

# TECHNOLOGY

**Grade 8**

**Book 2**

**CAPS**

**Learner Book**



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# TERM 3

## CHAPTER 1

# Levers, linkages and gears

In this chapter, you will revise what you learnt in Grade 7 about different types of levers and linked levers. You will pay special attention to whether a lever or a system of levers gives a mechanical advantage or a distance advantage.

You will also revise what you learnt earlier this year about how gear systems can give a mechanical advantage or a speed advantage. Then you will learn about a type of gear called a bevel gear. Bevel gears change the direction of rotation.

It is important that you understand mechanical advantage very well, because you will be doing calculations about mechanical advantage in the next chapter.

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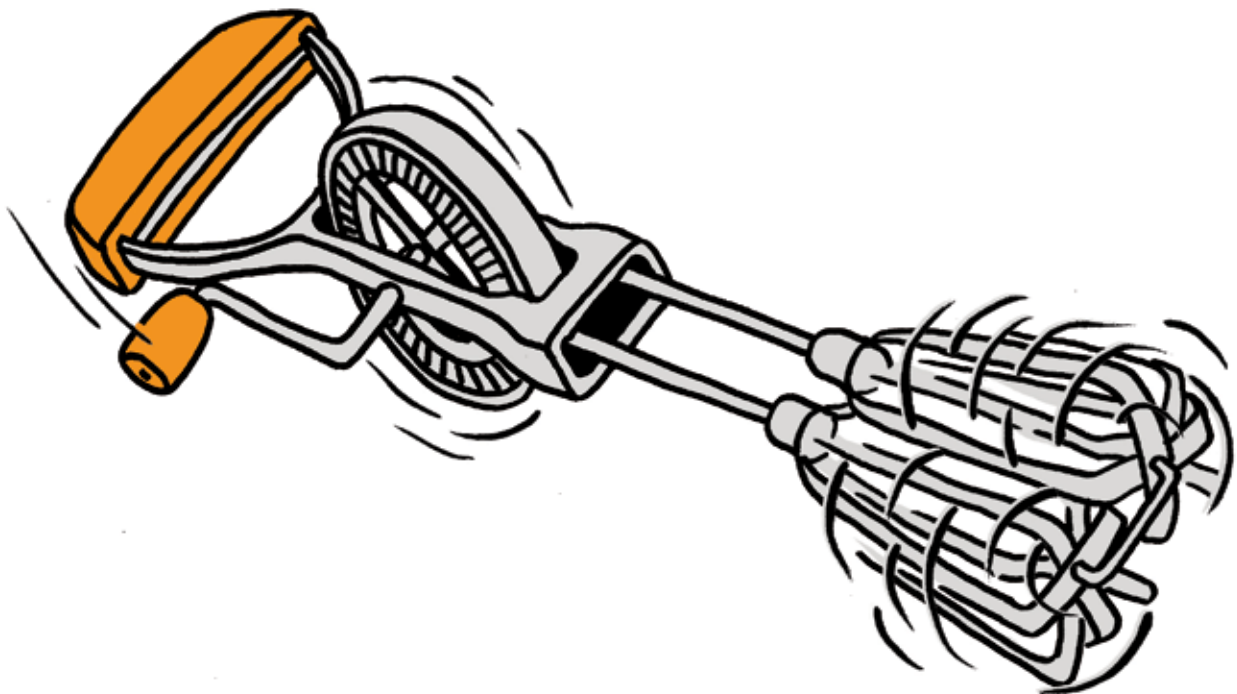


Figure 1: Gears are sometimes used to get a speed advantage.

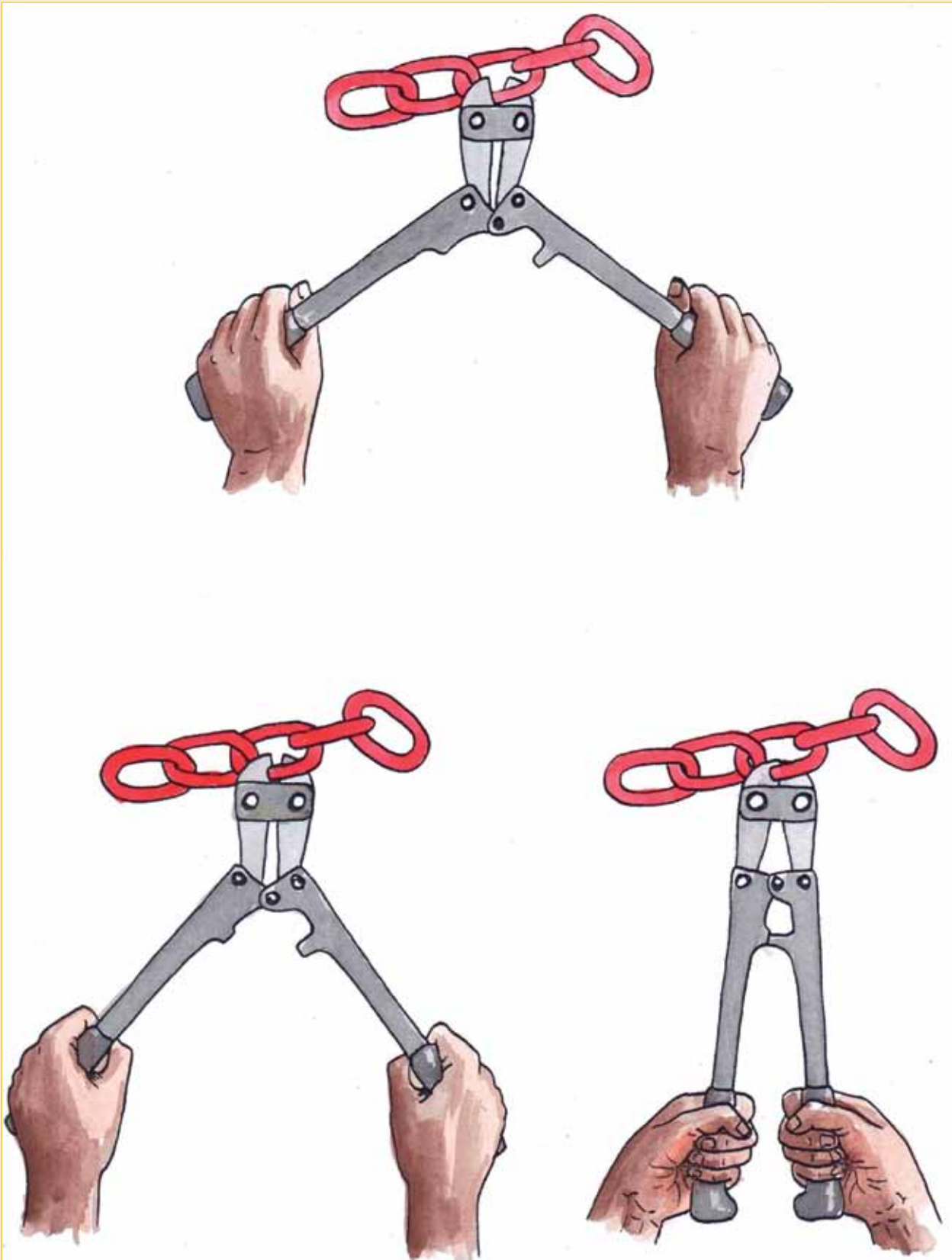


Figure 2: A bolt cutter uses a system of linked levers to give a very big mechanical advantage. Note that there are five pivot points!



## 1.1 Revision of levers and mechanical advantage

Mechanisms are parts of machines that help us to move things. Machines are usually made of many connected mechanisms. Some parts of a mechanism move, and other parts are used to hold the moving parts in place.

Mechanisms are useful because they help us to move things further, faster or by using less force.

Figures 4 to 7 show machines that you might have at home. Write down what each of these machines is used for, and how they make it easier to do the task.

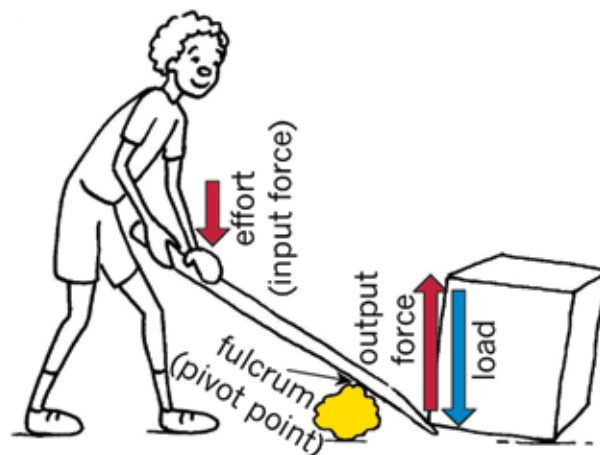


Figure 3

### 1. A bottle opener

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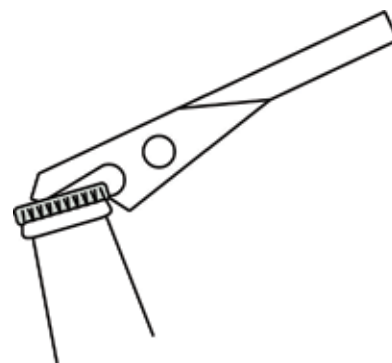


Figure 4: A bottle opener

### 2. A pair of scissors

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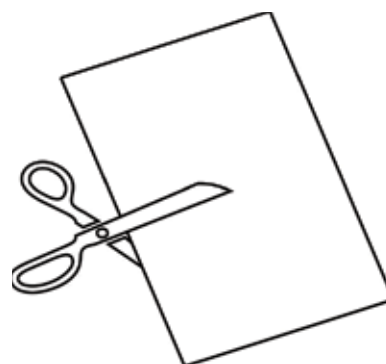


Figure 5: A pair of scissors

3. A hammer

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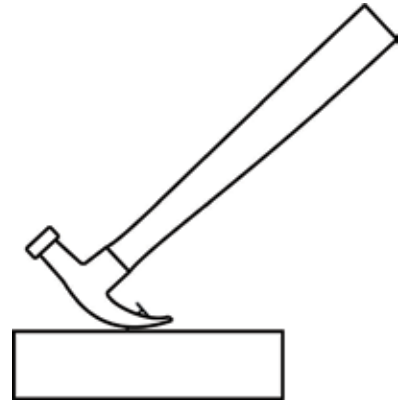


Figure 6: A hammer

4. A pair of pliers

.....

.....

.....

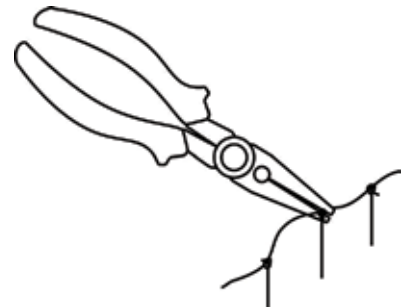


Figure 7: A pair of pliers

Levers allow you to change the direction of movement, the size of movement and the amount of input force that is needed for the output movement to happen.

### Do you remember what mechanical advantage is?

You already know that:

- If the input force is smaller than the output force, there is a mechanical advantage. You can say the mechanical advantage is bigger than 1.
- If the input force is bigger than the output force, there is not a mechanical advantage, but rather a distance advantage. You can say the mechanical advantage is smaller than 1.

When engineers, scientists and technologists design mechanisms, they want to know exactly how big the mechanical advantage in a system is. It is not good enough for them to say that the mechanical advantage is bigger than 1 or smaller than 1. They need a number to tell them exactly how big or small the mechanical advantage is. We call this number the mechanical advantage.

You can use the abbreviation **MA** for mechanical advantage.

The mechanical advantage is calculated by dividing the output force by the input force:

$$\text{mechanical advantage} = \text{output force} \div \text{input force} = \frac{\text{output force}}{\text{input force}}$$

You can also say that the mechanical advantage is the **ratio** between the output force and the input force.

If a lever makes it *easier* to lift a heavy weight, the input force is *less* than the output force, and the mechanical advantage is greater than 1.

For example, if the output force is 12 and the input force is 4, the mechanical advantage is **calculated** in the following way:

$$12 \div 4. \text{ This can also be written as } \frac{12}{4} \text{ or } \frac{12}{4}$$

The answer to this calculation can be written in different ways:

a ratio of 3 to 1

**OR** 3 : 1

**OR** 3.

This means that the output force is three times greater than the input force. You can also say that the lever gives a mechanical advantage of 3.

But you cannot get something for nothing. If the input force is 3 times less than the output force, you will have to move the input arm 3 times further than the output arm. Look at Figure 8 to see how this works.

These different ways of writing the answer all mean the same thing: they are **equivalent**. You can write an equals sign instead of “OR” between the different ways of writing the answer, because they are equivalent.

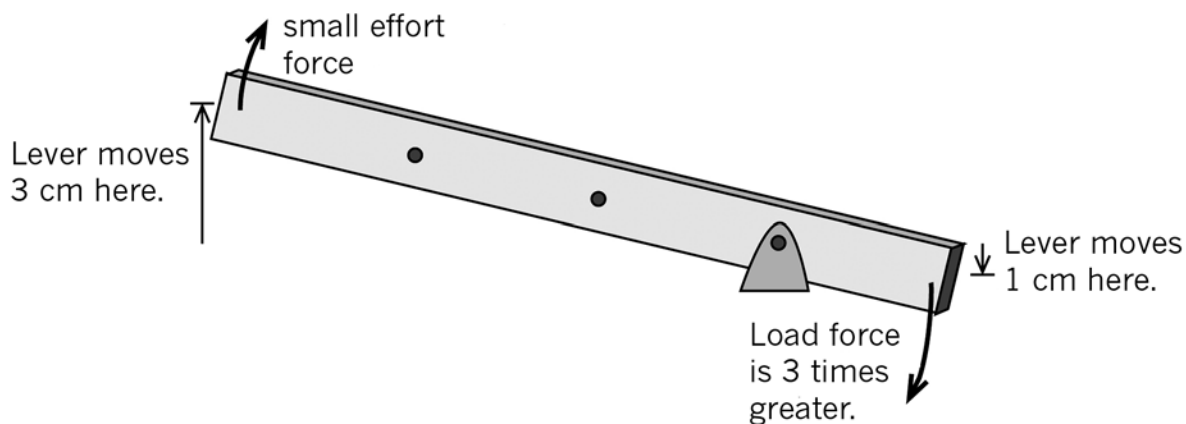


Figure 8: A mechanical advantage of 3

Not all levers give a mechanical advantage. Sometimes the input force is greater than the output force. These levers make it harder to move something, but the output movement will be greater than the input movement.

If a lever makes it *harder* to lift a heavy weight, the input force is *greater* than the output force, and the mechanical advantage will be less than 1.

If, for example the input force is 3 and the output force is 1, the mechanical advantage is output force  $\div$  input force =  $\frac{1}{3}$ , in other words 1 third.

In the example above, the output force is only 1 third as big as the input force. The output arm will move 3 times further than the input arm. In other words, this lever gives a **distance advantage** of 3.

Look at Figure 9 to see how this works.

When a mechanical system changes a small input distance into a larger output distance, the system gives a **distance advantage**.

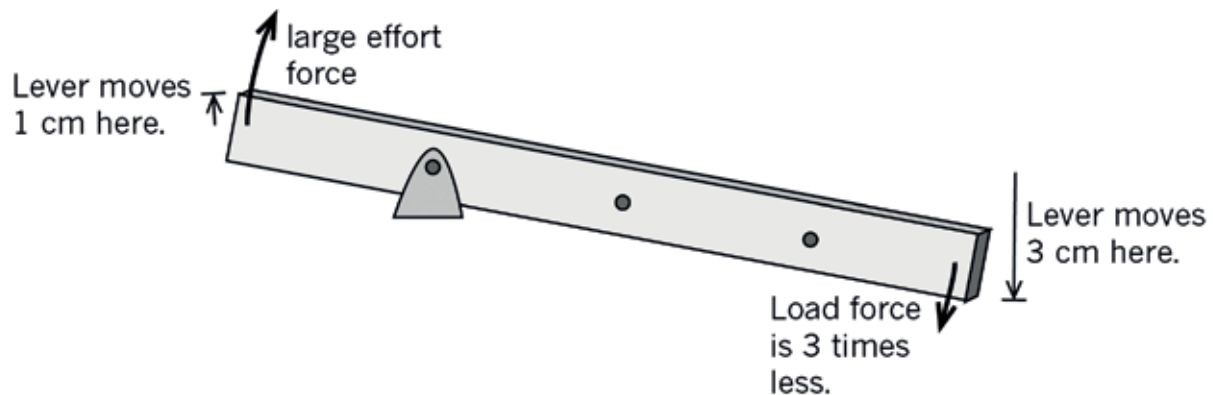


Figure 9: A distance advantage of 3

On a lever, the distances moved by the input arm and the output arm are directly related to their distances away from the fulcrum.

- If the distances from the fulcrum are equal, the distances moved will be equal.
- If the fulcrum is closer to the *input force*, the distance moved by the *input arm* will be *smaller*.
- If the fulcrum is closer to the *output force*, the distance moved by the *output arm* will be *smaller*.

If the distance between a fulcrum and the output is less than the distance between the fulcrum and the input, the output force will be *greater* than the input force and the lever gives a mechanical advantage.

If the distance between a fulcrum and the output is *greater* than the distance between the fulcrum and the input, the output force will be less than the input force and the lever gives you a distance advantage. In this case, you will not get a mechanical advantage.

## The first-class lever and mechanical advantage

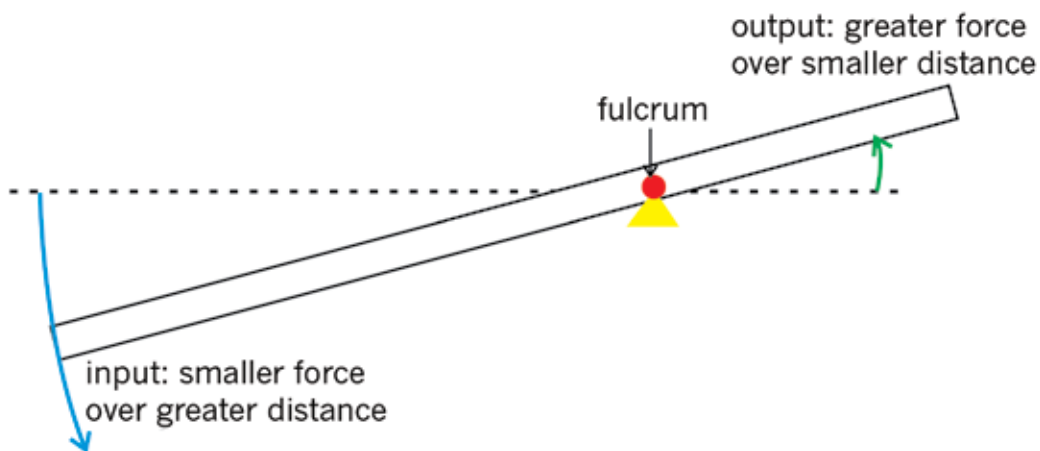


Figure 10: A small input force over a large input distance

A lever can change a *large* movement with a *small* input force into a *small* movement with a *large* output force. When you use a bottle opener, you use a small input force to pull up the long handle, and the lever mechanism makes the output force big enough to bend the top of the bottle.

If  $MA > 1$ , then a *small* input force over a *big* distance at one end, can move a *bigger* output force over a *shorter* distance at the other end. The bottle opener, scissors, hammer and pliers in Figures 4 to 7 are examples of this.

## The first-class lever and distance advantage

You can also use a lever the other way around. You can use a *big* input force over a *small* input distance. This gives a *smaller* output force over a *bigger* output distance. You can see this in Figure 11.

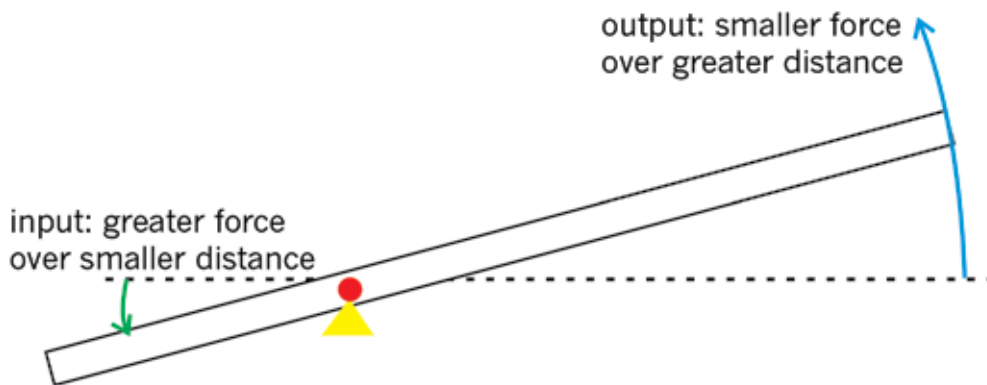


Figure 11: A large input force over a small input distance

These kinds of levers are often used to help cranes lift things very high. If, for example, the input arm moves 1 cm down and lifts the output arm 4 cm up, the lever is giving you a distance advantage. But the input force has to be 4 times bigger than the output force, so the mechanical advantage is less than 1:

$$MA = \text{output force} \div \text{input force} = \frac{1}{4} = 1 \text{ quarter}$$

When the  $MA < 1$ , there is not a mechanical advantage, but rather a distance advantage.

A big input force over a small distance at one end, produces a smaller output force over a bigger distance at the other end.

The pair of kitchen or braai tongs in Figure 12 is an example of a tool that gives a distance advantage.



Figure12: A pair of kitchen or braai tongs

## 1.2 Linked levers

Figures 13 and 14 show two types of tools that are used to cut twigs and branches from trees, called “pruning”.



Figure 13: Pruning shears



Figure 14: Loppers

1. How do you know that both of these tools use levers?

.....  
.....

2. How do you know that the levers used are first-class levers?

.....  
.....

3. Do both of these tools give a mechanical advantage? Explain your answer.

.....  
.....

4. Which of these tools will give you greater mechanical advantage? Explain your answer.

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

All first-class levers have the fulcrum between the input and the output.



Figure 15: A see-saw is a first-class lever. (This is an edited version of Winslow Homer's artwork 'The See-Saw', 1873.



Figure 16: A pair of scissors is a pair of linked first-class levers.

## First-class levers

The fulcrum or pivot point is the fixed point on a lever. The lever doesn't actually go up or down at the fulcrum point. All the other points on a lever rotate around the fulcrum.

In a first-class lever, the fulcrum is always between the input and the output.

The input force is the force that you apply to a lever to make it move.

The output force is the force that the lever exerts on the load.

## Systems of linked levers

A lever system that consists of more than one pair of levers that are connected to one another, is called a system of linked levers.

The bolt cutter in Figure 17 has two pairs of linked levers that are connected to each other. Figure 2 at the start of the chapter shows the movement of the parts of a bolt cutter.



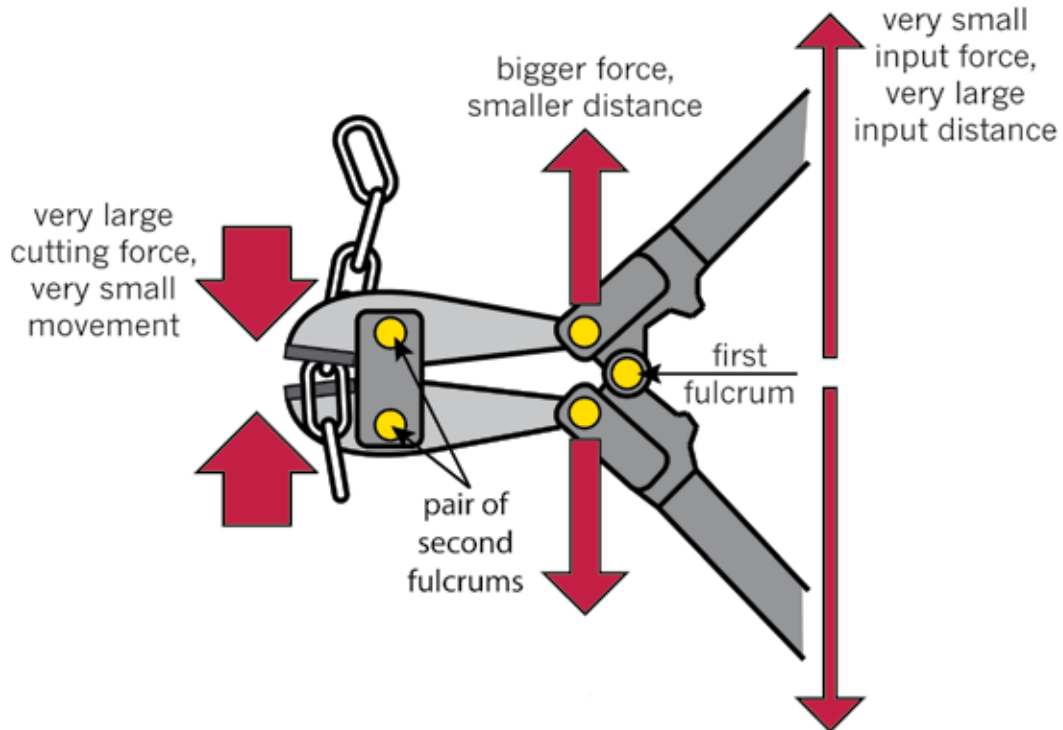


Figure 17: This is a bolt cutter. It consists of two pairs of linked levers.

- The pair of dark grey levers on the right have the handles on them. They share a single fulcrum.
- The pair of light grey levers on the left have the cutting blades on them. They have a separate fulcrum for each lever.
- There are also two pivot points in the middle of the two pairs of levers, to link them together. They have a different purpose from the other fulcrums, because they move together with the levers, instead of the levers rotating around them.

1. Are both the pairs of levers used in the bolt cutter first-class levers? Explain your answer.

.....  
.....

2. What can you say about the total mechanical advantage of the two pairs of levers linked to each other?

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

3. Look at the cutting levers (the end that cuts). What is different about the fulcrums of these levers compared to a pair of scissors?

.....  
.....

4. Compare the arrangements of the fulcrums in the bolt cutter and the pair of scissors. Why are the fulcrums arranged in a different way in a bolt cutter than in a pair of scissors?

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

### Second-class levers give a mechanical advantage

Second-class levers have the fulcrum at one end and the input at the other end. The output is between the input and the fulcrum.

A second-class lever always gives a mechanical advantage. The input is always further away from the fulcrum than the output, so the input arm always moves further than the output arm. This means that the output force will always be bigger than the input force.

So the MA is always greater than 1:

$$MA = \text{output force} \div \text{input force} > 1.$$

■ Second-class levers always give  $MA > 1$ .

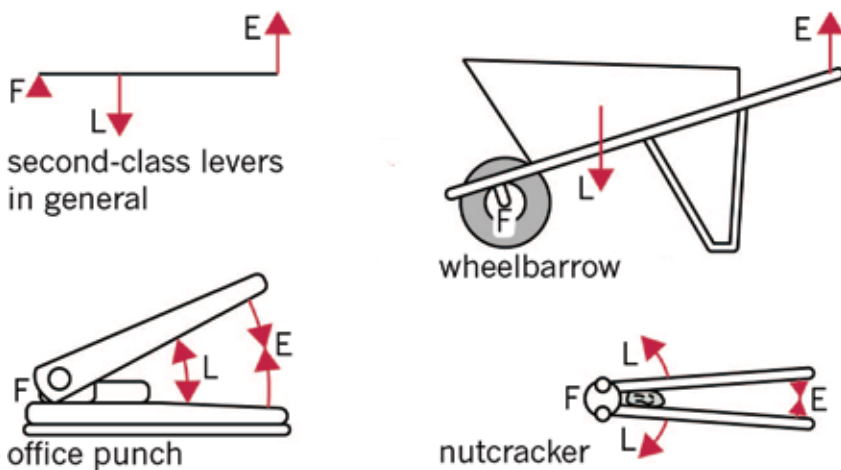


Figure 18: Second-class levers always give a mechanical advantage.

1. Give one more example of your own for each of the following types of levers.

(a) first-class lever

.....

(b) second-class lever

.....

### Third-class levers give a distance advantage

Third-class levers also have the fulcrum at one end, but the output is at the other end. The input is between the fulcrum and the output.

The input is always closer to the fulcrum than the output, so the output arm always moves further than the input arm.

This means that the output force will always be smaller than the input force.

So the mechanical advantage is always smaller than 1:

$$MA = \text{output force} \div \text{input force} < 1.$$

Third-class levers always give  $MA < 1$ .

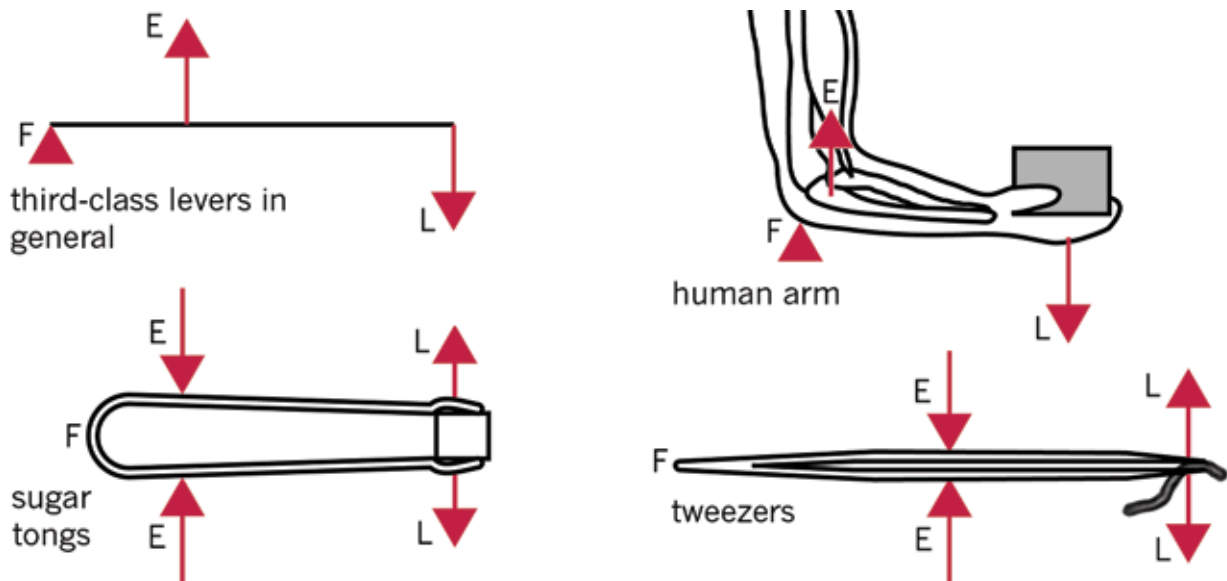


Figure 19: Third-class levers always give a distance advantage.

---

## 1.3 Gear systems

You learnt about gears in Term 1 this year. Do you remember? Here are a few reminders:

### Mechanical advantage and speed advantage

Gears are wheels with teeth. They can increase or decrease the **turning speed** of a wheel or axle.

The teeth of two gears **mesh** together so that if one gear turns, the other gear will turn as well, in the opposite direction.

- A *small* driver gear connected to a *large* driven gear will change a *fast* turning speed into a *slower* turning speed. This gear system will make the wheels turn with a greater turning output force than the input turning force of the motor. This system gives a mechanical advantage.
- A *large* driver gear connected to a *small* driven gear will change a *slow* turning speed into a *faster* turning speed. This system gives a distance or speed advantage.

You can also call **turning speed** the speed of rotation.

**Mesh** means that the teeth of the gears fit in-between one another.

### Torque and revolutions per minute

A turning force is called a torque.

The speed of a turning wheel is measured in revolutions per minute, or rpm.

## A small driver and a large driven gear

Look at the two connected gears in Figure 20. Gears that have teeth like these are called spur gears. Now answer the questions that follow:

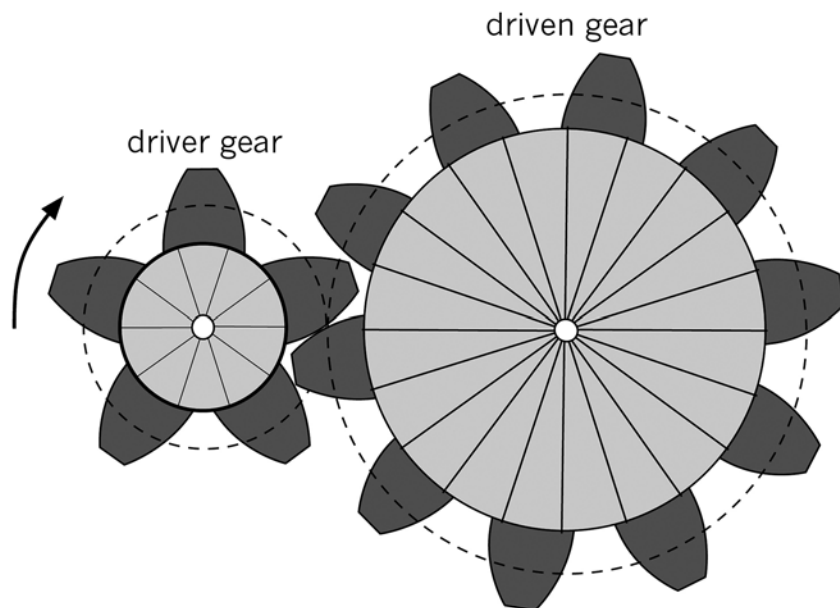


Figure 20

1. If the driver gear turns clockwise, which way will the driven gear turn?

.....

2. Count the numbers of teeth on the two gears in Figure 20. How many revolutions will the driver gear need to turn to make the driven gear turn once? Explain why this happens.

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

3. Will this system give a mechanical advantage? How do you know?

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

**Reminder:** A mechanical advantage means that the turning force at the output axle is greater than the turning force at the input axle.

## A large driver and a small driven gear

Look at the two gears in Figure 21. The driver gear is now large and the driven gear is smaller.

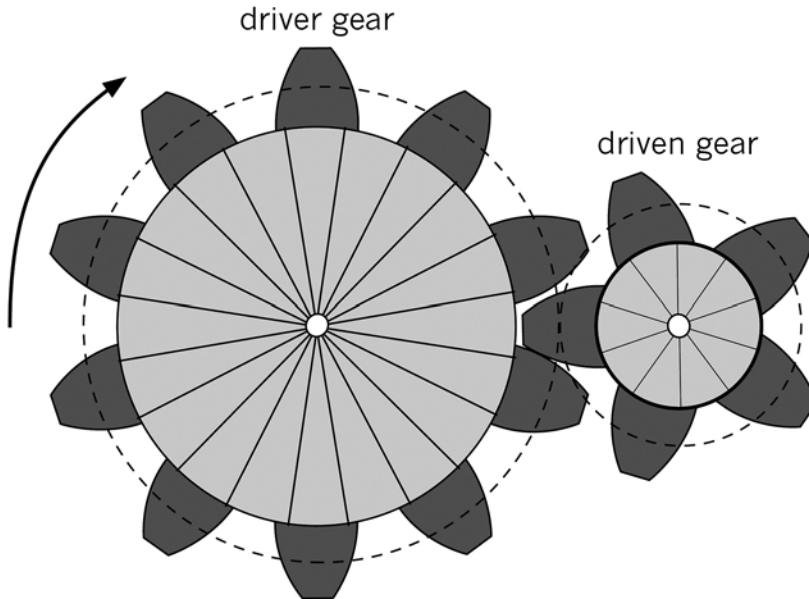


Figure 21

1. Will the driven gear turn faster or slower than the driver gear? Explain your answer.

.....  
.....

2. A driver gear has 10 teeth and the driven gear has 5 teeth. How many revolutions will the driver gear need to turn to make the driven gear turn once? Explain why this happens.

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

3. Will this gear system give a mechanical advantage or a speed advantage? How do you know?

.....  
.....

**Reminder:** A speed advantage means that the speed of rotation of the driven axle (output axle) is faster than the speed of rotation of the driver axle (input axle).

## Idler gears

Look at Figure 22. The driver and the driven gear are the same size. In the middle there is a small gear called an idler gear.

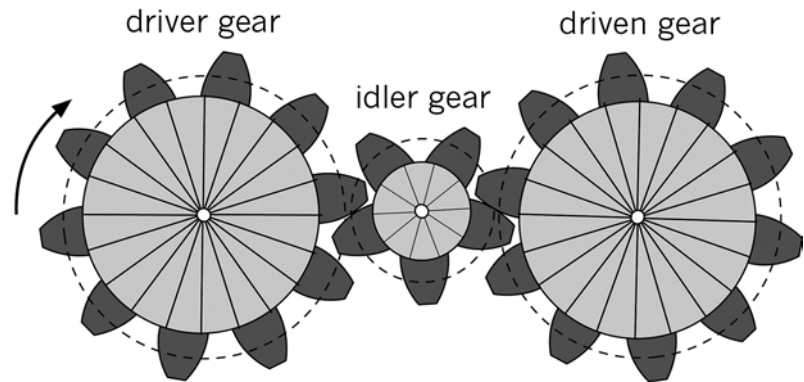


Figure 22

### What does an idler gear do?

An idler gear is a gear that turns between a driver and a driven gear. It allows the driver and the driven gears to turn in the same direction.

An idler gear does not change the mechanical advantage of a gear system.

When two gears mesh, they turn in opposite directions. This is called **counter rotation**.

When an idler is used between two gears, the direction of rotation of the driver and driven gear is the same. This is called **synchronised rotation**.

1. Will the idler gear turn faster or slower than the driver gear? Explain.

.....  
.....

2. Will the idler gear turn faster or slower than the driven gear? Explain.

.....  
.....

3. Will the driver gear and the driven gear turn at different speeds? Explain.

.....  
.....

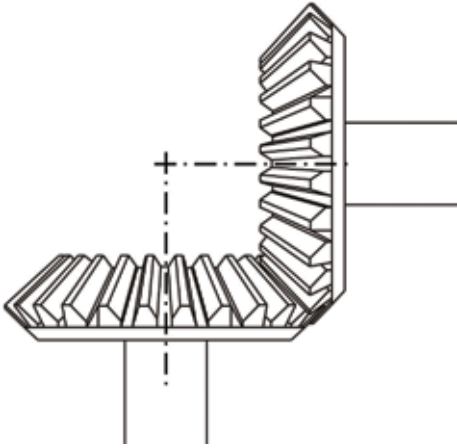
4. Will the driver gear and the driven gear turn in different directions? Explain.

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

## Bevel gears

Bevel gears are used when you want to change the direction of turning. Look at Figure 23. It shows how two bevel gears mesh together.

- The top gear will turn on a **horizontal** axle.
- The bottom gear will turn on a **vertical** axle.
- The bevel gear system changes the direction of rotation by 90°.



**Horizontal** means parallel to the ground. **Vertical** means at 90° (at a right angle) to the horizontal direction.

Figure 23: Bevel gears

Figure 24 on the next page shows a hand drill and an egg beater.

- The driver gear is a large bevel gear attached to a crank handle.
- The driven gears are the small bevel gears. The bottom bevel gear forces the drill to turn and the egg beater to rotate its blades.

1. Do you think the hand drill gives you a speed advantage or a mechanical advantage? Explain your answer.

.....  
.....

2. Explain how the bevel gears on the drill work.

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





Figure 24: A hand drill and an egg beater

---

### **Something you could do at home: Make a can crusher**

The lever on a real crane lifts a weight or load. The lever helps to lift the load higher. Levers are also used to squeeze or crush things. In this investigation, you will look at how a second-class lever can help you crush metal.

Many metal-working machines use levers to increase the input force, and the greater output force is used to cut metal sheet or to make holes in steel plates.

Empty cool-drink and food cans are waste that take up a lot of space. But it does not have to take up so much space, since most of the volume of a can is taken up by the air inside it. If you crush it, it will take up very little space. Before cans are recycled to make new steel, they are crushed. It's much cheaper to transport the crushed cans to a recycling factory since they require less space and you can transport more at a time.

Design a second-class lever to crush cool-drink and food cans. Make a rough sketch showing the dimensions. You can make this crusher from pieces of wood.

### **Next week**

Next week, you will learn how to do mechanical advantage calculations for levers and gears.

# CHAPTER 2

## Mechanical advantage calculations

In this chapter, you will learn how to calculate the amount of mechanical advantage lever systems and gear systems give.

You will also learn how to calculate the speed with which a gear in a gear system will rotate if you know how many teeth each gear has, and the speed with which the other gear is rotating.

2.1	Calculate the mechanical advantage of a lever .....	22
2.2	Calculate the distance advantage of a lever .....	26
2.3	Calculate the speed advantage of gears.....	27



Figure 1: A claw hammer can be used as a lever to remove nails from wood.

## 2.1 Calculate the mechanical advantage of a lever

In the previous chapter, you learnt that you can calculate a quantity to say exactly how big or small the mechanical advantage is. This quantity is a **ratio**. It is calculated by dividing the output force by the input force.

You also learnt that if the output force is greater than the input force, the mechanical advantage (MA) is greater than 1:  $MA > 1$ .

Look at the lever in Figure 2. This lever is making the output force bigger, so you can say that it is giving us a mechanical advantage. There are two “arms” on a lever: the **input arm** and the **output arm**. The lever below shows the input arm in blue and the output arm in red.

A **ratio** of 1 to 4 is written as 1:4. This is simply another way to write the fraction  $\frac{1}{4}$ . You also use a ratio to write the scale of a drawing.

The **input arm** is sometimes called the “effort arm”. The “output arm” is sometimes called the **load arm**.

### Calculations about a lever

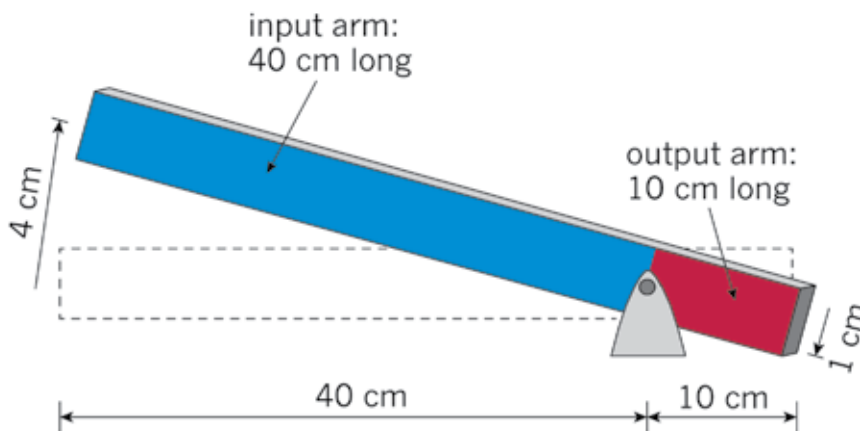


Figure 2: This lever has two arms: an input arm in blue and an output arm in red.

On the lever above, the input arm is 40 cm long and the output arm is 10 cm long. The input arm on this lever has been moved up by 4 cm. Study the picture and then answer the questions.

1. When the input arm is moved up by 4 cm, how far does the output arm move down?

.....

2. When the input arm is moved up by 2 cm, how far does the output arm move down?

.....

3. How far do you think the output arm will move if the input arm was moved up by 12 cm?

.....

4. Now you can confirm what you have already worked out. Use the values in Figure 2 to calculate the ratio of the length of the output arm to the length of the input arm.

.....

.....

.....

5. Use the values in Figure 2 to calculate the ratio of the output distance to the input distance.

.....

6. Calculate the ratio of the output distance to the input distance when the input distance is 2 cm. Use your answer from Question 2 above to help you.

.....

7. Calculate the ratio of the output distance to the input distance when the input distance is 12 cm. Use your answer from Question 3 above to help you.

.....

8. What can you say about the value of all of these ratios?

.....

---

## The ratio of input arm and output arm in levers

If the input arm is 400 cm long and the output arm is 100 cm long, then the output distance will always be:

$$\text{output distance} = \frac{100}{400} \times \text{input distance.}$$

If you lifted this lever by 20 cm, then:

$$\text{Output distance} = \frac{100}{400} \times \text{input distance} = \frac{100}{400} \times 20 \text{ cm} = \frac{1}{4} \times 20 \text{ cm} = 5 \text{ cm.}$$

This lever gives you a mechanical advantage because the input distance is larger than the output distance. We know that a lever with a larger input distance and a smaller output distance will give a mechanical advantage, so we can say that:

Input distance $\div$ output distance = length of input arm $\div$ length of output arm = mechanical advantage (MA)	But we also know that: Input distance $\div$ output distance = output force $\div$ input force = mechanical advantage (MA).
---	--

The ratio *input arm distance* : *output arm distance* is the same as the ratio *output force* : *input force*, and this is the mechanical advantage.

A lever with an input arm 400 cm long and the output arm 100 cm long will give a mechanical advantage of:

$$\text{MA} = \frac{\text{input arm distance}}{\text{output arm distance}} = 400 \div 100 = 4.$$

This means that the output force will always be four times larger than the input force; and the input force will always be four times less than the output force.

Consider the force needed to keep a weight of 20 kg from falling due to gravity. If this weight is on the output side of the lever discussed above, then what weight is needed on the input side of the lever to balance it?

$$\text{Weight on input side} = \frac{1}{4} \times 20 \text{ kg} = 5 \text{ kg.}$$

### Mechanical advantage

- $\text{MA} = \frac{\text{output force}}{\text{input force}}$
- $= \frac{\text{input arm distance}}{\text{output arm distance}}$
- $\text{output force} = \text{MA} \times \text{input force}$
- $\text{input force} = \frac{\text{output force}}{\text{MA}}$

## Calculations about a lever

Look at the lever in Figure 3. The lever is pushed down to crush a can.

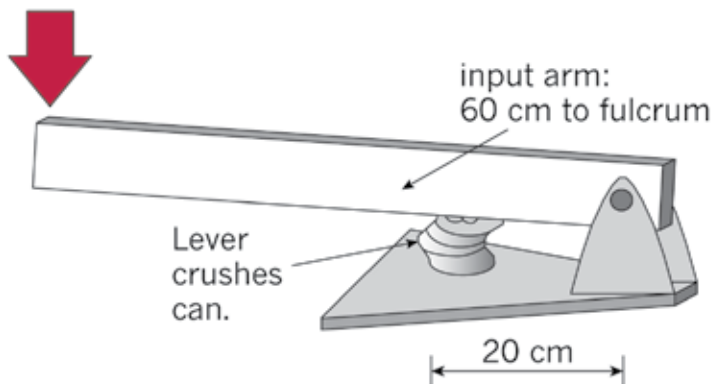


Figure 3: A lever crushing a can

1. How do you know that this lever will crush a can more easily than by hand?

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

2. With the can in the position shown, calculate the mechanical advantage that this lever will give.

.....

3. If you need an output force of 20 “units of force” to crush the can, how much input force do you need?

.....  
.....

Length can be measured in units of metres, and mass can be measured in units of kilograms.

You will later learn in physics about how force is measured in units of “Newtons”. But for the moment, you can call it “units of force”, or “units”.

4. The designer decides to make it even easier to crush the can. She moves the can closer to the fulcrum. This reduces the output arm to 15 cm. Recalculate the mechanical advantage of the lever.

.....

5. Recalculate the new input force needed to crush the can with an output force of 20 units.

.....

## 2.2 Calculate the distance advantage of a lever

Look at the lifting system in Figure 4. It uses a hydraulic cylinder for the input force. It is a system that could be used for lifting an engine out of a motorcar.

The lifting lever at the top is a third-class lever, because the input is between the fulcrum and the output.

A third-class lever always gives a distance advantage. It never gives a mechanical advantage.

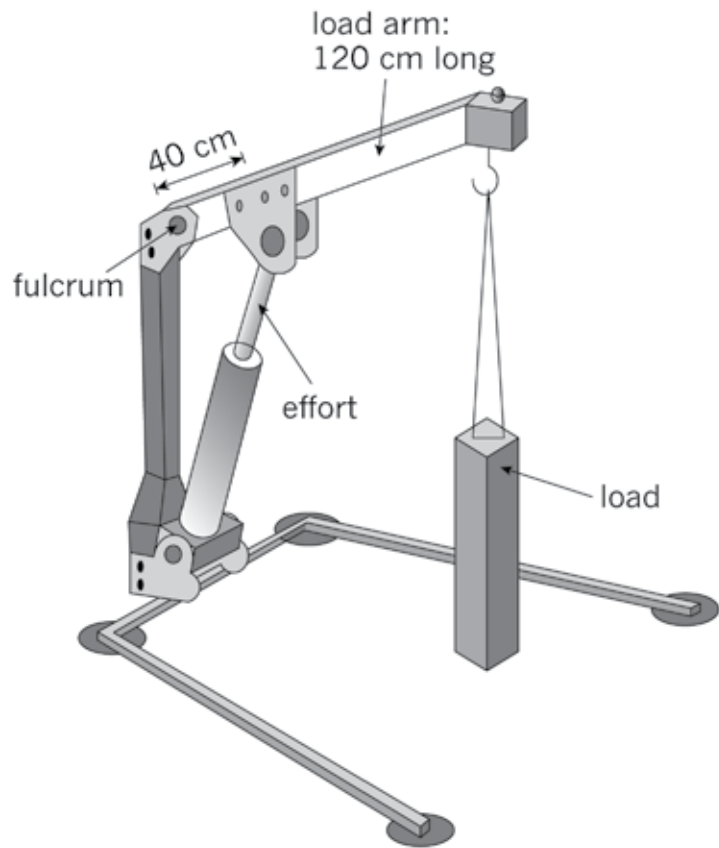


Figure 4: A lifting system

1. How long is the input arm on this lever?

.....

2. How long is the output arm?

.....

3. Calculate the mechanical advantage that this lever gives.

.....

4. Explain what this MA value tells you about the output and input forces.

.....

.....

