

Topic 3 Wave and particle models of energy transfer

Prior knowledge

Wave and particle models

- 1 temperature
- 2 A soundwave could be modelled with the particle model, for example the vibration of particles in air. Conversely, it could be modelled as the vibration of a wave, for example the vibrations of a string on an instrument.

Energy transfer

- 3 A dropped ball does not return to its original height because energy transfers are not 100% efficient and always include losses to unwanted forms of energy such as heat and sound.

Kinetic and potential energy

- 4 **a** The kinetic energy of an object can be increased by increasing the mass or the speed of the object.
b The gravitational potential energy of an object can be increased by increasing its mass or height above the ground. Gravitational potential energy will also increase if the object is placed in a stronger gravitational field.

Light and sound energy

- 5 Sound requires particles to travel; light does not and can travel through a vacuum.

Electrical circuits

- 6 Chemical potential energy in the battery is transformed into kinetic energy of the charge carriers in the circuit (electrons), which is then converted into heat and light energy by the bulb.

3.1 Energy of particles and heat conduction

Check your understanding

SC1: I can explain that all matter is made up of particles

In solids, particles are tightly packed in a fixed arrangement. In liquids, particles are close but can move past each other. In gases, particles are far apart and move freely.

SC2: I can explain how particles can pass on heat energy to nearby particles when they collide

When particles collide, kinetic energy is transferred between them, transferring heat energy in the process.

SC3: I can evaluate the usefulness of describing the conduction of heat in terms of particles

Answers may include:

Modelling atoms as spheres, modelling atoms as having a solid surface, simplifying the forces involved, ignoring the concept of a lattice, ignoring other forms of energy, and so on.

Lesson review

- 1 The two types of energy involved are: heat energy (the energy transferred) and kinetic energy (due to the motion of the particles).
- 2 **a** In a solid, particles are closely packed in a fixed, orderly arrangement.
b In liquids, particles are close together but not in a fixed position, allowing them to flow. Gases are similar to liquids, however the distances between particles are much greater.

- 3 In conduction, the particles move more and collide with nearby particles, transferring energy and causing them to move more in response. While the particle model makes several simplifications, it is very useful to explain the process of conduction. It helps to understand the small-scale interactions that lead to heat transfers across and between entire objects.
- 4 Solids are likely to be better conductors than liquids and gases because their particles are closer together, allowing collisions to occur more frequently.

3.2 Heat conduction in materials

Hypothesis

Sample hypothesis:

The metal will be the best conductor of heat, then the wood, then the plastic.

Results

Sample results:

Material	Time taken for bead to drop (s)
Plastic	23
Wood	21
Metal	12

Conclusion

- 1 Based on sample results: best conductor = metal; best insulator = plastic
- 2 Sample answer:

My results supported my hypothesis as the observed results showed that the bead on the metal spoon dropped first (because the butter melted more quickly). The butter on the plastic spoon melted last, as predicted, but there was not much difference between the wood and the plastic so I think that the experiment should be repeated to check which one melted first.

Evaluation

- 1 Any three from: The temperature of the water, the volume of the water, the thickness of the spoons, the amount of butter/wax, the type of butter/wax, the depth of the water, the size/mass of the bead.
- 2 The independent variable was the material being tested – the wood, plastic and metal.
- 3 The dependent variable was the time it took for the bead to fall.
- 4 The volume of the water and the temperature of the water are both controlled variables in the experiment. If the spoons are placed in different beakers, the measuring cylinder is required to ensure the volume of the water is the same, and the thermometer is required to monitor the temperature of the water for each material.

3.3 Heat convection

Worked example: Try yourself

CALCULATING DENSITY

Thinking	Working
Write out the known variables (note their given units) and the required equation.	$m = 350 \text{ g}$ $V = 250 \text{ mL}$ $\rho = \frac{m}{V}$
Substitute the values into the equation.	$\rho = \frac{m}{V} = \frac{350}{250}$
Calculate the density. Make sure to include the units.	$\rho = 1.4 \text{ g/mL}$

Check your understanding

SC1: I can explain how temperature affects the density of gases and liquids

As the temperature of a liquid increases, its particles move faster and spread apart, increasing the liquid's volume and decreasing its density.

