3

ENERGY

How do you feel when you say you have a lot of energy? How do you feel when you say you don't have any energy? Energy is hard to define. Even scientists struggle to define energy because it is such a big idea and relates to so many different areas of science. Energy appears in different forms and makes things happen. Without energy, nothing would move, nothing would change and nothing would happen. Energy cannot be created, nor can it be destroyed. However, it can transform (change) from one form into another.

EVERYDAY ENERGY 3.1

We experience energy every day in many different forms. Heat, light, sound, motion and electricity are only a few types of energy. All types of energy can be transformed into a different type, and some of that energy is almost always transformed into heat energy. Heat energy can also be transferred between objects or between substances.

Students:

» identify objects that have either kinetic or potential energy

» investigate everyday energy transformations involving heat, light, sound and motion

» describe the process of conduction, convection and radiation using examples

ELECTRICAL ENERGY 3.2

Electrical energy is one of the most versatile forms of energy. It can be transformed into almost every other type of energy, it is easily transported and it can be stored for long periods of time. Electricity has driven huge technological developments since we learned to produce and use it.

Students:

» relate electricity to the transfer of energy

» construct circuits and draw circuit diagrams with various components

» investigate everyday energy transformations involving electrical energy

» trace the history of the development of an electrical device (additional content)

INCREASING ENERGY EFFICIENCY 3.3

Energy efficiency measures how well a device transforms energy. All energy transformations produce by-product energy forms different from the useful energy type required. The more efficient the device, the less by-product energy is produced and wasted. Scientific research is continuing to improve the efficiency of devices to reduce wasted energy. This is increasingly important as non-renewable sources of energy begin to run out.

Students:

» identify that most energy transformations produce heat energy regardless of the transformation

» research ways in which scientific knowledge and technological developments have improved the efficiency of energy transfers or transformations

» discuss the implications for society and the environment of increasing the efficiency of energy transformations

3.1 EVERYDAY ENERGY

Energy is all around us. We use **electrical energy** to wash our clothes, to keep our food cool and to watch television. We use **thermal energy** (heat) to cook our food and to heat our homes and water. Light energy helps us see when it is dark, and **sound energy** brings our favourite music to our ears. These are just a few examples of different types of energy. We experience the effects of energy every time something happens – for something to happen, energy is required. However, what happens depends on the type and amount of energy involved.

THE ENERGY OF OBJECTS

Think about where you see energy – you are probably thinking of something related to electricity, but there are other forms of energy you may not be aware of. Any time an object moves or something changes, energy is involved to make that change happen.

Figure 3.1 Some examples of energy use in the modern world.

ACTIVITY 3.1.1: DIFFERENT FORMS OF ENERGY

With a partner or in a small group, brainstorm as many different types of energy you can think of. Spend some time carefully examining Figure 3.1, which shows some different types of energy and we use them in our everyday lives.

1. Make a list of all the energy types you can think of.
2. For each energy type, think of an example of where or when it could be used. For the energy types in Figure 3.1, try to come up with a different example from what is already shown.
3. X, Y and Z in Figure 3.1 do not have labels. Identify what type of energy is being used.
4. Create your own energy illustration showing either the energy you use every day or the energy used by another imaginary other person.

Potential energy

At some stage of your life you have probably been told that you have 'shown potential', perhaps while playing a sport or a musical instrument. This means you have demonstrated you still have room for improvement – that you have got more in you to improve your performance. **Potential energy** is a similar concept. Potential energy is the energy stored in objects that is waiting to be used. This stored energy can be the result of a change of shape (stretching or squashing), an object's height above the ground, or chemical reactions that change the chemical bonds within a substance.

Elastic potential energy

A trampoline has the ability to 'store' or hold energy for later use. The springs and the mat of the trampoline stretch under our weight and hold this as stored energy. The more the springs stretch, the more energy they hold. The energy is returned to our bodies when the springs and mat return to normal and we are thrown into the air. Energy stored through the stretching or squashing of the physical shape of an object is called **elastic potential energy**.

A bow and arrow is another example of energy being stored in this way. When the bowstring is stretched, it holds elastic potential energy. When the string is released, the energy pushes the arrow forward. Wind-up toys work in a similar way. You wind up the spring inside the toy and, when you let go, it releases its stored energy. Springs can be both compressed (squashed) and stretched, which means they can work in two opposite directions.

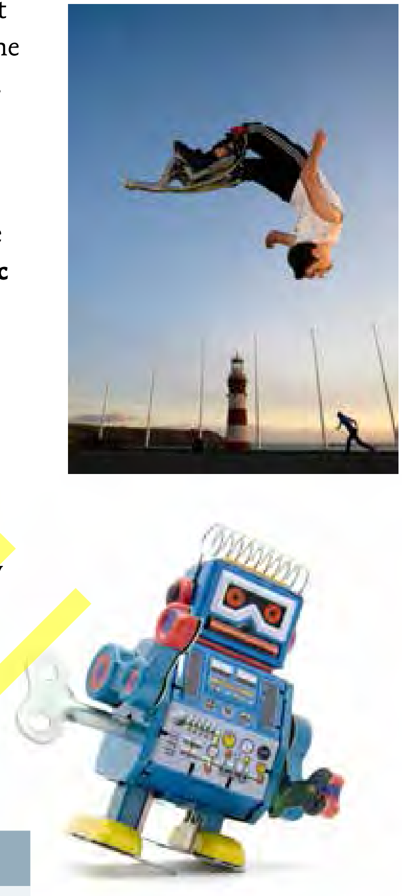


Figure 3.2 Some items release potential elastic energy to provide motion such as (a) jumping stilts and (b) wind-up toys.

ACTIVITY 3.1.2: RUBBER BAND BOATS

What you need: waxed cardboard (milk cartons work well), water bath or swimming pool, scissors, butterfly pins (also known as split pins), rubber band

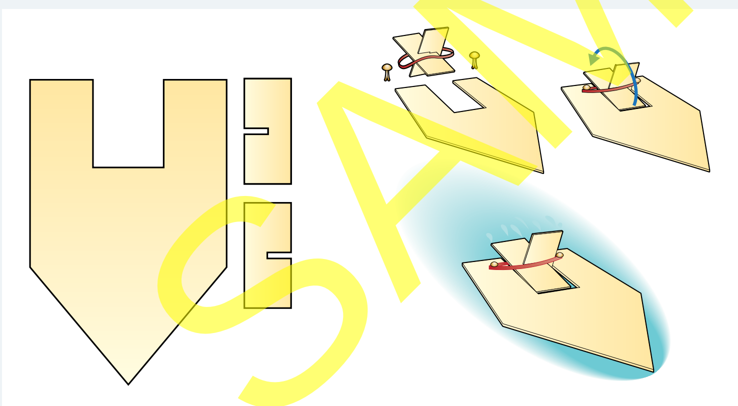


Figure 3.3 The parts and method of assembly for a rubber band boat.

1 Cut out the waxed cardboard to match the diagram in Figure 3.3.
2 Connect the propeller blades using the slots.
3 Loop the rubber band over the propeller.
4 Attach the propeller to the boat using butterfly pins.
5 Wind the propeller towards the back of the boat a number of times, place the boat gently on the surface of the water and release the propeller.
   - What happened to the boat when the propeller was released?
   - What types of energy are involved in this activity? Explain.
   - How could you make the boat travel further? How are you changing the energy when you do this?

Figure 3.4 This television has gravitational potential energy when raised above the ground.

Figure 3.5 Energy drinks contain a lot of chemical potential energy, but they release it too quickly for you to use properly. These drinks contain other ingredients you may want to avoid.

Figure 3.6 The chemical potential energy in dynamite can be released when the fuse is lit.

Gravitational potential energy

If we lift an object up, it gains **gravitational potential energy** (GPE). Any object in the air has the potential to fall due to the force of gravity. The larger the mass and the larger the height, the more GPE the object gains.

Have you ever noticed that falling a greater distance produces a greater 'thud' and can hurt more? This is because of the amount of GPE. As an object falls under the influence of gravity, the object's GPE can be transformed into other forms of energy. This happens when a child plays on a slide at the playground. As the child climbs up the ladder, their GPE increases. As the child comes down the slide, their GPE decreases but they go faster. The child may also feel the friction of the slide as heat energy.

Chemical potential energy

After we have done a lot of exercise, we often crave foods that we believe will restore our energy levels. These foods, usually sweet things, release stored chemical energy very quickly to satisfy our cravings. All foods have some energy stored in them, but the difference is how quickly the energy can be released.

The energy stored within a chemical substance is called **chemical potential energy (CPE)**. Using chemical reactions to break the bonds holding the atoms together releases the energy. The chemical substance which we use for energy is glucose. The chemical reaction of respiration within our cells breaks the bonds between atoms of glucose and releases energy. Energy drinks release lots of sugars into the bloodstream, usually much more quickly than it can be used. The extra sugar is stored in the liver or converted into fat.

Fuels, such as natural gas and petrol also contain chemical energy. A Bunsen burner uses the burning of natural gas to provide heat in the laboratory so you can perform your experiments. Petrol and natural gas have chemical energy stored in them, as do explosives and batteries.

These substances and objects all contain chemical potential energy that can be released when we need it. Some batteries can be recharged, which means the chemical potential energy within them can be replaced. Your MP3 player, laptop and mobile phone batteries can be recharged many times without damage because they transform between chemical and electrical energy.

Biomass energy

Biomass energy is potential energy stored in plants and animals. It is a type of chemical potential energy (CPE). The most common way of releasing biomass energy, and many other types of CPE, is by burning the material, such as burning wood to produce heat. Another common use of biomass energy is to ferment the sugar of various plants to produce ethanol (pure alcohol). The ethanol can be used as a biofuel – a biomass energy source that is burned to power machines. In Australia, we sell petrol for cars that contains 10% ethanol. Petrol of this sort is known as E10. Most modern cars can run on E10 just as well as they run on normal unleaded fuel.

Diesel fuel can also be blended with other materials, usually vegetable oils, to make biodiesel. This fuel reduces the production of carbon monoxide, particulates and hydrocarbons that are emitted when normal diesel fuel is burnt. This type of biofuel is available in various blends throughout Australia, though usually as B5 (5% oil) and B20 (20% oil). In fact, the first diesel engine was invented to run on peanut and other vegetable oils.

Figure 3.7 Ethanol is a biofuel that is already available as a part of E10 fuels in Australia.

EXPERIMENT 3.1.1: BIO-POWER!

Aim

To discover the energy content of a Cheezel.

Materials

- Cheezels
- Cork
- Needle or short metal wire
- Heatproof mat
- 150 mL beaker
- Water
- Tripod and gauze mat
- Boss head and clamp
- Thermometer
- Long matches or oven lighter
- Stopwatch or clock

WARNING

> Do not eat the Cheezels. NO food or drink should be consumed in a science laboratory.

Method

1 Push the eye of the needle into one end of the cork.

2 Now carefully push a Cheezel onto the sharp end of the needle.

3 Place the boss head and clamp over the heatproof mat, then attach the cork to the clamp.

4 Pour 20 mL of water into the beaker and record the temperature.

5 Place the beaker of water on the gauze mat and tripod, and adjust the clamp so the beaker is immediately above the Cheezel but not touching it.

6 Light the Cheezel using a long match or oven lighter. (It may take a while to catch alight.)

7 Allow the Cheezel to burn for 5 minutes or until it has gone out. During this time, record the temperature of the water every 30 seconds.

Results

Complete the following table for your results, using the formula below for calculating energy.

The amount of energy generated by burning the Cheezel is:

Energy (joules) = volume of water (mL) × 4.2 × change in temperature (°C)

Table 3.1 Water temperature and energy generated.

Time (s)	Temperature (°C)	Volume of water (mL)	Energy generated (J)
0		20	
30		20	
60		20	
90		20	

Discussion

1 How does this experiment demonstrate how biofuels can be used to create energy?

2 What does this experiment suggest about Cheezels as an energy source for humans?

3 What type of energy does this experiment investigate?

4 How could you improve or alter this experiment?

Figure 3.8 Burning is a common way to release chemical potential energy.

Conclusion

Write a statement about the energy content of a Cheezel, using your results as evidence.

Figure 3.9 The potential energy released from a nuclear explosion is much, much greater than from other types of explosions.

Nuclear energy

Although nuclear energy is used throughout the world, it is not used in Australia at the moment. **Nuclear energy** involves the splitting or fission of the nuclei of atoms. When atoms react in chemical reactions, they usually release only small amounts of energy. However, if the centres or nuclei of atoms can be made to react, like uranium-235, the amount of energy released is much, much larger. The amount of energy released is so huge that it can power whole cities or cause massive amounts of destruction. The Australian government is concerned about the risks associated with nuclear energy and is unlikely to use it in the near future.

