Achievement Standard 90938

Demonstrate understanding of aspects of wave behaviour

PHYSICS

1.4

Externally assessed 4 credits

Wave motion

Waves carry **energy** from one place to another. Waves can be either mechanical or electromagnetic. Examples of mechanical waves are sound, earthquake, and water waves; examples of electromagnetic waves are radio, microwave, light, heat, ultraviolet, X-ray, and gamma ray waves. Mechanical waves need a substance, called a **medium**, through which to travel; electromagnetic waves do not need a medium to travel through.

When a mechanical wave travels through a medium, each part of the medium is made to vibrate about a fixed point, but when the wave has passed through, the medium is left in the same position as it was before the wave arrived – the medium does *not* travel with the wave.

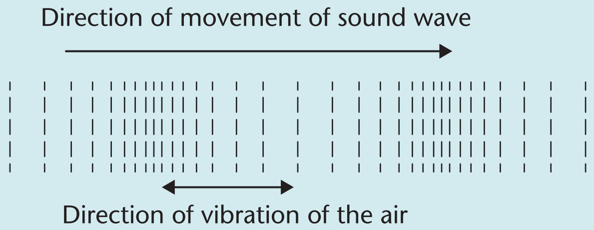
Creating waves

A wave is created by making the medium, in which the wave is to travel, vibrate at some point. A vibration is a movement out from the rest position, back to the rest position and then out and back in the opposite direction.

When a medium is vibrated, the wave the vibration causes sometimes travels *parallel* to the direction of the vibration and sometimes travels at *right angles* to the vibration.

If the wave travels at *right angles* to the local movement of the medium, the wave is called **transverse**. An example of a transverse wave is a wave on the surface of water.

If the wave travels *parallel* to the local movement of the medium, the wave is called **longitudinal**. An example of a longitudinal wave is a sound wave travelling through the air.



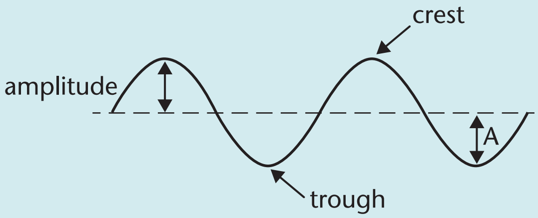
Properties of waves

The **amplitude** (symbol **A**) of a wave is the maximum distance the medium goes out, in either direction, from its middle (rest) position. The amplitude of a wave is a measure of the amount of energy the wave is carrying.

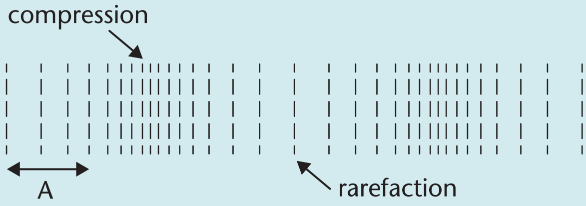
In a transverse wave, the positions of maximum displacement are called **crests** and **troughs**.

In a longitudinal wave, the positions of maximum displacement are called **compressions** and **rarefactions**.

Transverse wave



Longitudinal wave

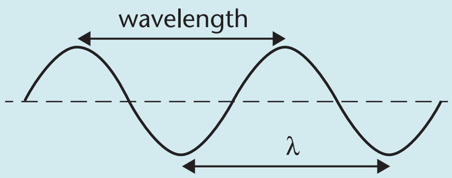


The amplitude of a wave sometimes determines the way the wave is experienced.

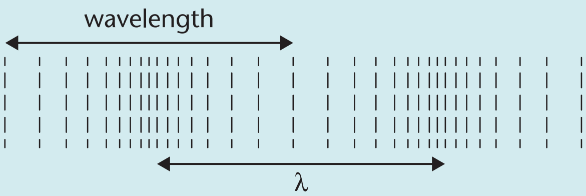
- The greater the amplitude of a sound wave, the more energy it is carrying and so the *louder* the sound.
- The greater the amplitude of a light wave, the more energy it is carrying and so the *brighter* the light.

