TECHNOLOGY

Grade 9

CAPS

Learner Book

Revised Edition

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Chapter 1
Orthographic drawing

In this chapter, you 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.

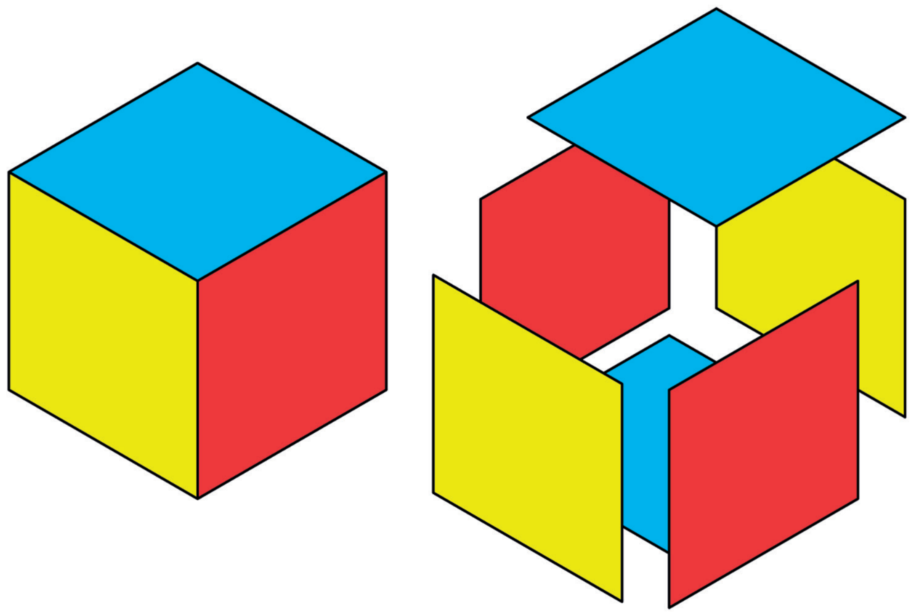


Figure 1

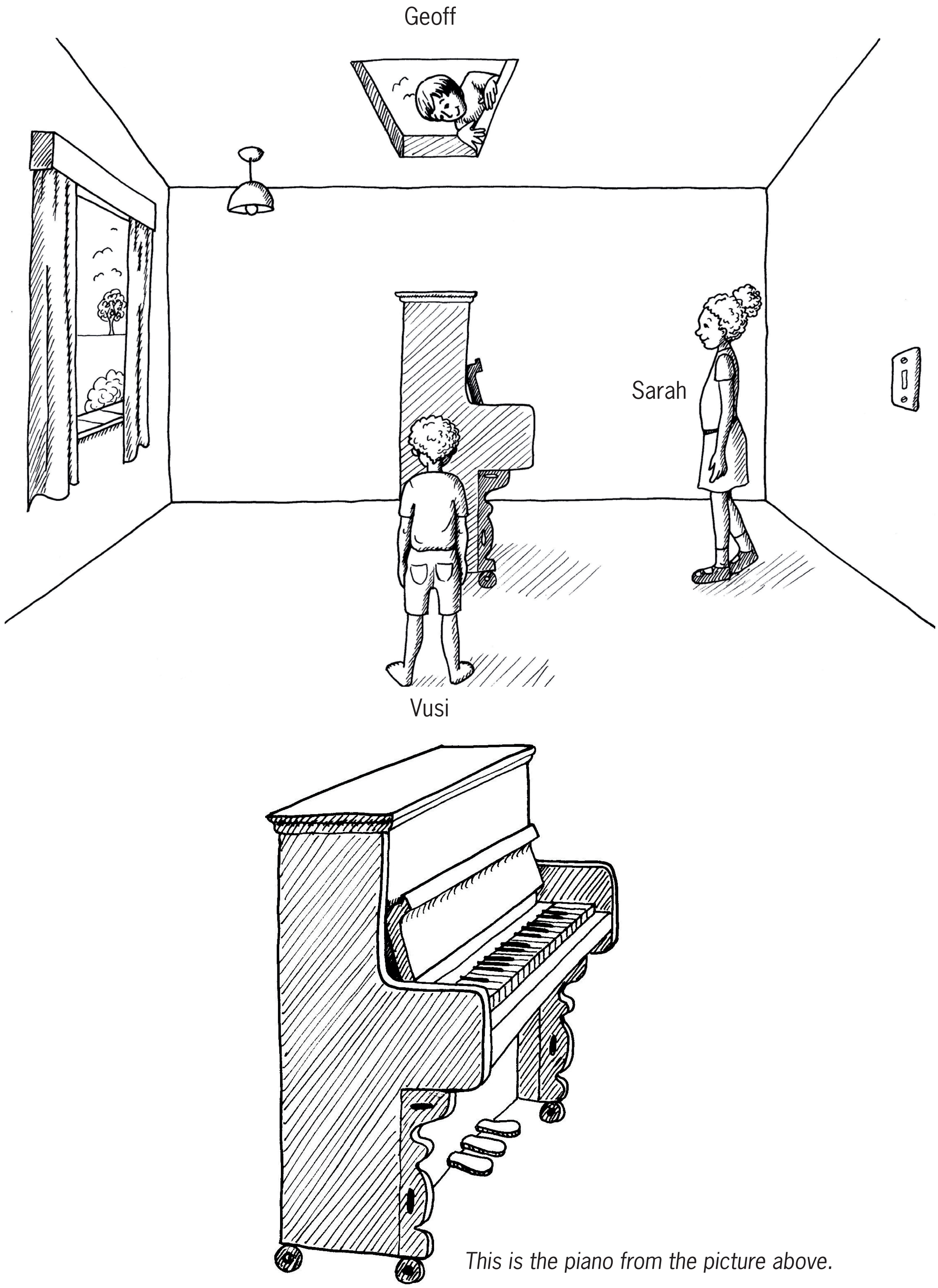
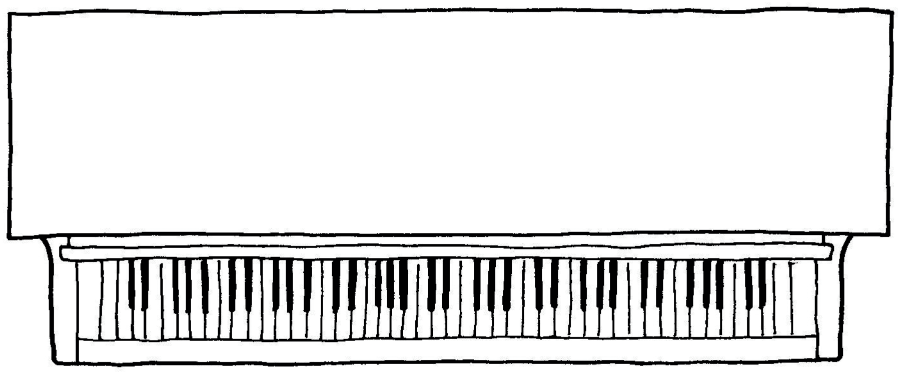
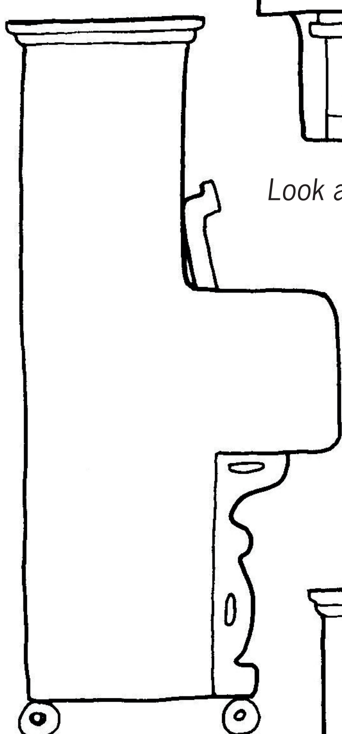


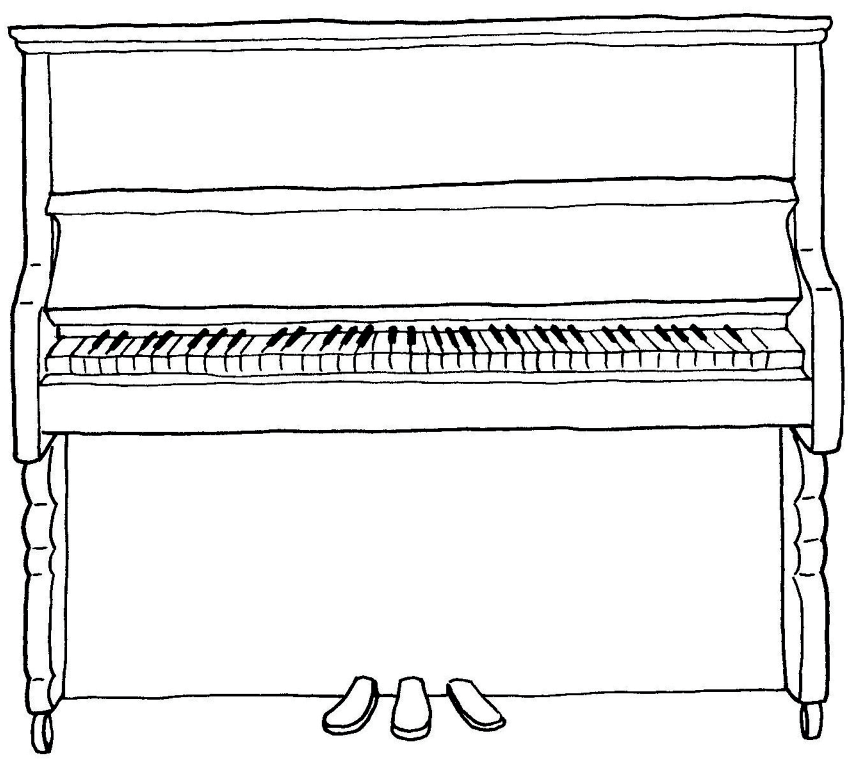
Figure 2



Look at this picture. Who sees it – Vusi, Geoff or Sarah?



Who sees this?



And who sees this?

Figure 3

1.1 About orthographic drawing

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.

simple sketch

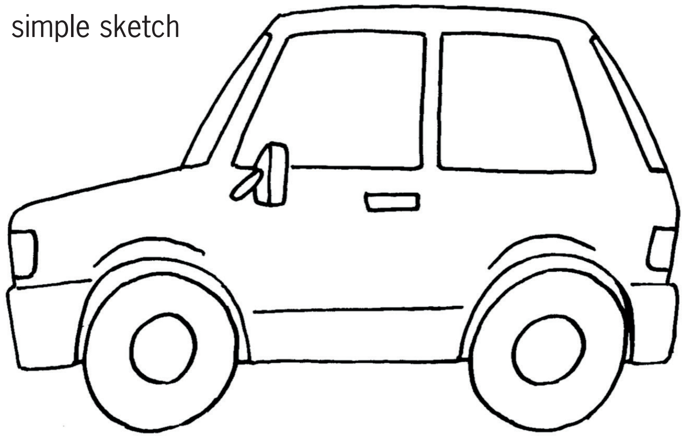


Figure 4

isometric sketch

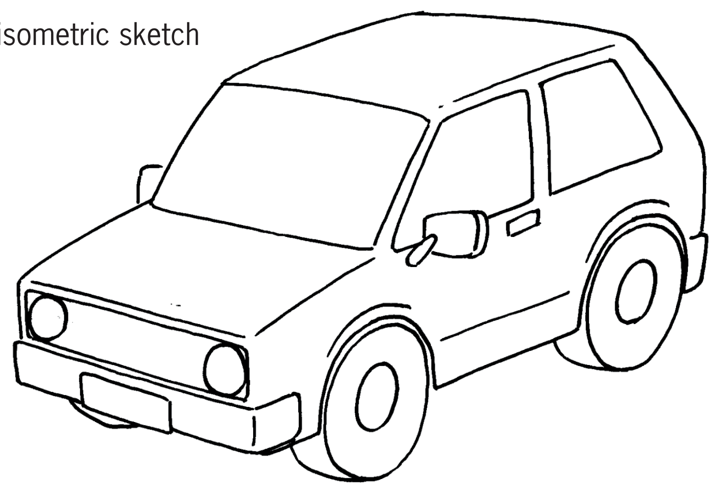


Figure 5

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

shading and colour

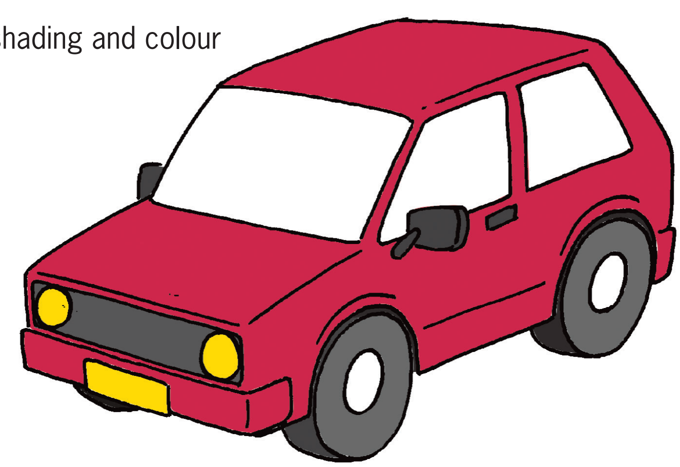


Figure 6

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?

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

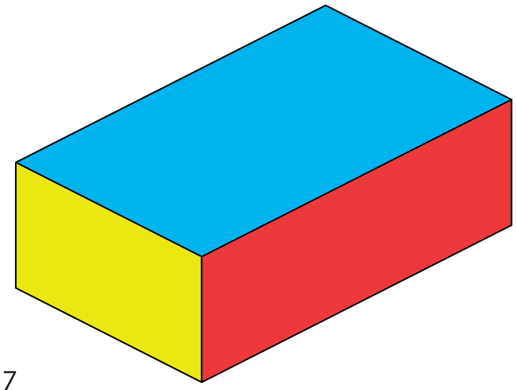


Figure 7

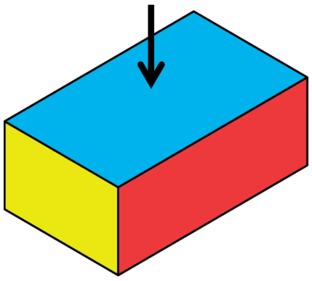


Figure 8

This is called the **top view.**

Figure 9

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

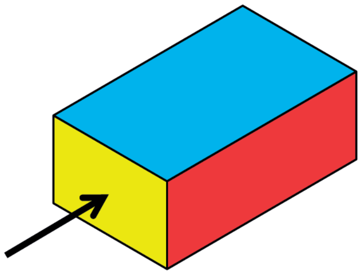


Figure 10

This is called a **side view**.

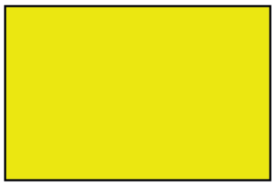


Figure 11

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

This is called the **front view**.

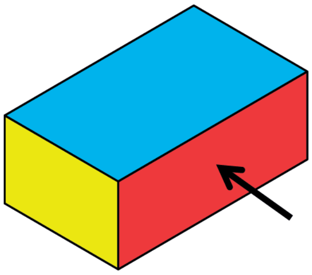


Figure 12

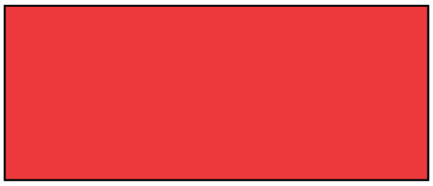


Figure 13

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**.

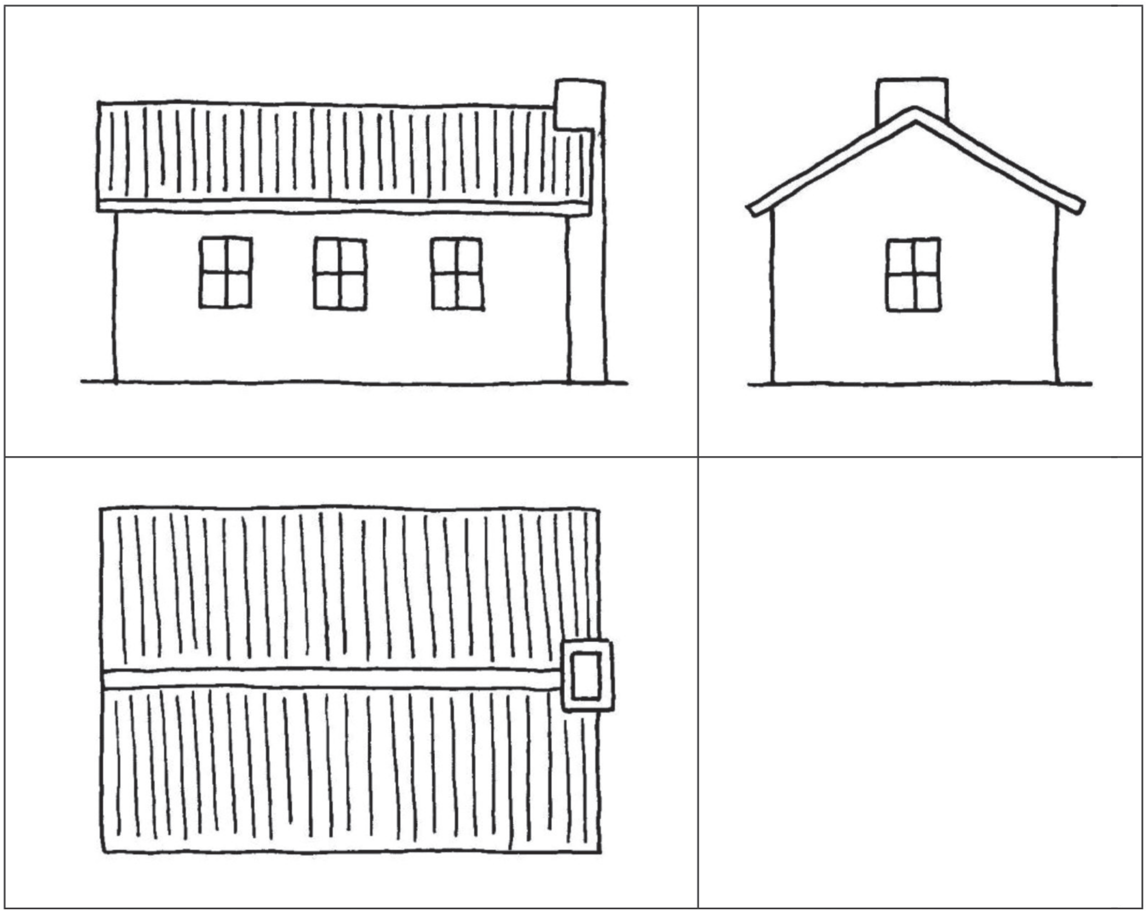


Figure 14

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.

Front view	Side view
Top view	

1.2 Do 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, viewed from the front. The other dimensions are shown on the side view in Figure 17 on the next page.

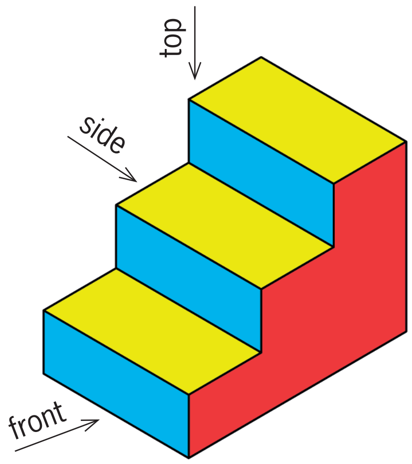


Figure 15

1. Figure 16 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.

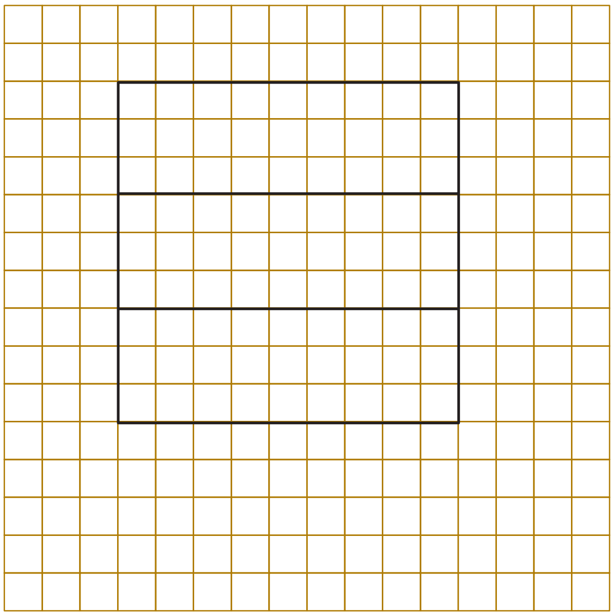


Figure 16

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).

The small lines on your ruler are 1 mm apart.

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

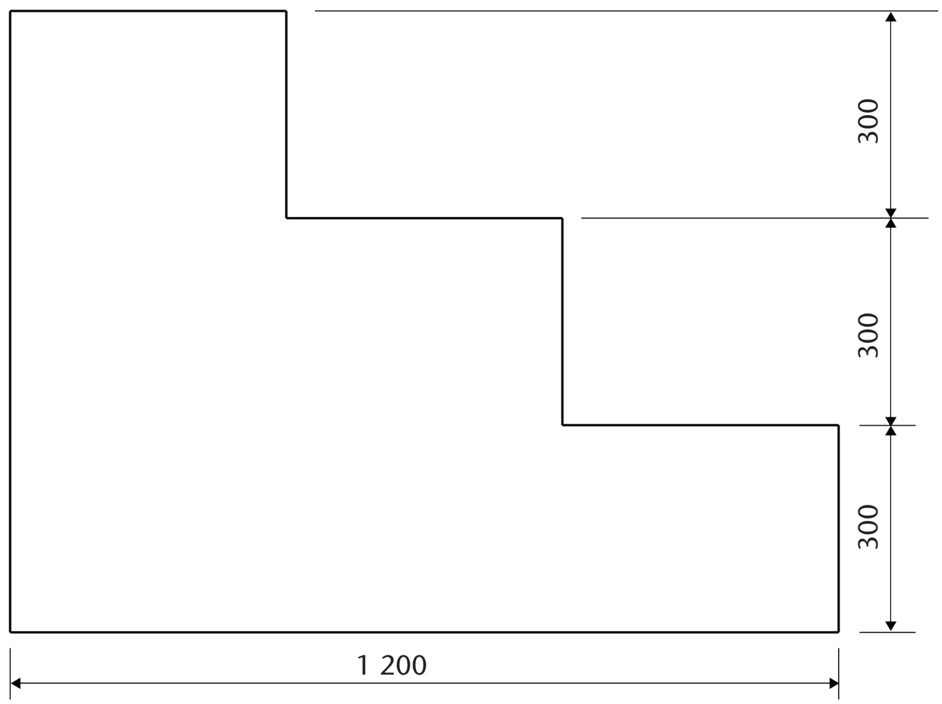


Figure 17: Side view of the staircase with measurements

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

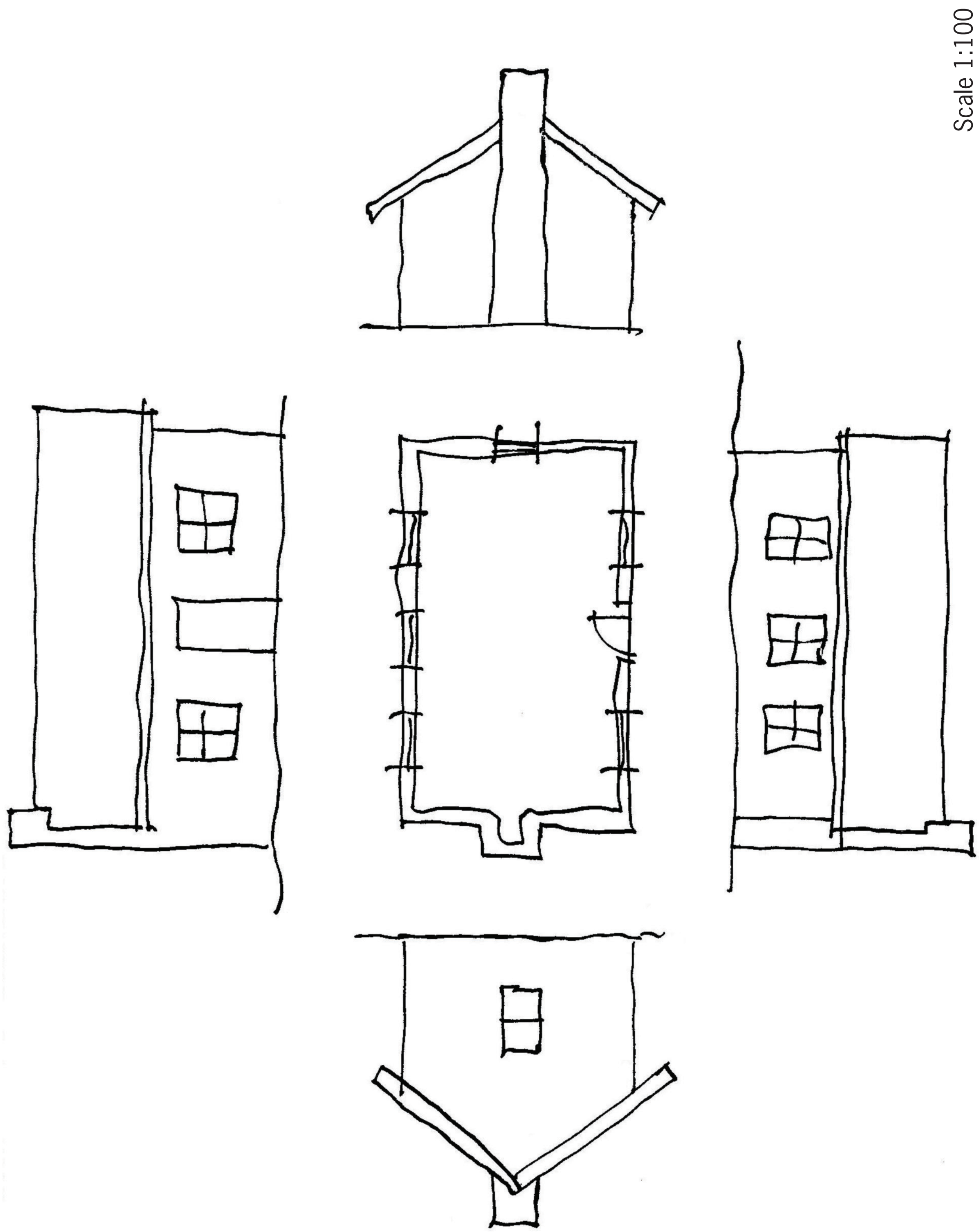


Figure 18: Preliminary drawings

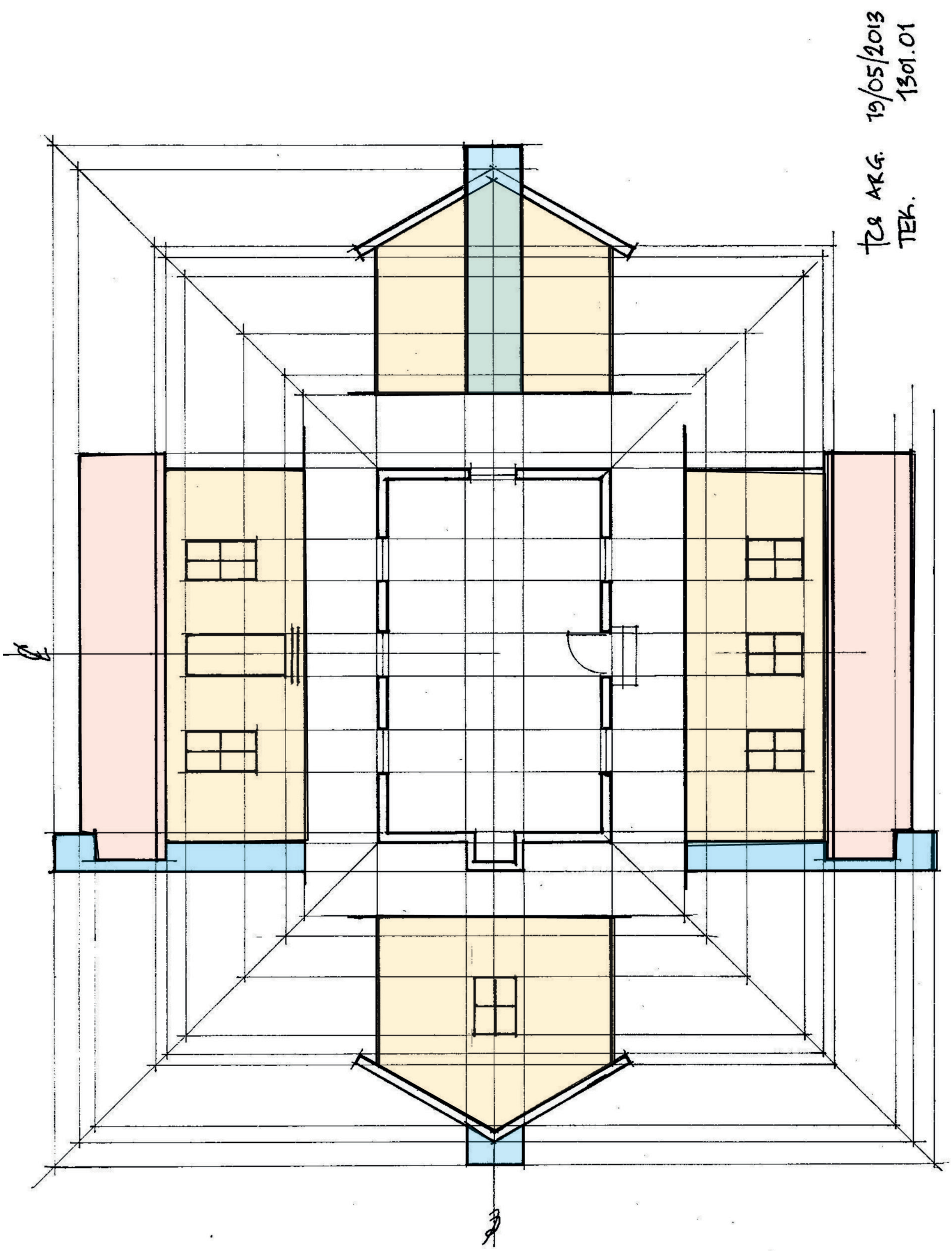


Figure 19: Final drawings

Different kinds of lines in drawings

Different kinds of lines are used in the following drawing:

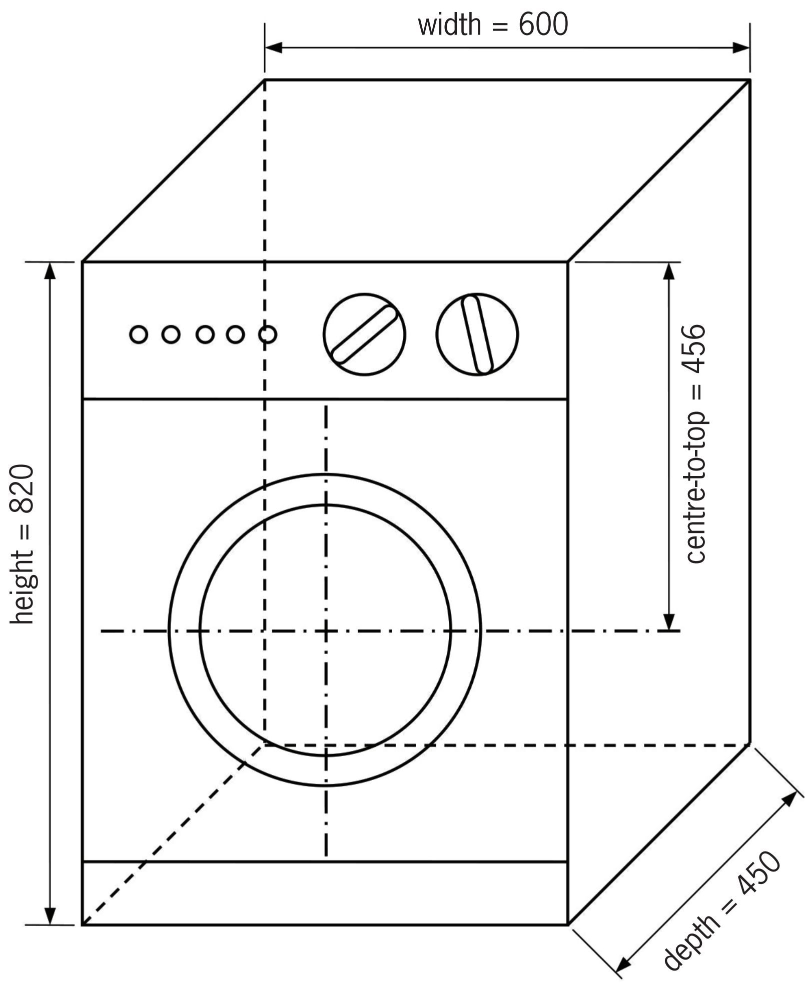


Figure 20

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

Use different kinds of lines

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

Next week

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

Chapter 2
Provide for wheelchairs

In this chapter, you will make accurate isometric and orthographic drawings with instruments.

Nelson Mandela High School in the Eastern Cape is brand new. It has a beautiful new community hall with a stage. Learners use the stage for dramas, fashion shows, music events and gospel choir performances. The architects designed great lighting and sound systems, but they forgot one very important thing: to provide access for wheelchairs so that disabled people can get onto the stage.

The principal asked the Grade 9 Technology students to design a mobile **staircase** and a **wheelchair ramp** that can be put in front of the stage.

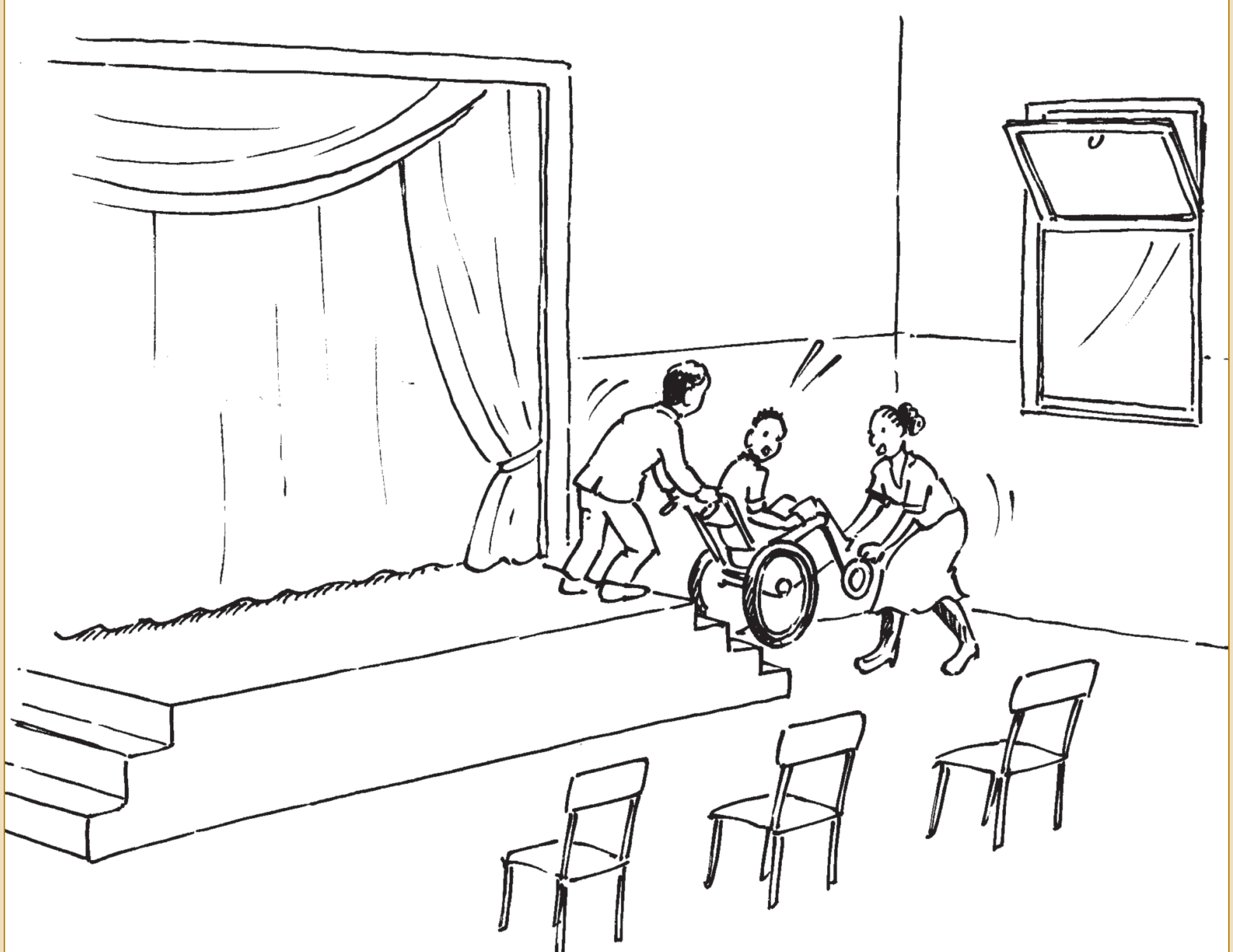


Figure 1

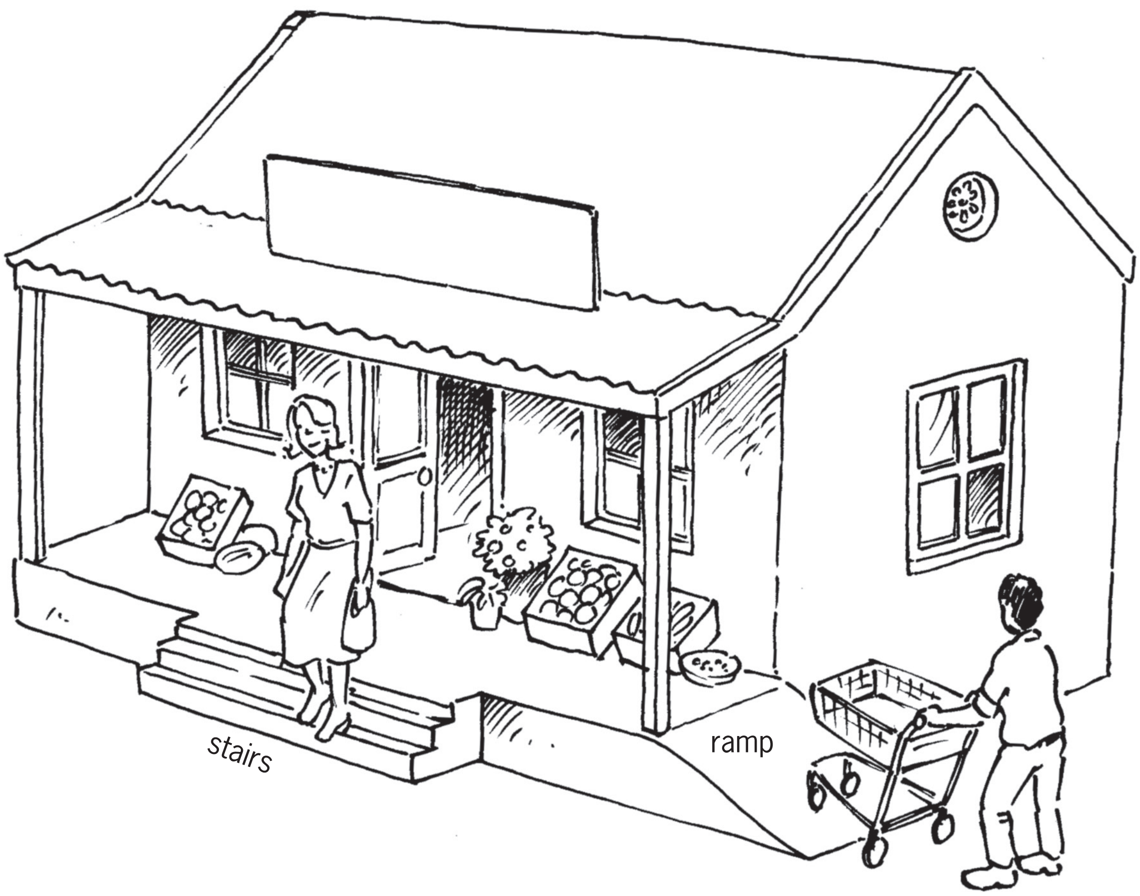


Figure 2

2.1 Stairs and a ramp

Look at the picture on the previous page to see what a ramp is.

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.

Visualise the combined staircase and ramp

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.

Isometric drawings

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

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.

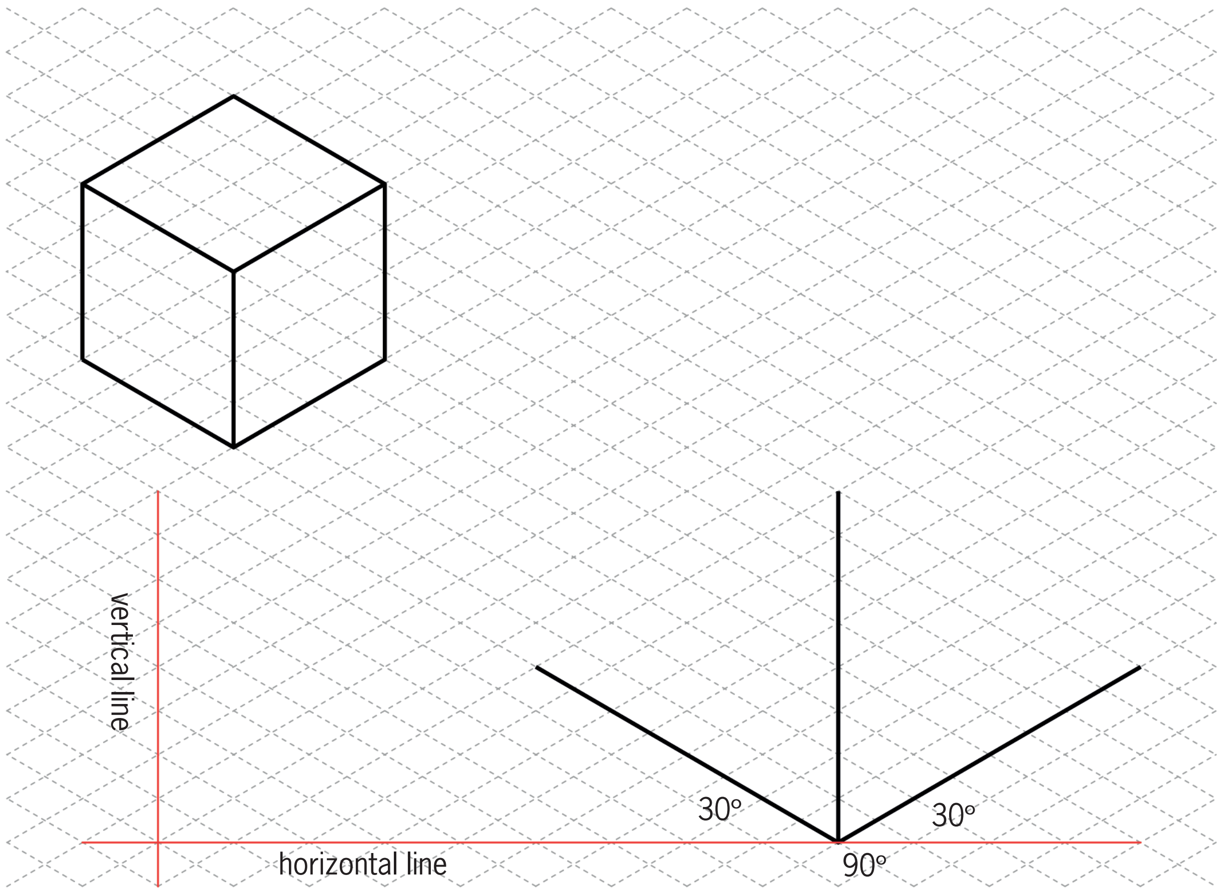


Figure 3

2.2 Isometric drawing

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!

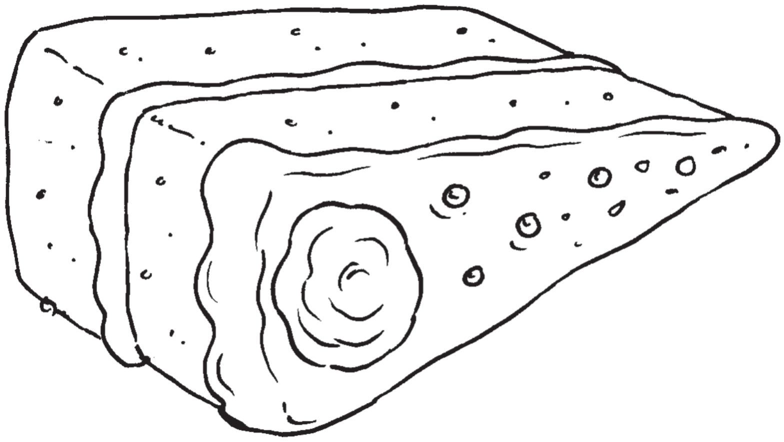


Figure 4

An isometric drawing of the wheelchair ramp

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 do an improved drawing 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.

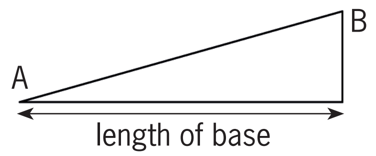


Figure 5

2.3 The plan in orthographic drawings

Sketch the staircase

Make a sketch of the staircase on isometric grid paper.
Remember that the staircase 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.

Homework

1. You have already made drawings of the staircase and of the wheelchair ramp. Sketch them together as one structure on isometric grid paper.
2. Does your stair/ramp look as if it could work? Does it meet all the principal's specifications? Did you remember the handrail?
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

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

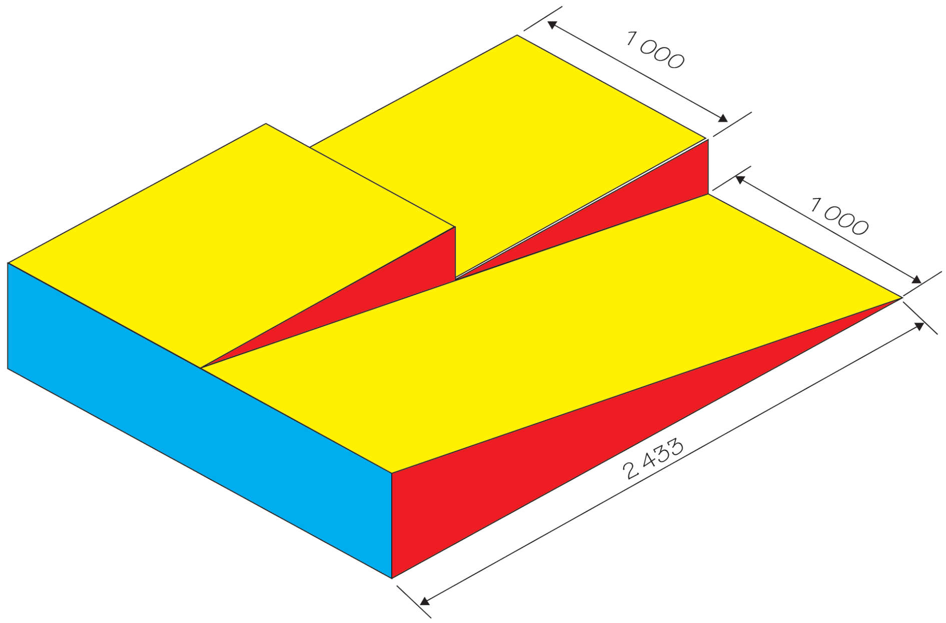


Figure 6: Is this design correct according to the specifications on page 16?

1. Compare the drawing in Figure 6 with the specifications for the ramp given at the beginning of this chapter. Write notes listing any specifications that are not met.
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.

   Do 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.

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

In this chapter, you will learn about the forces that act on structures and can break them. You will see how structures and parts of structures can be strengthened. You will also learn about different materials that are used in structures, and how materials differ from each other.

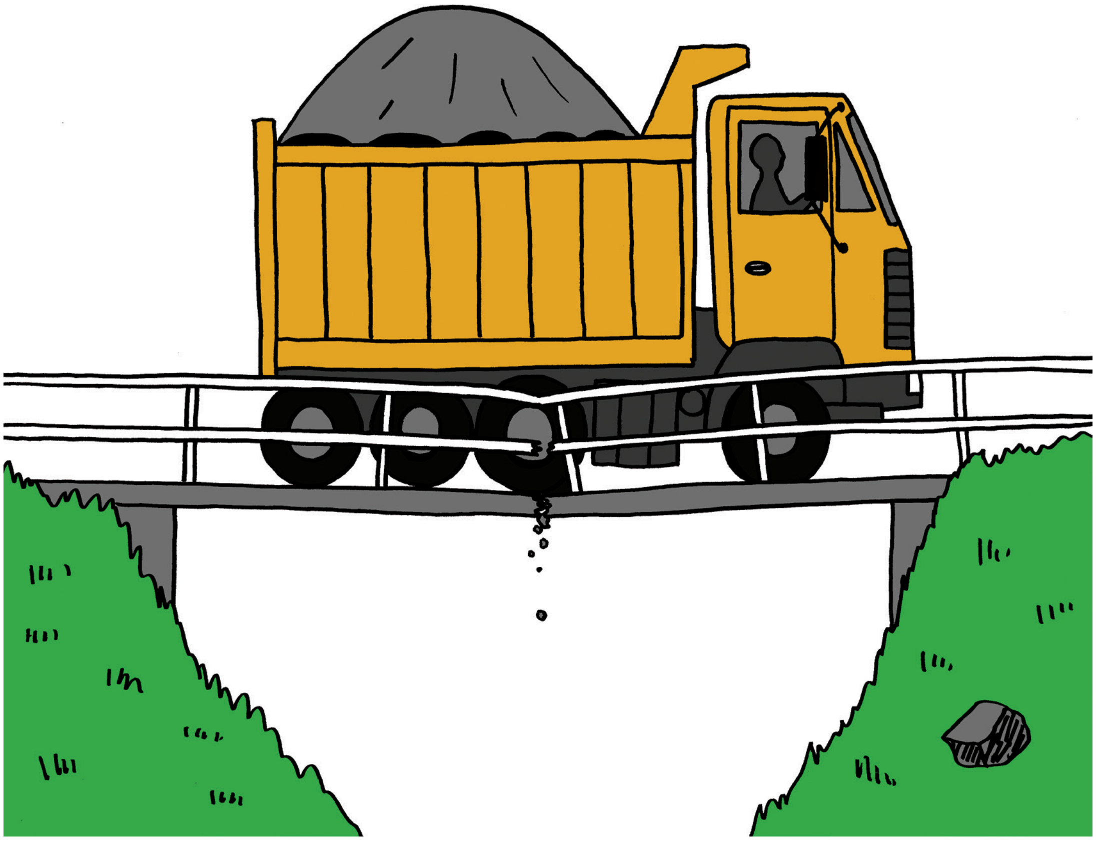


Figure 1: This bridge cannot withstand the forces acting on it.

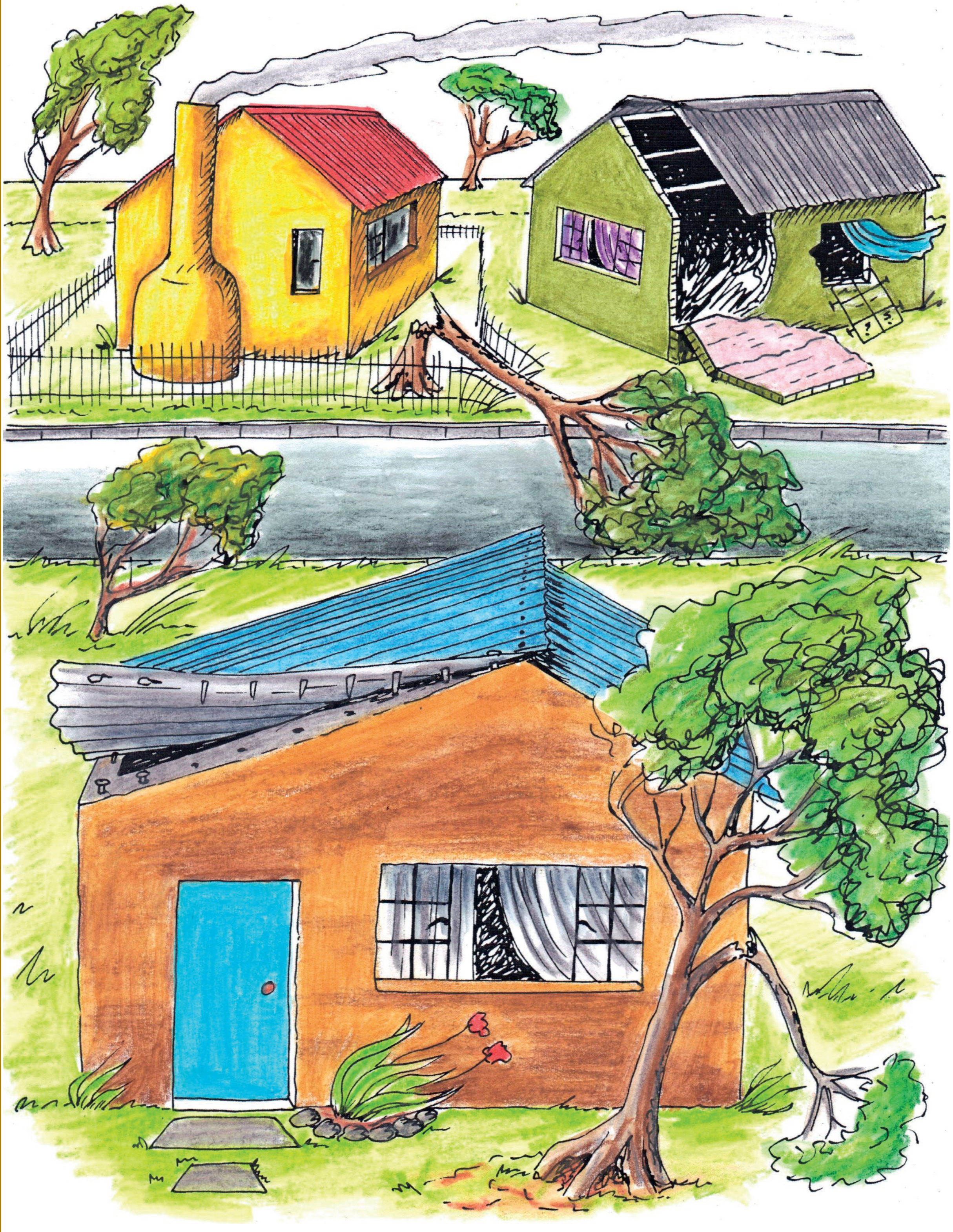


Figure 2: If the house is not strong enough, the wind may break it apart.

