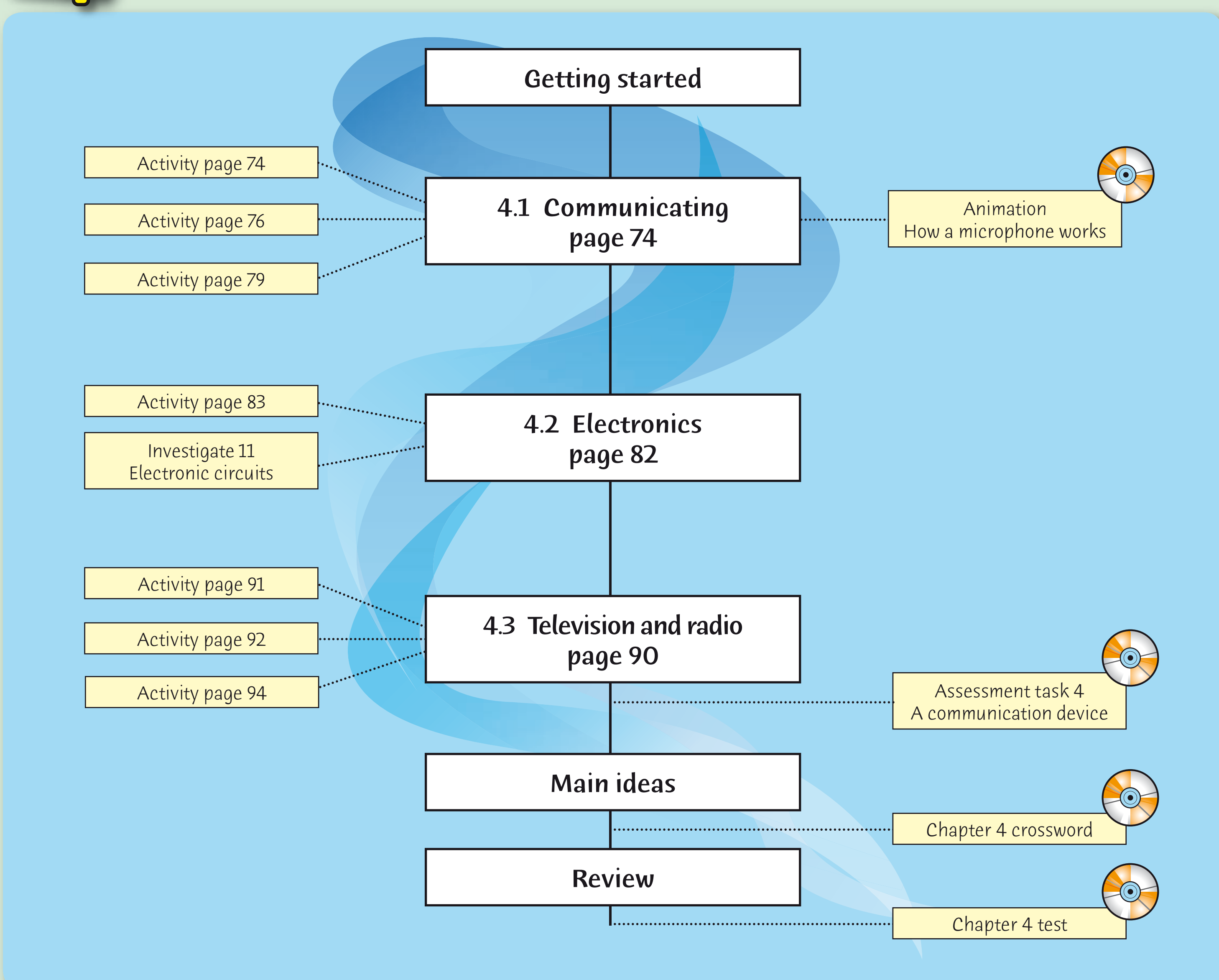
4 Communications technology

Planning page



Essential Learnings for Chapter 4

Essential Learnings	References		
	Student book (page number)	**Workbook (page number)**	**Teacher Edition CD (Assessment task)**
Knowledge and understanding *Energy and change* Energy is conserved when it is transferred or transformed	pp. 74–97		Assessment task 4 A communication device
Science as a human endeavour People from different cultures contribute to and shape the development of science	West p. 86		Assessment task 4 A communication device
Ways of working Draw conclusions that summarise and explain patterns, and that are consistent with the data and respond to the question	Activities pp. 92, 94		
Evaluate data, information and evidence to identify connections, construct arguments and link results to theory	Activities pp. 76, 91–92, 94 Investigate 11 pp. 84–85		
Communicate scientific ideas, explanations, conclusions, decisions and data, using scientific argument and terminology, in appropriate formats		pp. 24–25 p. 31	

QSA Science Essential Learnings by the end of Year 9

Vocabulary

amplifier
amplitude
analog
antenna
bytes
capacitor
communications
diaphragm
digital
electronics
fluorescent
frequency
hertz
light-emitting diode
microphone
microwaves
modulated
phosphors
pixels
plasma
resistor
semiconductor
transistor

Focus for learning

Discuss ways in which communications technology is changing our lives (page 73).

Equipment and chemicals (per group)

Activity page 76 — cathode ray oscilloscope (CRO), microphone, tuning fork or musical instrument, audio generator (optional), datalogger and sound probe (optional), computer (optional), galvanometer (optional)

Activity page 79 — optical fibre, binocular microscope or digital magnifying device (eg videoflex), clear plastic fruit juice or water bottle, torch or low-power laser

Activity page 83 — assorted resistors

Investigate 11 pages 84–85 — resistors (1 watt, 10 Ω, 22 Ω, 56 Ω, 390 Ω, 10 000 Ω, diode (1N4002 or similar), light-emitting diode, light-dependent resistor (eg ORP12), switch, ammeter (eg 1A range) or multimeter, power pack, 6 V torch bulb and socket, 4 connecting wires with alligator clips, two 10 cm × 10 cm pieces of cardboard, 5 drawing pins, thin bare wire, adhesive tape

Activity page 91 — cathode ray oscilloscope (CRO), bar magnet

Activity page 92 — computer and monitor, hand lens

Activity page 94 — cathode ray oscilloscope (CRO), audio generator

4 Communications technology

Getting Started

- Discuss ways in which technology such as broadband, mobile phones and digital TV is changing our lives.
- In the cartoon below you will see many different ways of communicating. Work in a small group and try to identify as many different examples as you can.

Starting point

1. You could start this topic with mystery or intrigue. Show part of a spy or wartime film or snippets from a TV program depicting the use of communications technologies (satellites, Morse code, spy cams and bugs, phones and so on). Snippets from the movie *Enigma* (about the British code-breakers working on decoding messages sent from the German Enigma machine in World War II) or the TV series *Alias* or *Spooks* might be a worth considering. For something completely light-hearted, you could show an episode of *Get Smart*!
2. Add to the mood of suspense or intrigue by setting a puzzle-solving activity. Teams of students could investigate components of communications technology using computers, and find clues to the puzzle in the information given. If possible, have a clear set of instructions and student worksheets at each computer workstation. Give the teams a time limit to complete each investigation before rotating to the next. They could investigate early communication methods (eg Morse code, wartime code-breakers, radios), the latest communication methods (eg BlackBerrys, mobile phones, broadband and 3G networking, Bluetooth) and future communication methods. Go to the *ScienceWorld 3* Webwatch and follow the links to the two Morse code sites.
3. Consider organising a presenter from the association for the hearing or vision impaired to talk to the class about communication techniques/technologies used to assist these people. People with vision impairments can learn braille and use voice recognition software to assist with written communication. Learning Auslan (Australian Sign Language) can assist those with a hearing impairment.
4. How do animals communicate? Turn this into a Think/Pair/Share activity. Get the students to list as many ways as they can. Next to each communication method they could write down examples of animals and the animal's behaviour that they have seen in real life, books or multimedia. Students could then construct a chart to display their information.

Hints and tips

- This topic is probably more appealing to boys than girls so be sure to keep the level of interest even for both. For girls, make it relational and interesting by talking about their social methods of communication (SMS, Facebook, MySpace and so on) and asking what they would like to see incorporated in future technologies. Boys may be keen to set up their own sound/music system and use computers to play interactive web games rather than as a relational tool.
- You might like to tell the students a little about Morse code and ask them to write some sentences from this chapter using it. Morse code was created by Samuel Morse in 1838 and is still used today, particularly by amateur radio operators. It was used to transmit messages via telegraph. It is made up of a series of short sounds (dots) and longer sounds (dashes). A telegraph works by changing words or voice into electronic signals. The signals are sent through a wire by switching the current on and off or changing the signal's intensity. At the receiving end the signals are changed back into letters or speech.
- The decoded sentence on this page is: *This sentence is in code*. In earlier printings the code for T in 'sentence' was incorrect.

Activity notes

As an extension activity, ask the students to devise ways in which they can communicate with the class non-verbally, and in the next lesson they can trial their ideas. Consider turning the activity into a competition, awarding points for creative and clear communication. The winner could be given a small treat such as a novelty science toy, fibre optic torch or LED flashing torch. You could attempt to teach a segment of your lesson using forms of communication other than talking. (Consider pre-recording your teaching segment as a podcast or vodcast or using some other multimedia technology.)

4.1 Communicating

Communication is the sending of a message (information) from one person to another. This message can be in written or spoken form, called *verbal communication*, or using gestures or symbols which are forms of *non-verbal communication*. However, communicating does not only occur between humans. In Getting Started you probably listed several examples of communication involving animals.

Communication involves the transmission of information from a sender to a receiver. The sender *encodes* this information into a message suitable for transmission. That is, the message is put into a *code*. The words that you are reading now are in a code which you have learnt over a number of years. These words form sentences which have meaning. Can you make any sense of this sentence? (See Check 2 on page 80.)

✶❊❉▲ ▲❄■✶❄■❃❄ ❉▲ ❉■ ❃❏❄❄

To understand a message like the one above the receiver has to *decode* it—change it from this code to a code that you can understand.

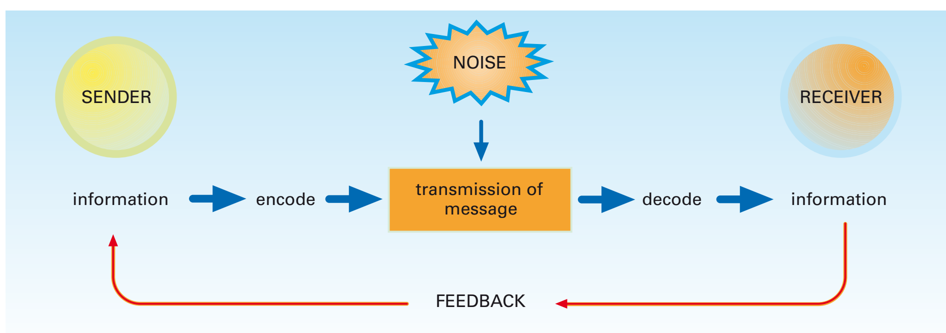
The flow diagram below shows the steps in the process of communication. *Feedback* is an important part of this process because it tells the sender whether or not the message has been received and understood. *Noise* is something that might interfere with the transmission of the message: for example, someone playing loud music while you are trying to talk on the telephone. Noise can also be electronic.

Activity

The teacher in the cartoon wants the students to set up an electric circuit.

- How does she know whether her message has been understood?
- What would you need to be able to do to decode her message?
- What is the effect of noise in this situation?

Fig 2 A model to show the steps in the process of communication



Learning experience

Ask students to come up with their own code, write some sentences in their code and get the person next to them to decode the sentences. Less creative students could use the example on this page as a guide or use Morse code. (Source the internet for the Morse code alphabet.)

Learning experience

What sorts of codes have been used in times of war? Turn this question into a research activity and get the class to generate more questions around this theme. For example:

- Why were codes used in wartime?
- Who used the codes?
- Who created the codes?
- Why was breaking the enemy's code so important?

In teams, the students can investigate their questions and report their findings to the class. Their presentation could be a series of diary entries, an interview with a wartime code-breaker in the form of a newspaper article, an audio recording or a role play.

Communication devices

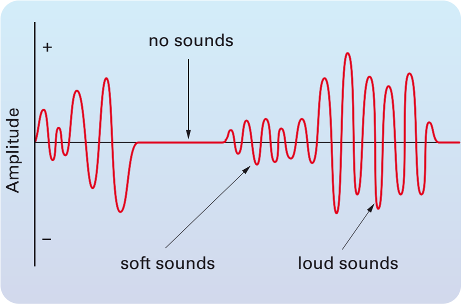
Communication devices such as a telephone require voice to be changed into electrical signals, radio waves or light pulses. These signals are transmitted over long distances and then changed back into voice which is heard by the receiver. Voice is changed into electrical signals by a *microphone* and the electrical signals are changed back to voice by a *loudspeaker*.

In previous studies you learnt that a magnet induces an electric current when it moves in a coil of wire. A microphone uses this principle. Sound waves make the diaphragm (DIE-a-fram) in the microphone vibrate. The coils of wire attached to the diaphragm vibrate near a magnet. This movement then creates a current in the wires which changes with the loudness of the voice. Soft sounds produce small currents and loud sounds produce larger currents. The pitch of the sound also affects the current.

A loudspeaker works in the opposite way to a microphone. The varying current in the wire passes through a coil near a magnet and this causes the coil to move. The coil is attached to a diaphragm which also moves. This movement causes the air next to the diaphragm to move and you hear a reproduction of the original sounds.

Digital and analog signals

In a microphone, the vibrating diaphragm produces a varying electrical signal like the one below. The size or **amplitude** of the signal determines the loudness of the sound.



