Achievement Standard 90937

Demonstrate understanding of aspects of electricity and magnetism

PHYSICS

1.3

Externally assessed 4 credits

Static electricity

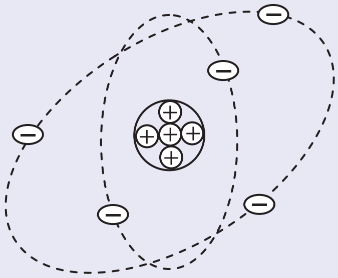
Charge

An atom consists of a central nucleus and surrounding electrons. Each electron has a **negative charge**.

The nucleus contains protons, which have a **positive charge**.

The *size* of the charge on an electron is exactly the *same* as the size of the charge on a proton.

The number of protons in the nucleus is the *same* as the number of surrounding electrons, so the atom, overall, is *neutral*.



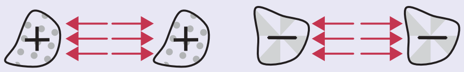
5 protons and 5 electrons make a neutral atom

Charging

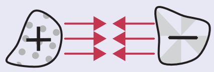
In some atoms, it is relatively easy to dislodge one or more of the outer electrons of the atom. If electrons are removed from the atoms of an object, the object has fewer electrons than protons so, overall, the object is positively charged.

If the electrons that have been removed from the atoms of one object are deposited on another object, the second object has *more* electrons than protons so, overall, the object is negatively charged.

Objects that have the same charge **repel** each other, objects that have opposite charge **attract** each other.



Like charges repel

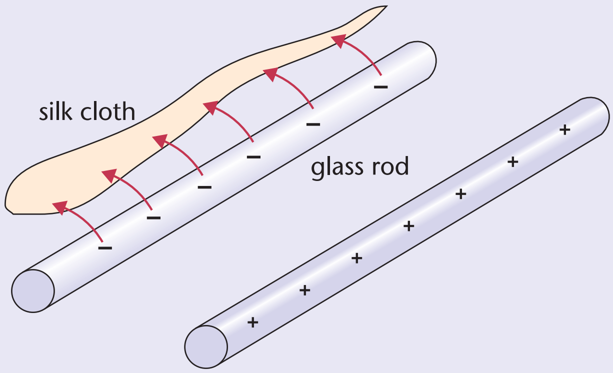


Opposite charges attract

As the charged objects get *closer* together, the force between them becomes *stronger*.

Charging by friction

One way to remove electrons from an object is to rub the object. For example, if something made of glass is rubbed with a cloth made of silk, electrons can be rubbed off the atoms of the glass and onto the cloth. The glass object loses electrons and so becomes positively charged; the cloth gains electrons and so becomes negatively charged.



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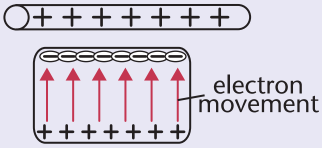
Charge distribution

If an object is uncharged (neutral), the equal quantities of positive and negative charge are usually evenly spread throughout the object.

If a charged object is brought close to an uncharged object, the attraction or repulsion felt by the electrons in the uncharged object makes the electrons move. How much the electrons move in the uncharged object depends on how good a conductor the uncharged object is.



A movement of electrons within an uncharged object causes an uneven charge distribution.

Losing charge (discharge)

If a charged object is touching a substance that is a conductor (such as moist air), the charged object gradually loses its charge due to electrons being transferred between the charged object and the conducting material.

A charged object can lose its charge very quickly if it is a conductor.

Earthing is one way to discharge a charged conductor. The Earth acts like a reservoir of electrons, so electrons can flow into or out of the Earth very easily and very quickly.