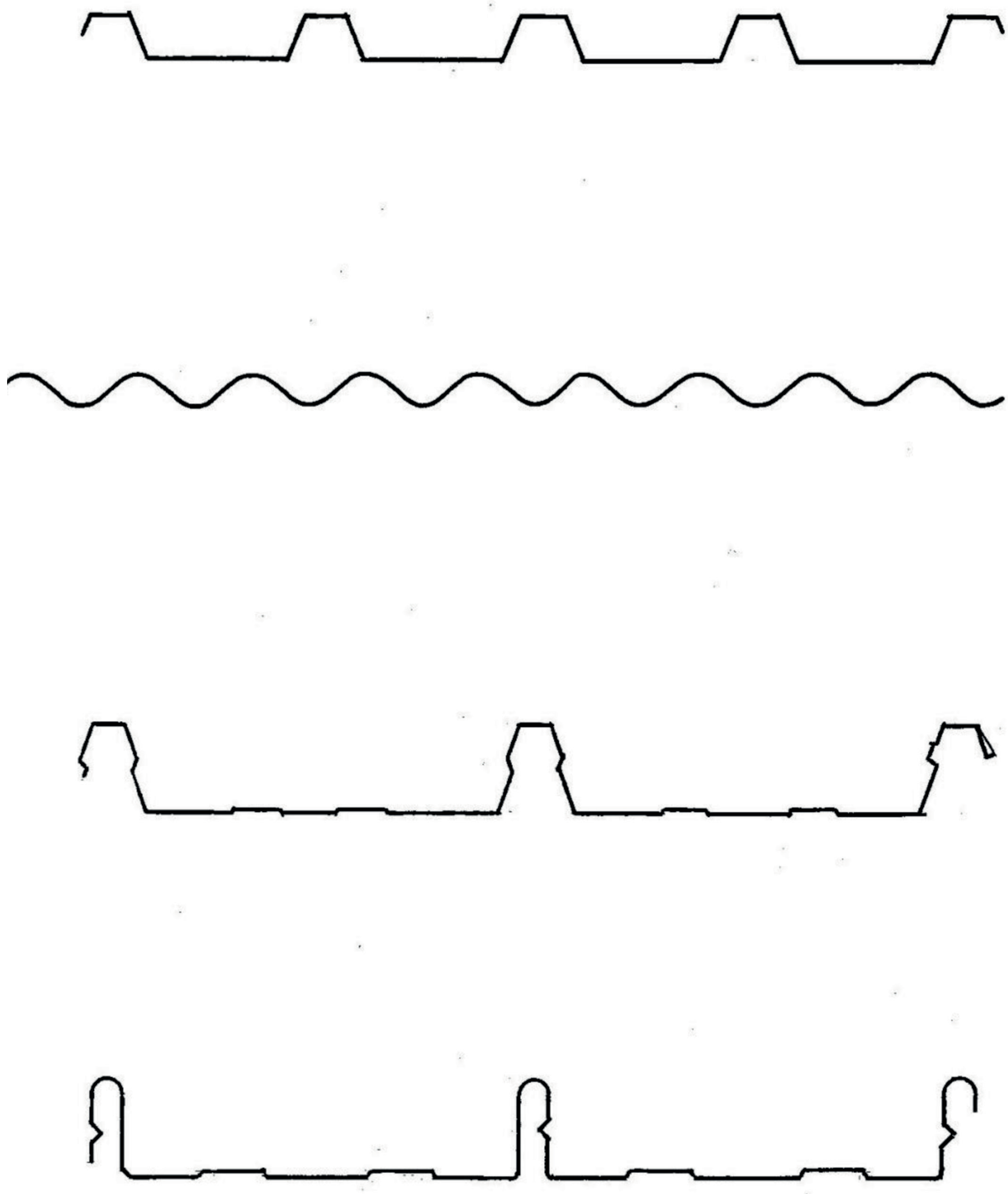


Figure 3: Roof sheets come in different shapes.

3.1 Forces act in different places

Identify and analyse forces

As the arrow shows, the weight of the boy in Figure 4 presses down on the chair.

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.

Figure 4: The boy sits still on the chair.

Figure 5: A man walking on a roof.

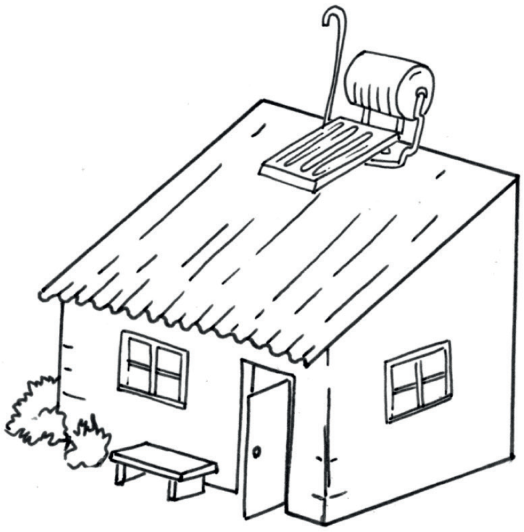


Figure 6: A solar heating system on a roof

2. (a) Is the load on the roof in Figure 5 always in the same place? Why do you say so?
   (b) Is the load on the roof in Figure 6 always in the same place? Why do you say so?
   (c) Are the loads on the bridge in Figure 7 always in the same place? Why do you say so?

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**.

Figure 7: Vehicles passing over a bridge

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.

When a moving object exerts a force on another object, you can say that the force is **dynamic**.

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.
   (b) A cat walking on the table.
   (c) A boy rolling a soccer ball over the table.
   (d) A man scrubbing the table.
5. What is the difference between the loads exerted on the two tables below?

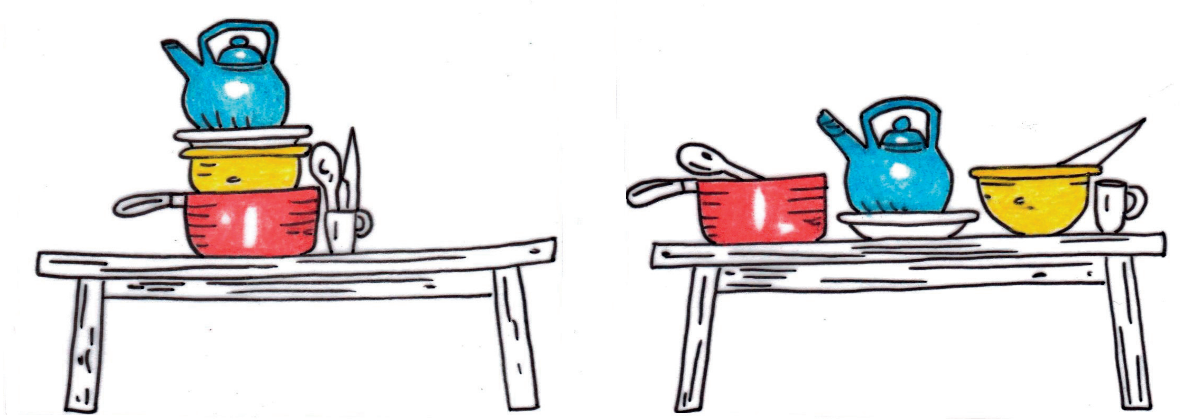


Figure 8: Different ways to place pots on a table.

Look at the different ways in which the two trucks below are loaded. On the one truck, the drums exert force everywhere on the cargo deck of the truck. On the other truck, the load is just one big drum. The single drum exerts force on a small part of the cargo deck.

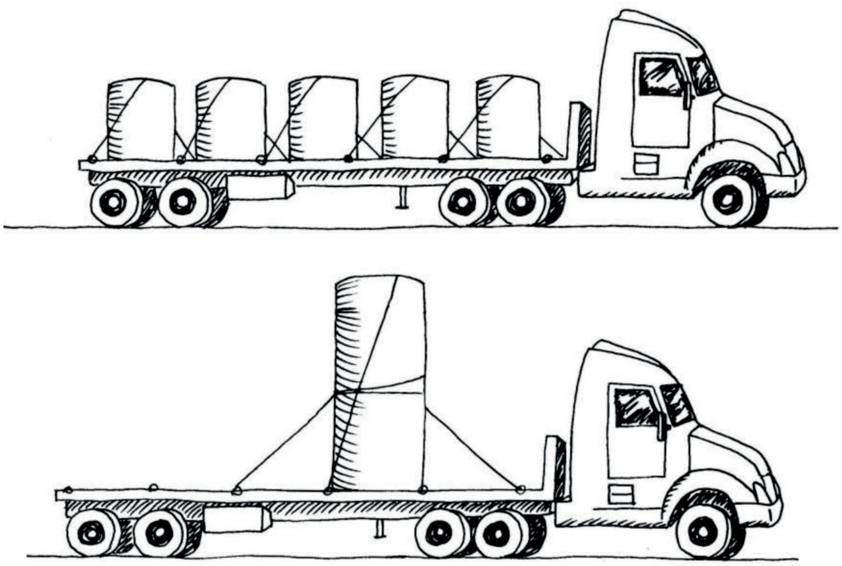


Figure 9: Different kinds of load on two trucks.

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?
   (b) Is the load static or dynamic? Why do you say so?
7. Think of people climbing up and down wooden steps.
   (a) Is the load even or uneven? Why do you say so?
   (b) Is the load static or dynamic? Why do you say so?
8. You have to design two wooden tables, and you are requested to use as little wood as possible. For one of the tables, 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.

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.

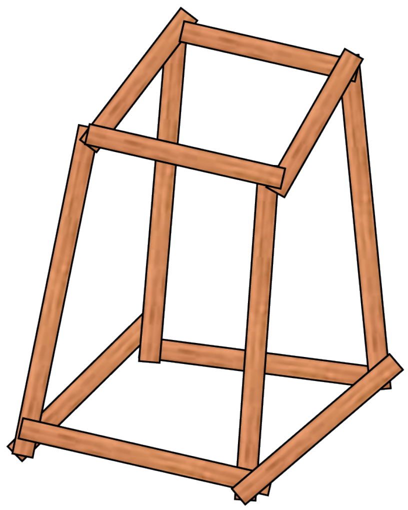


Figure 10: A frame structure made of planks.

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

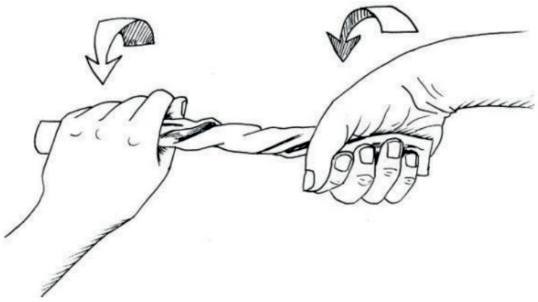


Figure 12

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

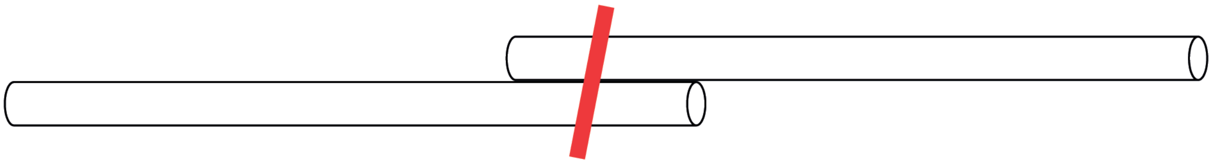


Figure 13

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

Find strength in shape

1. Fold a used A4 sheet of paper in half over its length.

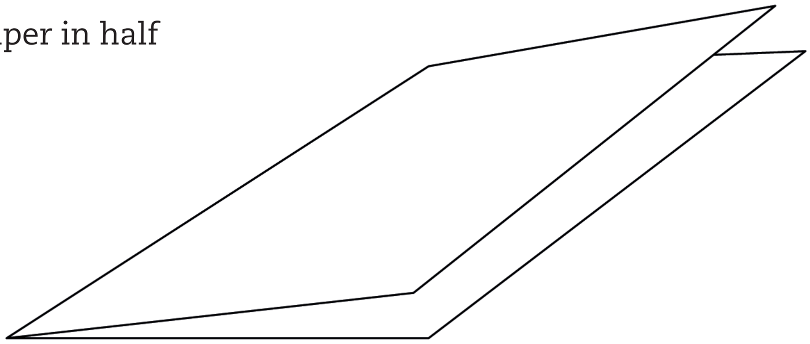


Figure 14

Fold it again.

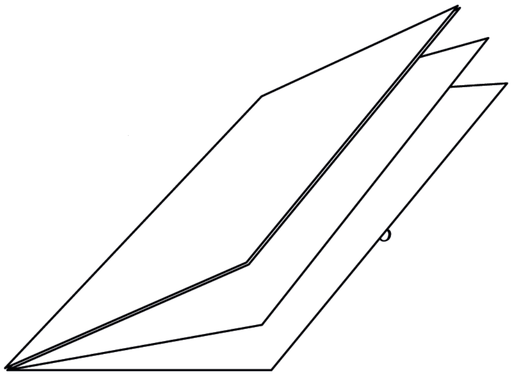


Figure 15

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

Make two more folded strips like this.

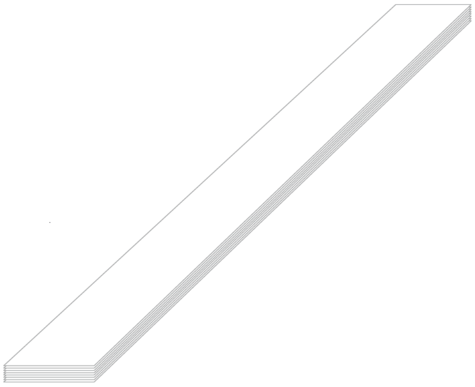


Figure 16

2. 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.

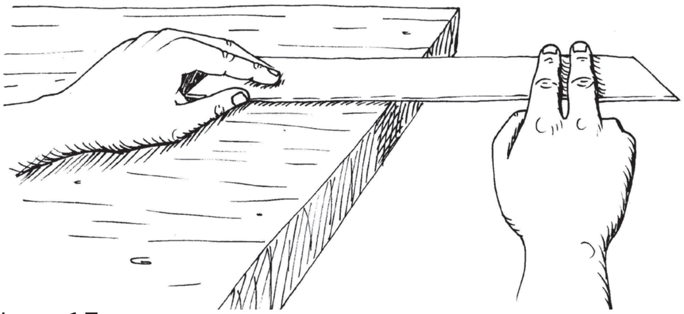


Figure 17

3. 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:

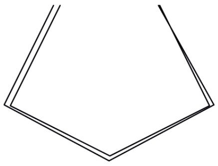


Figure 18

Then fold like this:

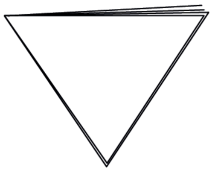


Figure 19

to make this triangular tube:

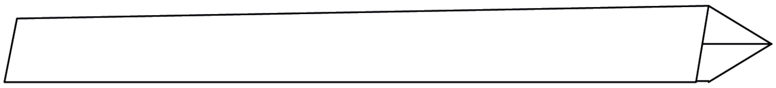
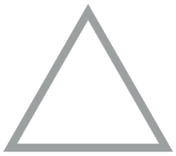


Figure 20

4. (a) 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.
   (b) What was easier to bend, the flat strip or the triangular tube?

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



This is the shape you see when you look at the end of the folded flat strip:

Figure 21

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

5. Make free-hand sketches of the cross-sections of a round tube, a square tube and a triangular tube.
6. Open your triangular tube and fold it again to make a T-profile, as shown on the right.

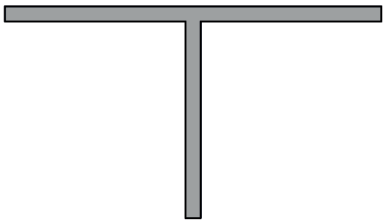


Figure 22

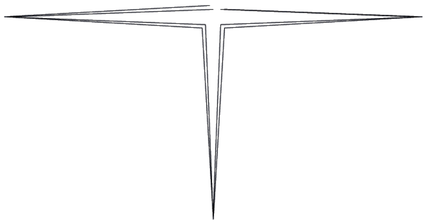


Figure 23

7. Let your T-shaped section stand upright on your desk as shown in Figure 24. 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.

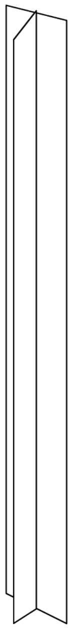
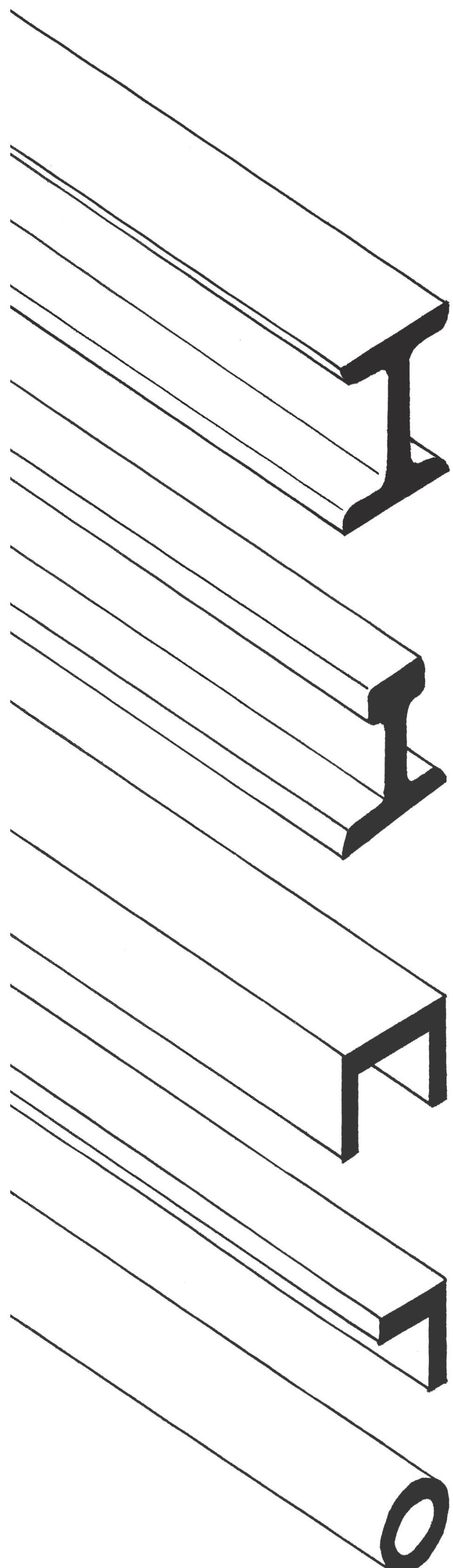


Figure 24

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).

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.

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



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

Imagine that you made a frame structure with straight pieces of wood.

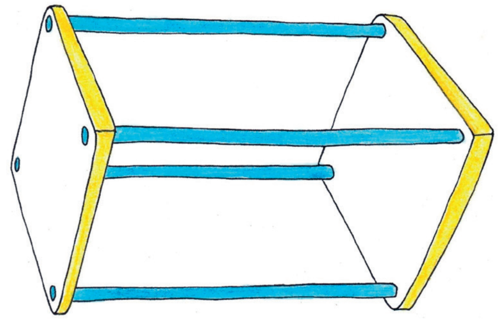


Figure 26

Now imagine that you twist this frame structure, like the person in the photograph is twisting the towel.

Figure 27

The frame structure could end up looking like this.

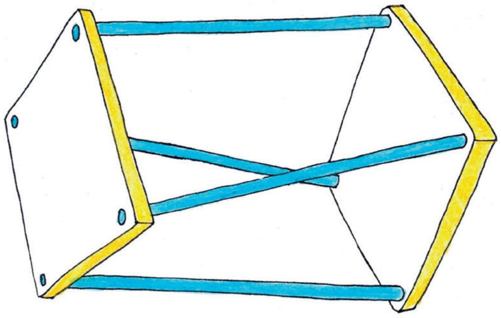


Figure 28

To prevent the structure from getting twisted like this, you could add more elements as shown here.

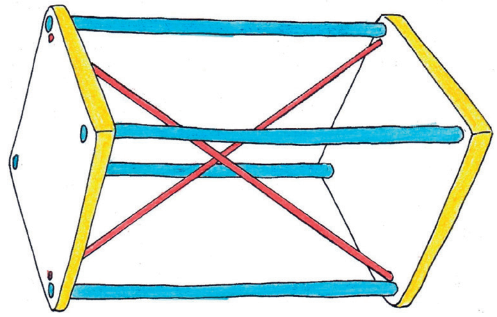


Figure 29

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

3.3 Different materials for different purposes

How materials can differ from each other

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

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?
   (b) Is the leg of a chair flexible or stiff?
   (c) Is a piece of wire flexible or stiff?
   (d) Is your shoe flexible or stiff?
4. Press your finger against your desk. Now press your finger against your arm. What was different when you pressed your finger against your desk from when you pressed your finger against your arm?
5. When you press your finger against a bag of sand, will it be the same as against your desk or arm?

Bricks are made by baking clay until it is hard.

Some materials are hard, and some materials are soft.

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

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.

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

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?

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.

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.

Figure 30

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	
The window frames	
The door	
The roof structure	
The roof cover	
The fence	
The paving around the house	

- 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.

2. Copy the table below. Fill in the materials 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		
Window frames		
Door		
Roof structure		
Roof cover		
Fence		
Paving around the house		

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.
4. What are the advantages and disadvantages of zinc roofs? Write your answer in table form.
5. In the old days, wagon wheels were made of wood. Today we use rubber tyres. Why did we change from wood to rubber?
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?

Next week

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

Chapter 4 PAT
A bridge to help the community

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.

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]

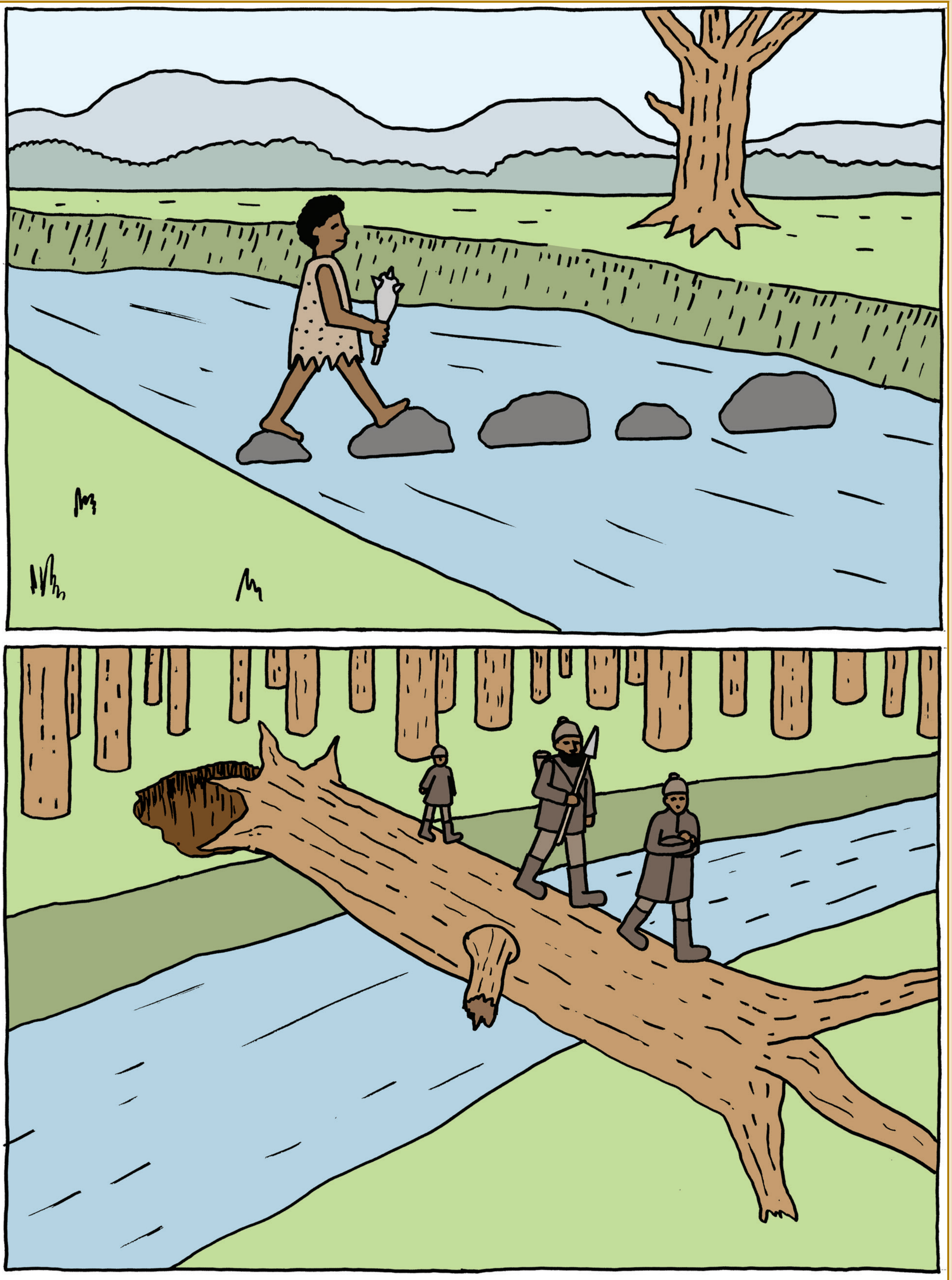


Figure 1

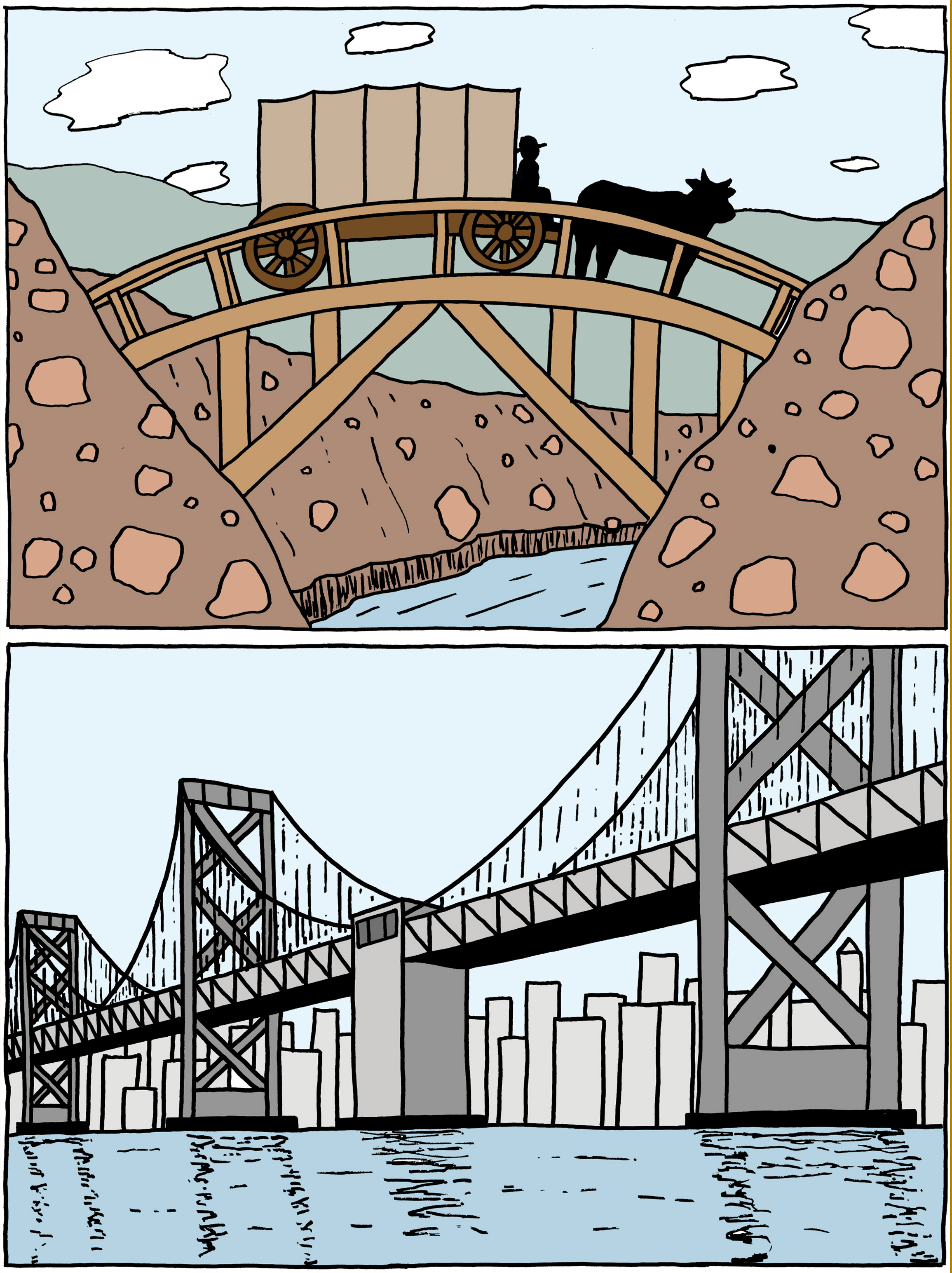


Figure 2

Week 1

Investigate Granny Margaret Thabang's problem (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 KwaNogawu 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.

3. Can you suggest a few ways to help Granny Margaret Thabang cross the river?

Thukela Municipality

REQUEST FOR TENDER – Access Bridge for KwaNogawu 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 meters wide at the crossing point. It rises during the summer rains and there are crocodiles in the river all year round.

Closing date:

Enquiries: Mrs Leslie Oats

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

A tender is a bid for work from a company. It gives details of how much the company would charge to complete a project.

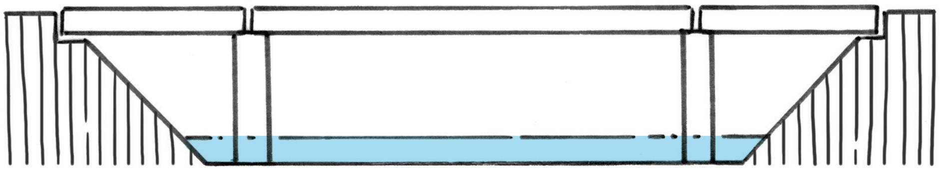
The uThukela Municipality placed a tender request in the newspaper asking contractors to submit tenders for a structure to help people safely cross the river at KwaNogawu village.

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.

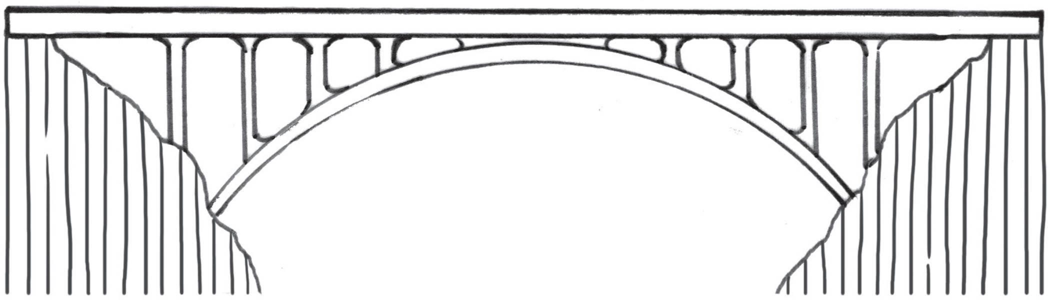
You are going to build a structure to help the community. Read the story again and then investigate the different bridges below to decide which structure will be the best solution for the problem.

Investigate structures to solve the problem (60 minutes)

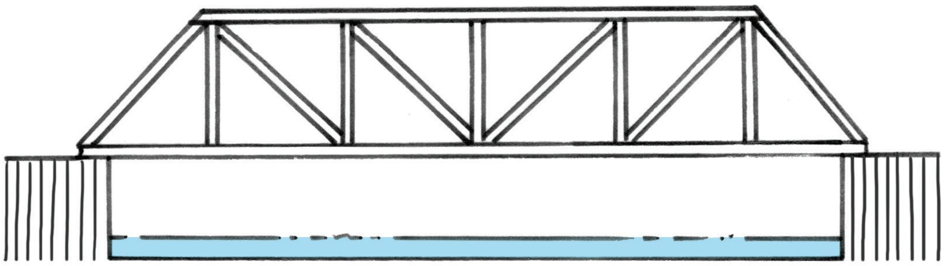
On the following two pages there are drawings of different types of bridges. You learnt about these bridges in Grade 8. Do you remember what the names mean? If you cannot remember, look at your Grade 8 book or ask your teacher to help you.



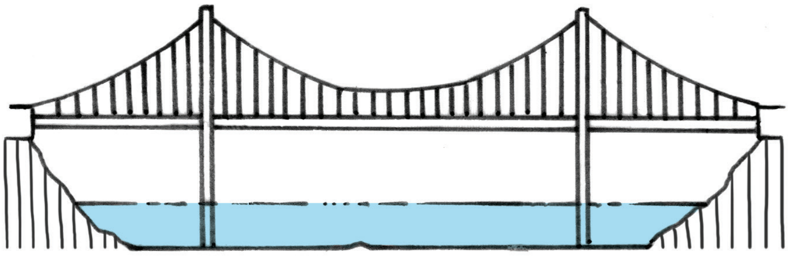
A: A beam and column bridge



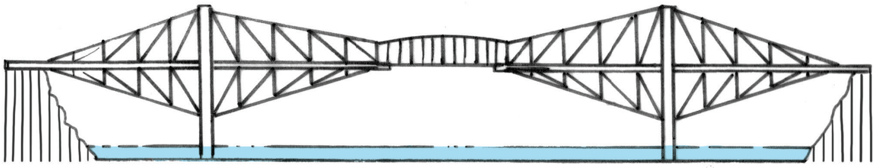
B: An arch bridge



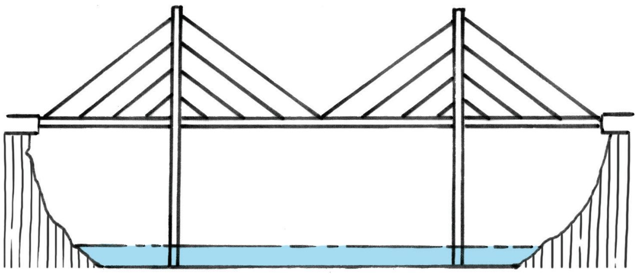
C: A truss bridge



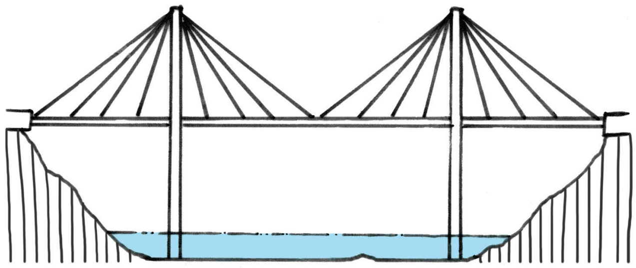
D: A suspension bridge



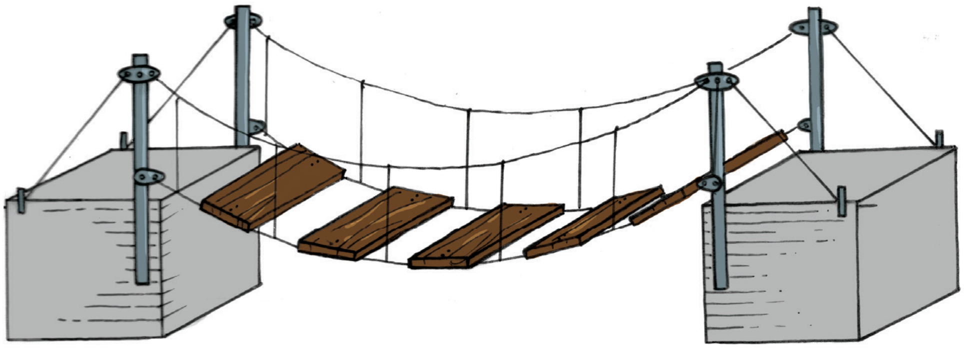
E: A cantilever bridge



F: A cable-stay bridge of the harp shape



G: A cable-stay bridge of the fan shape



H: A small suspension bridge

Figure 5

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 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.

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?		

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]

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:

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.

Design brief with specifications and constraints (30 minutes)

Write a design brief that explains what you want the structure to do. Your design brief has to list the specifications and constraints for your design.

Remember that specifications are things that your design **must** have and constraints are things that your design **cannot** have. The specifications and the constraints are usually listed in the tender notice.

Specifications could include the following:

- 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 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]

Draw a flow chart (30 minutes)

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 only "keywords" to write down your steps. Then draw a box around each step and an arrow between the steps.

"Visual" means something that you can see.

A "keyword" is a word that can replace a whole sentence. Example: for "Make a list of tasks", just write "list".

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.

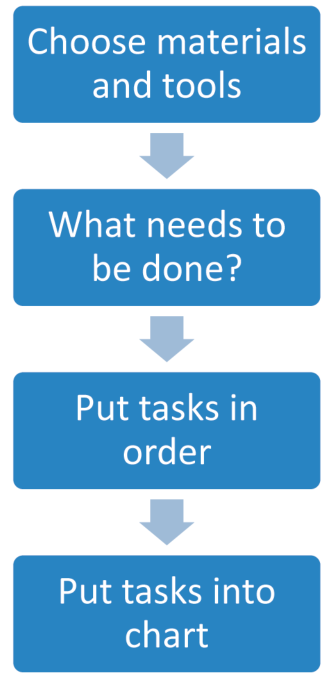


Figure 6

Week 3

Make working drawings (60 minutes)

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.

Have another look at Chapter 1 to remind you how to make orthographic drawings.

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]

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.

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.

Example:

Item description	Quantity	Price per unit (Rands)	Total (Rands)
Materials			
Cement (80 kg bags)	50	90	10 000
Pine Planks (200 cm × 30 cm × 2 cm)	200		
Bags of nails (10 × 3 cm)	10		
Bricks	5 000		
Steel I-beam (5 m × 6 cm)	20	1 000	20 000
Subtotal			
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	
Shovels and other equipment	25	10 per day	
Subtotal			
Other staff costs			
Engineer			
Architect			
Work manager			
TOTAL			

[Total: 10]

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.

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 a glue-gun?

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)

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 complete it.

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.

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

In this chapter, you will revise what you know about moving objects with air and water. You will learn more about the differences between pneumatic and hydraulic systems, and you will learn how to use hydraulic systems to make a small force move a heavy object.

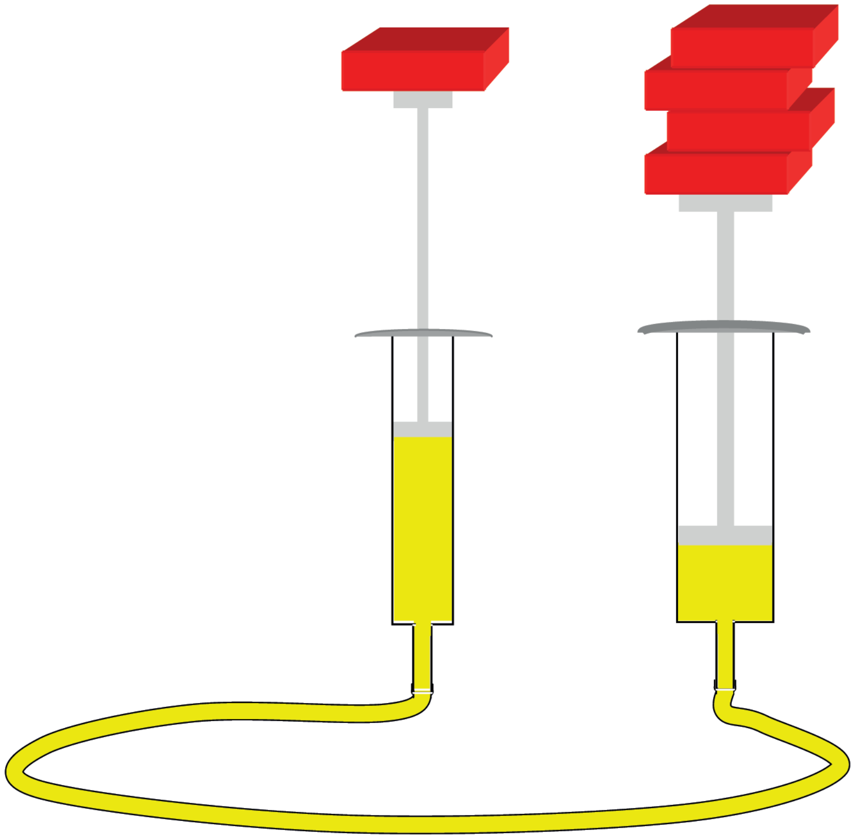


Figure 1

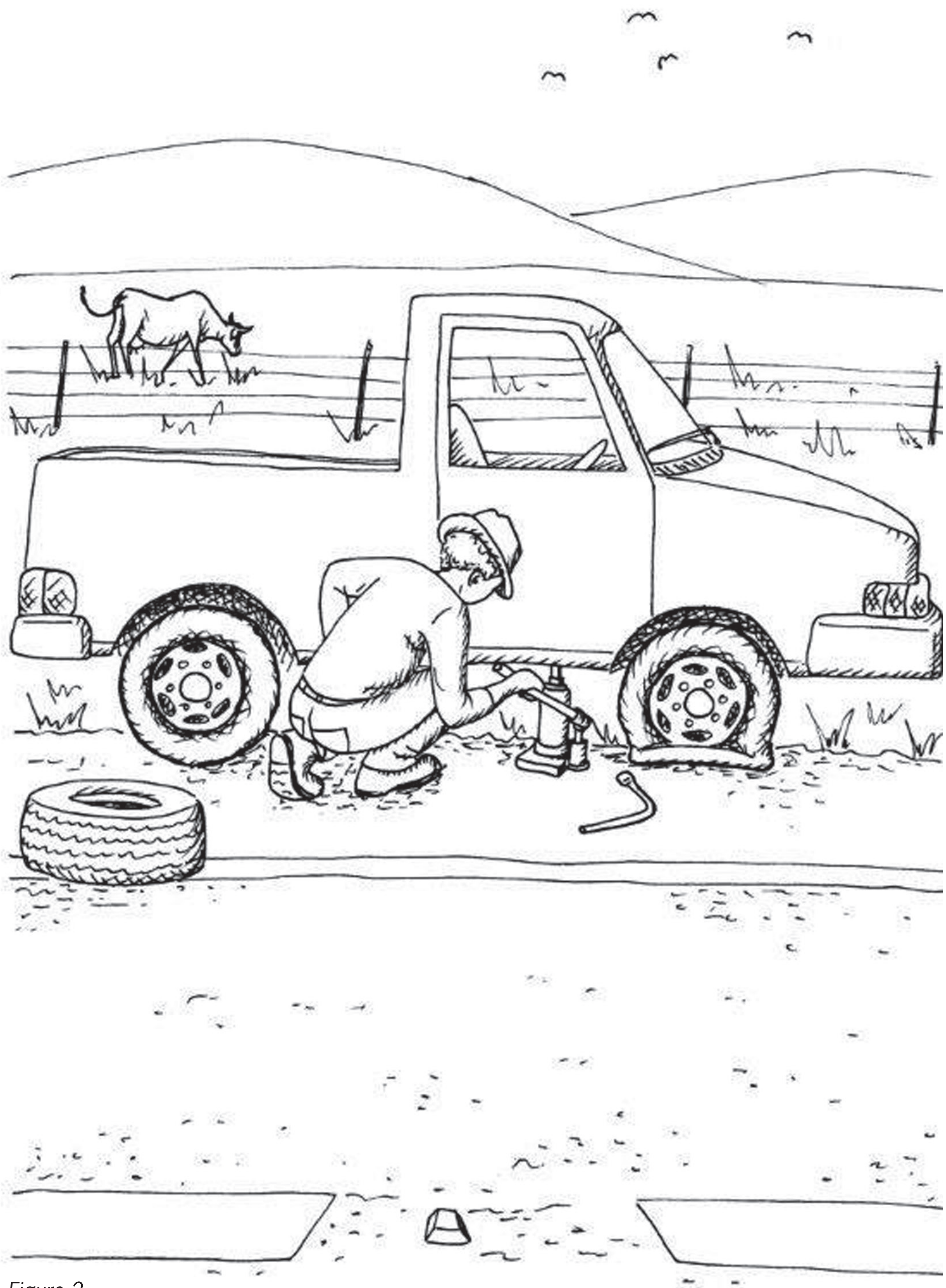


Figure 2

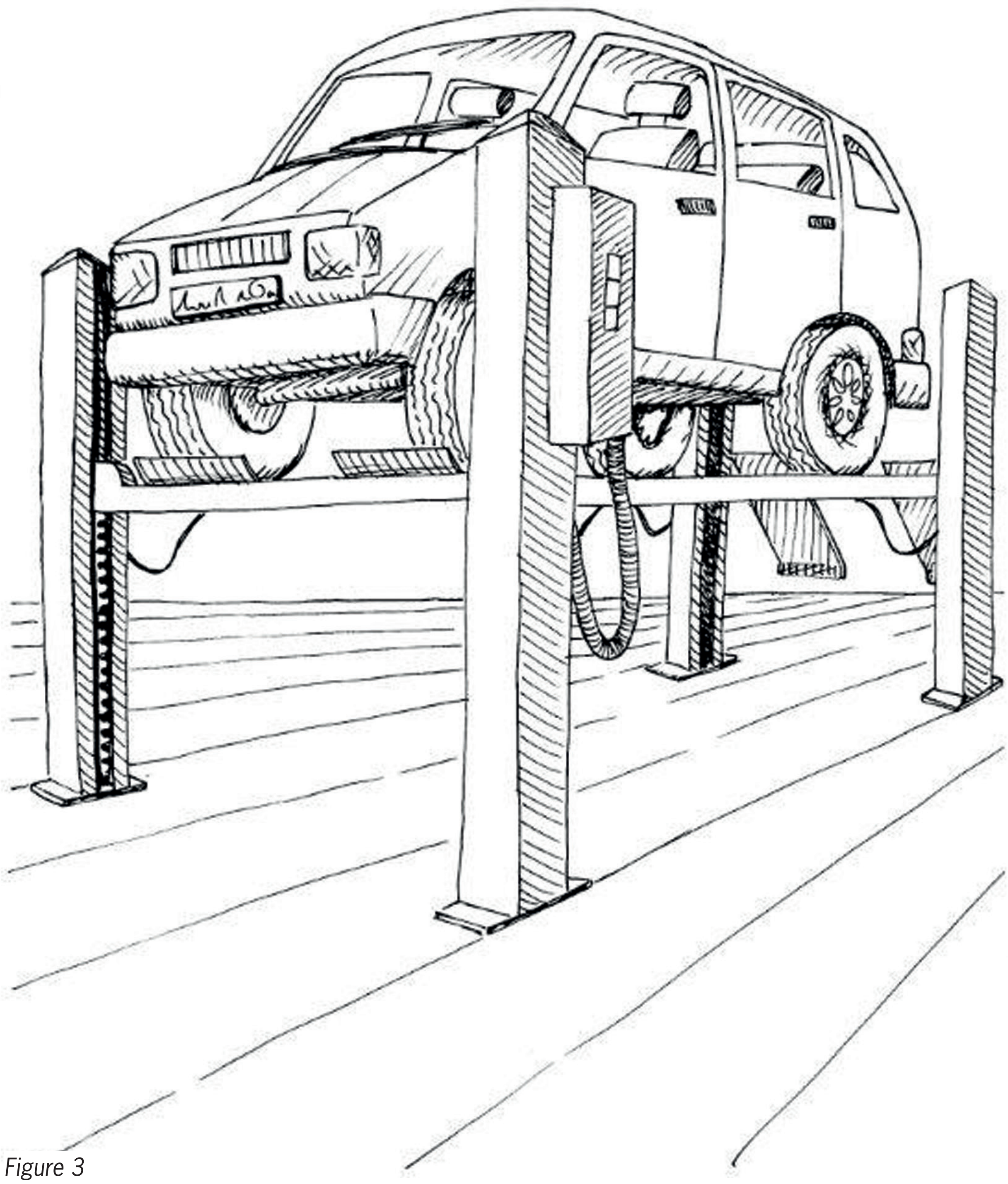


Figure 3

5.1 Use water and air to move objects

Compressible and incompressible substances

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

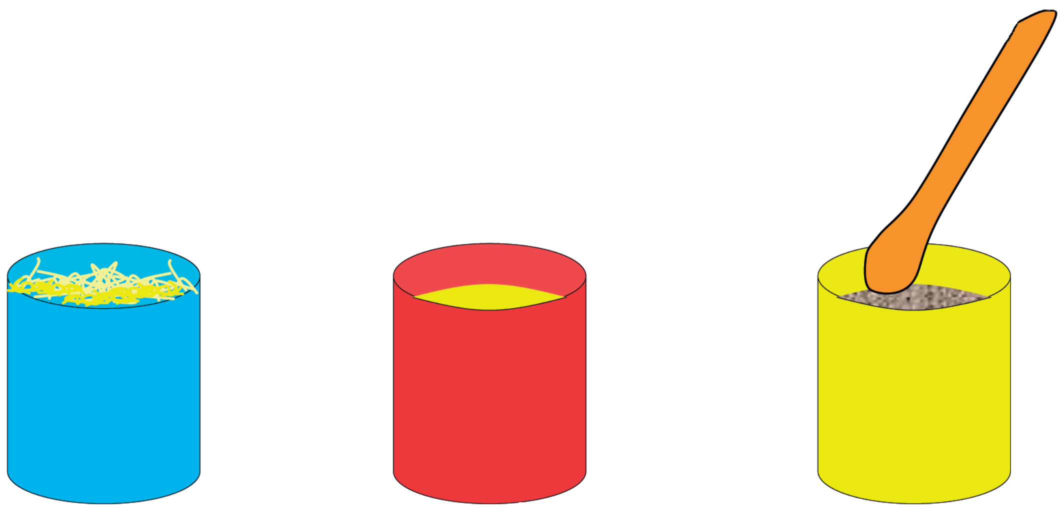


Figure 4

1. Do you think it is possible to use the wooden spoon to compress the sand so that it takes less space in the yellow tin?
2. Do you think it is possible to compress the straw?
3. Do you think it is possible to compress the water?

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

Air is compressible, but water is incompressible.

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**.

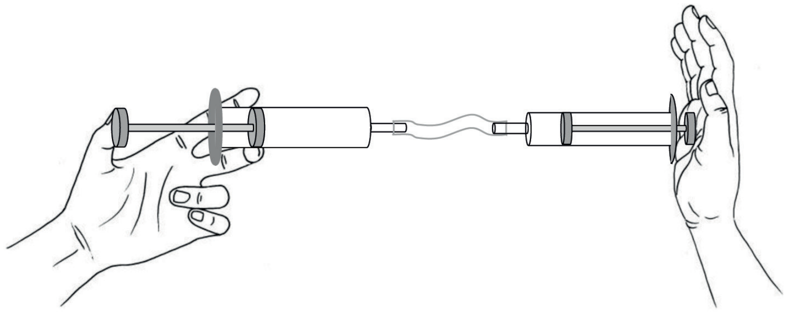


Figure 5

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.
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.

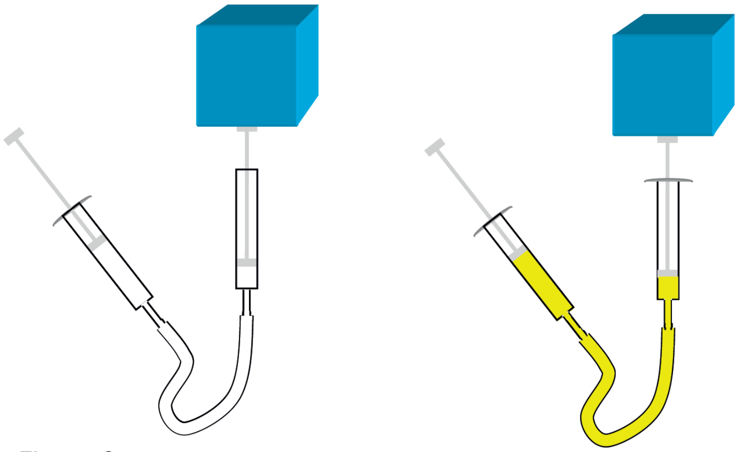


Figure 6

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.

5.2 Narrow and wide syringes

Think about loads and distances

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

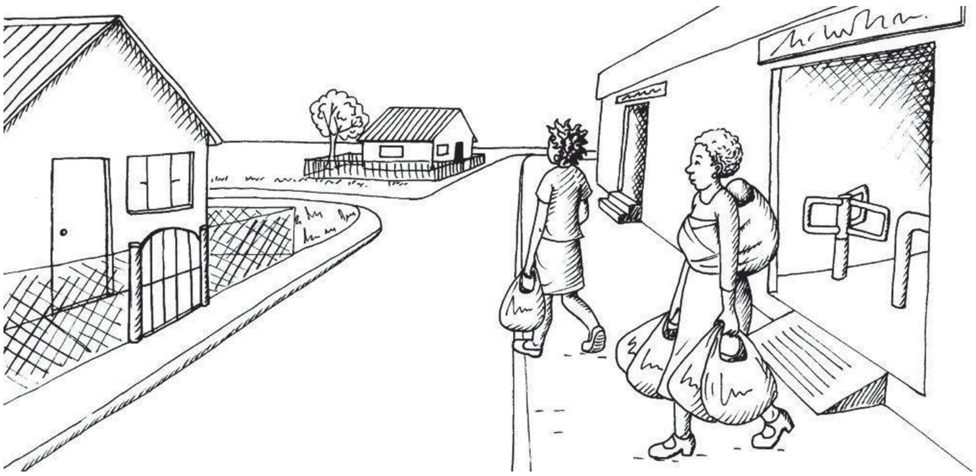


Figure 7

1. The woman carrying the big load has to walk only 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.

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.

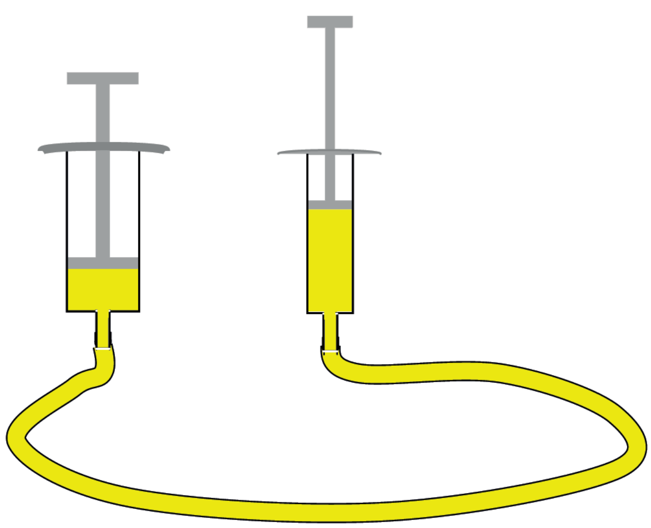
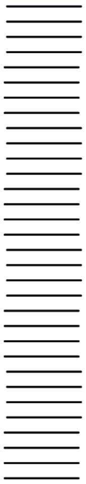


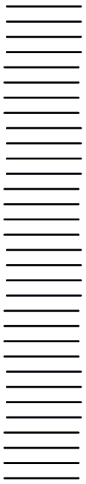
Figure 8

Action research: Input and output cylinders

You will now do more action research with two syringes. To do this, you need to make apparatus.

Copy these rulers onto a sheet of paper and attach them to a sheet of corrugated cardboard or a cereal box. The lines are 2 mm apart.





Use tape to attach your two-syringe system 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.

Instead of "master cylinder", you can say **driver cylinder**.