5. A person wants to use this system to lift an engine out of a car. He needs the engine to be lifted by 90 cm. How far will the hydraulic cylinder at the input need to move for the engine to be lifted 90 cm at the output?

.....

6. If the system is designed to lift objects by 180 cm, how far does the hydraulic cylinder need to move at the input?

.....



## 2.3 Calculate the speed advantage of gears

### The gear ratio

The gear ratio, which is also called the speed ratio or sometimes the velocity ratio, tells you how the speed of a driven gear will be changed by a driver gear.

Look at the two meshed gears in Figure 5. The driver or input gear has 5 teeth. The driven or output gear has 10 teeth.

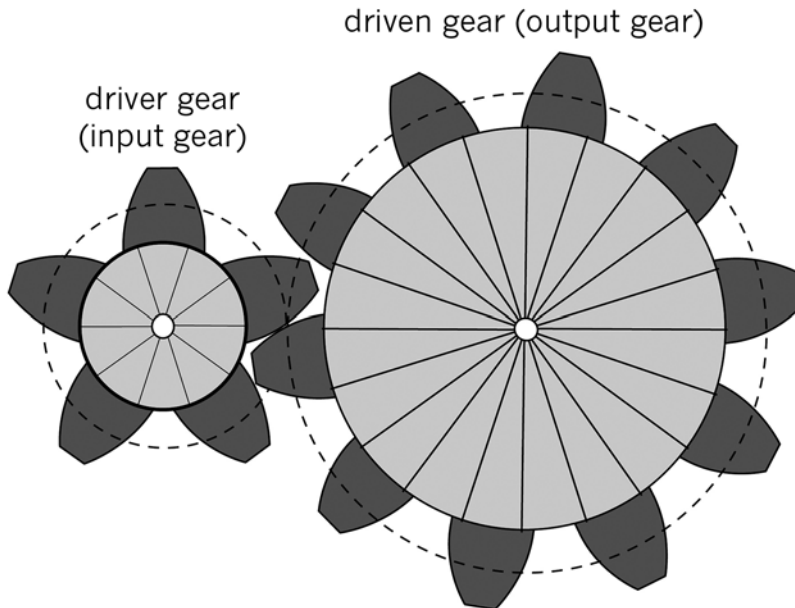


Figure 5

- If the driver moves one revolution, it pushes the 5 teeth on the driven gear.
- If the driver gear moves by 2 revolutions, then 10 of the driven gear's teeth are moved. So the driven gear moves 1 revolution. Two driver revolutions give 1 driven gear revolution. So the turning speed of the driven gear is  $\frac{1}{2}$  the turning speed of the driver gear. The speed ratio, which is the same as the gear ratio, is 1 : 2 or  $\frac{1}{2}$ .
- If the driver gear revolves 10 times, then the driven gear will only revolve 5 times.

$$\begin{aligned}\text{gear ratio} &= \frac{\text{rotational speed of input axle}}{\text{rotational speed of output axle}} \\ &= \frac{\text{number of teeth on output gear}}{\text{number of teeth on input gear}} = \frac{10}{5} = 2\end{aligned}$$

## Calculations using the gear ratio

The speed of a turning wheel is measured in revolutions per minute, or **rpm**. So if the driver gear is turning around twice every second, it has a speed of 2 rpm. A speed of 2 rpm on this system will give a speed of 1 rpm on the driven gear.

The gear ratio can be used to work this out:

$$\begin{aligned} \text{Driver gear speed} &= (\text{gear ratio}) \times (\text{driven gear speed}) \\ &= \frac{1}{2} \times 2 \text{ rpm} \\ &= 1 \text{ rpm.} \end{aligned}$$

**rpm** stands for “revolutions per minute”.

## The speed ratio and mechanical advantage

If a gear system gives a **speed advantage** because of its gear ratio, then it will give you a mechanical disadvantage. This means that if a driven gear revolves faster than its driver gear, it gives less turning output force to the machine.

If a driven gear revolves slower than its driver gear, it gives more turning output force to the machine.

### Speed advantage

When a driven (input) gear makes the driver (output) gear rotate faster, then the gear system gives a speed advantage.

## Calculations

1. The gear system in Figure 5 has 5 teeth on the driver gear and 10 teeth on the driven gear. Calculate the rpm of the driven gear if the driver gear rotates at 1 500 rpm.

.....

2. If a driver gear has 15 teeth and a driven gear has 60 teeth, calculate the gear ratio.

.....

3. Consider a gear system where the driver gear has 25 teeth and the driven gear has 15 teeth.

(a) If the driver gear rotates at 100 rpm, calculate the speed of the driven gear.

.....

(b) What can you say about the output turning force at the driven axle compared to the input turning force at the driver axle? How does that change in this system?

.....

.....

### Using the gear diameters to calculate the gear ratio

The easiest way of calculating the speed of a gear system is from the number of teeth on the gear wheels.

However, there is another way of calculating the speed of a gear system:

- If a gear wheel is small, it will have a small number of teeth and its diameter will be small.
- If a gear wheel is large, it will have more teeth and its diameter will be larger.

In Figure 5, the diameter of the large driven gear is 9,4 cm and the diameter of the small driver gear is 4,7 cm.

**Note:** The diameters are measured for the dashed circles in Figure 5, since those circles show where the gear teeth make contact.

The gear ratio is:

$$\text{gear ratio} = \frac{\text{diameter of driven gear}}{\text{diameter of driver gear}} = \frac{9,4}{4,7} = 2.$$

This is equal to the ratio calculated from the number of gear teeth:

$$\text{gear ratio} = \frac{\text{number of teeth on output gear}}{\text{number of teeth on input gear}} = \frac{10}{5} = 2.$$

---

## More calculations for you to do

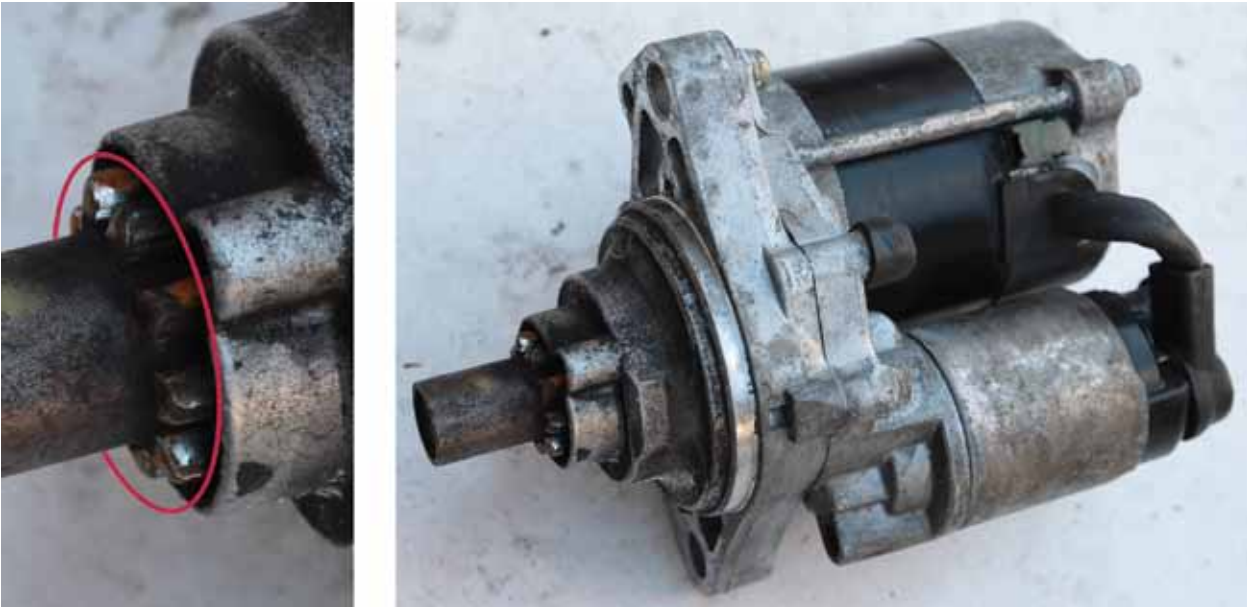


Figure 6: A car's starter motor has a small driver gear called a pinion, which is used to turn a bigger gear on the engine.

1. A starter motor of a car has a driver gear with a diameter of 4 cm. It drives a large gear connected to the crankshaft of the engine with a diameter of 60 cm. Calculate the gear ratio of the starter-motor system of this car.

.....

2. If the starter motor turns at 3 600 rpm, calculate the speed that the engine turns when the car starts.

.....

3. Do you think the turning output force that makes the engine turn is greater than, or less than, the turning input force of the electric starter motor?

.....

---

## Next week

Next week, you will learn how to draw gear systems. You will also write design briefs for gear systems with an exact speed advantage and an exact mechanical advantage.

# CHAPTER 3

## Drawing gear systems

In this chapter, you will learn how to draw gear systems. First you will do some orthographic or two-dimensional (2D) drawings that show the exact sizes and numbers of teeth on the gears. For these types of drawings, you do not have to draw the teeth, so it is much easier.

Then you will write a design brief for some gear systems of your own and produce specifications for the systems. You will learn to use drawing instruments and an isometric grid to draw your gear systems in three dimensions (3D).

3.1	Draw gears in two dimensions (2D).....	33
3.2	Write a design brief with specifications for gears .....	42
3.3	Draw gears in three dimensions (3D).....	46



Figure 1: The back of a tow truck showing the winch that is used to lift and pull cars that have broken down. A winch is a gear that gives a mechanical advantage. You will learn about winches in this chapter.

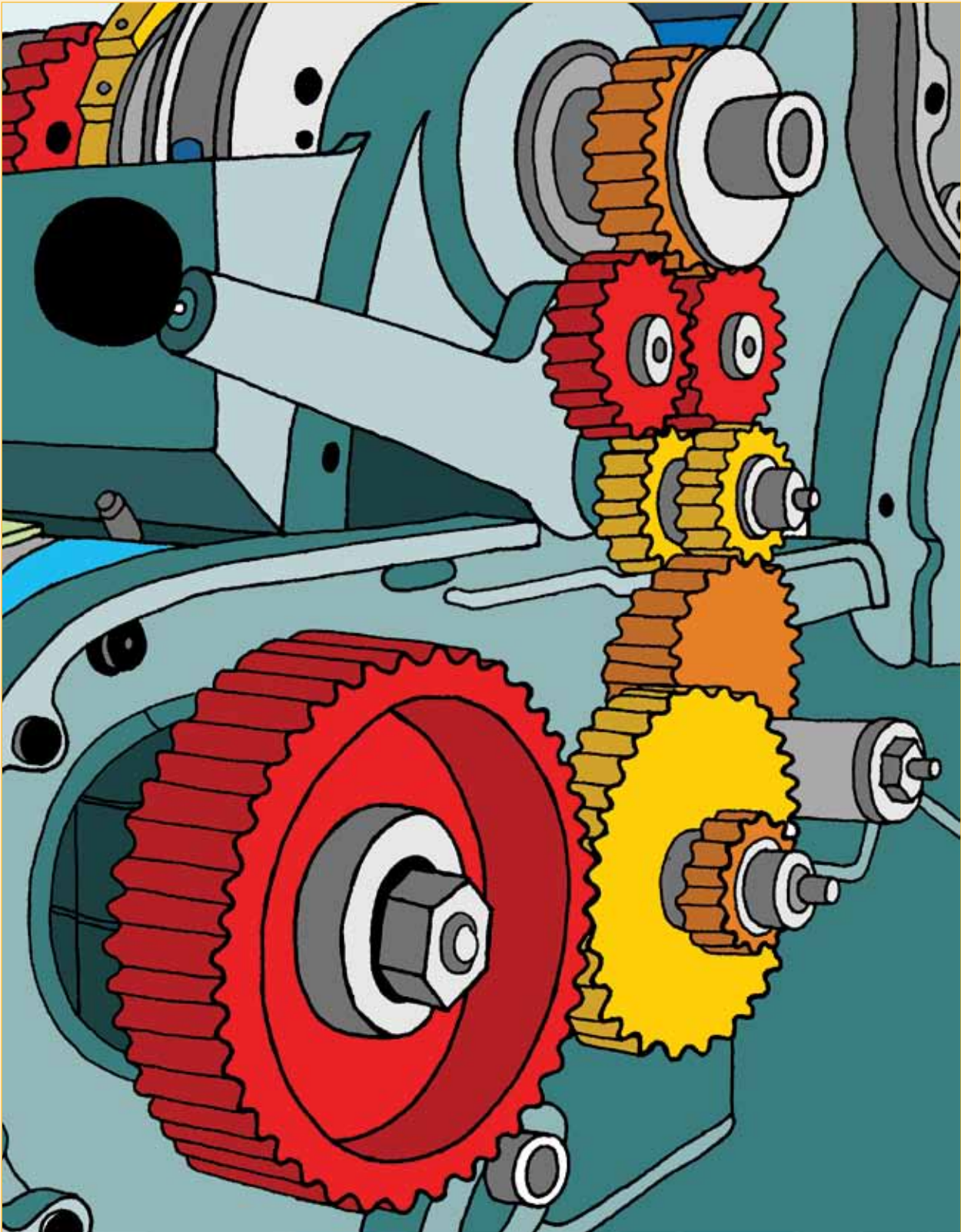


Figure 2: Spur gears with different radiuses. You will learn how to draw technical diagrams of gears when you are given the radius and the number of teeth of each gear. You don't need to draw the teeth!

### 3.1 Draw gears in two dimensions (2D)

When you draw a gear wheel, you show a number of different circle sizes, but you do not show the gear teeth. The specification for the gear wheels and teeth is shown using notes and tables.

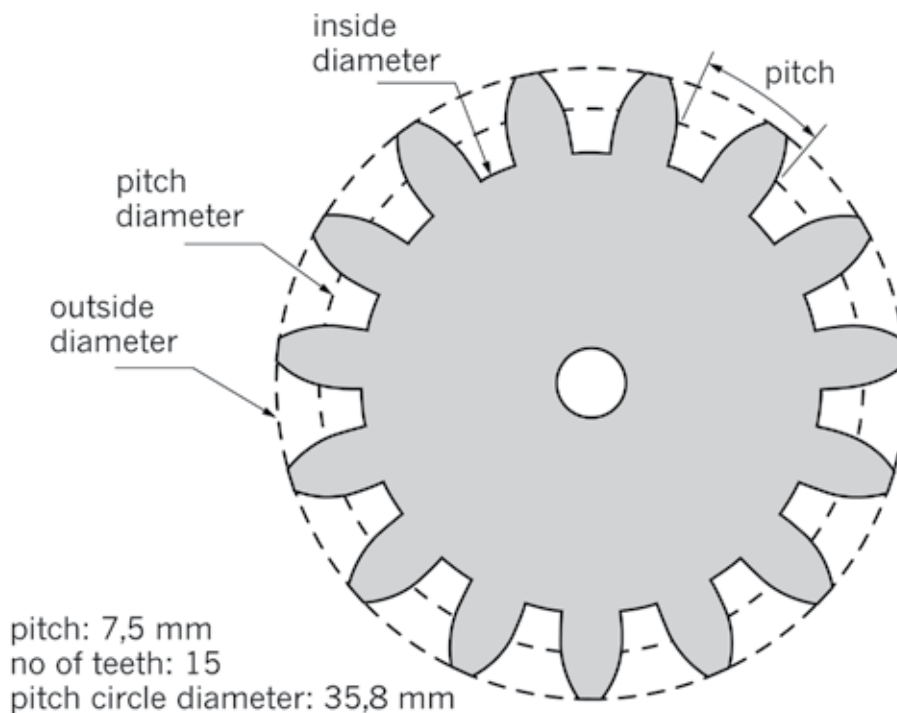


Figure 3: How to draw a gear wheel with 15 teeth

Figure 3 shows all the important information for a gear wheel:

- The **pitch** is the space for each tooth.
- The **pitch diameter** is the size of the circle that can fit all the teeth, up to where they mesh with the teeth of another gear.
- The **outside diameter** shows the size of the circle that surrounds the teeth.
- The **inside diameter** shows where the teeth are joined to the inner wheel.
- The **depth** of the teeth is the difference between the outside and inside diameters.

The pitch circle diameter on this gear is 35,8 mm. The distance around the pitch circle of this gear is the pitch circle circumference, which is:

$$\text{Circumference} = \pi \times D = 3,1428 \times 35,8 \text{ mm} = 112,5 \text{ mm.}$$

So the pitch, or the space for each tooth =  $112,5 \div 15 = 7,5 \text{ mm.}$

Look at Figure 4. This figure shows how to draw a gear wheel.

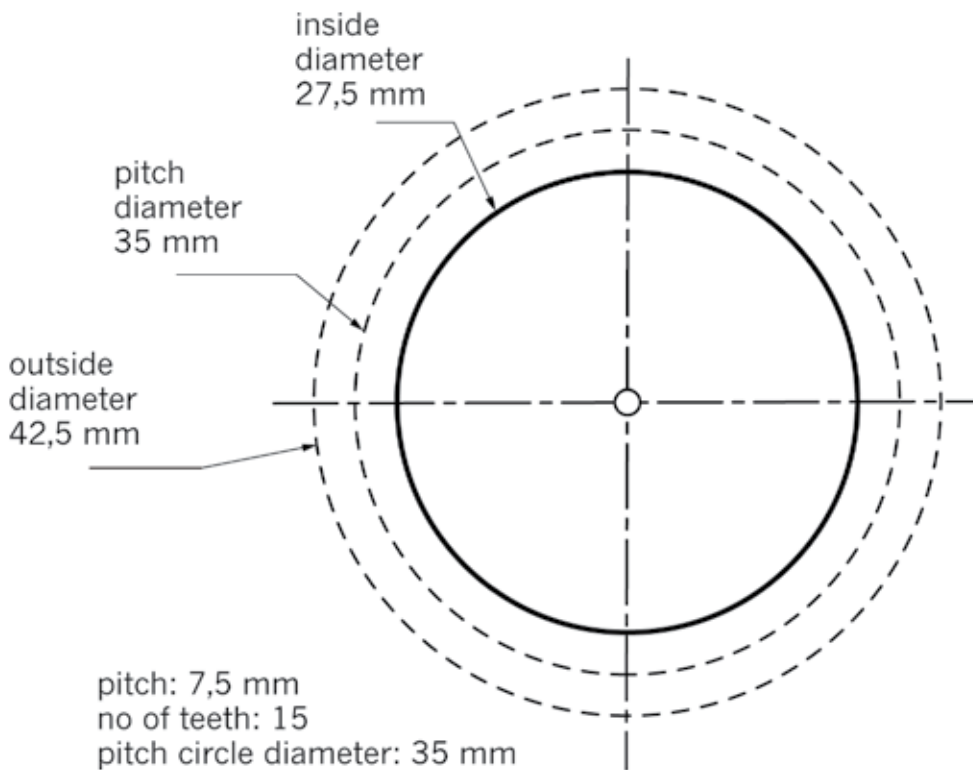


Figure 4: How to draw a gear wheel

Now draw this gear wheel on the grid by following these steps:

- Step 1: Draw two crossing centrelines to mark the centre of the gear wheel.
- Step 2: Draw the pitch circle using a compass. In this case, you will need to set the compass radius to  $\frac{1}{2}$  of 3,5 cm (35 mm), which is 17,5 mm.
- Step 3: Draw the outside diameter using a compass. You will need to set the compass radius to  $\frac{1}{2}$  of 4,25 cm (42,5 mm), which is a little more than 21 mm.
- Step 4: Draw the inside diameter. You will need to set the compass radius to  $\frac{1}{2}$  of 2,75 cm (27,5 mm), which is just under 14 mm.

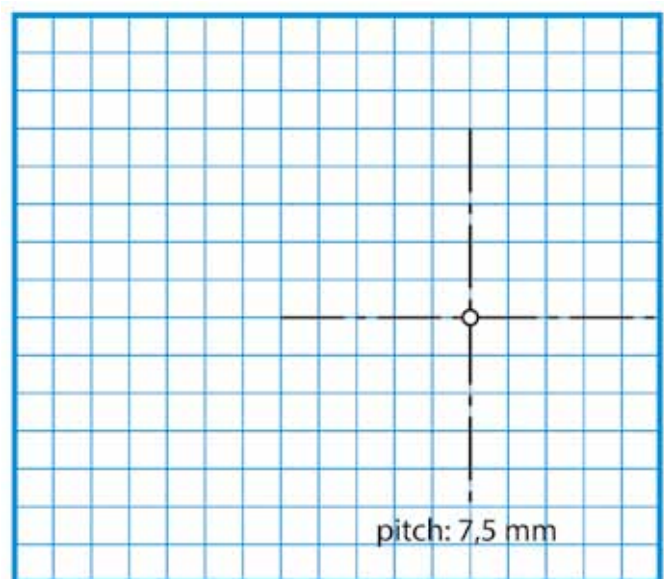


Figure 5



## Drawing meshing gears

Look at the drawing of the meshing gears in Figure 6. A small driver gear is shown on the left. It is driving a larger driven gear on the right.

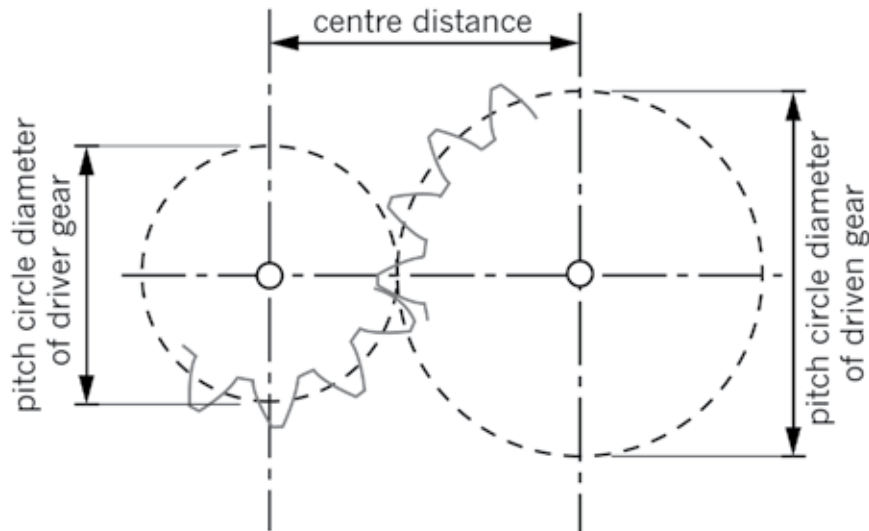


Figure 6: Meshing gears

Two spur gears will only mesh properly if:

- the size and shape of their teeth are the same, in other words the pitch and the depth of gear teeth on both gears are the same, and
- the pitch circle circumferences of the two gears are touching each other.

The line connecting the centres of the two gears is called the **centre line**. Centre lines are drawn as chain lines, with long and short dashes.

The distance between the gear centres is shown on this drawing as the **centre distance**. The exact centre distance for two meshing gears is the pitch circle radius of the driver gear plus the pitch circle radius of the driven gear.

**Remember:** The radius is  $\frac{1}{2}$  of the diameter.

If, for example, this driven gear had 15 teeth and a pitch circle diameter of 35 mm, and the driven gear had 30 teeth and a pitch circle diameter of 70 mm, then the centre distance would be:

$$\text{Centre distance} = \frac{1}{2} \times 35 \text{ mm} + \frac{1}{2} \times 70 \text{ mm} = 17,5 \text{ mm} + 35 \text{ mm} = 52,5 \text{ mm}.$$

## How to draw meshing gear systems

Look at the meshing gears in Figure 6 on the previous page. Figure 7 below shows how to draw a diagram of this gear system, which has a 15-tooth driver gear and a 30-tooth driven gear.

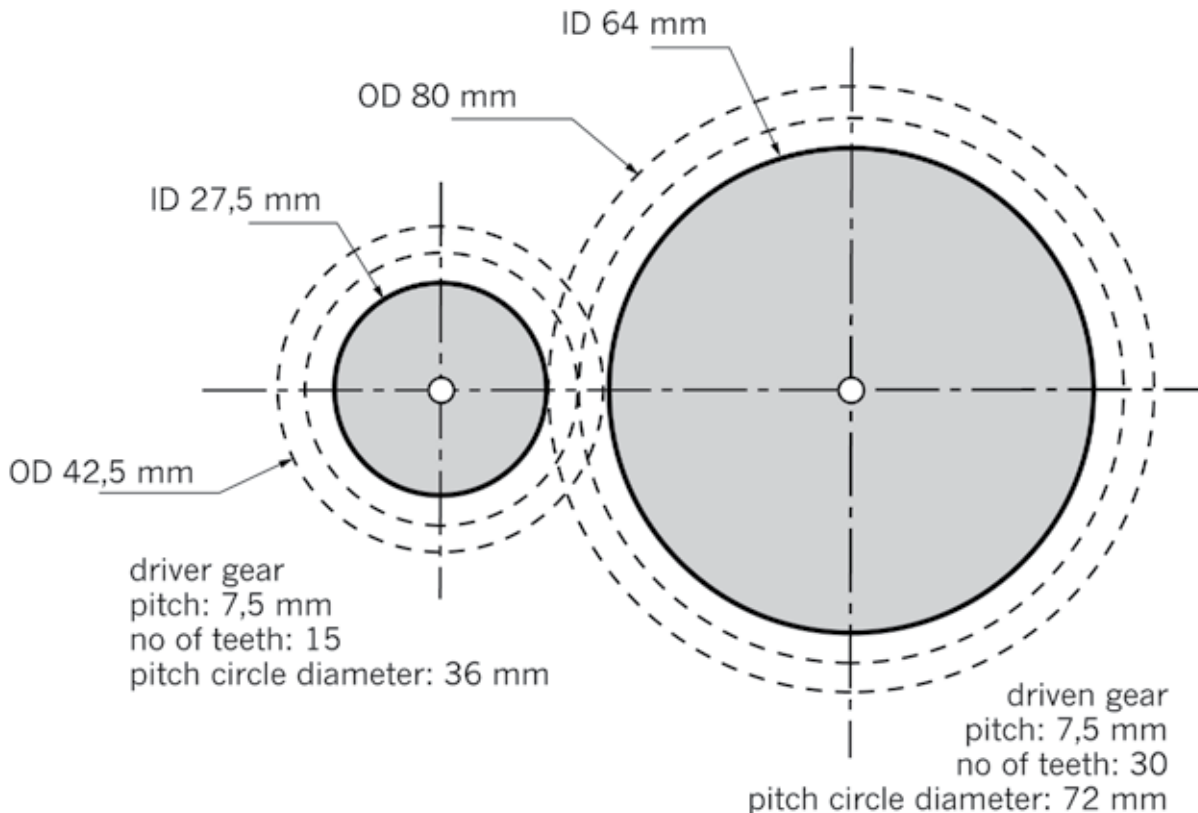


Figure 7

- **Step 1:** Start by drawing a horizontal centre line for both gears.
- **Step 2:** Draw a vertical centre line for the driver gear on the left. This marks the centre of the driver gear wheel.
- **Step 3:** Calculate the pitch centre distance. In this case, it would be:  $\frac{1}{2}$  of 36 mm +  $\frac{1}{2}$  of 72 mm = 54 mm.
- **Step 4:** Measure the centre of the driven gear from the centre of the driver gear.
- **Step 5:** Use a compass to draw the two pitch circles so that they just touch each other. In this case, the pitch circle of the driver gear will be 36 mm, so you will need to set the compass to a radius of 18 mm. The radius setting for the larger driven gear will be 36 mm, twice as big.
- **Step 6:** Use your compass to draw in the inside diameter (ID) and outside diameter (OD) circles.
- **Step 7:** Now add the information that tells people about the teeth. This is written underneath each gear wheel or on a table next to the drawing.

**Draw gear systems with the driven gear rotating in the opposite direction of the driver gear**

1. Use the steps on the previous page to draw a gear system with 15 teeth on a driver gear with a 36 mm diameter and 30 teeth on a driven gear with a 72 mm diameter. Use the grid paper in Figure 8. The driver gear drawing has been started for you.

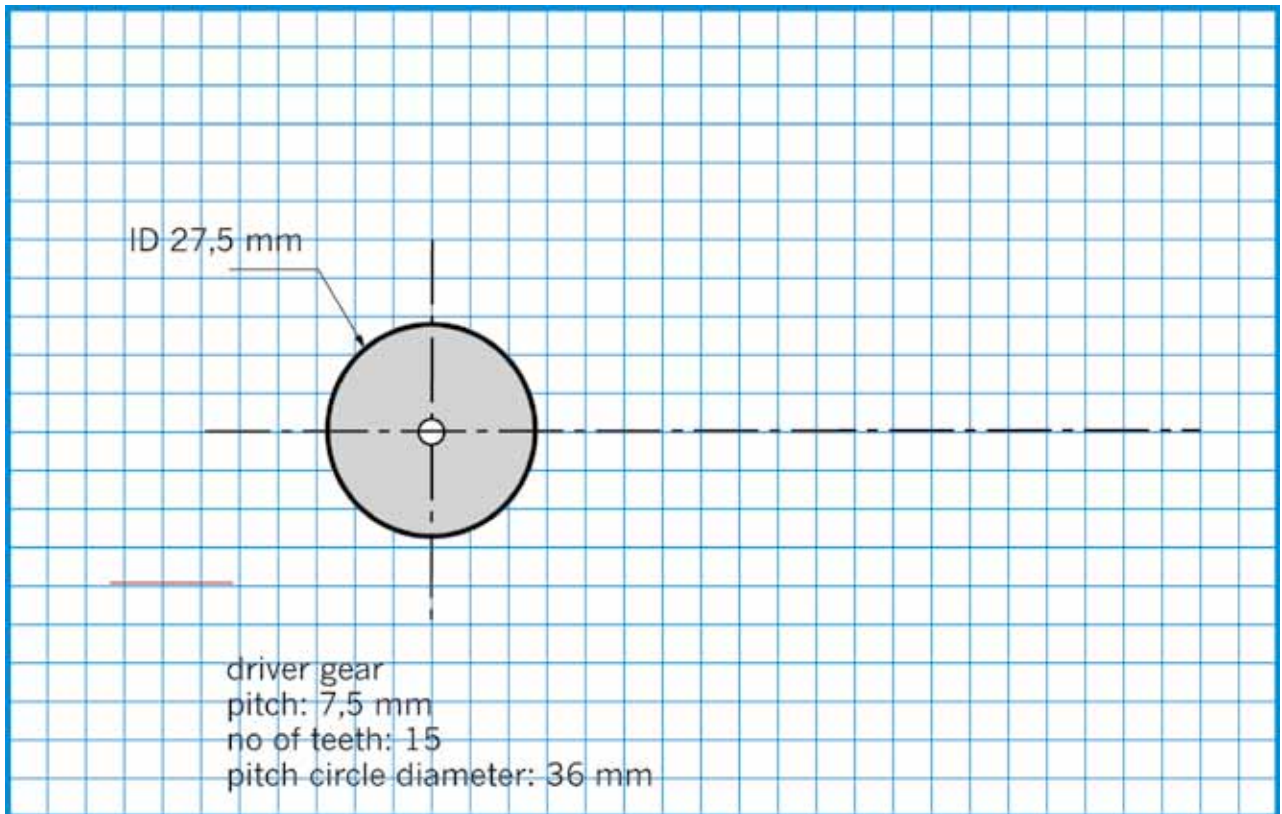


Figure 8: Draw the driven gear on the grid.

2. When you have finished your drawing, use arrows to show the direction of rotation of the driven gear if the driver is turning clockwise.
3. Will the driven gear be rotating faster or slower than the driver?

.....

## Draw gear systems with the driven gear rotating in the same direction as the driver gear

Do you remember what an idler gear does? It meshes between the driver and the driven gear. The idler does not change the gear ratio. All it does is change the direction of the driven gear. A gear system with an idler can have the driven and the driver gear turning in the same direction.

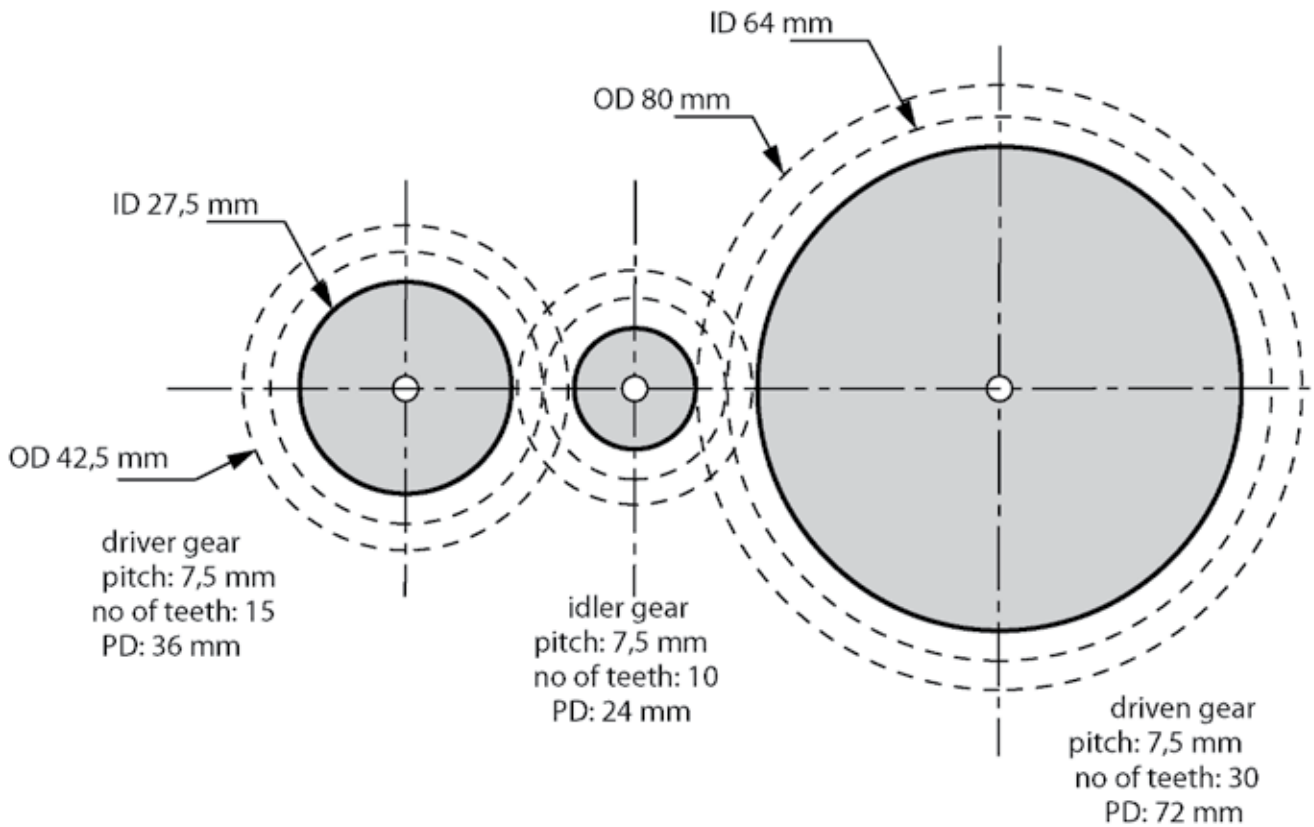


Figure 9

To draw a gear system with an idler, you will need to draw three gears instead of two. But the principle stays the same.

1. Draw the gear system in Figure 9 on the grid paper on the next page.
2. Draw arrows to show which way each gear will turn.
3. Do the driver and driven gears rotate in the same or in opposite directions?

.....

4. If the driver gear rotates at 1 500 rpm, how fast will the driven gear rotate?

.....

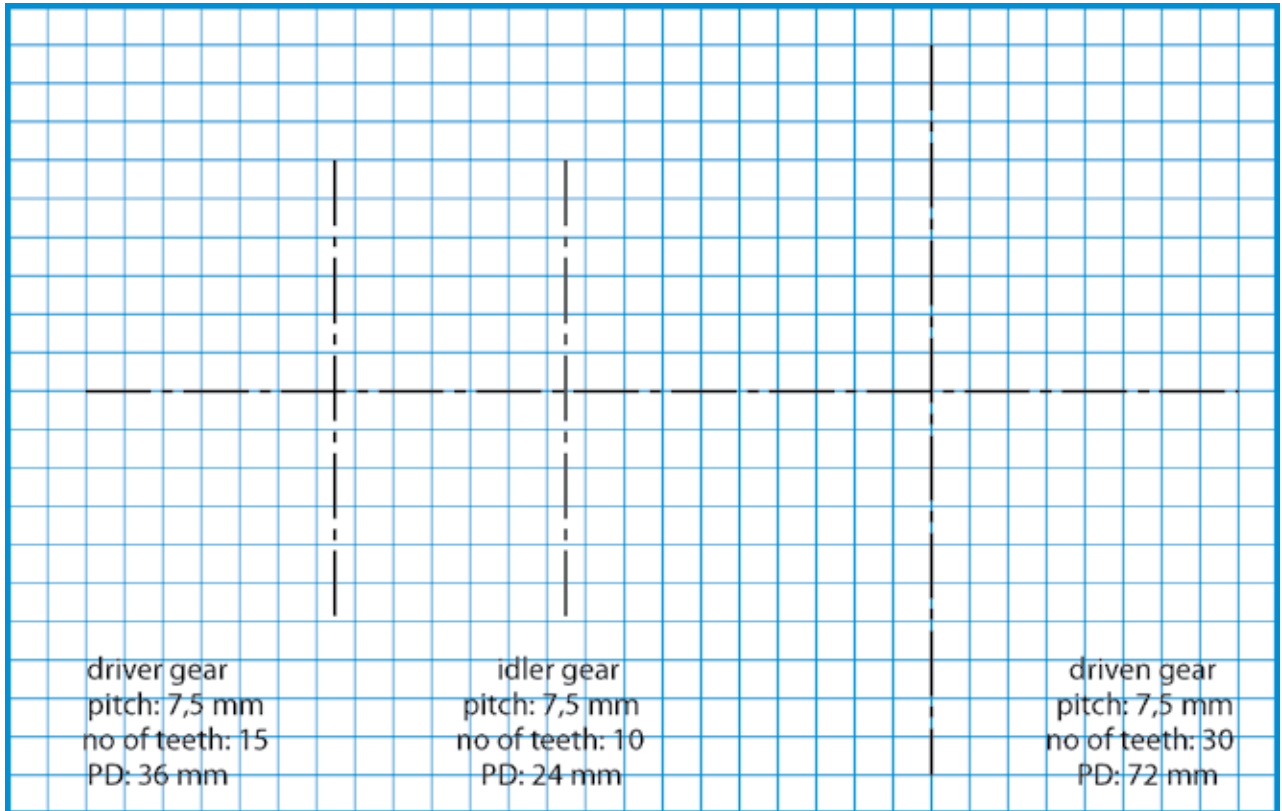


Figure 10

## Homework: Draw gear systems with the driven gear rotating faster than the driver gear

### Part A: Rotating in opposite directions

1. Draw the gear system shown in Figure 11. The driver gear has 45 teeth and a pitch circle diameter of 107 mm. The driven gear has 15 teeth and a pitch circle diameter of 36 mm. Use the grid paper in Figure 12.

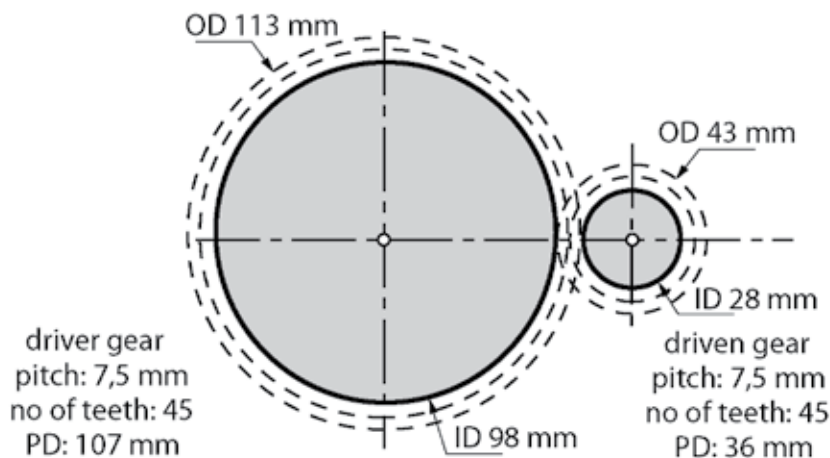


Figure 11

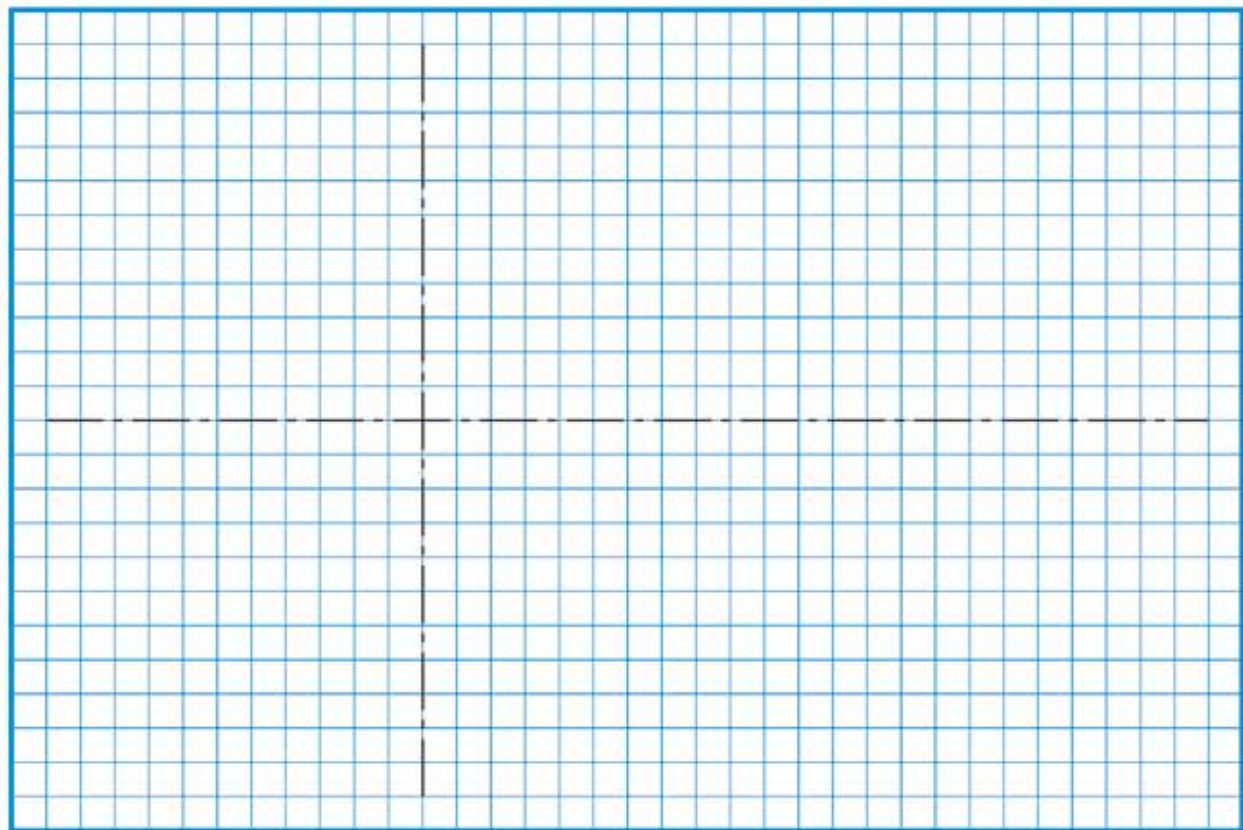


Figure 12: Draw your gear system on this grid paper.

2. What can you say about the speed of the driven gear compared to the driver gear?

.....

3. Does this system change the direction of rotation?

.....

### Part B: Rotating in the same direction

1. Add an idler to this gear system as shown in Figure 13. Now draw this new system on the grid paper in Figure 14.

2. Draw arrows on the drawing to show the direction of rotation of each gear.

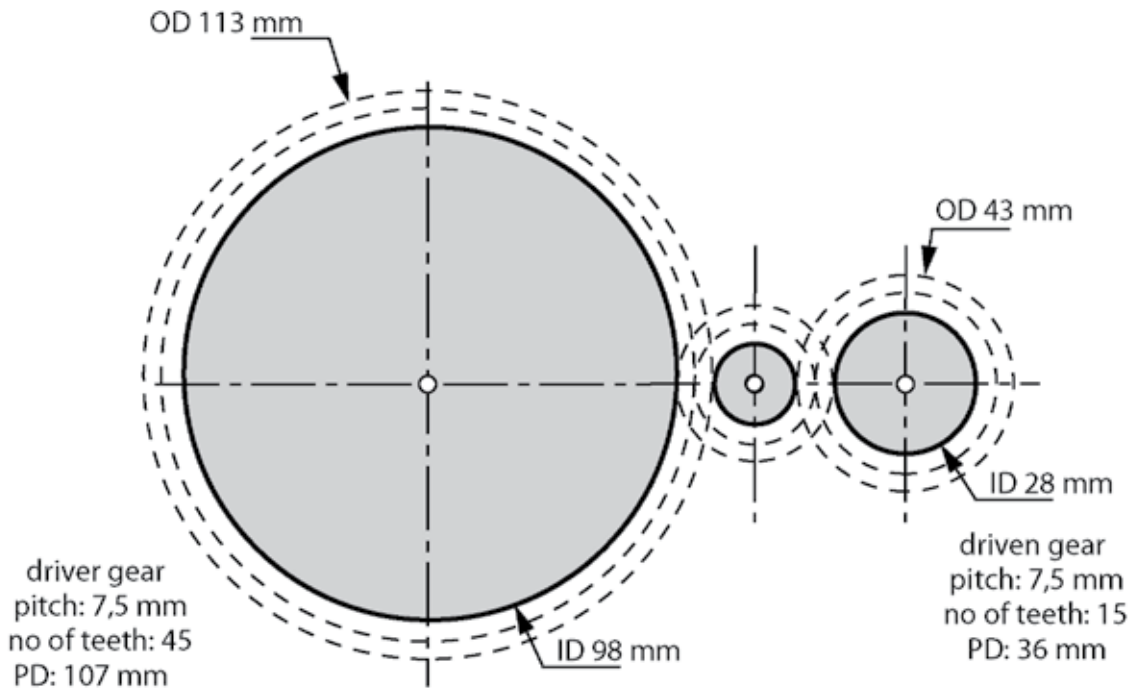


Figure 13

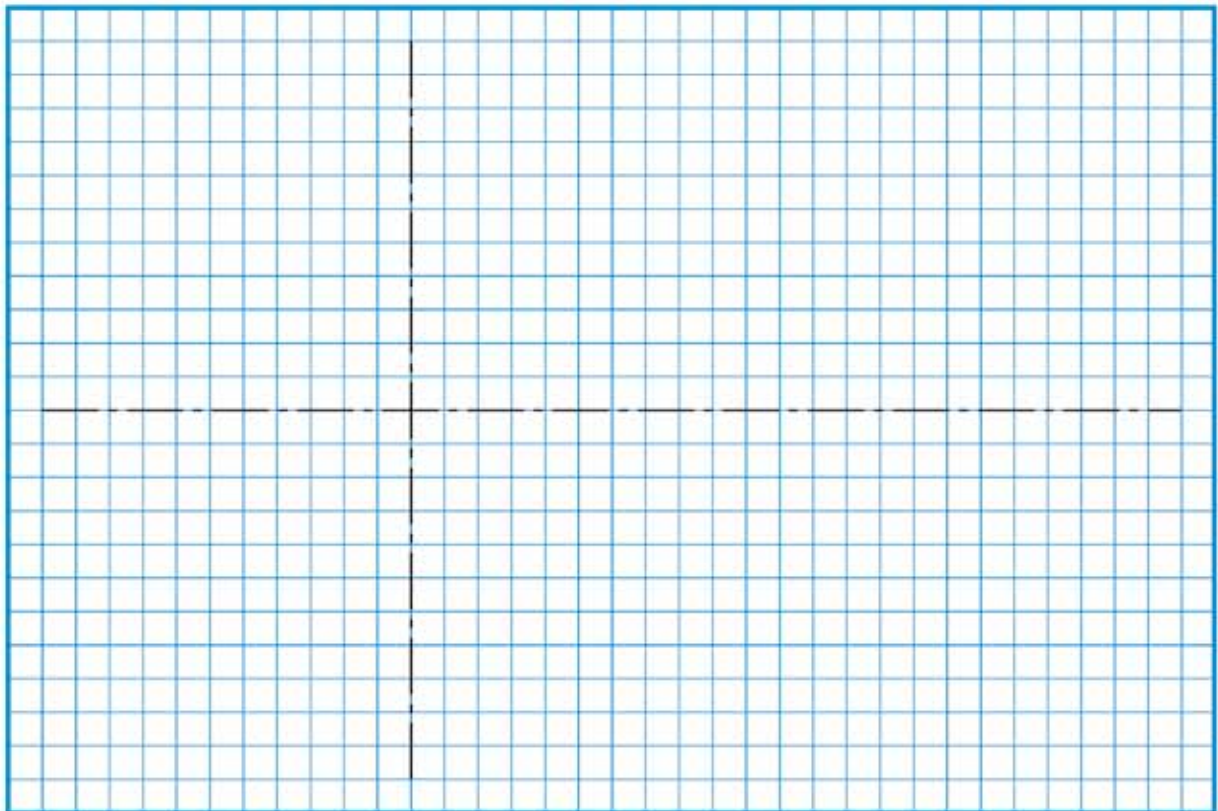


Figure 14: Draw your gear system with an idler gear on this grid paper.

3. What does the idler do?

.....

