TECHNOLOGY

Grade 9

Book 1

CAPS

Learner Book

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TERM 1

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.

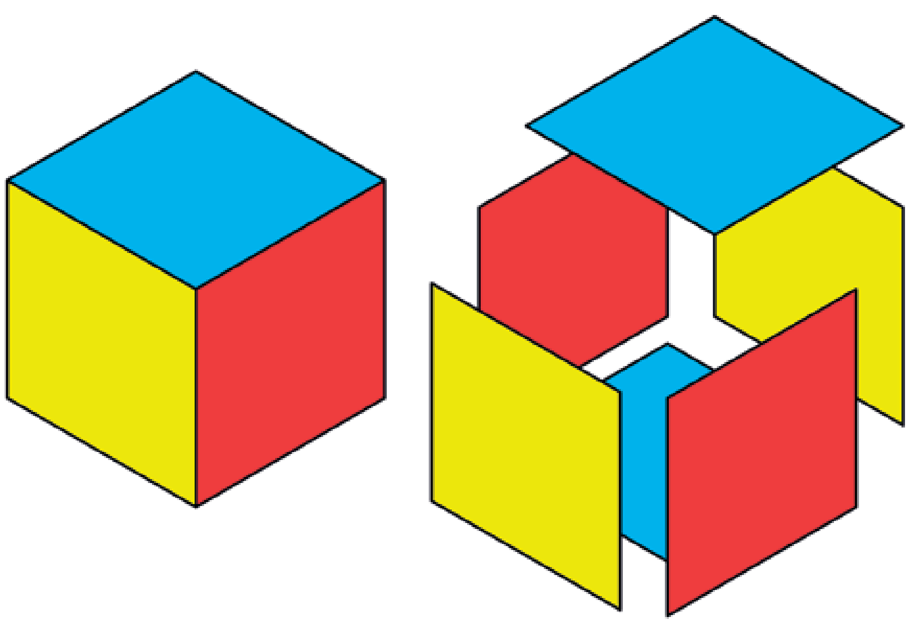


Figure 1

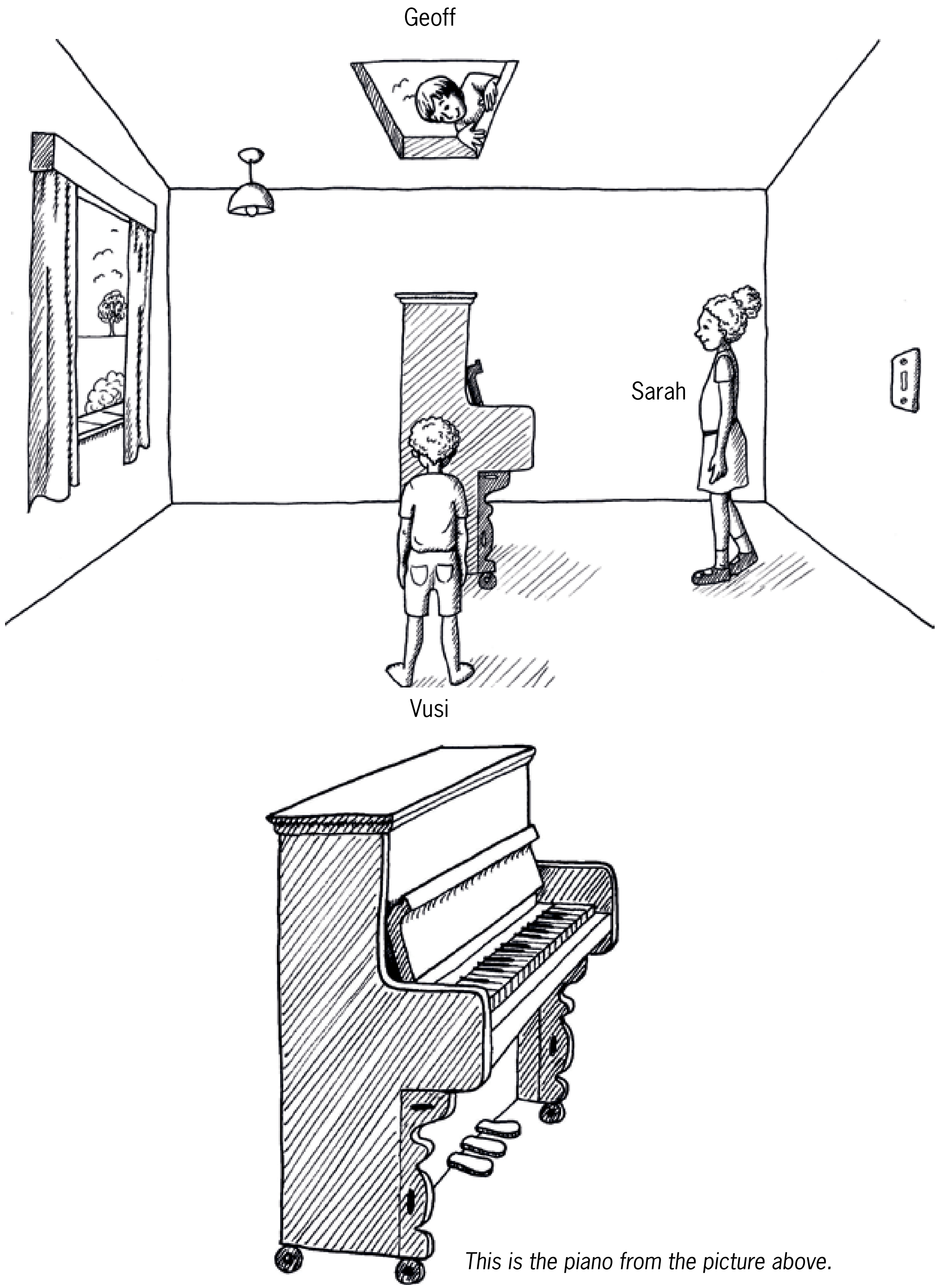
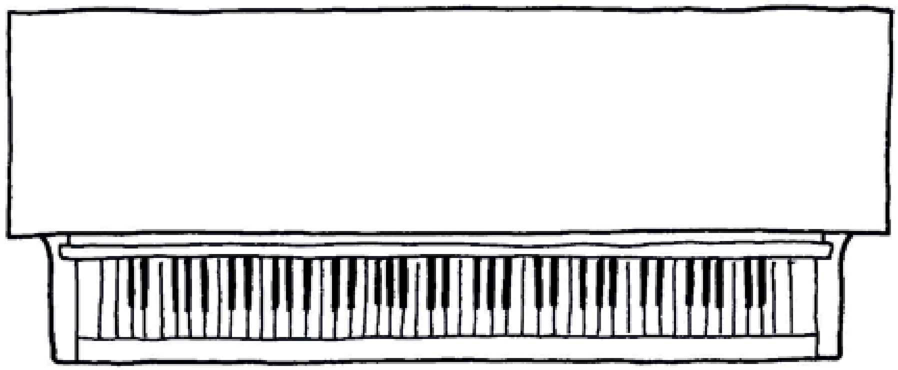
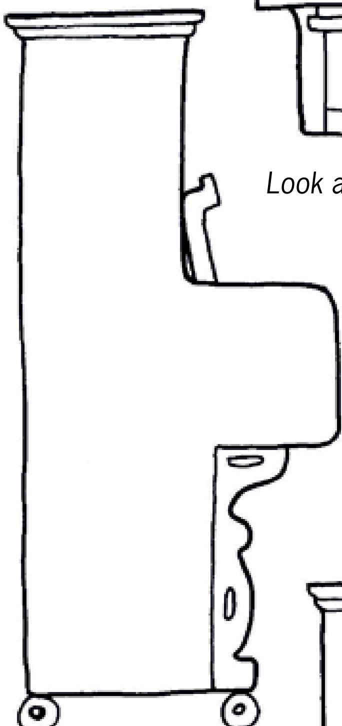


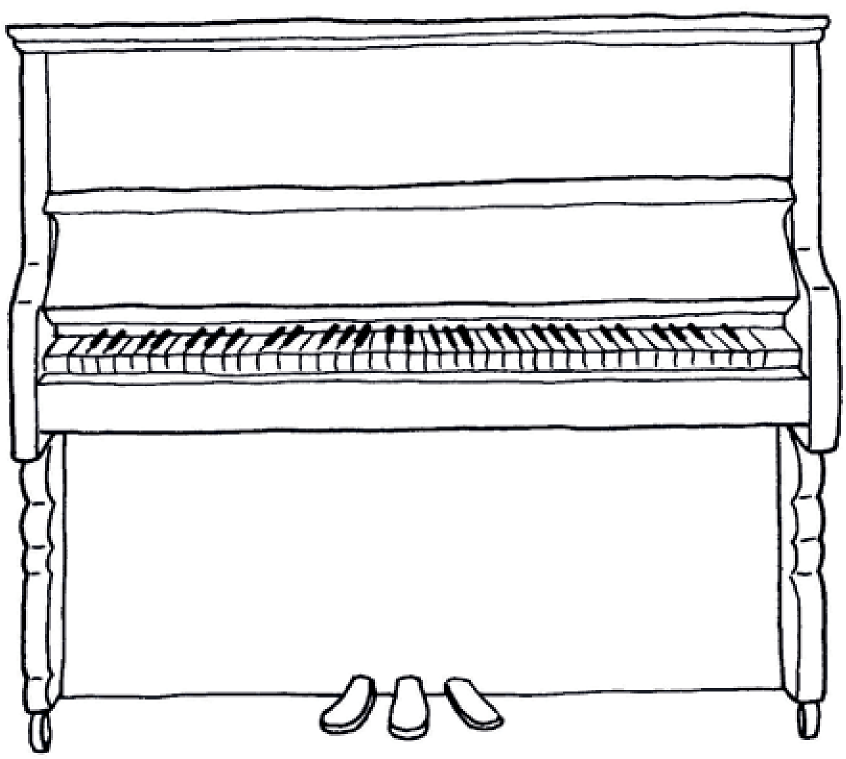
Figure 2



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

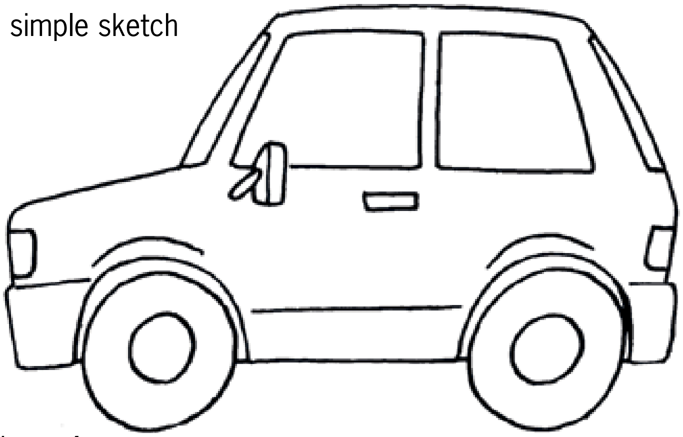


Figure 4

isometric sketch

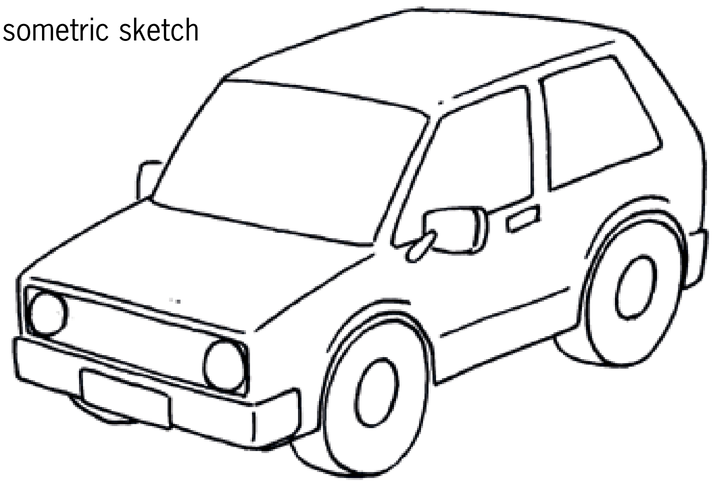


Figure 5

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

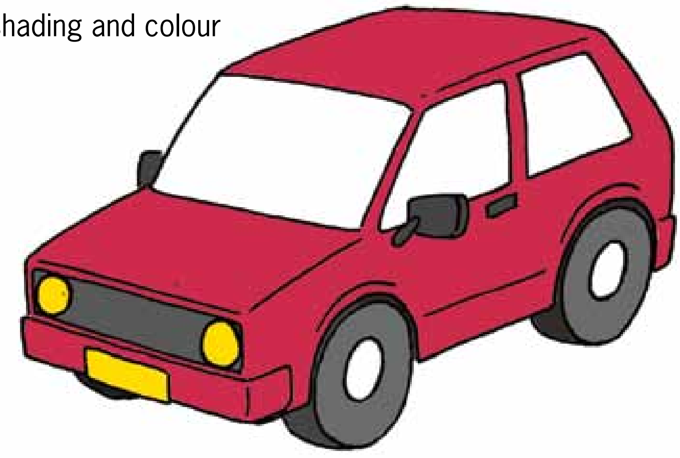


Figure 6

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.

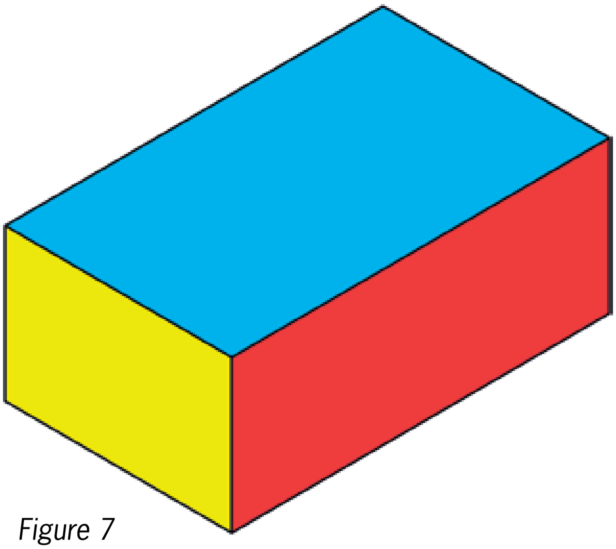


Figure 7

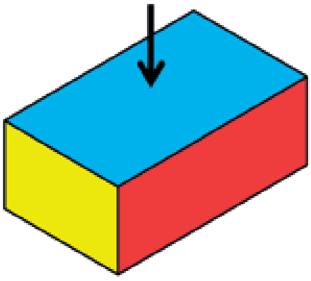


Figure 8

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.

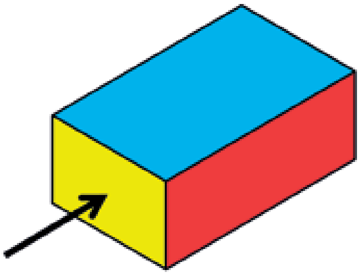


Figure 10

This is called a **side view**.

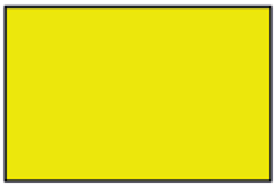


Figure 11

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

This is also called a **side view**.

It can also be called the **front view**.

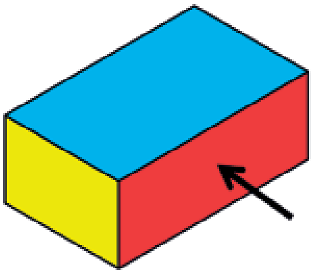


Figure 12

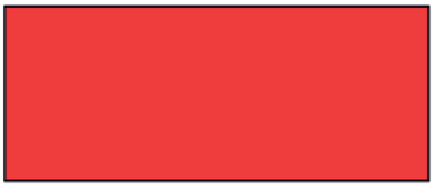


Figure 13

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**.

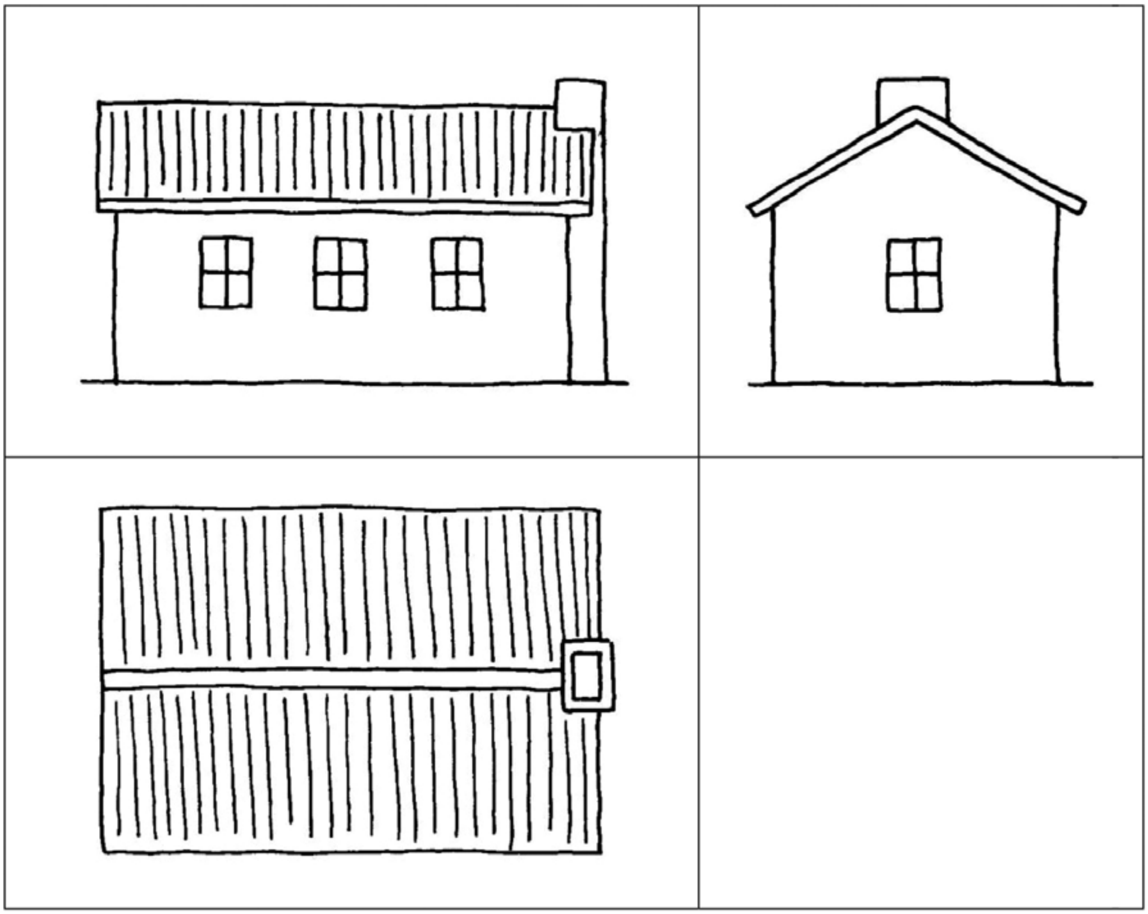


Figure 14

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 Make your first orthographic drawings

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

A front view of the staircase is shown in the upper left block below. Use construction lines to draw a top view and side view in the lower left and upper right blocks.

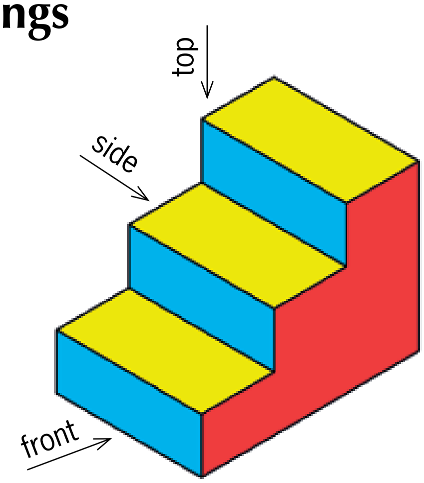


Figure 15

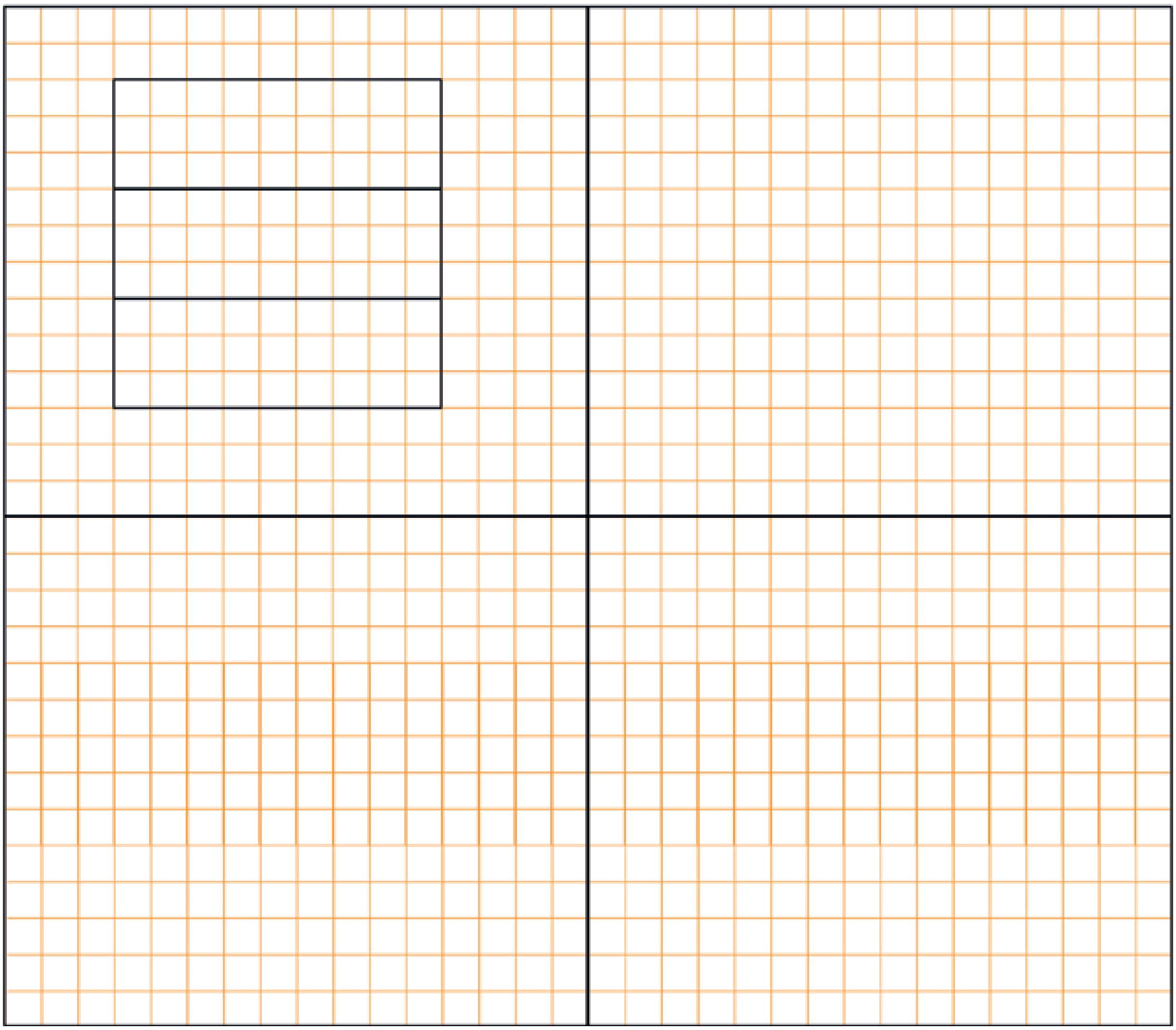


Figure 16

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.

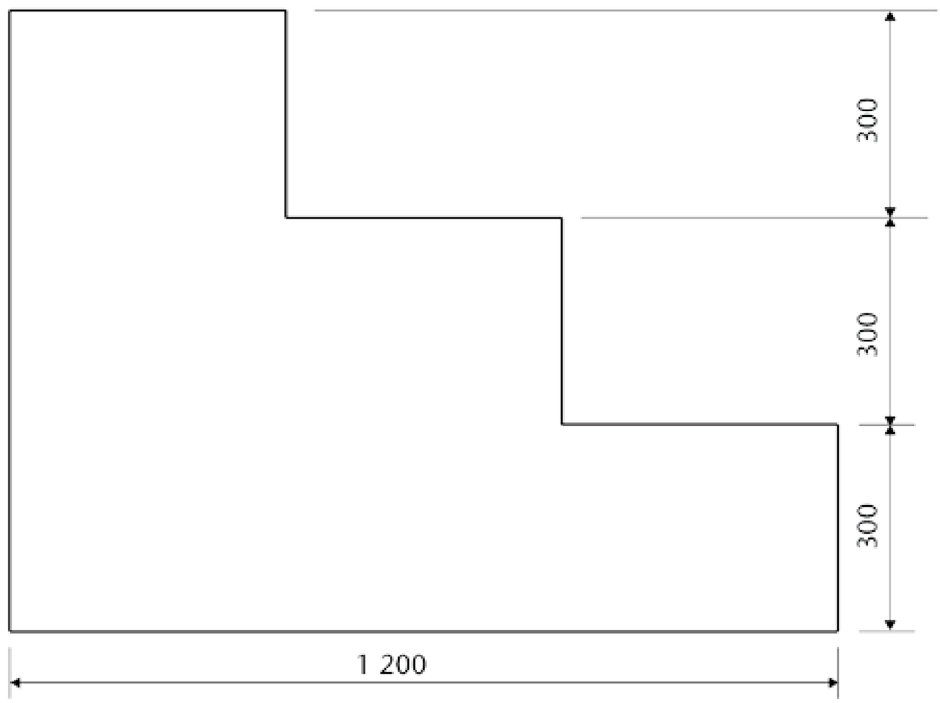


Figure 17: Side view of the staircase with measurements

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

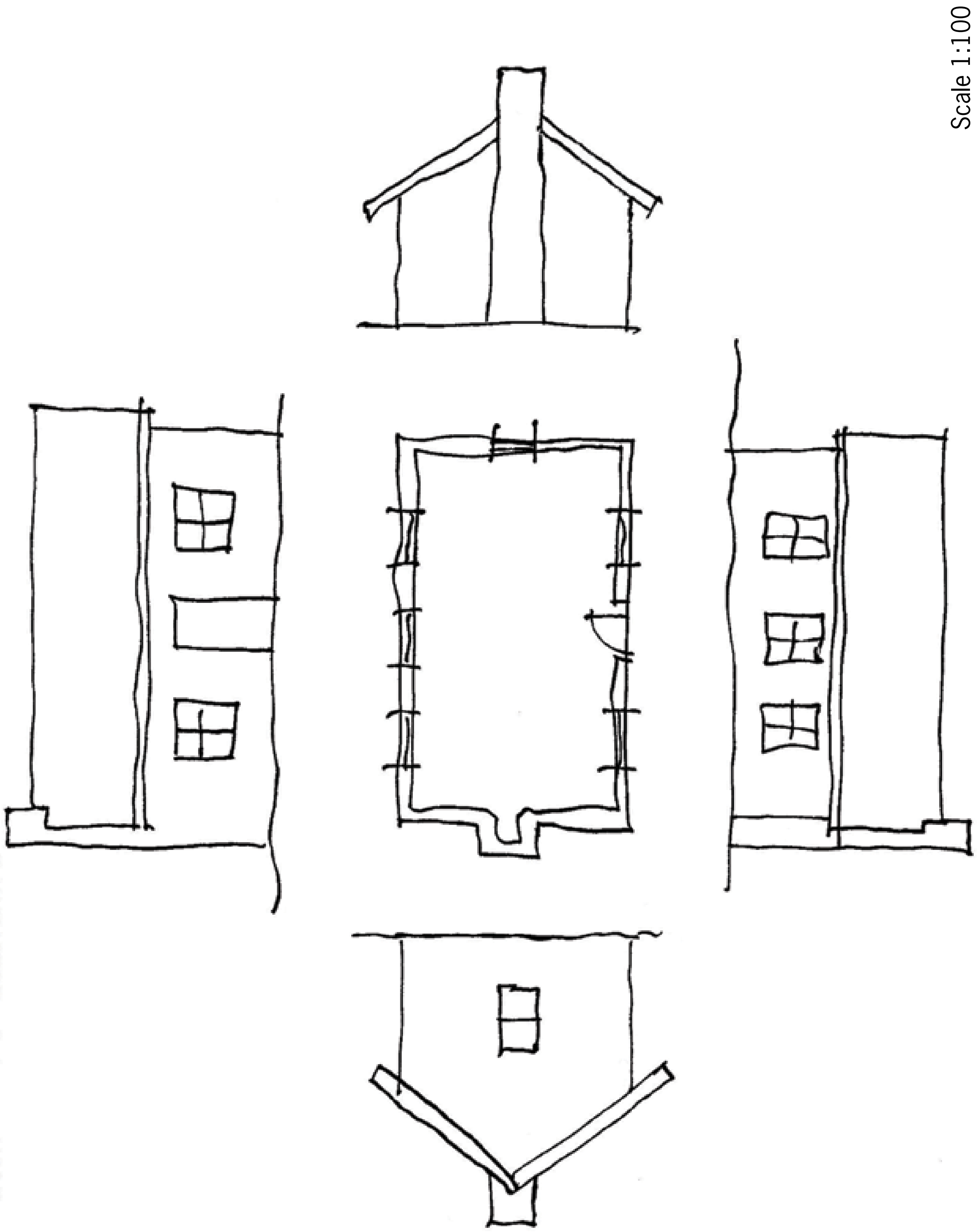


Figure 18: Preliminary drawings

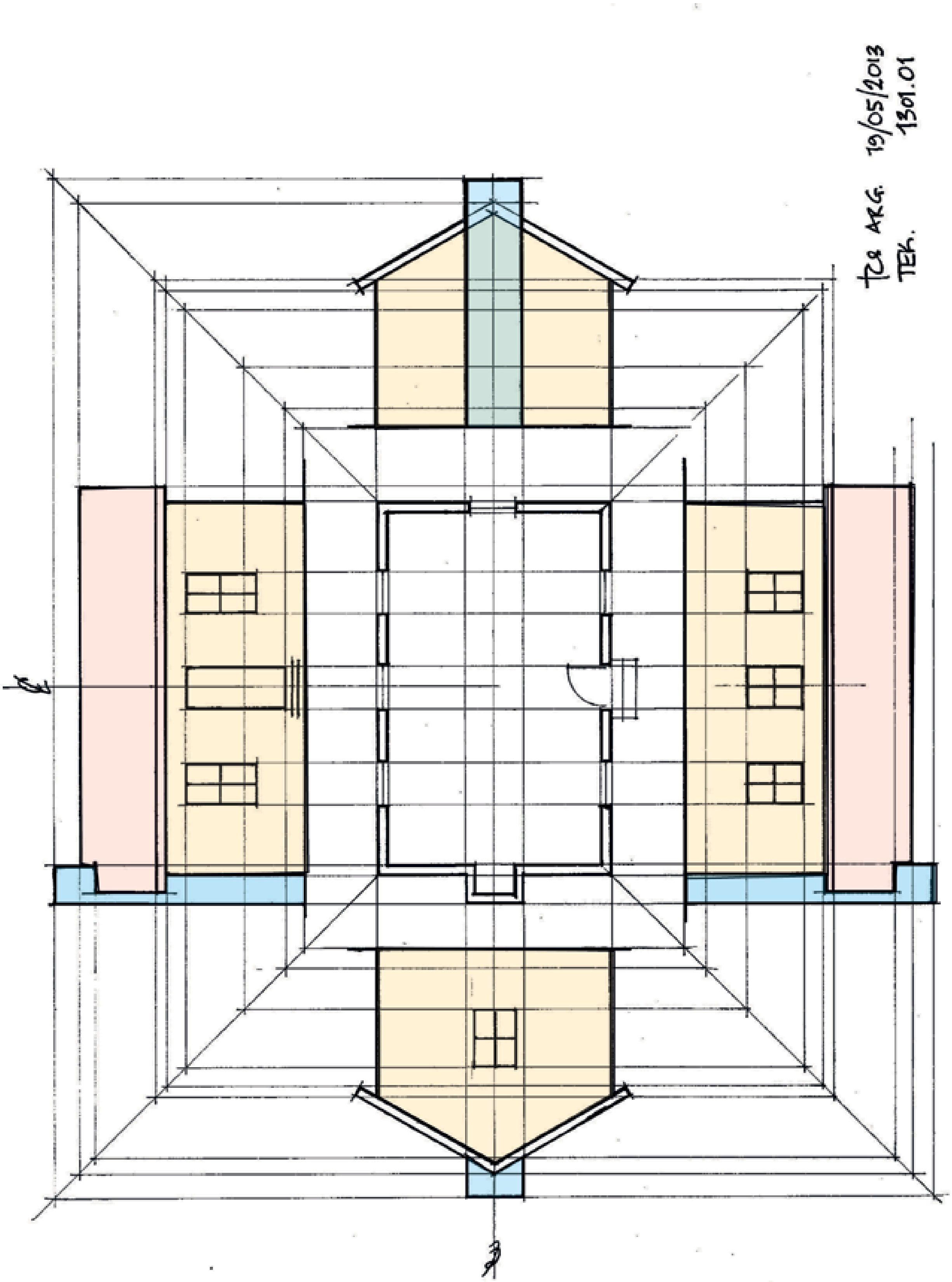


Figure 19: Final drawings

Different kinds of lines in drawings

Different kinds of lines are used in the following drawing:

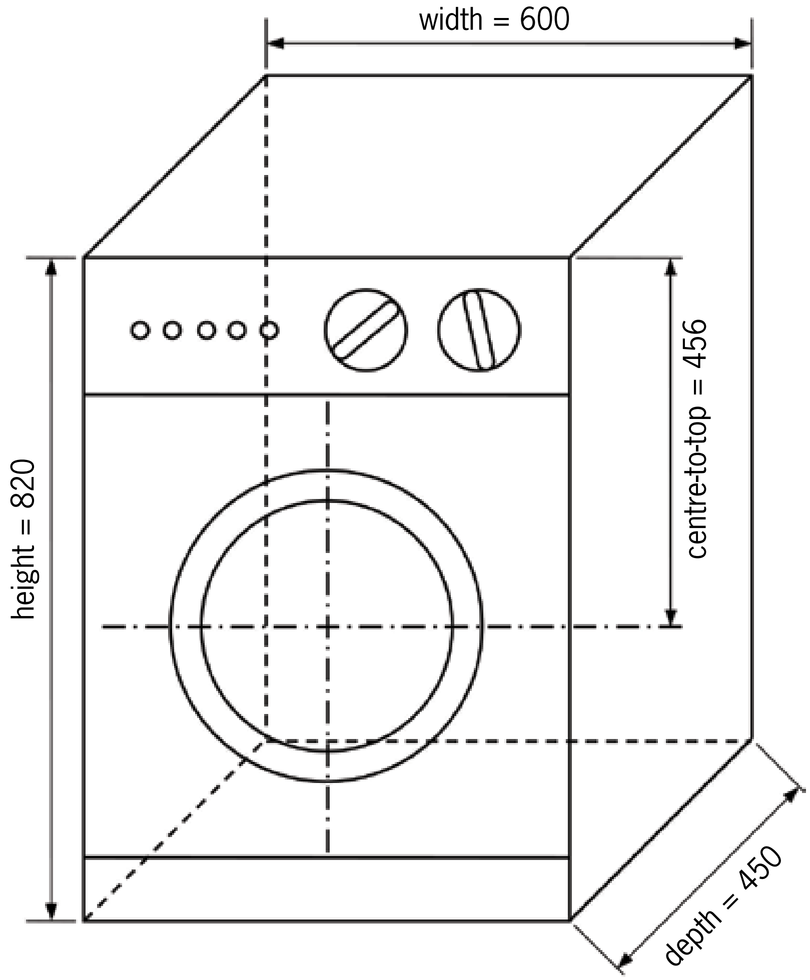


Figure 20

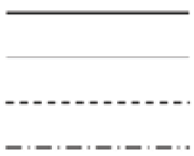
The following types of lines are used in the above drawing:

thick solid lines,

thin solid lines,

dashed lines, and

chain lines.



Make a free-hand copy of this drawing on the next page, in which you use the same types of lines.

Next week

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

Chapter 2
Provide for wheelchairs

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.