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 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				

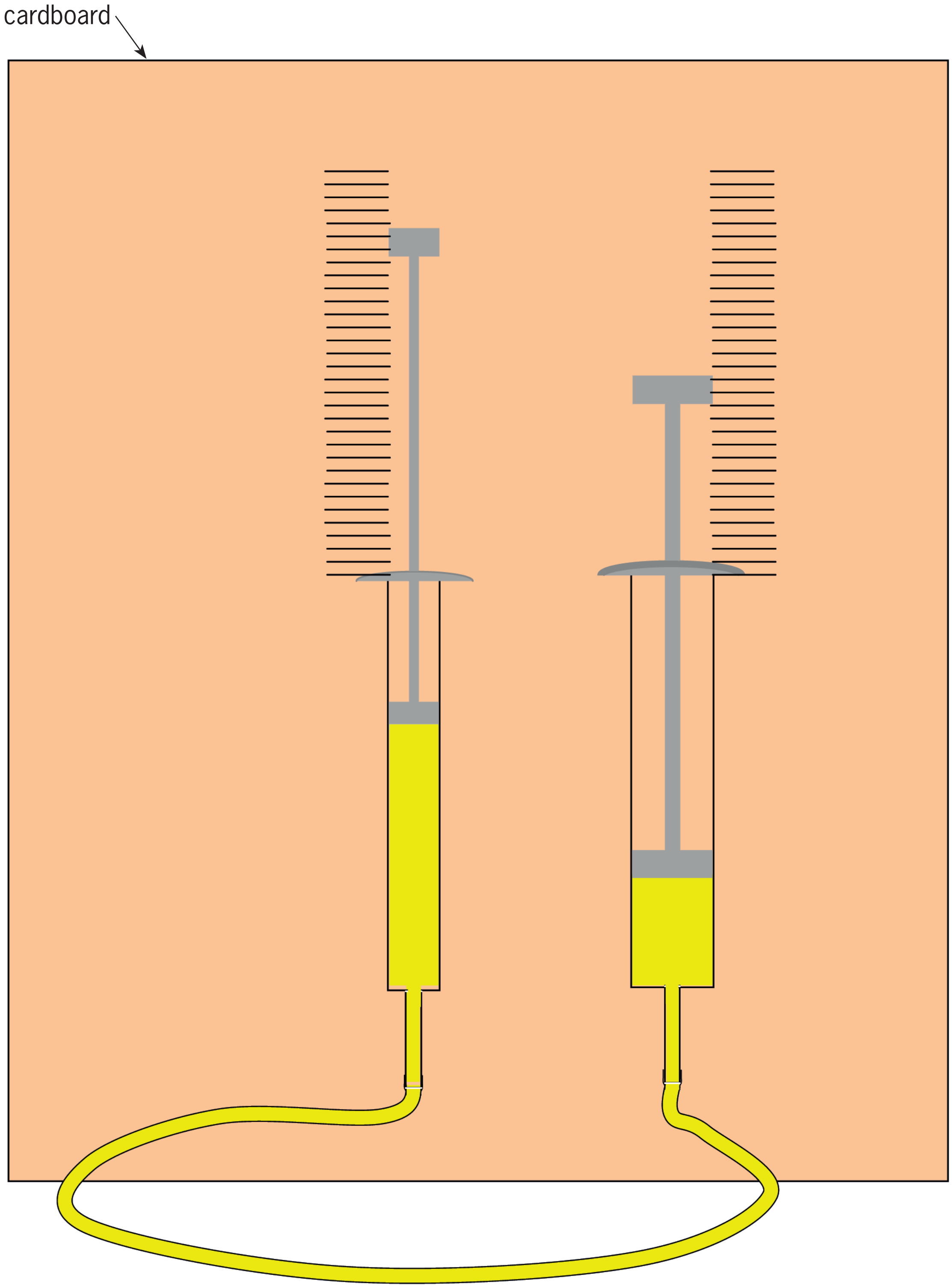


Figure 9

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?
9. Also predict what will happen if you press the plunger of the wide cylinder in by ½ cm, 1 cm or 2 cm. Copy the table below and fill in your predictions.

Wide master cylinder movement in cm	½	1	2
Narrow slave cylinder movement in cm			

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

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.

5.3 Change the size of forces using a hydraulic system

Figure 10 shows a plastic bag filled with water. If you were to 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**.

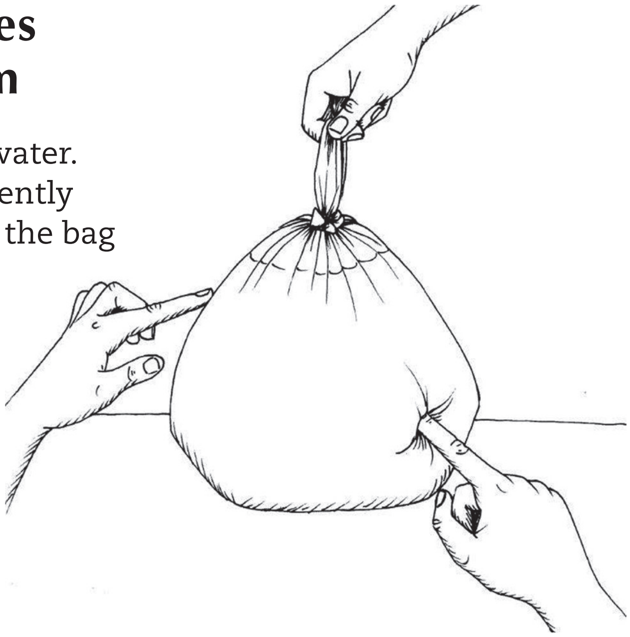


Figure 10

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.

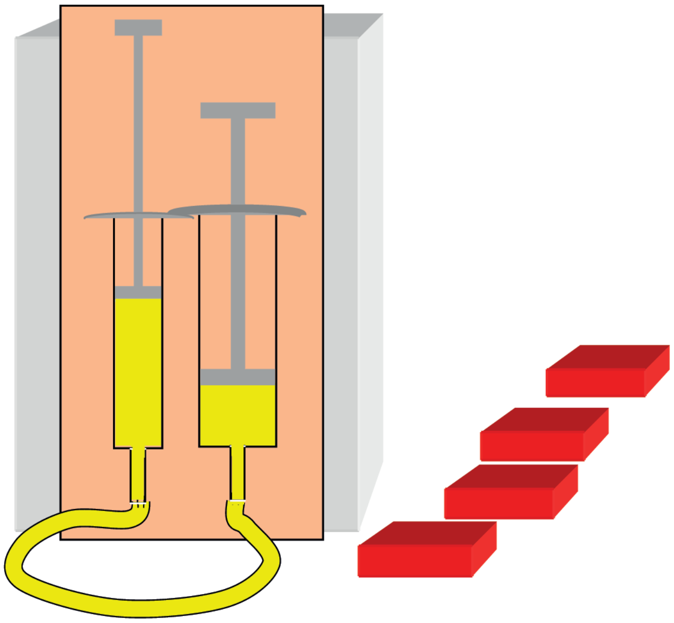


Figure 11

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?
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.

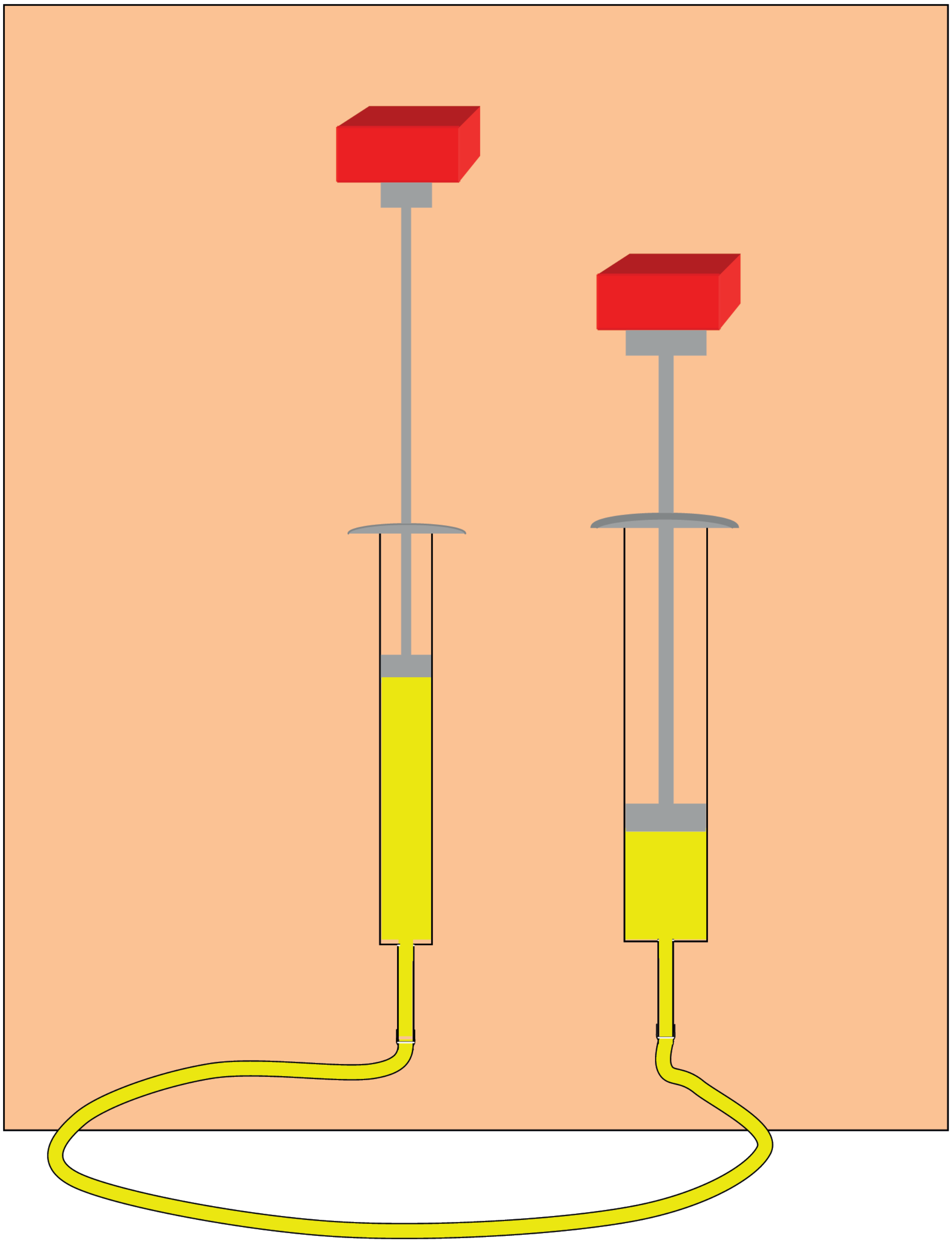


Figure 12

5. Think about what you have just observed. How do the boxes you have placed on the master cylinder affect the slave cylinder?

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.

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

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

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

In this chapter you will investigate how hydraulic systems are used in some practical situations.

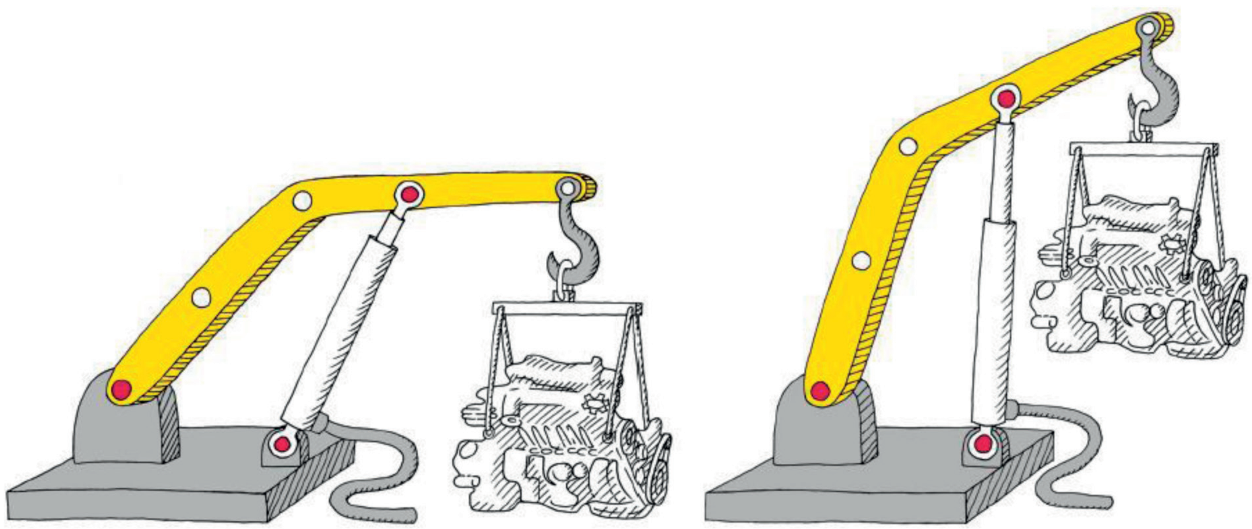


Figure 1

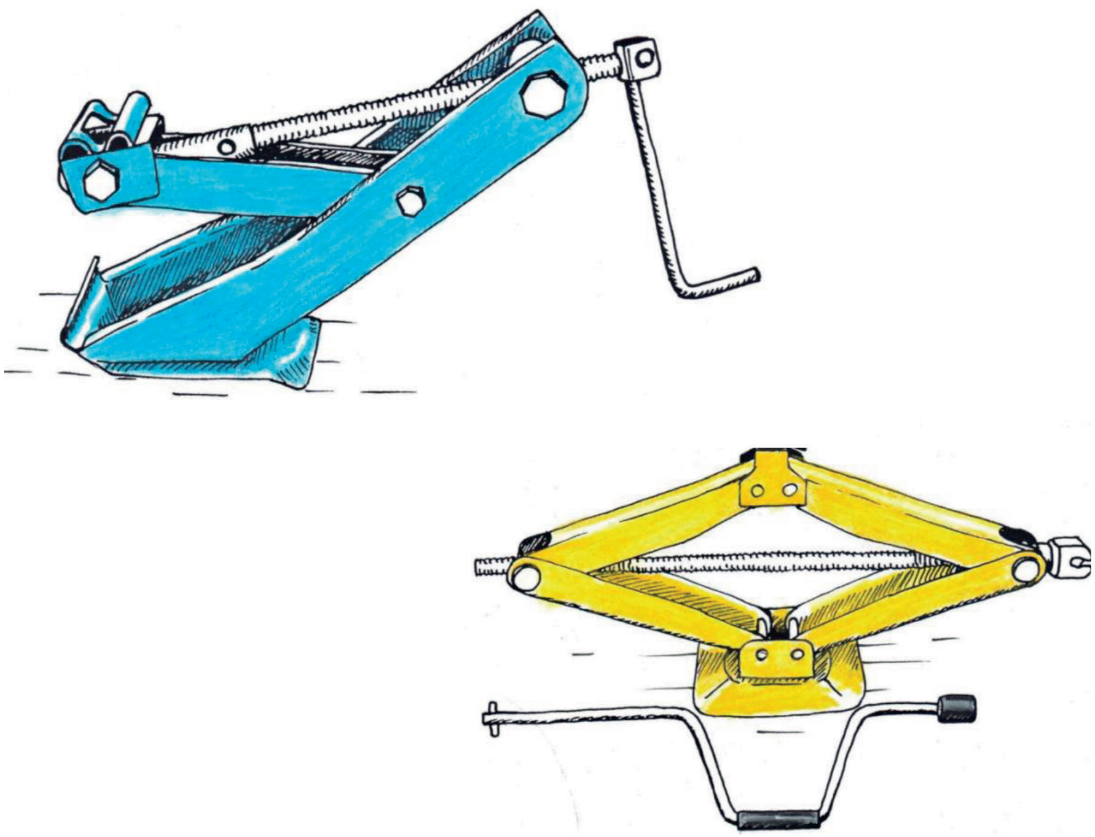


Figure 2: Mechanical jacks

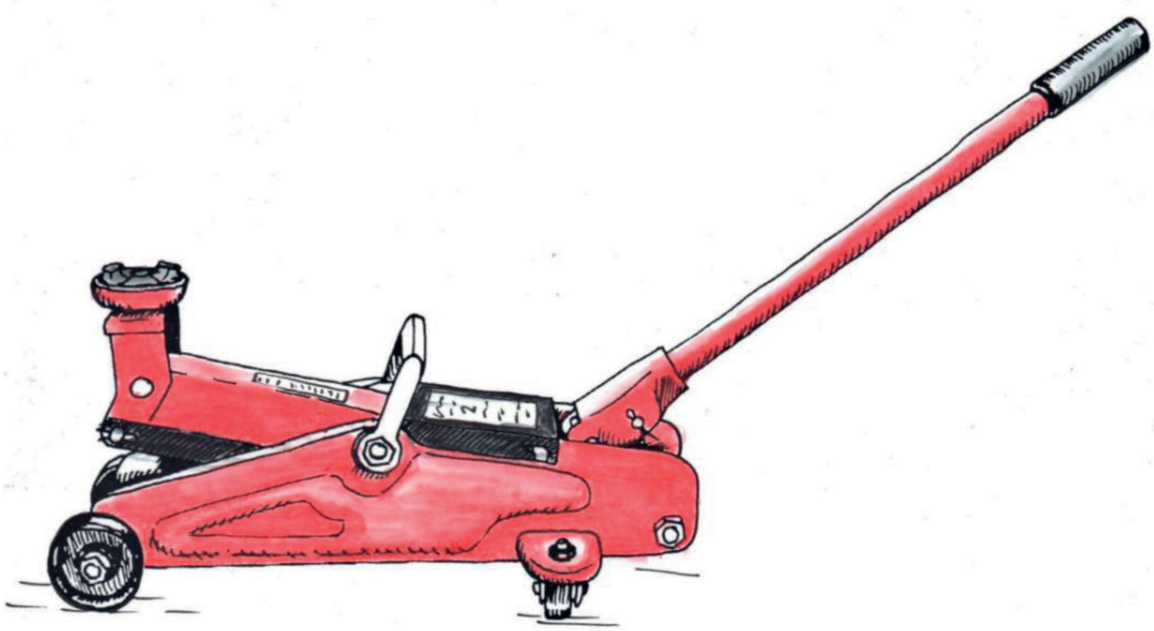


Figure 3: A hydraulic floor jack

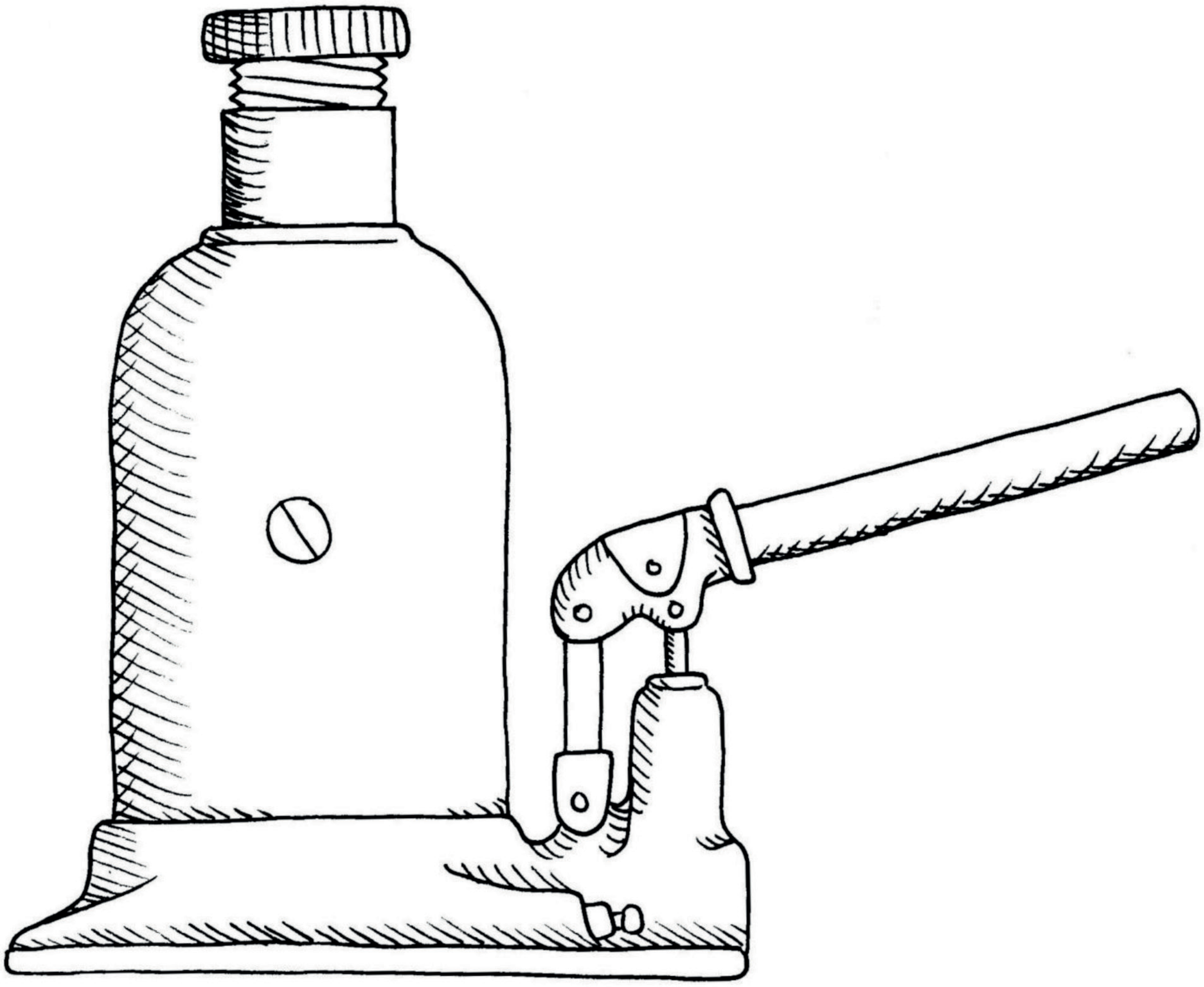


Figure 4: A hydraulic car jack

6.1 Using pressure to get things done

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

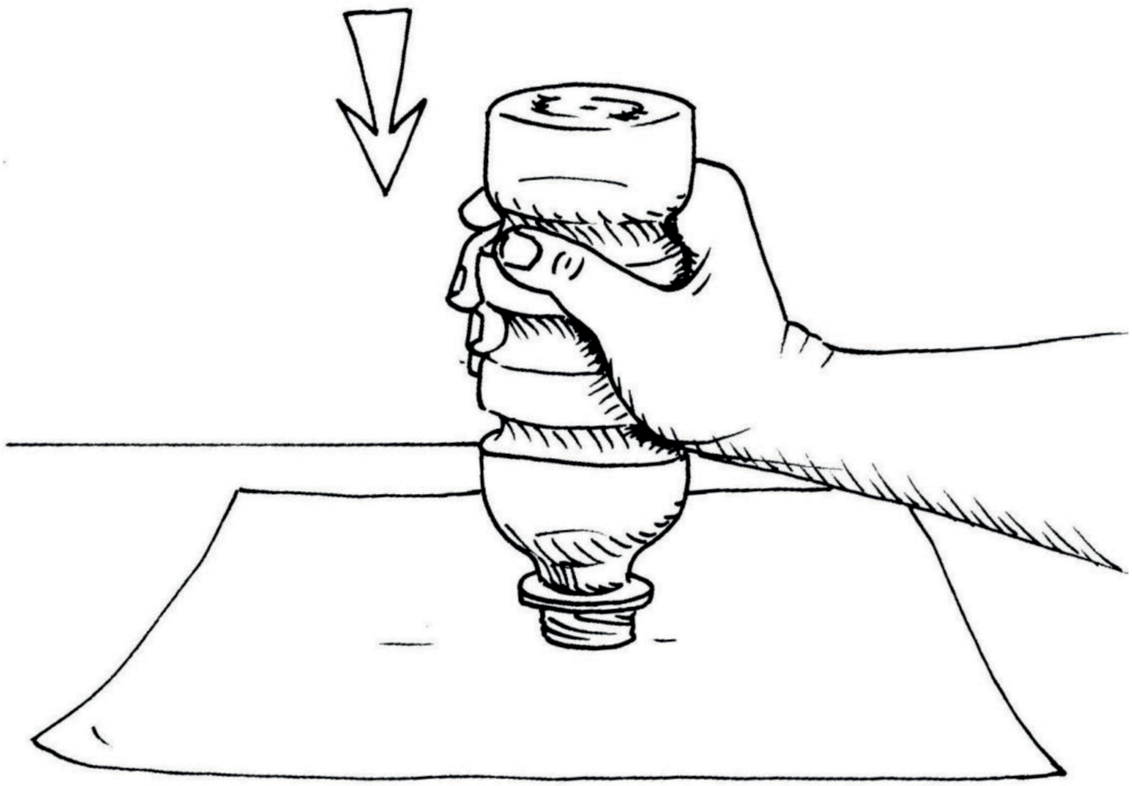


Figure 5

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

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 could be called a washer-making press.

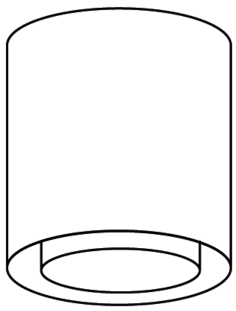


Figure 6

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.

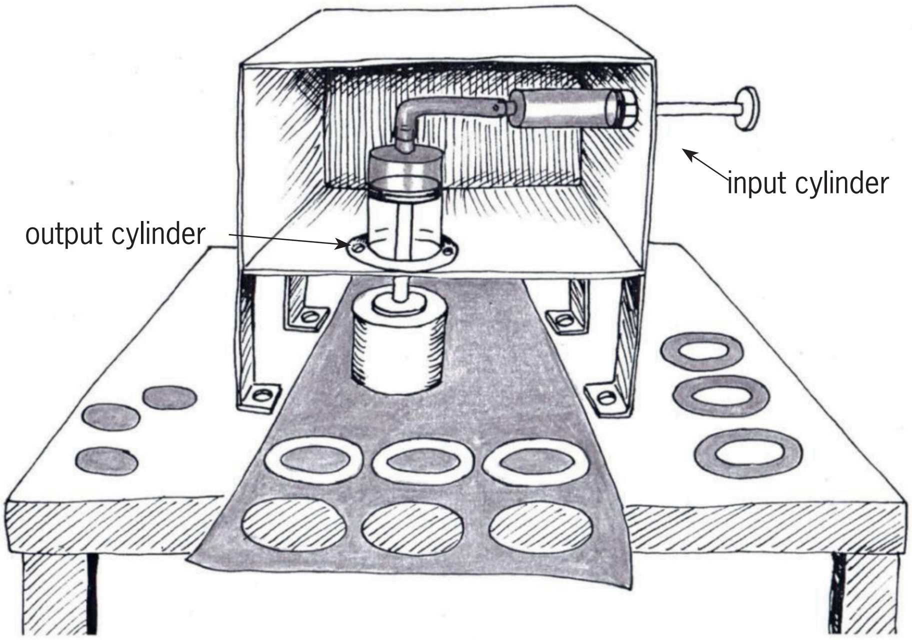


Figure 7

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.

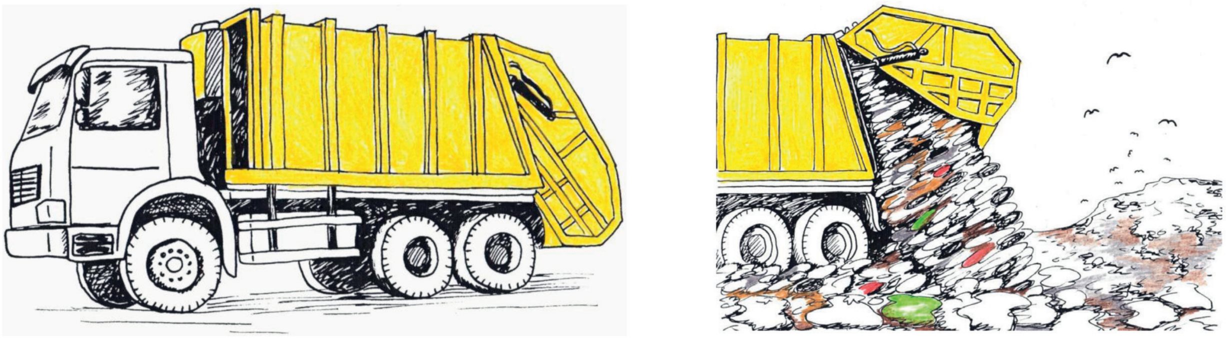


Figure 8

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.

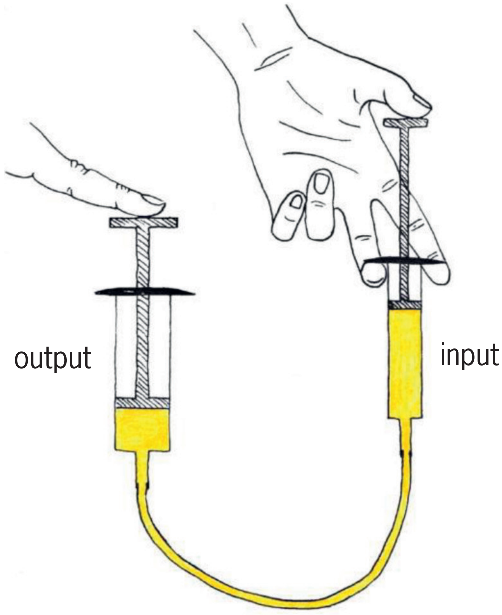


Figure 9

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?

   (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?

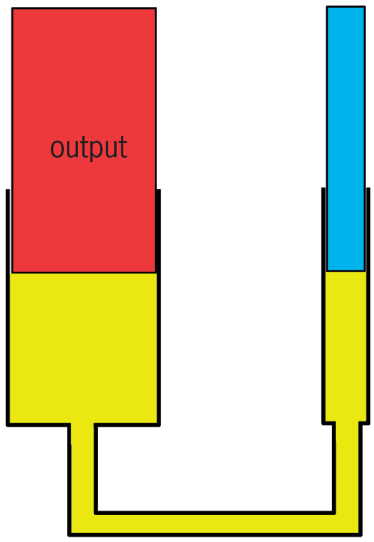


Figure 10

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.

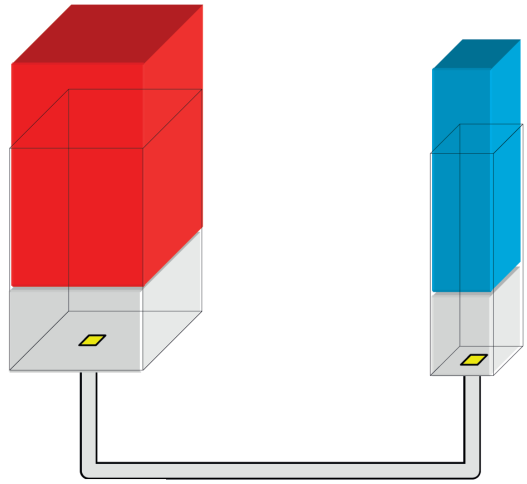


Figure 11

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

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

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 ¼ of the input distance.
- In the system in Figures 11 and 12, the mechanical advantage is four, and the distance advantage is ¼.

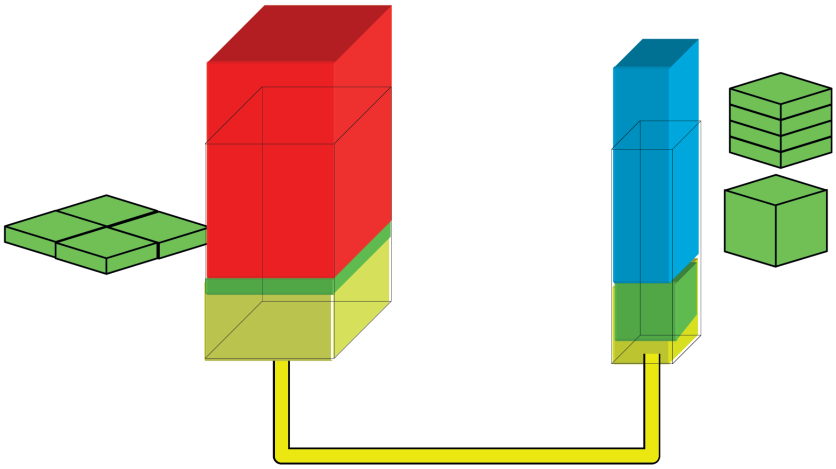


Figure 12

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

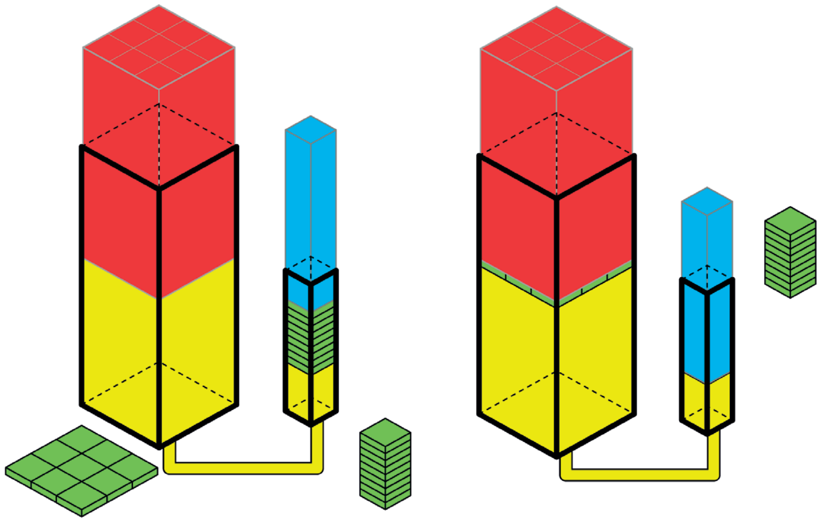


Figure 13

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

6.3 The hydraulic car 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.

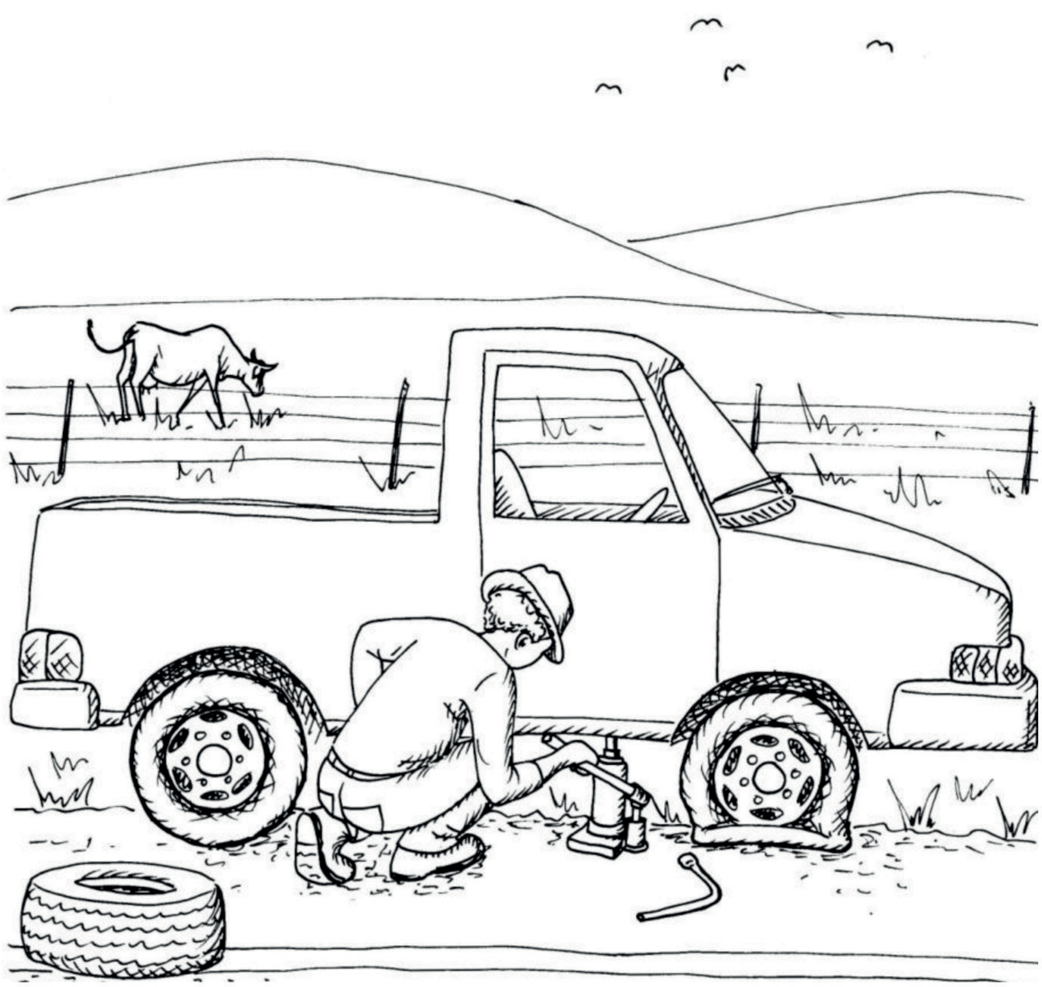


Figure 14

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

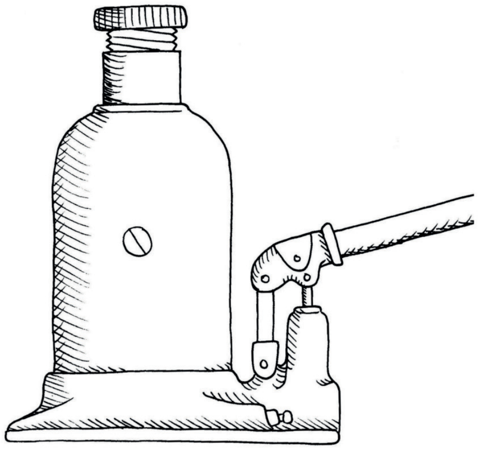


Figure 15: A hydraulic bottle jack

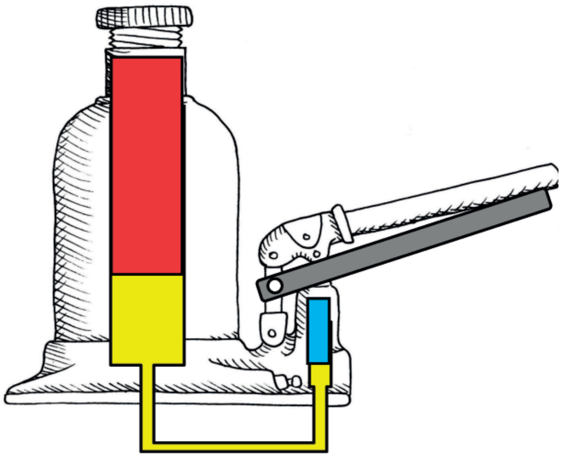


Figure 16

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.

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?

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.

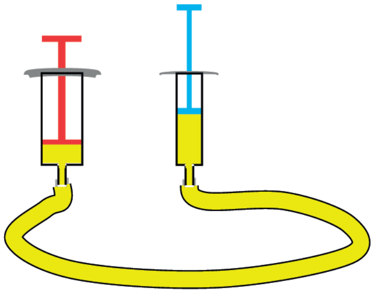


Figure 17

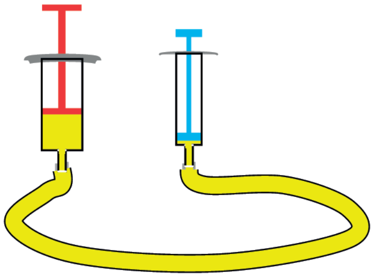


Figure 18

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?

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.

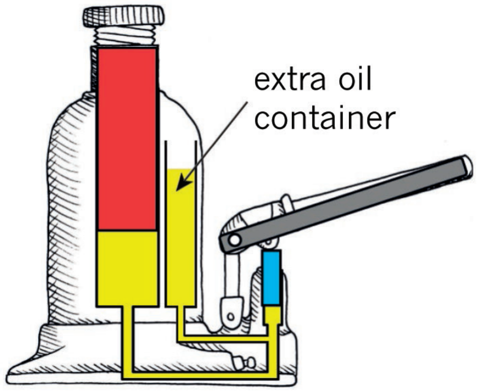


Figure 19

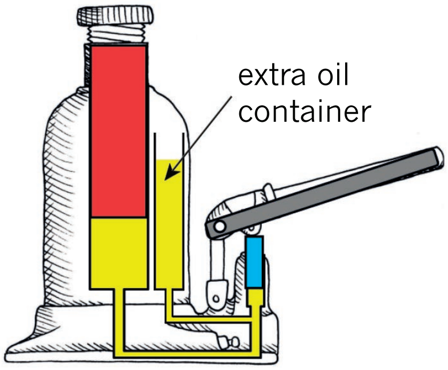


Figure 20

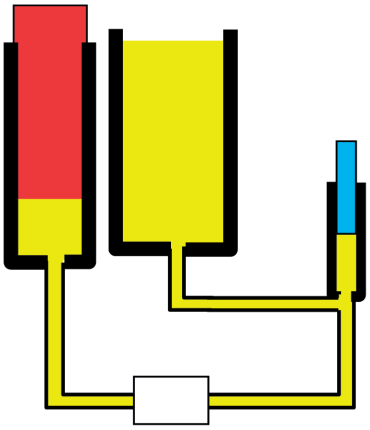


Figure 21

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.

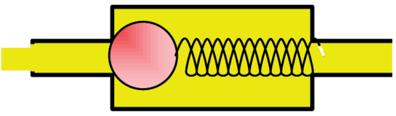


Figure 22: Ball valve closed

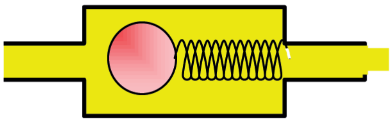


Figure 23: Ball valve open

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.

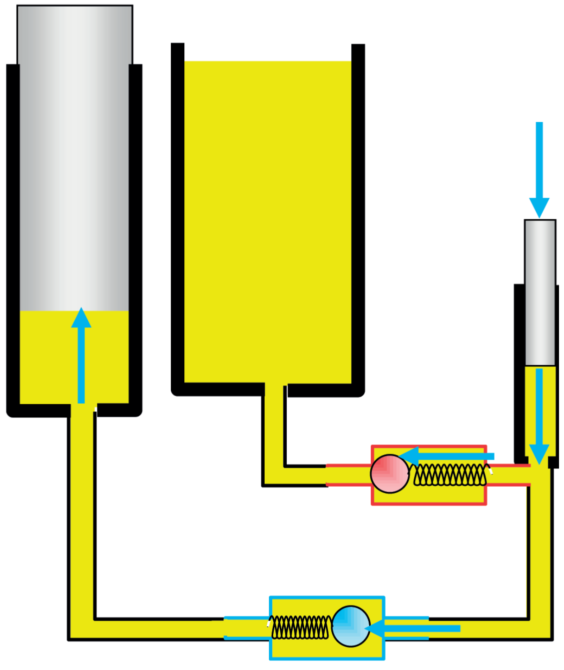


Figure 24

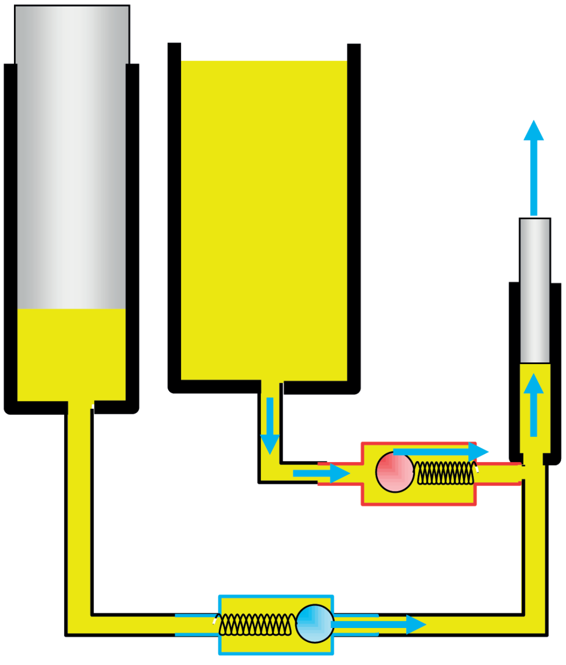


Figure 25

3. Make a systems diagram of how a hydraulic car jack works. The picture below may 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 Figure 26 below has a hole inside it into which the output cylinder fits. This tank is also called the "oil reservoir" of the hydraulic system.

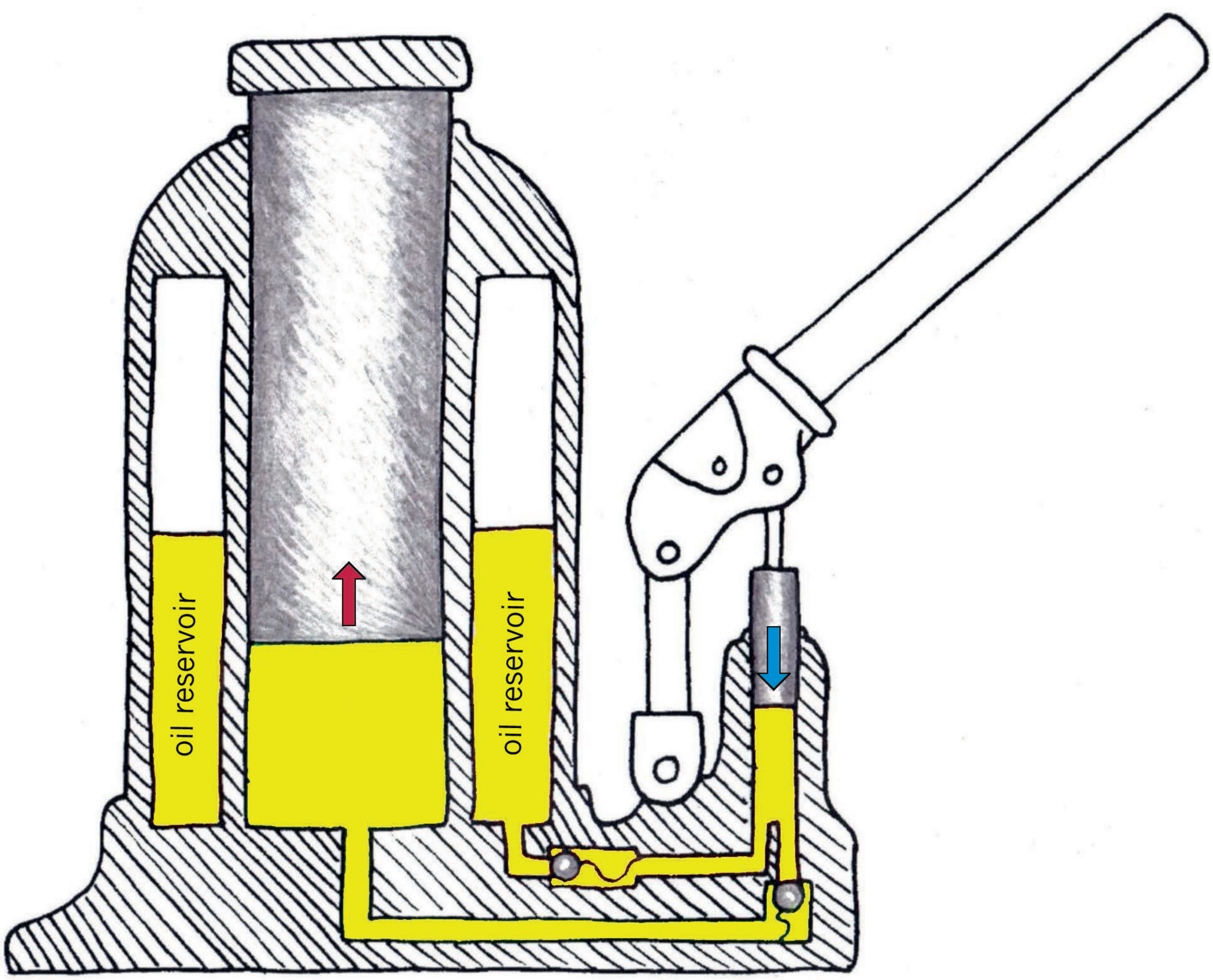


Figure 26: A few inner workings of a hydraulic car jack

An important question

What safety precautions should people take when using car jacks?

Evaluate the design of a hydraulic car jack

1. Who uses hydraulic car jacks?
2. What do you do with a hydraulic car jack?
3. Is a hydraulic car jack a good tool to lift a car? Explain.
4. What materials are hydraulic car jacks made of?
5. What does a hydraulic car jack cost, more or less?
6. Is it worth paying that amount for a hydraulic car jack?
7. Is it necessary for a hydraulic car jack to look pretty?
8. Is a hydraulic car jack safe to use?

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

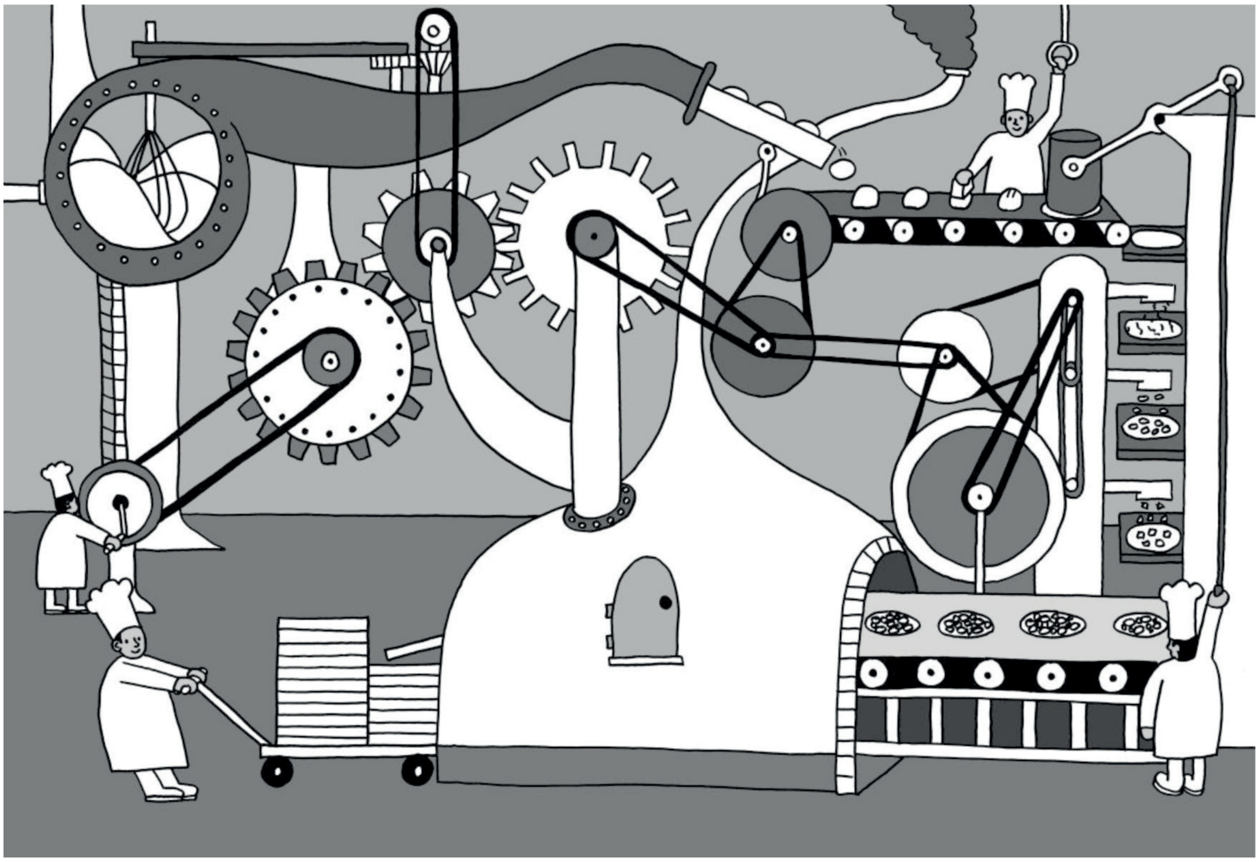


Figure 1

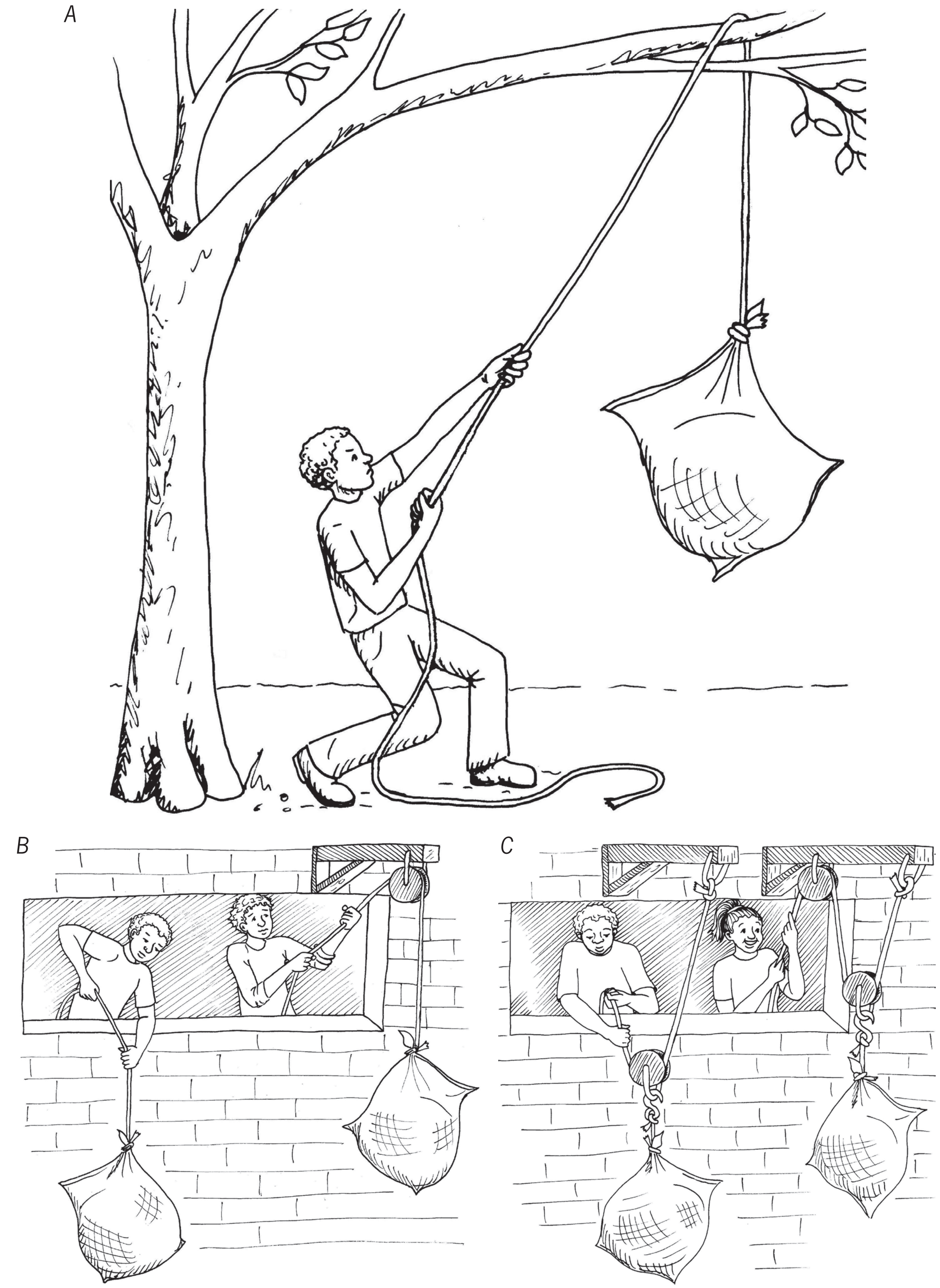


Figure 2: Which way of hoisting a heavy bag is the easiest?

7.1 Change direction with a string or rope

Different ways to lift something up

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 until 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 shown 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.

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

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.

When two surfaces rub against each other, there are forces that act on the materials, and parts of the materials may break. The forces that act when materials rub against each other are called **friction forces**. On a cold day, you sometimes rub your hands against each other to warm them up. The warmth comes from the friction forces.

To prevent friction from harming a rope that is used to change the direction of pulling an object, one may let the rope run over a wheel that is called a **pulley**.

