PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



EXAM QUESTION PACK

TOPIC 3: ELECTRIC CIRCUITS

ELECTRICAL QUANTITIES AND COMPONENTS

SCORE	PERCENTAGE
/715	%

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Q1.

A defibrillator is an electrical device designed to deliver a brief electrical signal to restore a normal rhythm to the heart. Electrodes are attached to the chest of a patient and a charged capacitor is discharged through the chest cavity.

In one defibrillator a 56 μF capacitor is charged by a potential difference of 2500 V.
During the discharge of the capacitor the resistance between the electrodes is 45 Ω.

Show that the time taken for 99% of the discharge to take place is about 12 ms and hence calculate the average current delivered by the defibrillator during this period.

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Average current = ...

(Total for question = 6 marks)

Q2.

A magician did a trick which he claimed was the most dangerous ever. He positioned himself midway between two charged spheres which were separated by a distance of about two metres. Each sphere was charged to a potential that would cause ionisation at a distance of one metre. He wore a protective suit of chain mail and a helmet consisting of a metal cage. The protective suit and helmet were earthed to a potential of 0 V.



A scientist said "there is no danger in this and I would happily do it tomorrow".

Explain whether this statement is justified.

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(Total for question = 3 marks)

Q3.

Some mobile phones have a capacitor touch screen made up of a sheet of glass with a thin metallic coating. The screen is charged and when it is touched some of the charge is transferred to the user. This causes a drop in electrical potential at the point where the screen is touched.

A capacitor is charged by connecting it across a battery and then discharged through a resistor. In the case of the touch screen the user provides a discharge resistance of about 900 Ω.

Explain how the capacitor discharges.

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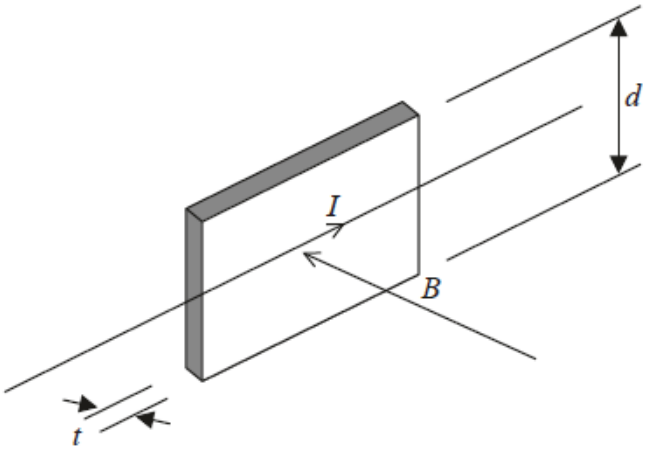
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(Total for question = 3 marks)

Q4.

Tiny sensors in smartphones could be used to determine the position of the phone on the Earth's surface by measuring the Earth's magnetic flux density.

A current *I* and a magnetic field of flux density *B* are applied to a slice of semiconductor as shown. The slice has thickness *t* and depth *d*.



Electrons collect at the top edge of the slice and the bottom edge becomes positively charged. As a result a potential difference known as a Hall voltage V_{HALL} develops.

Show that the units are the same on each side of the equation

$$V_{HALL} = \frac{BI}{nte}$$

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(Total for question = 3 marks)

Q5.

The photograph shows a statue of Buddha in Sri Lanka, which is protected by a lightning conductor.



© Valery Shanin/123RF

During a storm, a potential difference of 2.7 MV was generated between a cloud and the top of the lightning conductor on the statue. A flash of lightning passed between the cloud and the lightning conductor, producing a current of 25 kA for a time of 7.5 ms.

Calculate the energy transferred by the lightning strike.

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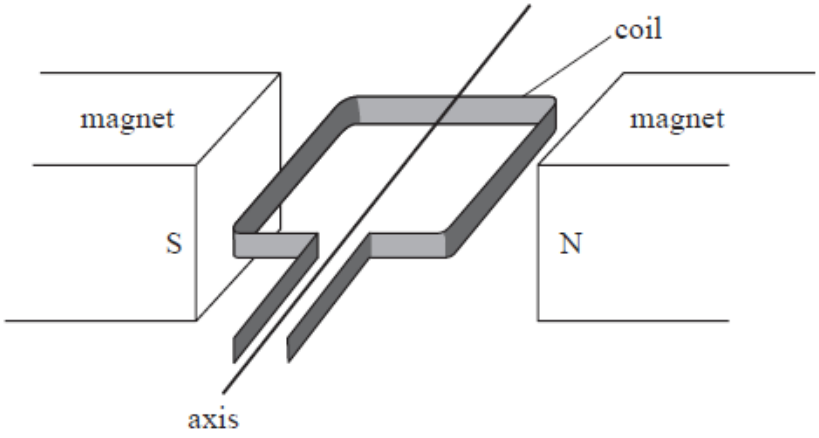
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Energy transferred = ...

(Total for question = 3 marks)

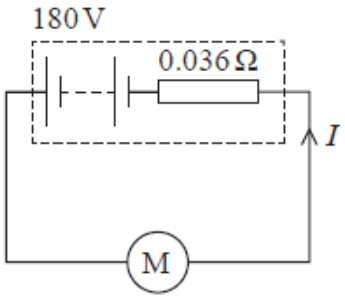
Q6.