The **wavelength** (symbol λ) of a wave is the distance from any point on a wave to the next equivalent point on the wave.

Transverse wave



Longitudinal wave



Wavelength is usually measured from crest to crest (or trough to trough) in a transverse wave and from compression to compression (or rarefaction to rarefaction) in a longitudinal wave.

The **frequency** (symbol **f**) of a transverse wave is the *number* of crests (or troughs) of the medium that pass a point every *second*. The frequency of a longitudinal wave is the *number* of compressions (or rarefactions) of the medium that pass a point every *second*. The unit of measurement for frequency is the **hertz**, **Hz**.

The frequency of a wave sometimes determines the way it is experienced.

- The frequency of a sound wave determines its *pitch.* The higher the frequency, the higher the pitch.
- The frequency of a light wave determines its *colour*. The colours of the rainbow are red, orange, yellow, green, blue, indigo, violet (ROYGBIV). The list is in the order of *increasing* frequency, so blue light has a much higher frequency than red light has.

The frequency of an electromagnetic wave determines what type of wave the electromagnetic wave is. Electromagnetic waves can be:

- radio waves
- microwaves
- infrared (radiant heat) waves
- light waves
- ultraviolet waves
- X-ray waves
- gamma ray waves

The list is in order of *increasing* frequency, so gamma rays have a much higher frequency than radio waves have.

The **period** (symbol **T**) of a wave is the *time* it takes for two adjacent crests (troughs) or compressions (rarefactions) to pass a point. The unit of measurement for period is the **second**, **s**.

Frequency and period have an **inverse** relationship:

$$f = \frac{1}{T}, \text{ or } T = \frac{1}{f}$$

The frequency, and hence period, of a wave does *not change* if the wave goes from one medium to another.

Speed of waves

The speed of a wave is constant in any particular medium, but if the wave travels from one medium into another the wave's speed changes.

A change in medium is not always obvious. For example, for both sound waves and light waves, hot air is a different medium from cold air; for a water wave, deep water is a different medium from shallow water.

Electromagnetic waves travel fastest when there is no medium to go through; that is, when they are travelling through a vacuum. The speed of *all* electromagnetic waves in a vacuum is 3×10^8 m s^{-1}

The speed of a wave can be calculated using the usual speed equation:

$$v = \frac{d}{t}$$

To calculate the distance travelled, use $d = vt$

To calculate the time taken, use $t = \frac{d}{v}$. The speed of a wave can also be calculated using the wave equation:

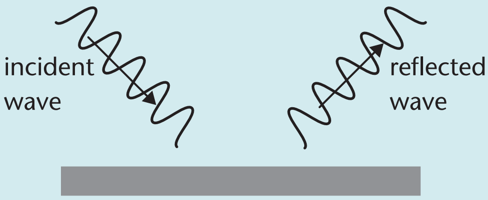
$$v = f\lambda$$

To calculate the frequency of a wave, use $f = \frac{v}{\lambda}$

To calculate the wavelength of the wave, use $\lambda = \frac{v}{f}$

Reflection of waves

If a wave strikes a surface it is **reflected**. The wave travelling towards the surface is called the **incident** wave.

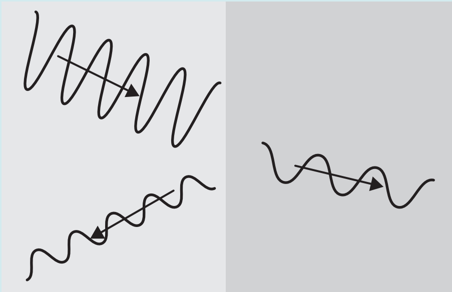


When a wave is reflected:

- the direction changes
- the frequency stays the same
- the speed stays the same
- the wavelength stays the same.

