen, water and carbon dioxide in the air and turns into "zinc carbonate". Zinc carbonate is quite tough and consequently, it protects the metal underneath it. If the zinc carbonate layer gets damaged, more zinc carbonate forms. This can repeat until there is no zinc left on the metal. Then the metal will start to rust. This means that galvanisation only slows down the corrosion of a metal. It doesn't prevent corrosion completely. If you need to protect metal properly for a very long time, it is best to galvanise and paint the metal, which is what people do with cars today.

The word **galvanisation** comes from Luigi Galvani's name. He was an Italian doctor and scientist who did experiments with electric currents in the eighteenth century.

There are two ways of galvanising metal. The one process is called "hot-dip galvanisation". The other process is called "electro-galvanisation".

Hot-dip galvanisation means that the ferrous metal gets dipped into a bath of **molten** zinc at a temperature of 460 °C. Water boils more or less at 100 °C, so you can imagine how hot that zinc is! Obviously, you need to do this with the right equipment and safety measures.

Hot-dip galvanisation has two definite advantages: it is relatively inexpensive and it is also very tough, because the zinc layer resulting from this process is thick. This makes it suitable for outdoor use, even over extended periods of time, such as 20 to 50 years. But there are disadvantages too. Firstly, the metal needs to go through a complex preparation process before it can be dipped into the molten zinc. Figure 7 shows these processes. It also makes the metal look dull and the zinc coating is not the same thickness throughout.

Electro-galvanisation means that the ferrous metal gets coated with zinc through a process called electroplating. You will learn more about electroplating in the next part of this chapter. For now, you only need to know that the zinc layer produced by electro-galvanisation is thinner than the hot-dip zinc layer, and not as tough, but it is the same thickness throughout. The zinc coating is also generally shinier and even small objects can easily be electro galvanised. This means that electro-galvanised metals are more commonly used indoors. For outdoor use, it will definitely have to be painted to make it last longer.

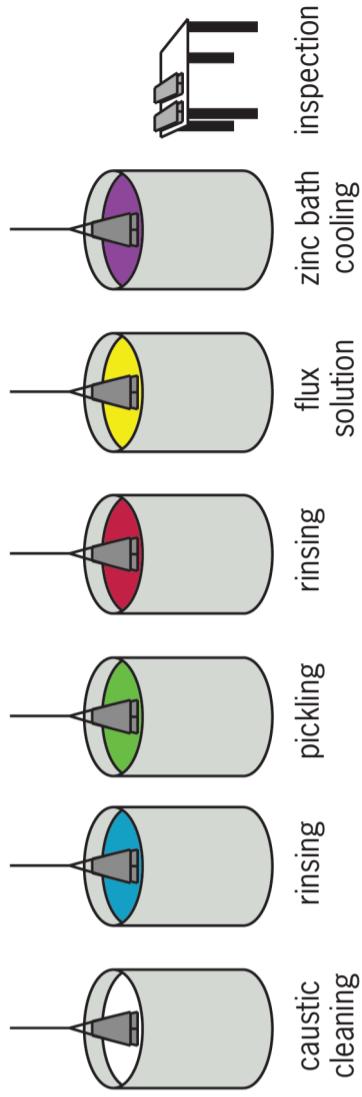


Figure 7: The processes that are followed when hot-dip galvanising metal

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Molten: when metal or rock is in liquid form because of very high temperature.



What have you learnt?

LB p. 220

Galvanising is a process that prevents corrosion. When galvanising metal, the objects are coated with zinc. This is relatively cheap. The zinc and zinc carbonate layer separates the iron from the oxygen and moisture. Objects that have been galvanised are not completely protected from rust. They only take longer to rust. To protect a metal completely, it is best to galvanise and paint it. Answer the questions below:

1. Briefly discuss the function and purpose of galvanising.

Galvanising is applied to ferrous metals to slow down corrosion. The surface of the zinc layer corrodes and forms an almost impenetrable layer of zinc carbonate. This layer prevents the ferrous metal from being in contact with air and moisture.

2. What metal is used to coat an object when galvanising it?

Zinc

3. What are the benefits of hot-dip galvanisation?

Hot-dip galvanisation is an inexpensive process, and it results in tough protection against corrosion that can last for as long as 20 to 50 years outdoors.

4. What are the disadvantages of hot-dip galvanisation?

The process involves very high and dangerous temperatures, it dulls the material it is used on, and does not provide an even layer of zinc on the metal surface. It produces a thick layer of zinc on the surface of the metal.

5. Name two examples of galvanised products.

Corrugated iron roof sheeting, electricity poles, car bodies, fence posts, buckets and baths, iron nails and screws

You can assist the learners with other answers by having them think about outdoor metal objects, or metal that has to be protected from corrosion.

17.3 Electroplating

LB page 221

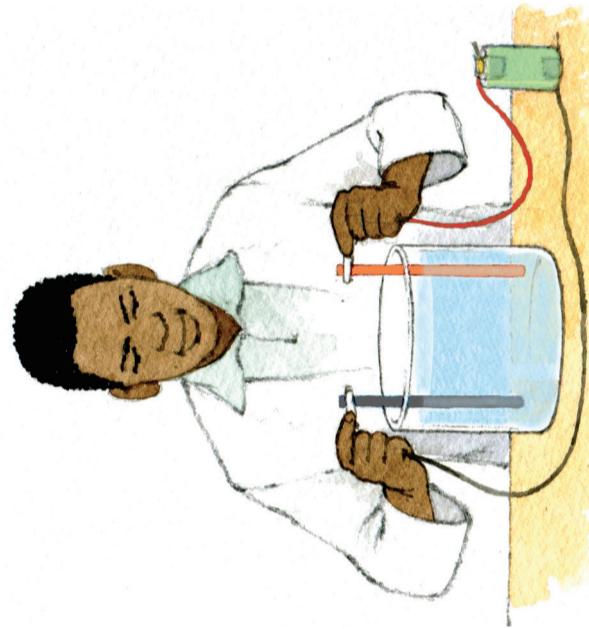


Figure 8

Electroplating coats one metal with a thin layer of another metal, by using electricity and a solution that is an **electrolyte**.

Electroplating can be used to protect metal from corrosion. This is why some steel objects are electro-galvanised. Or, electroplating can be used to make an inexpensive metal look better. For example, copper is often gold plated.

Let us say you want to plate a metal object with copper. Figures 8 and 9 shows how this can be done, and the instructions are given below:

1. Take the object that you want to coat, and connect one end of a black conducting wire to it. Connect the other end of the wire to the negative side of an electric cell.
2. Take a piece of copper, and connect one end of a red conducting wire to it. Connect the other end of the wire to the positive side of an electric cell.
3. Put the object to be coated as well as the copper piece into a container with copper sulfate electrolyte. The object and the piece of copper should not touch each other.

A solution that can conduct electricity is called an **electrolyte**. An example of an electrolyte is copper sulfate dissolved in water. The copper sulfate molecules break up into copper ions and sulfate ions. In Grades 10-12 Physical Sciences you will learn about **ions**. Below is a short introduction:

When a copper sulfate molecule dissolves in water, the sulfate part of the molecule takes away two electrons from the copper atom, and a positive copper ion and a negative sulfate ion are formed. The copper ion and sulfate ion can move separately in the solution.

How does it work?

(You will learn more about this in Grades 10-12 Physical Sciences).

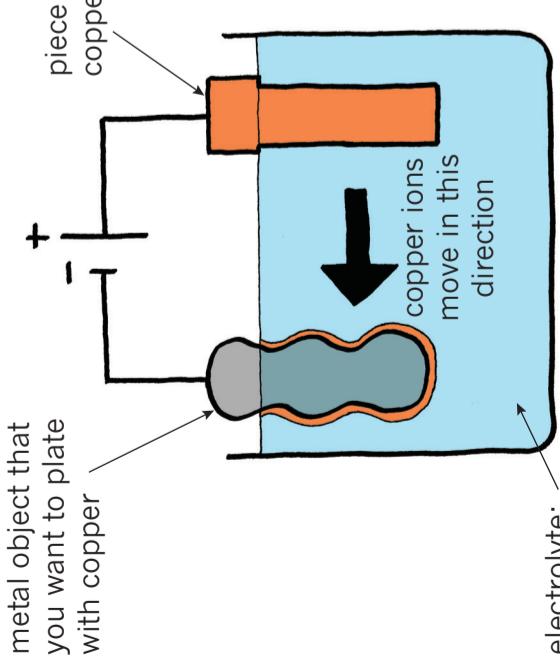
The negative side of the cell attracts the positive copper ions in the electrolyte, and pulls them onto the object. When they touch the object, they are given electrons by the electrical current and become neutral copper atoms. Continued on next page...



LB page 222

How does it work? (cont.)

The positive side of the cell attracts electrons, and takes them away from some of the copper atoms on the piece of copper. This changes those neutral copper atoms into positively charged copper ions. Those copper ions then become part of the electrolyte.



Safety warning

Copper sulfate and many other chemical substances are poisonous if you get them into your mouth or eyes. Never touch food while you are working with chemical substances, and always wash your hands after working with chemical substances.

4. A thin layer of copper metal will start to form on the object. The longer you let this process continue, the thicker this layer will become.

Work in a group to investigate corrosion

LB p. 223

In this experiment, you will observe the effect of salt and water on galvanised and ungalvanised steel. Once you have everything together, it will only take a few minutes to prepare this experiment. But then you have to put your experiment in a safe place where you can observe it for a week or more.

You need the following things for this activity:

- a plastic or glass container that is not made of metal,
- enough water to fill this container,
- a packet of table salt,
- two galvanised metal items, such as a galvanised nail, or bolt, or a piece of corrugated iron roof sheet (Hint: Look at your answer to question 5 on page 220), and
- something rough or sharp that you can use to scratch off the galvanised layer from one of the items, such as a nail or sandpaper or another piece of metal.

How to do this experiment:

- Heat the water and dissolve the packet of table salt in the water.
- When it has cooled down, pour the water and salt solution into the glass or plastic container.
- Take your two galvanised metal items and put one directly into the water and salt solution.
- Use the rough or sharp object to scratch off the galvanised layer from the other galvanised object.

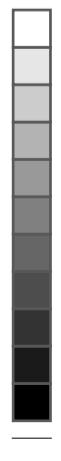
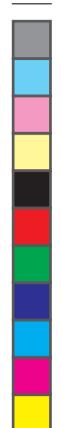
- Put the second object into the water as well. Do not let the two objects touch each other.
- Keep both objects in the water and salt solution for at least a week.
- Take them both out every day to see what has happened.

Answer the questions below:

1. Which item starts to corrode or rust first?
The object that has had the galvanising layer removed.
2. How long does it take for the metal to start corroding?
The learners should notice rust forming within a day or two. If not, the galvanisation has not been removed properly.
3. Is there a difference in the level of corrosion by the end of the week compared to the beginning of the week?
There will be continual corrosion over the week. The corrosion will be more after a longer time.



Figure 10: Coins are an example of a less expensive metal that has been electroplated with a more expensive metal for protection and to make it look better.



4. Why doesn't the other piece of metal corrode?

The galvanisation has protected the metal from the corrosion caused by the salt water, exactly as it was meant to.

What have you learnt?

You have learnt three methods of protecting ferrous metals against corrosion: painting, galvanisation and electroplating. Protecting metals against corrosion makes the metals last longer, which could reduce the need for mining. You can also easily reuse a rusted piece of metal if you clean the rust off and paint it. Reducing, reusing and recycling materials will have a positive impact on the environment.

Next week

In the next chapter, you will learn more about processing materials by extending the lifespan of food.

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CHAPTER 18

Preserving food

LB page 225
In the last chapter, you learnt about preserving metals by painting, galvanising and electropolating them. In this chapter, you will learn about different ways of preserving food, namely storing grain, pickling, drying and salting.

- | | |
|-------------------------------|-----|
| 18.1 Storing grain | 301 |
| 18.2 Pickling | 306 |
| 18.3 Drying and salting | 308 |

Materials required for this chapter:

In section 18.3, learners will complete a practical task. On pages 234 and 236 there are lists of the equipment and consumables they will need to complete the task. This chapter introduces learners to some basic technological processes that are used to preserve food. In their simplest form, many cultures, over thousands of years, have used these processes to prevent the decay of food. Today, these (and related technologies) form the basis of some of the world's biggest industries – all working to extend the useful shelf life of the food products we eat.

Section 18.1 deals with the preservation of grains. Section 18.2 deals with the preservation of mainly vegetables and fish, and Section 18.3 deals with a process that preserves the useful shelf life of meat.

18.1 Storing grain

The content of this lesson covers a traditional, as well as a modern, approach to preserving grain. You should set the scene for this lesson by outlining briefly the:

- importance of the technologies used to preserve food,
- impact that these technologies have had on culture and the nature of human society, and
- the extent of human dependence on these technologies today.

Learners should have read the content of this section before the lesson. You should ask learners questions and allow discussion to make sure that learners understand:

- what factors limit the natural goodness of grain as a food, and
- how each of the technological approaches mentioned in the section manages to limit or delay the spoiling of grain.

In some schools, it may be useful to encourage learners to describe other (possibly local) methods of grain preservation with which they are familiar. If this is done, it would be important to get learners to consider how those methods manage to control the factors that limit the useful shelf life of grain.

18.2 Pickling

Learners begin by reading about pickling as a common method of preserving plant foods, fish, and possibly some other forms of protein. What they are reading also gives a useful context within which to think about the process (sequence of steps) followed to take the food from its natural state to its preserved state. On a household (domestic) level, this is often called “a recipe”, but on an industrial level, one finds similar sequences of steps used in the large-scale preservation of food. For instance, in food processing plants (factories), one would find sequential points on the factory floor where the food and other ingredients are:

- washed,
- prepared (cut, crushed, skinned etc.),
- added to other ingredients,
- heated or cooled,
- sealed in containers,
- labelled, and
- prepared for delivery.