Hybrid electric vehicles (HEV) use the same device both as a generator to charge the car battery and as an electric motor to support the propulsion system. A simplified diagram of the device is shown. The coil can rotate freely around the axis.



The circuit diagram shows a car battery connected to an electric motor for a HEV.

The battery has an electromotive force (e.m.f.) 180 V and internal resistance 0.036 Ω.



The motor has a maximum power of 88 kW.

(i) Show that the current I drawn by the electric motor when operating at this power would be given by the equation

$$0.036I^2 - 180I + 88\,000 = 0$$

(3)

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(ii) Solving the equation above produces an answer of $I = 550$ A. At maximum power, the car can accelerate from rest to sixty miles per hour in under 7 s.

The maximum charge capacity of the battery within this HEV is 6.1 amp-hour.

Deduce whether the battery could maintain this current for up to 7 s.

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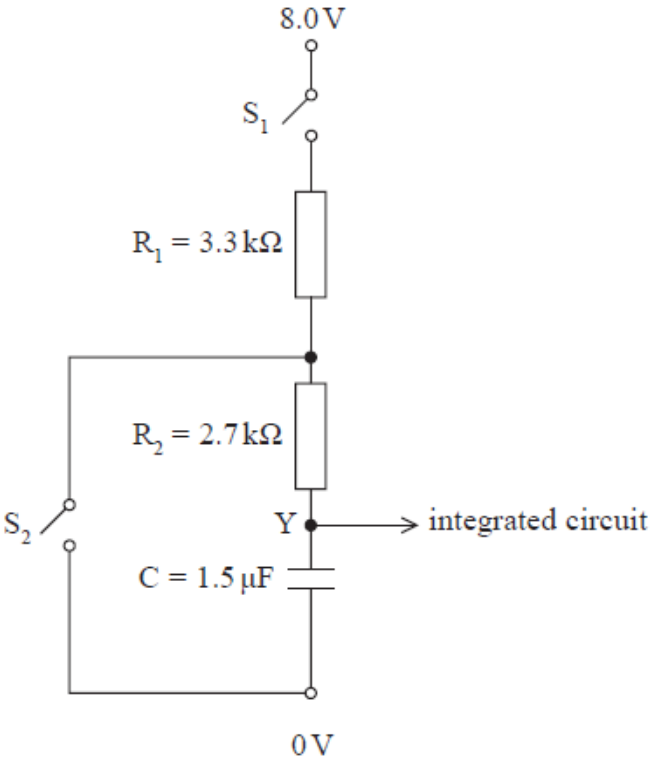
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(Total for question = 5 marks)

Q7.

The properties of capacitors make them useful in timing circuits.

The following circuit is used to provide an input Y to an integrated circuit.



When the potential at Y is 2.0 V, the switch S_2 is opened.

Calculate the power dissipated by the resistance R_1 when the potential at Y is 2.0 V.

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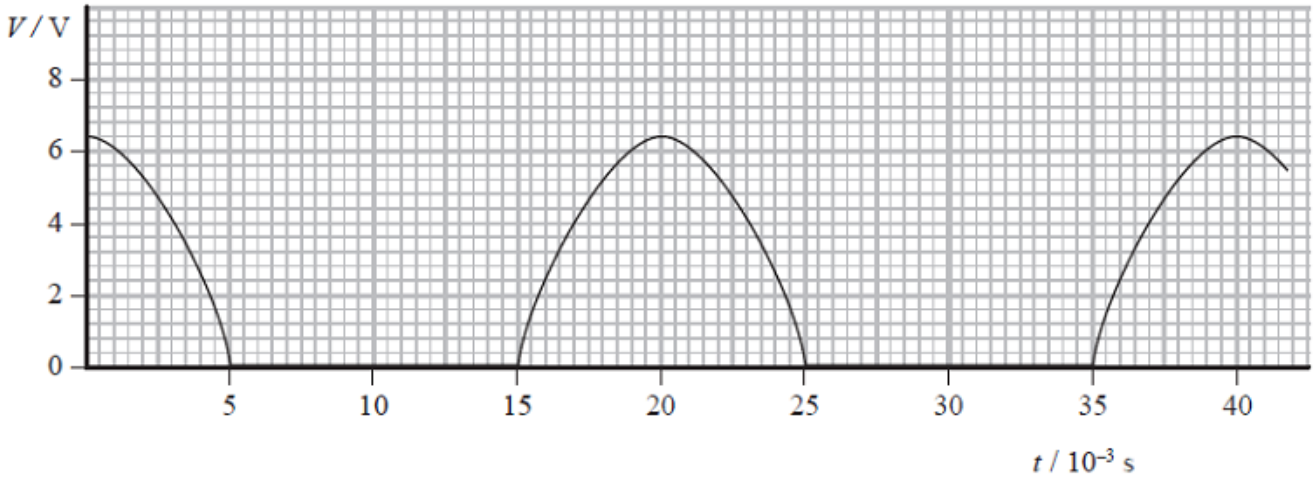
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Power dissipated = ...