Nuclear power can also be used in explosive weapons and some countries in the world possess such weapons (but not Australia). Thankfully, they are not used very often because their destructive power is huge.

Kinetic energy

The scientific term for the energy of movement is **kinetic energy (KE)**. You use kinetic energy every day of your life. Whenever objects or people move, they are using kinetic energy. The heavier an object is and the faster it is moving, the more kinetic energy it has. A fully loaded truck travelling at 60 kilometres per hour has much more kinetic energy than a small motorbike travelling at the same speed.

Cars are designed with safety features to absorb the kinetic energy of a collision. For example, a car's brakes are designed to absorb kinetic energy and slow the car down safely. An object stopping suddenly when hitting an obstacle will receive more damage than an object slowing down before gently coming to a stop. The kinetic energy of a sudden stop is what causes damage to the car and the people inside it.

Sound energy

Have you ever been at a very loud concert and stood near the huge **speakers**? If so, you will remember that you not only heard the deep bass sound, but also felt it in your body. You can feel the same vibrations in the car if you put your hand on the dashboard when the radio is on full blast. Sound is made when things vibrate. Every time you make a sound – whether it is playing a musical instrument, speaking, singing or even whispering – you are making vibrations. Vibrations are simply tiny movements back and forth. Vibrations can occur in gases, liquids and even in solids. If you put your ear to the desk in front of you and a friend taps at the other end of the desk, you will hear the vibrations.

Figure 3.10 Seatbelts and airbags in cars are designed to slow you down before you stop in a crash, reducing the kinetic energy and hopefully preventing injury.

Figure 3.11 The kinetic energy a drummer uses to hit the drum skins is transformed into sound energy.

Energy is needed to make sound. For example, a drummer uses energy to hit the drums, which vibrates the drum skin to make a sound. The more energy the drummer uses to hit the drum, the bigger the vibrations and the louder the sound will be. The sound travels to your ears through the air. The particles in the air also vibrate as the sound passes through.

ACTIVITY 3.1.3: SOUND ENERGY

What you need: tuning fork, wooden table or wooden box, acoustic guitar, electric guitar

1 Hit a tuning fork on the sole of your shoe and then listen to the sound it makes.
2 Repeat step 1, but hold the tuning fork so it is standing on a wooden table or wooden box. What difference did the table make to the loudness of the sound?
3 Repeat step 2, but see if you can feel the table or box vibrating this time. Why do you think this may have happened?
4 Compare the sound of an unplugged electric guitar to the sound of an acoustic guitar. Which is louder? Why do you think this is so?
5 Now place your hand on the body of the acoustic guitar as it is played. Can you feel the vibrations? What about with the electric guitar? Does this help explain why the acoustic guitar may be louder?
   - How do you change the way you play a recorder so it gives out more sound energy?
   - How does a pianist manage to play some notes softly and others very loudly?
   - When you want to yell or speak louder, how do you make the sound coming from your mouth louder?
   - How do drummers make their drums sound louder?

Figure 3.12 What energy does a tuning fork use and produce?

QUESTIONS 3.1.1: THE ENERGY OF OBJECTS

Remember

1 List four examples of devices or situations that involve potential energy.

2 Describe four devices, other than those mentioned already, that possess elastic potential energy.

3 Recall the scientific term for 'movement energy'.

4 Complete the following statement: When a person plays a musical instrument, ____________ energy is transformed into ____________ energy.

Apply

5 Identify three situations where you used kinetic energy today.

6 Identify an advantage of using 10% ethanol as a fuel source instead of normal petrol.

7 In terms of the energy involved, list one benefit and one problem with using nuclear power.

8 Identify the features of a car that would absorb:

   a the car's kinetic energy in a collision

   b the driver's and passengers' kinetic energy in a collision.

Research

9 Compare the amount of energy released from the burning of brown coal with reactive the equivalent amount of uranium-235 in a nuclear reactor.

10 Investigate the vibrations of sound further. If the size of the vibrations determines the volume of the sound, identify the feature of the vibrations that determines the note or the pitch of the sound.

Figure 3.13 Crash test dummies are used to test the safety features of cars.

TRANSFORMING ENERGY

We use a huge range of devices and equipment every day. Some electrical devices, such as earphones, produce sound. Some produce light or use light to analyse something, such as a barcode scanner at the supermarket. Others produce heat to dry and style our hair or to provide us with hot water for our showers. A gas stove produces heat to cook our food, petrol in the car produces motion, and solar panels collect and store sunlight as electricity. All these devices and pieces of equipment are energy transformers because they convert one type of energy into another.

ACTIVITY 3.1.4: ENERGY CONVERTERS

Consider each device in the following table, the energy it uses to work (the energy input) and the useful energy it produces (the energy output).

1 Work in groups to fill in the gaps in Table 3.2.

Table 3.2 Energy input and output of some devices.

Device	Energy input	Energy output
Drum		Sound
	Electrical	Sound
Light bulb		Light
Battery	CPE	
Car engine		Kinetic
	Elastic potential	Kinetic
Gas heater		Heat
Solar panel	Light	
Phone charger		Electrical

2 Discuss any patterns you see in the table. For example, are there any energy types that are more commonly 'inputs' rather than 'outputs'?

3 Extend the list with five more devices your group comes up with.

Representing energy transformations

Flow diagrams can be used to represent **energy transformations**. The arrow in the flow diagram is used to represent a number of things.

1 The arrow points in the direction of the transformation.

2 The energy input is written at the back of the arrow.

3 The useful energy output is written at the tip of the arrow.

For example, the battery in a mobile phone transforms chemical energy into electrical energy. The previous sentence describes this energy transformation, but using a flow diagram it would simply be:

Chemical energy → Electrical energy

Sometimes there is more than one energy output, so we try to concentrate on the main one. Minor energy outputs are known as by-products. Think how you would write the energy transformation in a light bulb. What is the energy input? What is the main energy output? Is there a by-product (wasted energy)?

In some devices there are several energy transformations in a row, resulting in an energy chain. For example, listening to music

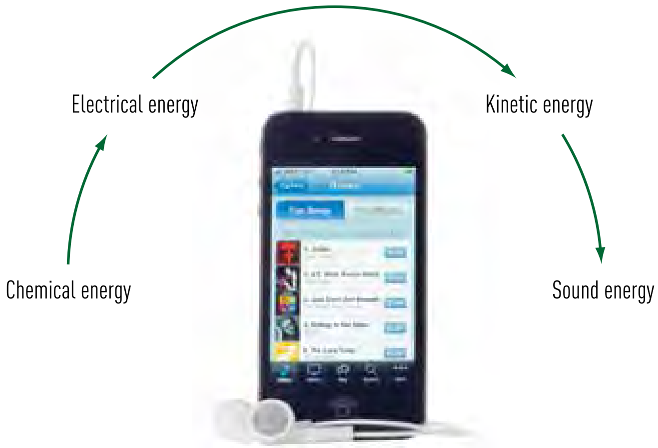


Figure 3.14 The energy chain involved in listening to music from a smartphone.

Chemical energy → Electrical energy → Kinetic energy → Sound energy

from a smartphone would be as described in the following paragraph:

The chemical energy stored in the battery of the smartphone is transformed into electrical energy. The electrical energy flows through the wires to the headphones, where it is transformed into kinetic energy as the tiny speakers in the headphones vibrate. This is then transformed into sound energy, which our ears detect.

As a flow diagram, this energy chain would be:

Transformations for heat

The most important energy transformations in our lives are those that keep us comfortable, reduce our stress and entertain our brains! Energy transformations involved in our comfort usually mean using heat for things like drying our hair, for cooking our food and for keeping us warm.

A hairdryer has two basic components: a fan and a heating element. When plugged in and switched on, the fan motor spins and the heating element heats up. So, a hairdryer converts electrical energy into heat energy and kinetic energy. The air blown by the fan is directed over the heating element, generating warm air, which flows out of the hairdryer. Some hairdryers have different speed and heat settings that control the amount of electrical energy flowing to each part of the device.

Other heating devices, such as toasters, also use heating elements to convert electrical energy into heat energy. Heating elements are made of certain types of wires that heat up quickly without melting when electricity flows through them.

Electric ovens are like oversized toasters and can have a fan in them, as does a hairdryer. Gas ovens and stoves use the chemical energy of the gas to produce heat by burning the gas. All these devices are very common – our homes would not be much use to us without energy converters.

No doubt your house has some sort of heating or cooling system, depending on where you live. Electricity can be used to heat your home or water supply, but burning natural gas is another option, as is utilising solar energy. All these heating and cooling devices are energy converters. If you wave a piece of cardboard in front of your face to cool yourself down, you are converting energy. The chemical energy inside your muscles is converted into kinetic energy (the movement of your hand) to assist the movement of thermal energy from your face into the surrounding air.

Figure 3.15 The heating element of an electric stove converts electricity into thermal energy. Some electrical energy also transformed into the by-product light energy, which is why the element looks red.

EXPERIMENT 3.1.2: MAKING AN ELECTRIC JUG

Aim

To make an electric jug.

Materials

- Power supply
- Pencil
- Thermometer
- 250 mL beaker
- Heatproof mat
- Two connecting wires
- Alligator clips
- Blu-Tack
- Approximately 70 cm of nichrome wire

WARNING

> Do not allow the two alligator clips to touch while the power is on.

Method

1. Coil the nichrome wire around the pencil, leaving a 10 cm straight section of wire at each end. Remove the pencil from the coil and make sure both straight ends of the wire are pointing in the same direction. Check that the coil will fit into the beaker.
2. Stand the beaker on the heatproof mat and add 50 mL water to the beaker, ensuring the nichrome coil remains below the water level.
3. Connect the straight sections of the nichrome wire to a power supply with alligator clips and connecting wires. Set the power supply on 12 V DC and switch on the power. Use the Blu-Tack to hold the setup in place on the top edges of the beaker.
4. Put the thermometer near the base of the beaker and check the temperature. Check the temperature again after 2, 4, 6, 8 and 10 minutes.

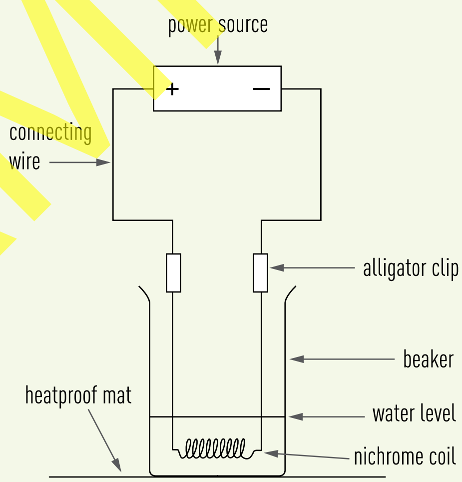


Figure 3.16 Experimental setup for an electrical jug.

Results

Record your results in a table, then convert these data to a time versus temperature line graph.

Discussion

1. What advantage do you think a coiled heating element has over a straight one?
2. Why must the two alligator clips not be allowed to touch while the power is on?
3. Approximately how long did it take for the water to get hot?
4. How could the speed of heating the water be improved?

Conclusion

Write two or three sentences to explain how electrical energy can be used to heat water.

Figure 3.17 Carrying materials can be made easier with machines.

Figure 3.18 Cycling requires fuel from food and by-products of heat and sound are produced by the rider.

Figure 3.20 Power lines provide electrical energy for public transport.

Transformations for motion

Transport is a vital part of our everyday lives. Which form of transport did you use to get around today? Each form uses an energy conversion. Even walking uses energy. We know this because, when we walk a long way, we get very tired. Humans have invested a lot of resources into improving transportation to reduce the energy we expend. Getting from one place to another is much easier with a car. Trucks and trains mean we can transport large quantities of goods in a short period of time.

When we ride a bicycle, the chemical energy stored in our bodies from the food we have eaten is transformed into kinetic energy and heat energy. A car engine also uses chemical energy that is stored in the petrol, converting it mainly into kinetic energy but with the by-products of sound, heat and electrical energy.

Figure 3.19 Hybrid cars use both a petrol engine and an electric motor to send power to the wheels.

Electric cars are being designed to run on the chemical energy stored in batteries, rather than petrol, to power an electric motor that makes the wheels turn. This will make electric cars less polluting and more energy efficient. Hybrid cars have been on our roads for many years. These cars have both a petrol engine and an electric motor with large banks of batteries, usually under the floor. The Toyota Prius and the Hybrid Camry were two of the first hybrid cars on our roads, but many more are being designed.

Public transport uses energy too. Metropolitan trains (and trams in some cities) convert electricity from overhead wires into kinetic energy to make them move.

Figure 3.21 Power lines are not practical in rural areas, so diesel fuel is used.