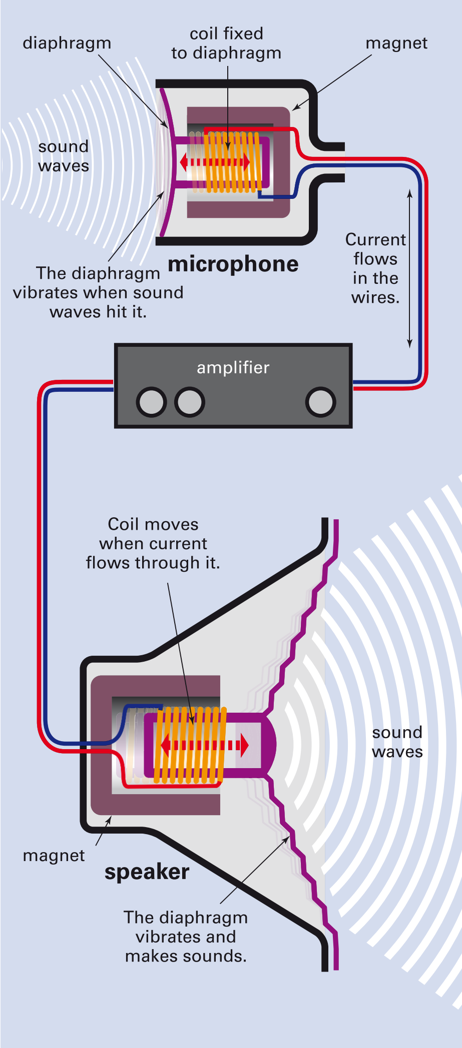


Fig 4 A microphone converts sound waves to electrical signals, and a loudspeaker converts electrical signals to sound.

To see an animation of this process, open **How a microphone works** on the CD. Working with technology

Hints and tips

- Lighthouses are communication beacons. What is their method of communication and who do they send messages to? If you are in an area with a lighthouse, see if you can organise for the class to be given a tour of it. How do most lighthouses operate today, and how did they operate in the past?
- Students may need a refresher lesson to review the meanings of electric current and electromagnetic induction. Remind them that current is the flow of charge and is not the voltage.

Learning experience

All sorts of codes are used today and are most often developed for security reasons or to alert others of danger. Find out how many students are aware of the different emergency colour codes. (Code red is for fire, code orange is to evacuate and so on.) Students in part-time employment have probably undergone a training session where they have been briefed on the workplace's emergency procedures and universal emergency codes. Ask a few of them to share their experiences and see how much they can remember.

Learning experience

Students could construct a sunshine wheel—a concept map with 'rays' radiating out from a central term. 'Communications technology' is the central term, and the rays radiating outwards are used to write connecting sentences. This activity doesn't have to be limited to theoretical concepts. Emotions and thoughts about the topic could also be explored. This learning tool could be used to find out what the students already know and what they want to know, or used as a progressive summary of the topic and added to each lesson.

Learning experience

The students could draw their own illustrations/cartoons depicting an everyday situation involving communications technology. They should provide labels or captions for their illustrations. Alternatively, they could prepare a flow chart of a sequence of events.

Hints and tips

Get the students to write a glossary of words and terms for this chapter. You might find it useful to give the class a glossary of computer/ICT terms as well.

Activity notes

- If you are not a physics teacher you might need some help from someone who is familiar with the equipment to set this up. The set-up could be done on a trolley so that it can be wheeled into the room. There are many different types of CROs so check the manual before fiddling with it. If the manual has been misplaced, the website given in the Webwatch might be of help: go to *ScienceWorld 3* Webwatch and follow the links to 'The CRO'.
- Consider getting the lab technician to demonstrate this activity to about 5–10 students at a time while you supervise the rest of the class.
- It is a good idea to use the equipment with an audio generator to produce pure sounds (see the Activity on page 94).
- Use several musical instruments, and even try humming or singing a note into the microphone.
- An alternative to this activity is to connect a microphone to a computer and analyse the waves using a program like Audacity or GarageBand. You can record the sound, play it back and analyse sections of the sound waves. (Audacity is software that can be downloaded from the internet and used to make podcasts.) A mobile phone or MP3/MP4 player can be used to record sound, then connected to the computer for analysis.

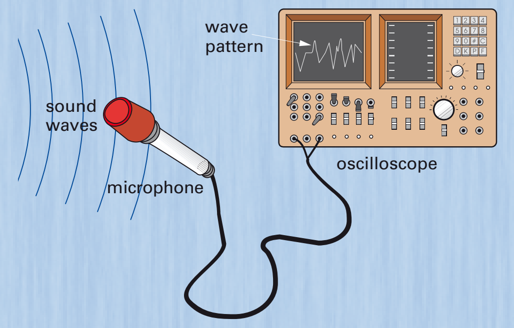
Activity

Teacher demonstration

Your teacher will set up a microphone attached to a cathode ray oscilloscope (CRO). The electrical signals produced by the microphone can be seen on the screen of the CRO.

Observe a variety of different sound patterns on the CRO. For example, speak into the microphone, sing a note or use a tuning fork or musical instrument.

What is the relationship between the amplitude of the waves on the CRO and the volume of the sound made?



Instead of using a CRO you could use a sound probe connected to a datalogger and then print out the wave pattern.

You could also connect a microphone to a galvanometer and observe the movement of the pointer as you speak into the microphone.

The wave pattern produced on the CRO when you speak into the microphone changes in amplitude as the volume of your voice changes. The wave pattern varies in value at different points in time. This type of signal is called an **analog** (AN-a-log) **signal**. The electrical signals which travel along the wires from the microphone in your telephone handset are similar to these waves.

Before 1980 telephone transmission in Australia was analog. Now, however, most transmissions between telephone exchanges use **digital signals**. A digital signal is made up of a sequence of *binary digits*—digits that have one of two values, 0 or 1. In electronic devices the value 1 is represented by a switch being on, and 0 by the switch being off.

The two words **b**inary dig**it** are shortened to the one word **bit**. Telephone transmissions (and computer data) are usually sent in millions of small units made up of eight bits which are called **bytes**. The digital signal to the right is a byte and has the value 10011010.

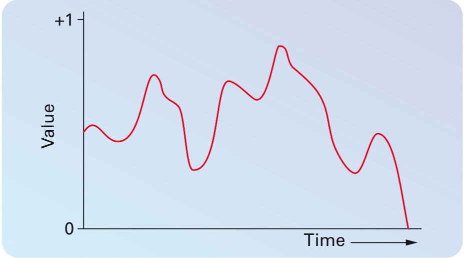


Fig 7 Analog signals vary continuously in value over time.

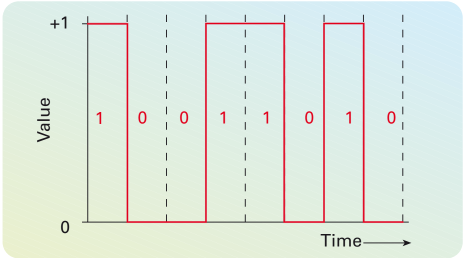
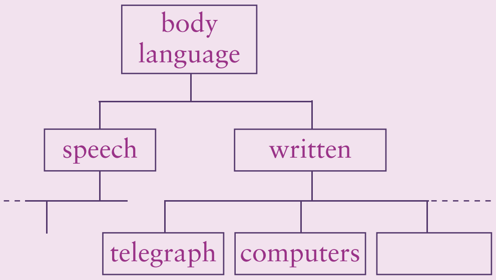


Fig 8 An eight bit digital signal—each bit can have a value of 1 or 0, but nothing in between.

Learning experience

Find and review photographs and information on various communications technologies. Consider researching the telegraph transmitter and receiver, early telephone equipment, the first digital electronic computer (developed during World War II), the first radio (wireless set), digital/cellular telephones, and the internet and email communications systems. Use the information to construct a time line that shows the development of communications technologies and the impact they have had on communication, our culture and society in general.

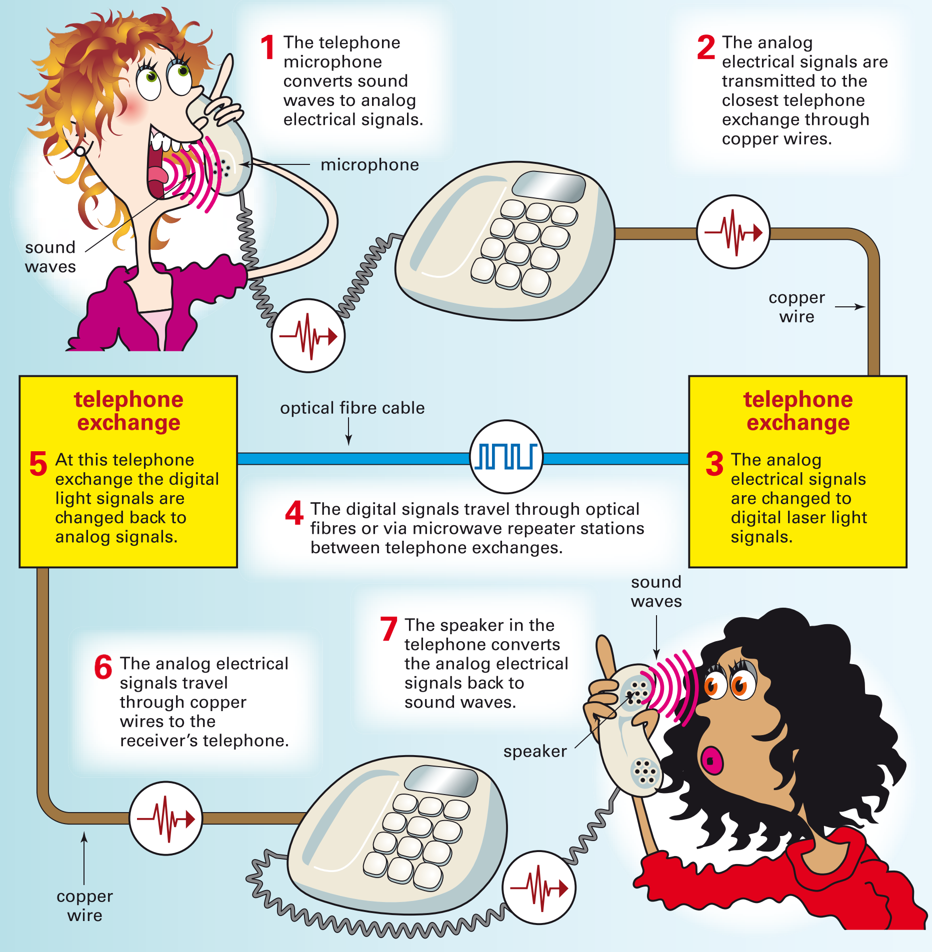
Alternatively, the students could investigate the same ideas but construct a 'family tree' of communications technologies, as shown in the diagram below, or some other display.



The telephone network

Analog signals from your telephone are converted to digital signals at the telephone exchange. These digital signals then travel through cables to other telephone exchanges. Most of the cables that link major Australian cities are now **optical fibres** made of glass.

The diagram below shows how the telephone network encodes the information in sound waves to electrical signals and then to optical signals. At the receiver's end the information is decoded back again to sound waves. Instead of using cables, telephone signals can also be transmitted via microwave repeater stations or even satellites, especially in isolated areas.



Note: Digital phones use digital signals rather than analog signals.

Hints and tips

Revise the material taught so far by giving the class a quick quiz. This will identify any concepts that need to be revised. Ask the students to write the answers only (no need for the questions). Try to ask some questions which test understanding rather than just memory.

Homework

Imagine what life would be like if we didn't have a phone or email system. Each student is to write about how their life and their family's life would be affected. Can they think of any people or groups that are not reliant on communications technologies? Are they disadvantaged? How would students cope if they lived with these people or group for a year?

Learning experience

Ask the students to problem-solve how cordless phones work. Have an ordered class discussion. Once students have agreed on an answer, get someone in the class to research the answer and present it to the class. Consider choosing a gifted or talented student for this exercise. Otherwise, each student could be assigned this for homework. Their information should be pictorial if possible.

Learning experience

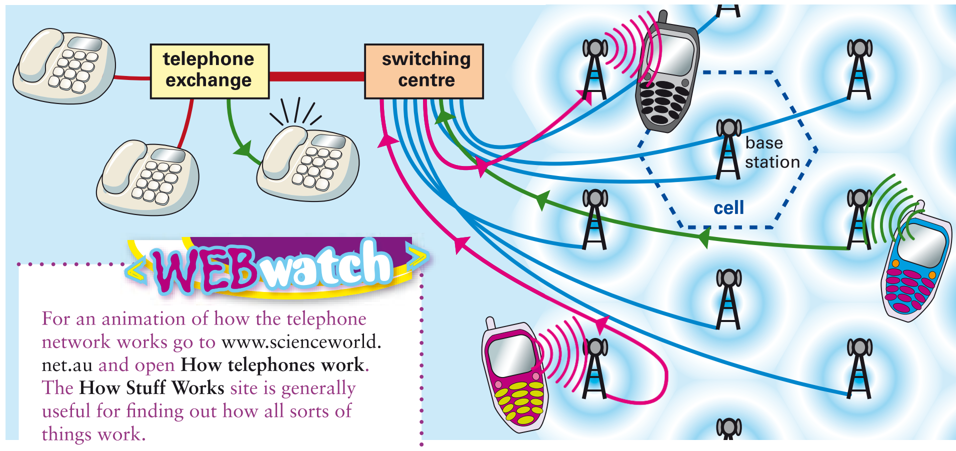
What are some possible consequences if a sent code or message is misunderstood? What sorts of implications could it have, and in which situations is it most important to get it correct? Come up with a possible scenario of a military code being incorrectly decoded. How easily can messages be misunderstood? Play a game of 'Chinese whispers' to illustrate the point. Then get the students to examine the questions posed by using the DOVE brainstorming method. This works best in small groups. The method is:

- D: defer judgement on any one else's ideas or comments
- O: opt for the unusual and creative
- V: generate a vast number of ideas
- E: expand on the ideas by piggybacking off others.

Get each group to share their findings. Doing this will help the class to recognise the value of fellow students' viewpoints. Ask them why they came up with those points and what they learned from this activity.

Hints and tips

- Ask if anyone in the class knows what the abbreviation SMS stands for (short message service). The students probably want to know how SMS works. Refer them to page 80 and as a class do point 3 of the Webwatch. If the class has access to computers they can do it individually or you could display it through a data projector for everyone to see. Discuss the information before getting students to write a summary or draw their own flow diagram of how it works.
- Students might want to know what the 3G network is. It is the third generation of mobile phone standards and technology (superseding 2G). The advantage of 3G technology is that service providers (networks) can offer a wider range of more advanced services, such as wide-area wireless voice telephony and broadband wireless, in a mobile environment. That is, all of these services can be accessed using a mobile phone on such a network. A typical 3G network can provide service at 5–10 MB per second.