## 3.2 Write a design brief with specifications for gears

Gear systems have two important uses:

- A gear system can give a mechanical advantage. In this case, a small driver gear is used to turn a larger driven gear. The output of the system turns more slowly, but with greater turning force.
- Gears can also give a speed advantage. In this case, a large driver gear will turn a smaller driven gear. The driven gear turns faster than the driver gear, but with less turning force.

In this lesson, you will design gear systems that use both these advantages.

### A design brief for a gear that gives a mechanical advantage

Look at Figure 15. It shows a winch for a **tow** truck. Winches are used to pull broken-down cars onto the back of a tow truck.

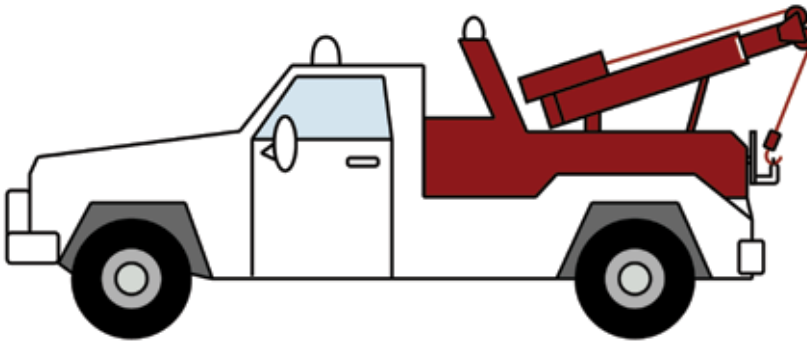


Figure 15: This mechanism is a winch. It is used to pull broken-down cars onto the back of a tow truck.

### A problem with this winch

The company using this winch has found that it is not powerful enough to pull large vehicles.

The company asked you to improve the winch. They want the winch to pull large vehicles that are three times as heavy as ordinary cars.

The word **tow** means to pull a car behind a moving truck for a certain distance. Tow trucks can tow cars, but they can also pull cars onto the back of the truck to carry them to the repair shop.

### Write a design brief

1. Write a few short, clear sentences that summarise the problem that needs to be solved, as well as the purpose of the proposed solution. Begin your first sentence with the words:

*I am going to design ...*

.....  
.....



2. Write a list of specifications for the new winch solution.

**Remember:** Specifications are lists of things that your solution must do, and some things that it must not do.

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

**A design for the improved winch**

3. Describe how you are going to improve this winch.

.....

4. How will you know that the winch can pull vehicles that are up to three times heavier than an ordinary car?

.....

5. Complete the drawing in Figure 16 to show how you will improve the winch. Draw the driver gear on top of the motor. Then show where you will place the winder, and draw the winder gear. Use a pitch of 7,5 mm and a depth of 5,0 mm for the gear teeth. Label your drawing with the pitch and number of teeth on each of the gear wheels.

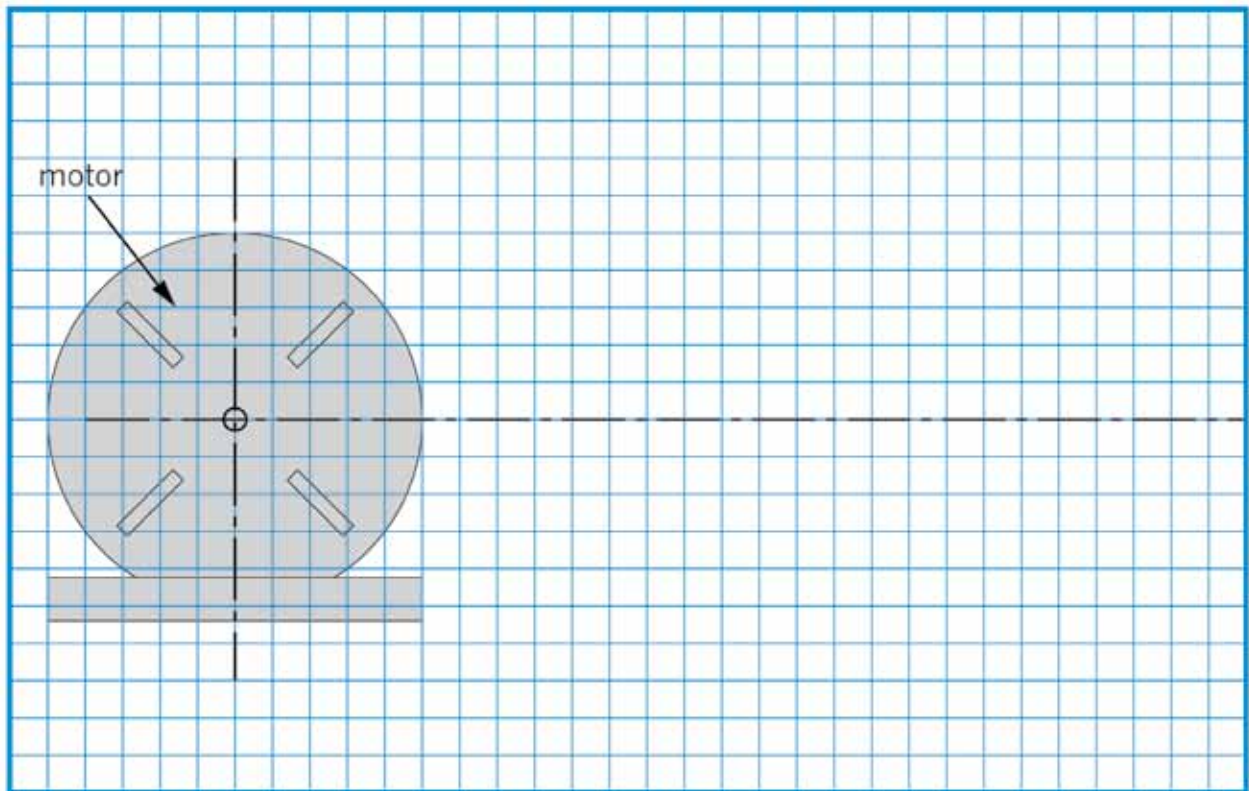


Figure 16: Use this grid to show how you will improve the winch.

## Write a design brief for a gear that gives a speed advantage

Look at the system shown below. It shows the inside of a wind turbine. The wind turns the propeller and the propeller turns an electric generator to make electricity.

### The problem with wind turbines

The blades of wind turbines turn slowly, at about 9 to 19 rpm. But the electric generator that is driven by a wind turbine needs to turn faster. A turbine manufacturer needs a gear system that will make the generator turn at least four times faster than the wind turbine. Can you help?

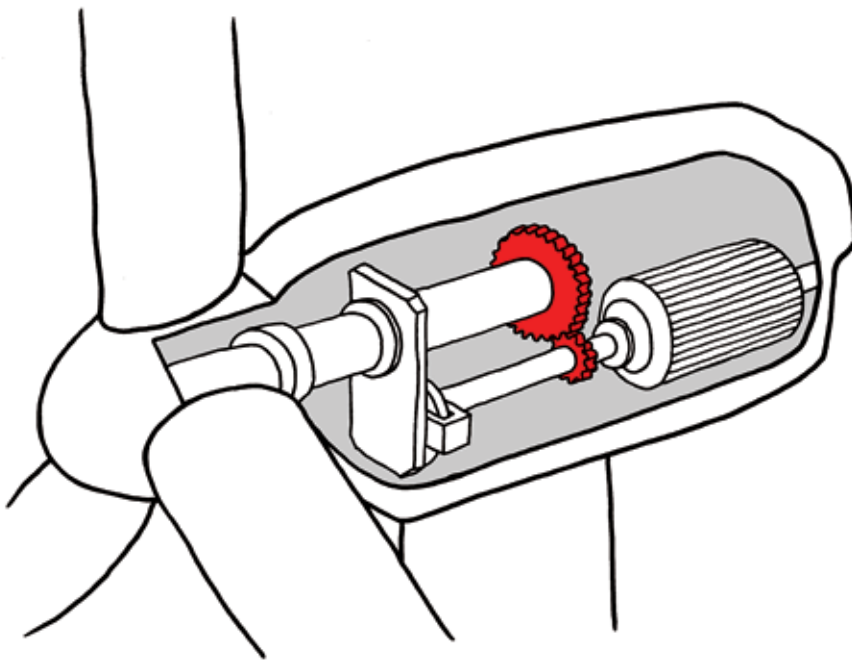


Figure 17: Inside a wind turbine

1. **Write a design brief.** You need to write a few short, clear sentences that summarise the problem that needs to be solved, and the purpose of the proposed solution. Begin your first sentence with the words:

*I am going to design ...*

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

2. **Specifications for your solution.** Write a list of specifications for the gear system solution.

.....

**A design for the improved wind turbine**

1. Draw your design on the grid in Figure 18. Your design should show how you will make the driven generator of the wind turbine move four times faster than the driver. Use a pitch of 0,75 cm and a height of 0,50 cm for the gear teeth.
2. Label your drawing with the pitch and number of teeth on each of the gear wheels.

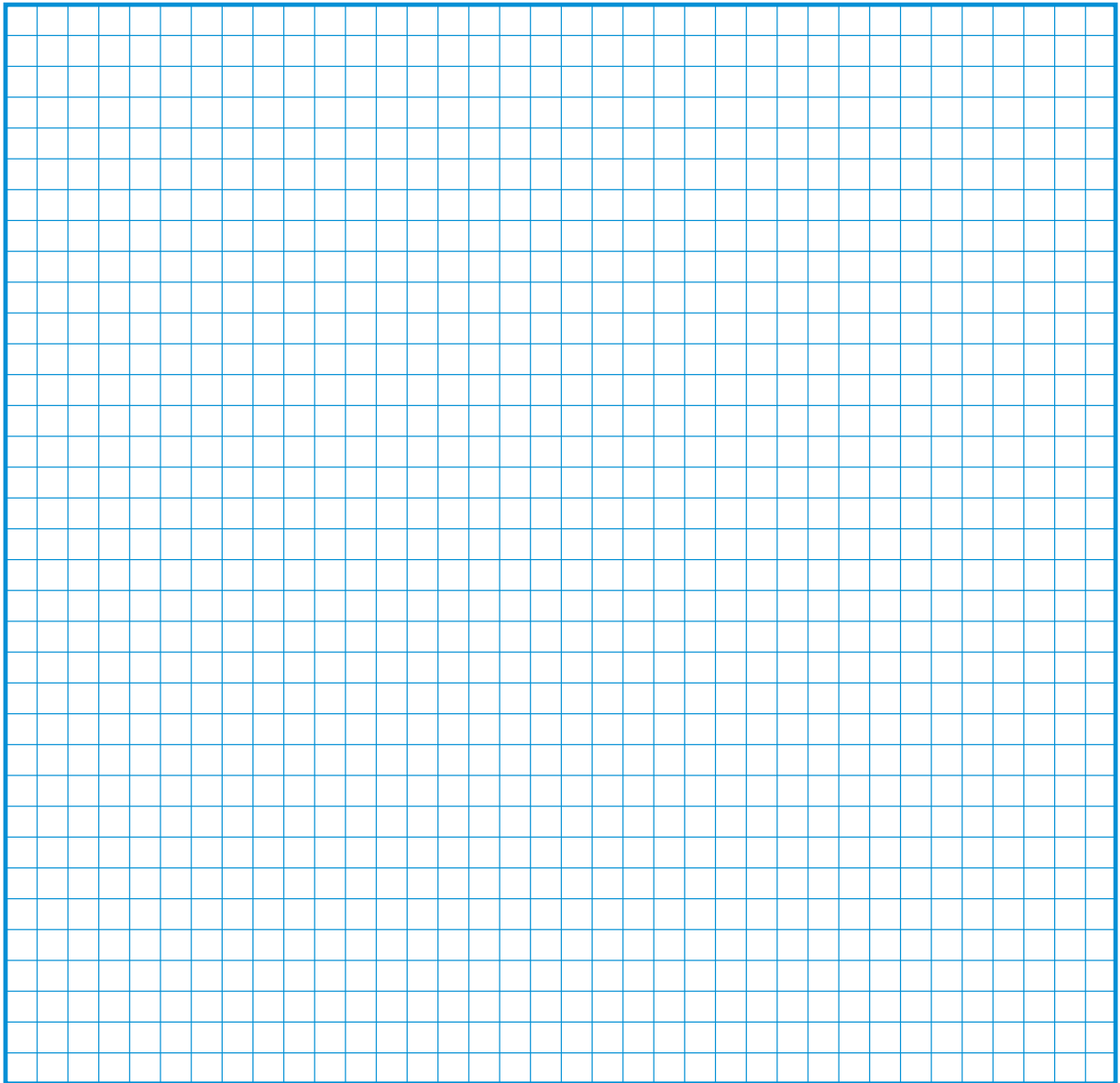


Figure 18: Draw your design on this grid.

### 3.3 Draw gears in three dimensions (3D)

Drawing gears in 3D is mostly about drawing circles in 3D. In this activity, you will draw 3D gears on isometric grid paper.

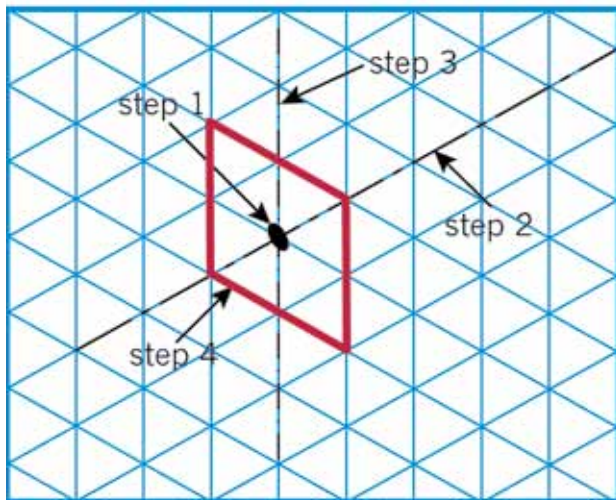
If you follow the instructions step by step, your drawing will be correct.

#### How to draw an isometric circle

Look at the pictures in Figure 19. They show how to draw a circle on isometric grid paper. This circle has a diameter of 2, so it is nearly the size of a small gear wheel. Below is an outline of how it can be done.

- **Step 1:** Make a dot where you want the centre of the circle to be.
- **Step 2:** Draw a horizontal chain line going from left to right up the sloping lines of the grid.
- **Step 3:** Draw a vertical chain line going through your centre point up the page.
- **Step 4:** Draw a guide box that will surround your circle. This box is shown in red on picture A.
- **Step 5:** Mark four dots at the centre points of the square. These dots are shown in red in Figure 19B. These dots mark the outside points of your circle.
- **Step 6:** Now sketch a curve joining these four dots. This shape is not a true circle. Its actual shape is an ellipse slanting at 30°.

A



B

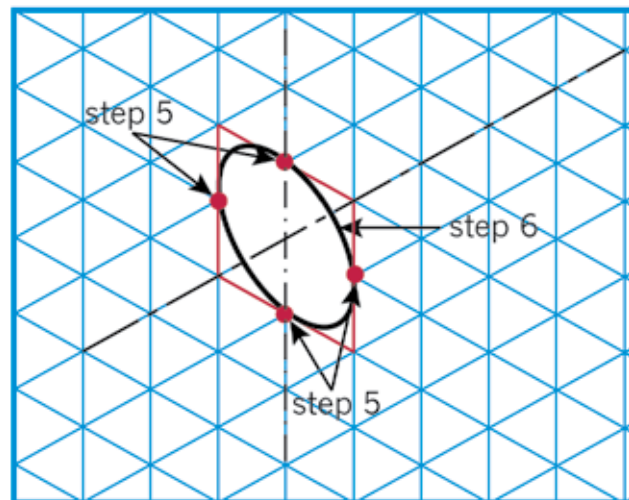


Figure 19 A and B: How to draw an isometric circle

- **Step 7:** Now see if you can draw one for yourself. Copy the diagram in Figure 20 A onto the isometric grid in Figure 20 B.

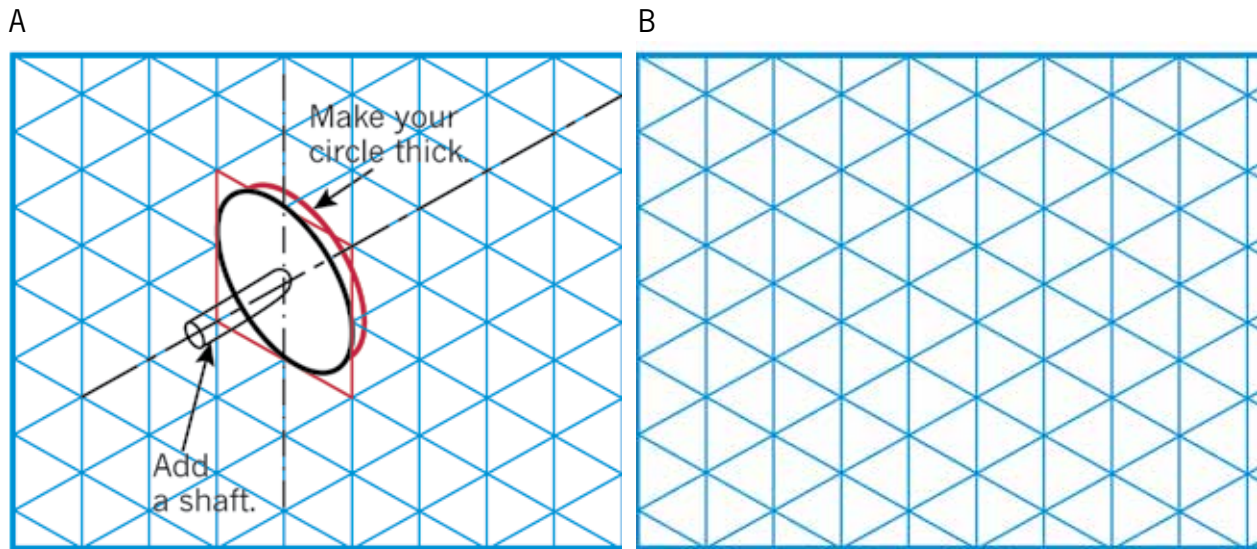


Figure 20 A and B: Draw your own isometric circle on grid B above.

## Draw the gear system that you designed for the winch

Look at the picture in Figure 21. Two gears have been drawn in 3D using isometric grid paper. The teeth of the gear are not shown.

1. Use the grid on the next page to help you draw the system you designed for the winch. Draw the gears to the same size as you specified for the winch in section 3.2.
2. Add a table of information to your drawing that gives all the information necessary for someone to make these gears.

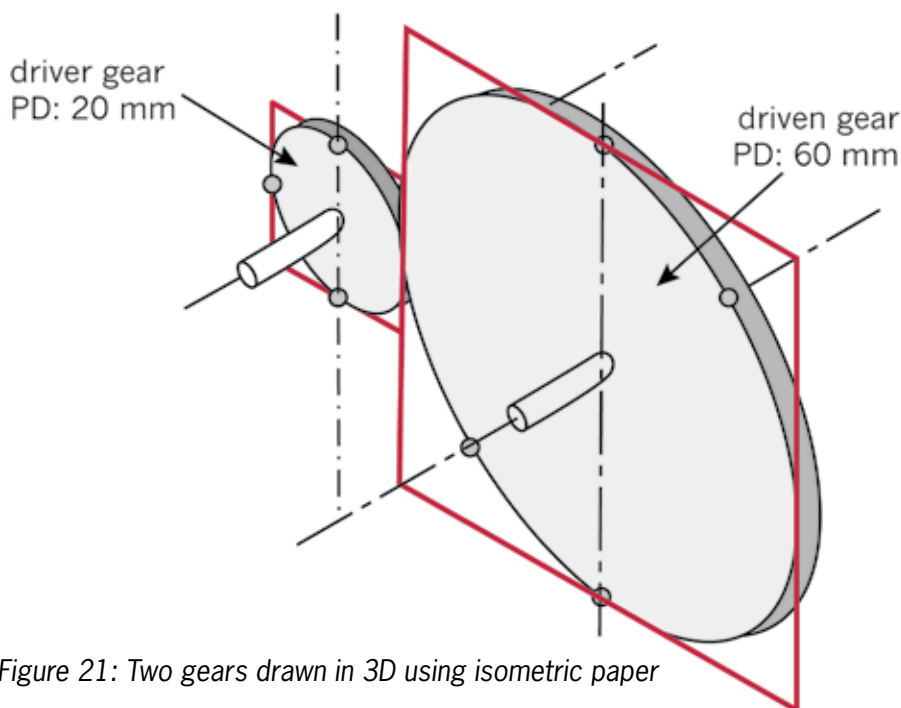


Figure 21: Two gears drawn in 3D using isometric paper

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Draw your gear system for the winch onto the grid in Figure 22:

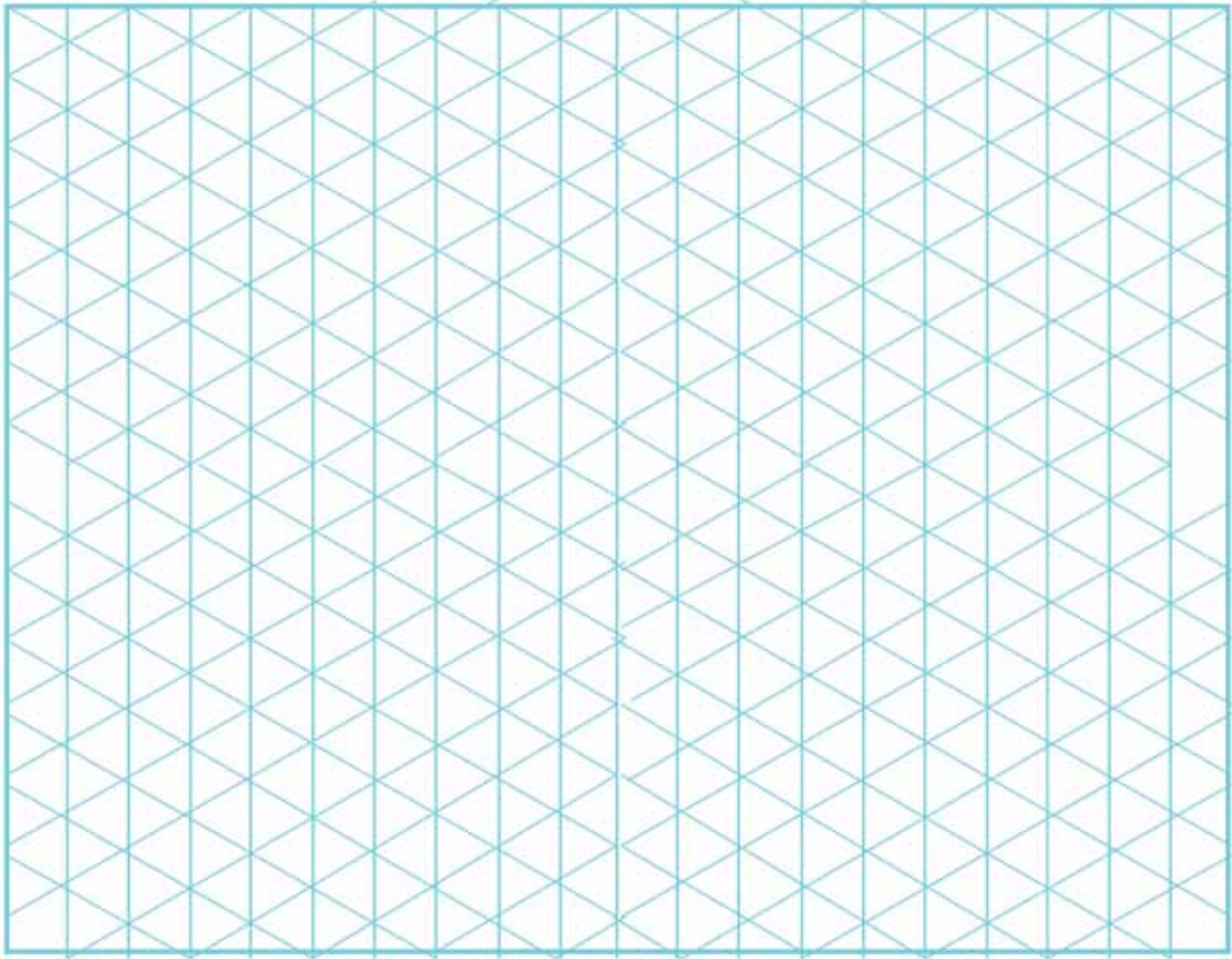


Figure 22: Draw your gear system for the winch in the grid above.

---

## Next week

Next week, you will investigate a type of gear called bevel gears. You will look at the gears on a bicycle and learn about chain and belt drives. Then you will learn how to analyse gear systems using the systems approach.

# CHAPTER 4

## Bevel gears, bicycles and systems diagrams

In this chapter, you will learn how to draw bevel gears. We usually draw bevel gears from the side to show how the driver gear changes the direction of the driven gear. Then you will look at the gears on a bicycle. You will analyse which gears give a speed advantage, and which gears give a mechanical advantage.

Then you will use the systems approach to draw gear systems and show how an input speed is changed by a gear system into a different output speed.

4.1	Sketching bevel gears .....	50
4.2	Chain drives .....	53
4.3	Gear systems diagrams .....	55



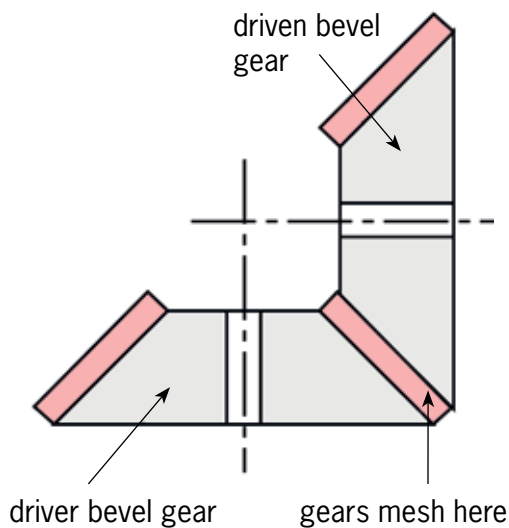
Figure 1: A photograph of the chain drive of a bicycle

## 4.1 Sketching bevel gears

Do you remember learning about bevel gears in Chapter 1? You learnt how bevel gears were used on a hand drill. Bevel gears are used when we want to change the direction of turning.

Look at Figure 2. It shows how you would draw two bevel gears of equal size.

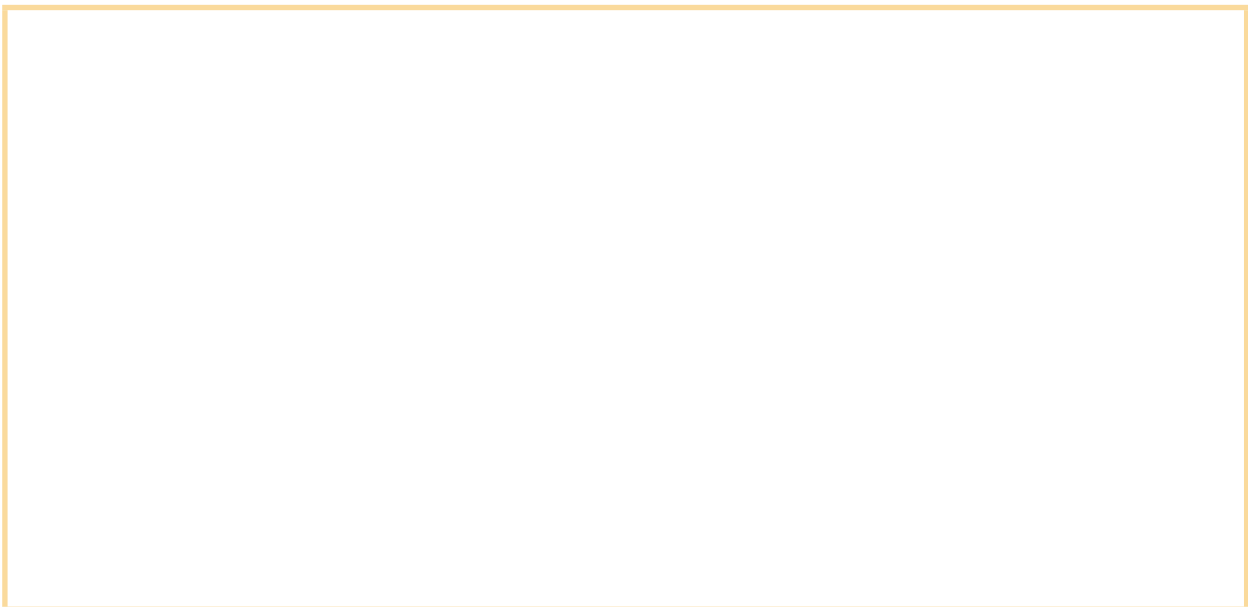
When you turn the driver gear at the bottom, the driven gear rotates at the same speed. But the **direction of rotation** is turned through 90°.



**Direction of rotation** means the direction that a gear rotates or moves in.

Figure 2: How to draw two bevel gears of equal size

1. Make a sketch of the system shown in Figure 2 in the space below.





## Changing the speed of a bevel gear

The driver gear and the driven gear of a bevel gear system do not have to be the same size.

If the driver gear has a pitch diameter of 50 mm and the driven gear has a pitch diameter of 100 mm, the driven gear will turn slower than the driver gear. This system will give you a mechanical advantage.

Study Figure 3 and then answer the following questions:

1. Make a sketch of the system shown in Figure 3 in the space below.

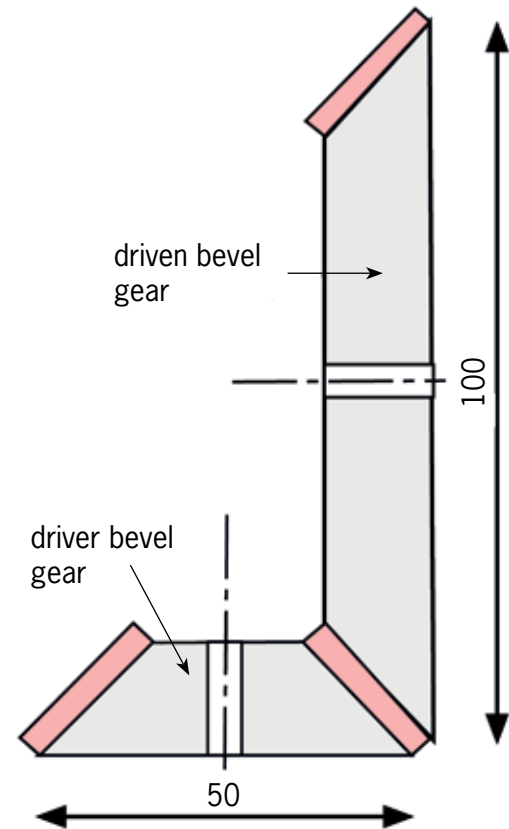
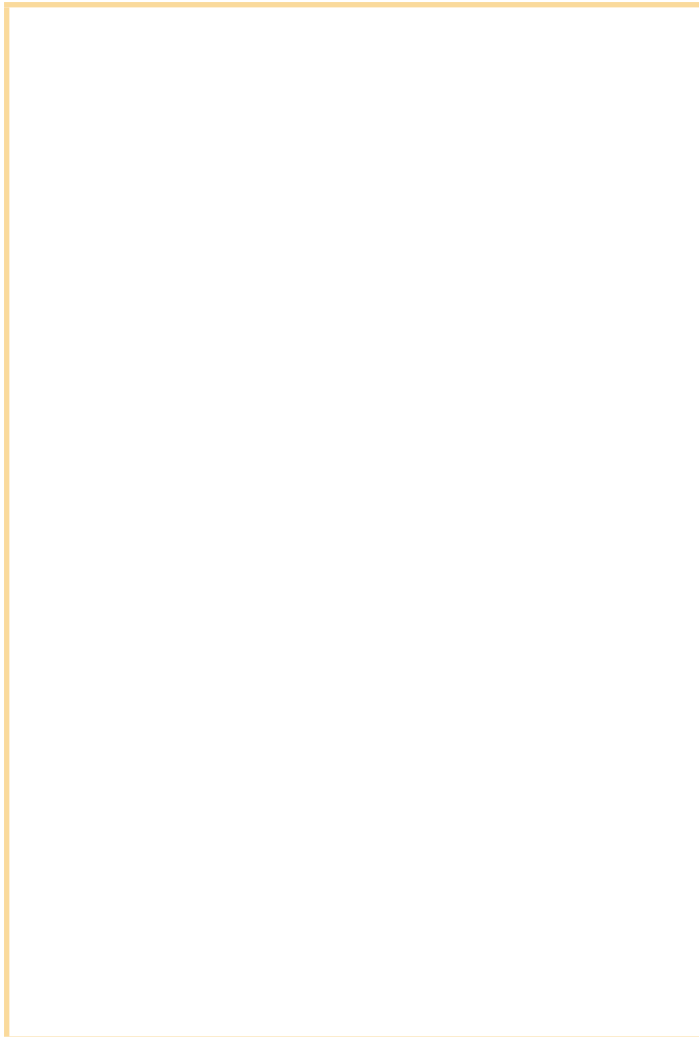


Figure 3

## Sketch a bevel gearbox system

Figure 4 shows a speed-reducing gearbox that gives a mechanical force advantage. This gear system has a straight gear system and a bevel gear system.

1. Make a 2D sketch of this system in the space below. Draw the straight gears as rectangles and the bevel gears like those shown in Figure 4.

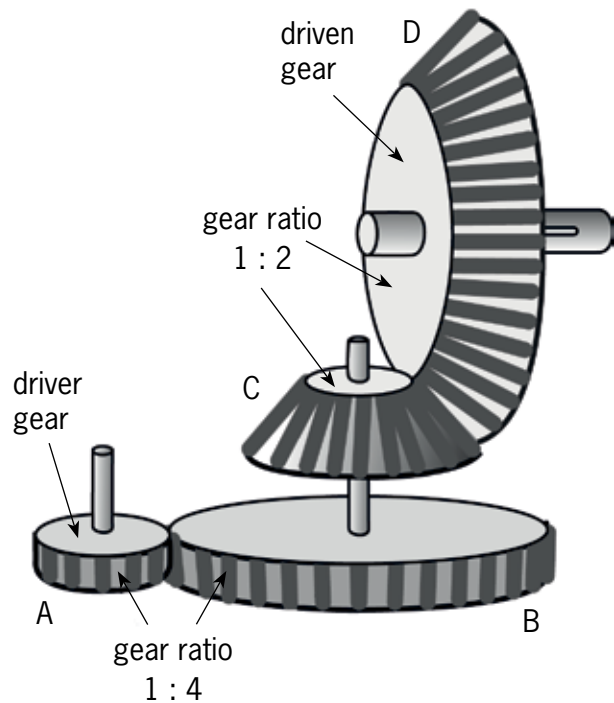
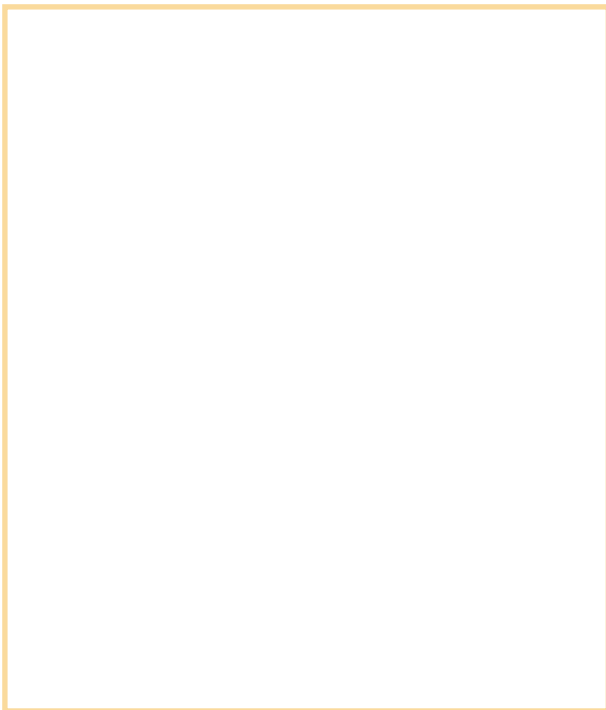


Figure 4: A straight and a bevel gear system

2. What is the mechanical advantage between the driver gear A and gear B?  
 .....
3. What is the mechanical advantage between gear C and the driven gear D?  
 .....
4. Calculate the total mechanical force advantage between the driver gear and the final driven gear.  
 .....

## 4.2 Chain drives

In this activity, you will investigate the gears on a bicycle. You will learn about chain drives and how they are like gear systems that have an idler gear.

Look at Figure 5. It shows the gear system on a modern bicycle.

When you ride a bicycle, you pedal. The pedals push the cranks up and down. The cranks force the chain wheel to turn.

Attached to the chain wheel is the chain. When a cyclist pedals, the chain is pulled around in a clockwise direction.

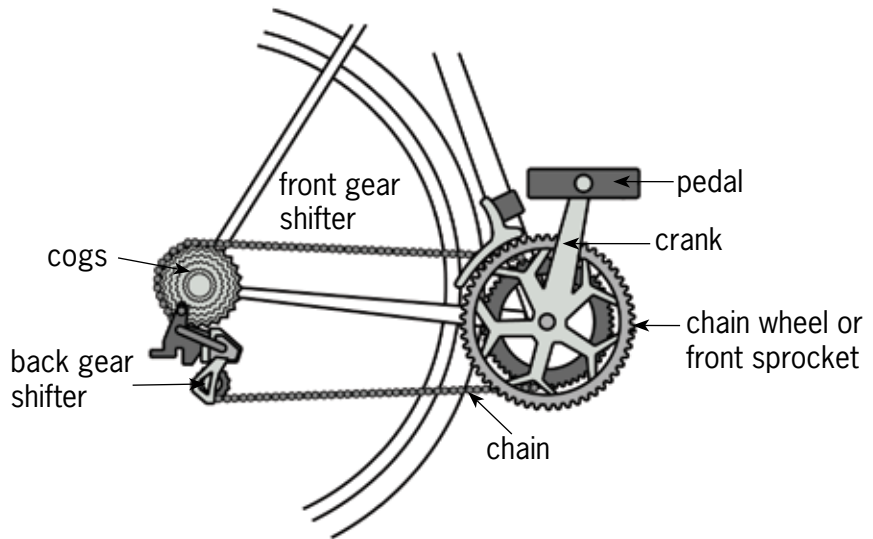


Figure 5: The gear system on a modern bicycle

The chain meshes with the gears on the cogs, which are attached to the back wheel. The gears make the back wheel turn and the bike move forwards.

### Questions

1. What do you call the large gear wheels at the front that are turned by the pedals?

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2. What do you call the group of gears that turn the back wheel?

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3. What connects the front gears to the back gears?

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4. What do you call the mechanism that changes the gears?

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## Investigating the chain drive of a bicycle

Bring a bicycle with gears into your classroom. Turn it upside down so that you can investigate how the gears work. Stick a piece of tape somewhere on the wheel. This will help you to count how far the wheel rotates for each pedal rotation.

Use the front gear shifter to put the chain onto the smallest gear of the chain wheel. Use the back gear shifter to put the chain on the biggest cog at the back.

1. Count the number of teeth on the smallest gear of the chain wheel and write it down.

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2. Use the back-gear shifter to put the chain onto the largest cog on the back wheel. Now count the number of teeth on this gear and write it down.

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3. If you rotate the crank by exactly one revolution, how many revolutions does the wheel make?

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4. Will this gear position give you a speed advantage? Explain why you say so.

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## Advantages of using a chain drive rather than spur gears

- Chain drives can easily and cheaply connect gears that are far away from each other.
- A chain can be adjusted easily if the distance between the axles of the two gears changes.
- With spur gears, the axles need to be aligned precisely, so that the gears mesh well but without too much resistance. With a chain drive, the axles do not have to be aligned precisely because the chain can bend sideways a little.

## 4.3 Gear systems diagrams

Sometimes a diagram of a mechanical system can be very complicated. Systems diagrams are simpler diagrams. A systems diagram does not explain how the system works. Rather, a systems diagram describes the input, process and output of a system. Have a look at Figure 6 below. It is a systems diagram for a bicycle.

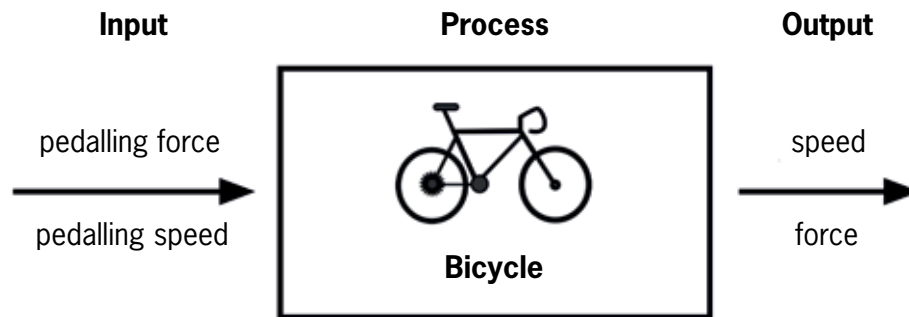


Figure 6: A systems diagram for a bicycle

### Input, process, output

Have another look at Figure 6 and read the information below. It tells you how this systems diagram for a bicycle works.

On the left, there is the input to the bicycle. The input is what you put into a bicycle when you ride it. It is the pedalling force and the pedalling speed.

In the process box in the middle is the bicycle.

The chain drive of the bicycle changes the input pedalling force and pedalling speed into an output.

On the right is the output. This is what you get out of a bicycle, which is speed.

A system diagram shows how a system will change inputs into outputs. The process changes the inputs into outputs.

When you change the pedalling force or the pedalling speed on a bicycle, the output speed will change. The systems diagram will help you to work out how these will change.

## Draw systems diagrams of gears and drives

You can use systems diagrams to represent gear systems instead of drawing them. Look at the systems diagram in Figure 7. It shows a belt drive system for a car's alternator.

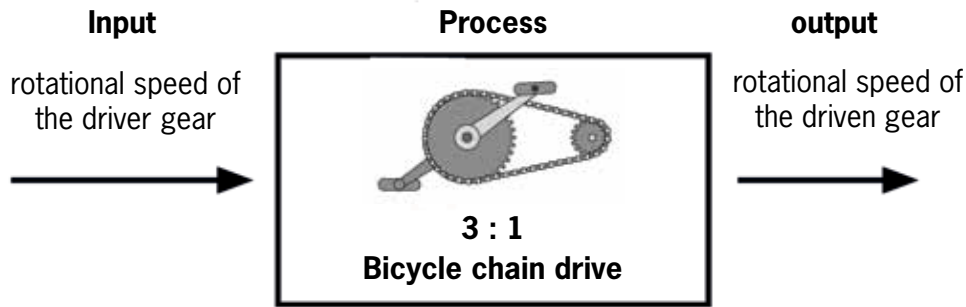


Figure 7: A systems diagram for gears

The system in Figure 7 gives a speed advantage of 3. You can use the diagram to work out what the output speed will be if the input speed should change.

If the input speed from the car's engine on the driver side is 500 rpm, then the alternator speed will be 1 500 rpm.

## A winch for a mine

A winch is used for a lift in a mine. The winch consists of an electrical motor and a winch drum on which cable is wound.

The winch must be able to lift 10 000 kg of mined rock. If the motor is connected directly to the winch drum, without a gear system, the winch can lift a maximum of 2 000 kg.

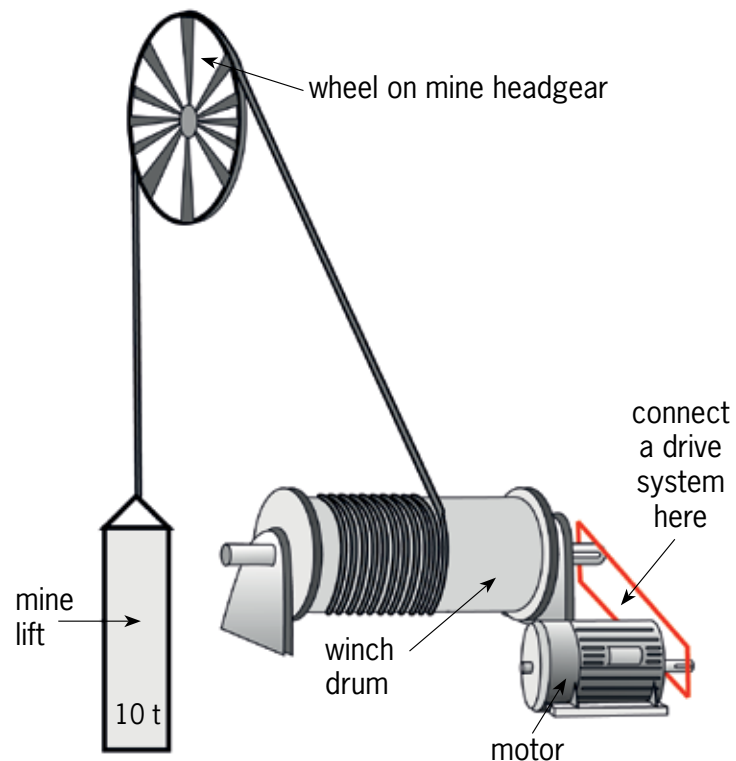


Figure 8: A winch for a mine

1. Calculate the mechanical advantage needed from a gear or chain-drive system to enable the winch to lift the load of mined rock.

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2. Sketch a drive system in the box below to show how the motor will make the winch turn. You do not have to sketch it to scale.

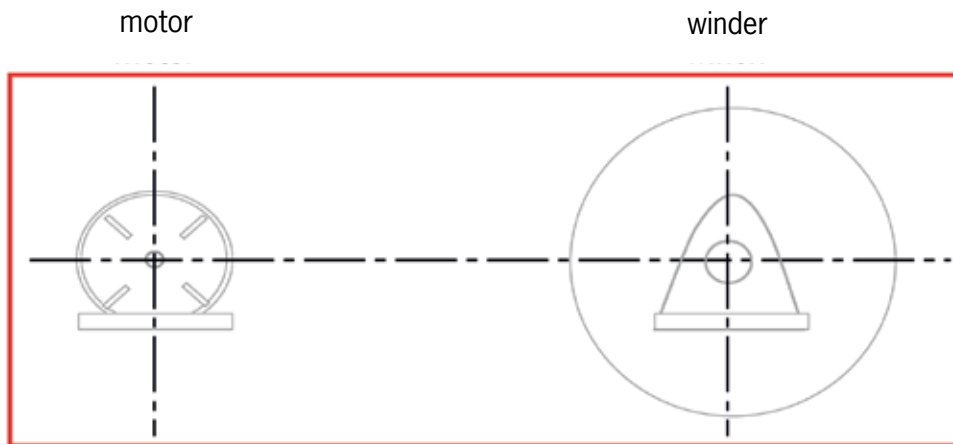


Figure 9

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## Next week

Next week, you will research a topic about the impact of mining on people and the environment, and give a presentation on that topic. Your teacher will divide you into teams today, and give each team a topic. There will not be a lot of time next week to prepare for your presentation, so it is very important that you start your preparation now. Read the article on your team's topic in Chapter 5 during the weekend.



## CHAPTER 5

# Investigate aspects of mining in South Africa

The mining industry is one of the most important contributors to the economy in South Africa. In this chapter, you will learn about the history of mining in South Africa, as well as the impact that mining has on communities, social life and the environment.

Four topics about mining are discussed in this chapter. You will work in teams, and each team will investigate only one of these topics, then give an oral report to the class on your topic. You will work in teams of three or four, and there must be at least one boy and one girl in each team.

5.1	Background information on different mining topics .....	61
5.2	Team discussions and preparation of reports.....	76
5.3	Presentation of reports .....	84



Figure 1: The oldest iron mine in the world – Lion Cave in Swaziland

## Notes to the teacher

Learners will present their research on different topics as *teams* in the last 60 minutes of the week. Ensure that teams are an appropriate size so that there will be at least four minutes for each team to present their research. This means that there cannot be more than 15 teams ( $15 \times 4$  minutes = 60 minutes).

Different teams will present research on different topics. There are four different topics. Assign a topic to each team, rather than letting learners choose for themselves. Letting them choose would mean that learners will take time to make their choices (there is no time to waste time during this week's work), and might result in certain topics being left out or not presented properly.

### 5.1 Background information on different mining topics (30 minutes)

Learners should read and make summarising and comprehension notes on the topic they were assigned. This is individual work. Thirty minutes is not enough time to do this, which is why learners were given homework at the end of the previous chapter to read the articles on their assigned topic. **Important:** *This means that you will have to assign topics to teams at the end of the previous week.*

If you have access to the internet and/or books and/or video material, you should use this to make more information available to learners on the different topics. For example, you may make a list of appropriate websites to consult, or may make photocopies for learners of newspaper articles that have to do with the topics.

### 5.2 Team discussions and preparation of reports (30 minutes)

Learners should work together in their teams to prepare their reports. Comprehension questions are given to guide them through their topics.

For homework, learners also have to read the articles on the other topics. This is crucial as teams will be required to ask questions of other teams after each presentation. Reading the articles on all the topics will ensure that the teams can ask informative questions.

### 5.3 Presentation of reports

Ensure that the teams adhere to the time limit for each presentation. Also allow time for the class to ask questions of each presenting team, which the team should answer.

