**Section A [35 marks]**

Four possible answers **A**, **B**, **C** and **D** are given for each question. Choose the **most appropriate answer** and shade your answers in pencil on the OMR answer sheet provided.

**1** Which row contains only base quantities?

**A** time, temperature, weight

**B** potential difference, length, mass

**C** charge, temperature, length

**D** amount of substance, current, mass

**2** Four students each make a series of measurements of the acceleration due to gravity *g*. The table shows the results.

Which student obtains a set of results that can be described as accurate but not precise?

| student | results, $g$ / m $s^{-2}$ | | |
|---|---|---|---|
| **A** | 9.81 | 9.82 | 9.83 |
| **B** | 8.57 | 9.79 | 11.05 |
| **C** | 7.90 | 8.12 | 9.25 |
| **D** | 8.47 | 8.49 | 8.49 |

**3** A hot air balloon ascends from rest with an acceleration of 2.50 m $s^{-2}$, in the absence of air resistance. When it reaches a height of 48.0 m above the initial ground level, an object of mass 5.00 kg is released from the balloon.

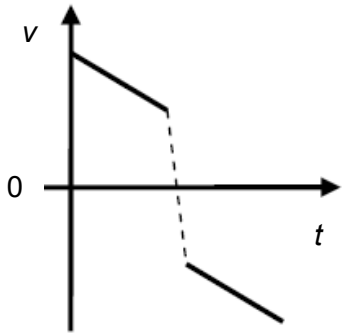
What is the speed of the object just before it impacts the ground?

**A** 28.3 m $s^{-1}$ **B** 31.1 m $s^{-1}$ **C** 34.4 m $s^{-1}$ **D** 35.8 m $s^{-1}$

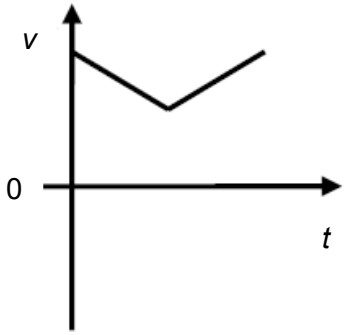
**4** A tennis ball is thrown vertically up, hitting the ceiling before it falls down.

Which graph best represents the variation with time *t* of the velocity *v* of the ball before and after hitting the ceiling? Assume that the effect of air resistance is negligible.

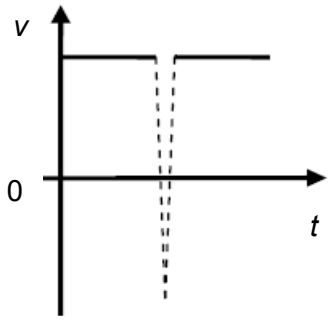
**A**



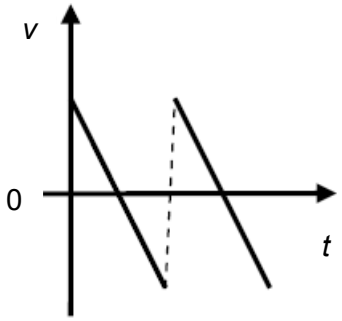

**B**




**C**




**D**




**5** Which is a scalar quantity?

**A** air resistance **B** mass **C** displacement **D** velocity

**6** Three forces, 3.0 N, 4.0 N and 5.0 N are added to obtain a resultant force **R**. What is the minimum value of **R**?

**A** 0 N

**B** 2.0 N

**C** 4.0 N

**D** 6.0 N

**7** Which situation will friction be classified as a nuisance?

**A** car braking

**B** heat generated when a box is pushed across a rough surface

**C** person holding an object

**D** student walking

**8** A machine is able to lift a solid object with maximum mass of 600 kg on the surface of the earth. The same machine is able to lift another solid object with maximum mass of 3600 kg on the surface of the moon.

Why is this so?

**A** The mass of the machine is lesser on the surface of the moon than on the surface of the earth.

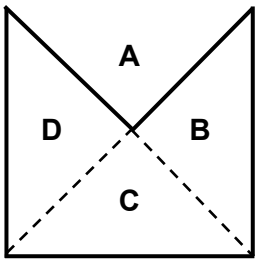
**B** The weight of the machine is lesser on the surface of the moon than on the surface of the earth.

**C** The mass of the 3600 kg object is lesser on the surface of the moon than on the surface of the earth.

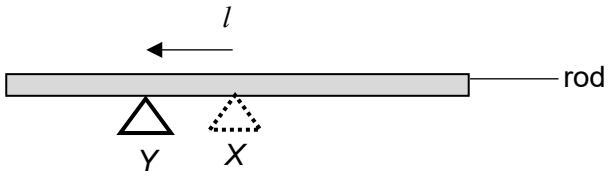
**D** The weight of the 3600 kg object is lesser on the surface of the moon than on the surface of the earth.

**9** A thin square plate has the triangular region **A** removed.

Which region of the plate does the centre of gravity now lie?



**10** An uniform thin rod of mass 20.0 g is balanced when a pivot is placed at point *X*. The pivot is now shifted *l* cm to the left of its current position to a point *Y*, and an object of 40.0 g is placed on the rod to balance this new arrangement.




Where should the object be placed?

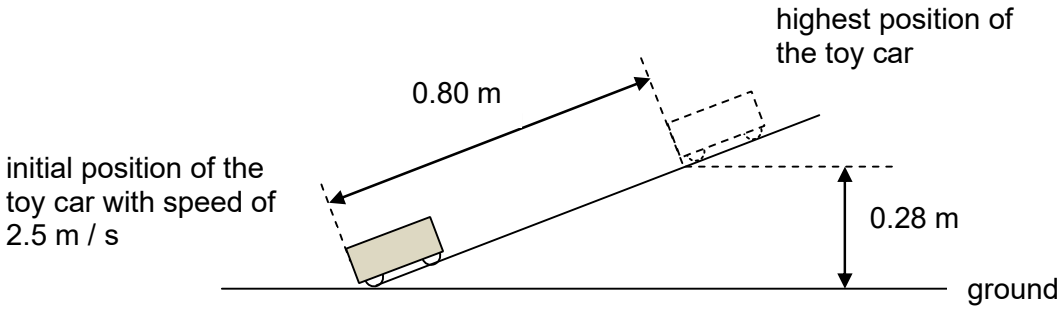
**A** 0.5*l* cm to the left of X

**B** 0.5*l* cm to the left of Y

**C** *l* cm to the left of Y

**D** 2*l* cm to the left of Y

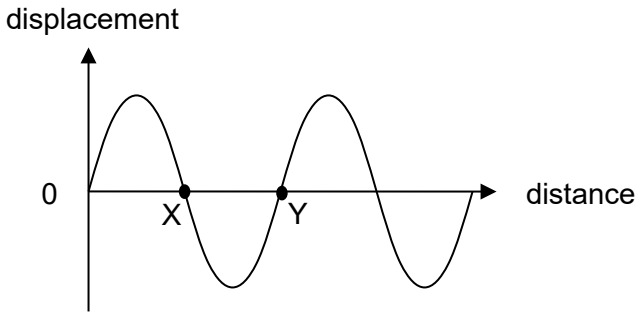
**11** The diagram shows a 0.50 kg toy car moving up a rough slope with an initial speed of 2.5 m / s. It is only able to move a distance of 0.80 m up the slope to its highest point 0.28 m above the ground.




What is the average resistive force acting on the toy car as it moves up the slope?

**A** 0.236 N **B** 1.72 N **C** 1.95 N **D** 3.67 N

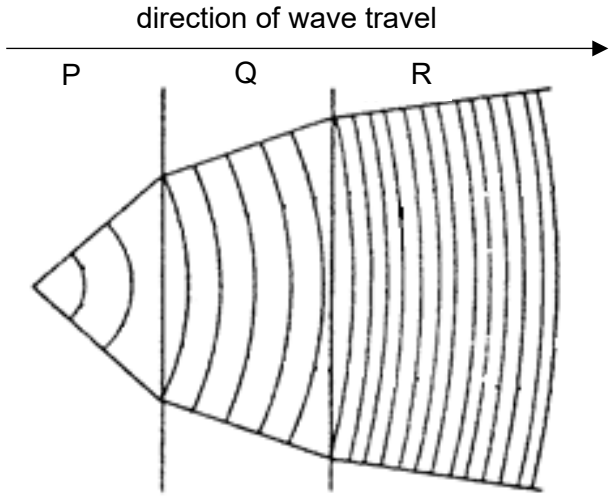
**12** The diagram below shows the displacement-distance graph of a longitudinal wave in air.