WEBwatch

For an animation of how the telephone network works go to www.scienceworld.net.au and open **How telephones work**. The **How Stuff Works** site is generally useful for finding out how all sorts of things work.

Fig 10 A mobile phone network

Mobile phones

Mobile phones don't need to be connected by wires. Instead they have a built-in radio transmitter and receiver. When you make a call the mobile phone sends out a radio signal. This signal is picked up by a base station that has several antennas on top of a tower or tall building. The base station is connected to a switching centre which switches the call to other base stations or to the fixed telephone network.

In the USA, mobile phones are called *cell phones*. This is because the base stations form a network of hexagonal cells, as shown above. The cells range in size from 100 metres across to more than 30 km. The base stations receive mobile phone calls from the cell around them. Each call is then passed from cell to cell until it reaches its destination. The base stations also return calls to the cell around them.

Faxes and modems

The telephone network also carries data from fax machines and computer modems, as well as from credit card and EFTPOS terminals in shops. Most of the data sent from these devices is digital. This means that the copper wires connecting these devices to the exchange have to be able to carry electrical digital signals as well as analog ones.

On the other hand, the optical fibres connecting telephone exchanges carry digital information only.

Fax machines send and receive documents containing words, graphics or photos. The document is fed into the fax machine where a light scanner reads the degree of lightness or darkness on the page. The scanned data is then encoded into digital signals which are sent through the telephone network.

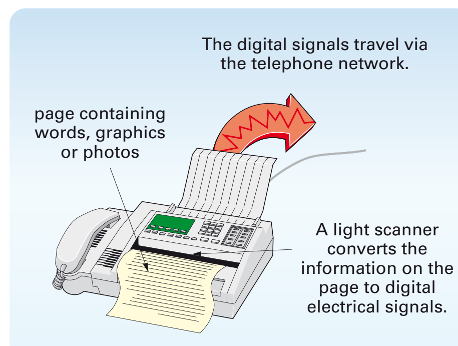


Fig 11 Fax machines convert written information to digital electrical data.

Issues

- Get the students to debate the issue 'Mobile phones cause cancer'. Organise three teams of students:
  1 General public
  2 Mobile phone companies
  3 Health professionals/research scientists.

  The general public team will decide who wins the argument and devise a set of marking criteria to assess the other two teams. Their role is also to investigate if there is a solution to the problem. Mobile phone companies argue against phones causing cancer, while many health professionals and research scientists argue that they do. Allow sufficient brainstorming, research and debating time. It is probably better if you organise the team members, and an easy way is to assign all students with the numbers 1 to 3. Students need to be aware of the rules of debating and to cooperate in establishing a respectful environment.
- An alternative issue to debate could be 'Exposure to the radiation from mobile phone towers causes cancer'. A recent media release from RMIT (Royal Melbourne Institute of Technology) suggests it does. An unusually high number of workers on the top floor of the RMIT building contracted brain tumours—and a mobile phone tower was located on the top of the building. The students could investigate this further and find out where any mobile phone towers are located in their vicinity.

Learning experience

There are many new communications technologies today that were not widely available when the students' parents or grandparents were their age, including infrared technology, Bluetooth, Wi-Fi, BlackBerrys, mobile phones and some wireless technologies. Get the students to choose a new communications technology and write an explanation of what it is, what it is used for and how it works so that a younger brother or sister or a great-grandparent would understand. Encourage the students to present their work creatively.

Optical fibres

The optical fibres used in the telephone network are very thin pure glass fibres. Each fibre consists of a glass core, a glass cladding and a protective outer jacket, and the whole fibre is thinner than a human hair.

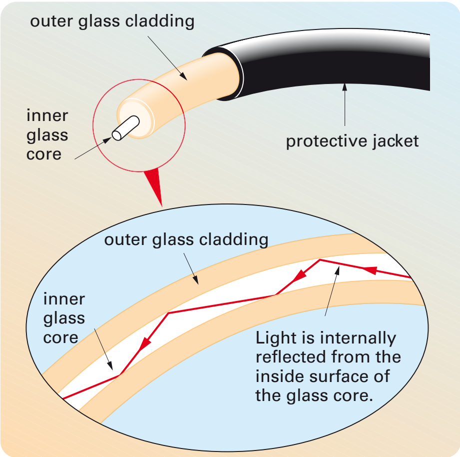


Fig 12 How light pulses travel through optical fibres

At telephone exchanges the electrical signals from local telephones are converted to pulses of laser light. These laser pulses are narrow high-intensity light beams of a single colour (wavelength). They are digital (on or off) and they travel through the optical fibre by *total internal reflection*. That is, the light can travel around bends and even loops by reflecting off the inside surface of the inner glass core. One optical fibre can carry up to 2 billion pulses of light per second.

The advantages of optical fibres are that they can carry much more information more quickly than copper wires do. They are lighter and cheaper to make, and they produce a better quality of communication with very low noise.

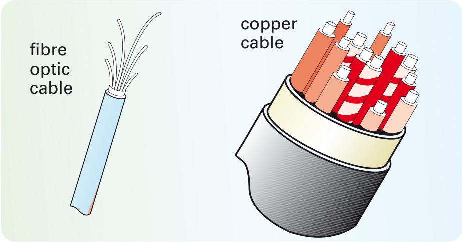
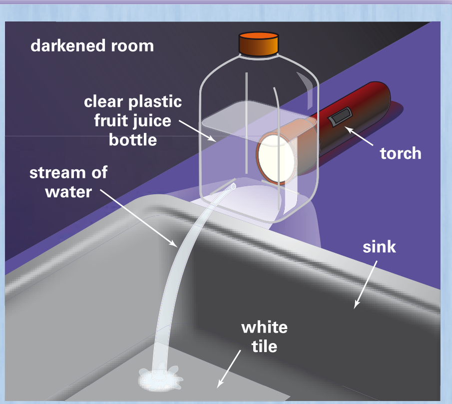


Fig 13 A copper cable which can carry 10 000 telephone calls is much larger and heavier than a fibre optic cable which carries the same number of calls.

Activity

1 Set up a binocular microscope and look at the end of an optical fibre.
Sketch what you observe.
2 The diagram on the right shows the equipment you need to make a model which demonstrates how optical fibres work.
3 Use the diagram as a guide to make the model. You will need to test it in a darkened room, or test it at home at night.
4 Can you improve the design of the model? Discuss your design with your partners.



Hints and tips

As the students enter the room, hand them a card containing a word or phrase relating to the chapter (*analog signal*, *digital signal*, *byte*, *binary system*, *telephone network*, *optical fibres*, and so on). When seated, randomly ask some students to read out the word and in one minute they have to describe what it is, its function, how it is used and any other useful information they know about it.

Activity notes

- Optical fibre is not easy to source so your lab technician will need some advance notice for ordering it. The ICT department of the school may have a broken cable that can be used.
- It is better to do this activity in a darkened room.
- Only about 40× magnification is needed, so other digital magnifying devices may be more suitable, such as a Video Flex, AVerVision 300p multimedia camera or similar.
- Ask students to bring along some suitable containers prior to the lesson. Bottled water containers work well.
- You will need to make sure the bottle lid is off to ensure a good water spout.
- A low-power laser (either a pointer or key ring type) can be used very successfully. The students still need to be cautious about laser light and eyes.
- To avoid water wastage, aim the water spout so that it fills another container such as an ice-cream container.

Learning experience

Any interested or gifted and talented students could investigate photonics. Ask them to come up with 5–10 questions to investigate. Often these students are fast workers, so let them do their investigating when they have finished their set class work. Give them the freedom to decide how they will present their research.

Homework

If a fibre optic cable is damaged, how is it fixed? How can the cables be damaged? Who is it costly for and why? The students could present their information as a 'User guide for maintaining and repairing fibre optics'.

Learning experience

Give students the following scenario:

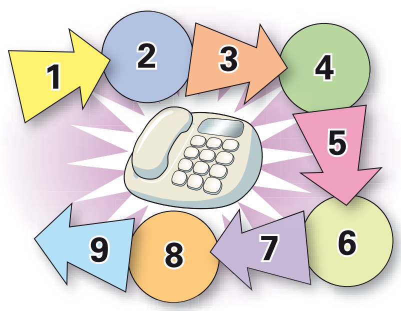
You travel overseas to Europe and decide to phone home and tell your family all about the exciting things you have done. After dialling the number, you hear the dial tone, then a click, and then your mum's voice. After your conversation it occurs to you that even though you are halfway across the world, you could hear your mum's voice without any time delay. How is this possible? How fast does your voice travel over the phone?

Ask students to devise a way to answer these questions, using the material they have previously learned from Chapter 3 Light and Sound. Challenge the students to work individually or in pairs, rather than as a group, for this task.

Check!

1 a The diagram below shows how a telephone network works. Select words from the following list to match the numbers in the diagram. You will need to use some words twice.

analog electrical signals	sound waves
digital light signals	microphone
telephone exchange	speaker



b Which of the numbered arrows could represent a distance of many thousands of kilometres? Explain your answer.

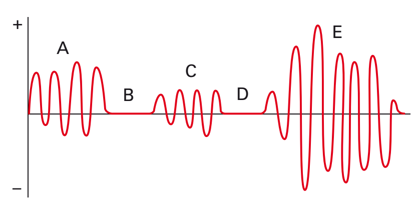
2 If you were given an incomplete code for the coded words on page 74, can you decipher the message?

✳ = T	❇ = I	▲ = S
✳ = E	■ = N	❏ = O

3 The CRO wave pattern below was made by sounds which were directed into a microphone.

a In which periods were there no sounds?

b Which sound was the the loudest?



4 A speaker and a microphone work in opposite ways. Explain what this means. Use the words *sound waves, diaphragm, vibrate, coil, magnet* and *electric current* in your answer.

5 Construct an energy flow diagram that shows all the energy conversions that occur in Fig 4 on page 75. Use the words *sound energy, kinetic energy* and *electrical energy*. Below is the start and end of the diagram.

sound energy → microphone - - - - - - - - → sound energy

6 How are mobile phones different from fixed telephones in the way they transmit and receive voice messages?

WEBwatch

1 Use the internet to research whether mobile phones can cause cancer. A good way to start is to go to www.scienceworld.net.au and follow the links to **Mobile phones—communications on the go** (NOVA).

2 Use the internet to find out other uses for optical fibres besides those in telephone networks.

3 How does SMS work? Go to www.scienceworld.net.au and follow the links to **How SMS works**.

Check! solutions

1 a The correct sequence is:
Step 1—sound waves
Step 2—microphone
Step 3—analog electrical signals
Step 4—telephone exchange
Step 5—digital light signals
Step 6—telephone exchange
Step 7—analog electrical signals
Step 8—speaker
Step 9—sound waves.

b The steps that could represent thousands of kilometres are 3, 5 and 7.

2 The decoded message is likely to be *This sentence is in code*, although the last word could be another word such as *hope*.

3 a There were no sounds in the periods B and D.

b The sounds were loudest in period E.

4 When sound waves reach a microphone they cause the diaphragm to vibrate. This diaphragm is connected to a coil of wire, which also vibrates near a magnet. This produces an electric current which can carry the message through a wire to a speaker. In the speaker the opposite process occurs and sounds are produced.

5 sound energy → kinetic energy (microphone) → electrical energy → kinetic energy (speaker) → sound energy

6 Mobile phones are different to fixed telephones because they have a built-in radio transmitter and receiver. When a call is made, these signals are sent to a base station and then to a switching station for connection to a fixed line or to another base station to connect to another mobile phone. This is different to fixed phones that use wires or 'landlines'.

challenge

1 **a** Why is feedback an important part of the communication process?

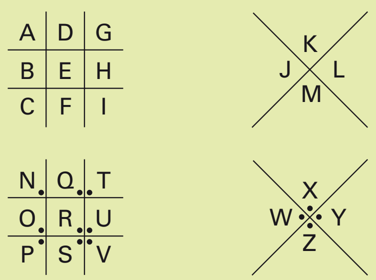
b During a conversation, the person listening might say 'Yes', 'I see' or OK'. Explain why these responses are forms of feedback.

c Give some examples of non-verbal feedback that might occur during a conversation.

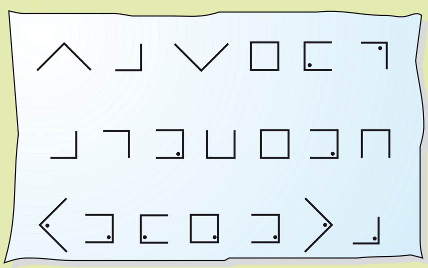
2 Look at the telephone network diagram on page 77. Use this to construct an energy flow diagram that shows all the energy conversions that occur during a telephone conversation.

3 Use the code to decode the following message.

Code



Message



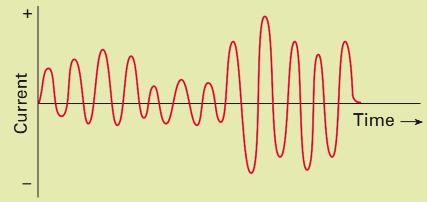
a What would happen if the message was turned upside down?

b Try to improve the code to overcome this problem.

c What other problems arise using this code?

4 A digital signal is made up of eight bits having the values 11001011. Using Fig 8 on page 76 as a guide, draw a graph of this signal.

5 The graph below shows the current produced by a microphone when a person speaks into it. The vertical axis has both positive and negative values. The horizontal axis is measured in units of time.



Using your knowledge of how a microphone works, explain:

a why the current has positive and negative values

b why the value of the current varies with time.

6 Encoding is changing one type of code to another. Decoding is the reverse process. Describe where signals are encoded during a telephone conversation and where they are decoded. In your description include the type of device used in the processes. (Use the telephone network diagram on page 77 as a guide.)

7 Study the data in the table below.

Colour of light	Speed of light (m/s) in air	Speed of light (m/s) in glass
red	2.988×10^8	1.983×10^8
blue	2.998×10^8	1.958×10^8

a Describe the information in the table.

b In optical fibres, pulses of laser light are transmitted in the glass core. If white light is used, suggest why the pulses of light become stretched out or 'smeared' after travelling through a very long optical fibre.

c Suggest how the problem in **b** could be overcome.