(Total for question = 3 marks)

Q8.

The graph shows how the output *V* from the terminals of a power supply labelled d.c. (direct current) varies with time *t*. This type of supply will not allow current to flow backwards through it.



(a) A student connects a capacitor across the terminals of this power supply in order to try to produce a constant voltage.

Suggest how this produces a constant voltage.

(2)

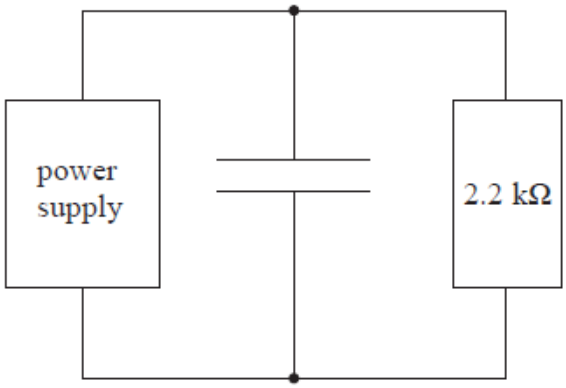
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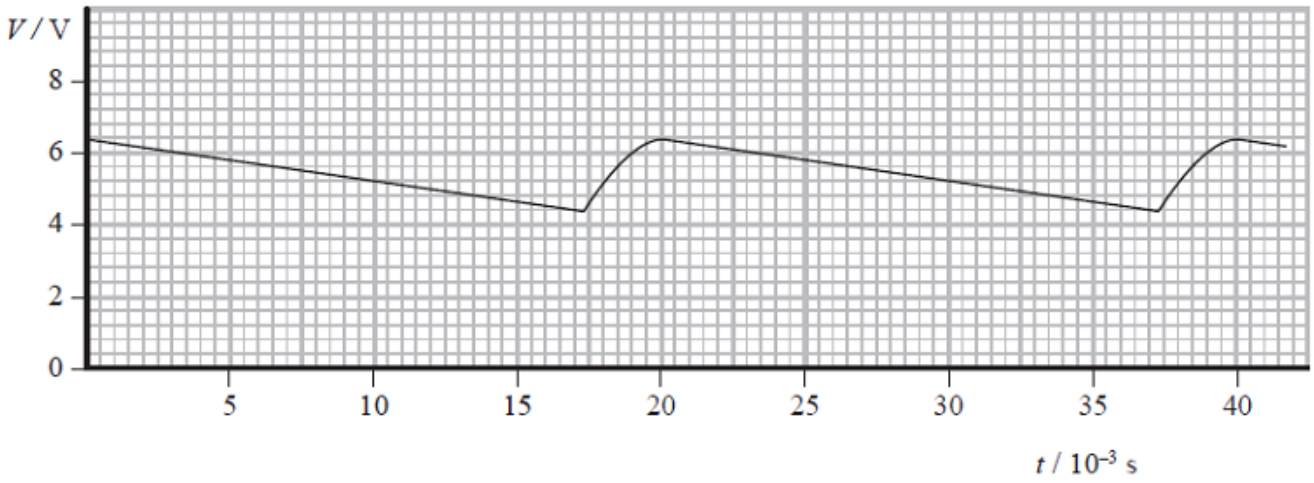
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(b) The student then connects a resistor across the capacitor as shown.



The graph shows the variation of the potential difference V across the resistor with time t.



(i) Estimate the average potential difference across the resistor.

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Average potential difference = ...

(ii) Calculate the average current in the resistor.

(2)

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Average current = ...

(iii) Determine the time in each cycle for which the capacitor discharges through the resistor.

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Discharge time = ...

(iv) Calculate the charge passing through the resistor during one discharge of the capacitor and hence determine the capacitance of the capacitor.

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Charge = ...

Capacitance = ...

(c) The student wants to produce a potential difference across the same resistor that has less variation in magnitude.
State, with a reason, what the student could do to achieve this.

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(Total for question = 12 marks)

Q1.

Our understanding of the atom has developed over time, from early models in which atoms were considered to be hard incompressible spheres, through to the nuclear model of the atom and the ladder model in which electrons exist in a discrete number of allowed energy states.

The nuclear model of the atom was established following a series of experiments in which alpha particles were directed at thin gold foil.

(i) An alpha particle approaching a gold nucleus, $^{197}_{79}Au$, head-on will be brought to rest and returned along its original path.

Calculate the minimum distance between the alpha particle and the nucleus for alpha particles of energy of 5.5 MeV.

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Minimum distance = ...

(ii) It is observed that electrons, with energy of 5.5 keV, are diffracted as they pass through the thin gold foil.

Explain a conclusion about the electrons that can be made from this observation.