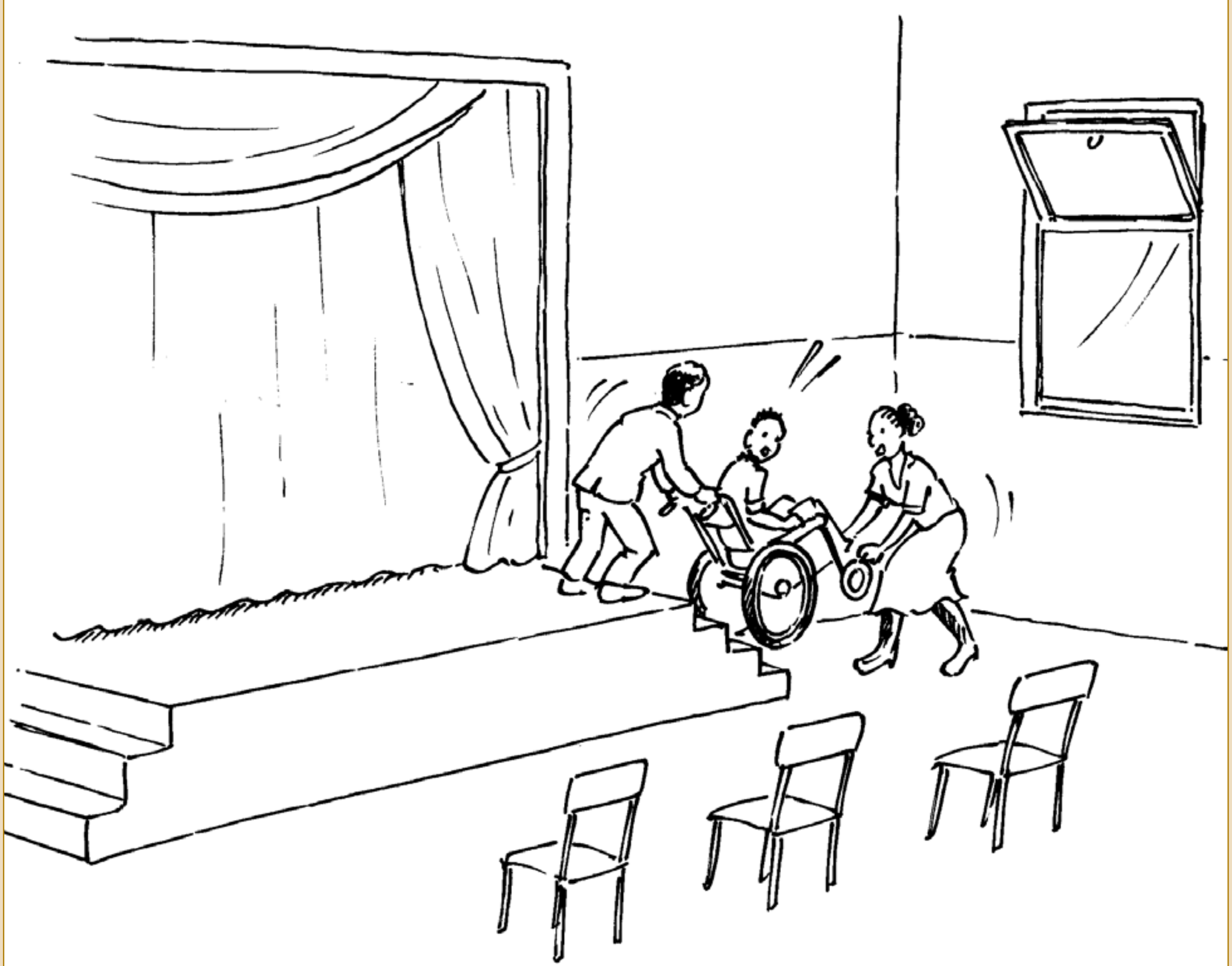


Figure 1

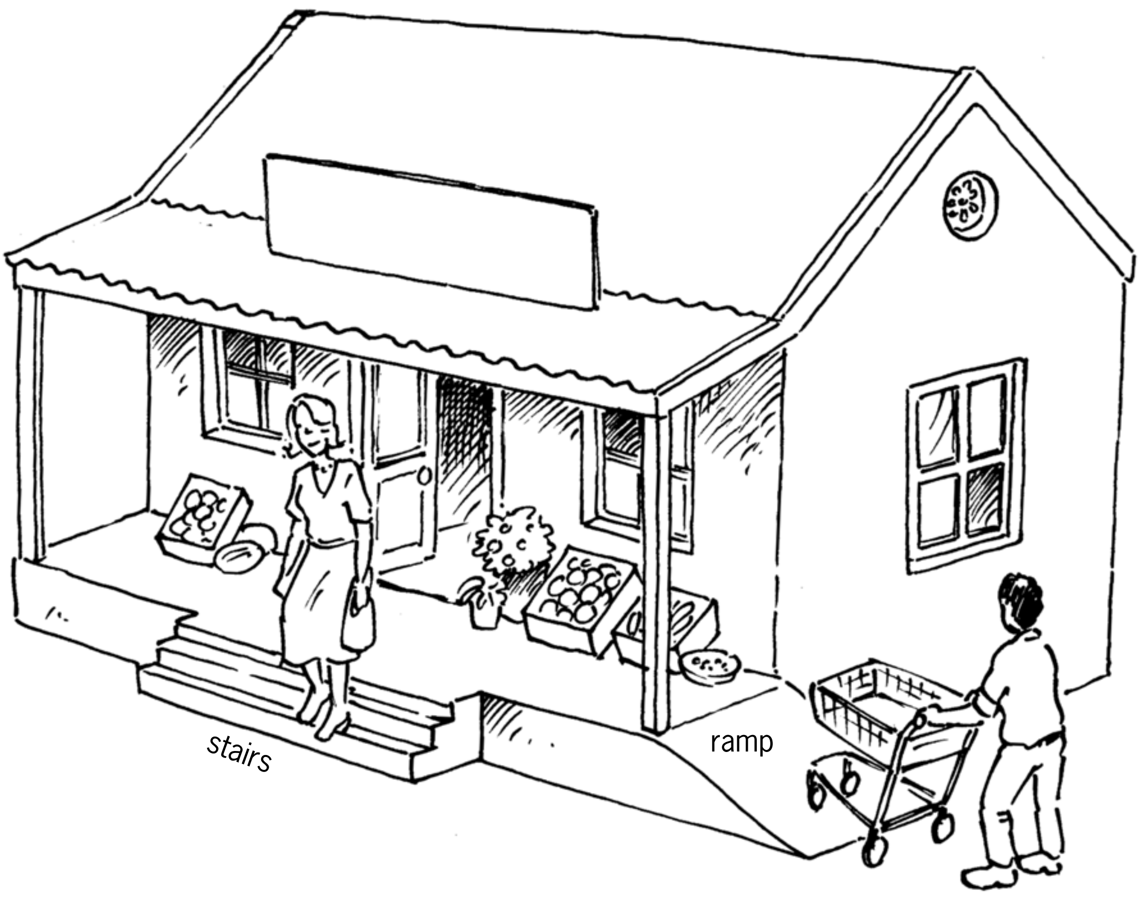


Figure 2

2.1 Stairs and a ramp

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.

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

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.

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.

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.

Activity for homework

Look at the red 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.

Now use a ruler and sharp pencil to finish drawing the cube below.

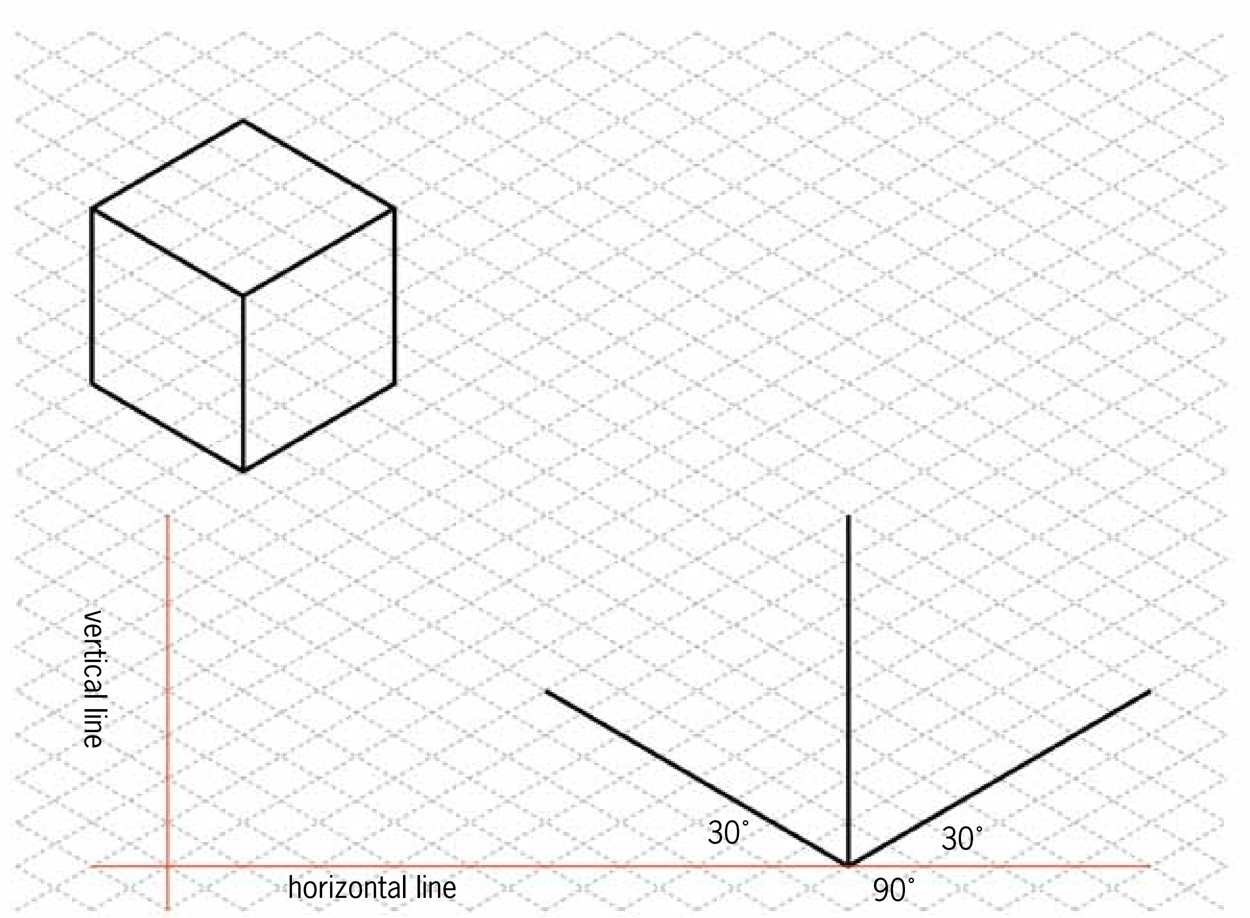


Figure 3

2.2 Isometric drawing

In Chapter 1, there is an isometric drawing of a staircase. What do you think an isometric drawing of the ramp would look like? It could look a bit like a slice of birthday cake!

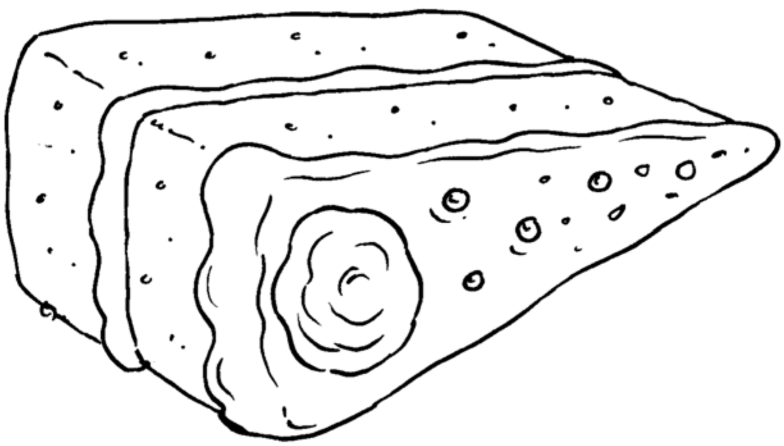


Figure 4

1. Make a sketch of the wheelchair ramp that looks like the slice of cake above, on the top part of the isometric grid on the next page.
2. Now make a better sketch on the bottom part of the page.
3. Look at the list of specifications at the beginning of section 2.1 and write 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.

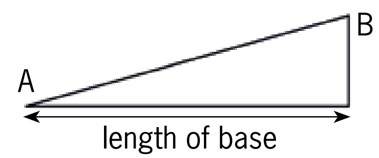
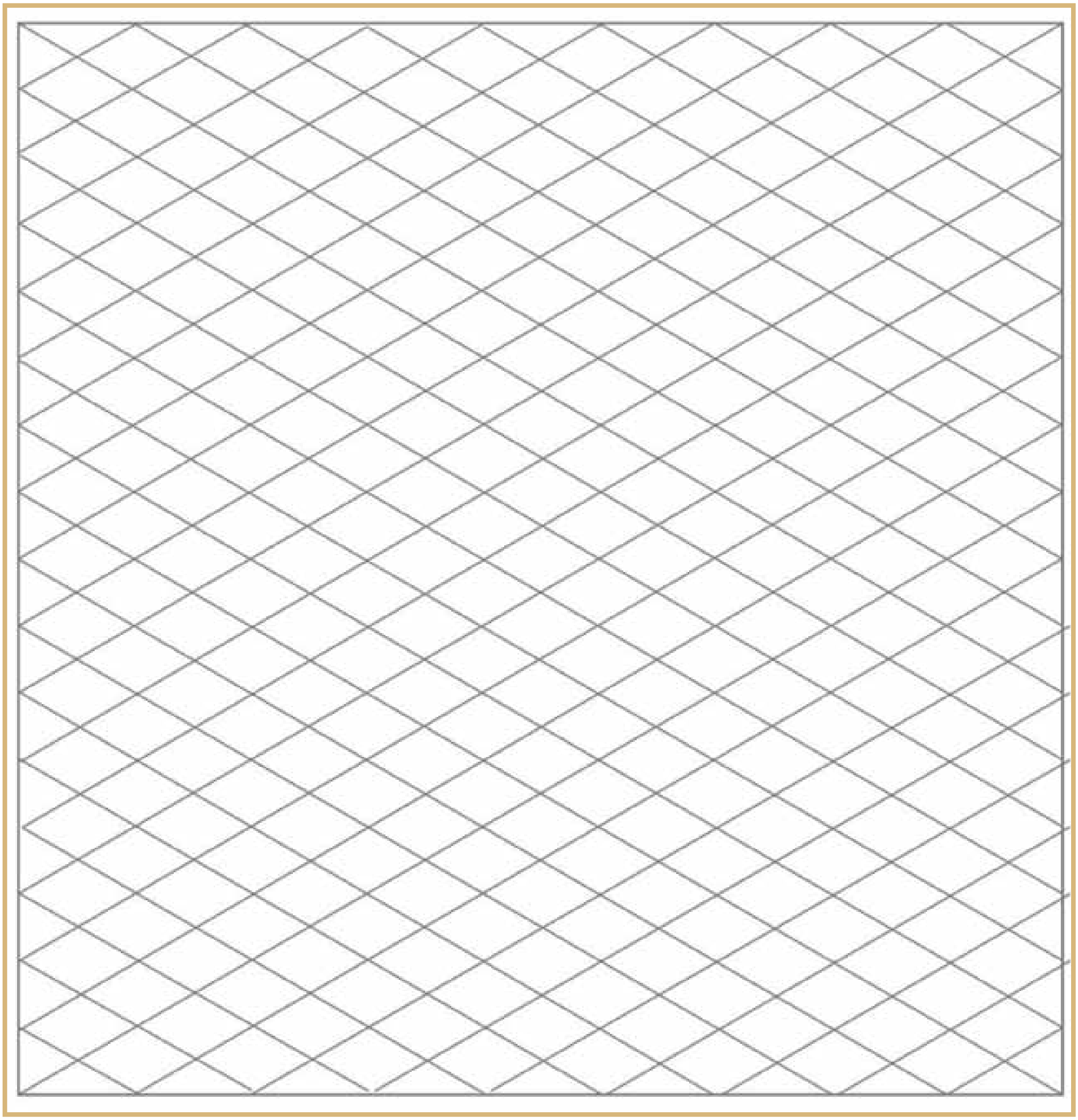


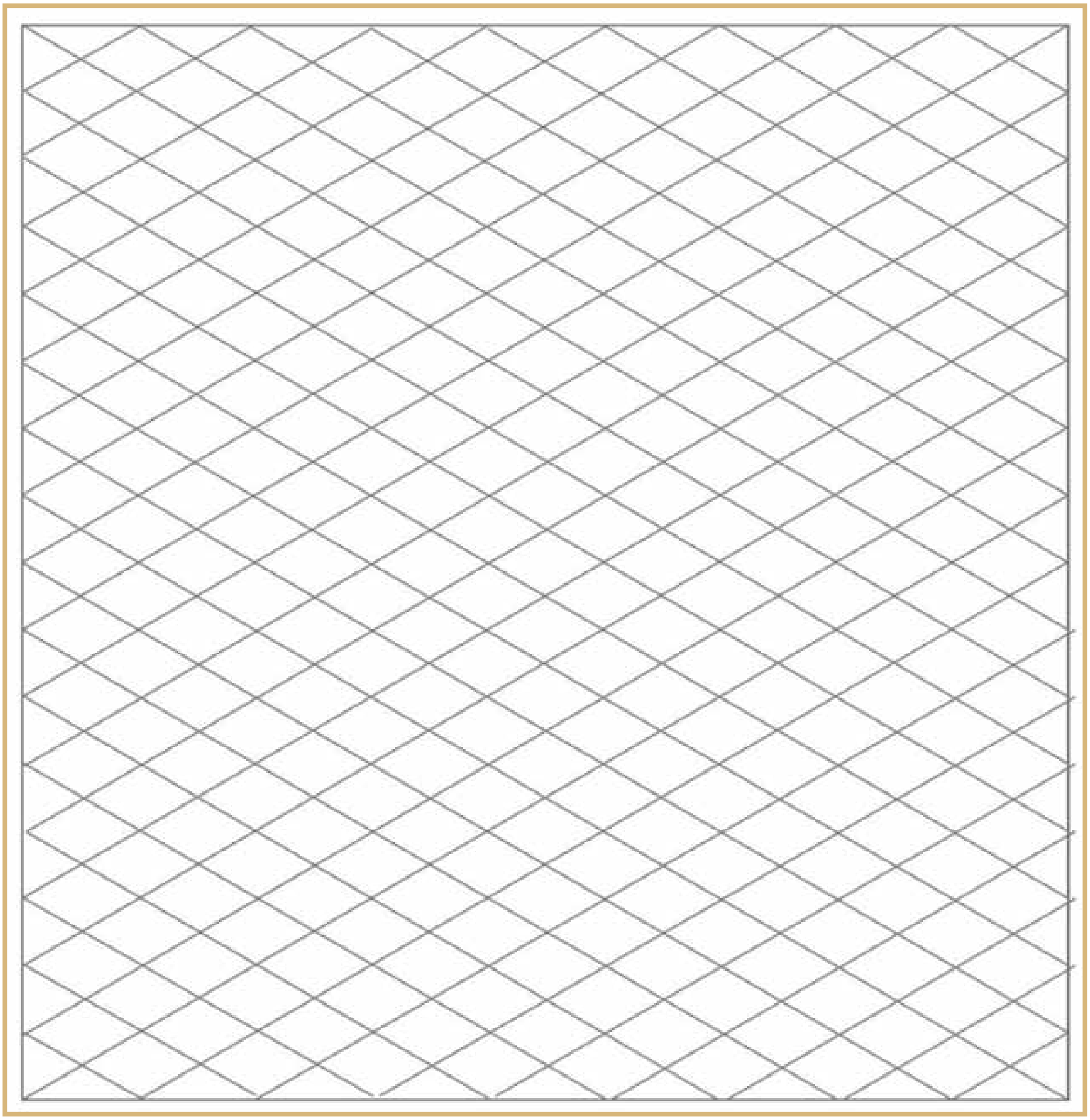
Figure 5



2.3 The plan in orthographic drawings

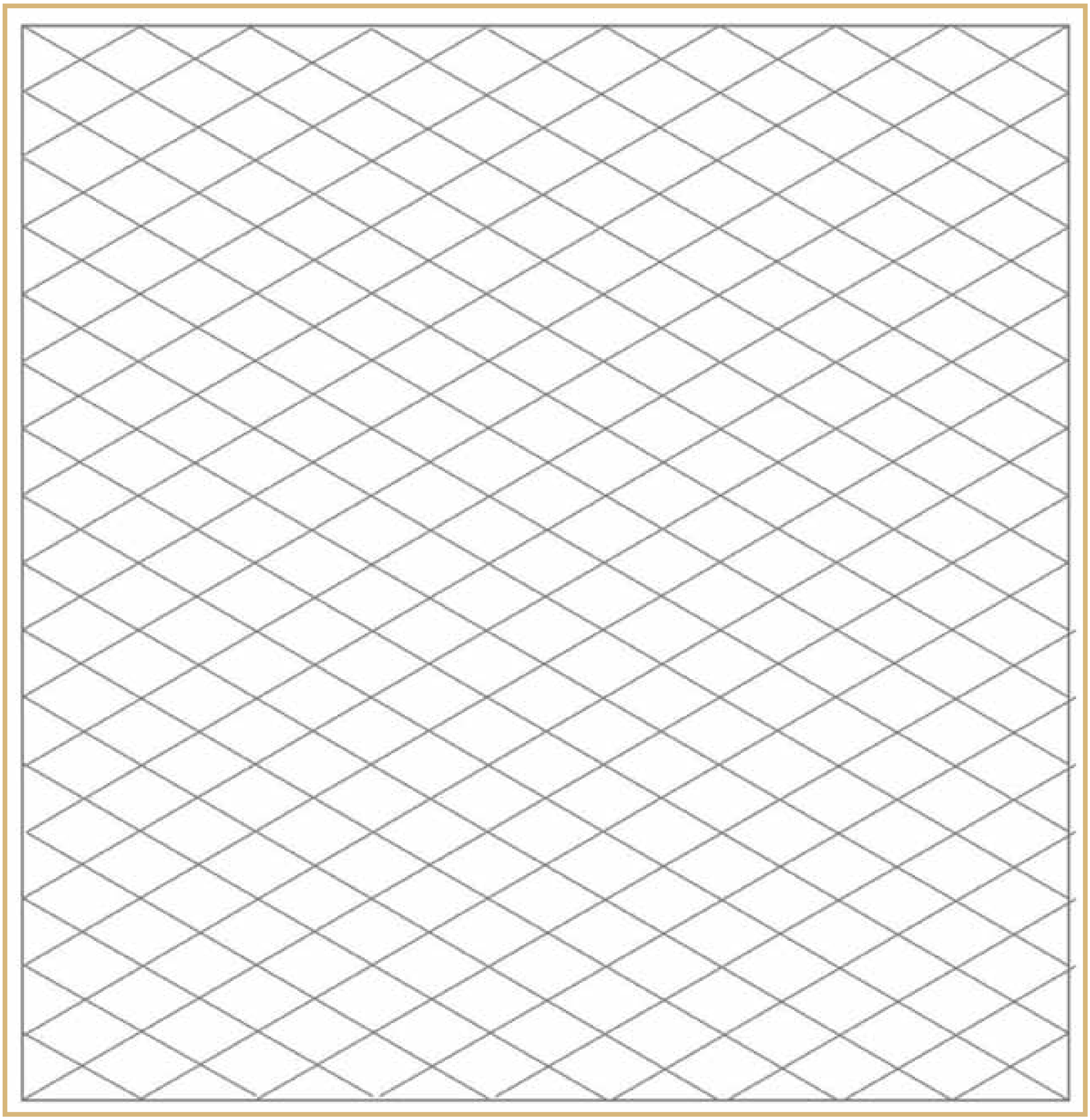
Make a sketch of the staircase on the isometric grid below. Remember it has only three steps. Look at the list of specifications and write the following on your drawing:

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



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

Another student designed the ramp and staircase shown below, but this learner didn't follow the specifications on page 16 correctly.

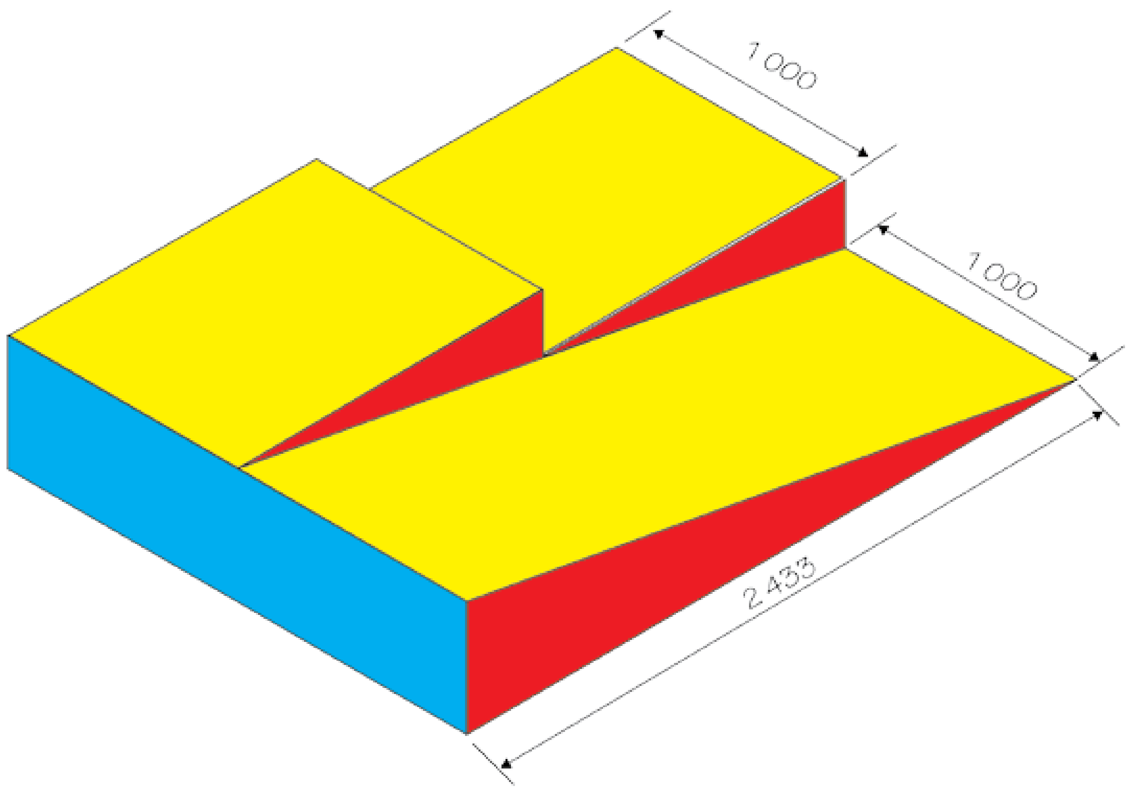


Figure 6: Is this design correct according to the specifications on page 16?

1. Compare the above drawing with the specifications for the ramp, given at the beginning of this chapter. Write notes below to indicate any specifications that are not met.

 ....

 ....

2. On the next page, draw a first-angle orthographic projection of your own design of the stair/ramp, according to the specifications given at the beginning of the chapter. Note that the specifications require three steps. Draw the top view, a side view from the ramp side, and a front view as a person that approaches the stairs to climb them will see the stairs or ramp. You do not have to draw the handrail as well.

 Make all the drawings to exact measurements, but keep in mind that if you draw it full size, it will not fit on the paper. So think of a scale that will fit on this workbook paper. Mark the real measurements on all the sides.

The next chapter

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.

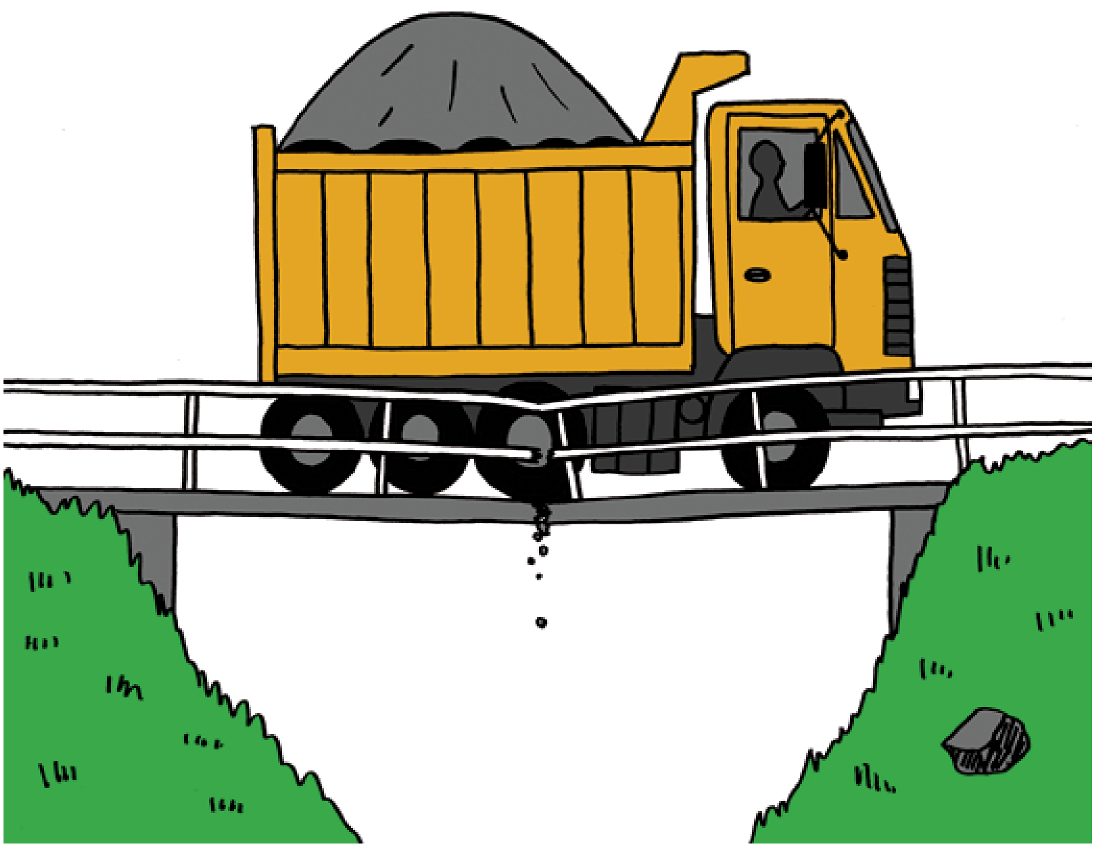


Figure 1: This bridge cannot withstand the forces acting on it.

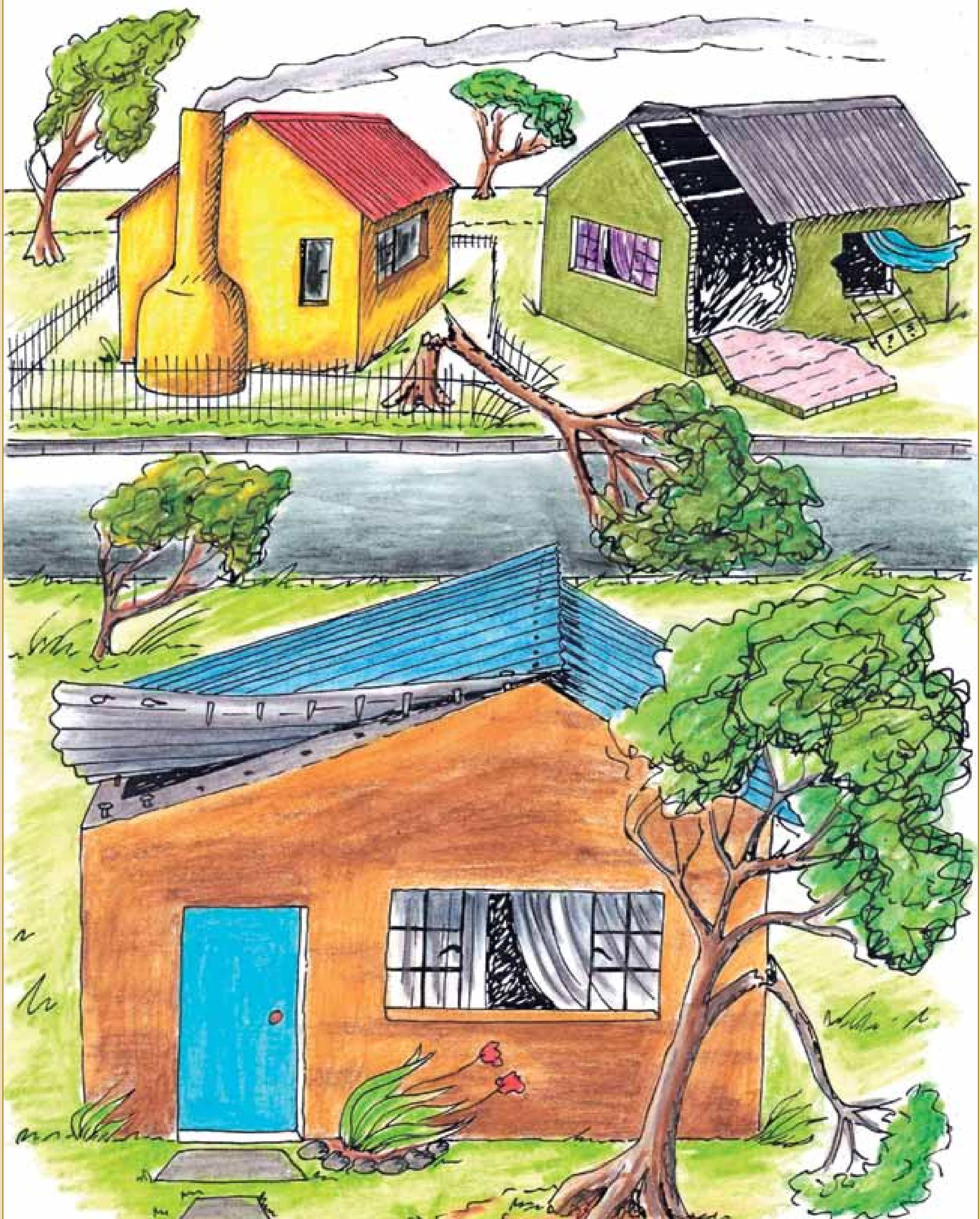


Figure 2: If the house is not strong enough, the wind may break it apart.

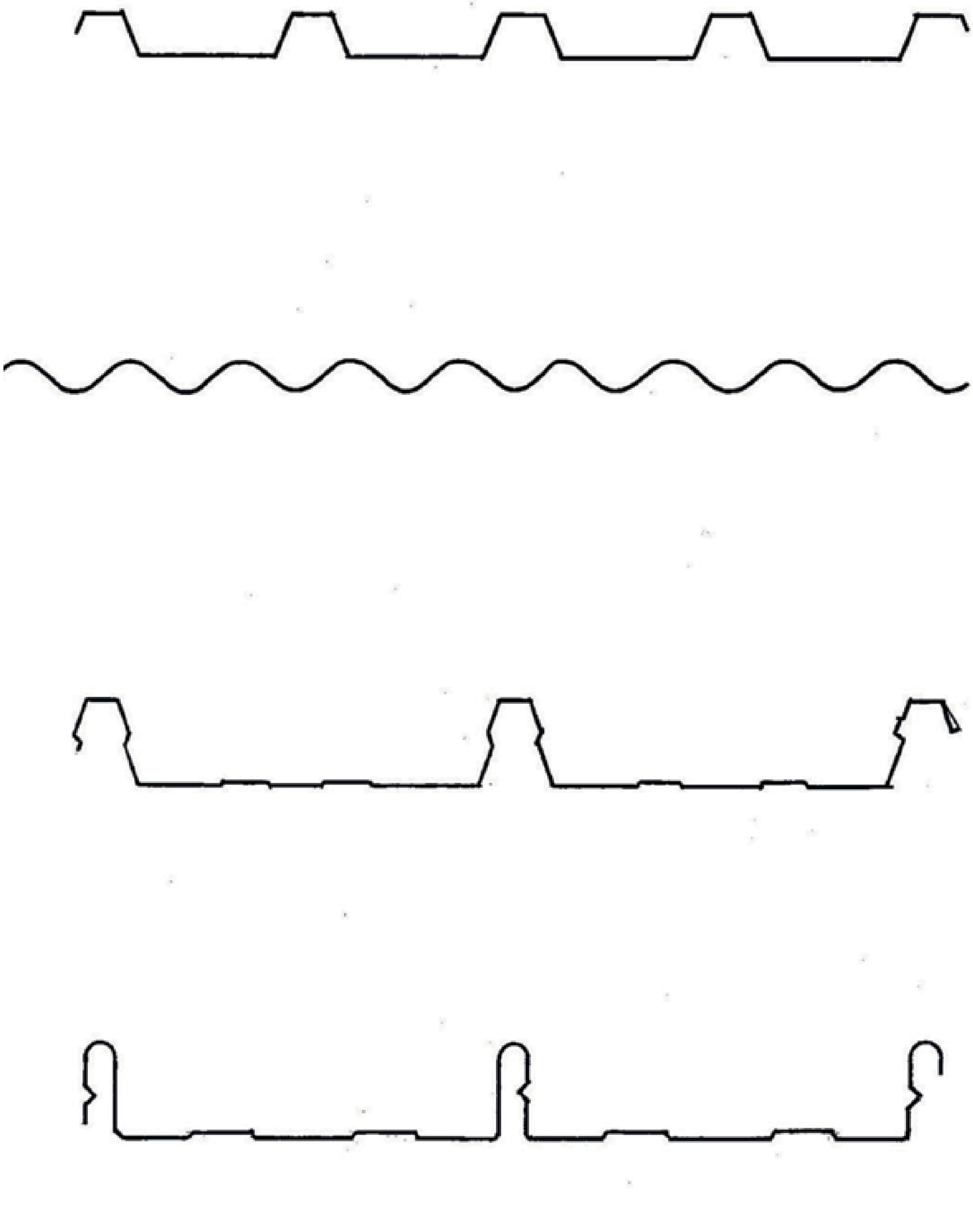


Figure 3: Roof sheets come in different shapes.