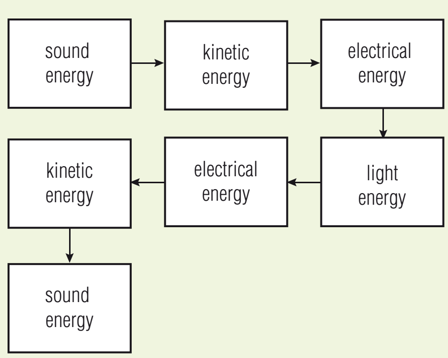
Challenge solutions

1 a Feedback is an important part of the communication process because it confirms (or checks) that the message has been received. This enables the sender to proceed with the rest of the message.

b These words indicate that the message is being received and understood. This enables the sender to proceed with confidence, as explained in **a**.

c Examples of non-verbal feedback would include signals (eg waving), gestures (eg cupping your hand near your ear) and facial expressions (eg frowning or smiling).

2



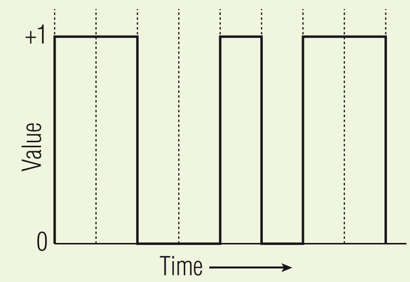
3 The decoded message is: *Make up a code of your own.*

a If the message was turned upside down it would not make sense. All of the letters (except E) would be different.

b One way to overcome this problem is to use symbols that are the same when upside down. One example would be dots and dashes, such as those used in Morse code.

c Other problems that arise using this code are that there are no capital letters or punctuation marks and there are no spaces between the words.

4



5 a The current has positive and negative values because it is alternating, which means it travels in one direction for a fraction of a second and then in the reverse direction for a fraction of a second, and so on.

b The strength of the current varies because it depends on the changing loudness of the voice of the person speaking into the microphone.

6 When sound waves reach a microphone they cause the diaphragm to vibrate. This diaphragm is connected to a coil of wire, which also vibrates near a magnet. This produces an electric current which can carry the message through a wire to a speaker. In the speaker the opposite process occurs and sounds are produced.

7 a The information in the table shows that while the speed of red and blue light is the same in air, red light travels more quickly in glass than blue light.

b White light is made up of light waves that have different wavelengths. As shown in the table, these different light waves travel at different speeds as they travel through optical fibres. So, over a long distance the pulse of white light becomes 'stretched' or 'smeared'.

c This problem is overcome by using light waves that have the same wavelength (eg laser light).

Hints and tips

Revise the chapter so far by giving the students a 'match the word and meaning' worksheet to place into their notebooks. Don't allow them to use their textbook unless they really need to. They can swap sheets with the person next to them for correction. Make sure ESL students understand what to do, as extra assistance may be required.

4.2 Electronics

Communication devices such as mobile phones, computers and fax machines all have one thing in common—they need electricity to work. Before the 1950s most communication devices contained bulky parts which used a lot of electrical power. During the 1950s tiny electronic components made from the elements silicon and germanium replaced the older bulky devices.

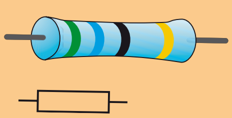
Electronic components such as diodes, resistors and transistors are now very small and cheap to manufacture, and they also use very little electric power. This means that they can be operated for long periods using either mains power or batteries.

A great breakthrough in electronics has taken place with the development of the 'microchip' or *integrated circuit*. The microchip contains thousands of electronic components etched onto the silicon by a photographic process.

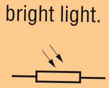
Fig 22 Microchips are the brains behind the many electronic devices we use every day, such as this calculator.

Resistors

Resistors control the amount of current in a circuit. The coloured stripes on the resistor indicate the size of the resistance. Resistance is measured in ohms (Ω).



Light-dependent resistors (LDR) are light-sensitive resistors. The resistance of the resistor decreases with the intensity of the light. That is, more current flows in bright light.

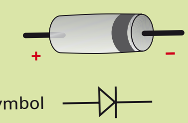


Thermistors are heat-sensitive resistors. The amount of current flowing through the resistor usually increases with the temperature.

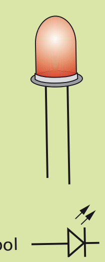
Diodes

Diodes allow current to flow in one direction only, making that part of the circuit a one-way street for the current. They are used in electronic circuits to stop current flowing in unwanted directions.

One end of a diode is marked with a band. This end should be connected to the negative side of the circuit.



Light-emitting diodes (LED) are electronic light bulbs—they glow red, green, yellow, orange or blue when electricity is passed through them. They are widely used in digital displays, traffic lights and tail-lights on cars.



Learning experience

Students could investigate how supermarket scanners work and draw a flow diagram of the communications technology involved.

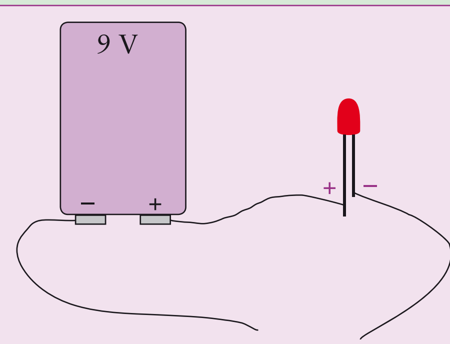
Learning experience

How did Silicon Valley in the USA get its name, and what is it famous for? What importance does it have for today's society? How have we become reliant on the microchip? Is there an alternative to the microchip? If they all suddenly stopped working what do you think would happen?

As a class, get students to suggest ways in which these questions could be answered. Ask them to order the questions in the way that they would like to answer them and write extra questions that need to be asked before they can successfully answer the given ones. The students should be specific and detailed with their explanations/reasoning.

Learning experience

Students can make their own tester to check if a material conducts electricity. Use three connecting wires to connect a 9 V battery and an LED as shown. Make sure students have correctly connected the positive/negative LED legs to the correct terminal. Touch the ends of the wires to a material to complete the circuit and see if the LED lights up. If it does, the material conducts electricity.



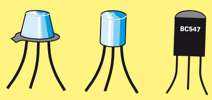
Note: The long leg of the LED is positive.

Transistors

Transistors are devices that can act like switches, turning the current in a circuit on and off. They can also increase the size of the current. In this way they act as amplifiers.

Transistors are made in different shapes, but each of them has three electrodes (legs), and the symbol remains the same.

Transistors have various shapes.



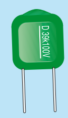
symbol 

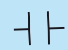
Capacitors

Capacitors are used in electronic circuits to store electric charge for a short time before allowing it to flow to other parts of the circuit. They are used to separate different parts of a circuit so that each can have a different current. They consist of two conducting plates separated by an insulating material called a dielectric.

The amount of charge that can be stored for each volt across a capacitor is called its *capacitance*. This is measured in farads (F), although microfarads (μF) are more commonly used in electronics.

Capacitors have various shapes.





symbol

Activity

In the next investigation you will be using resistors in circuits. For this you will need to know how to tell the value of a resistor by using the coloured bands on it.

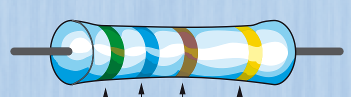
Your teacher will give you some resistors. Use the information below to work out their values in ohms.

The resistors you will use have four coloured bands on them. The code for the coloured bands is shown in the table.

To read the code, hold the resistor with the gold or silver band on your *right*. Then start with the first colour on the *left*.

Colour	Value	Colour	Value
black	0	green	5
brown	1	blue	6
red	2	purple	7
orange	3	grey	8
yellow	4	white	9

This resistor has a resistance of 560 Ω.



The colour of Band 1 gives the value of the first digit.

The colour of Band 2 gives the value of the second digit.

The colour of Band 3 tells how many zeros follow the first two digits.

The colour of Band 4 tells how precise the value of the resistor is.

Hints and tips

- The prefix *micro-* indicates a magnitude of 10^{-6} (one millionth). Students have probably heard of nanotechnology and know that many electronic components are able to be produced at this size. The prefix *nano-* indicates a magnitude of 10^{-9} (one billionth). This is very, very tiny!
- Find out if there are any students in the class who belong to an electronics club. Does the school have one? Enthusiastic students could start up their own club. It would be worth seeing if other schools in the area have a school club and gain ideas from them before launching into one. Students might be able to link up with other schools via the internet for ideas and assistance.

Activity notes

- Electronic components are relatively cheap if bought in large quantities.
- The resistors and other electronic components are small and easily mixed up, so it is a good idea to organise them in clearly labelled, segmented plastic containers. Have a monitor to check that they are returned correctly.
- When viewing the resistors, make sure that the gold or silver band (ie band 4) is on the right-hand side. This is the tolerance (precision) and is usually a percentage, eg ± 20%. It is worth discussing its meaning with the class.

Learning experience

Get the students to pull apart some disused or broken electrical devices and see if they can identify the different electrical components. Make sure any power leads have been removed and that students follow the standard safety precautions. Calculators, transistor radios, mini CD players and so on could be used. The ICT department will probably have a box of items and might be more than happy to get rid of them. You might need to get a class set of jeweller's tools (fine screwdrivers, etc) to help in opening the devices.

Issues

Are there any disadvantages of communications technologies? Get the class to suggest how society could be disadvantaged and explain why they think that. (Some examples of disadvantages are the loss of cultural identity and polluting waste materials from the manufacture of devices.)

Lab notes

Part A

- Remind students to connect the leads to the DC terminals of the power pack.
- Insist on having a switch placed in the circuit.
- Check that all the bulbs supplied are 6 V.
- The lab technician could set the resistors up using breadboards. This ensures the students have the correct resistor values and that the resistors are all facing the same direction.
- Before the students start, remind them of the difference between electron flow and conventional current. Ask them why it is important to know this for this investigation.
- Make sure the students do not leave the circuit connected for longer than necessary or the resistors will become very hot and may blow. (You will be able to smell it if this happens.)
- Consider revising Ohm's law with the class and get fast workers or mathematically able students to use the law to check results and make predictions.

Investigate

11 ELECTRONIC CIRCUITS

Aim

To set up circuits using electronic components.

Materials

- resistors (1 watt) 10 Ω, 22 Ω, 56 Ω, 390 Ω, 10 000 Ω
- diode (1N4002 or similar)
- light-emitting diode
- light-dependent resistor (eg ORP12)
- switch
- ammeter (eg 1A range) or multimeter
- power pack
- 6 V torch bulb and socket
- 4 connecting wires with alligator clips
- two 10 cm x 10 cm pieces of cardboard, 5 drawing pins and some thin, bare wire
- adhesive tape

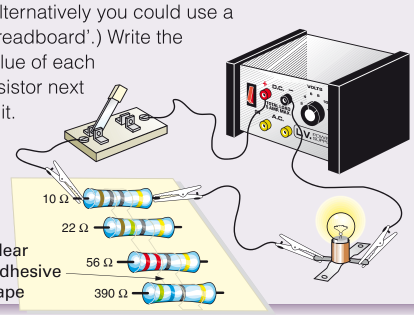
Planning and Safety Check

- Read through Part A and describe to your partner what you have to do. Swap roles and do the same for Part B (which itself has two parts).
- What precautions are necessary when using a power pack?

PART A Resistors

Method

1 Use the clear tape to tape the four lower value resistors to one of the pieces of cardboard. (Alternatively you could use a 'breadboard'.) Write the value of each resistor next to it.



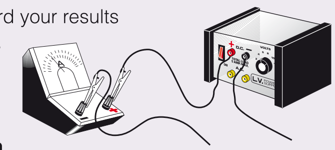
2 Connect up the circuit as shown bottom left. Set the power pack on 6 V DC and connect each resistor in turn.

Observe the glow of the light bulb for each resistor. Record your observations.

3 Take the light bulb out of the circuit and replace it with an ammeter.
Note: Remember to connect the positive (red) terminal of the ammeter to the positive side of the power pack.

4 In turn, find the current flowing through each resistor.

Record your results in a table.



Discussion

1 Write a generalisation linking the resistance to the glow of the light bulb.

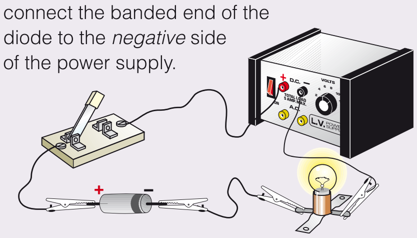
2 Write a generalisation linking the resistance to the current flowing in the circuit.

3 Predict the effect of a very large resistance (10 000 Ω) on the glow of the light bulb. Then test your prediction.

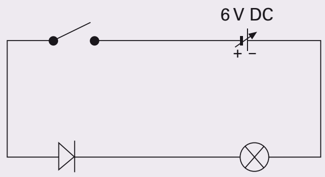
4 Why do the resistors heat up when you leave the power pack on for a while? Suggest why higher value resistors heat up more.

PART B Diodes

1 Set up the circuit as shown. Make sure you connect the banded end of the diode to the *negative* side of the power supply.



The circuit diagram for the set-up is shown below. In this circuit the banded end of the diode is shown by the vertical line in the symbol, and this is connected to the negative side of the power pack.



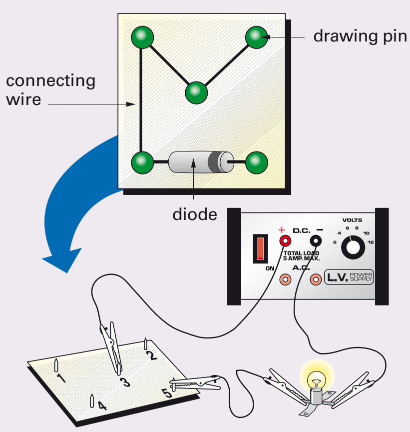
2 Set the power pack to 6 V DC.

Record your observations when you close the switch.

3 Disconnect the diode and turn it around so that the banded side is connected to the *positive* side of the power supply.

Record what happens this time.

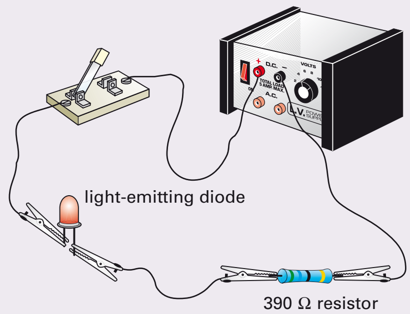
4 To make a puzzle for your partner, push five drawing pins into the second piece of cardboard as shown. Connect a diode between two of the pins. Then connect some bare wire between the other pins.