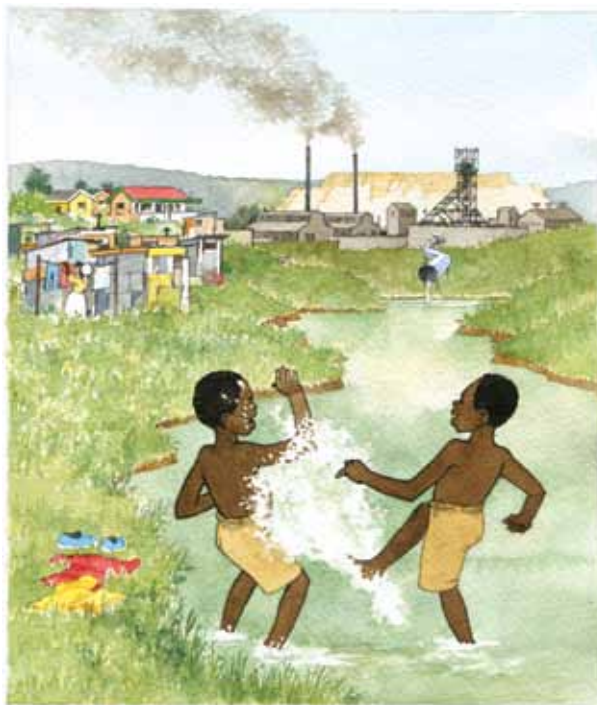


Figure 2

## 5.1 Background information on different mining topics

Your teacher will divide your class into different teams, and tell each team which topic they need to investigate during this week. Each team will only investigate one of the following topics:

- The impact of mining on the environment: Acid mine drainage
- The impact of mining on the environment: Dust pollution
- Indigenous mining in South Africa before the modern era
- The equality or inequality of job opportunities in mining for men and women

In this lesson, you will work individually and read an article about the topic that your team will investigate. After reading the article, you should make notes in the space provided. Write down the points that you think are most important, as well as the points on which you would like to get more information. For homework, you should find out more about these topics, for example by looking in books, asking older people and looking on the internet.

The four different articles are given below. Remember that you should only read the one article that is about the topic your team will investigate.

### Topic A: The impact of mining on the environment: acid mine drainage

Mining is very important to South Africa. The mining industry has led to our country becoming very important as a provider of metals and **ores**. South Africa is one of the biggest producers of precious metals such as gold and platinum, and the country also has large amounts of iron, zinc, chrome and copper ore that are very important to many of our factories. Coal is also mined and this mineral provides the energy for many of our power stations.

Because mining is such a large industry, it also provides employment for large numbers of people, both skilled and unskilled.

An **ore** is a type of rock that contains important minerals, including metals. These ores are mined and then refined to extract the valuable material.

But, like any industry, it is also a cause of problems due to the way the ore is being mined. Before you investigate these problems, you need to understand a little about the mines themselves. Some mines are known as opencast or surface mines. These are mines where the workers do not have to go underground, but instead dig a very large hole to remove the ore after stripping off the surface material. These mines are easier to work on. Coal mines and iron-ore mines are often opencast mines, as coal and iron ore are closer to the surface than precious metal ores, such as gold.



Figure 3: An opencast or surface mine. Note the water collecting in the hole.

Underground mines are mines where shafts and tunnels have to be dug to reach the supply of ore that is being mined. All of South Africa's gold mines are underground mines, with shafts that are sometimes kilometres deep. The deepest mine in the world is the TauTona mine in Carletonville, South Africa: it is nearly four kilometres deep! Mining is dangerous work, and there are very strict safety precautions on all mines.



Figure 4: The headgear of an underground mine. The shaft goes straight down into the ground under the wheels of the headgear, sometimes kilometres deep.

One of the problems with mining is that eventually the ore, or metal, will run out. When this happens to a very big mine, what is left are many kilometres of underground tunnels. It is impossible to fill these tunnels because the ore that was mined has been processed to remove the valuable mineral. What happens normally is that the mine entrance is sealed and the tunnels are left as they were during mining. But they don't stay empty.

If you have ever dug a hole in the ground near a river, or on a beach, you will know that water soon starts gathering at the bottom. This happens when you have dug beyond the **water table**.

All mines that are underground will be dug beyond the water table. While miners are working underground, large pumps are constantly pumping the water that gathers in the tunnels out of the mine. But once the mine is abandoned, the pumps are removed and the water starts to build up, exactly as it would in the hole you dug.

It would be fine if this water just filled the mine, but a **chemical reaction** occurs as the water drains through the rocks into the mine. The water reacts with chemicals in the ground that contained the ore, and turns into an acid. Acids can be very destructive in the wrong environment.

You come across mild acids every day. Try this experiment:

At home, pour yourself a glass of water, and then add one teaspoon of vinegar and stir. Take a sip. It is healthy, but for most people it tastes too strong, as if it is burning your mouth and throat.

Now pour yourself another glass of water. This time, add three teaspoons of vinegar to it and stir. Now drink a little bit from this glass as well. Could you taste the difference? Scientists would say that the first glass of water was slightly acidic, and that the second glass of water was more acidic.

The **water table** is the level in the ground where enough water is present to flow.



Figure 5: Holes dug in the ground often go below the water table, and then the hole fills with water.

A **chemical reaction** takes place when materials react with other chemicals and a change occurs to the molecules of the materials, forming new substances.

The acid that is produced in mines is a lot stronger than your vinegar water! The water has mixed with sulphides and can eat away solid metals and stone. It is very poisonous to plants and animals.

Acidic liquids are very corrosive. They can destroy solid materials.

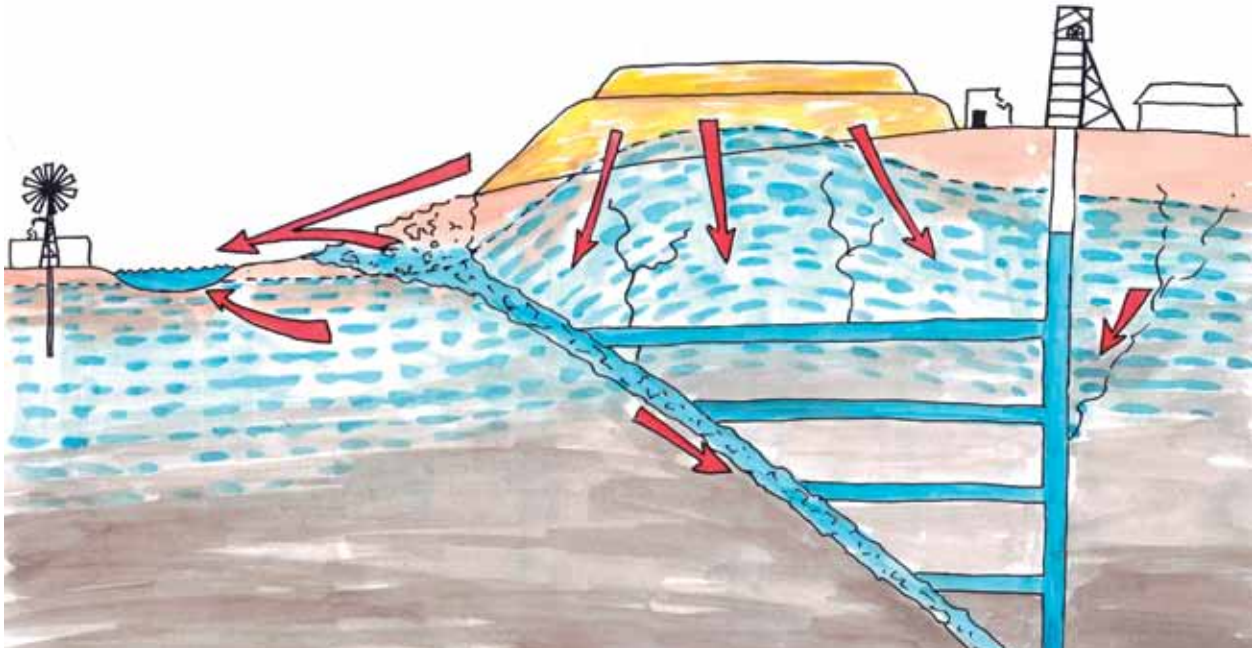
It would be less harmful if the acid water stayed in the mine, but due to many reasons the acidic liquid often leaks out. In some cases, the water level in the mine rises to the level of the surrounding water table, and then the acid pollutes all the water in that area. In other cases, the surface of the mine is higher than surrounding areas. Remember that most of the gold mines in Johannesburg were on a ridge. The acidic liquid will flow out of gaps in the rock like an ordinary spring, and pollute the rivers and streams it enters, killing fish, animals and plants.



Figure 6: Acid mine drainage is ugly, poisonous and smells bad.

When large mines, such as the gold mines in Gauteng, are closed, acid leaking from the mines can cause a lot of problems to the surrounding environment. These problems have to be solved before communities have to be removed to escape the effects.

The gold mines in Gauteng are located on the Witwatersrand, or the “White Water Ridge”. Rivers flow away from each side of this ridge, and are easily polluted.



*Figure 7: This illustration shows how water in the water table can fill up mines when they aren't being pumped dry.*

**Notes: Acid mine drainage**

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## **Topic B: The impact of mining on the environment: dust pollution**

Anyone who has been to Johannesburg will know the mountains of yellow and white sand that comes from the mines. These are called mine dumps. What are these dumps actually made of, and why do they exist?

Ore has to be crushed and then treated with chemicals before the metal in it can be dissolved. After this the chemical that contains the dissolved metal is separated from the waste material, then more chemicals are added and the metal is recovered. The metal is then melted and poured into large ingots, or bricks, of metal that can be transported to the factories that will use them.

But what remains? All the crushed ore and chemicals that have been used to extract the metal become waste material that has to be stored. It can't be put back into the mine since people are still working there, so it is either put into large dams, or piled in dumps. The waste material is normally a mixture of water, dissolved chemicals, and finely ground dust or small particles. This is called "slurry". The slurry has to dry in the open air. A ton of gold ore only produces a gram or two of gold, so a lot of slurry is left after extracting the gold.

Many of the chemicals added to extract gold are still in the slurry, and some of them are very poisonous, such as cyanide.

The compounds in the slurry are ground to fine sand. Once the water dries, it leaves a layer of tiny particles that can easily be blown around.

When gold mines in Johannesburg first started producing waste material, the slurry was pumped into storage dams. After a while, as the slurry dried and more waste material was produced, the dams grew upwards into dumps. The centre of these dumps was lower than the outside, so that more slurry could be pumped into the middle. The slurry was then pushed out towards the edges as it dried, leaving more space in the middle. These dumps grew into the huge mine dumps that line the mining areas of Johannesburg.

It is not just gold that produces mine dumps. However, since the old gold mine dumps in Johannesburg are so close to communities living there, it is a very noticeable problem. Other mining towns and cities have similar problems. When new mines start, people working at the mines often build houses nearby, and often a whole town develops around a mine.





Figure 8: Dust blowing off mine dumps can affect people and the environment.

In the early days of mining, the impact of mine dumps on the environment was not known. Once people became aware of the negative effects of the dust that comes off these mine dumps, they started looking for a solution to this problem. First, trees and grass were planted on the mine dumps to prevent the wind from blowing the dry dust into the towns.



Figure 9: A mine dump planted with trees and grass to reduce dust pollution.

But because of the toxic chemicals in the dumps, the trees and grass did not grow very well. Later, mining companies started to extract any remaining gold from the waste material in these mine dumps. Since the process used to extract gold a hundred years ago was not very effective, a lot of gold remained in the waste material. Once they processed these mine dumps to extract any remaining gold, they removed the dumps altogether. The remaining waste material was then stored where it could not be blown into nearby towns or cities.

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**Notes: Dust pollution from mine dumps**

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**Topic C: Indigenous mining in South Africa before the modern era**

The history of South Africa is closely linked to mining. Gold and diamond mining has generated much wealth for the country over the last 150 years. The mines in South Africa today produce gold, diamonds, silver, platinum, chromium and many other minerals. In 2010, South Africa produced 15% of the world’s gold, and 78% of the world’s platinum supply.

But of equal importance to our history was the ability to make iron tools and implements. This period is known as the Iron Age. The ability to **smelt** ore and make iron tools was discovered in North Africa. Some of these communities moved southwards to find better rainfall and more productive land to provide crops.

**Smelting** is the process where ore is melted in a very hot oven called a “furnace”, to separate the iron from the rest of the ore.

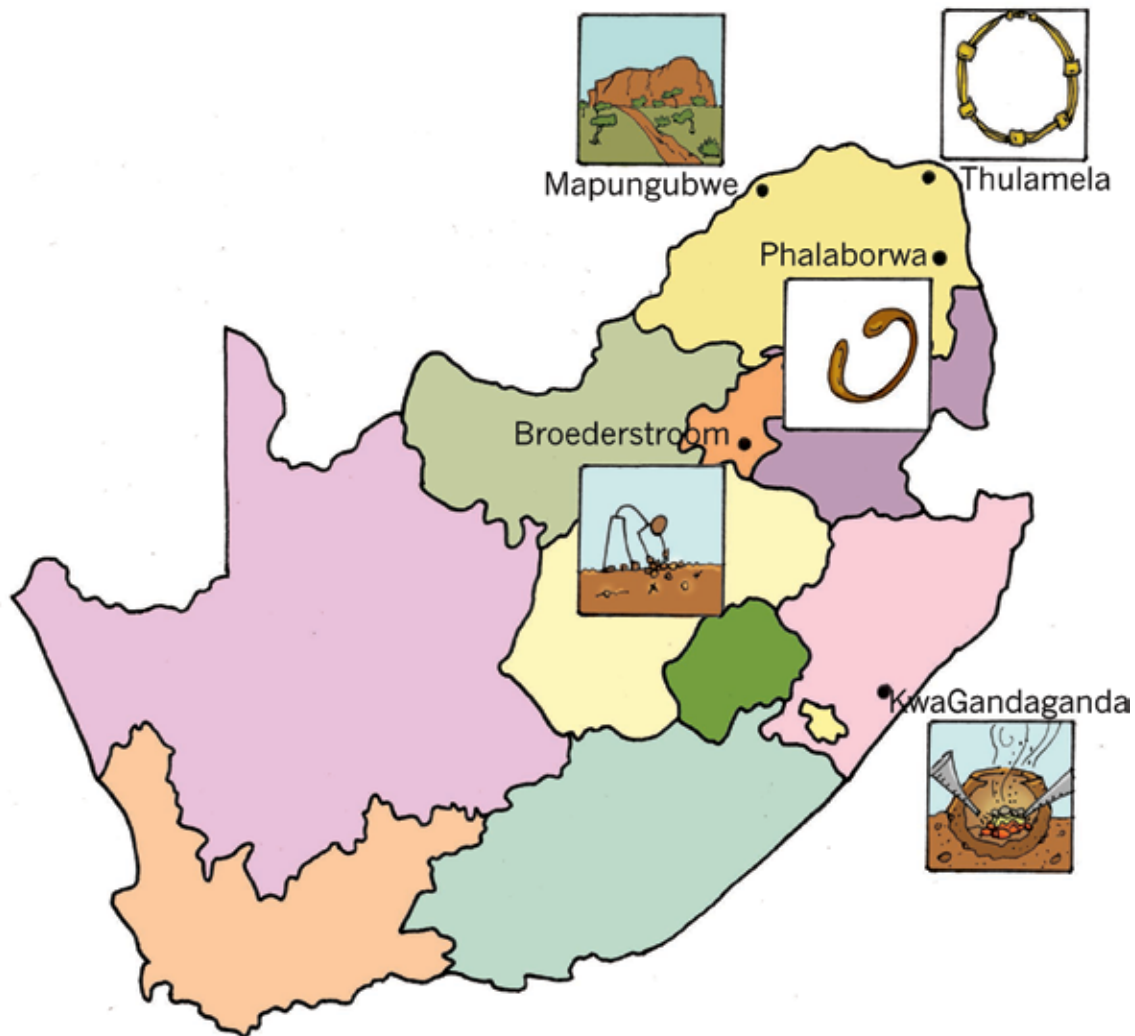


Figure 10: Locations of a few mining sites in South Africa during the Iron Age.

About 1800 years ago, the areas where people coming from the north would settle in was influenced by the discovery of iron-ore deposits. Even **nomads** would settle near a source of iron ore and plant crops such as ground beans, sorghum and millet.

**Nomads** are people who have no fixed homes, and move from place to place in search of water and food.

This would lead to an increase in cattle and other stock animals, and often the community would grow and prosper in that area. They would stop their nomadic lifestyle and stay in one place to build a community. However, sometimes they would have to move to a different area due to drought or poor soil. Other groups were not as fortunate to find deposits of iron ore, and so continued moving south as well. With these groups of people continually moving south, the knowledge of how to smelt iron came to the country that is now known as South Africa. Historians and geologists have found many places in our country where Iron Age settlers lived and built their smelting ovens. Studying these places has helped us to learn more about the history of these people.

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The Iron Age people also knew how to make pottery by baking clay. The styles of pots and artwork found at these Iron Age sites have helped historians to determine the general date when these sites were occupied. The Iron Age people built huts and cattle kraals as well, and these ruins have been studied in places right across the country, from Mpumalanga to the Kei River.



*Figure 11: Typical Iron Age tools: simple but efficient*

Initially, iron-ore deposits were discovered by the Iron Age settlers as the deposits were exposed by soil erosion. Soon the settlers learnt how to find sources of iron ore by studying the different types of rock in the area and comparing it to other sites where they had found iron ore. About 1300 years ago, holes and shafts were being dug to produce the ore. A lot of trees were required near the iron-ore deposits, as the smelting process required a lot of charcoal to provide enough heat. A supply of fresh water was also important.

The process of smelting ore was regarded as a secret to be kept by the older men of the community. They would build a clay oven that had a small hole at the top as a chimney, and three or four other holes on the side where air could be blown in. To smelt the ore, it would be put into the oven in layers of ore and charcoal, then the charcoal would be set alight and a lid would be placed over the burning fire.



Figure 12: Illustration of how an early iron smelter was constructed and used

The men used “bellows” made of soft goat’s or sheep’s skin to continually blow air into the oven to create the high temperature needed to smelt the ore. This could take many hours, often a whole day or night. When the charcoal was finally burnt out, the oven would be opened and a lump of iron removed.

This lump would be heated over another fire and hammered into the shape of the tool or implement required. It was a difficult process, but it changed the way the people lived at that time, and so it is one of the most important eras in our history.

**Notes: Iron Age technology**

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## **Topic D: The equality or inequality of job opportunities in mining for women and men**

Discrimination against women has been an ongoing struggle across the globe for centuries. Women were, and in some countries are still, mostly seen as second-class citizens under the control of their fathers, husbands or other male members of their family. Women were expected to stay at home, clean and cook for the family, and raise the children, often without any help from men. Very few women received a proper education or were allowed to work for money. Those who did work, mostly did only part-time jobs and for little money. They often got married and/or had children at a young age, before they could study to qualify for higher-paying jobs.

There were many women who fought hard for the rights of all women, including the right for women to vote in elections. In many countries, women were first allowed to vote only about 80 to 100 years ago, because many men thought women were not clever enough to vote. Many of the protesting women were put in jail and even mistreated for their actions.

For us to understand gender bias, we have to understand that it develops from a very young age. Girls are often taught that they cannot do what boys can, but is this the truth? For instance, boys play with toy cars and girls play with dolls. This often leads to the mistaken ideas people have about adult men and women. Many people still think that women are more emotional than men, have to be pretty, have to be willing to have children and have to care for their families. And many people still think that only men can be physically strong, that only men are clever and hard-working enough to do jobs with a lot of responsibility, that a real man does not show his emotions and that a husband has to only contribute financially to his family.

But what is gender bias in work situations? It is when one gender is perceived to be superior to another, and this gender is given more or better employment opportunities as a result. During the twentieth century, a lot of research was done on the physical and mental abilities of men and women, and it was proven that men and women are equally capable of doing most jobs. There have been changes in laws that prohibit discrimination on the basis of gender, and as a result the number of women in the workplace has increased rapidly.



Figure 13: Men and women share duties above ground in modern mines.

So, when you think of people working in mines deep underground, what picture comes to mind? You probably see a man, physically strong and holding a drill in a dark hot tunnel. Why do you not see a woman holding a big drill, deep in a hot dark tunnel?

Until the early 1990s, women in South Africa were prohibited from working in underground mines. As we said earlier, since 1994 there have been numerous changes to the laws in South Africa to reduce and remove gender and racial inequalities within different industries. The mining sector was one of them, but statistics show that gender equality is not happening as quickly as it should be. Even today, only 5% of mineworkers in South Africa are women, and the majority of these work in offices as clerks or administration officials. Very few women work directly with the physical extraction of minerals. There are, however, a lot of women involved in informal mining, such as extracting coal, clay, copper and other minerals for the sake of their own and their families' survival. This proves that women are physically capable of doing the job, even though they are not employed as physical workers.

These days anyone who wants to work underground can do so, but they have to pass a fitness test first. This test is not only for strength, but for stamina as well. Stamina refers to the ability to do physical work for a specific period of time without harming your body. In addition, the miners have to pass a **heat-tolerance test** and it has been discovered that women can handle high temperatures better than men!

A **heat-tolerance test** is used to make sure that people can handle long periods working in high temperatures. The temperature in an underground mine is much hotter than at the surface.

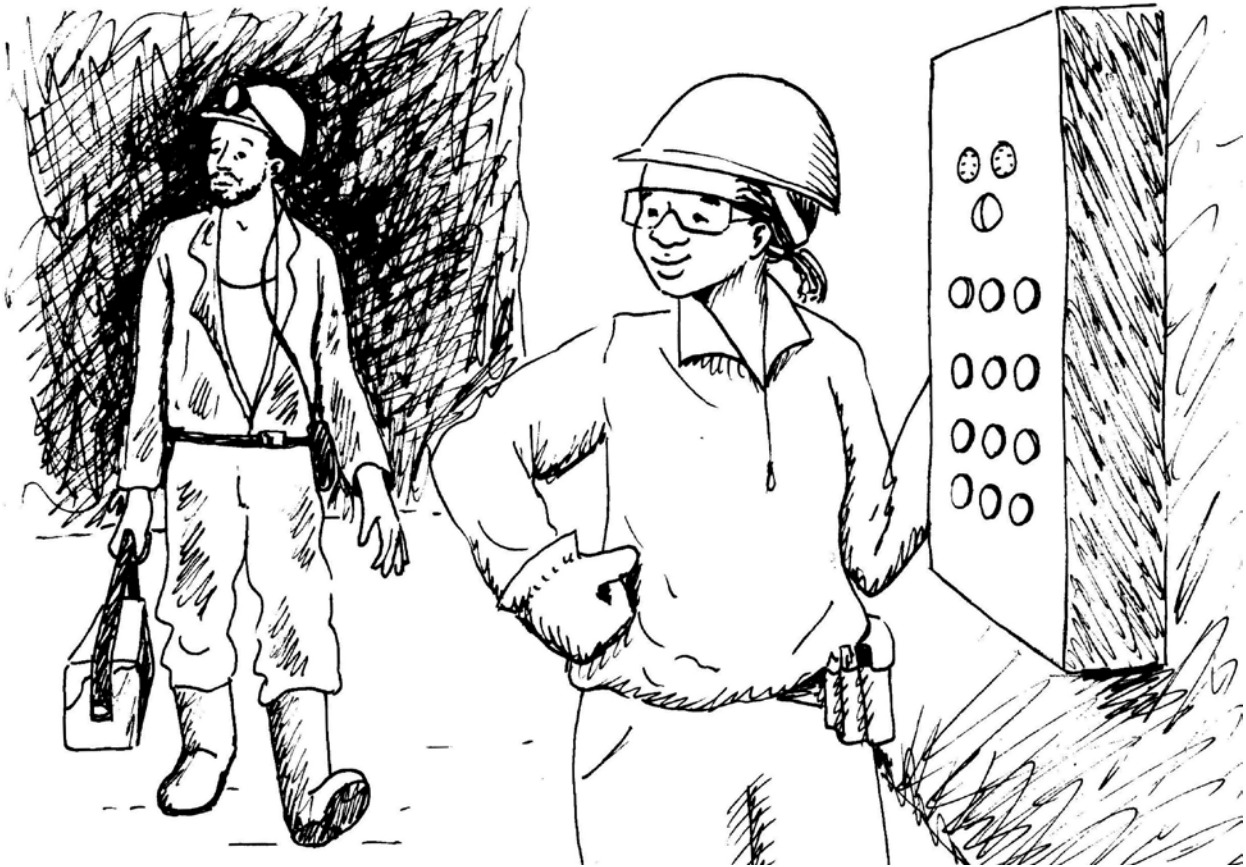


Figure 14: Women and men can share underground work in mines.

So it doesn't matter if you are a man or a woman, if you pass the test you can work underground, mining ore.

Another area where a bias has been noted is in the payment for work done. Although women are doing the same job as men, they are being paid less than their male counterparts. This practice is called wage discrimination, and there are also laws against this type of unfairness. However, because some women are desperate for work, they have no choice but to accept lower wages.



Apart from wage discrimination, there are many reasons why women are still not working in the formal mining sector to the same extent as men. For example:

- low levels of training amongst women, specifically a lack of technical training,
- unsupportive work cultures in the mining sector, despite changes in law,
- a lack of mentorship and facilities,
- the physical nature of mining, and
- historical bias against women in the mining industry.

For women to gain better access to careers in the mining industry, the perceptions that men and women have about this situation needs to change. Women have already proved that they are capable of doing the same work as their male counterparts, and therefore they should not only be allowed to do so, but they should also be rewarded and promoted by the same standards.

**Notes: Gender bias in mining**

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## 5.2 Team discussions and preparation of reports

After reading through each of the articles in the previous lesson, you were asked to make notes on what you understood to be the main problems or opportunities presented by the topic. You were also asked to find out more about each topic.

You will now work in your teams to prepare a report on the topic allocated to you. This report needs to consider the history and background of the topic. The reports must be informative and, when necessary, need to be investigative. For some of the topics, the team might have suggestions as to how problems can be solved or lessened. These suggestions will form an important part of the report.

Each team will give a short presentation to the class next week. You have this whole lesson to prepare. Each of you has to do a part of the presentation.

To help you prepare your report, some additional questions are given below about the four different topics. Discuss the questions about your team's topic now.

### **Topic A: The impact of mining on the environment: acid mine drainage**

You are not required to give solutions to acid drainage: these are very complicated and expensive processes! The purpose of this exercise is to understand how acid leaking from old mines can cause problems, and how communities can take precautions to not be affected by it.

1. What is acid mine drainage?

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2. Why do you think it wasn't seen as a problem when the mines were started?

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3. What effect can acid mine drainage have on communities, water supplies, houses and other buildings, and on the environment?

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4. How can communities affected by acid mine drainage be assisted?

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5. Who should be investigating the problem, and who should be assisting with the solutions?

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6. What should the mining industry be doing to fix existing problems and prevent future problems?

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## Topic B: The impact of mining on the environment: dust pollution

1. Give a short history of why there are so many mine dumps in South Africa.

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2. Why do towns develop around mines?

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.....  
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3. How does dust blowing from mine dumps have a negative impact on people and the environment?

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4. Why is dust from mine dumps more dangerous than dust from fields?

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5. How can dust blowing from mine dumps be prevented?

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6. Why is the problem in Johannesburg reducing? Give a few reasons, and then make suggestions as to how you think other communities can learn from Johannesburg's experience.

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7. What other ideas does your team have to reduce the problem around the country?

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8. When new mines are dug in future, what plans should be made by the engineers to avoid problems with the mine dumps they produce?

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## Topic C: Indigenous mining in South Africa before the modern era

1. Why is the history of early mining important to understand and study?

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2. Why did groups of people from North Africa move southwards?

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3. How important was mining as a skill to the migrating people?

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4. What resources would the migrating people look for? Why were these resources important?

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5. How do we know so much about the Iron Age settlers? What would you look for if you were searching for signs that they had lived at a specific place?

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6. How has mining affected the growth of South Africa?

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7. What does the future of mining look like?

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## Topic D: The equality or inequality of job opportunities in mining for women and men

1. What is gender bias?

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2. Has it affected the growth of industry and commerce (business) in South Africa, and if so, how?

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.....  
.....

3. What has been done to change and get rid of gender bias in the mines of South Africa?

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.....

4. Does your team think that the changes have been successful?

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.....  
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5. What else can be done to reduce gender bias in mining and other areas in the workplace?

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**Homework: Prepare to ask and answer questions**

Read through all four of the articles given in lesson 5.1, so that you know the background about the other three topics that other teams will talk about. You will ask the other teams questions after they have given their presentations. Make a few notes below to help you:

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## 5.3 Presentation of reports

During the previous lesson, each team spent the lesson preparing an oral report on one of the mining topics. You were all asked to read the articles on the other three topics to enable you to ask questions on the other teams' topics.

Get together in your team first and spend five minutes revising your presentation. You will only have two minutes to do your presentation. You can use visual aids such as a poster to show the class what you mean.

Your teacher will then ask the teams in turn to make their presentations. Remember to ask the other teams questions after they have presented their topics. The idea is not to make them look bad, but to learn from them by asking those questions.



Figure 15: A team giving a presentation to their class, using illustrations and a blackboard to help the speaker.

**Homework: Reflect on the weeks' work**

1. What was your topic about?

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2. Compare advantages and disadvantages of the mining industry to South African society.

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3. What can be done to improve people's understanding of mining?

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4. What can be done to make mining more beneficial to society?

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### Next week

Next week, you will start your Mini-PAT for this term. You will design and build a model of a lifting system for a mine. You will also prepare a tender for building the lifting system.

# CHAPTER 6: MINI-PAT

## A mine needs a lifting system

This mini-PAT will run over four weeks. For this mini-PAT, you should form teams. Each team will pretend to be a mechanical engineering company. Each company will submit a tender for the design and construction of a “mine-lifting system”, commonly called “mine shaft headgear”.

The lifting system is used to take miners underground and back up again. It is also used to lift the mined ore to the surface. After you have designed your lifting system, you will have to make a model of it. The model will have a mine winch, shaft headgear and a lift cage.

<b>Week 1</b> .....	<b>89</b>
Investigate: Mine shaft headgear and head frames.....	[7]
Investigate: Mine winches.....	[5]
Design: Design brief, specifications and constraints for a mine shaft headgear .....	[8]
<b>Week 2</b> .....	<b>98</b>
Evaluate: Choose and combine the best ideas .....	[6]
Make: Sketch your team’s final design .....	[5]
Make: Draw your head frame design.....	[4]
Make: Draw your head frame design to scale .....	[5]
Make: Draw your head frame design as a 3D isometric projection.....	[6]
<b>Week 3</b> .....	<b>106</b>
Make: List of materials and budget.....	[5]
Make: A model head frame .....	[13]
<b>Week 4</b> .....	<b>113</b>
Make: Complete your model .....	[2]
Communicate: Present your tender .....	[3]
Evaluate different tenders .....	[1]

[Total marks: 70]



*Figure 1: This is the tower above an old mine shaft. A cable winds around “sheave” wheels on the “headgear” at the top. These cables are attached to a lift that transports miners, machines and ore into and out of the mine.*



*Figure 2: This photograph shows detail of sheave wheels used for pulling in a cable. The sheave wheels in the photograph are used for a cable car, but they are similar to the sheave wheels used on a mine’s winch system.*

## Week 1

### An opportunity to tender for a mining contract

Platinum, a very valuable metal, has been found on land belonging to a tribe in a rural area. Samples show that the platinum is only 500 m below the surface. An international and South African joint venture company, called Platinum Stars, has decided to invest money in this project. They want to sink a shaft to the 500 m point to take a few samples. Then they will decide on the best mining method.

Your engineering company wants to submit a **tender** for the construction of the shaft headgear. The headgear must be able to transport miners and equipment 500 m underground. It must also be able to lift platinum ore that weighs 10 tons back up to the surface.

A **tender** is an offer by someone to do work at a certain price. When a company “puts out a tender”, it invites people to apply to do a job for them.

### Headgears and mine winches

#### An overview of a mine shaft

Study Figure 3 on the following page. This picture shows a mine’s lifting system. The whole lifting system is called the **headgear**. There are four main parts to a mine’s headgear:

**Part 1: The winch or hoist** is in a winding house. This part of the system is used to wind or unwind the steel cable.

The hoist is attached to a motor and a control system.

The mine cage and the skips are lowered into the mine when a steel cable unwinds from the winch.

The mine cage and skips are raised when the steel cable winds up again.

**Part 2: The sheave wheel** is a pulley wheel that sits above the mine shaft. The hoist cable passes over the sheave wheel and then down the shaft of the mine.

The sheave wheel reduces the sliding friction of the mine cable.

**Part 3: The head frame** is the structure that supports the sheave wheel. It must be strong enough to keep the sheave wheel in place when it lifts the heavy mine cage.

The left “legs” of the head frame slope towards the hoist. This is due to the tension in the cable pulling the whole frame in that direction. The sloping legs prevent the head frame from toppling or falling over.

**Part 4: The cage and skips.** The cage is used to transport miners and equipment up and down the mine. Attached alongside or underneath the cage are skips.

Skips are used to bring the ore and the waste rock out of the mine.

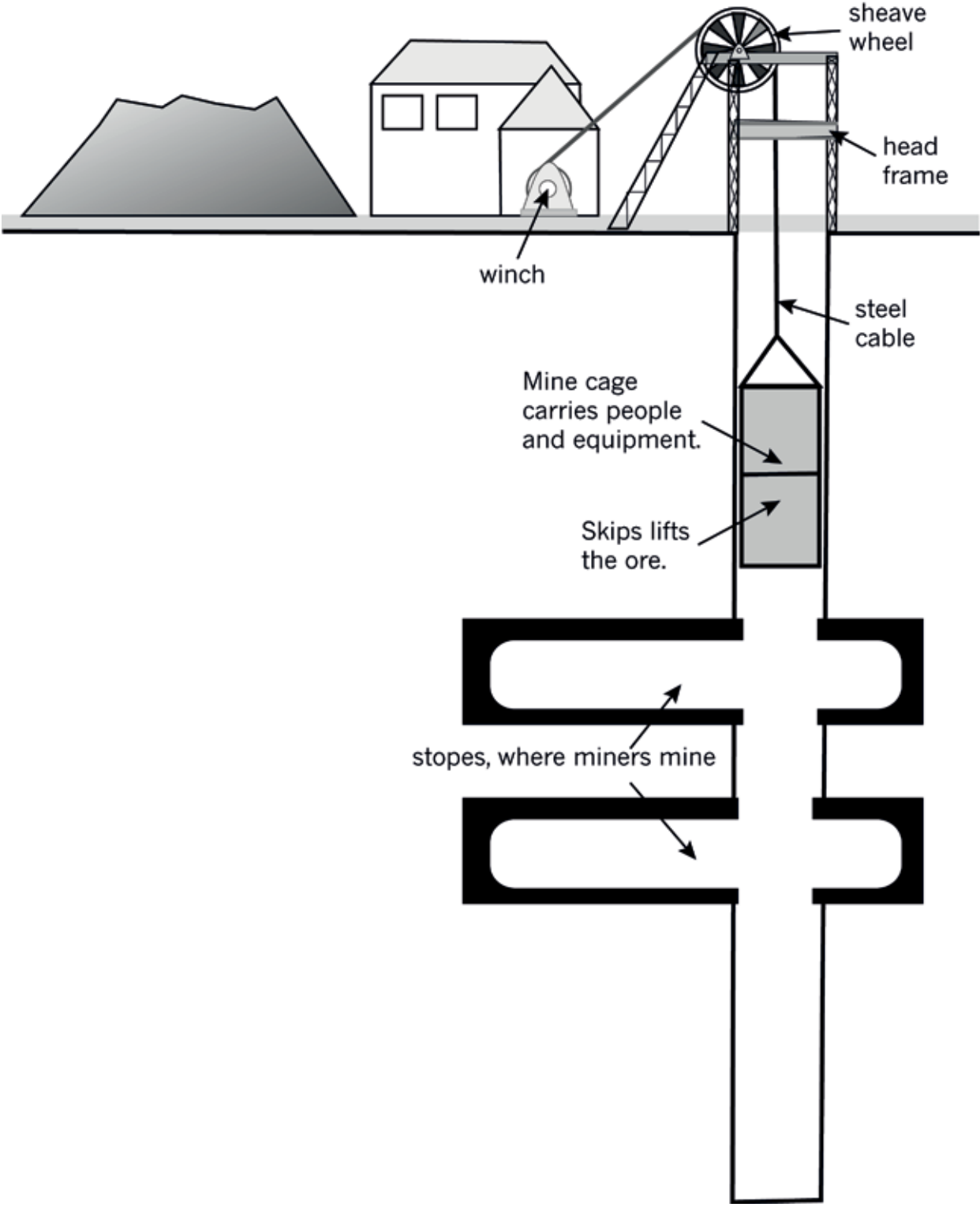


Figure 3: A mine's lifting system



**Investigate: Mine shaft headgear and head frame (30 minutes)**

**Individual work**

Use the picture in Figure 3 and your own information to answer the questions below:

1. What does the headgear of a mine do? (½)

.....  
.....

2. What happens in the winding house of a mine? (½)

.....  
.....

3. Explain what a sheave wheel is and what it does. (½)

.....  
.....

4. What does a head frame do? (½)

.....

5. Why do the legs on a head frame always slope towards the winch? (½)

.....

6. What do you call the two parts of the lift that goes down a mine? (½)

.....

7. What do these two parts of the lift do? (½)

.....  
.....

---

Look at the photograph in Figures 1 and 2. The photographs show the head frame and sheave wheel on the tower above a mine shaft.

Study the structure of the head frame and then answer the questions below. You will have to use your knowledge of frame structures to answer the questions.

8. Do you think I-beams are a good thing to use for head frame supports?  
Why? (½)

.....  
.....

9. Where do you see triangulation used on this structure? Explain how triangulation helps to make the head frame structure stronger. (½)

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

10. What has been used to stop the head frame from being pulled over by the winch? (½)

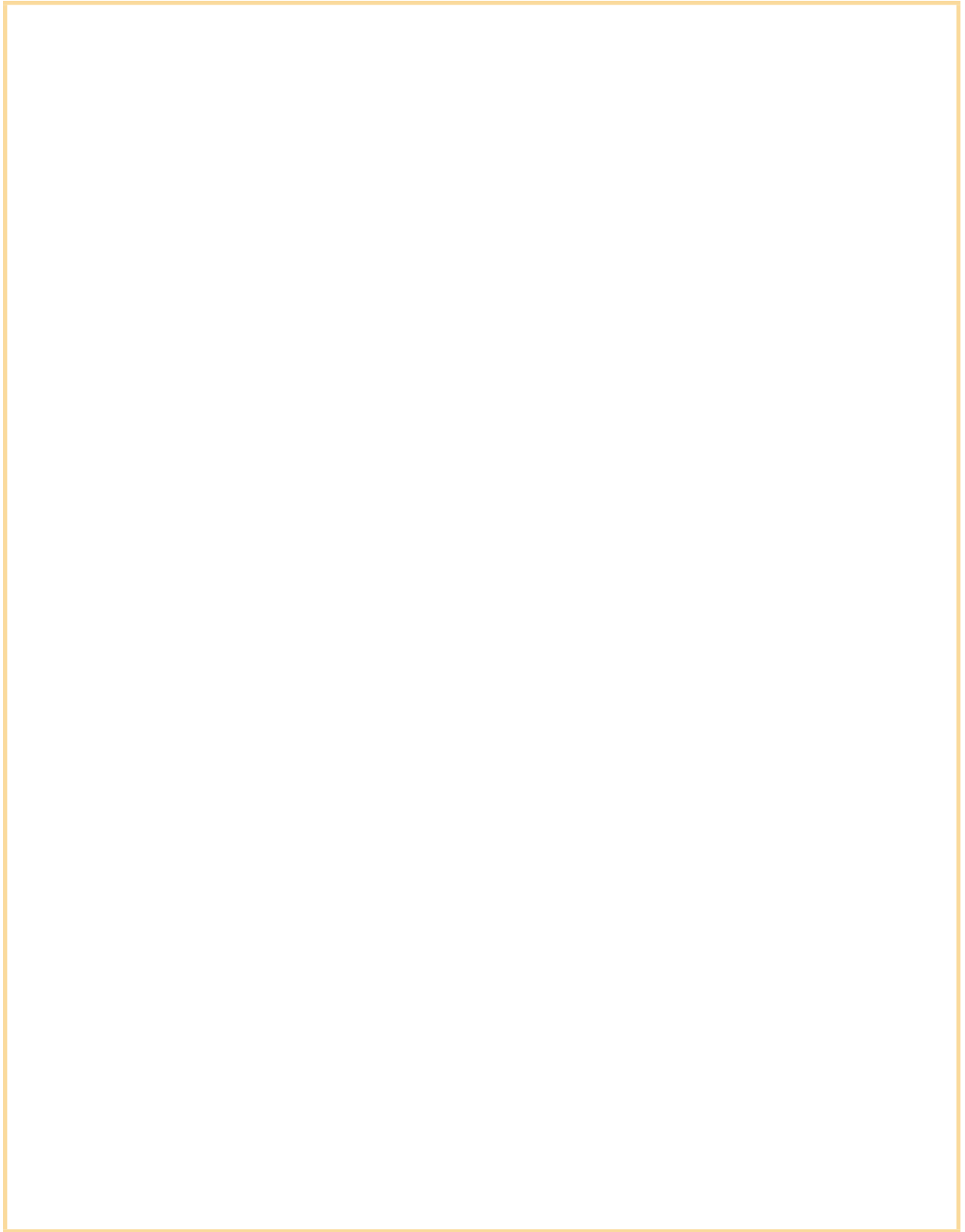
.....  
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11. Look at the sheave wheel. Has it been placed in the middle of the upright column? Why do you think it is important to place the sheave wheel in exactly the right place on the head frame? (1)

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

12. Make a 2D sketch of a head frame and sheave wheel in the space on the next page. (1)

Total [7]



## Investigate: Mine winches

(30 minutes)

### Individual work

Look at the pictures in Figure 4. The pictures show two different types of mining hoists. The first one has one sheave wheel, while the second has two sheave wheels. Use these pictures to help you answer the questions below:

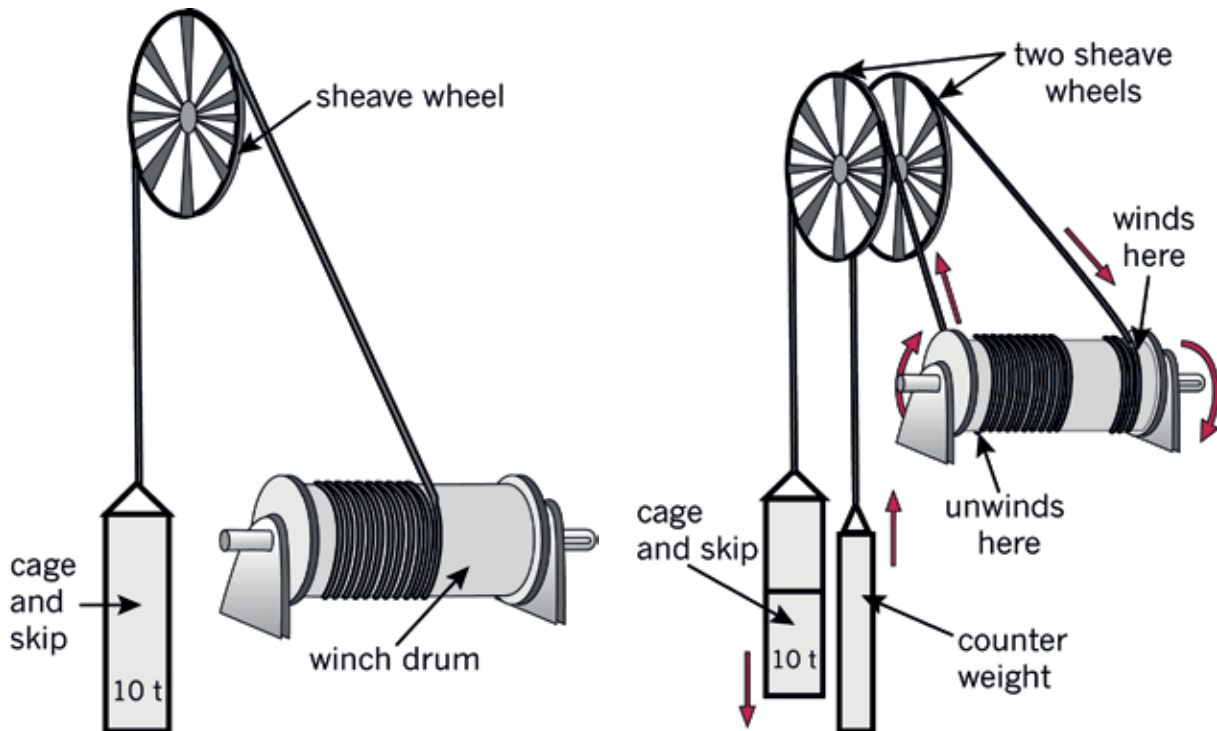


Figure 4: These are both mine winches with drum hoists. The winch on the right has two sheave wheels and a counterweight.

1. What are the differences between the two mine winches shown here? (½)

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

2. What do you think a counterweight does for a mine winding system?  
**Hint:** imagine winding the winch by hand. (1)

.....  
.....

3. If the mine winch drum diameter is 6 m, calculate how far the cage will drop for each single rotation of the drum. (½)

.....  
.....

4. If the mine winch drum diameter is 6 m, calculate how far the counterweight will lift for each single rotation of the drum. (½)

.....  
.....

5. Calculate how many turns of cable you will need on the drum for your cage and skip to move up and down by 500 m. (½)

.....

6. Which of the two systems in Figure 4 do you think will need the largest motor? Explain your answer. (1)

.....  
.....

7. Which system will be safer? Explain your answer. (1)

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

Total [5]

**Design: Design brief, specifications and constraints for a mine shaft headgear (60 minutes)**

**Individual work**

Sketch a whole headgear solution that might impress Platinum Stars. You should mark your sketch with the approximate sizes for:

- the depth of the shaft,
- the carrying load of the skip and the mass of the counterweight,
- the approximate size of the winding drum,
- the approximate height of the headgear and the sheave wheel, and
- the approximate sizes of the mining cage and skip.

**Note:** You might have to do a bit of research on your own.

---

Have another look at the scenario titled “An opportunity to tender for a mining contract,” at the start of this chapter.

**Write the design brief. Use the following questions to help you:**

1. What is the opportunity you are tendering for? (½)

.....

2. What do you need to do to tender for this project? (½)

.....

3. Write the design brief in the space below. Start your paragraph with: (1)

*We are going to design and make ...*

.....

**Write a list of specifications and constraints**

4. **Think about people:** Write down at least two things that the mine winch system must do *for people*. How should it help the mineworkers? What should it do, or not do, for the local people who live near the mine? (1)

.....

5. **Think about purpose:** What is the headgear for? What must it do? How fast must it travel? How far? How much weight does it need to carry? Write down at least two things about the purpose of this mine-winch system. (1)

.....

.....

.....

.....

6. **Think about safety:** What will happen if something goes wrong? What must your system have to try to prevent things from going wrong? What things must your system have to deal with emergencies when something does go wrong? Write down at least two things that will help to ensure that your design is safe. (1)

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

7. **Think about the environment:** Write down at least two things to help the environment when you design and make this headgear system. (1)

.....  
.....

8. **Think about appearance:** Do you think appearance matters when you design something such as headgear? Can your head frame's appearance help you to win the tender? Write down at least two things about the way you want your headgear to look. (1)

.....  
.....

9. **Think about costs:** What can you say about your costs for this project? Do you want the most expensive and the best of everything, or the cheapest and simplest, or something in-between? (1)

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

Total [8]

## Next week

Next week, you will do Week 2 of your mini-PAT. You will form engineering companies, evaluate ideas and choose the best idea. You will draw your solutions and begin to prepare your company's tender.

---

# Week 2

## Your company prepares a tender

This is the second week of the mini-PAT for mechanical systems in Grade 8. During this week, you will form your own engineering company.

Then you will combine all of the ideas you came up with last week, and choose one idea to for your tender.

You will present this tender to the mining joint venture company, Platinum Stars, later in this mini-PAT.

Platinum Stars will only accept tenders from companies. That means that you cannot submit a tender as an individual person.

A company is formed when two or more people come together for business reasons or goals.

Your business goal will be to do engineering work for Platinum Stars.

---

### Form a company (20 minutes)

#### Team work

1. Choose your company partners by arranging yourselves into teams of 3 to 5 people. Write down the names of each company member. This list of names will need to appear on your tender document. Also write your ID number next to your name.

.....  
.....

2. Write a mission statement: Write one short sentence saying what your company will do, how you will do it, who you will do it for, and why you think you will be able to do it well. Start your sentence with the words:

*'We at Underground Mining Engineers aim to ...*

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



**Evaluate: Choose and combine the best ideas (40 minutes)**

### Combine your specifications and constraints

#### Team work

Look at the specifications and constraints that you did last week. They won't be exactly the same. Make a new list that includes the best of everyone's specifications and constraints. Everyone in the team should write this list in their workbooks.

1. **Think about people:** (1)

.....

2. **Think about purpose:** (1)

.....

.....

3. **Think about safety:** (1)

.....

.....

.....

4. **Think about the environment:** (1)

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5. **Think about appearance:** (1)

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6. **Think about costs:** (1)

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Total [6]

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## Combine your head frame and sheave wheel ideas

### Individual work

Look at all the sketches you made last week of the head frame and sheave wheel. Use your specifications and constraints and discuss which combination of ideas will work best.

1. Now make a sketch of your company's final design in the space below. [5]



**Make: Draw your head frame**

**(60 minutes)**

**Individual work**

Look at Figure 5. It is a working drawing for a small head frame design.

This view shows:

- the size of the sheave wheel,
- the height of the sheave wheel, and
- the distance between the front and back legs.