Transmission of waves

If the surface that a wave strikes is the boundary between two mediums, the wave, as well as being reflected, is **transmitted** into the second medium.

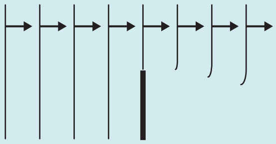


When a wave is transmitted from one medium into another:

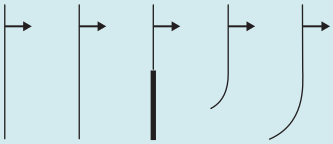
- the speed changes
- the direction changes
- the frequency stays the same
- the wavelength changes
- the amplitude decreases.

Diffraction of waves

If *part* of a wave is stopped by a barrier, the wave that continues bends around the edge of the barrier. The bending of a wave around the edge of a barrier is called **diffraction**. The *amount* of bending that happens depends on the *wavelength* of the wave: the longer the wavelength of the wave, the more the wave bends around the edge of the barrier.

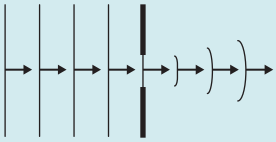


Short wavelength wave bends slightly around the edge of the barrier



Longer wavelength wave bends much more around the edge of the barrier

If a wave passes through a *gap* in a barrier, diffraction occurs at *both* edges of the gap so the wave passing through the gap tends to become circular in shape.



Wave passing through a gap

Questions
Wave motion

Question One: Water waves

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A radio-controlled toy boat is sailing in a lake. As it sails, waves are produced behind the boat. At one point of travel, the boat produces 10 waves in 5.0 seconds.

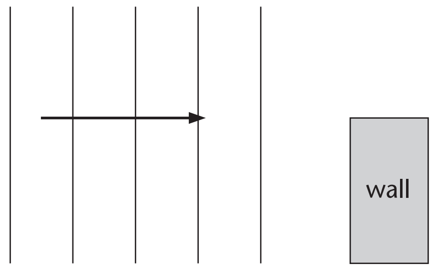
a. i. Define the term 'period'.

ii. Calculate the period of the waves produced.

b. A paddle from a canoe produces 9 waves in 15 s. Each wave travels 4.8 m in 12 s.

Calculate the wavelength of waves produced by the paddle.

A gentle wind causes straight waves on the lake surface. The diagram shows waves approaching the edge of a wall. The depth of the water is the same on either side of the wall.



c. Describe and explain what happens to the waves when they pass the edge of the wall.

You may draw waves on the diagram to aid your explanation.

d. A short time later, a wind produces waves of **higher** frequency.

Explain how the pattern of waves would be different from those produced in **c.** when the waves pass the edge of the wall.

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Question Two: Radio-controlled boat

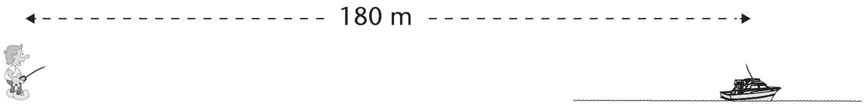
A radio-controlled toy boat has a small siren that produces a sound. The siren can be turned on by sending radio waves from a remote control.

a. State TWO differences between the radio waves and the sound waves.

b. The siren produces a frequency of 800 Hz, and the wavelength of the sound waves in air is 41 cm.

Show that the speed of sound in air is 328 m s^{-1}.

c. The boat is 180 m from the remote control. A radio wave is sent to turn on the siren. A person is standing with the remote control.



Calculate the time from when the remote control sends the radio wave to when the person hears the sound.

Explain any assumptions you make.

The speed of sound in air is 328 m s^{-1}.

d. Explain how sound energy is transferred from the siren to the person holding the remote control, even though no air particles move from the siren to the person.