What is the region at point X and point Y?

| | X | Y |
|---|---|---|
| **A** | rarefaction | rarefaction |
| **B** | crest | trough |
| **C** | compression | compression |
| **D** | compression | rarefaction |

**13** The diagram shows circular wavefronts travelling from region P into Q and then into R in a ripple tank.




Which are the shallowest and deepest regions?

| | shallowest region | deepest region |
|---|---|---|
| **A** | R | P |
| **B** | Q | P |
| **C** | Q | R |
| **D** | P | R |

**14** The table shows the boiling point of three different substances.

| substance | alcohol | ether | hexane |
|---|---|---|---|
| boiling point / °C | 79 | 35 | 68 |

How many of the above three substances will be in liquid state at a temperature of 77 °C?

**A** none **B** one **C** two **D** three

**15** The figure shows a saucepan used for cooking.

Which combination best describes the thermal properties of the insulating handle?


| | specific heat capacity | melting point |
|---|---|---|
| **A** | low | low |
| **B** | low | high |
| **C** | high | low |
| **D** | high | high |

**16** The diagram shows a puddle of water on a pavement.

Which factor does not affect the rate of evaporation of the water?

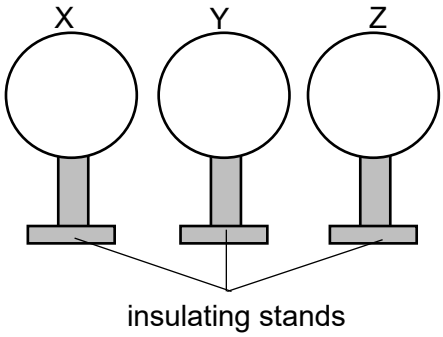
**A** depth of water

**B** humidity of surrounding air

**C** surface area of water

**D** temperature of water

**17** Three electrical conductors mounted on insulating stands, are placed close to one another without touching. Conductor X is positively charged. Both conductors Y and Z are neutral.




After conductor Z is earthed momentarily, what is the charge on conductor Z?

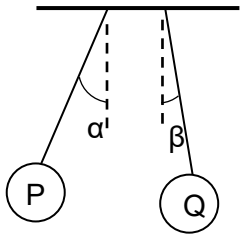
**A** neutral

**B** positive

**C** negative

**D** the charge cannot be determined

**18** Two charged conducting spheres P and Q are suspended near each other using insulated strings as shown. Sphere P has a smaller net charge than sphere Q, and angle α is greater than angle β.




Which statement is correct?

**A** Sphere P has a greater mass than sphere Q.

**B** Sphere P experiences a greater electric force of repulsion than sphere Q.

**C** Sphere Q experiences a greater electric force of attraction than sphere P.

**D** Sphere Q experiences a greater tension than sphere P.

**19** Which situation does not describe a possible solution to prevent electrostatic charging from becoming a potential hazard?

**A** Wearing a conducting wrist strap that is connected to the ground when handling electronic components

**B** Connecting a copper strip from the top of a building into the ground

**C** Hanging a metal chain from a moving lorry to the ground

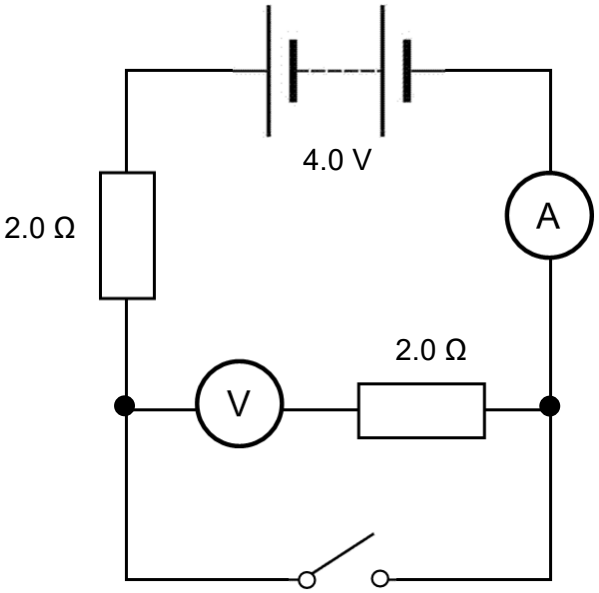
**D** Replacing the tyres of airplanes with insulating rubber

**20** A wire carries a current of 10 A. The charge of a single electron is $1.60 \times 10^{-19}$ C.

How many electrons pass through a given cross section of the wire in one minute?

**A** $1.0 \times 10^{16}$ **B** $1.0 \times 10^{18}$ **C** $3.8 \times 10^{19}$ **D** $3.8 \times 10^{21}$

**21** The diagram shows a circuit with a battery of e.m.f. 4.0 V, connected to two resistors of resistance 2.0 Ω, an ammeter and a voltmeter.




What are the readings on the ammeter and the voltmeter when the switch is closed?

| | ammeter reading / A | voltmeter reading / V |
|---|---|---|
| **A** | 1.0 | 0.0 |
| **B** | 2.0 | 0.0 |
| **C** | 1.0 | 2.0 |
| **D** | 2.0 | 2.0 |

**22** 6.0 J of energy is supplied by a battery when 3.0 C of electrons passes through it.
What is the electromotive force (e.m.f.) of the battery?

**A** 0.50 V

**B** 2.0 V

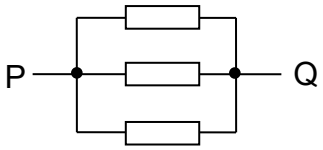
**C** 3.0 V

**D** 18 V

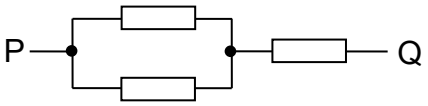
**23** Three identical resistors are connected across PQ.

Which combination has the lowest effective resistance across PQ?

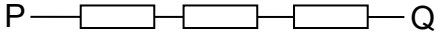
**A**



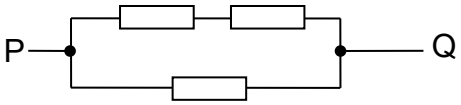

**B**



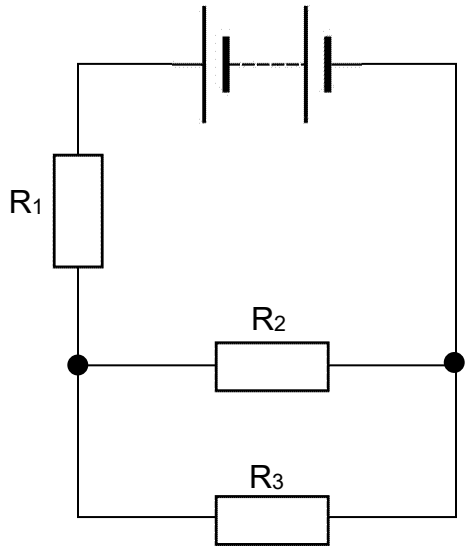

**C**




**D**



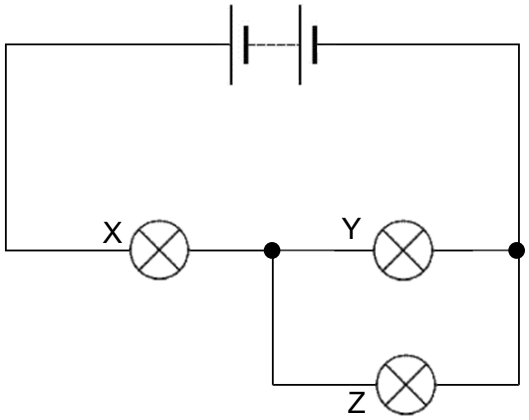
**24** The diagram shows a circuit with three identical resistors.




Which row shows the possible values for the potential difference (p.d.) across each resistor?

| | p.d. across $R_1$ / V | p.d. across $R_2$ / V | p.d. across $R_3$ / V |
|---|---|---|---|
| **A** | 1.5 | 1.5 | 1.5 |
| **B** | 1.5 | 3.0 | 3.0 |
| **C** | 3.0 | 1.5 | 1.5 |
| **D** | 4.0 | 3.0 | 3.0 |

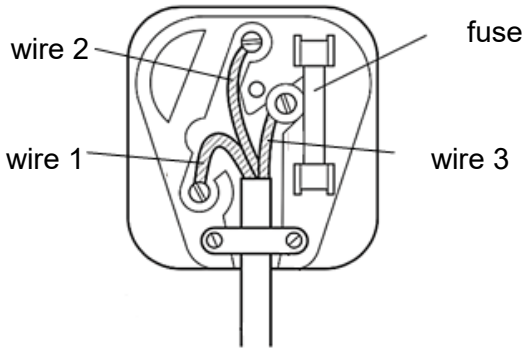
**25** The diagram shows three identical lamps X, Y and Z connected in a circuit.