3.1 Forces act in different places

Identify and analyse forces

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

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

1. In each of the pictures on this page and the next, make an arrow to show how the load acts on the structure.

Figure 4: The boy sits still on the chair.

Figure 5: A man walking on a roof.

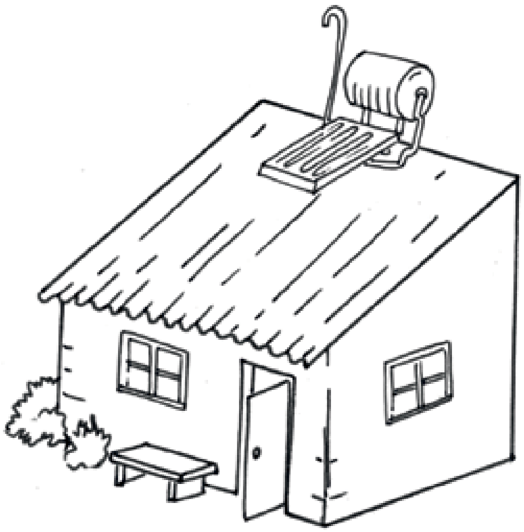


Figure 6: A solar heating system on a roof

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?

....

Figure 7: Vehicles passing over a bridge.

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

3. In the above picture, 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?

....

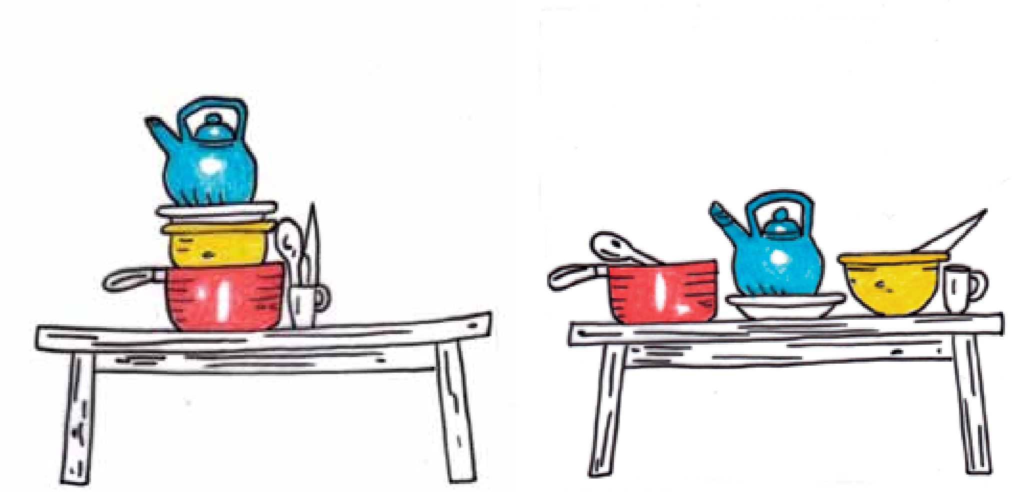


Figure 8: Different ways to put pots on a table.

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.

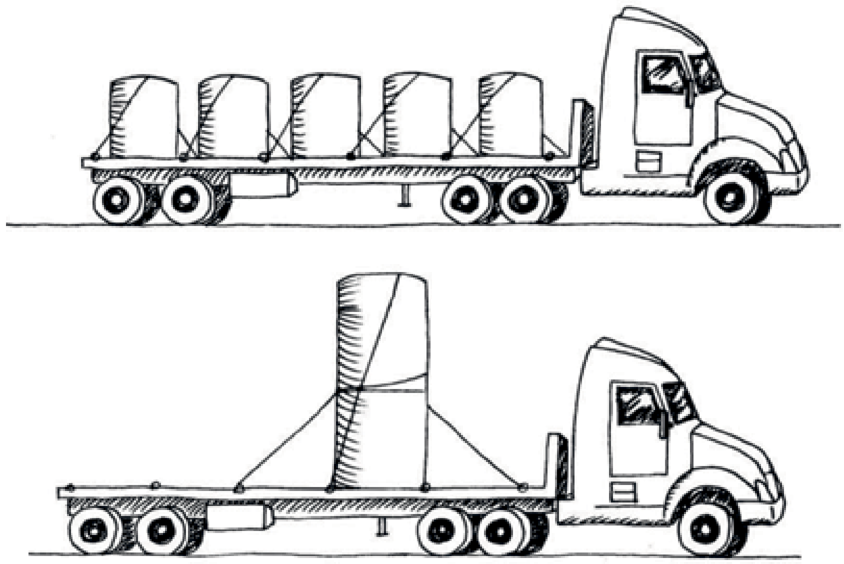


Figure 9: Different kinds of load on two trucks.

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 the one table, the design brief states that the load on the table will always be static and even. The design brief for the other table states that it has to carry the same weight as the first table, but the load will sometimes be dynamic and uneven. Describe how your designs for the two tables will differ, and explain why.

   ....

   ....

   ....

   ....

   ....

   ....

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.

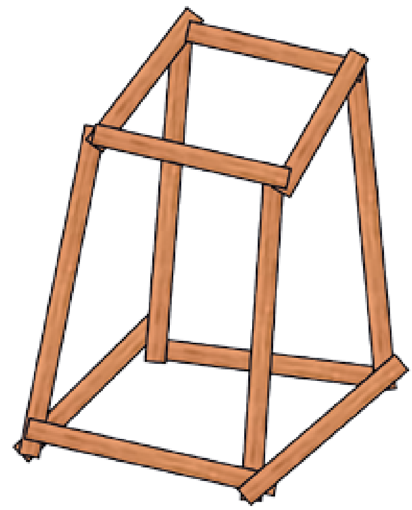


Figure 10: A frame structure made of planks.

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**.

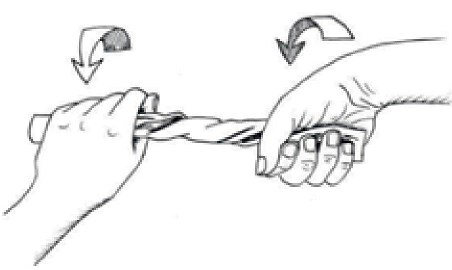


Figure 12

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

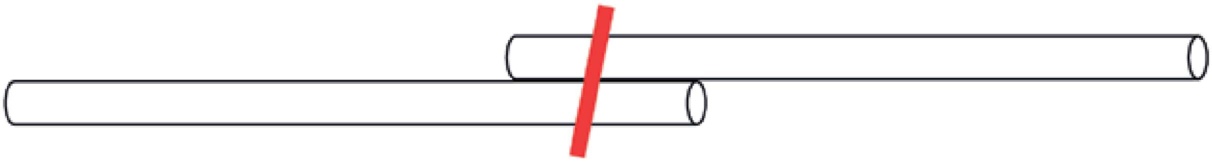


Figure 13

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.

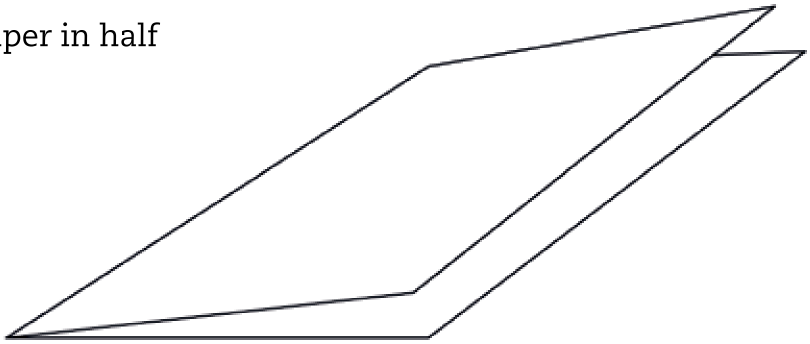


Figure 14

Fold it again:

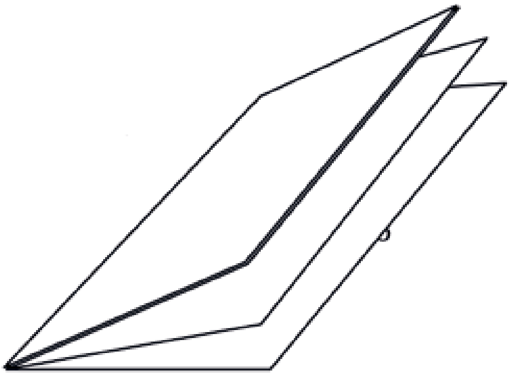


Figure 15

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

Make two more folded strips like this.

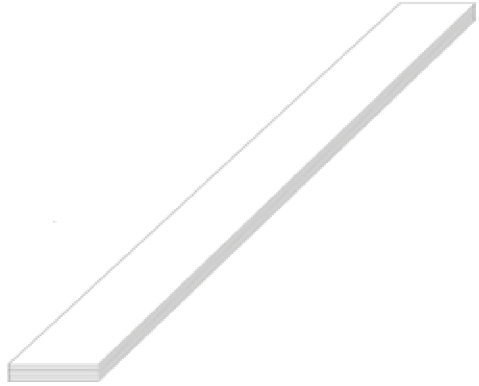


Figure 16

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.

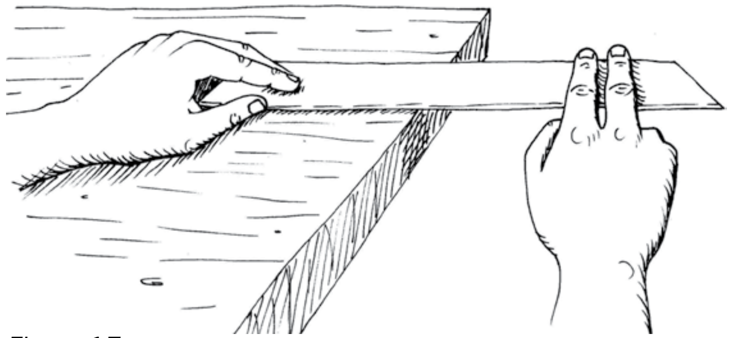


Figure 17

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:

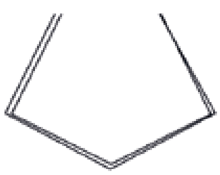


Figure 18

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, in the space below.

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

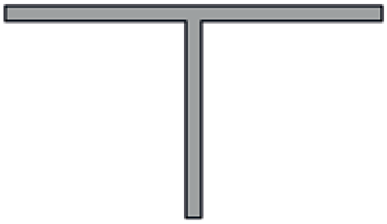


Figure 22

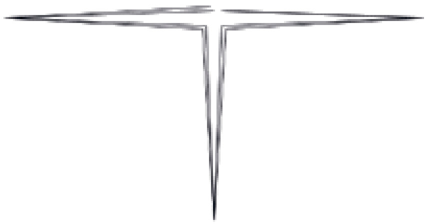


Figure 23

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

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

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

   ....

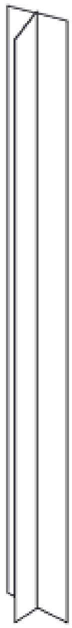


Figure 24

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.

....

....

....

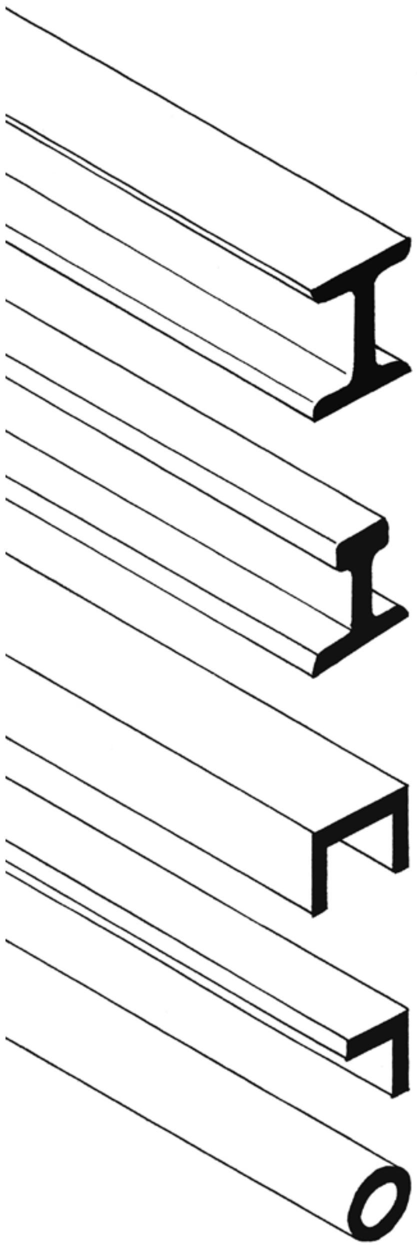


Figure 25: Metal cross-sections

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

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

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

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

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

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

Using internal cross-bracing to resist twisting

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

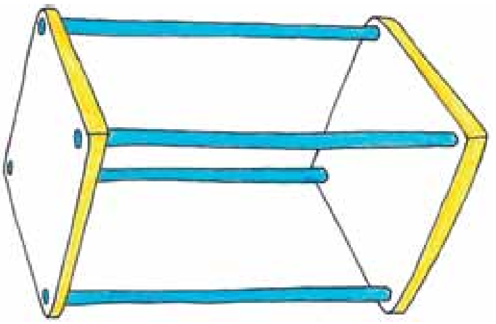


Figure 26

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:

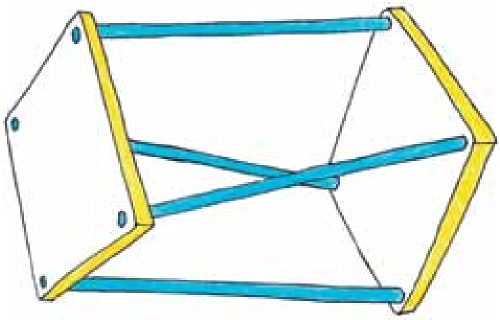


Figure 28

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

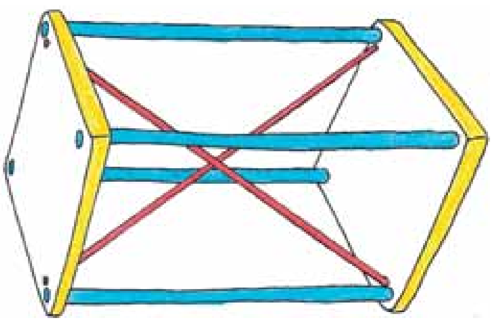


Figure 29

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 highest density: wood or rock?

....

(b) What material has the highest 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.

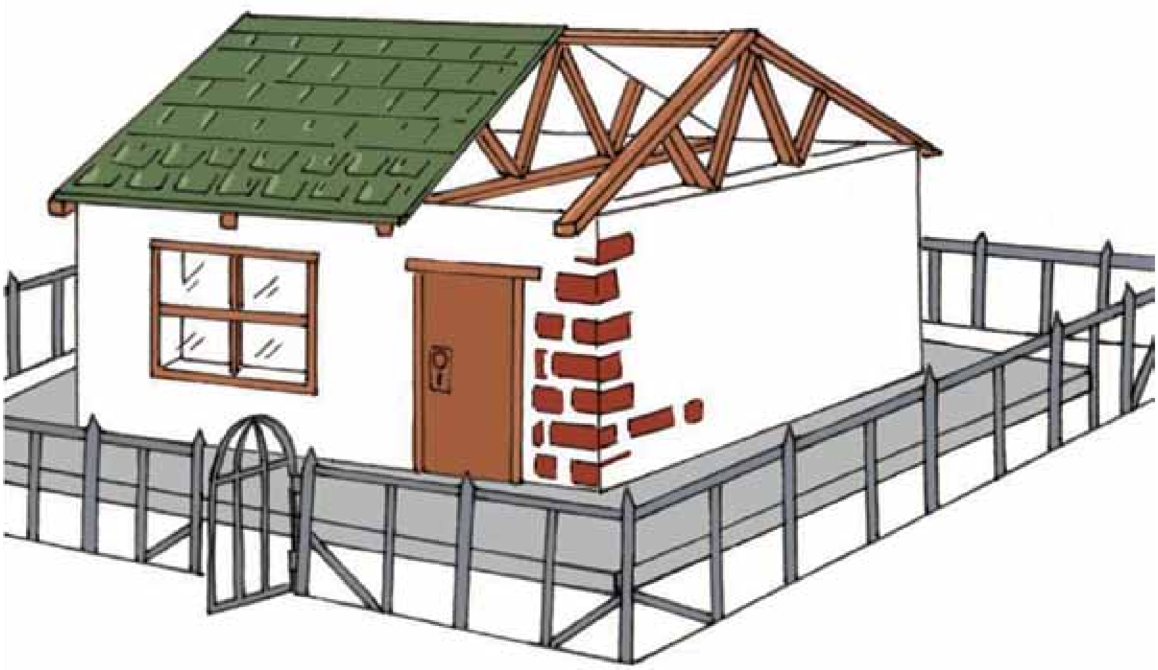


Figure 30

1. Different parts of the house are listed in the left column of the table below. In the right column, fill in what 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 stop rusting, you have to cover steel with special paint.

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

Part of the house	**Material**	**Reasons for choice of material**
Walls		
Window frames		
Door		
Roof structure		
Roof cover		
Fence		
Paving around the house		

3. Some houses have tile roofs, other houses have zinc roofs. What are the advantages and disadvantages of tile roofs?

Advantages of tile roofs	Disadvantages of tile roofs
....	....
....	....
....	....
....	....

4. What are the advantages and disadvantages of zinc roofs?

Advantages of coated iron roofs	Disadvantages of coated iron roofs
....	....
....	....
....	....
....	....

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 Mini-PAT 1

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 marks: 70]

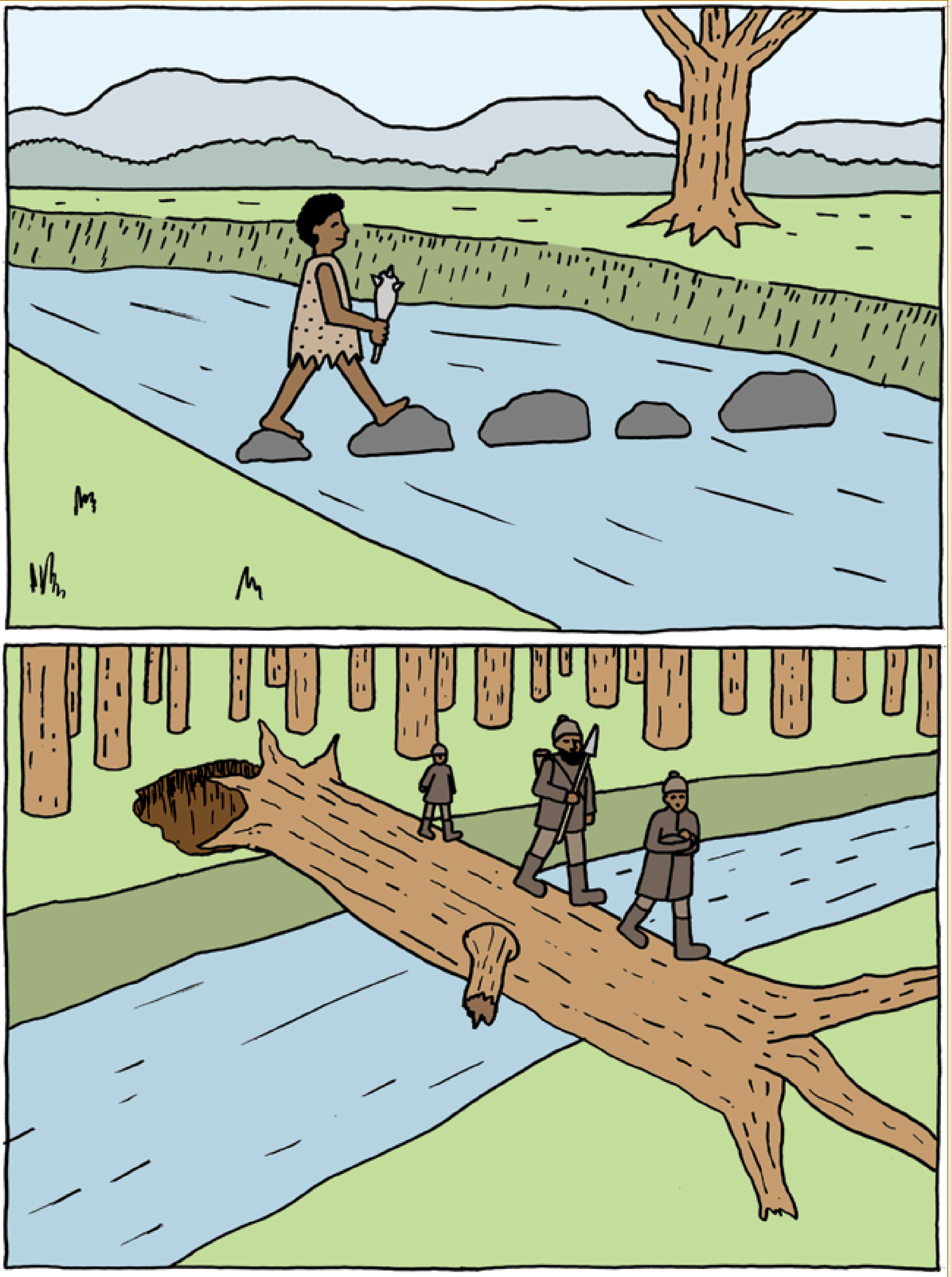


Figure 1

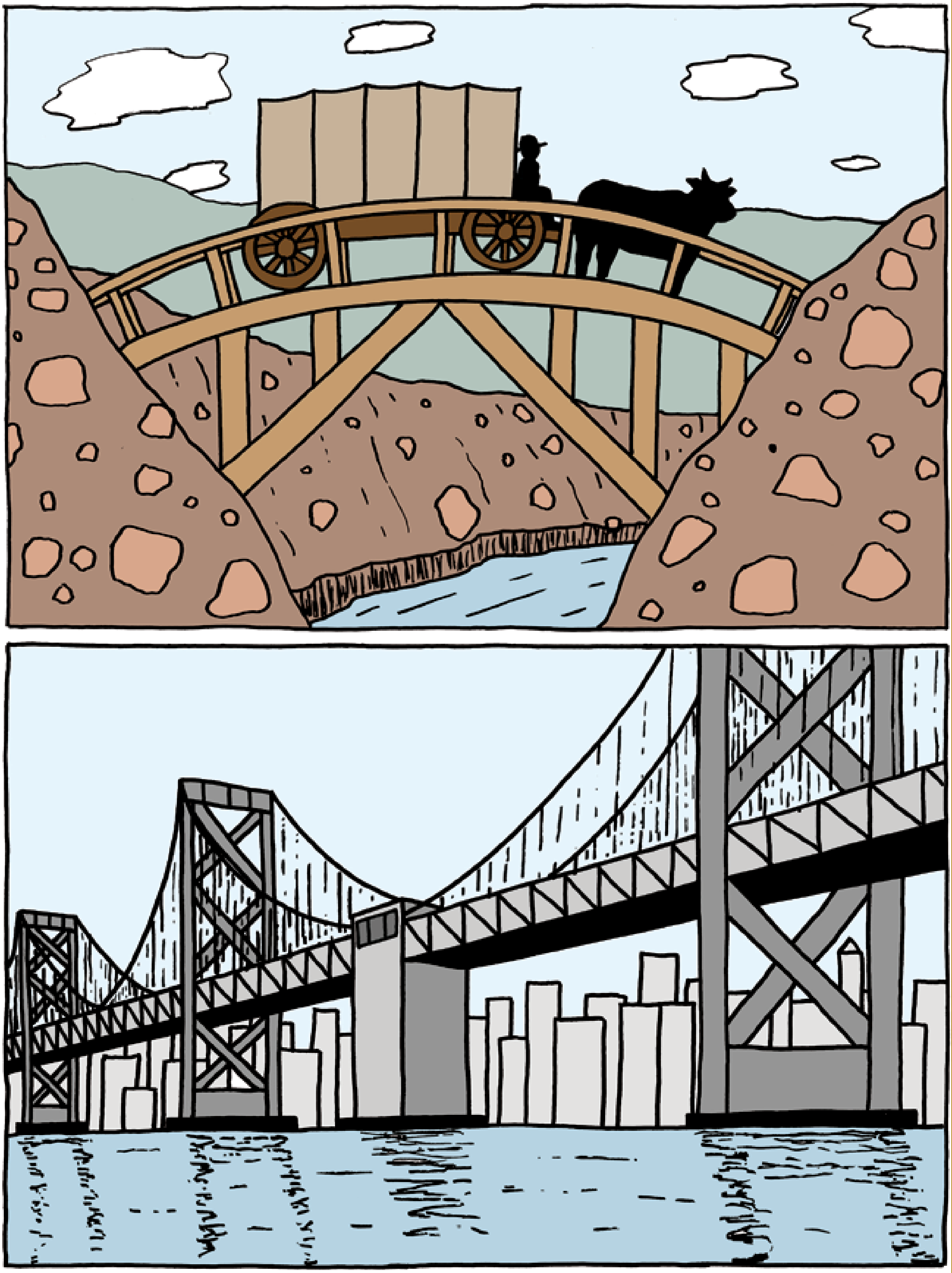


Figure 2

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 <u>KwaNogawu</u> 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 Thukela 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 winter rains and there are crocodiles in the river all year round.

Closing date: 28 February

Enquiries: Mrs Leslie Oats

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

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 Thukela 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.

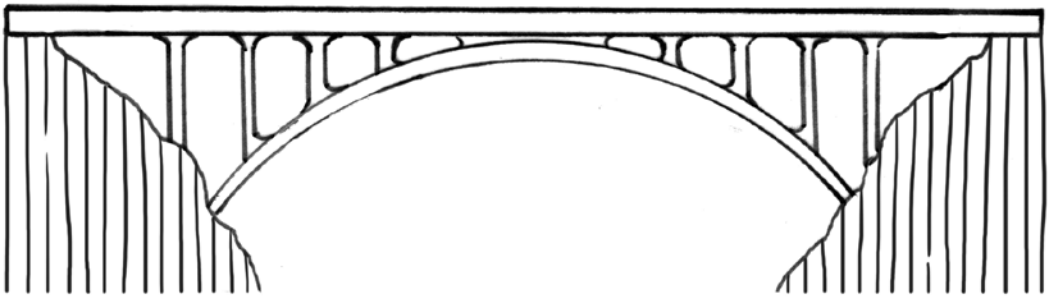
Municipalities are not allowed to choose a contractor without giving as many contractors as possible a chance to apply. This is to stop anyone from being favoured over others, and to prevent corruption. Each contractor writes a tender document, which is a description of their plan for the project and 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.

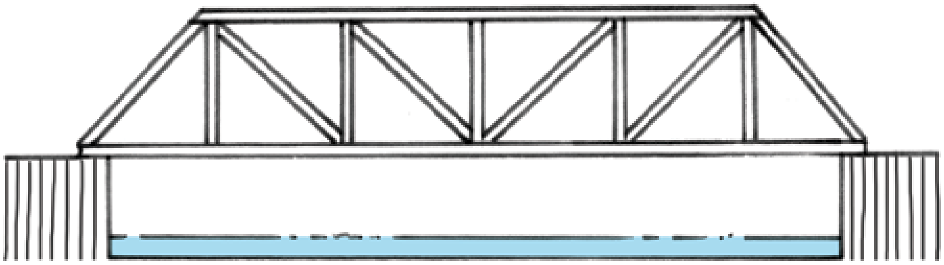
Investigate structures to solve the problem (60 minutes)

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

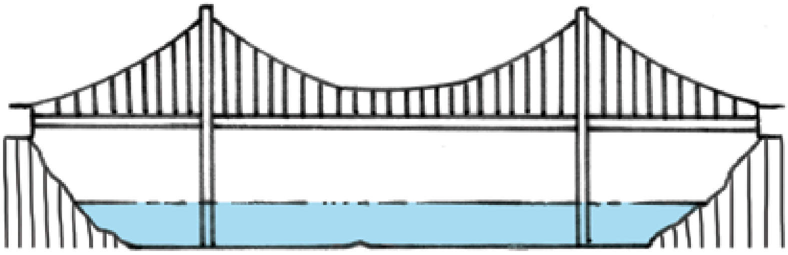
A: A beam and column bridge



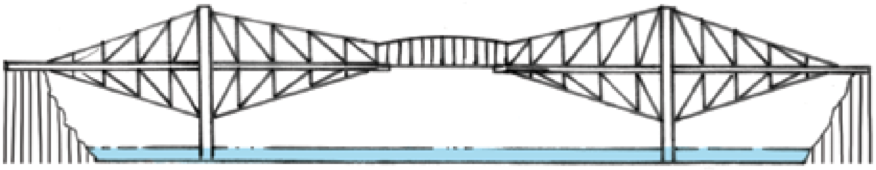
B: An arch bridge



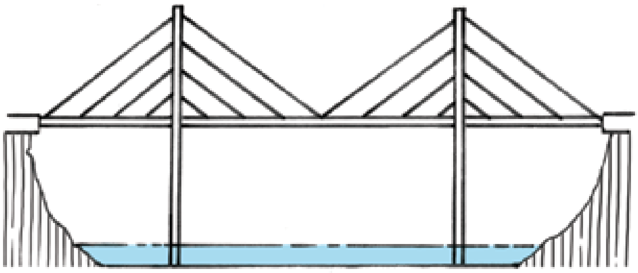
C: A truss bridge



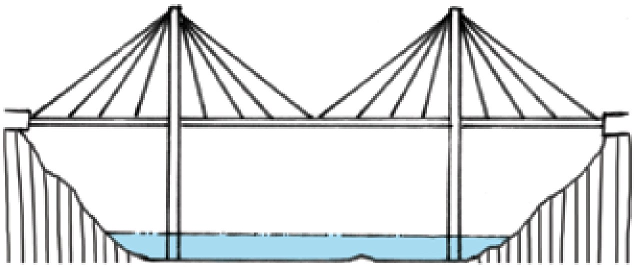
D: A suspension bridge



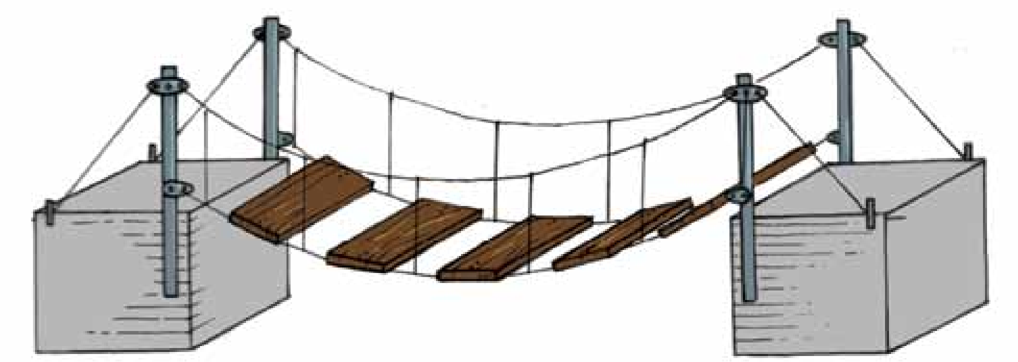
E: A cantilever bridge



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.

Use the following list to help you to investigate each of the bridges in Figure 5 on the previous page. Also bring pictures of bridges to school. You can find photographs of bridges in old newspapers and magazines.

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]

Sketch your ideas here:

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, 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 of 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.

Draw your adapted sketches in the space on the next page. This is your final solution and it will form the basis of your working drawing.

Make your sketches here:

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. Use the open space below to write your design brief.

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 to find work when this project ends.
- The bridge has to be user-friendly for disabled and older people.

Constraints could include the following:

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

Total [10]

Write your design brief in the space below and on the next page:

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

Look at the example of a flow chart below. Now draw a flow chart of how you will build your bridge. Do this on the next page.

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.

"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'

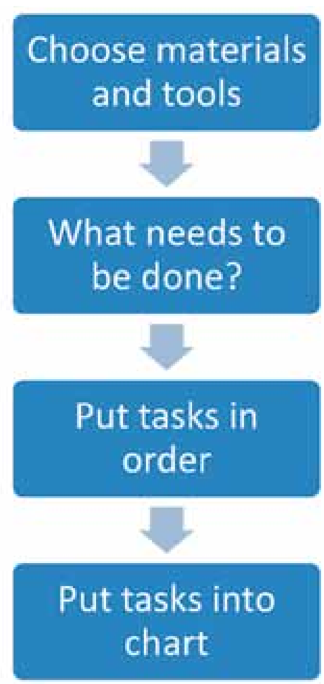


Figure 6

Draw your flow chart here:

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.

Draw your first-angle orthographic projection drawings here: Total [10]

Front	Left view
Top view	

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.

On the following page, there is an 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.

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			

Your own list will be different, because it will depend on the materials you have chosen to use to build your bridge. If you are not completely certain of amounts or lengths, always 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 to 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.

Write your own budget on this page and the next.

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 glue-guns?

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

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

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

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

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

Make a model of your bridge (60 minutes)

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

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

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

Total [20]

Week 5

Design an evaluation instrument (60 minutes)

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

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

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

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

Write your checklist here:

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 to 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

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.