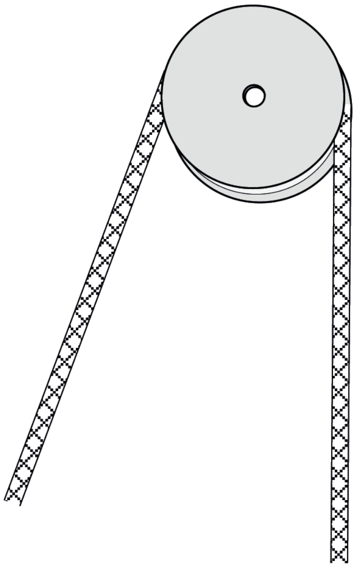


Figure 4: A pulley

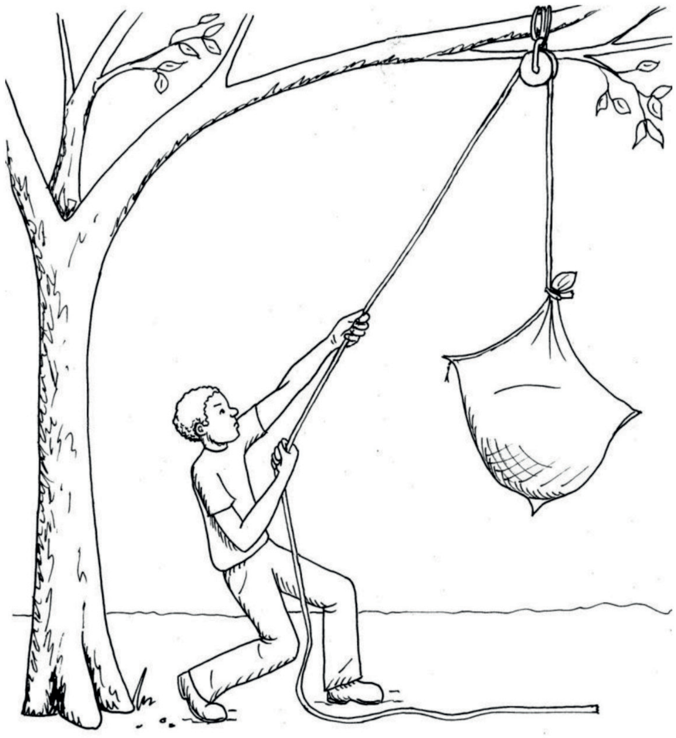


Figure 5: The man uses a pulley to lift the sack

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.

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.

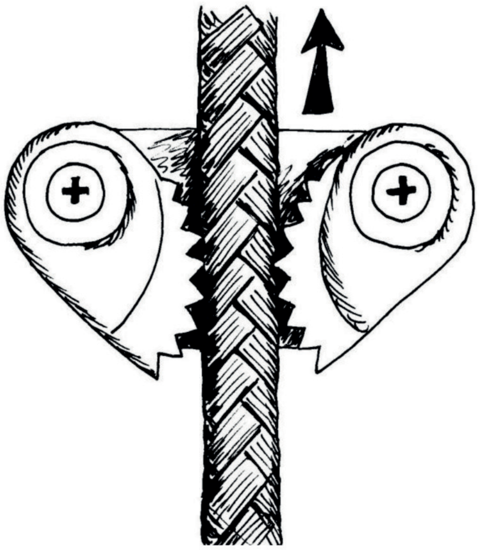


Figure 6: A cam cleat

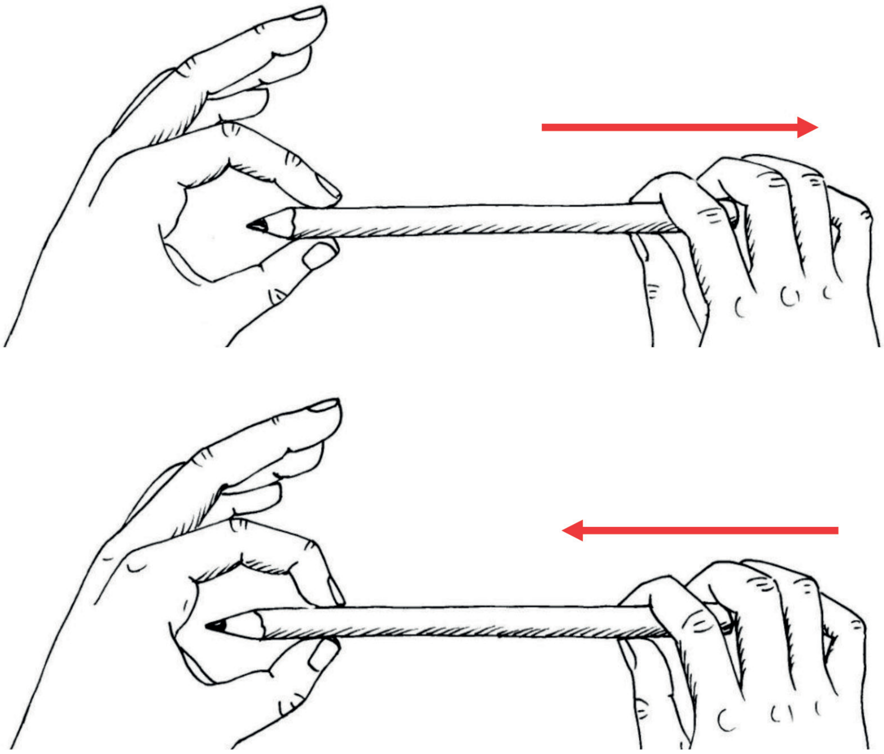


Figure 7: You can slide a pencil between your thumb and forefinger to feel how a cam cleat works.

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

An important experiment

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. Keep your left hand still!
Let the string slide through the handle.

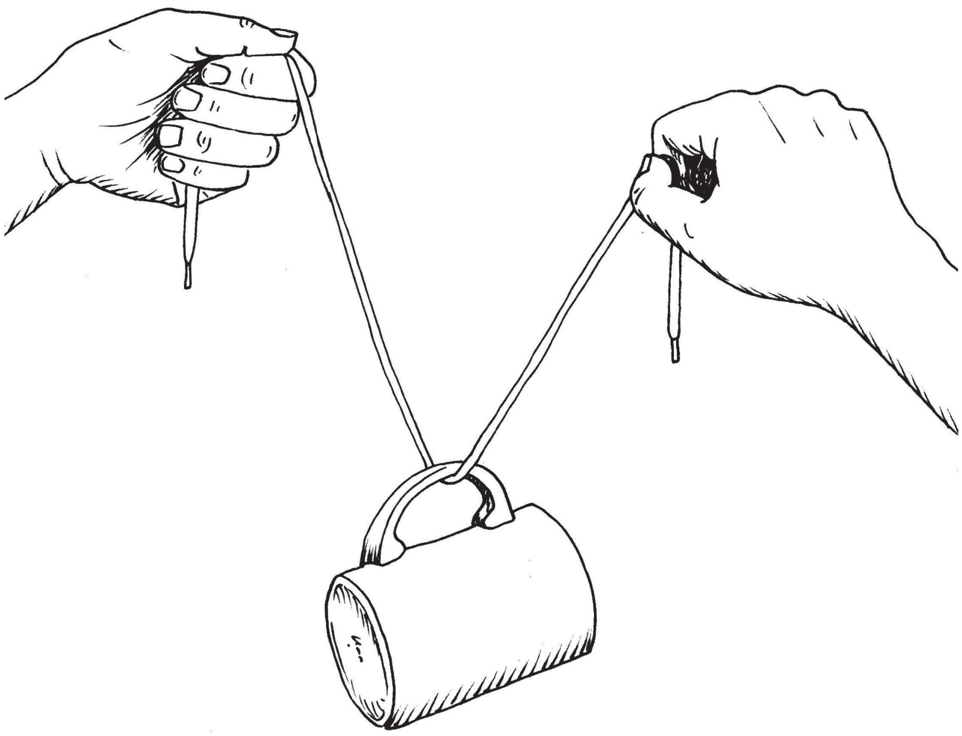


Figure 8

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.

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 below, 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**.

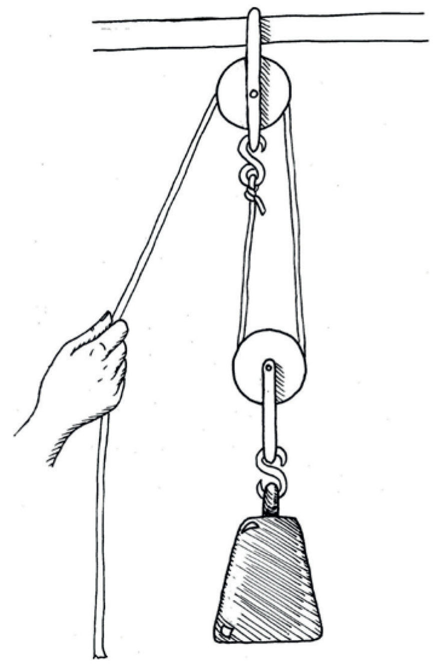


Figure 9: A block and tackle

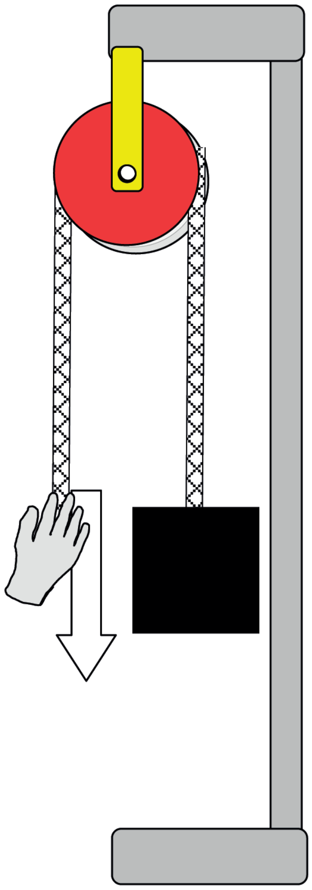


Figure 10A

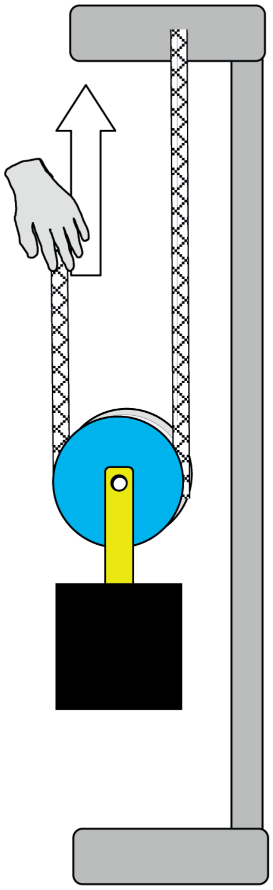


Figure 10B

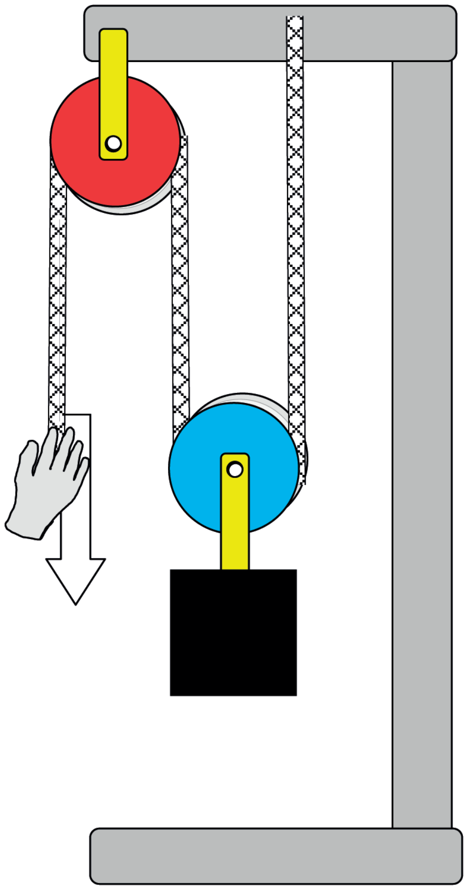


Figure 10C

Questions about pulley systems

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

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 page 84.

Figure 11 on the next page 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.

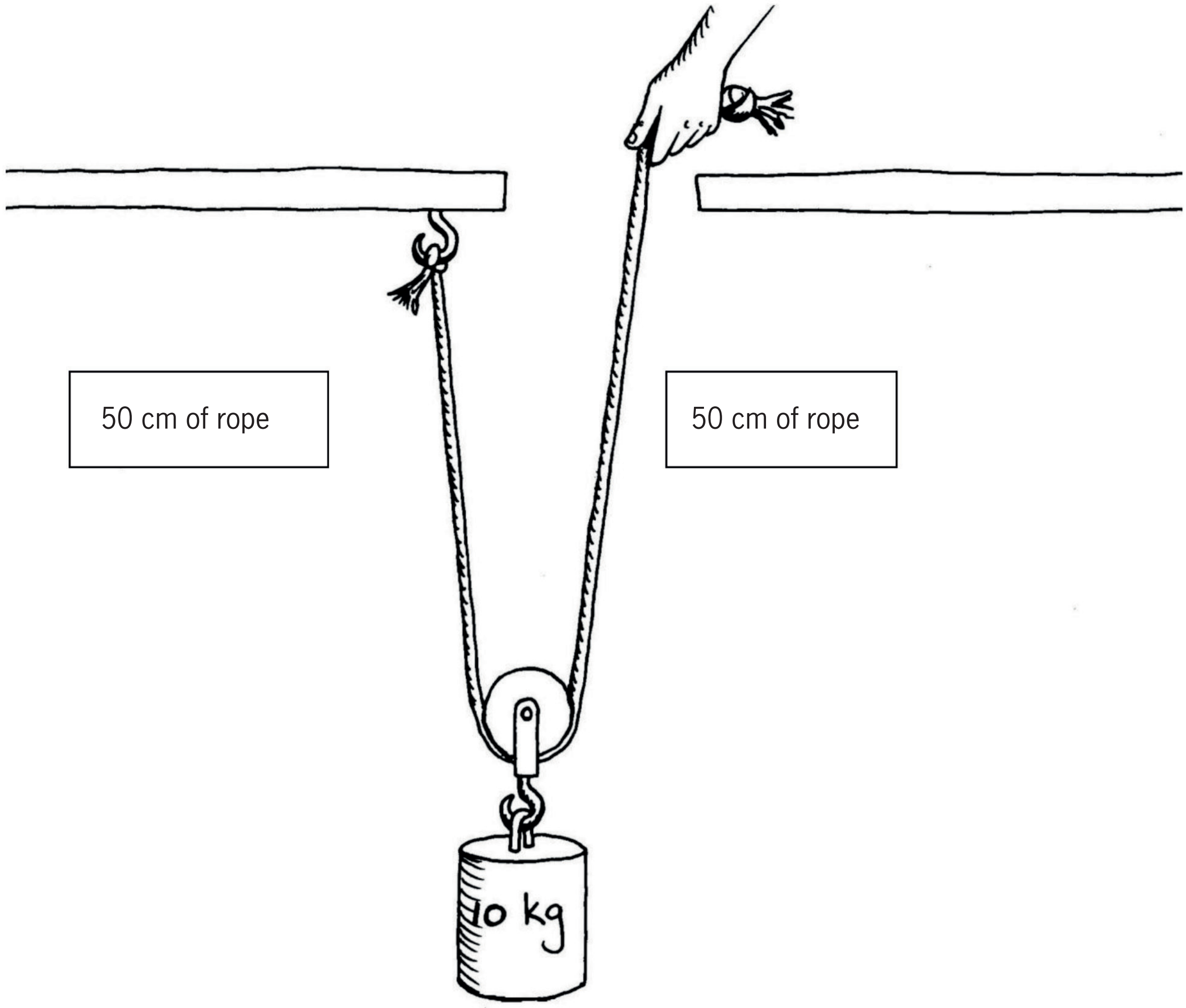


Figure 11: Single moveable pulley system

7.3 Mechanical control systems

You can ride a bicycle very fast.

Figure 12

However, to be safe when you ride a bicycle, you need to be able to control the speed. You need **brakes**. One type of bicycle brake is shown in the picture on the right. The diagrams on the next page will help you to understand this picture better.

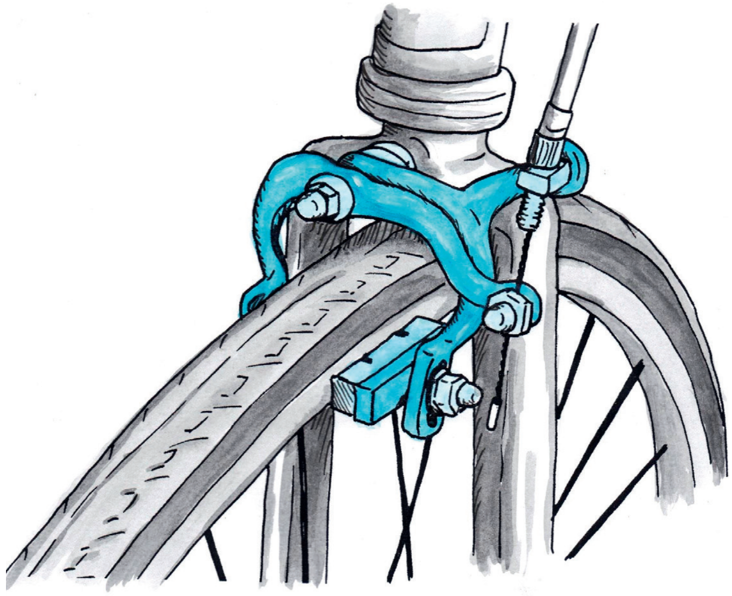


Figure 13

Think of a pair of scissors:

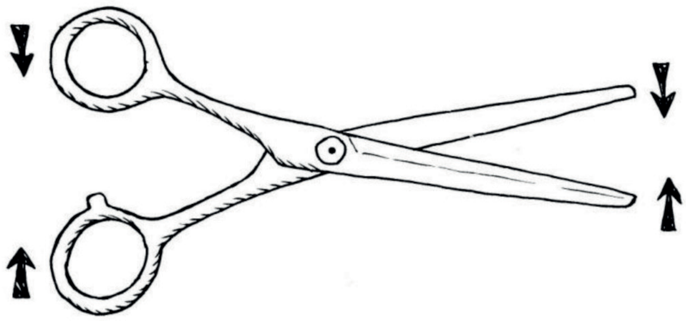


Figure 14

A pair of scissors can also be made like this:

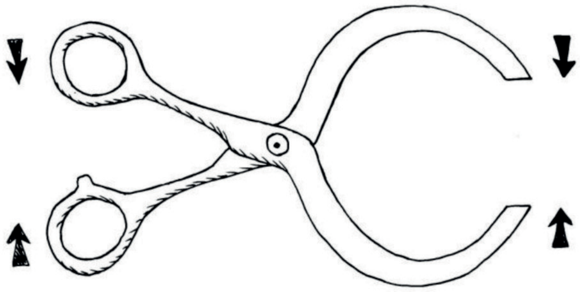


Figure 15: An instrument like this is sometimes called ***a pair of callipers.***

The handles could be bent like this:

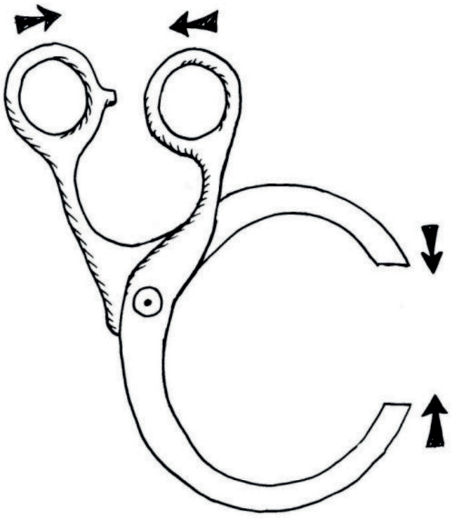


Figure 16

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

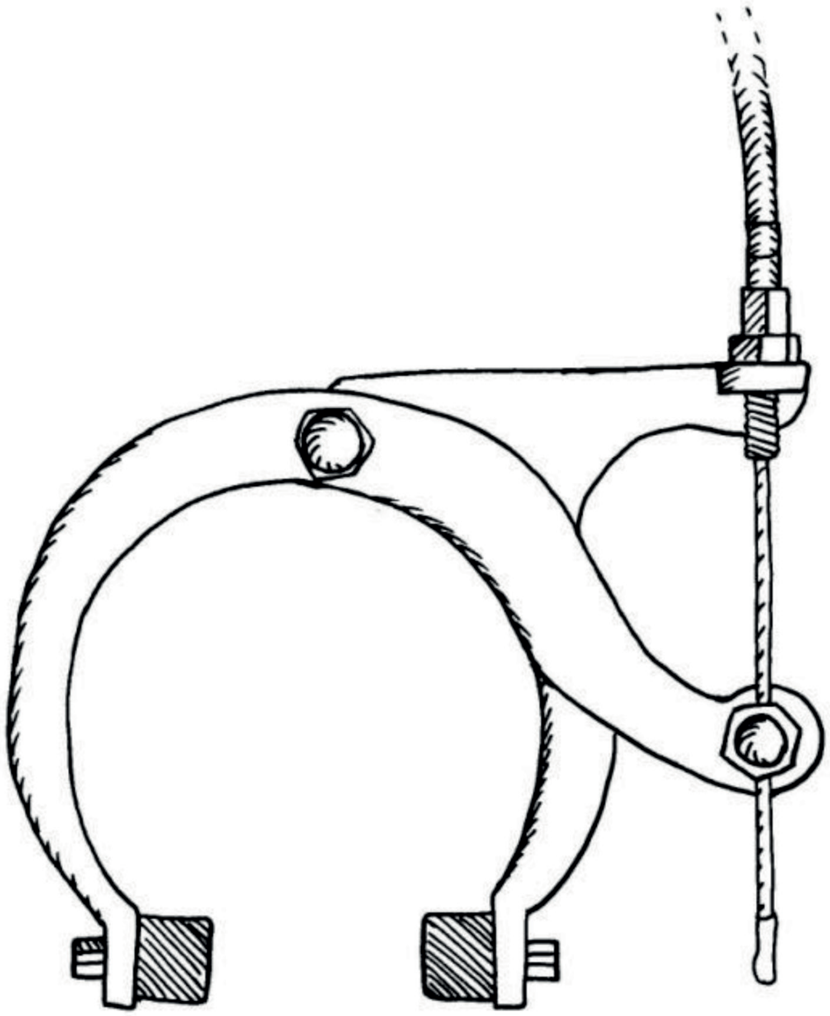


Figure 17: Calliper brake for a bicycle

Investigate a calliper brake system

1. Do the following:
   (a) 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.
   (b) 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.

Car disc brakes also use a calliper. This calliper 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

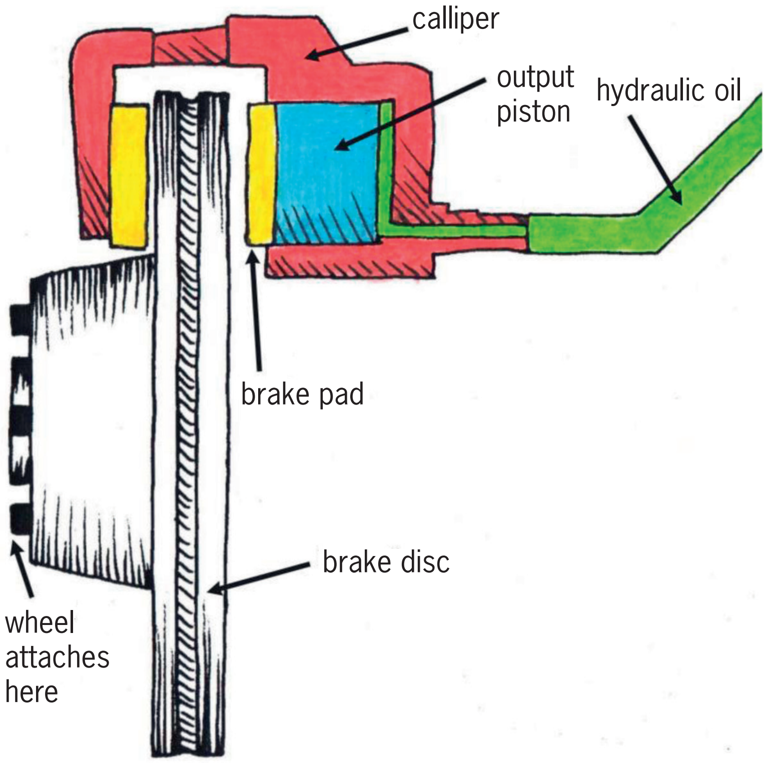


Figure 20: The parts of a car disc brake

A disc brake system consists of a brake disc, a calliper 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

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.

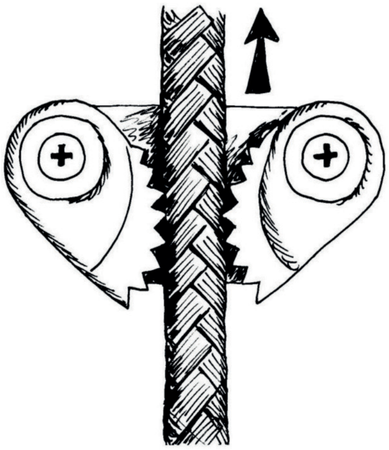


Figure 21

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

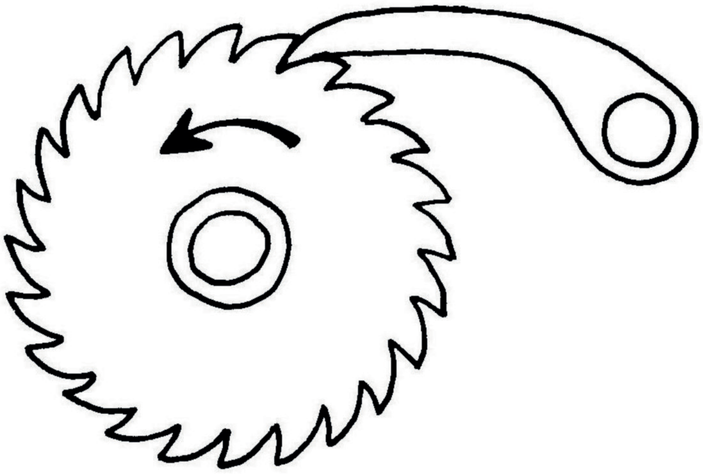


Figure 22: A ratchet and pawl

Draw a block and tackle system

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.

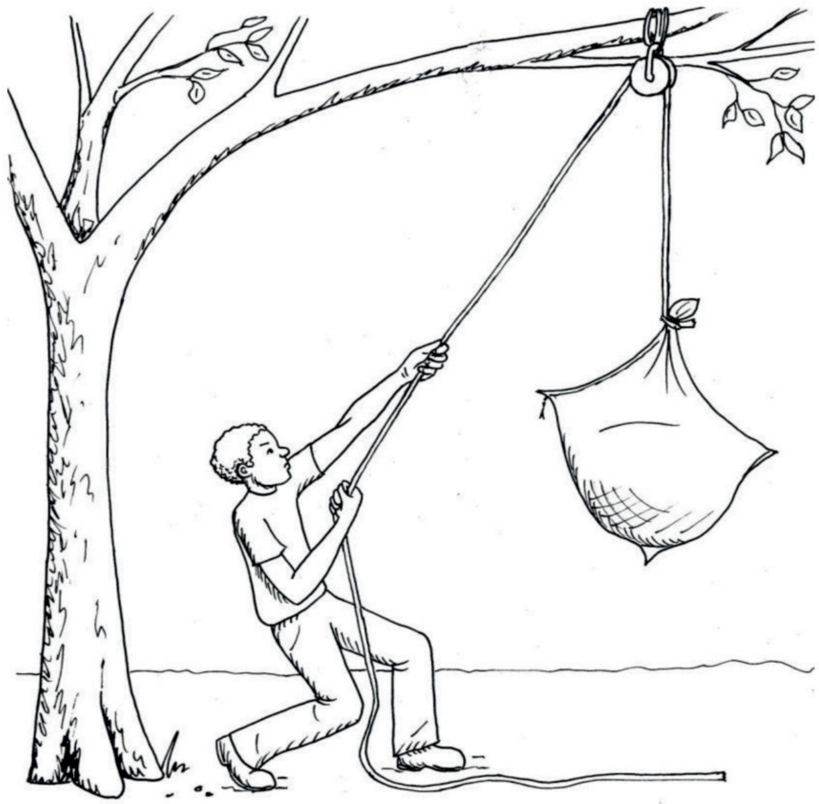


Figure 23: The man wants to lift the sack right up to the branch.

A question to make you think

Look at the pictures below. Why is it easier for the girl to get over the wall, than it is for the boy? Try to explain how this is similar to levers, hydraulic systems and moveable pulley systems.

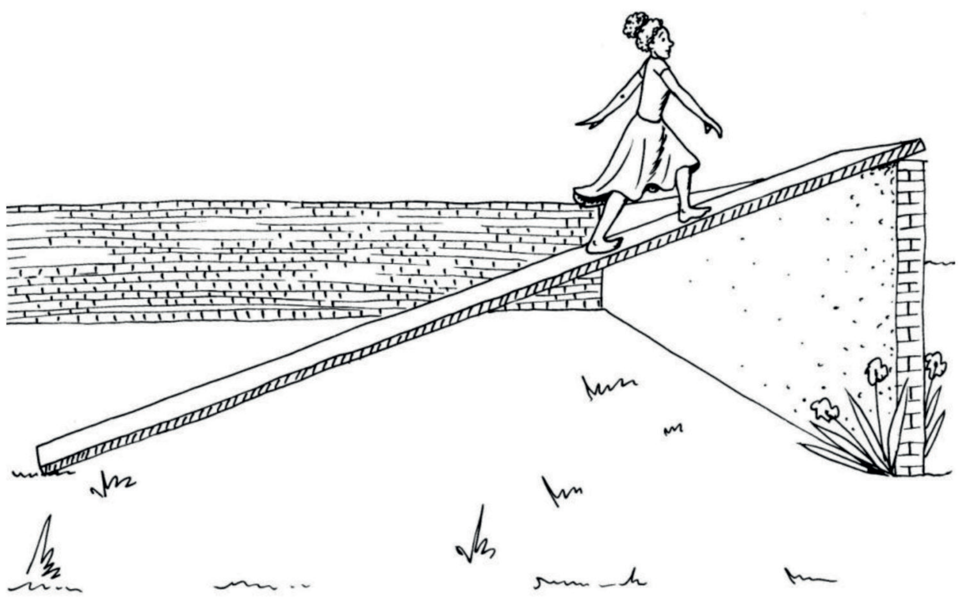


Figure 24

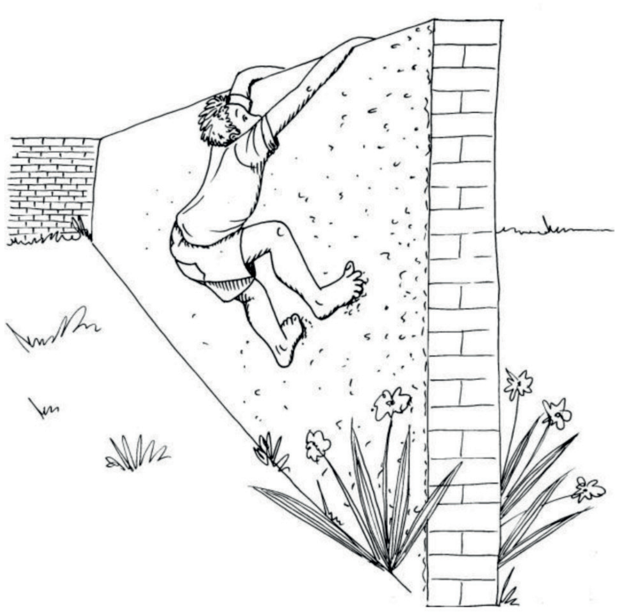


Figure 25

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.

Figure 1

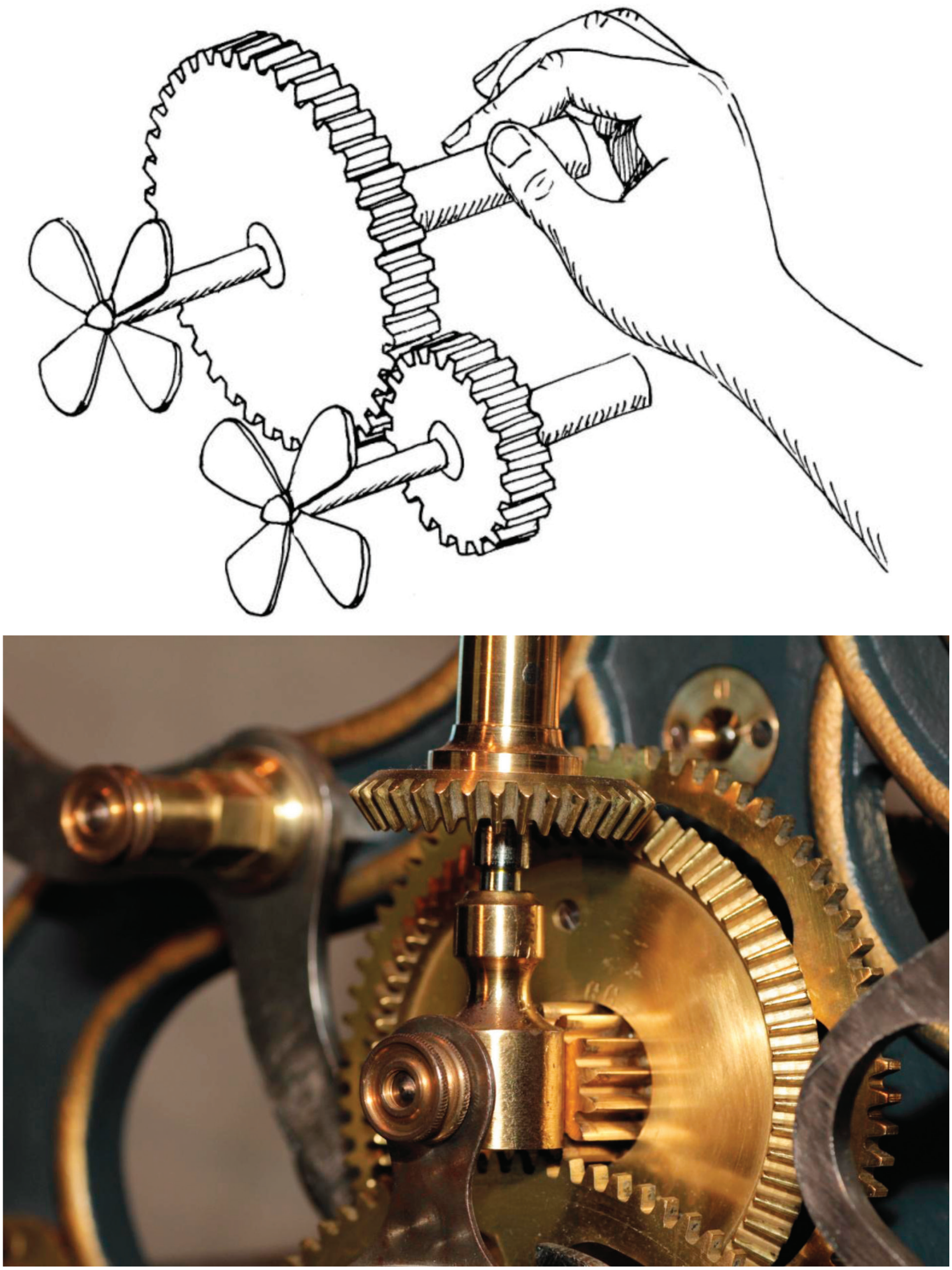


Figure 2

8.1 Direction of rotation of spur gears

Questions about counter rotation and idler gears

1. (a) How many teeth do each of these gears have?
   (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?
   (d) Through which part of a full revolution did each gear turn?

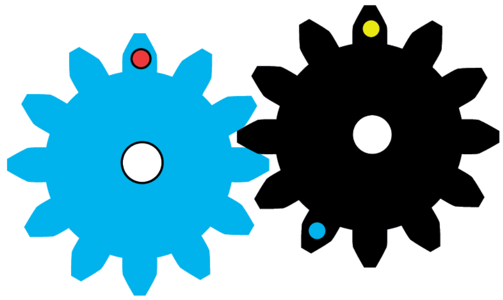


Figure 3

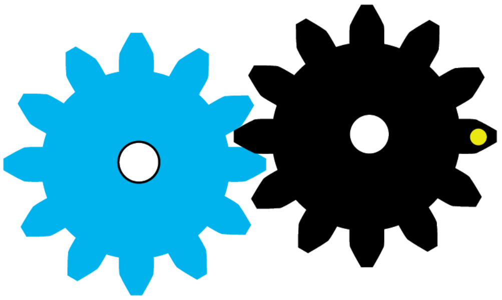


Figure 4

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.

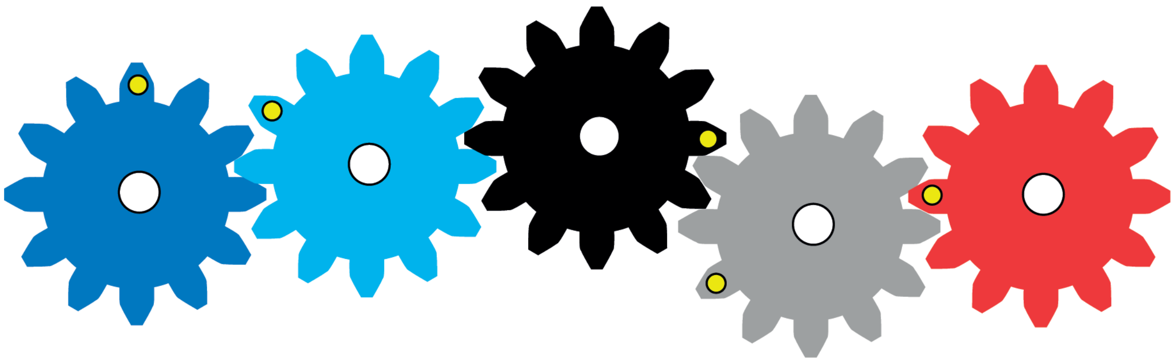


Figure 5

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

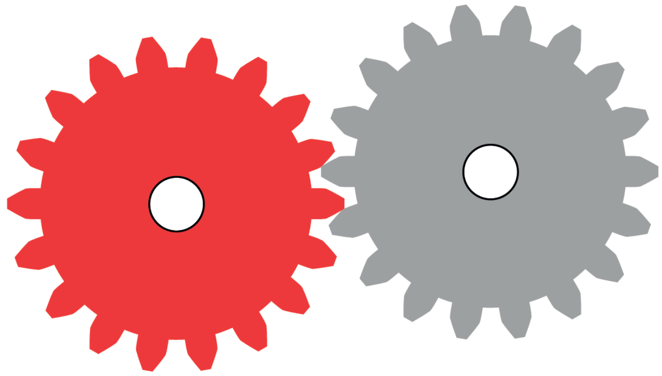


Figure 6: Counter-rotation

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?

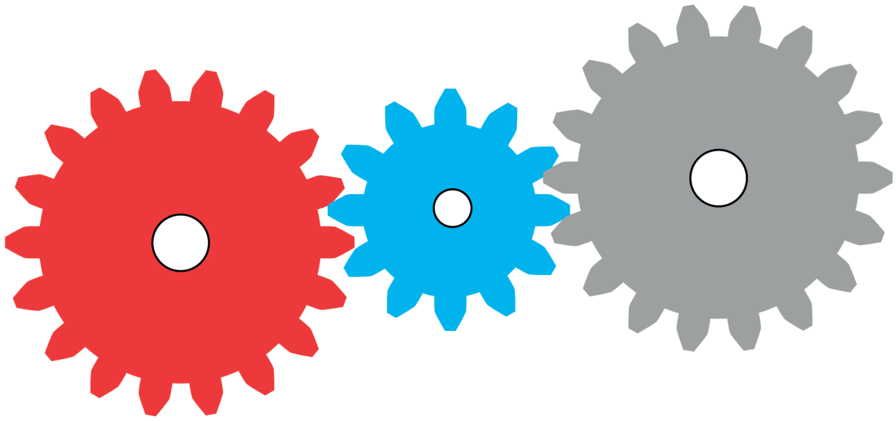


Figure 7: A blue idler gear

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?

Number or rotations of driver and driven gears

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.

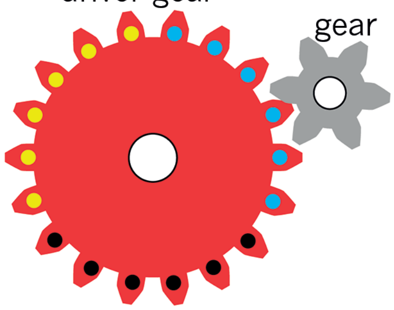


Figure 8

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

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?
2. If the red driver gear makes 8 full revolutions, how many revolutions will the grey driven gear make?
3. How many revolutions should the red gear make for the grey gear to make 12 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?

Speed of rotation of driver and driven gears

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 in Figure 9 makes 12 revolutions in one minute, how many revolutions will the driven gear make in the same time?
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?

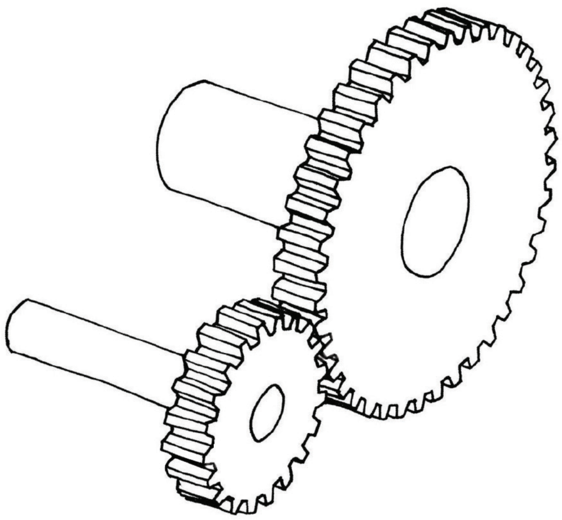


Figure 9

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

8.2 Gear ratio, rotational speed and rotational force

Figure 10: A road roller

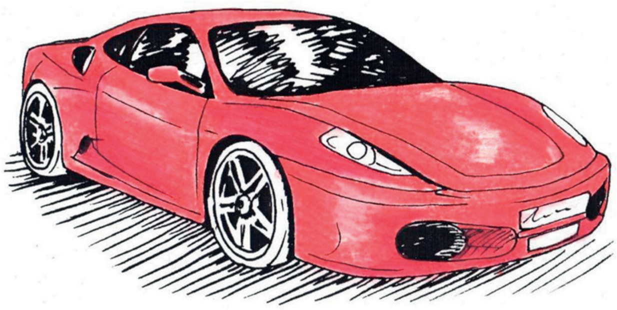


Figure 11: A sports car

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

1. 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.

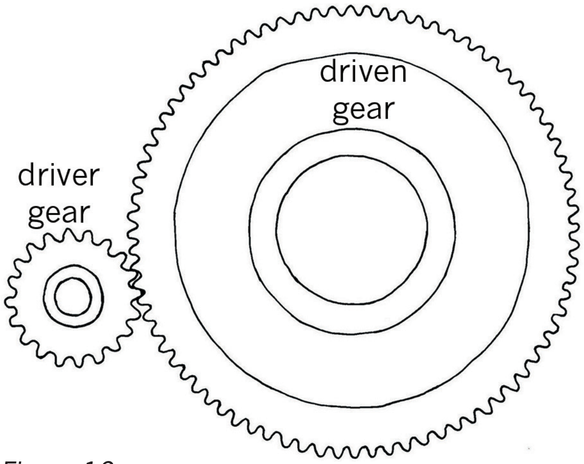


Figure 12

Revision of what you learnt about gears in Grade 8

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.

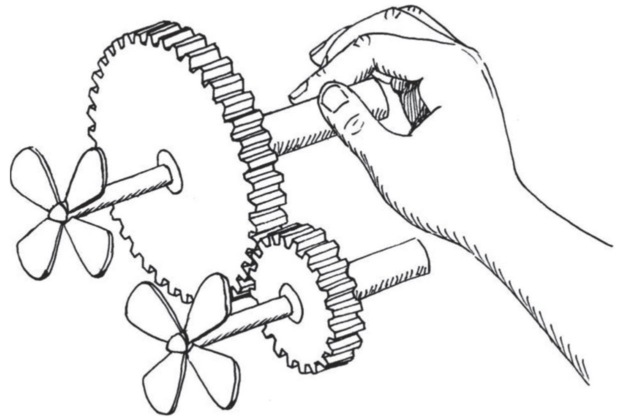


Figure 13

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:

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

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

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

1. Calculate the gear ratio of the set of gears in Figure 12.
2. In Figure 12, if the input axle is rotating at 120 rpm, at what speed is the output axle rotating?
3. In Figure 12, which axle will turn with the greater force, the driver or the driven axle?

Gear ratio and **speed ratio** is the same thing. It can also be called "velocity ratio".

You can write a gear ratio in different ways, for example "2 to 1", "2:1" or simply "2",

Turning force is also called **torque**.

Comparing turning forces on the input and output axles

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.

Note: You will only consider axles with the same diameter in this chapter. When the diameters of the axles around which the ropes are wound are different, you also need to think about that to compare turning forces.

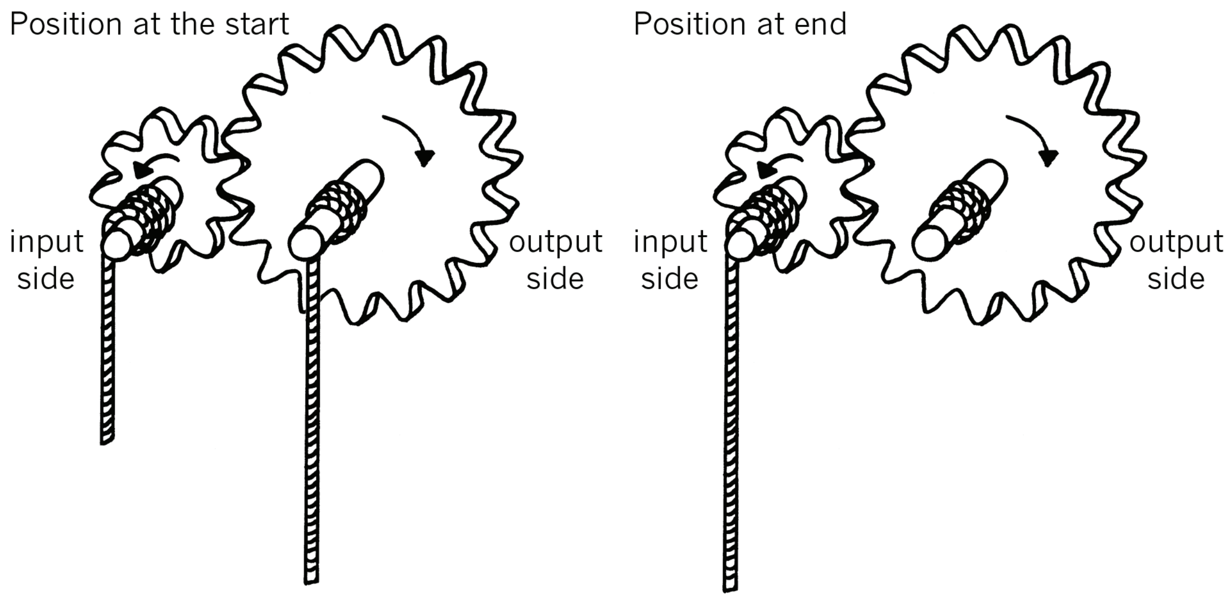


Figure 14

1. What is the gear ratio?
2. For one full revolution of the input gear, how many revolutions will the output gear make?
3. If you pulled the input rope down by 2 cm, how far would the output rope be pulled up? Copy the “position at end” drawing in Figure 14 and draw the vertical part of the output rope to show where the output rope will be after you pulled the input rope down by 2 cm.
4. 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.

5. Look at Figure 15. If you pulled down with a force equal to 3 kg on the input side, how heavy a load could be lifted on the output side?

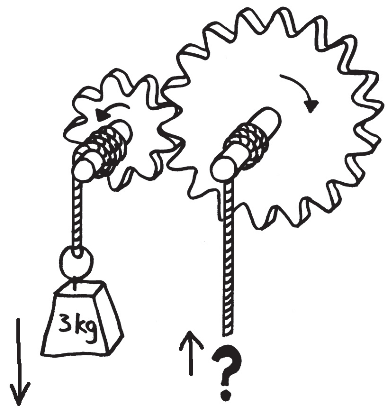


Figure 15

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)

6. Use the formula above to check your answer to question 5.
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?
   (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?
   (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 others words, how many teeth should the input and the output gears have?

8.3 Other types of gears

Bevel gears

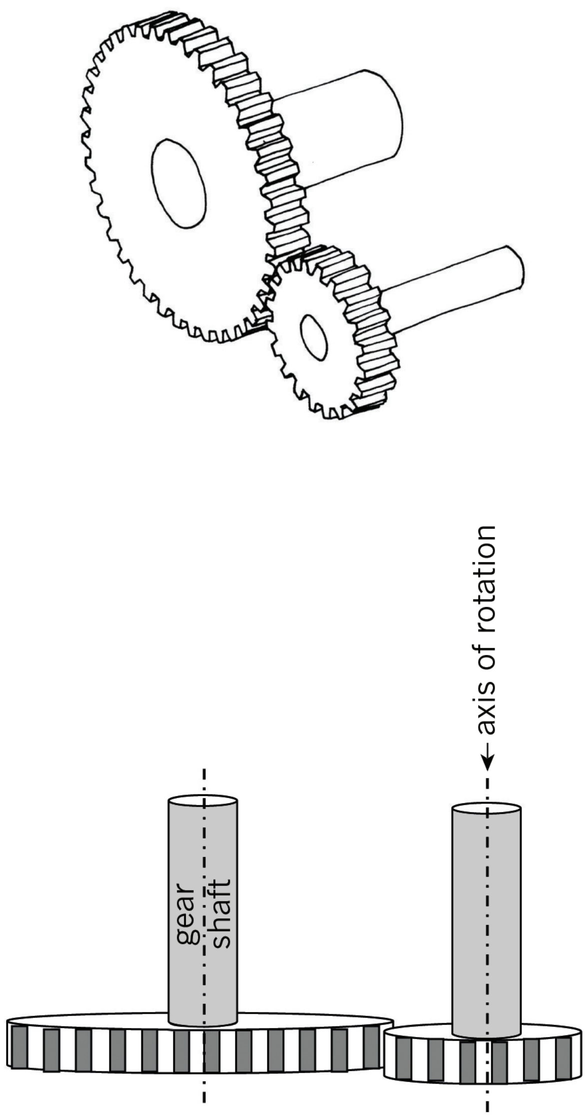


Figure 16: Two spur gears with shafts parallel to each other

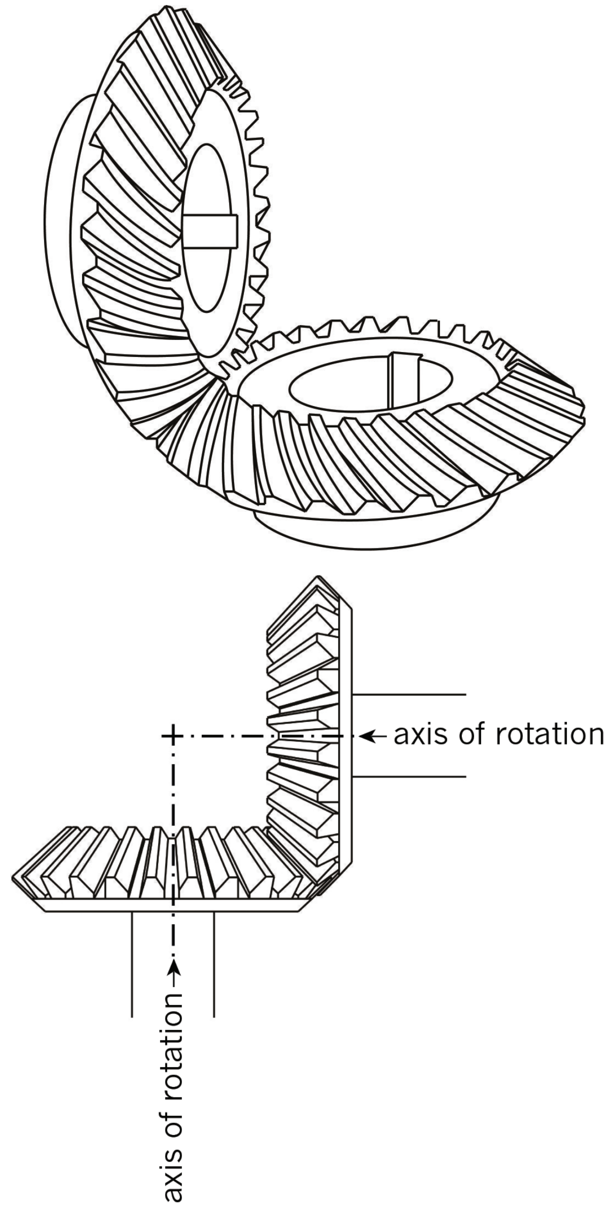


Figure 17: Two bevel gears with shafts at 90° to each other

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. These are called **bevel gears**.

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.

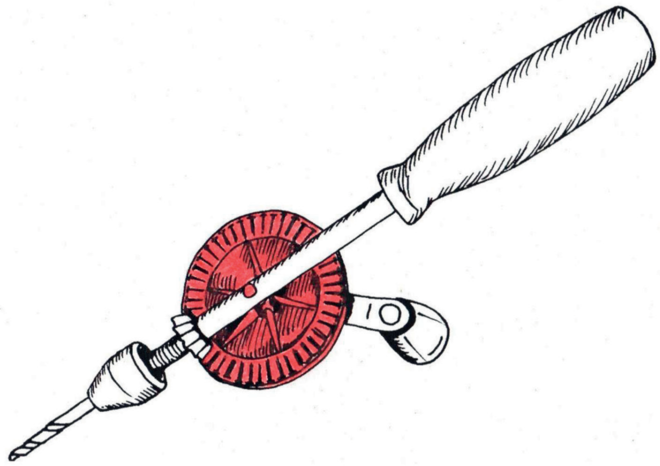


Figure 18: A hand drill

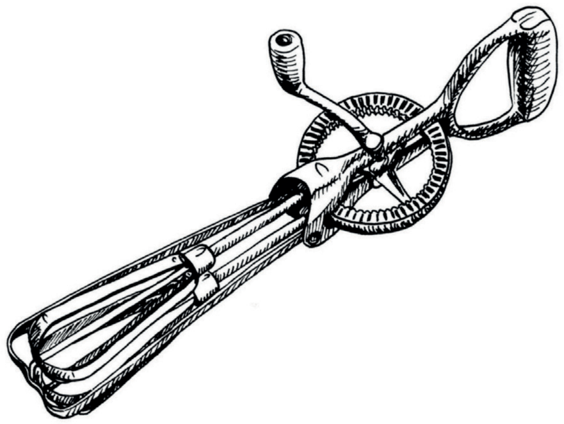


Figure 19: A food mixer

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.
2. Why is fast rotation needed to beat eggs properly?
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?
   (b) How many revolutions will the driver gear make if the driven gear makes 60 revolutions?
   (c) How fast should the driver gear turn to make the driven gear turn at 36 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.