Achievement Standard 90939

Demonstrate understanding of aspects of heat

PHYSICS

1.5

Externally assessed 4 credits

Essential exam notes

Heat

Heat energy and temperature

The particles of a substance are moving. If the substance is a gas or a liquid, the particles are free to move in any direction. In a solid, the particles vibrate about a fixed position. The **temperature** of a substance is the *average* kinetic energy of its particles. Because temperature is a measure of *average* energy, the *quantity* of the substance does not affect its temperature.

Temperature is measured in **degrees Celsius**, **°C**. Ice melts at 0 °C and water boils at 100 °C.

The **heat** in a substance is the *total* energy of all the particles of the substance. Because heat is a measure of *total* energy, a greater *quantity* of the substance will have more heat than a lesser quantity at the same temperature.

Heat is measured in **joules**, **J**.

Specific heat capacity

To raise the temperature of a substance, heat energy must be given to its particles. The **specific heat capacity**, **c**, of a substance is the amount of heat energy that must be given to *one kilogram* of the substance to raise its temperature of by *one degree Celsius*.

Specific heat capacity is measured in joules per kilogram per degree Celsius (**J kg^{-1} °C^{-1}**).

The increase or decrease in the temperature of a substance is linked to the amount of heat gained or lost by the substance by the equation:

$$Q = mc\Delta T$$

where:

- Q is the amount of heat energy absorbed or given out by the substance (J)
- m is the mass of the substance that is being heated or cooled (kg)
- ΔT is the change in temperature (°C).

The **power** of a heating device or extractor is the rate at which energy is gained or lost while the temperature changes.

Power, **P**, can be calculated using the equation:

$$P = \frac{E}{t}$$

where:

- E is the energy gained or lost
- t is the time taken.

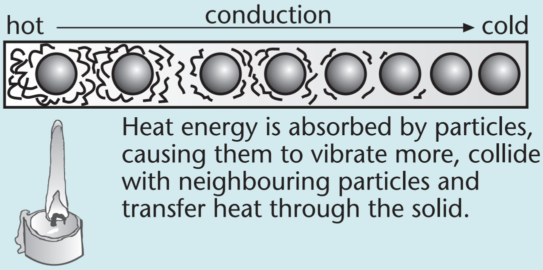
Power is measured in **watts**, **W**. Another common unit is the kilowatt (kW).

1 kW = 1 000 W.

Heat transfer

Heat energy is transferred from one place to another by conduction, convection and radiation.

When heat energy is transferred by **conduction**, the more vigorous vibration of the particles of the hot region of a substance causes adjacent particles to vibrate faster, thus spreading the heat energy throughout the substance.



Conduction is the only way heat is transferred through a solid. Metals are good conductors of heat. Liquids, gases and non-metal solids are poor conductors of heat. A substance that is a *poor* conductor of heat is called an **insulator**. Air is a particularly poor conductor of heat, so materials that are designed to provide good insulation often contain a high proportion of trapped air.

If the faster moving (higher temperature) particles of a substance physically move from one place to another within the substance, the heat is transferred by **convection**.

The flow of different temperature particles through a liquid or gas is called a **convection current**.

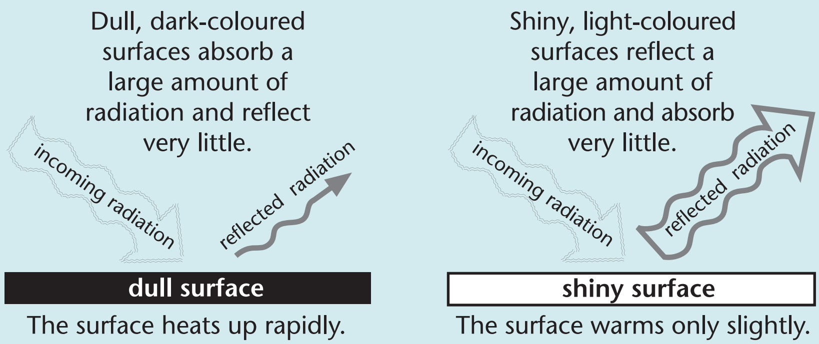
Liquids and gases transfer heat by convection. Convection currents occur because, if a region of a gas or a liquid is heated, it expands, becomes less dense, and hence moves upwards through the denser regions of the substance. The hotter substance that has risen is replaced by the colder substance, creating a circular movement of the substance – the convection current.