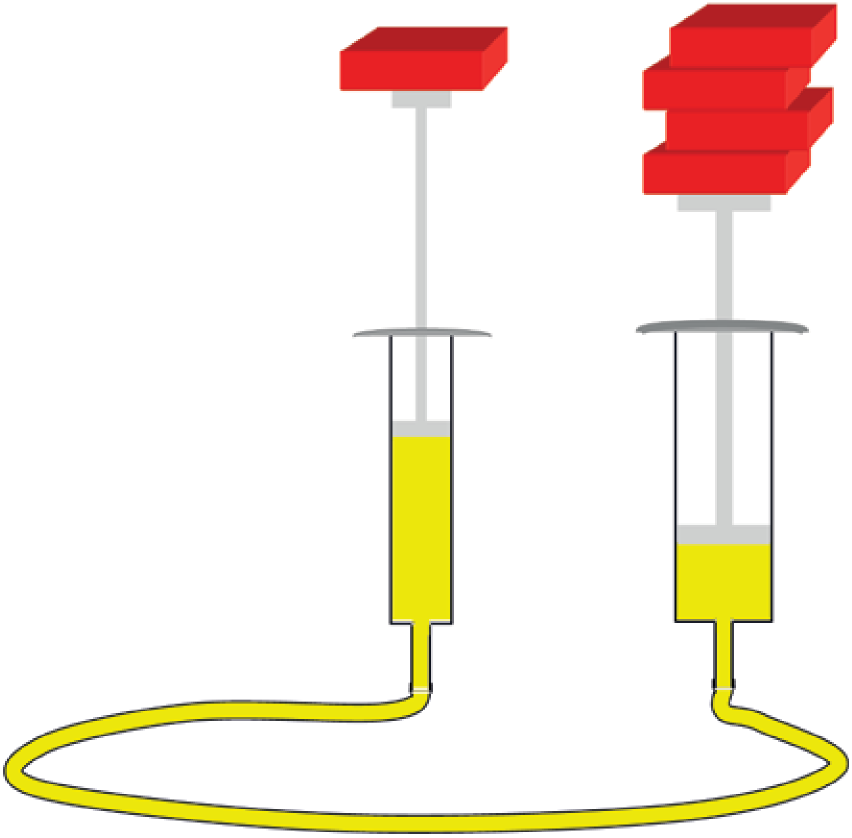


Figure 1

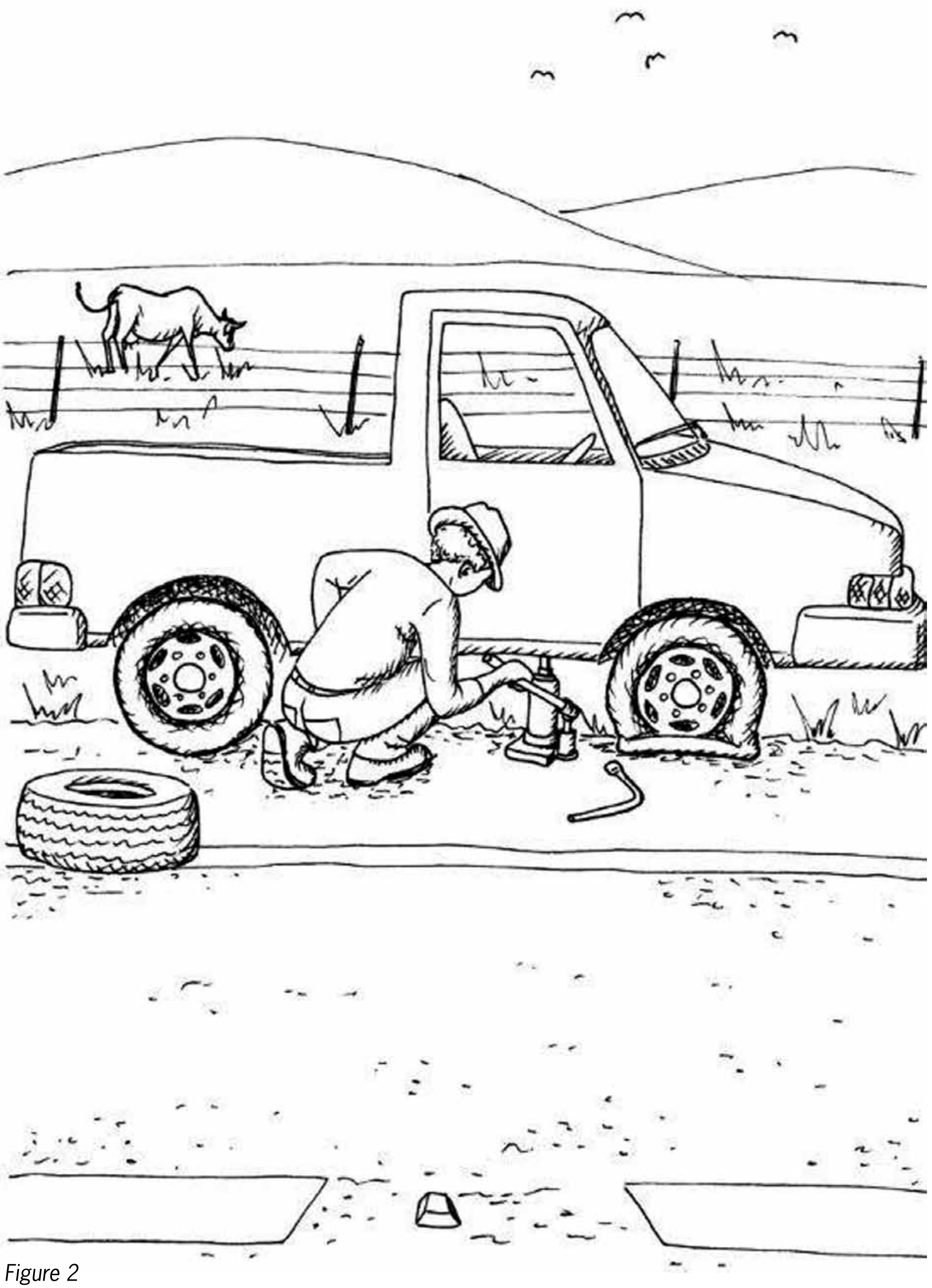


Figure 2

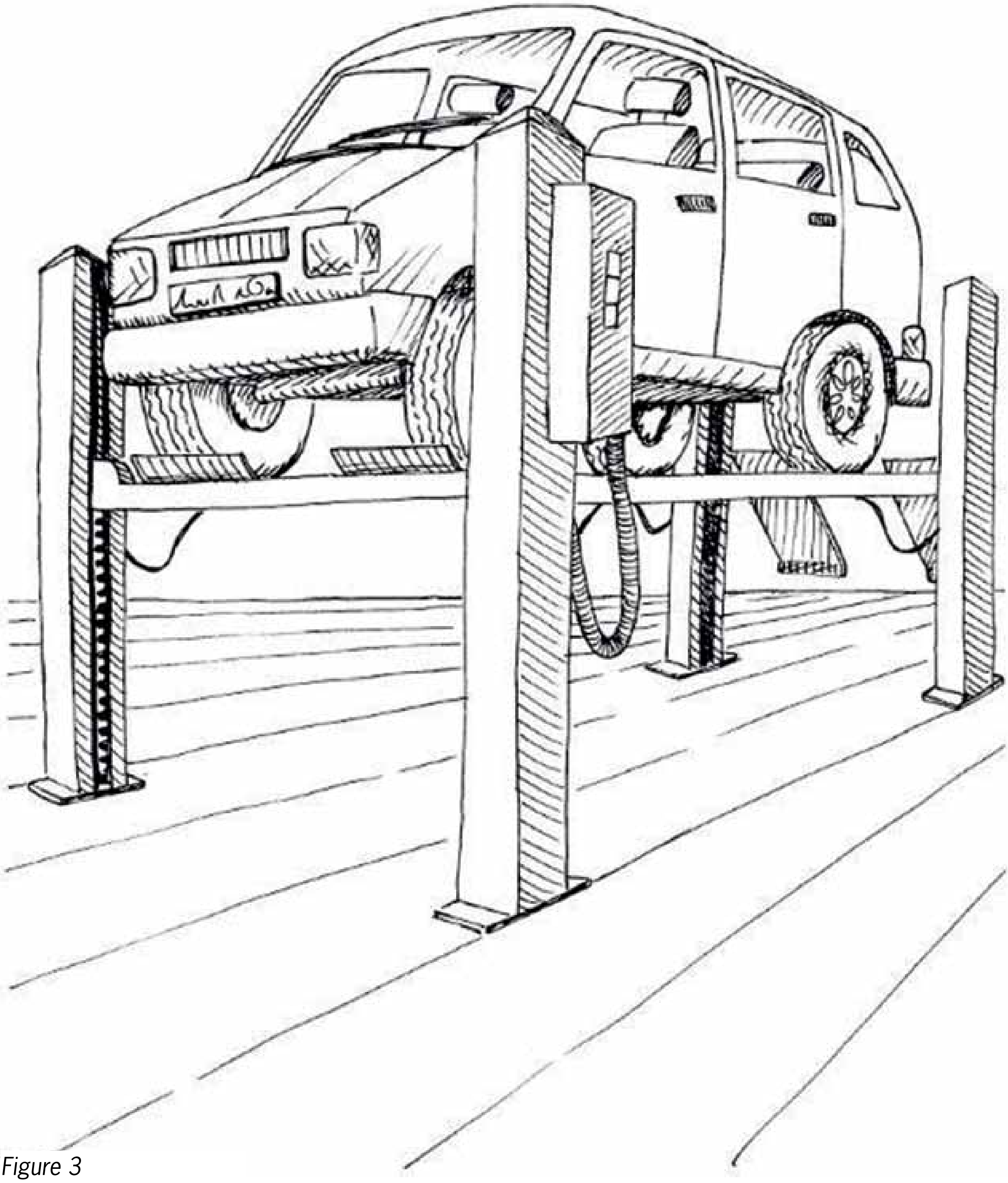


Figure 3

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.

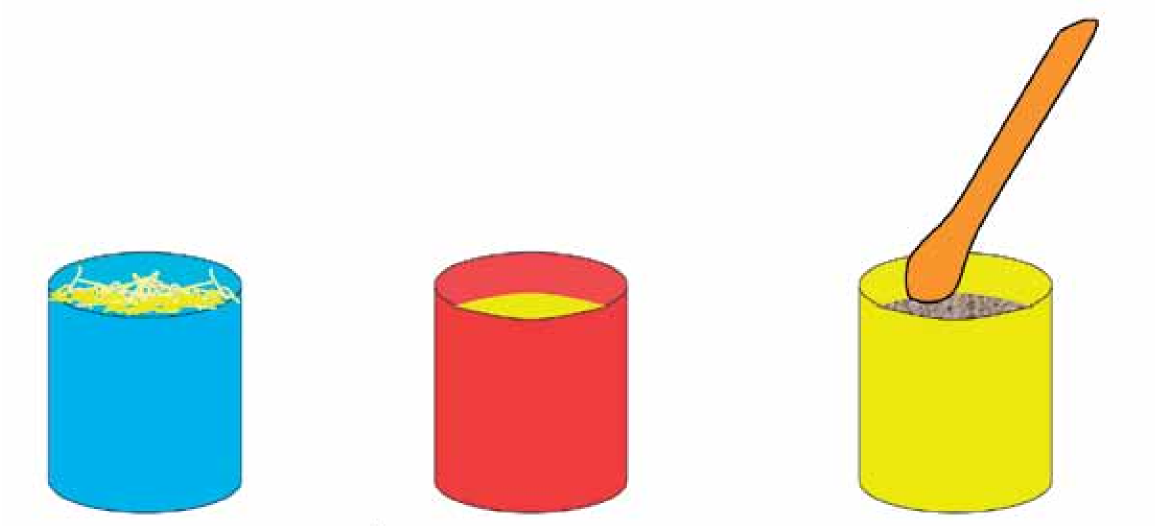


Figure 4

1. Do you think it is possible to compress the sand with the wooden spoon so that it takes less space in the yellow tin? Yes/No ......
2. Do you think it is possible to compress the straw? Yes/No ......
3. Do you think it is possible to compress the water? Yes/No ......

Straw, grass and paper bundles are **compressible**. This means that it can be compressed to take up less space.
Sand is **incompressible**. That means it cannot be compressed to take up less space.

4. (a) Is water compressible or incompressible? ....
   (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 it is filled with water or oil, it is called a **hydraulic system**.

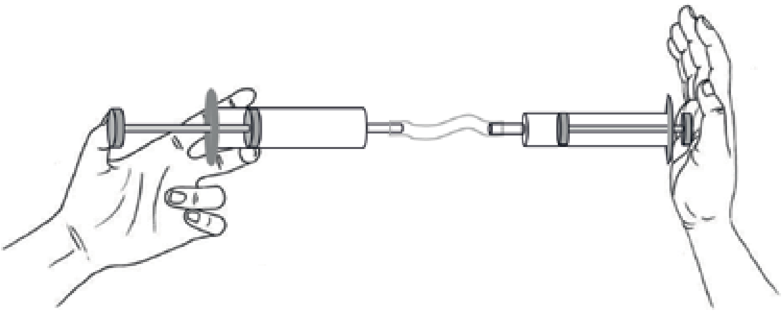


Figure 5

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.

....

....

....

A pneumatic and a hydraulic system are shown below. 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.

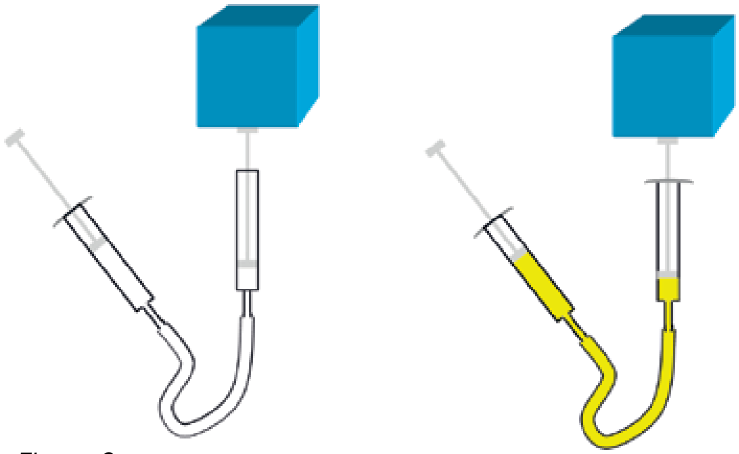


Figure 6

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

Figure 7

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

   ....

   ....

   ....

The picture 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.

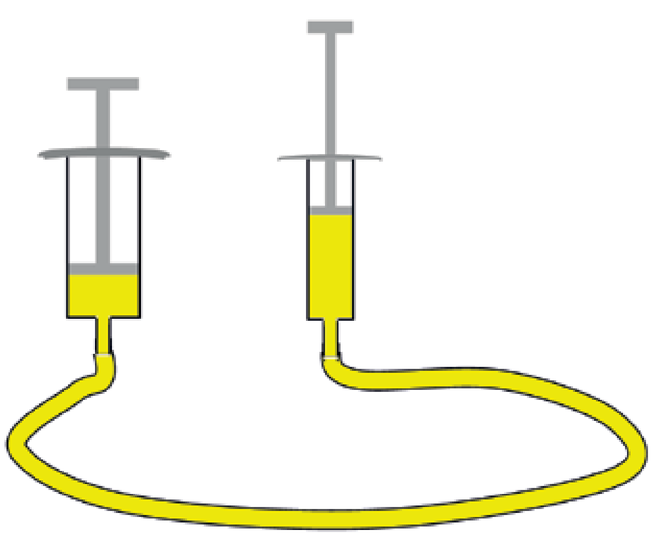
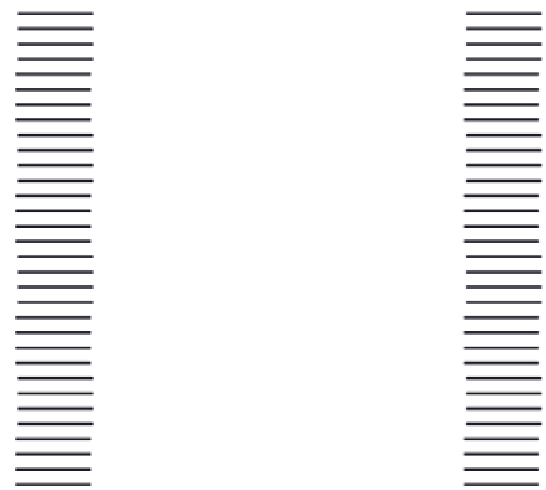


Figure 8

Action research

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

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



Attach your two-syringe system with tape to the cardboard sheet or box, as shown 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 1 cm in.
4. Measure how far the output cylinder plunger has moved.
5. Enter your measurement in the table below.
6. Repeat steps 1 to 4, but now push the input cylinder 2 cm in.
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				

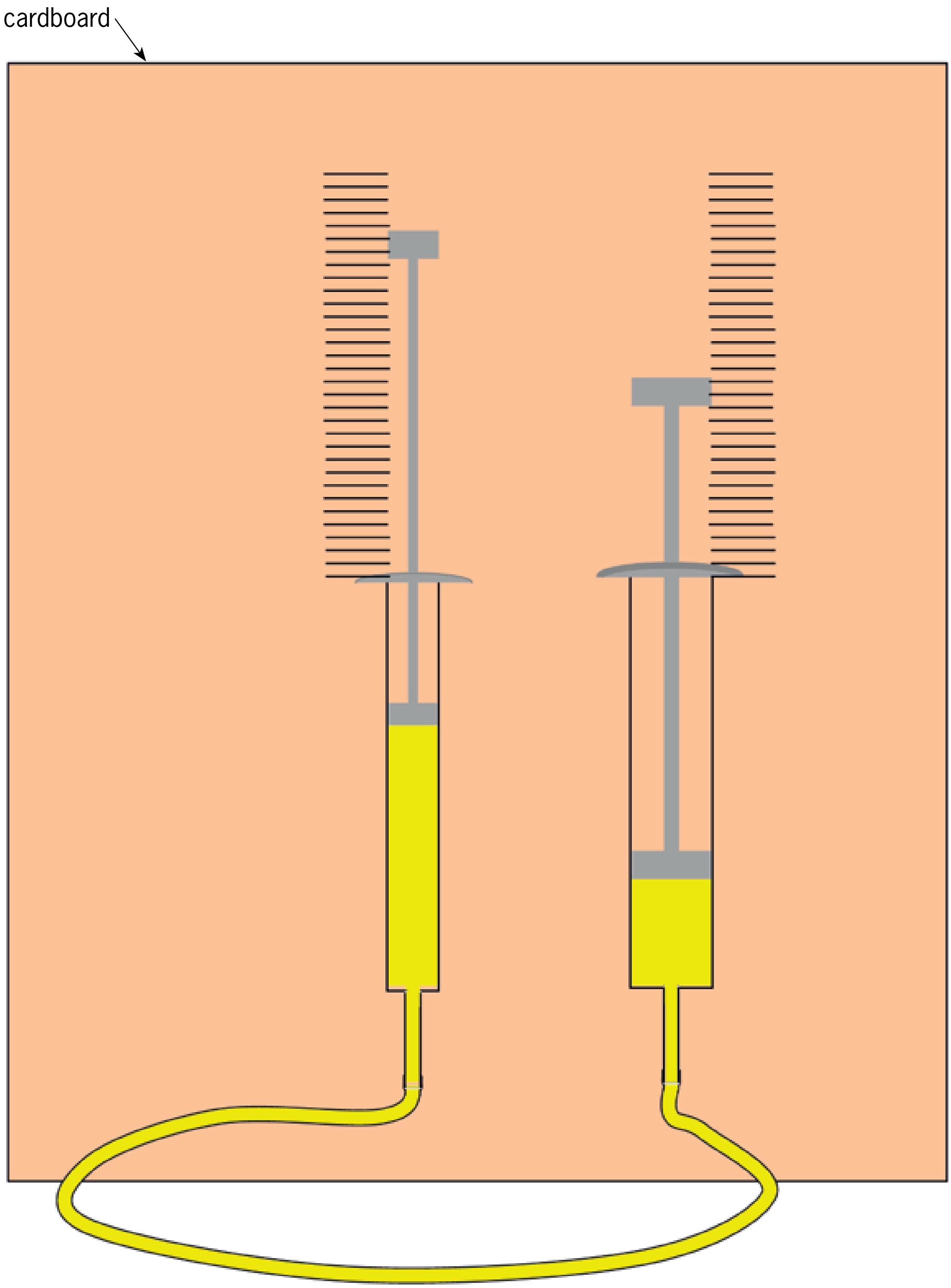


Figure 9

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 1 cm in?

....

....

9. Also predict what will happen if you press the plunger of the wide cylinder ½ cm, 1 cm or 2 cm in. Write your predictions on the table below.

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.

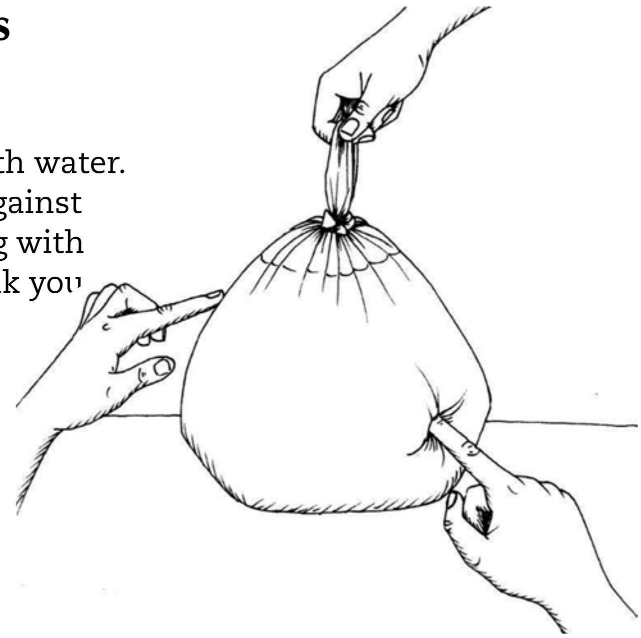
Wide master cylinder movement in cm	½	1	2
Narrow slave cylinder movement in cm			

> 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

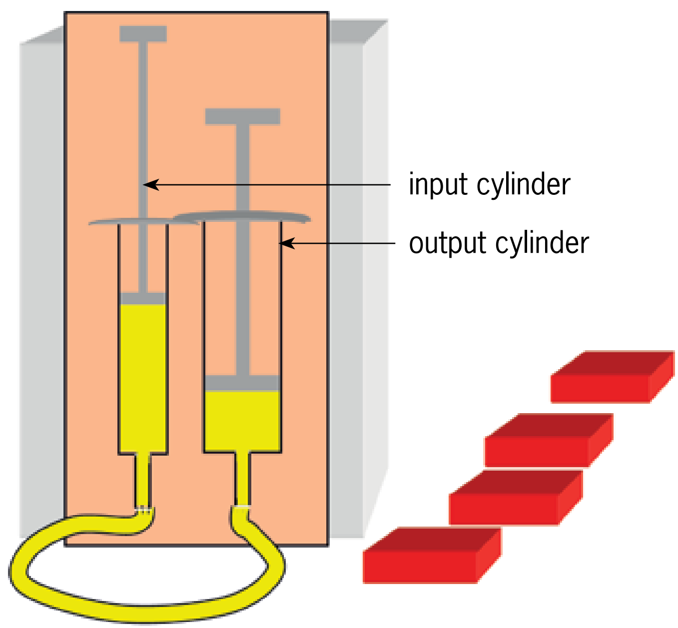


The picture shows a plastic bag filled with water. If you put your left index finger gently against the bag and then pressed against the bag with your right index finger, what do you think you would feel with your left index finger?

When pressure is applied to a flexible container with liquid, the same pressure is felt everywhere in the container. The pressure is "transmitted" or "transferred" through the liquid.

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

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



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.

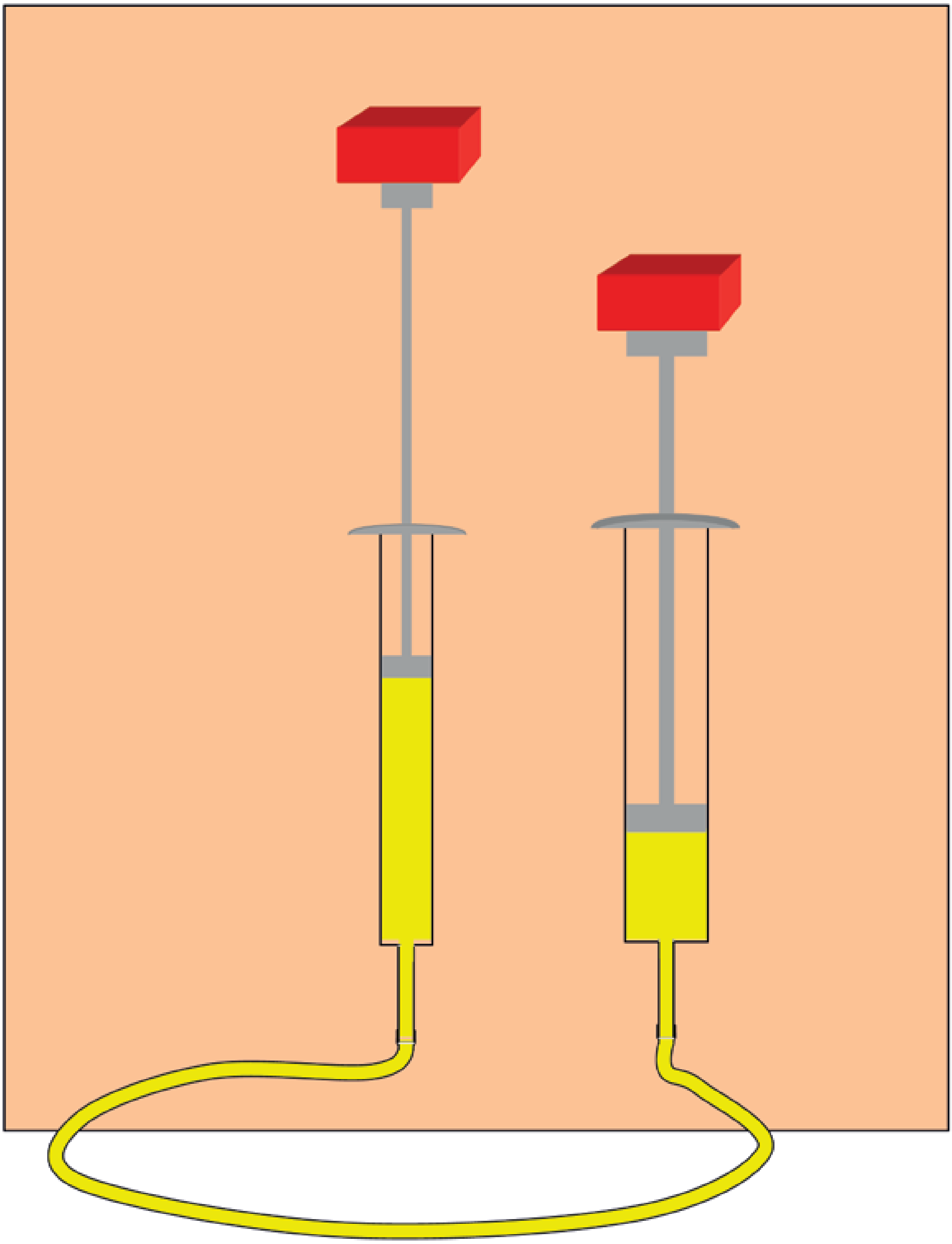


Figure 10

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 your answer in the space below.

....

....

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.

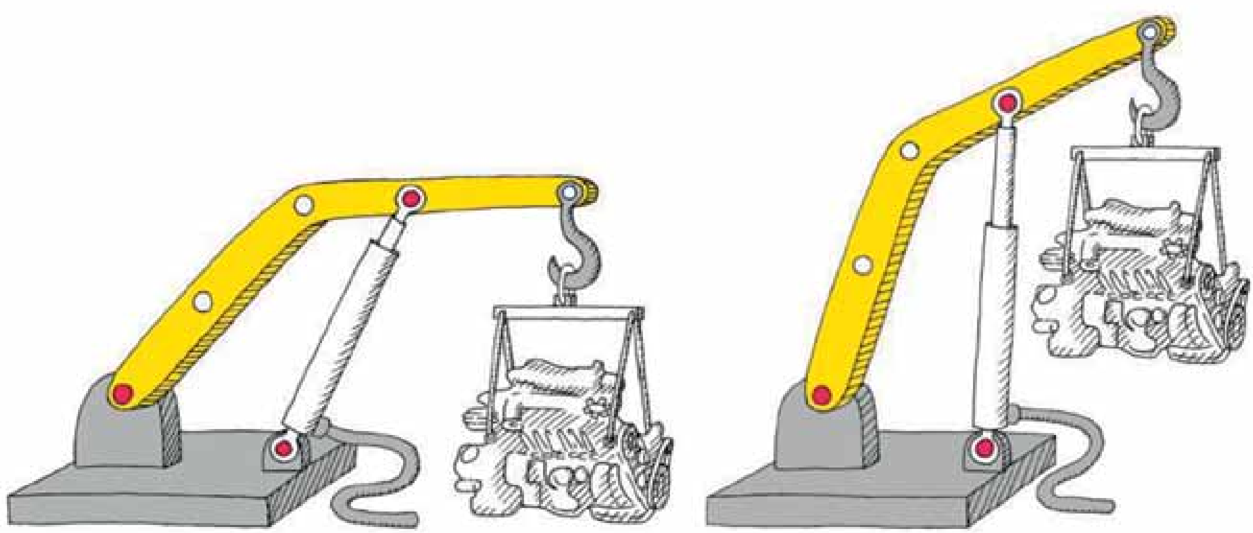


Figure 1

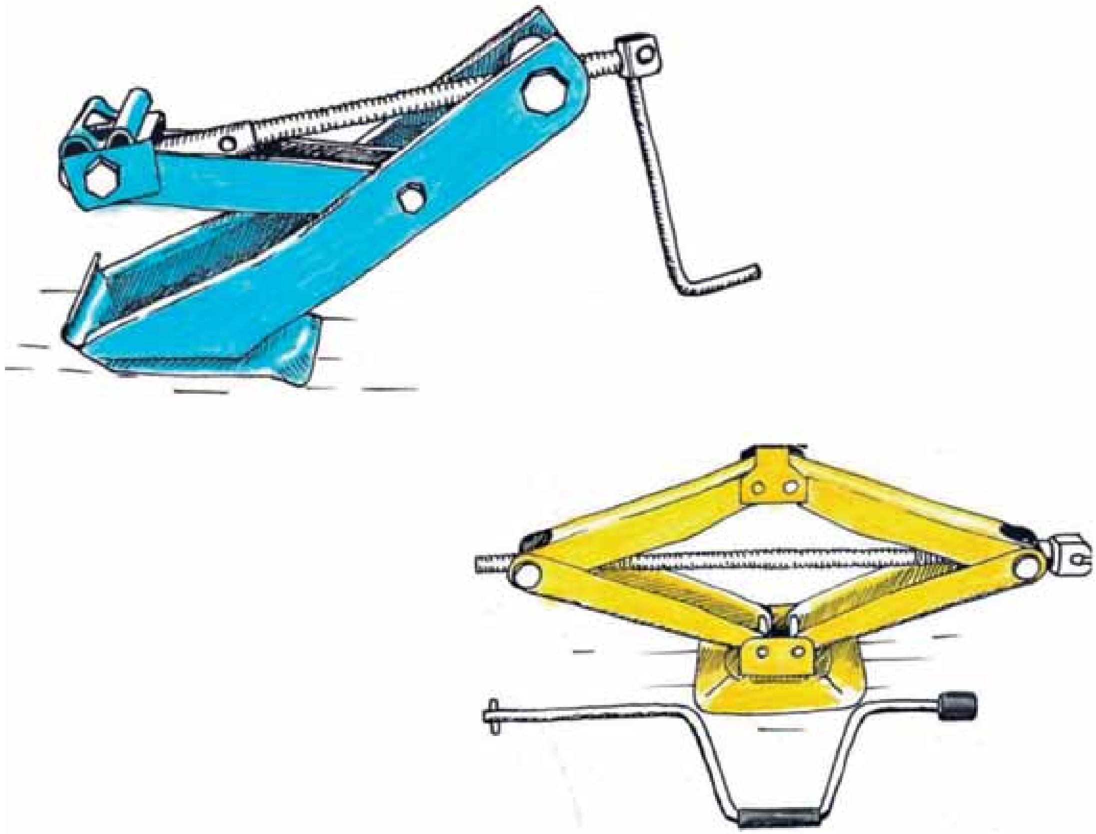


Figure 2: Mechanical jacks

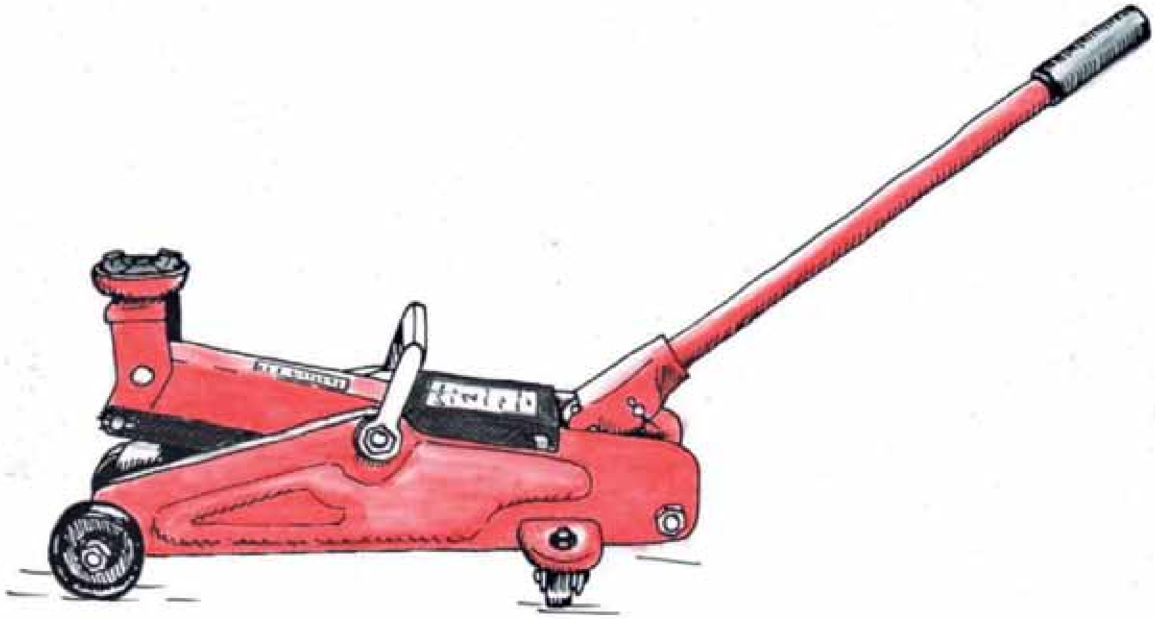


Figure 3: A hydraulic floor jack

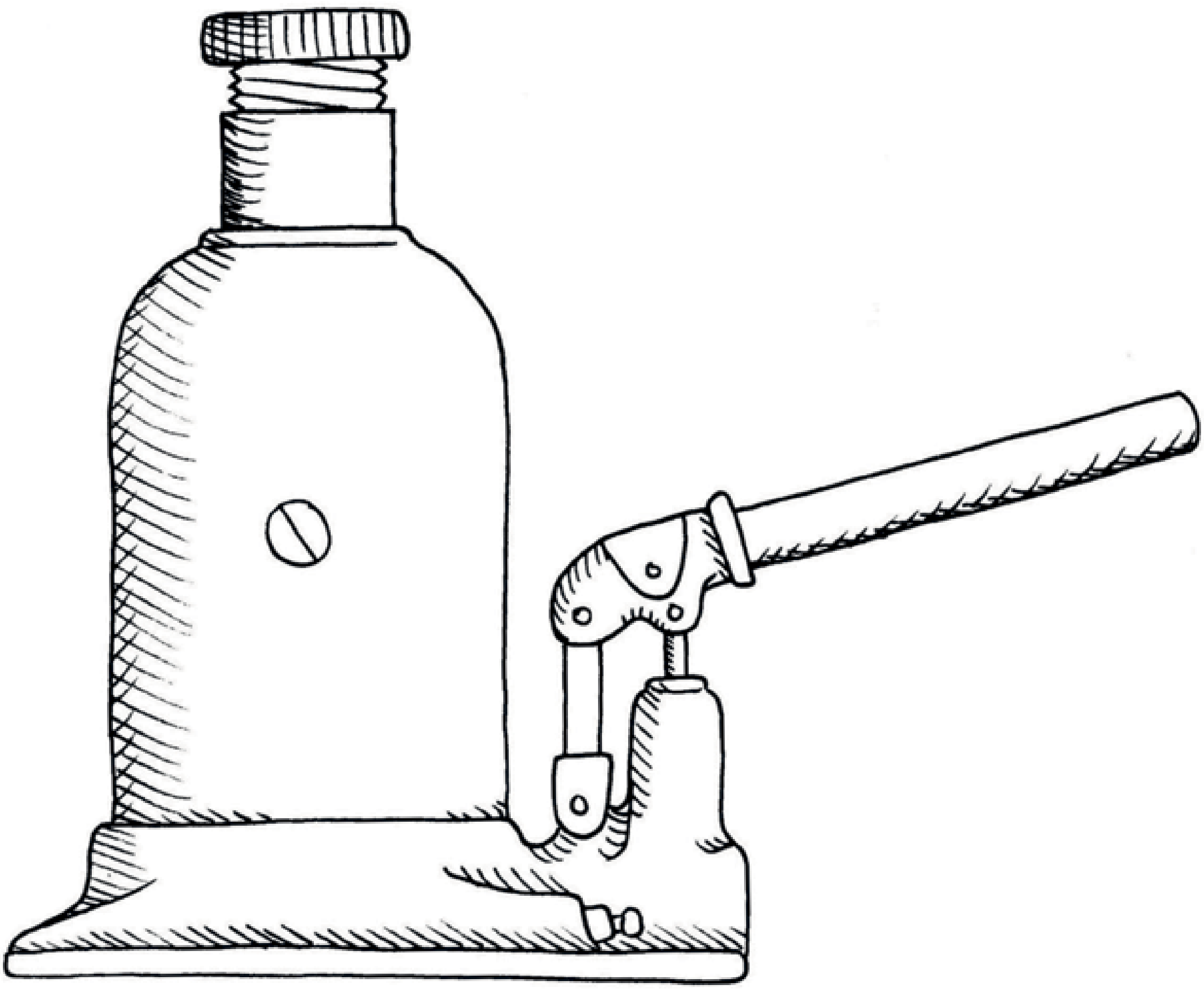


Figure 4: A hydraulic car jack

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 that paper.

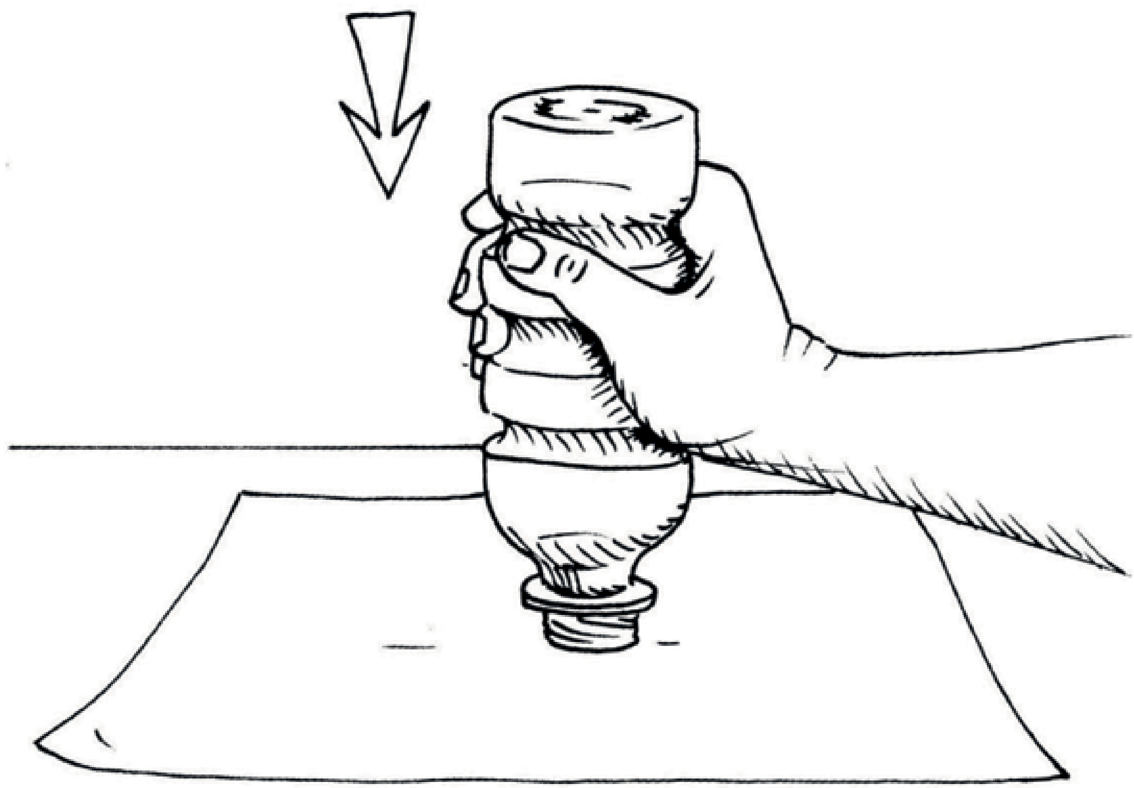


Figure 5

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

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 on the next page to show how this can be done. The machine that you design can be called a washer-making press.