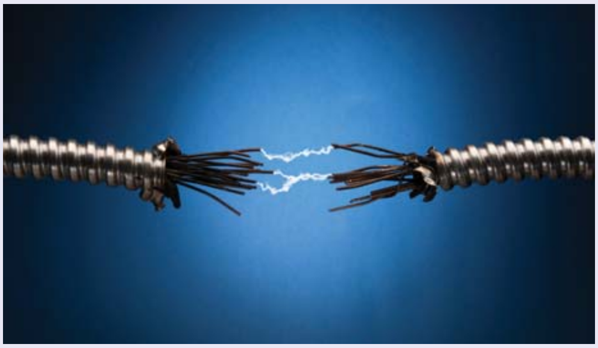
Discharge through air

If two objects are oppositely charged, the electrons in the negatively charged object are attracted to the positively charged object.

The closer the oppositely charged objects are to each other, the stronger is the pull on the electrons. Sometimes the pull gets so strong that the electrons jump the gap between the objects and flow through the air.

This discharge is often accompanied by a *crackling* sound and sometimes a spark can be seen to jump across.

A discharge can also be produced when a neutral object (such as the Earth) is close to a charged object. The charged object alters the charge distribution of Earth so that positive charge is close to negative charge. Again, the pull on the electrons can be large enough to make them flow across the air gap. A common display of this discharge is when lightning strikes.



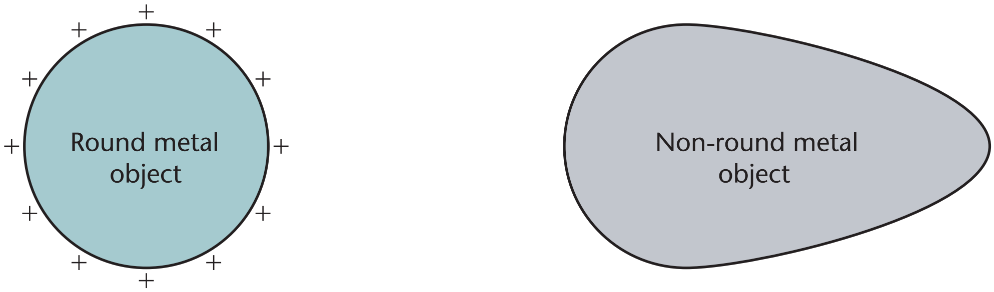
1.3

Year 2018
Ans. p. 118

Question Four: Van de Graaff generator

a. Below are two **positively** charged metal objects. The round object has charge evenly distributed over the surface, as shown.

Draw the charge distribution to show how the positive charges are distributed along the surface of the non-round metal object.



b. Explain why copper is a good conductor of electricity, whereas glass is a poor conductor of electricity.

A Van de Graaff generator is an electrostatic generator that uses a moving belt to accumulate electric charge on a hollow metal globe, which sits on the top of an insulated column. The largest air-insulated Van de Graaff generator in the world was built in the 1930s. It is now on display at Boston's Museum of Science.

The Van de Graaff generator can generate 2.0 MV (2.0×10^6 V). During a demonstration, a spark was measured to last for 0.001 s. The spark carried 100 kJ (1.0×10^5 J) of energy.

c. i. Calculate the amount of current that flows during the spark.

ii. Electrical currents above 100 mA are extremely hazardous for humans. Explain whether or not it would be safe for the current created by this demonstration to hit a spectator.