Radiation occurs when heat is transferred by infrared radiation. Infrared radiation is a type of electromagnetic radiation and can thus travel through a vacuum.

Radiant heat energy is produced by hot objects. The nature of the surface of the hot object affects the amount of radiant heat energy produced. Black, matt surfaces are the best radiators; shiny, white surfaces are the worst radiators.

When radiant heat energy falls on a substance, the heat energy can be absorbed by the surface particles, causing the temperature of the surface of the substance to rise. The radiant heat energy can also be reflected. When this happens, heat energy is not transferred to the substance.

Black, matt surfaces are the best absorbers, and so the worst reflectors, of radiant heat. Shiny, white surfaces are the best reflectors, and so the worst absorbers, of radiant heat.



States of matter

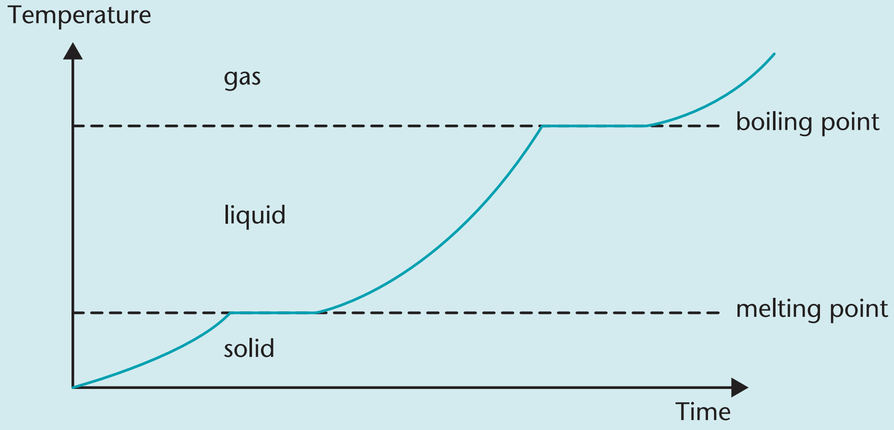
There are three state of matter – solid, liquid and gas. When a substance changes from one state to another, it is undergoing a **phase change**.

During a phase change, heat energy is either absorbed or released but the temperature of the substance does not change. **Latent heat**, **L**, is the amount of heat energy absorbed or released when *one kilogram* of a substance changes its state (or phase) while the temperature remains constant. The amount of heat energy, Q, needed to change the state of a mass, m, of a substance can be found from the equation:

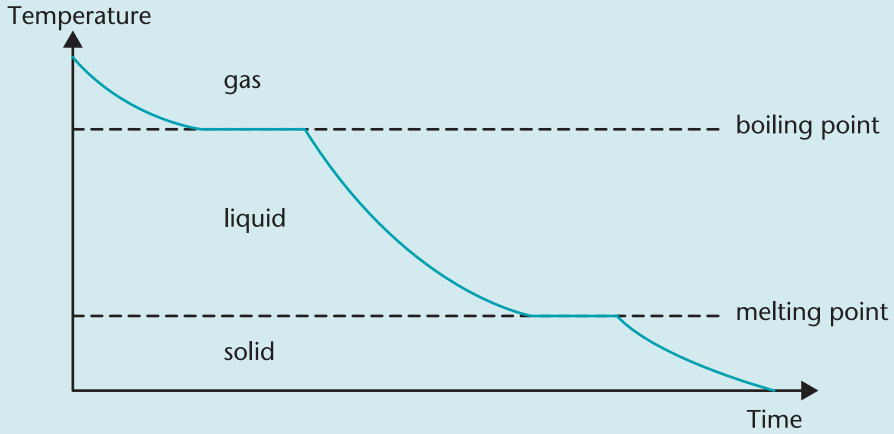
$$Q = mL$$

The variation of the temperature of a substance that is being heated or cooled can be shown on a heating or cooling curve.