SC2: I can describe how warmer fluids rise and cooler fluids sink to create convection currents

Warmer fluids rise because, as their temperature increases, their particles move faster and spread out. The spreading out of the particles means this fluid is less dense. Meanwhile cooler fluids sink because their particles move less, making cool fluids denser.

SC3: I can describe examples of heat convection in the environment

Convection currents in the atmosphere distribute heat from Earth's surface. This process creates winds which flow in one direction during the day, and the opposite direction at night due to temperature differences between land and water. As the warm air rises it takes heat and water vapour with it, which influences weather patterns by creating wind and clouds.

Lesson review

- 1 As the temperature of a substance increases, its density decreases.
- 2 As water at the bottom is heated, it becomes less dense and rises. Cooler water at the top sinks, creating a circular flow known as a convection current.
- 3 In both solids and gases, increasing temperature decreases density. In solids, this effect is minimal because expansion is limited. However, in gases, the effect is much more pronounced because gas particles spread out significantly when heated, leading to a greater decrease in density.
- 4 Increasing global temperatures can intensify convection by enhancing temperature differences between land and water. This strengthens convection currents, leading to stronger winds and increased cloud formation. As a result, extreme weather events such as cyclones, thunderstorms, and heavy rainfall may become more frequent and intense, contributing to more unpredictable climate patterns.

3.4 Transfer of electrical energy

Check your understanding

SC1: I can describe an electric current through a metal wire as a flow of electrons powered by a voltage

Voltage provides electrons with kinetic energy causing them to move around a circuit.

SC2: I can describe electric current as a measure of the flow of electrons

Voltmeters measure the difference in electron energy as they flow through a circuit. They are connected in parallel with the component being measured so they can measure this difference between two points.

Ammeters measure electric current, which is the rate of electron flow through a circuit. They are connected in series with components so they can measure the flow of electrons through the circuit.

SC3: I can explain how electrical energy can travel through a circuit much faster than the drift velocity of electrons in the conductor

An electron does not need to travel all the way from the power source to a lightbulb to switch it on because each electron pushes on nearby electrons, causing them to move together almost instantly.

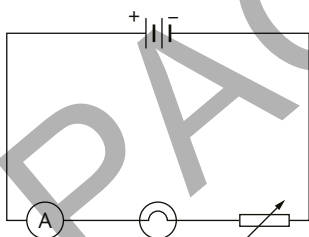
Lesson review

- 1 Voltage provides kinetic energy to electrons causing them to flow in a circuit.
- 2 Current is the flow of electrons around an electric circuit. The voltage is provided by the power source and this pushes/forces the electrons to move in a certain direction, which results in the electric current.
- 3 Electron current moves from the negative terminal of a power supply to the positive terminal. Conventional current is in the opposite direction.
- 4 Electrical energy travels faster than individual electrons because each electron pushes on nearby electrons causing them to move together.

3.5 Using resistance to control electric current

Method

1



Results

Sample table:

Resistance change	Brightness of lightbulb	Current
increasing resistance	gets dimmer	decreases
decreasing resistance	gets brighter	increases

Conclusion

With a larger variable resistance, the current in a circuit decreases and the lightbulb goes dimmer. With a lower variable resistance, the current in a circuit increases and the lightbulb becomes brighter.

Evaluation

- Answers may include:
 - How to connect an electrical circuit.
 - How to vary the current in a circuit by varying the resistance.
 - How current and resistance are related in a circuit.
 - How current and resistance control the brightness of a lightbulb.
- Variable resistors are used in volume controls, fan speeds, wiper blade speeds in cars, heat settings on stoves, the dial on a power supply.

3.6 Longitudinal and transverse waves

Check your understanding

SC1: I can explain, using diagrams, how particles move in relation to the direction of transfer of energy in longitudinal and transverse waves

In a transverse wave, the direction of particle motion and the flow of energy are at right angles to each other.

SC2: I can describe examples of longitudinal and transverse waves

Answers should demonstrate vibration at right angles to the direction of energy. For example, the vibration of a diving board.

SC3: I can use the wave equation to relate the speed, wavelength and frequency of a wave

$$\lambda = \frac{v}{f}$$

The wave equation shows that, as frequency (f) increases, wavelength (λ) decreases. They are inversely proportional, assuming the wave speed (v) remains constant.