5 Turn the cardboard over and number each of the pins without your partner seeing. Now ask your partner to use the test circuit to find out where the diode is connected and which is the negative end.

Ask your partner to explain how they solved the puzzle.

6 Set up the circuit below containing a light-emitting diode (LED). The 390 Ω resistor is used to reduce the current in the circuit so that the LED does not 'burn out'.



7 Experiment with the LED to find out:

a whether the LED allows current to flow in one direction only

b if the short leg of the LED is the positive or negative side

c if a current that lights an LED will light a torch bulb.

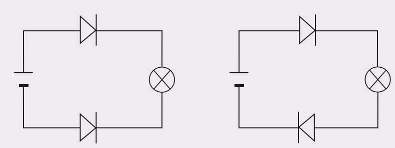
Write a report of your findings.

Discussion

1 Draw circuit diagrams using the correct symbols for the circuits in Steps 3 and 6.

2 Does an LED look brighter when viewed from the top or from the side?

3 Look at the circuits below. Will the light bulbs glow?



Lab notes

Part B

- Make sure students know how to connect diodes correctly.
- Again, breadboards can be used instead of using cardboard.
- Insist that the students neatly rule their circuit diagrams and use the correct symbols.
- Some students will get through this investigation very quickly and will need some extension work to go on with. If electronics kits are available they could chose a design to build.

Hints and tips

- Sometimes students find summarising an article challenging. A useful technique is to get them to read each paragraph and then write down a summary of that paragraph. This summary should be one or two sentences long. Doing this enables them to generate a set of summary points for the entire article—a skill worthwhile developing. ESL students could initially write their summary in their native language and then translate it.
- How many devices can the students list that use a microphone? Did they know that currently there are more than two billion microphones sold each year? About half of the market is for inexpensive low-grade microphones which are mainly used in toys. The rest are high-quality microphones used in devices such as computers, digital cameras, iPods and mobile phones. Mobile phone manufacturers are the biggest users. Mobile phones are getting smaller while incorporating a larger number of features. Is a digital microphone in a mobile phone likely? Find out if one has been developed and, if so, what its use will be. Is the electret microphone likely to be superseded? Explain.

Learning experience

Find out if the music and performing arts department has a broken stage microphone that the students can pull apart.

Science in action

Jim West and the electret microphone

Jim West was born in 1931 to African-American parents in Virginia, USA. Jim said that 'in those days in the South, the only professional jobs that seemed to be open to a black man were a teacher, a preacher, a doctor or a lawyer.' So his parents were disappointed when he chose to study physics instead of medicine. He went to university and began working as an intern at Bell Labs in New Jersey during his summer holidays. He joined the company full time in 1957.

A new type of microphone called a *condenser microphone* had been invented at Bell Labs in 1916. It is essentially a capacitor (see page 83) with two plates with a voltage between them. One of the plates is made of very light material and acts as the diaphragm. When sound waves hit the diaphragm, it vibrates. This changes the distance between the plates and therefore changes the capacitance, creating a small electric current. However, these microphones were not suitable for widespread use in telephones because they were expensive and required a large battery. So West and a colleague were given the task of inventing a new technology to produce a microphone that was small, high-quality and cheap to manufacture.

After several years of experimenting, West and his colleague patented an *electret microphone*. It uses a thin plastic film with a metallic coating. When exposed to a strong electric field the film retains its electric charge, and doesn't need a battery. These electret microphones can be made very small and are now in virtually every telephone in the world.

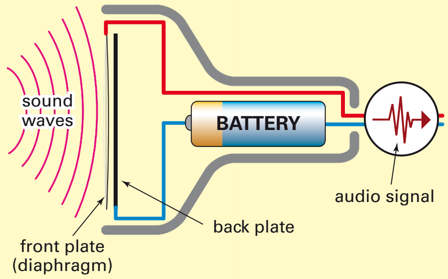


Fig 37 A condenser microphone

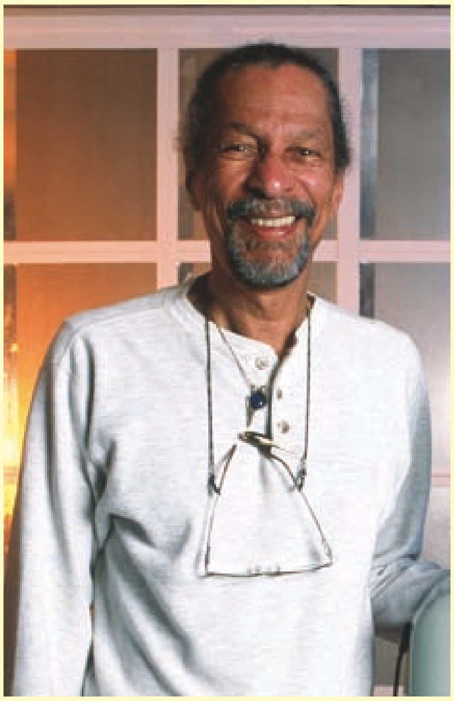


Fig 38 Jim West invented the electret microphone in 1962.

Jim West is still working and says 'My hobby is my work. I have the best of both worlds because I love what I do.' He is active in a program aimed at encouraging more women and people from minorities to enter the fields of science, technology and engineering.

Questions

1. Why were Jim West's parents disappointed when he decided to study physics?
2. Why is the electret microphone suitable for use in mobile phones?
3. How is an electret microphone different from a condenser microphone?

Learning experience

Ask the students to list five communication devices and, for each one, decide if it would be improved by becoming larger or smaller. What do they think is the optimal size? Are there any features they would like removed or added? What modifications would they make? Do the devices improve the quality of life? The students should critically assess the performance of the devices to identify limitations and capabilities, and justify their answers. This activity encourages the students to be more divergent in their thinking.

One method to help them organise their responses is to divide a large sheet of paper into columns, as shown below.

Name of device	Making the device larger would …	Making the device smaller would …	Optimal size is … because …	The following features should be removed because …	The following features should be added because …	Modifications made are … because …	Improving the quality of life—why/why not?

Semiconductors

Diodes and transistors are made from materials called **semiconductors**. These materials, which include the elements silicon and germanium, have properties in between conductors and insulators.

Silicon is the most important semiconductor material. It is made from sand (silicon dioxide), and it is cheap and easy to manufacture in pure form. In pure form silicon does not conduct electricity very well. But when very small amounts of another substance, such as arsenic or boron, are added (this process is called *doping*) the silicon conducts electricity.

An atom of silicon has four outermost electrons. An atom of arsenic has five electrons, one more than silicon. When silicon is doped with arsenic and wires from a battery are placed at each end of the crystal, a current flows. The fact that the extra electrons in the arsenic atoms are relatively free to move causes the doped crystal of silicon to conduct electricity. This type of doped semiconductor is called *n-type* or negative type because of the extra electrons.

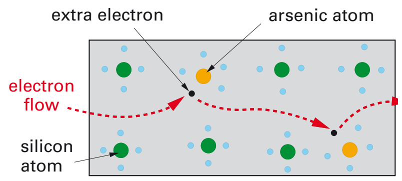
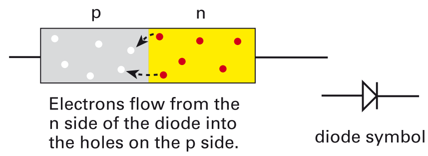


Fig 39 How an electric current is carried through an n-type semiconductor by mobile electrons

Boron has only three outermost electrons, one less than silicon. When silicon is doped with boron, the crystal also conducts electricity. It seems that the boron atom creates an electron space or 'hole' into which electrons from the silicon can flow, causing an electric current. This type of doped semiconductor is called *p-type* or positive type.

Diodes

A diode is made by placing an n-type crystal next to a p-type crystal. When this is connected in a circuit the 'extra' electrons in the n-type crystal can jump across to the holes in the p-type crystal. However, if the battery terminals are reversed, the electrons cannot jump back in the other direction. This is why diodes carry current in one direction only. (By convention, the arrow in the diode symbol points in a direction *opposite* to that in which the electrons flow.)



In the diagram above you will notice that the electrons flow in the opposite direction to the arrow in the symbol. When scientists first studied electricity they thought it was a flow of positive charge—from positive to negative. It was a long time before they discovered that it was, in fact, negatively charged electrons which were moving. By this time everyone had been thinking about current flowing from positive to negative for so long that it was impossible to change. This flow from positive to negative is called 'conventional current'.

Transistors

A transistor is made of three pieces of semiconductor crystal sandwiched together. This is why transistors have three legs (electrodes).

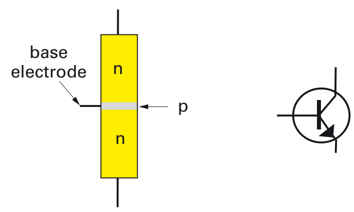


Fig 41 An n-p-n transistor and its symbol

A transistor can be used as a miniature switch, as shown on the next page. It works like a gate where one person can control the movement of thousands of people.

Hints and tips

- If student interest in this topic is waning, reignite it by showing another segment from a spy movie. Check the interest level of the girls in the class. Try to choose a movie with a balance of male and female characters.
- Revise the properties of an electrical insulator and conductor. Get the students to recall materials that are good insulators and conductors of electricity.

Homework

Ask students to find out how the electronics of a transistor radio work. Enthusiastic students could build their own radio. Kits or electronic supplies can be found in most Dick Smith or Jaycar Electronics stores.

Learning experience

The students could make a set of summary cards for this chapter. On one side of the card they can have a diagram or word, and on the back its definition/explanation. Get the students to place the cards on the table, with the definition/explanation side down. In pairs, students take turns selecting a card, then try to explain the meaning of the diagram or word. If they explain it correctly, they keep the card. The winner is the person with the most correct explanations.

Learning experience

Students could investigate the German Enigma machine used in World War II. Why was it given the name 'Enigma'? Who used it and for what purpose? How were the signals sent? How and by whom were the signals decoded? What was the significance of cracking the code? What do you think could have been the consequences if the code was not broken? How might our lives be different today? German Enigma machine simulators can be found on the internet and students could have some fun trying them. Go to the *Science World 3* Webwatch and follow the links to 'Enigma'.

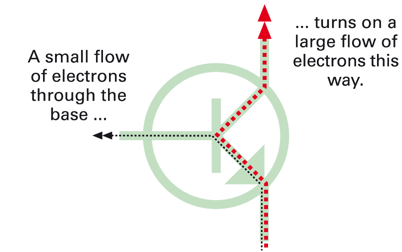


Fig 42 How a transistor works. When a small current is applied through the base leg, a large current can flow through the other two legs.

A transistor can also be used as an amplifier, as in the circuit below. When the microphone on the left is turned on the current it produces is not enough to power the loudspeaker. However, the small current flowing into the transistor is amplified, producing a larger copy of the original signal from the microphone. This amplified current is large enough to operate the loudspeaker.

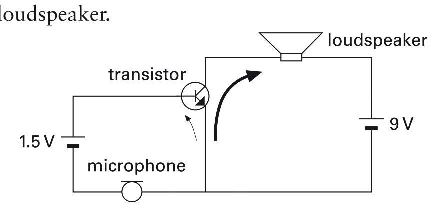
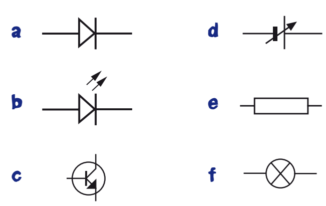


Fig 43 In this circuit a transistor amplifies a small microphone current to produce a large current in the loudspeaker.

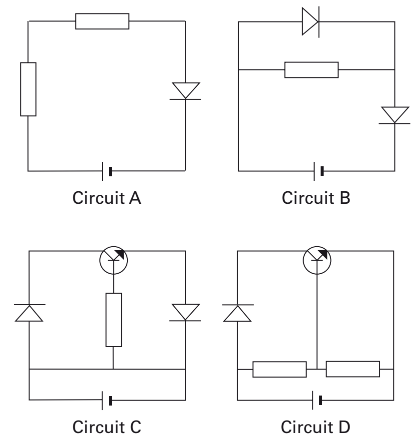
Check!

1 What do the following symbols represent?

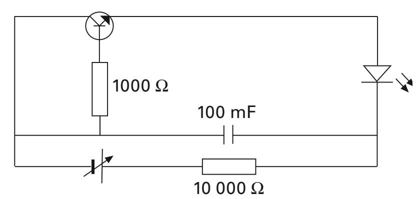


2 How is a resistor different from a diode? In what units is resistance measured?

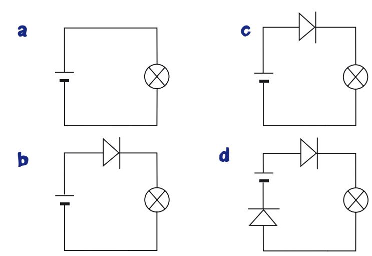
3 Which one of the following circuits contains a battery, one resistor, one transistor, and two diodes?



4 List the equipment you would need to build the following circuit.



5 In which of the following circuits would you expect the light bulb to glow?



Check! solutions

1 These symbols represent:
- a a diode
- b a light-emitting diode
- c a transistor
- d a DC power source
- e a resistor
- f a light bulb

2 A resistor will oppose the flow of and will reduce the amount of current flowing in a circuit. A diode provides negligible resistance to electric current but will only allow current to flow in one direction in a circuit. The units of electrical resistance are ohms (Ω).

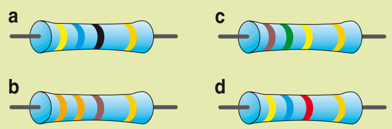
3 This combination of components is only found in circuit C.

4 The list of components you would need is:
- 6 V battery
- diode
- light-emitting diode
- transistor
- 1000 Ω resistor
- 10 000 Ω resistor
- 100 μF capacitor
- several connecting wires.

5 You would expect the bulb to glow in all circuits except **c**. In **c** the band on the side of the cell is connected to the positive side of the cell and no current will flow.

challenge

1 Use the resistor code table on page 83 to find the values of the following resistors.



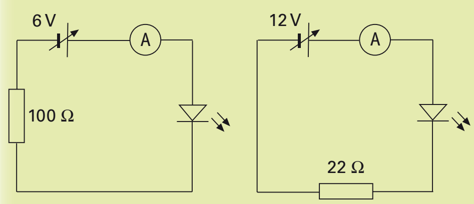
2 Why were very small portable radios not available in the 1930s?