Rack-and-pinion gears

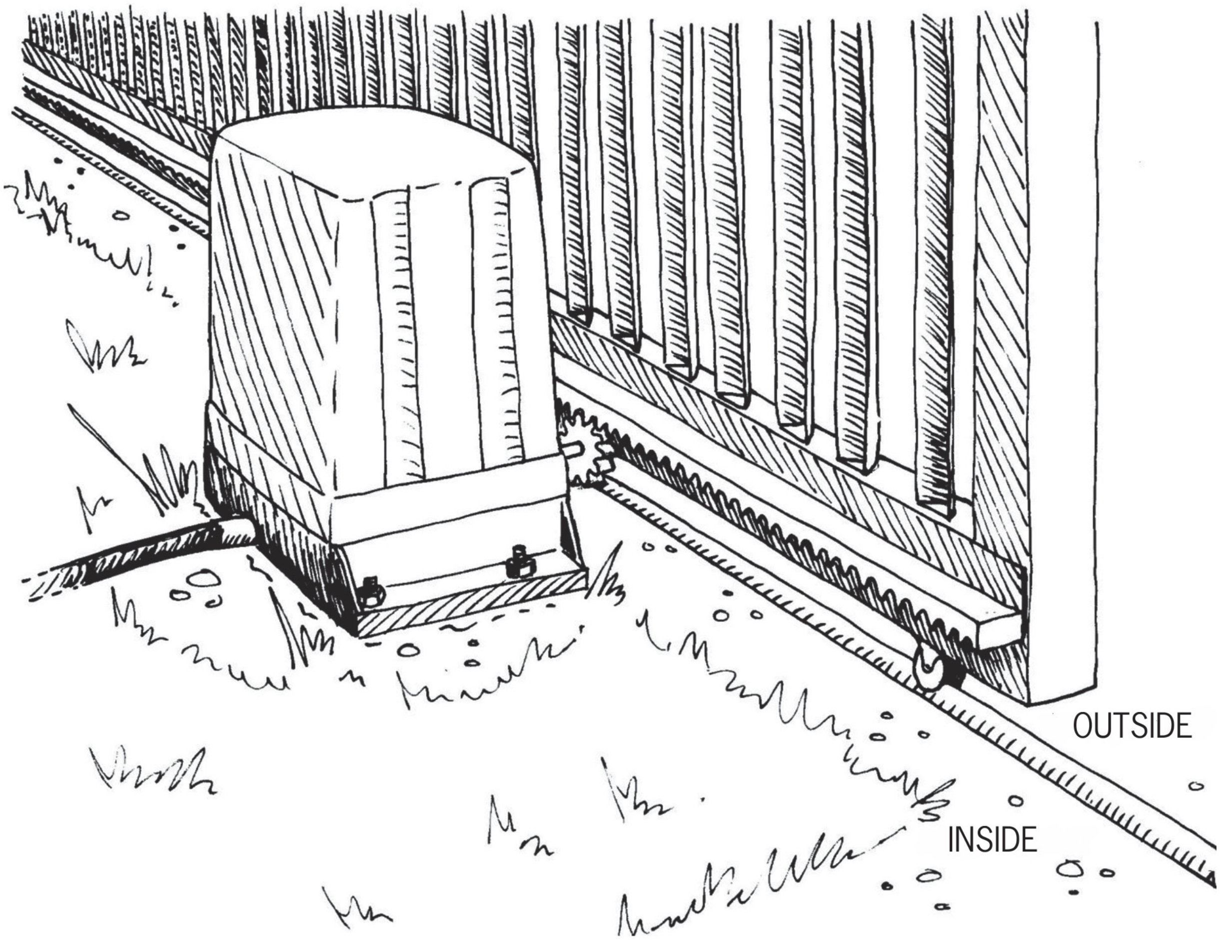


Figure 20: A rack-and-pinion gear in a security gate

Questions about rack-and-pinion gears

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

When something moves around and around, 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**.

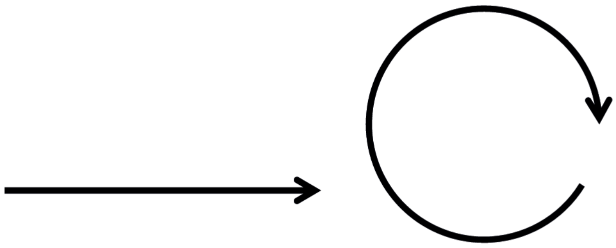


Figure 21

The gear wheel is called the **pinion gear**.

The straight bar with teeth is called the **rack gear**.

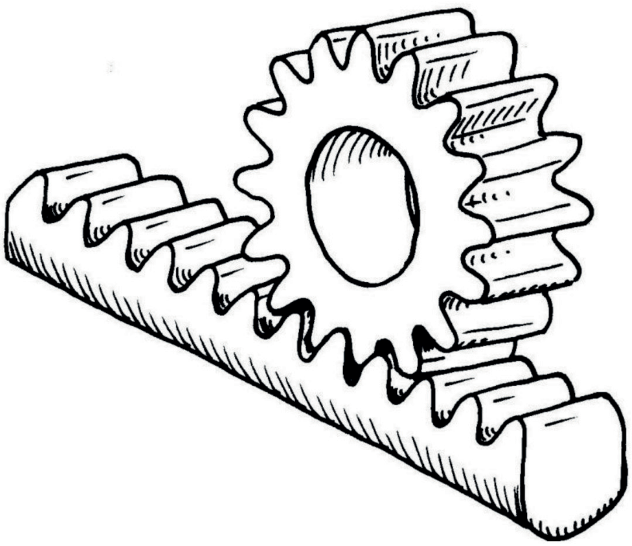


Figure 22: A rack-and-pinion gear set

3. Which part of a rack-and-pinion gear set rotates?
4. Which part of a rack-and-pinion gear set moves in a straight line?
5. If the distance between two teeth on the rack is 3 cm, and the pinion gear has 18 teeth, how far will the rack move if the pinion gear makes one full revolution?

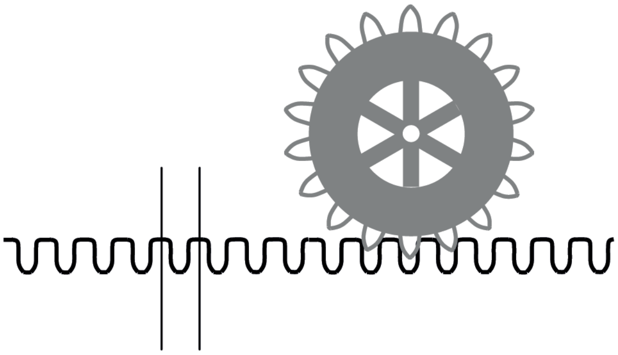


Figure 23

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.

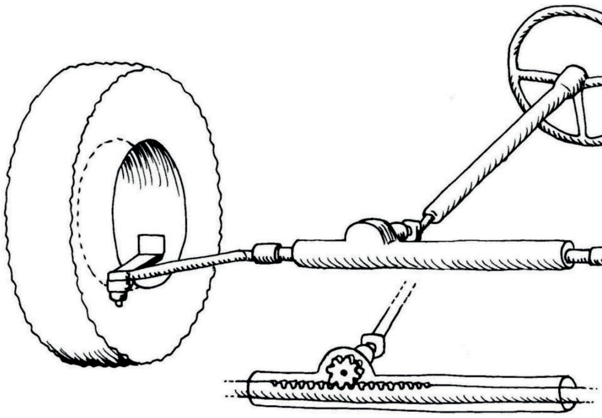


Figure 24: A rack-and-pinion car-steering system

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

Worm gears

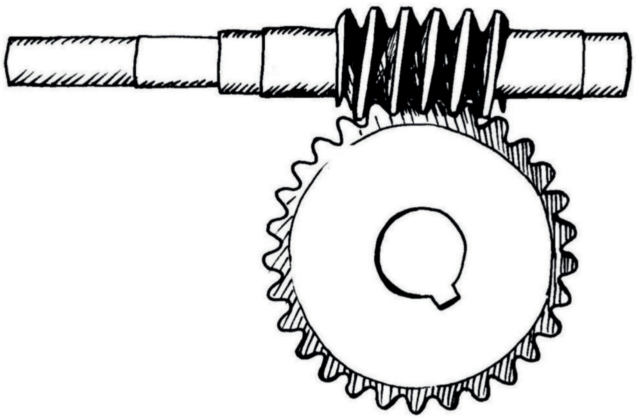


Figure 25: A worm gear set

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.

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.

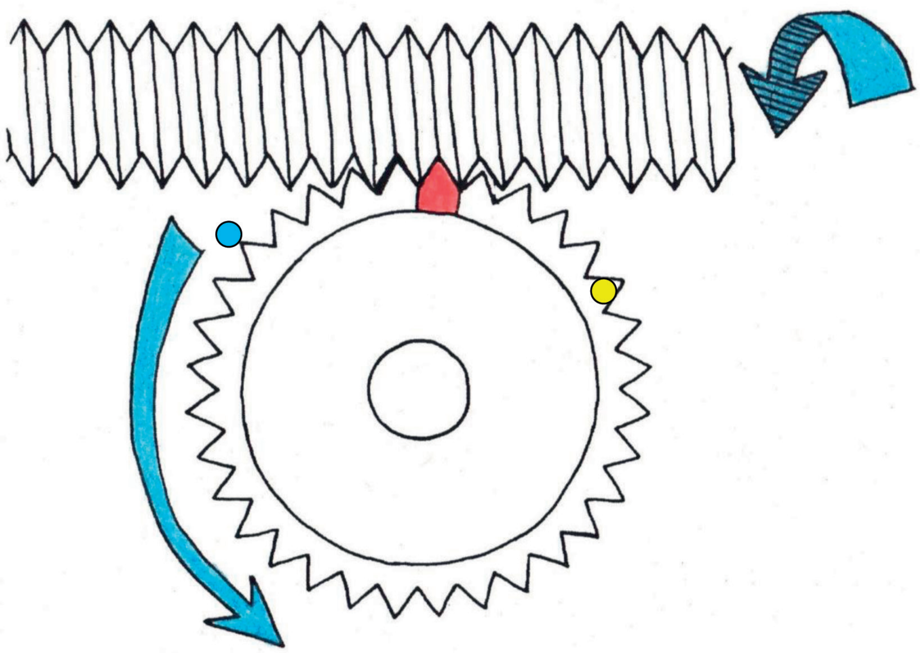


Figure 26

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

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?
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?
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 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.

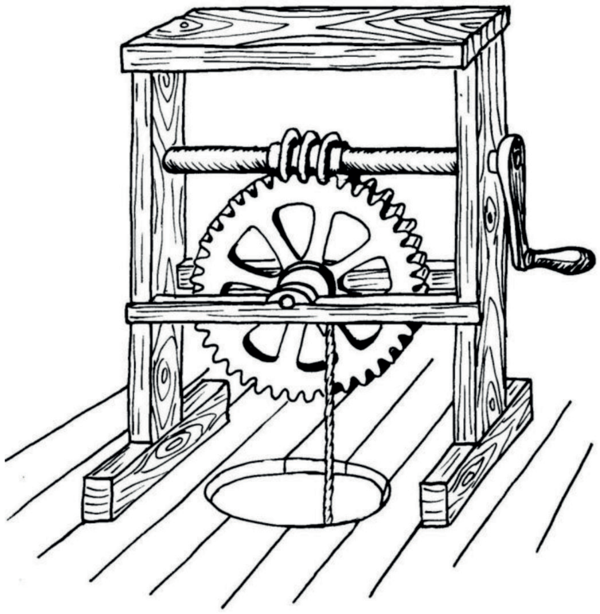


Figure 26: A worm and worm wheel used many years ago to lift heavy loads

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.

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.

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

This week, you will evaluate items in the home that use different mechanisms. You will write a report on three of these items. You will also make an artistic drawing of your classroom, as seen from the inside.

Figure 1: A can opener

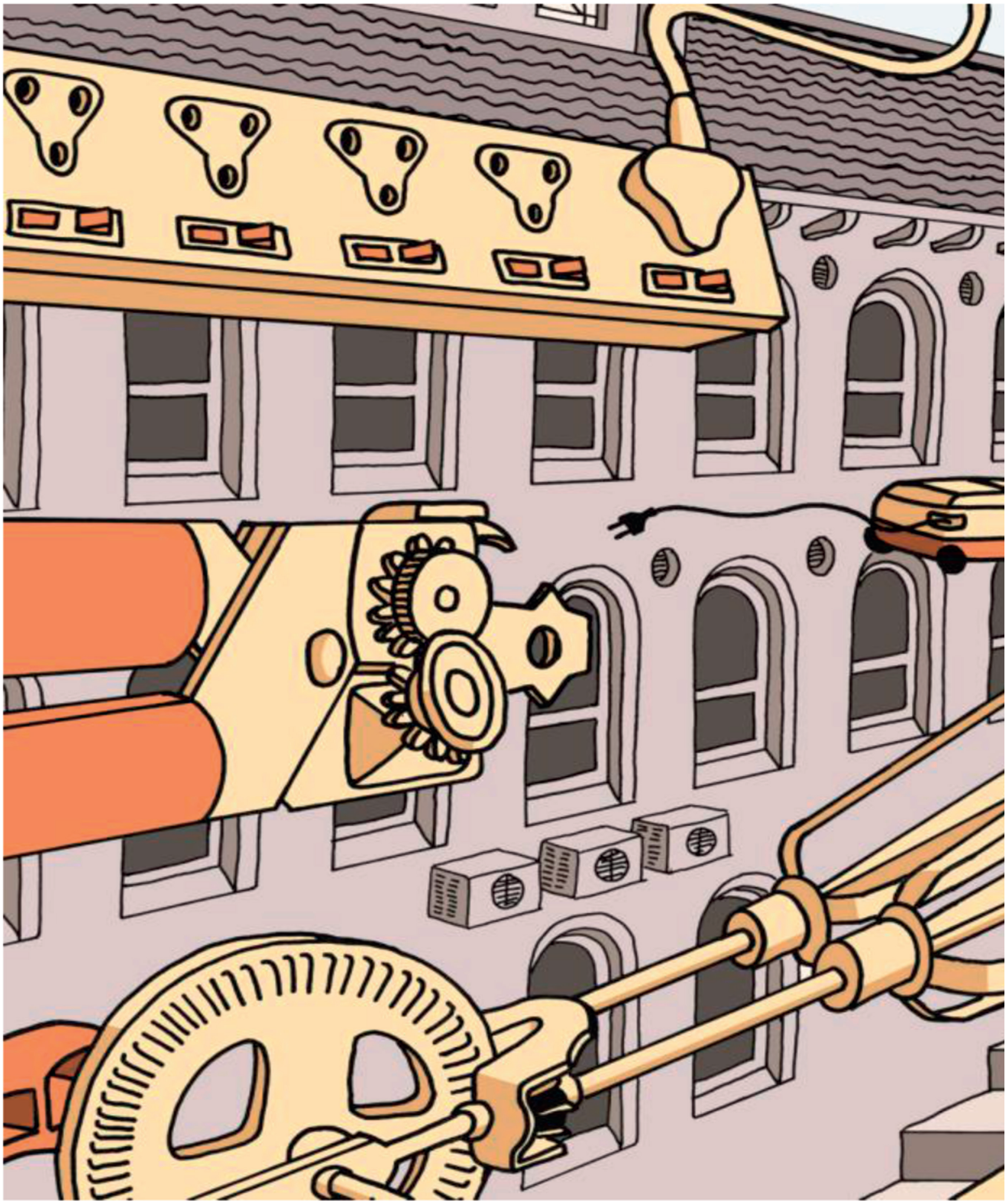
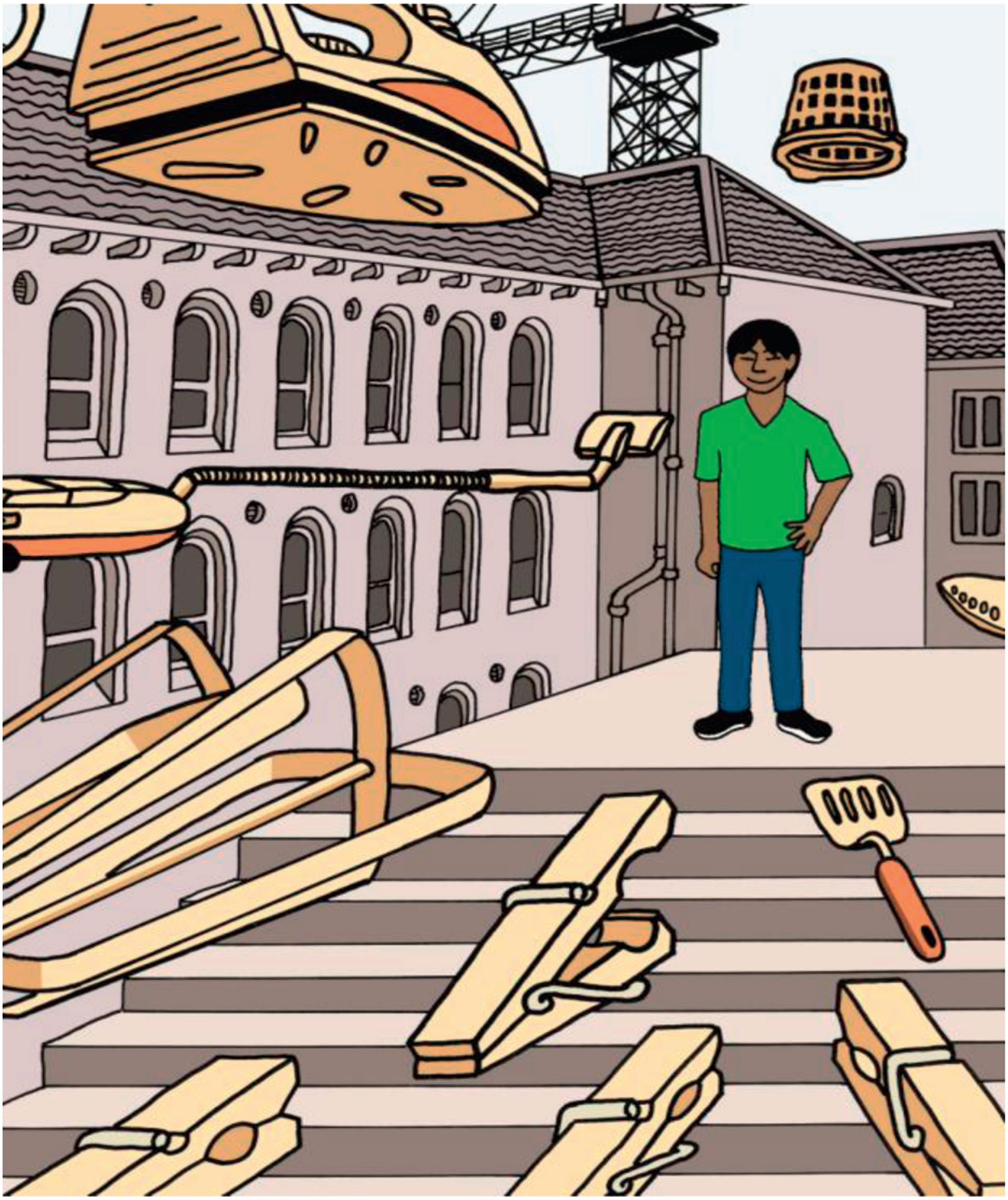


Figure 2



9.1 Tools at home

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.

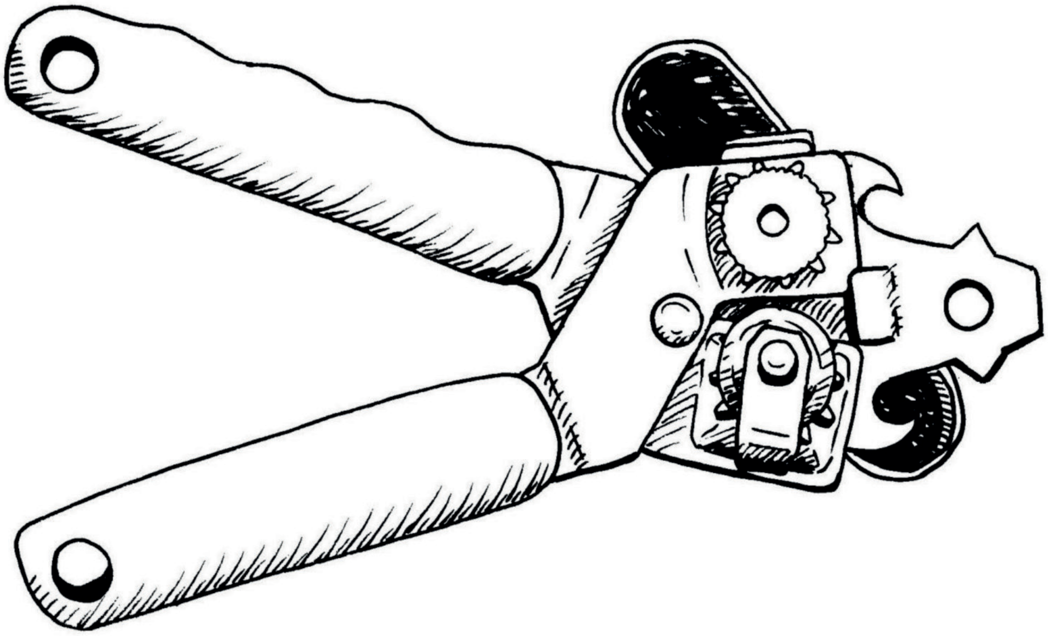


Figure 3

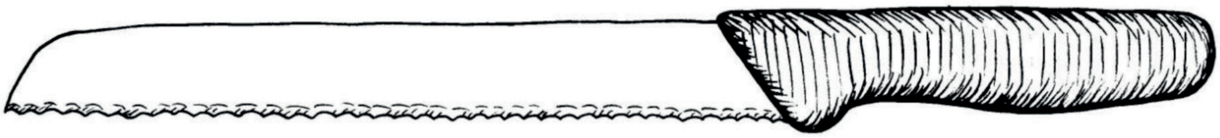


Figure 4

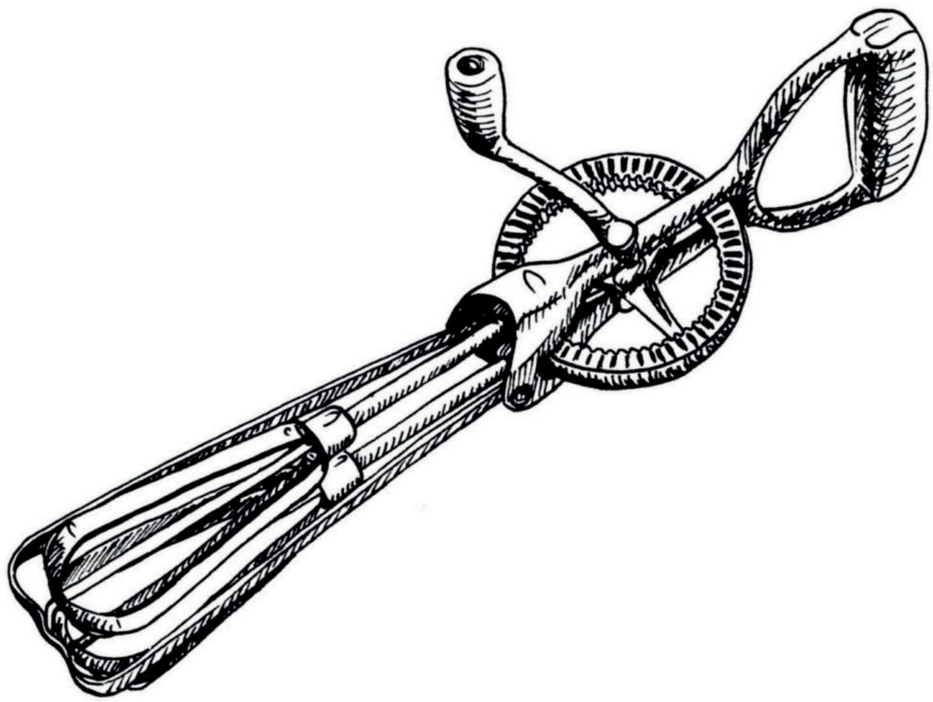


Figure 5

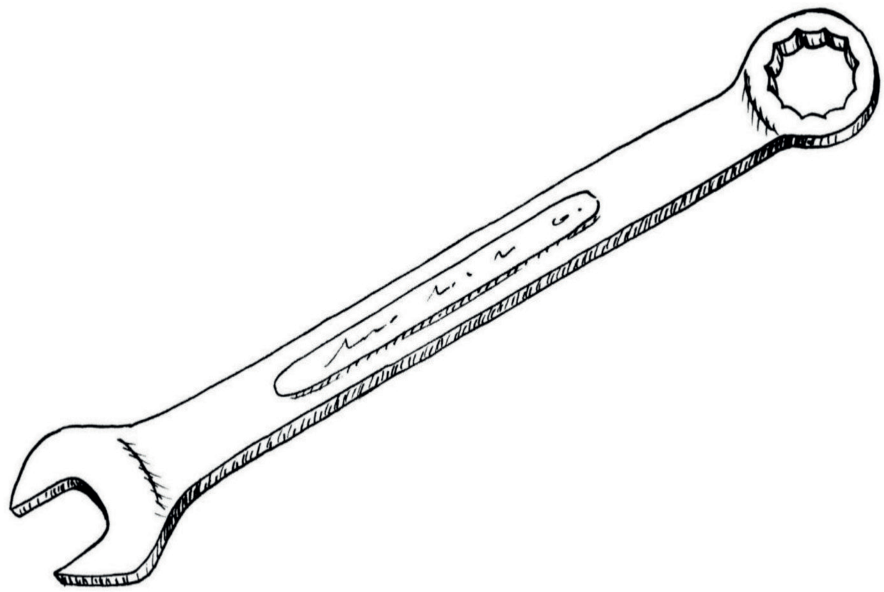


Figure 6

Evaluate household tools

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

Copy the table below and use questions like the ones below in your evaluation:

Name of the tool	
Who will use it?	
What can you do with the tool; what is its purpose?	
How does it give you a mechanical advantage?	
What material is it made of?	
Why is it made of this material?	
What other materials could be used to make this tool?	
How much do you think you should pay for it?	
What can go wrong when using it? How can it harm you?	
What safety precautions should you take when you use this tool?	

2. Describe three tools that people sometimes use that are not on the list above.

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.

The **horizon** is the line where it seems as if the earth's surface meets the sky.

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**.

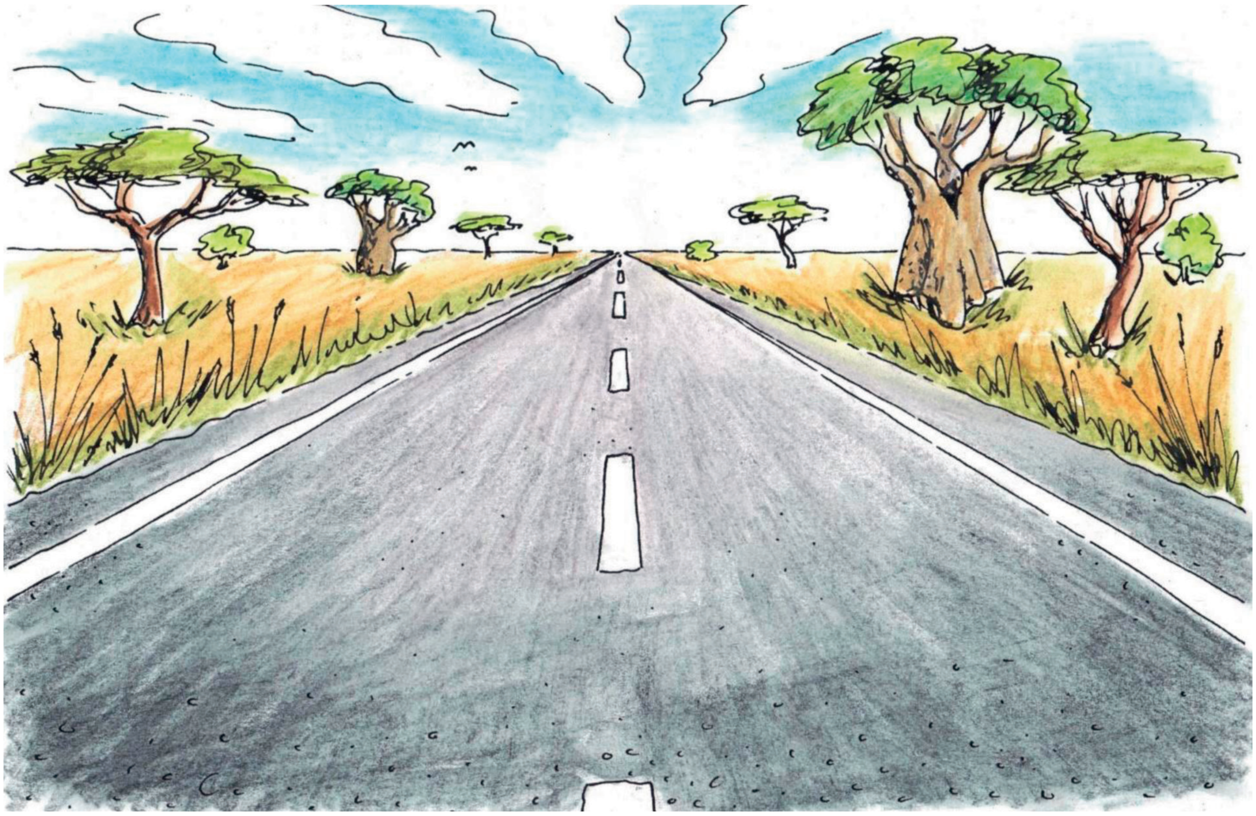


Figure 7: Vanishing point at the horizon

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**.

Perspective means a view. In Technology, it refers to the drawing technique of representing 3D objects in 2D. This means you can draw objects to look real even though you are drawing on a flat surface.

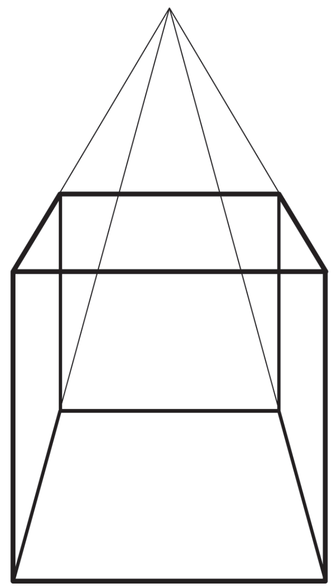


Figure 8: Drawing of a cube in 3D single vanishing point perspective

These are the steps to follow:

1. Draw one face of the cube. Select a vanishing point.
2. Draw very feint 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 perpective

1. Draw a simple wooden object using single vanishing point perspective. Remember to use feint 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.

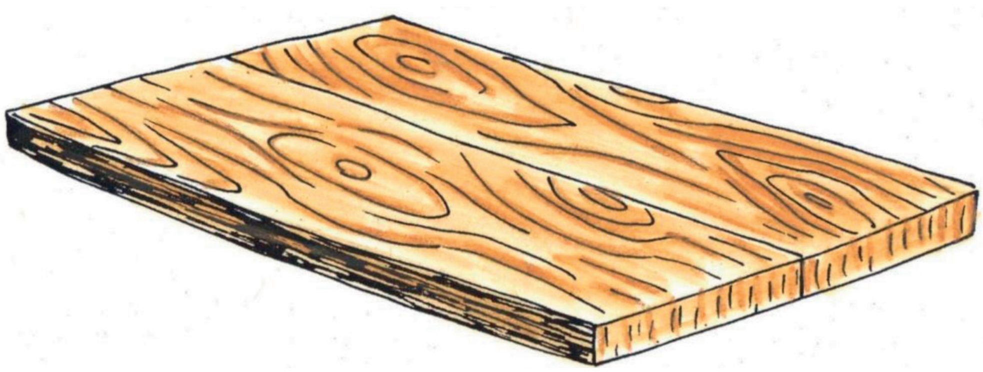


Figure 9: Adding wood grain makes things look realistic.

9.3 Draw your classroom

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.

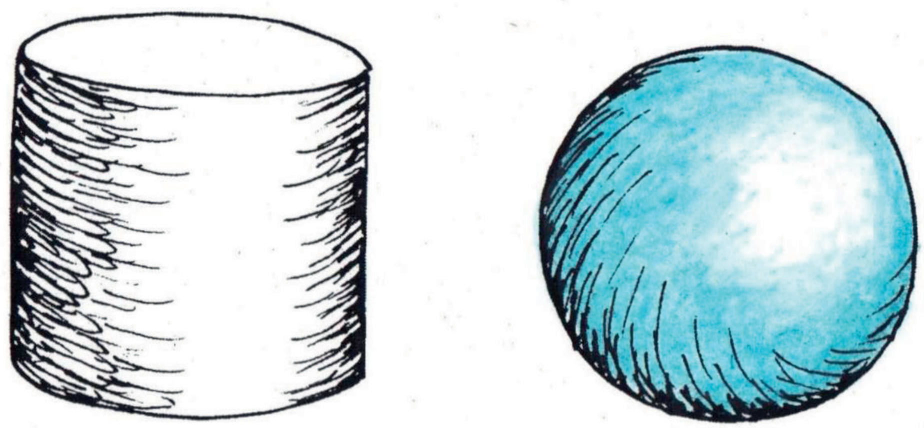


Figure 10: Shading helps to make drawings look more 3D.

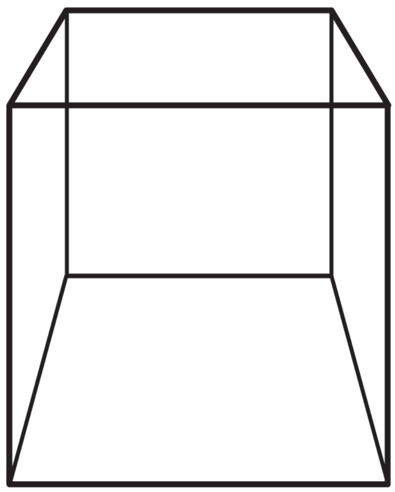


Figure 11: Making lines in front and on top darker also helps to make a drawing look more 3D.

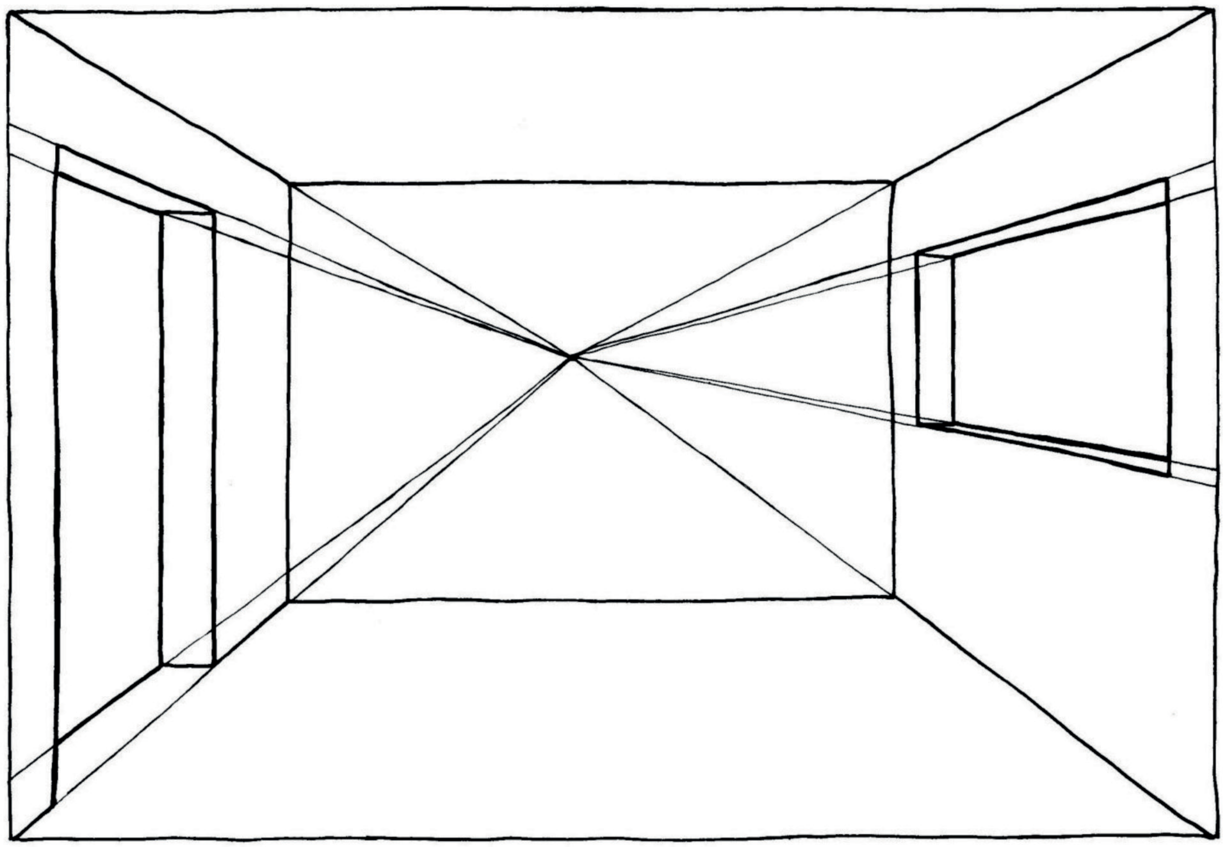


Figure 12: Single vanishing point drawing of the inside of a classroom

Single vanishing point drawing of your classroom

1. Now 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.

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

This chapter is a formal assessment task. This task should take you three weeks, from Week 7 to 9. The scenario: Maria's construction company needs a tip truck.

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]

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?
2. Which abilities and skills would Maria need to design and build houses?
3. What kinds of equipment will her company need to build houses?

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?

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 ………… *that will* ………… [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. [2]
3. Write down the constraints. Remember that the constraints are the tools, materials and time that you have available to make the model. [2]
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 in Figure 3 below.

Figure 3

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.

A

B

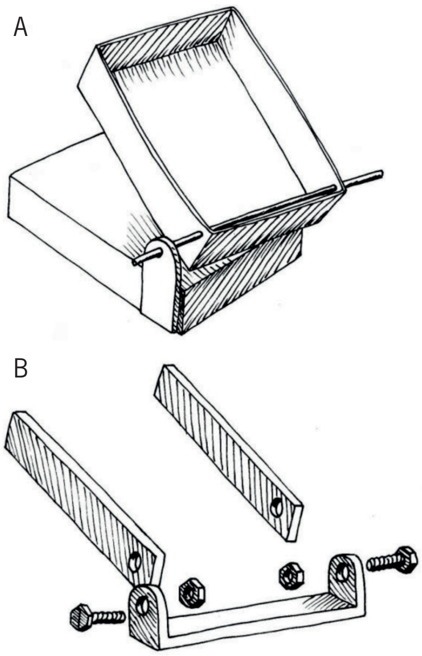


Figure 4

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 rights shows you how to make something tilt upwards by using a hydraulic system.

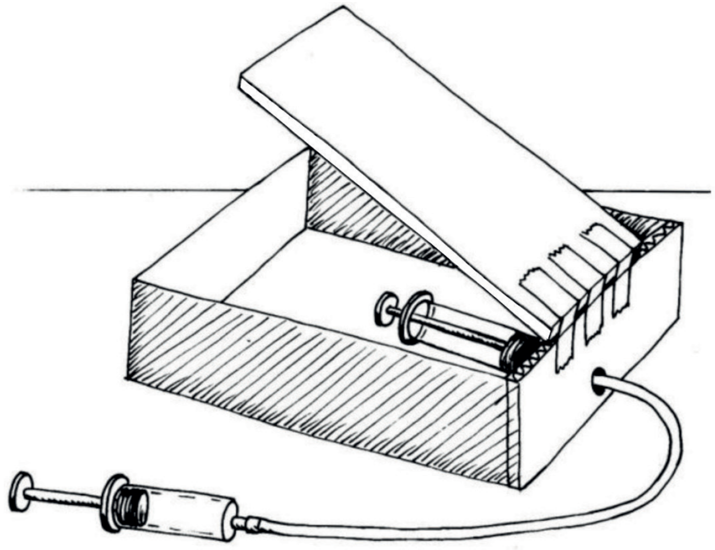


Figure 5

- 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.

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.

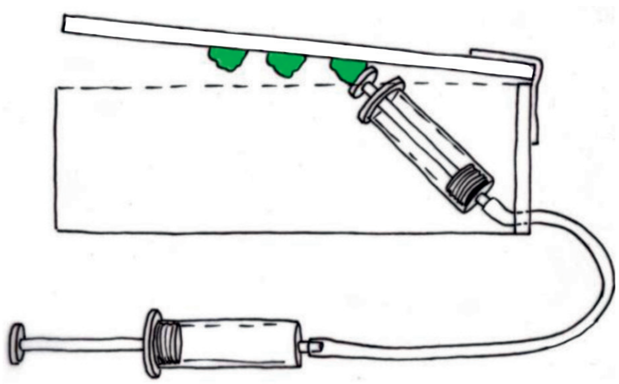


Figure 6

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.

   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.

Make sure the cardboard at the back of the box does not get wet.

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

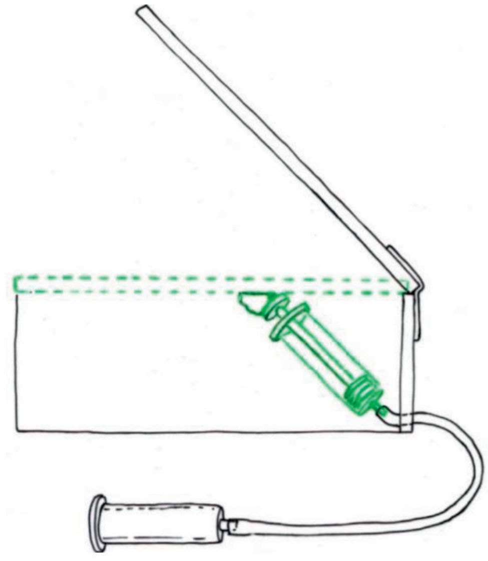


Figure 7

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?

   [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?

   [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?

   Look at the picture below of a tip truck. Pay special attention to the door at the back of the load bed.

Figure 8

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.

   [3]

   [Total: 9]

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. [Total: 5]

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

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.

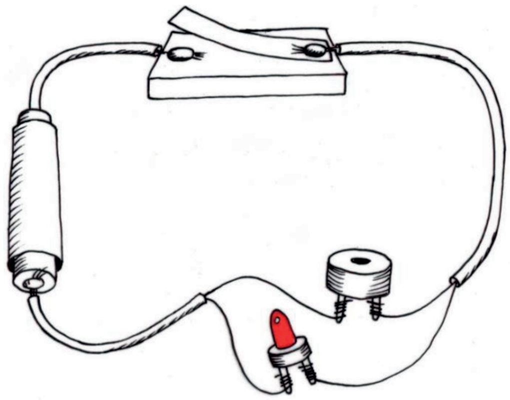


Figure 9

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.

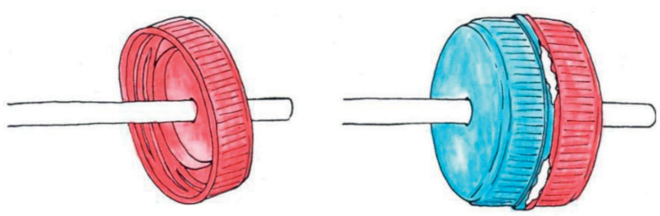


Figure 10

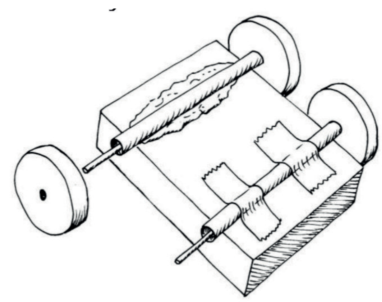


Figure 11

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

Remember that there are constraints on the materials that you can use. You can only use materials that you can find. There are also constraints on the tools that you can use. You can only use tools that you can find, and that are safe for you to use.

Rewrite and complete the following sentences:

1. *I am going to make …*
2. *I will need the following materials:* [3]
3. *I will need the following tools:* [3]

[Total: 6]

Make your part or parts (2 × 30 min = 60 minutes)

Begin work on your part, but keep checking with the others in the group that the parts will fit together. Make new sketches if necessary.

[Total: 12]

Week 3

Assemble the model tip truck (2 × 30 min = 60 minutes)

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]

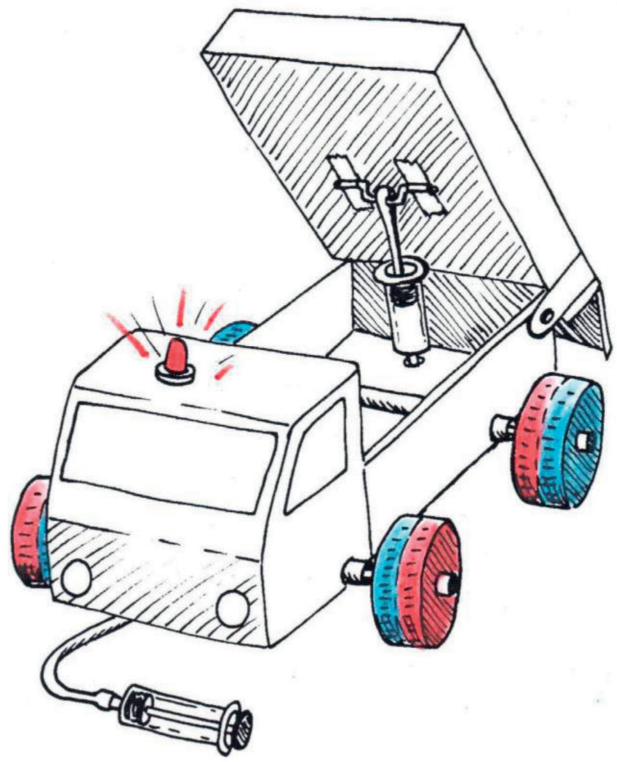


Figure 12

Presenting your project (2 × 30 min = 60 minutes)

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".

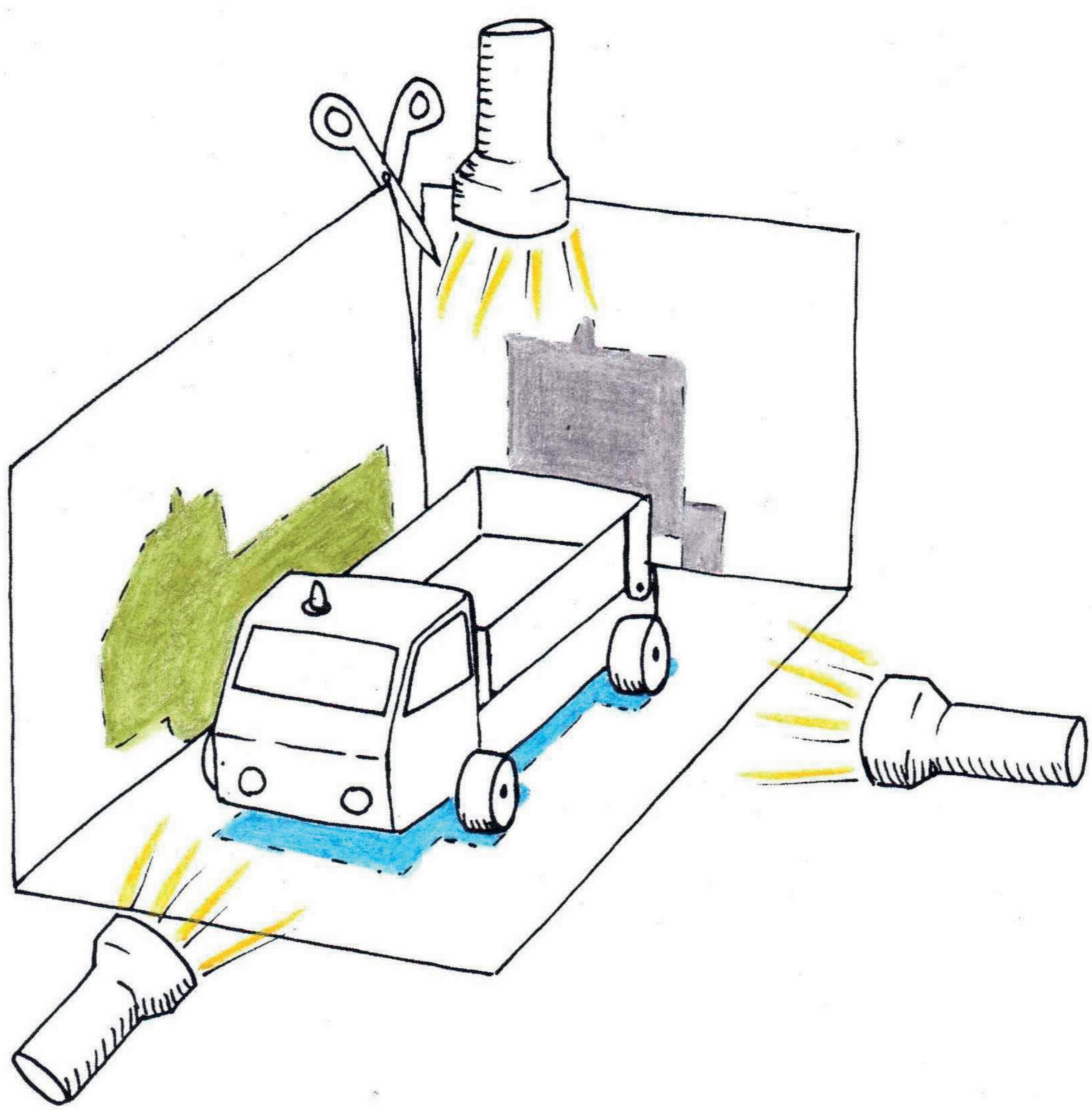


Figure 13

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. Copy this drawing and then use red projection lines to complete the top view of the truck. Then use blue lines to complete the front view. Finally, add the labels for "front view", "top view" and "side view" to your drawing.

[Total: 10]

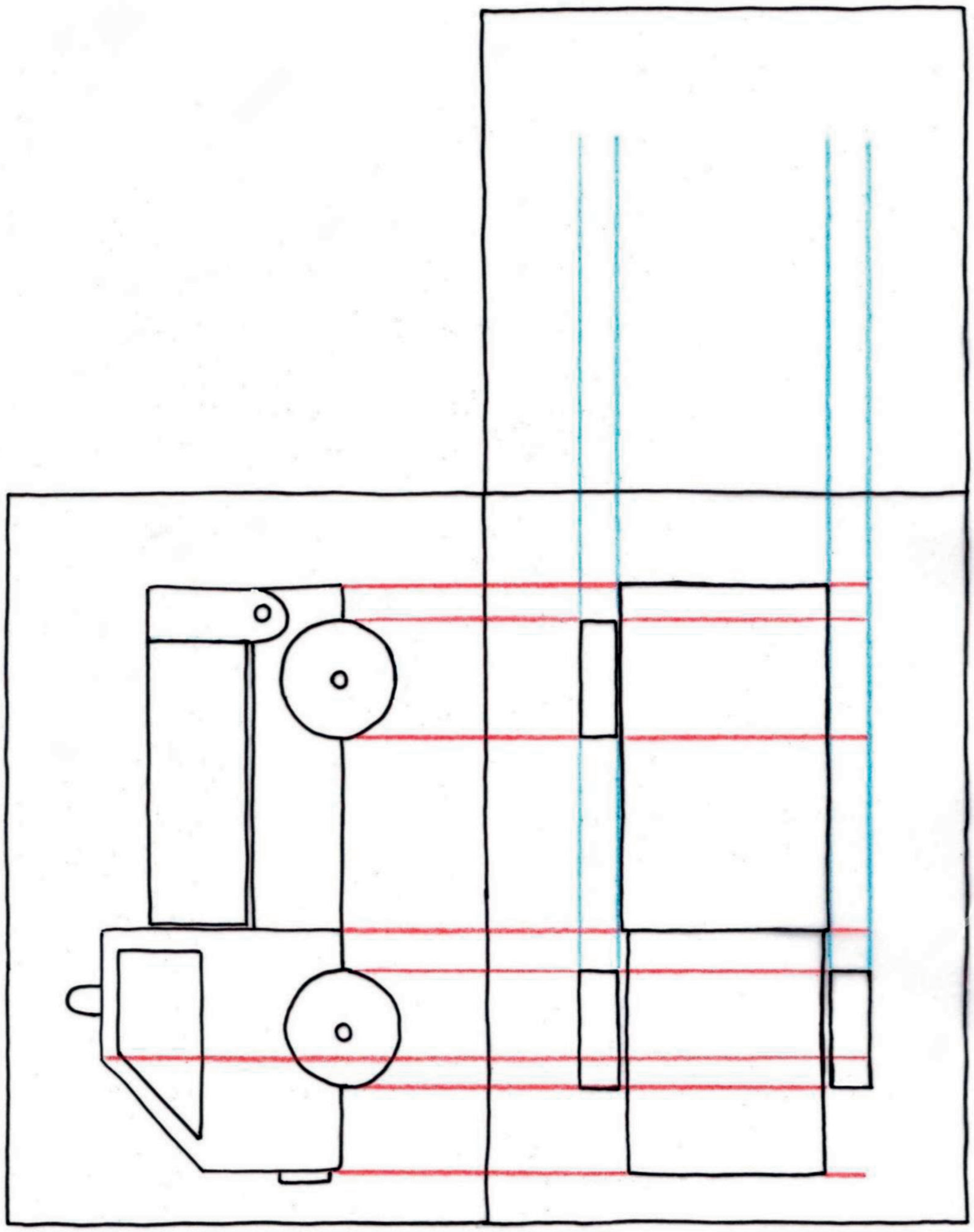


Figure 14

Evaluate your model

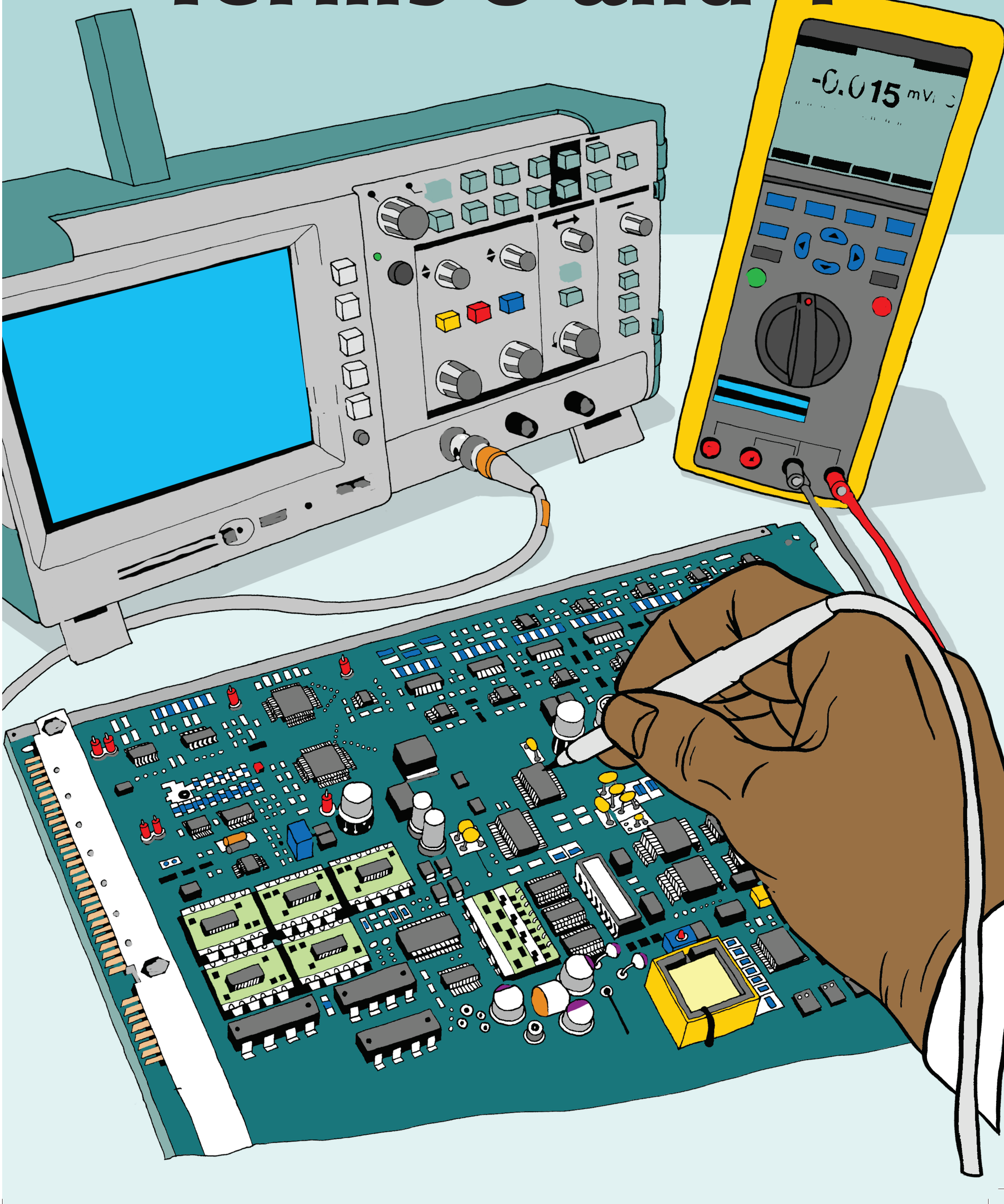
When you evaluate a model, you ask questions about it. Most of the questions relate to the specifications. Turn back and read the specifications again.