Heating curve



Cooling curve



NCEA practice

Questions
Heat

You may use the following data for any question:

Specific heat capacity of water	= 4 200 J kg^{-1} K^{-1}
Latent heat of fusion of ice	= 3.3×10^5 J kg^{-1}
Latent heat of vaporisation of water	= 2.3×10^6 J kg^{-1}

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Question One: Heat transfer

a. There are three different heat transfer methods.

Name each heat transfer method and name the medium (solid / liquid / gas) for each method that would allow for maximum heat transfer to occur.

1. ______________________________

____

2. ______________________________

____

3. ______________________________

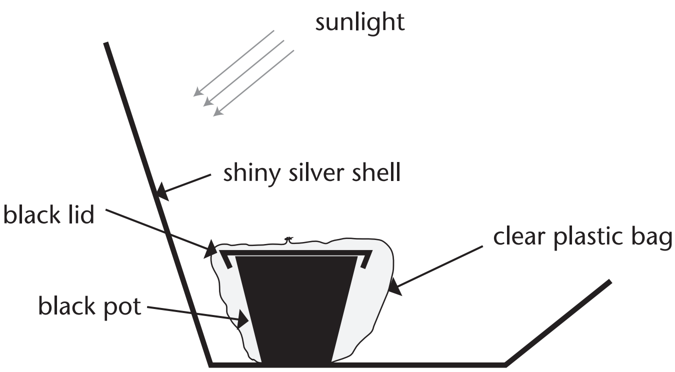
____

The picture shows a solar cooker being used to heat food. It consists of an L-shaped shell with a silver interior wall. There is a platform in the middle for a cooking pot. A black cooking pot with a lid will be placed inside a closed clear plastic bag.

The diagram shows a side view of the cooker.

The main features of the cooker are:

- the shiny interior wall of the cooker
- the black surface of the pot
- the L-shaped reflector shell.



Answers and explanations

Note: The Achieved (A), Merit (M) and Excellence (E) ratings given with answers supplied are based on professional judgements made by the author.

Achievement Standard 90937 (Physics 1.3): Demonstrate understanding of aspects of electricity and magnetism

1.3 Static electricity

Question One: Charge interactions

p. 4

a. The hair will have a positive charge because the rubbing of the plastic against the hair has rubbed negatively charged electrons off the hairs onto the comb. If the hairs have negative charge removed, they are left with an overall positive charge. (M)

b. Like charges repel and opposite charges attract. If either of the rods is brought close to the charged hanging tape, it will feel a force and move. If the tape has a negative charge, it will move towards rod A, but away from rod B. If the tape has a positive charge, it will move towards rod B, but away from rod A. (M)

c. The positively charged spray will attract electrons in the ground to the surface. As the tree is grounded, electrons will travel up the tree and into the leaves, giving them a negative charge. When an object is charged, the charge distributes itself around the outside, so both the top and bottom surfaces of the leaves will be negatively charged and so both top and bottom surfaces will attract the positive spray droplets. (E)

d. As the two pieces of clothing rub against each other while they are tumbling around in the dryer, electrons are rubbed from one piece onto the other, making both pieces charged; the piece that has electrons rubbed off will be positive, the piece that has electrons rubbed onto it will be negative. When the clothes and the air in the dryer are dry, the electrons cannot be conducted back to where they came from, so the two pieces of clothing remain oppositely charged when they are removed from the dryer. As opposite charges attract, the pants and shirt stick together. (E)