3 Security beams in the doorways of shops sometimes use a light-dependent resistor. How do they work?

4 a In which of the two circuits below would the LED glow more brightly? Explain.

b If the LED in the circuits below has a resistance of 50 Ω, find the current flowing in each circuit.

c Suggest why LEDs, rather than light bulbs, are used in electrical appliances.



Circuit A Circuit B

5 Suppose you are making an electronic fire alarm. Which electronic component could you use to detect the fire? Explain.

6 An undoped semiconductor like pure silicon will not conduct electricity at low temperatures. However, as the temperature rises the ability of the silicon to carry current increases. Suggest how electronic thermometers might use this material to measure temperature.

7 a Explain in terms of electrons how semiconductors differ from conductors and insulators.

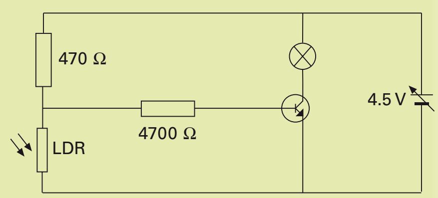
b Explain how an n-type semiconductor differs from a p-type.

8 The circuit below can be used to switch on a light when the Sun goes down.

a Explain how a light-dependent resistor (LDR) works.

b Explain what happens in the circuit during the day and when the Sun goes down.

Hint: Consider the effect the two resistors and the LDR have on the electric current in the different parts of the circuit. During the day the resistance of the LDR is about 500 Ω and at night about 200 000 Ω.



(You might like to build this circuit if your teacher can organise the components.)

try this

1 Use library resources to find out what microchips or integrated circuits are. Where are they used?

2 Use an electronics kit, eg Dick Smith's *Funway*, to build a simple everyday device such as flashing lights, a siren, a radio or a Morse code sender. You simply follow the instructions to put the electronic components together to make the device.

Challenge solutions

1 The values are:

a 46 Ω

b 330 Ω

c 150 000 Ω

d 5600 Ω

2 Small portable radios were not available in the 1930s because they needed small electronic components (eg transistors), which were not available then.

3 Usually the light beam completes a circuit but when it is broken by someone walking through the door, an alternative circuit is activated which rings a bell to alert the shopkeeper.

4 a The LED would glow more brightly in circuit B because there is less resistance and a greater current flowing.

b In circuit A the total resistance is 150 Ω and the voltage is 6 V (using Ohm's law $I = \frac{V}{R} = \frac{6}{150} = 0.04$ A).

In circuit B the total resistance is 72 and the voltage is 12 V (using Ohm's law $I = \frac{V}{R} = \frac{12}{72} = 0.17$ A).

c LEDs are used because they are smaller, last longer, don't get as hot and use much less power than light bulbs.

5 The best electrical component to use for detecting a fire would be a thermistor or heat-sensitive resistor because when it is heated it will conduct a greater current.

6 These electronic thermometers use numerals which consist of seven light-emitting diodes (LEDs). Circuits can be constructed so that as the temperature varies, the current also varies. This will cause certain combinations of LEDs to glow, giving a readout of the temperature on the thermometer.

7 a Semiconductors are made from pure substances such as silicon, which does not allow electrons to pass through it (it is an insulator), together with a very small amount of another substance. This mixture conducts an electric current. Conductors are usually made from pure substances (metals) that conduct electrons. Insulators do not allow electrons to pass through them.

b An n-type (or negative-type) semiconductor consists of silicon mixed with other elements such as arsenic, which have extra electrons. A p-type (or positive-type) semiconductor consists of silicon mixed with other elements such as boron, which creates a 'hole' for electrons to flow into.

8 a A light-dependent resistor (LDR) is a light-sensitive resistor. Its resistance decreases in brighter light, thus allowing more current to flow.

b In the circuit diagram given, when the sun is shining brightly the LDR has a low resistance and allows a current to flow through the outer circuit, and the bulb does not glow. Only about 10% of the current flows through the 4700 Ω resistor because it has approximately 10 times more resistance, and this current is not sufficient to activate the transistor. When the sun goes down the LDR has a greater resistance. This forces more current through the 4700 Ω resistor and the transistor which, in turn, allows more current to flow through the light bulb, causing it to glow.

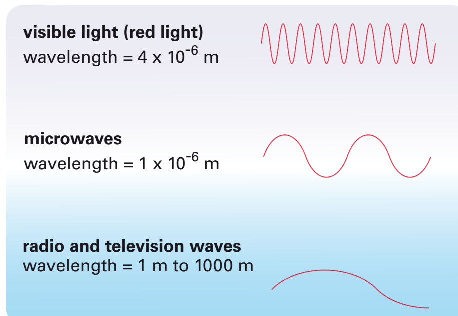
Hints and tips

Give the class a quick quiz to see what they can recall from the previous chapter on light and sound. Relate the questions you ask to this topic. Can the students see how the ideas they learned from the previous chapter relate to this chapter?

4.3 Television and radio

In 1896 Guglielmo Marconi, an Italian inventor, patented the radio, or 'wireless' as it was known. The first television picture was produced by John Logie Baird, a Scotsman, in 1925. Black and white TV was introduced to Australia in 1956 and colour in 1975. We now have satellite, cable and digital TV.

The information sent by television and radio is transmitted via *electromagnetic waves* of long wavelength. These waves are received by a metal aerial or antenna which converts electromagnetic waves into electric current. This current is then decoded into pictures or sound.



How does television work?

The heart of a TV set is the picture tube. This is a type of **cathode ray tube** (CRT) which is also found in a cathode ray oscilloscope (see the activity on page 76). It is called a cathode ray tube because the image is formed by a beam of electrons which are produced at a heated negative terminal called a *cathode*. The electrons are attracted to a hollow positive terminal called the *anode* which is just in front of the cathode. The electrons pass through the anode in a narrow beam. They then strike the back of the screen which is coated with a special material that glows when electrons hit it.

The direction of the electron beam in the cathode ray tube is controlled by two sets of deflecting plates—one positioned horizontally, the other vertically. A changing electric current in the plates creates a changing electric field between the plates which, in turn, affects the direction of the electron beam.

The picture tube in a colour TV is similar to the cathode ray tube in a CRO except that it has three electron guns instead of one. The TV tube also has deflecting coils instead of plates. The coils create a magnetic field which alters the direction of the electron beams.

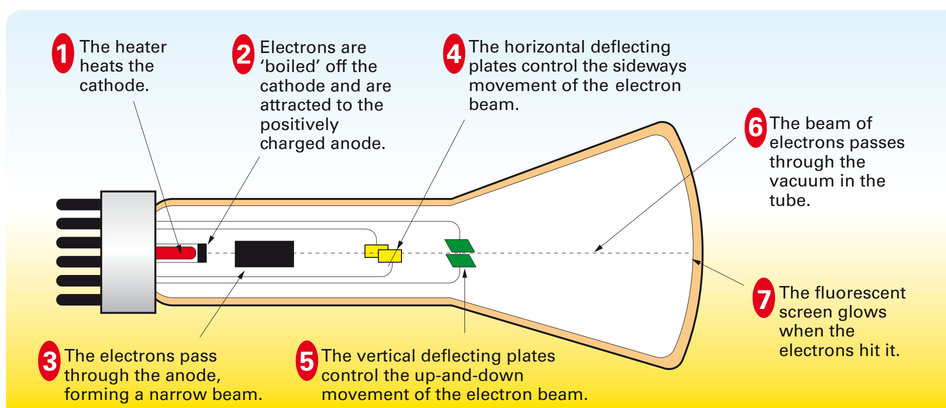


Fig 53 A cutaway drawing of a cathode ray tube from a CRO

Learning experience

To help cognitive development, give the students a higher-order thinking task. Bloom's taxonomy is a useful model for ensuring students' higher-order thinking. The following is an example, and a rubric marking grid could be developed to go with it.

Remembering	How many ways can you communicate with other people? List or draw all the ways that you know. Describe one of the technologies from your list, draw a diagram and label the parts. Collect 'communications technology' pictures from magazines and create a collage.
Understanding	How do you communicate with your friends when you are at home? Explain the method of communication and draw a flow diagram to show the process. Explain how you felt the first time you used SMS on your phone or emailed someone. Write out the instructions for a first time SMS/email user.
Applying	Explain why some communications technologies are large and others small. Survey the class or 10 classmates to see what communications technology they use. Display the information on a chart or bar graph. Select two different communications technologies and critique them. If you had to choose one of the technologies, which would you choose and why?
Analysing	What problems are there with modern types of communications technology and their uses? Outline the problems in a report. Use a Venn diagram to compare three different types of electronic communication devices.
Evaluating	What changes would you recommend to communications technology companies to improve the design and communication techniques of the devices they make? Is there something better than a mobile phone? Explain.
Creating	Predict what you think communications technologies will be like in 10 years' time. Invent a communication device. After careful planning, draw or construct the device. Discuss, write about it and report to the class. Make an advertisement for your invented communication device. Write a mobile phone ringtone ditty with words about using different forms of communications technology.

Activity

Your teacher will set up a CRO and adjust the controls to give a spot on the screen. When the *time sweep* control is on the largest setting, the spot moves very slowly across the screen. The *position* knobs control the vertical and horizontal deflecting plates.

1 Watch what happens to the spot when the position knobs are adjusted.

2 Hold a bar magnet near the spot on the screen.

How does the magnet affect the position of the spot?

What inference can you make about the way the deflecting plates work?

Warning: Do not hold a magnet near a colour TV set. You will do permanent damage to it.

Inside the TV picture tube, the electron guns fire electrons at the screen. The deflecting coils sweep the electron beams over the screen making a horizontal line. After the first horizontal sweep the deflecting coils move the electron beams down to sweep across a second line. Each complete picture on the TV screen is made up of 625 horizontal lines and each set of 625 lines is redone 25 times every second. These changes are far too fast for our eyes to detect, so we see a continuous picture on the screen.

The inside of the screen is coated with three different substances in very small strips or dots called *pixels*. These substances are called **phosphors** (FOS-fours). One phosphor glows red when struck by an electron beam, the other glows green and the third glows blue. The picture on the screen is built up of millions of red, green and blue strips or dots. The shadow mask positioned close to the screen makes sure the electron beams strike the correct phosphors.

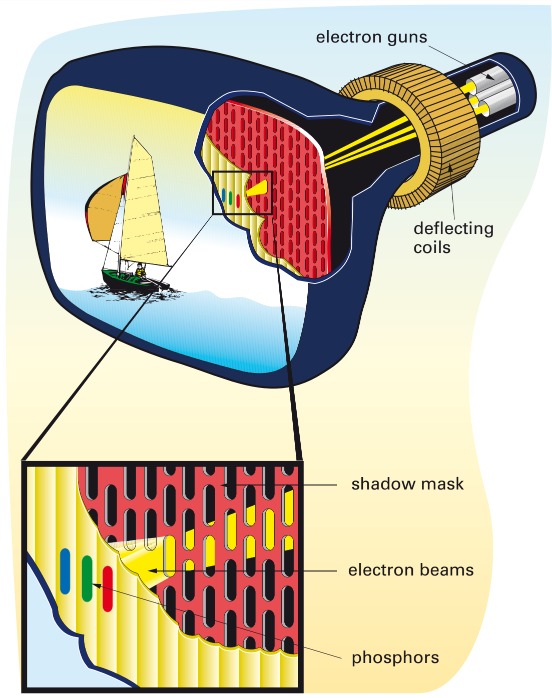


Fig 55 Inside a TV picture tube

Hints and tips

Ask students why the coloured phosphors are red, green and blue. They should be able to link this topic to the material in the previous chapter on mixing coloured lights. If necessary, go over different colour combinations.

Activity notes

- See Activity notes for page 76.
- Make sure students do not hold a magnet close to a computer monitor.

Homework

Some of the students' grandparents or great-grandparents might have made their own television set, especially if they lived in Britain or America. For electronics enthusiasts in the post-World War II period, making your own TV was quite a popular hobby. Often the picture displayed shades of green rather than black and white.

Ask students to further investigate the history and science of television. Can the students go a week without watching TV? (Is there anyone willing to try the challenge?)

Learning experience

A rather fun and challenging activity is to get the students to compile an A to Z alphabet of words relating to communications technology. You may like to get them started: A is for analog signal, B is for byte, C is for cathode ray oscilloscope, and so on. ESL students or students with language difficulties may need extra assistance. The students could build up their alphabet by adding to it progressively.

Activity notes

- Refer the students back to the Activity on page 61. The same principle of mixing coloured lights applies here.
- A results table is a good way for students to display their data. Use the headings ‘Colour’, ‘Prediction’ and ‘Observation’.

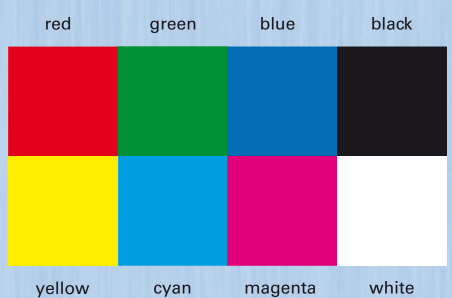
Activity

A: Observing phosphors
A computer monitor is similar to a TV screen. Before you turn it on, use a magnifying glass or hand lens to look at the screen.

The vertical lines that you observe are the pixels, separated by thin black lines. Each pixel is made up of three individual phosphors that glow red, green and blue when struck by electrons.

B: Observing colours

1 Open a computer program such as *Word* or *Paintbrush* and find the colour palette. Alternatively you can make your own as shown below. You need the three primary colours (red, green and blue) and the three secondary colours (yellow, cyan and magenta), plus black and white.



2 Use the hand lens to look at a white patch on your palette. Notice the spots or strips of colours. Can you see the individual red, green and blue spots?

3 Predict what you will see if you look at the black patch. Give a reason for your prediction. Use the hand lens to check your prediction.

4 Use the hand lens to look at the red, green and blue patches on the screen. Record the colours of the phosphors in each patch.