Trains that travel to country areas or interstate usually run on diesel fuel and do not need overhead electrical wires. The engines in these trains burn diesel fuel, transforming its chemical potential energy into kinetic energy. Ships and planes use a similar process in their engines.

Engine design is part of an engineer's job. It is important to make the engines reliable (so they don't break down) and efficient (so they can run for a long time on the minimum amount of fuel). These are challenges engineers need to overcome. Clever ideas are being trialled all the time to make more efficient engines for our transport requirements.

Figure 3.22 Aircraft use higher-quality fuels than road transport vehicles to minimise weight and waste.

Transformations for light and sound

Humans are one of the few animals that are known to do things just for fun. In fact, humans have taken entertainment to a whole new level. Massive amounts of time, energy and money are dedicated to entertaining ourselves.

These days, light is used extensively for entertainment. Television and other screens display pictures that are made up of thousands of dots of red, green and blue light. The dots are known as pixels (one megapixel is one million pixels). When an electrical signal reaches a pixel, it glows. Making different combinations of pixels glow with different combinations of brightness can produce any colour. To produce yellow, both the red and green pixels glow. To make white, all three of the pixel colours glow. Our eyes merge the coloured light from the pixels together to make the colour we see. All the coloured pixels over the entire screen merge to form the picture of the television show or DVD we are watching.

Both CD and DVD players use light energy from a laser to read the information stored on the CD or DVD. Tiny microscopic pits on the surface of the disc make up the digital code. The laser, which is a very pure type of light, reads the code. The code is then transformed into sound, information or pictures. CD and DVD burners also use a laser but, instead of reading the code, the laser burns or etches the code onto the disc as a series of pits.

Speakers come in a range of sizes, from the tiny earphones that come with smart phones or MP3 players to the huge speaker systems used at concerts. Earphones are simply a pair of tiny speakers that connect to an audio source. The music files stored on an MP3 player are transformed into electrical energy using chemical energy from the battery. The wires carry the electrical energy and the tiny speakers vibrate to transform the electrical energy into sound energy.

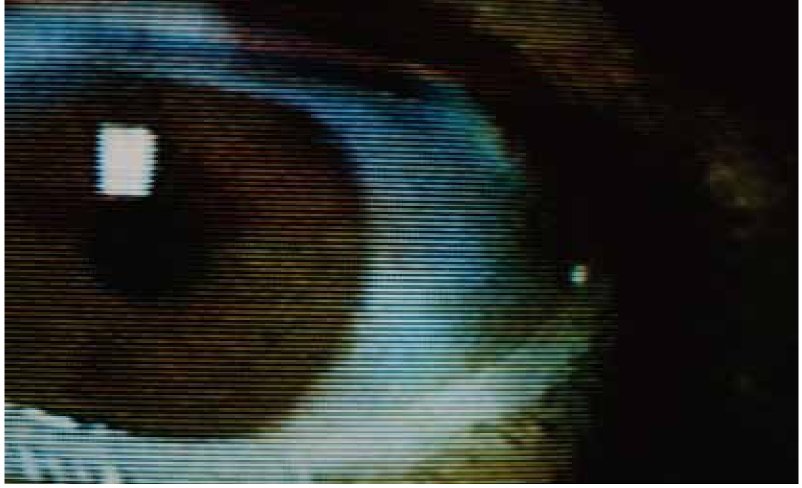


Figure 3.23 The picture you see on the television screen is made up of thousands of coloured dots called pixels.

A mobile phone also uses a speaker to produce the sound of a person's voice or the various ringtones and beeps that the phone makes. Home phones use a speaker too, as do televisions, CD systems, radios and many other devices. They all transform electrical energy into sound energy.

The microphone in a mobile phone transforms the sound energy from our voice into electrical energy, which can then be sent as a radio wave signal to another phone. Nowadays, smart phones have a lot of different parts inside them because of the number of jobs we now expect them to do.

A television remote control uses light energy to communicate with the television set. Most remote controls use infrared light, which is an invisible type of light usually associated with heat. The remote control sends a pulse of infrared light that represents a particular command, such as to change the channel or to increase the volume. An infrared light detector on the television receives the light signal and transforms it back into electrical energy, which then carries out the command.

Figure 3.24 Earphones transform electrical energy into kinetic sound energy.

Figure 3.25 The internal components of (a) an iPod and (b) a mobile phone.

Figure 3.26 A television remote control uses an infrared LED to operate the television.

ACTIVITY 3.1.5: INVESTIGATING ENERGY TRANSFORMATIONS

What you need: model dynamo/generator, model steam engine, radiometer

Figure 3.27 Some devices that transform energy.

1 Carefully identify the different parts of each of the devices listed above. In what ways are they similar? How do they differ?
2 Rotate the handle of the dynamo to make a lamp work.
3 Watch the model steam engine as it runs.
4 Shine a bright light on the vanes of the radiometer.
   - What energy transformations are involved in each of the devices investigated?
   - Which of the devices is/are producing electrical energy? How do you know?
   - Suggest an application in the real world for each device.

QUESTIONS 3.1.2: TRANSFORMING ENERGY

Remember

1 Recall the features that make hybrid cars different from regular petrol-driven cars.
2 Recall why country trains mostly use diesel instead of overhead electrical wires.
3 Describe the importance of energy and energy transformation in transportation.
4 Describe how electrical energy is transformed into thermal energy in a toaster or hairdryer.
5 Suggest three examples, other than those provided, of how light energy can be used.

Apply

6 Identify the by-product energy transformations of a car.
7 Choose three energy-converting devices mentioned in this section and draw flow diagrams for the energy transformations they perform.
8 Draw an energy chain for how we get the energy to run a race from eating an apple. (Hint: Start with the sun.)
9 Propose some of the advantages and disadvantages an electric car has over a petrol car.

Research

10 Many device use remote controls. List as many as you can think of. Investigate how they send their different signals.

TRANSFERRING HEAT ENERGY

Most energy transformations result in at least some of the energy being converted into heat. Heat energy is more properly called thermal energy. All substances, such as water and air, are made of molecules. These molecules move around at different speeds, depending on the temperature. When air or water is hot, the molecules move faster than when they are cold.

When substances are heated, they expand to occupy more space because heating gives the molecules more kinetic energy to move further and faster, spreading the substance out. The molecules do not get bigger, but the spaces between the molecules do. Heat energy travels through materials in three different ways: conduction, convection and radiation.

Conduction and convection

Thermal energy always moves from a hotter substance to a cooler substance. This energy transfer can occur by conduction or convection. Radiation is a different type of energy transfer that will be discussed later on in this section.

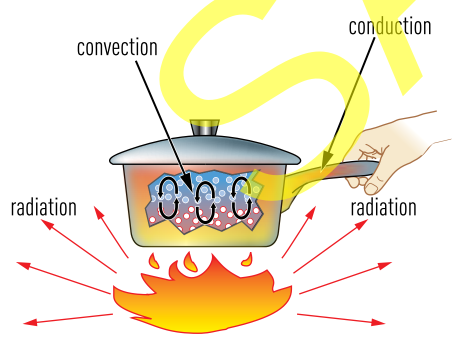


Figure 3.28 Thermal energy can be transferred in three main ways; conduction, convection and radiation.

Heating by conduction

Heat transfer by **conduction** is the transfer of thermal energy when two objects make direct contact with each other and heat transfers from the hotter object to the cooler object.

Consider what happens when a saucepan of water is heated on a gas burner:

- When the gas burns, chemical potential energy is transformed and thermal energy is released.
- The hot molecules in the gas flame move quickly and occasionally bump into atoms of the relatively cold metal of the saucepan.
- Energy passes to the slowly vibrating atoms in the bottom of the saucepan so that they vibrate faster.
- These quickly vibrating atoms in the saucepan then bump into other nearby metal atoms, transferring energy to them. This heats the saucepan.
- When the saucepan heats up, thermal energy is transferred to the water inside the saucepan that is touching the metal.

Although the energy moves through the metal of the saucepan and into the water, the atoms in the metal do not change their positions.

Figure 3.29 Only the bottom of this saucepan is being heated, but conduction will transfer the heat through the metal to the water inside.

Conductors and insulators

A thermal conductor is any material that allows thermal energy to flow easily through it. All metals are conductors although some are better conductors than others. Thermal insulators are materials that slow down the transfer of thermal energy because their molecules don't allow the energy to flow very easily. Insulators such as socks, jumpers and blankets keep us warm in cold weather. They make it difficult for our 'body heat' to escape, insulating us against the cold. Insulation in the roof and walls of a house prevents heat gain and loss during summer and winter. So insulation can hold heat in or keep it out.

Heating by convection

In liquids and gases, thermal energy can also move by **convection**. Tiny circular currents, called convection currents, carry the thermal energy. A convection current is movement within a liquid or gas that is driven by differences in the thermal energy of the molecules.

Think again about what is happening when a saucepan of water is heated on a gas flame:

- Energy transfers by conduction from the hot saucepan to the water molecules that are touching the metal.
- The water molecules in contact with the metal have more energy and are moving faster than the molecules in the water above. Because they are moving faster, they take up more space and so are less dense than the cooler water.
- Less dense substances float on more dense substances. As a result, the heated water molecules near the bottom of the saucepan begin to rise, leaving room for the denser, cooler water molecules to sink down and take their place.
- The heated water molecules take thermal energy with them as they move.

Convection can occur in air as well as in liquids. The sun heats the ground, and the warmed ground then heats the air touching it by conduction. The warmed air is less dense than the cooler air above it, so it will rise, taking the energy with it. This distributes the energy through a much deeper layer of air than could occur just by conduction from the ground. This process of convection in the air is what drives the weather on the Earth.

DEEPER UNDERSTANDING

Living in Iceland

Iceland is just south of the Arctic Circle, in the North Atlantic Ocean. Maximum temperatures in the capital, Reykjavik, range from about –3°C in winter to about 13°C in summer. For much-needed heating throughout the year, Icelanders rely on a renewable source of heat energy: geothermal energy. Iceland is a highly volcanic and geologically active island. The abundant energy from the hot water and steam just below the ground is used to generate electricity, and used directly as heating. Geothermal heating has been used since the times of the Roman Empire to heat buildings and water. This energy is so inexpensive that some footpaths in Reykjavik are heated in winter.

Figure 3.30 The Blue Lagoon is a geothermal spa near Reykjavik, Iceland.

Questions

1 Explain the process of energy transfer via heating.

2 Suggest why almost 90% of Iceland's households use geothermal energy for heating and hot water.

3 What other sources of energy are used to heat homes throughout the world?

EXPERIMENT 3.1.3: INVESTIGATING THE TRANSFER OF HEAT ENERGY BY CONVECTION

Aim

Carefully read the experiment and write an appropriate aim. The title of the experiment may be a hint. Remember that an aim should start with 'To ... '.

Materials

- Bunsen burner
- Heatproof mat
- Tripod
- Gauze mat
- Matches
- Stopwatch
- 500 mL beaker
- Retort stand
- 2 boss head and clamp sets
- 2 thermometers

WARNING

> Warning: be careful when heating liquids and near naked flames, do not leave them unattended. Handle hot glassware with a towel or tongs.

Method

1 Add approximately 300 mL of water to the beaker.

2 Assemble the apparatus as shown in Figure 3.31. Ensure the lower thermometer is not touching the bottom of the beaker and that the bulb of the top thermometer is about 2 cm under the surface of the water.

3 Read the temperature of the water with both thermometers and record both values in the results table as Time 0.

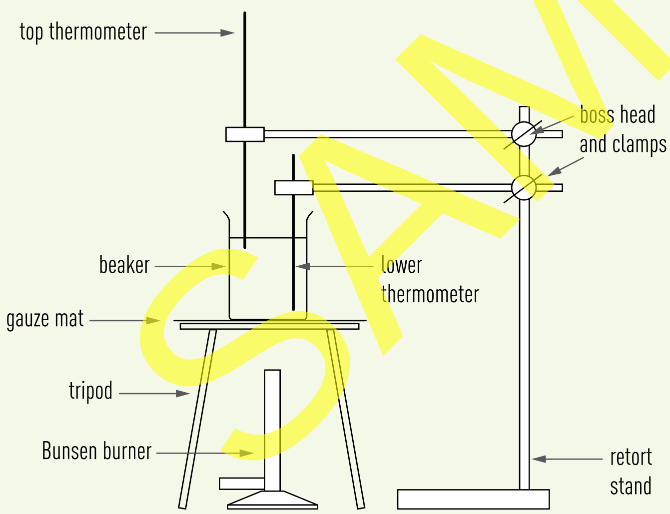


Figure 3.31 Experimental setup.