How does the brightness of X and Y change when Z blows?

| | X | Y |
|---|---|---|
| **A** | decreases | increases |
| **B** | increases | decreases |
| **C** | stays the same | increases |
| **D** | increases | stays the same |

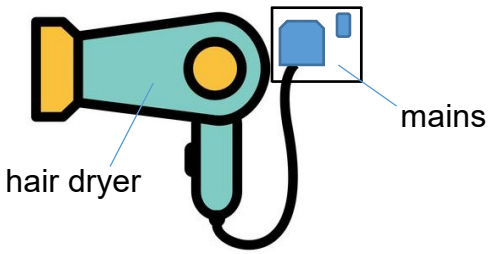
**26** The diagram shows a standard mains plug.




What are the correct colours for the wires?

| | wire 1 | wire 2 | wire 3 |
|---|---|---|---|
| **A** | blue | brown | yellow and green stripes |
| **B** | blue | yellow and green stripes | brown |
| **C** | brown | yellow and green stripes | blue |
| **D** | yellow and green stripes | brown | blue |

**27** A hair dryer is plugged into the mains as shown in the diagram.



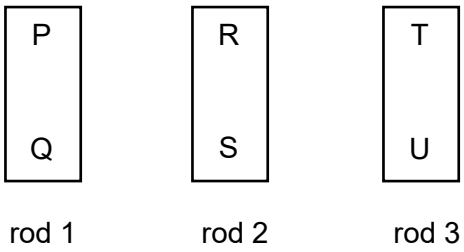

However, once the hair dryer is switched on, the earth leakage circuit breaker (ELCB) trips and cuts off the power supply.
The user switches back the ELCB and the power supply is turned on.
However, the hair dryer is not working even though the ELCB did not trip again.
The user then hypothesise a few reasons for this electrical fault that takes place as follows:

I The live wire frays and comes in contact with the outer metal casing.
II The fuse melts and cuts off the electric current to the hair dryer.
III The hair dryer draws too much electric current that causes the ELCB to trip in the first instance.

Which reasons are possible?

**A** I and II only
**B** I and III only
**C** II and III only
**D** All of the above

**28** The ends of three metal rods are tested by holding end Q of rod 1 close to the others in succession.

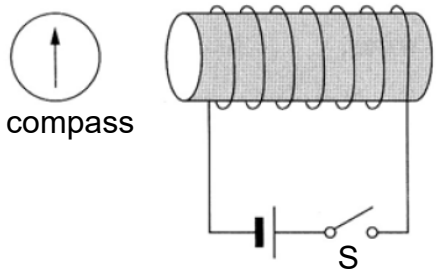



The results are as follows.
End Q: attracts end R,
attracts end S,
attracts end T,
repels end U.

Which metal rods are permanent magnets?

**A** rod 1 only
**B** rod 3 only
**C** rod 1 and rod 2
**D** rod 1 and rod 3

**29** The diagram shows a compass placed near a solenoid with switch S opened. The needle points north.




When switch S is closed, the strength of the magnetic fields of the Earth and the solenoid are similar at the position of the compass.
What is the orientation of the compass needle?

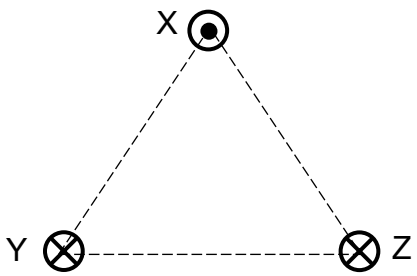
**A** 

**B** 

**C** 

**D** 

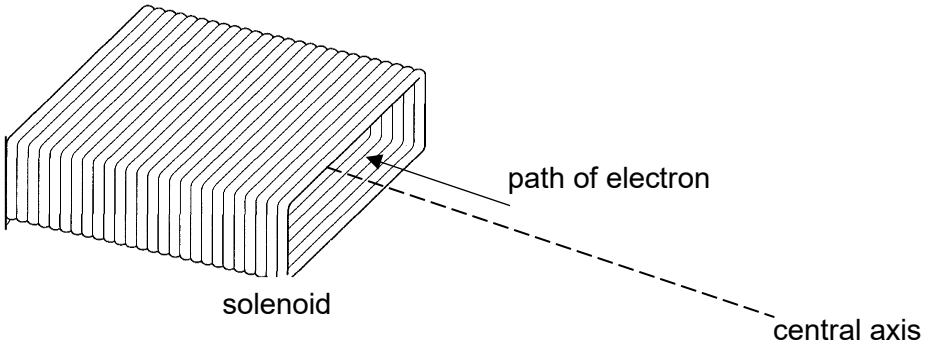
**30** Three long straight wires pass through the corners of an equilateral triangle XYZ.
They carry equal currents into or out of the paper in the directions as shown.




What is the direction of the resultant force on the wire at X?

**A** downwards **B** leftwards **C** rightwards **D** upwards

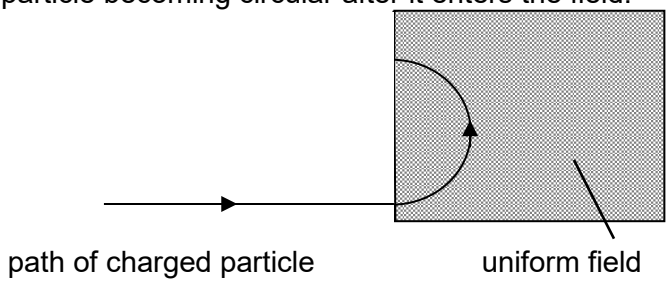
**31** An electron is moving inside a long current-carrying solenoid, parallel to its axis as shown.




Which statement about the magnetic force acting on the electron is correct?

**A** The force acts in the direction of motion of the electron.
**B** The force acts opposite to the direction of motion of the electron.
**C** The force acts towards the centre of the solenoid.
**D** No force acts on the electron.

**32** A charged particle moves into a region where there is a uniform field. The diagram shows the path of the charged particle becoming circular after it enters the field.




Which row is correct?

| | charge of particle | direction of field | type of field |
|---|---|---|---|
| **A** | negative | downwards | electric |
| **B** | negative | out of the page | magnetic |
| **C** | positive | into the page | electric |
| **D** | positive | out of the page | magnetic |

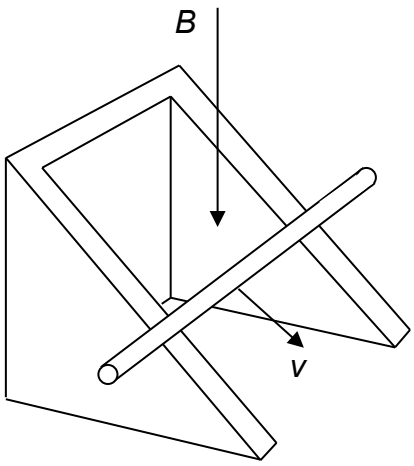
**33** What is Lenz's Law?

**A** The induced current is always in a direction to oppose the current that produces it.
**B** The induced current is always in a direction to oppose the change in magnetic flux linkage producing it.
**C** The induced electromotive force is always in a direction to oppose the electromotive force that produces it.
**D** The magnitude of the induced electromotive force is proportional to the rate of change of magnetic flux linkage or the rate at which the magnetic field lines are cut.

**34** Which of the following will not induce an electromotive force in a solenoid?

**A** moving a current-carrying wire beside the solenoid
**B** another nearby solenoid carrying an alternating current
**C** having a strong bar magnet at rest in the middle of the solenoid
**D** moving the solenoid towards a bar magnet

**35** In a region of uniform magnetic field *B* that is directed vertically downward, a metal bar slides at a velocity *v* down a smooth conducting track inclined at an angle to the horizontal.




What is the direction of the induced current (if any) through the metal bar and conducting tracks when viewed from the top?

**A** anti-clockwise
**B** clockwise
**C** no current, since the magnetic field and the motion of the metal rod are not perpendicular
**D** no current, since there is no closed circuit

**End of Section A**

**Section B [65 marks]**

Write your **answers to Questions 36 to 49 in the spaces provided in each question**. Show your workings clearly where necessary. All quantitative answers should include appropriate units and be quoted to a suitable number of significant figures.

**Question 39 (b) indicated with an * is optional and will count towards your total marks**. Your total marks for the whole paper will remain limited to a maximum of **100 marks**.

**36** A pair of vernier callipers is used to measure the external and internal diameters of a hollow pipe. The readings obtained are shown in Fig. 36.1 and Fig. 36.2, with both readings having the same zero error = - 0.02 cm.