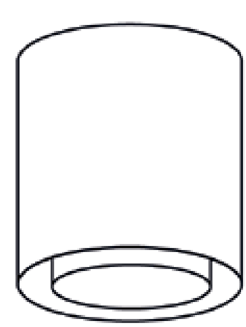


Figure 6

Instead of using a lever to exert a big enough force to cut the washers, a hydraulic pushrod can be used.

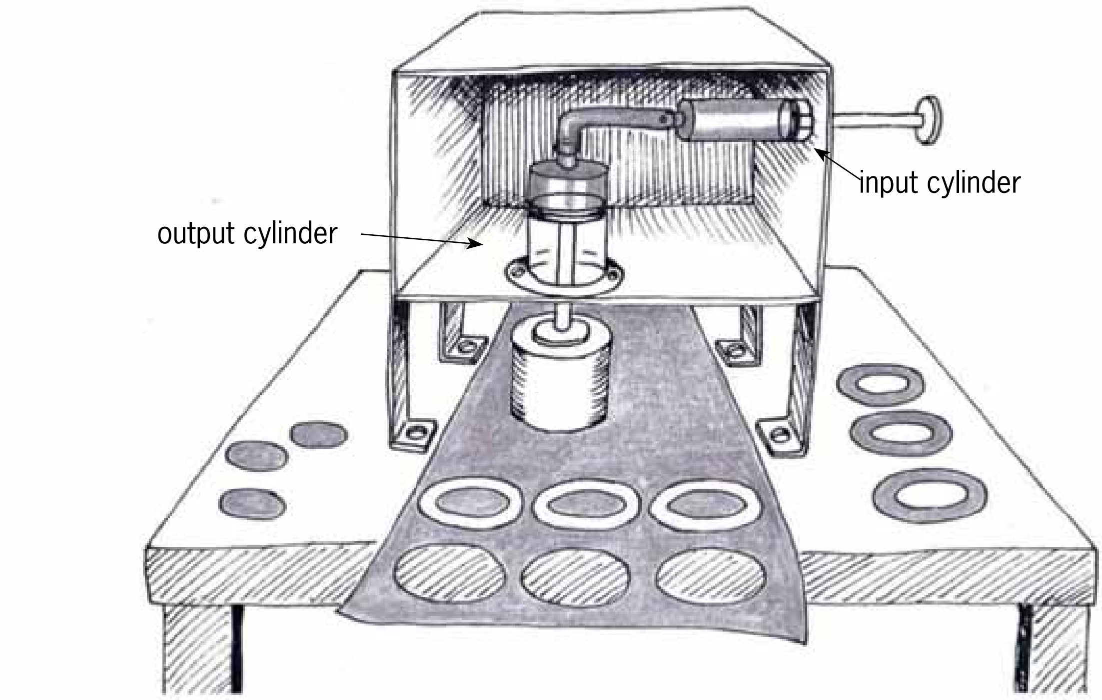


Figure 7

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.

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

Figure 8

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. 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.

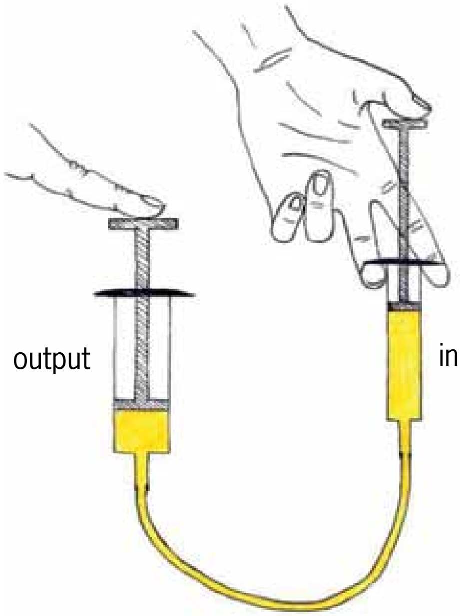


Figure 9

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.

2. (a) Imagine a hydraulic system such as this 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?

....

....

....

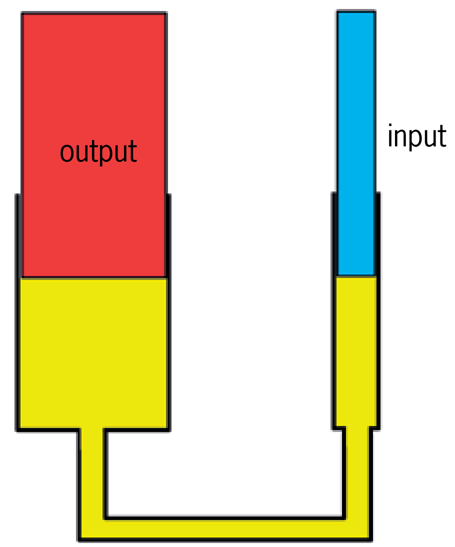


Figure 10

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

1. 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.

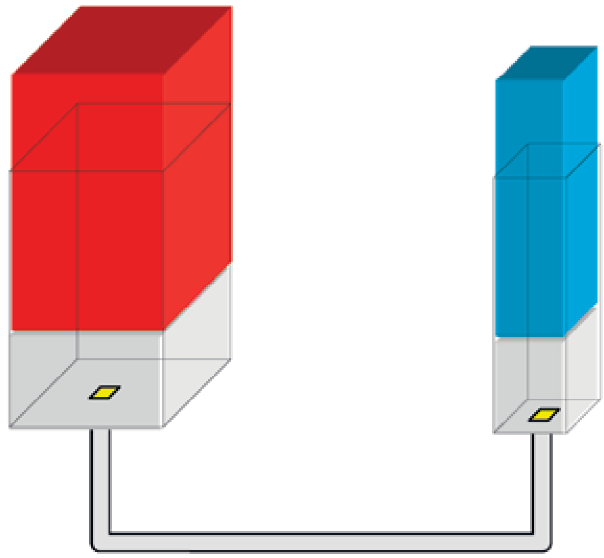


Figure 11

2. The volume of liquid that is pushed down on the right rises up on the left and pushes the red cylinder upwards.
3. If the blue cylinder moves down by 12 mm, by how much will the red cylinder move up?

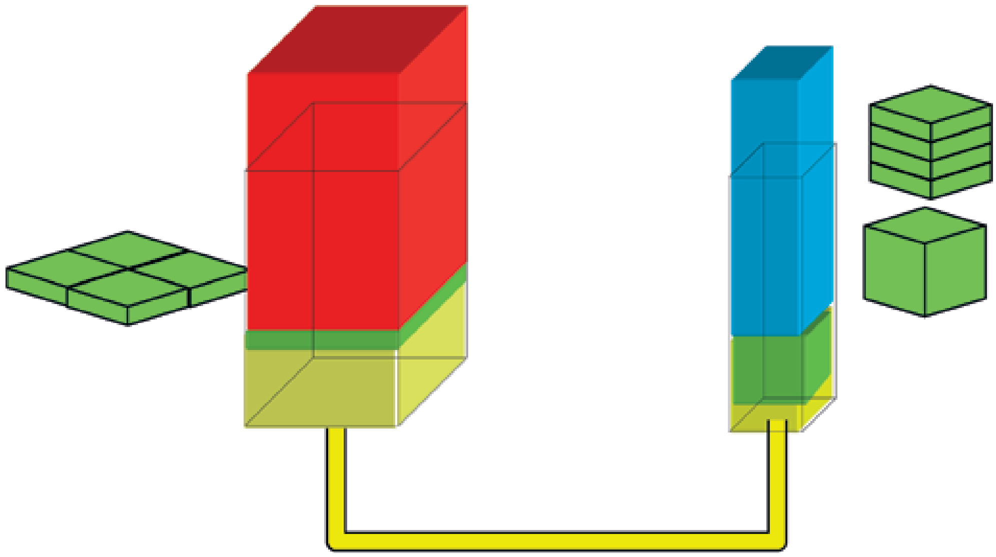


Figure 12

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 one makes at a right angle with the height of the cylinder. It is called the **cross-sectional area**.

If you struggle to understand what is written above, think of a roll of polony or a brick-shaped bread. Every piece that you cut from the polony or bread has exactly the same shape and size, and therefore also has the same surface area.

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 ¼ of the input distance.

In this case the mechanical advantage is four, and the distance advantage is ¼.

4. 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?

   ....

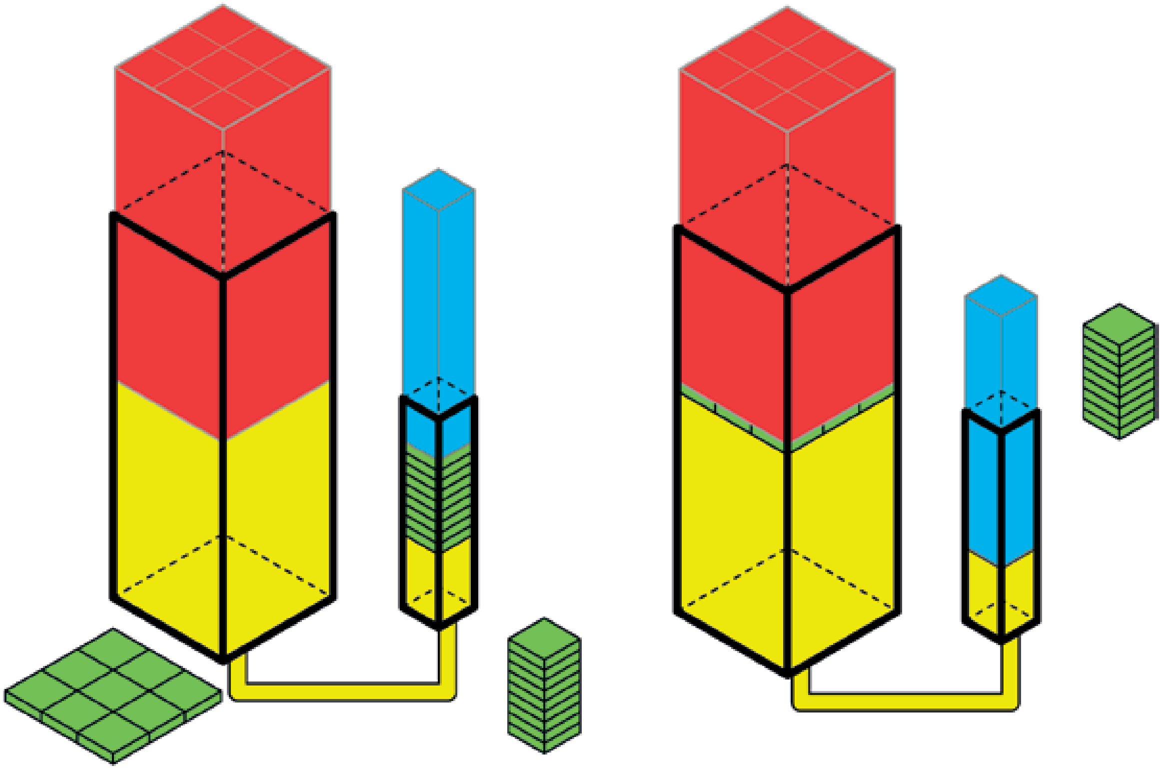


Figure 13

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

....

6. 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

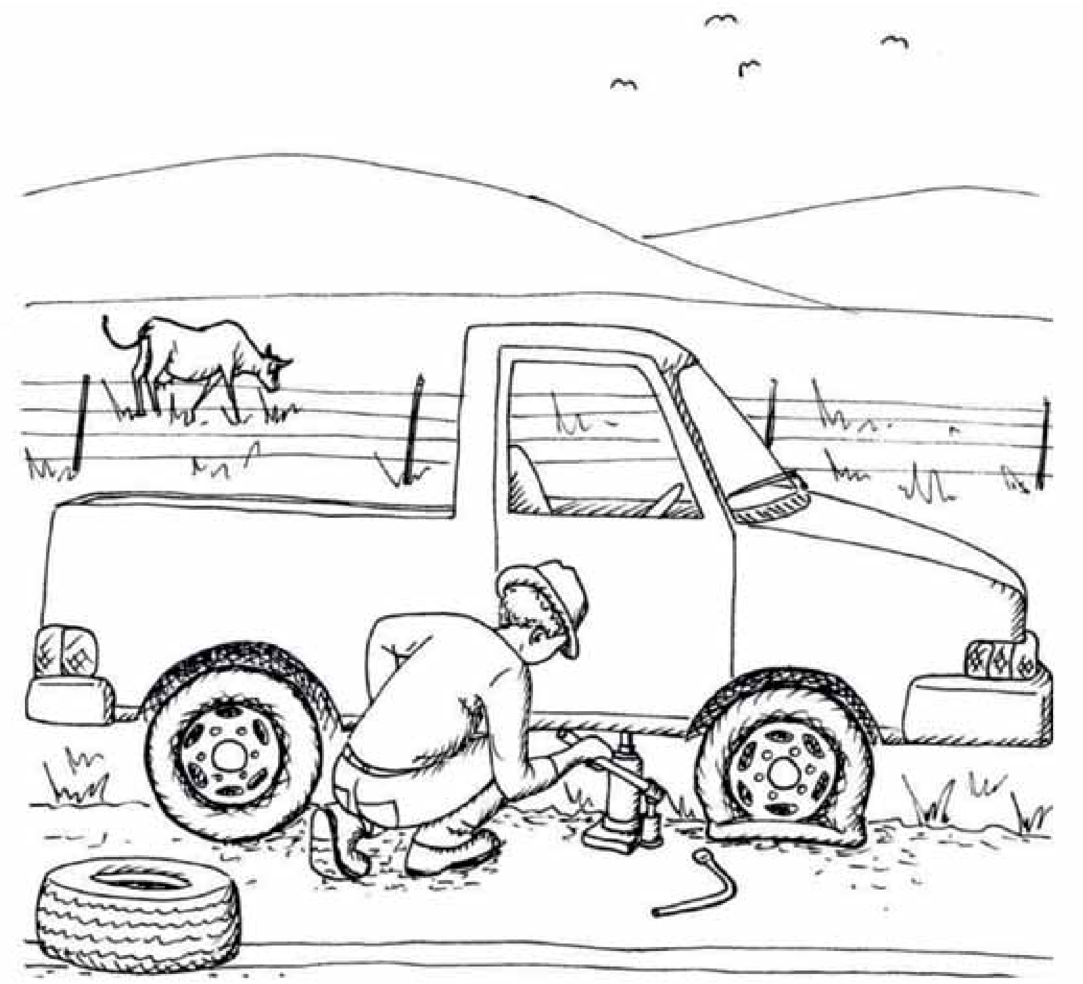


Figure 14

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

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

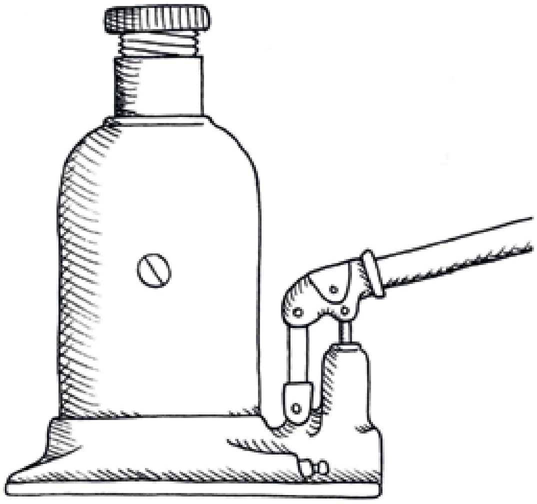


Figure 15: A hydraulic bottle jack

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

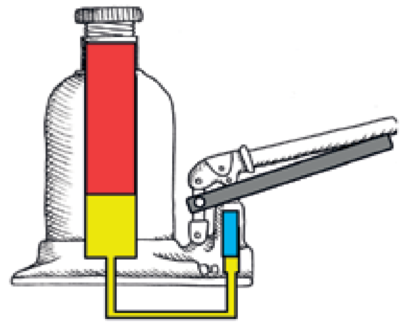


Figure 16

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.

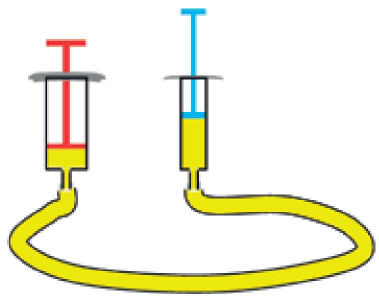


Figure 17

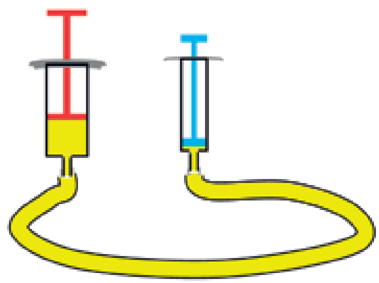


Figure 18

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

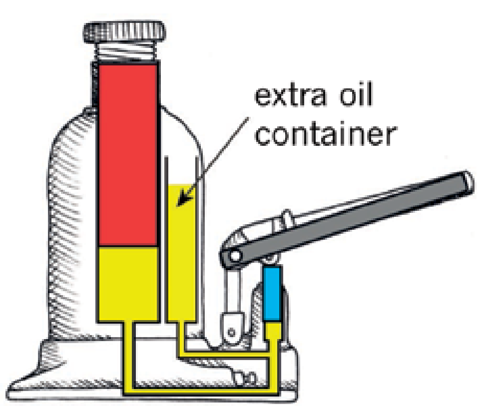


Figure 19

underneath the red cylinder. Perhaps something like a water tap should be placed at the white box in the diagram on the right.

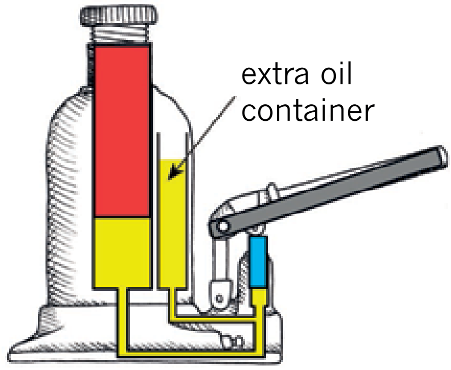


Figure 20

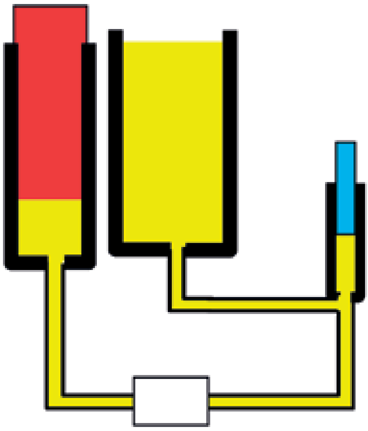


Figure 21

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.

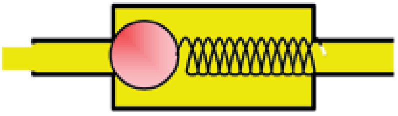


Figure 22: Ball valve closed

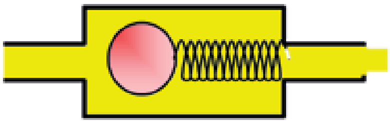


Figure 23: Ball valve open

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.

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.

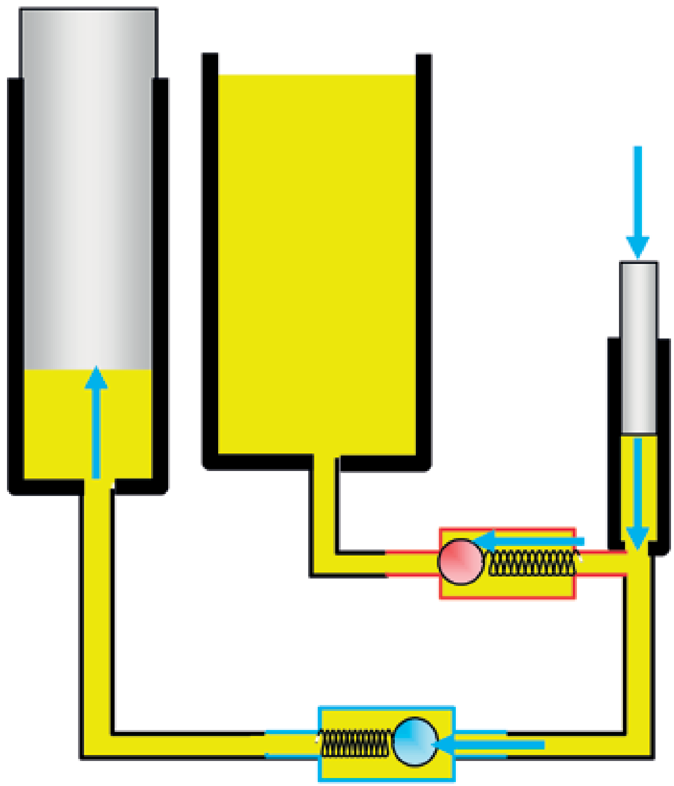


Figure 24

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.

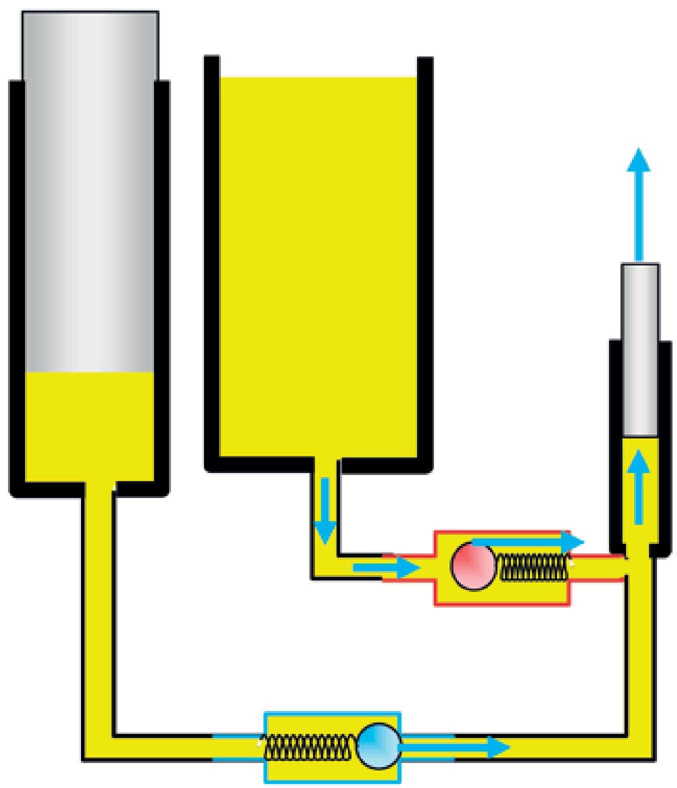


Figure 25

Make a systems diagram of how a hydraulic car jack works on the next page. The picture below can help you to think of the different things that happen between the input and output of a car jack. The systems diagram must show in different steps what happens inside the jack if you press down and pull back the lever twice.

Note that the additional tank of oil in the drawing below has a hole inside it into which the output cylinder fits. This tank is also called the "oil reservoir" of the hydraulic system.

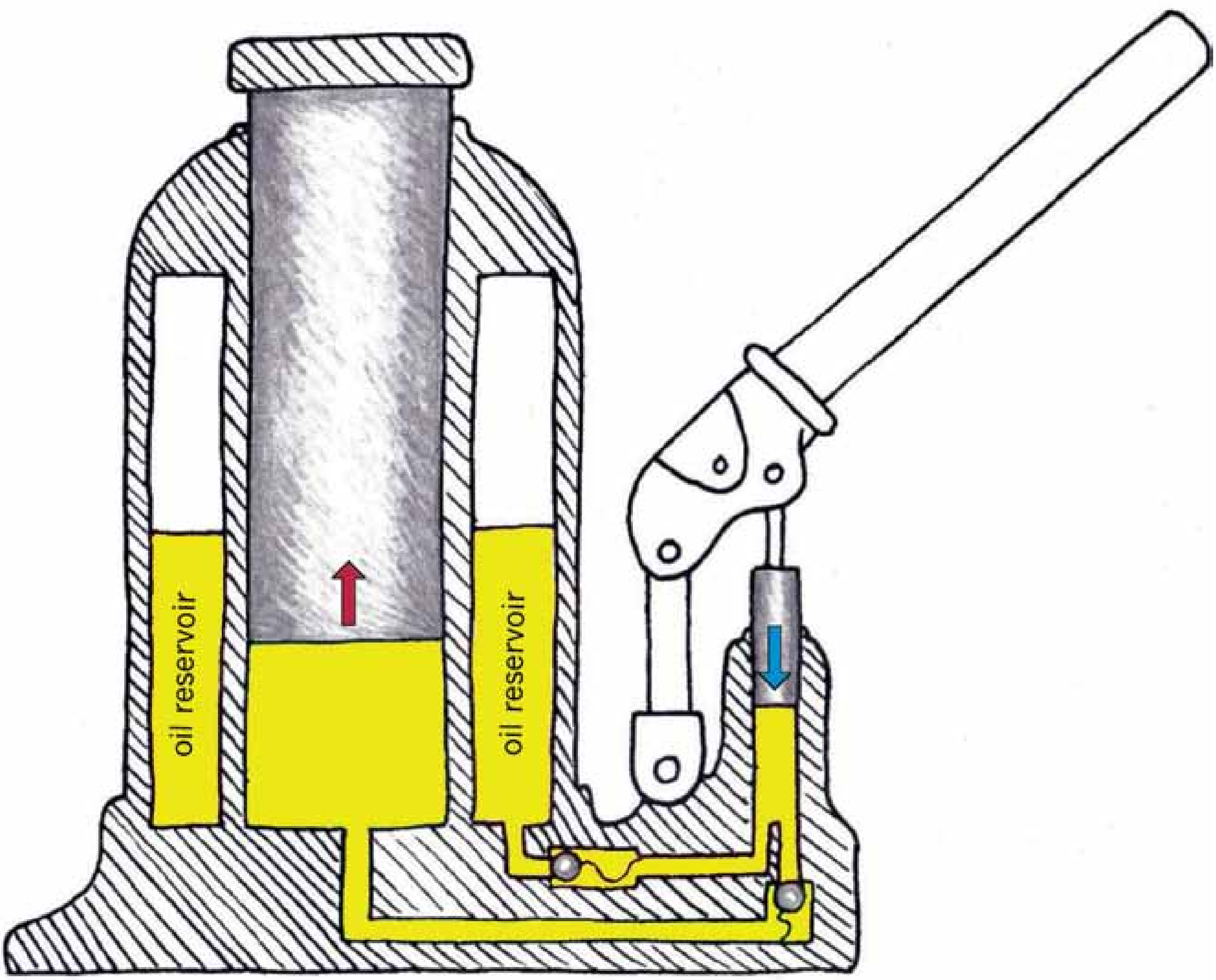


Figure 26: A few inner workings of a hydraulic car jack

Sketch your systems diagram of a car jack on this page.

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

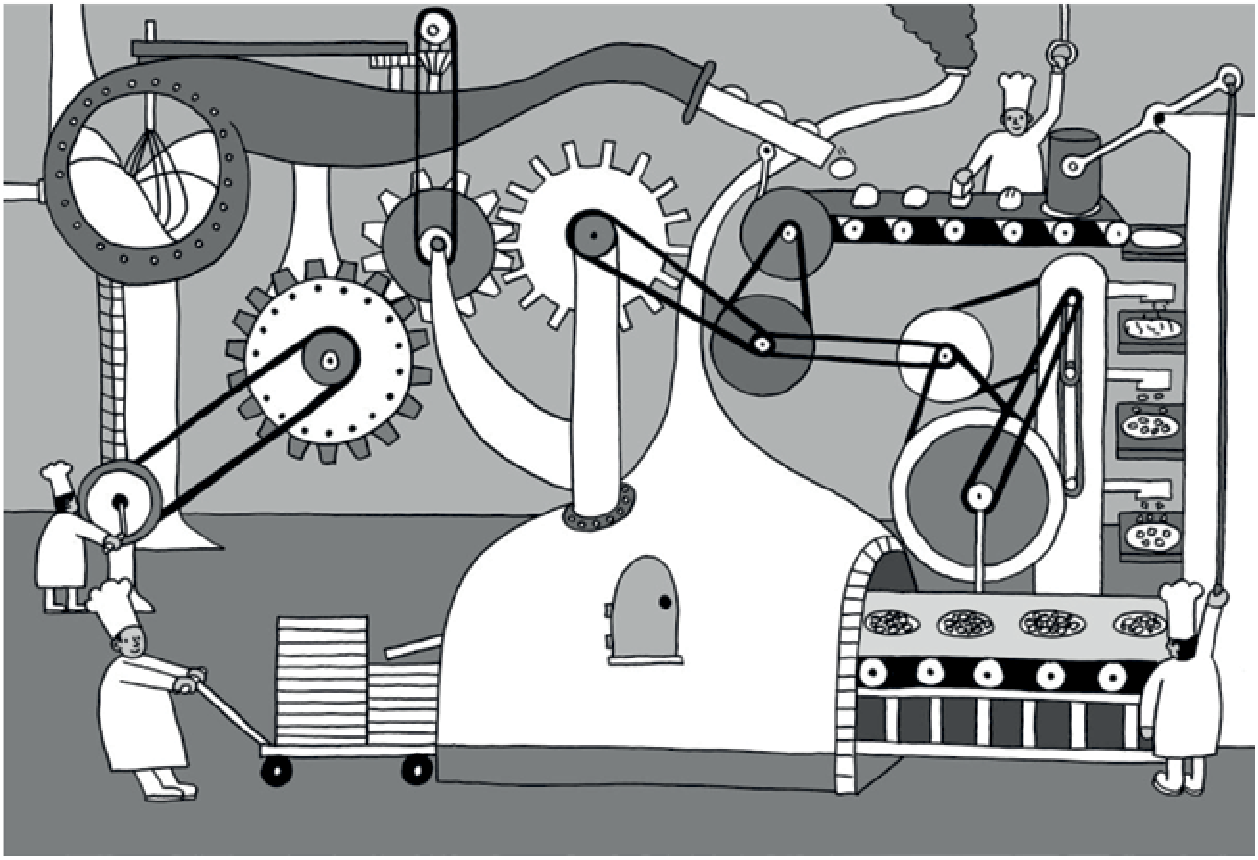


Figure 1

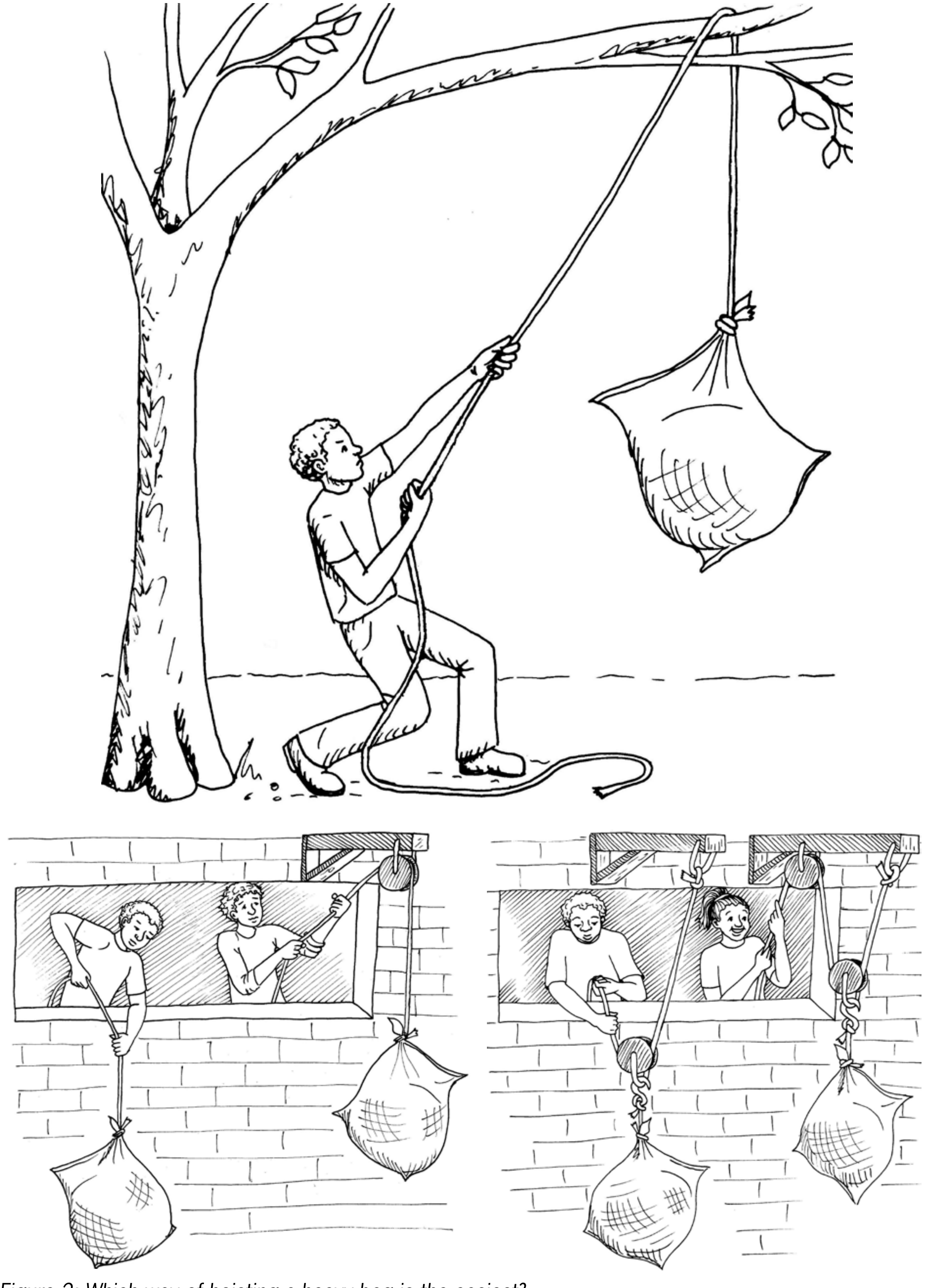


Figure 2: Which way of hoisting a heavy bag is the easiest?

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 till the wind has dried the grain out. To get the sack up, he slung a rope over the branch and fastened the one end of the rope to the sack.

1. (a) Mark the direction in which the man pulls with an arrow, on the picture on the previous page.
   (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**.

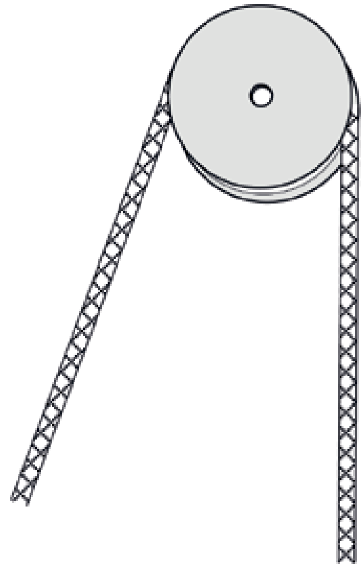


Figure 4: A pulley

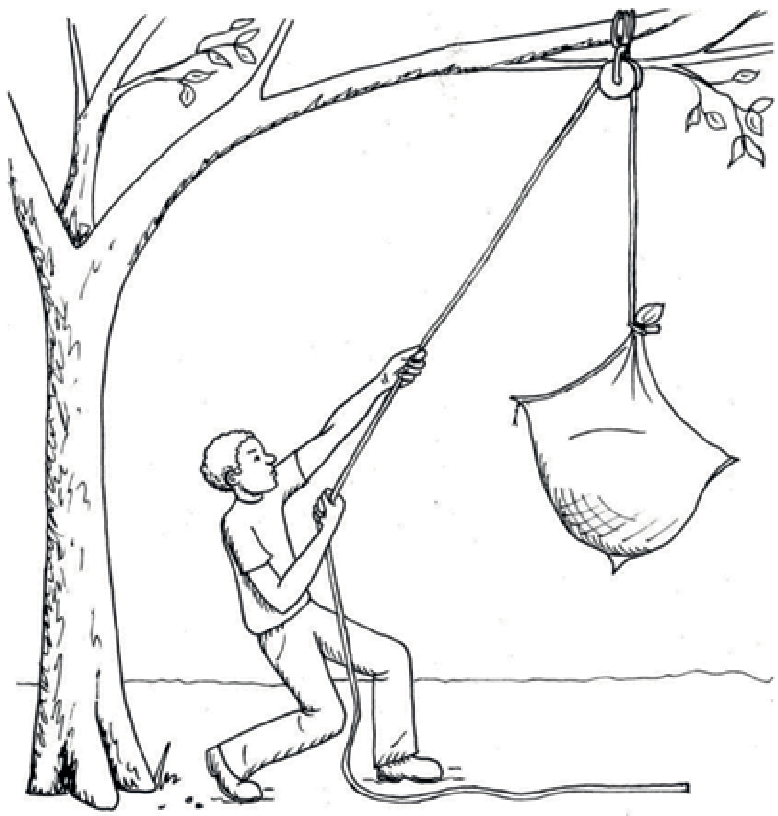


Figure 5: The man uses a pulley to lift the sack

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.