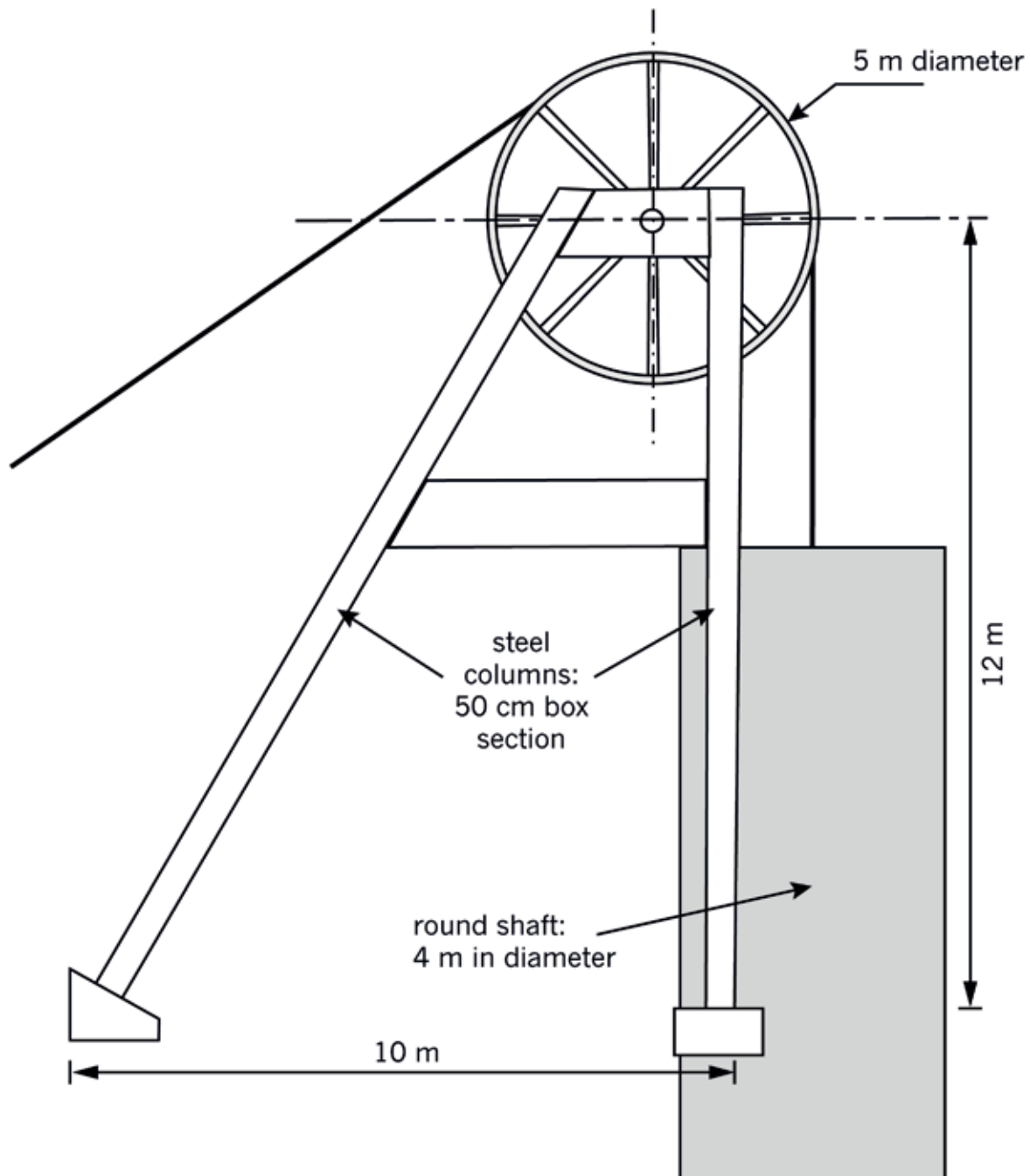


Figure 5: A working drawing of a head frame

- 
1. Draw your head frame in the grid below. Use Figure 5 to help you. You should show all the dimensions for the main parts of your head frame design.

**Note:** You may need to add triangulation to make your structure stronger.

You don't have to draw this to scale.

Don't show dimensions.

[4]

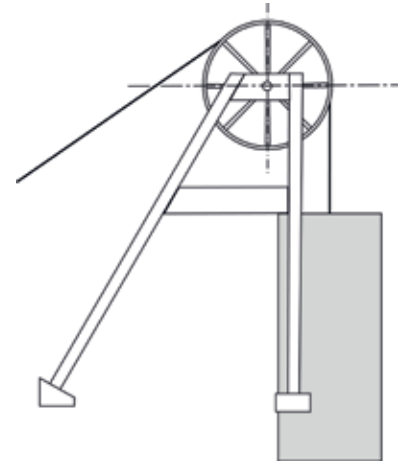
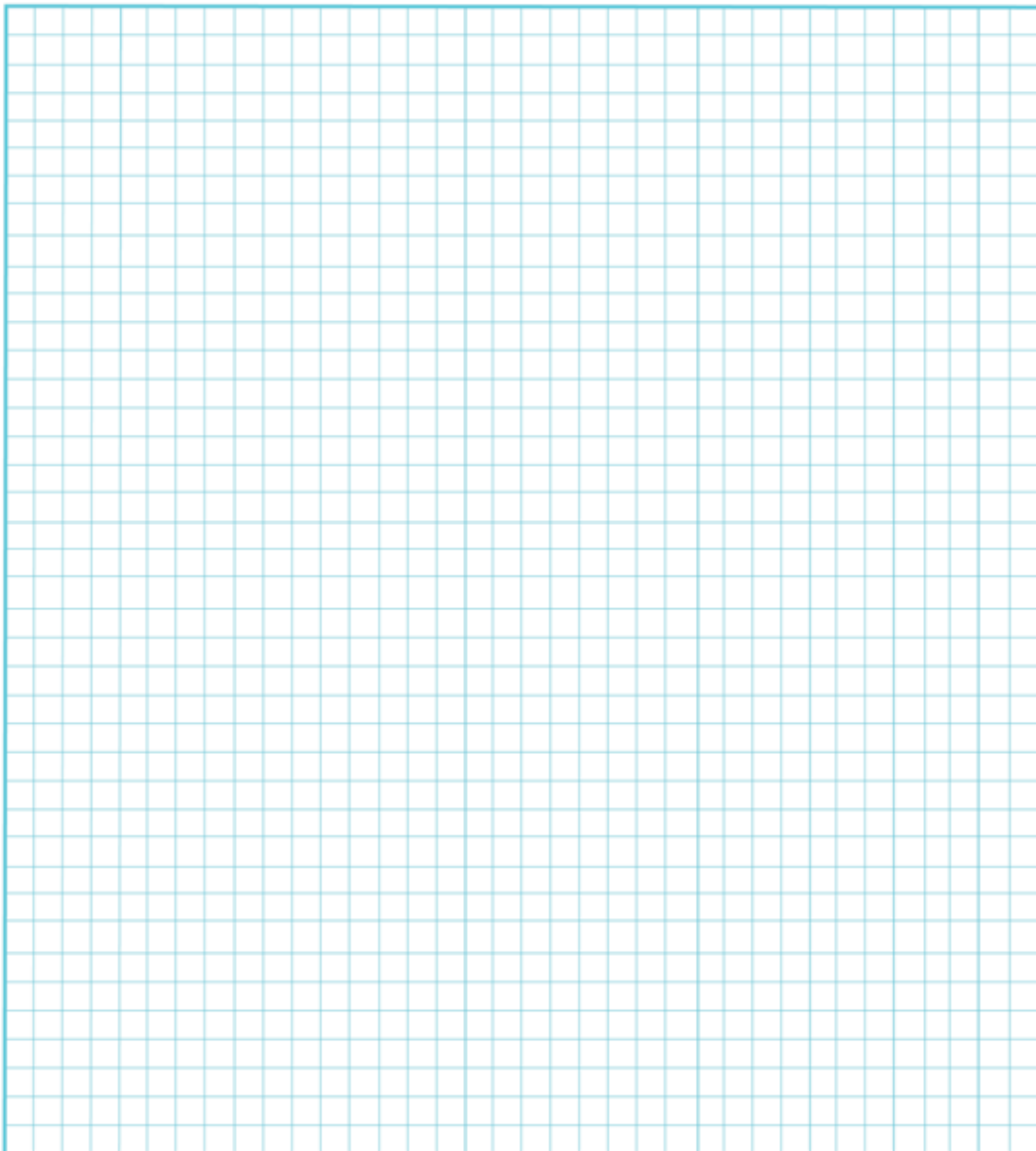


Figure 5 repeated



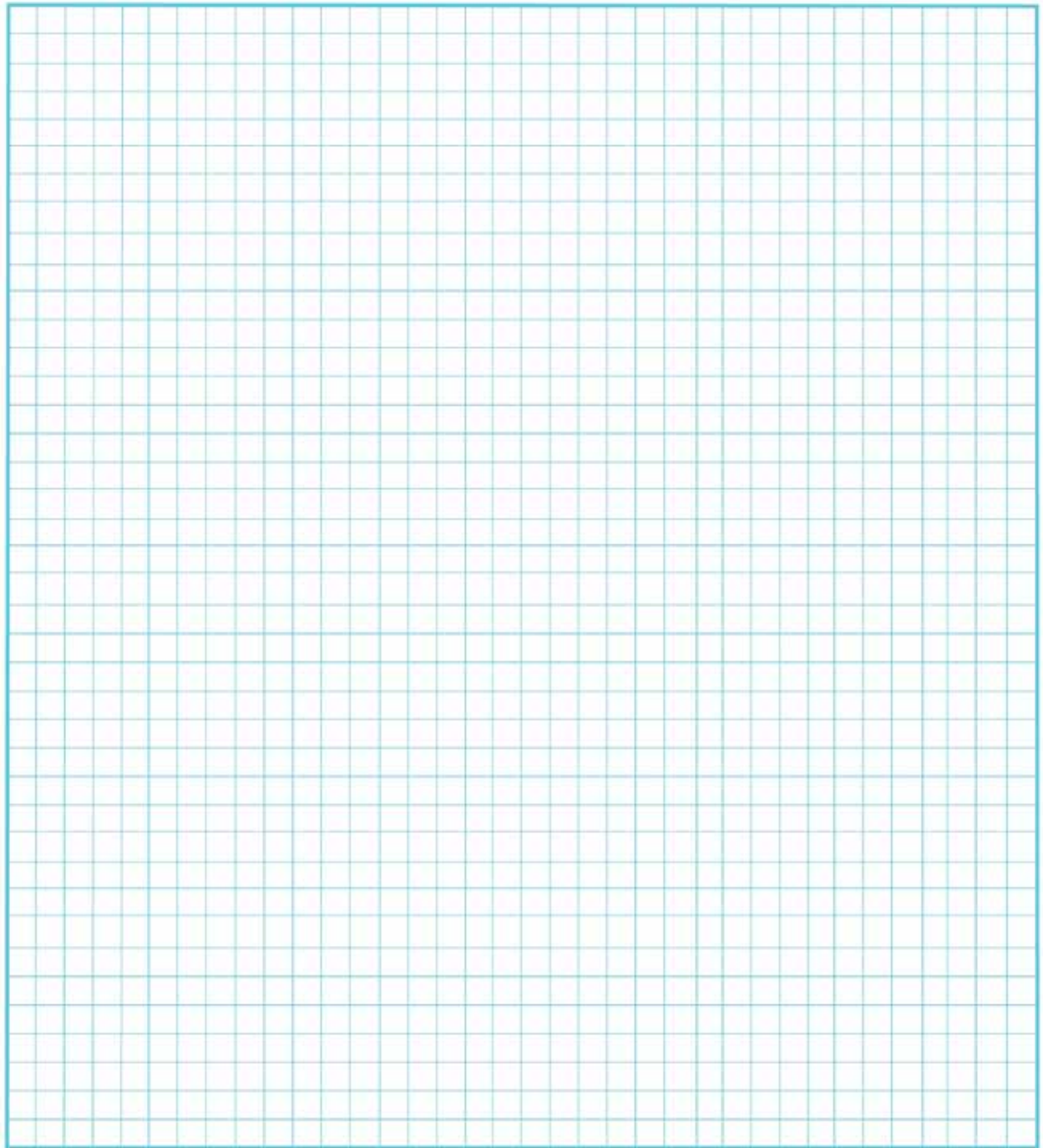
## Make a 2D scale drawing

2. Now use rulers and set squares to draw a more accurate version of your company's head frame design. Use the grid below. [5]

### Scale:

Suggested scale for a small head frame: 1 cm = 1 m.

Suggested scale for a larger head frame: 1 cm = 2 m.



## Make a 3D isometric drawing

The picture in Figure 6 shows a 3D isometric view of a head frame design. The drawing has been done on **isometric** grid paper, using instruments such as rulers and setsquares.

This view shows all three dimensions of the structure. You can see the sizes and the detail of the height, width and length.

**Isometric** means equal measure.

One little triangle in this grid, represents 50 cm in each direction of the real structure.

That means that a line that crosses 10 triangles is 500 cm or 5 m long.

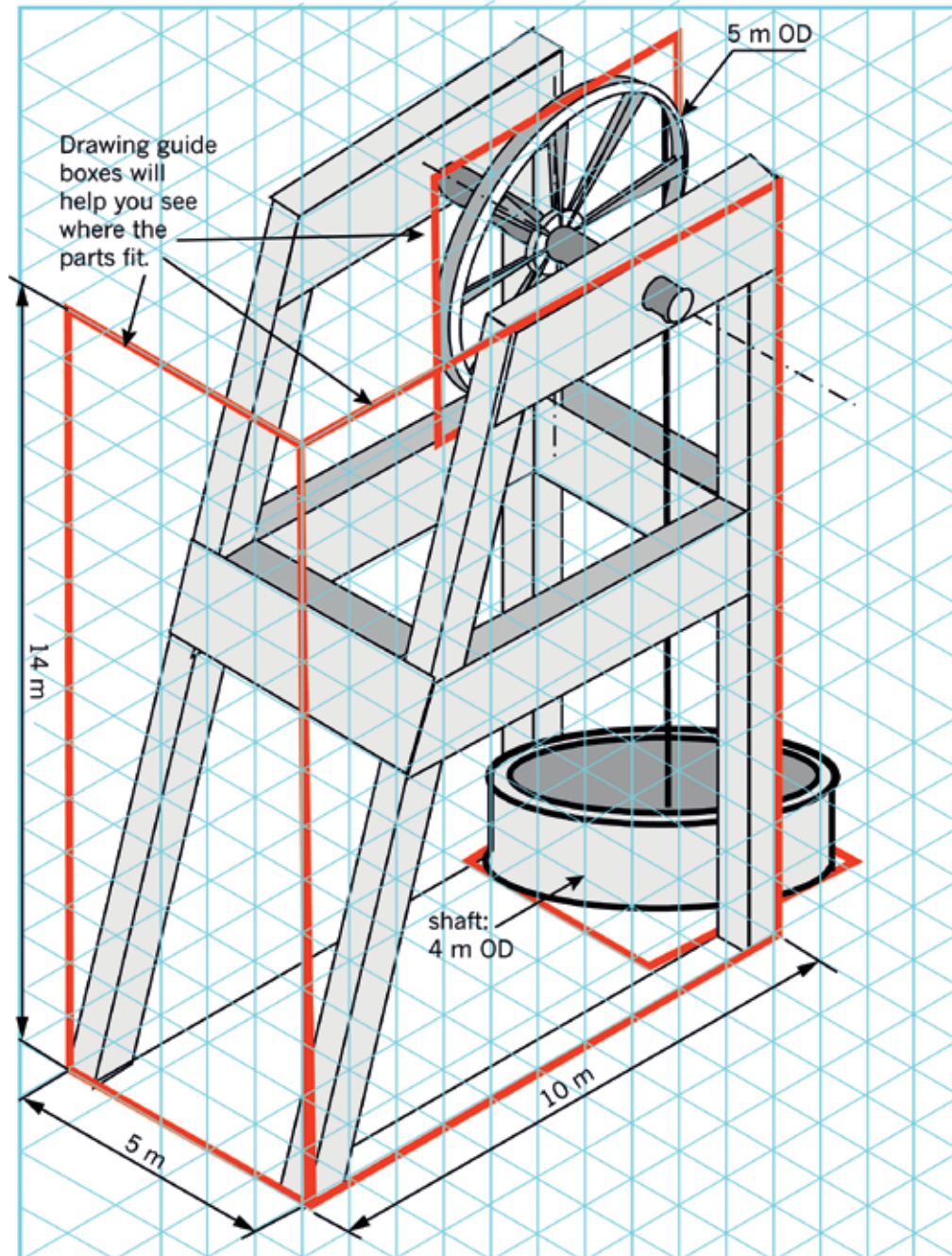
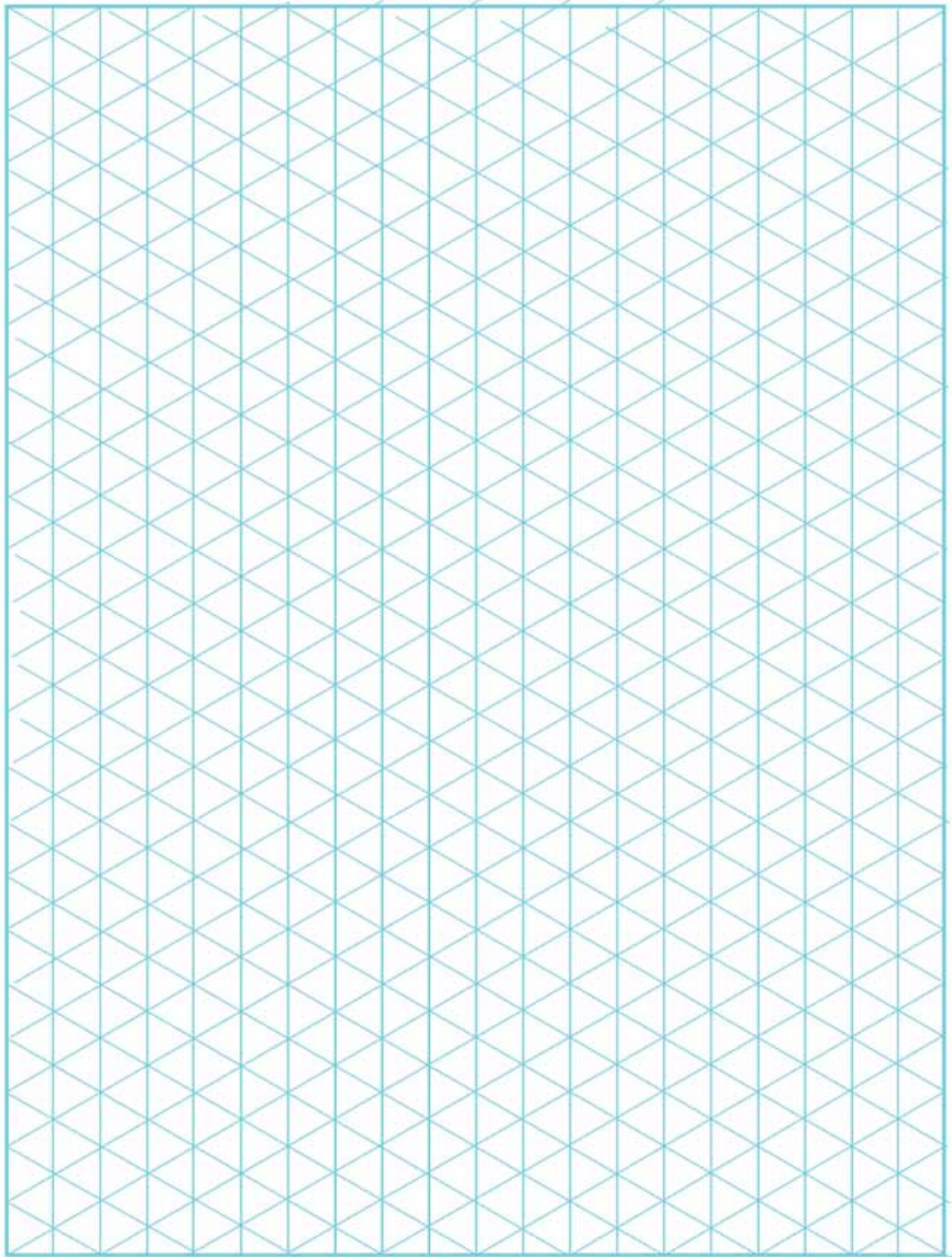


Figure 6: A 3D isometric view of a head frame design

3. Make a 3D drawing of your own head frame on the isometric grid below. [6]



Total [15]

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## Week 3

### How much will it cost?

To win a tender, you will have to show that your design is going to be the best and the best value for money. The table on the next page will help you to work out a tender budget.

**Design: Make a list of materials and work out the budget** (30 minutes)

#### Individual work

Hints:

- Look at your head frame drawing. Calculate the total length of steel column you will need for the legs of the head frame. Then enter the total length into the Quantity Needed row of the table. Calculate the cost of the total length of steel columns that you need to buy and enter the amount into the table.
- Calculate the total length of steel you will need for the cross braces and enter this total into the table. Calculate the cost of the steel needed for bracing.
- Complete the rest of the table. Enter quantities you will need and calculate the cost estimate for each item.
- Your project advisor says that you will need one project manager, one engineer, four artisans, four semi-skilled workers and 12 unskilled workers on the project, and that it will take six months to complete. Calculate the labour cost estimate for each of these workers.
- Calculate the “subtotal” for each of the three cost categories, namely “steel for the head frame”, “lift components” and “labour”.
- What will your total project cost be? Add up all of the subtotals of the different cost categories to calculate the total project cost.

#### Mark allocation

- good estimates of materials quantities (1)
  - correct calculation of labour quantities (person/hours) (1)
  - calculations of cost estimate per item (2)
  - calculation of subtotal and total project cost (1)
- Total [5]



<b>Item</b>	<i>cost per unit</i>	<i>quantity needed</i>	<i>cost estimate</i>
-------------	----------------------	------------------------	----------------------

**Costs of steel for the head frame**

steel column	R500 per metre		
steel for cross braces	R20 per metre		
<b>Sub-total: Costs for steel frame</b>			_____

**Costs of lift components**

sheave wheels	R 150 000		
winch and motor	R 1 200 000		
cable	R 100 per metre		
cage and skip	R 350 000		
<b>Sub-total: Costs of lift components</b>			_____

**Labour costs**

project manager	R 30 000 per month		
engineers	R 30 000 per month		
artisans	R 25 000 per month		
semi-skilled workers	R 20 000 per month		
unskilled workers	R 12 000 per month		
<b>Sub-total: Labour costs</b>			_____

**TOTAL PROJECT COST:** \_\_\_\_\_

## Make a model head frame

(30 minutes + 60 minutes)

### Team work

Now it is time to make a model of your head gear. You will need to make several different parts:

- the head frame with its sheave wheel,
- the mine winch, and
- the model lift.

In this activity, you will make the first part, the head frame.

**Remember:** Your teacher will watch you while you make your model to see how well you:

- work as a team,
- measure and mark things properly,
- cut and join parts accurately and with the correct tools,
- finish and decorate your model, and
- use safe working practices.

### Safety tips:

Never play with cutting tools. Never point the sharp end at someone else. Keep your tools neat and clean and in good working order. Do not spill glue or leave the lid open as the fumes are poisonous.

Not everything you try will work well. So don't be afraid to change your designs to improve them as you go along.

## Make the steel columns

You can make your steel columns using cardboard. Look at Figure 7 to help you. You can make round or rectangular columns depending on the **former** you use:

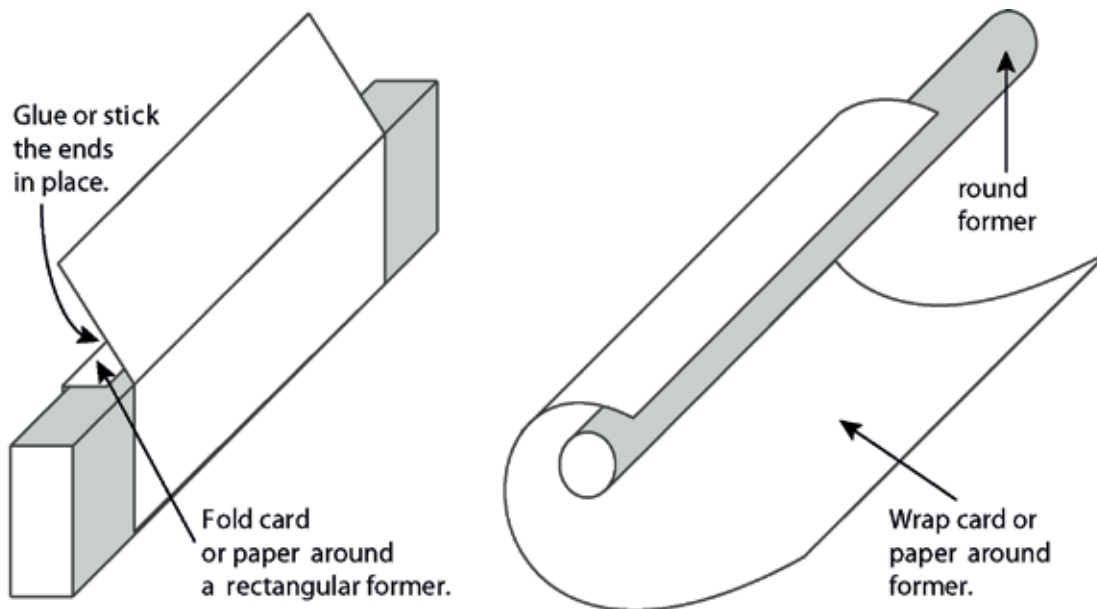


Figure 7: How to make the steel columns

- If you use a rectangular former, you will get a channel. A strip of wood 2 cm × 1 cm will work well for this.
  - If you use a round former, you can make round columns out of cardboard. A 10 cm dowel works well for this.
1. Choose how you will make your columns and then make all the pieces you will need for your model. Have another look at Figure 7 to help you. (1)

A **former** is a shape that can be used to make tubes. For example, when you wrap a flat sheet over a rectangular former, you make a tube with a rectangular cross section.

## Make the cross braces

You can make cross braces by joining flat pieces of corrugated cardboard together. You can use tape or glue to join the flat pieces. Look at Figure 8 to help you. Figure 8 shows three types of cross braces: angle irons, T-beams and I-beams.

2. Decide which of these cross braces you need for your head frame. Then make the cross braces you need. You will use these cross braces and the columns you made earlier to make a model of your head frame. (2)

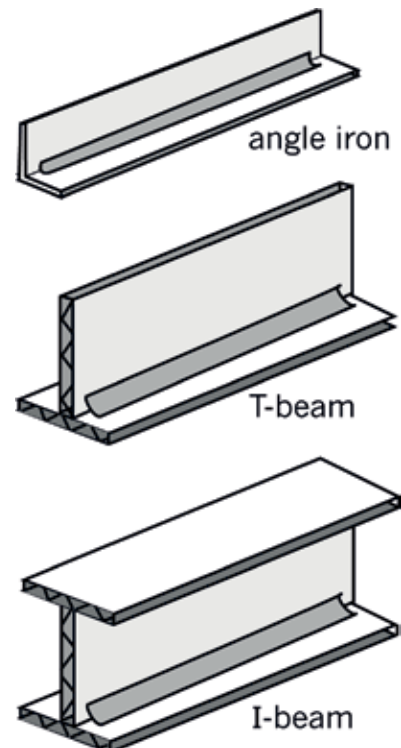


Figure 8: Cross braces

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## Make flat frames

Look at Figure 9. This figure shows one side of a frame.

- T-Beams have been used to join the vertical and the sloping column.
  - Cross bracing has been added to strengthen the lower half of the frame.
3. Carefully cut your beams to the right size and shape to fit neatly between the columns. Then glue or tape them on. (2)
  4. Cut your angle sections so that they can fit across the columns. Trim the ends so that the outside of the angle can be joined to the side of the column, but remember that the angle has to fit neatly between the columns. (2)
  5. When you are happy with your first side frame, make the second in exactly the same way. (1)

## Join your side frames

6. Now make your head frame by joining your two side frames together. (2)

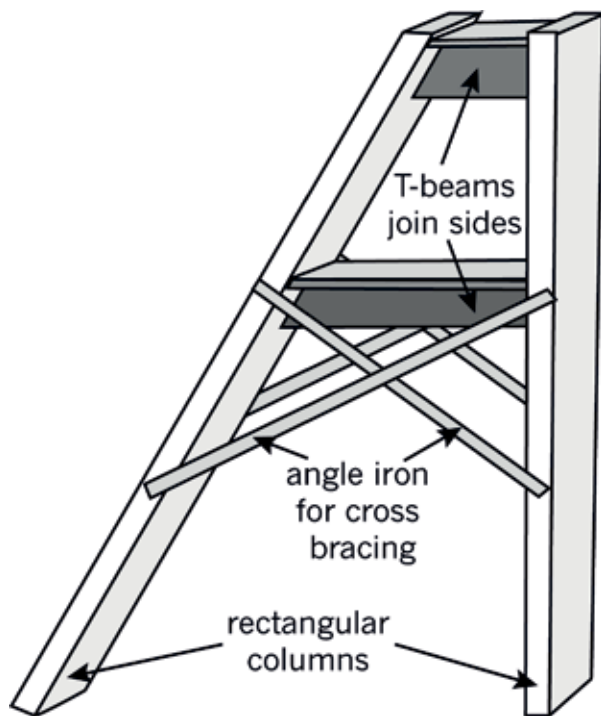


Figure 9: How to make one side of a frame

## Make a sheave wheel

Look at the pictures shown in Figure 10. They show two ways to make a model sheave wheel:

- You can use a round cardboard box, such as the ones used to pack cheese triangles.
- You can cut three circles from corrugated cardboard and sandwich them together.

For both methods, a plastic straw has been used to make a bearing through the middle of the wheel. This bearing will make the wheel turn easily on its axle or shaft.

7. Make your own sheave wheel. Try to make it as close to the correct scale size as you can. Use Figure 10 to help you. (1)

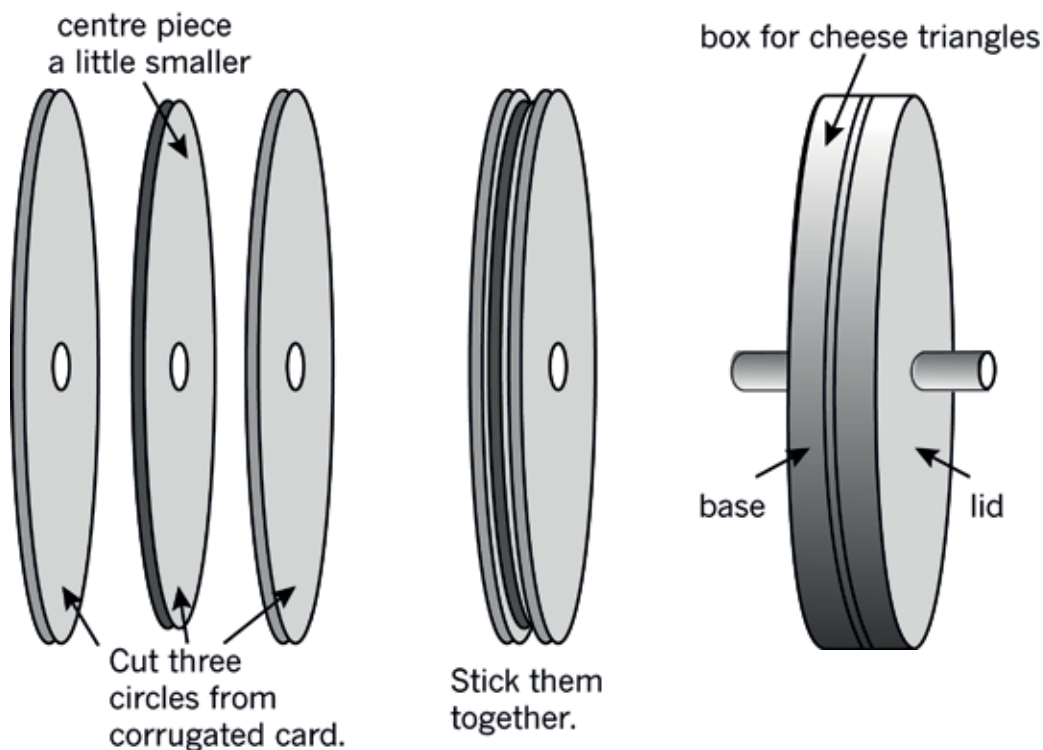


Figure 10: Two ways to make a model sheave wheel

---

## Mount the sheave wheel on an axle and fit it to the frame

Your sheave wheel has to turn easily. It needs to have an axle passing through the centre of the wheel. You can use a dowel stick, about 4 mm in diameter, or a long nail (about 60 cm long) for your axle.

Look at the picture in Figure 11. A sheave wheel has been added to the top of a head frame in the following way:

- The axle is taped onto the top of the head frame.
- The wheel, with a straw through its centre, can rotate freely on the axle.
- Extra pieces of straw have been added to keep the wheel in the centre of the axle.

8. Now add your sheave wheel to its head frame. Use Figure 11 to help you. (2)

Will your axle bend? Have a look at the axle supporting your wheel. This axle will have to carry all the weight of the lift. Does it have enough support? If the distance between the axle and the supports are too long, then it will bend and might break.

If you need to, add extra supports for the axle at the top of the head frame.

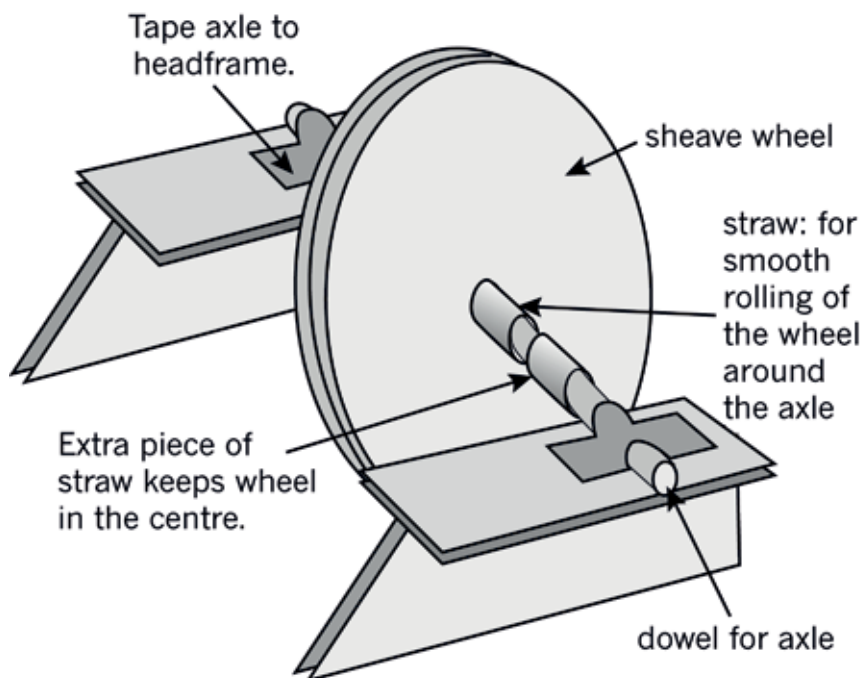


Figure 11: How to add a sheave wheel to the top of a head frame

Total [13]

---

## Next week

Next week, you will complete your mini-PAT. You will make a winch and a lift and then you will present your tender.

## Week 4

### Communicate a headgear tender

This week is the last week of your mini practical assessment task for mechanical systems in Grade 8.

You will make your mine winch and add it to the head frame you completed last week. Then you will add a lift, commonly called a cage, to your model.

After testing your system and adjusting it, you will collect all the work you have done so far for this mini-PAT, and use it to prepare a tender presentation to present to the tender board of the Platinum Stars Mining Company.

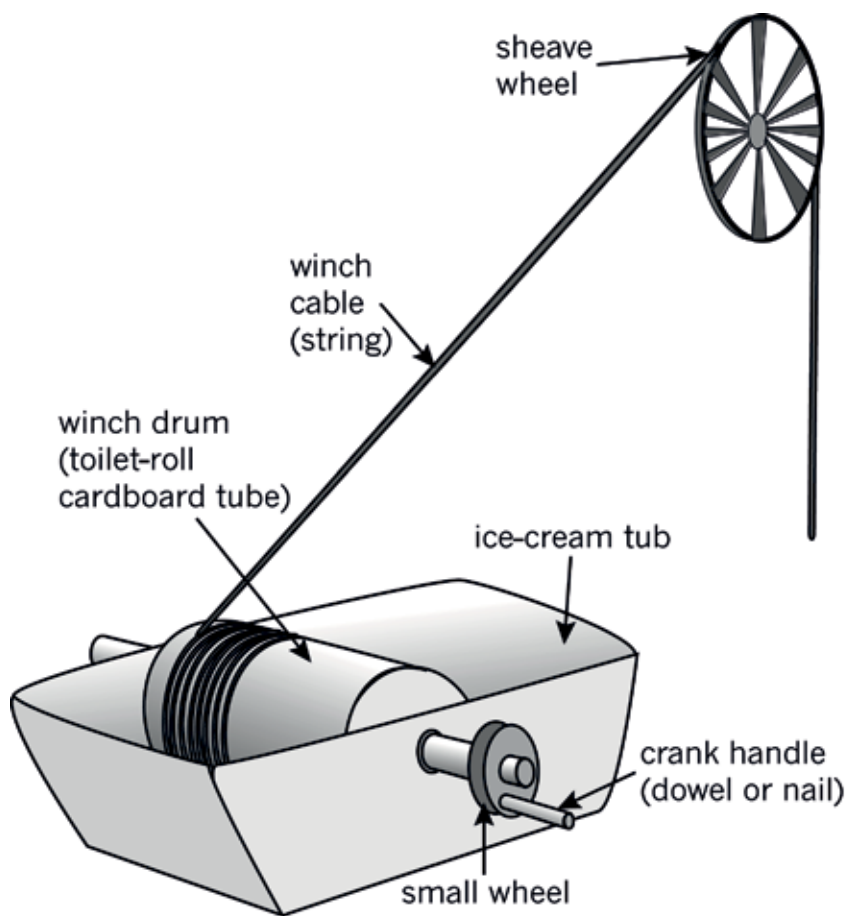


Figure 12: How to make a model mine winch

---

## Complete your model: Make a winch and cage (20 minutes)

Do you remember investigating crank winches in Chapter 4 and in this chapter? Look at Figure 12 again. It shows you how to make a model mine winch yourself.

- The winding drum for this mine winch was made from a toilet-roll cardboard tube.
- The winch drum has been put onto a 2 l plastic ice-cream tub. This will be the winch house.
- This winch does not have a motor attached. Instead it uses a crank handle. But if you have a motor, then you can connect a belt drive or a gear system to the winch's drive wheel instead.

Here are a few important things to remember when making a mine winch such as this one.

- The drum has to turn when the crank handle is turned. That means that the shaft that connects the small wheel with the crank handle to the winding drum must be tightly attached to the drum, and to the drive wheel. You can use glue or tape to make sure that the shaft is firmly stuck onto the drum and wheel.
- The shaft must be able to turn easily in the holes on the sides of the ice-cream container.
- The rope or string must be firmly attached to the winding drum and it must not be able to come off. Imagine what would happen to the lift cage if it did.

1. Make a winch drum of your own. Remember it must be able to lift and lower a cage into the mine.

Will your cage be square or round? You can use a paper-towel tube for a round cage or any square box for a square cage. Tie your lift cage to the shaft side of the sheave wheel. [2]

### Shafts and axles:

The centre of a wheel is called a **shaft** when it turns with the wheel.

When the centre of the wheel stays still and the wheel slides over it, it is called an **axle**.

### Test your head gear

With your cage and your winch attached to the head frame, you now have a complete system.

Test your system to ensure that you can lift and lower miners, and lift mined ore from a shaft underground.



**Evaluate the head gear**

**(10 minutes)**

**Evaluate your solution**

Look at the model your team has made.

1. Do you think the head gear is suitable for transporting miners to a depth of 500 m underground, and for lifting mined rock samples from underground? Explain your answer.

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

2. What have you done to ensure that your system will be safe?

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

3. What have you done to make your headgear look good so that the community will not complain about the mine ruining the area?

.....

4. Do you think the environment will be damaged in any way by your structure?

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

5. Why should the tender board choose your head gear?

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

6. Are there any things the tender board won't like?

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

---

## Present your solution to Platinum Stars

(90 minutes)

### Prepare your tender

1. Prepare a team presentation to the tender board of the Platinum Stars Mining Company. Each member of your team should talk about one of the points below:
  - Your head frame ideas. This person should show the sketches and drawings you did while designing your head frame.
  - Your winch idea. This person should show the sketches and drawings you did while designing your mine winch.
  - The budget. This person should talk about the costs of making your headgear.
  - Why the tender board should choose your solution. This person should use your 3D model to convince the tender board that your solution is the best.

### Present your tender

2. Now present your tender bid to the tender board. (3)

### Evaluate different tenders

3. While listening to other people's tender presentations, write down some of the best points about their tenders.

.....  
.....

4. Which tender do you think should win? Explain your decision.

**Remember:** To be good at evaluating you must show that you can judge other people's work objectively. (1)

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

Total [4]

# TERM 4

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## CHAPTER 7

# Electrical systems and control

In this chapter, you will learn how to make light bulbs light up by building electric circuits. You'll learn about circuit components, input and output devices, and control devices such as switches. Finally, you will learn how to draw these components in circuit diagrams, using the correct symbols.

7.1	Explore simple circuits .....	120
7.2	Parallel connections: Two, three or more paths for current .....	125
7.3	Input, output and control devices in a circuit .....	130



Figure 1



---

## 7.1 Explore simple circuits

### Make bulbs light up

You need all the components (parts) shown in Figure 2 to do this activity.

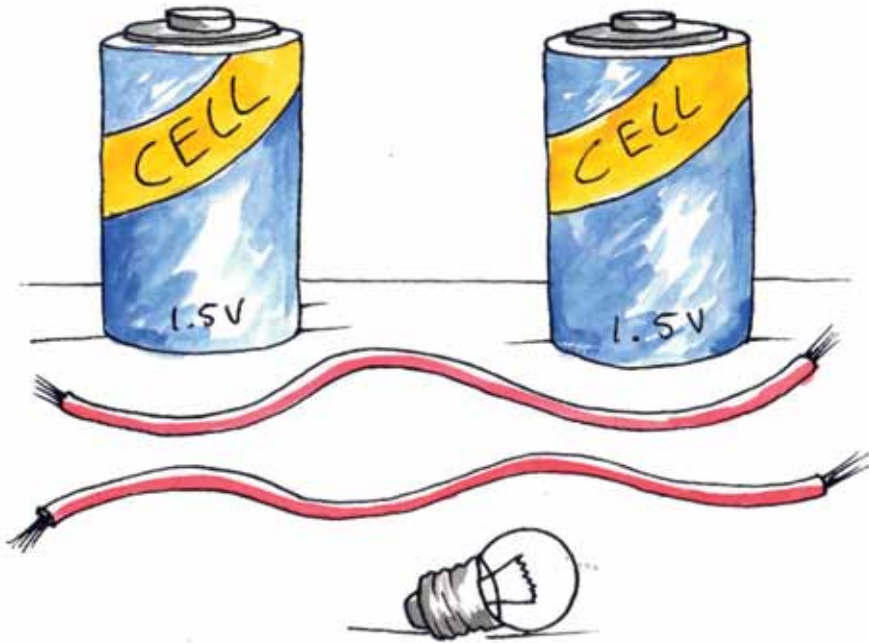


Figure 2: Components to make an electric circuit

Divide into teams of four to six learners. Two teams can work together if there is only one cell per team. Discuss the following in your teams, and do the experiments:

- Find out how to connect the parts to make the bulb light up. Find three or more ways to make the bulb light up.
  - Touch the glowing bulb using your fingers. What does it feel like?
  - Look inside the glass part of the bulb. Which part of the bulb gets hot?
  - What happens when you connect two cells instead of one cell?
  - How can you make the bulb flash on and off?
-

From this activity you found that a bulb will glow only if the wires touch it on the screw contact and the solder knob at the bottom.

You found that you must connect metal parts to make a path from the knob of a cell, through the bulb, and back to the flat end of a cell. This path is called a circuit. The current will not flow if there is a gap in the path of the conductors.

An electric circuit is a complete path of conductors. The cells cause a current of electricity to flow around the circuit. The current will flow only if the circuit has no breaks in it.

The cells provide the energy to make the electricity flow through the circuit, and the electricity flowing through the “filament wire” inside the light bulb makes it glow.

Cells use a chemical reaction to make electricity flow through a circuit. In Chapter 9, you will learn more about the chemical reactions in a cell.

## The voltage of a cell

The cells have a number, for instance “1,5 V”, printed on them. Find that number on your cells. The number represents 1,5 volts. You say that the cell has a *voltage* of 1,5 volts.

When you connected two cells end-to-end you made a two-cell battery with a voltage of 3 volts. The 3 volt **battery** can give more energy to the bulb and so the bulb will glow much brighter.

When two or more cells are connected to provide electrical current to a circuit, you call it a **battery of cells**, or simply a **battery**. You can also call a single cell a battery.

## Connecting bulbs in series

**For this activity, you will need the following:**

- a battery made from three cells in series in a **cell holder** (the cells must be fairly new),
- three bulbs in bulb holders,
- connecting wires,
- a **push switch**, and
- a small piece of paper with the words “indicator bulb” on it.

You can make a simple **cell holder** by rolling three cells in a sheet of A4 paper. Put sticky-tape on the rolled-up paper to keep it in place and around the ends of the battery. Push the wires under the tape, to touch the battery terminals.

You can make a **push switch** from a piece of stiff plastic and two metal paper-fasteners. A push switch only makes electrical contact while you keep it pressed in.

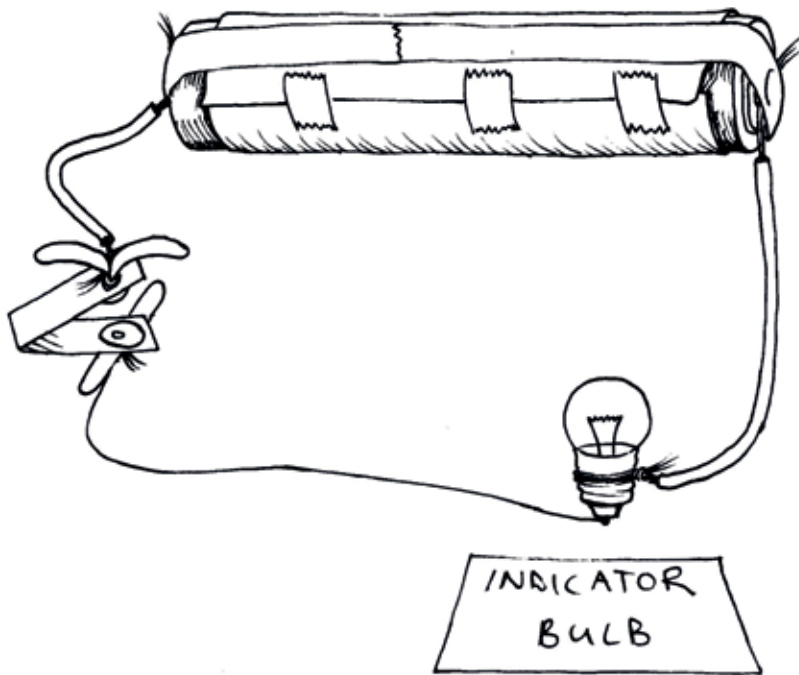


Figure 3

Set up the circuit shown in Figure 3. Press the switch to make the bulb glow, and notice how brightly it glows. This first bulb will be your *indicator bulb*.

If the indicator bulb is bright, the *current* is *big*.

If the indicator bulb is dim, the *current* is *small*.



Now connect another bulb in the circuit as shown in Figure 4.

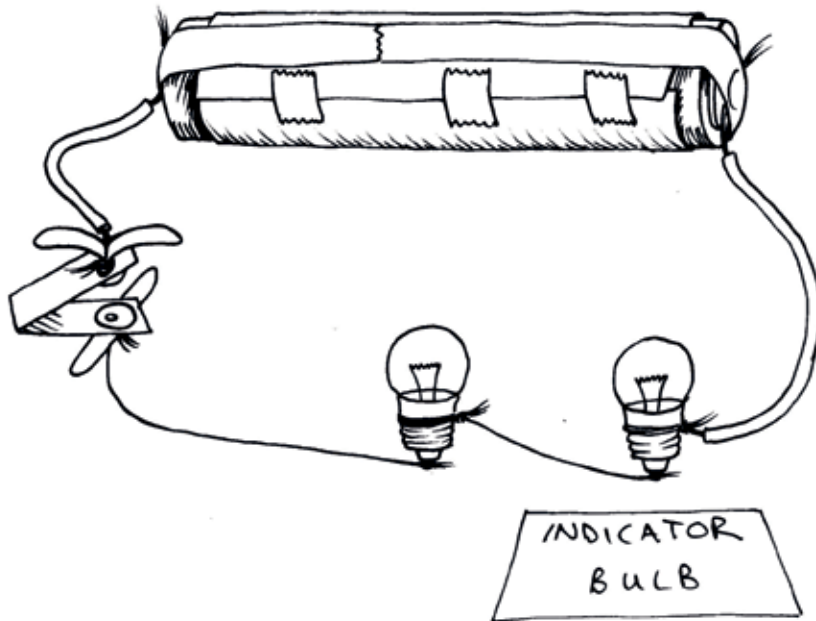


Figure 4

Cover the new bulb with your hand and look only at the indicator bulb. The indicator bulb is not as bright as before. What do you know about a current that has to run through two bulbs?

Connect a third bulb to the circuit as shown in Figure 5.