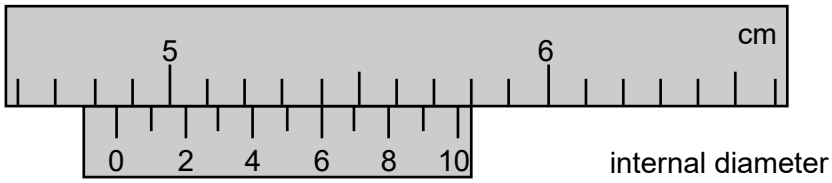



**Fig. 36.1**

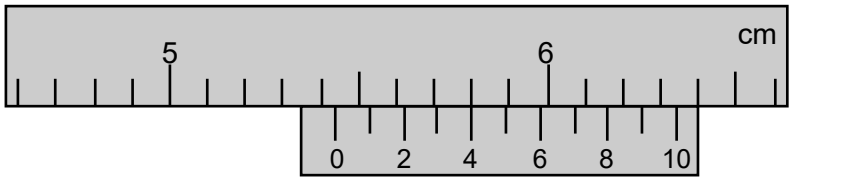



**Fig. 36.2**

**(a)** Explain why zero error is classified as a systematic error.

.....

..... [1]

**(b)** Calculate the corrected internal diameter of the pipe.

internal diameter = ..... [1]

**(c)** Calculate the thickness of the pipe.

thickness = ..... [2]

**37** A ball is launched vertically upwards with an initial velocity $u$ from the table surface, and travels 1.0 s before returning to the table surface. It bounces and then travels 0.60 s before returning to the table surface, without any further bounce.
Assume negligible air resistance.

**(a)** Show that $u = 4.9$ m s$^{-1}$. [1]

**(b)** Fig 37.1 shows the velocity-time graph of the motion of the ball for the first second.

On Fig. 37.1, complete the velocity-time graph for the duration of the second bounce. [2]

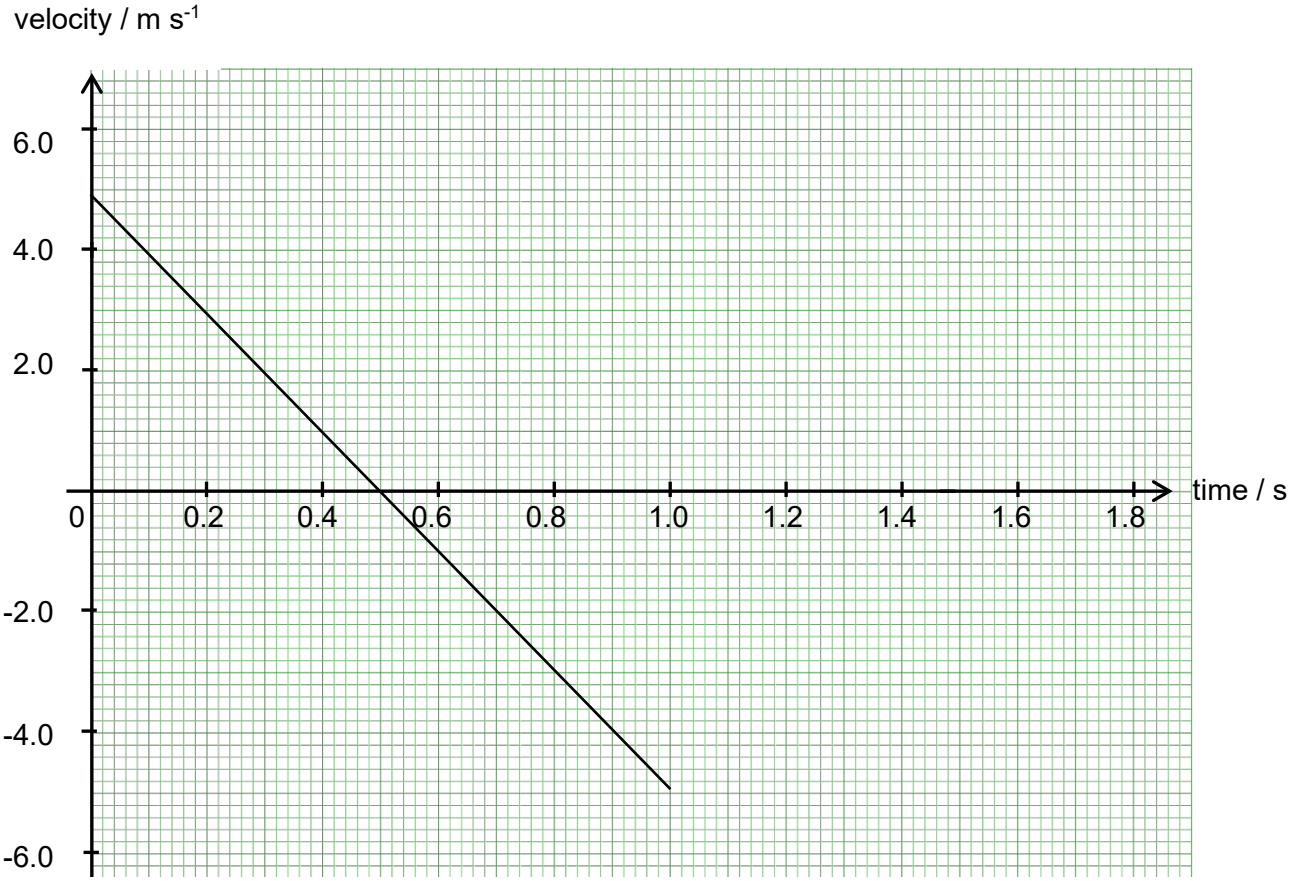



**Fig. 37.1**

**38** Fig. 38.1 (not drawn to scale) below shows an instant where three forces are acting on a moving boat on a still lake. Two forces acting on the boat, 80.0 N and *F*, are perpendicular to each other. In addition, there is a drag force of 40.0 N acting on the boat by the water, in the opposite direction of the motion and acceleration of the boat. The mass of the boat is 100.0 kg.

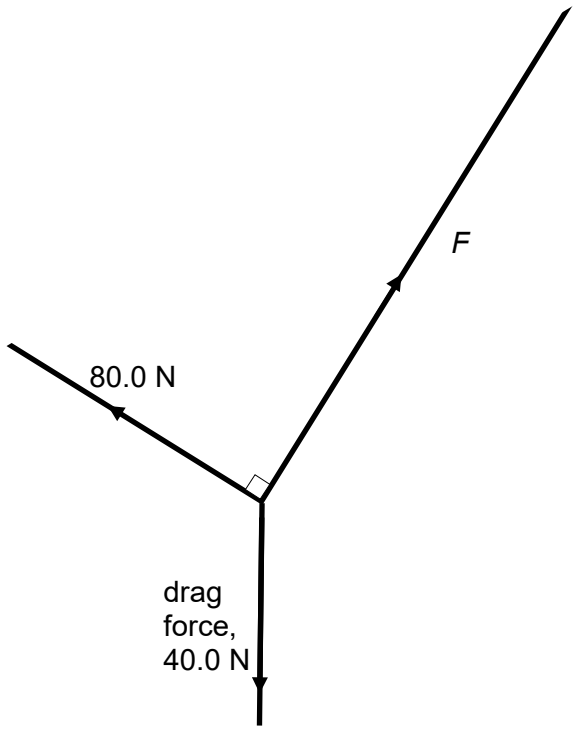



**Fig. 38.1**

**(a)** Given that the acceleration of the boat is 2.00 m $s^{-2}$ at this instant, calculate the resultant force acting on the boat.

resultant force = ..... [1]

**(b)** Hence or otherwise, calculate the magnitude of the unknown pulling force, *F*.

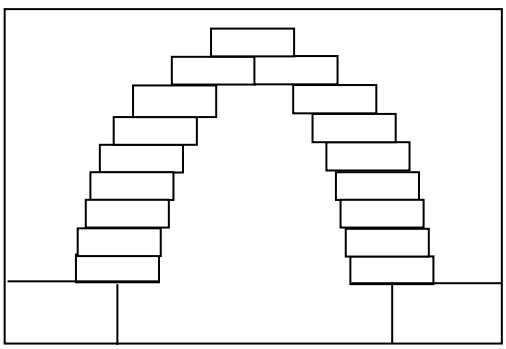
magnitude of unknown force, *F* = ..... [3]

**(c)** Identify the force that forms an action-reaction pair with the drag force acting on the boat by the water.

..... [1]

**39** Similar bricks are stacked on top of one another to form a corbel arch, in a way that part of each brick extends beyond the one beneath. This stacking arrangement allows the brick just on top to be placed in a position that is just about to topple.

Fig. 39.1 shows the cross-sectional view of the stacked bricks used to form a corbel arch.



corbel arch

**Fig. 39.1**

**(a)** An uniform brick A of weight 0.50 N and length 0.12 m is placed on a wooden beam, as shown in Fig. 39.2. The wooden beam is kept horizontal throughout.

The brick is placed on top of a uniform wooden beam of weight 2.0 N and length 0.30 m. The position of the brick is adjusted until it is just about to topple. The beam is pivoted at the left edge and is connected to a cable 0.20 m from this edge.