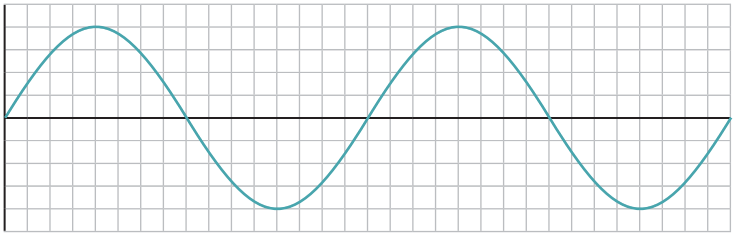
Question Five: Ligo

Year 2018
Ans. p. 121

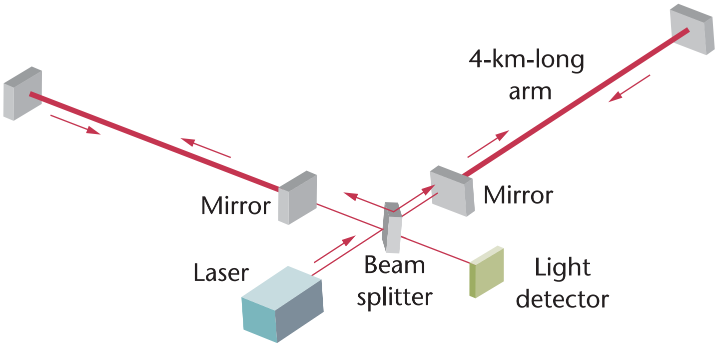
1.4

a. i. Describe the property that all transverse waves have in common.

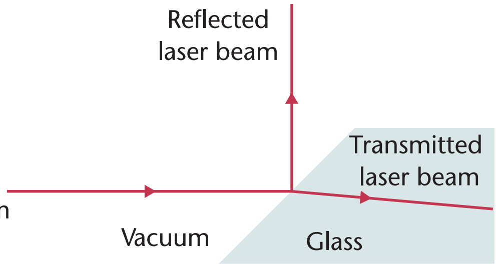
ii. Draw labelled arrows on the diagram below to show the wavelength and amplitude of the wave.



The Laser Interferometer Gravitational-Wave Observatory (LIGO) is a large-scale physics experiment and observatory created to detect cosmic gravitational waves. The first detection of gravitational waves was reported in 2016. Below is a diagram of how the LIGO observatory is set up.



b. LIGO tunnels are kept at an ultra-high vacuum, which contains almost no particles. The beam splitter, which is made of glass, reflects half the light and transmits half the light, as shown below.



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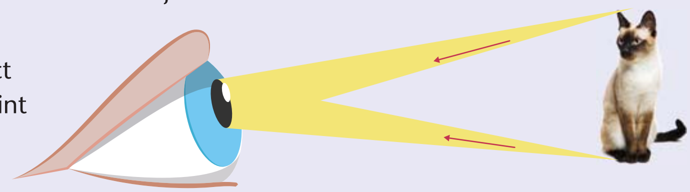
Light waves

Light is an electromagnetic wave. Light travels in a straight line unless something causes it to change its direction. If light falls on a surface, light is reflected. If the surface is the boundary between two mediums, light is both reflected and transmitted.

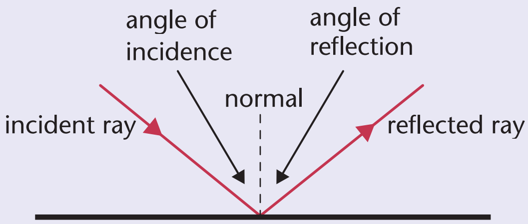
We see an object if light from the object goes into our eyes. Most objects do not produce their own light; the light that is *reflected* off an object allows us to see the object.

If you are looking at an object, your brain locates the *position* of each point on the object at the tip of a *cone* of light going from the point into your eye.

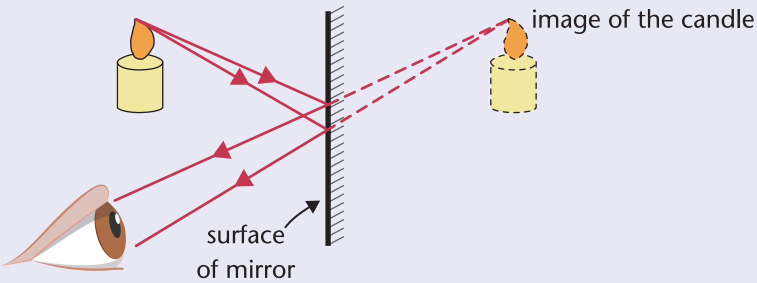


Reflection of light

When light is reflected, the **angle of reflection** is always *equal to* the **angle of incidence**.

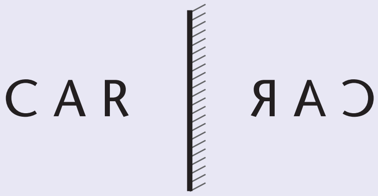


If the reflecting surface is smooth, such as the surface of a mirror or the flat surface of water, the reflection that occurs allows an **image** to be seen. An image is seen because, when light enters the eye, the brain assumes the light has travelled in a *straight* line from the object the eye is seeing.