4 Light the Bunsen burner and turn it to the blue flame.

5 Record the temperature of the water with both thermometers every 30 seconds for 3 minutes.

6 Use your table of results to draw a line graph that shows the change of temperature over time at the two locations. See the Science Skills box for instructions on how to draw a scientific graph. Draw both lines on the same set of axes.

Results

	Temperature (°C)	
Time (s)	Lower thermometer	Upper thermometer
0		
30		
60		
90		
120		
150		
180		

Discussion

1. Describe any differences between the temperatures of the water at the bottom of the beaker compared with the water at the top of the beaker at time 0. Explain why this might be.
2. Describe any differences between the temperatures of the water at the bottom of the beaker compared with the water at the top of the beaker over the 3 minutes.
3. If you continued this experiment until the water was boiling, would you expect any differences in water temperature between the bottom and top of the beaker? Explain your answer.
4. Describe how the water was heated in the beaker using your knowledge of thermal energy, convection and using your results as evidence.

Conclusion

Write two or three sentences to address your aim and explain what you know about the convection of thermal energy.

SCIENCE SKILLS

Drawing scientific graphs

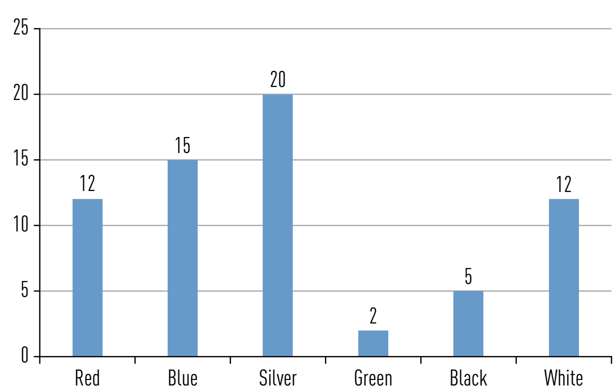
Many scientific experiments collect lots of data. The easiest way to summarise this data and to see any patterns or trends is to use the data to draw a graph. The most common types of graph used in science are line graphs, sector graphs (pie charts), column graphs and histograms. The type of graph you draw depends on the type of data you have collected.

Column graphs

Column or bar graphs are used when data falls into distinct groupings, for example if you were recording the colours of cars you saw passing your window over a set time period, you could produce a table such as:

Car colour	Red	Blue	Silver	Green	Black	White
Number	12	15	20	2	5	12

In a column graph, the discrete grouping is usually displayed on the x-axis, and the numbers are displayed on the y-axis, as shown below.



Sector graphs

Sector graphs, also known as pie charts, are also used to display data that has discrete groupings. In contrast to a column graph, a pie graph displays the data as proportions of a circle. For the data above, the whole circle represents the total number of cars seen.

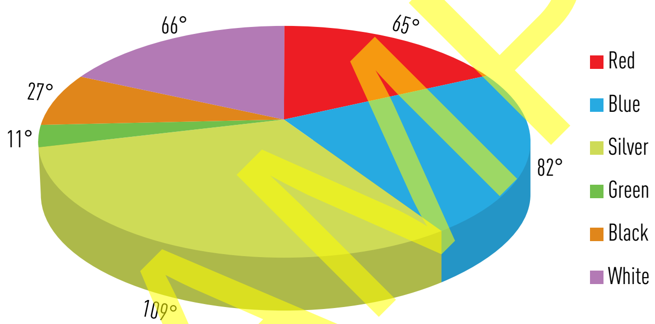
Car colour	Red	Blue	Silver	Green	Black	White	Total
Number	12	15	20	2	5	12	**66**

Next, divide each value by the total and multiply by 100 to get a percent:

Car colour	Red	Blue	Silver	Green	Black	White	Total
Number	12	15	20	2	5	12	**66**
Percentage	12/66 = 18.2 %	15/66 = 22.7%	20/66 = 30.3%	2/66 = 3%	5/66 = 7.5%	12/66 = 18.2%	**100%**

Next, you need to calculate how many degrees each sector will represent on the pie graph. A full circle has 360°, so we do the following calculation:

Car colour	Red	Blue	Silver	Green	Black	White	Total
Number	12	15	20	2	5	12	**66**
Percentage	12/66 = 18 %	15/66 = 23%	20/66 = 30%	2/66 = 3%	5/66 = 8%	12/66 = 18%	**100%**
Degrees	12/66 x 360 = 66°	15/66 x 360 = 82°	20/66 x 360 = 109°	2/66 x 360 = 11°	5/66 x 360 = 27°	12/66 x 360 = 66°	**360°**



Now a sector graph can be created by drawing a circle and using a protractor to measure out the sectors that represent each car colour:

Line graphs

Line graphs are used to show how one continuous variable changes in relation to another variable. The independent variable (the variable that you change) is always on the horizontal x-axis. The experimental or dependent variable (the variable you measure for your results) is placed on the vertical y-axis.

Steps for drawing a scientific line graph

1 Give your graph a title that briefly explains what the graph is showing. Both the variables should be a part of the title. For example, *The change in plant height over time*. In this example, time will be the independent variable, and the height of the plant will be the dependent variable.

2 The length of your axes and the spacing of units will depend on your data. Identify the highest values for each variable, and base your axes on those, adding a few extra unit lengths in case you need to extend (extrapolate) your results to predict what would have happened if you'd continued your experiment. For example, from the data table below, the horizontal axis needs to go up to at least 12 days, while the vertical axis should go up to 250-300 mm.

Time (days)	0	1	2	3	4	5	6	7	8	9	10
Height (mm)	0	0	1	4	15	28	49	73	102	148	195

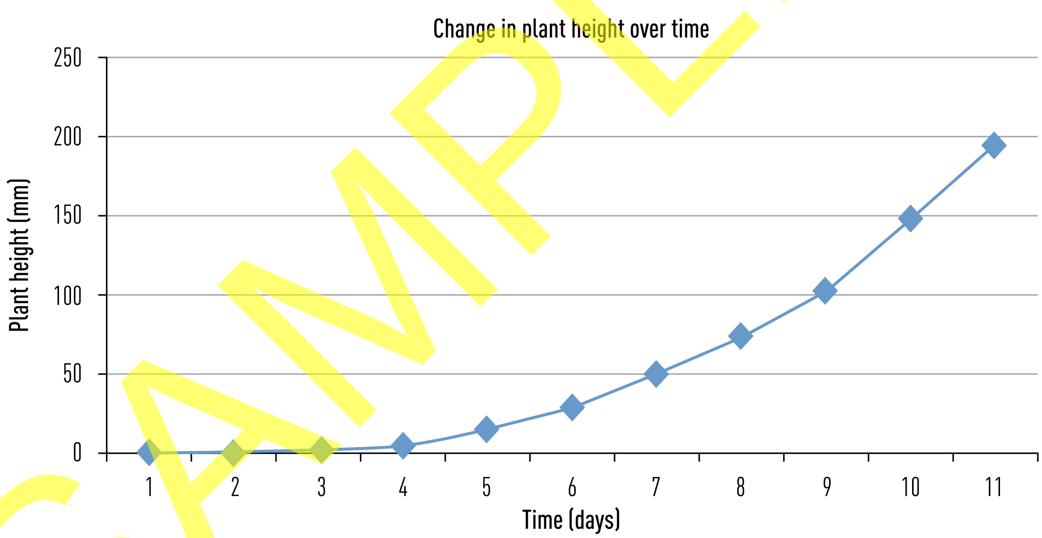
3 Label each axis with the variable and the units you have used to measure it.

Using pencil, plot each point of data from the table.

4 Join the points with a line of best fit. This does not necessarily mean you rule a straight line through the first and last point. You may have to hand-draw a curve in some cases. The line may not pass through every single point, but should be a smooth line that passes near as many points as possible. This line of best fit shows you if there is any trend (pattern) in your data to indicate a relationship between the two variables. It also identifies any outliers, which are data points a long way from the line of best fit that may indicate a mistake in your data recording or method.

5 You can even draw more than one set of data on the same graph axes, if they are using the same variables. For example, you might want to compare the electrical efficiency of 3 different brands of kettle. When you place multiple lines on the same graph, you must label each line, or draw them in different colours and provide a key.

A graph of the above data may look like:



Your turn

You carried out an experiment to compare the efficiency of 3 different brands of kettle when boiling different amounts of water. The results were as follows:

		Amount of water (mL)					
		250	500	750	1000	1500	2000
Time taken to boil (sec)	Kettle A	50	100	150	200	300	400
	Kettle B	62	110	134	169	278	367
	Kettle C	48	92	151	223	341	443

Draw an appropriate graph to display this data.

Heating by radiation

When you go outside on a warm day you are being exposed to **radiation**. Unlike convection and conduction, when something radiates energy, the medium (substance) through which it travels is not affected. Radiation is a type of energy and can be in forms such as visible light, ultraviolet light, radio waves, microwaves and infrared radiation. Radiation is not necessarily absorbed when it meets a substance – it may be reflected or transmitted. For example, radiation from the sun is transmitted through the atmosphere – some of the radiation is reflected from the tops of clouds, some is absorbed by the ground and some is reflected by the ground.

Radiated energy that is absorbed gives the molecules of the substance more energy to vibrate, increasing their thermal energy.

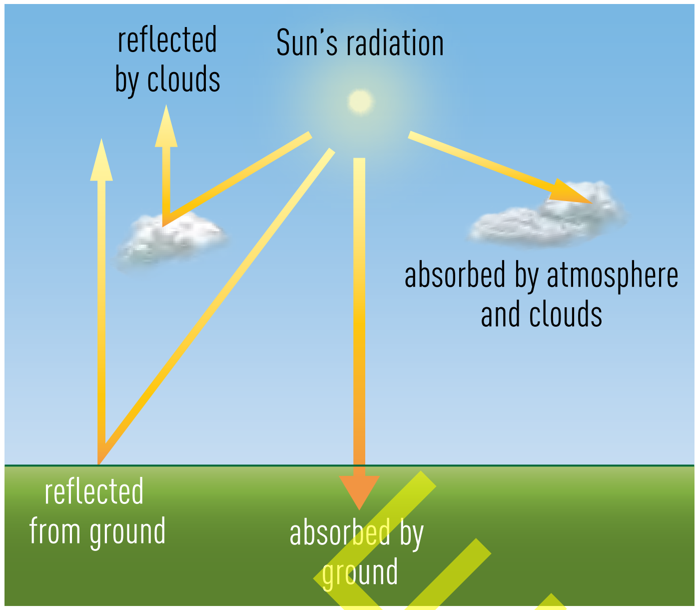


Figure 3.32 Radiation from the sun does several things, depending on weather conditions.

ACTIVITY 3.1.6: INVESTIGATING HEATING BY RADIATION

What you need: 3 cm square of black paper, 3 cm square of white paper, 3 cm square of aluminium foil, 3 thermometers, sunlight (alternatively, use an incandescent lamp or heat lamp), 3 stopwatches

1 Work in groups of three.
2 Place the bulbs of the thermometers under the different materials and then place them in the sunlight (or under a lamp, making sure that they are all 6 cm from the lamp).
3 Use a table to record the temperature of each thermometer every minute for 10 minutes.
4 Draw graphs of the change in temperature for the different materials.
   - Which surface was the best at absorbing radiation?
   - Which surface was the best at reflecting radiation?
   - How could this understanding be applied to choosing colours for clothing or materials for housing?

Figure 3.33 A household heater such as this one, radiates heat energy to its surroundings.

DEEPER UNDERSTANDING

Solar snakes

Snakes and other reptiles rely on thermal energy from the sun. Reptiles are poikilothermic (pronounced poy-kilo-thermic); their temperature takes on the temperature of their surroundings. 'Cold-blooded' isn't a very scientific description because their blood is very rarely cold at all. Reptiles regulate their body temperature by moving from sunny to cooler areas.

Snakes and lizards lie at right angles to the direction of the sunlight to maximise the amount of solar radiation falling on their skin. They increase the surface area exposed to the sun by expanding their ribcages. Many reptiles can also darken their skin to absorb more heat from solar radiation.

Snakes and lizards are also often seen lying on hot roads or rocks that have absorbed thermal energy from the sun. In this case, they are using conduction from the hot rocks to transfer heat.

When a reptile is too hot, it will lie parallel to the sun's rays, move into the shade, lighten the colour of its skin, open its mouth wide, or burrow under cool soil. Reptiles are much more active in warmer temperatures and hibernate (a sleep-like state) in colder seasons.

Think about the role of energy in this process and how it is related to the living matter, in this case the snake's body and its blood.

Figure 3.34 Bearded Dragons darken their skin and spread out their bodies to help absorb solar radiation.