Once you are sure that learners know what pickling is and understand that it is one of a number of food preservation technologies used in human societies, move on to the questions at the end of the section.

For homework, learners should ask adults in their community for a recipe for pickling. (This links to the curriculum outcome of promoting ingenious knowledge systems.) They should then make a list of the ingredients and quantities (question 1), as well as a list of the processing steps (2). Learners' answers will depend on what foods are available in their environment, cultural preferences, and costs. Hence, the example answers given in the teacher guide are not the only correct answers.



18.3 Drying and salting

Learners do a practical task in this section. The practical task should ideally be completed individually. However, if for some reason groups must be formed, then it should be groups of only two learners per group.

Learners begin by reading a short introduction to drying, using meat as an example. It would be useful to start by giving each learner a small piece of biltong to examine. In tasting it, they will certainly recognise the taste of salt and possibly spices. The importance of these elements in preserving food has made them extremely valuable during certain periods of history. The European search for the source of certain spices was a major reason why the original European settlers and many Malay people ended up at the Cape in the 16th and 17th centuries.

Use this initial discussion on meat preservation to introduce the practical activity described on pages 235 and 236. It is important that each learner produce a sample of preserved spinach. Your organisation of equipment should therefore allow all learners to wash, pre-dry and expose their sample to sunlight. That means that each learner will need spinach, paper towels, access to water, and some kind of grid on which to dry their "processed" spinach leaf.

It is vital that you, as teacher, complete this practical task yourself before you begin planning this lesson. It is only by doing it yourself that you will know:

- how much space and access to equipment each learner will need,
- how many paper towels are needed to process each piece of spinach,
- how much pressure to exert on the spinach when removing moisture, and
- what the effect of sunlight will be on the spinach after 1, 2 and 3 days of exposure.

You need a clear idea of what the optimum duration of exposure to sunlight is. It will be one of the things learners will decide on at the end of the activity.

The aim of this activity should be for learners to establish what constitutes the most effective process (recipe) for producing dried spinach. That means spinach that can be stored for some time without spoiling. This will mean examining and comparing samples that have been exposed to sunlight for between 1 and 3 days to see which degree of exposure has the best effect.

This means that your planning must include:

- the management of the practical task,
- the organisation and recording of the samples left outside for drying, and
- assisting learners with the analysis of their samples and the creation of a recipe for the drying of spinach.

LB page 226



Figure 1

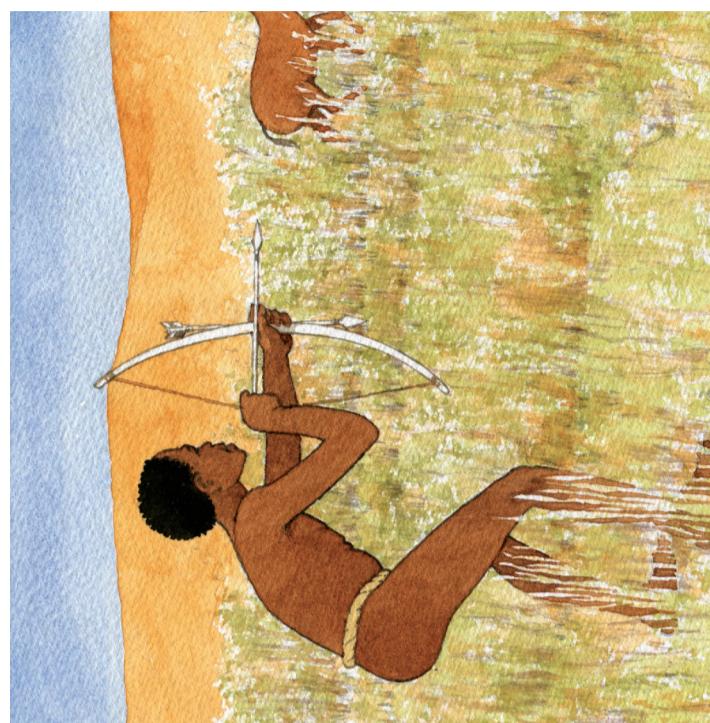
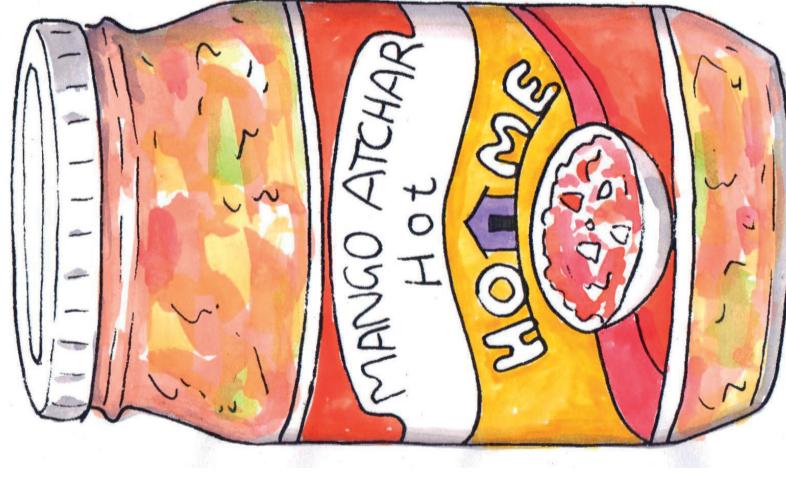


Figure 2



18.1 Storing grain

LB page 228



Food begins to spoil the moment it is harvested. Food preservation has been part of all cultures throughout history. Food preservation enabled ancient humans to live in one place and form a community. The discovery of food preservation methods meant that ancient humans no longer had to consume hunted animals or harvested food immediately. They could preserve some of their food to eat at a later time. So they did not have to travel all the time in search of fresh food.

It is interesting that different cultures preserved their local food sources using the same basic methods of food preservation, for example heating, freezing, pickling, canning, salting, fermenting, drying and refrigerating.

Food preservation is one of the oldest technologies. People ate what they grew on the land and what they hunted. They had to take good care of their food to prevent it from going off and making them ill. They also had to find ways of preserving food so that they would be able to eat even when there were no crops to harvest or when they could not hunt.

Food preservation is about the treatment, handling and storage of food to ensure that it does not lose its nutritional value or quality. An important part of food preservation is to create conditions that prevent dangerous bacteria from growing.

Grain is a staple food for most of the world. Different grains are eaten in different parts of the world, for example in China and Japan, rice is the staple grain that is eaten.

In South Africa, wheat and maize are the main grains that are grown and eaten. Maize is also used to make a fermented drink, a type of beer that some people drink on special occasions.

A **staple food** is a food that is eaten most often by a group of people and forms the largest part of their diet.

Structures for storing grain

People have always had some method of storing their grain produce. Improvements in storage methods have also been observed over time and people used the best methods for their situation or need, for example storing grain in sacks. Grains produced by farmers who farm as a business and on a large scale are stored in "silos". These are huge cement or metal structures that hold the grain from many farms in one place until it can be used or exported. The silos keep the grain cool and free from moisture, insects and rodents.

Figure 3



LB page 229

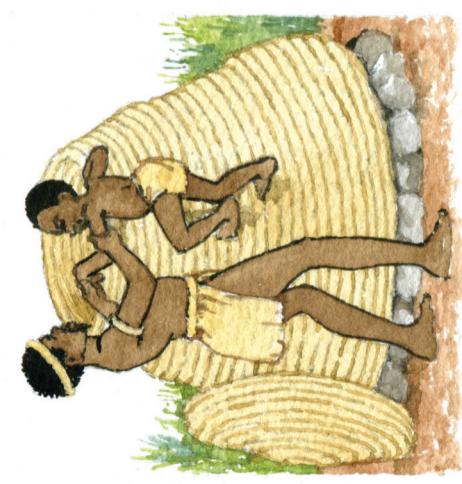


Figure 4: A traditional Zulu grain silo

A good storage container should:

- keep grain cool and dry,
- protect grain from insects, and
- protect grain from rats and mice.

LB page 230

The process of storing grain

First, grains need to be harvested. Small-scale or subsistence farmers do this by hand. Figure 6 shows harvesting on a much bigger, industrial scale with a combine harvester and a tractor.

Second, the seed, which is the edible part of the grain, needs to be loosened from the plant's casing that protects the seeds. The casing is inedible and it is called "chaff". This process is called threshing. Figure 7 shows the seeds still in their casing.

The third step is called "winnowing". Winnowing is the process whereby the loosened seed is separated from the chaff. Figure 8 shows the separated, edible seeds, and the inedible chaff in the bucket.

There are various traditional winnowing techniques. Nowadays, people use combine harvesters to harvest, thresh and winnow.



Figure 6: Harvesting on an industrial scale with a combine harvester and a tractor

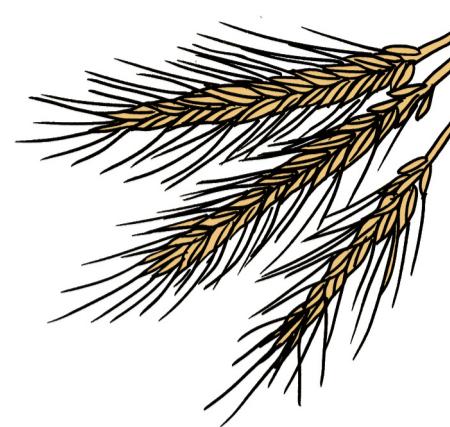


Figure 7: Wheat before harvesting, threshing and winnowing

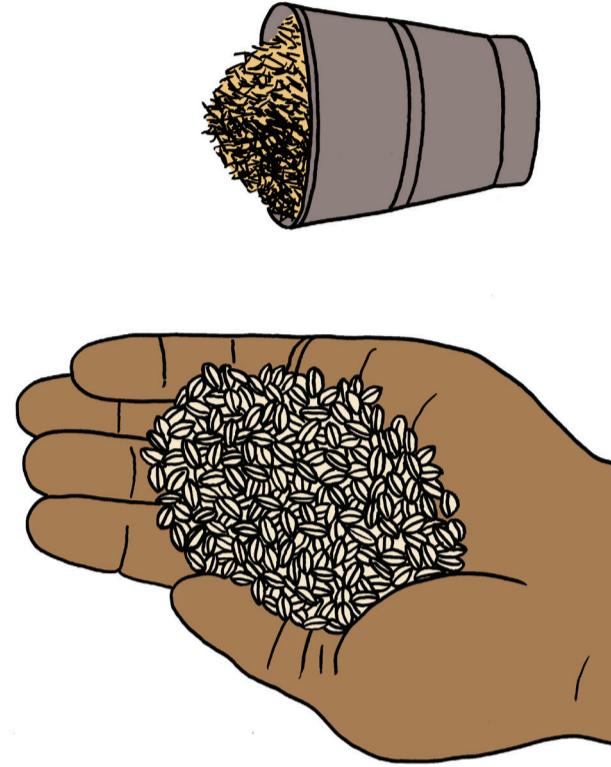


Figure 8: Grain separated from the chaff

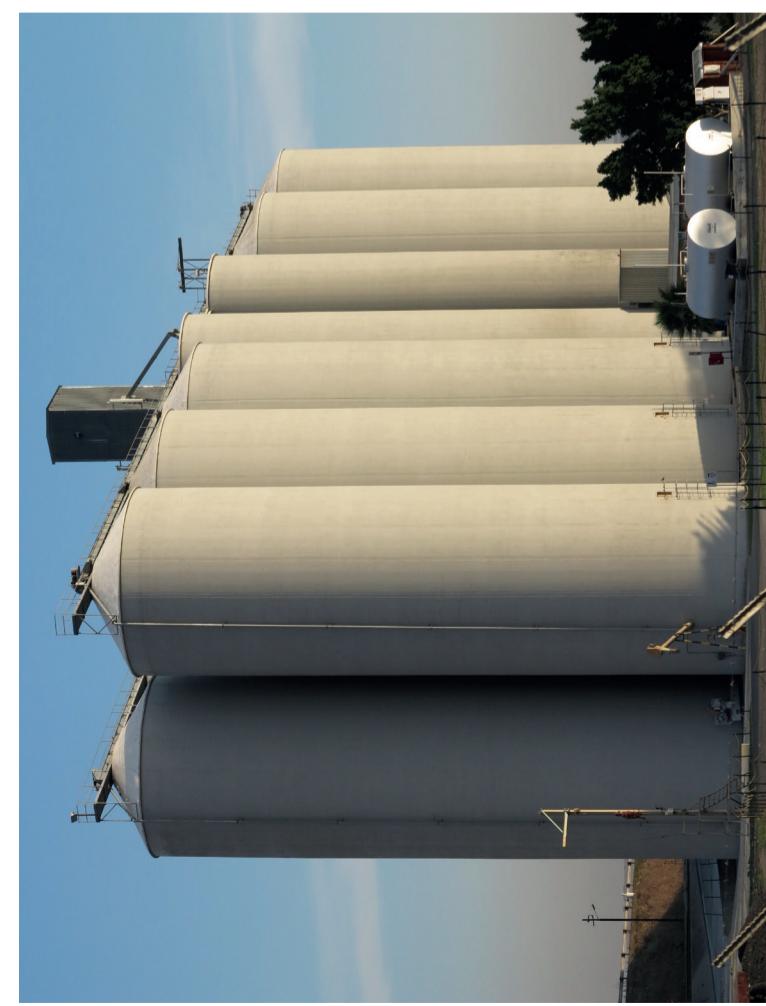


Figure 5: Modern industrial grain silos



LB page 231

Fourth, the grain is dried to prevent fungus and bacteria from growing on the seeds. The ideal moisture content for wheat is about 14%.

Nowadays, people use grain-drying machines, but in the old days, people dried grain with the help of the sun. Figure 9 shows a modern grain-drying machine.

Finally, the dried grain is stored. The humidity and temperature of the air are the two most important factors here.