The image that is seen in a plane (flat) surface is the *same size* as the object and is the *same distance* behind the mirror as the object is in front of the mirror (image distance = object distance).

In addition, the image in a plane surface is **laterally inverted**. For that reason, if you look at your image in a mirror and wave your right hand, it appears as though it is the left hand of the image that is waving. Lateral inversion is the reason why the following image of writing is inverted.



Questions: Heat

Year 2021
Ans. p. 124

Question One: Keeping cool

a. State the three types of heat transfer.

1. ______________________________

2. ______________________________

3. ______________________________

Masdar City in Abu Dhabi is being developed as one of the world's most sustainable cities.

b. The roof and tiles of some of the buildings above have highly reflective coatings. Explain how this helps to keep the inside of the building cool on a bright day.

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c. An office room at 20.5 °C contains 85.8 kg of air. (The specific heat capacity of dry air is 1 006 J kg^{-1} $°C^{-1}$.) The sunlight entering through its windows corresponds to an energy influx of 422 W.

Calculate how long it takes to heat the air in the room up to 25.0 °C.

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Year 2020
Ans. p. 125

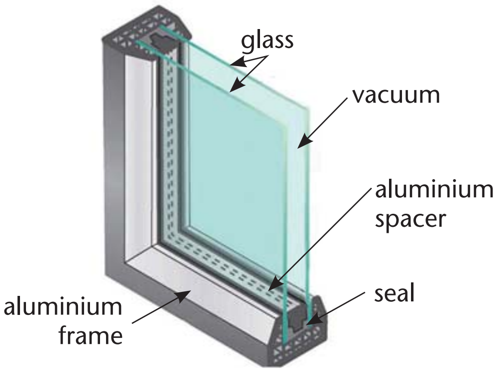
Question Five: It's cold inside

Martha's house is poorly insulated, and gets very cold overnight. On many mornings, moisture in the air has condensed to water on her windows.

a. State how the average kinetic energy and the average speed of the water particles changes when steam undergoes condensation on the cold windowpane.

b. To help insulate her home, Martha plans to get her windows fitted with double glazing. A typical double-glazed windowpane is shown in the diagram. It consists of a strong aluminium frame that holds two sheets of glass with a vacuum between them.

Describe the process of heat loss through the windows, and explain, in terms of relevant types of heat transfer, how double glazing would minimise this heat loss.



1.5

Achievement Standard 90940

Demonstrate understanding of aspects of mechanics

SCIENCE

1.1

Externally assessed 4 credits

Straight-line motion and force

The motion (movement) of an object such as a car or a ball is described in terms of its speed and its acceleration.

Speed and acceleration

Speed, **v**, is the distance the object travels in a certain time. Speed is calculated using the formula:

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

Δ means 'change in', so Δd is a 'change in distance' or distance travelled; Δt is a 'change in time', or time taken.

Distance, **d**, is measured in **metres**, **m**; other units are kilometres, km, and millimetres, mm.

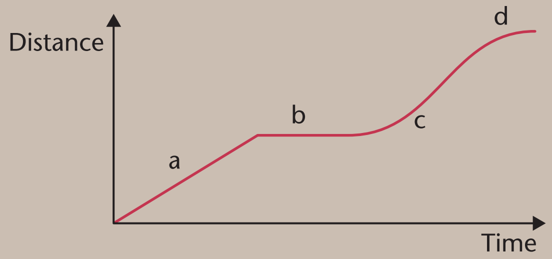
Time, **t**, is measured in **seconds**, **s**; other units are minutes, min and hours, h.

So speed, v, is measured in metres per second, **m s**$^{-1}$; another common unit is kilometres per hour, km h^{-1}.

If the speed to be calculated is an *average* speed, Δd is the *total* distance travelled and Δt is the *total* time taken. If the speed is constant, Δd can be *any* distance and Δt is the time taken to travel the chosen distance.