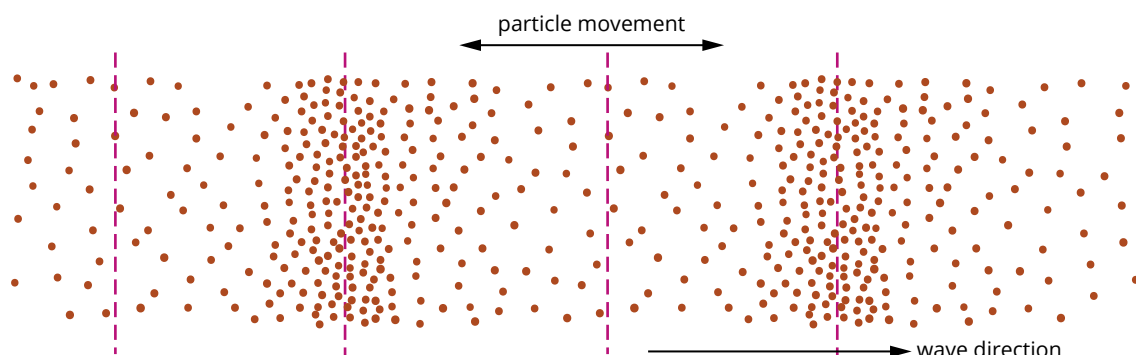
Worked example: Try yourself

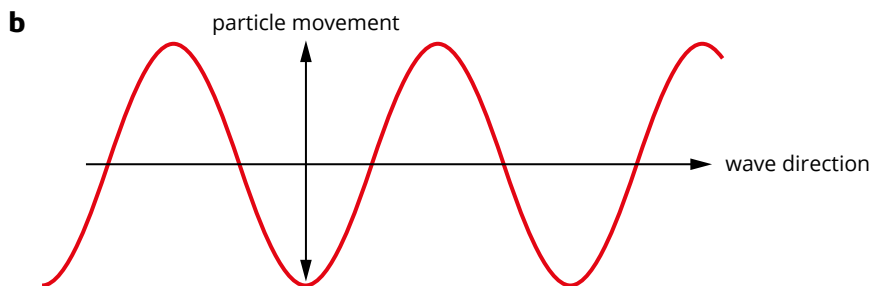
THE WAVE EQUATION

Thinking	Working
Recall the wave equation.	$v = f\lambda$
Determine from the question which quantity is unknown. Use algebraic techniques or the triangle to rearrange the equation to find the required quantity.	$\lambda = \frac{v}{f}$
Determine the known values and substitute them into the equation.	$\lambda = \frac{2.5}{0.8}$
Solve for frequency and include the units.	$f = 3.125\text{Hz}$

Lesson review

1 a





c In longitudinal waves, particles move parallel to the wave direction, while in transverse waves, particles move perpendicular to the wave direction.

2 The motion of a skipping rope is a transverse wave. It is similar to the way the guitar string vibrates in the example from this chapter.

3 a $v = f\lambda$
 $= 1.5 \times 120$
 $= 180 \text{ m/s}$

b $v = f\lambda$
 $\lambda = \frac{v}{f}$
 $= \frac{340}{6000}$
 $= 0.057 \text{ m}$

c $v = f\lambda$
 $f = \frac{v}{\lambda}$
 $= \frac{12}{3.2}$
 $= 3.75 \text{ Hz}$

4 If the frequency is doubled and the speed remains constant, the wavelength will be halved.

3.7 Investigating sound waves

Prediction

Sample predictions:

I predict that, if the volume is increased, then the amplitude will increase OR if the volume is decreased, then the amplitude will decrease.

I predict that, if the pitch is increased, then the frequency will increase OR if the pitch is decreased, then the frequency will decrease.

Results

Sample table:

	Volume		Frequency	
	Increasing	Decreasing	Increasing	Decreasing
Sound	gets louder	gets quieter	gets higher-pitched	gets lower-pitched
Amplitude	increases	decreases	no effect	no effect
Wavelength	no effect	no effect	decreases	increases
Frequency	no effect	no effect	increases	decreases

Conclusion

- 1 longitudinal wave
- 2 transverse wave
- 3 When the loudness of a sound wave is increased/decreased, the amplitude of the wave is increased/decreased.
- 4 When the pitch of a sound wave is increased/decreased, the frequency of the wave is increased/decreased.