- 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 term

Enjoy your winter holidays! After the holidays, you will learn more about electrical circuits and parts that can be used in them.

Terms 3 and 4



Term 3: Electrical | Electronic systems

Chapter 11
Component symbols and simple circuits

In this chapter, you will revise the work you did on electrical systems and control in Grade 8. You will also revise simple circuits, circuit diagrams and connecting cells, and lamps and switches in series and parallel. You will then do action research on the effects of changing the voltage in a circuit.

Figure 1: A torch and batteries

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

In series means the cells are connected end-to-end, and the current flows through each cell in turn.

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 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.

1. Draw a circuit diagram of the circuit in Figure 2.

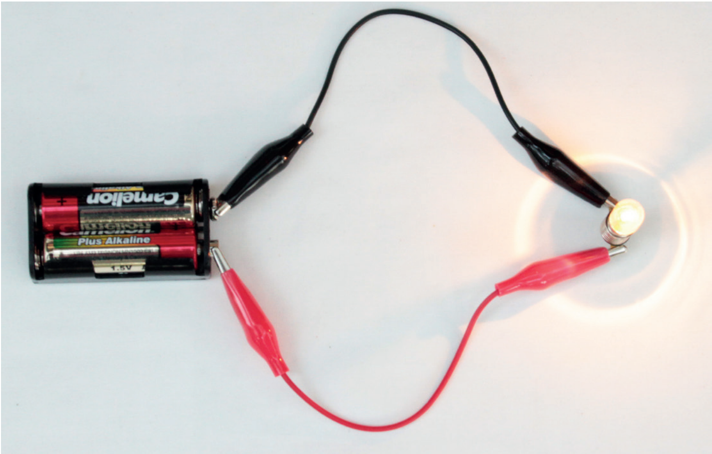


Figure 2: Two cells in series connected to a lamp

2. Figure 3 below shows three cells connected in series in a circuit. Draw a circuit diagram of the circuit.

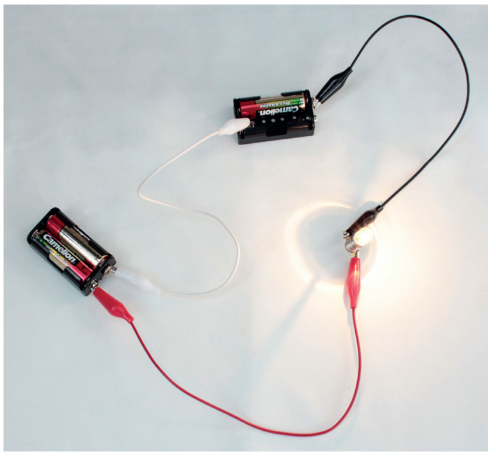


Figure 3: Three cells in series connected to a lamp

When cells are connected in series, their total voltage is the sum of the voltages of the three cells:
1,5 V + 1,5 V + 1,5 V = 4,5 V

Cells in parallel

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 below 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.

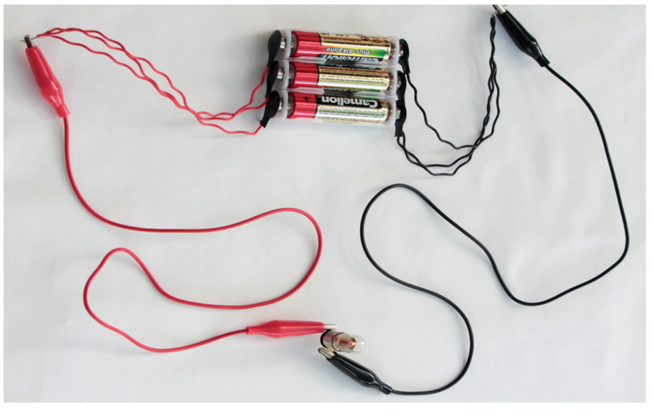


Figure 4: Three cells in parallel connected to a lamp

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 on.

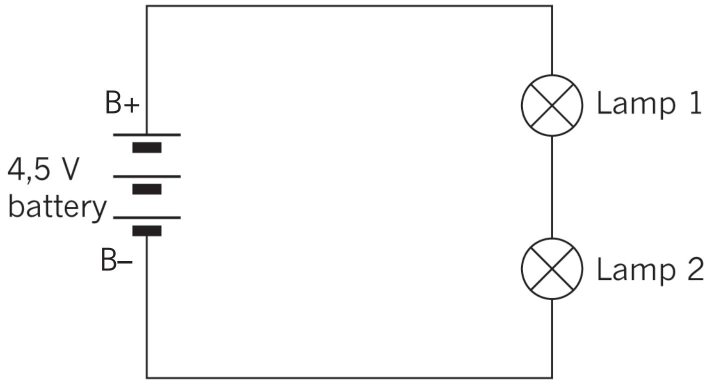


Figure 5: Two lamps in series

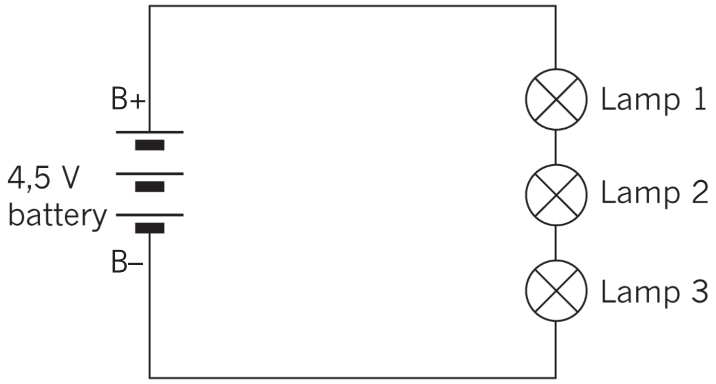


Figure 6: Three lamps in series

1. How does increasing the number of lamps in series change the current and voltage in the circuit?

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

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.

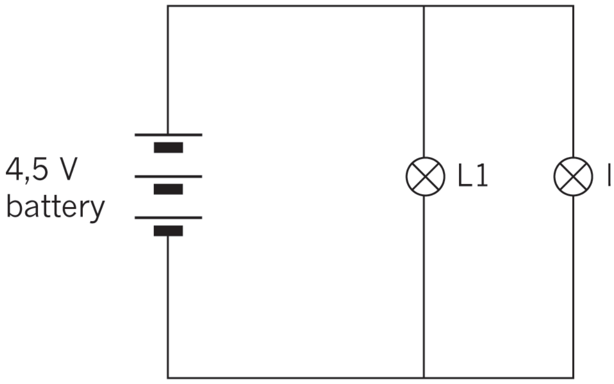


Figure 7: Circuit diagram of two lamps in parallel

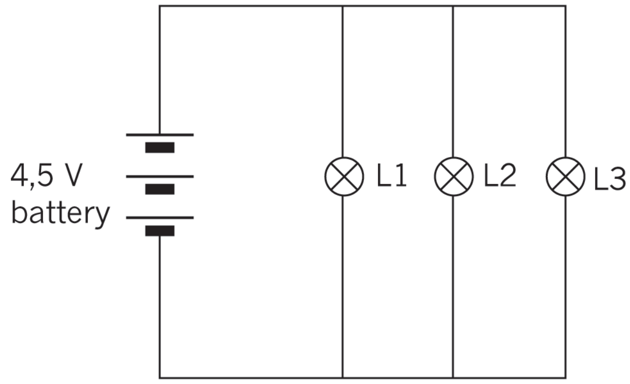


Figure 8: Circuit diagram of three lamps in parallel

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:

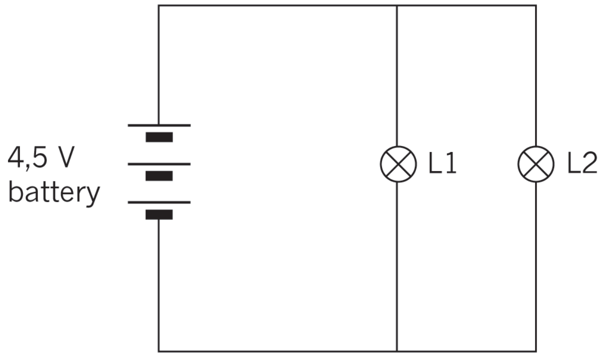


Figure 9

(a) What is the voltage drop across lamps 1 and 2?

(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?

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.

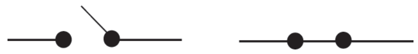


Figure 10: Symbols for an open switch and a closed switch

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.

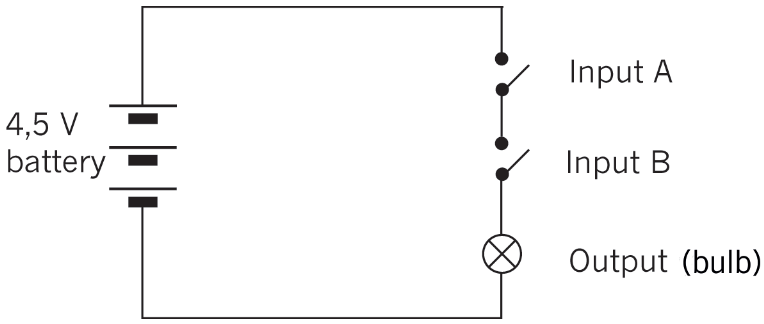


Figure 11: Circuit with two switches in series

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.

1. 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	
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.

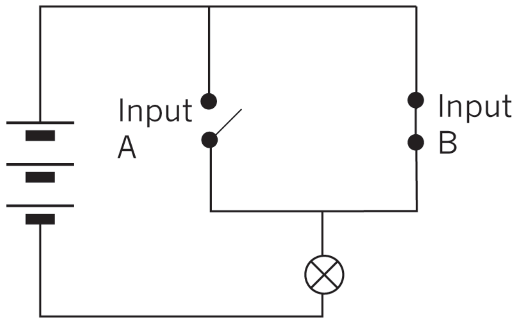


Figure 12: Circuit with two switches in parallel

Do you see that the current can go through the closed switch, even if the other switch is open?

1. Draw up a truth table for the circuit in Figure 12.

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

1. Would the lamp glow in each of these circuits? Explain your answer.

(a)

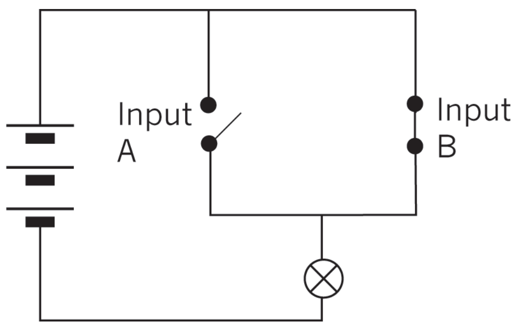


Figure 13

(b)

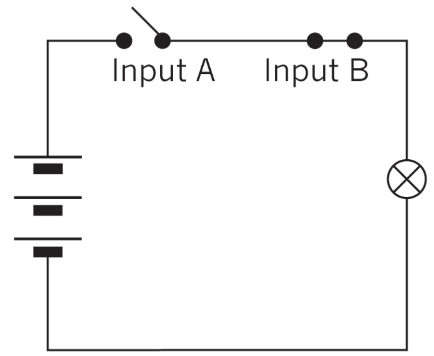


Figure 14

(c)

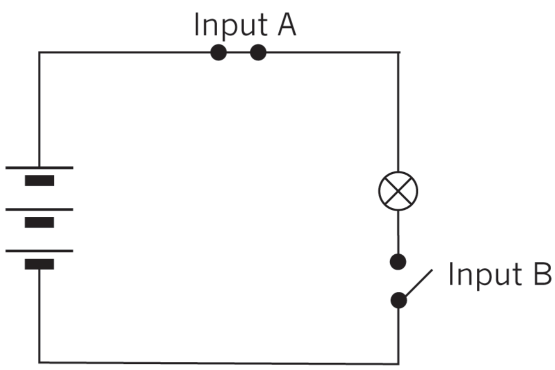


Figure 15

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

(b) Is this an AND function or an OR function? Explain your answer.

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.

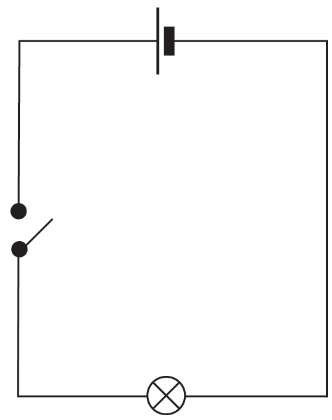


Figure 16

1. Look at the circuit diagram on the right.
   Set up this circuit and check that it works, by closing the switch.
   Does the lamp 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.

2. Add another lamp to the circuit in series with the first one.
   (a) Draw a circuit diagram for this circuit.
   (b) What do you notice about the brightness of the lamps?
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.
4. Write down your conclusions about changing the number of cells and the number of lamps in the circuit.

11.3 Testing voltage and current in circuits (Ohm's Law)

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.

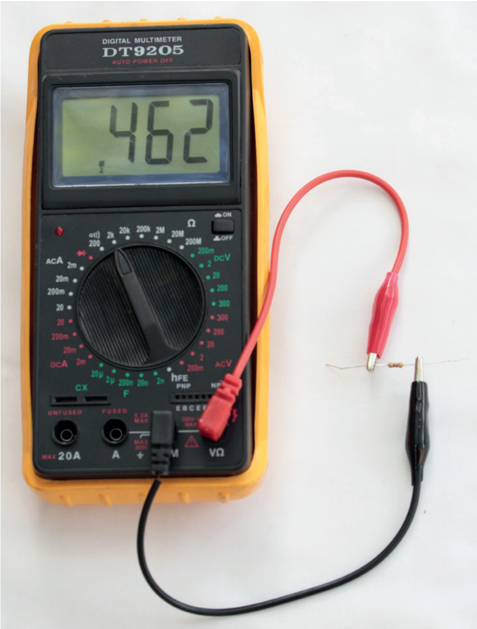
V: volts (potential)
A: amps (current)
Ω: ohms (resistance)

Begin by reading the text below on how to use a multi-meter correctly.

Measuring resistance

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 Ω, 2 kΩ, 20 kΩ, 200 kΩ and 2 MΩ.
- 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, kΩ or MΩ.



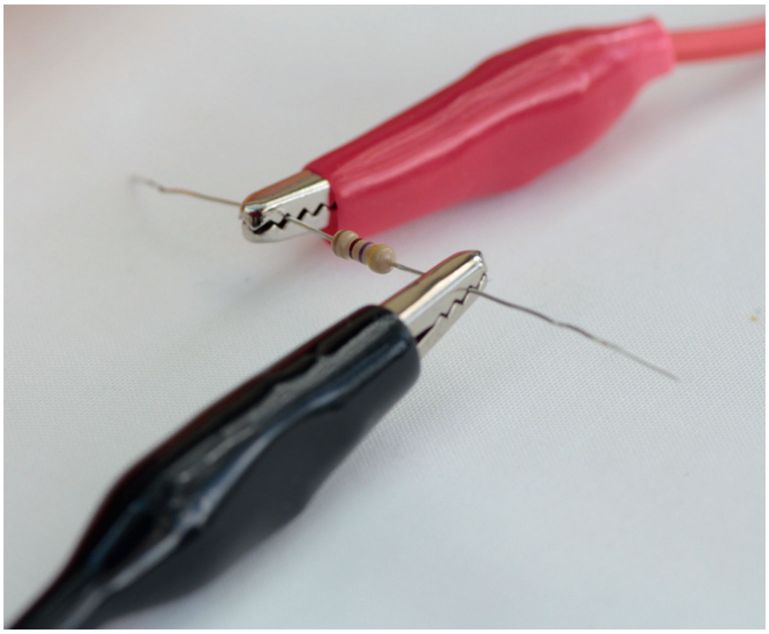


Figure 17: Multi-meter set and connected to measure resistance

Measuring voltage

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.

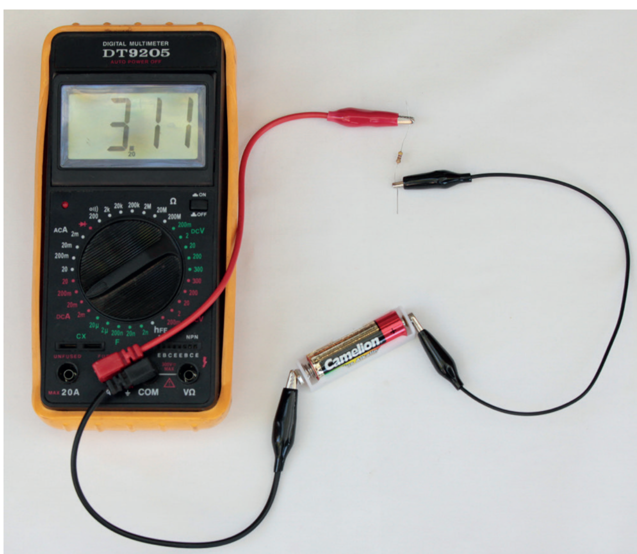


Figure 18: Multi-meter set and connected to measure current

Measuring current

Identify the section of the dial 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

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**.

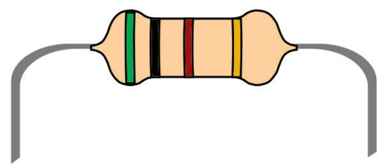


Figure 19: A 500 ohm resistor

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.

In the next chapter, you will learn how the colour bands on a resistor tell you the resistance (ohms).

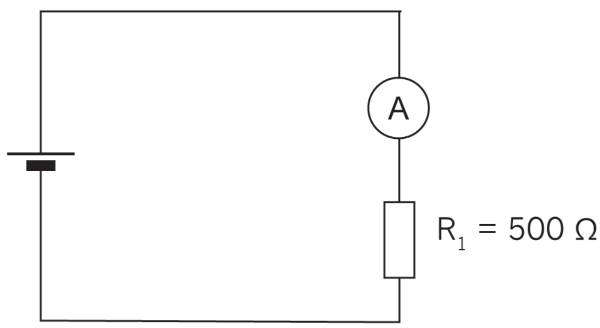


Figure 20: Circuit with one cell, resistor and ammeter

An **ammeter** is always connected in series with the part of the circuit for which you measure the current, so that it measures the full current through that part of the circuit. It has a very small resistance so that it does not change the current in the circuit.

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.

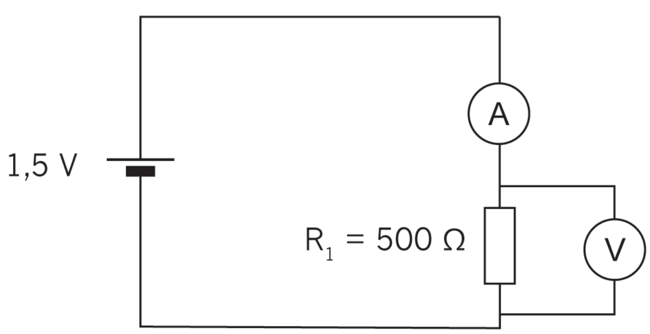


Figure 21: Circuit with one cell, resistor, ammeter and voltmeter across resistor

A **voltmeter** is always connected in parallel with the part of the circuit for which it measures the voltage between two points. Very little current flows through a voltmeter since it has a very high resistance.

Record the readings.

3. Now connect a second cell in series as shown in the circuit diagram below:

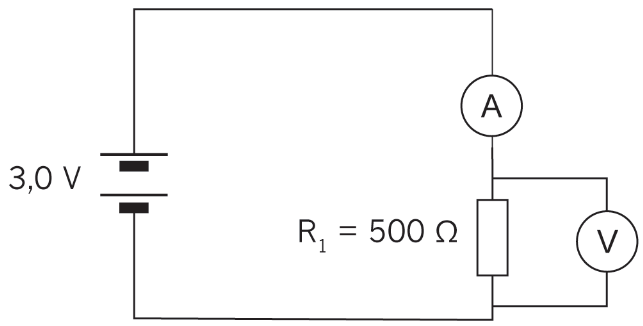


Figure 22: Circuit with two cells in series, resistor, ammeter and voltmeter across resistor

Record the readings.

4. Now connect a third cell in series as shown in Figure 23.

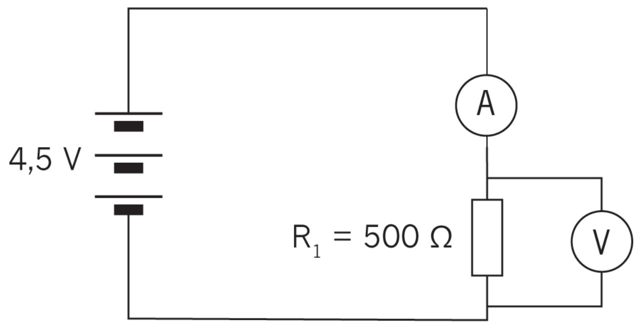


Figure 23

Record the readings.

5. Copy the table below and fill in your readings.

	With one cell	**With two cells**	**With three cells**
Voltage			
Current			

6. Copy the set of axes below onto graph paper. Plot the graph.

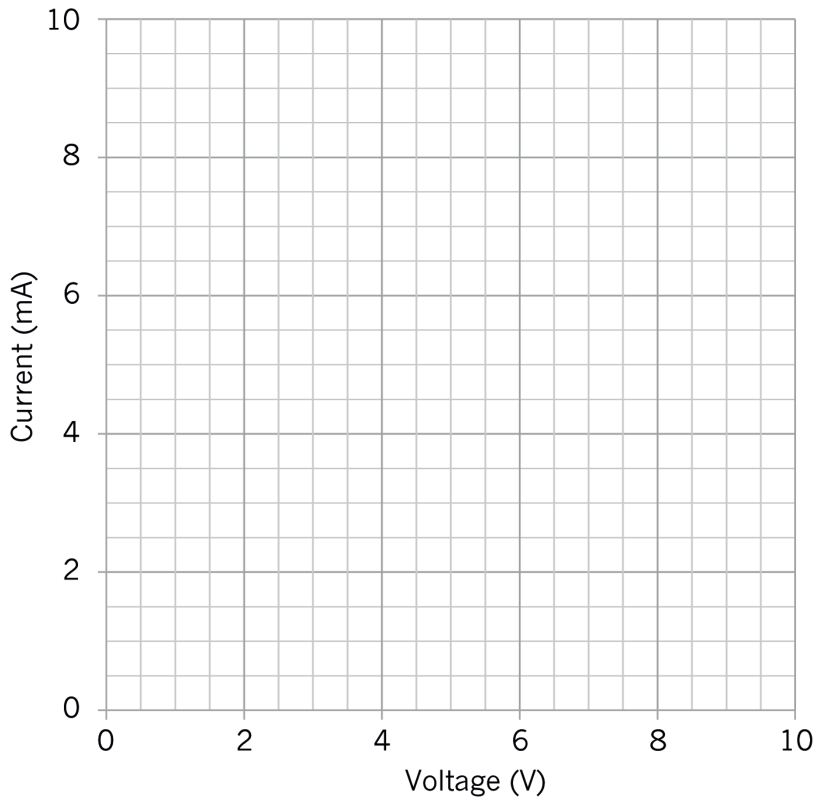


Figure 24

7. Describe the relationship between voltage and current for a 500 Ω resistor.

- 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

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.

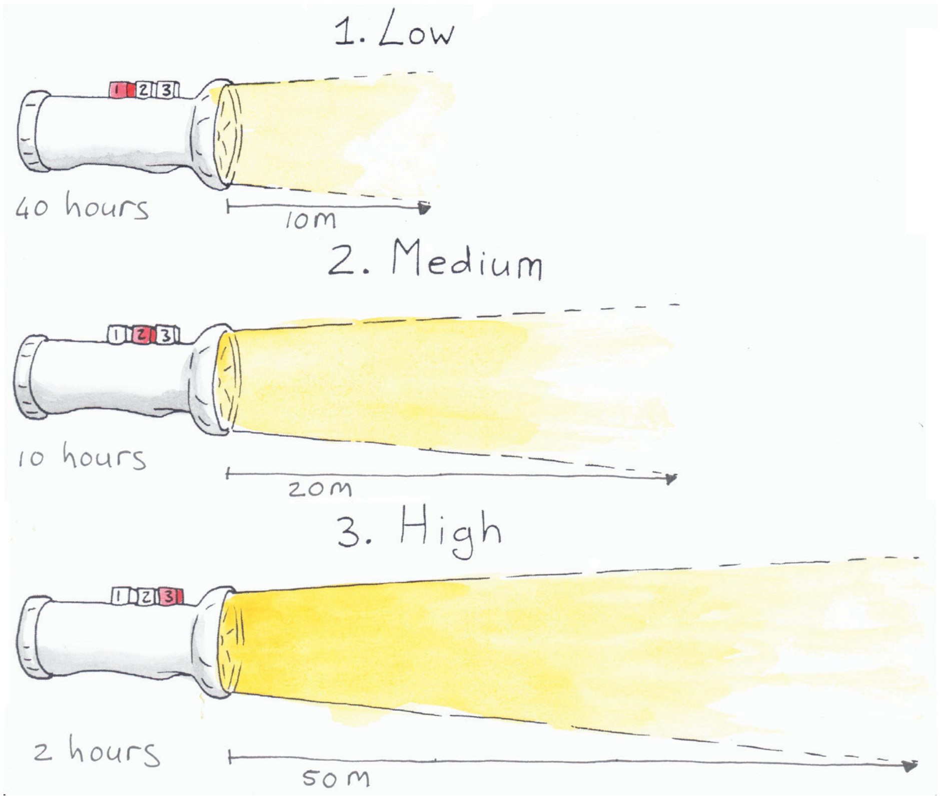


Figure 1: You can change the brightness of the light on some torches. The brighter the light you choose, the faster the battery will run out.

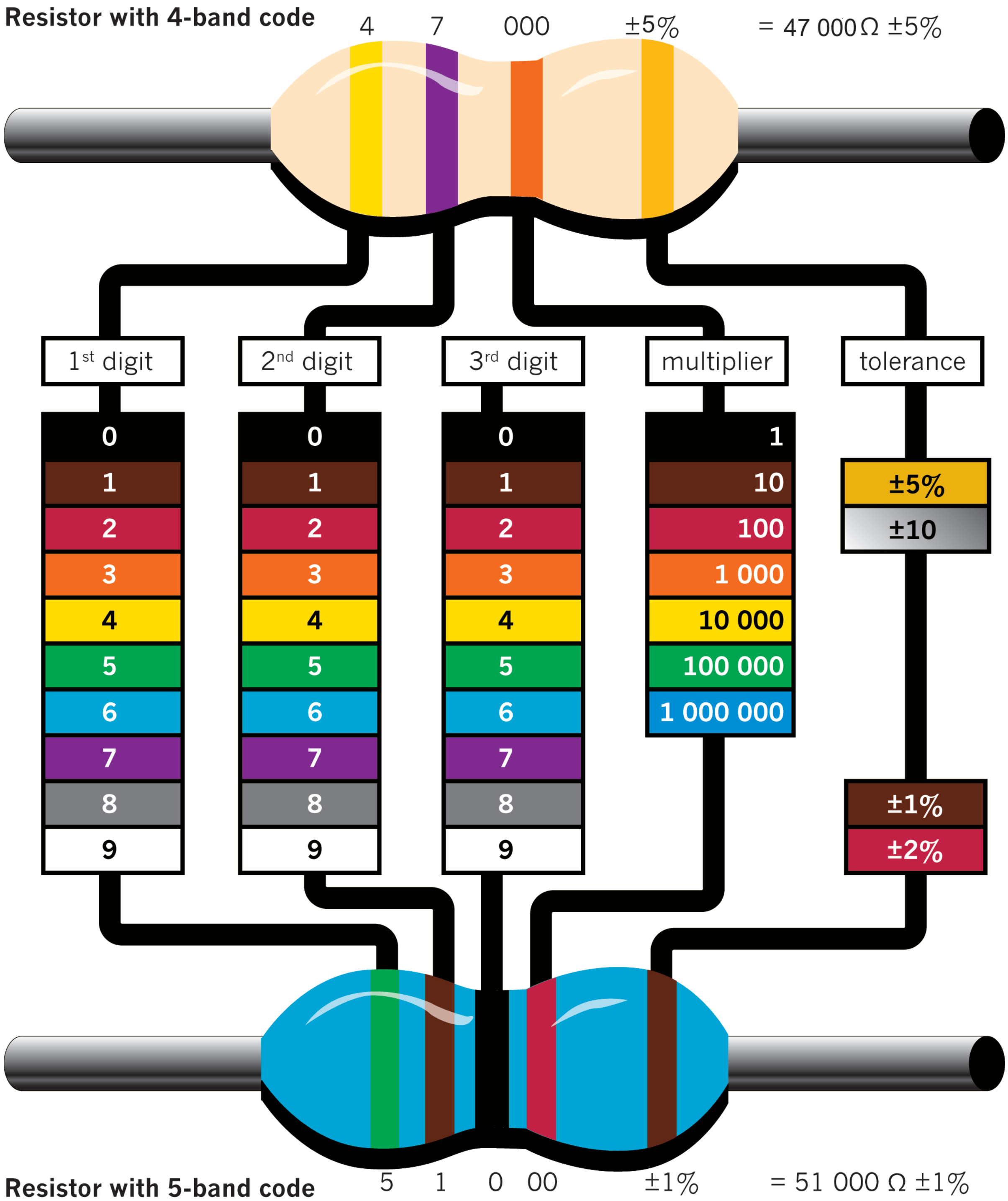


Figure 2: How to read the colour bands on a resistor to find out what its resistance is. (You will only work with resistors with four-colour bands, such as the one at the top.)

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 electrical 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.

When something **emits** light, it is a source of light. A light bulb is a source of light, but a mirror is not a source of light as it only reflects 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.

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.

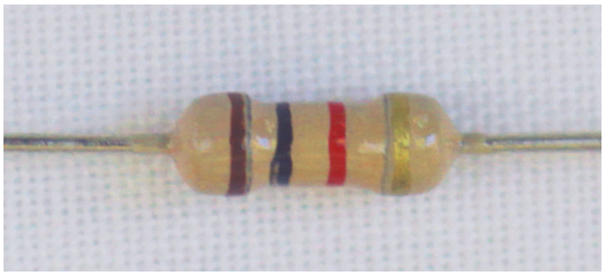


Figure 3: A typical resistor

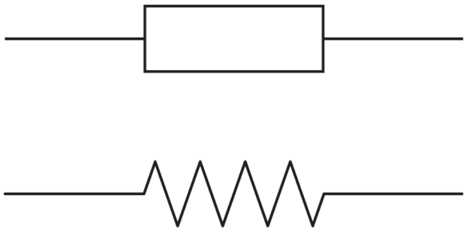


Figure 4: Circuit symbols for resistors

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.

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.

Units of measurement: ohms, kilo-ohms and mega-ohms

- 1 kΩ = 1 000 Ω = 10^3 Ω
- 1 MΩ = 1 000 kΩ = 1 000 000 Ω = 10^6 Ω

Kilo means multiply by a thousand, for example 1 km = 1 000 × 1 m.

Mega means multiply by a million.

The resistance of resistors

1. Work out and write down the resistance of each of these resistors:

(a)

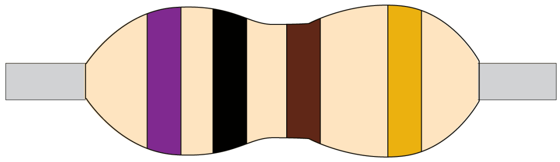


Figure 5

(b)

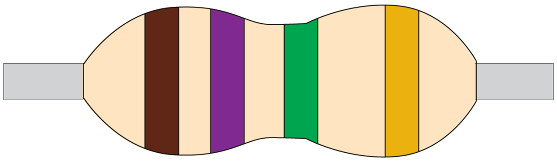


Figure 6

(c)

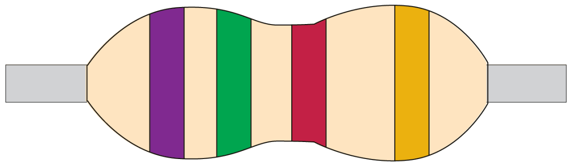


Figure 7

(d)

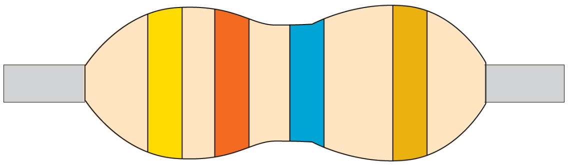


Figure 8

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 kΩ

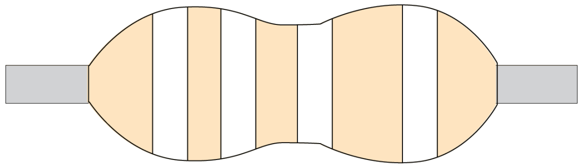


Figure 9

(b) 300 Ω

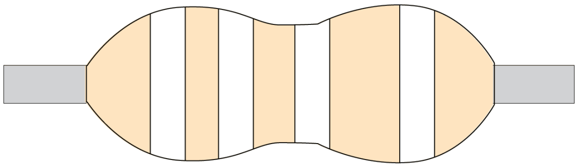


Figure 10

3. Describe the function of a resistor as a component in an electrical circuit.

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**.

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.

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.

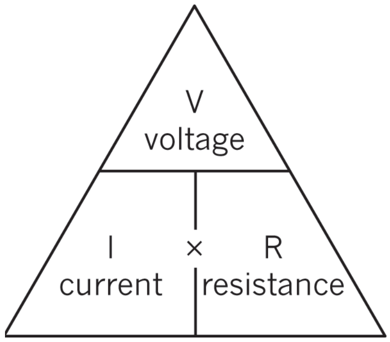


Figure 11

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:

$$I = \frac{V}{R}$$

Questions

Consider the following circuit in Figure 12 on the right:

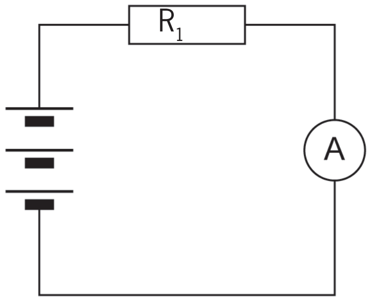


Figure 12

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?
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?

3. How would you describe the relationship between the current and the voltage in a circuit?
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
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

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.

$$R = \frac{V}{I} = \frac{12\text{ V}}{2\text{ A}} = 6\ \Omega$$

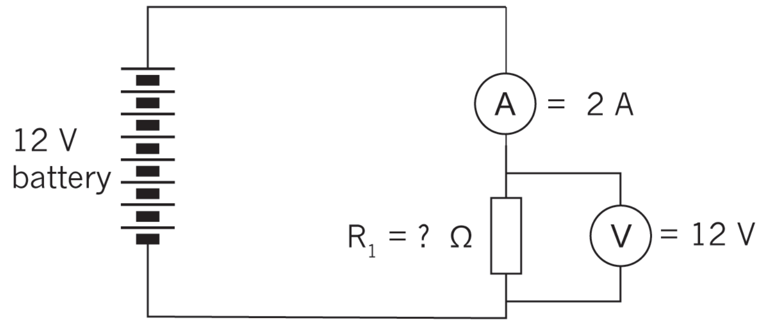


Figure 13

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.

$V = I \times R$

$= 2{,}5\ \text{A} \times 4\ \Omega$

$= 10\ \text{V}$

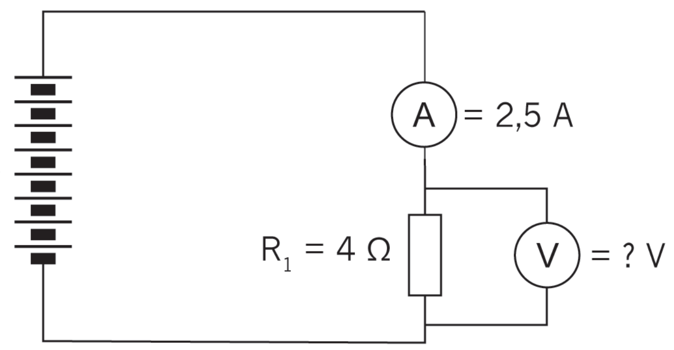


Figure 14

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.

$I = \frac{V}{R}$

$= \frac{12\ \text{V}}{3\ \Omega}$

$= 4\ \text{A}$

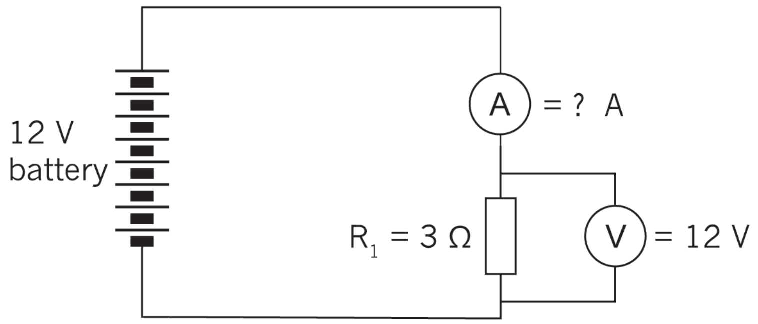


Figure 15

Questions

1. What will the potential difference be if the current in a circuit is 10 A and the total resistance is 1 000 Ω?
2. Given V = 10 V and R = 1 kΩ, what will the value of the current be in a circuit?
3. Given V = 20 V and R = 5 kΩ, solve for the current.
4. 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?
5. A 9 V battery maintains a current of 3 A through a radio. What is the resistance in the circuit?
6. If the voltage across a circuit is increased four times, what would you expect to happen to the current through the circuit?

7. (a) In the circuit below, calculate the resistance value of the resistor.

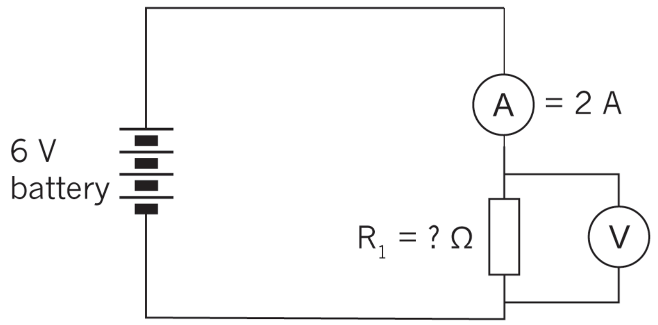


Figure 16

(b) If two more cells are added to the circuit, will the current increase or decrease? Check your prediction using the formula.

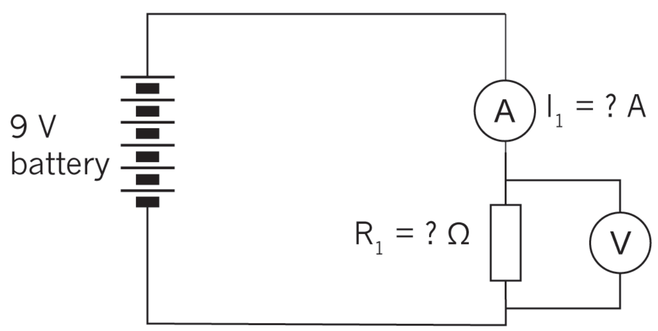


Figure 17

8. Calculate the battery voltage for the circuit below:

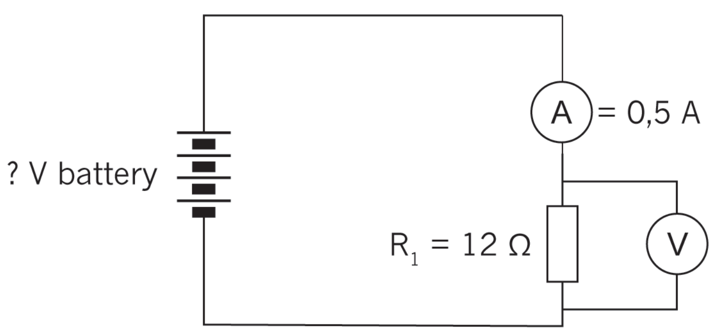


Figure 18

9. Look at the circuit below:

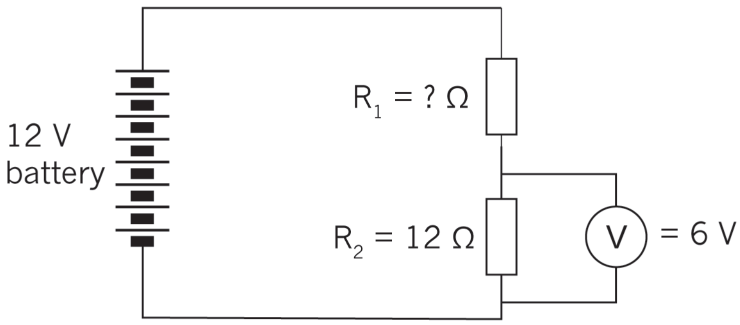


Figure 19

(a) Calculate the current through R_2.
(b) What will the current be through R_1?
(c) What will the voltage across R_1 be?
(d) What will the resistance value of R_1 be?

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

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.

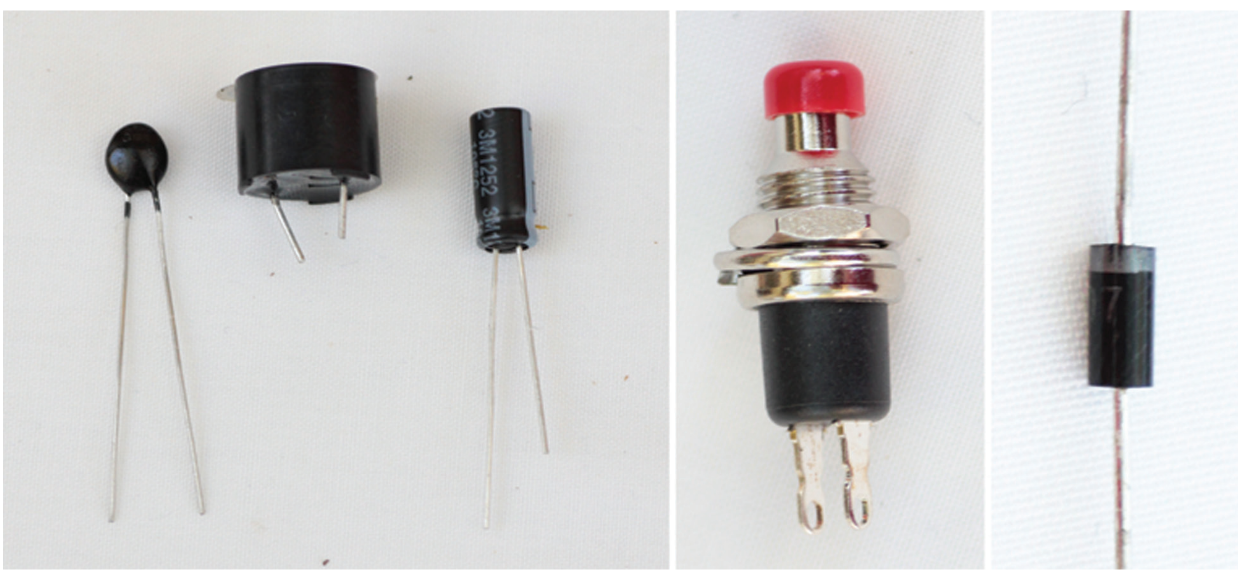


Figure 1: A few examples of electronic components that we will deal with in this chapter

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.

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.

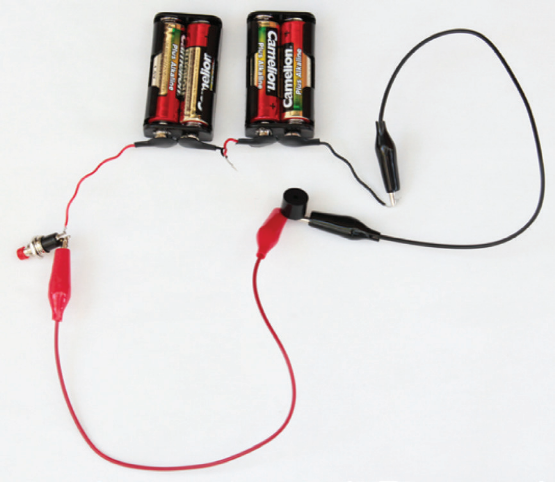


Figure 2: A simple doorbell circuit

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.
2. Explain in your own words how this circuit works.

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.

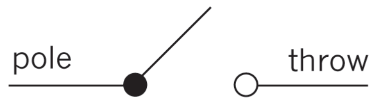


Figure 3: The symbol for an SPST switch

An example of an SPST is a light switch. 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.

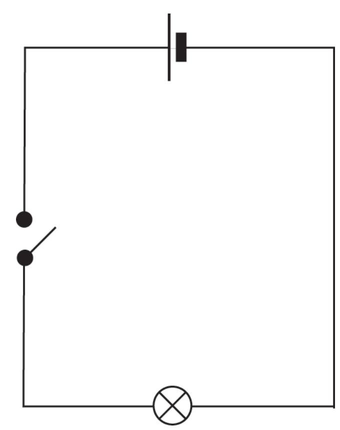


Figure 4: A typical light circuit with an energy source, switch and lamp

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.

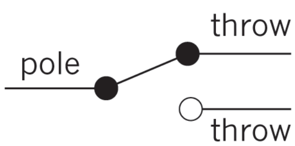


Figure 5: The symbol for an SPDT switch

A lighting circuit

The circuit diagram below shows a two-way lighting circuit.

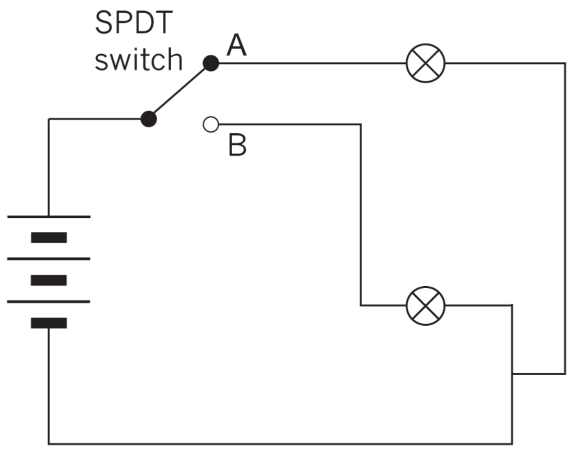


Figure 6: A circuit with a battery, two lamps and an SPDT switch controlling two outputs

1. Explain in your own words how this circuit works.
2. Think about how you can use an SPDT switch. You can make up an example, as long as it makes sense.
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.
4. Look at the circuit diagram below. It shows how one light can be controlled by two different switches.

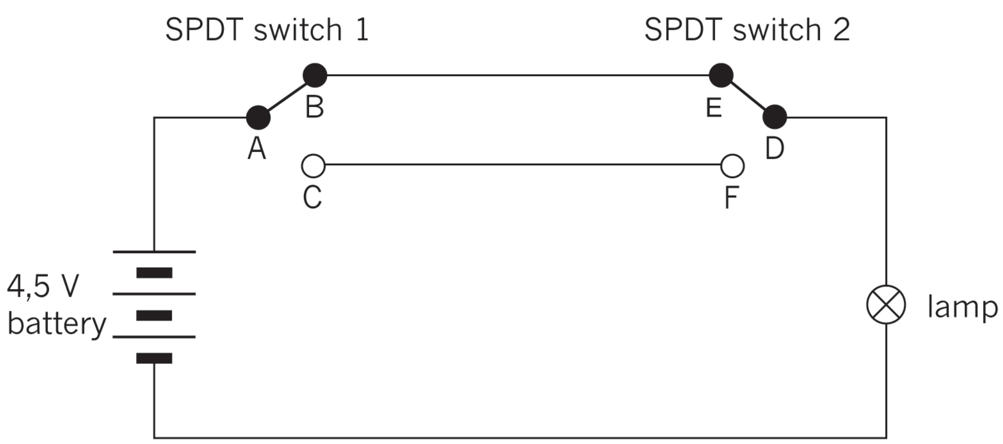


Figure 7: A circuit with two SPDT switches is often used to control a lamp with one switch at each end of a long passage. It is also used to control a lamp with one switch at the bottom of a staircase, and the other switch at the top of the staircase.

(a) Will the lamp turn on if A connects to C and D connects to F?
(b) Will the lamp turn on if A connects to C and D connects to E?

(c) Will the lamp turn on if AB and ED are closed?
(d) Will the lamp turn on if DF and AB are closed?
(e) Explain why the type of circuit in Figure 7 is useful for controlling the lamp in a long passage-way.

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.

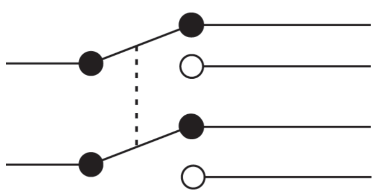


Figure 8

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.

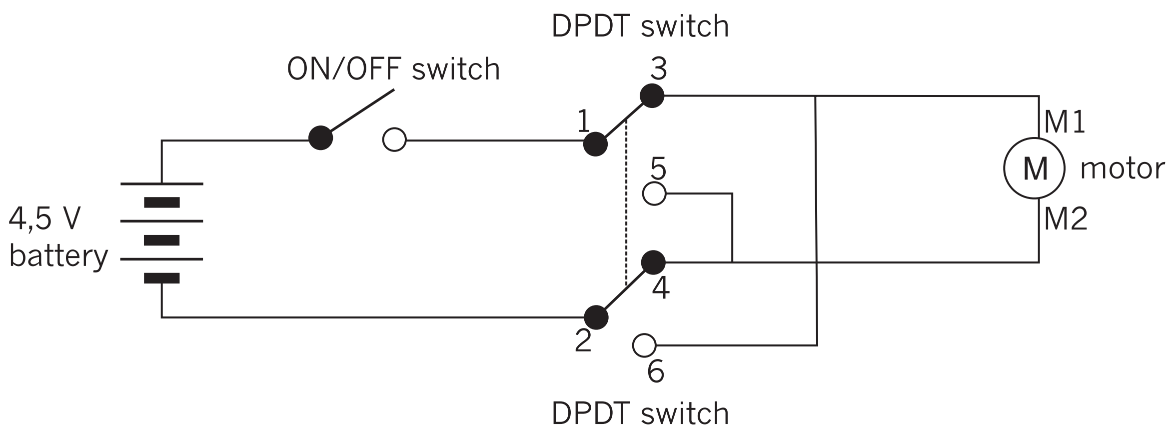


Figure 9: A circuit where a DPDT switch controls the direction in which an electric motor turns

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.

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

1. Explain in your own words how this circuit works.
2. Explain the difference between an SPDT and a DPDT switch.

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.

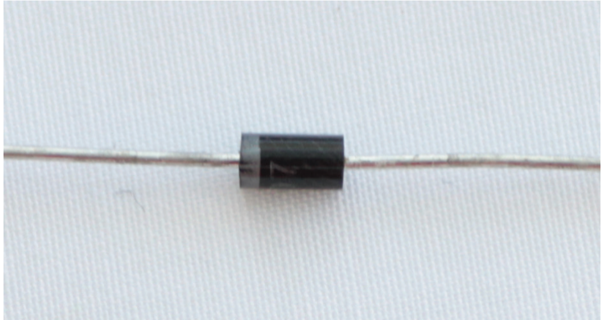


Figure 10: A diode

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.

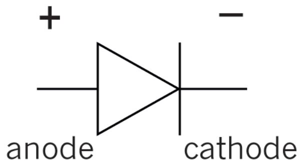


Figure 11: Circuit symbol of a diode. The current flow in a diode is in the direction of the arrow head.

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.

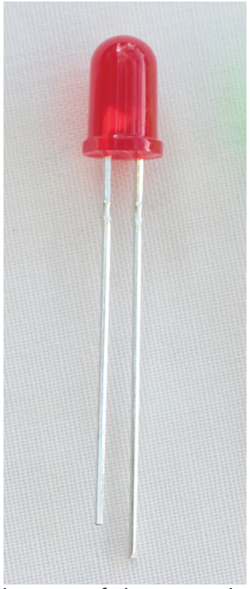


Figure 12: An LED. The longer of the two wires coming out of the LED should be connected to the positive terminal, and the shorter wire to the negative terminal.

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.

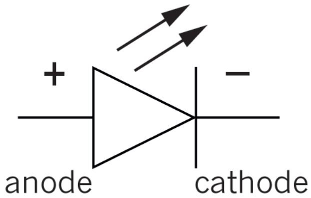


Figure 13: The circuit symbol for an LED.

To protect an LED from too much current, a resistor has to be added to the circuit, as in the diagram below.

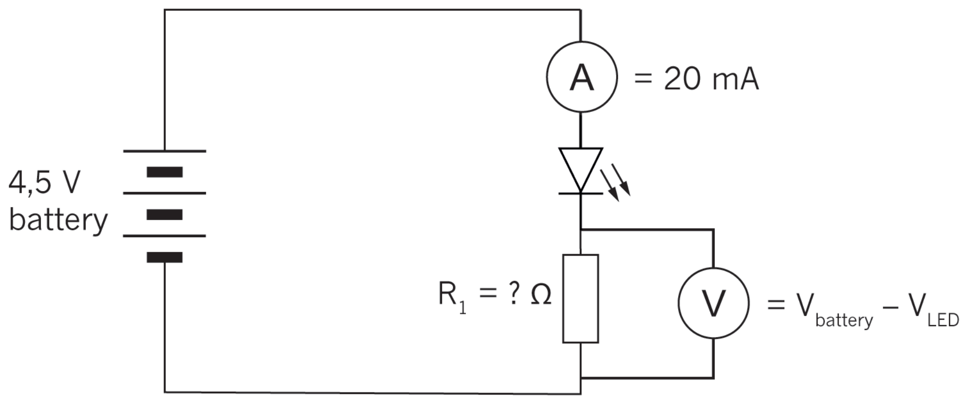


Figure 14: LED circuit with a current-limiting resistor.

Questions

1. Describe the function of a diode in your own words.
2. List at least four places where LEDs are used. Don't use the examples already given.
3. How can you make sure that a diode is connected correctly?
4. Draw the circuit symbols for a diode and for an LED.

13.3 Transistors

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**.

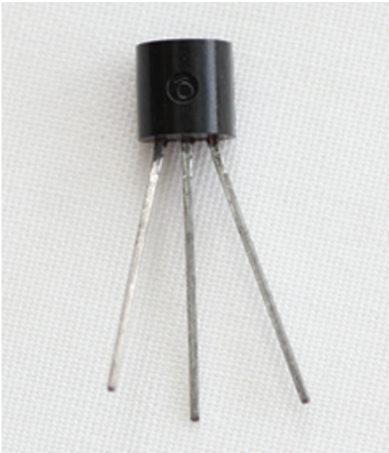


Figure 15: One type of transistor

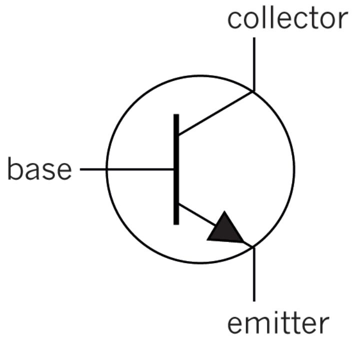


Figure 16: The circuit symbol for an npn transistor

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.

A transistor circuit

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".

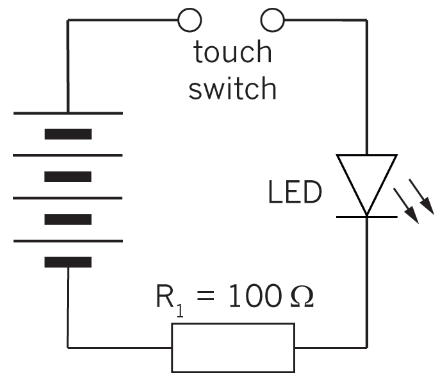


Figure 17: A simple touch switch circuit that will not work well

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.