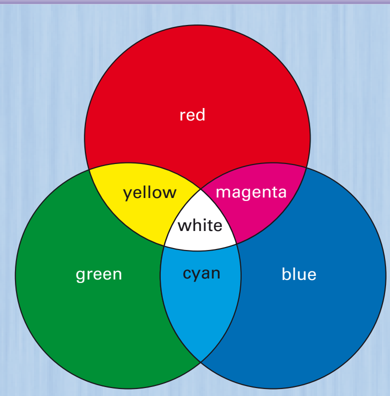


Fig 57 A colour mixing wheel

5 Use the colours in the colour mixing wheel to work out which two primary colours combine to give yellow. Then observe the yellow patch on the screen.

6 Repeat Step 5, but this time look at the cyan and then the magenta patches.
Which phosphors combine to give yellow, cyan and magenta?
How are other colours such as orange and purple formed?

Teacher note: The phosphors are easier to observe on a TV screen, but you will need to use a video on pause. You could video the test pattern on this page.

WEBwatch

Go to www.scienceworld.net.au and follow the links to this website.

How television works

A comprehensive site with links to digital TV, satellite TV, plasma displays, DVD players and VCRs.

Learning experience

Ask the students to do the Webwatch in class (if you have access to computers) or as a homework exercise.

LCD screens

The picture tubes used in the older CRT TV and computer screens are quite bulky. The flat screens now used in many computers and some TV screens use **liquid crystal displays (LCDs)**. A liquid crystal has the properties of both a liquid and a solid. The long molecules in a liquid crystal stay in position like those in a solid, but they also move around like the molecules in a liquid.

To make an LCD, two polarising filters (like those in polaroid sunglasses) are used. When these are arranged at right angles to each other, no light passes through them (see Fig 58 below). The liquid crystals are placed between the filters and arranged in a twisted pattern that allows light to pass through. However, when an electric field is passed through the liquid crystals, the twist disappears. This means that light can no longer pass through—that area of the screen appears dark.

LCDs do not give off light. Those in digital watches and calculators have a mirror behind them to reflect light. This is why they don't work in the dark. In flat screen TVs, each pixel is an LCD instead of a phosphor. The LCDs are lit from the back by tiny fluorescent tubes. They have red, green and blue filters above them to produce colours.

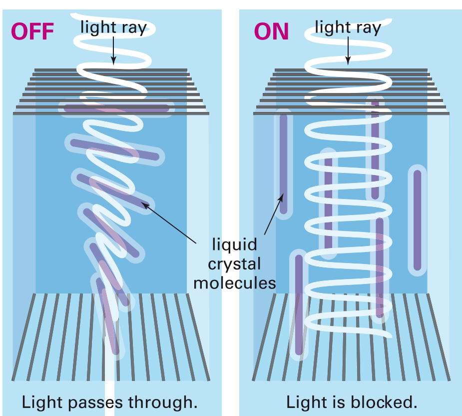


Fig 58 How a liquid crystal display (LCD) works

Plasma screens

Many people are now buying plasma TV screens. These are much larger than normal screens but are only about 15 cm thick. So they can be mounted on the wall in a home theatre. However, at this stage they are still very expensive.

In a *plasma* screen each pixel consists of three tiny fluorescent cells, like fluorescent lights. Inside each fluorescent cell is a mixture of xenon and neon gases. When a voltage is passed through this gas, high-speed electrons are produced. These electrons collide with the atoms in the gas, knocking out more electrons and creating positive ions. The resulting mixture of positive ions and electrons is a plasma. Particles speed rapidly in all directions, bumping into each other. These collisions excite the atoms in the plasma, causing them to release ultraviolet radiation. When this UV radiation hits the phosphors on the bottom of the cell, it produces red, green or blue light.

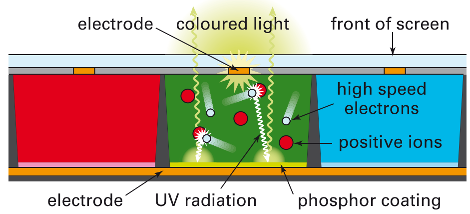


Fig 59 How a plasma screen works (above)

Hints and tips

- Reflective questioning is a powerful way to engage students in thinking about *how* they are learning new concepts and skills. At various points throughout the lesson, questions can be asked to support student learning. Questions should be focused on students' understanding and thinking, interpersonal development and personal learning. 'What did you learn?', 'How do you know that you have learnt it?' and 'How will you use that learning again?' are useful questions that encourage students to make the connections between areas of learning.
- Plasma is the fourth state of matter. It is a very hot ionised gas in which the number of positive ions and electrons are approximately equal, making the plasma virtually neutral but highly conductive.

Learning experience

Get the students to review the sunshine wheel they started on page 75 and add to it. If there is no more room for entries, ask them to create a second wheel. What do they know now that they didn't know earlier?

Learning experience

Collectively, how many televisions do the students in the class have? Of these, how many are CRT, LCD or plasma? Do a survey and have the students graph the results. What conclusions can be made from the graphed data?

Learning experience

The students could add to their communications technology alphabet (see the Learning experience on page 91) and include P for plasma.

Hints and tips

Divide the class into two equal groups, then have the students stand in two circles, one within the other. Students in the inner circle face outwards, directly facing another student in the outer circle. Give a one-minute time limit for each student to share something they have learned from this chapter, before one circle moves sideways to the next person, and the students share another fact. Five rotations are probably sufficient. This strategy is called 'Inside/Outside Circles', and it enables discussion between students while encouraging movement and interaction.

Activity notes

- See Activity notes for page 76.
- At very high frequencies, sounds that are barely audible can cause headaches if students are exposed to them for too long.

Radio and TV transmission

Your favourite radio station might have a call sign of 107.5. What does the 107.5 mean? And what is the difference between AM and FM?

Each commercial radio station in Australia has its own broadcast frequency which you can tune in to with your radio tuner. To understand what frequency means, your teacher may set up a CRO as in the activity below to show you different wave patterns.

A microphone converts sound waves into an electronic audio signal. These are low frequency waves and if broadcast would travel only a few metres through the air. To overcome this problem, radio stations mix this audio signal with a much higher frequency wave with more energy, which can travel hundreds of kilometres through the air. This wave is called a *carrier wave*, and the combined audio signal and carrier wave is called a *modulated wave*.

AM

There are two ways to combine an audio signal with a carrier wave. One way results in a wave that has its *amplitude modulated* or varied. Radio stations that broadcast in this form are called **AM** stations.

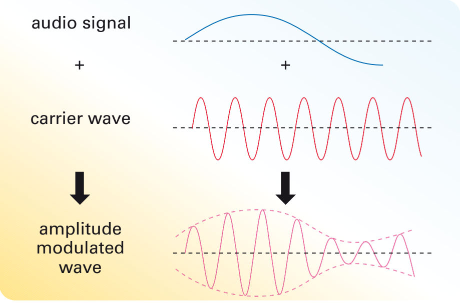


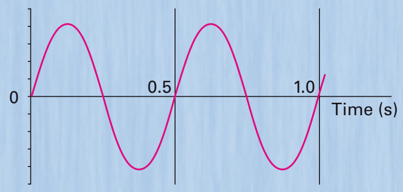
Fig 61 Modulated waves from an AM station. The frequency is the same as the carrier wave but the amplitude varies.

Activity

Your teacher will connect an audio generator to a CRO.

1 Look at the wave pattern produced by the generator. What do you notice when the pitch of the sound is changed?

The **frequency** of a wave is the number of waves that pass a point in one second. Frequency is measured in hertz (Hz), where one hertz is one wave per second. The wave below has a frequency of 2 Hz. Two complete waves pass each point every second.



What happens to the frequency when the pitch of a sound increases?

What happens to the wavelength of the wave when the pitch increases?

Make a generalisation about the pitch of sound and the frequency. Make another generalisation about the frequency of a wave and its wavelength.

2 Turn up the volume on the generator. Now turn the volume down.

Record what happens to the shape of the wave on the screen.

Make a generalisation about the loudness of a sound and the amplitude of the waves.

Does changing the volume affect the frequency or wavelength of the waves?

Learning experience

Ask the students to list as many methods of communication in use today as they can. How many of these methods do they use, and which ones? Find out the methods their parents, grandparents and if possible their great-grandparents used to communicate when they were teenagers. How have communication techniques changed?

Students can then think up a set of relevant questions about this topic to ask family members and record an audio interview with each person. Five minutes per person is probably enough (unless they have a fascinating story to tell).

FM

The second way of broadcasting is to combine an audio signal with a carrier wave to produce a wave whose frequency changes but whose amplitude stays the same. This type of radio wave is called *frequency modulated* or **FM** (see Fig 63 on the right).

FM stations broadcast on a much higher frequency than AM stations. AM stations broadcast at frequencies between 520 kHz and 1600 kHz (1 kHz = 1 kilohertz = 1000 Hz). FM stations broadcast at much higher frequencies, between 87 MHz and 108 MHz (1 MHz = 1 megahertz = 10^6 Hz).

The steps in sending and receiving radio signals are shown in the diagram below.

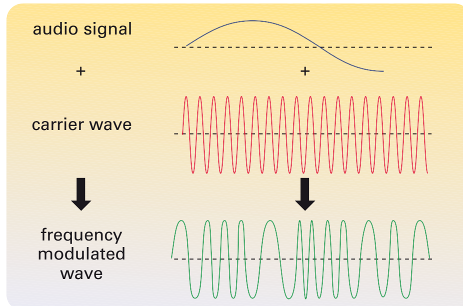
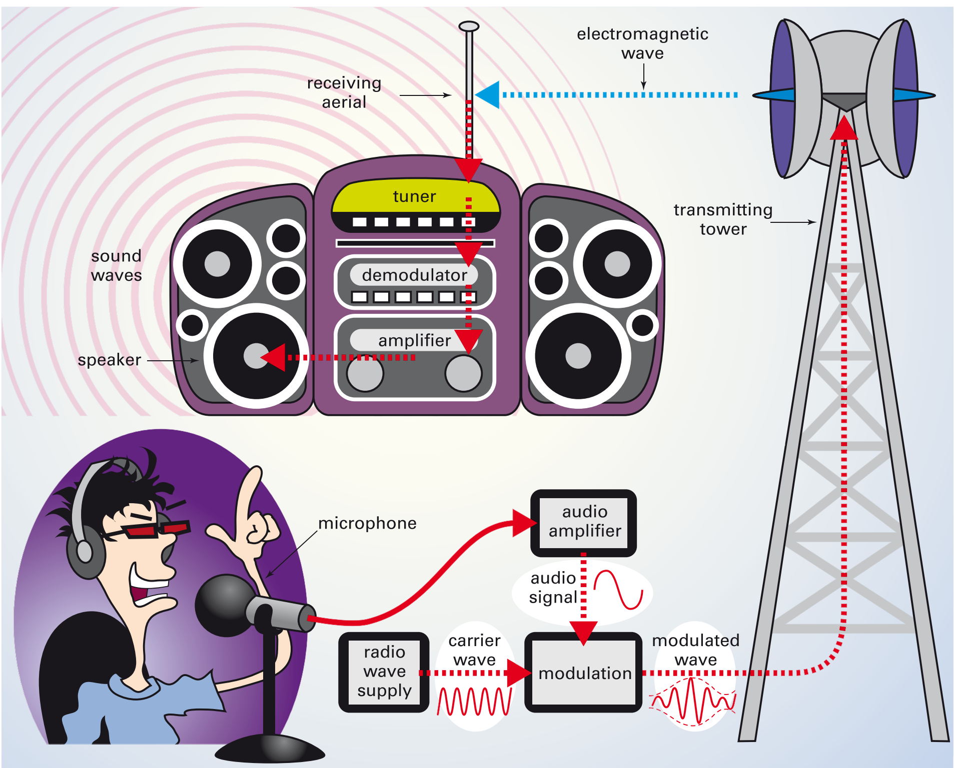


Fig 63 Modulated waves from an FM station. The amplitude is the same as the carrier wave but the frequency varies.



Hints and tips

Draw a table on the board to compare the differences and similarities of AM radio, FM radio and TV transmission. Some students find information presented in a tabular form easier to remember.

Homework

Ask students to prepare a booklet entitled *How to get the best radio and TV reception*. The booklet should contain valid information about AM and FM radio waves.

Learning experience

Turn the diagram of the steps in sending and receiving radio signals into a set of written steps.

Learning experience

Students can make their own radio. Commercial kits are available and range in cost from about $15 to $80. Circuit diagrams can be found on the internet and bulk supplies of electronic components can be obtained from suppliers such as Jaycar or Dick Smith Electronics.

Check! solutions

1 There are three electron guns in a colour TV set because there are three primary colours. All other colours can be formed from various combinations of these three colours.

2 A very simple way to test if an electron beam is affected by a magnetic field is to hold a magnet near the screen of a CRO.

3 When the cathode is heated, electrons are produced that are attracted to the positive electrode (anode). They are accelerated and focused into a beam. When this beam hits the fluorescent screen it can be seen as a glowing spot.

4 a WIZ is the FM station because of the higher frequency.
b kHz stands for kilohertz, which is a frequency of 1000 cycles per second. MHz stands for megahertz, which is a frequency of 1 000 000 cycles per second.
c You would predict that the station that can be heard 300 km away would be FUN because AM stations have lower frequencies, which travel much further through the atmosphere.

5 TV signals consist of both video and audio parts. These can be transmitted through a cable or optical fibres. They can also be transmitted through the atmosphere and space using towers and satellites. These signals also travel at the speed of light (3×10^8 m/s) which means that they come from the other side of the world to your receiver in less than a second!

The carrier wave frequency determines the radio station's broadcast frequency. For example, AM station 873 has a carrier wave frequency of 873 kHz, while FM 104 has a carrier wave frequency of 104 MHz.

Television transmission is much more complicated than radio because the signals have to carry both sound and pictures. The colour and the brightness of the TV picture are transmitted on a video signal which is similar to an AM signal. The sound is transmitted separately as an FM signal. A TV antenna picks up the signals and relays them to the TV set where the picture signals and sound signals are synchronised.

With cable TV the signal travels directly to your TV without being transmitted.