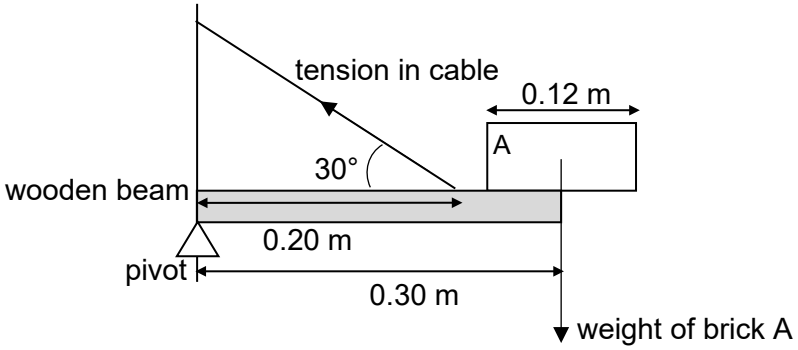



**Fig. 39.2**

Calculate the magnitude of the tension in the cable.

tension = ..... [2]

***b)** The position of brick A is now shifted closer towards the pivot. A second brick B is added on top of brick A, and a third brick C is placed on top of brick B.

Fig. 39.3 shows the cross-sectional view of all 3 identical bricks on the wooden beam.

The position of all 3 bricks are now adjusted until they are just about to topple. The wooden beam is kept horizontal throughout.

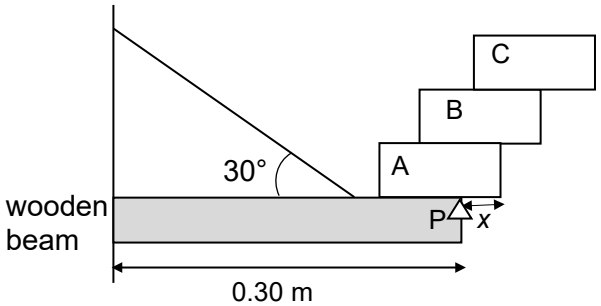



**Fig. 39.3**

***i)** By considering all 3 bricks as one object, hence or otherwise, prove that the largest equilibrium extension where the 3 bricks are just about to topple occurs when $x$ = 0.020 m. [2]

***ii)** Hence, or otherwise, create a general expression in terms of $n$ bricks to calculate the maximum total distance $D$ from the right edge of the beam to the right edge of the $n^{th}$ brick, as shown in Fig. 39.4.
Assume the bricks remain stable with this stacking arrangement.

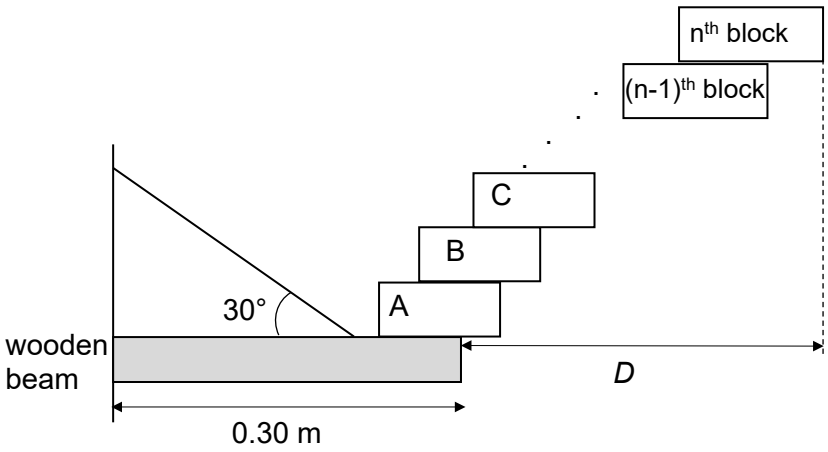



**Fig. 39.4**

general formula = ..... [1]

**40** Fig. 40.1 shows the dam and reservoir of a hydroelectric power station.

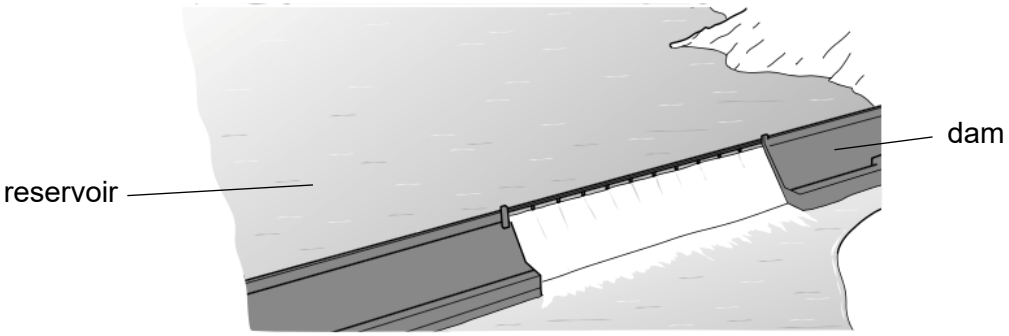



**Fig. 40.1**

A hydroelectric power station uses a renewable energy source by collecting water in a reservoir and releasing this water by opening the gates. The water will then flow and turn the turbine to generate electrical energy.

**(a)** When the power station operates at full capacity, the electrical power output is $6.8 \times 10^9$ W.

**(i)** Calculate the total electrical energy output of the power station if it operates at full capacity for 30 days.

total electrical energy output = ..... [2]

**(ii)** Suggest why, in practice, the power station does not operate at full capacity throughout these 30 days.

.....

..... [1]

**(b)** The electrical energy generated from the hydroelectric power station is used to power up factories and households. One such example of electrical energy usage in households is the air-conditioners unit system. This system comprises four air-conditioner units connected to the outdoor compressor unit as shown in Fig. 40.2.

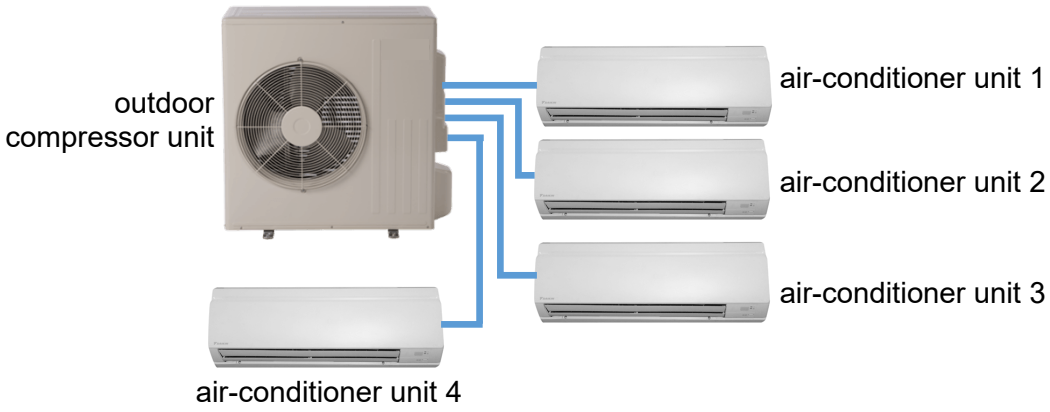



**Fig. 40.2**

Each air-conditioner unit has a power rating of 240 V, 1000 W and is connected to the power supply.

**(i)** State what is meant by the term power rating of 240 V, 1000 W.

.....

..... [1]

**(ii)** The system is operating at 100 % efficiency and the cost of energy usage is \$0.20 per unit, calculate the cost of electrical energy for four air-conditioner units being switched on for 8.0 hours per day for a period of 30 days.

electrical energy usage = ..... [2]