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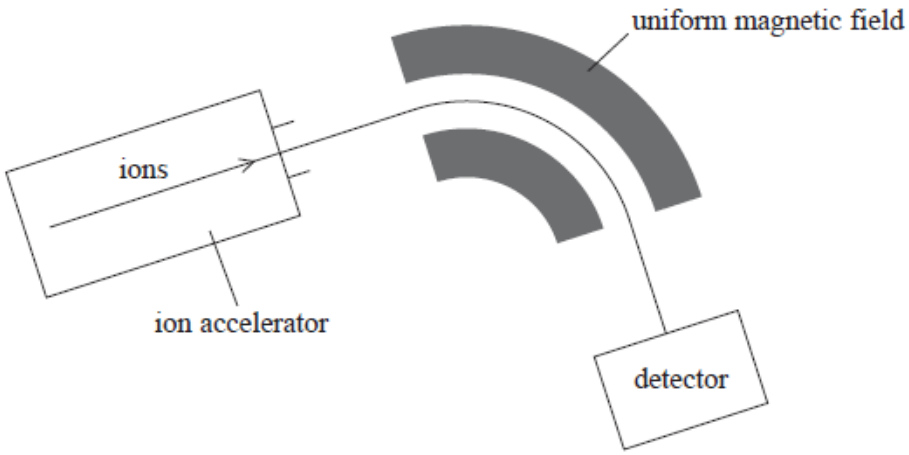
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(Total for question = 7 marks)

Q2.

Mass spectrometry is a technique used to separate ions based on their charge to mass ratio.

The atoms in a sample are ionised and then accelerated and formed into a fine beam. This beam is passed into a region of uniform magnetic field and the ions are deflected by different amounts according to their mass.



Analysis of mass spectrometer data shows that chlorine exists in nature as two isotopes, chlorine-35 and chlorine-37.

In a mass spectrometer, chlorine-35 ions are accelerated through a potential difference of 8.50 kV to produce an ion beam.

Show that the speed of singly ionised chlorine-35 atoms is about 2.2×10^5 m s^{-1}.

mass of an ion of chlorine-35 = 34.97 u

(4)

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(Total for question = 4 marks)

Q3.

A rechargeable cell stores a maximum energy of 4200 J. The cell has an e.m.f. of 1.5 V and after 2.0 hours use the cell is completely discharged.

Assuming the e.m.f. stays constant, the charge passing through the cell during this time is

☒ **A** 1400 C

☒ **B** 2800 C

☒ **C** 5600 C

☒ **D** 6300 C

(Total for question = 1 mark)

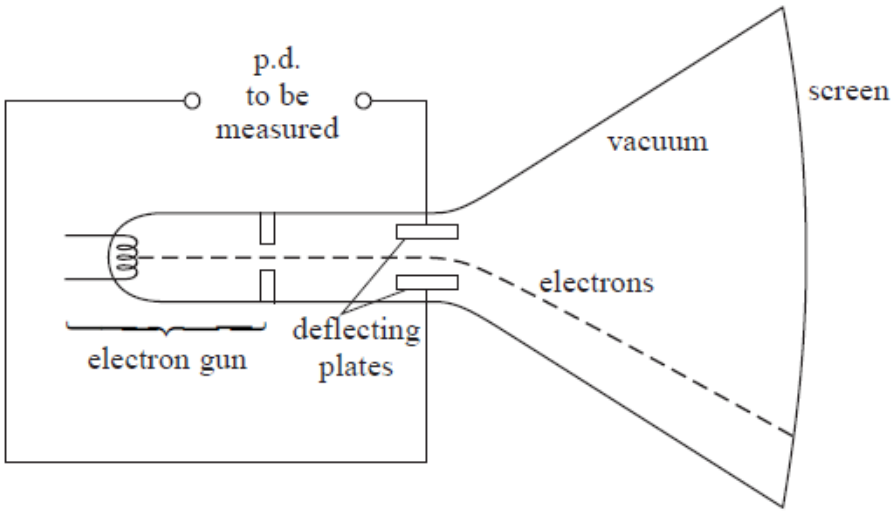
Q4.

Cathode ray tubes are used in oscilloscopes.



The diagram shows a simplified cathode ray tube that can be used to determine the magnitude and polarity of a potential difference (p.d.).

The cathode ray tube consists of an electron gun, a pair of deflecting plates and a fluorescent screen.



(a) The electron gun includes a filament. When this filament is heated, electrons are released and are accelerated by a p.d. of 1.5 kV to form an electron beam.

(i) Name the process by which electrons are released from the heated filament.

(1)

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(ii) Show that the maximum velocity of the electrons is about 2×10^7 m s^{-1}.

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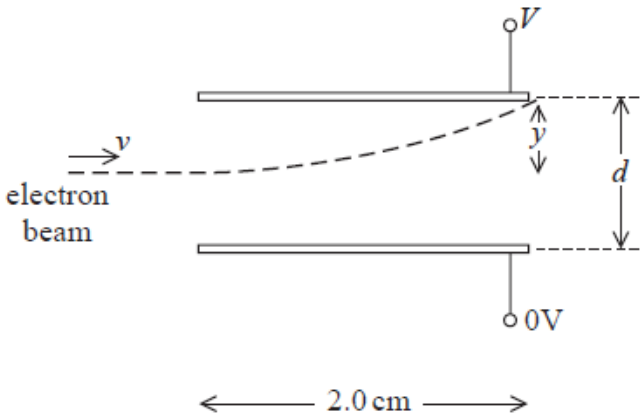
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(b) The electron beam then enters a uniform electric field between the two parallel horizontal deflecting plates. The magnitude and direction of the deflection is determined by the p.d. *V* that is applied across the plates.