Radio and TV reception

The frequency of the radio or TV broadcast determines the quality of reception and how far away the broadcast is received. Broadcasts that are transmitted on relatively low frequencies can be received much further away than higher frequency ones. The lower the frequency of broadcast the greater the range. For example, low frequency amateur radio broadcasts can be heard from overseas countries thousands of kilometres away because the radio waves are reflected from the ionosphere in the Earth's atmosphere. However, the radiation from the Sun affects the gases in the ionosphere, so these broadcasts suffer from interference (noise), especially during the day.

Local AM stations broadcast on a lower frequency than amateur radio. Their signals can travel many hundreds of kilometres from the transmitting tower and are less affected by interference from the Sun.

The very high frequency waves transmitted by FM radio and TV stations suffer less interference and the sound quality is usually far superior to AM stations. However, these waves travel only in straight lines and are not reflected by the atmosphere. So if your antenna is behind a hill or mountain, your radio and TV reception will be poor. Another disadvantage of FM radio and TV waves is that they normally have a range of only about 100 km. With satellite TV this problem is overcome by beaming the signal up to a satellite and then back down to your TV.

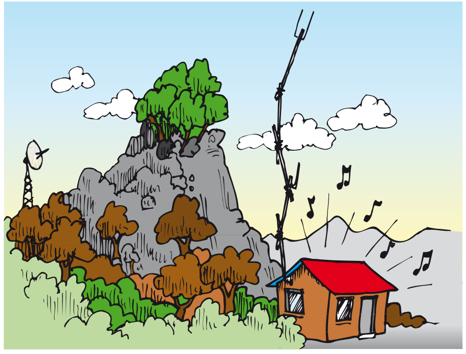


Fig 65 You have to be in the line of sight to receive good quality FM radio and TV broadcasts.

Check!

1 Why are there three electron guns in a colour TV set?

2 How can you show that an electron beam is affected by a magnetic field?

3 Use the diagram of the cathode ray tube on page 90 to explain in your own words how a glowing spot is formed on the screen of a CRO.

4 Radio station FUN broadcasts on a frequency of 690 kHz while station WIZ broadcasts on 94.5 MHz.
a Which is the FM station?
b What do kHz and MHz mean?
c Which station do you predict could be heard 300 km away? Why?

5 How is it possible to receive live TV broadcasts of events taking place on the other side of the world?

Learning experience

Thinking/content questions and personal learning questions can be used to conclude a topic. They encourage the individual learner to think about their learning and skills development. Get the students to reflect on their progress by asking them questions such as:

- What did you learn from today's lesson/the previous lessons on this chapter?
- What are some concepts that you learned from this chapter?
- Why is being able to solve a problem an important skill?
- How did you feel when you had to share your ideas with the class/group?
- What did you learn about yourself during this chapter?
- How did you assist others with their learning?

6 Why do radio stations use a carrier wave to transmit their broadcasts? What is the difference between a carrier wave and a modulated wave?

7 Suppose you use a magnifying glass to look at the phosphors in a very small area of your TV screen. At 10 second intervals you record the colours of the phosphors that are glowing (0 = phosphor not glowing).
Use the colour wheel on page 92 to determine which colours you will see at the five recording times if you are standing back from the TV screen.

Interval number	Colours of phosphors
1	red, 0, 0
2	red, green, 0
3	0, green, blue
4	0, 0, 0
5	red, green, blue

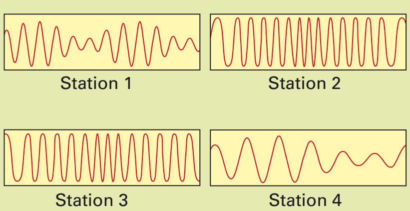
challenge

1 If someone next door is using a power tool it may cause interference on your TV set. How?

2 Construct a flow chart to show how a free-to-air TV picture gets from a studio at the TV station to the TV set in your home.

3 Make inferences from the following observations.
- a The car radio goes crackly when you drive under high voltage power lines.
- b People living in valleys have to have very tall TV antennas.
- c TV and radio signals can be picked up by aerials inside houses.
- d AM radio fades when you drive through an underpass or tunnel but FM does not.

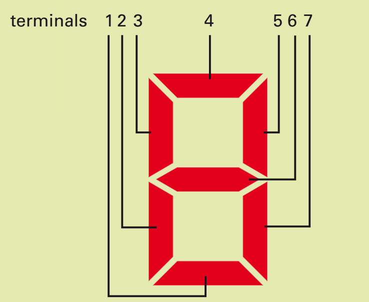
4 The diagram below shows modulated radio waves from four stations.
- a Which are FM stations? How do you know?
- b Which AM station broadcasts at a higher frequency?



5 Suggest how feedback could be achieved with TV and radio transmissions to make them a true form of communication according to the flow diagram on page 74.

6 Most TV transmissions are digital. Screen colour information is transmitted in a three-bit binary code. The first bit codes for red, the second bit for green and the third bit for blue. For example, the binary code for the screen colour red is 1 0 0.
What are the digital codes for the screen colours black, green, cyan, yellow, blue, magenta and white?

7 Each of the numerals in a digital clock has seven segments, and each segment is a separate LED. When current flows through a particular combination of the seven terminals (marked 1 to 7 on the diagram), the LEDs glow and a number is formed.
- a Which terminals have current flowing through them when the numeral 3 is glowing?
- b Digital clocks have four seven-segment LEDs separated by a colon (:). Which terminals on each of the four segments are illuminated when the clock reads 12:45?



8 Find out what the difference is between analog and digital TV.

Check! solutions

6 The sound waves that are produced by a microphone are called the audio signal. These have a very low frequency and will only travel a few metres through air. If this wave is mixed with a higher frequency wave (called a carrier wave) it is able to travel hundreds of kilometres through the air. This combined wave is called the modulated wave.

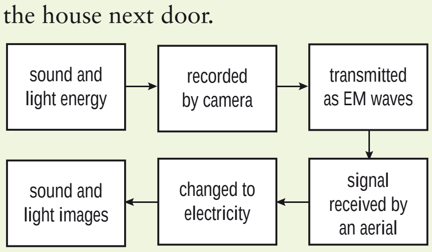
7 If you had been standing back from the screen you would have seen the colours below:

Interval no.	*Colour*
1	red
2	yellow
3	cyan
4	black
5	white

Challenge solutions

1 When electricity flows through wires to an appliance it causes an electromagnetic field. This can interfere with other forms of electromagnetic radiation such as radio and TV signals in your home, or the house next door.

2



3 Likely inferences are as follows.
- a Radio signals are distorted by the magnetic fields around high voltage power lines.
- b TV signals tend to travel in straight lines, therefore aerials in valleys will not pick up very strong signals.
- c TV and radio signals can pass through the walls and roof of a house.
- d Radio signals do not travel very well through rocks and concrete, which surround tunnels.

4 a The FM stations are 2 and 3 because the pattern shows that the frequency rather then the amplitude is modulated. Stations 1 and 4 are AM stations.
- b AM station 1 broadcasts at a higher frequency than AM station 4.

5 Feedback occurs when the person receiving the message communicates with the sender of the message. Live talkback radio is an example of feedback and so are live TV shows where people at home (rather than in the audience at the studio) can participate and influence what happens on the show. Ideally, the person watching the show should be seen and heard as is often done with interviews in sports clubs during a match.

6

Colour	*Binary code*
black	000
green	010
cyan	011
yellow	110
blue	001
magenta	101
white	111

7 a Current will flow through terminals 4, 5, 6, 7 and 1.
- b To read the time 12:45 the LEDs would be:
  - LED 1: segments 5, 7 (possibly 2 and 3)
  - LED 2: segments 4, 5, 6, 2, 1
  - LED 3: segments 3, 6, 5, 7
  - LED 4: segments 4, 3, 6, 7, 1

8 (Answer overleaf)

8 Analog signals are basically waves whereas digital signals are pulses that are 0 or 1 in value. Most countries are converting or have converted from analog to digital TV. This has started in Australia and is currently due to be completed sometime between 2010 and 2012. There are several significant advantages in using a digital TV signal instead of analog:

- Although the strength of both types of signal decreases with distance, the digital signal does not fade; that is, it is either there or not there.
- A digital signal enables much more information to be transmitted in a particular bandwidth, and this results in better picture and sound quality.
- All computers use digital signals to store data on disk and convey information through modems. If TV also uses the same system it will mean that the TV can be used as a computer monitor and vice versa. This means that the TV can be truly interactive.

Main ideas solutions

1 transmitted, decoded
2 electrical, light
3 digital
4 resistors
5 semiconductors
6 electromagnetic
7 three, phosphors, plasma
8 lower

MAIN IDEAS

Copy and complete these statements to make a summary of this chapter. The missing words are on the right.

1 Communication occurs when information is encoded by a sender, _____, then _____ and understood by a receiver.

2 Electronic communication devices such as telephones, modems and fax machines encode messages into _____ signals or _____ pulses which are then sent over long distances.

3 Optical fibres transmit information in the form of _____ light pulses.

4 Diodes, transistors, _____ and capacitors are electronic components used in communication devices.

5 Diodes and transistors are made from _____. These are substances that conduct electricity when doped with small amounts of another element.

6 Television and radio signals are transmitted though the air as _____ waves of long wavelength.

7 In a cathode ray tube, _____ electron guns fire electrons which hit _____ and create tiny spots of colour on the TV screen. The newer flat screens use liquid crystal displays or _____.

8 Radio signals are made up of an audio signal mixed with a carrier wave. AM radio signals have a _____ frequency than FM radio signals.

decoded
digital
electrical
electromagnetic
light
lower
phosphors
plasma
resistors
semiconductors
three
transmitted

Try doing the Chapter 4 crossword on the CD. Working with technology

REVIEW

1 Which of the following statements is *incorrect*?
A A microphone converts sound energy into electrical energy.
B Noise affects the quality of the transmitted message.
C Analog signals can only have a value of 0 or 1.
D When the diaphragm in a microphone vibrates, an electric current is induced in the coils of wire.

2 Match the correct descriptions in List B with the electronic terms in List A.

List A	List B
resistance	1 lets electric current pass in one direction only
transistor	2 an electronic light bulb
LED	3 stores charge
diode	4 can act as a switch or as an amplifier
capacitor	5 is measured in ohms
LDR	6 is measured in amps
current	7 its resistance changes with the intensity of the light

Review solutions

1 C

2 1 diode
2 LED
3 capacitor
4 transistor
5 resistance
6 current
7 LDR

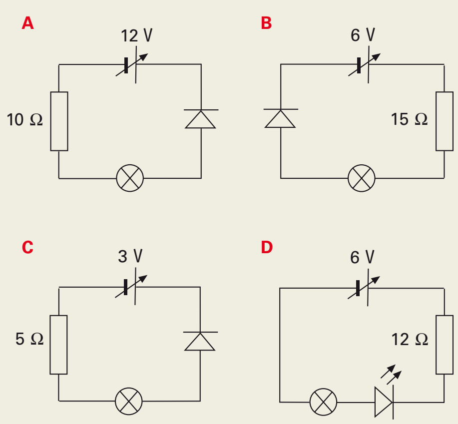
REVIEW

3 Match the pieces of television equipment with the functions listed below:

antenna	speaker
electron gun	phosphor
deflecting coil	brightness control

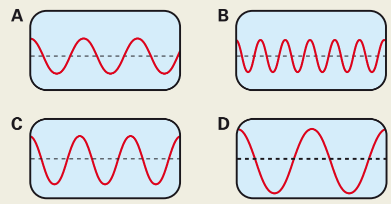
a changes electrical energy into sound energy
b gives off light when struck by electrons
c alters the number of electrons hitting the TV screen
d changes electrical signals into electron beams
e alters the direction of the electron beam
f changes electromagnetic waves into electric current

4 **a** In which of the following circuits will the light bulb glow? Explain your answer.
b If the diodes and light bulbs each have a resistance of 50 Ω, which circuit has the largest current flowing through it?

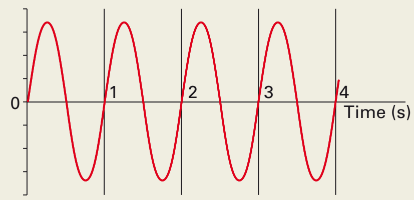


5 A fax machine is connected by wires to the telephone exchange which, in turn, is connected to other exchanges by optical fibres. Draw a flow diagram that shows all the energy changes that occur when you send a fax to your friend in another state.

6 Four wave patterns were produced on the screen of a CRO by a sound generator. Which sound:
a is the loudest?
b has the lowest pitch?
c is quiet and has a high pitch?

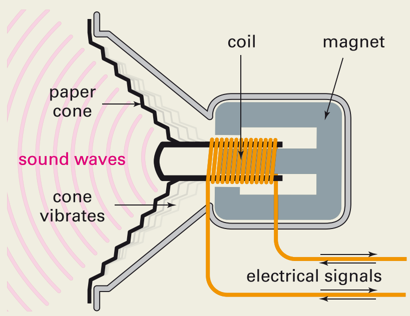


7 The wave below was produced on a CRO connected to an audio generator.



a What is the frequency of the wave?
b Sketch this wave in your notebook. On the same sketch, draw the wave produced by a sound of higher pitch but the same loudness.

8 Use the diagram below to explain how a loudspeaker works.

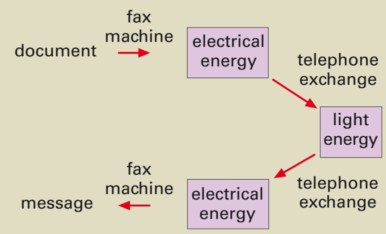


Check your answers on page 333.

3 **a** speaker
b phosphor
c brightness control
d electron gun
e deflecting coil
f antenna

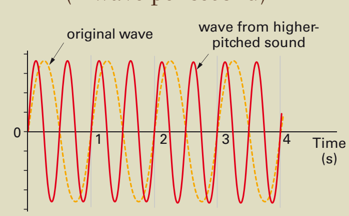
4 **a** The light bulb will glow only in circuit B where the negative end of the diode (the straight line in the symbol) is connected to the negative side of the battery (short fat stroke).
b Circuit A has the largest current. This is because it has the largest voltage and the resistance in each circuit is about the same.
To calculate the actual current in each circuit you can use Ohm's law.

5



6 **a** D
b D
c B

7 **a** 1 Hz (1 wave per second)
b



8 The sound waves cause the paper cone to vibrate. This causes the coil to move in and out of the magnet. This movement then creates an alternating current in the wires.

Chapter 4 Communications technology 99