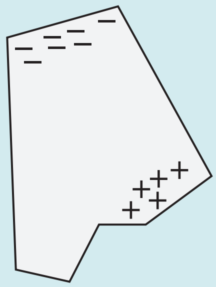
Question Two: Electrostatic dusters

p. 4

a. The rubbing between the nylon fibres and the table (the surface being dusted) causes electrons to be rubbed off the fibres onto the table. Because the fibres have lost electrons, they have fewer negative electrons than positive protons, which makes the fibres positively charged. (M)

b. All fibres will have the same charge. Therefore, each fibre will repel all other fibres because like charges repel. The repulsive force between the fibres will make them stick out from one another as much as possible. (M)

c. As the positively charged fibres get close to a dust particle, the electrons in the dust particle are attracted towards the fibres. Therefore, the surface of the dust particle closest to the fibres becomes negatively charged, leaving the bottom of the dust particle surface positively charged. The attraction between the surface of the dust particle closest to the fibres and the fibres (opposite charges) is greater than the repulsion between the bottom of the dust particle surface and the fibres (like charges); so, overall, the force between dust particle and fibres is attractive and the dust particle jumps onto the fibres.



Charge distribution on dust particle

(E)

d. i. A spark is a stream of charged particles, usually electrons. (A)

ii. The door knob is a conductor and is connected to Earth (which is a sea of electrons). When the cleaner touches the knob, his positively charged body attracts electrons from Earth and they flow from the ground into his body, neutralising the positive charge. (M)

iii. $P = \frac{E}{t} \Rightarrow E = Pt$ To use $E = Pt$, need to find P

$P = IV \Rightarrow P = 2.5 \times 10^{-7} \times 9\,000 = 2.25 \times 10^{-3}$ W

$E = Pt = 2.25 \times 10^{-3} \times 0.0015 = 3.375 \times 10^{-6}$

$= 3.4 \times 10^{-6}$ J (E)

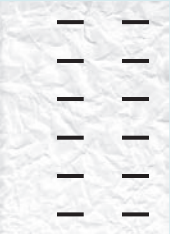
Question Three: Sticky stuff

p. 7

a. The rubbing between Sally's hand and the plastic lunch-wrap causes electrons to be rubbed from one thing to the other. The thing that has gained electrons is negatively charged, the thing that has lost electrons is positively charged. (M)

b. Sally's dad is wrong, because the negative charge that is transferred is produced by the separation of negative charge from positive charge. Before the separation, both types of charge existed, but because they are equal in size, the effect was neutral charge. (E)

c. i.



(A)

ii. Plastic is an insulator, so the charges that have been transferred onto it stay there and the plastic stays charged. The charge on the plastic is opposite to the charge on Sally's hand and, as opposite charges attract, the plastic sticks to Sally's hand. Aluminium is a conductor, so any charge that happens because of rubbing electrons on or off is quickly neutralised by the transfer of electrons between the air and the aluminium. As the aluminium is neutral, it does not stick to Sally's hand. (E)

Question Four: Lightning

p. 8

a. The negative charge on the bottom of the cloud pushes electrons in the tree and in the surface of the ground deeper below the surface. Therefore the tree and ground surface have fewer electrons than protons and so have a positive charge. (M)

b. The bottom of the cloud is *closer* to the top of the tree than to the ground. Therefore the push on the electrons in the tree is greater than the push on the electrons in the ground, leaving the tree more strongly positively charged than the ground. Thus the pull between the positively charged tree and the electrons in the cloud is greater than the pull from the positively charged ground. Therefore, the pull from the top of the tree is more likely to be strong enough to pull the electrons through the air. (E)

c. Only electrons can flow. Electrons in the bottom of the cloud are attracted to the positively charged tree, so electrons flow from the cloud down to the tree. (M)