Questions

1 Why does increasing the surface area of the snake's skin allow more energy to be absorbed into its body?

2 Does the body of the snake store thermal energy? Explain your answer.

3 Why would opening its mouth allow the snake to cool down?

4 Poikilothermic animals need a lot less energy from their food compared to homeothermic animals, which maintain a constant body temperature. Suggest a reason why this is, and describe why this may be an advantage for poikilothermic animals such as snakes.

QUESTIONS 3.1.3: TRANSFERRING HEAT ENERGY

Remember

1 Identify an everyday situation where thermal energy is transferred by:

  a conduction

  b convection

  c radiation.

2 Recall the possible pathways of solar radiation from the sun, depending on the weather conditions.

3 From your everyday experience, list some examples of where good thermal insulators and conductors are needed. Identify the materials used in each case.

4 List some examples of common devices that work by the movement of light, infrared radiation, microwaves or radio waves.

5 Identify what happens when a substance absorbs radiation.

Apply

Overmatter

EVERYDAY ENERGY

3.1 CHECKPOINT

Remember

1 Match these terms with their correct meanings: [6 marks]

Nuclear energy	Another name for stored energy
Biomass energy	The energy of an object when lifted up
Elastic energy	Used widely throughout the world to generate electricity from atoms
Kinetic energy	The energy stored in a compressed spring
Gravitational energy	Possessed by all moving objects
Potential energy	Energy stored in plants and animals

2 Identify whether the following statements are true or false. Rewrite the false statements to make them correct.

- **a** Springs only hold stored energy when they are stretched. [1 mark]
- **b** Nuclear energy provides much more energy than chemical reactions. [1 mark]
- **c** When an object is thrown up in the air it gains gravitational potential energy. [1 mark]
- **d** Sound energy is a type of potential energy. [1 mark]
- **e** Petrol contains nuclear energy. [1 mark]

3 Identify the main form of energy in each of these situations:

- **a** water flowing over a waterfall [1 mark]
- **b** a boy riding his skateboard [1 mark]
- **c** a stretched rubber band [1 mark]
- **d** a mobile phone battery [1 mark]
- **e** a racing car travelling around the race track [1 mark]
- **f** a clap of thunder [1 mark]
- **g** a rollercoaster at the highest point of the ride [1 mark]

4 Name a device that transforms:

- **a** elastic energy into kinetic energy [1 mark]
- **b** gravitational energy into electrical energy [1 mark]
- **c** kinetic energy into electrical energy [1 mark]
- **d** light energy into electrical energy [1 mark]
- **e** electrical energy into sound energy. [1 mark]

5 Identify the type of heat transfer that happens when you touch something hot. [1 mark]

Apply

6 A gas flame used in cooking emits some radiant energy. Explain how you would be aware of this heat transfer. [1 mark]

7 Draw labelled diagrams of the three methods of transferring energy by heating. [3 marks]

8 Identify the input energy source for a car, the main useful source of energy it produces and some of the by-product forms of energy it produces. [3 marks]

Figure 3.35 What are all the energy transformations that happen in a moving car?

9 Have you ever swum in the sea and noticed that the water is warmer near the surface at the end of a hot day? Explain why convection currents don't work very well to heat water when the heat source is above. [3 marks]

10 Think of your day today. How many different energy forms have you possessed, used or witnessed? Identify the most commonly used form of energy and suggest a reason why this might be the case. [3 marks]

Critical and creative thinking

11 Energy types rarely exist alone. Different types of energy often work together to make something happen. Think about some of the things energy is responsible for. Choose one thing and identify the type or types of energy involved. If more than one type of energy is involved, link the different types with arrows. Compare your scenario with a friend and see who can come up with a scenario that involves the most forms of energy. [3 marks]

12 Create a story that analyses the energy transformations in a device. There needs to be at least four steps in the story. Convert your story into an energy chain, written in the correct format. [4 marks]

Research

13 The massive earthquake and tsunami in Japan in March 2011 caused extensive damage to the Fukushima nuclear power plant, north of Tokyo, and created an emergency situation. Research this disaster and present a two-minute news report to the class that highlights the issues surrounding the use of nuclear energy. [4 marks]

TOTAL MARKS:
[/42]

ELECTRICAL ENERGY

3.2

Electricity is a form of energy that most people are very familiar with, and probably don't know how they would live without it. Electricity is a very versatile form of energy that can be relatively easily stored, and transformed into almost any other form of energy. It powers your mobile phone and laptop, runs the lights and the refrigerator in your house, and is vital in communication over long distances. People's reliance on electricity continues to grow as technological advances make more and more devices available to the general public.

ELECTRICAL CIRCUITS

You may recall from Year 7 that all matter is made up of atoms, and that atoms contain charged particles. Negatively charged particles called electrons circle around the outside of the positively charged nucleus in the centre of the atom. When separated, electrons and the nuclei have electrical energy. In static electricity, the tiny electrons can be rubbed off one object and on to another creating static charge. When this charge is discharged, the electrons return to the nuclei in a rush, creating a zap and sometimes even a spark. The sound, sensation and sight of a spark are the result of the transformation of electrical energy into sound, kinetic and light energy.

If the charges are contained in a substance that is a good electrical conductor, such as a wire, the separated charges can easily move back together. The electrons are able to flow through the wire from one place to another and may pass through a device. As they do so, the electrical energy they had as a result of being separated from their nuclei gets changed (or transformed) into some other form, such as light and heat energy in a light bulb.

The flow of electrical energy from one place to another along a pathway made from a conductive material is called an electrical current.

Electric circuits

The pathway travelled by electrical energy is called an **electric circuit**. As negatively charged electrons move around an electric circuit, they carry electrical energy from the energy source, such as a battery, to the device that uses the energy, such as a torch. Devices have 'gaps' in the pathway called

Figure 3.36 These devices and many more rely on electrical energy. How would your life be different without them?

switches to control the flow of electricity in a circuit. If the switch is open the pathway is broken and no electricity flows.

The essential requirements for an electric circuit are a power source, the wires or pathway, and a **load** or a component such as a light bulb or resistor. Electrons need a component to transfer their energy to otherwise they transfer energy to the wires which transform the energy into heat. Without a load on the circuit, the wires can get hot enough to melt or even catch fire. Many house fires can start as a result of electrical energy.

ACTIVITY 3.2.1: LEMON BATTERIES

What you need: copper metal (foil or uninsulated wire), galvanised nails, 4 lemons per group, 6 alligator clip leads (short), LED (light-emitting diode), multimeter (optional)

1 Roll the lemons and squeeze gently to soften the skin and make sure they are juicy on the inside.
2 Make a slit in the lemons and insert a strip of copper foil. Use a marker to indicate positive + on each lemon near the copper foil. At the opposite end of each lemon push in the galvanised nail and mark it as negative –.
3 Connect the lemons in a line with alligator leads from the + copper terminals to the – galvanised nail terminals.
4 Connect the alligator leads to the last copper terminal and galvanised nail. Connect the lead from the copper to the positive side of the LED (the long leg of the LED). Connect the galvanised nail lead to the negative side of the LED (the short leg of the LED). The LED will not glow if it is connected the wrong way around.
5 Darken the room and look carefully at the LED. It should have a faint glow.
6 If you have time, repeat the activity using potatoes instead.
   - How do you think the lemons are able to act like a battery?
   - How is the electrical energy in the lemons getting to the LED?
   - What energy transformations are happening for the LED to light up?

Figure 3.37 Fruits and vegetables can be used as a source of electrical energy.

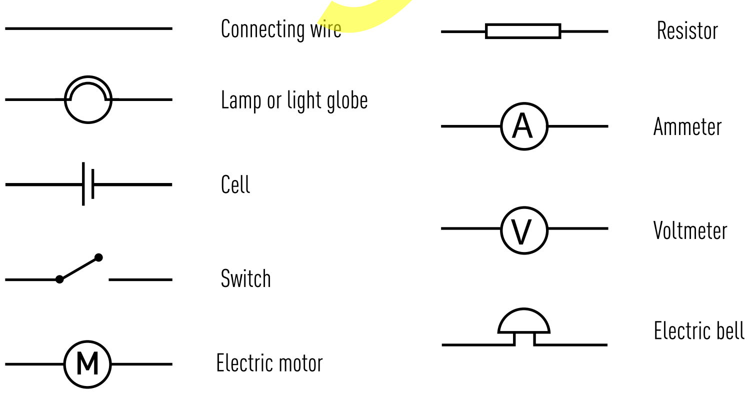


Figure 3.38 Some common symbols used in circuit diagrams.

Circuit diagrams

Circuits and their components are represented using **circuit diagrams**. Rather than drawing a picture of the different devices, each component of a circuit is represented by a symbol (Figure 3.38). Straight lines are used to represent the wires that connect the components together and form the circuit. The connecting wires are usually drawn using a ruler and form right angles where they join.

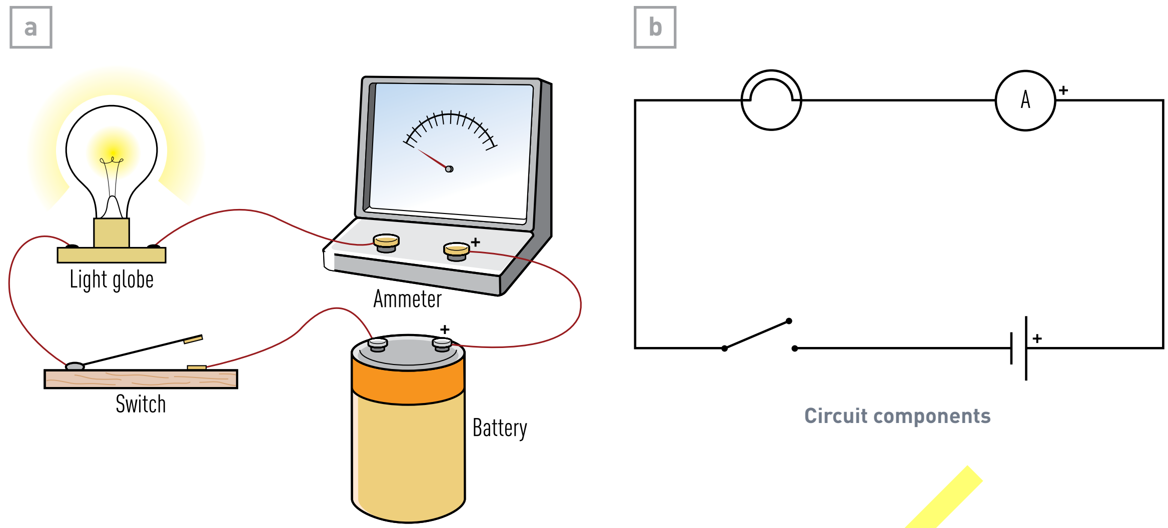


Figure 3.39 (a) A simple circuit. (b) A circuit diagram of the same circuit.

A cell is a power source. It could be a battery cell, a power pack or a plug point in the wall.

An ammeter is a device that measures the current or flow of electrons through the circuit. The ammeter counts the electrons in packets called coulombs. The number of electrons that pass through the circuit is measured as coulombs per second, or amperes (A) – commonly called amps. To use an ammeter, it must be connected as part of the circuit so all the electrons flowing around the circuit also flow through the ammeter.

A voltmeter is a device that measures the voltage, which is the amount of energy the electrons are transferring to the components. Voltage is measured in volts (V). To use a voltmeter, it must be connected over the top of a component so it can measure the difference in the energy of the electrons from just in front of the component to just after it.

Connecting a number of components in a loop of connecting wire is called a **series circuit**. When the circuit has more than one pathway for the electrons to travel, it is called a **parallel circuit**. Electrons transfer their energy differently in series and parallel circuits.

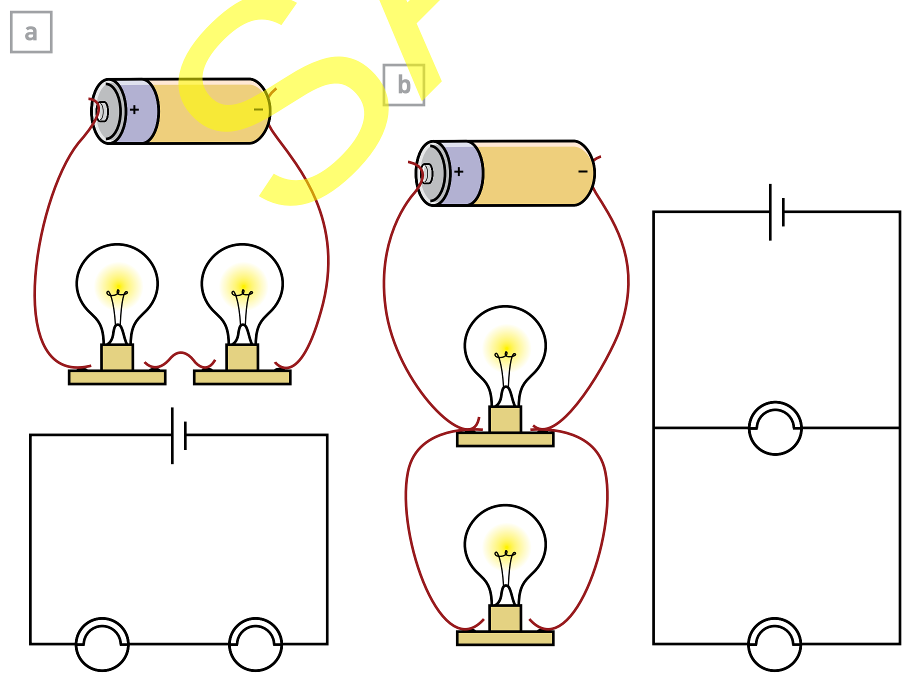


Figure 3.40 (a) A series circuit. (b) A parallel circuit.