The diagram shows one possible path of the electron beam as it passes between the plates.



(i) Show that the acceleration of an electron, of mass *m* and charge *Q*, is given by

$\frac{VQ}{dm}$

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(ii) Calculate the magnitude of the vertical deflection y of the beam as it leaves the plates.

V = 50 V
d = 0.01 m

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y = ...

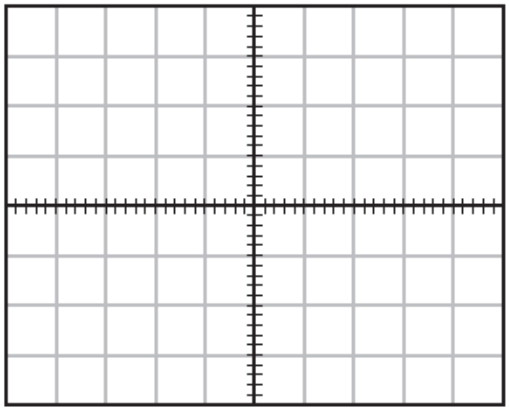
(c) A laboratory oscilloscope with the time base turned off operates in the same way as this simplified cathode ray tube. A student uses an oscilloscope in this way to monitor an alternating p.d. of 53 V_{rms}

On the grid, draw the trace that would be seen on the screen.

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1 square = 25 V

(Total for question = 14 marks)

Q5.

A volt can be defined as a

(1)

☒ **A** coulomb per joule.

☒ **B** coulomb per second.

☒ **C** joule per coulomb.

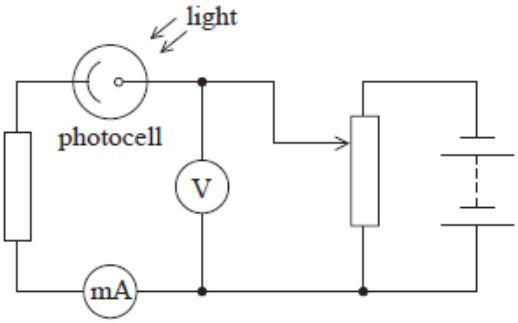
☒ **D** joule per second.

(Total for question = 1 mark)

Q6.

A student has been learning about the photoelectric effect.

The student sets up a circuit to investigate the photoelectric effect.



The student illuminates the photocell with light of known frequency f. A current is produced in the circuit due to the emitted electrons. He adjusts the potential difference, using a potential divider, until the reading on the milliammeter is zero and records the corresponding reading V_s on the voltmeter. He repeats this procedure for other frequencies of light.

When the reading on the milliammeter is zero the maximum kinetic energy of the emitted electrons is given by eV_s.

Explain how the student can use his results to determine a value for the Planck constant h using a graphical method.

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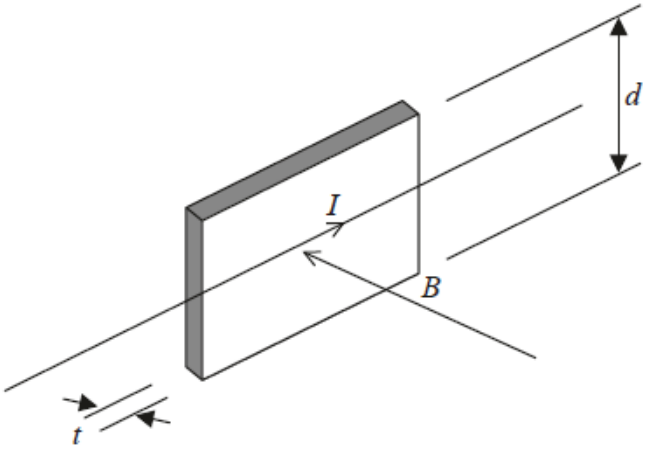
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(Total for question = 5 marks)

Q7.

Tiny sensors in smartphones could be used to determine the position of the phone on the Earth's surface by measuring the Earth's magnetic flux density.

A current I and a magnetic field of flux density B are applied to a slice of semiconductor as shown. The slice has thickness t and depth d.



Electrons collect at the top edge of the slice and the bottom edge becomes positively charged. As a result a potential difference known as a Hall voltage V_{HALL} develops.

Show that the units are the same on each side of the equation

$$V_{HALL} = \frac{BI}{nte}$$

(3)

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(Total for question = 3 marks)

Q8.

The photograph shows a statue of Buddha in Sri Lanka, which is protected by a lightning conductor.



© Valery Shanin/123RF

During a storm, a potential difference of 2.7 MV was generated between a cloud and the top of the lightning conductor on the statue. A flash of lightning passed between the cloud and the lightning conductor, producing a current of 25 kA for a time of 7.5 ms.

Calculate the energy transferred by the lightning strike.