The motion of a travelling object can be illustrated on a *graph* of distance against time. The **gradient** (slope) of the graph line is the speed of the travelling object.

Example



a: constant gradient means constant speed

b: zero gradient means zero speed, so stopped

c: increasing gradient means increasing speed, so acceleration

d: decreasing gradient means decreasing speed, so deceleration.

Acceleration, **a**, is how much the speed *changes* in a certain time. Acceleration is calculated using the formula:

$$a = \frac{\Delta v}{\Delta t}$$

Therefore acceleration is measured in metres per second per second, **m s**$^{-2}$; another common unit is km h^{-2}.

The motion of a travelling object can be illustrated on a *graph* of speed against time. The **gradient** (slope) of the graph line is the acceleration of the travelling object; the **area** under the graph line is the distance the object has travelled.

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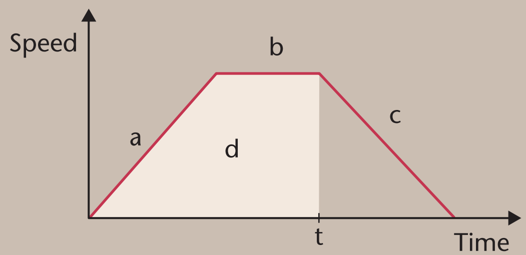
Example



a: a positive and constant gradient means the speed is increasing at a constant rate (constant acceleration)

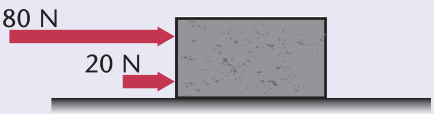
b: zero gradient means zero acceleration, so constant speed

c: a negative and constant gradient means the speed is decreasing at a constant rate (constant deceleration)

d: the distance travelled from the start, in time t, is the shaded area.

Force

A **force** is a *push* or a *pull*. A force, **F**, has a size and a direction. The size of a force is measured in **newtons**, **N**. An arrow is used to show the direction of a force. If more than one force is acting on an object, the **net** force, $\mathbf{F}_{net}$ that the object feels is the combination of all the individual forces. Forces acting in the *same* direction *add* together, while forces acting in *opposite* directions are *subtracted*.



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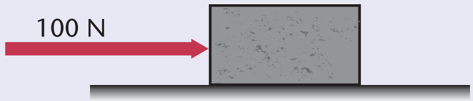

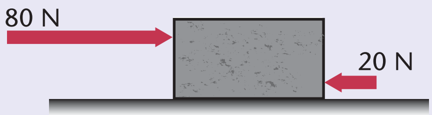

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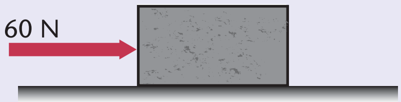
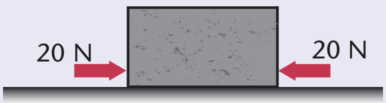


If there is a net force acting on an object, the forces are said to be **unbalanced** and the motion of the object changes. If a net force acts on a *stationary* object, the object accelerates in the direction of the net force. If the object on which a net force is acting is already moving, the object *accelerates* if the direction of the net force is in the *same* direction as the motion. The object *decelerates* if the net force is acting in the *opposite* direction to the motion. If the direction of the net force is not *parallel* to the direction of the motion, the object also changes its *direction*. If the forces acting on an object combine to give a net force of zero, the forces are said to be **balanced** and the motion of the object does not change. If the object was stationary, it continues to not move; if the object was moving, it continues to move at a constant speed.



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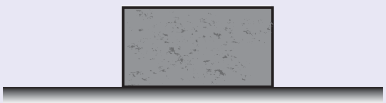


A net force acting on an object causes acceleration (deceleration is negative acceleration). Acceleration can be found from the formula:

$$F_{net} = ma$$

where m is the mass of the object being accelerated.