ACTIVITY 3.2.2: DRAWING AND CONNECTING CIRCUITS

What you need: power supply, 2 light bulbs, 7 electrical leads, 2 resistors, a switch, ammeter, voltmeter

1 Draw a circuit diagram for each of the following circuits and check it with your teacher.

   Circuit 1: One light bulb connected to a power supply. This is a simple circuit.

   Circuit 2: Two light bulbs in a row connected to a power supply. This is a series circuit.

   Circuit 3: Two circuits connected to the power supply at once – one resistor and one bulb placed on each loop of this double circuit. This is a parallel circuit.

   Circuit 4: A switch inserted into circuit 3 so that it can switch off one of the light bulbs independently of the power supply switch. (Keep this circuit connected to answer some of the questions that follow.)

2 For each circuit, connect the components together to match your circuit diagram.

3 Turn on your circuit and check that it operates as desired.

4 Turn off the electricity before you move onto the next circuit.

   - Which circuit arrangement made the light bulbs brighter: circuit 1 or circuit 2?
   - Why does the switch in circuit 4 only affect one of the light bulbs?
   - Use a voltmeter to measure the voltage across each light bulb in circuit 4. What does this tell you about the transfer of energy in this type of circuit?
   - Add an ammeter to each loop in circuit 4 to measure the current coming from the power supply. What does this tell you about the flow of electrons in this type of circuit?

Transistors and integrated circuits

The invention of a component called the transistor in 1947 heralded the dawn of the electronic age. The team who invented it received the 1956 Nobel Prize.

A transistor is made from a material called silicon. The three legs of a transistor are known as the collector, base and emitter. A transistor has two main functions. Firstly, it can act as a switch, although it has no moving parts. In this role it can control the functioning of many electronic circuits, including computers. Secondly, a transistor can act as an amplifier. When a small current flows into a transistor, the transistor amplifies it to produce a larger current. The transistor replaced larger devices called vacuum tubes or valves that were used to amplify radio signals. This made the new 'transistor radio' much more portable.

Figure 3.41 A 1950s transistor radio

A semiconductor is a material that carries or conducts electricity better than an electrical insulator (which doesn't conduct electricity at all) but less than a pure conductor. Electrical conductors and insulators behave the same as thermal ones. Electrical conductors carry or pass electricity easily and electrical insulators block electricity.

These days, many millions of semiconductor devices can be printed onto wafers of silicon, called silicon chips. The finished device is called an **integrated circuit** (IC) or microchip. An IC is a miniaturised electronic circuit. It may contain many thousands of components yet it is only 5 mm square and 1 mm thick.

Figure 3.42 Transistors come in different shapes and sizes. The miniaturisation of transistors has revolutionised electronics and computing.

Figure 3.43 When it was introduced in March 1998, this operational amplifier, containing 50 transistors, was the world's smallest integrated circuit. Even smaller integrated circuits are now used in phones, games and many other electronic devices.

QUESTIONS 3.2.1: ELECTRICAL CIRCUITS

Remember

1. Recall how energy is transferred in a simple circuit.
2. Identify the essential components of an electrical circuit.
3. Describe the similarities and differences between series and parallel circuits.
4. Identify the role of a switch in a circuit.

Apply

5. Draw a series circuit containing a cell, a switch, a light bulb and an electric bell. Is it possible to turn the bell on while the light bulb is off? Explain your answer.
6. Draw a parallel circuit with a single light bulb and a resistor on one pathway, and an electric motor on the other.
7. Redraw the parallel circuit in the previous question but this time insert a switch that will turn the light bulb on and off without affecting the motor.

ELECTRICAL ENERGY TRANSFORMATIONS

Figure 3.44 Compact fluorescent lights (CFLs) are an energy-saving form of lighting.

Figure 3.45 (a) Light-emitting diodes (LEDs) are tiny bulbs that use very little energy. (b) LEDs are commonly used in torches.

Electrical energy is very versatile as it can be transformed into most other forms of energy. We rely on electrical energy for heating and cooling, for making dark places light, and for recording and producing sound. Many of the energy transformations already discussed in this chapter involve electrical energy at some stage.

Electric lighting

Humans have been using light energy for thousands of years in both simple and complex gadgets, but the most obvious use of light is for illumination. You may be using light for this purpose right now. What types of light bulbs are installed in the room you are in?

Fluorescent tubes are common in schools. These are long glass tubes filled with mercury gas. This type of light bulb doesn't generate much heat, so it is more efficient than the older-style incandescent (or filament) light bulbs and uses less electrical energy to produce the same amount of light. The Australian Government started to phase out the sale of incandescent light bulbs from November 2009, replacing them with **compact fluorescent lights** (CFLs), which are used as an energy-saving alternative. Most CFLs are designed to replace existing filament bulbs and fit in the same sockets. The CFLs use less energy than the filament bulbs and last much longer.

Light-emitting diodes (LEDs) are tiny light bulbs. When they are grouped together they can produce extremely bright light with very little energy. LEDs come in a large range of colours and are being used extensively for illumination in torches, traffic lights and garden lighting. They tend to last a long time before they 'blow', which makes them a good alternative to incandescent bulbs in traffic lights and other signs.

Solar cells are a relatively recent invention that turn light from the sun directly into electricity. Solar cells are now being used to power many devices such as calculators, streetlights and even cars.

Everyday electrical energy

Most people living in Australia have access to electricity and have come to depend on it. As well as for our lighting, we use electrical energy around the house every day. Electricity is generated in different types of power stations. Whether these power stations are fuelled by coal, geothermal energy, wind, wave or nuclear energy, they all have one thing in common – a **generator**. A generator moves a strong magnet inside a dense coil of wire. The movement of the magnetic field within a coil of wire attracts the negatively charged electrons and starts them moving in the wire. Moving electrons means electrical energy.

Figure 3.46 Solar-powered signs are becoming common all across our country. These signs transform solar radiation into light energy.

ACTIVITY 3.2.3: ELECTRICAL ENERGY TRANSFORMATIONS

Imagine you are walking around your house and your neighbourhood. Try to think of all the devices that either plug into the wall or run off batteries. With a partner, or in a small group, try to complete the examples of energy transformations in Table 3.3. See if you can come up with some different energy transformations involving electrical energy.

Table 3.3 Examples of energy transformations.

Input energy	Output energy	Example 1	Example 2
Electrical	Kinetic		
Electrical	Chemical potential		
Chemical potential	Electrical		
Electrical	Light		
Light	Electrical		
Electrical	Sound		
Electrical	Thermal		

Transporting electrical energy

Besides having a large range of transformations, electrical energy has other advantages over other types of energy. Electrical energy can be transferred from one place to another without having to change form. Overhead transmission lines transport electricity from a power station to our houses, our schools and our businesses.

The voltage or the electrical energy carried in the transmission lines between towns is extremely high, usually between 130 000 and 500 000 V. Before it reaches your suburb the voltage is dropped to around 11 000 V, but this is still enough energy to power almost the whole of your suburb!

Devices called **transformers** reduce the amount of energy in the power lines to make it safer to use. The electricity is your house is only 240 V. If the voltage of the electricity in your house were higher than this, devices using the electricity could not transform that much energy fast enough and would end up producing heat instead. This can cause sparks and fires.

Your laptop, mobile phone and MP3 player do not need 240 V of energy, and therefore have step-down transformers as a part of their charger cables. The big block on the plug or on the cable itself contains the transformer. As the step-down transformer reduces the amount of energy in the electricity, some of that energy is transformed into heat. You can often feel this heat when your device has been on for a long time.

Storing electrical energy

Most forms of energy cannot be stored for use at a later time. You cannot collect sunlight in a box to read by at night! But electrical energy is so easily transformed into chemical energy and back again, it is like we are storing electricity. Batteries of all shapes and sizes store electrical energy in the form of chemical potential energy.

Batteries can be single use or rechargeable. Single use batteries are thrown away once they are 'dead'. The chemical reactions that take place inside them to release electrical energy cannot be reversed, so once the ingredients of the reaction have run out, no more electricity can be released.

Rechargeable batteries use different chemicals and their reactions are reversible. When you put electrical energy back into the rechargeable battery, the chemical products are broken back down into the ingredients again.

These reversible chemical reactions are not perfect though. After a while the ingredients break down or are turned into something else. So even rechargeable batteries fail after a while.

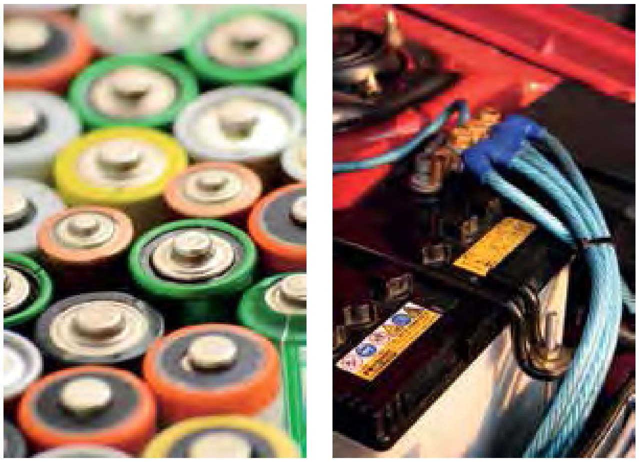


Figure 3.47 Batteries come in all different shapes and sizes, but they all transform chemical potential energy into electrical energy.

QUESTIONS 3.2.2: ELECTRICAL ENERGY TRANSFORMATIONS

Remember

1 Recall the three common types of light bulbs.

2 Identify the function of step-down transformers.

3 Recall at least two places where you would find step-down transformers.

Apply

4 Draw a labelled flow chart to explain the voltage conversions of electrical energy from the transmission lines to the power line in your street, and then to the electricity that comes into your house.

5 Identify an advantage of CFLs over incandescent light bulbs.

6 Explain how a battery is different to a generator in the way it produces electrical energy.

7 Solar-powered lights use light energy to produce light energy. Explain whether or not any energy transformations have occurred.

8 Propose why the Australian Government is phasing out incandescent light bulbs.

ELECTRICAL ENERGY

3.2
CHECKPOINT

Remember

1 Recall three advantages of LEDs over incandescent bulbs. [3 marks]

2 Complete the following sentences:

- **a** Electrical energy is carried by ____________ around a circuit. [1 mark]
- **b** Electrical energy is measured in ______________. [1 mark]
- **c** The amount of electrons moving in a circuit is measured in ______________. [1 mark]
- **d** Every electrical circuit needs a ______________, connecting wires and a load. [1 mark]

3 Recall the function of a voltmeter. [1 mark]

4 Explain how a switch works in an electrical circuit. [2 marks]

Apply

5 List the different types of light bulbs in order from most efficient to least efficient. Explain why they are so different. [4 marks]

6 Explain why electrical energy can be used to produce sound, light, heat and motion. [1 mark]

7 Describe the steps you would take to determine the exact amount of electrical energy being used by a light bulb in a circuit. [3 marks]

8 Examine Figure 3.48 carefully and answer the following questions:

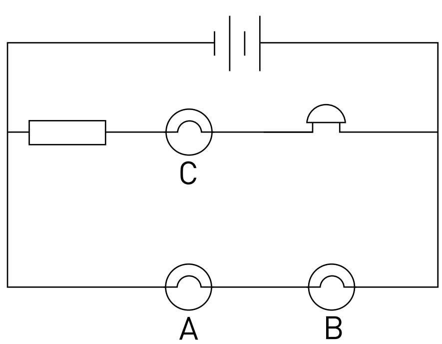


Figure 3.48 An electrical circuit.