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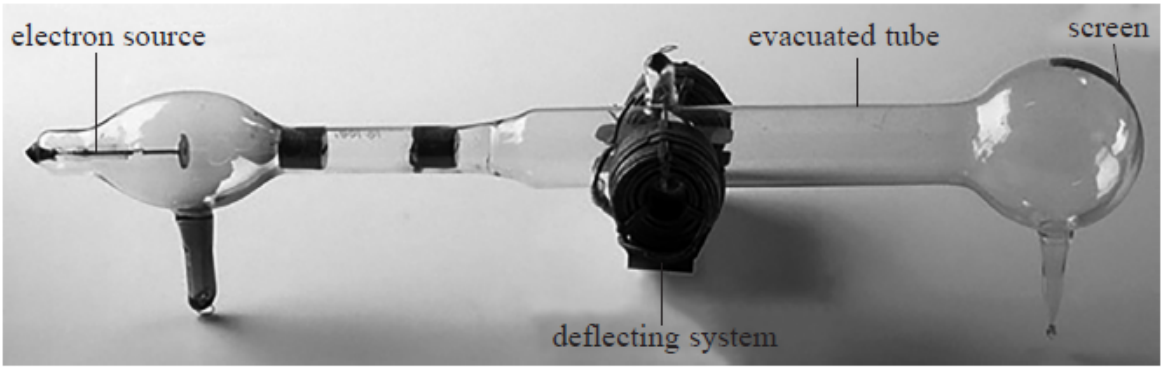
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Energy transferred = ...

(Total for question = 3 marks)

Q9.

At the end of the 19th century, J.J. Thompson used electric and magnetic fields to deflect beams of charged particles. A photograph of his apparatus is shown.



© Science Museum London

Electrons were accelerated through a potential difference to produce a beam of high-energy electrons. The beam was then deflected in perpendicular directions by the magnetic and electric fields. The final position of the beam on the screen was determined by the charge and mass of the electrons.

In a modern version of Thompson's experiment, a uniform electric field of electric field strength E is applied so that the electric and magnetic forces on the electrons are equal and in opposite directions.

(i) Show that for electrons to be undeflected their velocity must be given by

$$v = \frac{E}{B}$$

where B is the magnetic flux density of the magnetic field.

(2)

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(ii) The beam is produced by accelerating electrons through a potential difference of 250 V.

The electric field strength is 1.4×10^4 V m^{-1}. The magnetic flux density is 1.5×10^{-3} T.

Calculate the value of the specific charge e/m for the electron using this data.

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e/m = ...

(Total for question = 5 marks)

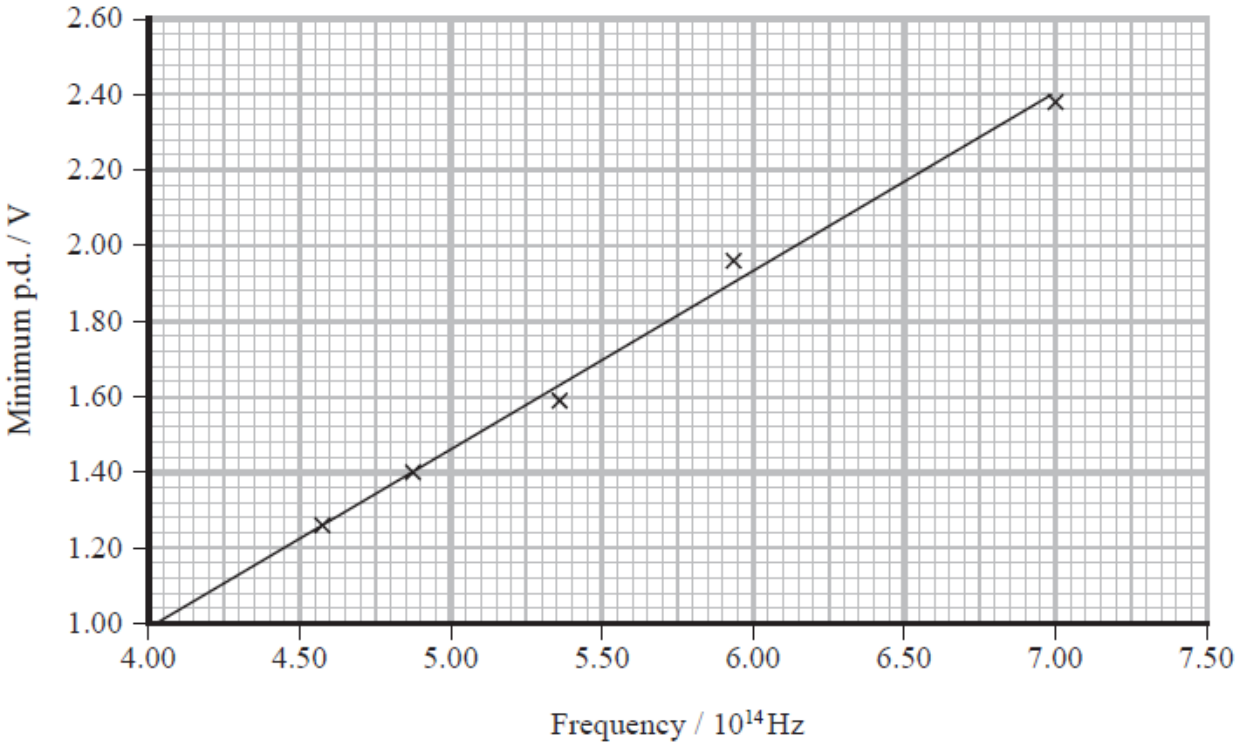
Q10.