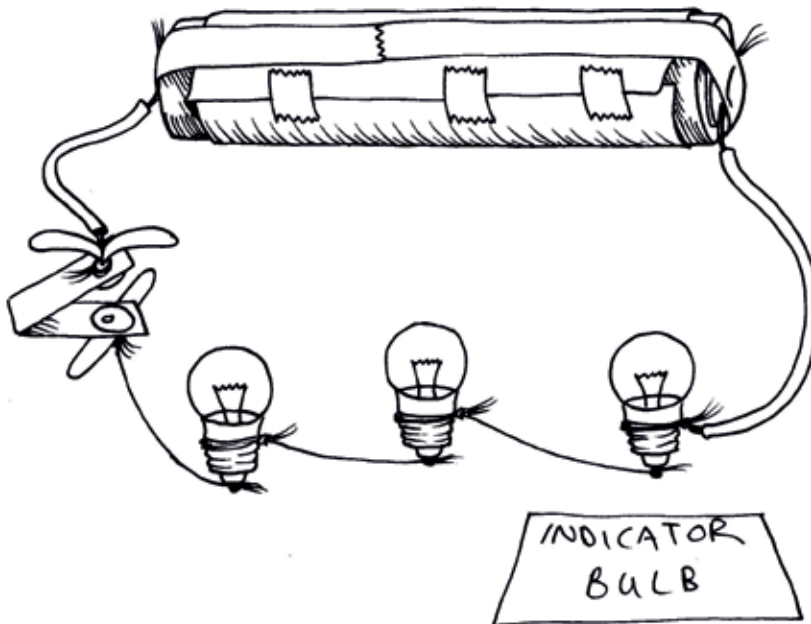


Figure 5

Cover both new bulbs with your hand and look only at the indicator bulb. How has the current changed?

---

## Series connection

When we connect bulbs with only one path for the current, as in Figure 5, we say that the bulbs are connected “in series”. The current must go through each bulb in the row.

1. What will happen if you add a fourth bulb?

.....

2. If we add more bulbs to the circuit in series, the indicator bulb will glow more dimly. This tells us that if we add more ..... the current becomes

.....

---

## Resistance

The same battery can produce big and small currents. The current depends on the resistance.

As we add more bulbs in series, the battery finds it harder to push current around the circuit, and the current becomes smaller and smaller. The reason is that the filament wire in each bulb has resistance. The bulbs have resistance and therefore we say they are “resistors”.

The bigger the resistance, the smaller the current.

- Good conductors have low resistance, bad conductors have high resistance. Examples of good conductors are copper, gold, silver and aluminium. They have low resistance.
- Examples of medium or bad conductors are tungsten, graphite – the black compound in your pencil – and **nichrome**. They do conduct electricity, but not very well. The filament-wire in a bulb is made of tungsten.
- Examples of very bad conductors are plastic, glass and wood. They have such high resistance that a battery cannot make any current flow through them. We say they are good “insulators”. The plastic covering on electrical wire is the insulator for the wire.

**Nichrome** is an alloy (mix) of nickel and chromium. It is often used in electrical appliances such as heating elements since it has a high resistance.

## 7.2 Parallel connections: Two, three or more paths for current

Figure 4 shows two light bulbs connected in series to make them light up. Connect them again and try to remember how brightly they glow.

Now connect the two light bulbs in a different way, as shown in Figure 6 below.

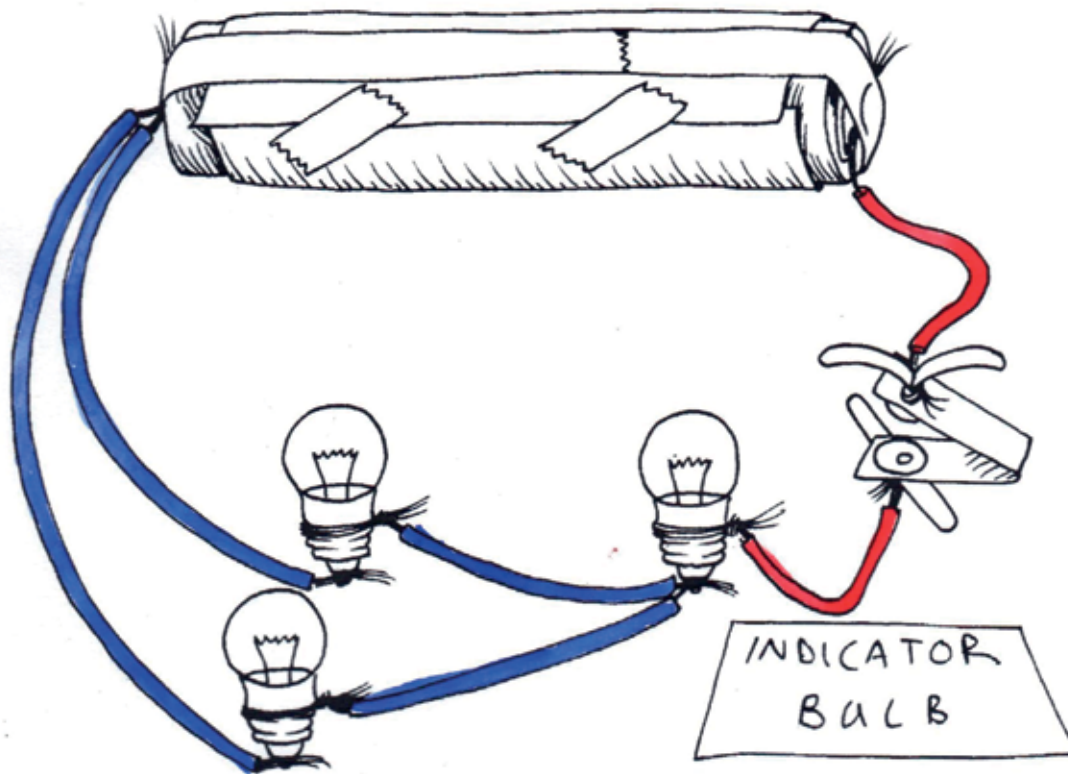


Figure 6

Both bulbs light up when you press the switch, but now they burn brighter than they did when they were connected as in Figure 4.

All the current provided by the cell passes through the red wire. But that current is split between the two blue wires.

When resistors are connected in a circuit so the current is split between the resistors, you say that the resistors are connected in “parallel”.

## Connect three resistors in parallel

**For this activity, you will need:**

- a battery of 3 good cells,
- 4 bulbs in bulb holders,
- a press switch, and
- 8 connecting wires.

Look at the circuit in Figure 7.

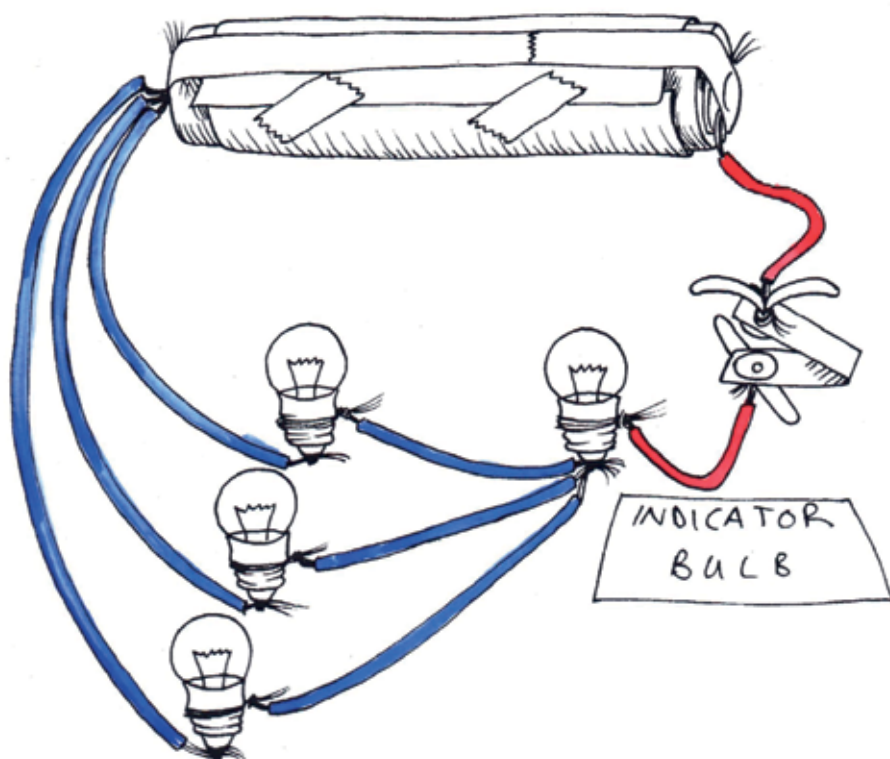


Figure 7

1. How many paths for a current can you see? With your finger, follow the paths for a current from the positive terminal of the battery through the bulbs, to the negative terminal of the battery.

.....

2. Will the indicator bulb be as bright, brighter or dimmer than in Figure 6?

.....

3. Test your idea. Make the circuit in Figure 6 and then add a bulb as in Figure 7

4. Was your idea correct?

.....

When you connect bulbs so that the current has two or more paths to go through, you are connecting bulbs in parallel.

If you make more parallel paths for current, the battery can put out more current.

This is the same as saying that if you add more paths in parallel, then the resistance in the circuit becomes less.

## Short circuits

Look at the circuit in Figure 8. Someone has made a mistake and connected the orange wire from the terminal to the switch.

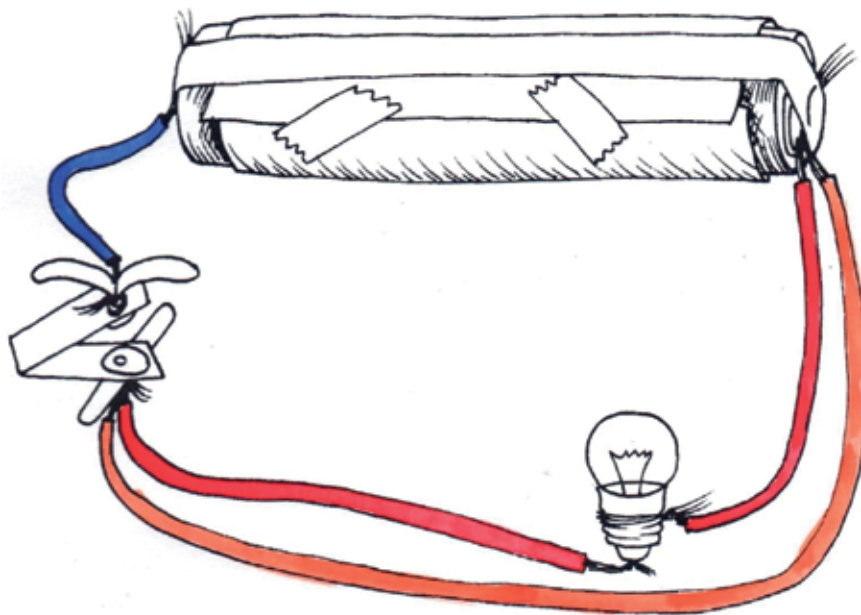


Figure 8

Find the orange wire. Does it have a bulb connected to it?

This wire is a zero-resistance path for current. If you press the switch, the battery will put out as much current as it possibly can. It will do that because it finds a zero-resistance path.

Almost all of the current supplied by the battery will go through the orange wire, and only a very small amount of current will go through the bulb.

The battery will put out its energy as fast as it possibly can. Therefore it will get hot and it will be “dead” or “flat” in about 10 minutes.

The person’s mistake was to make a parallel path for a current with the wire. We call that path a **short circuit**.

A **short circuit** is a parallel path for current that has almost zero resistance.

---

5. Why does the bulb not glow if you make a short circuit path?

.....  
.....

6. What happens to the wire forming the short circuit? Why?

.....

7. Look at Figure 9. The bulb is glowing, but if you press the switch, the bulb stops glowing. Explain the problem, and draw a picture on the next page to show how you would connect the circuit in the correct way. The bulb should glow only when you press the switch.

.....  
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.....  
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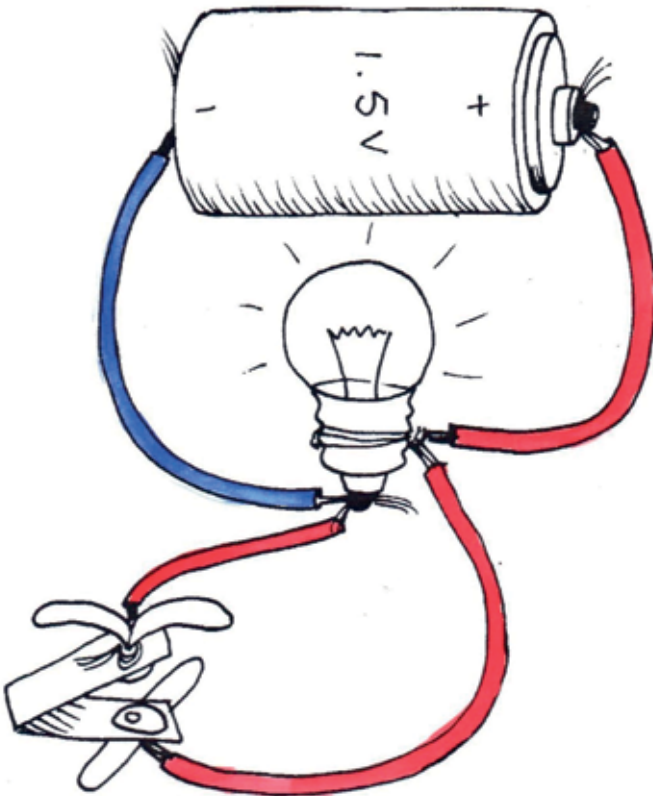


Figure 9



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## Why short circuits are dangerous

ESKOM supplies energy at 230 volts which can make a heater red-hot. This is safe in a heater, since only the resistor in the heater gets hot, and not the wires from the plug. But if the insulation is broken on the wires, the wires may touch each other and create a short circuit. The current will not go through the heater, but take another path along the wires instead. The current will give off all of its energy to the wires. Then the wires can become red-hot and set fire to something.

All electrical appliances must only be used in the way the manufacturer recommends. Never attempt to fix a broken electrical appliance without expert help, and always make sure that appliances are switched off, or even unplugged when not in use.

## 7.3 Input, output and control devices in a circuit

An electrical circuit uses an input of electrical energy to provide an output of some type of energy. Examples are described below:

- A light bulb uses the *input* of electrical energy provided by a battery to give the *output* of light. You can say that a light bulb *converts* electrical energy into light energy.
- The resistance wire or element in a kettle gives an *output* of heat energy.
- The loudspeaker of a radio converts an output of sound energy. This means that it gives out sound from the energy that is going into it.
- An electric motor gives an *output* of movement or kinetic energy.

We can use a systems diagram to describe an electrical circuit:

energy input  $\Rightarrow$  control device  $\Rightarrow$  energy output

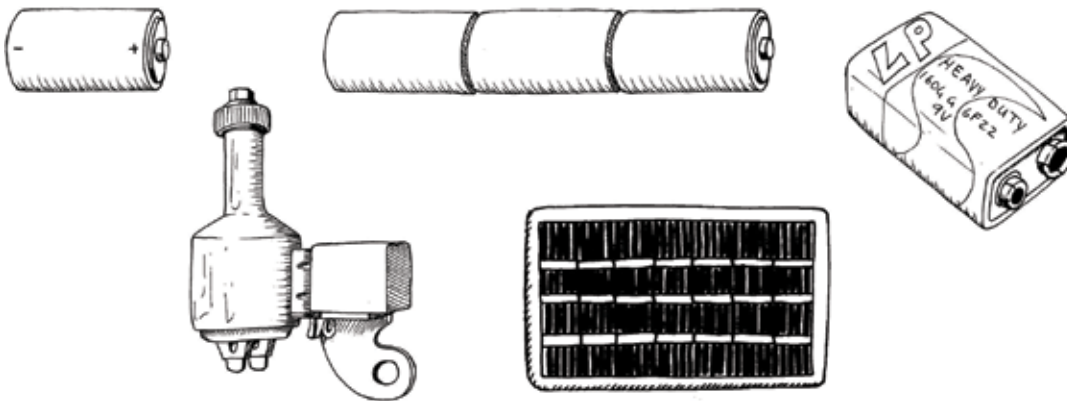


Figure 10: Input devices

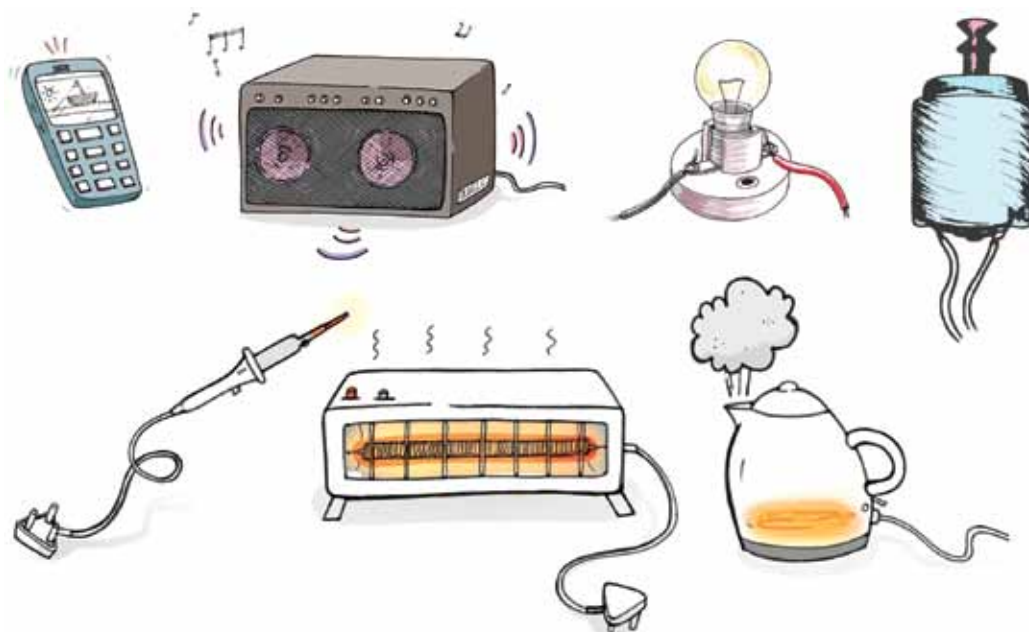


Figure 11: Output devices



Bulbs, heaters and other output devices have resistance. That means the electricity loses energy as it passes through the device, and it transfers the energy to the device. So a bulb is a resistor, and a heater element is also a resistor.

■ Output devices have resistance.

## Control devices

We want to switch circuits on and off, control how much energy output we get from a circuit, or control how much current flows in certain parts of the circuit. We can do this with the use of control devices. Examples of control devices are switches, dimmer-switches and resistors.

You have seen a light-switch on the wall of a room. That type of switch is called a “rocker switch”. A “press switch” is used for doorbells. It completes the circuit only while you press it in. A “slide switch” is used for table lamps.

A “dimmer switch” lets you control the brightness of the lights in a room. A dimmer switch uses a resistor that allows you to control the current by twisting a knob. This is called a **variable** resistor.

To “vary” means to change, so this device is called a **variable** resistor.

Some resistors are not variable, and they have a fixed (unchanging) resistance. When you design a circuit, you can choose a resistor with the right amount of resistance to control the current in a part of the circuit.

In Grade 9, you will learn about more types of control devices.

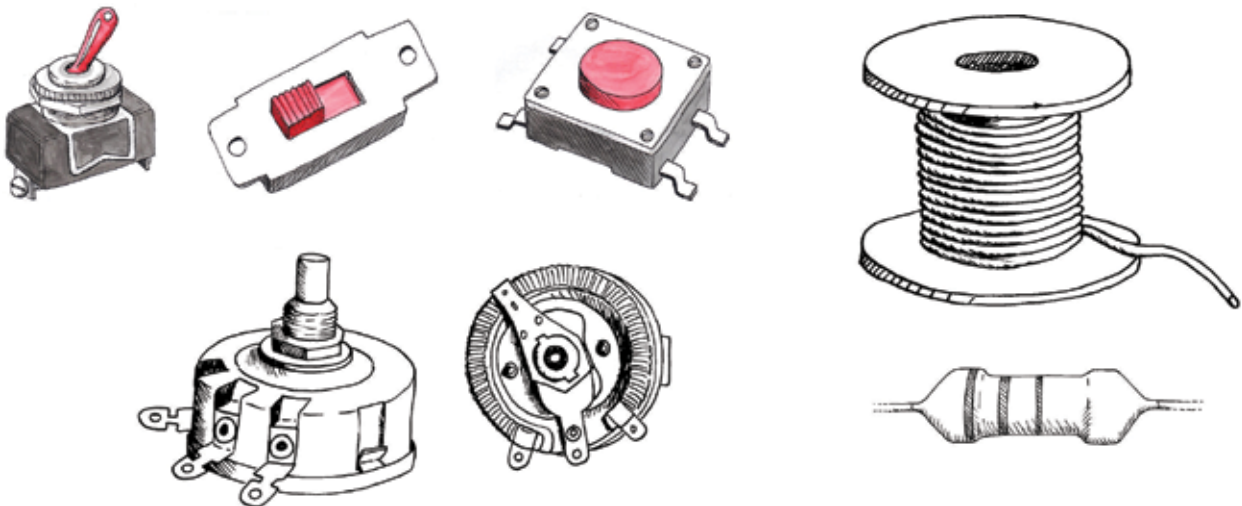


Figure 12: Control devices

## Design and make a switch – different types of switches

A switch has a gap where the conductors do not make contact.

- When you press the switch, you complete the circuit and the current can flow through. You have **closed** the switch.
- When you move the switch to break the circuit, you have **opened** the switch.

To switch on a circuit, you **close** the switch. To switch off a circuit, you **open** the switch.

**For this activity, you will need:**

- a circuit with a battery,
- an output device such as a bulb, beeper or motor, and
- the materials and tools you need to make a switch.

1. Design and make your switch.
2. Test your switch.

Different switches can work in different ways, for example the switch can:

- close only while you press it,
- close and stay closed even after you remove your hand,
- close when somebody lifts up a heavy object,
- close when somebody opens a door, or
- close after a certain number of minutes.

3. Look at the ideas for switches in Figure 13. Explain how each one will work.

(a) Switch A:

.....  
.....

(b) Switch B:

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

(c) Switch C:

.....  
.....

(d) Switch D:

.....  
.....

(e) Switch E:

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

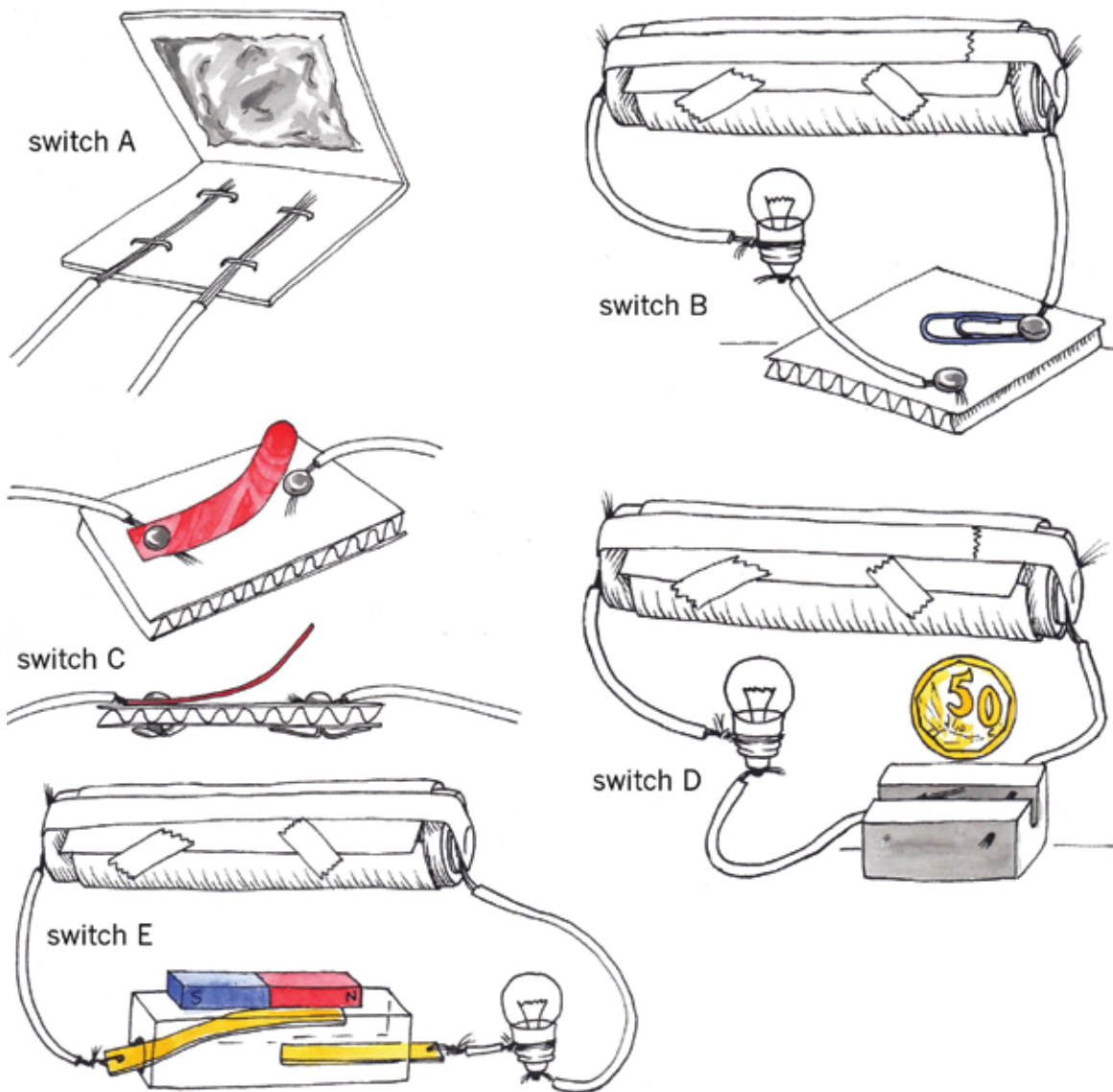
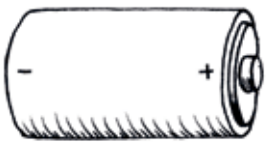


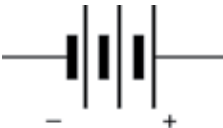
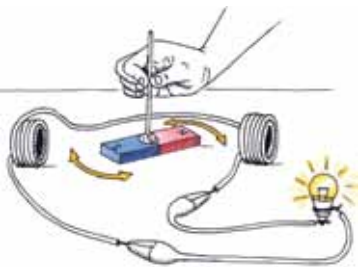


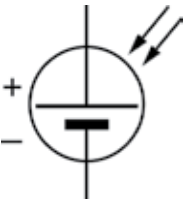




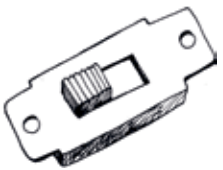

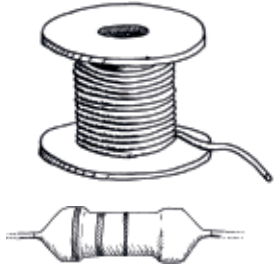
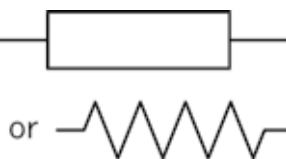
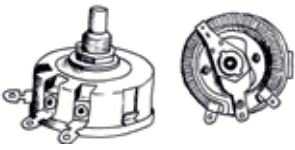
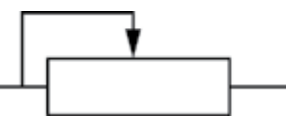

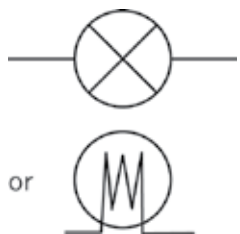
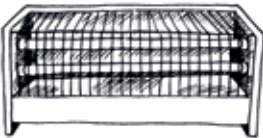





Figure 13: More ideas for making switches

## The symbols used to draw circuit diagrams

After you have worked with real electric circuits, you can start drawing them with symbols instead of trying to draw what the circuit really looks like. Engineers, scientists and technicians mostly use symbols and diagrams.

A list of symbols for different electrical components is given on the following two pages. In Grade 9, you will learn the symbols for even more components.

Picture of the part	Symbol for the part	Name of the part
<b>Input devices</b>		
		A single cell: These cells usually give 1,5 volts.
		A battery of three cells in series, usually giving 4,5 volts.
		A generator converts rotational movement into electricity, by using a magnet and coils of copper wire.
		A photo-voltaic cell: This input device changes light energy into electricity.
		Any good conductor: Usually it is a wire or copper strip, but a fork or a coin could also be a conductor.

<b>Control devices</b>		
		a switch
		A resistor: This can be made from nichrome wire that is a weak conductor, or from graphite as in a “carbon resistor”.
		A variable resistor: Dimmer switches are variable resistors. The picture of the bottom of a variable resistor shows the coiled resistance wire inside it.
<b>Output devices</b>		
		A bulb, also called a lamp: Bulbs are also resistors.
		A heater: The resistance wire in a heater gets hot when electrical current flows through it.
		A buzzer or a beeper produces sound as an output.
		An electric motor: It converts electrical energy into rotational movement. It is similar to a generator, but works in reverse.

---

## Homework: Revision

1. Draw the circuit diagram for Figure 4 below:



2. Draw the circuit diagram for Figure 6 below, but show a beeper connected in parallel with a bulb instead of two bulbs in parallel.



---

## Next week

Next week, you will learn about different energy sources that people use to provide them with heat and light.

# CHAPTER 8

## Energy supply for the people

In Chapter 7, you learnt about electrical circuits and electrical components. You also learnt about the international signs that are used to draw diagrams for these circuits.

In this chapter, you will learn more about the practical aspects of electricity and how it affects people, particularly in informal settlements and rural areas. You will learn what different sources of energy are used for heating, lighting and cooking, and how illegal electricity connections cause problems for the country.

Lastly you will discuss how our country needs to provide access to electricity for households, industries and buildings such as schools and hospitals. You will write a report on this topic.

8.1	Energy usage in rural and informal settlements .....	140
8.2	Unsafe and illegal electricity connections .....	148
8.3	Sharing electricity fairly.....	152

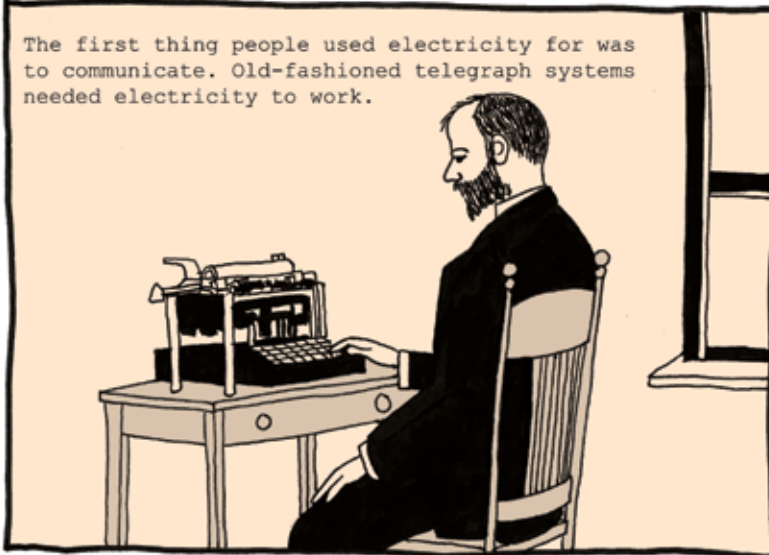


Figure 1: Pylons that carry the country's main electricity supply

There was a time when absolutely no-one in South Africa had electricity. A hundred years ago, even the President used candles for light and a coal stove to cook food.



The first thing people used electricity for was to communicate. Old-fashioned telegraph systems needed electricity to work.



It was convenient, because the telegraph made it possible for people to send messages over long distances.

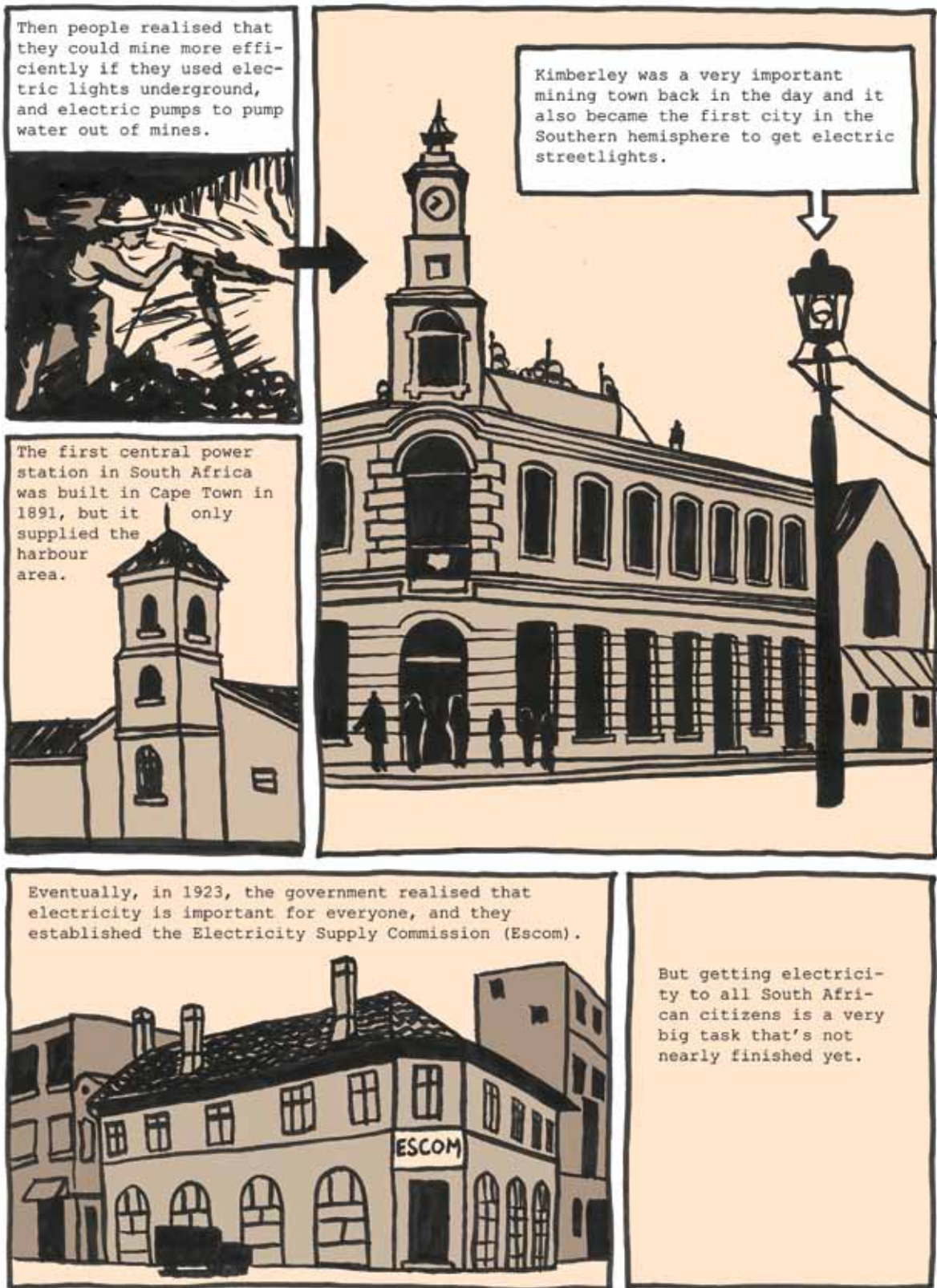


After that, people started to light up public buildings with electric lights. Cape Town Station was the first public building in South Africa to use electric lighting, and it was safe and convenient.



Figure 2





---

## 8.1 Energy usage in rural and informal settlements

### Before electricity: Clever ways of finding and using energy

In earlier times, before the introduction of electricity, communities made clever plans to get light and heat – aspects of life that modern humans, entirely dependent on various forms of electricity, simply take for granted. Let's see what communities in our country used for fuel and lighting before the advent of electricity.

African smiths discovered how to produce high temperatures in their village furnaces by burning wood. In these furnaces, they manufactured steel for weapons and implements. The furnaces date back over 2 000 years. Wood from the indigenous *acacia robusta* tree, which is particularly hard and therefore smoulders when it is lit, was used in these Iron-age furnaces. The same wood was also used for cooking fires and for lighting purposes.

Early “ovens” that were created by digging large holes and lining them with dung and other heat-retaining substances, were also used thousands of years ago.



Figure 3: A pit fire

## Energy for heating, lighting and cooking in rural and informal settlements in the late twentieth century

Electricity was introduced in the country early in the twentieth century, but was mainly allocated to cities and industrial areas. As the century progressed, electricity reached more populated areas, but rural and informal settlements were still mostly not connected. As late as 1994, only 1% of rural households had access to electricity! Other methods had to be used.

### Heating

Coal and charcoal were the fuels mainly used for heating in the absence of firewood. Wood was cheaper than coal, but it was harder to obtain because the areas around the settlements had been stripped by earlier inhabitants.

Another source of energy was gas, but this was also expensive, and needed special equipment such as gas bottles and factory-made **elements** to heat the houses and shacks.

Paraffin was another popular source of energy because it was easy to obtain and the heaters that burnt paraffin could be bought quite cheaply. But paraffin has safety concerns, which you will look at later in this chapter.

A heating **element** converts electricity to heat through resistance encountered in the material the element is made of. When gas is used, the burning gas heats the element, which retains and radiates heat.

### Lighting

Lighting is a necessity in daily life. Imagine trying to do your homework in the dark! By 1994, candles were still the main source of lighting in rural areas. Eighty-two per cent of households relied on candles to provide lighting after dark.

Lights using paraffin as a fuel source made up most of the balance – nearly 17% of the households. People who used gas for cooking could also use the gas for lighting, and a few households relied on their wood and coal fires to provide light. Gas, wood and coal were not very efficient.

A very small number of people could use electricity: almost less than 1% of the population of informal settlements.

### Cooking

Paraffin was the fuel mostly used for cooking in informal settlements: over 90% of the people used paraffin cookers. Wood-burning and coal-burning stoves were used by almost all of the other households, with gas only occasionally being used for cooking.

Even though some areas were supplied with electricity, less than half of these people used it to cook. Stoves and electrical appliances were too expensive for most people living in informal settlements.



Figure 4: A paraffin stove

### **Fire risks due to open fires as a source of energy**

Open flames are always dangerous. Informal settlement housing is normally built from materials that burn easily, and the shacks and houses are often built very close together. People without electricity who are forced to use fire for heating, lighting and cooking have to be extremely careful. Carelessness can cause major fires. When a major fire occurs, emergency services have difficulty putting it out since there are no access roads for their fire engines or water points for their hoses. But due to the lack of basic services, such as electricity, people opt for the use of alternative, often dangerous, energy sources out of necessity.

A rural settlement is far away from any towns, cities or big industries, such as mines. An informal settlement consists of temporary houses for people who moved closer to a town, city or industry, usually to find work.

Rural settlements are often far away from power stations, as well as from towns and cities where there are already electricity transmission lines. It is expensive to build electricity transmission lines to far-away places. It also takes times to plan and build them.

Some people in rural settlements cannot afford to pay for electricity.

Informal settlements are usually built very quickly and without planning, so there is no time to plan or build electricity transmission lines before the people move there.

Some people in informal settlements cannot afford to pay for electricity either.

1. Imagine you were put in charge of changing the way electricity is supplied to benefit the population of the country.
  - (a) Looking at the percentages of the population that had an electricity supply, what would your main goal be?  
.....
  - (b) Which section of the population do you think needs the most attention?  
.....
  - (c) Write four or five things that you will investigate before you decide to supply a rural or informal settlement with electricity for the first time.  
*For example: I would investigate the safety aspects of allocating electricity to informal settlements.*  
.....  
.....  
.....  
.....  
.....  
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## The present: Energy for all South Africans

The South African government announced its policy to provide free basic services to the poor in 2000, the main areas of focus being free basic water, sanitation and power supply.

Electricity is generally cheaper than traditional forms of energy such as coal, paraffin, candles and wood. Even if the direct cost of electricity is not cheaper than the direct cost of wood, the indirect savings or advantages need to be taken into account. For example, members of a rural family could spend hours gathering and chopping firewood, hours that could be spent doing something else if they had electricity.

For the government to achieve their aim, about 210 000 households a year are being connected to the **national grid** and another 10 000 a year are supplied with **renewable energy**.

Of the 12,8 million households that are electrified in South Africa, about 52 000, mostly in rural areas, are being supplied by basic solar power. This is when the sun's energy is gathered to charge batteries that are then used to power appliances.

The electricity network across South Africa is called the **national grid**. It includes power stations, power lines and substations.

**Renewable energy** is energy that comes from resources that will not run out. The sun and wind are the most common sources of renewable energy.

By 2013, 85% of the country had been given access to electricity. In 1994, only 37% of the country had electrical power, so it can be said that the government's policy is effective.

The government is also encouraging poorer people to get connected to the electricity system by offering an amount of free electricity. This is currently 50 kWh per household, per month.

## Investigate: Energy resources



Figure 5: An informal community with an electrical supply. Notice the control boxes at the top of the poles. They control how much electricity each household uses and have a built-in safety mechanism for when there is a short circuit.

Andile lives here. He plans to be an engineer and wants to find out what the people in his community need. He already knows the following:

- The people in this community pay for energy when they use vehicles such as cars, buses and taxis. The petrol is the energy resource these vehicles need.
- The people also pay for energy when they buy food to eat. Food is the energy resource they need to function.

Now he wants to ask them about the energy they use for heating their homes in winter, for cooking food and boiling water, and for light at night.

He separates the *energy resources* from the *systems* they use. For example, paraffin is an energy resource that people pay for. But they use paraffin in different systems: paraffin stoves, paraffin heaters, paraffin lamps, and even fridges that work with paraffin.

---

**Help Andile get his questionnaire ready: Individual work**

Complete the table below and on the next page by writing what you expect people living in different households will tell you about the different energy resources they use and the different systems they use them in. The first table is for households that do not have electricity, and the second table is for households that do have electricity.

You will find pictures of systems that use the energy resources in Chapter 5, Chapter 7 and in this chapter.

<b>Households without electricity</b>		
<b>I think that people will tell us about these ENERGY RESOURCES:</b>	<b>I think we will hear about these SYSTEMS and USES of the energy resources:</b>	<b>DISADVANTAGES or RISKS of using these energy resources:</b>
paraffin		
coal		
wood		
candles		
batteries		
gas		
sunlight		



<b>Households with electricity</b>		
<b>I think that people will tell us about these ENERGY RESOURCES:</b>	<b>I think we will hear about these SYSTEMS and USES of the energy resources:</b>	<b>DISADVANTAGES or RISKS of using these energy resources:</b>
paraffin		
coal		
wood		
candles		
electricity that is not supplied by batteries		
batteries		
gas		
sunlight		

---

## 8.2 Unsafe and illegal electricity connections

ESKOM and other companies generate (make) electricity and supply it to users through long wires called power lines. The users include shops, factories, mines or people who live in flats, shacks or houses. The users connect to the big power lines through thinner cables that go through metering boxes. The metering boxes measure the amount of energy used.



Figure 6: A meter that measures legal electricity usage



Figure 7: Illegal electricity connections in an informal settlement. Notice that there is no control box at the top of the pole for measuring electricity usage or for cutting off the electricity in case of a short circuit.

The electricity company needs money to buy coal, new generators, and to pay the people that maintain the generators. This is why we have to pay for electricity.

Electricity is not a cheap energy resource, which is why some people make illegal connections. Look at Figure 7. You can see the wires people have connected to an electricity pylon. These are illegal connections; the word “illegal” means “against the law”.

The law says that only a qualified electrician can connect a building to the main electricity supply from the municipality, which is called “the mains”. The mains supply electricity with an energy level of about 220 volts. This much energy is enough to kill you. This means poorly connected wires can really hurt someone and cause a short circuit that could start a fire. You learnt about short circuits in Chapter 5.

Electricians have been trained to make proper and safe connections, and know how to connect the mains to the metering box. However, there are people who think they know how to work with electricity, and they connect wires to the mains on their own. Since this is illegal they don’t connect a metering box. They will often use bare wire, without any insulation, that hangs in trees or lies on the ground. They leave wires where they can easily come into contact with corrugated zinc-iron walls and roofs, or gates and fences, or be cut by metal window-frames. They forget or don’t know that all these metal objects can become conductors that will carry 220 volts of electricity if they come into contact with the illegal live wires from the mains. These connections can easily cause short circuits that often cause fires in shacks and houses.

## The price of stolen electricity



Figure 8: An electrical substation. These are often targeted by electricity thieves.

Illegal connections are dangerous, and cost the whole country money! How does electricity theft affect the following groups of people, and what actions can they take to help stop this crime?

This is a discussion task. Work in groups of three or four.

1. The community:

(a) How are they affected by electricity theft?

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.....  
.....

(b) What actions can they take to help prevent electricity theft?

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2. Schools:

(a) How are they affected by electricity theft?

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(b) What actions can they take to help prevent electricity theft?

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3. The government.

(a) How are they affected by electricity theft?

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(b) What actions can they take to help prevent electricity theft?

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## 8.3 Sharing electricity fairly

In section 8.1, you learnt how South Africa’s government is improving the electricity supply so that more people can have access to electricity in their homes.

Electricity has to be generated by ESKOM, and they not only have to supply individual households, but also tend to the whole country’s electricity needs. As you know, some systems are targeted by thieves, such as street lights and traffic lights. These are municipal systems. Who else requires electricity?

### Consumers of electricity

Work with a classmate on this exercise.

- Try to think of every situation where electricity is required by users in South Africa.
- Think about transport, manufacturing and private users.
- Think about “hidden situations” where electricity is used, such as pumping water to households.
- Does your school use electricity?

Examples are given below to guide you.

User	Item
Railways	Electrical trains
	Stations
Hospitals	Lighting
	Machines
Factories	
Mines	
Shops	

As a class, discuss the sharing of resources in the country. Use your lists to discuss the following points. Appoint someone to make notes on the blackboard. These are some of the topics you need to cover, but you must discuss the use of electricity in depth, so add other discussion points as they arise:

- Who do you think is the greatest user of electricity in the country?
- Which group of people need electricity the most? (For example, do you think factories are more important than households?)
- Do you think that the supply of electricity affects job creation in South Africa?
- Who would suffer the most if there was a power failure for a long period of time?
- Are informal settlements ready for electricity supply?
- What steps should be taken against people who steal electricity by using illegal connections?
- What safe alternative energy sources do you think can be used where national grid electricity is not available?

During and at the end of the discussion, make notes based on the points the class has raised. You can use these notes as references to help you in the next section.

Your notes:

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## Write a report on electricity usage in South Africa

Write a report in the space below on what you have learnt about electricity usage in the country. In this report, you should comment on the following topics:

- How does the availability of electricity influence the type of appliances people use in their households? Do people in households that don't have electricity have the same kind of appliances as people who do have electricity?
- How are rural and informal settlements disadvantaged by their lack of access to electricity?
- What is the impact of electricity theft and what can be done to prevent this crime?

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## Next week

In the next chapter you, will learn about batteries and photovoltaic cells.



# CHAPTER 9

## Electrochemical cells and batteries

9.1	Electrochemical cells and batteries.....	156
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9.3	Photovoltaic cells .....	163



Figure 1: Different appliances that use electrochemical cells or batteries of cells. One of these appliances also uses a photovoltaic cell. Can you tell which one?

## 9.1 Electrochemical cells and batteries

In Chapter 7, you used cells such as the one in Figure 2 below.



Figure 2

The cells have a positive terminal and a negative terminal. The positive terminal is the knob on the top of the cell and the negative terminal is the flat end of the cell. The terminals are marked + for positive and - for negative. Find the + and - marks on the cell or battery you have.

The voltage of a cell is also shown on it. Find the number on the cell or battery you have. It will be 1,5 V or 9 V. The voltage is the amount of energy that the cell can give to the electricity.

In Natural Sciences this year, you will learn about chemical reactions. An “electrochemical cell” uses chemical reactions between substances inside the cell to give energy to electricity.

### What is inside a cell?

You can buy two types of electrochemical cells. The pictures below are called “cut-away diagrams”. The cell is drawn as if the outer covering has been cut away to show you the inside.