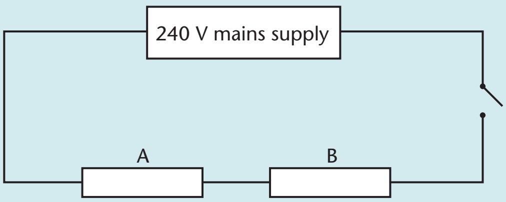
d. The charge at the bottom of the cloud will create an opposite charge in the copper rod. Because the tip of the rod is closest to the cloud, the pull on electrons is greatest between the cloud and the tip of the rod, so any flow of electrons will be between the cloud and the tip of the rod. The electrons that hit the rod are conducted safely to the ground rather than being conducted through the building causing heat that could possibly generate fires. (E)

1.3 Electric circuits

Question One: Electric stove top

p. 13

a.



(A)

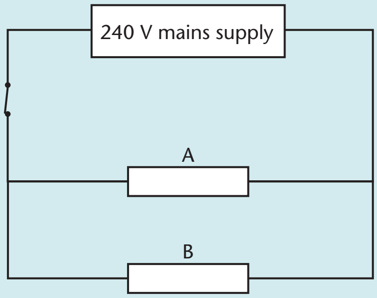
b. When current goes through a resistor, the size of the current is not changed. The two heating coils are connected in series and so whatever current flows through the first one, there is only one way for it to go and that is through the second one. As neither coil affects the size of the current, the same current will flow through both heating coils. (M)

c. $P = IV$ The current, I, is not known but can be found from Ohm's law.

$$V = IR \Rightarrow I = \frac{240}{50 + 40} = 2.667 \text{ A}$$

$$P = IV = 2.667 \times 240 = 640 \text{ W}$$ (E)

d.



(A)

e. $P = IV$ and so the total power output depends on the current that is drawn from the mains supply. The current drawn depends inversely on the total resistance of the circuit, $V = IR$. As the two resistors connected in series have a greater resistance than when they are connected in parallel, the current drawn from the supply is greater when the resistors are connected in parallel. Therefore, the power output is greater when the resistors are connected in parallel. (E)

Question Two: The mechanic's light

p. 15

a. i. The bulbs are connected in *parallel*. (A)

ii. A bulb is bright if it is connected across a 12 V supply. Because the branches in a parallel circuit all have the same voltage, and because each bulb is in its own branch, the voltage across each bulb will be the voltage of the battery branch which is 12 V. (M)

b. Because there are 5 branches:

$$I_{battery} = 5 \times 0.30 = 1.5 \text{ A}$$

$$V = IR \Rightarrow R = \frac{V}{I} = \frac{12}{1.5} = 8.0\ \Omega$$ (M)

c. i. $P_{1\ bulb} = IV = 0.30 \times 12 = 3.6$ W

$P_{5\ bulbs} = 5 \times 3.6 = 18$ W (M)

ii. Each of the 4 remaining bulbs will glow with the same brightness, because each bulb is independently connected across the battery. As one bulb is no longer working, the total brightness will be 80% of what it was. (E)

d. Because the bulbs are connected in series, the voltage of the battery will be divided amongst them, so each bulb will have a voltage that is much less than 12 V. The total resistance of the circuit will be the sum of the individual resistances of the bulbs, so will be much greater than the total resistance in the parallel circuit. Therefore, the current through each bulb will be much less than 0.30 A. As both voltage and current are much less than before, the power output (brightness) of each bulb will be drastically reduced. (E)

Question Three: Lighting up

p. 16

a. $R_{tot} = 8 \times 12.5 = 100$ W (A)

b. The brightness of a lamp depends on the power delivered to it. $P = IV$. If P is too small then either (or both) the current through or voltage across each lamp is too small. Both the voltage and the current can be increased by using a power pack with a greater voltage. (M)

c. All the lamps in the circuit will go out because the defective light bulb will cause a break in the circuit. As the circuit is a series circuit, a break stops the current to all lamps. (M)