Evaluation

- 1 Sample response: The pitch of a sound wave relates to its frequency. The loudness of a sound wave relates to its amplitude.
- 2 Sample response: This investigation developed the skills of observation, inference, prediction and communication. I successfully used equipment to generate and record data.
- 3 Sample response: A continued investigation into sound waves might look at more complicated waves such as the waves produced by musical instruments or by voices, singing or talking.

3.8 Modelling waves

Method

Sample method:

- 1 Stretch the slinky out with one person holding it at each end.
- 2 Set up a tape measure alongside where the slinky is stretched and turn on a recording device with all apparatus in view.
- 3 Create a transverse wave by moving the slinky left and right.
- 4 Allow the slinky to come to a complete stop.
- 5 Create a longitudinal wave by moving the slinky towards and away from you.
- 6 Allow the slinky to again come to a complete stop.

Results

Sample results, based on method above:

- 1 A transverse wave was produced.
- 2 A longitudinal wave was produced.
- 3 Possible questions:
 - a How does the speed at which the hand is moved affect the wavelength and/or frequency of the produced wave?
 - b How is the amplitude of the wave increased?
- 4 Possible responses to questions above:
 - a Increasing the speed the hand moves increases the frequency of the produced wave. It also decreases the wavelength of the wave.
 - b Supplying greater energy by moving the hand with a wider range of motion increases the amplitude of the produced wave.

Conclusion

Sample answer: The slinky was excellent for modelling wave behaviour. Both transverse and longitudinal waves were modelled effectively, and the properties of wavelength, frequency, amplitude and wave speed were all investigated.

Evaluation

- Answers may include: The slinky does not show the nature of a wave. It does not transmit sound, for example, and it does not show different colours of light waves. However, generally, it is very good at modelling the characteristics of waves. Complex waves are not easily modelled by a slinky.
- Answers may include: An oscilloscope is very good at modelling waves when connected to a signal generator. It can model more complex waves.

3.9 Electromagnetic radiation

Check your understanding

SC1: I can describe the properties of electromagnetic waves, including speed, wavelength and frequency

Electromagnetic radiation is comprised of electric and magnetic fields.

SC2: I can describe how the concept of photons can be useful for explaining the properties of electromagnetic radiation

Light is massless and always travels at the speed of light. Matter particles have mass and can travel at a range of speeds.

SC3: I can compare different forms of electromagnetic waves in terms of wavelength, frequency or energy of photons

Despite humans being able to detect infrared radiation as heat, ultraviolet light is the form of light which contains more energy. This is because ultraviolet light has a higher frequency than infrared radiation (energy is proportional to frequency).

Lesson review

- The speed of electromagnetic waves in a vacuum is approximately 3×10^8 metres per second.
 - As wavelength increases, frequency decreases. They are inversely proportional, assuming the wave speed remains constant.
- $$v = f\lambda$$

$$f = \frac{v}{\lambda}$$

$$= \frac{3 \times 10^8}{7 \times 10^{-7}}$$

$$= 4 \times 10^{14} \text{ Hz}$$
 - $$v = f\lambda$$

$$\lambda = \frac{v}{f}$$

$$= \frac{3 \times 10^8}{6 \times 10^{14}}$$

$$= 5 \times 10^{-7} \text{ m}$$
- The wave model cannot explain the photoelectric effect because waves build up energy over time, but the photoelectric effect either occurs instantly, or not at all. This suggests the energy is delivered in a single burst, via a particle, which the wave model cannot account for.
- Ultraviolet, X-ray and gamma radiation.
 - Energy is directly proportional to frequency. This means that as the frequency of radiation increases, so does its energy. Ionising radiations are those with higher frequencies, explaining why they have higher energy and can cause ionisation.