Warm, moist air will encourage bacteria and mould to live on and destroy the grain, even if the grain has been dried beforehand. Cool, dry air will help to keep the grain intact for longer.

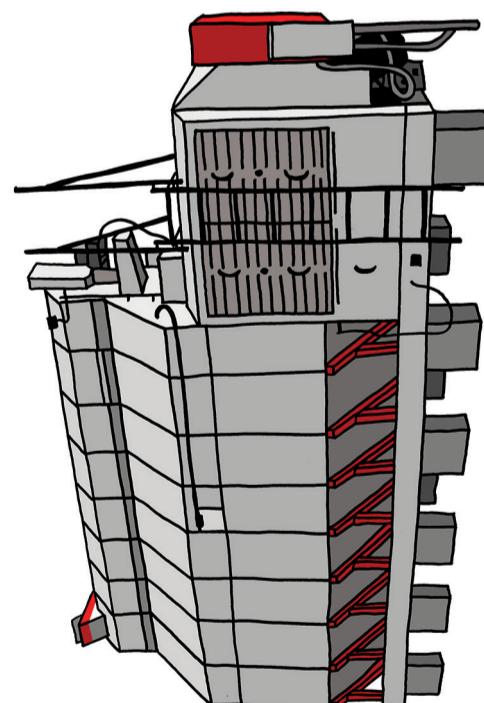


Figure 9: A modern grain-drying machine

There are all kinds of insects that damage grains, such as weevils and mites. Mites are very small insects that eat grains. Weevils are small insects that lay their eggs inside the grain. When the **larvae** hatch, they eat the seeds.

Rodents, such as rats and mice, can also cause great damage to grains. They eat large amounts of grain if they're not controlled. Besides that, they carry deadly diseases that can contaminate the grain and spread to humans if consumed. Now you can imagine that storing very large amounts of grain, for instance in a big, modern silo, is a complicated job, because air flow and temperature, insects and rodents, bacteria and fungi need to be controlled. But luckily, storing small amounts of grain is relatively easy. You need to put the grain into a clean, dry, airtight container and keep it in a cool place that is dry, with no direct sunlight or rodents.

Larvae: the stage of an insect's life after it's hatched from the egg, but before it has changed into a mature insect.

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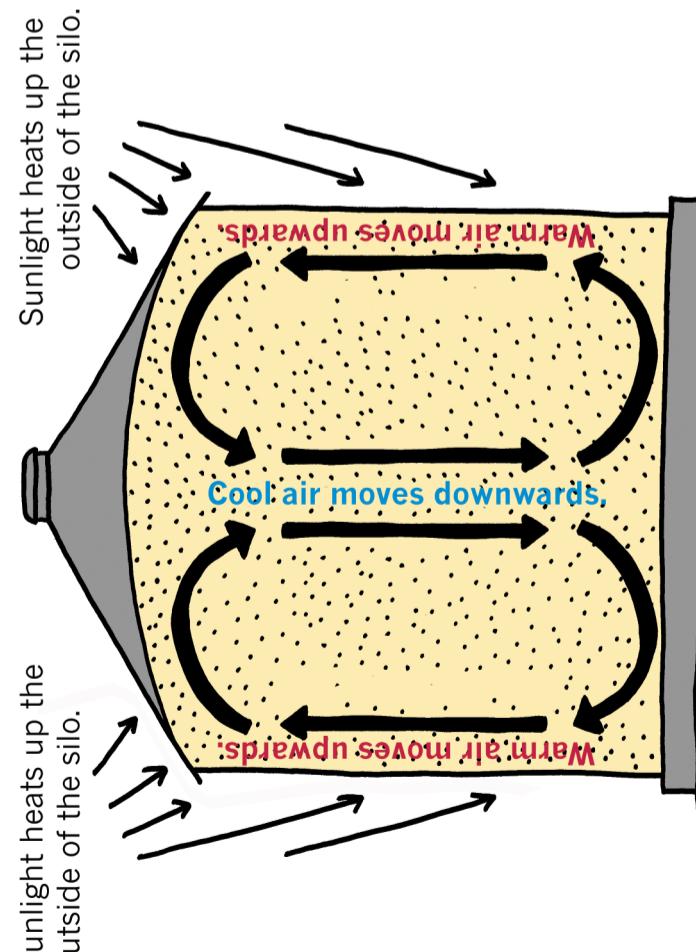


Figure 10: Schematic cross section of the air movement in a grain silo



18.2 Pickling

Most food products deteriorate because of the presence of micro-organisms, such as bacteria, yeast or mould. Remember that not all bacteria is harmful. We need good bacteria to perform certain functions in our bodies and to make certain food products, such as yoghurt and cheese.

In the past, people had to store fresh food so that it was safe to eat long after it was harvested. There were no fridges or freezers to stop food from going off. Fruit and vegetables were dried, salted, pickled or made into jam so that they could be eaten long after they were picked. Dried, pickled, salted foods and jams meant that people had a bigger variety of food and nutrients in their diet for a longer time.

Pickling possibly originated when food was placed in wine or beer to preserve it. Both wine and beer have a low pH level. People then found many uses for the **brine** that was left over from the pickling process.

Brine is a watery mix of vinegar and salt.

Pickles have become very popular. There are many pickling recipes available, and people often experiment with different combinations of vegetables, herbs and spices.



Figure 11: Examples of pickled foods

Make your own pickles

Homework:

Ask adults in your community about how pickles can be made.
1. Make of list of ingredients, also showing the quantities of the ingredients.

Learner's own answers. For example:

6 pickling cucumbers, sliced in half lengthwise,
1 red bell pepper, sliced,
1 cup water,

1 cup white vinegar,

1 cup white sugar,

2 $\frac{1}{2}$ tablespoons pickling salt,

2 cloves garlic, peeled,

12 black peppercorns,

$\frac{1}{4}$ teaspoon dried dill, and

1 pinch crushed red pepper flakes.

A few rules for pickling:
• Use clean jars and lids.
• White vinegar is better to use as it does not discolour the vegetables the way brown vinegar would.
• Use ingredients that are as fresh as possible.

2. Using the ingredients in your list, prepare an instruction sheet for another group of learners to use in preparing their pickles. Write your instructions in point form. Show the flow of activities from start to finish.
1. **Thoroughly clean and prepare a glass jar with a tight-fitting lid.**
 2. **Take 6 pickling cucumbers and slice them in half lengthways. Place them in the jar.**
 3. **Add a sliced red bell pepper, two peeled cloves of garlic and 12 black peppercorns to the jar.**

What we know today as tomato sauce was originally an oriental pickle sauce for fish. It spread to Europe by the spice route, and eventually to America where someone added sugar to it. Spices were added to these pickling sauces to make tasty recipes.

LB page 233

Chutney is another favourite South African pickled product, normally made with fruit. For pickling, we can use salt and water. Often, an acid such as vinegar is also added to the salt water.

Pickling preserves the food because the brine creates an environment where oxygen is not present. Therefore, the micro-organisms contained in and around the food cannot grow and multiply and, in turn, cause the food to go bad.

The food to be pickled is placed in a clean glass jar. A hot brine mix is poured over the food and covers it completely. The brine is poured until the jar is full. A clean, tight-fitting lid seals the jar. Pickles last for many months, depending on the type of food.



4. Pour 1 cup of water and 1 cup of white vinegar into a pot.
5. To the liquid, add 1 cup of white sugar, 2 $\frac{1}{2}$ tablespoons of pickling salt, a $\frac{1}{4}$ teaspoon dried dill and a pinch of crushed red pepper flakes.
6. Heat and stir the brine on the stove until it is almost boiling - do NOT bring to the boil.
7. Pour the liquid over the cucumbers until the jar is completely full.
8. Put the lid on tightly.

Successful preservation of food depends on inhibiting the growth of micro-organisms such as bacteria, and preventing access to insects.

3. Name and briefly discuss three advantages and three disadvantages of this method of food preservation.

1. The food can be kept for a long time without refrigerating it.
2. Many different types of food can be pickled.
3. Pickling adds to the taste and flavour of food, and many people eat pickles for this reason.
 1. You need specific ingredients and materials to pickle food.
 2. You need heat to pickle food.
 3. Some people do not like the taste of food that has been pickled.

LB page 235

Answer the following questions:

1. Explain what you understand about the purpose of food preservation.
7. Pour the liquid over the cucumbers until the jar is completely full.
2. Explain the process of drying food for preservation purposes.

Normally fresh meat has to be eaten soon after it is obtained, or it will rot. The settlers would slaughter a large animal, and have more meat than could be eaten quickly before rotting. They had no way of keeping food cool, so they had to preserve the meat through other methods. This allowed them to use the meat when they needed it for longer periods of time.

3. Briefly discuss why salt is so important in the drying method of preserving food.

Salt prevents the growth of micro-organisms, because micro-organisms dry out (lose moisture) in a very salty environment. It also repels insects, keeping the food free from egg-laying parasites.



Figure 12: Biltong

South African **biltong** is a rich inheritance from innovative Dutch settlers from the seventeenth century. They brought recipes for dried meat from Europe. They used the sun to dry meat during their trek across southern Africa.

The basic meat spices were readily available in the Cape Colony. The spices for making biltong include a dramatic blend of vinegar, salt, sugar, coriander and other available spices.

Drying is one of the oldest methods of food preservation. Drying preserves food by removing enough moisture from the food to prevent decay and spoilage.

The water content of properly dried food varies from 5% to 25%, depending on the type of food.

18.3 Drying and salting

The word **biltong** is from the Dutch "bil" (rump) and "tong" (strip or tongue).



Dry your own food

LB p. 235

Tip:

When drying food, the key is to remove moisture as quickly as possible at a temperature that does not greatly affect the flavour, texture or colour of the food.



Figure 13

You will need the following things for this activity:

- spinach,
- cold water,
- a knife,
- a large bowl, and
- paper towels.

Follow these steps:

- Find fresh spinach sold loose or in a bunch. Choose spinach that is crisp and green.
- Fill a large bowl with cool water and add the spinach.
- Rinse the spinach in the water to remove any dust or dirt particles.
- Remove the water from the bowl and refill it with fresh, cool water. Continue to rinse out the spinach in fresh water until all of the gritty particles are gone.
- Lift the spinach from the water and place it on a paper towel.
- Roll spinach into sausage shapes, cover it with another paper towel and gently press on it to remove the moisture.
- Replace the paper towel and gently press on the rolled spinach with a dry towel until all the water is removed.
- Place the prepared spinach rolls, covered with paper towel, on a sieve and leave them in the sun to dry for a few days.
- Place the dried spinach in a plastic container for storage until you need to cook it.

Record your observations during this practical activity:

1. Describe what the fresh spinach looked like.

Fresh spinach is dark green and keeps its leaf shape. When spinach is not fresh anymore, its shape "collapses" (it becomes limp or "wilted") and its colour can be come lighter green.. Until it is washed it can be very gritty.

2. List all the steps you took and explain why you did them.

1. Cleaned the spinach repeatedly in a bowl with fresh water to remove grit and dirt particles.
2. Placed spinach on a paper towel to remove moisture.
3. Carefully rolled spinach into sausage shapes to squeeze out more moisture.
4. Used more paper towel to carefully squeeze spinach "sausages" to remove more moisture.
5. Put spinach rolls on a sieve, covered with paper towels, in the sun for a few days.
6. When they were dry, stored the spinach rolls in a plastic container.

3. What was the effect of the weather conditions on your drying process?

The warmer the day the quicker the spinach rolls dried out. If it rained, I placed the rolls under shelter to prevent them from getting wet.

4. Indicate whether the results of this experiment were a success or not. Motivate your answer.

Each learner will have their own response to this question. Find out whose methods worked and the results, and if any learner's method failed. Ask them to share their experiences with the class.

What have you learnt?

You have learnt how people long ago thought innovatively to develop ways of preserving food to extend its lifespan.
You have learnt how the principles of grain storage, pickling and drying of food assist in increasing the lifespan of food.

Next week

Next week, you will learn more about reducing, re-using and recycling plastic to reduce its negative impact on the environment.

CHAPTER 19

Plastics

LB page 237

In this chapter, you will learn about various types of plastic. You will also learn that plastic can be recycled, and why this is important.

- 19.1 What are plastics, and what properties do they have? 310
- 19.2 Types of plastic, recycling, and identification codes 313
- 19.3 What have you learnt? 316

Learners should bring plastic products and containers to school for this week's activities. Figure 1 below suggests a few types of plastic products they can bring.

It is important that learners bring a wide variety of plastic products. They have to bring plastic products with recycling codes at the bottom to identify which type of plastic it is made of. The selection should include clear, translucent and opaque types of plastic, and hard and soft types of plastic. A few examples of what they can bring are cold drink bottles, milk bottles, peanut butter jars, shampoo bottles, polystyrene cups, margarine tubs, plastic plates, plastic eating utensils, freezer bags, flip-flops (plastic sandals), combs, lunch boxes, and/or geometry triangles.



Figure 1: Bring plastic items such as these to school for this week's lessons.

Materials required for this chapter:

This chapter requires learners to investigate plastics by handling and describing actual plastic objects in the classroom.

It is critical that a sufficient number of different plastic product samples are collected and brought to class. Collection should start at least a week before the start of this chapter. You must monitor the type and number of products arriving so that you are able to make up for shortages of any particular types of plastics.

The selection should include plastics with the following different properties:

1. How it looks:

- clear or transparent (you can see through it),
- translucent (lets light through, but you cannot see clearly through it), and
- opaque (does not let light through).

2. How it feels:

- hard,
- soft,
- rubbery, and
- spongy.