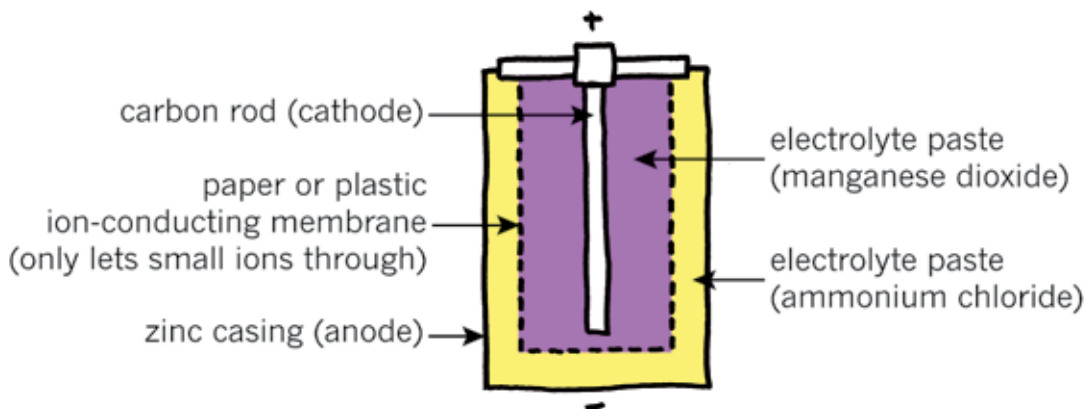


Figure 3: A zinc-carbon cell

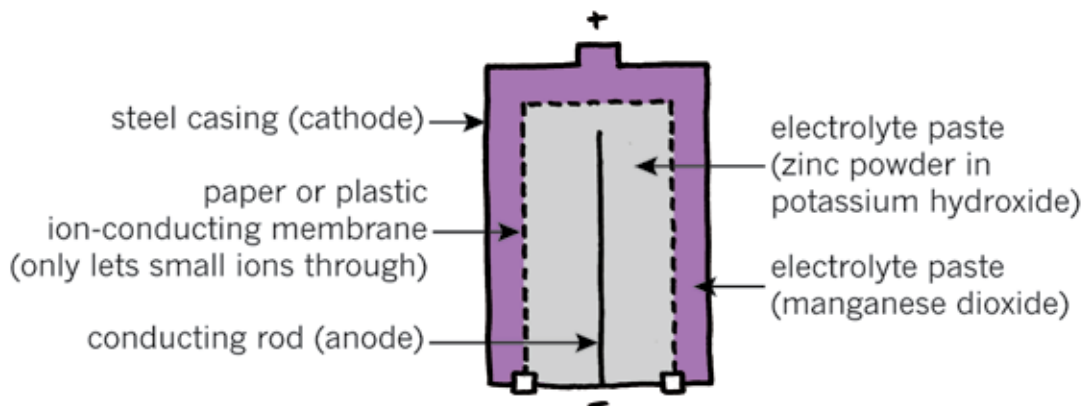


Figure 4: An alkaline cell

The zinc-carbon cell in Figure 3 is a less expensive kind of cell that does not last as long as an alkaline cell. Both types of cells have a “positive electrode” and a “negative electrode”, and these electrodes are in a syrupy substance called an “**electrolyte** paste.”

The **electrolyte** in the alkaline cell contains potassium hydroxide, which is an alkali. This is the reason for the name of the cell.

In the zinc-carbon cell, the negative electrode is made of zinc metal. This zinc has been shaped into the casing that contains the paste of electrolyte. Outside the zinc casing is a thin steel casing, which prevents you from seeing the zinc.

1. Which part of the zinc-carbon cell is the positive electrode?

.....

In the alkaline cell in Figure 4, the steel casing is the positive electrode. The knob on the top of the cell is part of the casing. The casing is usually wrapped in plastic, except for the knob at the top.

2. Which part of the alkaline cell is the negative electrode?

.....

## Make a cell and a battery

This activity has two parts. First, each team in the class will make one cell. Then all the teams will connect their cells to make a battery and light a light bulb.

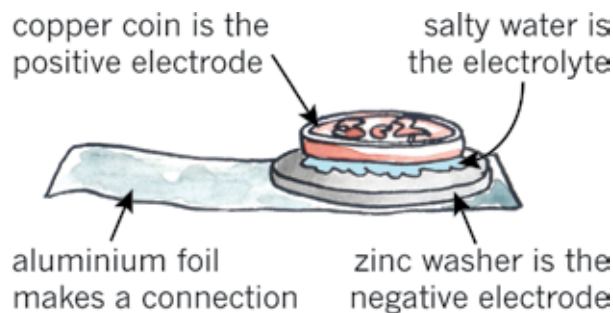


Figure 5: A home-made cell

### Each team needs:

- two 5-cent coins or pieces of copper of about the same size,
- a **galvanised** metal washer, which is a disc with a hole in the middle,
- a piece of cloth or cardboard about the same size or slightly smaller than the 5-cent coin, soaked in salty water,
- a piece of cooking foil, about the size of two fingers next to each other, and
- sticky tape.

**Galvanised** means it's coated with zinc.

### Your teacher needs:

- a voltmeter or multimeter,
- a bowl of salty water – 1 teaspoon of salt to 100 ml of water,
- a light bulb,
- a beeper that will work at 3 volts, and
- six crocodile-clip wires, three insulated with red plastic and three with black plastic.

### Part 1: Make your cell

- Fold the cooking foil lengthwise, so that you have a long piece that is double in thickness. Put it on the table. The foil is made of aluminium, which is a good conductor.
- Squeeze the salty water out of the cloth.
- Next, put the zinc washer on the foil, put the wet cloth on the washer, and put the copper coin on top of the wet cloth.
- The cloth must not hang over the zinc washer, and the salt water must not run down the sides of the coin and washer. If this happens, it will create a short circuit between the copper and zinc, which you don't want.

The zinc washer is your *negative electrode*, the copper coin is your *positive electrode*, and the salt water is your *electrolyte*.

Now you have made a cell. The cooking foil is the negative terminal where you can connect the voltmeter.

Call your teacher to measure the voltage!

### Part 2: Make a battery

Each team should bring their cells to the front table and connect the cells as seen in Figure 6 below.

You will connect six cells, but Figure 4 only shows four cells, to make the picture easier to understand.

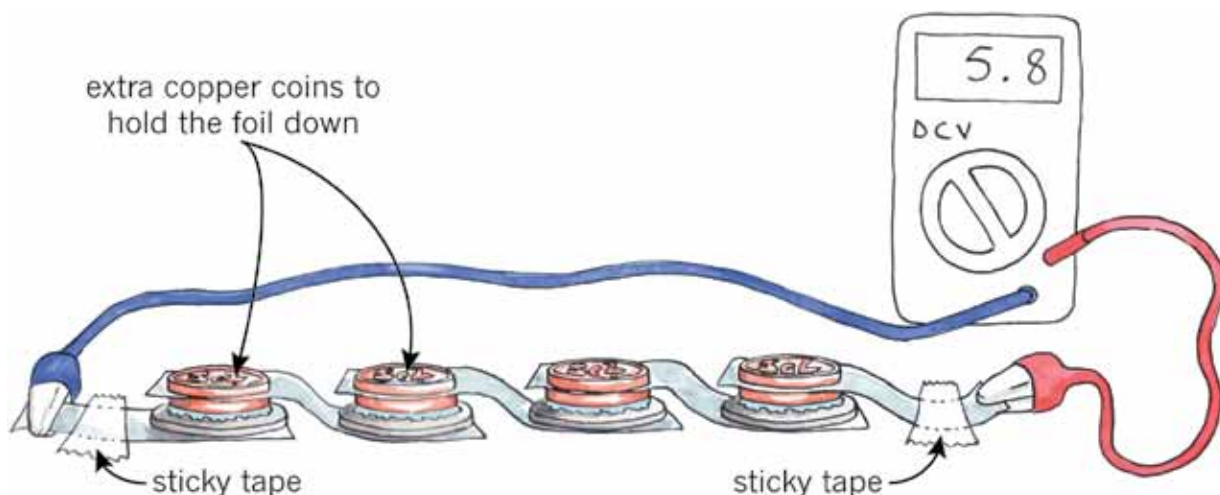


Figure 6: Connecting cells in series to make a battery

You have two 5-cent coins. The first one is the positive electrode of the cell, and the second 5-cent coin is there to press the foil down on the first coin to make good contact.

Use sticky tape to hold the cooking foil down on the table, and connect wires to the ends. The ends of the foil are your terminals.

Your teacher will measure the voltage of the whole battery. With six cells, the voltage of the battery will be about 6 volts or slightly less.

Now connect a light bulb to the positive and negative terminals of the battery. Does the light bulb glow?

Connect a beeper to the positive and negative terminals. Remember to connect the red wire to the positive terminal. Can you hear it beep?

1. What are the two different metals used for the positive and negative electrodes?

.....

2. How is the voltage of the battery different from the voltage of one cell?

.....

.....

## Batteries do not provide the full amount of volts

Before you connect the bulb or beeper, the battery has energy but it is not producing a current, and its voltage is about 5,8 V. As soon as you connect the bulb or beeper and the battery makes a current flow through the circuit, the voltage drops to about 1,8 V. This happens because the current loses a bit of its energy in the battery as it passes through the salt water and all the connections at the electrodes. You call this the “internal resistance” of the battery.

## 9.2 Rechargeable batteries

### Car batteries are rechargeable

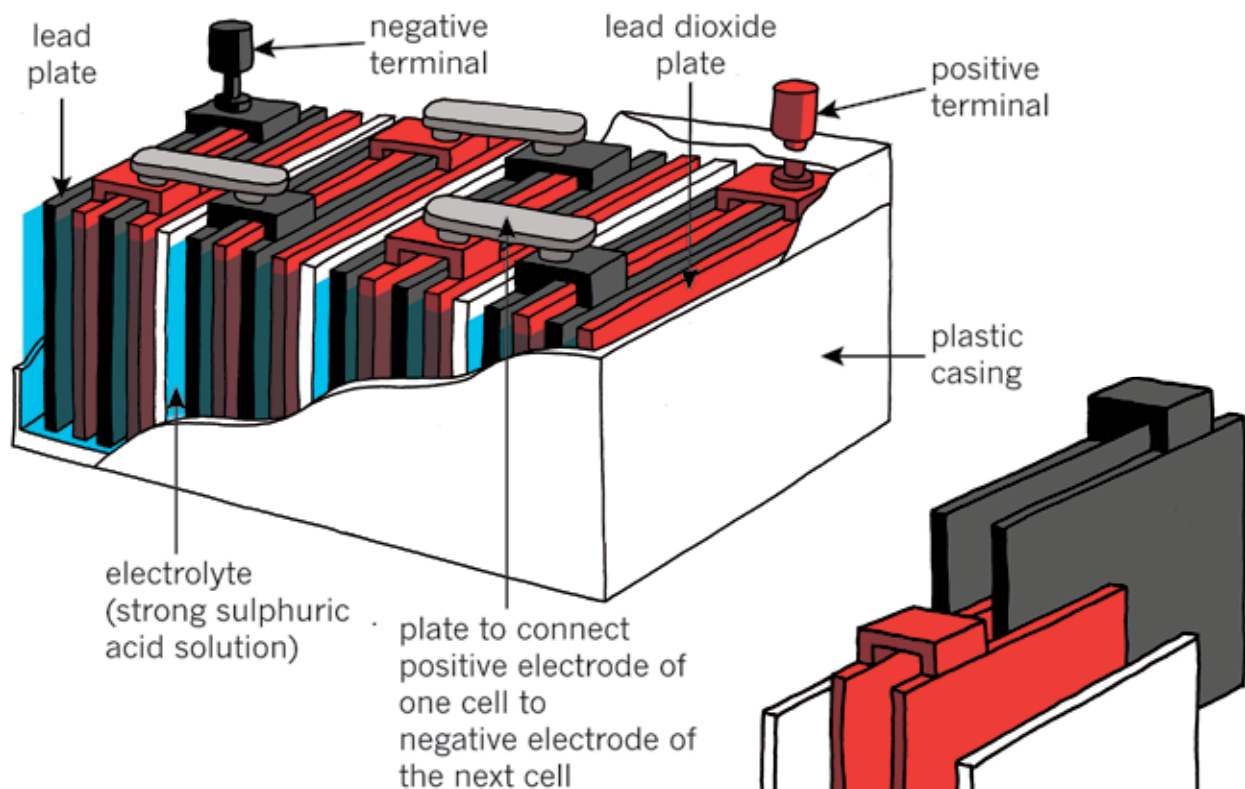


Figure 7: A car battery

Figure 8: One of the cells in a car battery, shown after it has been taken apart

Figures 7 and 8 show the inside of a car battery. The colour red is used to show the positive electrodes, and dark grey is used to show the negative electrodes. The colour blue is used to show the liquid electrolyte. The electrodes and electrolyte do not really have these colours. Everything inside a battery looks mostly grey.

A car battery has six cells and it can give energy at 12 volts. To keep the diagram in Figure 7 simple, only four cells are shown.

1. What kind of diagram is Figure 7?

.....

2. What is the positive electrode in each cell made of?

.....

3. What is the negative electrode made of?

.....

4. What kind of electrolyte is between the electrodes?

.....

5. Are the cells in a car battery in series or in parallel?

.....

6. A car needs 12 volts and a very big current to turn the starter-motor and start the engine. Sometimes, on cold mornings, a car won't start. A mechanic can test the battery, and might say "There is one dead cell in this battery". If the battery has a dead cell, what voltage will the battery give?

.....

7. On a voltmeter, the battery might show that it will give 12 volts, but when you try to start the car, it won't start. Give a possible reason why the battery is not strong enough to start the car.

.....

8. What can you measure to test your idea?

.....

A car battery is different to the cells and batteries we usually buy. When we have taken all the energy from the battery, we can recharge the battery and give it energy again. A motor car has a "generator" or "alternator" that takes energy from the engine and gives it to the battery while you drive the car. You will learn about generators in the next chapter. A cell-phone battery is also a rechargeable battery.

## Batteries with cells in series or in parallel

In Chapter 7, you learnt about connecting bulbs in series or in parallel. You can also connect cells in series or in parallel. You might get confused between “bulbs in series” and “cells in series”. Look at the two figures below.

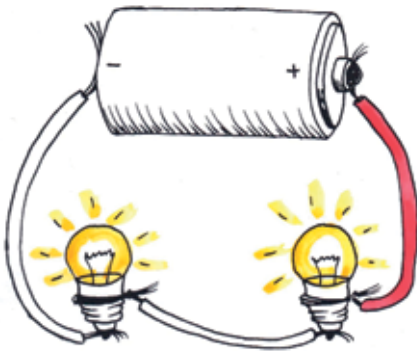


Figure 9: Bulbs in series

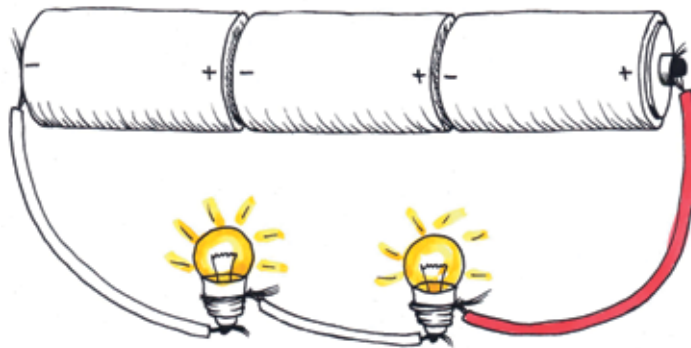


Figure 10: Cells in series

The bulbs in Figure 10 glow brighter than those in Figure 9 because they share the 4,5 V from the cells in series, so they get 2,25 V each. The bulbs in Figure 9 share the 1,5 Volts from one cell, so they get only 0,75 V each.

You might also get confused between “bulbs in parallel” (in Chapter 7) and “cells in parallel”.

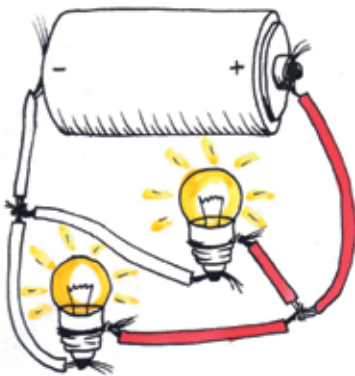


Figure 11: Bulbs in parallel

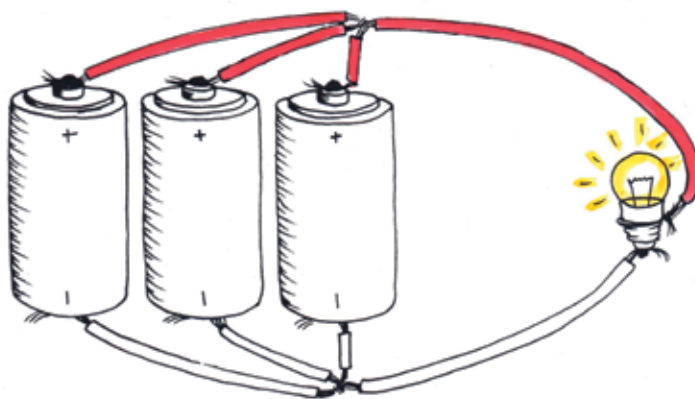


Figure 12: Cells in parallel

In Figures 11 and 12, each bulb gets 1,5 V. Therefore, the bulbs in these figures glow brighter than those in Figure 9 (0,75 V per bulb), but dimmer than those in Figure 10 (2,25 V per bulb).

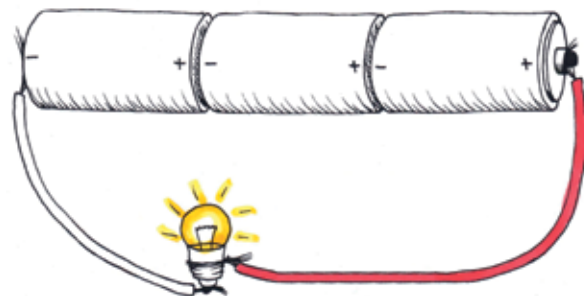


Figure 13



1. Compare the circuits in Figures 12 and 13. Each circuit has three cells and one light bulb, but the components are connected differently.

(a) In which circuit will the light bulb glow the brightest? Explain your answer.

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

(b) In which circuit will the light bulb glow for the longest amount of time before the cells are “dead” or “flat”? Explain your answer.

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

### 9.3 Photovoltaic cells

This photo shows a type of energy input device that you learnt about in Chapter 7. In this device, the energy it gives does not come from reactions between chemicals. Instead, it gives energy that comes from light. This device is called a photovoltaic cell. Photovoltaic comes from “photo” meaning “light” and “voltaic” meaning you can get volts from the device.

The black parts in this picture are a special substance called a semiconductor. This semiconductor substance is made of thin layers, like sheets of plastic laid on top of each other. When light hits these special layers, the energy of the light is given to electric charges in the layers. The positive charges gather on one side and the negative charges on the other side.

When charges are separated like this, there is potential energy between them. If you connect wires to the positive and negative sides, the charges will flow through an output device such as a bulb, beeper or motor.

People often store the electrical energy generated by photovoltaic cells in a rechargeable electrochemical battery. The photovoltaic cells generate electrical energy during the day when the sun shines, and this energy is then stored in the rechargeable battery. When it is dark at night, the photovoltaic cells do not generate any electrical energy. But then people can use the electrical energy stored in the rechargeable battery to power lights and other devices.



Figure 14: Photovoltaic cells on a pole

### Where we use photovoltaic batteries

Perhaps someone in the class has a calculator that has a little photovoltaic battery. When you hold the photovoltaic cell in sunlight, the calculator can switch on. It will work even if you move it into the shade since it has a little battery that stores the energy.



Figure 15: Photovoltaic cells in a calculator

Photovoltaic cells can be very big. They can be big enough to cover the roof of a house.

The house then gets its electricity from sunlight. You might also see photovoltaic cells outside a shop where you go to recharge your cell phone.

1. Why do you think the shop has photovoltaic cells outside instead of inside?

.....

2. On which side of the roof of a house will you put photovoltaic cells? Why?

.....

### What have you learnt?

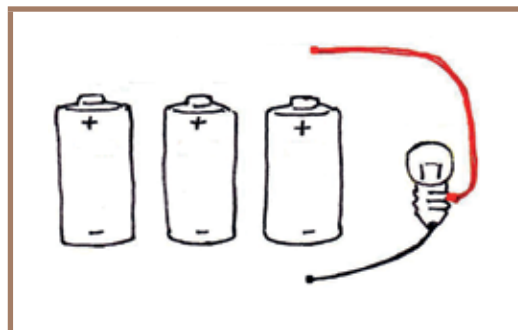
1. Complete the following sentence:

A ..... reaction inside an electrochemical cell produces ..... energy.

2. What kind of cell does *not* use chemical reactions to produce energy?

.....

3. When you connect the terminals of cells in series, you connect positive to negative to positive to negative, and so on. The cells don't have to lie head to tail. They can lie next to each other. Draw wires between the terminals of these cells to show how you would connect them in series.



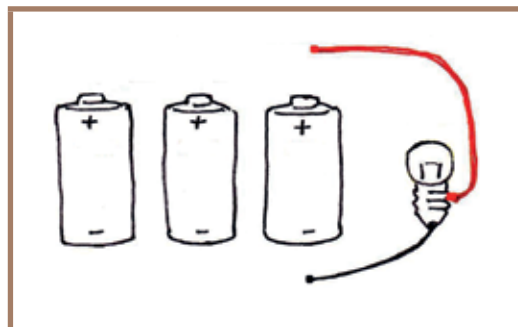
.....  
.....  
.....  
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4. If you connect the three 1,5 V cells in series, what voltage will the battery give you?

.....

5. Draw wires between the terminals of these cells to show how you would connect them in parallel.

6. If you connect the three 1,5 V cells in parallel, what voltage will the battery give you?



.....

### Something you could try at home

You can make a cell using a lemon or a potato, with a piece of zinc-coated metal and a piece of copper. These cells work in the same way as the cell you made in Figure 5. The lemon or the potato plays the same role as the piece of cloth or cardboard soaked in salty water. They

are electrolytes through which certain small ions can move to complete the circuit. They are also membranes that prevent other, bigger ion, such as the metal ion, from moving from one electrode to the other.

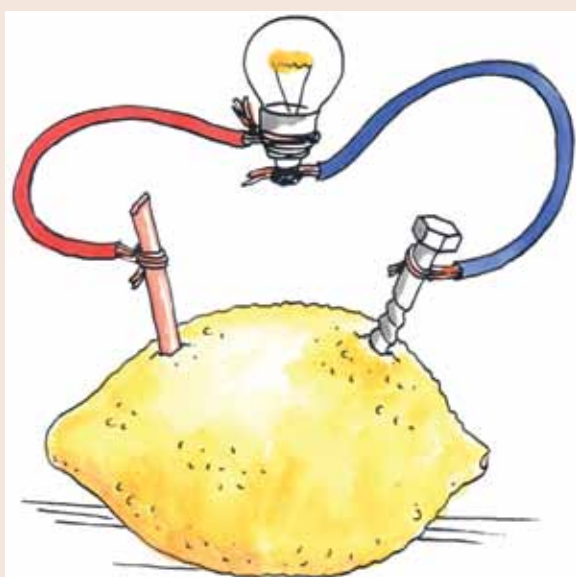


Figure 16: A cell made using a lemon

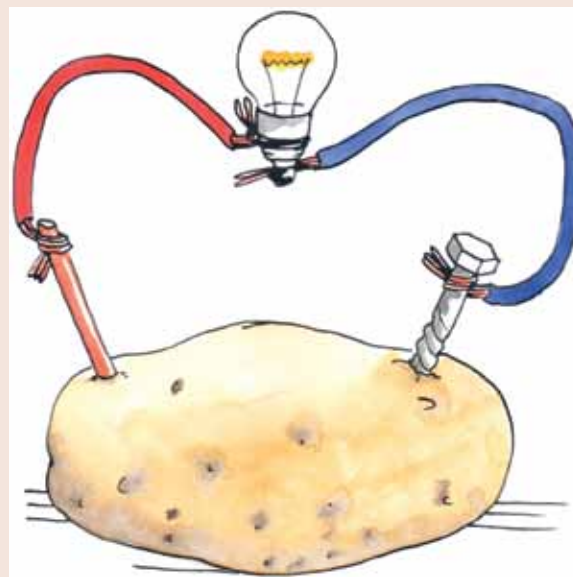


Figure 17: A cell made using a potato

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## Next week

Next week, you will learn how electricity is generated and distributed around the country, and about the environmental and social impact of electricity generation.

Read about where electricity comes from in Grade 8 Book 1 Chapter 10, on pages 141 to 148. The environmental impact of burning coal and other fuels is also discussed there.

# CHAPTER 10

## Generating electricity for the nation

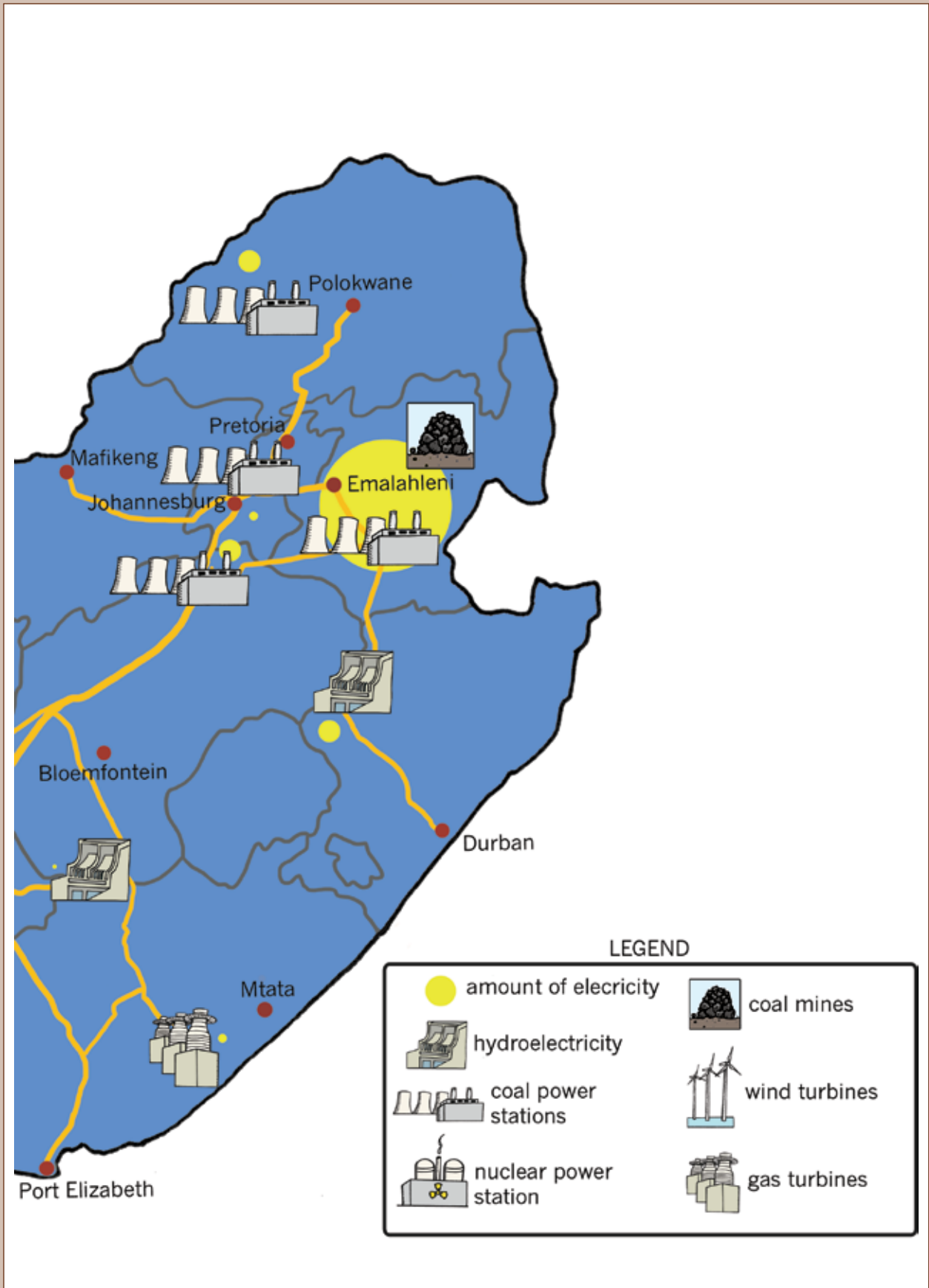
In this chapter, you will learn about the various ways in which electricity is generated in different types of power stations. You will also compare the advantages and disadvantages of different types of power stations.

You will learn how electricity is distributed from the power stations to different parts of the country, to reach the people who use it.

10.1 How electricity is generated in coal-power stations .....	170
10.2 Other types of power stations .....	175
10.3 Transmission of electricity across the country .....	185



Figure 1: The locations of different types of power stations across the country



## 10.1 How electricity is generated in coal-power stations

When you switch a light on, where does the energy in the bulb come from? You can control the energy with a switch, but what is behind the switch?

In this chapter, you will find the answer to these questions, and find out where the power is generated. Before you investigate the country's electricity supply, you will look at the ways electricity can be generated, and how this affects your daily life.

South Africa uses many power stations for its electricity supply. There are different types of power stations: coal, nuclear, hydroelectric, gas, wind and solar. Figure 1 shows where in South Africa these different types of power stations are located.

There are no solar-power stations in South Africa yet, but plans are in progress to start building it.

You will start this week by learning about coal-power stations for two reasons:

- Most of the electricity in the country, about 85%, is generated by coal-power stations.
- Coal-power stations use the technologies of generators and turbines that are also used in most other types of power stations.

### Generators

There are three main systems that give us energy for lights, computers, cell phones and all other electrical appliances. You can get energy from batteries, photo-voltaic panels and generators.

The main source of electricity in South Africa comes from large generators. These work exactly the same as any small generator you might come across. It is important to understand how a generator works as it is used in most types of power stations.

#### How a generator works

If you move a magnet near a coil of wire, you will create a voltage across the copper wire. Look at Figure 2.

If you connect a bulb across the ends of the wire, a current will flow around the circuit. To make the current bigger, you can use more copper wire in the coils, use a stronger magnet, or move the magnet faster.

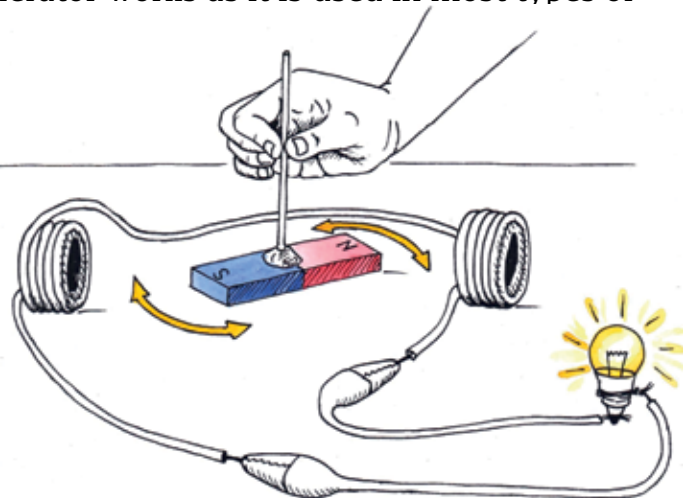


Figure 2: A home-made generator



If the person in the picture leaves the magnet on the table, how much current will flow in the circuit? Your answer can be “a big current”, “no current” or “a small current”. Give a reason for your answer.

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

Now look at the girl on the bicycle. She is pedalling fast and has a generator connected to the back wheel of her bicycle. A bicycle generator is also called a “dynamo”.

The dynamo gives energy to the lamp only when the roller is spinning. The girl on the bicycle has to pedal faster than usual since she is transferring some of her energy to the dynamo, which not only makes her wheels move, but also lights the lamp.



Figure 3: The dynamo on a bicycle

If you open a dynamo, you will see that it has copper coils similar to the drawing in Figure 2. As the girl pedals, the copper coils spin inside the magnets, and this movement generates electricity.



Figure 4: A bicycle dynamo and light attachment



Figure 5: The exposed copper coils in a dynamo

Power stations have big dynamos called generators. They work exactly the same way as the dynamo in the pictures above but are much, much bigger! They also require a lot more energy to turn than only one person pedalling. In the next section, you will learn the various ways energy is provided to these big dynamos.

## Thermal power stations

Thermal means “caused by heat”. In thermal power stations, turbines are driven by steam. The steam is formed by evaporating water through a source of heat. The water is heated to form high-pressure steam by using a heat source such as burning coal or gas, nuclear reactions, or light from the sun. The water is turned into steam that drives a turbine, which makes an electrical generator turn. An electrical generator can also be called an “alternator”. After the steam has been used, it is cooled down so that the water can be used again.

Most of the world’s energy comes from burning **fossil fuels** such as coal, oil or natural gas. This results in high levels of air pollution, particularly from greenhouse gases that contribute to climate change. Fossil fuels will run out in the future.

**Fossil fuels** are carbon-based fuels that are taken from the earth, and are made of the remains of living things that died millions of years ago.

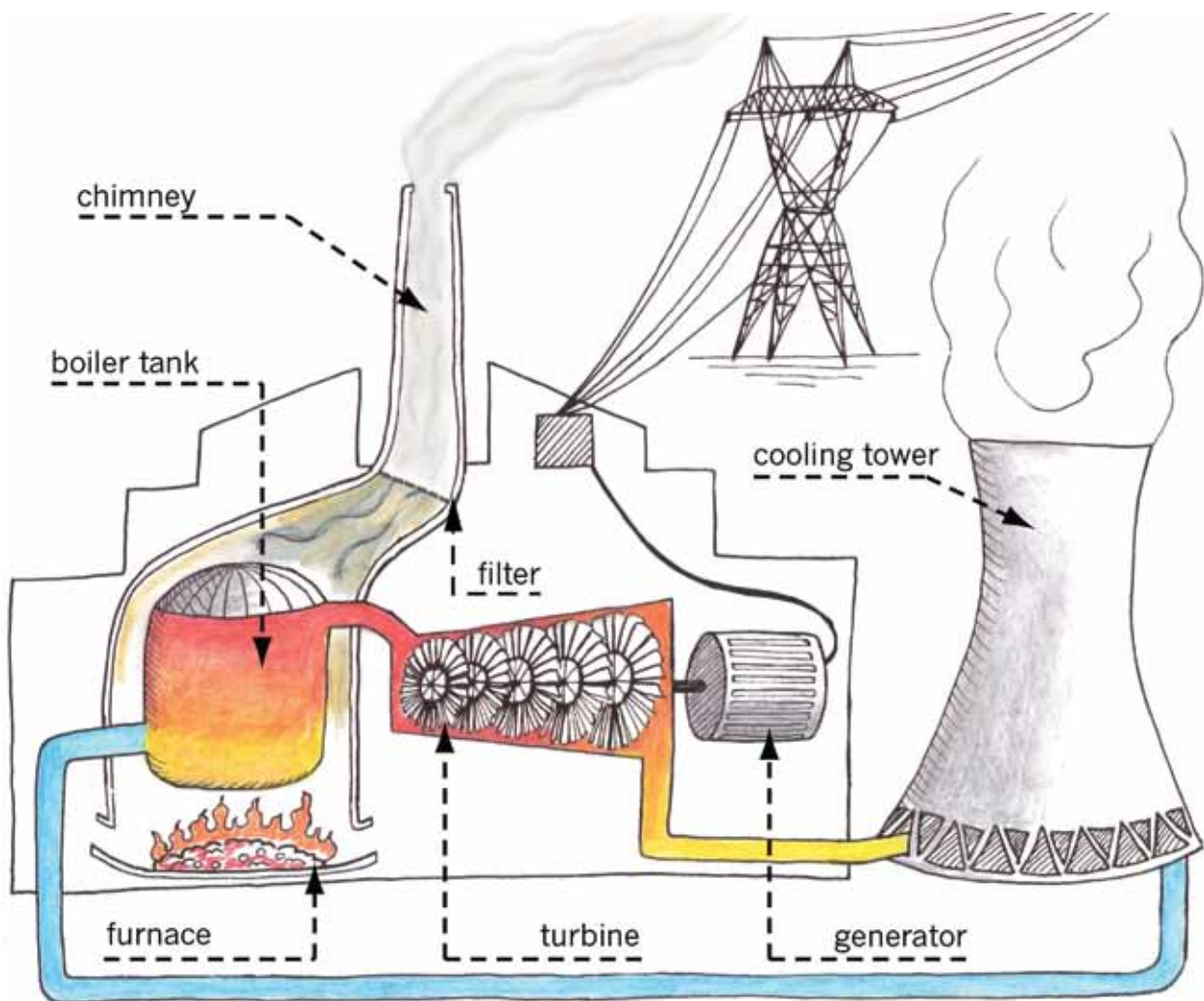


Figure 6: A coal-fired power station

## Coal-fired power stations

The energy conversion process starts with the burning of coal that generates heat to convert water into steam at a very high temperature and pressure. The heat and pressure energy contained in the steam is used to drive the turbines, converting it into a rotational movement, in other words kinetic energy. You saw an example of this with the bicycle dynamo – it is exactly the same process. There is a generator attached to the turbine shaft.

- **Reasons for using coal as an energy source**

For centuries, coal was the only fuel source available in large quantities. Power stations were built near coal mines so that coal did not have to be transported over long distances.

Most of the coal-fired power stations in South Africa are found in Mpumalanga where huge coal deposits were discovered. Coal-power stations are the cheapest way to generate electricity. It is even cheaper in South Africa since the coal here is close to the surface and therefore easy to mine.

- **Impact on the environment**

Burning fossil fuels creates air pollution due to the carbon dioxide that is emitted during the process. The fires needed to produce steam from water emit a lot of carbon dioxide into the air, a lot more than a wood or coal fire in your home does. Coal has been used for centuries to generate heat.

Sulphur dioxide and nitrogen oxide are two other gases emitted from coal-fired power stations that have a negative impact on the environment. Newer power stations use specific technologies to trap these gases so that they are not released into the atmosphere. In the past, when these two gases were released from coal-fired power stations, they caused “acid rain”. Acid rain is rain that contains high levels of sulphuric or nitric acid, caused by the water mixing with sulphur dioxide and nitrogen oxide.

Scientists and engineers are working on plans to capture carbon dioxide and store it underground, but this is expensive and has not yet been done on a large scale anywhere in the world.

---

## Questions on coal-fired power stations

1. Write what you see as the positive and negative aspects of using this type of fossil fuel to generate electricity.

Positive	Negative

2. What is the energy source mainly used in South Africa for conversion into electrical energy?

.....

3. Why do you think the energy source in question 2 above is not the ideal energy source to be used?

.....

.....

---

## 10.2 Other types of power stations

Your teacher will divide the class into five groups, A to E. Each group will do the reading and questions for only one other type of power station. **Work individually.**

### Topic A: Gas-turbine power stations

As an alternative to coal, the water in a power station can be turned into high-pressure steam using burning gas. Gas is also a fossil fuel, and is normally found underground in areas where coal or oil is present.

Gas turbines in South Africa are equipped to burn a variety of fuels, ranging from oil to gas. Gas turbines have advantages over coal-burning power stations because of their design. Maintenance is done considerably faster, resulting in continuous availability of power.

The **national grid** is the network of transmission lines that are connected and supplied by all the power stations in the country.

Gas turbines are also capable of being started without an outside power source, which is very important. If the **national grid** had to suffer a complete breakdown, the gas turbines can be started and will generate power to start the other power stations.

There are four gas-turbine power stations in South Africa.



Figure 7: A gas-turbine power station

### The future of gas turbines

South Africa has only recently started using gas for power stations so there is still a supply that will last for many years. Two of the new gas-turbine power stations, Ankerlig in Atlantis, and Gourikwa in Mossel Bay, both in the Western Cape, are going to double the size of their generators in the next few years, adding a lot of power to the national grid.

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### Reasons for using this type of energy source

As explained earlier, the ability to start a power station without power from the same network is very important for the national grid. There is still plenty of gas available in the world, however, in South Africa only small amounts can be mined. After pipes have been placed into a **gas field** it will supply the power station without needing to be mined or transported.

A **gas field** is an underground area where organic matter has decayed to form large pockets of gas trapped by layers of rock.

### Impact on the environment

Burning gas produces much less sulphur dioxide, nitrogen oxide and ash than burning coal. But it is a fossil fuel, so it still produces carbon dioxide pollution.

Do you think gas-burning power stations will have a big impact on generating electricity in South Africa?

### Questions on gas-turbine power stations

1. Write down the positive and negative impacts you think burning gas for electricity will have.

Positive	Negative

## Topic B: Nuclear power stations



Figure 8: A nuclear power station

There is a nuclear power station, called Koeberg, close to Cape Town.

Unlike gas-burning or coal-burning power stations, a nuclear power station operates using three separate water systems. One of the biggest fears that people have about nuclear power stations is that **radioactive** material might escape and pollute the air of nearby areas.

It is very important for the three systems to be separate. The first system, the radioactive water in the reactor, is in a closed system. It does not come into contact with the other two systems and therefore does not contaminate the water in these systems. The second water system cools down the radioactive steam that has driven the turbines. It flows through the condensers where the third water system cools the steam back into water. The first water system circulates back to the steam generator where it is turned into steam again.

The third cooling system for the condensers uses sea water at a rate of 80 tons per second to cool the steam. After it has cooled down, the steam is returned to the sea.

**Radioactive** substances give off energy that is dangerous to living things. It can cause cancer and other health risks, so it is important that people are shielded from radioactive material.

---

- **Reasons for using this type of energy source**

Many places don't have a supply of fossil fuels to power generators. Small amounts of nuclear fuel can generate enormous amounts of electricity.

Nuclear-power stations require very little maintenance. Because the water used in the first system is recycled, there is very little waste of precious water. The cooling water is unpolluted and returned to the sea.

- **Impact on the environment**

Radioactive material creates radioactive waste, which is extremely dangerous. Although the amount of waste is very small, it remains active and dangerous for many thousands of years! There is currently no long-term solution for the safe storage of radioactive waste. The best solution at the moment is to put it in very thick layers of concrete and lead, and bury it where no one is likely to dig it up. Many countries do not use nuclear fuel for power since they are concerned that even the buried waste will harm the environment. Nuclear power has been used around the world since the 1950s as an alternative source of energy.

### Question on nuclear-power stations

1. List the positive and negative aspects of this type of energy in the table below.

Positive	Negative



## Topic C: Solar power

Solar power means that the heat and light of the sun is used as a source of energy. Solar energy is a realistic option in South Africa since it is such a sunny country. South Africa experiences more sunshine than most places in the world, and there is a lot of potential for the widespread use of solar power. Solar power would be a very good idea in low-income housing projects, but the initial cost of solar energy is very high as large areas of **solar panels** are needed.

**Solar panels**, or photovoltaic cells, convert sunlight to electricity.

Solar energy is a very good alternative for areas that are far away from the national grid, such as farms, rural clinics and water-pumping stations. In these cases, heat can be produced to power generators or photovoltaic cells can be used to produce electricity directly from sunlight. South Africa does not have a solar-powered plant yet, but ESKOM is currently constructing a solar-powered plant in Northern Cape. To help you understand how this will work, look at Figure 9 below that shows how mirrors and sunlight can be used to heat up a can of water.

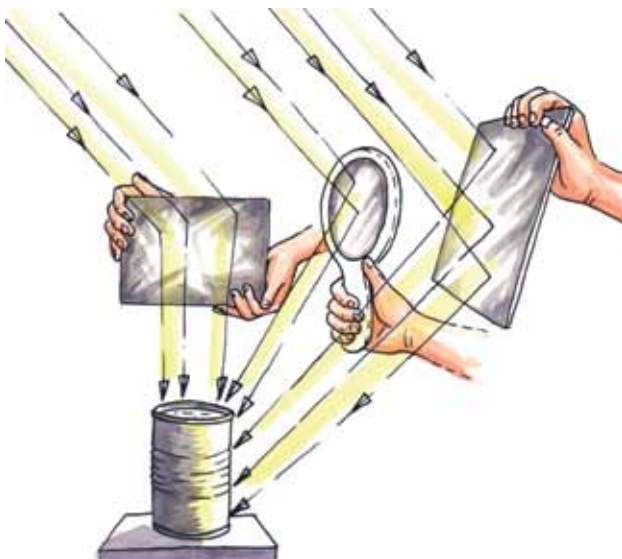


Figure 9: Solar power used to heat water in a tin can.



Figure 10: Mirrors in a solar-powered power station focus light onto heating towers.

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### How does a steam-driven solar-power station work?

The solar-power station shown in Figure 10 has thousands of large mirrors, known as “heliostats”, that move to follow the sun and reflect the heat to a point on a tower. Salt water is pumped up the central tower, where it is heated to approximately 600 °C. This water is then used to generate steam. The steam is used in the same way as it is in a coal-power station to generate electricity.

- **Reasons for using this type of energy source**

Solar energy is a realistic option in any sunny country. Solar energy can be used in areas far away from the national grid and can be set up to provide power for smaller communities.

We could take the pressure off South Africa’s largely coal-based energy supply by using solar power. This would also give the country a larger overall energy capacity and help us to achieve our target of a 34% reduction in carbon-dioxide emissions by 2020.

- **Impact on the environment**

Solar power produces no pollution. However, the power stations can take up a lot of space due to the large mirrors. They could be regarded as visual pollution.

### Question on solar-power stations

1. Write the positive and negative aspects of using solar power to generate electricity in the table below.

Positive	Negative

## Topic D: Hydroelectric-power generation

The flow of water can be used instead of steam to drive turbines. In hydroelectric-power stations, the potential energy of water stored in a dam is converted into electrical energy. There are two different types of hydroelectric-power stations.

- A simple hydroelectric-power station uses the downwards flow of water to generate electricity.
- A hydroelectric-pumped storage scheme can also pump water back into the dam during times when there is electricity from other power stations that is not being used. Such a scheme plays the role of a rechargeable battery, as it stores electricity when it is not being used. It can also be used in the same way as a simple hydroelectric-power station to generate electricity, by letting water flow downwards out of the dam.

Hydroelectricity is renewable and does not pollute the environment. Large-scale hydroelectric schemes are, however, expensive and require the construction of large dams that have an impact on the environment and communities. Imagine you lived along a river, and you were ordered to move because a hydroelectric dam was to be built there. How would you feel about it?

Hydroelectric-power stations are able to come on line within three minutes. They are therefore convenient to use during times of the day when there is a very high demand for electricity, when this demand is more than the other power stations can provide.

Unfortunately, due to South Africa's limited water resources, only a small amount of electricity can be generated by hydroelectric-power stations.

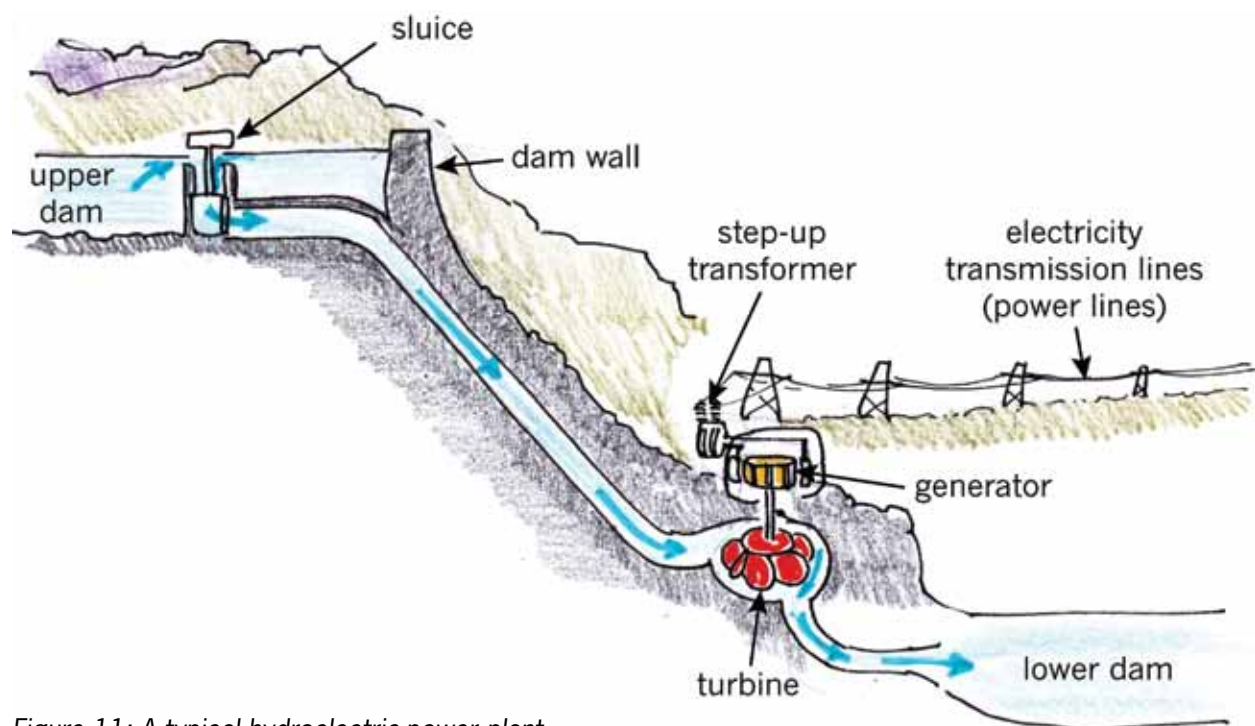


Figure 11: A typical hydroelectric-power plant

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- **Reasons for using this type of energy source**

It is a renewable energy source and can be used to ensure the country has enough electricity during periods of high electricity consumption. Hydroelectric-power stations are cheap to operate, even cheaper than coal-fired power stations.

- **Impact on the environment**

Dams and waterways need to be constructed for a hydroelectric-power station. It may be cheap to produce the electricity once the dam is completed, but the costs of building a dam are enormous, and the impact on the countryside can be severe.

An environmental impact plan must be in place, and communities that could be affected have to be taken into consideration. Some people may even have to move because their houses and farms are located where the dam will be built.

### Question on hydroelectric-power stations

1. In the table below, write down the positive and negative aspects of a hydroelectric-power station.

Positive	Negative

## Topic E: Wind turbines

For thousands of years, people have used windmills and energy derived from the wind to pump water and to grind mealies. After a breakthrough by scientists, wind can now also be used to generate electricity. Like the sun and water flowing down a river, this is a renewable energy source and does not negatively impact the environment or pollute it. Across the world, wind farms are being built. These are areas where wind is used to turn huge windmills that generate electricity.

Wind speed and direction change from day to day, depending on the weather and the season. When something changes in an unpredictable way, it is called “erratic”. The patterns of wind direction and wind speed are studied and used for electricity generation in areas that have consistent winds. This does not mean that there has to be strong winds or gales for the system to work. What is needed is a steady wind that won’t damage the machinery.