3.10 Energy transfer and wi-fi

Plan

1 Answers may include:

Wi-fi technology operates by utilising radio waves to transmit and receive data wirelessly. These radio waves carry energy in the form of electromagnetic radiation. The process begins when a device, such as a smart phone or laptop, converts the data it wants to send into radio waves. These waves are then transmitted through an antenna in the device, which emits them into the surrounding space. On the receiving end, another device with a wi-fi receiver antenna captures these radio waves and converts them back into the original data, allowing us to access information, browse the internet and communicate seamlessly. This transfer of energy through radio waves is what enables the wireless connectivity we enjoy with wi-fi technology.

2 Answers may include:

Scientists have made remarkable discoveries and developed key concepts that form the foundation of wi-fi. One major scientific contribution is understanding the principles of electromagnetism, which involves the relationship between electric and magnetic fields. Through this understanding, scientists have developed methods to generate and manipulate radio waves, which are essential for wireless communication. Additionally, advancements in electronics and materials science have led to the creation of compact and efficient components, such as antennas and transmitters, which enable the efficient transfer of data via wi-fi. Continuous scientific research and innovation have allowed wi-fi technology to evolve, offering faster speeds, increased range and improved reliability for seamless wireless communication.

Design

1 Answers may include:

- **Simplicity:** An effective infographic should have a clean and uncluttered design. It should focus on conveying the most important information concisely and avoiding unnecessary details.
- **Visual appeal:** The visual elements of an infographic, such as colours, icons and illustrations, should be visually appealing and help enhance the understanding of the content. The use of appropriate fonts and hierarchy ensures easy readability.
- **Organisation:** The information in an infographic should be logically organised, using a clear structure such as sections or flow charts. Each section should have a clear heading or title to guide the viewer.
- **Data presentation:** If your infographic includes data, it should be presented in a visually compelling way, using charts, graphs or diagrams. Clear labels, legends and scales should be provided to aid understanding.
- **Storytelling:** An effective infographic tells a story or conveys a message. It should have a clear narrative flow, guiding the viewer from one point to another, making the information easier to comprehend and remember.
- **Relevance:** The content of the infographic should be relevant to the audience and effectively address their needs or interests. It should provide valuable and meaningful information in a concise format.
- **Credibility:** Infographics should be based on reliable sources and accurate information. Including citations or references adds credibility to the content and helps viewers verify the information presented.

2 Answers may include:

Key content would include how science has contributed to advances in wi-fi technology and the ways that energy is transferred through wi-fi.

Improve

1-3 Answers may include elements such as quality of information, organisation of information, engagement by the audience, presentation and new learnings.

Evaluate

1 Answers may include:

The aspect of energy transfer that I was investigating in this inquiry was the use of radio waves to carry energy in the form of electromagnetic radiation to enable wi-fi technology.

2 Answers may include:

The skills that I used in this activity included research, analysis, communication, critiquing and creativity.

3.11 Investigating protection from UV radiation

Hypothesis

Sample hypothesis:

Sunscreens with a higher SPF will block more UV radiation than those with a lower SPF.

Method

Sample method:

- 1 In a dark room, cut out four rectangular pieces of UV photosensitive paper and four pieces of transparent plastic, all the same size.
- 2 Label each plastic rectangle: 'control', 'SPF 15', 'SPF 30' and 'SPF 50'.
- 3 Spread a layer of sunscreen on each of the plastic rectangles.
- 4 Use Blu Tack to stick each piece of UV photosensitive paper onto a plastic rectangle, so you have four samples. Place the samples into a cardboard envelope so they are protected from sunlight until the experiment is run.
- 5 Move outside to run the experiment.
- 6 Place the samples flat on the ground in direct sunlight. Set a timer for 30 minutes.
- 7 After 30 minutes, take the samples back inside. Remove the UV photosensitive paper and follow any instructions with the paper to set the images.

Results

1 Sample answer:

In comparison to the control, there should be a difference in colour for the papers that used sunscreen. There may be a gradient of change of colour across the different SPFs used.

Depending on the SPFs used, this difference may not be visible for the time allotted. The SPF value is based on the amount of time that the sunscreen protects against sunburn. So, an SPF 50 and SPF 30 may not show much of a difference over a 30-minute period.

2 Errors may include:

not sufficiently covering the areas with sunscreen

not leaving the paper out in the sun long enough to determine differences

exposing the paper to sunlight before beginning the test.