- **a** Identify whether the circuit above is series or parallel. [1 mark]
- **b** Identify all the components within the circuit. [4 marks]
- **c** If the component labelled A were to break, explain what would happen to components B and C in terms of electrical energy. [3 marks]

9 Explain why step-down transformers are required before electricity reaches your house. [1 mark]

Research

10 Many types of light energy exist. Research the electromagnetic spectrum and different types of radiation it contains. List them, and state a use for each type. [4 marks]

11 Car batteries are a vital component in a car. Investigate what they are used for and how they are recharged. Present your information as an annotated poster or a short presentation. [4 marks]

12 Investigate the development of the light bulb throughout history. Who invented the first light bulb? What other types of bulbs have been invented? What do the most modern light bulbs look like? What is their advantage over older versions? Present your findings on an annotated timeline including diagrams. [5 marks]

Figure 3.49 Illumination technology has changed a lot over the years.

TOTAL MARKS:
[/40]

3.3 INCREASING ENERGY EFFICIENCY

Energy efficiency is a phrase being used more and more often. It is also often paired with the term sustainability. But what is energy efficiency? How do we become more energy efficient? In what ways have scientific knowledge and technological developments helped to increase the efficiency of energy use and transformations? What are the benefits of energy efficiency to society and to the environment?

ENERGY EFFICIENCY

Energy efficiency is a measure of how much energy is transformed into the desired energy type, compared with the amount that might be a by-product and lost as heat, sound or other types of energy. Most energy conversions are inefficient and lead to the production of wasted energy. A light bulb is designed to transform electrical energy into light energy, so if heat energy is also produced it takes energy away from the original purpose – to produce light.

The most common form of by-product energy is heat, or thermal energy. Thermal energy is difficult to use, it cannot be stored, and often damages the device itself if too much is produced.

Reducing the amount of by-product energy transformed by a device is the ultimate goal of many scientists, which promotes the search for better energy efficiency. Engineers strive to design the best devices possible with the highest efficiency ratings. You have probably seen that many appliances now come with efficiency star ratings.

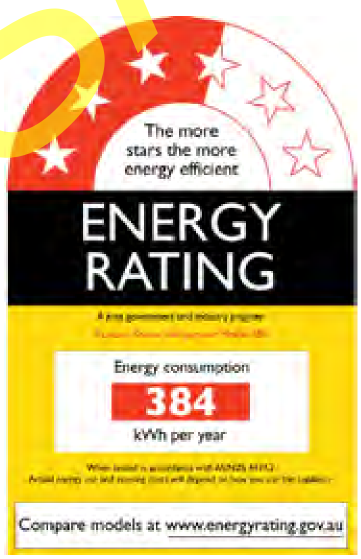


Figure 3.50 More stars mean an appliance is more energy efficient.

A trampoline transforms elastic potential energy into gravitational potential energy so you can bounce. If a device like a trampoline transforms most of its input energy into the useful output energy, then it is considered to be a very energy-efficient device. All energy transformations produce by-product energy forms. In the case of the trampoline, by-product energy forms include heat and the sound of the springs squeaking. Both these by-product energy forms reduce the amount of 'bounce' energy and are said to be 'wasted' energy. The less wasted energy, the more energy efficient the device. Energy efficiency is calculated as the percentage of useful energy transformed out of all the available input energy.

Take the trampoline example in Figure 3.51. The input energy was 500 units and the useful output energy was 400 units. This means that the trampoline is 400 ÷ 500 = 0.8 efficient, or 80% efficient, which is not too bad. Most energy transformations for everyday appliances do not get this high. Scientists are constantly trying to design the best appliances possible with the highest efficiency ratings. This would make the devices better for the environment and cost less to power. Do you and your family always buy the most efficient appliances? Are you familiar with the star ratings on appliances?

More stars mean that the appliance is more energy efficient. When you are using an appliance with a high-star rating you know that less energy is being wasted. This mean you pay less on your electricity and gas bills, as you are only paying for the energy being used rather than lots of energy being 'wasted'.

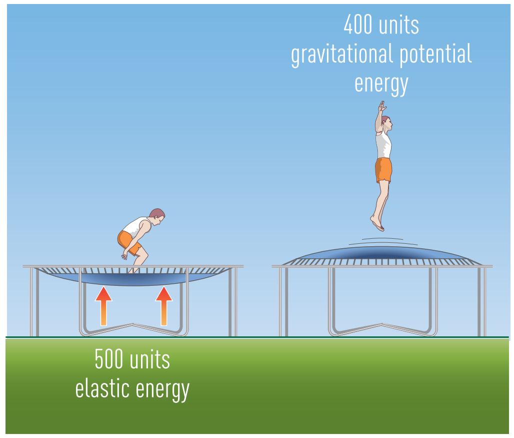


Figure 3.51 500 units of energy are stored in the springs of the trampoline. At the highest point, the jumper has 400 units of gravitational potential energy. Where have the 100 'missing' units gone?

ACTIVITY 3.3.1: ENERGY EFFICIENCY RATINGS

Many people leave their energy efficiency rating stickers on their appliances, but if yours have been removed, a quick Internet search will find out the rating of your appliances.

Investigate the energy efficiency rating of your major household appliances, such as the refrigerator, washing machine, clothes dryer and dishwasher.

- Is the number of stars related to the energy consumption?
- Identify the full name of the unit kWh.
- Compare your results with some classmates. Are particular appliances typically more or less efficient than others?

QUESTIONS 3.3.1: ENERGY EFFICIENCY

Remember

1 Define the term 'energy efficiency'.
2 Explain why by-product energy transformations are considered 'wasted' energy.

Apply

3 Explain why it is better to buy energy-efficient appliances.
4 Propose a reason why 6-star energy-rated appliances are rare.
5 A friend of yours is considering buying a 2-star energy-rated device because it is slightly cheaper than a 4-star device. Outline the advice you would give your friend.

EFFICIENT ENERGY GENERATION AND USE

It is becoming more common to read and hear about how we need to be more energy efficient in our lives. In these cases, people are usually referring switching off lights at home when we are not using them, or changing our light bulbs at home to more economical ones. There are other ways though to improve our energy efficiency.

ACTIVITY 3.3.2: WHICH IS THE MORE ENERGY EFFICIENT?

What you need: 2 different electric kettles of the same power rating (e.g. 2000 W), 500 mL measuring cylinder, thermometer, stopwatch

1. Empty both kettles and fill each of them with exactly 500 mL of cold tap water.
2. Check that the temperature of the water in both kettles is the same.
3. Plug both kettles in and turn them on at the same time. Use the stopwatch to time how long each one takes to boil the water.
4. Double-check at the end that the temperature of the water in both kettles is 100°C.
5. When both kettles have cooled down, tip the water out and repeat the experiment.
   - How do you know which kettle is the most energy efficient?
   - Why was it important to keep the conditions exactly the same for both kettles?
   - Was it really necessary to check the water temperature at the end of the test? Why?
   - Why was the experiment repeated?

Efficient lighting

Light energy is essential to our lives and people have invented lots of devices to help us see in the dark. The humble electric light bulb revolutionised the world when it was invented. Oil and gas lamps were popular in the past, and a torch helps us see at night when we go camping. Have you ever used a torch with LED lights instead of a filament or incandescent light bulb? Do you know why it is better than the older type?

NUMERACY BUILDER

Cost comparison

Table 3.4 A comparison of light bulbs.

	Incandescent bulb	CFL bulb	LED bulb
Wattage (watts)	60	14	10
Estimated life (hours)	1000	10 000	50 000
Cost per bulb	$1.50	$3.50	$35.00
Bulbs needed for 50 000 hours of use	50	5	1
Comparative cost for 50 000 hours of use	$375		

To calculate the cost of buying and running each of the three types of light bulb listed in Table 3.4, we need to compare them over the same length of time, for example, 50 000 hours. In this time only 1 LED bulb would be needed as they last the longest. It would require 5 CFL bulbs as they last about 10 000 hours. However, 50 of the older incandescent bulbs would be needed as they only last about 1000 hours each.

Example

Incandescent bulbs

The number of incandescent bulbs needed for 50 000 hours of use is 50, at $1.50 each. So the total base cost of buying the bulbs is:

$$50 \times \$1.50 = \$75$$

Now look at electricity running costs. Incandescent bulbs use 60 watts or 0.06 kilowatts (60 ÷ 1000) of electrical energy.

The number of kilowatt hours (the unit we use to pay for electricity) is:

$$0.06 \text{ kW} \times 50000 \text{ hours} = 3000 \text{ kWh}$$

At an average cost of 10 cents per kWh (or $0.10) that would cost:

$$3000 \text{ kWh} \times \$0.10 = \$300$$

So the total cost of buying and running enough incandescent bulbs for 50 000 hours is:

$$75 + 300 = \$375$$

Your turn

Perform similar calculations for the CFL bulb and the LED bulb to complete the table and see which is the most cost-effective alternative.

Some things to consider

- Estimated figures are given in the table. At the time of writing this textbook, LED bulbs were expensive at approximately $35 each. This figure may have changed since then so it might be worth researching current prices.
- An estimated cost of electricity as $0.10 per kWh was used for the example. You might also like to research more current figures.

Efficient electrical energy generation

Just as the efficiency of electrical energy usage can be measured, so too can the efficiency of electricity generation. Many different energy transformations can take place to result in electrical energy, but not all of them are efficient. To calculate electricity generation efficiency as a percentage, the electrical energy output is divided by the energy input before being multiplied by 100:

$$\text{Efficiency} = \frac{\text{energy input}}{\text{energy output}} \times 100$$

Figure 3.52 Solar panels can convert sunlight into electricity to heat water for your house.

Solar panels

When it is sunny outside, your school or home could benefit from solar panels on the roof to transform the sunlight into usable electricity. This electricity could power the lights, computers, cooling or heating system. Anything connected to a power point could run off the solar panels.

A solar panel system at home could pay for itself after 4–7 years and may last approximately 25 years. The electrical energy generated by the solar energy can be used in a wide range of appliances. In many of these appliances, the electrical energy will need to be changed or transformed one or more times for the appliance to do its job. For example, a toaster changes electrical energy into thermal (heat) energy. Another benefit of using solar panels is that you do not have to pay for the electricity the panels generate. You may even get a refund from the electricity company if the panels generate more electricity than the home or the school uses.

Figure 3.53 Installing solar panels on your roof could make a big difference to your electricity bills. It is something your household should consider?

Figure 3.54 A Magenn Air Rotor System (MARS) wind turbine.

Scientists and engineers are still researching and investigating solar panel design to improve their efficiency. The first solar panel was only around 7% efficient. That is, for every 100 W of sunlight that hit the panel, only 7 W of electricity was produced. Improvements are still being made to the design of solar panels to maximise their efficiency.

In May 2013, researchers at the University of New South Wales discovered that hydrogen atoms could be used to improve the efficiency of the silicon-based solar cell to around 23%. That may not seem like much of an improvement, but every little bit counts. Because there is so much energy in sunlight, even a 1% improvement makes a dramatic difference to the amount of electrical energy that can be transformed.

Wind turbines

Wind power is increasing in popularity as a non-polluting, renewable energy source. Worldwide it is increasing at a rate of approximately 35% every year. Some countries, such as the United States, the Netherlands, Germany, the United Kingdom and Denmark, rely heavily on wind power. Denmark currently uses the wind to supply 20% of its electricity, with plans to increase this to 35% by 2015. In Australia, wind farms account for only 1% of our electricity production. However, South Australia has embraced wind power technology with about 15% of its energy produced by wind farms, and there are plans for more wind farms in the future.

In the production of wind power, there are no chemical or heat energy steps. The kinetic energy of the wind spins the rotor blades, which spins the generator and produces electricity.

Future wind turbines may take the form of blimps that float between 100 and 300 metres high in the air. The Magenn Air Rotor System (MARS) is one such proposal. Originally designed for generating electricity in remote areas, the blimp is tethered to the ground and the whole structure spins as the wind blows over and around it. Inflated with a low density gas such as helium, the MARS is relatively easy to install and deploy.

Figure 3.55 The generator inside a wind turbine.

The most notable features of a wind turbine are the tall towers and huge rotor blades that spin at anything from 5 to 20 revolutions per minute (rpm). The actual generator component is tiny in comparison.

Wind power is increasing in popularity as an energy source for two main reasons. Advances in wind power science are increasing the cost-effectiveness of wind power. Wind turbine design has come a long way and wind power now rivals coal and oil in terms of cost, as well as offering many other advantages. The second main reason for wind power popularity is that wind power is non-polluting when operating. The burning of coal and oil contribute vast amounts of greenhouse gases to the Earth's atmosphere, which most scientists believe leads to the enhanced greenhouse effect and global warming. Whenever a wind farm feeds electricity into the grid, it saves the equivalent amount of energy from being generated from coal and oil, which reduces pollution.

Figure 3.56 A wind farm in South Australia.