Examples of things they can bring:

a piece of electric cord	shampoo bottles	margarine tubs
cold drink bottles	polystyrene cups	plastic plates
milk bottles	freezer bags	combs
peanut butter jars	plastic shopping bags	lunch boxes
plastic eating utensils	plastic sandals ("foam" or "rubber" sandals are also made from types of plastics)	bubble wrap
clear food containers	plastic pipes (including hose pipes)	plastic sponges (almost all sponges are made of plastic)
pens	rulers and/or geometry triangles	fleecy blankets
switches	handles from pots	any clothes that are made of "polyester" (look on the labels inside the clothes)
plastic rope or fishing line		

In Grade 8, learners studied the environmental impact of plastic bags and the need to reuse or recycle them. In this chapter, learners find out what plastics are, and they investigate various types of plastics and their particular properties. This is important because the properties of materials determine for which purposes those materials can be used, and for which not. Learners are also asked to consider what happens to these different types of plastics once the objects are no longer wanted. They investigate types of plastics and the importance of identification codes, which enable the efficient recycling of many plastics.



19.1 What are plastics, and what properties do they have?

The aim of this lesson is to enable learners to physically investigate a variety of plastic products in order to find out more about what plastics are, and to discover the amazing and varied properties of different types of plastics.

Learners should be organised into teams of three or four.

Introduction

One way of introducing this topic might be to give the teams five minutes to read page 238 and the top of page 239. The learners search for about 6 key facts about plastics and record these using key phrases. They may also record any questions that arise from their reading. You then allow teams to share these facts with the whole class, and you answer any questions that have arisen. The learners can add to these facts as they proceed through the sections on plastics.

Mastering vocabulary relating to the properties of plastics

Twelve possible properties are listed on page 239. You could instruct each learner in a team to learn the meanings of three or four of these words, for homework. The following day, they should explain the meanings of the words to the rest of their team. In that way, the meanings of all properties will be explained within a team.

Learners are now ready to do the activity “Investigate properties of plastic objects”.

The plastic products that have been collected are used for this activity. Follow the directions given on the top of page 240. Make sure that each team has four different types of plastic objects.

It is the type of plastic used to make the object, and not the object itself, that is being investigated. So, you should ask each team to select two of their objects that have different recycling codes, and describe their properties.

You should observe the objects of all the teams. In some cases, you should tell a team which two of their objects to select for their investigation. This is to make sure that the whole class investigate as many different types of plastic (with different recycling codes) as possible.

Make sure that each learner is involved and that each learner records the answers in their notebooks. Finally, check their work and correct any misconceptions.

19.2 Types of plastic, recycling, and identification codes

The first part of this lesson introduces the two main types of plastics, namely thermosetting plastics and thermoplastic plastics. This is relevant to the second part of this section, on recycling plastic. Thermosetting plastics are very difficult to recycle, whereas thermoplastic plastics can be recycled fairly easily.

As the name suggests, thermosetting plastic can be moulded only once. This is because when the plastic is being made, certain chemical reactions are used to cause cross-links to form between different long-chain molecules, in so doing, causing the plastic to become harder. Thermosetting plastics do not soften and change shape when they are heated, but they will burn if they are heated enough. Thermosetting plastics include polyurethanes, polyester resins, epoxy resins, and synthetic rubber. They are useful for manufacturing heat-resistant objects such as saucepan handles, kitchen work surfaces and light fittings.

Thermoplastic plastics become soft and pliable when they are heated, and harden when cooled. Examples include polyethylene, polypropylene, PVC, nylon (polyamide) and acrylics.

Thermoplastic plastics can be moulded repeatedly.

Why we have to recycle plastic

Learners read the text on page 241, so that they can answer the questions that follow on it.

Different types of plastic need different processes to recycle it

The table showing the codes for different types of plastics should be explained to the learners. This table will be used for the activity in section 19.3. The recycling code of a plastic product can normally be found on the bottom of the product.

19.3 What have you learnt?

This section consists of five questions that enable learners to check what they have learnt, and enables you to assess the extent of their learning. The questions also require critical thinking: learners have to recognise that choosing a type of plastic with properties that are suitable/fit for the purpose of the product, is an important part of the design process of any plastic product.

Learners should work individually during this activity.

Question 1 requires learners to complete a table. Each learner should complete the table for the same four plastic objects that her or his team investigated in section 19.1.



19.1 What are plastics, and what properties do they have?

Up to about 100 years ago, most clothes as well as many tools and appliances were made of plant or animal materials, such as cotton, wool, wood, animal skin, and bird feathers. But then, chemistry scientists invented ways to make synthetic materials with similar properties to natural materials, and sometimes with useful properties that no natural materials have. Most of these synthetic materials are made from mineral oil, and most of them are called plastics. Synthetic materials are usually cheaper and lighter than natural materials with the same properties, and factories can mould the synthetic materials into unique shapes.

Rulers were once made from wood, but are now made from plastic. Buckets were first made from wood, then from galvanised steel, but now they are made from plastic as well. Milk came in heavy glass bottles or steel cans, but now comes in plastic bottles. Ropes were twisted from sisal plant **fibres**, but most ropes are now made from plastic fibres. Cars were made mostly from steel, wood and leather, but now many parts are made from plastics.

All around you, there are objects made of different types of plastic. Look at your shoe soles, your pen and ruler. In winter you may wear a fleecy jacket that feels like wool. That woolly substance is actually made of plastic fibres. Many clothes and most carpets are made from plastic fibres.

There are also disadvantages to synthetic materials. You learnt in Grade 8, Chapter 8 that most plastics do not bio-degrade as natural materials do. This means plastic waste lasts a very long time.

When you look at a piece of cloth closely you will see that it is woven from many thin threads, like very thin pieces of rope. If you use a microscope to look even closer, you will see that each thread is made of different long, thin pieces that hook or twist into one another. These long and very thin pieces are called **fibres**. In the close-up photo below you can see the plant fibres from which a specific fabric is made.



Figure 2: Close-up photo of plant fibres that were spun and woven to make a fabric

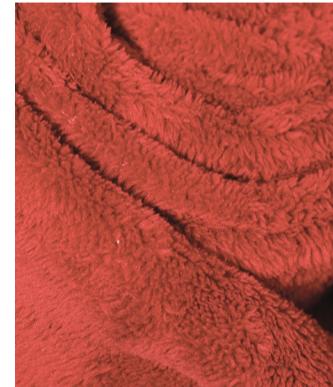


Figure 3: A "fleece" blanket is made from fibres of a type of plastic called polyester.

Plastics are examples of polymers. A polymer is a material that is made from **molecules** that have carbon atoms, hydrogen atoms and other atoms joined in long chains. Cotton, wool, leather, hair, starch, wood and rubber are examples of natural polymers. The molecule chains join together in different ways, so that there are many different kinds of polymers with different properties.

Plastics are man-made (synthetic) polymers. They are most often made from mineral oil, because the molecules in this oil are chains of carbon atoms, but shorter chains than in plastics.

Different properties of plastics

Depending on the type of plastic and the form in which it is made, it may have a few of the following properties:

- **Transparent** means you can see clearly through the plastic.
- **Translucent** means light can shine through the plastic even though you can't see through it.
- **Tough** means the plastic will not break or shatter if you hit it or drop it.
- **Elastic** means you can stretch the plastic far and it will still return to its original shape.
- **Flexible** means the plastic can bend without breaking.
- **Rigid** means the plastic will resist bending and stretching, but if you apply a big enough force to bend or stretch it, it will break or even shatter.
- **Heat-resistant** means the plastic will not melt easily.
- **Fire-resistant** means the plastic will not burn easily.
- **Waterproof** means water will not pass through the plastic.
- **Foamed** means the plastic has been processed to fill it with small air bubbles.
- **Electrically insulating** means the plastic does not allow electricity to conduct through it.
- **Thermally insulating** means the plastic does not allow heat to be conducted through it easily.

In many of these cases, you cannot simply say the plastic has a specific property or does not have a specific property. For example, you cannot simply say a type of plastic is flexible. You need to say how flexible it is, for example very flexible or only slightly flexible.



Investigate properties of plastic objects

LB p. 240

Work in teams of three or four.

- For this activity, your teacher asked you to bring different plastic objects to school.
- Each team should take two of the objects and describe their properties. Write the name of the object and then write its properties next to it.
 - Now swap your two plastic objects with those of another team that have different objects. Then write down the names and properties of the other team's objects.

19.2 Types of plastic, recycling, and identification codes

Thermoplastic and thermosetting plastics

The raw materials from which many plastic products are made, are liquids or soft materials that can be stirred, similar to glue or clay. When these materials are heated and/or mixed with other chemicals, they "set" or become hard and rigid. After they set, you cannot make them soft again by heating them. So you cannot shape them into new products. They will burn, but not turn soft again. Plastic such as this is called **thermosetting plastic**.

Examples are epoxy-resin glue, shoe soles, car tyres, electrical plugs, pot handles, electronic circuit boards, and kitchen worktops. Thermosetting plastics cannot be recycled by simply reheating them. They can, however, be turned back into oil through a high-temperature chemical process called "pyrolysis". Other plastics melt when they are heated, and can then be shaped into new products. These are called **thermoplastic plastic**. Cold drink bottles and detergent bottles are thermoplastic. If you pour boiling water into it you can change the shapes.

Safety warning:

Wear protective heat-resistant gloves, protective glasses and fire-resistant clothing if you try to melt plastic, since molten plastic can splatter and cause serious burn injuries.

Never try to melt plastic by using a flame, since the plastic can start to burn, and it can release poisonous gases.

LB page 241

Why we have to recycle plastic

Waste plastic in the environment is a big problem. Most types of plastic will not bio-degrade, but will last for hundreds of years.

Landfills are usually near cities so that garbage trucks don't have to travel too far to dump the waste. But that means people can never build houses on that land or grow crops on it.

Any materials that go into a landfill will never be used again. Instead, people will need to extract more raw materials such as oil, coal, steel, wood or glass from the earth. Then they will burn more coal to generate electricity in order to process the raw materials.

Not all plastics go into landfills, though. A lot of plastic just remains where someone has tossed it, or is dumped into rivers and then goes into the ocean.



Figure 4: Plastic waste on a sea shore. This photo was taken in Hawaii, which is why there is black volcanic rock on the seashore.



In some parts of the ocean, wind causes the water to flow round and round in one place. These areas are much bigger than South Africa. They are called “ocean gyres”. Here, millions of floating plastic bottles, bags and little plastic flakes about the size of this block □ gather.

Turtles mistake the plastic bags for jelly fish and swallow them, which kills them. Large and small fish swallow the small plastic flakes. Sea-birds eat these fish and the plastic in the fish kills the sea-birds.

So plastic being dumped in the environment is a big problem. But many types of plastic can be **recycled**.

Reasons for recycling

1. Write down two reasons why we should recycle plastic items.

- **The more plastic is recycled, the less materials are needed for new products.**
- **Recycling plastic means that it won't be added to garbage landfills that use up space.**
- **Plastic litter can kill animals.**
- **Plastic litter lasts for hundreds of years.**
- **Litter is ugly.**

LB pages 242–243

Different types of plastic need different processes to recycle it

Waste of different types of plastic need to be sorted so that each type of plastic can be recycled separately. Manufacturers have agreed on a set of codes to show which type of plastic a product is made of.

Codes and names	Examples of products	Properties	Recycled products
PET polyester	cold drink bottles, polyester fabric for clothes	clear; tough; good barrier for liquids and gases; heat-resistant	fibres to make fabrics for clothes, bags and carpets; food and drink containers

HDPE high density polyethylene	bottles for milk, juice, water and laundry products	somewhat rigid; tough; resistant to chemicals; good barrier for liquids and gases	bottles; pipes; buckets; crates; flower pots; bins; plastic planks; floor tiles
PVC polyvinyl chloride	pipes; coating (sheaves) of electrical wires	resistant to chemicals; electrically insulating; tough; can be rigid or flexible	gutters; floor tiles and mats; electrical boxes; garden hoses
LDPE low density polyethylene	thin plastic films, for example to cover food or books; flexible lids and bottles	flexible; tough; good for sealing; barrier to moisture	garbage bags; floor tiles; bins
PP polypropylene	large moulded parts, for example car parts	resistant to chemicals; tough; heat-resistant; barrier to moisture	car battery cases; brooms and brushes; bins; trays
PS polystyrene	protective packaging; disposable cups; bottles; trays; thermal insulation (especially in roofs)	can be rigid or foamed; low melting point; in foamed form it is an excellent heat insulator	plates for light switches; rulers; thermal insulation; foam packaging
OTHER	acrylic or perspex sheets (can be used as a replacement for glass windows); “ABS” for making car bumpers	depends on the type of plastic; “ABS” has very good shock-absorbing properties	plastic planks



19.3 What have you learnt?

LB page 244

Identify the types of plastic on the table **LB p. 244**

Look again at the four plastic products that your team looked at in the activity in section 19.1. Turn them upside down and try to find a symbol for the recycling code.

1. Copy and complete the table below:

Learners must refer to the table on the previous two pages to help them.

Code and name of the type of plastic	Properties	What products could be made from this recycled material?
Object 1		
Object 2		
Object 3		
Object 4		

2. Why do manufacturers often choose to make their products from plastic?

Plastic is cheap, strong, waterproof and airproof. It is easy to manufacture products with many different, and complex/intricate, shapes from it. It can be recycled, which saves raw materials.

3. Why do manufacturers put recycling codes on the bottom of containers?

Each type of plastic has different properties. If you want to make a product from recycled plastic, you want to know that the properties of the recycled plastic will suit the product's purpose. To know the properties of recycled plastic, you need to know which type of plastic was recycled to make it. For this reason, recyclers sort waste plastic into different types of plastic. Each type of plastic waste is recycled separately.

4. Why do they not use the same type of plastic for everything that can be manufactured?

Each type of plastic has different properties. To make a product, you want to choose a type of plastic that has properties that suit the purpose of the product.

5. Think of three objects that could not be made of plastic.
engines that run at very high temperatures, electrical conductors, very hard tools such as saws and drills

Next week

In the next chapter, you will learn how plastics are recycled to make new products.