The Planck constant can be determined in a school laboratory using light emitting diodes (LEDs).

An LED emits light when the potential difference (p.d.) across it is large enough to transfer sufficient energy to an electron to result in the emission of a photon.
The electron must have energy greater than or equal to the photon energy.

The minimum p.d. required to produce light from LEDs emitting different frequencies was measured by increasing the p.d. from zero until light was first seen.

The graph shows the results.



Determine the value of the Planck constant given by this graph.

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Value of Planck constant given by graph = ...

(Total for question = 4 marks)

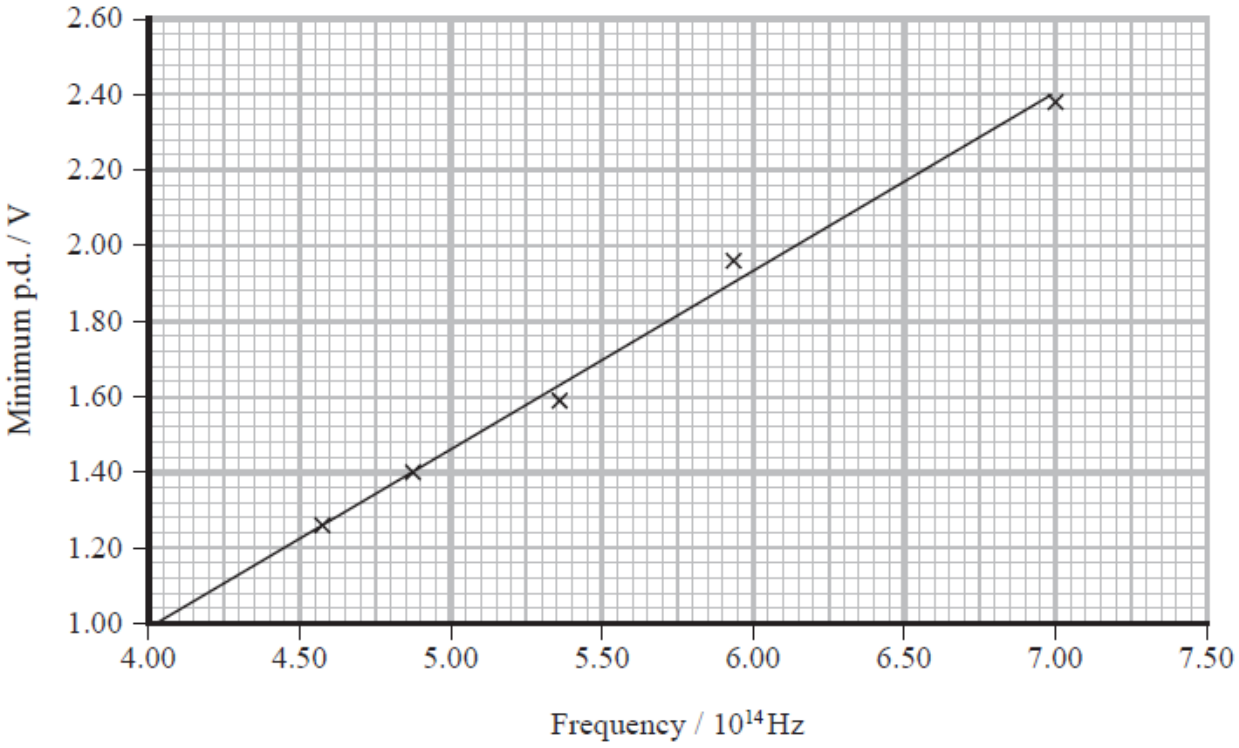
Q11.

The Planck constant can be determined in a school laboratory using light emitting diodes (LEDs).

An LED emits light when the potential difference (p.d.) across it is large enough to transfer sufficient energy to an electron to result in the emission of a photon.
The electron must have energy greater than or equal to the photon energy.

The minimum p.d. required to produce light from LEDs emitting different frequencies was measured by increasing the p.d. from zero until light was first seen.

The graph shows the results.



There are two problems with using LEDs to determine the Planck constant:

- when the p.d. is increased and the LED first emits light it is difficult to see
- the LEDs do not emit a single frequency but also light of frequencies slightly above and below the recorded frequency.

Discuss the extent to which these problems are consistent with obtaining a result from this graph for the Planck constant which is higher than the accepted value.

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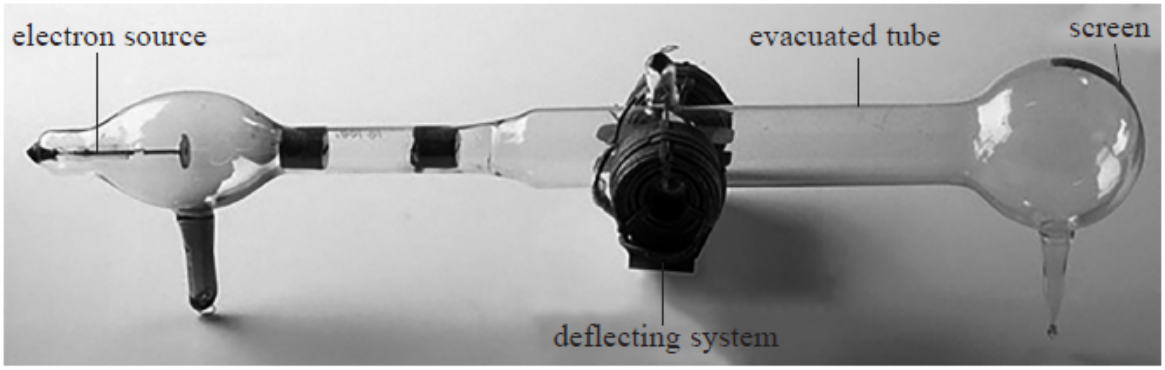
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(Total for question = 3 marks)

Q12.