**(iii)** Fig. 40.3 shows a typical home circuitry system of a household where various safety features are installed.

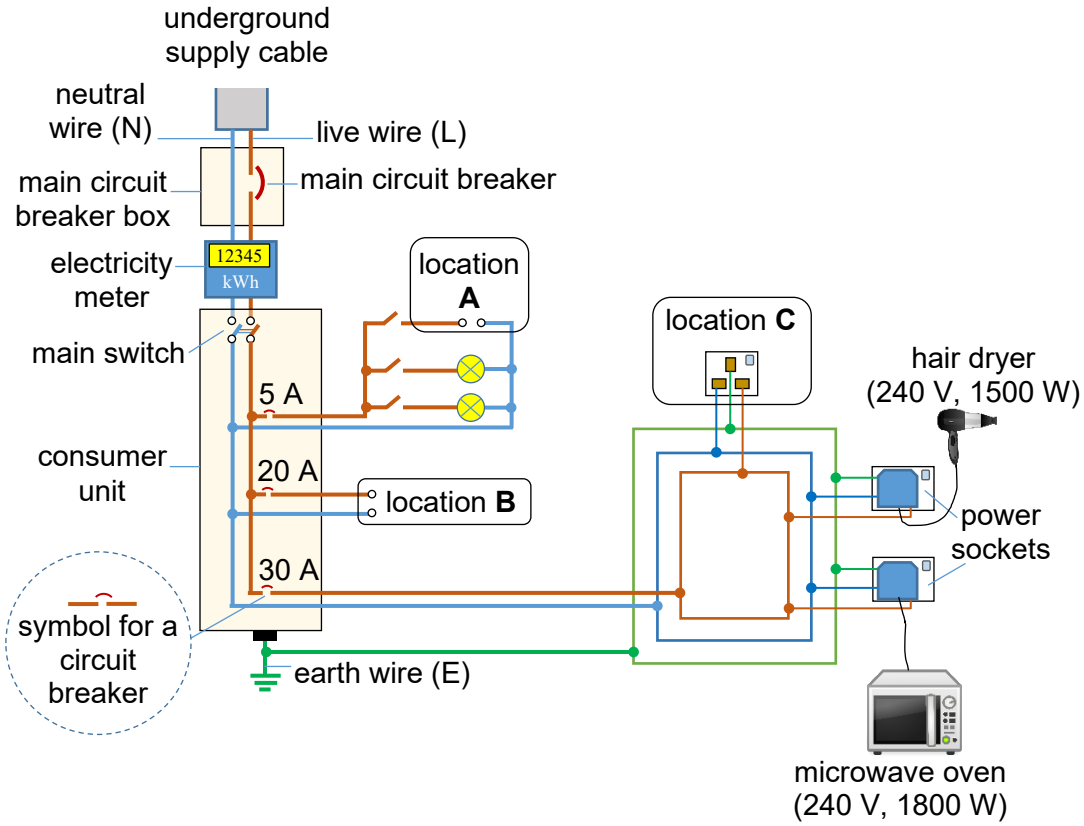



**Fig. 40.3**

Suggest which desired locations **A**, **B** or **C** should the four high powered air-conditioners unit system be connected to the home circuitry system for safe usage of the 4 air-conditioners units.
Explain your answer.

.....

..... [1]

**41** **(a)** Define the frequency of a wave.

..... [1]

**(b)** Indoor wifi signals, travel at a speed of 3.0 x $10^8$ m $s^{-1}$, use radio waves as shown in Fig. 41.1. A digital device placed at a distance of 36 complete wavelengths away from a router, transmits such wifi signals directly to the router.

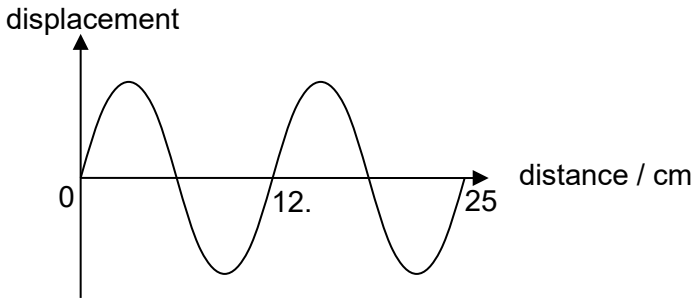



**Fig. 41.1**

Calculate the time taken for the wave to reach the router from the digital device.

time taken = ..... [2]

**42** A sample of pure water in gaseous state cools from 110 °C to –20 °C.

**(a)** On Fig. 42.1, draw the graph of temperature *T* against time *t* as the sample cools from 110 °C to –20 °C. The temperature of the surrounding medium is kept constant. Label with suitable values of temperature. [2]

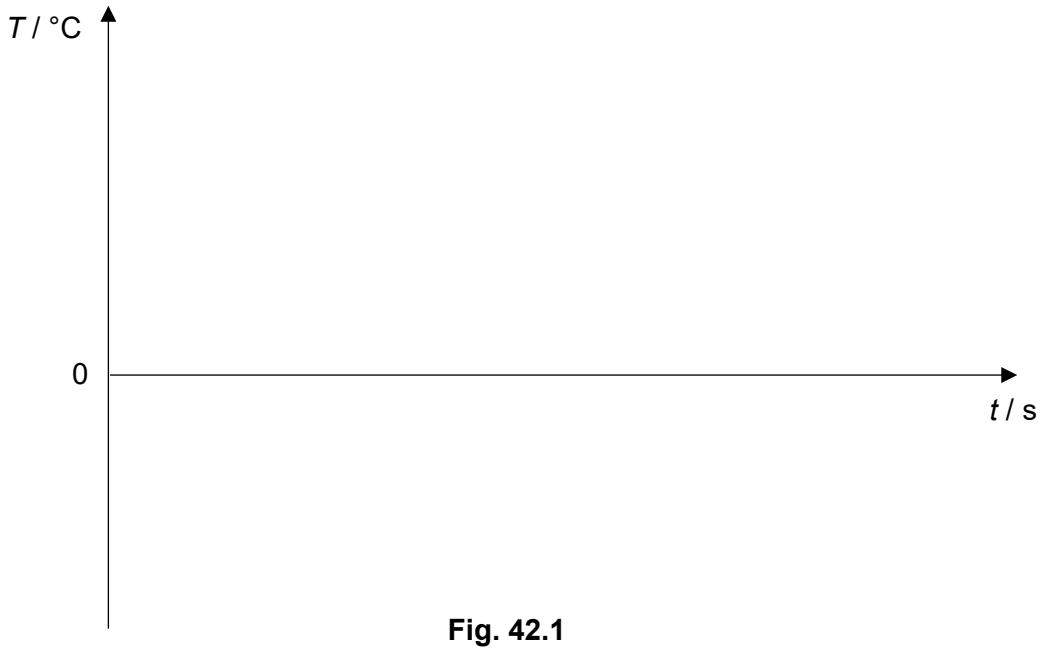



**Fig. 42.1**

**(b)** Describe what happens, in terms of changes involving the motion of the molecules, as the sample cools from –5 °C to –15 °C.

.....

..... [1]

**43** Two vertical plates P and Q are arranged as shown in Fig. 43.1. Plates P and Q are positively charged and negatively charged respectively.


**Fig. 43.1**

**(a)** Draw the electric field pattern between plates P and Q in Fig. 43.1. [2]

**(b)** Fig. 43.2 shows the plates P and Q as part of an electrostatic precipitator system that is used to remove dust and smoke particles as the industrial exhaust fumes travel upwards and pass through the positively-charged fine wire mesh between the plates.

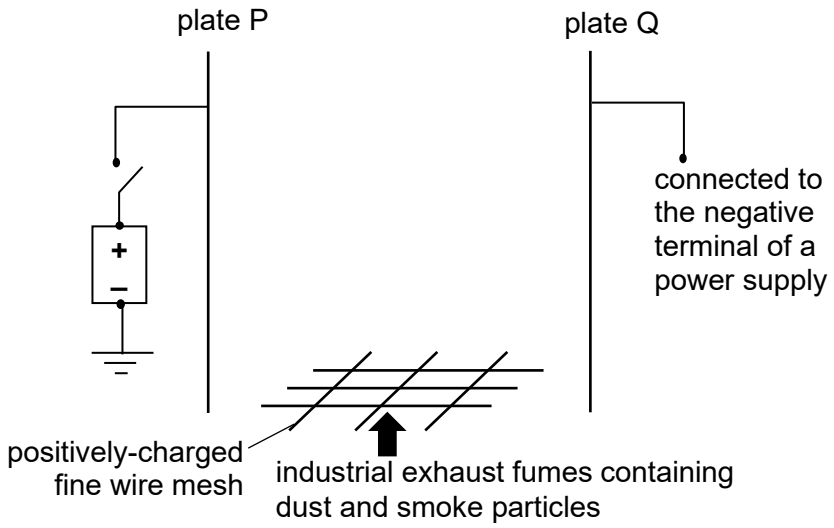



**Fig. 43.2**

Describe and explain what happens to the dust and smoke particles as they pass through the positively-charged fine wire mesh between the plates.

.....

..... [2]

**44** Fig. 44.1 shows a circuit used to detect changes in levels of light. A fixed resistor is connected in series with a 6.0 V power supply and a light-dependent resistor (LDR).

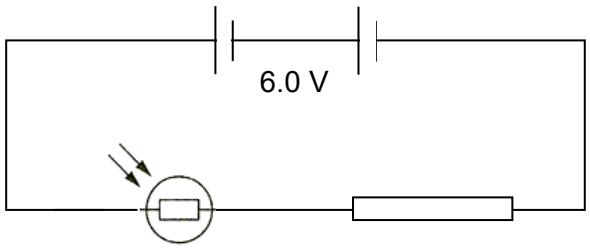



**Fig. 44.1**

**(a)** The fixed resistor is a solid cylinder of length 35.0 mm, radius 0.030 mm, and is made from a material of resistivity $5.0 \times 10^{-4}$ Ω m.
Calculate the resistance of the resistor.

resistance = ..... [2]

**(b)** Fill in the boxes with one of the following phrases 'increases', 'no change' or 'decreases'. Each phrase may be used more than once. [2]

| | current through fixed resistor | potential difference across fixed resistor |
|---|---|---|
| the level of light on the LDR decreases | | |

**(c)** The LDR in Fig. 44.1 has a resistance of 2.4 kΩ in dim light and 200 Ω in bright light. It is desired that the potential difference across the fixed resistor should range from 1.5 V to 4.8 V. To achieve this, the original fixed resistor in **(a)** is replaced with a new fixed resistor.