Conclusion

Sample conclusion:

- 1 The effectiveness of different sunscreens in blocking out UV radiation was successfully evaluated. Three sunscreens of different SPF values (15, 30 and 50) were analysed against a control group using photosensitive paper. The test was carried out during the day, where the test papers were left in the sun for 30 minutes. Sunscreen of different SPF values was applied over clear plastic slides above each piece of photosensitive paper.

- 2 There was a clear difference between the control and the papers that had sunscreen across them. And there was a noticeable difference between the SPF 15 test with the other two (SPF 30 and SPF 50). It can be concluded that wearing sunscreen is effective at blocking out UV radiation.
- 3 The sunscreen was not applied evenly over the test screens. On repeating the experiment, a new technique to evenly apply the sunscreen should be employed. For example, scraping a predetermined amount of each sunscreen across the plastic slide using an instrument such as a spatula.
- 4 There was not much of a difference between the SPF 30 and SPF 50 tests. Further research is needed to confirm the effectiveness of these different SPF products. Errors may have been introduced due to the length of time the tests were left in the sun. In a repeat experiment, longer lengths (>30 minutes) of time could be used to amplify any differences between each SPF grading.

Evaluation

- 1 Strong elements of investigations may include:
Length of time left in the sun, using the same brand of sunscreen at different SPFs and technique for applying sunscreen to plastic slides
- 2 Strong elements of conclusions may include:
Reference to the aim of the investigation, highlighting of key errors, suggestions on how to reduce errors if repeating the experiment, and notes on how the experiment contributes to the broader scientific understanding of protecting from UV radiation

3.12 Investigating heat radiation

Hypothesis

Sample hypothesis:

White objects will radiate the most heat over a given time.

Method

Sample method:

- 1 Collect three cans of the same size but of three different colours and place next to each other in a plastic tray.
- 2 Heat water in a kettle and switch it off before boiling.
- 3 Carefully use a funnel to fill each can with the hot water from the kettle and place a thermometer in each can.
- 4 Record the starting temperature of the water in each can.
- 5 Start the stopwatch and record the temperature of the water in each can every minute for 15 minutes.
- 6 Plot the temperatures of the water on the same axes to compare the variation in temperature.

Materials

Sample materials, based on method above:

- 3 different-coloured cans
- kettle
- 3 thermometers
- plastic tray
- stopwatch
- funnel
- retort stand
- bosshead and clamp
- heat-proof gloves

Safety notes

Sample safety notes, based on method and materials above:

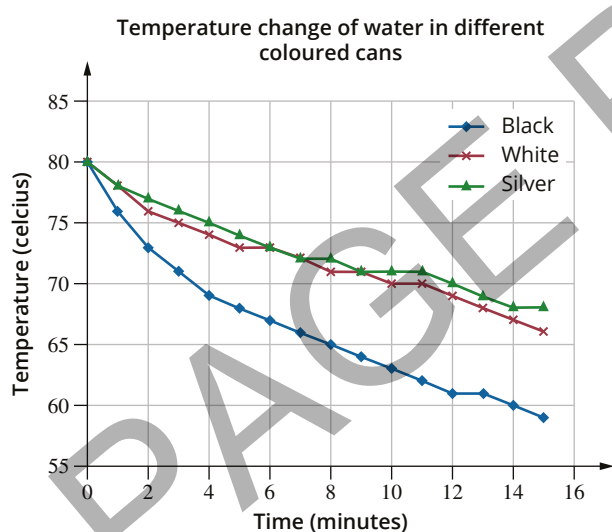
- Stand the cans on a plastic tray to catch any spills.
- Use the funnel to slowly pour the hot water into the cans.
- Avoid touching the cans containing the hot water.
- Use retort stand and clamp to secure the thermometer.
- Be careful not to knock the thermometers which might tip the cans over.
- Try to avoid the thermometers sitting on the bottom of the cans.
- Wait for the water to cool down before emptying the cans at the end of the experiment.