When using the formula $F_{net} = ma$, the unit for m must be kg; the unit for a must be m s^{-2}

Questions: Straight-line motion and force

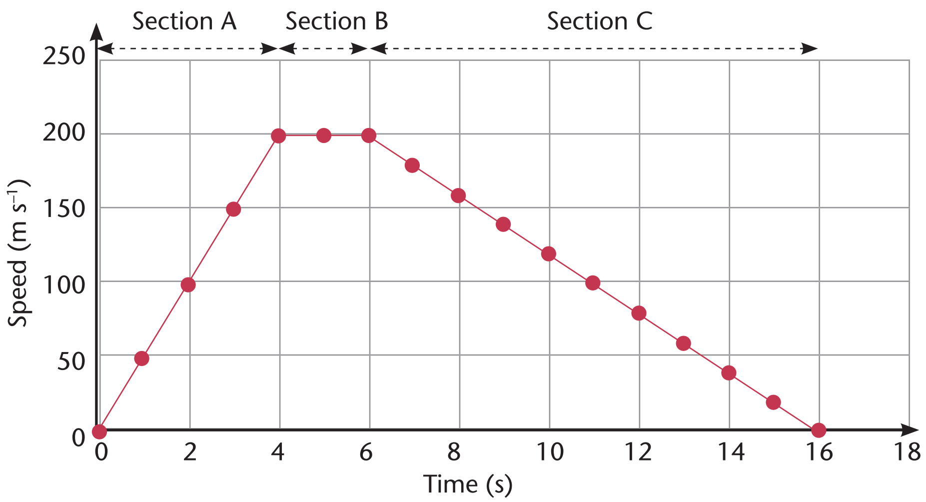
Question One: Dragsters

Year 2021
Ans. p. 127

Dragsters are designed to travel short distances very quickly.

Below is a speed/time graph of a dragster.

Speed/time graph for dragster



a. What is the maximum speed of the dragster?

______________________________ m s^{-2}

b. i. Using the graph, show the acceleration of the dragster in the first 4 seconds is 50 m s^{-2}

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ii. The mass of the dragster is 1050 kg.
Calculate the net force required to accelerate the dragster at 50 m s^{-2}

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1.1

Energy, work and power

Energy

Energy can be *active* or *stored*.

Active forms of energy are:

- kinetic energy – the energy of an object when it is *moving*
- light energy
- heat energy
- sound energy.

Forms of energy that are stored and have an effect only when they are changed to active energy are called **potential** energy. Some forms of potential energy are the following.

- Chemical potential energy – changed to active energy by chemical reactions. Food, fuels and explosives contain chemical potential energy.
- Elastic potential energy – energy stored when a spring is stretched or compressed, or when a rubber band is stretched. It is changed to active energy when the tension is released.
- Gravitational potential energy – the energy an object gains when it is lifted up. This energy is changed to active energy when the object falls down.
- Electrical energy – energy that is stored in a power source (such as a battery). This energy is changed to active energy when the circuit is switched on.
- Nuclear energy – energy that is stored in an atomic nucleus. This energy is changed to active energy in nuclear reactors or atomic bomb explosions. Solar energy (light, heat and other forms of energy) is produced from nuclear reactions within the Sun.

1.1

All forms of energy are measured in **joules**, **J**. Another common unit is the kilojoule, kJ. 1 000 J = 1 kJ

Gravitational potential energy, E_p, is the potential energy an object has *because of its height*. When an object is lifted or lowered, the object's gravitational potential energy increases or decreases according to the equation:

$$\Delta E_p = mg\Delta h$$

where:

- ΔE_p is the change in gravitational potential energy in joules, J
- m is the mass, in kilograms, of the object
- g is the strength of gravity, 10 N kg^{-1}
- Δh is the change in *vertical* height, in metres.