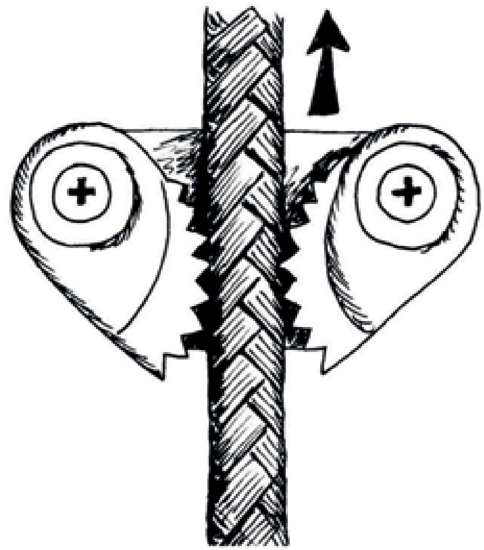


Figure 6: A cam cleat

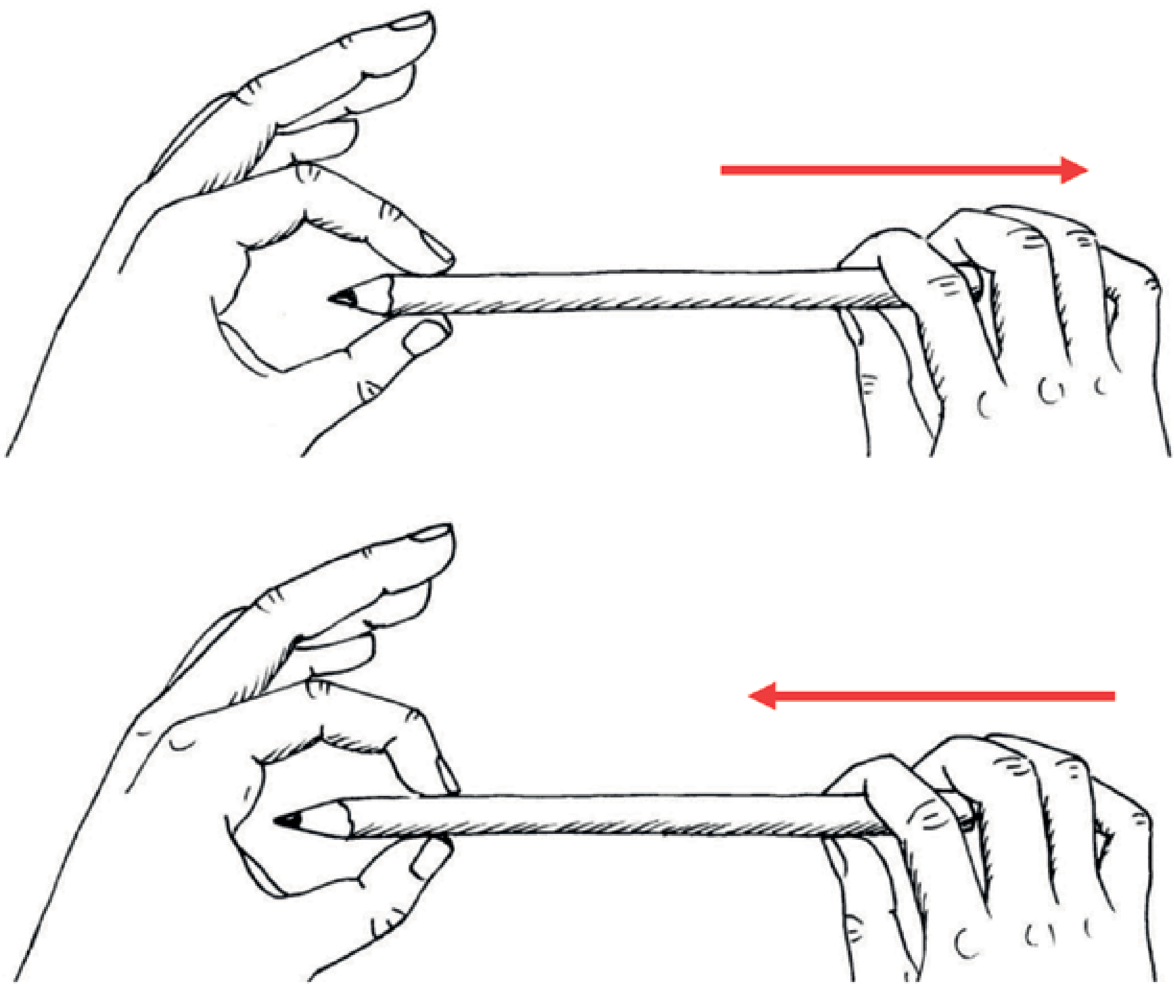


Figure 7: You can slide a pencil through your thumb and forefinger to feel how a cam cleat works.

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

An important experiment

You need a piece of string or a shoelace, and a cup or beaker with a handle.

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

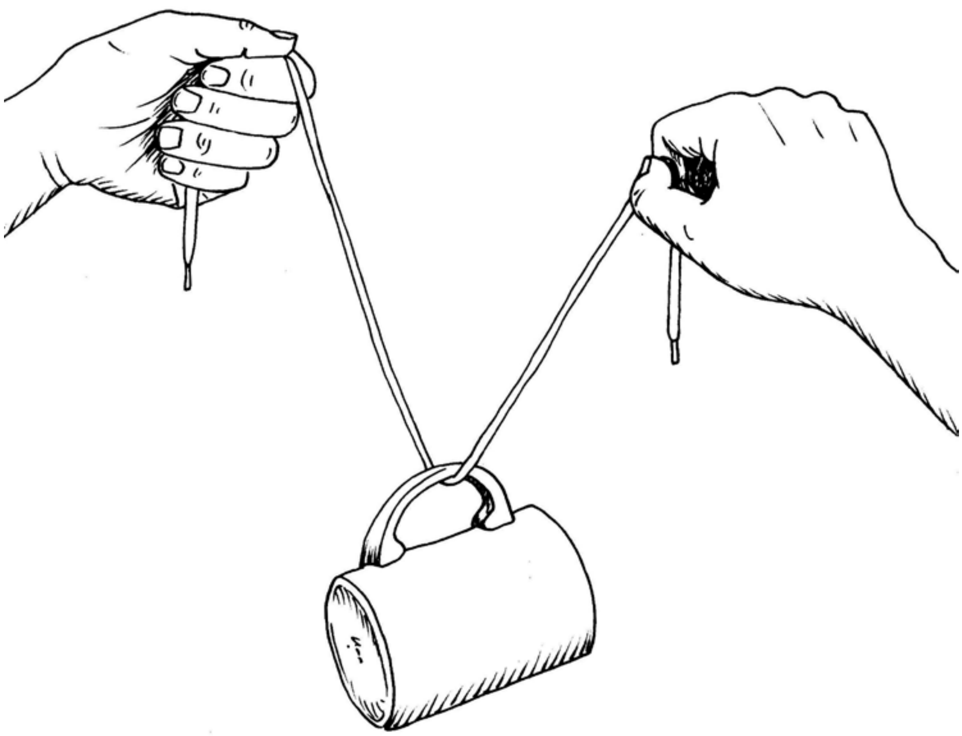


Figure 8

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

....

....

....

....

7.2 Different ways to use a pulley

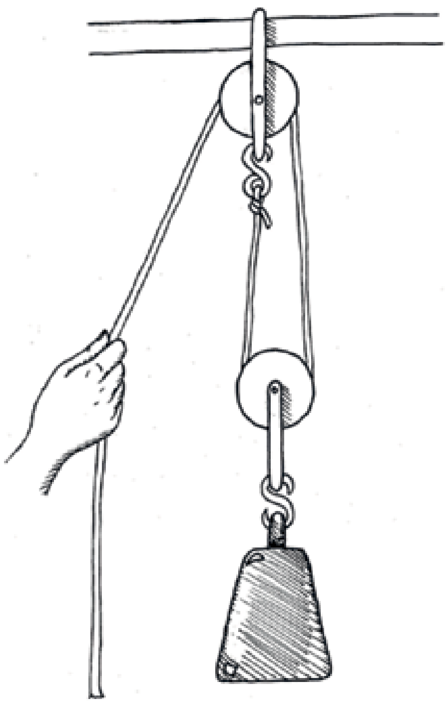


Figure 9: A block-and-tackle

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

Look carefully at the three diagrams on the opposite page, that show different ways in which pulleys can be used when lifting an object with a rope.

In the diagrams, 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 10C shows a **single wheel fixed pulley system**.

Figure 10B shows a **single wheel moveable pulley system**.

Figure 10A shows a **pulley block system**, also called a **block and tackle**.

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?

   ....

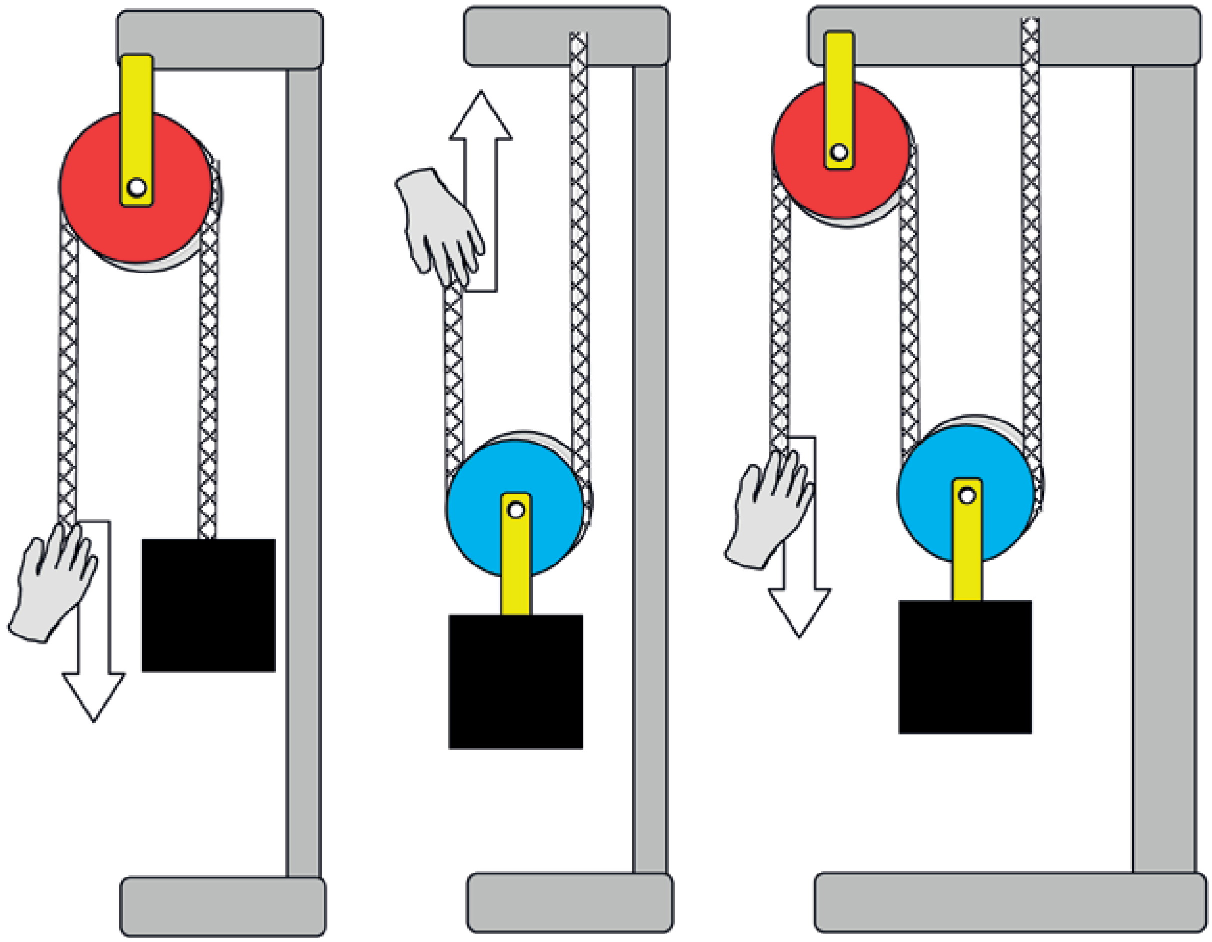


Figure 10A   Figure 10B   Figure 10C

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

2. In what way do the moveable pulleys, shown in blue, help to make it easier to lift the black object? If you have difficulty with this question, remember what you experienced when you did the experiment with the string and the cup on page 103.

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. . . .

. . . .

The picture below could help you to better understand how a moveable pulley system works.

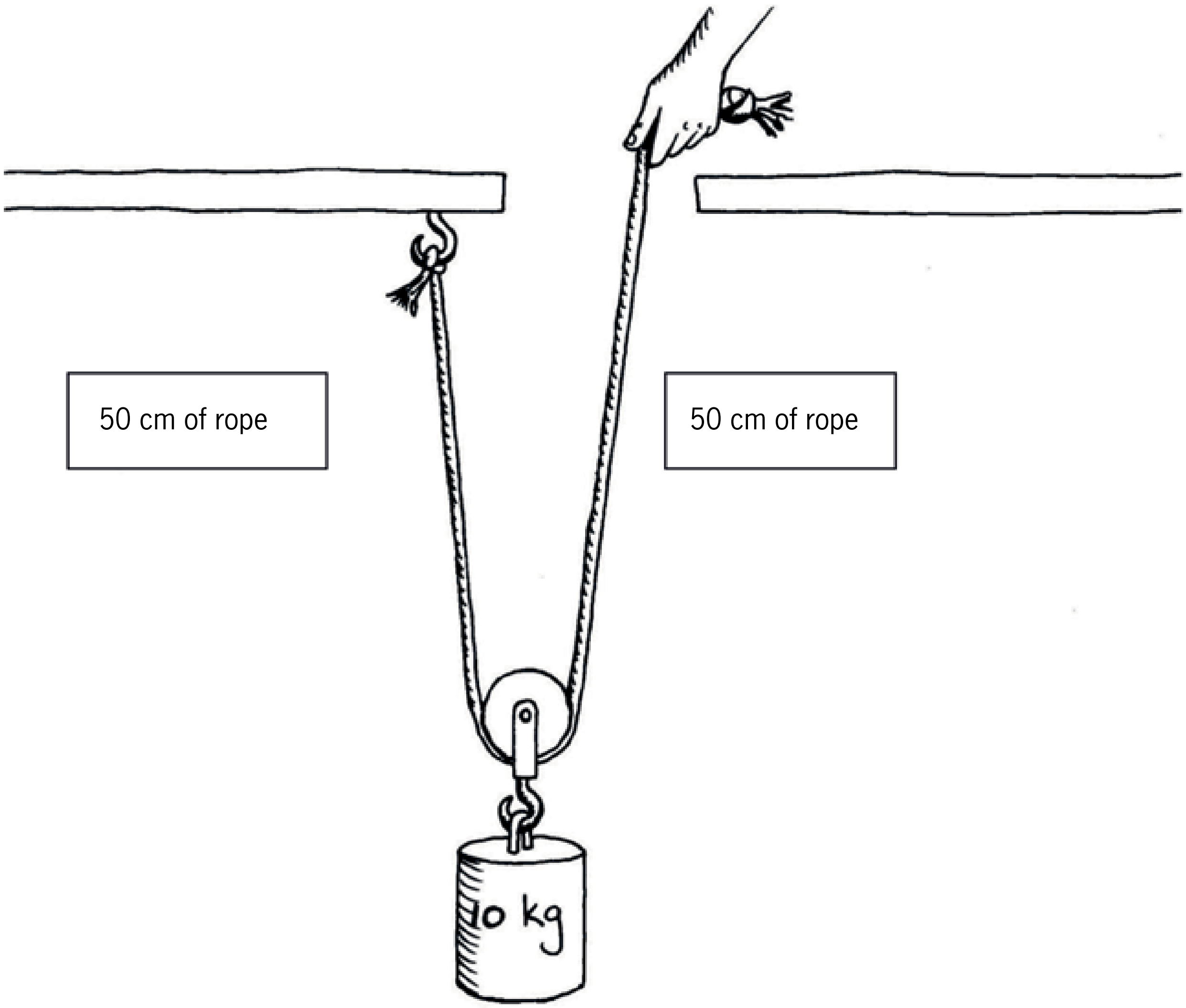


Figure 11: Single moveable-pulley system

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.

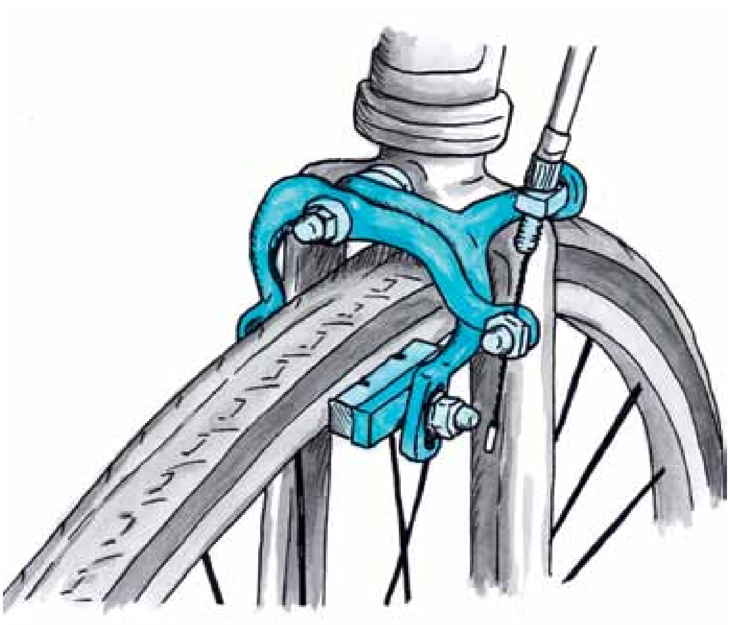
Because the hand moves twice the distance of the load, the force required is the same as you would need to pick up half the load (5 kg) directly.

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 photograph on the right. The diagrams on the next page will help you to understand this photograph better.



Figuur 13

Think of a pair of scissors:

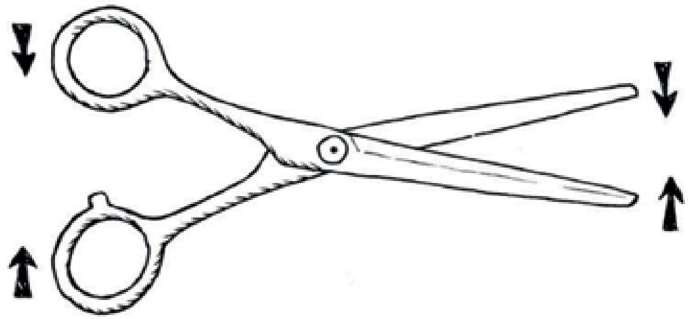


Figure 14

A pair of scissors can also be made like this:

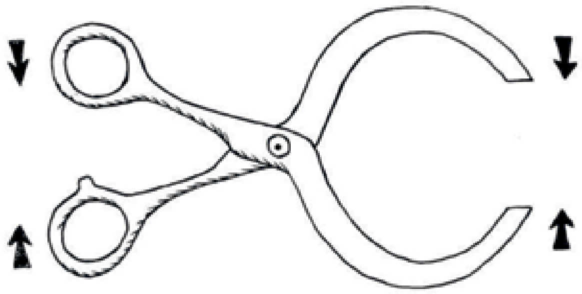


*Figure 15: An instrument like this is sometimes called **a pair of callipers.***

The handles could be bent like this:

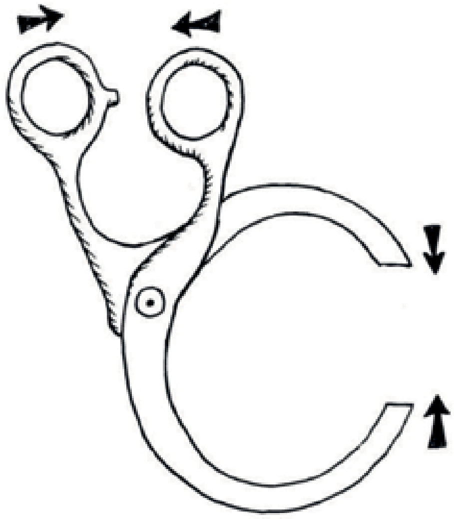


Figure 16

The brake system in the photograph (Figure 13) is actually a pair of callipers, as you can see from Figure 17 on the opposite page.

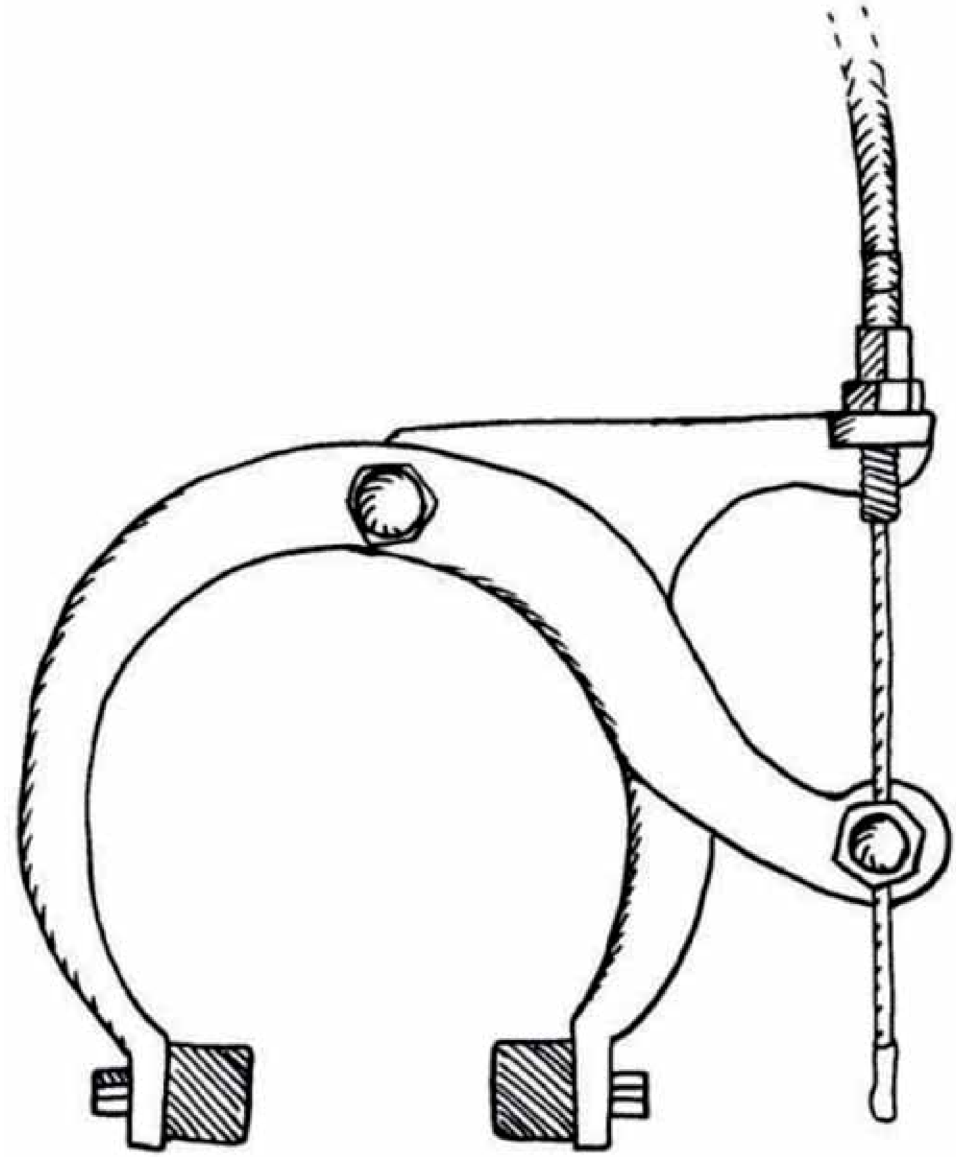


Figure 17: Calliper brake for a bicycle

1. Do the following:
   (a) On the picture above, draw the part of the bicycle wheel that fits between the brake blocks. This is the front view.
   (b) On the next page, 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 pivot.
   Use arrows to show how the parts move when the brake is pulled.

Make your drawing of the side view of a bicycle calliper brake system here:

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

Figure 18: Disc brake on a car

Figure 19: Disc brake on a motor cycle

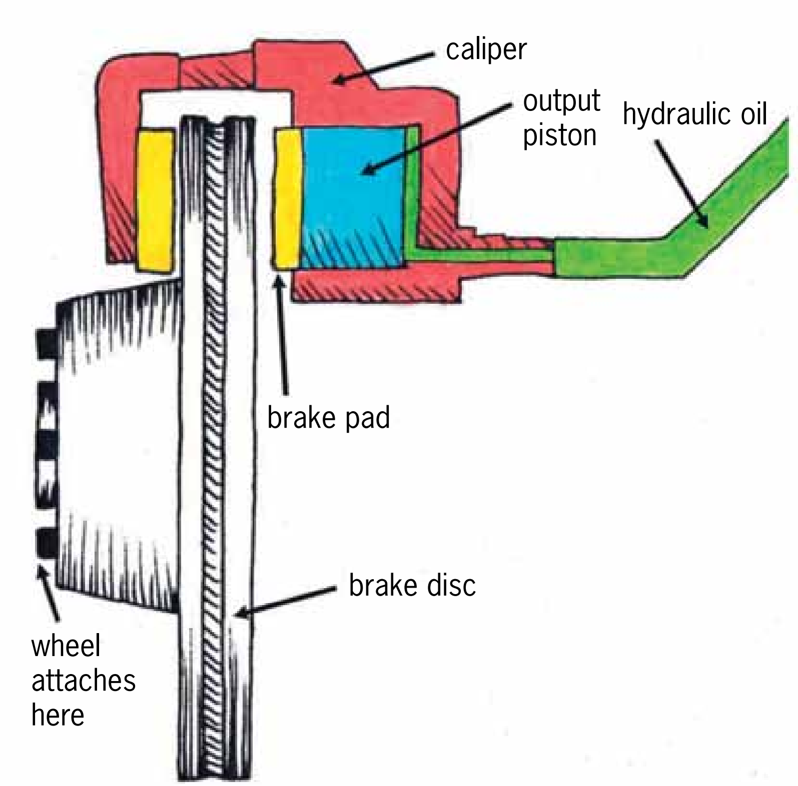


Figure 20: The parts of a car disc brake

A disc brake system consists of a brake disc, a caliper and brake pads.

When the brake pedal is pushed, it moves the input piston, which pushes hydraulic oil into the output piston.

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

One-way control systems

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.

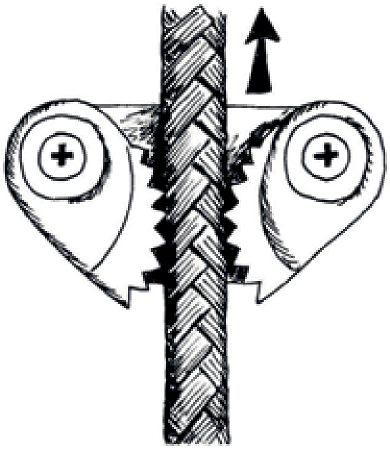


Figure 21

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

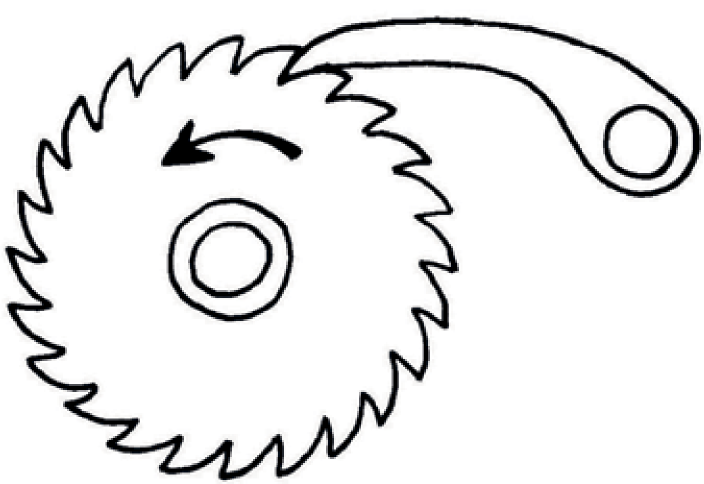


Figure 22: A ratchet and pawl

1. Make a free-hand sketch at the bottom part of the next page 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.

Draw a block and pulley with a one-way control system in the space below:

A question to make you think

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

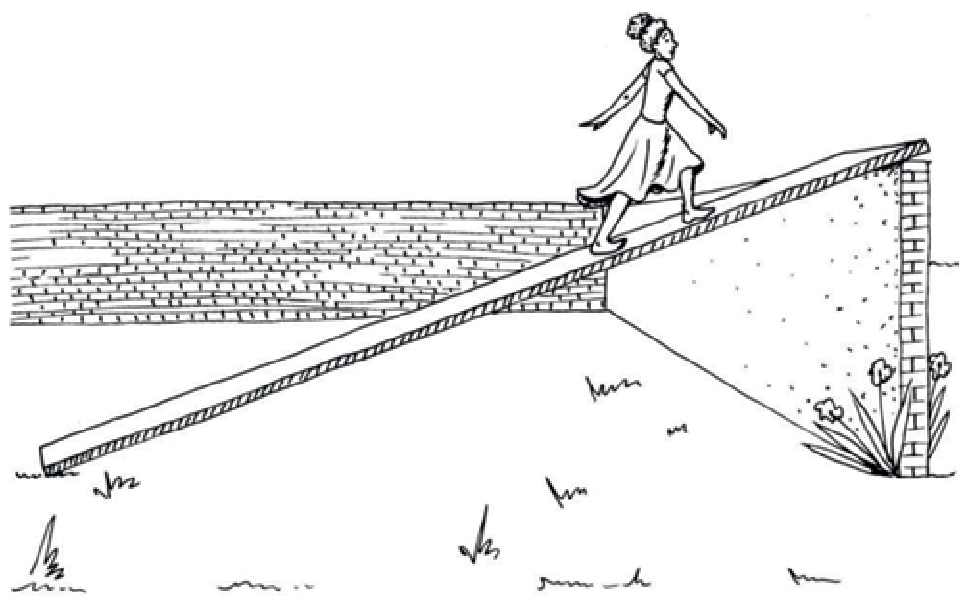


Figure 24

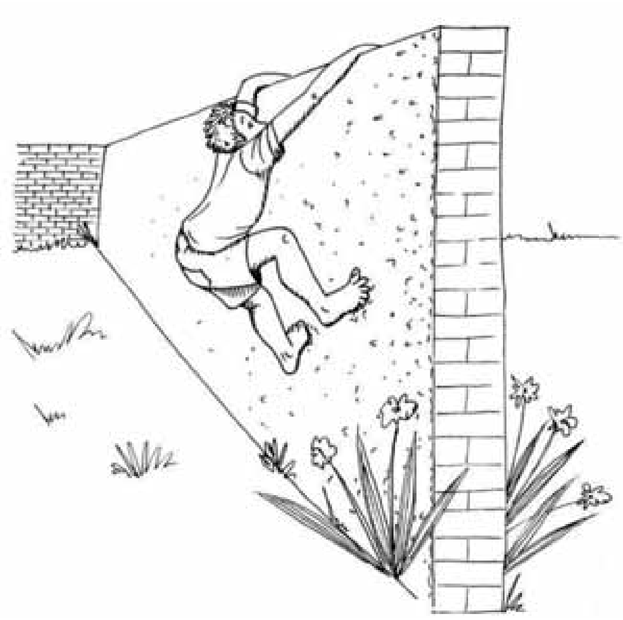


Figure 25

Next week

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

Chapter 8
Gears

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

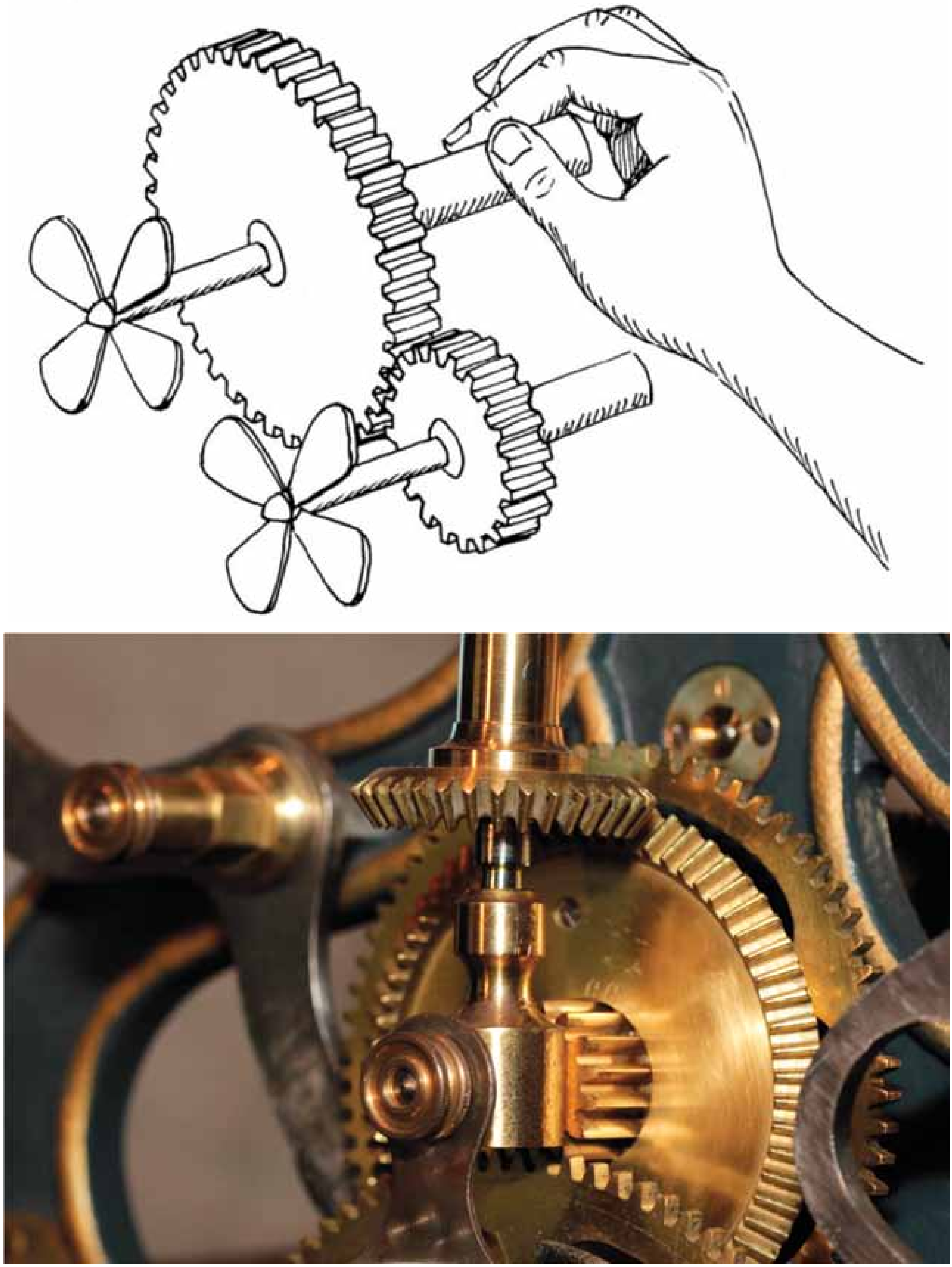


Figure 2

8.1 Direction of rotation of spur gears

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. Draw arrows next to Figure 4 to show where the blue and red dots will be.

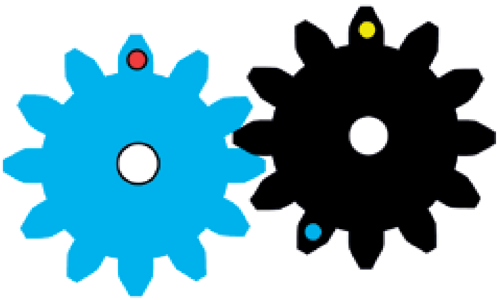


Figure 3

   (c) In what direction did the blue gear turn?