CHAPTER 20

Recycling and manufacturing with recycled plastic

In this chapter, you will learn how plastic waste is recycled to make new products.

- | | |
|--|-----|
| 20.1 Moulding recycled plastic pellets into products | 321 |
| 20.2 Recycling plastic to make new products | 324 |
| 20.3 What have you learnt? | 327 |

LB page 245

Materials required for this chapter:

Copies of page 247 for each learner to write and draw on (it can be black-and-white copies). At least 10 plastic bottles with lids. Different sizes would be beneficial, for example, 500 ml, 1 litre and 2 litre cold drink bottles. Each learner needs to handle a bottle and investigate marks on the bottle that were formed because of the injection moulding and blow moulding processes. An example of a plastic chair will be useful.

In Grade 8 Chapter 8, learners focused on pollution in relation to plastic bags, and the need to reuse or recycle them in order to protect our environment. In this term, they have so far investigated various types of plastics and their properties. Learners are now also aware that different types of plastics need to be recycled separately, and that recycling codes are put on products to enable easy sorting.

Some of these plastics, for example the high-density polyethylene (HDPE) used to make plastic milk bottles, are processed into pellets. The pellets are then used as raw material and processed into various new products. Diagrams and questioning are used to develop learners' understanding of these processes.

20.1 Moulding recycled plastic pellets into products

In this section, learners are introduced to two types of processes required for making plastic bottles. The first process is injection moulding to make "preforms" from pellets. The second process is blow moulding, which transforms the "preforms" into bottles.

It could be helpful and interesting for learners to do the following before they read the explanation of injection moulding on page 246:

- Allow the learners to examine a plastic bottle and ask them to suggest how they think it has been made. This will help to get them interested.
- Next, the learners could try to identify parts of the machine shown in Figure 2 on page 247. You should supply the vocabulary for the parts: the hopper (input funnel); plastic pellets (the raw material); the screw; the barrel; the heater (not shown on the drawing); the mould, the cooler (not shown on the drawing).
- Ask the learners: "Is there heating or cooling at a stage, or at different stages, of the process? Why?" Give one or two minutes for learners to discuss this in pairs, and then ask some learners to respond to this question to the whole class.
- Next, the learners could try to work out the steps in the process by studying Figure 2.
- Learners could then read page 246 to check their work.
- They could also make a simple systems diagram of this process showing the input, the stages of the process and the final product.
- Finally, they could answer the questions at the bottom of page 246.

A 2-litre milk bottle is an excellent example of blow moulding.

You can mention to learners that friction caused by the screw causes heat, which contributes to melting the plastic pellets. It also mixes the plastic and ensures that it is heated uniformly whilst moving it forward into the mould.



When answering the question on page 248, learners can actually try the lids on the different sized bottles to see for themselves that the openings are identical.

20.2 Recycling plastic to make new products

Learners draw on their knowledge and investigation to complete the questions on the case study "The cyclical process of recycling plastic".

It should be noted that often a mixture of recycled and virgin (new) material is used when making new plastic products.

You should monitor learners as they complete this task. Observe their work and question them about their answers to check their understanding.

Question 6 on page 249 requires original thinking about different things that need to be done to plastic waste before it will be ready to recycle into new products.

Question 7 tests learners' comprehension of what they have learned so far about plastic recycling. They have to summarise this information by representing it as a systems diagram.

The systems diagram must show the different processes that form part of plastic recycling. These processes were discussed earlier in the chapter, and Figure 5 illustrates all of them together.

When learners made systems diagrams for the first time, for gear systems, there was only one process. Later, in Grade 8 section 14.3 (see p. 234 in the Teacher Guide) they made a systems diagram for a gear system with two processes. Now they will make a systems diagram for a system with more than two processes. Something else that is special for the recycling systems diagram, is that the output of the last process becomes the input of the first process. This is because this system is a closed 'cycle', with no input from outside the recycling system.

20.3 What have you learnt?

You need to observe the learners during this exercise to ensure they are individually applying thought and effort to the task.

Once the exercise has been completed and the work handed in, you should discuss these questions to ensure all learners have a sound understanding of these aspects of manufacturing with recycled plastic.

Learners benefit from feedback, and therefore need their marked work to be returned as soon as possible.

An excellent video called "Plastic Injection Moulding" by Bill Hammock (who is known as the "engineerman") is available on YouTube. It is not essential, but this is a fascinating short video that will really enhance knowledge and interest in this topic.

20.1 Moulding recycled plastic pellets into products

There are two steps to making plastic bottles, injection moulding and blow moulding.

Step 1: Injection moulding to make preforms from pellets



Figure 1: A preform of a plastic bottle

Injection moulding is used to make plastic "preforms" of bottles. Preforms are like small bottles with very thick walls that already have the neck and screw-thread of the final bottle. Figure 1 shows the preform for a plastic bottle. Figure 2 shows the injection-moulding machine at different times of the injection-moulding process. In this picture, the plastic is the coloured substance. The raw material going into the machine is small, almost round pieces of plastic called pellets.

They are initially hard since they have not been heated yet, and are shown in blue. The plastic must be soft and hot for the injection process to work. The pellets are pushed forward by a screw that is turned by a motor. At the same time, the pellets are heated until they melt. The turning force of the screw creates pressure that pushes or injects the molten plastic into the mould. Once the mould has been filled, the opening of the mould where the molten plastic came in is closed, and the mould is left to cool.

The plastic in the mould solidifies as it cools down. Once it has cooled down sufficiently, the two halves of the mould open so that the preform that was made can be taken out.

Questions for you to answer

LB p. 246

Copy Figure 2 roughly (or use the photocopy that your teacher gives you), and answer the following questions.

- Find the mould and label it.
- Where will you put a heater on the machine to melt the plastic pellets? Draw an extra part or parts for the machine to show where the heater should be, and label it.
- Look carefully at a plastic bottle. You will find a very thin ridge where the two parts of the mould joined. If you cannot see it, feel around the neck of the bottle with your finger. Why is the mould line on both sides of the neck?



The two halves are joined together, so there will be a joining line on each side.....

LB page 247

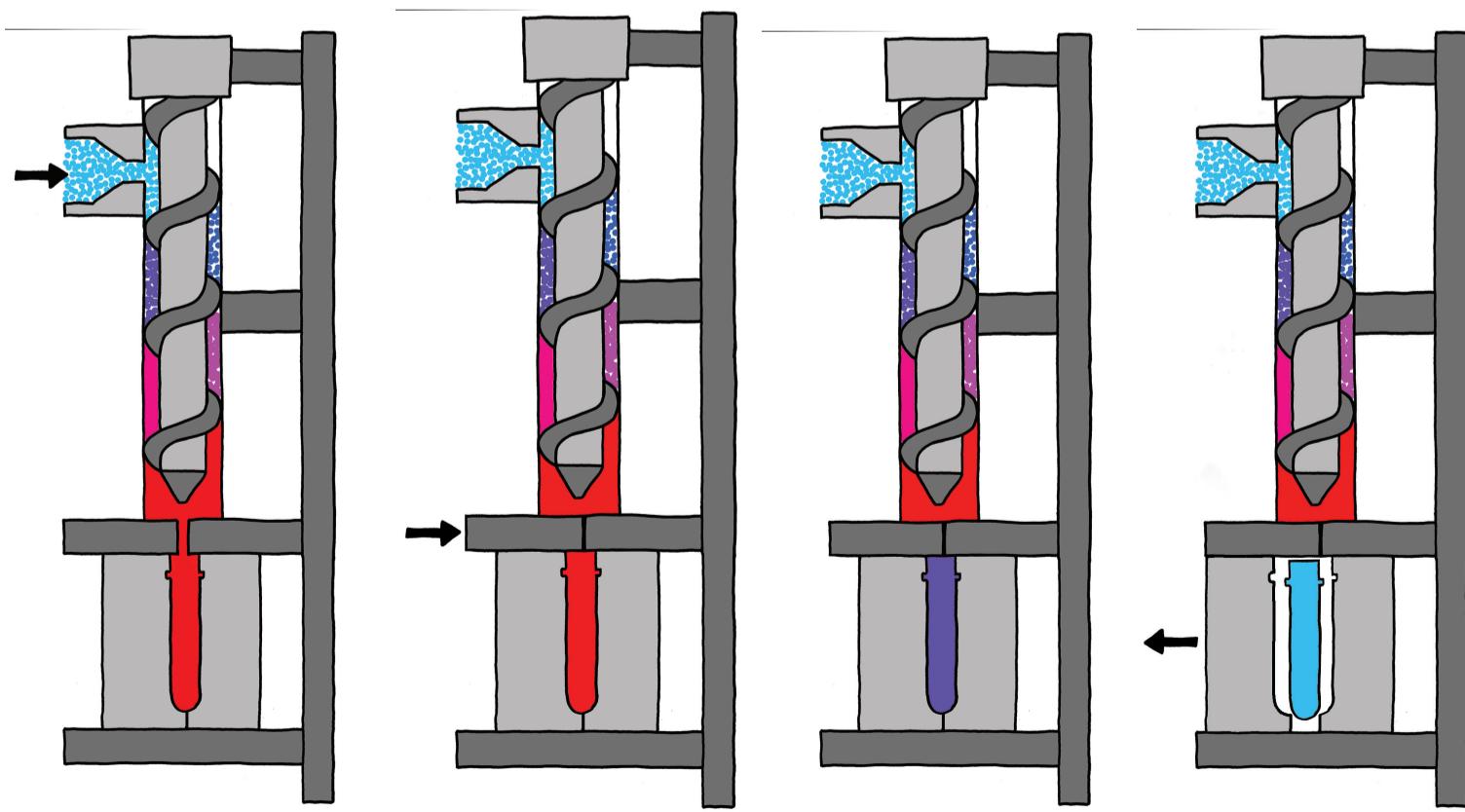


Figure 2: The injection-moulding process

Step 2: Blow moulding to shape preforms into bottles

LB page 248

Next, the preform goes to a blow-moulding machine. This machine blows hot air under high pressure into the preform. This heats the lower part of the preform so that it becomes soft and can change its shape. The high air pressure forces the walls of the preform to expand into the mould, similar to blowing up a balloon.

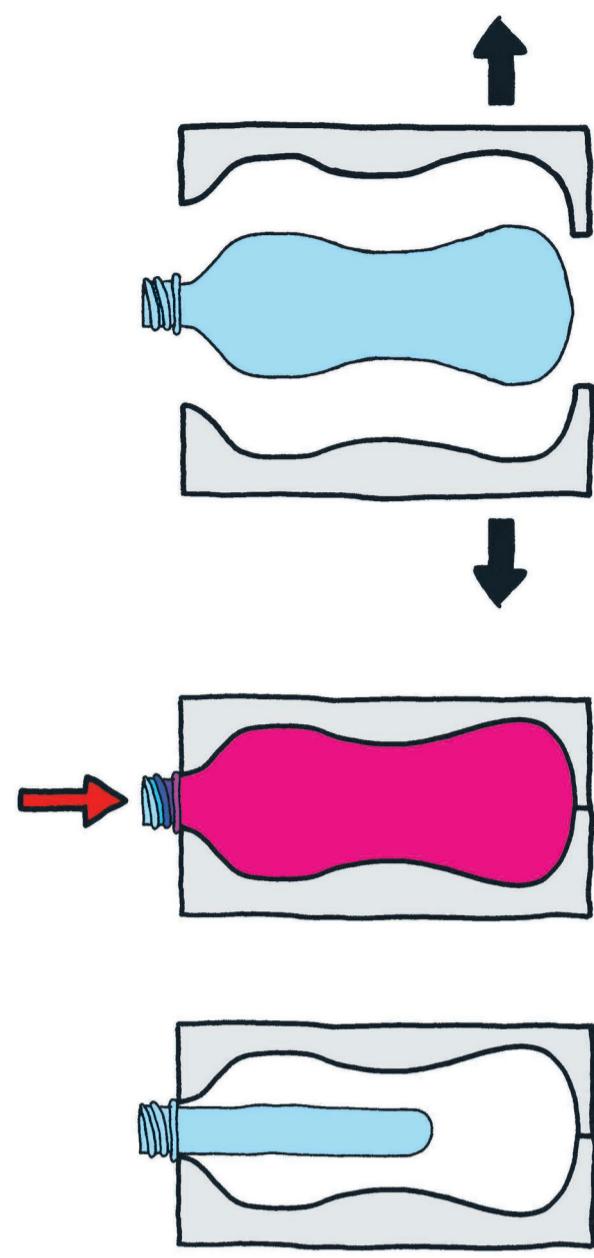


Figure 3: Blow-moulding of a preform to make a plastic bottle

The same type of preform can be made into different shapes of bottles, since it can be blown into different moulds. But all the bottles will have the same screw-on cap.

Question for you to answer

LB p. 248

1. Why will all the different-shaped bottles fit the same cap?

Because the preforms were all the same shape.



20.2 Recycling plastic to make new products

In Chapter 19, you learnt why we should recycle plastic containers and other products. In this chapter, you will learn how PET plastic can be recycled and made into a new raw material.

Figure 5 on the next page shows the plastic recycling process.

Each type of plastic waste is pressed into bales that can easily be transported. At the recycling factory, the plastic waste is shredded into small pieces, to make it easier to handle and wash.

Case study: The cyclical process of recycling plastic

LB p. 249

1. Why should plastics be separated into different types before it can be recycled? **Each type of plastic has different properties. If you want to make a product from recycled plastic, you want to know that the properties of the recycled plastic will suit the product's purpose. To know the properties of recycled plastic, you need to know which type of plastic was recycled to make it.** **Different types of plastic have different melting points, and some types need special treatment before they can be recycled.**
2. How do the recycling codes on the plastic containers help to sort them? **The codes show the sorters which type of plastic each container is made of. They can then place the containers into the correct bin.**
3. The containers are not only plastic. If you look carefully at a container, what other materials can you find? You can look at some of the containers your classmates brought to class.
Containers have other materials added to them. Paper and thinner plastic labels; hard plastic caps made of a different type of plastic; foam seals in the lids, etc. Sometimes the containers still have left-over material inside, for instance syrup, face cream, sour milk, etc.
4. Are all the plastic containers in the bin clean? Is this important?
Usually, the containers are not clean. This is a problem for recyclers. People are always advised to clean their empty containers by emptying the last bits out and rinsing them with warm water before putting them in the recycling bin.