In South Africa, research on the potential of wind energy as an electricity-generating option was carried out in various places. Different ways of generating electricity through wind were studied. An important factor is cost. It doesn’t make sense to put systems in place that will make electricity too expensive to buy.

After investigating all the options, ESKOM started the Klipheuwel Windfarm Research Facility on the West Coast near Cape Town in 2002.

The generators need wind speeds of between 47 km and 57 km per hour for full power operation, but they can start generating electricity in winds as low as 11 km per hour. If a gale force wind blows, the turbines shut off automatically at winds over 90 km per hour to prevent damage to the generators.

Wind is an erratic resource that is not always available when needed.

- **Reasons for using this type of energy source**

Wind is a renewable energy source, and is particularly powerful in coastal areas. It can be used where fossil fuels are unavailable. These conditions are best along the coastlines.



Figure 12: A big new wind turbine behind a much smaller, old wind pump

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- **Impact on the environment**

While it is a clean source of energy in terms of greenhouse gases, environmental impacts can include noise, visual pollution as well as affecting birdlife. The farms need large pieces of land, which in some places can be expensive to buy.

## Questions on wind turbines

1. Do you think Eskom should build more wind turbines?

.....

2. Write down the positive and negative aspects of this form of generating electricity in the table below.

Positive	Negative

## 10.3 Transmission of electricity across the country

The electricity that power stations generate is distributed across the whole country.

The map on the next page shows the main **transmission** lines that are used to **distribute** electricity from the power stations to different parts of the country.

The combination of the transmission and the distribution cables form a network called the national grid. Electricity is fed into the national grid, and it has to be distributed across the country to cities, towns and rural areas.

The South African government announced its policy to provide free basic services to the poor in 2000. The government has focused mainly on electricity supply, which has led to a higher demand on our national grid.

Electricity supply must be consistent and reliable, since electric equipment can be damaged if there are changes in the voltage and current.

It is very difficult to store large quantities of electrical energy. The energy provider must always match the demand of the consumers. These consumers range from households to huge factories, transport systems and the use of heavy machinery.

Specific equipment has to be installed to ensure that the correct voltages reach the users. In this section, you are going to learn about this type of equipment.

As the demand increases, more power stations must be brought on line. This means that the power they generate needs to be added to the national grid.

It is interesting to note that the electricity demand not only varies from day to day, but from minute to minute. The **peak demand** periods are early in the morning and in the evening.

**Transmission** means the action or process of sending something.

**Distribution** refers to the action of sharing something among a number of recipients.

**Peak demand** means the highest demand during a day.

These pylons transmit high-voltage current between the power stations and the substations.

These pylons carry cables that transmit electricity at a high voltage from power stations to substations.

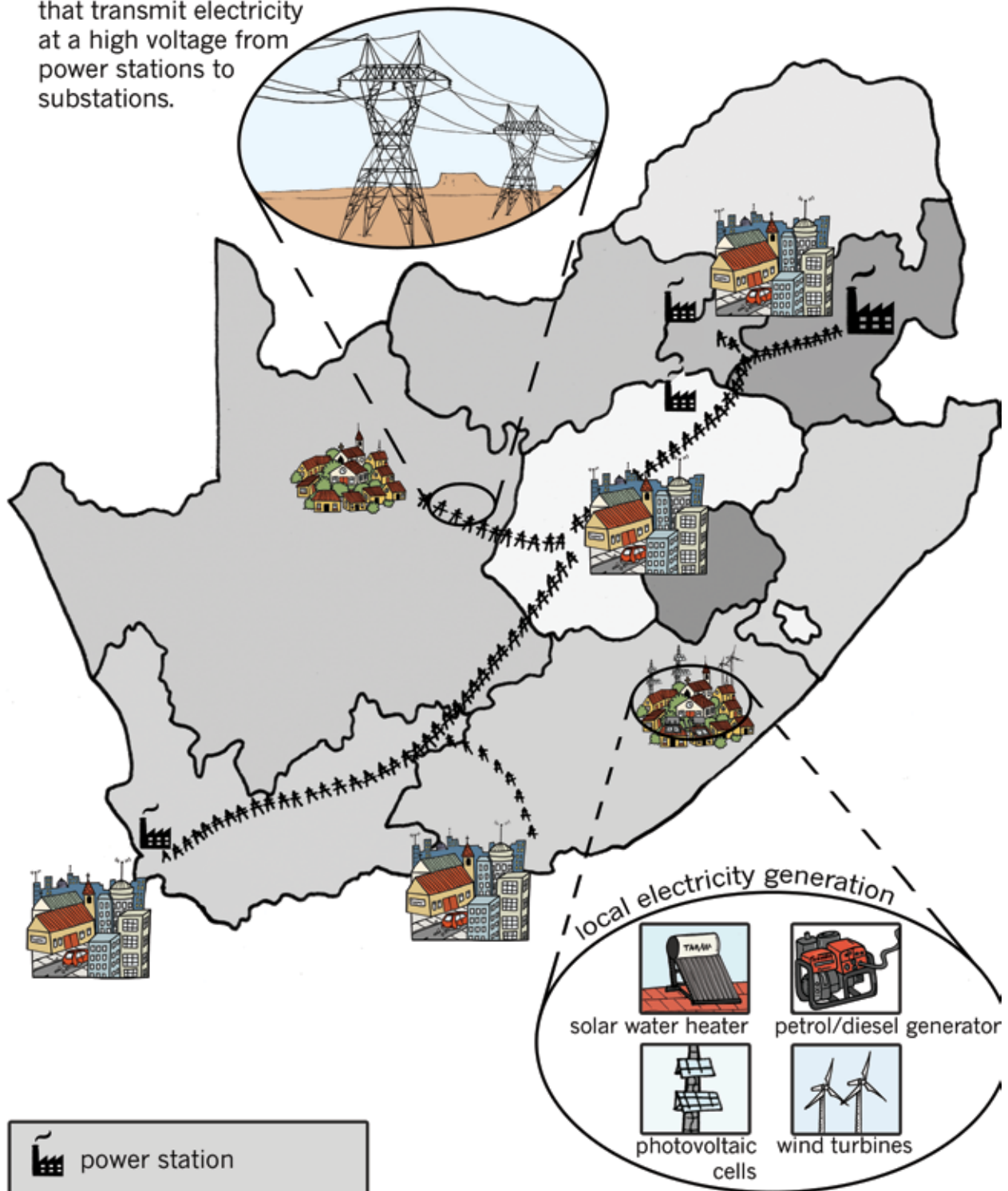


Figure 13: Map of electricity transmission in South Africa. Notice that the grid does not reach all rural areas. Electricity is generated locally in these places.



## Step-down and step-up transformers

Electricity is transferred from power stations to consumers over long distances through the wires and cables of the national grid. When a current flows through a wire, a bit of energy is lost in the form of heat. The higher the current, the more energy is lost. To reduce these losses, the national grid transmits electricity at a low current, but this requires a high voltage. Remember Ohm's law!

Step-up transformers are used at power stations to produce the very high voltages needed to transmit electricity through the national grid's power lines. When the electric energy reaches the consumer area, it is transformed, which means changed, to a lower and safer voltage. Step-down transformers are used locally in sub-stations to reduce the voltage to safe levels.

If you don't quite understand this, think of water flowing through a pipe. The wider the pipe, the more water can be pushed through. When it reaches the other end, the water is funnelled into smaller pipes to be used in homes and factories. The same principle is used to distribute electricity.

- A transformer that increases the voltage is called "a step-up transformer".
- A transformer that decreases the voltage is called "a step-down transformer".

Figure 14 shows how electricity reaches your house so that you can turn on the lights and watch educational programmes on your television.

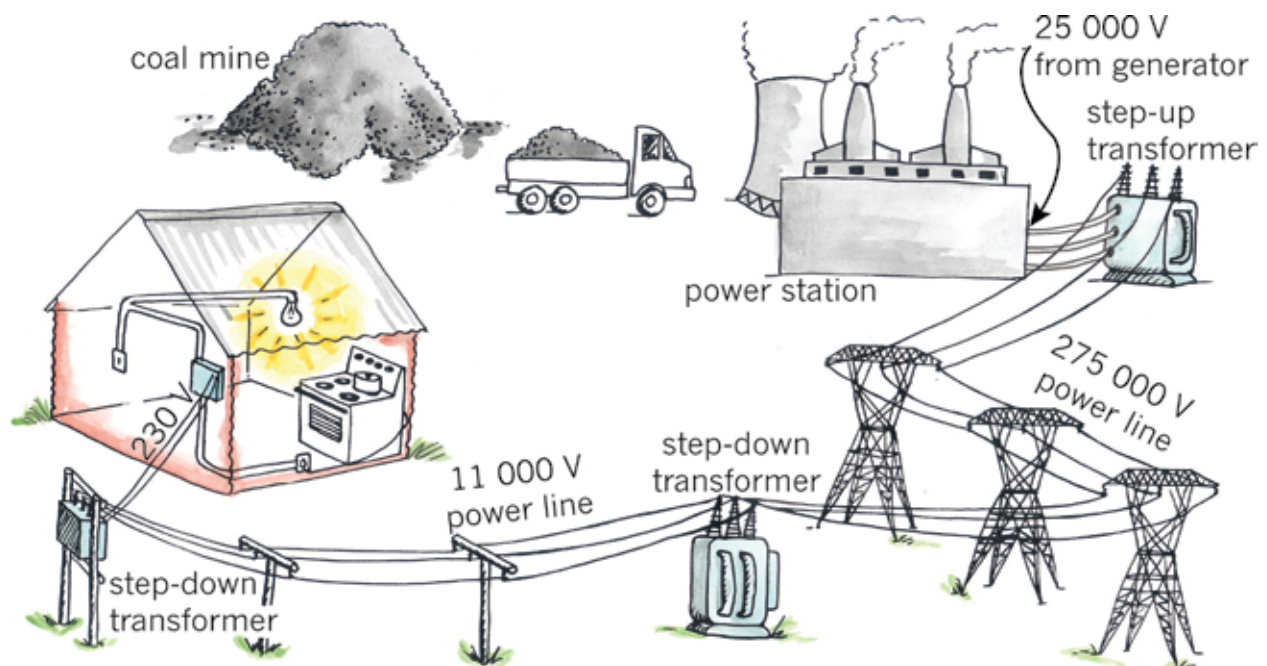


Figure 14: The path of electricity to your home

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## What have you learnt?

1. Name three renewable ways in which electricity can be generated.

.....

2. What is the national electrical energy grid?

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

The national electricity energy grid is often simply called the national grid.

3. What is the function of a transformer?

.....

4. In the area where you live, what, in your opinion, will be the most suitable energy source to be converted to electricity for your community? Why do you say so?

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## Next week

During the next three weeks, you will do your mini-PAT for this term. You will design and build an alarm system.

# CHAPTER 11: MINI-PAT

## Circuits with logic control

In this chapter, which brings you to the end of this term, you will start by revising the circuits you made in Chapter 7 at the beginning of this term. Then you are going to use this knowledge to make an alarm system for a shopkeeper.

You will only do **individual work** during this Mini-PAT.

<b>Week 1: Circuit diagrams and Ohm's Law .....</b>	<b>191</b>
Revise: The effect of connecting more cells in series (45 minutes)	
Revise: Circuits with resistors in series and parallel (45 minutes)	
How a door-operated push switch works (30 minutes)	
<b>Week 2: Logic gates and truth tables; Design brief and specifications .....</b>	<b>195</b>
Switches with AND-type control (15 minutes)	
Switches with OR-type control (15 minutes)	
Truth tables (30 minutes)	
Combining AND-control with OR-control (15 minutes)	
Design brief and specifications (15 minutes)	[4]
Investigate: Components you could use (15 minutes)	[3]
Design: Draw a circuit diagram (15 minutes)	[6]
<b>Week 3: Design, make and communicate .....</b>	<b>203</b>
Make: Draw the layout of your alarm system in the shop (15 minutes)	[6]
Make: A cardboard model of the shop (15 minutes)	[10]
Design: A door-operated push switch (30 minutes)	[8]
Make: The switches for your alarm system (15 minutes)	[12]
Make: Add your circuit to your model of the shop	[12]
Evaluate: Test your alarm system	[2]
Communicate: Make an advertisement for your alarm system	[7]
	Total marks [70]



Figure 1: How are the systems in this picture controlled?

# Week 1

## Circuit diagrams and Ohm's law

This section revises the circuits which you learnt about in Chapter 7. You found that the more cells you connected in series, the brighter the bulb glowed.

### Revise the effect of connecting more cells in series

(45 minutes)

#### You will need:

- a cell holder big enough for three cells,
- two or three crocodile-clip conducting wires, and
- a light bulb rated for 3,8 V or slightly more.

Look at the three circuits below:

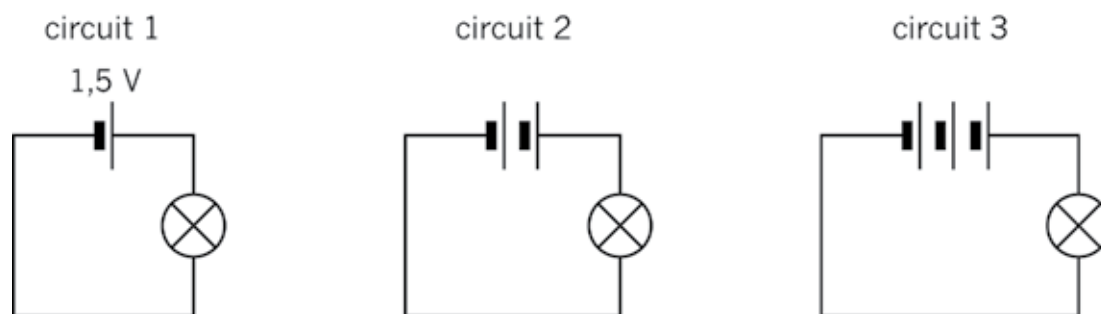


Figure 2: Each cell adds 1,5 V to the battery.

1. What voltage does the battery in circuit 3 promise to give?  
.....
2. Predict how bright the bulbs will glow in circuits 1 to 3. To show your prediction, draw brackets around the bulbs in the diagram. (⊗) means dim, ((⊗)) means medium bright and (((⊗))) means very bright.
3. Now build each of these circuits and test your predictions. Does the bulb in each circuit glow as brightly as you predicted it would?

---

### The relationship between voltage and current

If the current through the bulb is small, the bulb will glow dimly, and if the current is big, the bulb will glow brightly.

4. Write a sentence about the relationship between the voltage and the current. Use the following phrases in your sentence:

- “across the bulb”,
- “through the bulb”,
- “the voltage is”,
- “the bigger is the current”, and
- “the bigger”.

.....  
.....

5. You can state the relationship between current and voltage in another way. Complete the following sentence:

If you increase the ..... across the bulb, you also increase the ..... the bulb.  
.....

The sentence above summarises **Ohm’s law**.

---

**For this activity, you will need:**

- a battery of three cells,
- three bulbs rated for 3,8 volts, and
- six crocodile-clip conducting wires.

1. The diagrams in Figure 3 show you the circuits you are going to build. Before you build them, show your predictions of how bright the bulbs will glow on the diagrams using brackets as you did before. Then connect the components and test your predictions.

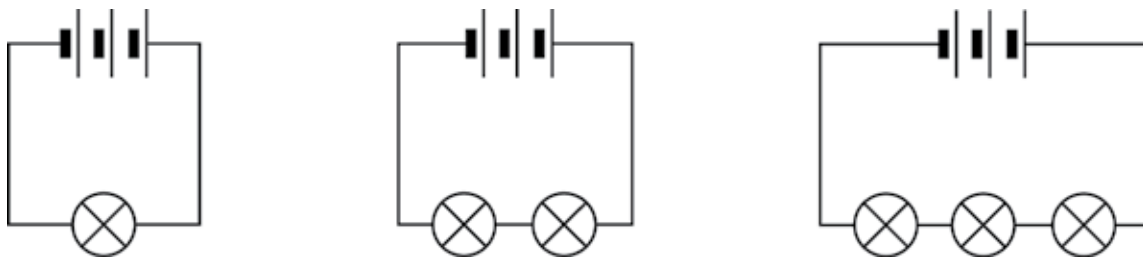


Figure 3: Bulbs connected in series

2. Look at Figure 4, and show your predictions of how bright the bulbs will glow when they are connected in parallel. Then connect the components and test your predictions.

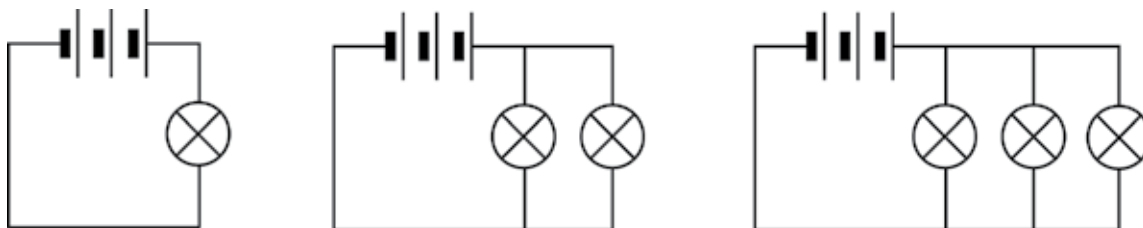


Figure 4: Bulbs connected in parallel

## How a door-operated push switch works

(30 minutes)

A refrigerator has a light bulb inside that lights up when you open the door.

1. Will the light turn off when you close the fridge door? Why?

.....  
.....

2. Figure 5 shows a photo of a fridge with its door open. On this photo, find the switch that controls the light and draw a circle around it with your pencil.

3. Homework: When you open a fridge at home, press this button in to see whether the light goes off.



Figure 5: Find the switch for the fridge's light.

- Many push switches turn on a circuit when they are pressed in, and turn off the circuit when they are not pressed in.
- But the push switch for the fridge light works the other way round. It turns off the circuit when it is pressed in, and it turns on the circuit when it is not pressed in.

Figure 6 shows you how this type of switch works. The switch opens the circuit as long as the door is closed.

4. What happens when the door moves away from the plastic knob? How does the switch complete the circuit?

.....  
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.....  
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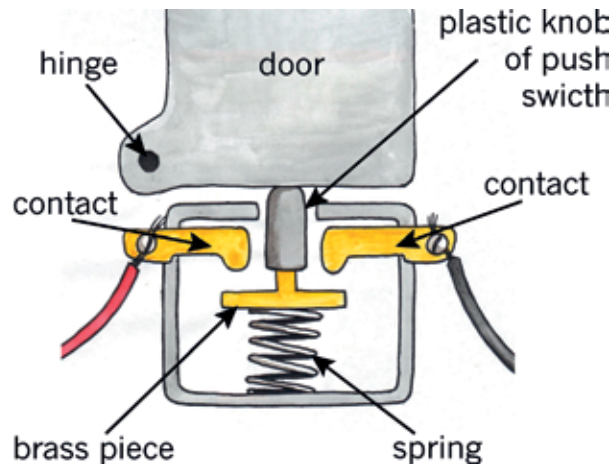


Figure 6: Top view of the parts inside a door-operated push switch: The grey parts are non-conducting and the yellow parts are conductors.



## Week 2

### Logic gates and truth tables Design brief and specifications

#### Switches with AND-type control

(15 minutes)

The circuit in Figure 7 has AND-type control. Now let's see where people would use a circuit such as this one. Figure 8 shows an electric paper-cutting machine that is used to cut many sheets of paper simultaneously. An electric motor turns gears that press the blade of the machine down to cut the paper.

A worker who uses the machine could easily cut his or her fingers, so the machine has a safety system in place.

To make the blade come down, the worker must use both hands to press two switches at the same time. If he or she presses only one switch, the blade will not move. So the machine will not work unless his or her hands are both out of the way.

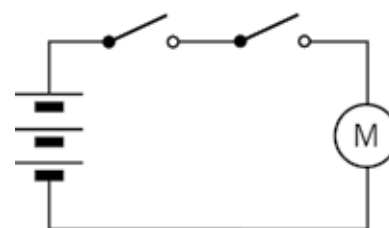


Figure 7: A circuit with AND-type control

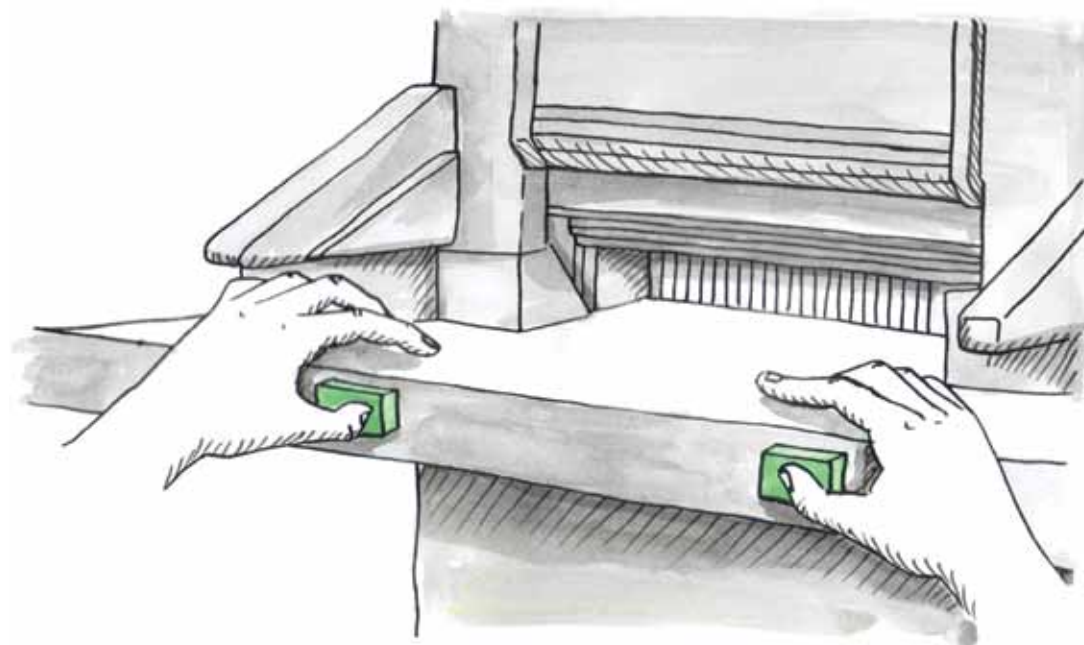


Figure 8: An electric paper-cutting machine

This machine's circuit has AND-type control. Switch 1 and Switch 2 must both be closed, by pressing them, before the motor will work.

## Switches with OR-type control

(15 minutes)

The circuit in Figure 9 has OR-type control. This type of control is used to switch on the light inside a car when you open one of the front doors. This is very useful when you get in or out of the car at night.

The light turns on when the driver opens the door, and turns off when that door is closed. If a passenger gets in at the other front door, the light goes on again, even if the driver's door is closed.

So the car has a circuit that switches on the light if *either* the driver's door is open or the passenger's door is open. This circuit has OR-type control.

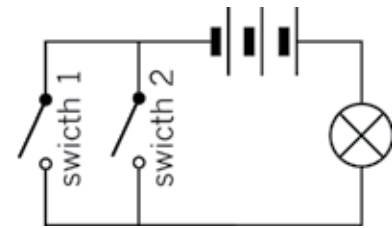


Figure 9: This circuit has OR-type control.

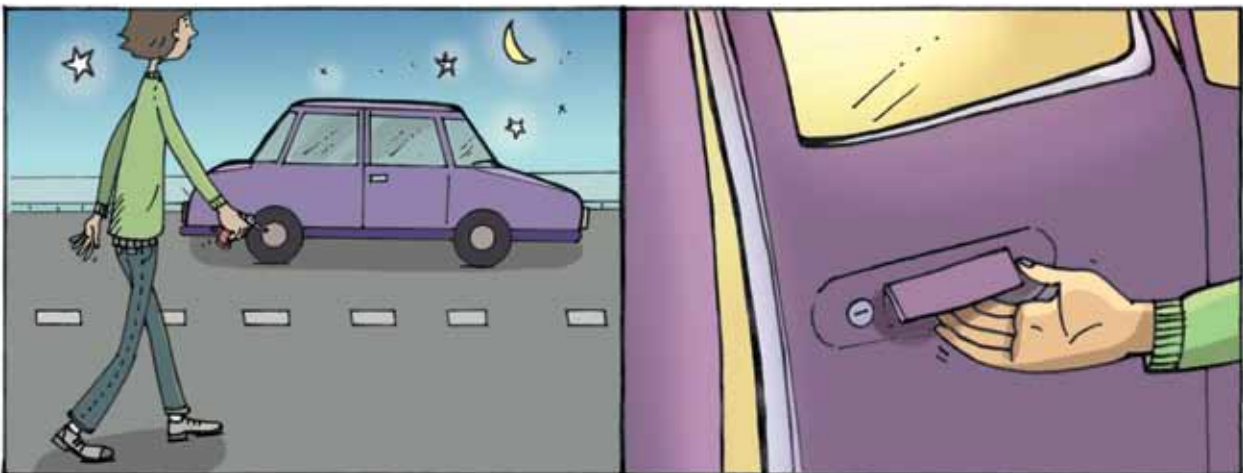


Figure 10: The inside light goes on when you open one of the front doors.

A car's cabin light uses OR-type control because the bulb lights up if *either* the switch on the driver's door or the switch on the passenger's door is closed (on). It also lights up if they are both closed (on).

1. Look at the circuit in Figure 9. Both the switches are open (off). How can you get the bulb to light up? Think of three things you can do with the switches.

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

The door-operated switch for the light inside the car is the same type of switch used for a fridge light, as shown in Figures 5 and 6.

**Truth tables****(30 minutes)**

A computer gives many outputs depending on many inputs. To do this, it uses many AND-type and OR-type circuits inside a more complicated circuit. The AND and OR parts of the complicated circuits are called “logic gates”.

Computer designers and programmers need methods to write down all the possible “states” that the system can be in. A state is one possible combination of values for all the inputs. “Truth tables” help them to write down all the possible states. Computers have millions of possible states. But to understand the method of truth tables, you only need to understand the truth tables of systems with a small number of states.

Look back at Figure 8, showing the electric paper-cutting machine. The operator has to press both switches to make the cutting blade move. So the circuit controlling the motor uses AND-type control.

Below is a truth table for this circuit. The inputs are the two switches. Each row of the table shows one possible combination of the inputs, and the output corresponding with it. So each row shows one possible state.

switch 1	switch 2	Does the blade move?
off	off	no
off	on	no
on	off	no
on	on	yes

A truth table is sometimes written using numbers instead of “on” or “off”:

- For the inputs, which are the switches, a “1” means “on” and a “0” means “off”.
- For the outputs, a “1” means “yes, it gives the output”, and a “0” means “no output”.

1. Complete the truth table below for the paper-cutting machine’s circuit.

switch 1	switch 2	output (Does the blade move?)
0	0	0
0	1	
1		
1		

---

2. Now make a truth table for the light inside the car. If any one of the two front doors is open, the light is on. So this is a truth table for OR-control.

state	driver door switch	passenger door switch	output Does the light turn on?
only driver door open	1	0	
only passenger door open			
both driver and passenger doors open			
no door open			

A truth table shows all the possible states a circuit can be in, depending on the different combinations of the inputs.

It is a list of the inputs and the output or outputs for every possible state.

---

**Combining AND-control with OR-control**

**(15 minutes)**

Many buses have push switches for passengers to let the driver know they want to get off at the next stop. The circuit diagram might look like Figure 11. In this circuit diagram, there are two push switches for passengers. Any one of these switches can ring the bell next to the driver.

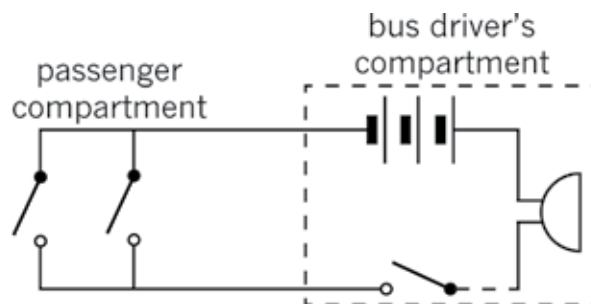


Figure 11: A circuit for passengers to tell the driver that they want to get off

1. Write SW1 and SW2 next to the two switches for the passengers.

When school learners go on an excursion, they sometimes ring the bell many times just for fun. This prevents the driver from concentrating on the road, so he or she has a “master switch” to turn off the bell.

2. Which switch gives the bus driver control over the whole circuit? Write SW<sub>master</sub> next to that switch.

The passengers have OR-control because switch SW1 or switch SW2 can ring the bell.

However, the driver has AND-control. For the bell to ring, SW<sub>master</sub> and one of SW1 or SW2 must be on.

3. Complete a truth table below for the bell circuit of the bus.

SW <sub>master</sub>	SW1	SW2	output from the bell
1	0	0	
1	1	0	
1	0	1	
1	1	1	
0	0	0	
0	1	0	
0	0	1	
0	1	1	

---

## Write a design brief and specifications

(15 minutes)

### The scenario:

Mr Abdullahi has set up a shop. The customers are happy with his low prices. He sells food and clothing cheaply because he co-operates with other shopkeepers in the area. They work together to negotiate with the big suppliers of clothing and food to get cheaper prices.

Sometimes Mr Abdullahi is alone in the shop. If he has to work in the office at the back of the shop, he closes the two front doors of the shop, but the doors are not locked. He will only know if someone comes in at one of the doors if he sees them or if they call him.

Can you make him an alarm system that will tell him when a door opens? Sometimes Mr Abdullahi has an assistant in the shop, and then he does not need an alarm, so he wants a switch to turn the alarm system on and off.

1. Write the brief here. The design brief is a short statement that describes the need and what type of solution will meet that need. (1)

*Project brief:*

*I am going to design and make a*

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

2. Now write specifications for the solution. Specifications have detail about the system you are going to make. Remember that the system:
  - should make a sound when either one of the two doors are open, and
  - should have a switch to turn the whole system off. (3)

*Specifications:*

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

Total [4]

**Investigate: Components you could use (15 minutes)**

1. What type of devices can you use for the alarm to make a loud sound? (1)

.....

2. What type of battery can you use? Remember that a 9 V battery will burn out motors that are rated for 1,5 V. Beepers also have their own voltage ratings, and you must find out what these are. (1)

.....

.....

3. How can you make a switch that will close the circuit when the door is opened? Find a switch in this chapter or another chapter that will meet these requirements. (1)

.....

Total [3]

---

**Design: Draw a circuit diagram****(15 minutes)**

1. Should the alarm system use AND-control or OR-control? Explain. (2)

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

2. Often designers look at circuits that have already been designed, to see whether any of those circuits will do the job. Look at Figures 7, 9 and 11 again. Which of these circuits will work? (1)

.....

3. Draw that circuit again in the space below. Give names for the different switches and show them as labels on your circuit diagram. (1)

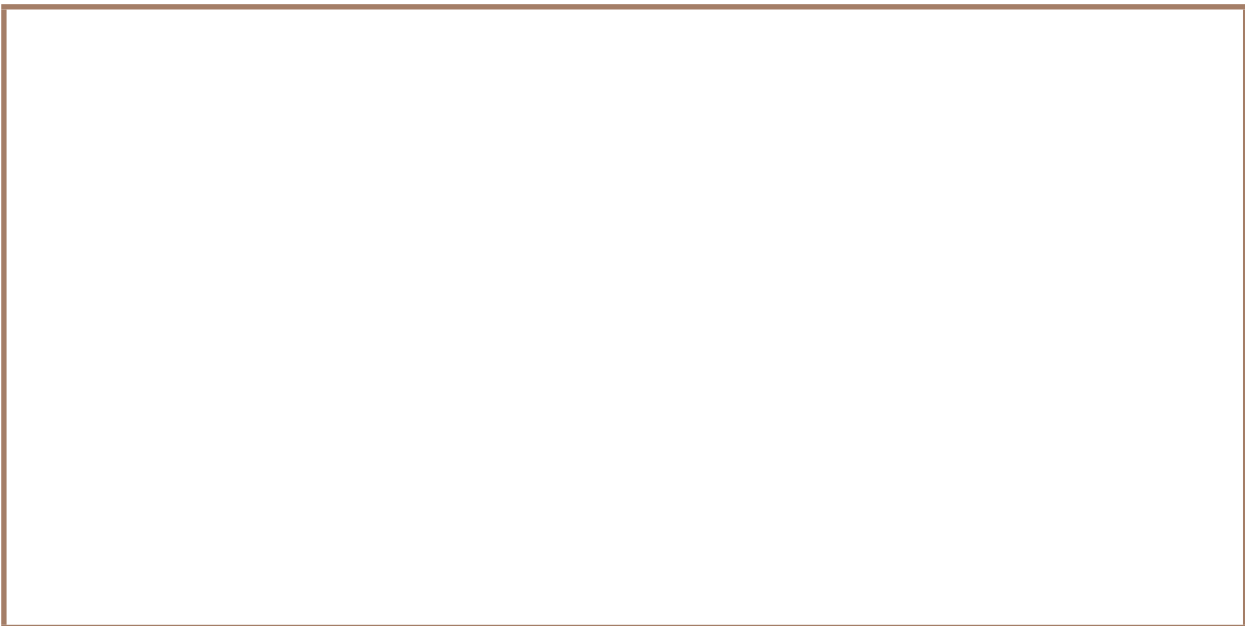


Figure 12: The circuit diagram for your design of the alarm system

4. Show more information on your circuit diagram in Figure 12. Draw dashed lines around the part of the circuit that is in the front of the shop, and other dashed lines around the part that is in the office.

**Hint:** Look at Figure 11 again to see how dashed lines were used to show the part of the circuit in the bus driver's compartment. (2)

Total [6]



## Week 3

### Design, make and communicate

#### Draw the layout of your alarm system in the shop (15 minutes)

Figure 13 shows a simple sketch of the shop.

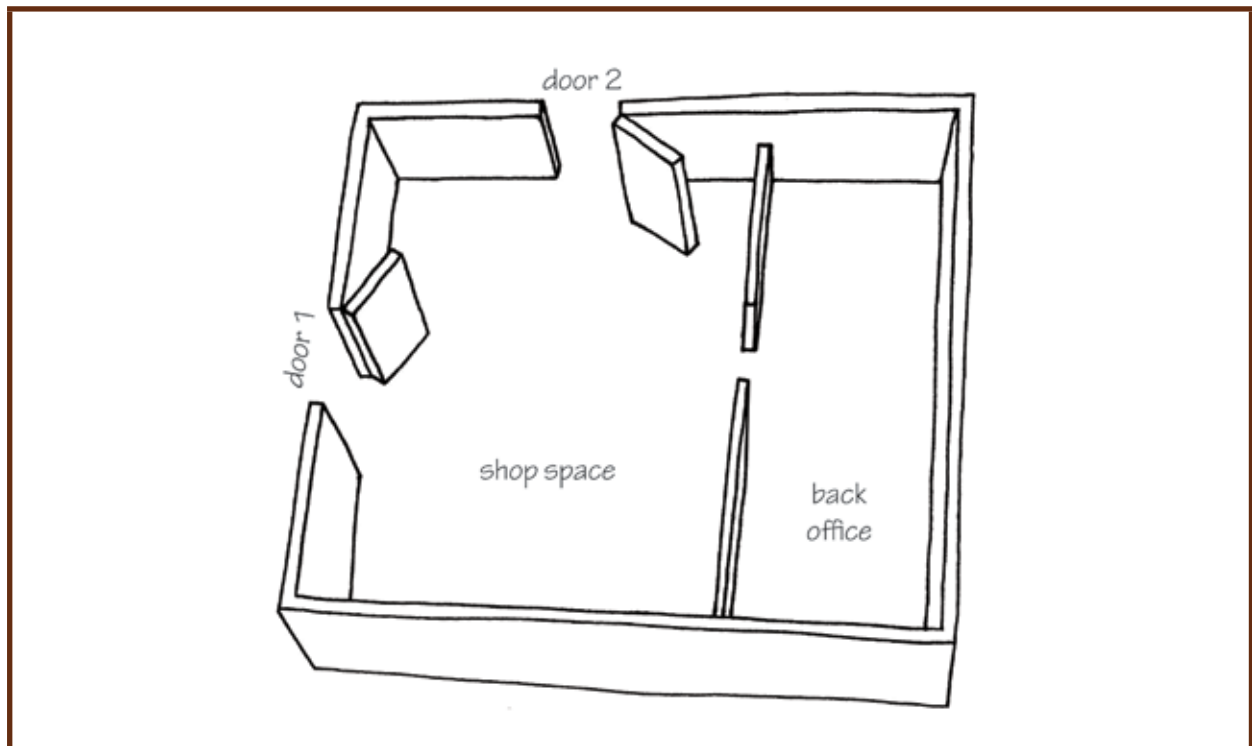


Figure 13: A design of the placement and wiring of the alarm system

Draw on Figure 13 to show where you will put all the switches and other circuit components. Also show the connecting wires for the circuit. Put in labels for the circuit components. The circuit components should be connected as shown by the circuit diagram that you made for Figure 12. [6]

#### Make a cardboard model of the shop (15 minutes)

Make a model of the shop out of a cardboard box. Cut two doors in the box. The model should not have a roof, so that you can see inside it. Make the model as simple as possible, otherwise you will not have enough time to finish building the alarm system. [10]

## Design a door-operated push switch

(15 minutes)

Figures 14 to 16 show examples of how push switches that are off when they are pressed in can be made.

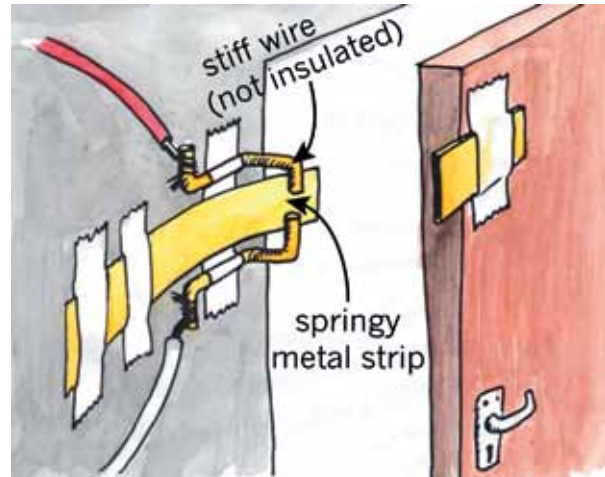
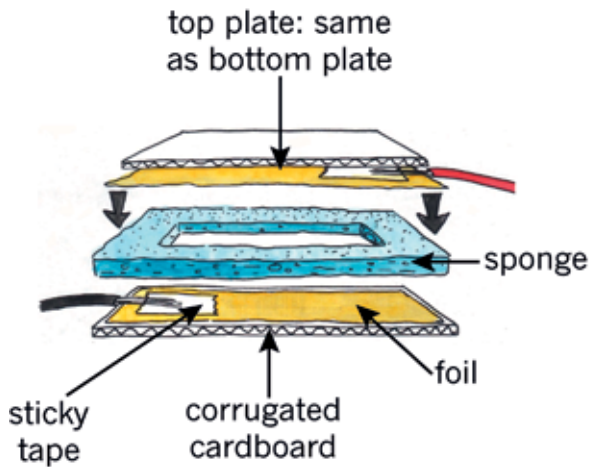


Figure 14: A pressure switch under a carpet

Figure 15: A moving contact switch

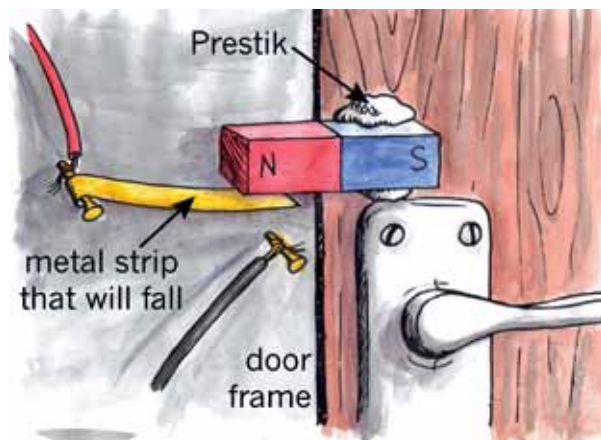


Figure 16: A magnetic switch

Use an idea or ideas from these examples to design your own door-operated push switch that is on when the door is open and off when the door is closed. Make a sketch of your design on the next page. Add labels to explain the different parts of your switch design. [8]



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**Make the switches for your alarm system (30 minutes)**

Make two of the door-operated push switches that you designed. Remember that they need to fit on the doors of your cardboard model of the shop. [12]

Do not make a master switch, as you don't have enough time for that. You can simply connect two crocodile clips of conducting wires to "switch on" the master switch, and disconnect them to open the circuit and "switch off" the master switch.

---

## Add your circuit to your model of the shop

(30 minutes)

Now add all your circuit components and conducting wires to your cardboard model of the shop. Your design of the placement and wiring of the alarm system in Figure 13 will help you to connect all the circuit components in the correct way.

Stick the wires to the walls of the box with tape to make your model neat.

Connect all the circuit components.

In a real building, the alarm wires are stuck to the walls or are in the ceiling. The door switches are on the *inside* of the doors. If they were on the *outside*, a burglar could disconnect them.

[12]

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## Evaluate: Test your alarm system

(15 minutes)

When you evaluate the project, ask yourself: “Did I solve Mr Abdullahi’s problem?” The following questions will help you to test whether your alarm fulfils all of the specifications. Do these tests:

1. Does the alarm make a noise when you open only door 1?
2. Does the alarm make a noise when you open only door 2?
3. Does the alarm make a noise when you open both doors?
4. Can Mr Abdullahi switch the system off and leave the doors open?
5. Complete a truth table for the system.

[2]

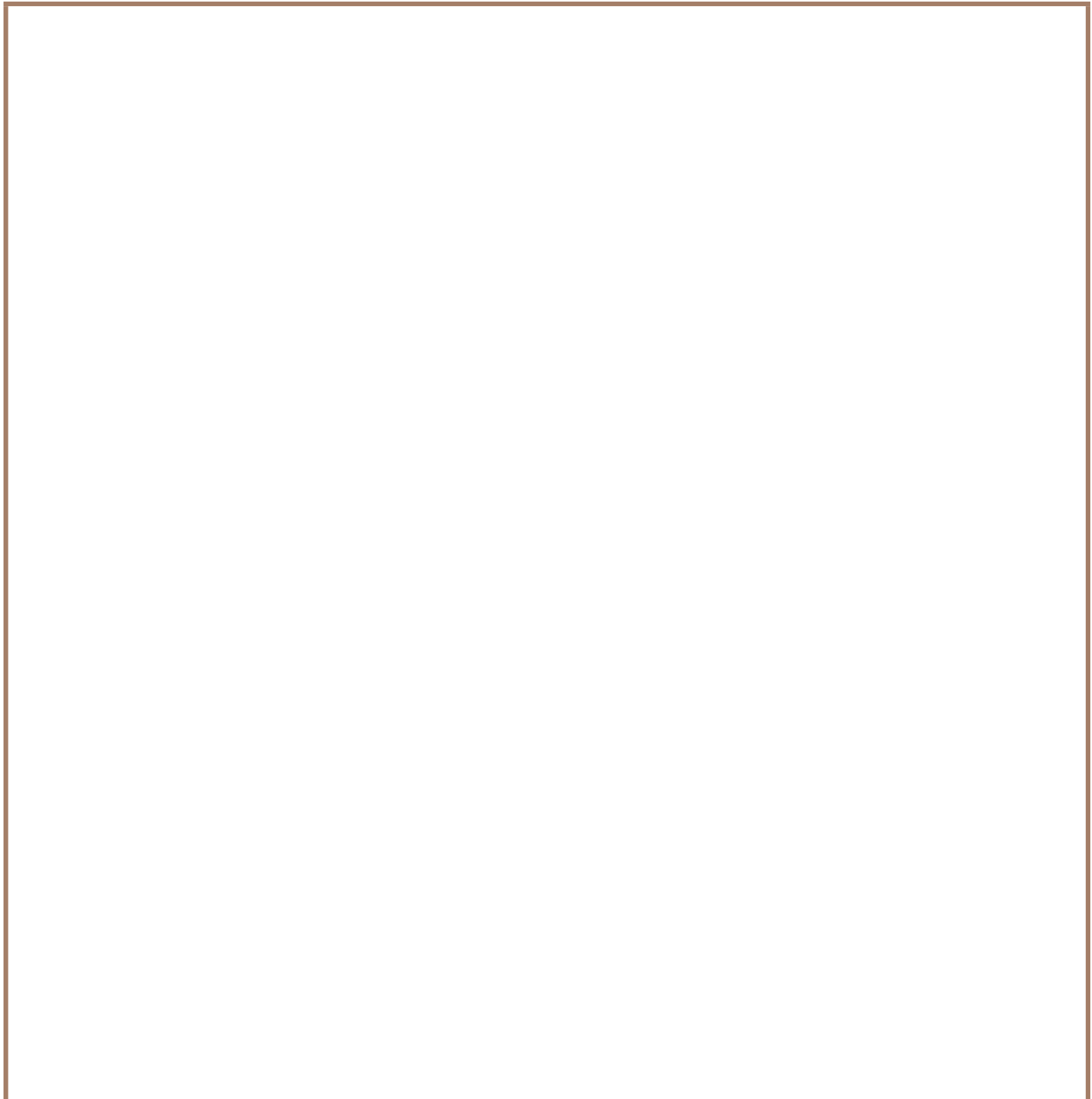
master switch	switch 1	switch 2	output
1			
1			
1			
1			
0	0	0	
0	0	1	
0	1	0	
0	1	1	

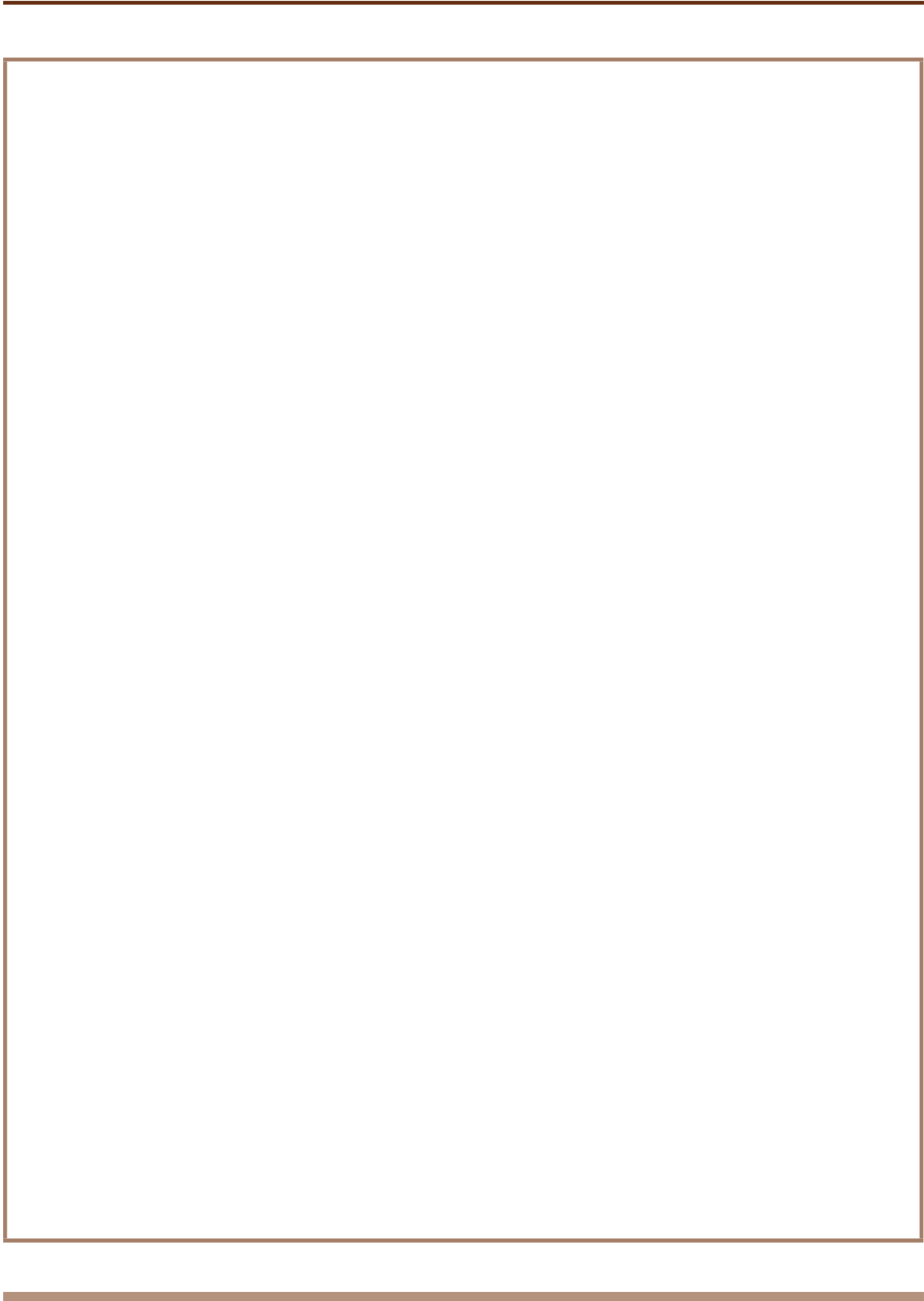
**Homework: Make an advertisement for your alarm system**

Mr Abdullahi likes your system so much that he offers to advertise it to other shopkeepers. He thinks some of them will pay you to build and install alarms for them.

He asks you to make a poster that shows the shop and the doors, some of the parts of the alarm system, with a few sentences that explain how the system works.

Make a poster to advertise your alarm system on the next page. But first sketch rough ideas for your poster on this page. [7]





**Notes**

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## Notes