QUESTIONS 3.3.2: EFFICIENT ENERGY GENERATION AND USE

Remember

1 Recall at least two methods of improving electrical efficiency around your home and school.

2 Recall how a generator transforms energy into electrical energy.

3 Identify the unit of energy used by electricity companies to determine the amount of electrical energy you have used.

4 Identify some devices in your home that need a supply of electrical energy. Do any of them have non-electric options? (For example, a whisk or wooden spoon could be used instead of an electric mixer in the kitchen.)

5 Explain what it means if a device is said to be 'cost-effective'.

Apply

6 Suggest some problems with using solar panels as a main source of electrical energy.

7 Explain what it means if a new energy system 'pays for itself'.

8 List some advantages of the MARS wind turbine over the wind turbines currently in use.

9 A large group of wind turbines in the same location is called a wind farm. Suggest a possible location for a wind farm. List as many features of a suitable location as you can.

3.3 CHECKPOINT

INCREASING ENERGY EFFICIENCY

Remember

1 Identify the significant features that help to determine what type of light bulb is the most cost-effective. [2 marks]

2 Describe the energy transformations that occur in a solar panel. [3 marks]

Apply

3 Explain why most wind turbines are mounted on towers 40–100 metres high. [1 mark]

4 Coal-fired power stations in New South Wales run 24 hours a day, 7 days a week. Determine whether wind power or coal fired power could be considered more reliable. Explain your answer. [2 marks]

5 Explain energy efficiency. [2 marks]

Analyse and evaluate

6 Calculate the percentage efficiency of a device if it transforms:

a 20 units of input energy into 12 units of useful output energy [1 mark]

b 600 units of input energy into 500 units of useful output energy. [1 mark]

7 Describe where the missing units of energy went in the previous question. [1 mark]

Critical and creative thinking

8 Research and identify where the major wind farms in New South Wales are located. Create an annotated poster that identifies their locations, their electrical energy production capabilities, how they compare to other wind farms around the country and what plans are in place to build more wind farms in the state. [5 marks]

9 Prepare and carry out an audit of your home lighting. How many of each type of light globe do you have? Could the lighting in your home be improved? Research lighting costs and efficiency on the Internet, at a hardware store or a lighting store. Use the information gathered to produce a cost analysis for improving the lighting at your home. Are there alternatives that would cost less? Prepare a report with a summary of your findings and recommendations for improvement. [5 marks]

Ethical understanding

10 Solar panels and wind turbines may not be as efficient as coal-fired power but there are many other advantages. Which form of energy would you prefer to supply your power and why? [3 marks]

11 Propose some problems associated with expecting people to change their current lighting systems or energy usage at home. [3 marks]

Research

12 Investigate the star rating system for indicating the energy efficiency of appliances. Identify what each star indicates. Present your information as an annotated poster or a short presentation. [3 marks]

TOTAL MARKS:
[/35]

3 CHAPTER REVIEW

1 Fill in the gaps using the words in the Word Bank below:

Energy comes in many different forms, such as thermal, light, sound, _____________, electrical and potential energy. It cannot be created or _____________, but it can be transferred or _____________ into a different type.

Thermal energy can be _____________ in three different ways: conduction, _____________ and radiation. Electrical energy is transferred in electrical _____________ and then transformed into almost any other form of energy by the _____________ in the circuit.

Most energy transformations also produce by-product energy, most commonly _____________, which reduces the _____________ of the device. Scientific knowledge and technological developments have led to the improvement of energy efficiency, such as the invention of CFLs and _____________. Increased energy efficiency means less energy is _____________, which is _____________ for individuals and better for the environment as fewer resources are consumed.

WORD BANK

circuits	efficiency	more	wasted
components	heat	economical	
convection	kinetic	transferred	
destroyed	LEDs	transformed	

Identify objects that have either kinetic or potential energy

2 Define the following terms and provide an example for each:

a gravitational potential energy [2 marks]

b biofuel [2 marks]

c kinetic energy. [2 marks]

3 Explain all the ways that energy can be stored. [2 marks]

4 Identify whether a spring or a string has more advantages for storing elastic potential energy. Explain your answer. [2 marks]

Investigate everyday energy transformations involving heat, light, sound, electricity and motion

5 Compare an electric to a petrol-driven car to answer the following questions:

a Identify the main energy transformations that occur in a petrol-powered car. [2 marks]

b Identify the differences for an electric car. [2 marks]

c Identify the advantages and disadvantages of each type of car. [2 marks]

d Explain how hybrid cars are different to both petrol and electric cars. [2 marks]

6 Explain the difference between an energy flow diagram and an energy chain. [1 mark]

7 Identify a device that performs the following energy transformations and draw an energy flow diagram or energy chain as appropriate:

a light energy to sound energy [2 marks]

b kinetic energy to heat energy [2 marks]

c electrical energy to sound energy [2 marks]

d chemical potential energy to light energy. [2 marks]

3 CHAPTER REVIEW

Figure 3.57 Electric kettles use both conduction and convection to boil the water.

Describe the process of conduction, convection and radiation using examples

8 Compare and contrast conduction, convection and radiation. [3 marks]

9 When a hot brick is placed into a bucket of water, the water gets hotter as thermal energy spreads from the brick into the water. Identify if this process is called conduction, convection or radiation? Explain your choice and why it is not the other options. [2 marks]

10 An electric kettle uses a heating element to heat water. This process involves both conduction and convection. Explain where each process occurs to heat the whole jug of water. [2 marks]

Relate electricity to the transfer of energy

11 Define the term 'electrical energy'. [2 marks]

12 Describe why circuits are needed to transport electrical energy to components and devices. [1 mark]

13 Compare conduction of thermal energy with the transfer of electrical energy. [2 marks]

Construct circuits and draw circuit diagrams with various components

14 Explain why circuits are drawn as diagrams rather than as detailed pictures. [1 mark]

15 Draw a circuit diagram for a circuit that contains a power supply and three light globes in a parallel circuit, with a switch in series with one of the light globes. [2 marks]

16 Explain the difference between two light bulbs in a series circuit and two bulbs in a parallel circuit in terms of the electrical energy they use. [3 marks]

Trace the history of the development of an electrical device (additional content)

17 Briefly describe the development of the light bulb and explain why these improvements have been made. [3 marks]

18 Explain why scientists and engineers continue to research the design of solar panels. [3 marks]

Investigate everyday energy transformations involving electrical energy

19 Draw an energy flow diagram for the following activities:

- **a** a loudspeaker [1 mark]
- **b** using a hairdryer [1 mark]
- **c** listening to an iPod [1 mark]
- **d** a microphone. [1 mark]

20 Electrical conductors and insulators behave the same as thermal ones. Electrical conductors carry or pass electricity easily and electrical insulators block electricity.

Identify that most energy transformations produce heat energy regardless of the transformation

21 Define the term 'by-product'. [1 mark]

22 List four different energy transformations that produce heat as a by-product. [4 marks]

23 Calculate the percentage energy efficiency of a device that turns 200 J of input energy into 150 J of useful output energy. [2 marks]

24 What is the percentage efficiency for a device that transforms 40 J of energy into 30 J of useful sound energy and 10 J of wasted heat? [2 marks]

3 CHAPTER REVIEW

Research ways in which scientific knowledge and technological developments have been used to improve the efficiency of energy transfers or transformations

25 Explain why LEDs are becoming more commonly used than incandescent bulbs. [2 marks]

26 Compare LEDs, CFLs and incandescent bulbs in terms of their energy efficiency. [3 marks]

Discuss the implications for society and the environment of increasing the efficiency of energy transformations

27 'Solar panels for my house are too expensive and will cost me too much money in the long term'. Evaluate this statement and write a response to support or disagree with it. [2 marks]

28 Calculate the cost of running a 15 watt CFL light globe for 100 000 hours if it costs $4.00 for each bulb, the bulbs last 10 000 hours each and electricity costs $0.15 per kWh. [3 marks]

29 Is there an endless supply of energy on the Earth or do you think it will run out one day? Justify your answer. [4 marks]

30 What are two major benefits wind power offers over conventional coal-fired power stations? [2 marks]

TOTAL MARKS:
[/80]

RESEARCH

Choose one of the following topics to conduct further research. A few guiding questions have been provided for you but you should add more questions that you want to investigate. Present your findings in a format that best fits the information you have found and the understandings you have formed.

Energy-efficient housing

In previous societies, energy efficiency was important because people had limited access to the types of energy supplies and their applications that we have today. Research how civilisations in tropical areas designed their homes to keep them cool and damp free. What different types of energy-efficient practices have humans used throughout the ages?

Perpetual motion machine

What is a perpetual motion machine? Is it possible to build one? Who has tried to do it and what were their designs? How efficient were the machines? Is anyone working on one of these machines nowadays?

Reflect

Me

1 What new science laboratory skills have you learned in this chapter?

2 What was the most surprising thing you found out about energy?

3 What were the most difficult aspects of this topic?

My world

4 Why is it important to understand energy?

5 How important is it for scientists to understand energy transformations?

My future

6 How might energy resources change in the future?

7 Do humans need to change the way they use energy?

KEY WORDS

biomass energy
chemical potential energy (CPE)
circuit diagram
compact fluorescent light (CFL)
conduction
convection
elastic potential energy (EPE)
electric circuit
electrical energy
energy
energy efficiency
energy transformation
generator
gravitational potential energy (GPE)
integrated circuit (IC)
kinetic energy (KE)
light-emitting diode (LED)
load
nuclear energy
parallel circuit
potential energy
radiation
series circuit
solar cell
sound energy
speaker
thermal energy
transformer

3

MAKING CONNECTIONS

Design your own mousetrap car

Many devices transform energy from one form to another. The humble mousetrap works on this principle. It uses the elastic energy stored in a spring as its input and converts that to kinetic energy as the trap springs shut. In this activity, you will use the elastic potential energy of a 'loaded' mousetrap to build a model car that can run on its own mousetrap 'engine'.

When engineers design new machines, they produce very detailed plans called blueprints. Engineers also consider the concept of energy efficiency. For this challenge, you will need to work like an engineer. Follow the engineering process and use your understanding of energy transformations and energy efficiency to produce the best working model of a mousetrap car.

Challenge

Identify the problem: to build a vehicle powered by a household mousetrap.

Questioning and predicting

Some questions to consider are:

- How you will get the movement from the mousetrap to the wheels?
- How heavy or light will your machine be?
- What materials will you use to make the machine?
- How are you going to construct it?

Planning and conducting: engineering blueprints

Design

- Produce a detailed plan of your car design that shows how the elastic energy stored in the spring will be transferred to the wheels. Detail the materials you will use for each component. Remember, there may be some Lego parts that you can incorporate into your car design, and your school may be able to supply some of the equipment for you.

Improve

- Reassess your design and incorporate any modifications it needs to improve its performance.

Build

- Build your prototype.

Processing, analysing and evaluating

Assess it

1 How energy efficient is your model? If parts of your car rub too much on each other they will create friction and the car will not travel very far. For example, if the wheels or axles are too tight, they will create drag and slow your car down. Consider how to loosen or lubricate

parts so this does not happen. Real cars use oil and grease for lubrication to prevent this happening.

2 How far did your car run?
3 What advantages did it have over other students' designs?
4 Did anything go wrong with your car?
5 How could your design be improved?
6 What types of energy were involved in your mousetrap vehicle?

Communicating

Imagine you had to explain to someone how you followed the engineering process so that they could build on your work. You want them to learn from your mistakes and understand why you made certain choices along the way. Present your thinking, processes, data and evaluation in a clear, interesting and appropriate way.

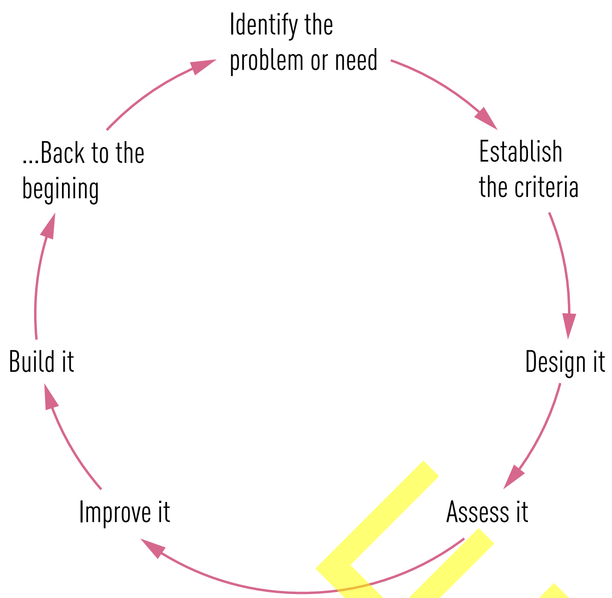


Figure 3.58 The development process.