Calculate the resistance of this new resistor.

resistance = ..... [2]

**45** Fig. 45.1 shows the relationship between the current *I* in conductor X and the potential difference *V* across it. When *V* is less than 1.60 V, the current is negligible.

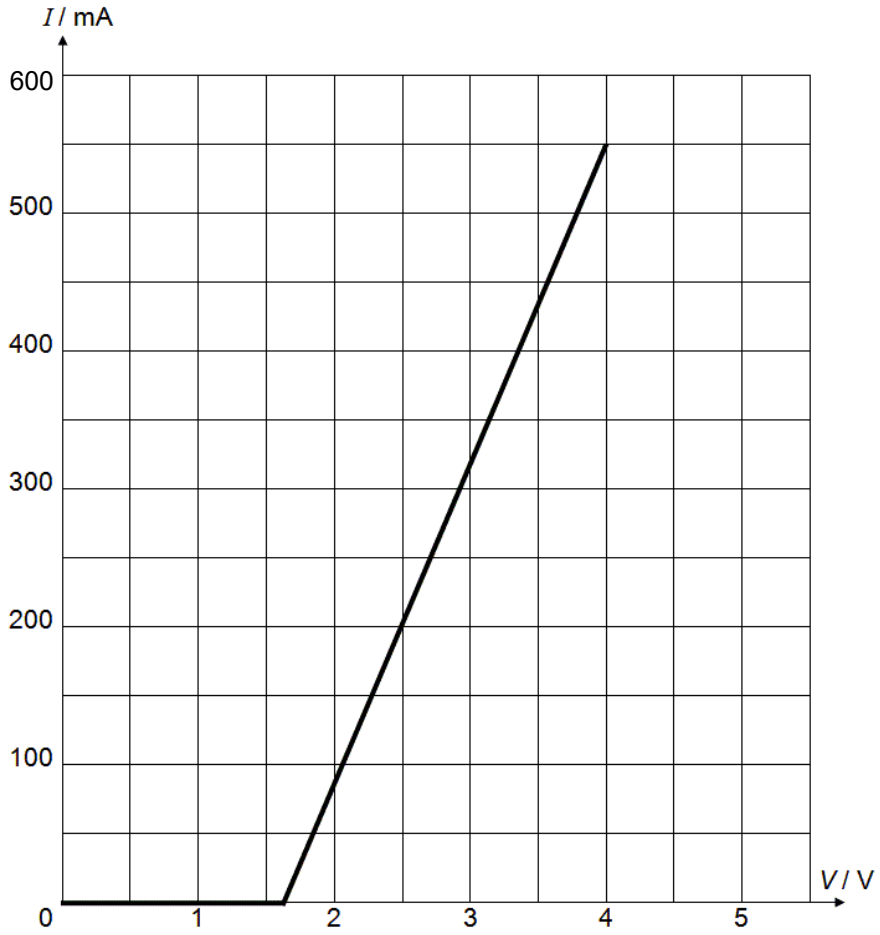



**Fig. 45.1**

**(a)** On Fig. 45.2, sketch how the resistance $R$ of conductor X varies with the potential difference $V$ across it, from $V$ = 2.50 V to 4.00 V. Label with suitable values of $R$. [2]


**Fig. 45.2**

**(b)** Fig. 45.3 shows conductor X connected in a circuit with a battery of e.m.f. 2.5 V and two other fixed resistors.

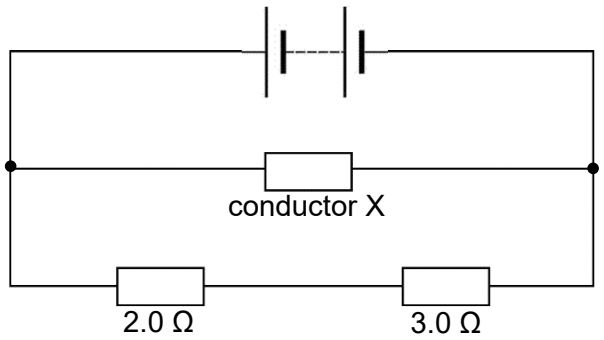



**Fig. 45.3**

Calculate the effective resistance of the circuit.

effective resistance = ..... [2]

**46** Fig. 46.1 shows a door sensor using a reed switch.

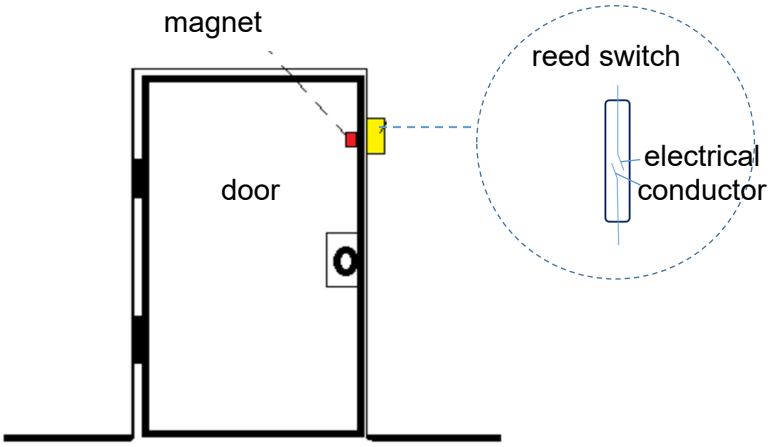



**Fig. 46.1**

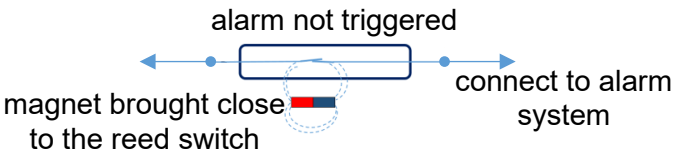



**Fig. 46.2**

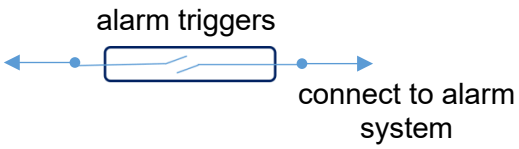



**Fig. 46.3**

When the door is closed, the magnet is brought close to the reed switch and magnetise the electrical conductor to close the reed switch. The alarm will not be triggered when the reed switch is closed as shown in Fig. 46.2.

However, when the door opens, the magnet is brought away from the reed switch which causes the electrical conductor to lose its induced magnetism and this opens the circuit. The alarm will then be triggered as shown in Fig. 46.3.

**(a)** Explain why the ends of the reed switch come in contact when the magnet is brought close to the reed switch in Fig. 46.2.

.....

..... [2]

**(b)** There was a device fault of a particular brand of the door sensor where users reported that there was a significant time lag to trigger the alarm when the door is opened. From the investigation, the company found that the reed switch is working normally however, the material used to manufacture the electrical conductor was incorrect.

Suggest and explain a correct material needed to manufacture this electrical conductor.

.....

..... [2]

**47** Fig. 47.1 shows a simple d.c. electric motor.

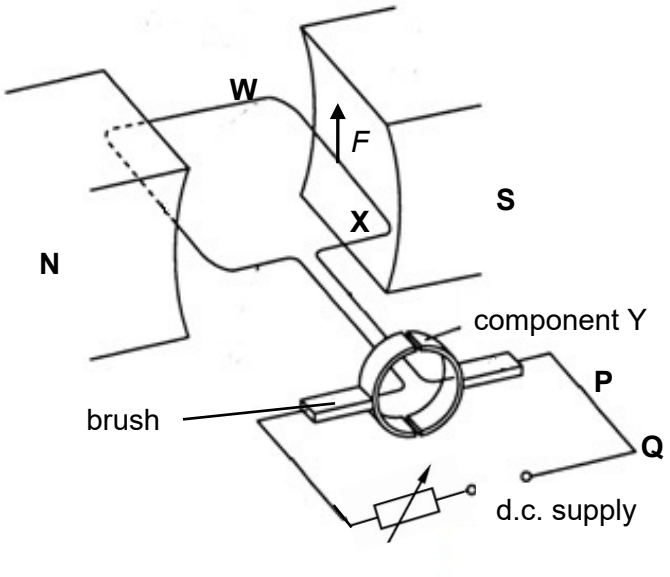



**Fig. 47.1**

**(a)** In order to produce a continuous rotation of the coil, component Y is needed.

State the name and function of the component Y.