Results

Sample table and results:

	Time (minutes)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Temperature of water (°C)	Black can	80	76	73	71	69	68	67	66	65	64	63	62	61	61	60	59
	White can	80	78	76	75	74	73	73	72	71	71	70	70	69	68	67	66
	Silver can	80	78	77	76	75	74	73	72	72	71	71	71	70	69	68	68

Sample graph, based on results above:



Conclusion

- 1 black
- 2 Sample answer: My results did not support my hypothesis that said the white can would radiate the most heat over a given time (that is, have the greatest temperature change). The temperature drop for the black can was significantly more than the other cans which suggests that black objects radiate heat more quickly than the other colours tested.

Evaluation

- 1 Any three from: The temperature of the water, the thickness of the can, the type of paint, the volume of the water, the shape of the can, the size of the cans, the temperature of the surroundings.
- 2 Sample answer, based on method above:
The experiment was valid because the controlled variables that would have affected the results were kept the same. The cans used were the same size, the same volume of water was added to each can, the paint used to coat the cans was the same type and the starting temperature of the water was the same.
(Note that answers should include reference to the controlled variables.)

Topic review

Remember

- 1 Conventional current is defined as the flow of positive charge, moving from the positive terminal of a power supply to the negative terminal. This direction is established by convention and is opposite to the actual movement of electrons, which flow from the negative to the positive terminal.
- 2 **a** Longitudinal waves are waves where particles move parallel to the direction of energy transfer, such as sound waves. Transverse waves are waves where particles move perpendicular to the direction of energy transfer, such as waves on the surface of water.
b To model longitudinal waves, compress and release a spring along its length. To model transverse waves, move the spring up and down perpendicular to its length. Observe the resulting wave patterns.
- 3 The basic principle behind wi-fi technology is the use of radio waves to transmit data wirelessly between devices, allowing for internet and network connectivity without physical cables.

Understand

- 4 Particles transfer heat energy to nearby particles through vibration and collision, where kinetic energy is passed from one particle to another.
- 5 By increasing the resistance in a circuit, the current decreases. This is because resistance impedes current. Conversely, decreasing resistance results in a greater flow of current.
- 6 An ammeter is connected in series, allowing the current to travel through the ammeter. A voltmeter is connected in parallel, allowing the voltmeter to measure the potential difference between two points.
- 7 Radio waves have lower frequency than visible light. Energy is proportional to frequency; therefore, radio waves have less energy than visible light.

Apply

- 8 Sample answer: If a metal of high conductivity is heated to melt an ice cube, then it will take a short time to melt the ice cube. The higher the conductivity, the quicker it is to melt. This is because the increased conductivity will allow conduction to occur more easily, transferring heat at a faster rate.
- 9 **a** Sound waves transfer energy through the vibration of particles in a medium (longitudinal waves), while electromagnetic waves transfer energy through oscillating electric and magnetic fields (transverse waves) and do not require a medium.
b Sample answer: Set up a camera at one end of the school oval. Stand at the other end and make a loud sound, such as by using a drum or a party-popper. Record the event on video and then analyse the footage, noting the time difference between when the sound is made and when the camera detects the sound.

10 a $v = f\lambda$

$$f = \frac{v}{\lambda}$$

$$= \frac{300\,000\,000}{0.12}$$

$$= 2\,500\,000\,000 \text{ Hz}$$

$$\approx 2.5 \text{ gigahertz}$$

b $v = f\lambda$

$$\lambda = \frac{v}{f}$$

$$= \frac{346}{466}$$

$$= 0.74 \text{ m}$$

$$\approx 74 \text{ cm}$$

c $v = f\lambda$

$$= 0.5 \times 5$$

$$= 2.5 \text{ km/s}$$

- 11** A higher voltage will increase the energy available to the electrons. The increased energy causes the electrons to move more quickly, which results in a higher current flowing through the circuit, assuming the resistance remains constant.

Analyse

- 12** Convection is generally more effective than conduction in transferring heat in a liquid. This is because convection involves the bulk movement of the fluid, allowing heat to be transferred more rapidly over larger distances. In contrast, conduction relies on slower particle-to-particle collisions, making it less efficient for heat transfer in a liquid.
- 13** Sample answer: Place the object in front of a UV flashlight or in sunlight and use a UV camera to measure the decrease in brightness.

Extension: Research task

- 14** P-waves are longitudinal waves, while S-waves are transverse waves. This difference makes P-waves faster, allowing them to travel through both solids and liquids. In contrast, S-waves are slower and only travel through solids.