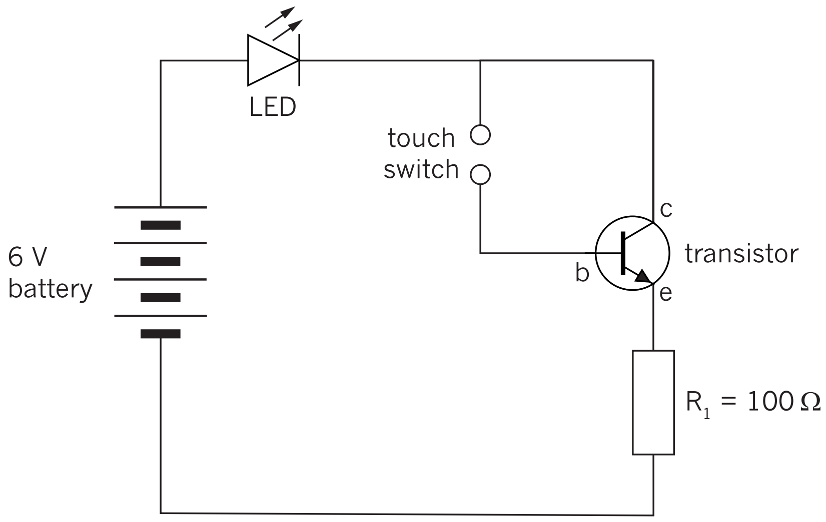


Figure 18: Circuit using a transistor as an electronic switch

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.

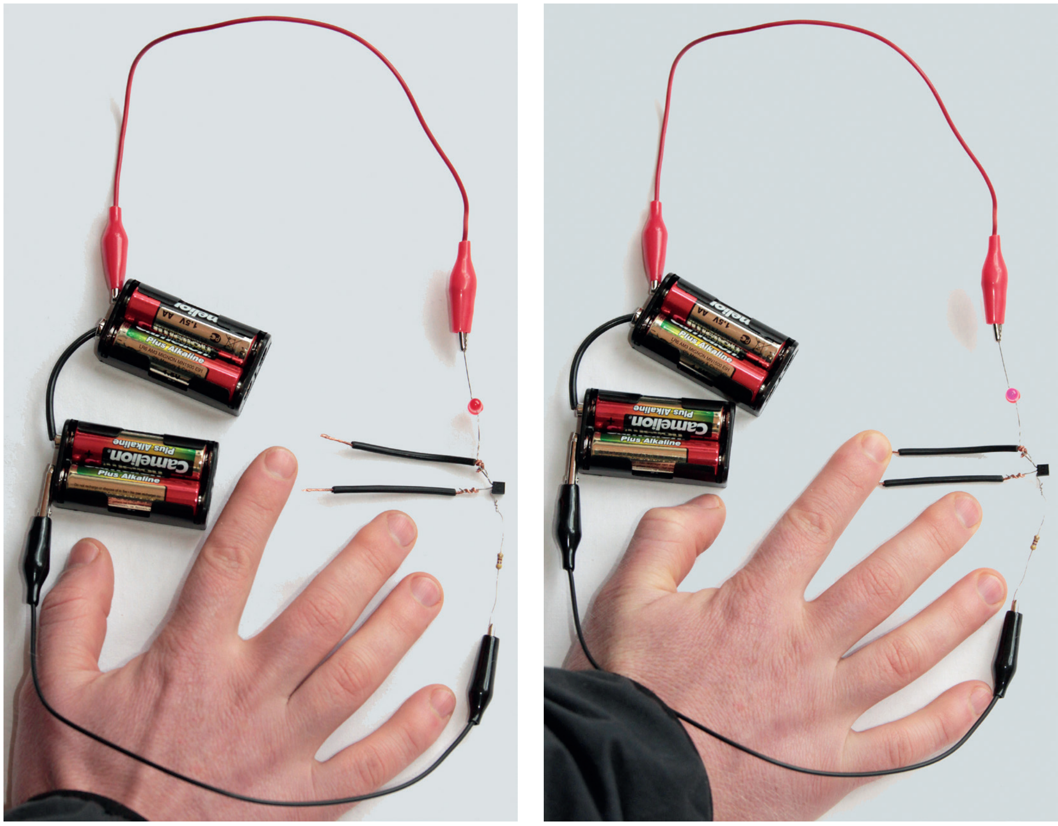


Figure 19: The construction of a touch switch circuit with a transistor and an LED.

2. Explain how the different parts of the transistor are connected in this circuit.
3. Explain what you expect to see when the touch switch is activated.
4. Touch the two terminals of the touch switch with one finger. Describe what happens.

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.

Chapter 14
Electronic components 2

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.

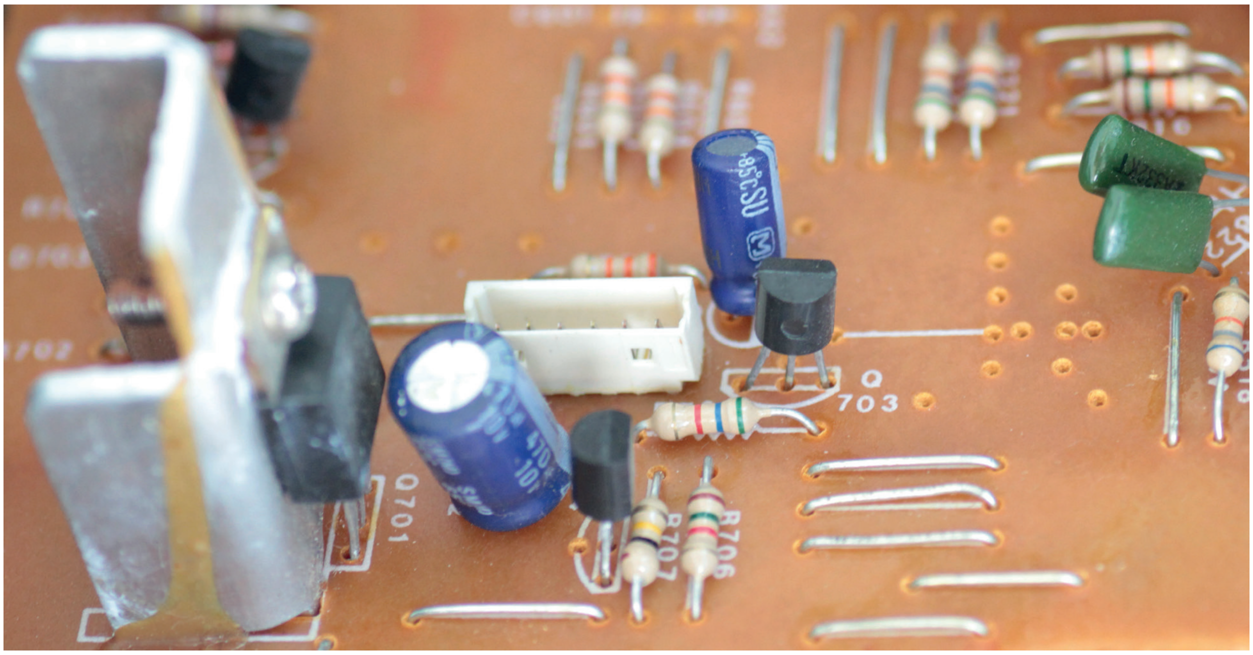


Figure 1: Components connected on a printed circuit board

Figure 2: Measuring the resistance of a thermistor at room temperature.

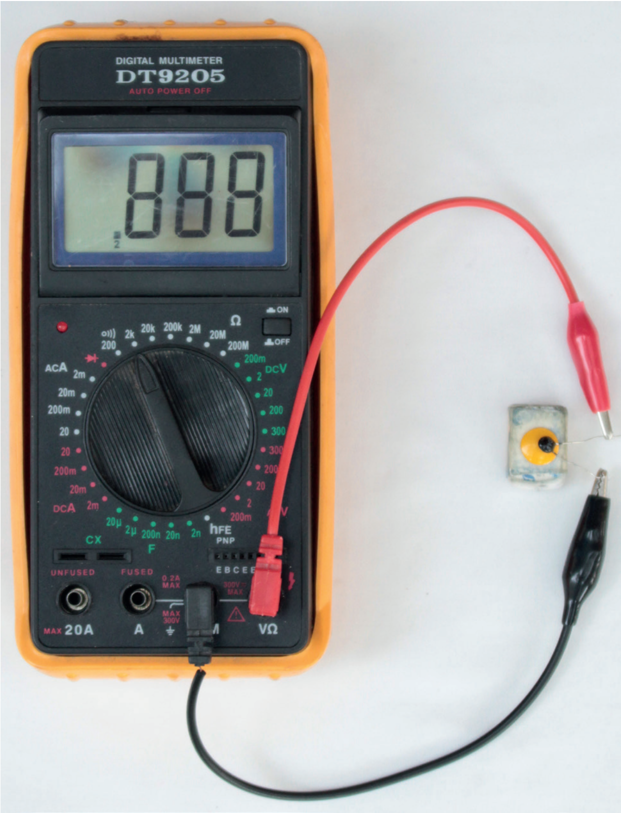


Figure 3: Measuring the resistance of a thermistor while heating it with a hot object. You can heat a metal thumb tack by pressing it into an eraser, and then rubbing it hard against a piece of wood or plastic for one minute.

Safety warning: *The thumb tack can get very hot and burn your skin, which can cause a wound.*

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 MΩ.
- When an LDR is exposed to a light of high intensity, the resistance value will decrease. It could drop from 1 MΩ to 2 kΩ.

The resistance of an LDR increases when it becomes darker.

An LDR has two terminals that can be connected to a circuit in either direction.

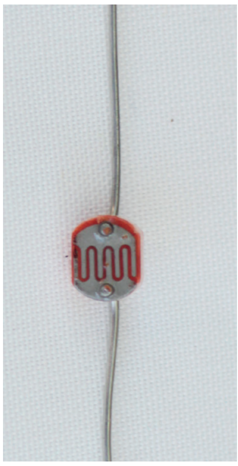


Figure 4: A light-dependent resistor

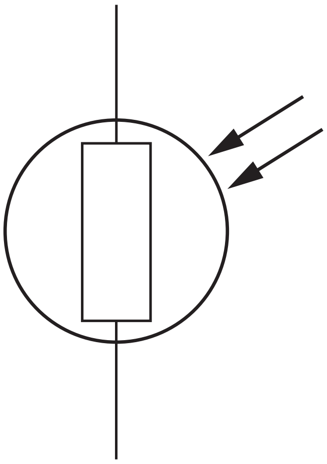


Figure 5: The circuit symbol for a light-dependent resistor

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 *npn* transistor is the control device, and an LED is the output device.

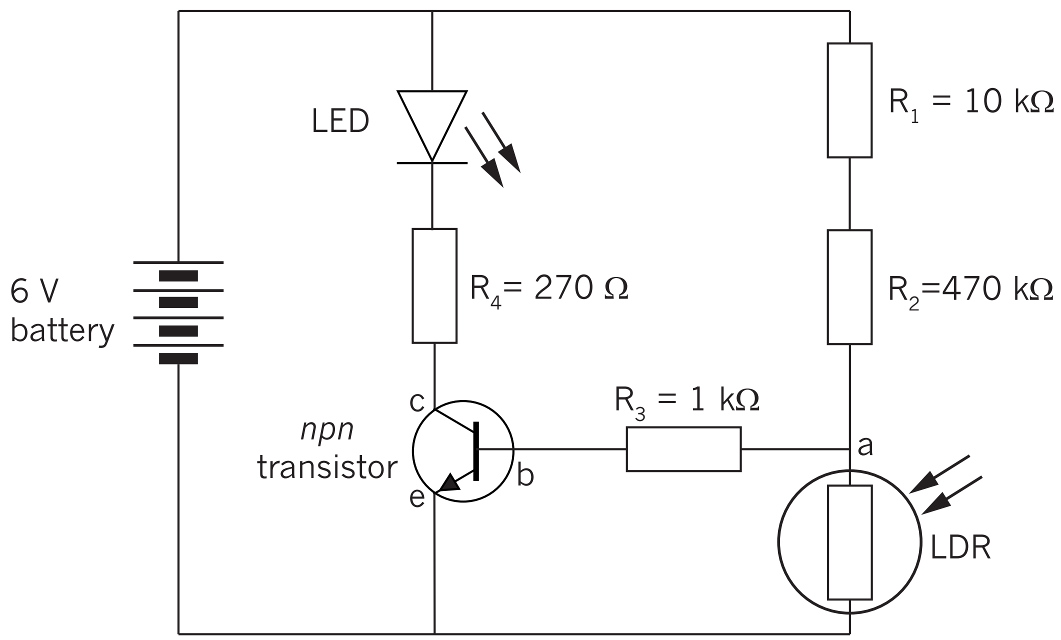


Figure 6: Circuit diagram of a day/night switch

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.
2. What is the role of the LDR in the circuit?
3. Describe how the transistor is connected to the circuit.
4. What is the role of the transistor in this circuit?

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.

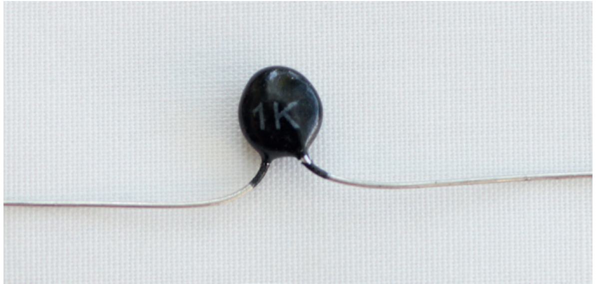


Figure 7: A thermistor

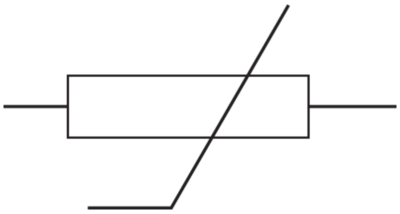


Figure 8: The circuit symbol for a thermistor

Uses of thermistors

1. Write four examples of situations in which electronic devices that use a thermistor of either type would be useful.

Measuring the resistance of a thermistor

Figures 2 and 3 on 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?
2. Give reasons for your answer.

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.

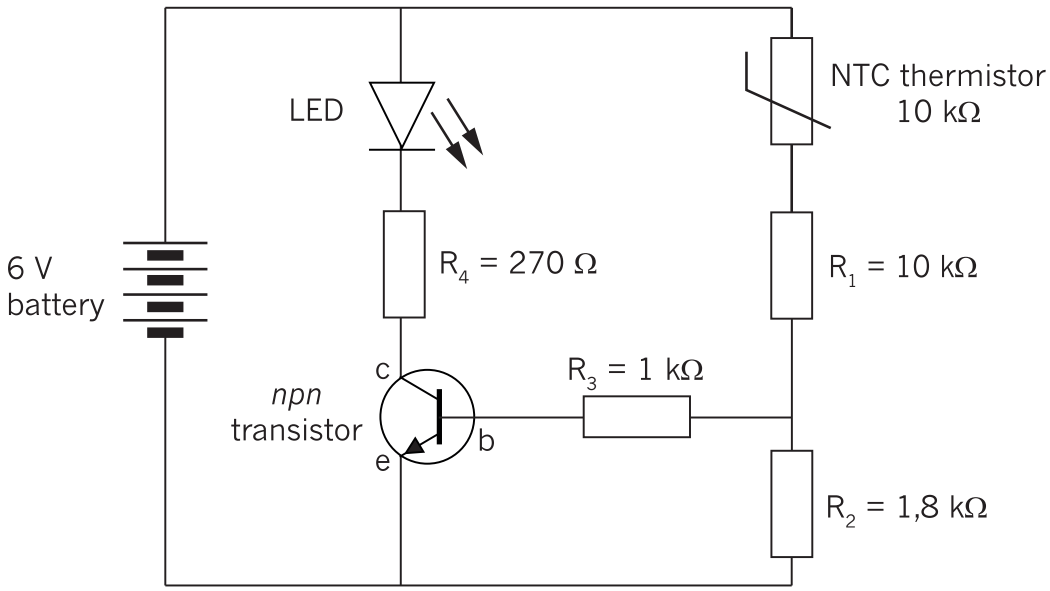


Figure 9: Diagram of a simple fire alarm with an NTC thermistor

1. What is the role of the thermistor in the circuit?
2. Describe how the transistor is connected to the circuit.
3. 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.

14.3 Capacitors

A capacitor stores the potential energy that results from separating positive and negative charges. A capacitor consists of two metal plates separated by an insulator called a dielectric. The ability of a capacitor to separate 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-).

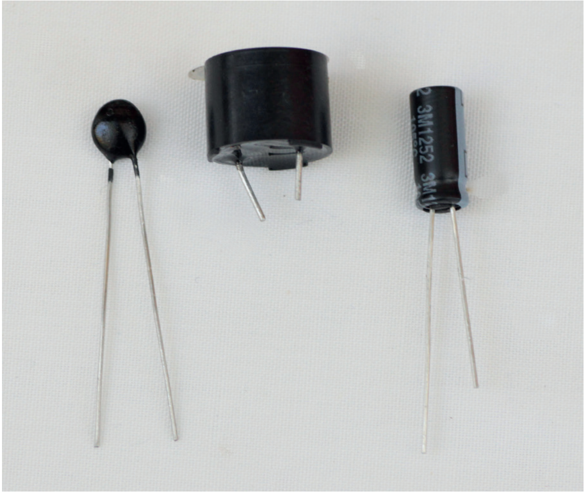


Figure 10: Different types of capacitors

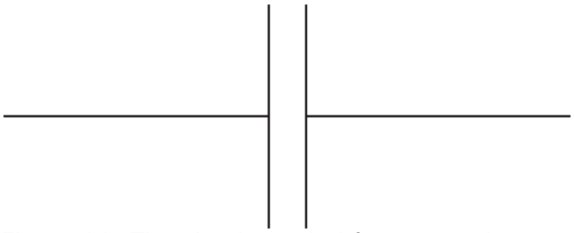


Figure 11: The circuit symbol for a capacitor

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 LED_1, 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 R_1. While the capacitor is charging, LED_1 will be ON.

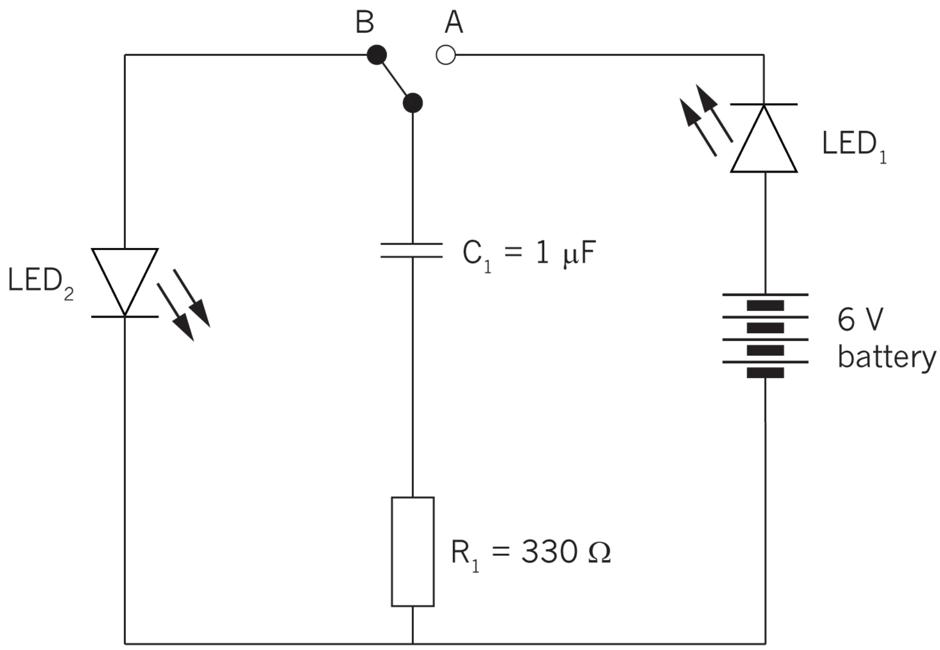


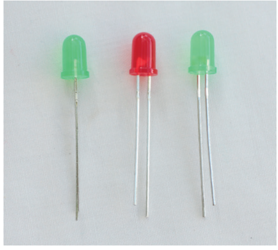
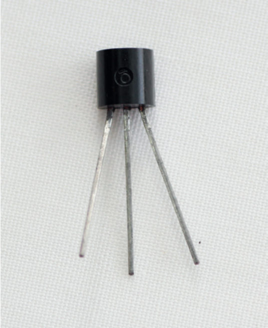
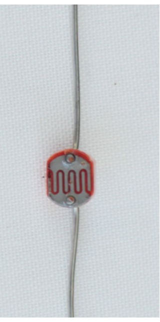
Figure 12: Capacitor charging and discharging circuit

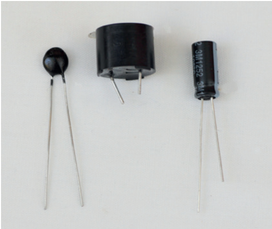
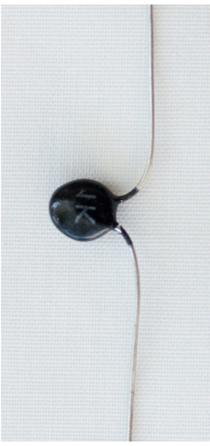
After the capacitor has been charged and the switch is switched to position B, a current will now flow from the + plate of the capacitor through LED_2, and through the resistor R_1 to the negative plate of the capacitor. While the capacitor is discharging, LED_2 will be ON.

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

1. 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
			
			
			

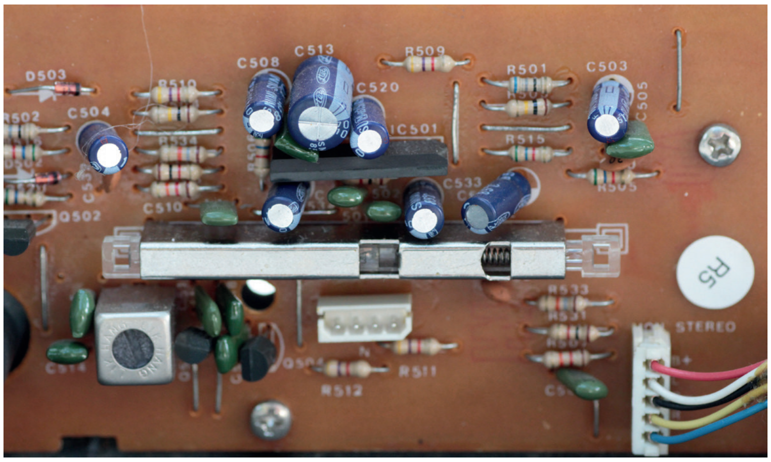
Name of component	Picture	Symbol	Use
			
			
			

Next week

Next week, you will draw circuit diagrams and build simple circuits.

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 13 and 14.



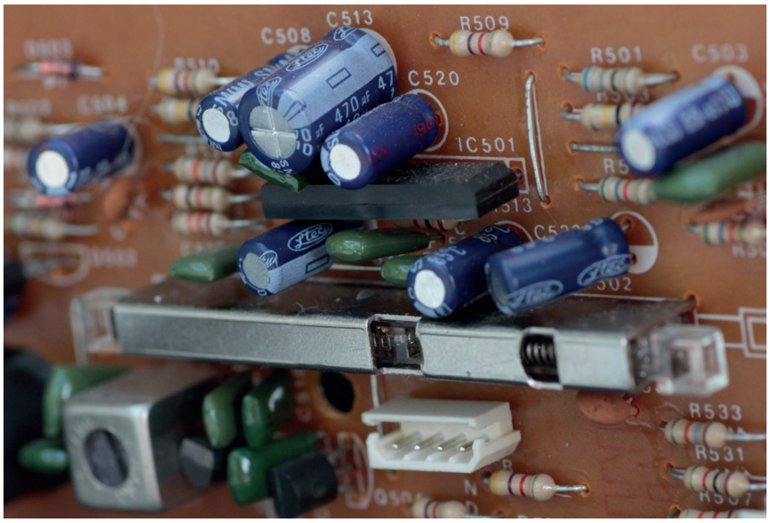


Figure 1: A part of the circuit for a radio

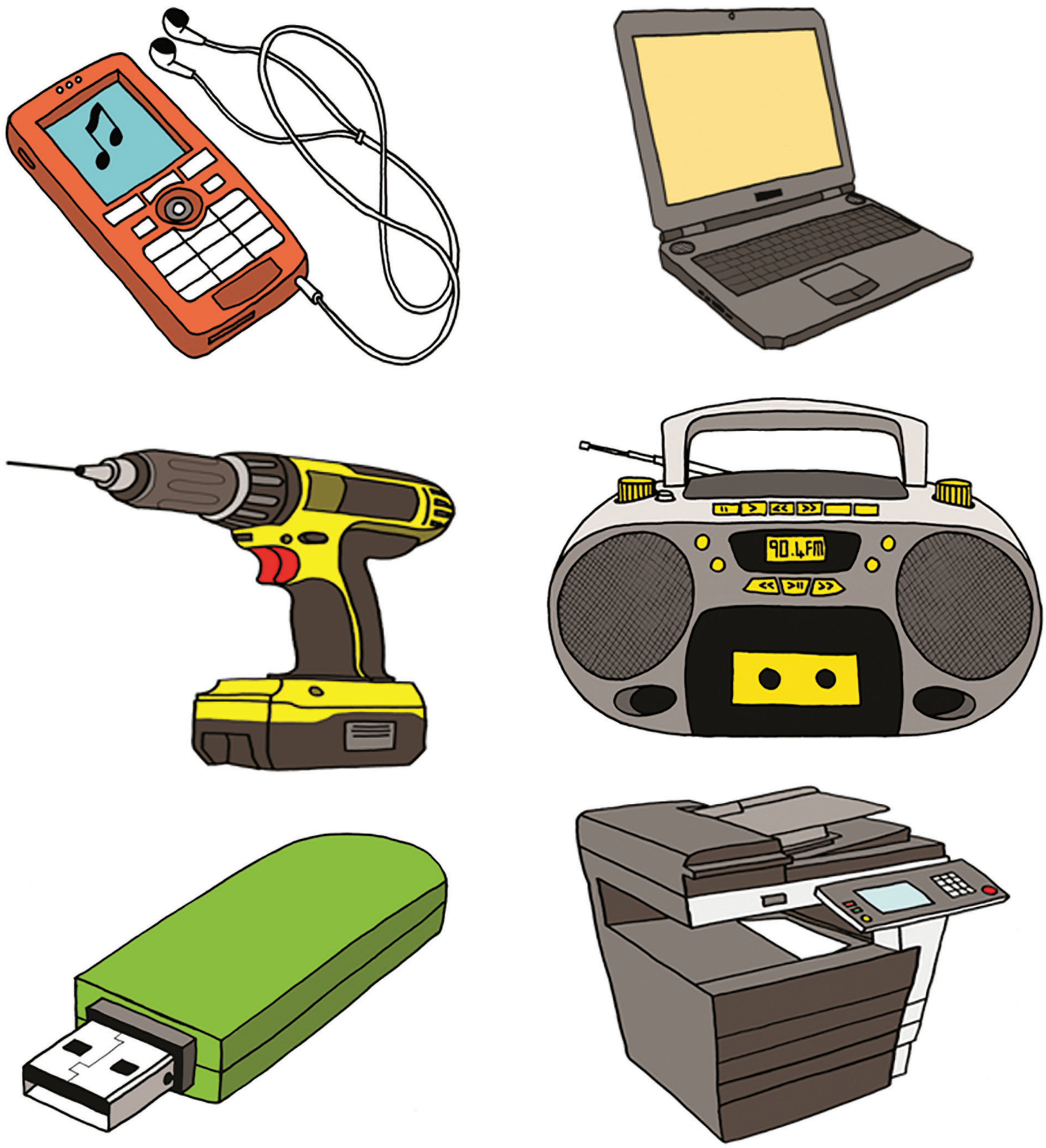


Figure 2: All of these appliances contain electronic circuits.

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 Ω 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.

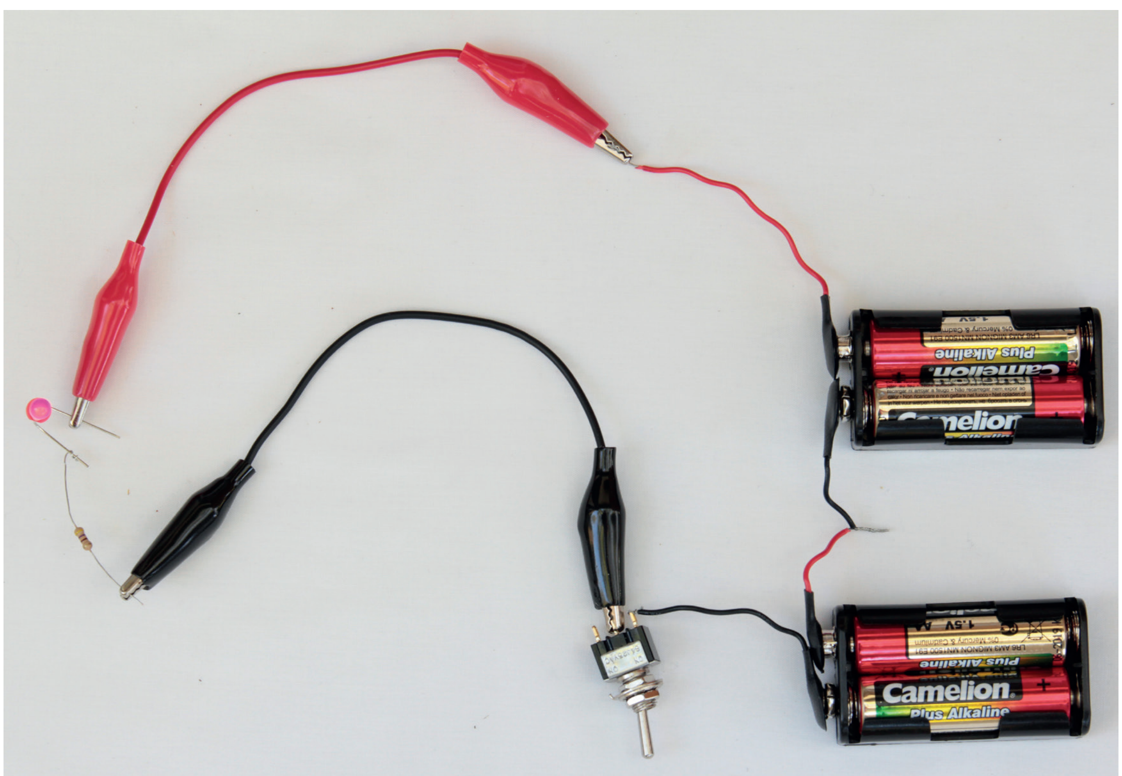


Figure 3: A circuit with an LED, a battery, a switch and a resistor

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 below shows a circuit in which an LDR regulates the current through the circuit.

Figure 4: A circuit where the current is regulated by a light-dependent resistor

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
   (b) The LDR is in bright sunlight
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.

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.

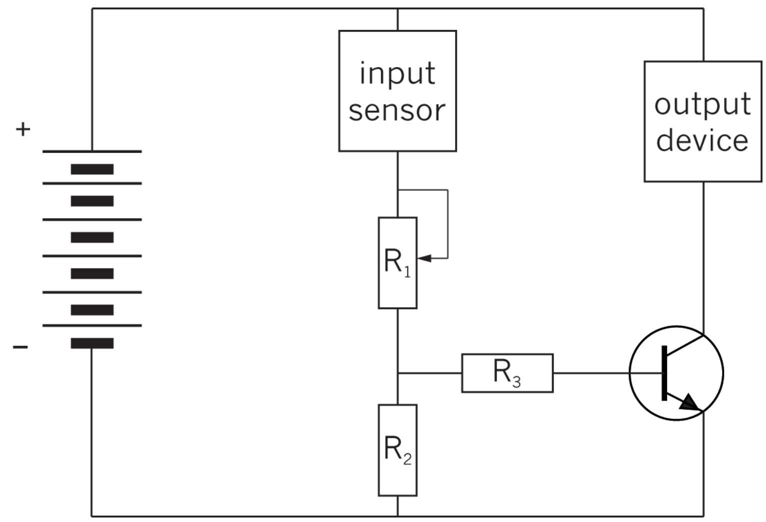


Figure 5: The circuit diagram for the control circuit

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.

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.

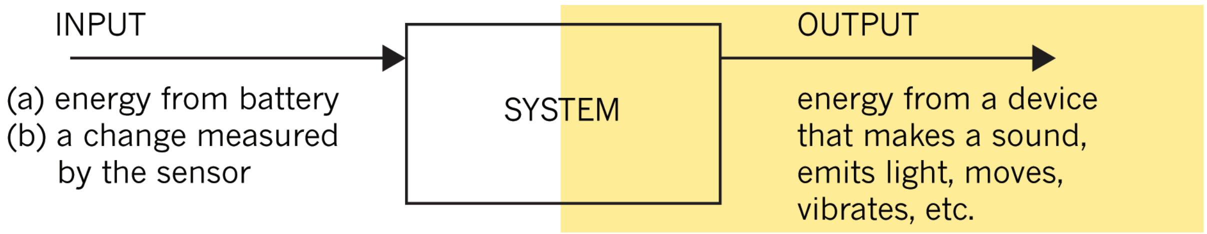


Figure 6: A systems diagram of a control circuit

Figure 7 shows how the circuit in Figure 5 is the same as the systems diagram.

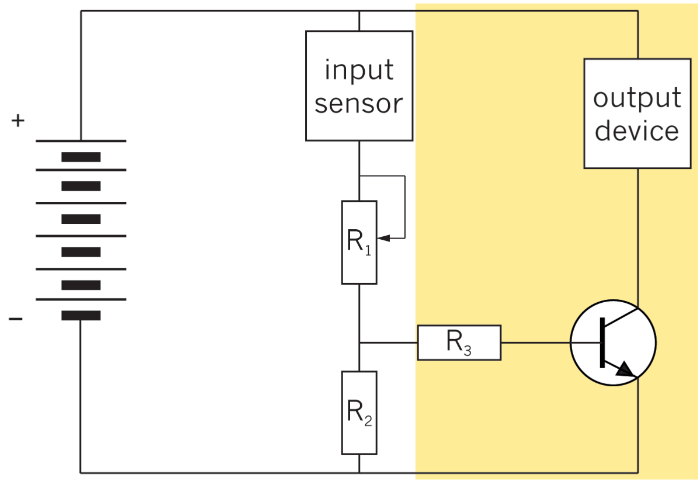


Figure 7

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?
2. What type of device will you use as the output device?
3. What voltage does the battery supply to the circuit?
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.

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 to 1 400 kΩ (variable resistor)
- R_2 = 820 Ω
- R_3 = 1 kΩ
- input sensor: 10 kΩ

5. Show the specified resistances of the components on your circuit diagram.

15.3 Build a fire-alarm circuit

Build a circuit and test it

Work in pairs to build the circuit.

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

- 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

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 Ω resistor,
- a 1 000 μF capacitor, and
- an SPDT switch.

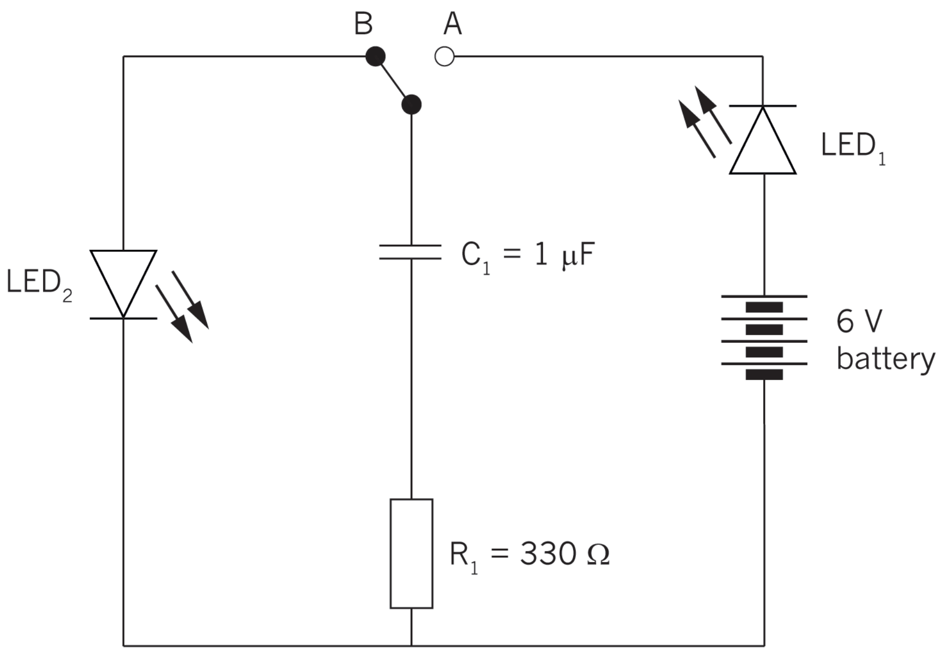


Figure 8: A time-delay circuit

1. Build the circuit. Put the switch to A and observe the LEDs. Describe what happens and explain it in detail.

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 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.

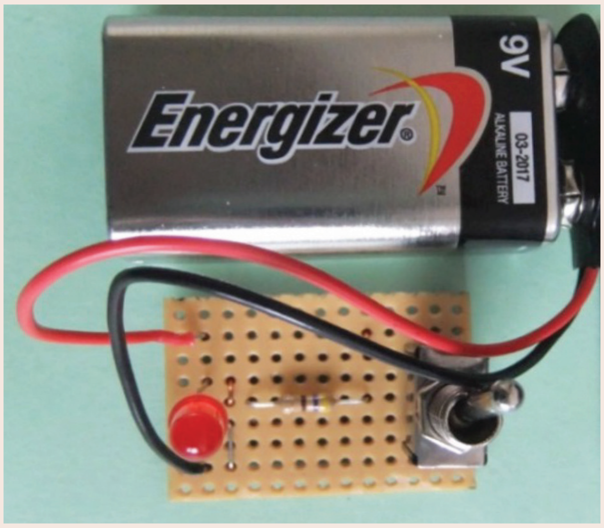


Figure 9: A simple LED circuit built on a strip board

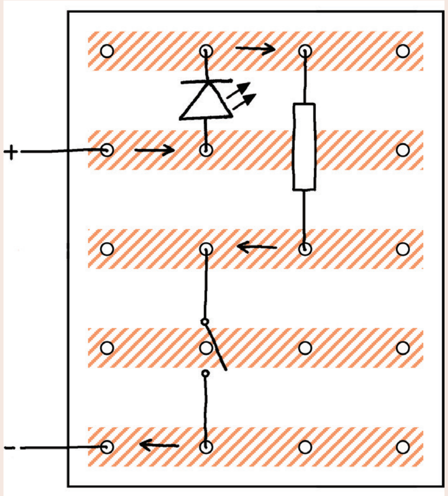


Figure 10: One possible layout of the simple LED circuit on a strip board

Figure 10 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.

The arrows on Figure 10 are drawn to help you understand how current flows through the copper strips at the back of the strip board. The current flows in the direction of the arrows.

The connectors of the components are soldered to the copper strips at the bottom of the strip board. This is to ensure that they make proper electrical contact with the copper strips.

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.

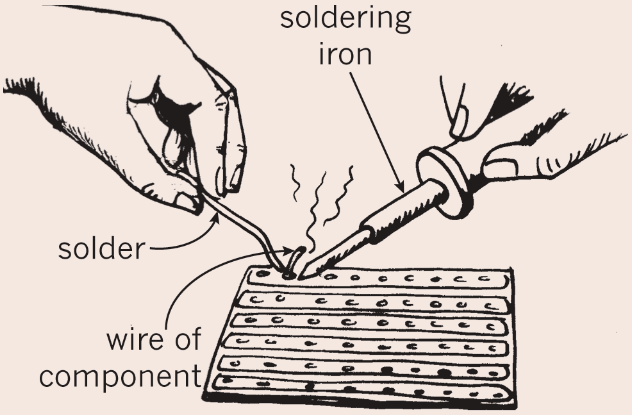


Figure 11: Soldering components onto the back of a strip board

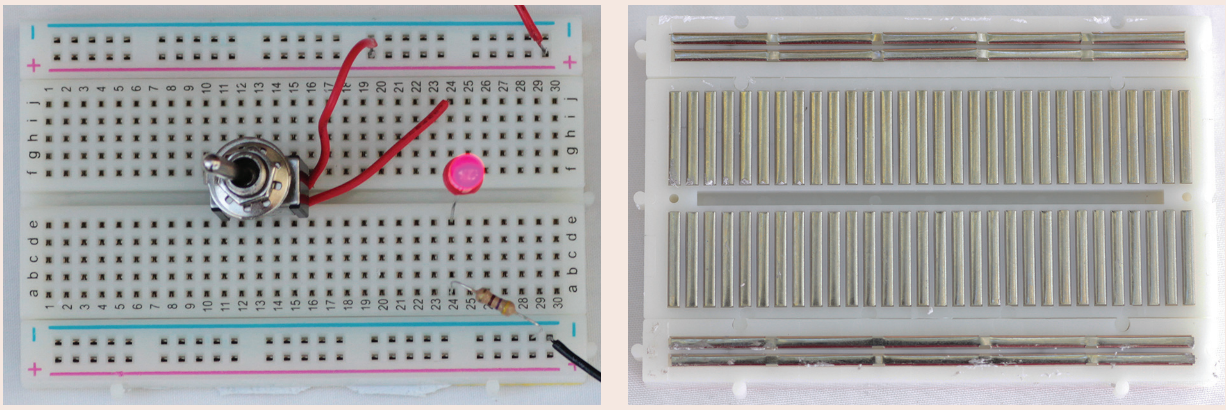


Figure 12: The front and back of a bread board

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.

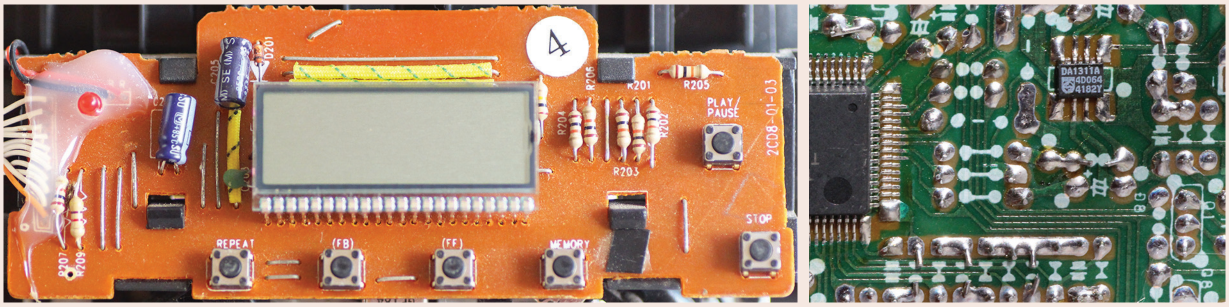


Figure 13: The front and back of a printed circuit board

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

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.

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]

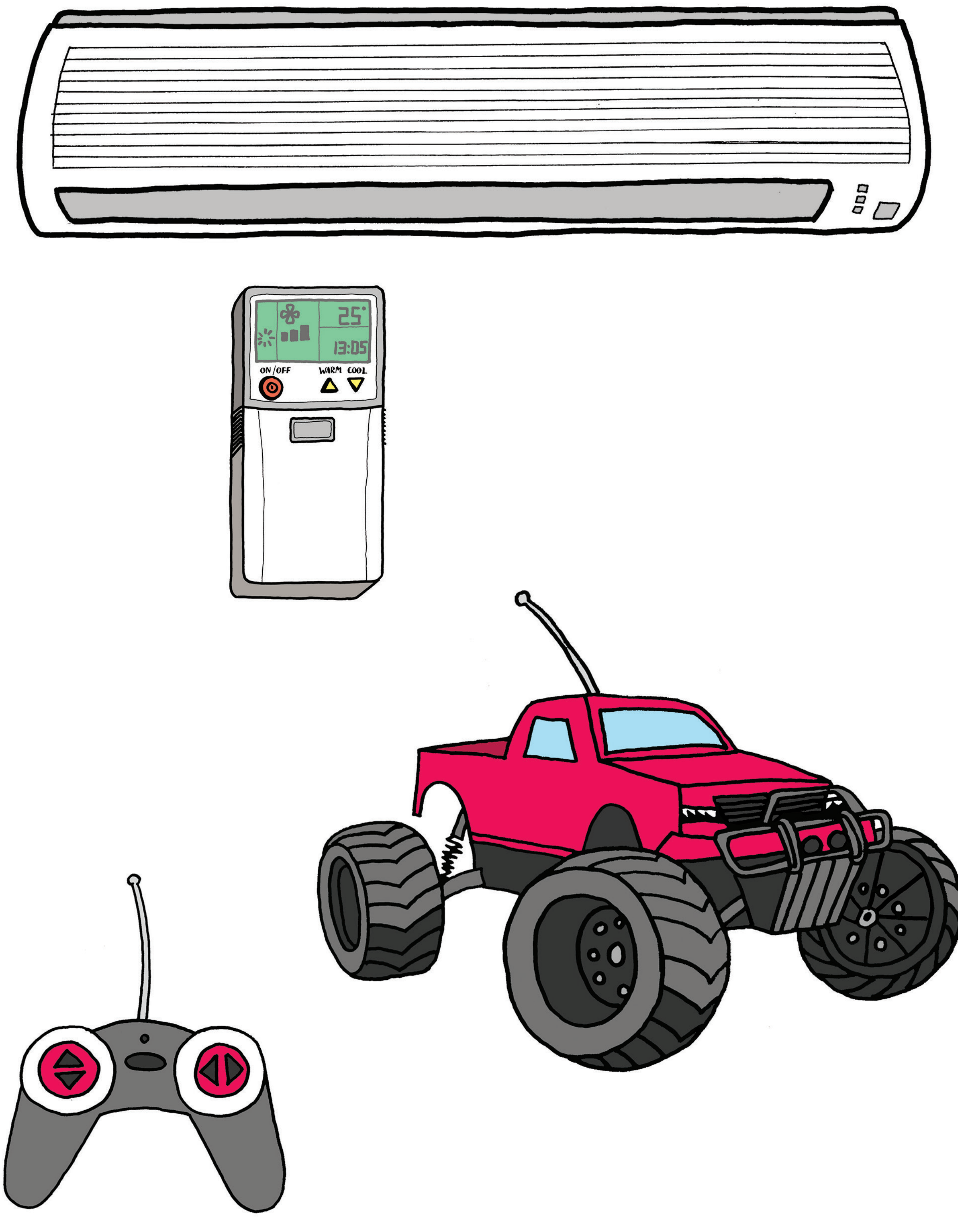
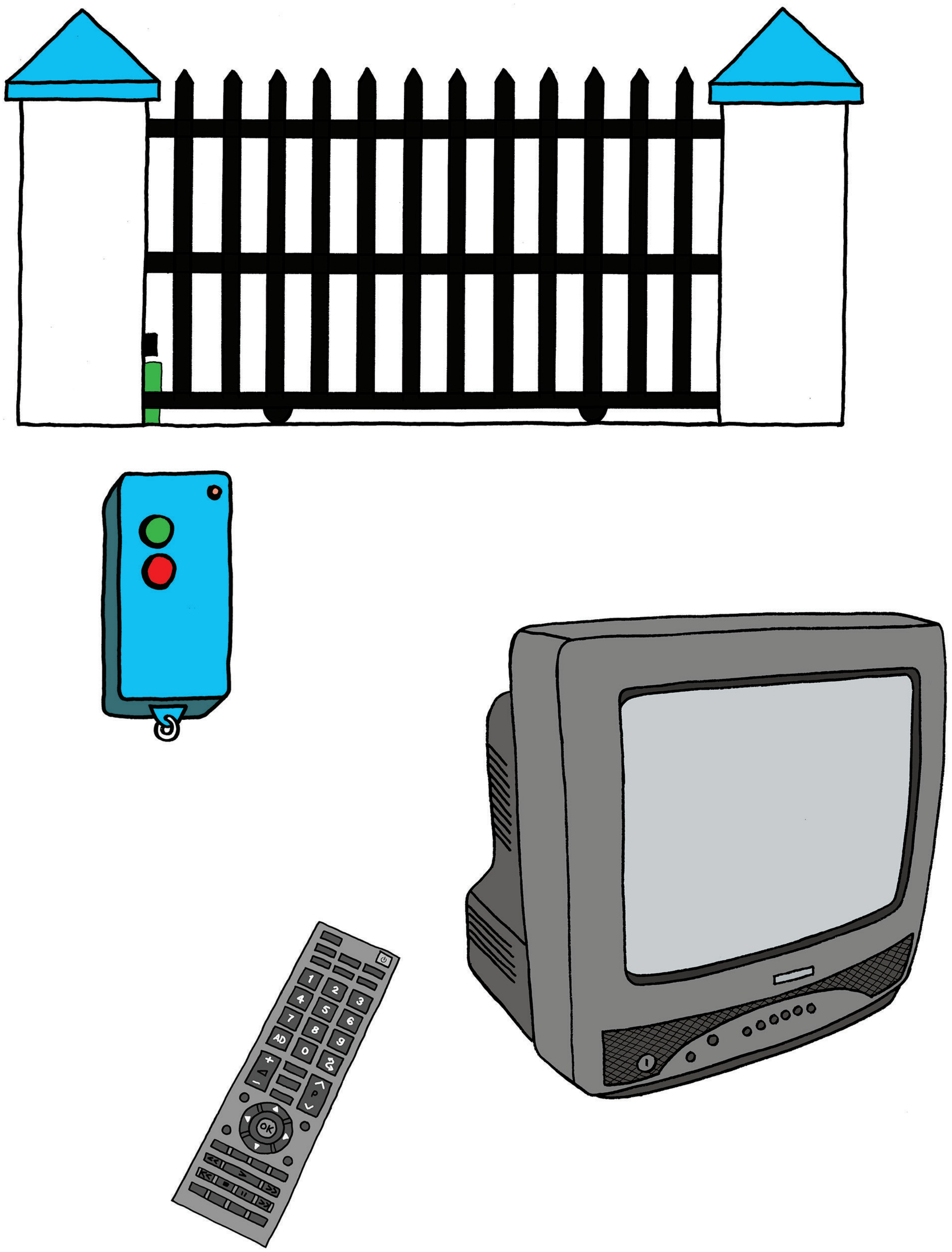


Figure 1: Many everyday devices use electronic control circuits.



Week 1

Situations where electronic circuits control electric circuits (30 minutes)

An **electronic circuit** is different from an electric circuit because it only uses a very small current, and because it uses electronic control devices such as thermistors, LDRs, diodes and transistors.

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

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]
2. Give two examples of situations or applications where electronic circuits are used. [1]
3. Give three examples of situations or applications where electronic circuits and electric circuits are used together. [3]

[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 (infinitely 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.

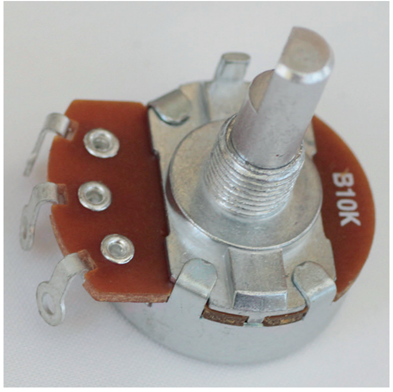


Figure 3: The control knob of a stove plate is connected to a variable resistor. This controls the current through the heating element. The bigger the current, the hotter the plate will be.

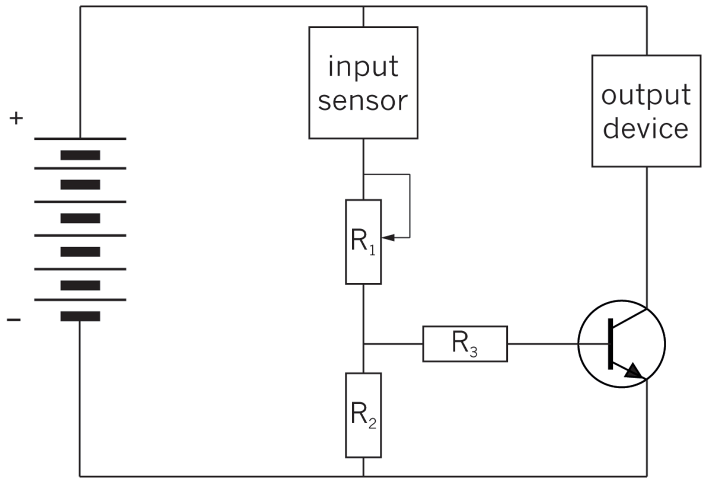


Figure 4: The control circuit that you built in Chapter 15 for a fire alarm

1. Name three input components that you know of.
2. Name three output devices that you know of.
3. Name a device that uses a control knob to set the level of something.

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.

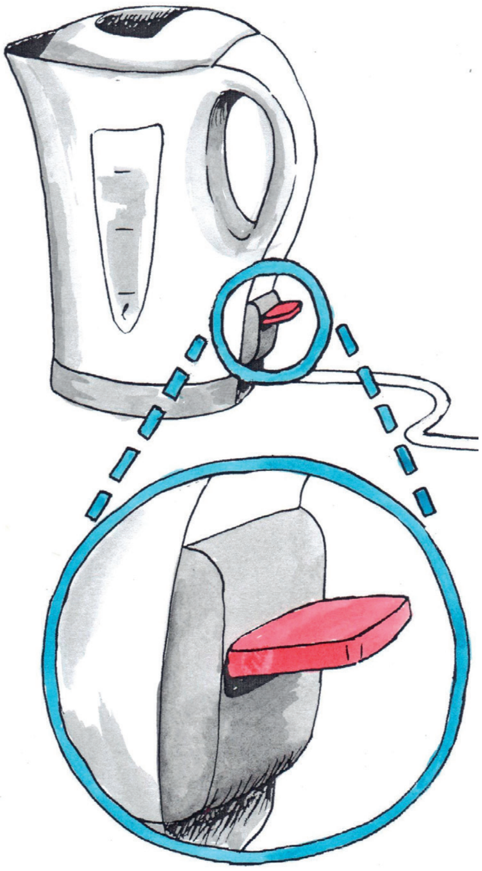


Figure 5

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.

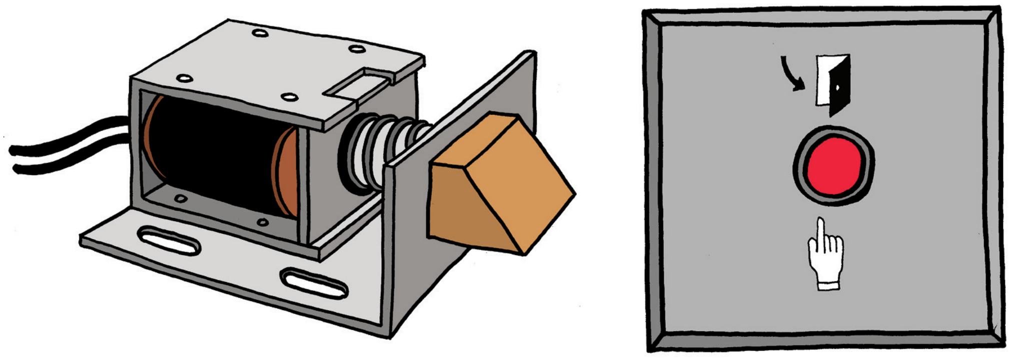


Figure 6: An electric door lock

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".