.....

..... [2]

**(b)** The permanent magnets exert an upwards force *F* on the right side of the coil at the instant shown in Fig. 47.1.

On Fig. 47.1, indicate with an arrow the direction of the current in section **PQ** of the circuit. [1]

**(c)** Explain the purpose of the variable resistor shown in Fig. 47.1.

.....

..... [2]

**(d)** On Fig. 47.2, draw the graph of force *F* against time, from the instant shown in Fig. 47.1. The period of revolution is indicated as *T*. [1]

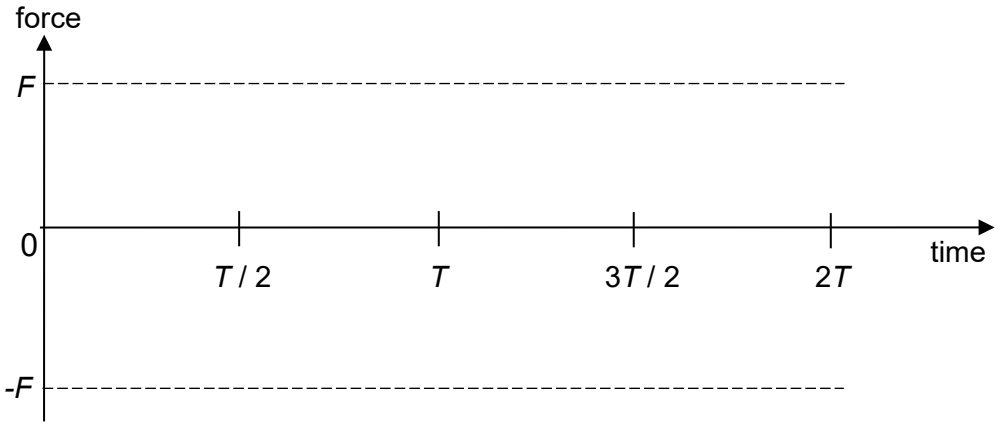



**Fig. 47.2**

**48** Fig. 48.1 shows a uniform magnetic field directed into the page. A metal bar OP rotates clockwise with uniform speed about O in a plane perpendicular to the field. The motion induces an electromotive force (e.m.f.) across the bar.

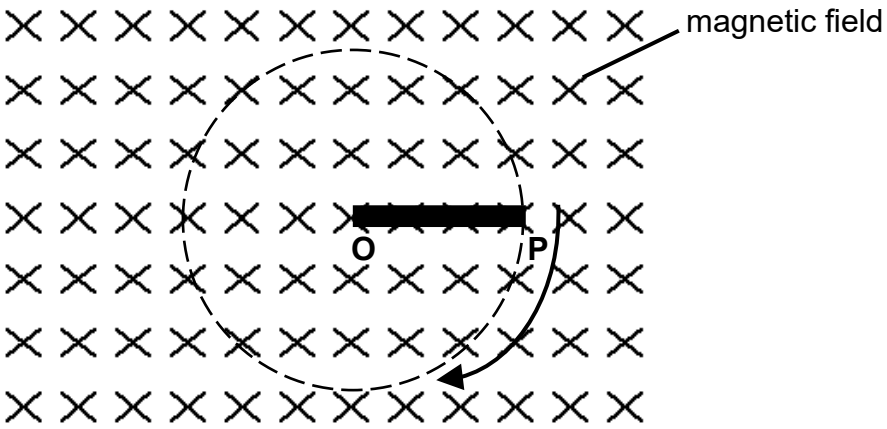



**Fig. 48.1**

**(a)** On Fig. 48.1, indicate with an arrow, the direction of the movement of electrons in the bar due to the induced e.m.f. [1]

**(b)** A student states that the magnitude of the induced e.m.f. remains constant as the bar completes one revolution.

Comment on the student's statement.

.....

..... [1]

**(c)** Without making changes to the bar, state two ways of inducing a greater e.m.f. in the bar.

.....

..... [2]

**49** Heating is the process of transferring thermal energy from place to place as a result of a difference in temperature.

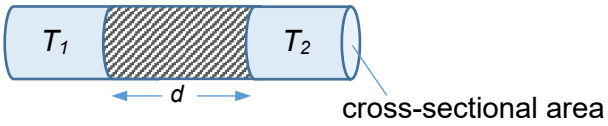



**Fig. 49.1**

Heat conduction can be examined using the arrangement shown in Fig. 49.1, where heat travels along a metal rod from a hot region at temperature $T_1$ to a cool region at temperature $T_2$. If heat is conducted only along this rod, then the rate of heat flow is proportional to the temperature gradient, which is:

$$\text{temperature gradient} = \frac{T_1 - T_2}{d}$$

where $d$ is the length of the rod. The greater the difference in temperature, the greater the rate of heat flow.
The rate also depends upon the cross-sectional area of the rod. A thicker rod will transfer more heat in a given time, so the rate of heat flow, $\phi$ can be shown as

$$\phi = k \times A \times \frac{T_1 - T_2}{d}$$

where $A$ is the cross-sectional area of the rod and $k$ refers to the thermal conductivity of the material. The thermal conductivity $k$ is measured in W $m^{-1}$ $K^{-1}$.

**(a)** Determine the S.I. base units for the rate of heat flow $\phi$.

S.I. base units of $\phi$ = ..... [2]

**(b)** Fig. 49.2 and Fig. 49.3 show the information of a metal rod.

| | |
|---|---|
| cross-sectional area *A* | 5.2 $cm^2$ |
| distance *d* | 0.12 m |
| temperature $T_1$ | 330 K |
| temperature $T_2$ | 303 K |

**Fig. 49.2**

| material | thermal conductivity / W $m^{-1}$ $K^{-1}$ |
|---|---|
| aluminium | 237 |
| brass | 125 |
| bronze | 50 |
| copper | 398 |

**Fig. 49.3**

**(i)** Calculate the rate of heat flow of the metal rod if brass is used.

rate of heat flow = ..... [2]

**(ii)** State one assumption in your calculation in **(b)(i)**.

..... [1]

**(iii)** Based on Fig. 49.2 and Fig. 49.3, state and explain the choice of material for the metal rod so that the rate of heat flow is the greatest.

.....

..... [1]

**(c)** One application of heat flow in metal rods can be seen in heat pipes shown in Fig. 49.4. It is an enclosed pipe containing a liquid. Different liquids are used, depending on the temperature range required. The bottom end is in contact with the heat source and the top end is kept cool. The heat supplied at the bottom of the pipe vaporises the liquid, and the hot vapour rises up the pipe. When it reaches the cold end it condenses into a liquid, which flows back down the wall of the pipe.

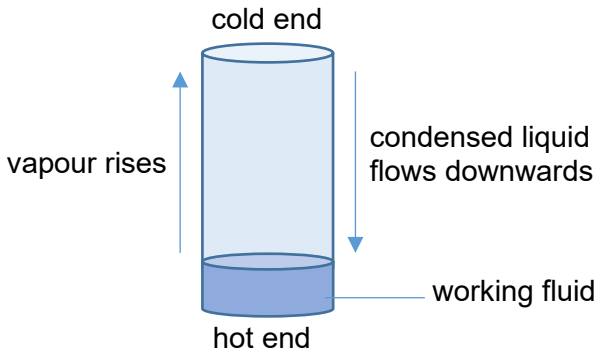



**Fig. 49.4**

Turning the vapour into liquid considerably reduces its volume, which aids the flow of vapour from the hot end. Not only does the vapour carry heat up the pipe due to its temperature, but it also carries the latent heat of vaporisation, which is given off when the vapour condenses. This constitutes a very effective means of transporting heat as the vapour, carrying the latent heat, rises up the pipe much more quickly than conduction occurs along a metal rod.

**(i)** Define latent heat.

.....

..... [1]

**(ii)** The working fluid in this heat pipe is pentane with the following specifications as shown in Fig. 49.5.

| | |
|---|---|
| mass of pentane | 1.4 kg |
| initial temperature of liquid pentane | 303 K |
| boiling point of liquid pentane | 309 K |
| specific heat capacity of liquid pentane | 2330 J $kg^{-1}$ $K^{-1}$ |
| specific heat capacity of gaseous pentane | 1660 J $kg^{-1}$ $K^{-1}$ |
| specific latent heat of vaporisation of pentane | 3.575 X $10^5$ J $kg^{-1}$ |

**Fig. 49.5**

Calculate the amount of thermal energy absorbed by pentane at the hot end of the pipe if its temperature is at 330 K and the cold end is at a temperature 303 K.

amount of thermal energy = ..... [3]

**End of Section B**