   ....

   (d) Through which part of a full revolution did each gear turn?

   ....

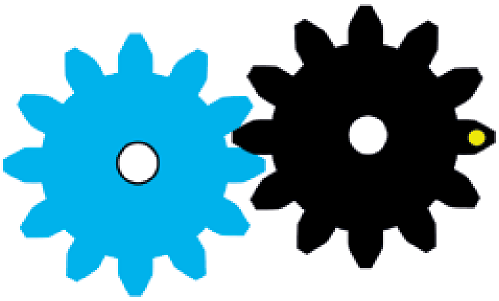


Figure 4

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. Indicate with arrows where each of the yellow dots will be afterwards.

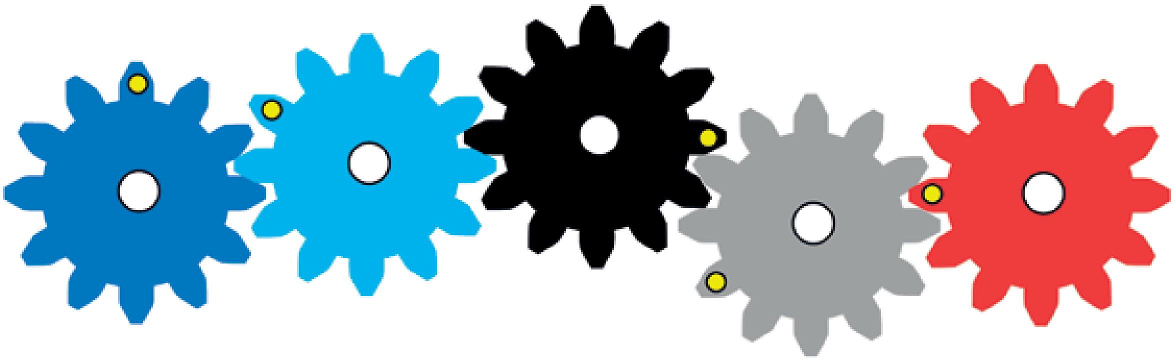


Figure 5

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

....

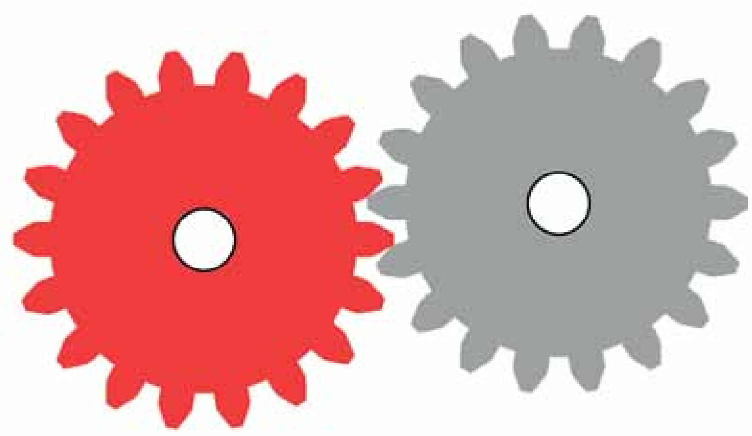


Figure 6: Counter-rotation

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?

....

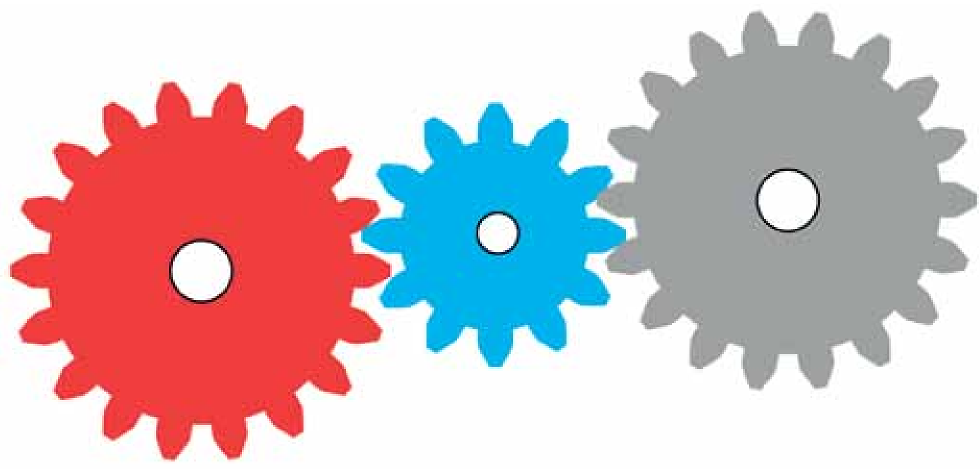


Figure 7: A blue idler gear

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.

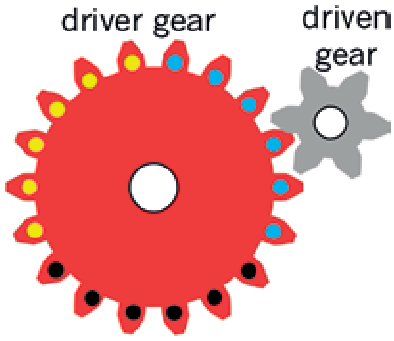


Figure 8

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

   ....

   ....

   ....

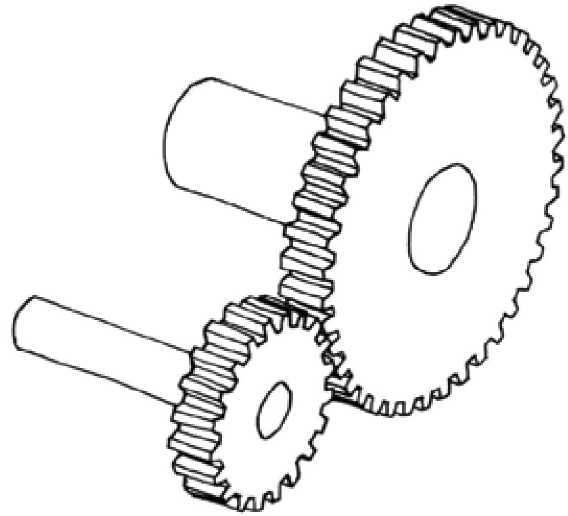


Figure 9

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

   ....

> 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 want 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.

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.

   ....

   ....

   ....

   ....

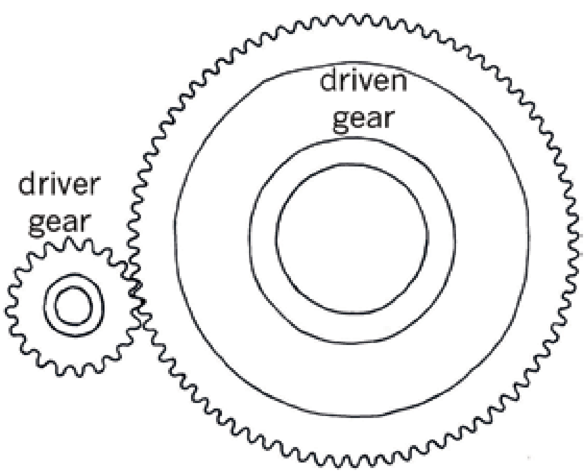


Figure 12

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.

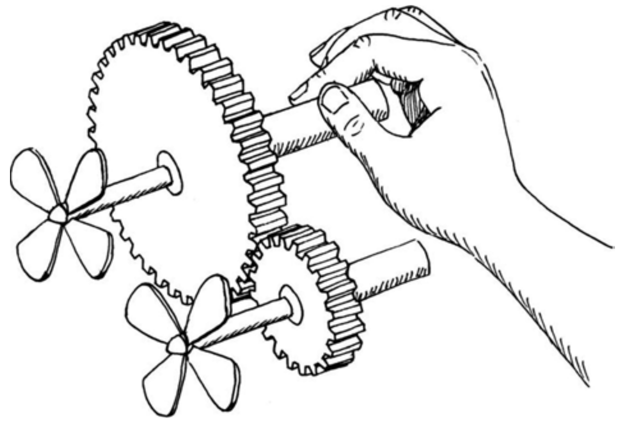


Figure 13

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.

   ....

   ....

   ....

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**.

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 greatest force, the driver or the driven axle?

   ....

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.

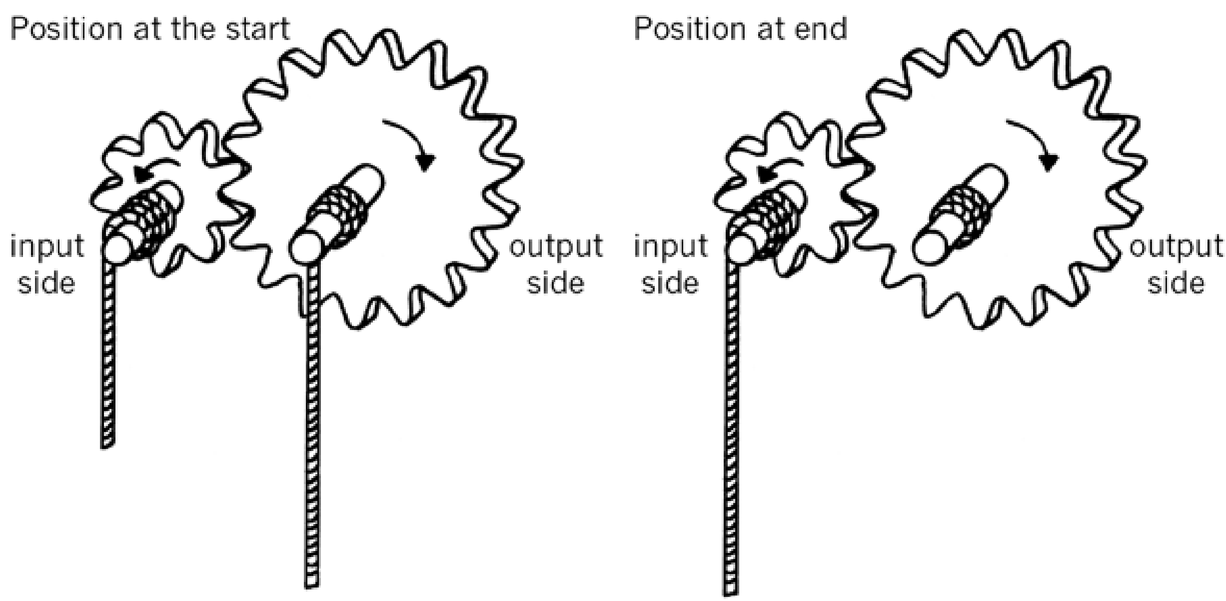


Figure 14

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

....

....

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.

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5. If you pull down with a force equal to 3 kg on the input side, how heavy a load can be lifted on the output side? Write this below and also on Figure 15.

   ....

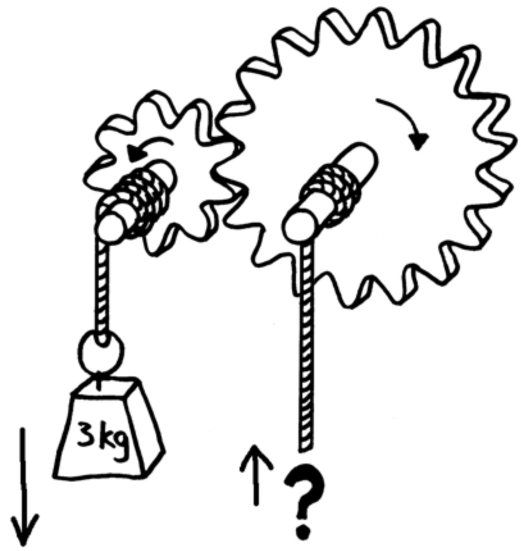

Figure 15

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 6 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.

   ....

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   ....

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?

   ....

   ....

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   (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?

   ....

   ....

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   ....

   (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?

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8.3 Other types of gears

Bevel gears

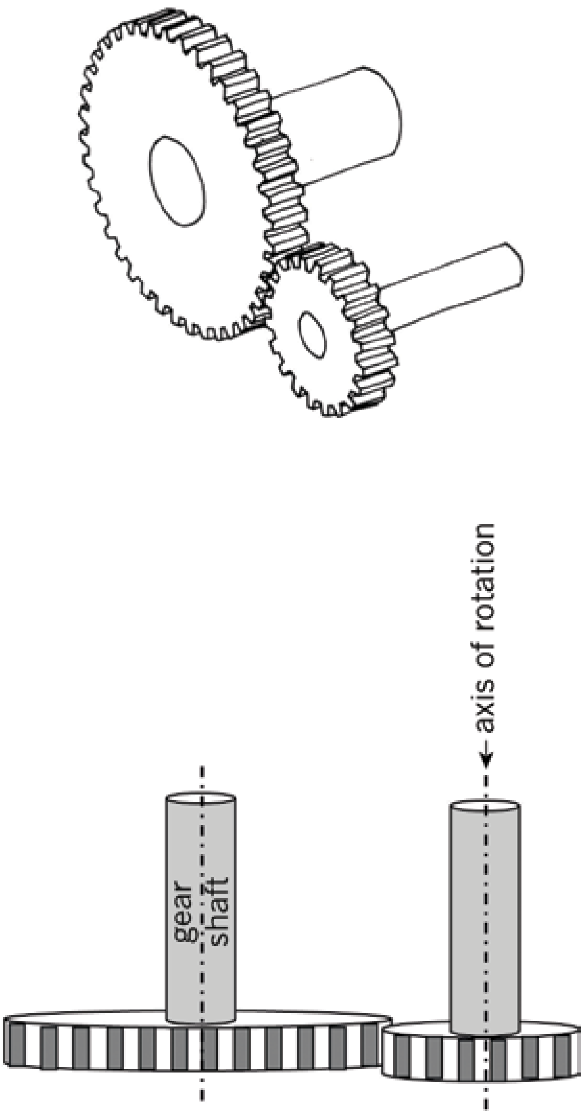

Figure 16: Two spur gears with shafts parallel to each other

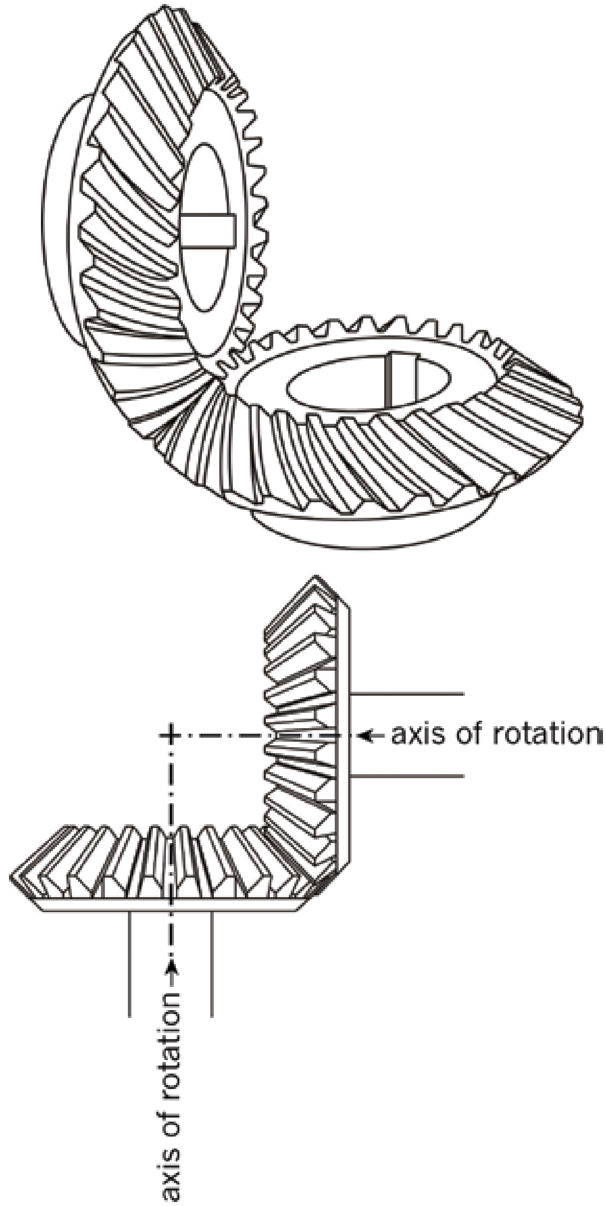

Figure 17: Two bevel gears with shafts at 90° to each other

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. They 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.

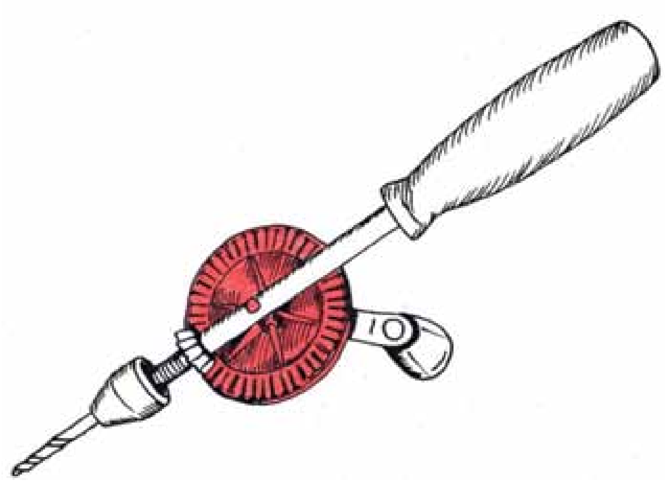

Figure 18: A hand drill

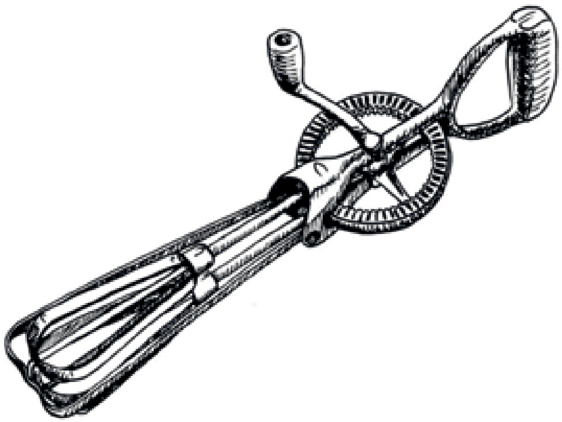

Figure 19: A food mixer

1. Do you think bevel gears can also be used to change the speed of rotation? Explain your answer and give examples.

   ....

   ....

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2. Why is fast rotation needed to beat eggs properly?

   ....

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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.

   ....

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Rack-and-pinion gears

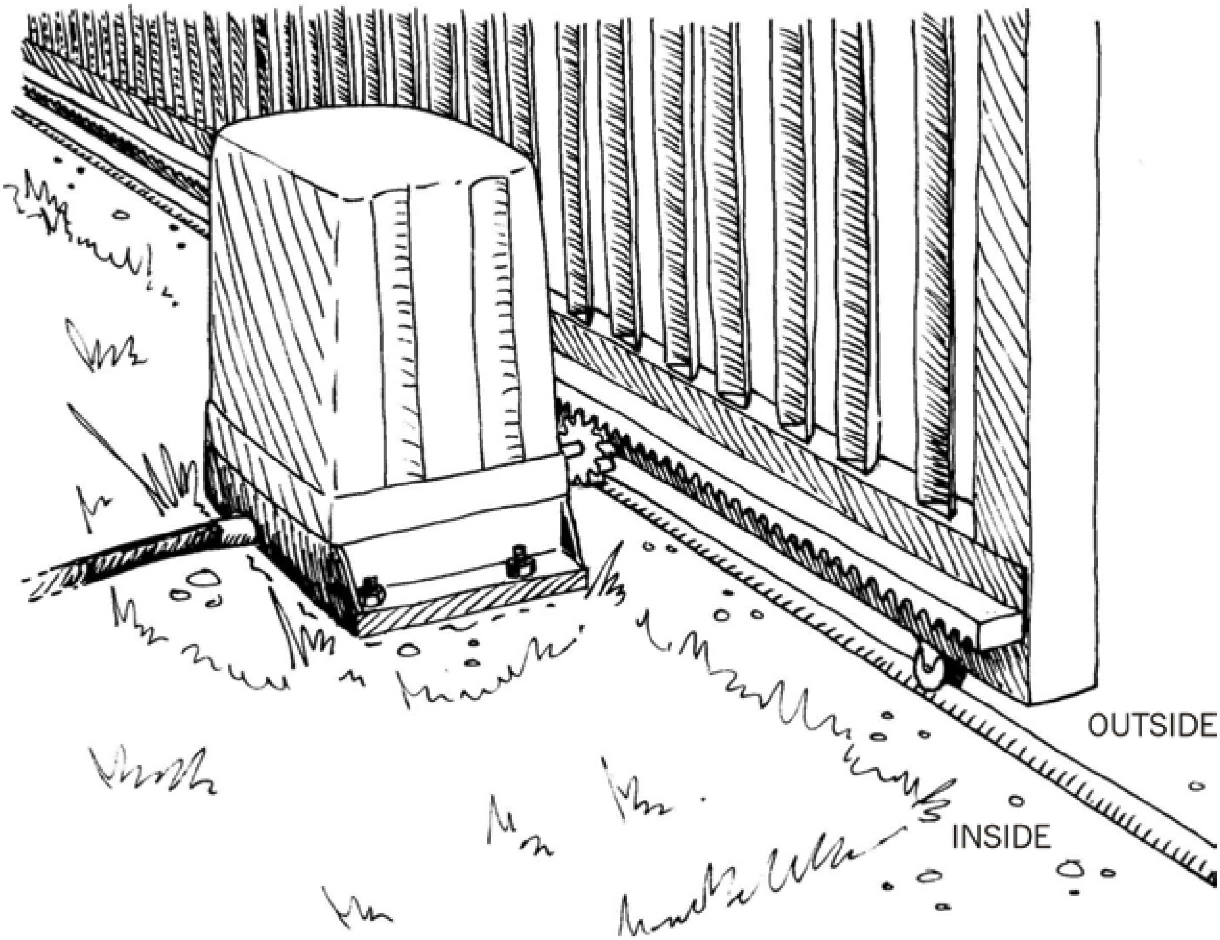


Figure 20: A rack-and-pinion gear in a security gate

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?

   ....

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

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

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

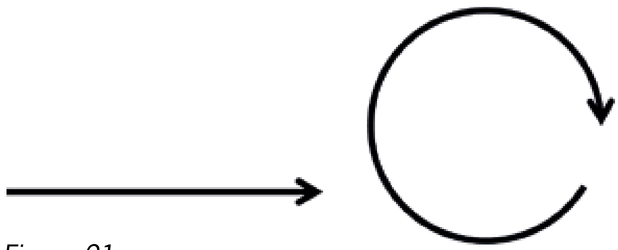
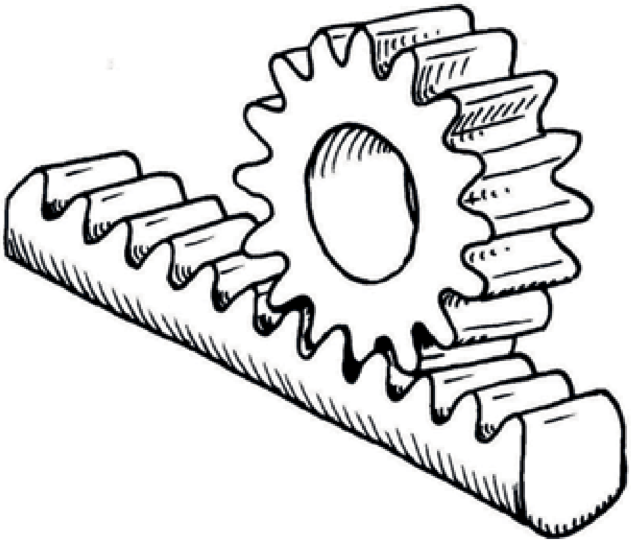


Figure 21



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 has 18 teeth, how far will the rack move if the pinion makes one full revolution?

....

....

....

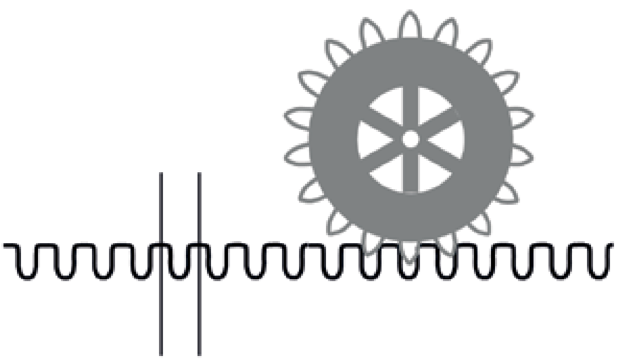


Figure 23

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.

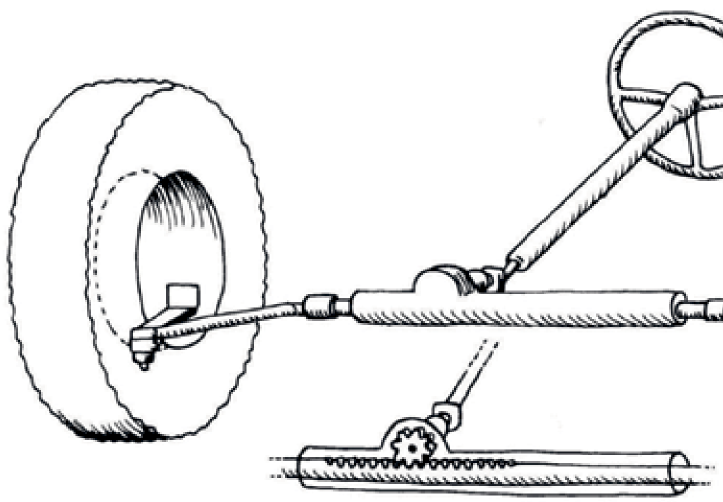


Figure 24: A rack-and-pinion car-steering system

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

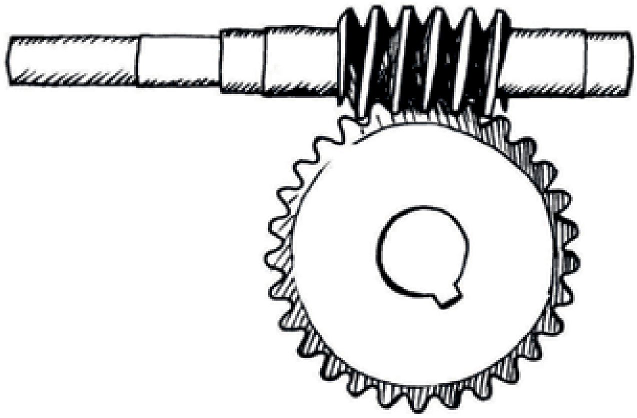


Figure 25: A worm gear set

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.

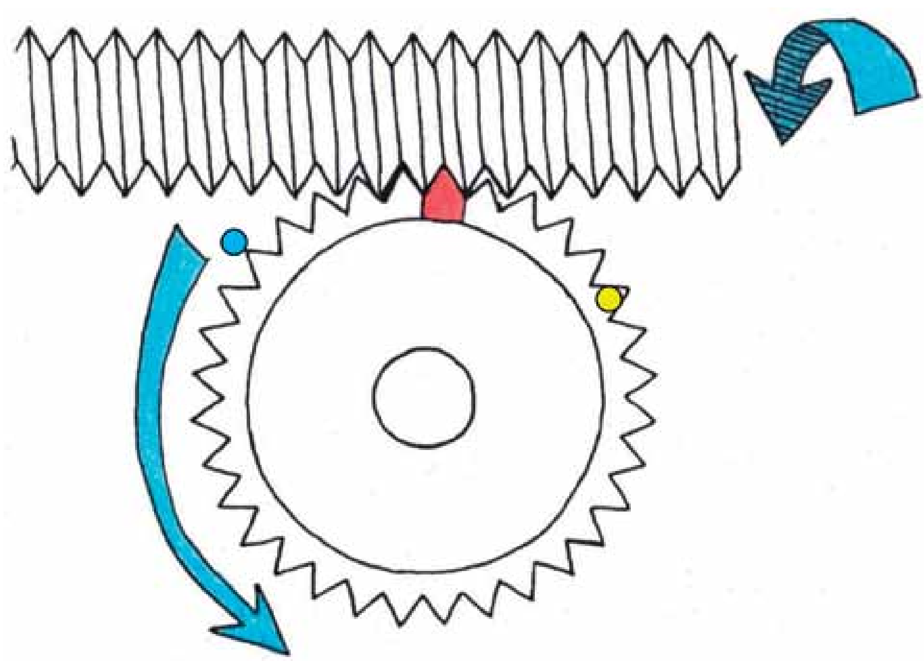


Figure 26

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.

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.

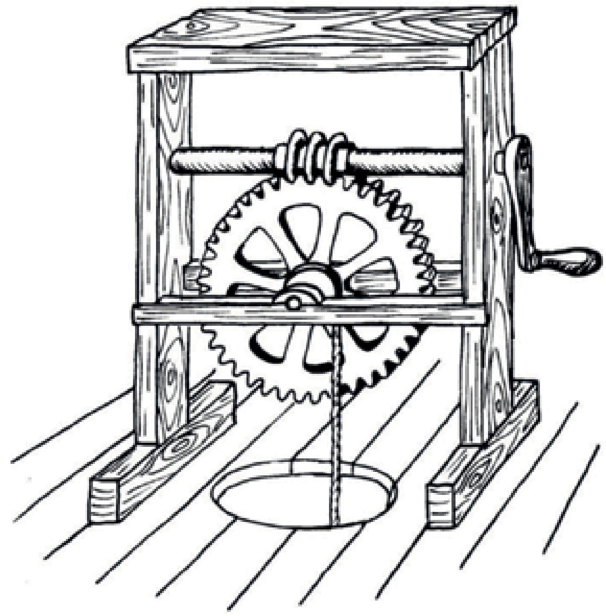


Figure 27: A worm and worm wheel used many years ago to lift heavy loads

Try to explain something, and design a jack

There is another useful thing about worm gears: the worm can turn the worm wheel, but the worm wheel cannot turn the worm. That is why worm gears are used for elevators.

Imagine you are in an elevator that is lifted by an ordinary spur-gear set and the power goes off.

Explain what would happen and why.

You learnt about hydraulic car jacks in Chapter 6. There are also other kinds of car jacks. In the space below, 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

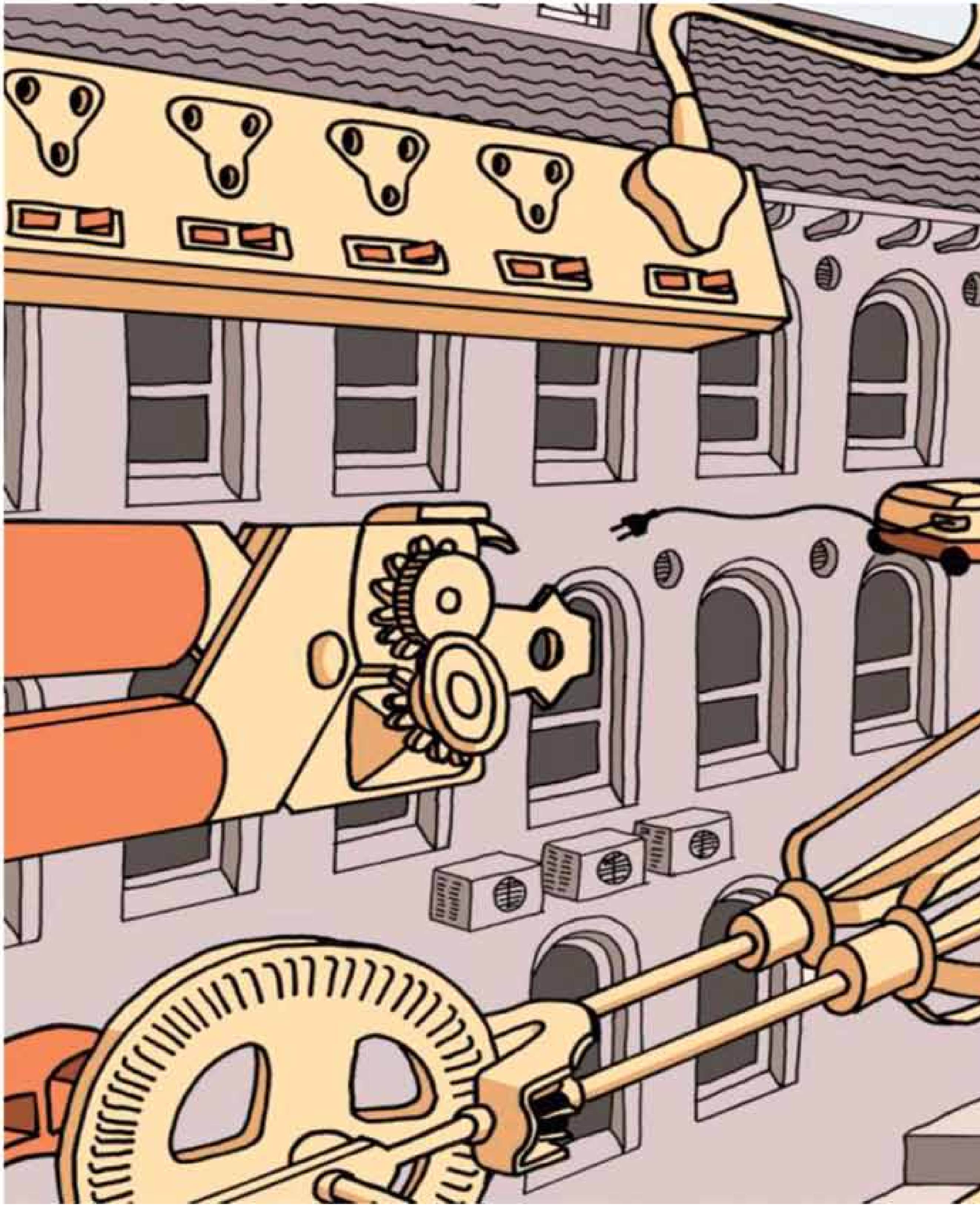
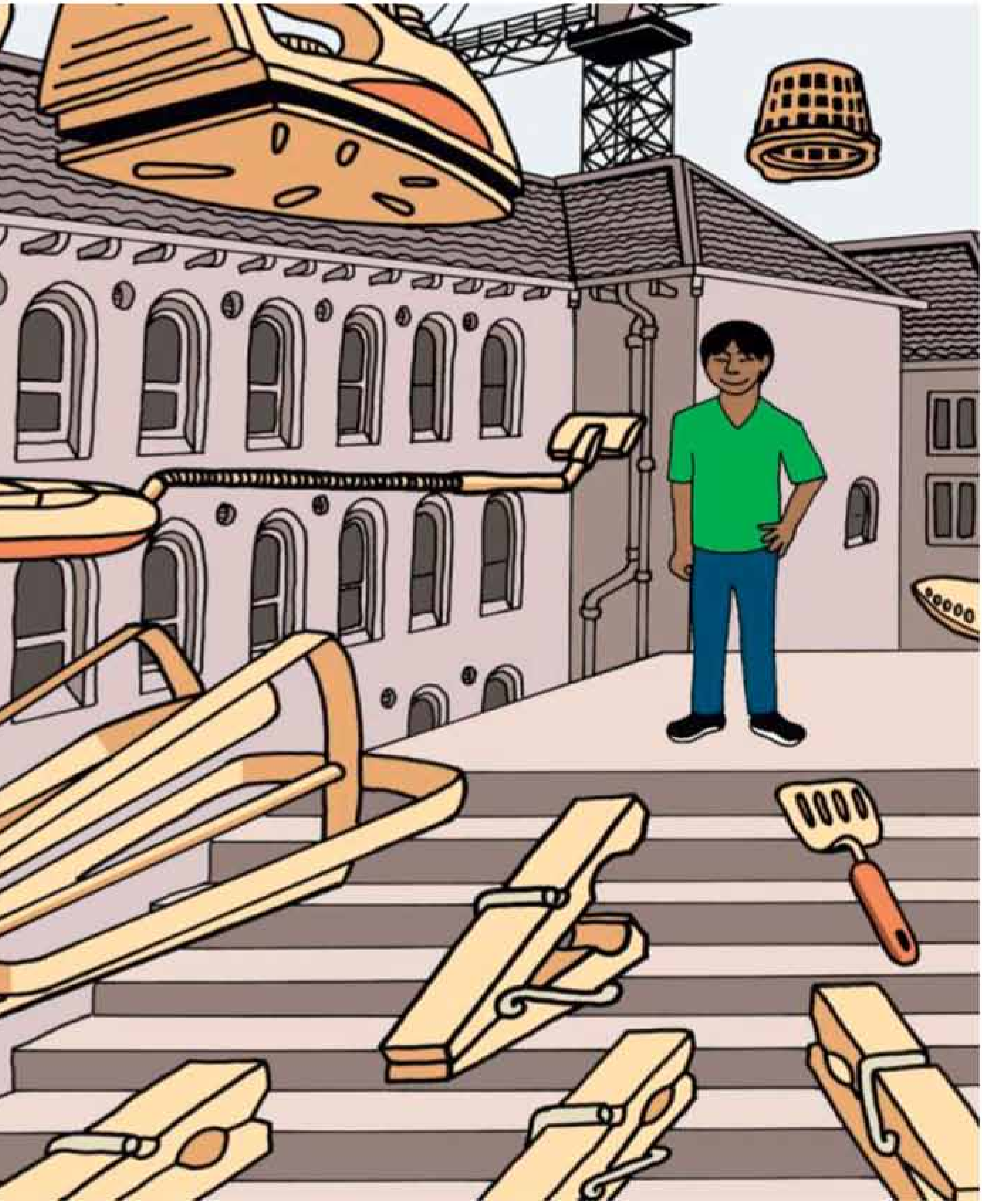


Figure 2



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.