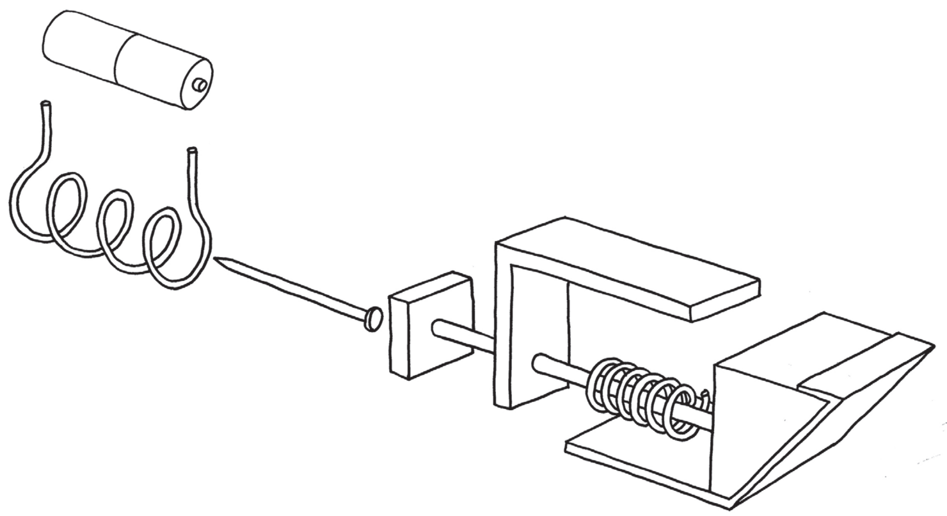


Figure 7: A 3D assembly drawing of the parts inside an electric door lock

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. [2]

Specifications

2. What parts should the device have where the user must press or turn something by hand? [1]
3. Are there part(s) of the device that would sometimes be moved by the user, and other times be moved automatically? [1]
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]
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.
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?

Constraints

7. What property should the container of the device have, for safety reasons? Give the reason(s) as well. [1]
8. Make a time schedule showing how much time you have to design and make the product.

Planning to make

9. Make a list of all the materials you will need.
10. Make a list of all the tools you will need.

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]

[Total: 12]

Week 2

Evaluate as a team: Learn from one another's designs to make a better design together (60 minutes)

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.

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.

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."*

- Once you have several ideas on the table, start thinking about how and whether the different ideas will work or not. Don't talk about "Mary's design" or "Sipho's design". Rather talk about "Design C" or "Design B". Once someone has put a design on the table, you talk about the design. You do not talk about the person. You evaluate the designs. You do not evaluate yourself or someone else.

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."*

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]

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]

[Total: 8]

Make individually: 2D working drawing and 3D drawings of your design (60 minutes)

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]

Look back at Chapter 1 page 7 for an explanation of first-angle orthographic projections.

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. [7]

[Total: 15]

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.*

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.

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.

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.
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.

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)

1. Decide which part of the presentation each of you will do. Write it down. [1]
2. 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. [1]
3. For homework, you should practise your part of the presentation.

[Total: 2]

Giving the presentations (90 minutes)

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]

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.

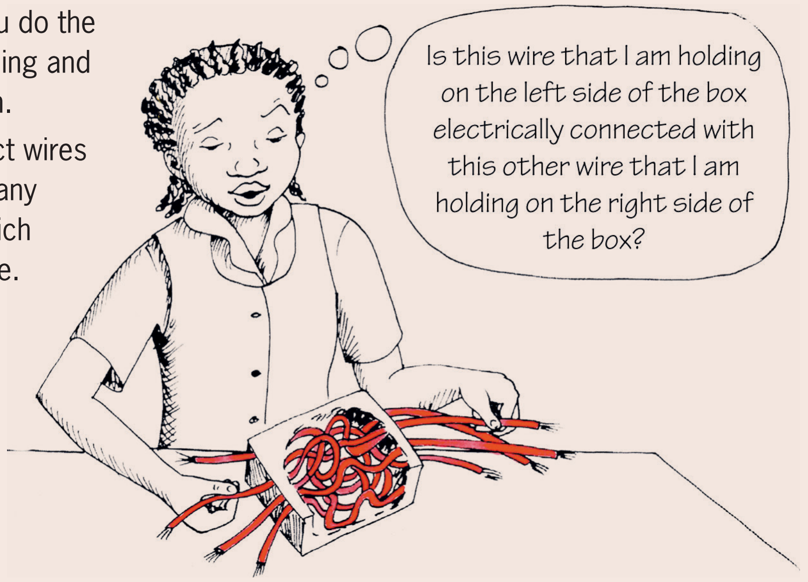


Figure 8

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.

Safety warning:

First switch off the power supply before you do a test such as this one.

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.

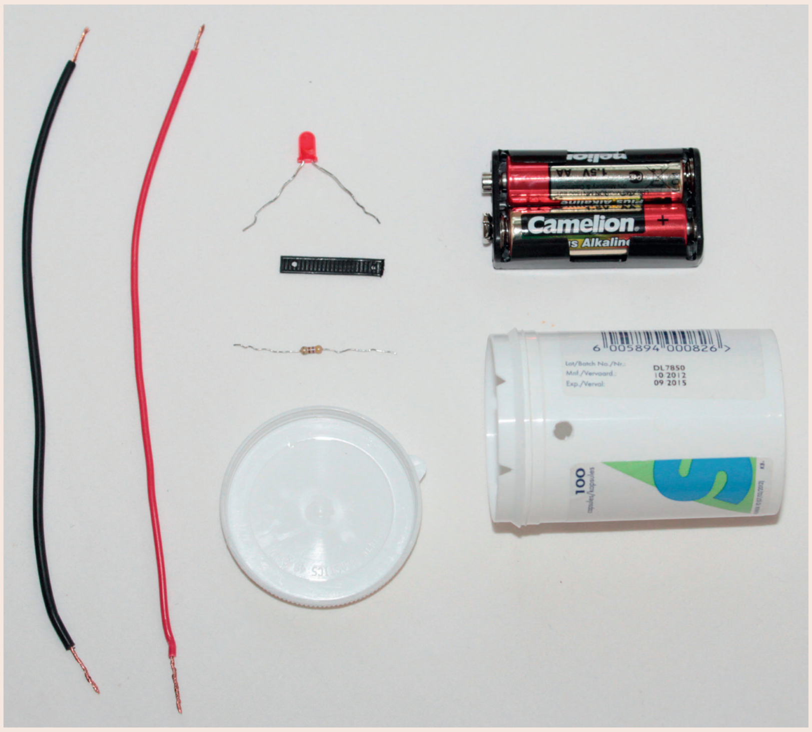


Figure 9

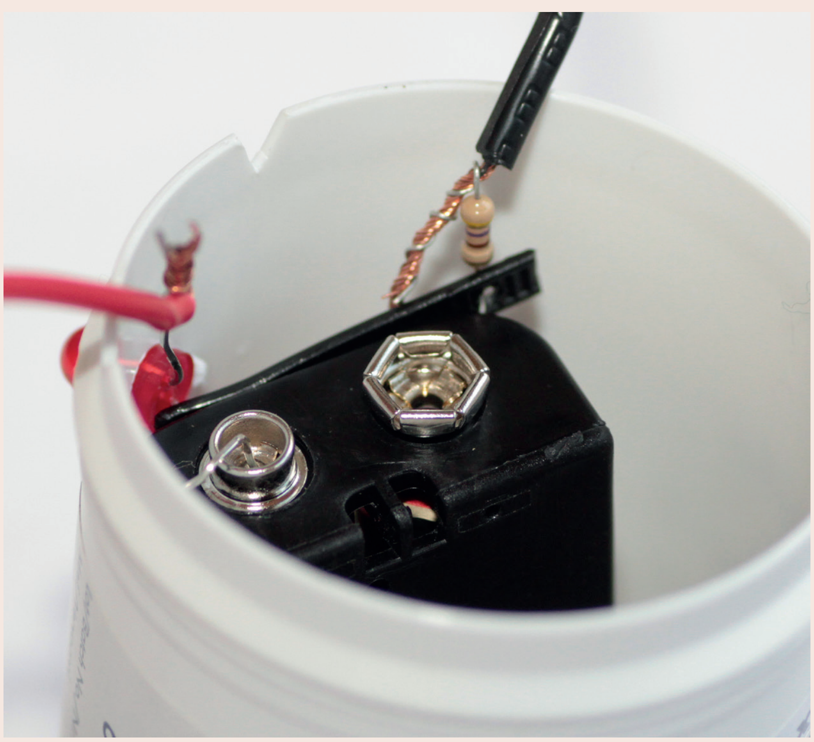


Figure 10

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.

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. Examples are: aluminium, copper, zinc and gold. They are generally more expensive than ferrous metals.

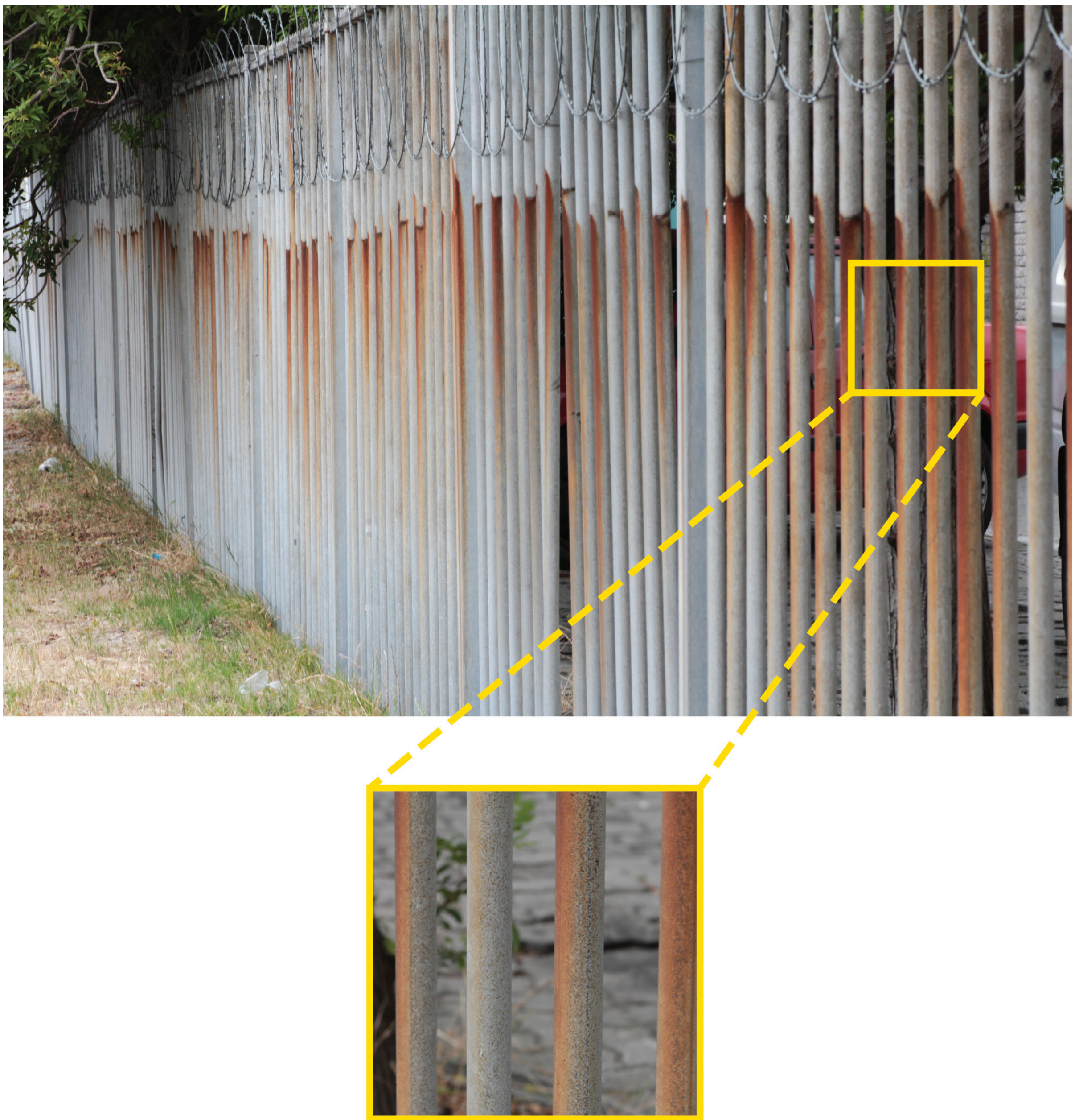
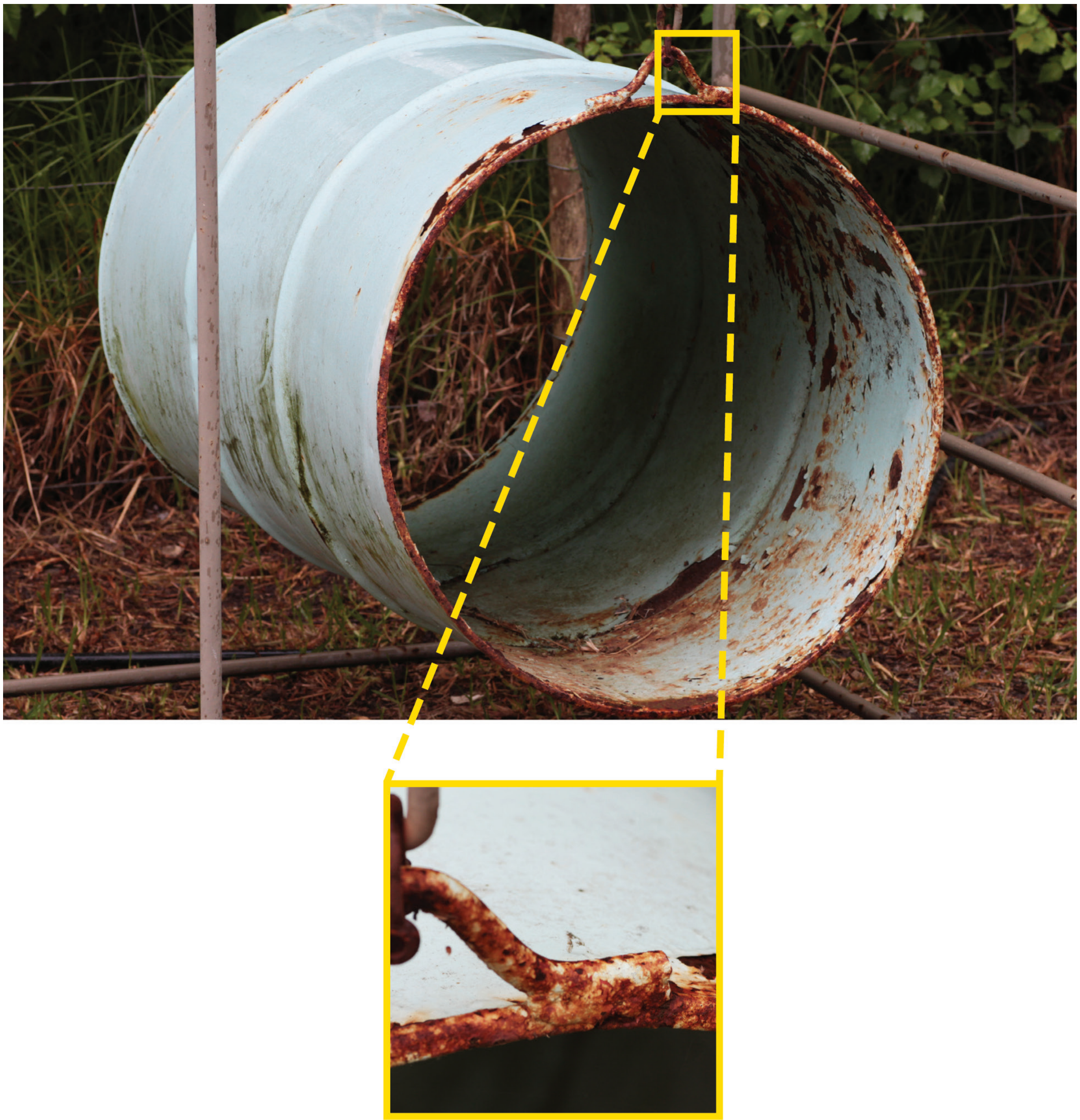


Figure 1: Examples of metal corrosion or rust



17.1 Painting metals

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.

Figure 2: A woman painting a door frame

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.

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.

Figure 4: Wire brush

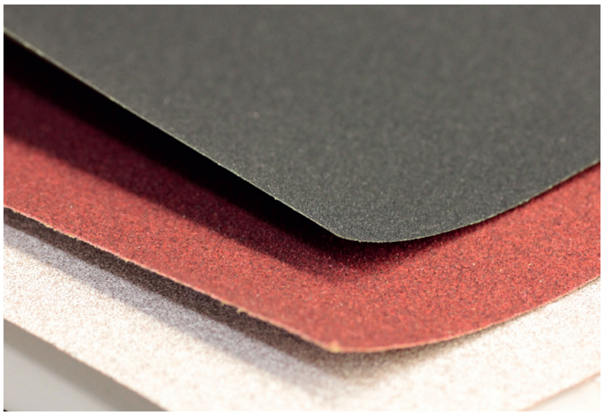


Figure 5: Sandpaper

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 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

Answer the questions below:

1. What materials do you need to use when painting metals?
2. Write a brief outline explaining why it is important to use a primer coat when painting metals.
3. In your own words, briefly explain why boats and ships have to be painted on a regular basis.
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.

17.2 Galvanising

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.

Molten: when metal or rock is in liquid form because of very high temperature.

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.

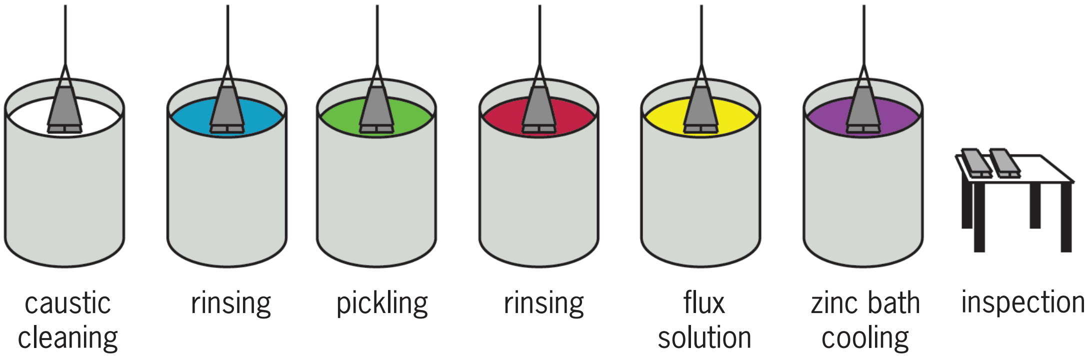


Figure 7: The processes that are followed when hot-dip galvanising metal

What have you learnt?

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.
2. What metal is used to coat an object when galvanising it?
3. What are the benefits of hot-dip galvanisation?
4. What are the disadvantages of hot-dip galvanisation?
5. Name two examples of galvanised products.

17.3 Electroplating

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.

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 ormed. The copper ion and sulfate ion can move separately in the solution.

Let us us say you want to plate a metal object with copper. Figures 8 and 9 show 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.

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...

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.

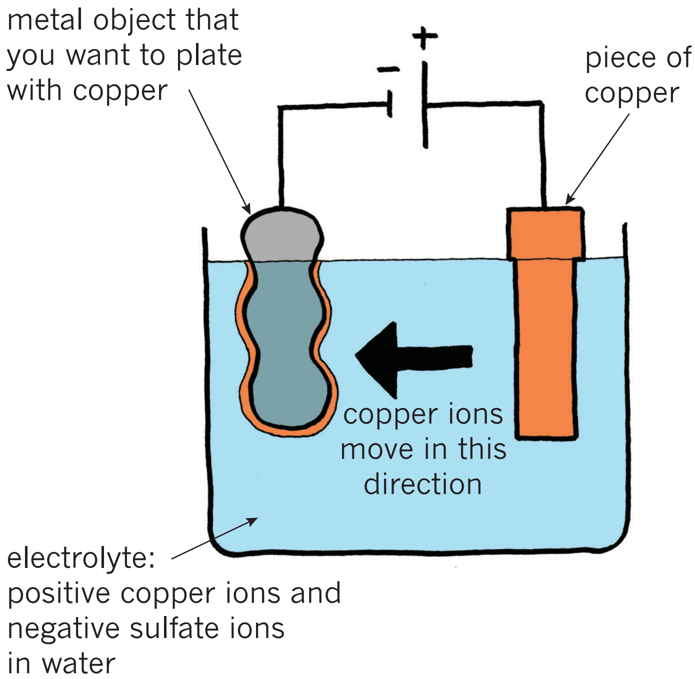


Figure 9: How an electroplating system is assembled

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.

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.

Work in a group to investigate corrosion

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?
2. How long does it take for the metal to start corroding?
3. Is there a difference in the level of corrosion by the end of the week compared to the beginning of the week?
4. Why doesn't the other piece of metal corrode?

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.

Chapter 18
Preserving food

In the last chapter, you learnt about preserving metals by painting, galvanising and electroplating them. In this chapter, you will learn about different ways of preserving food, namely storing grain, pickling, drying and salting.

Figure 1

Figure 2


TOMATOES
Whole Peeled
HOME
400g net • 224g drained •
BRILLIANT!
CRISPY
Oven Chips
MANGO ATCHAR
Hot
HOME

Figure 3

18.1 Storing grain

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.

A **staple food** is a food that is eaten most often by a group of people and forms the largest part of their diet.

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.

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 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.

Figure 5: Modern industrial grain silos

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.

Figure 6: Harvesting on an 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 7: Wheat before harvesting, threshing and winnowing

Figure 8: Grain separated from the chaff

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.

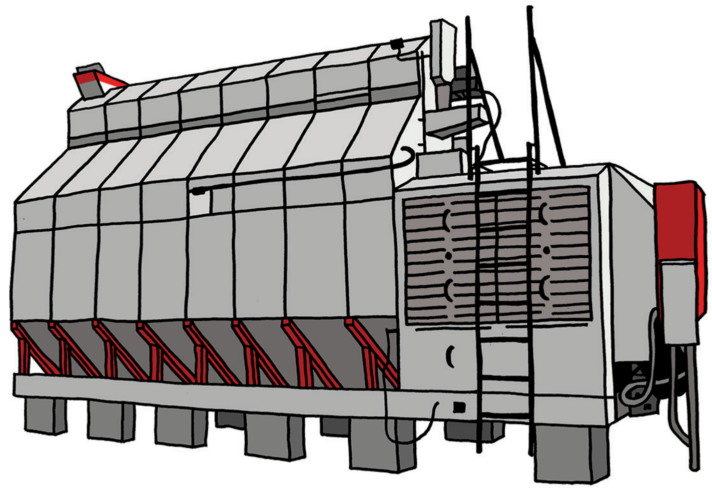


Figure 9: A modern grain-drying machine

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.

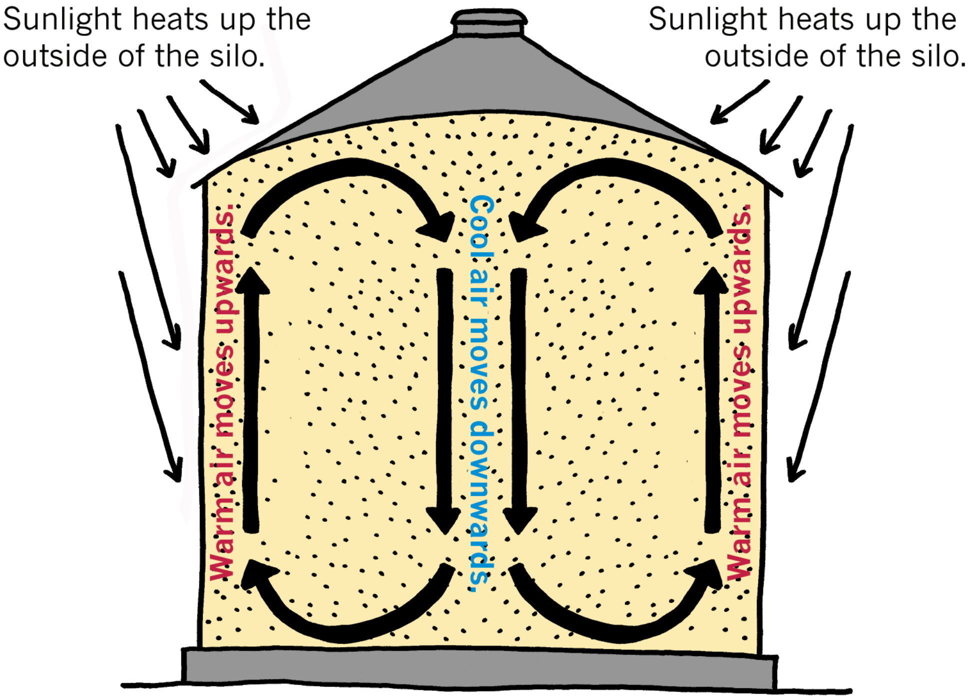


Figure 10: Schematic cross section of the air movement in a grain silo

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.

Larvae: the stage of an insect's life after it's hatched from the egg, but before it has changed into a mature insect.

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.

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.

South Africa has a few favourite pickles. Achaar is a traditional pickle that was brought to our country by the Malay people more than a century ago. It can be eaten as a side dish or with curry, and is widely enjoyed, especially in the Western Cape. Achaar is made from vegetables such as cauliflower, carrots, cabbage and beans, that have been finely cut and are mixed together with mustard, turmeric, coriander, vinegar and sugar.

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.

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.

Vegetables and fish are the two most common food types that are pickled. 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.

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.
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.
3. Name and briefly discuss three advantages and three disadvantages of this method of food preservation.

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.

18.3 Drying and salting

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 word **biltong** is from the Dutch "bil" (rump) and "tong" (strip or tongue).

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.

Figure 12: Biltong

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.

Successful preservation of food depends on inhibiting the growth of micro-organisms such as bacteria, and preventing access to insects.

Answer the following questions:

1. Explain what you understand about the purpose of food preservation.
2. Explain the process of drying food for preservation purposes.
3. Briefly discuss why salt is so important in the drying method of preserving food.
4. In South Africa, there are many cultures and methods of food preservation. Name one culture and food type they preserve. Briefly explain the process this culture follows in preserving this food type.

Dry your own food

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.

Before you touch any food, wash your hands thoroughly to remove dirt and bacteria.

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.
2. List all the steps you took and explain why you did them.
3. What was the effect of the weather conditions on your drying process?
4. Indicate whether the results of this experiment were a success or not. Motivate your answer.

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

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.

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.

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.

The word **plastic** was originally used to describe a property that materials such as rubber have, namely that they can be given a new shape. Most synthetic polymers have this property, and therefore they were given the name "plastics".

Molecules are made of atoms that join together. You know from Natural Sciences that molecules are much too small to see, even with a microscope.

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

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.

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.

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.

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.

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.

To **recycle** means to process waste materials to make new products from it.

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.

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
1 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
2 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
3 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
4 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
5 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

6 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
7 OTHER other type of plastic, or more than one type of plastic used in the same product	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?

Identify the types of plastic on the table

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:

	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?
3. Why do manufacturers put recycling codes on the bottom of containers?
4. Why do they not use the same type of plastic for everything that can be manufactured?
5. Think of three objects that could *not* be made of plastic.

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

There are two steps to making plastic bottles, injection moulding and blow moulding.

Step 1: Injection moulding to make preforms from pellets

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.

Figure 1: A preform of a plastic bottle

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

Copy Figure 2 roughly (or use the photocopy that your teacher gives you), and answer the following questions.

1. Find the mould and label it.
2. 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.
3. 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?

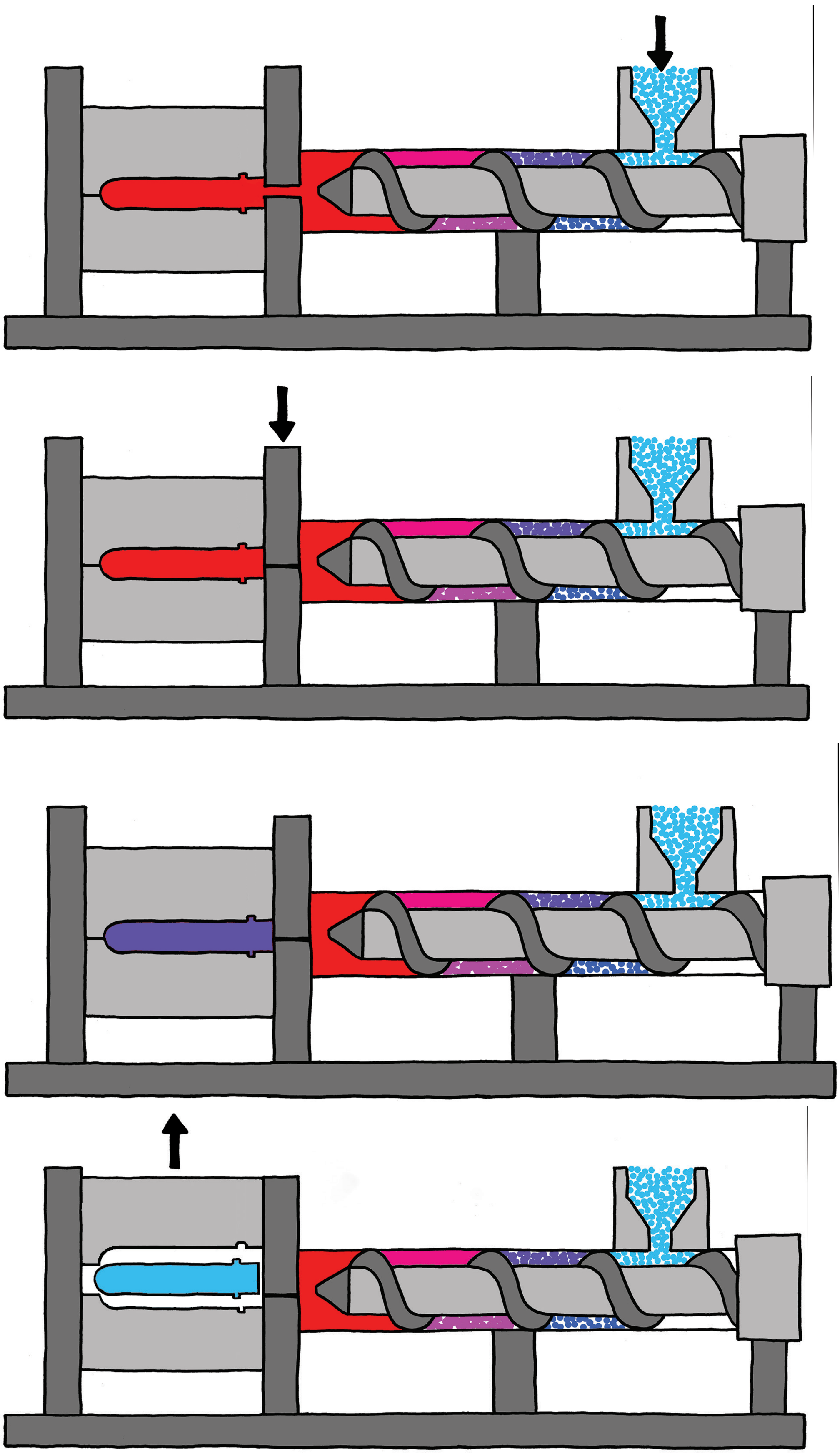


Figure 2: The injection-moulding process

Step 2: Blow moulding to shape preforms into bottles

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.

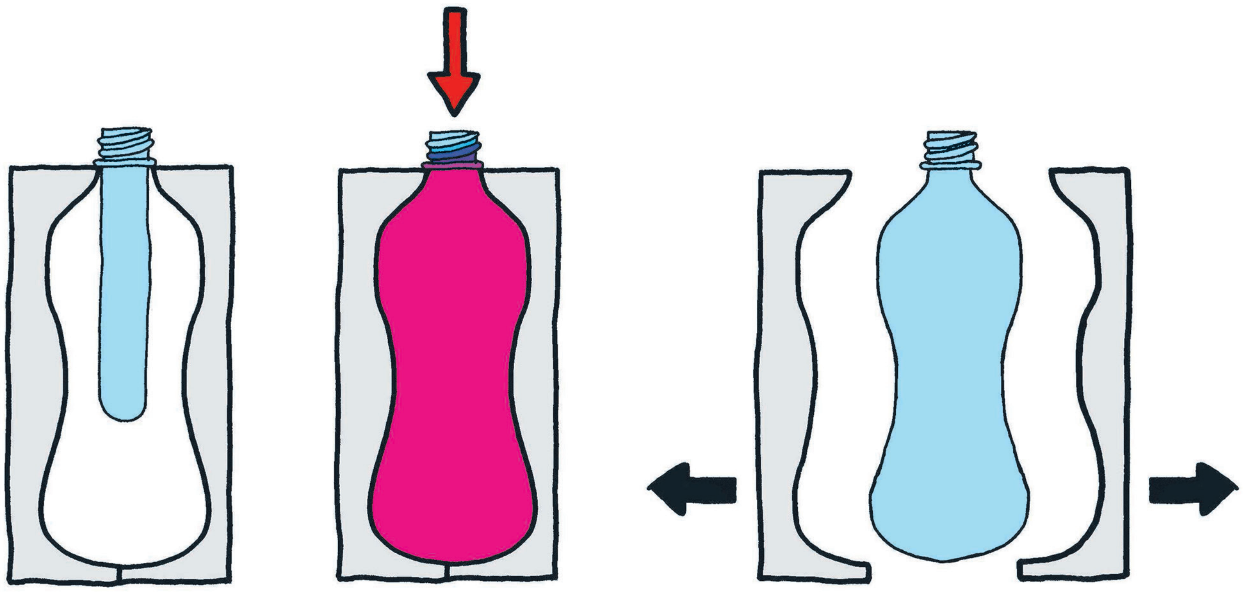


Figure 3: Blow-moulding of a preform to make a plastic bottle

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

1. Why will all the different-shaped bottles fit the same cap?

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

1. Why should plastics be separated into different types before they can be recycled?
2. How do the recycling codes on the plastic containers help to sort them?
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.
4. Are all the plastic containers in the bin clean? Is this important?
5. Waste plastic bottles and other plastic containers take up a lot of space. How can this problem be minimised?
6. Name four things that need to be done to plastic waste before it will be suitable to turn into new products.
7. Copy and complete the systems diagram in Figure 4 on the next page 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.

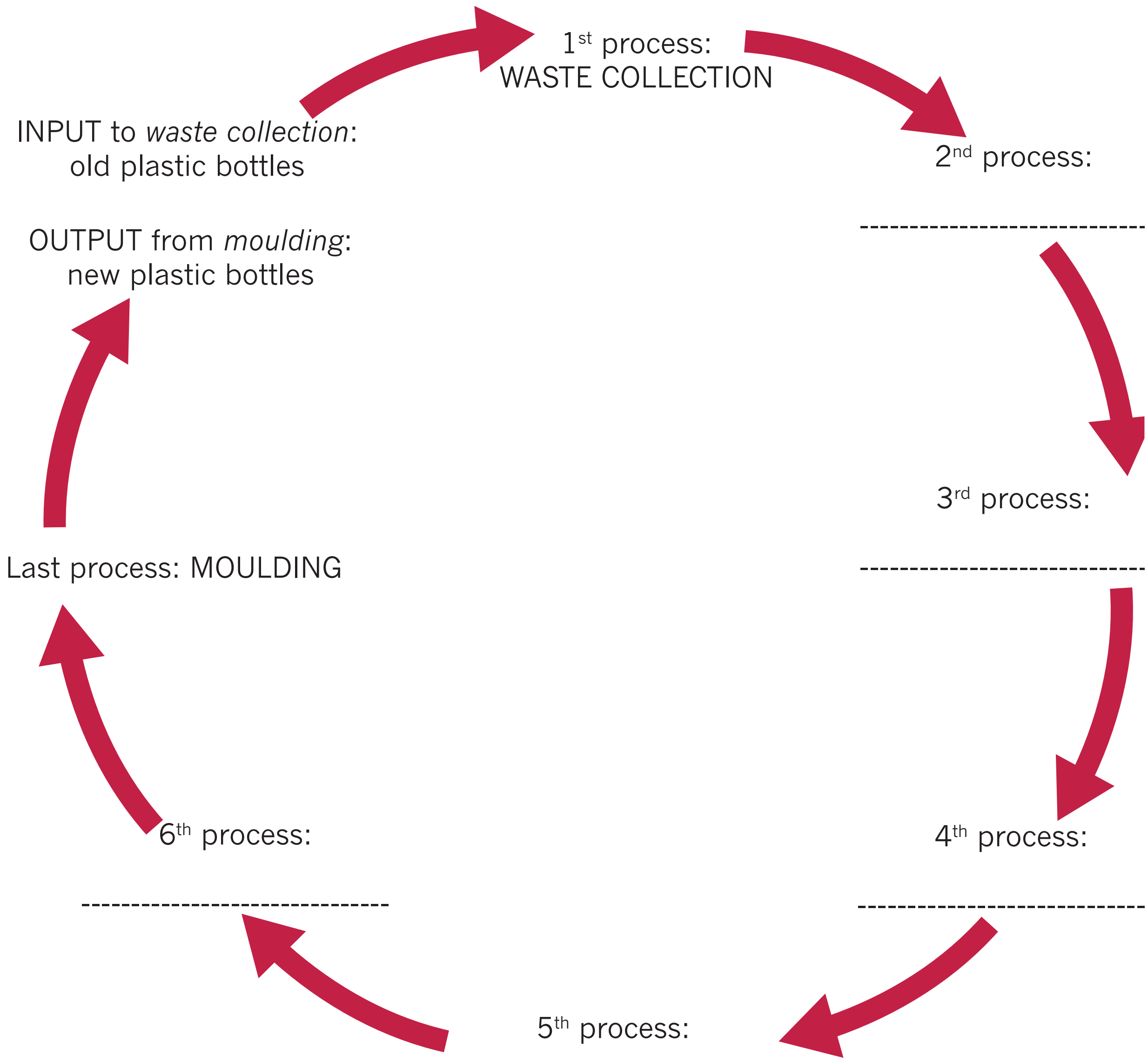


Figure 4: Systems diagram of the plastic bottle recycling process

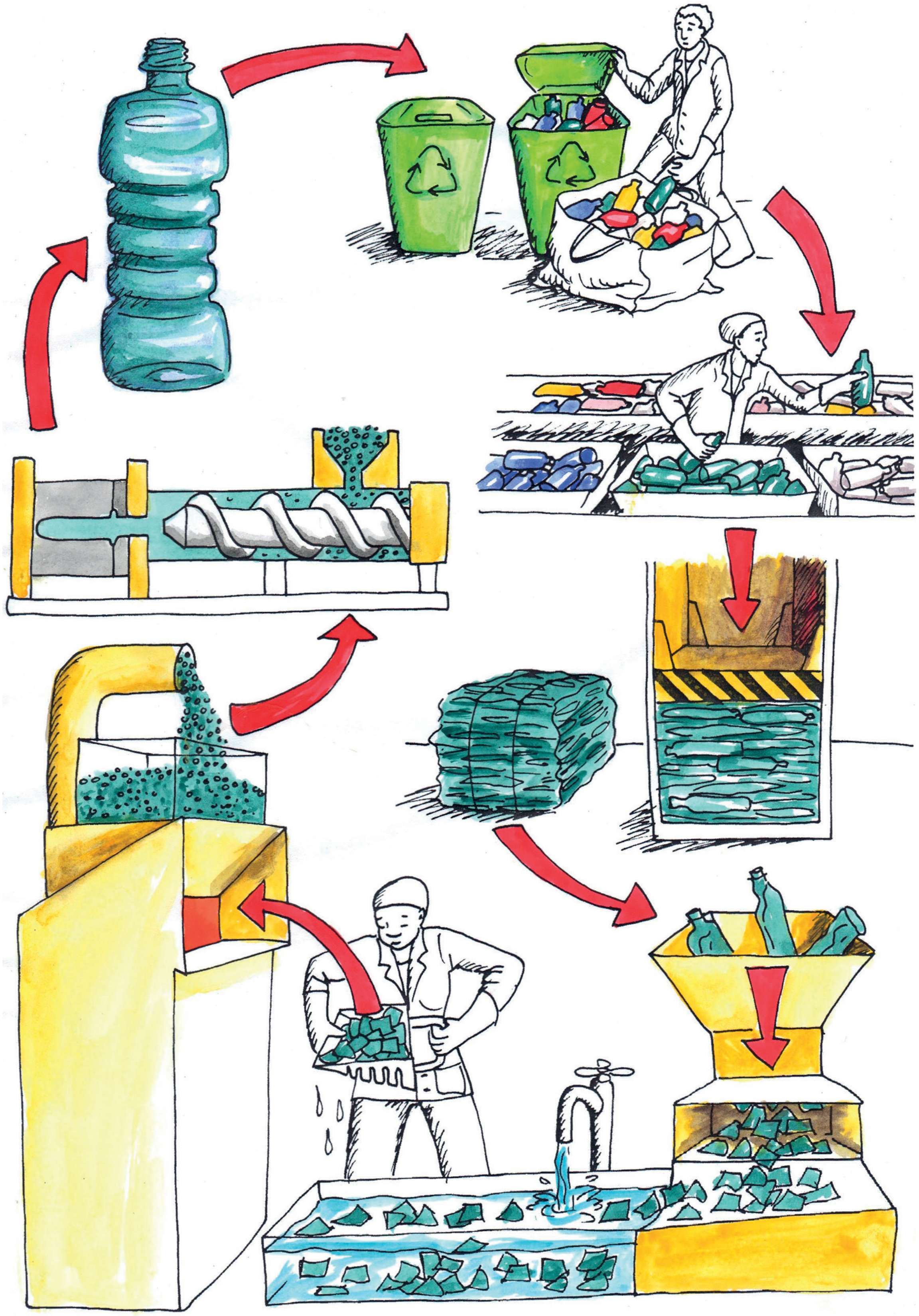


Figure 5: The steps to turn waste plastic into new plastic products

20.3 What have you learnt?

1. What is the raw material for the bottles in this process?
2. How can consumers and house-owners make it easier for recyclers to process plastic products to make new bottles?
3. A manufacturer can buy one type of preform and then make different-shaped bottles. How can this be done?
4. Which type of moulding do you think is used to make solid plastic chairs?
5. What are the differences between injection moulding and blow moulding?

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.

Chapter 21 PAT
Reduce, re-use and re-cycle: Working with plastics

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.

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]

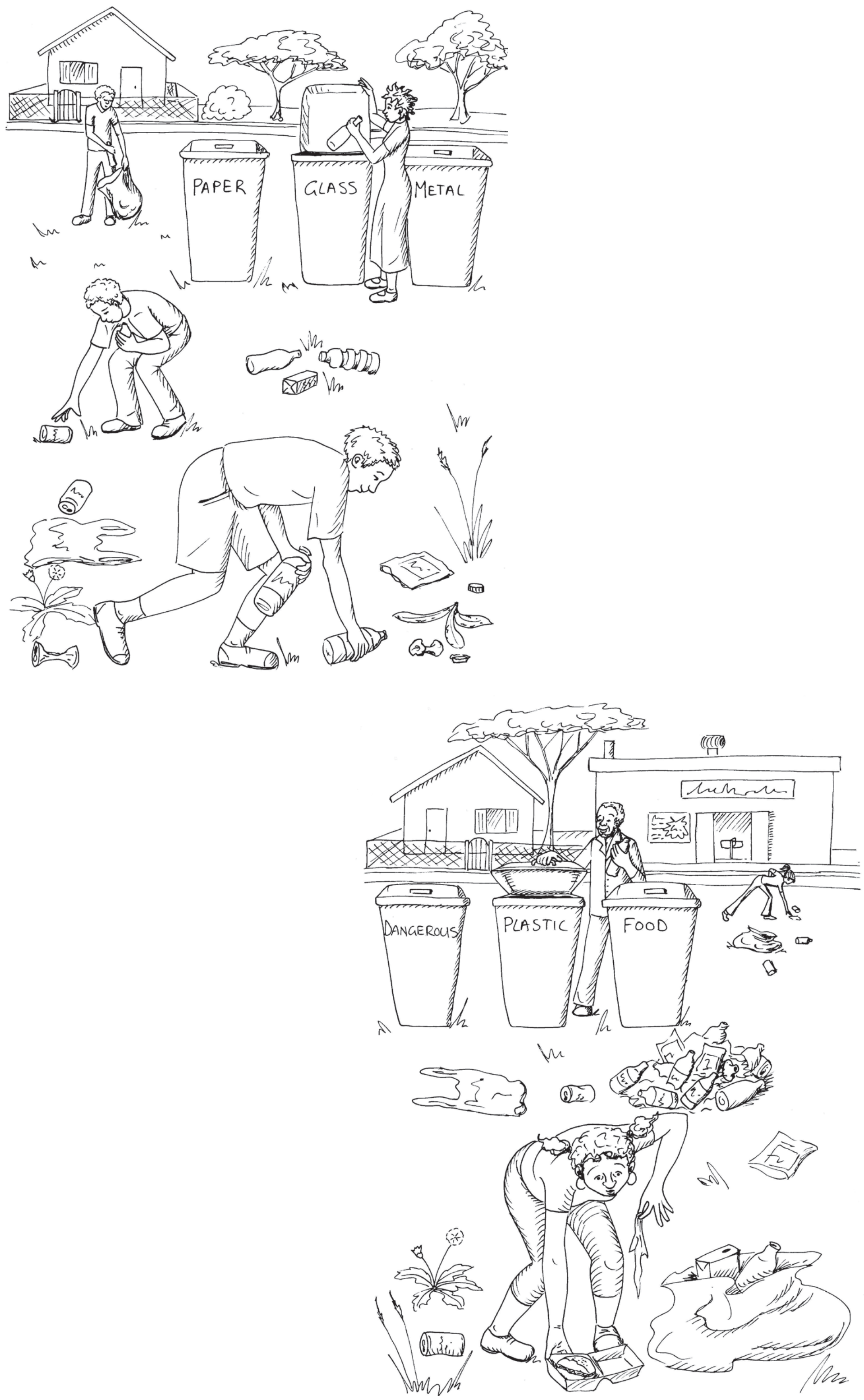


Figure 1: Improving your environment by picking up and sorting waste

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.

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 "braai-skottels" in which they can make fire and barbeque food outside.

Figure 2: A "braai-skottel" made from an oil tank cut through the middle

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 f*actory where new plastic is made from the old plastic. At a recycling factory, the old plastic is washed and shredded into very small pieces.

You learnt in the previous chapter how plastic pellets are moulded into new shapes.

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.

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)

1. 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

2. 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	
clay floor tiles	
windows	
paint	
chair backs	
light bulbs	
bottles for dish-washing soap	
sponges	
the outside of a TV or radio	

3. 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.

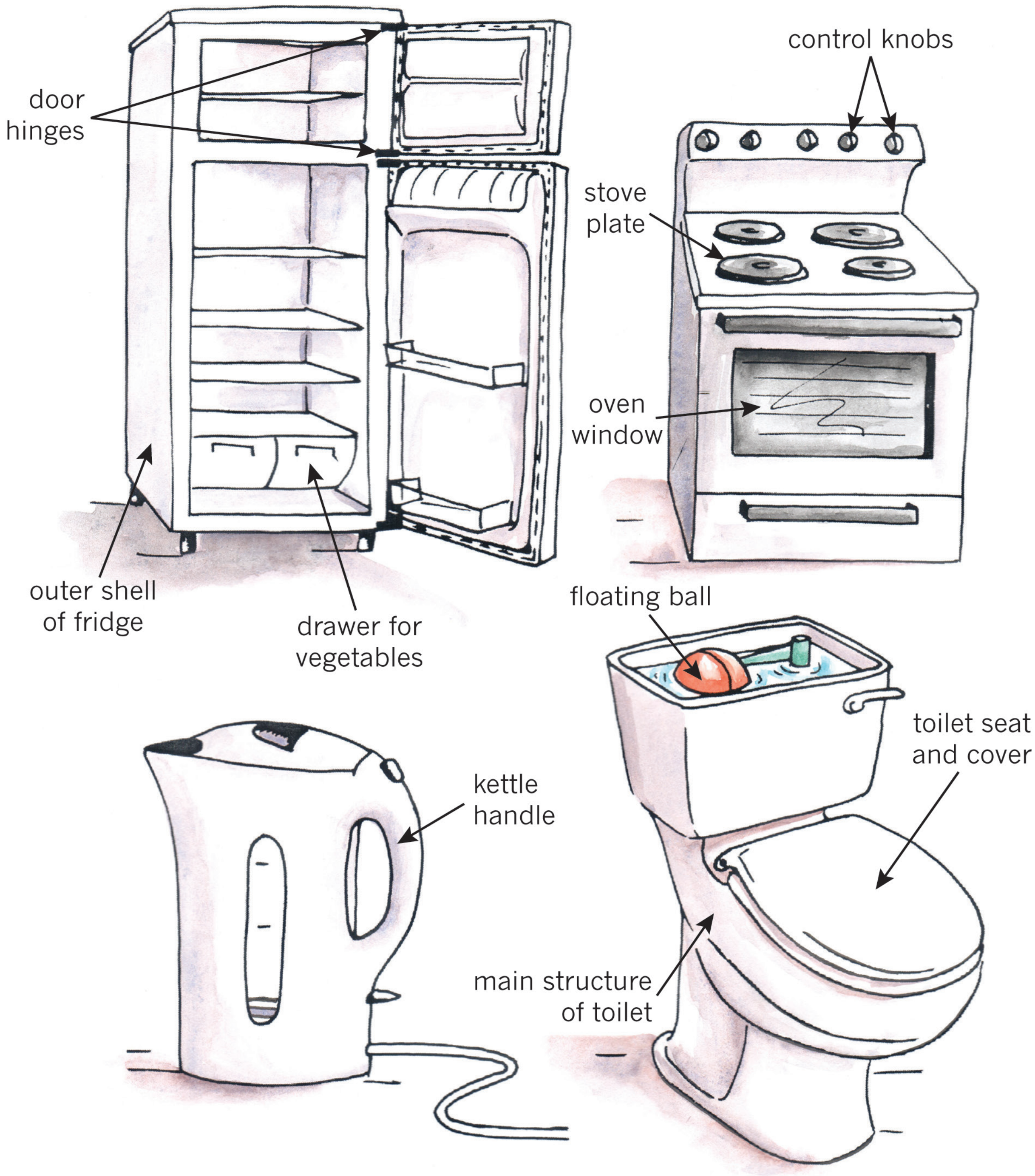


Figure 3: Different parts of typical household appliances

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.

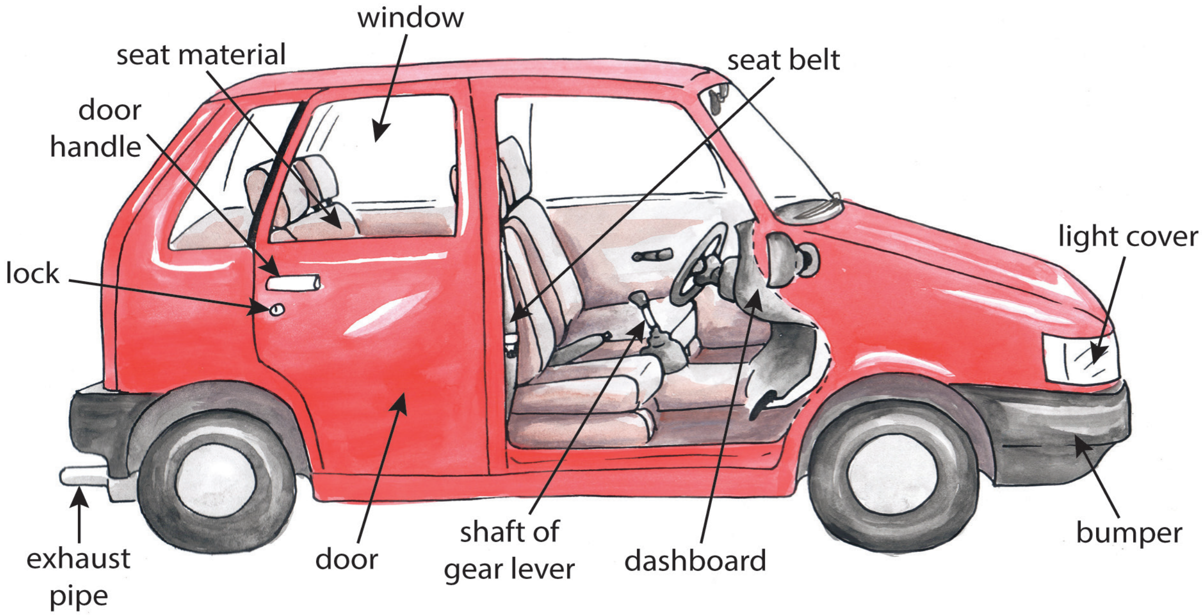


Figure 4: Different parts of a motor car

5. How can you test whether a material is plastic or metal?
   Hints: Think about hardness, strength, magnetism, sound, heat and fire.

Safety warning:
Burning plastic can start a fire and release poisonous gases. Molten plastic can cause serious burn wounds.

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

1. What is the purpose of the product? [½]
2. How does this reduce the amount of work that somebody has to do? [½]

Figure 5

Scenario B

Figure 6

3. What is the purpose of the product? [½]
4. Can this product save you money? How? [½]

Scenario C

Figure 7

5. What is the purpose of the product? [½]
6. Can this product save you money or time? How? [½]

Scenario D

Figure 8

7. What is the purpose of these products? [½]
8. Can this product save you money or time? How? [½]

[Total: 4]

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]
2. Answer the following questions to identify the *specifications* for your design:
   (a) What is the purpose of your product? [½]
   (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]
   (c) Should your product be supported in some way to stay upright? How? [½]
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]
   (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]
   (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]

[Total: 4]

Week 2

Initial rough design sketches (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.

The word **innovative** comes from the word "new". An innovative solution to a problem is a solution that nobody else thought of before.

Show notes and labels on your sketches to help explain your ideas. [10]

Final orthographic drawing (30 minutes)

Choose your final design from your rough sketches. Then draw your product to scale using first angle orthographic projection. Show dimensions. [15]

Practise marking out, cutting and making holes in plastic (60 minutes)

You need the following materials for this activity:

- two or more old plastic bottles that have been cleaned,
- a marker pen or “koki” 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.

Figure 9: Making a hole in the bottle

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.

Once the hole is big enough to insert one blade of the pair of scissors, start cutting with the scissors, as shown in Figure 10.

Sandpaper the sharp edges of the hole in the bottle smooth, so that it can’t cut you.

Figure 10: Cutting the bottle

Week 3

Make the product you designed (90 minutes)

You can make more sketches if you realise that you need to change some things about your design. [25]

What have you learnt during this term? (30 minutes)

1. What metal is used on the surface of a sheet of corrugated iron to protect it from corrosion? [1]
2. Give some examples of steel products that have been galvanised. [1]
3. Painting and galvanising are both methods to stop steel from corroding. Each method coats the steel with another substance. What is the difference between the two methods? [4]
4. How would you protect a steel bridge from rusting? Which of the three processes that you have learnt about in this term do you think would be most appropriate for this task and why? [2]
5. Give two examples of food that is preserved by the process of drying. [1]
6. Why do manufacturers print a symbol like the one in Figure 11 on the bottom of plastic products? [1]

Figure 11

7. Why do designers prefer to use plastics instead of steel for certain parts of cars? Give four reasons. [2]

[Total: 12]

Make a record of the term's work

Put all the written work and drawings that you did in this term in a file, neatly and in the correct order. Your teacher will evaluate your file.

Make sure your work pages contain headings to show for which chapters and sections the work was done.

Your file should contain the following:

- answers to the questions about painting, galvanising and electroplating,
- your notes about what you observed when you electroplated a metal object,
- answers to the questions about storing grain, pickling food and drying food to preserve it,
- your notes about how you dried some food to preserve it,
- your records of the kinds of plastic that the class collected and sorted by the codes on the containers,
- a systems diagram for recycling plastic and producing pellets for re-manufacture,
- the investigation of plastics in a car – notes you made,
- the investigation of plastics in a house – notes you made,
- your sketches and notes of ideas for a product to be made from old plastic bottles, and
- your orthographic drawing of the product.

Also hand in the product that you designed and made by reusing old plastic bottles. You teacher will give this back to you after evaluating it.