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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: The Ioniser

p. 4

a. To make the dust particles negatively charged, electrons must flow off the needle onto the surface of the dust particle. Electrons cannot flow if the needle is not made of a conducting material. (A)

b. When a dust particle gets close to the negatively charged needle, electrons at the surface of the particle are repelled and move down slightly, leaving the surface with a positive charge. This surface positive charge means the particle is attracted to the negative needle and when contact is made electrons are attracted across, making the particle negatively charged. Because the particle is now negatively charged, it is repelled from the like-charged needle and attracted towards the oppositely charged plate. (M)

c. $P = \frac{E}{t} = \frac{4 \times 10^{-4}}{0.008} = 0.05$ W

$P = IV \quad \Rightarrow \quad V = \frac{P}{I} = \frac{0.05}{2.0 \times 10^{-6}} = 25\ 000$ V (M)

d. If the layer of dust becomes too thick, the charged dust particles that are attracted to the plate are not able to touch the plate, and so, because dust is not a conductor, they do not lose their charge. This means that there is a build-up of negatively charged dust particles on the outer surface layer that act against the positive charge on the plate. This then reduces the attractive force that pulls the dust particles onto the plate, making it less effective. (E)

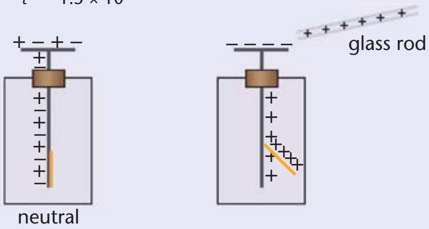
Question Two: Electroscopes

p. 6

a. The process is charging by friction. (A)

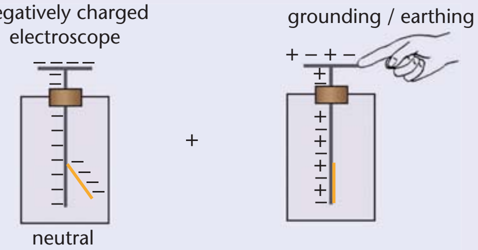
b. $P = \frac{E}{t} = \frac{12.5 \times 10^{-3}}{1.5 \times 10^{-3}} = 8.333 = 8.3$ W (M)

c.



Opposite charges attract, so the positively charged glass rod attracts negative electrons upwards into the metal disc. This leaves the metal plate and the gold leaf with a positive charge. Because like charges repel, the gold leaf is repelled away from the metal plate. (M)

d.



When the electroscope is negatively charged, there is an excess of electrons that are evenly distributed over the metal disc and metal plate, so the leaf will be repelled away from the stem. When the metal disc is earthed, the excess electrons flow down into earth, leaving the electroscope uncharged. Because there is now no force pushing the leaf away from the stem, it falls back to lie against the stem. (E)

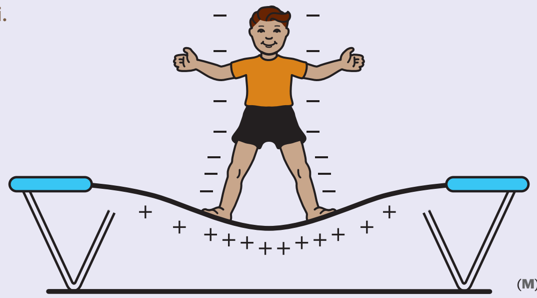
Question Three: Jumping on a trampoline

p. 8

a. Static electricity is the presence of charged particles that are free to move but the forces acting on them are such that they remain stationary. (A)

b. i. When Ewan lands on the mat, the mat stretches downwards and so there is rubbing between the surface of the mat and the soles of Ewan's feet. This rubbing causes electrons to be rubbed off the mat onto Ewan's feet. (M)

ii.



(M)

c. i. Polypropylene is an insulator, so when Ewan's negatively charged feet touch the polypropylene mat, even though it is positively charged, electrons cannot flow across from his body, so Ewan does not feel a shock. The metal of the frame is a conductor, so when Ewan's negatively charged hands touch the metal, the electrons on Ewan's body flow from his body into the metal so Ewan feels a shock. (E)

ii. If the mat was made of a material that conducts electricity he would not become significantly charged at all. This is because any electrons that might be rubbed off the mat onto his feet would be attracted back onto the mat rather than allowed to build up and spread over his body. (E)