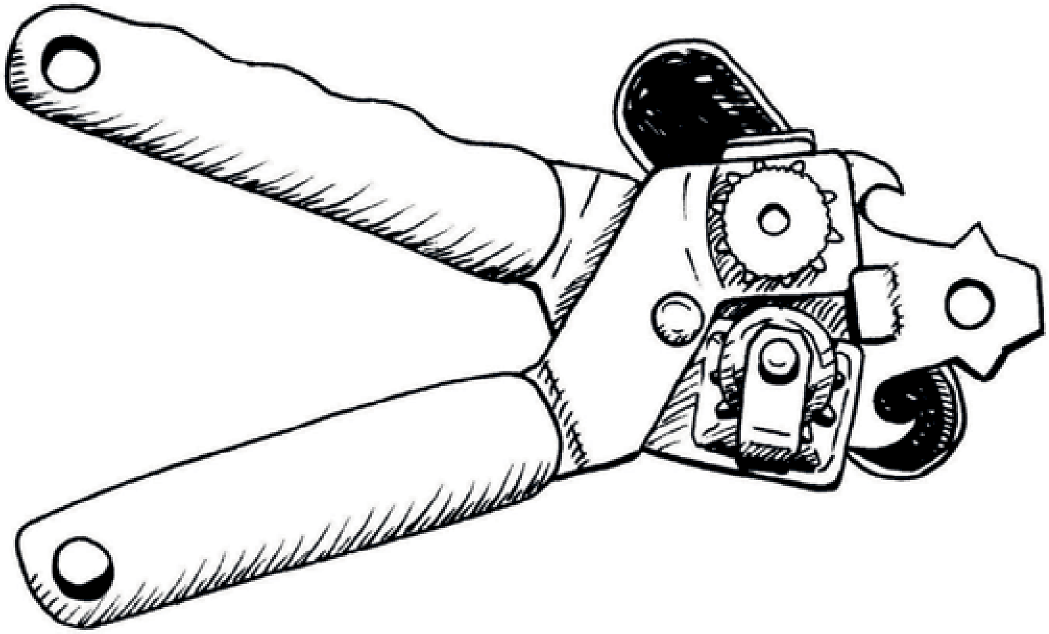


Figure 3

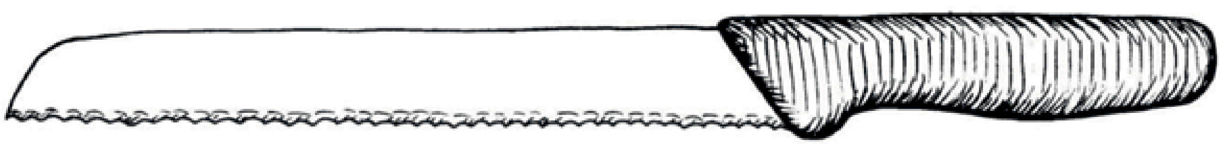


Figure 4

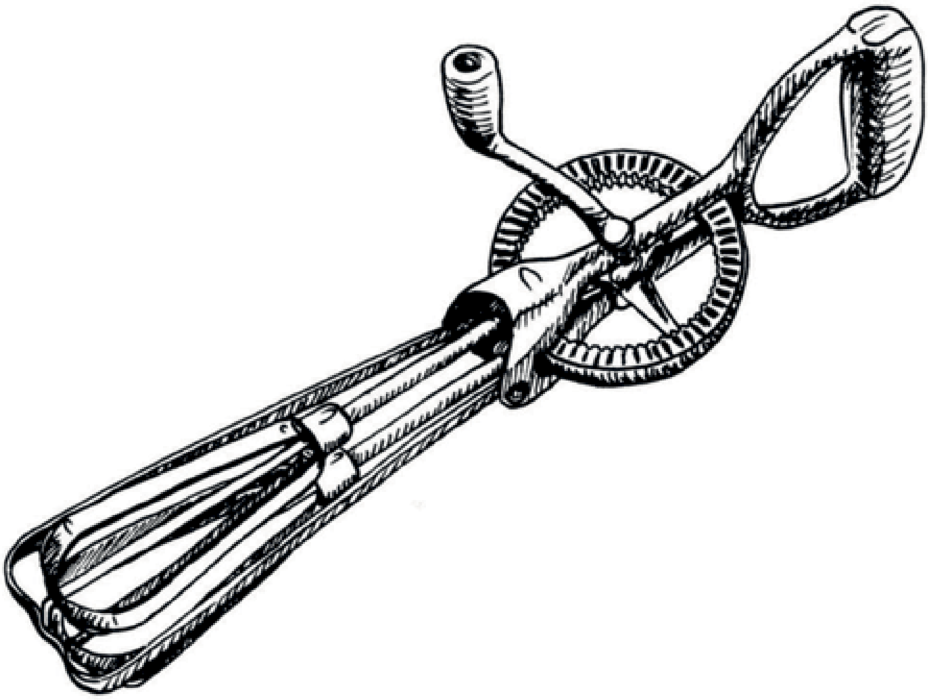


Figure 5

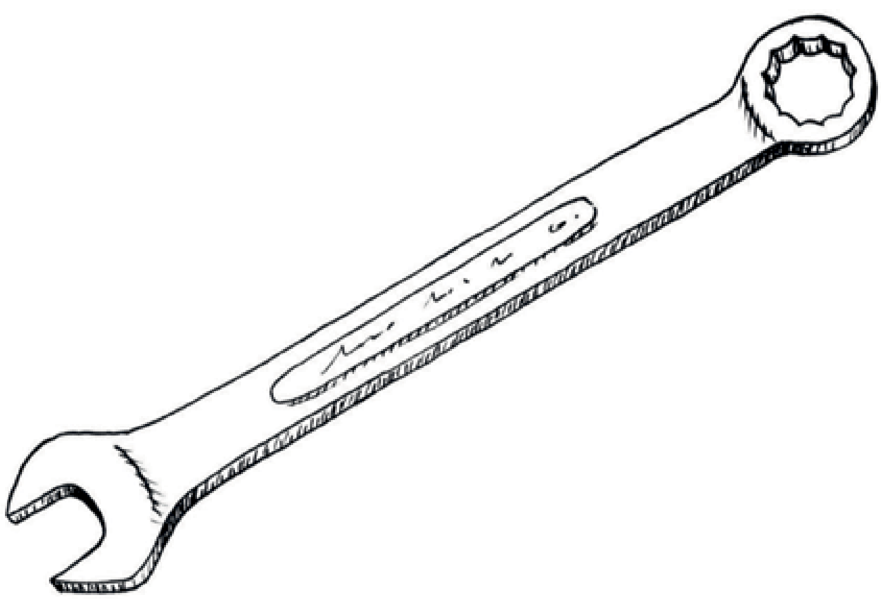


Figure 6

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

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?	

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?	

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?	

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.

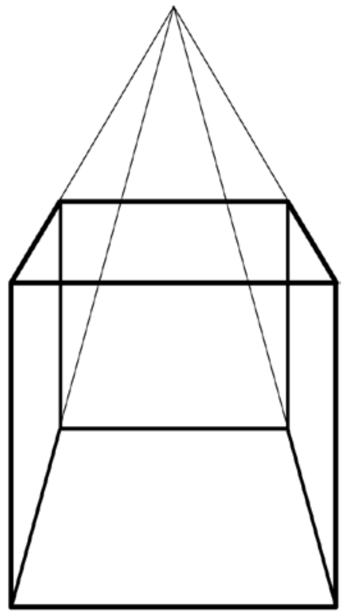


Figure 8: Drawing of a cube in 3D single vanishing point perspective

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.

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.

Then make your drawing more realistic by showing the texture of the wood grain, colour and shading.

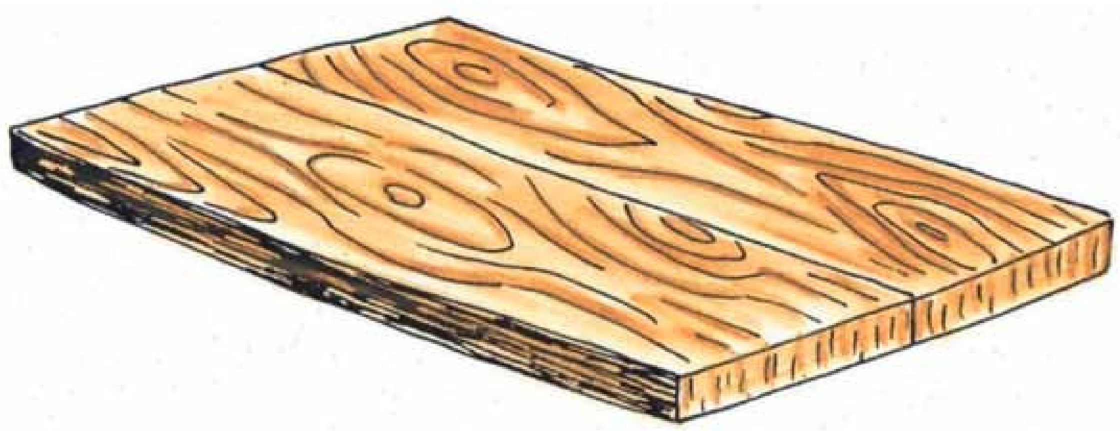


Figure 9: Adding wood grain makes things look realistic.

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.

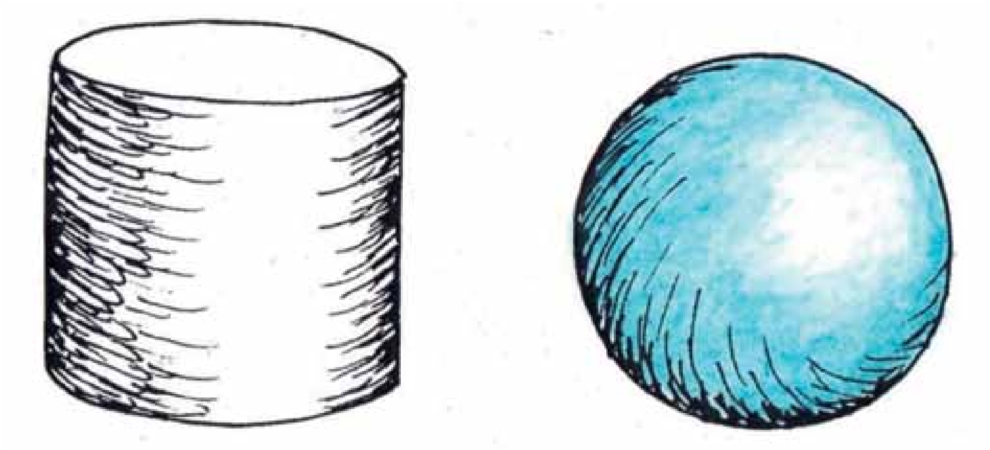


Figure 10: Shading helps to make drawings look more 3D.

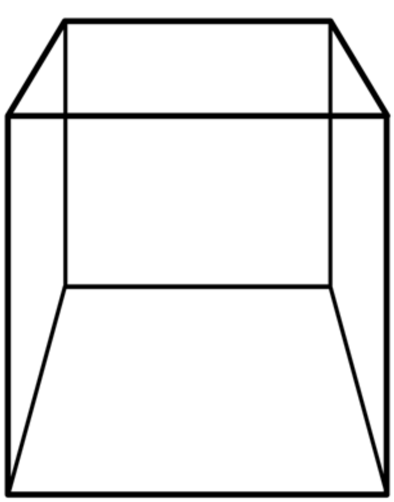


Figure 11: Making lines in front and on top darker also helps to make a drawing look more 3D.

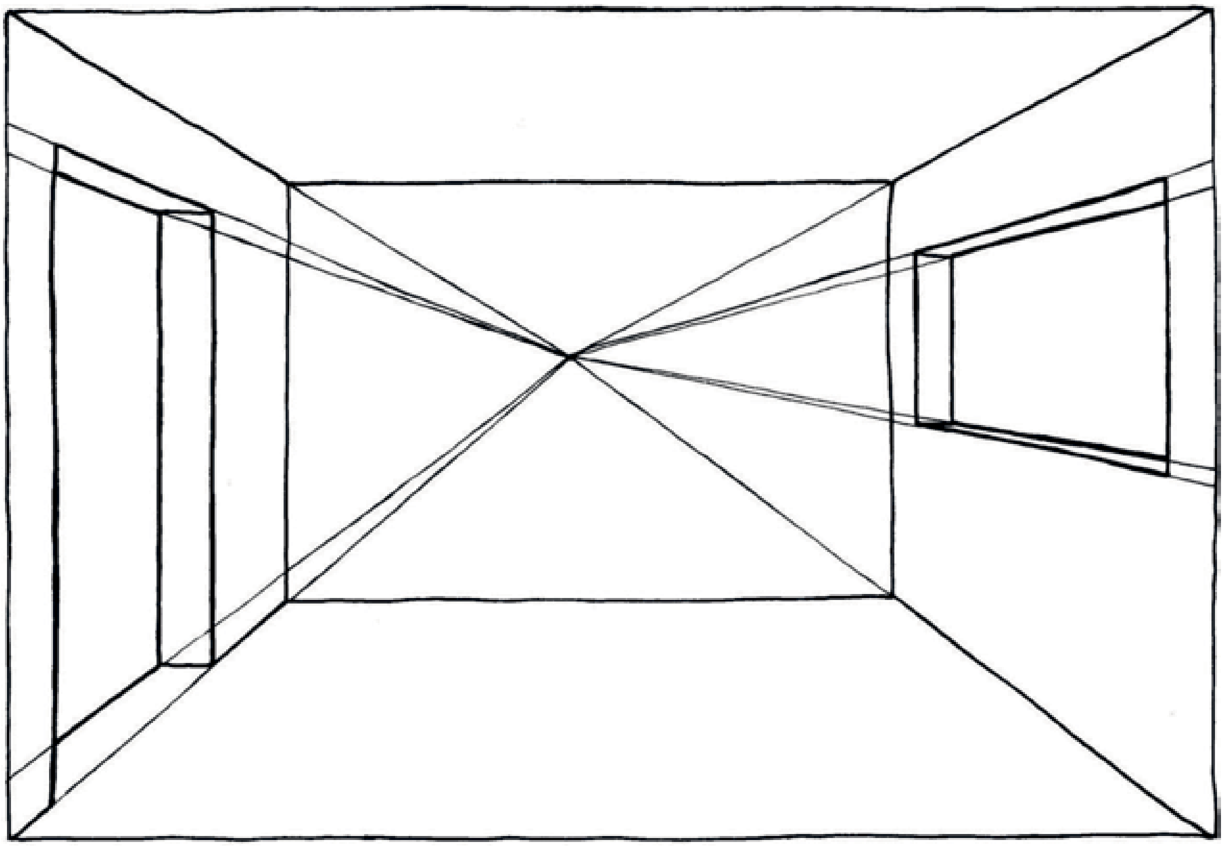


Figure 12: Single vanishing point drawing of the inside of a classroom

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 in the box on the following page.

Draw your classroom here:

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?

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 practise, 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 Mini-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) .... [9]
- How to make wheels and a truck body (questions 1 & 2) .... [5]

Design:

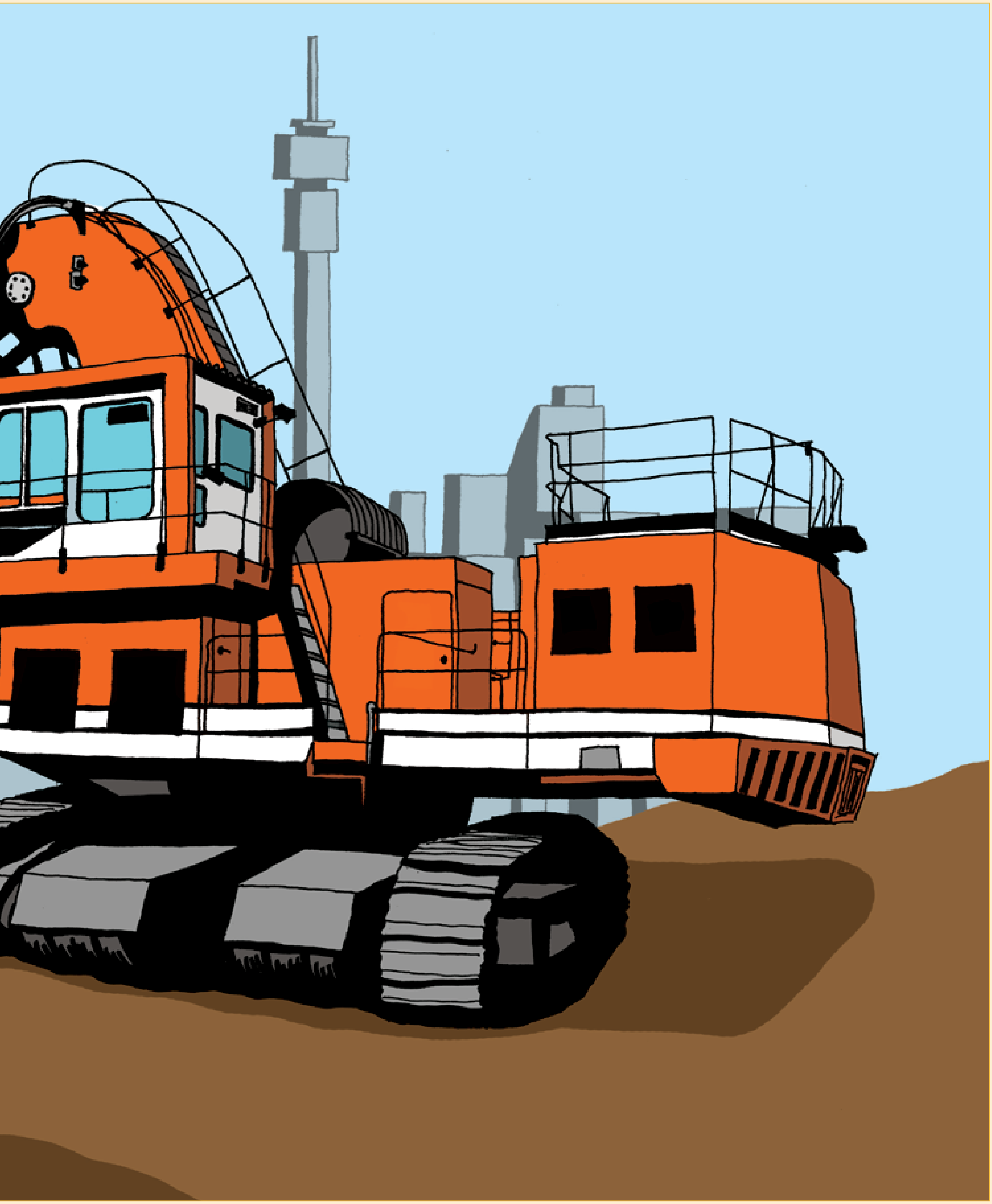
- Design brief with specifications and constraints .... [5]
- How to put a door on the load bed so that it swings open by itself when the load bed tilts up (question 5) .... [5]
- Design all the parts of the tip truck (chosen sketch) .... [6]

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 marks]

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 in the space below:
   I am going to help my group design and make a ………… that will ………… (1)

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

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   ………………………………………………………………………………………………

   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)

   ………………………………………………………………………………………………

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3. Write down the constraints. Remember that the constraints are the tools, materials and time that you have available to make the model. (2)

   ………………………………………………………………………………………………

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4. Form teams of four and compare your specifications. Total [5]

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

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

Look at the photograph of a tip truck below.

Figure 3

How to 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.

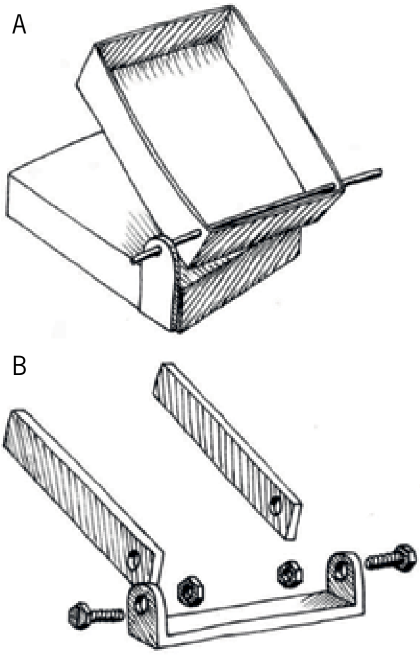

Figure 4

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.

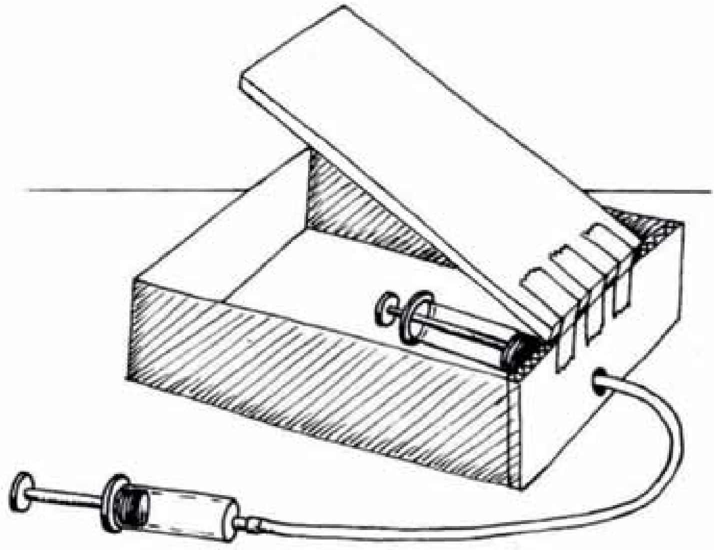

Figure 5

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.

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

Push the end of the tube through the back of the box and push it onto the driven syringe. 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 the drawing below. Put a piece of Prestik under the cardboard sheet so that the slave piston can push against it.

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.

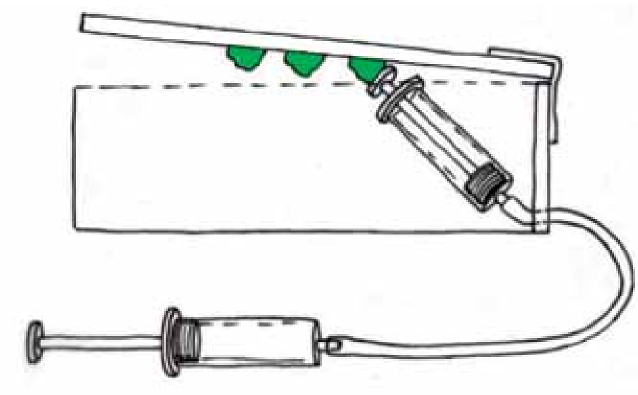

Figure 6

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. 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.

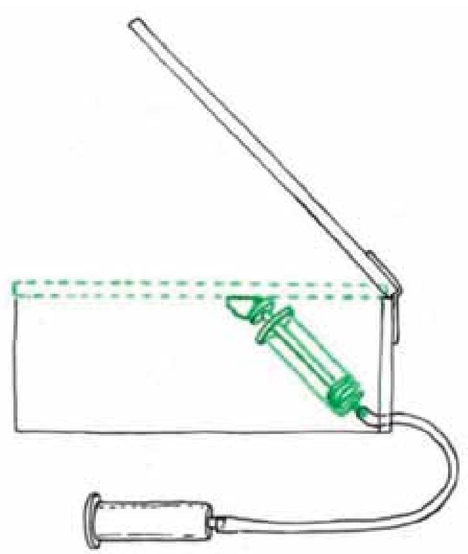

Figure 7

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 below. 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.

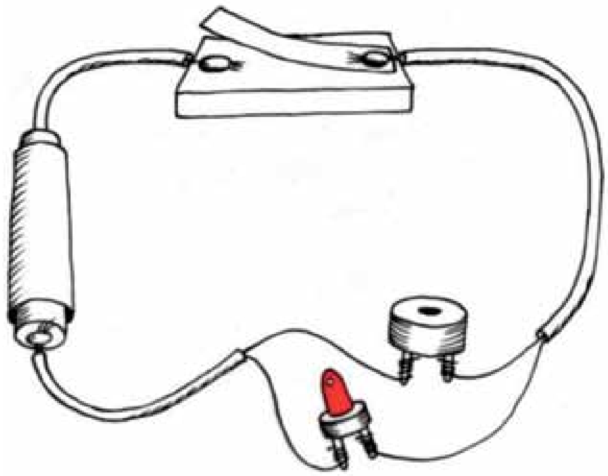

Figure 9

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 here. 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.

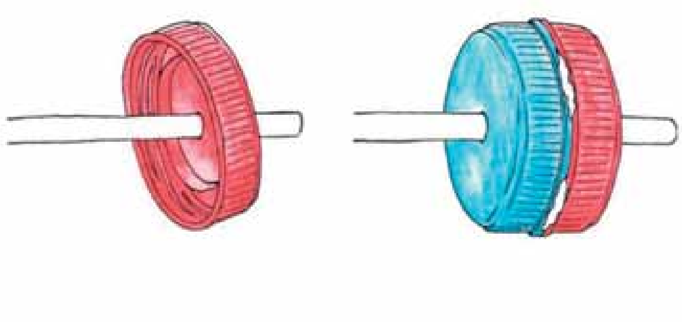

Figure 10

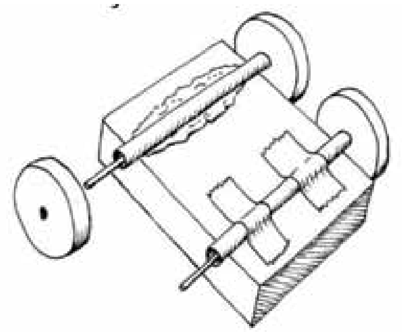

Figure 11

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, and show the syringe and the hinges on this sketch.

Week 2

Design your tip truck (30 minutes)

You will work as a team of three or four to design and make different parts that will fit exactly together to make a model tip truck that works. Each person will make only one part.

Remind yourself why you are making this model, and look again at the specifications.

Design all the parts of the tip truck

Draw your designs on the following pages. Give a title for each drawing, to show what the drawing is about. Also use labels to show what the different parts of a 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. Use loose pages if you need more space to draw better ideas.

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. You will have to check the measurements of all the parts on your designs to make sure that they will fit together. If they won't fit you will have to adapt the designs to make them fit.

Individual work: Get ready to make your parts

Complete the following sentences individually:

1. *I am going to make* …………

   ……………………………………………………………………

   ……………………………………………………………………

2. *I will need the following materials:*

   ……………………………………………………

   ……………………………………………………

   ……………………………………………………

There are **constraints** on the materials that you can use. You can only use materials that you can find.

[3]

3. *I will need the following tools:*

   ……………………………………………………

   ……………………………………………………

   ……………………………………………………

There are **constraints** on the tools that you can use. You can only use tools that you can find, and that are safe for you to work with.

[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]

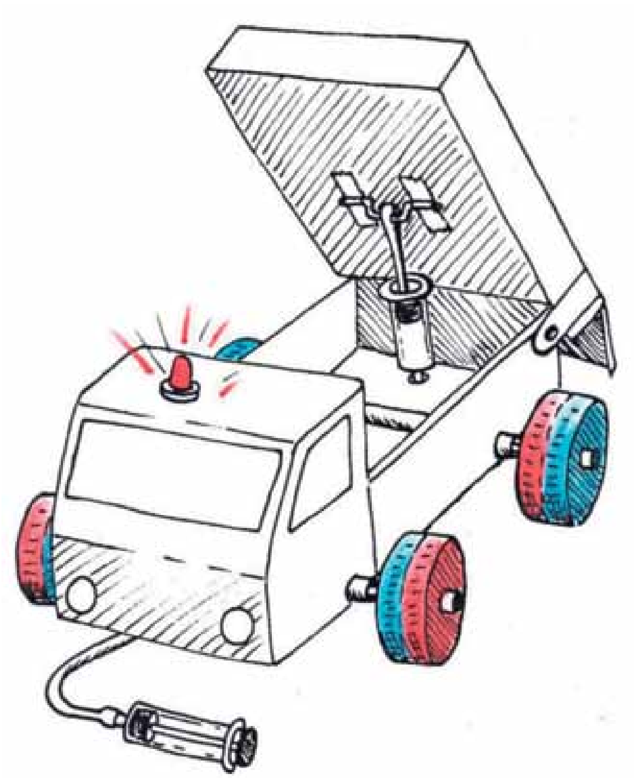

Figure 12

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 and drawing below shows how the model is projected onto the paper, in order to draw an “orthographic first-angle projection”.

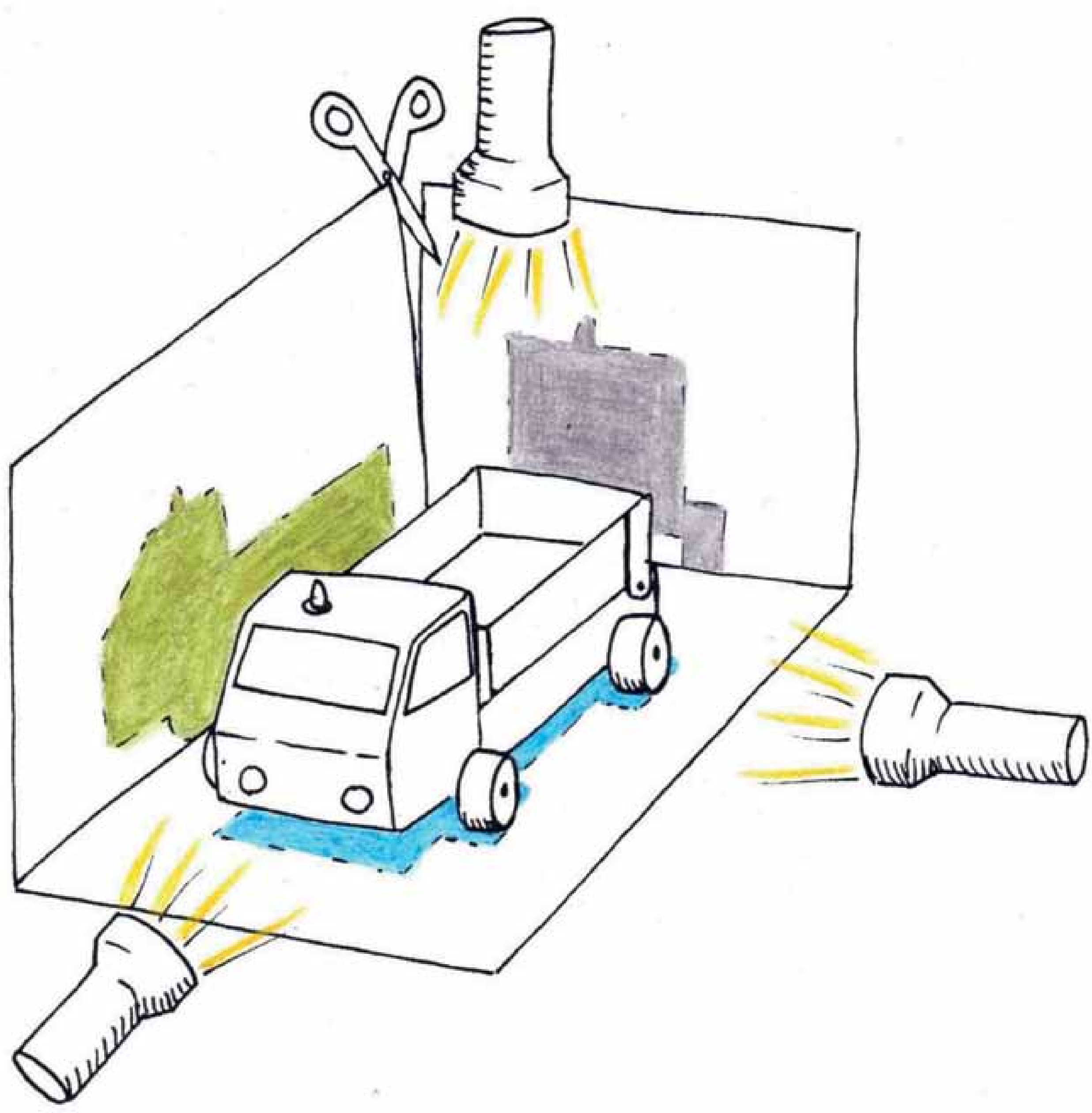

Figure 13

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”.

On the next page, there is an exercise in completing an orthographic first-angle projection of the truck.

The side view has been drawn for you. Use the red projection lines to complete the top view of the truck. Then use the blue lines to complete the front view. Finally add the labels for "front view", "top view" and "side view" to your drawing.

Total [10]

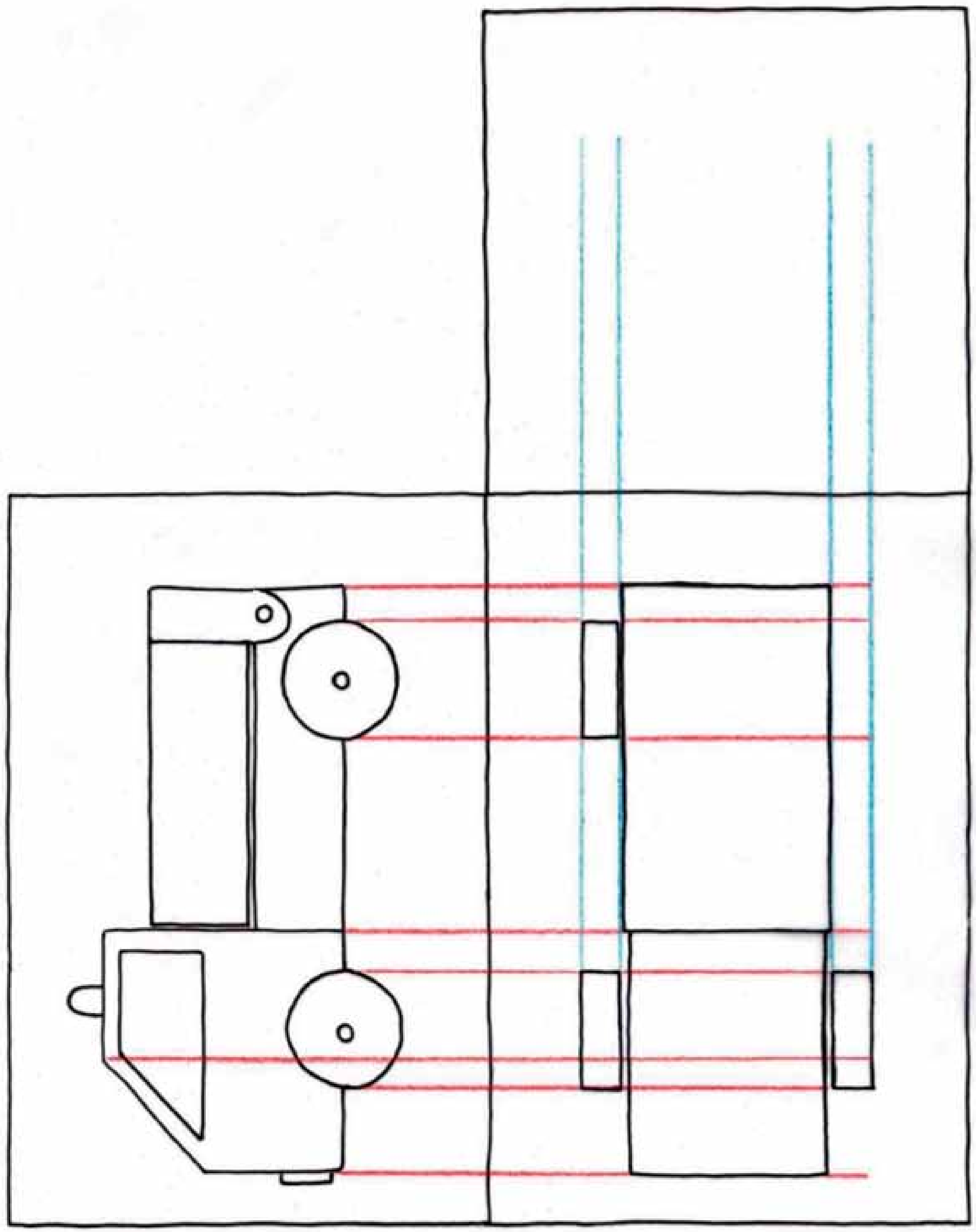

Figure 14

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.

Notes

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