LB page 249

5. Waste plastic bottles and other plastic containers take up a lot of space. How can this problem be minimised?

People can crush or flatten plastic containers (by standing on them) before disposing of them, so that the plastic waste will take up much less space.

6. Name four things that need to be done to plastic waste before it will be suitable to turn into new products.

Sorting into different types of plastic; pressing the material in containers into bales (a large bundle of compressed material tied with rope or wire) for transporting to the recycling factory; shredding the material into flakes; washing and removing bits of labels and old contents; melting the flakes into pellets; packaging and labelling the bags of pellets.

7. Copy and complete the systems diagram in Figure 4 by giving descriptions of the different steps of the recycling process. Hint: When something is recycled, it means that the output is also the input, since the process is a cycle or circular.

LB page 250

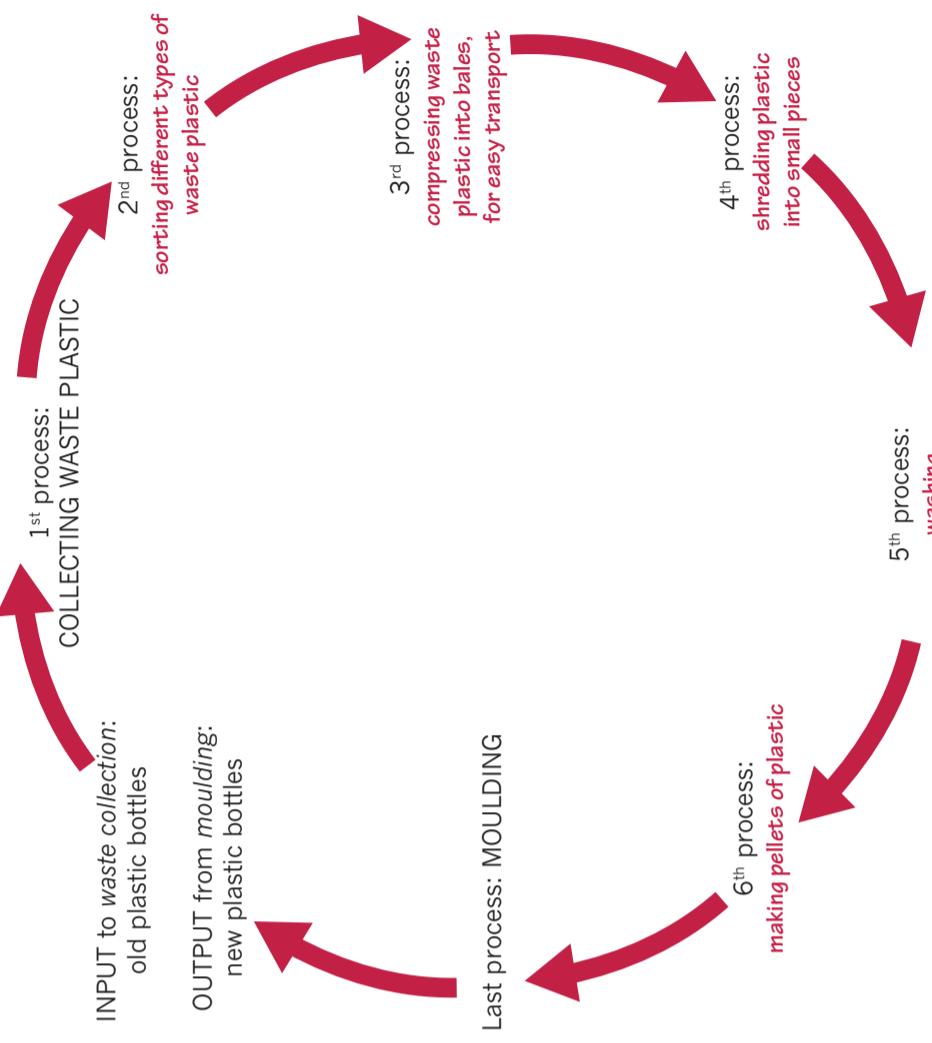


Figure 4: Systems diagram of the plastic bottle recycling process



LB page 251

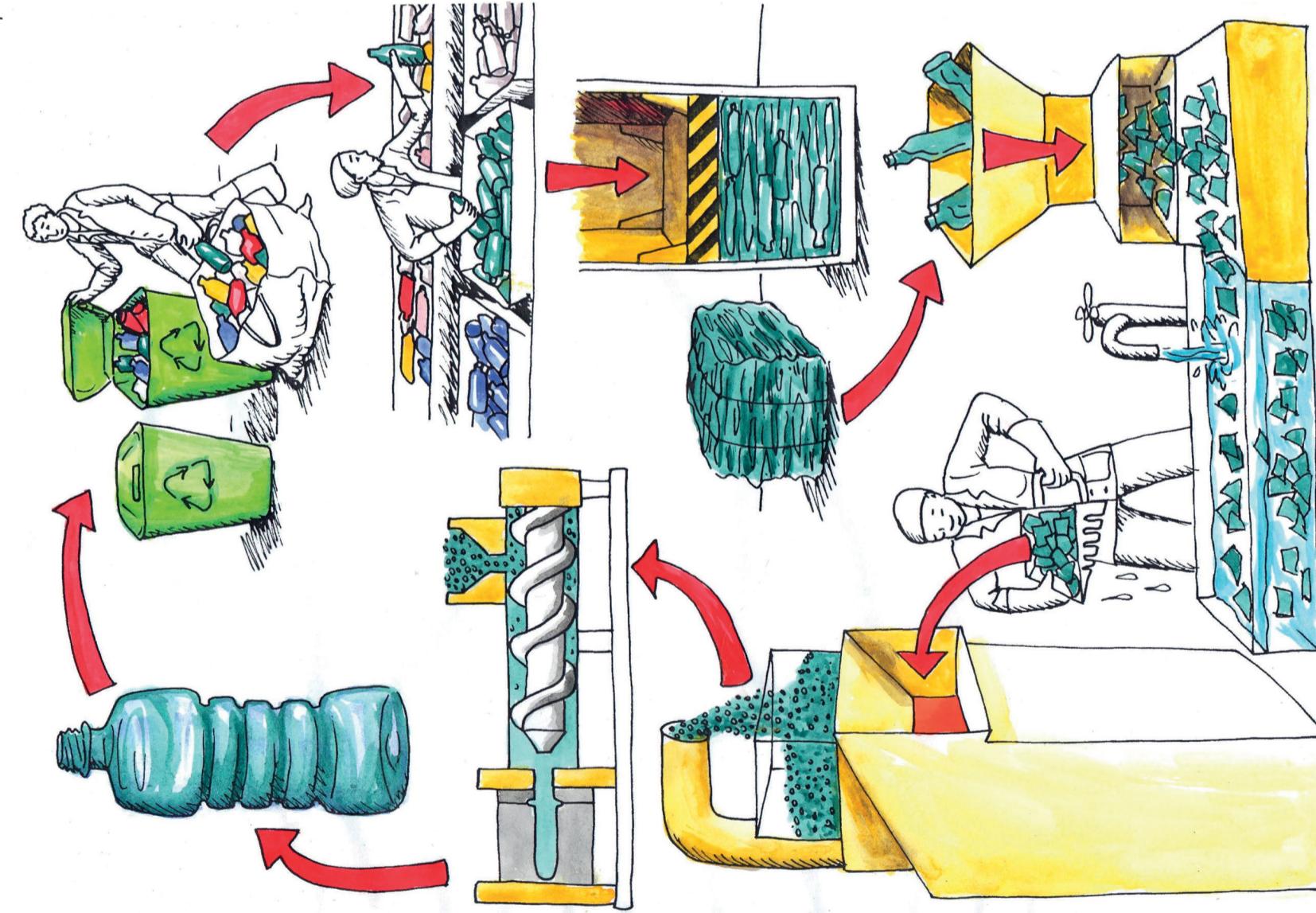


Figure 5: The steps to turn waste plastic into new plastic products

20.3 What have you learnt?

1. What is the raw material for the bottles in this process?
pellets of PET from used bottles
2. How can consumers and house-owners make it easier for recyclers to process plastic products to make new bottles?
Wash out the bottles and other containers; remove the labels if possible; remove the hard caps; crush or flatten the containers so they take up less space; take the plastic products to a recycling centre; set up a recycling centre at school.
3. A manufacturer can buy one type of preform and then make different-shaped bottles. How can this be done?

The manufacturer can use different moulds during the blow-moulding stage.

4. Which type of moulding do you think is used to make solid plastic chairs?
Injection moulding
5. What are the differences between injection moulding and blow moulding?
Injection moulding uses plastic pellets as raw material, and pushes or injects the molten plastic into the mould using the pressure created from the turning screw. Injection moulding produces solid products.
Blow moulding uses preforms as raw material. It shapes the preforms by blowing hot air under high pressure into it, to make the preforms expand into the mould.
Blow moulding produces hollow products.

Next week

Over the next three weeks, you will do your PAT for this term. You will reuse old plastic bottles for a new purpose. The new purpose will be different from the old purpose of storing liquid. You will first design the new product you want to make. Then you will make the necessary changes to old plastic bottles in order to make the new product.

LB page 252

CHAPTER 21 PAT

Reduce, re-use and recycle: Working with plastics

LB page 253

In this PAT you will design and make a useful new product from old plastic bottles. But first, you will look at how plastic is used in everyday life.

You will **only do individual work** in this PAT.

Week 1 340

Investigate: Plastics in the classroom and at home

Different scenarios: Reusing plastic bottles

Design brief for the scenario that you chose

Week 2 348

Design: Initial rough design sketches

Make: Final orthographic drawing

Skills development: Practice to mark out, cut and make holes in plastic

Week 3 350

Make the plastic product you designed

What have you learnt during this term?

Assessment

Investigate: Different scenarios reusing plastic bottles..... [4]

Design brief for the scenario that you chose..... [4]

Design: Initial rough sketches [10]

Make: Final orthographic drawing [15]

Make the plastic product you designed [25]

Communicate: What have you learnt during this term? [12]

[Total: 70]

Materials required for this chapter:

a range of different waste plastic objects	A4 and A3 paper for drawings
string	permanent marker pens to make marks on plastic
sandpaper	nails of different sizes
thin wooden dowels	to make holes in plastic
skewer/sosatie sticks	many strong pairs of scissors to cut plastic
thin wire	sticky tape to join different plastic parts together
glue	
rulers	

A4 and A3 grid paper for isometric and orthographic drawings

This chapter seeks to develop learners' ability to design solutions to technological problems. Learners do only *individual work* in this PAT.

You must complete some version of this design task *yourself before the week that the PAT starts*. You must use the same materials and tools that learners will use. This will ensure that resources are not overlooked, and problems and issues related to the management of the task are identified and sorted out before learners start with the task.

You must acquire or collect all materials and tools (including waste plastic) for this PAT in advance. Do not rely on learners to bring all the needed materials.

All tasks/questions are essential for the design process, even if no marks are allocated.

All tasks/questions in the PAT should be completed/answered, even the tasks/questions for which no marks are allocated for evaluation. This is because all the tasks/questions are essential parts of the design process. So, if certain tasks/questions are not done, then learners will not be able to do the subsequent tasks/questions successfully.

Week 1

In this week, learners are told that they will be required to design a useful product using mainly waste household plastic of some kind. The aim of this week is to get learners to *identify a need* that will form the focus of their design.

Plastics in the classroom and at home (60 minutes)

These exercises provide background information on plastics found in homes and classrooms.

Different scenarios for reusing plastic bottles (30 minutes)

These exercises provide examples of some ways in which such plastics might be redesigned to fulfil new functions and meet new needs.

Learners answer questions that make them think about the needs that can be met by reusing waste plastic. It would be useful for you to give examples of such needs, such as:

- a need to store things,
- a need to protect things, or
- a need to contain things.

Design brief for the scenario that you chose

(30 minutes)

Learners can choose one of the scenarios given in the previous section for the product that they will design and make.

Some creative learners could come up with innovative ideas that are very different from the four given scenarios. If they do so, check that their ideas are simple enough for them to finish their designs and models within the time constraints of this PAT. If they can keep their innovative ideas simple, then allow them to go ahead with their own design ideas.

You should instruct learners to keep a record of their ideas, as well as how their ideas develop. This record should be clear but should also contain rough ideas and rough sketches. Learners should also record “mistakes” that they made.

By the end of the week, each learner should have:

- a record of her/his ideas, and
- a design brief. It may be added to later, but in its earliest form it should say something like this: “Use waste plastic to make an exercise wheel for a pet mouse. The mouse must be able to climb on and off the wheel on his own.”

Week 2

Each learner now has a design brief to work towards.

Initial rough design sketches

(30 minutes)

Drawing initial rough design sketches is a way for learners to identify all of the “design issues” related to their design brief. They communicate their thoughts on the “design issues” through the rough design sketches they draw, and the labels and notes that add to these sketches.

In the case of the example of a design brief given earlier (an exercise wheel for a pet mouse), the design issues might include:

- How big a wheel will a mouse need?
- What waste plastic object could be used to make the exercise wheel?
- What frame will the wheel turn on? What will the frame be made of?
- How will the mouse get on and off the wheel?
- How can we make sure that the wheel turns smoothly on the frame?

While learners try to identify these issues, you should move around the class discussing them with individual learners.

- Learners must record these issues by adding labels to their rough design sketches, and by making notes on the side where necessary.

For homework, learners should draw more design sketches to:

- Show different details of their design,
- Show improvements to their initial design,
- give more clear specifications to resolve the “design issues”, and
- add dimensions to their design sketches.

By the end of the homework section, learners must have refined their designs to the point where they think it will work.
Learners must keep all of the material produced for this homework in their record of the design's development.

Final orthographic drawing

(30 minutes)

During this lesson, learners make working (orthographic) drawings based on their newest design sketches. In most cases, learners will only need to draw a front and a top view.

The drawing needs to be to scale. That will make it possible to use the drawing to make decisions about how parts will fit together, and whether it is possible for a load (like the mouse) to be carried by the structure or machine.

Titles, dimensions and labels must be included.

As learners begin with their working drawings, they will become aware of new problems faced by their design. This is normal, and changes to the orthographic views will need to be made in such cases. However, this means that this section of the work may take longer to complete and may spill over into the next section.

This is an important phase in the design. You should move and interact with learners, considering their work and getting them to think about their designs.

NB: You must collect learners' working drawings and give learners feedback on it, before the learners start making their products in week 3.

Practise marking out, cutting and making holes

(60 minutes)

In this section, learners practise working with plastics and tools in a safe, accurate and neat way. You need to supervise this carefully to ensure the safety of the learners. At the end of this lesson, learners must make a list of the materials that they need to make their design. If there are any materials that they do not yet have, their homework for the next week is to collect those materials and bring them to school. If they do not do that, they will not be able to complete their models in the next week.



Week 3

Make the product you designed

Learners are now at the stage where they begin to make the solutions to their design brief. By this stage, they will already have gathered the materials they need.

You, however, should ensure that all the necessary tools are available.

Learners immediately start with making their designs at the beginning of this week.

You must make provision for the labelling and safe storage of learners' work between lessons.

You should expect learners' designs to change throughout this stage. Making the product has the effect of showing the designer flaws that were not previously obvious. Learners must record their original designs as well as the changes to it, so that the teacher can see the progress/ improvement of the design.

Help learners to structure their work so that they do not run out of time. Insist that the last 10 minutes are used to finish off and clean workspaces. By the end of the 90 minutes, all learners must have completed the making of their designs.

Inform learners that their record of work for the previous three weeks (their design "portfolio") must be handed in to you at the start of the next lesson. This includes their made product. You will assess their work in the way that is shown on the bottom of page 253.

What have you learnt during this term?

Learners answer questions that force them to reflect on everything that they learnt about during this term.

LB page 254

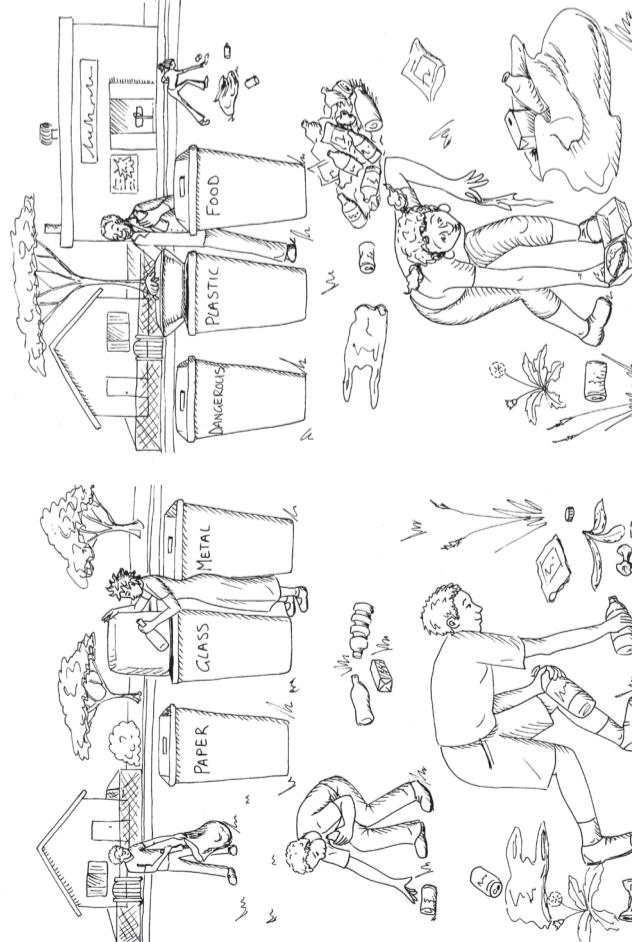


Figure 1: Improving your environment by picking up and sorting waste

LB page 255

Reduce, re-use, recycle

In Grade 8 Term 4, you learnt that the environment is damaged when more and more things are made and thrown away. You learnt that waste is formed in order to make new products, and that the products themselves become waste when they are thrown away. You can reduce the negative impact of this practice on the environment in different ways:

Firstly, you can buy fewer things, which is called *reducing your consumption*.



Figure 2: A "braaiskottel" made from an oil tank cut through the middle

Secondly, you can use some things over and over, so that you don't have to buy new things. This is called *re-using* things.

You can also re-use something for a different purpose than it was originally made for. For example, many people use old hot-water tanks (geysers), or oil tanks to make "braaiskottels" in which they can make fire and barbecue food outside. But what if something you own gets broken or you don't have any use for it anymore? Then you have to throw it away. Fortunately, there is a clever way of throwing things away, by separating the different types of waste.

For example, if you and your family collect all your plastic waste separately, then someone can take that plastic to a recycling factory where new plastic is made from the old plastic. At a recycling factory, the old plastic is washed and shredded into very small pieces.

It is then melted and "moulded" in the shape of "pellets". The pellets can then be used as the raw material to make new plastic products.

You learnt in the previous chapter how plastic pellets are moulded into new shapes.



Week 1

Plastics are easy to form into complicated shapes, do not corrode, have high electrical resistance, are tough and can be made in many colours.

Plastics in the classroom and at home (60 minutes)

- Copy the table below. Look around you on your desk, at your clothes and in your school bag. Make a list of all the things you can see that are made of plastic. Also write down whether it is made of hard or soft plastic and thick or thin plastic.

Plastic item	Hard or soft	Thick, thin, or woven
plastic bag	soft	thin
rucksack or briefcase	soft	woven
shoe sole	hard	thick
shirt	soft	woven
pencil box	hard	thick

Note to the teacher: Many clothes are made from a combination of a plastic fibres (such as polyester) and natural fibres (such as cotton). But some clothes are made only from plastic fibres. For example, some body warmers, jerseys and blankets are made from pure polyester. Ask learners to check the labels on their school jerseys or tracksuits to see what it is made of.

- The table below lists different things that you can see in a house. Copy the table below and write “yes” or “no” next to each item to show whether it is made of plastic or not. You can also write down if there are exceptions. Add more items in the empty rows of the table.

vinyl floor tiles	yes
clay floor tiles	no
windows	no
paint	yes, except old-fashioned oil paint
chair backs	yes, except for wooden chairs
light bulbs	no
bottles for dish-washing soap	yes
sponges	yes
the outside of a TV or radio	yes, except if it has a metal cover

- Look at the illustrations of household appliances below. The arrows point to different parts of the appliances, and labels are given to describe the different parts of the appliances. Write down the parts that are made from plastic.

The parts made from plastic are labelled “P” in the drawing below.

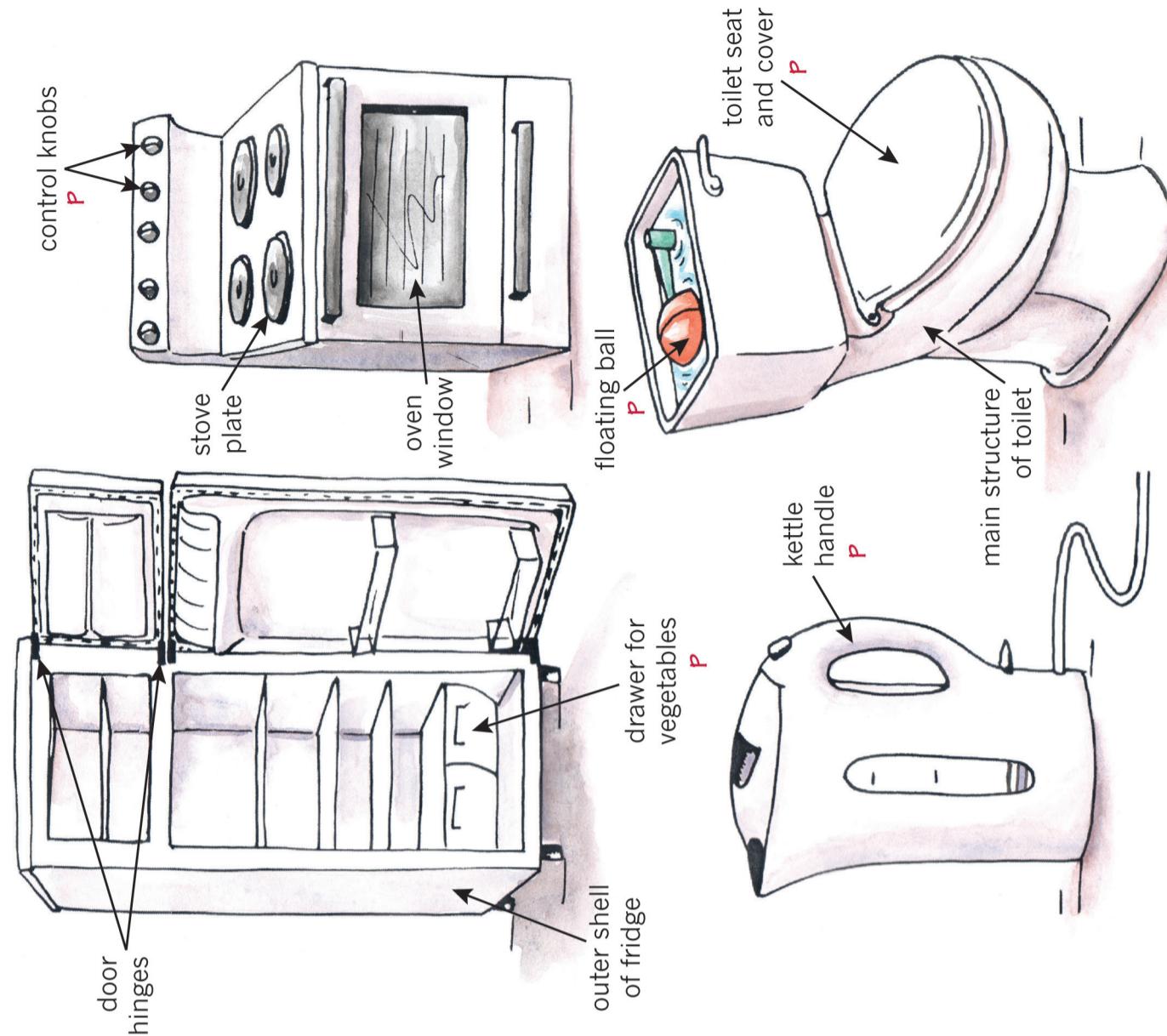


Figure 3: Different parts of typical household appliances



4. A long time ago, cars were heavy because most of their parts were made of steel, cast iron and even wood. Nowadays, cars are much lighter, and therefore they use less petrol to travel each kilometre. One way that was used to make cars lighter is to use more plastic when building them, instead of using metal. Look at the illustrations of the inside and outside of a car below. The arrows point to different parts, and labels are given to describe these different parts. List all the parts that are made of plastic.
- The parts made from plastic are labelled "P" in the drawing below.

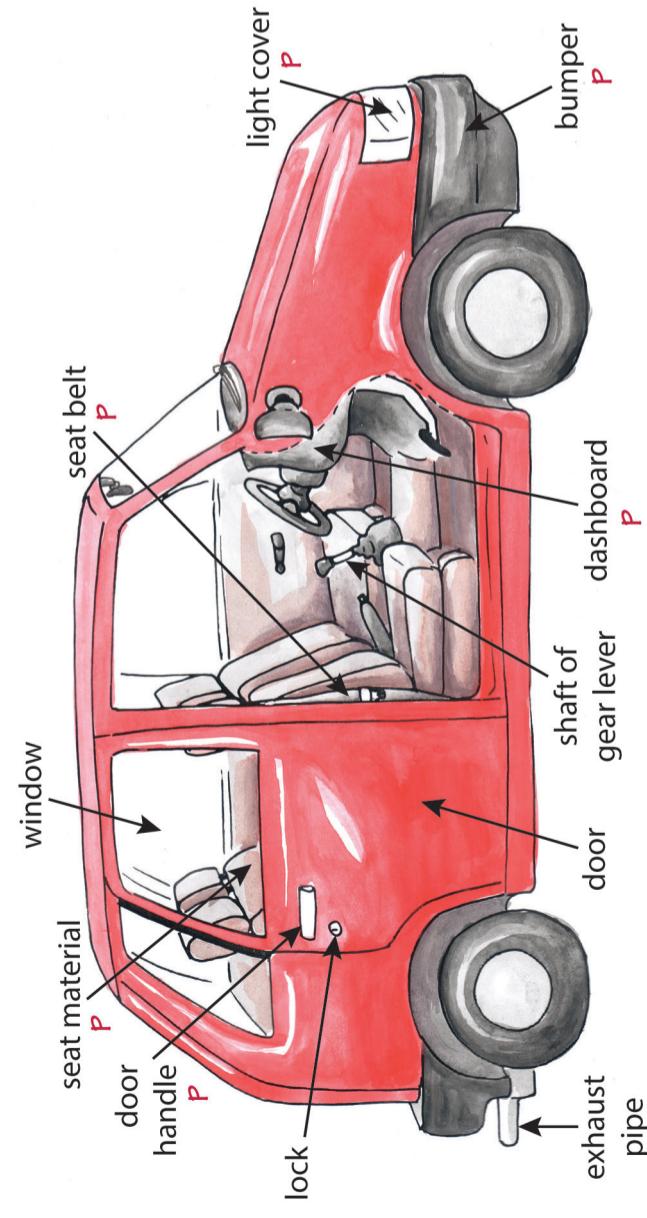


Figure 4: Different parts of a motor car

5. How can you test whether a material is plastic or metal?

Hints: Think about hardness, strength, magnetism, sound, heat and fire.

Try to press your fingernail into it: Most plastic

is soft enough that you can leave a mark.

Hit it with a pen: Metal makes a high sound, like a bell.

Plastic bends more easily than metal of the same thickness.

Many metals are magnetic: no plastics are magnetic.

Most plastic materials can melt or burn when exposed to heat and/or flames.

Metal will never burn, and it will only melt at very high temperatures.

Note: If some learners think that there can also be plastic magnets, then explain the following:

Plastic objects (like a ruler or comb) can be rubbed and will then attract small pieces of paper or hair, but it will not influence the direction shown by a compass. The force exerted by the plastic ruler is an **electrostatic force**. In contrast, a magnetised piece of metal will change the direction shown by a compass - this is caused by a **magnetic force**.

Different scenarios for reusing plastic bottles (30 minutes)

On the following pages, you are shown photos of four scenarios in which new products were made from old plastic bottles.

Each of the products solves a certain problem. In other words, it satisfies or addresses a certain need. Answer the questions for each scenario about the problem or need. Then choose one of these scenarios for the product that you will design and make.

Scenario A



Figure 5

1. What is the purpose of the product?
The product is used to feed birds.

[1/2]

2. How does this reduce the amount of work that somebody has to do?
It reduces the amount of work because someone does not need to put out seeds for the birds every day.

Scenario B



Figure 6

3. What is the purpose of the product?
The product is used to store dry food such as rice so that it cannot get wet or be eaten by insects or other animals.
4. Can this product save you money? How?
Yes, you don't have to buy food containers. Your food won't go bad.

Scenario C



Figure 7

5. What is the purpose of the product?
It traps flies so that there will be fewer flies around the house.
6. Can this product save you money or time? How?
Yes, you don't have to buy poison to keep flies away, or you don't have to swat flies by hand.



Scenario D



Design brief for the scenario that you chose (30 minutes)

Answer the following questions to identify the specifications and constraints for the scenario that you chose.

1. Give a description of the product you are going to make. [1]

Learner's own answer.

2. Answer the following questions to identify the specifications for your design:

- (a) What is the purpose of your product? [½]

Learner's own answer.

- (b) Should your product keep some things inside (contain it) and keep other things out? What should it keep in and what should it keep out? [½]

Learner's own answer.

- (c) Should your product be supported in some way to stay upright? How? [½]

Learner's own answer.

3. Answer the following questions to identify the constraints of your design:

- (a) Make a list of all the materials that you can easily find and use to make your product. You will design your product so that you will only need to use these materials to make it. [½]

Learner's own answer.

- (b) Make a list of all the tools that are available to you, and that you know how to use, for working with the materials you have identified above. You will design your product so that you will only need to use these tools to make it. [½]

Learner's own answer.

- (c) Make a time schedule showing how much time you have available to design and make the product. You will design your product so that it is simple enough that you can design and make it in the limited time available to you. [½]

7. What is the purpose of these products? [½]

It makes it possible to use less water to help plants grow.

8. Can this product save you money or time? How? [½]

Yes, you don't have to water your plants every day, and you will pay less for water.

[Total: 4]

Figure 8



Week 2

Initial rough design sketches

Make rough sketches of your design ideas for the product that you want to make. You can make sketches for different ideas and later decide which one you are going to make.

Try to design and make a product that is slightly different from the photos of the products on the previous pages, to address the need. In other words, try to make an **innovative** design.

Show notes and labels on your sketches to help to explain your ideas. [10]

The word **innovative** comes from the word “new”. An innovative solution to a problem is a solution that nobody else thought of before.

LB page 261

Practise marking out, cutting and making holes in plastic (60 minutes)

(30 minutes)

Make rough sketches of your design ideas for the product that you want to make. You can make sketches for different ideas and later decide which one you are going to make.

Try to design and make a product that is slightly different from the photos of the products on the previous pages, to address the need. In other words, try to make an **innovative** design.

Show notes and labels on your sketches to help to explain your ideas. [10]

Learners' own ideas.

They should sketch at least two different design ideas.

They should use labels and notes to explain their sketches.

Final orthographic drawing

Choose your final design from your rough sketches. Then draw your product to scale using first angle orthographic projection. Show dimensions. [15]

Learners' own design.

It is very hard to draw the shape of a plastic bottle accurately. Learners can approximate the shape of a plastic bottle using rectangular and triangular shapes with rounded corners. The dimensions of the plastic bottle should, however, be correct.

One or more of the views on the drawing should show the circular shape of the cross section of a bottle, and should also indicate the radius or diameter.

(30 minutes)

You need the following materials for this activity:

- two or more old plastic bottles that have been cleaned,
- a marker pen or “kokki” pen,
- nails of different sizes to make holes in the plastic,
- a strong pair of scissors to cut the plastic,
- sandpaper, and
- sticky tape to join different plastic parts together.

First make sure that the plastic bottles are clean and that all the labels and glue have been removed.

This is how to cut a plastic bottle:

First make a small hole with a thin nail where you want to start cutting. Hint: It will be easier to make the hole if you keep the cap of the bottle on and tightly secured, because then the bottle will not collapse as you press the nail in.

Then make the hole bigger by moving a thick nail around in the hole to make it bigger, as shown in the photo below. You can also use a cutting knife to make a short cut where you can then put the blade of the scissors in.

Safety warnings

A pair of scissors should not be used like a knife. If you do that, it can slip and you can cut yourself.

Do not try to cut the thick, hard parts of the bottle. If you do that, the scissors can slip and you can cut yourself.



Figure 9: Making a hole in the bottle

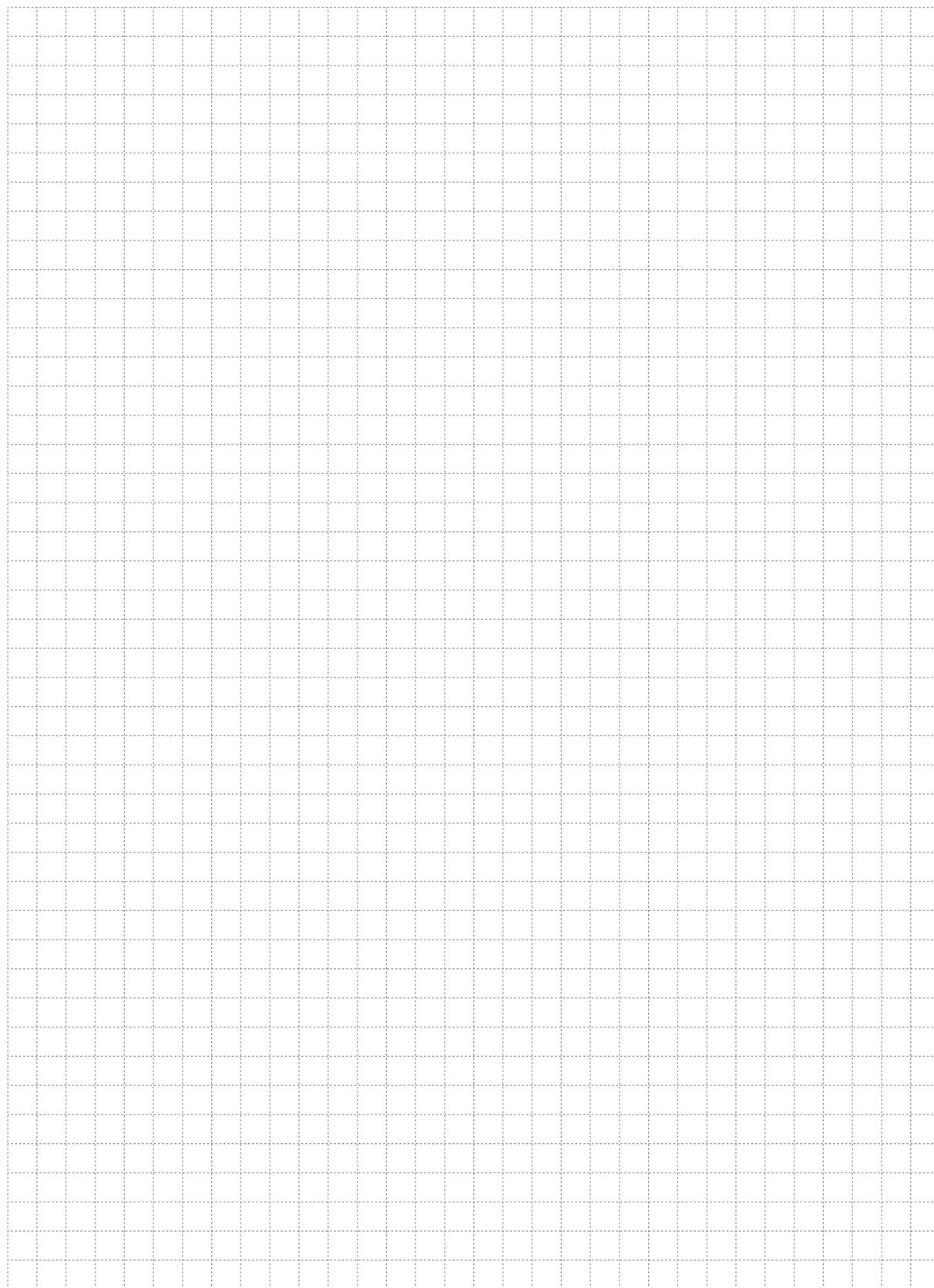


Figure 10: Cutting the bottle

Once the hole is big enough to insert one blade of the pair of scissors, start cutting with the scissors, as shown in the photo on the right.

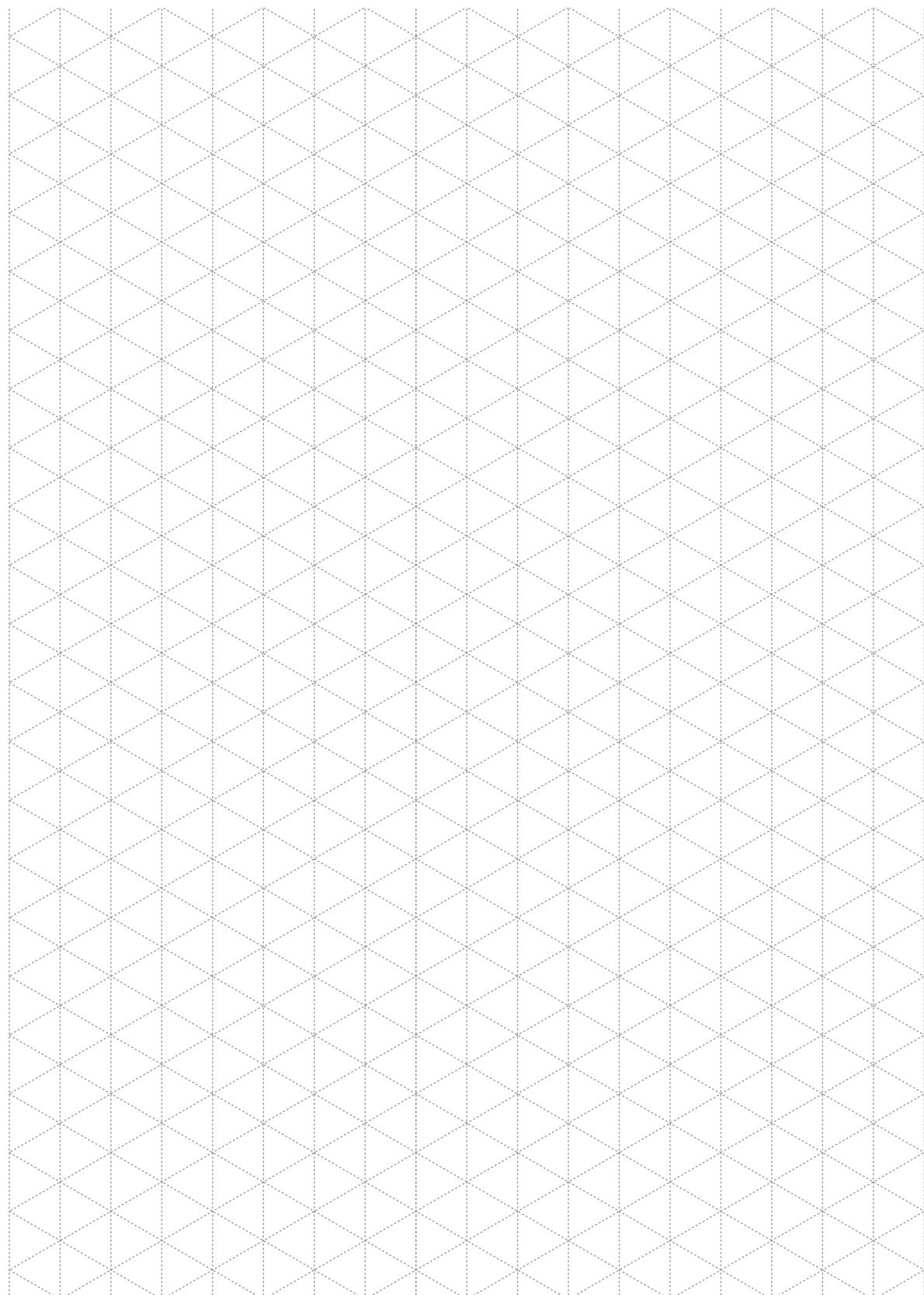
Use sandpaper to make the sharp edges of the hole in the bottle smooth so that it can't cut you.





Square grid paper, 5 mm spacing





Isometric grid paper, 10 mm spacing. Hold paper so that this text is horizontal.





Isometric grid paper, 10 mm spacing. Hold paper so that this text is horizontal.