At the end of the 19th century, J.J. Thompson used electric and magnetic fields to deflect beams of charged particles. A photograph of his apparatus is shown.



© Science Museum London

Electrons were accelerated through a potential difference to produce a beam of high-energy electrons. The beam was then deflected in perpendicular directions by the magnetic and electric fields. The final position of the beam on the screen was determined by the charge and mass of the electrons.

Explain how electrons from the source become a beam of high-energy electrons.

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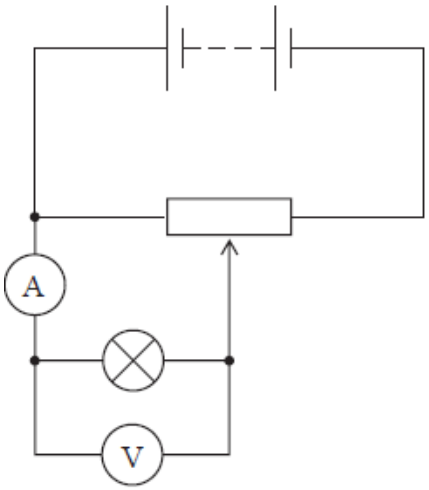
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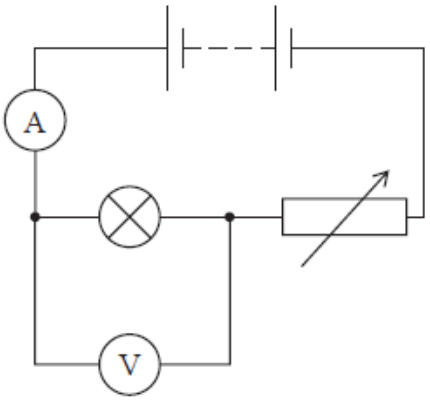
(Total for question = 2 marks)

Q1.

A student is planning to collect data to produce a current-potential difference graph for a filament lamp. Her teacher suggests two circuits that she could use.



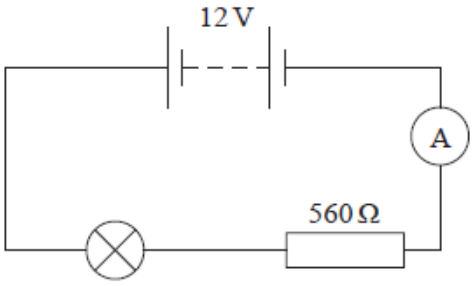
Circuit 1



Circuit 2

Circuit 1 uses a potential divider and circuit 2 uses a variable resistor to vary the potential difference across the filament lamp.

The student sets up the following circuit with the filament lamp. The battery has negligible internal resistance.



(i) The reading on the ammeter is 17.5 mA.

Calculate the value of the potential difference (p.d.) across the filament lamp.

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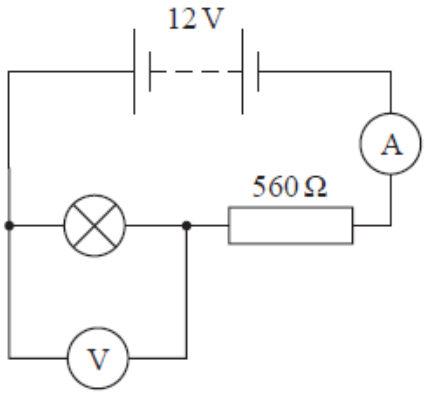
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pd across filament lamp = ...

(ii) When a voltmeter with a resistance of 1.5 kΩ is connected as shown, the p.d. across the filament lamp decreases.



Explain why the p.d. across the filament lamp decreases.

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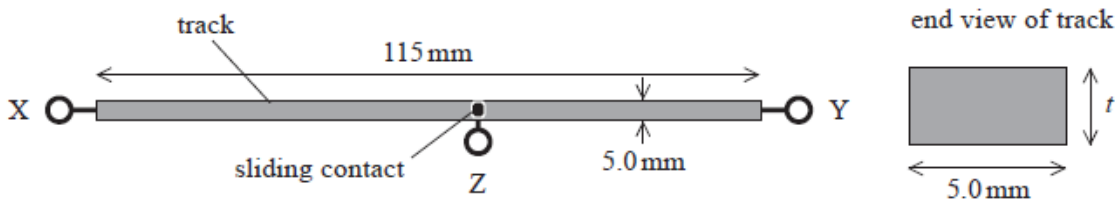
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(Total for question = 5 marks)

Q2.

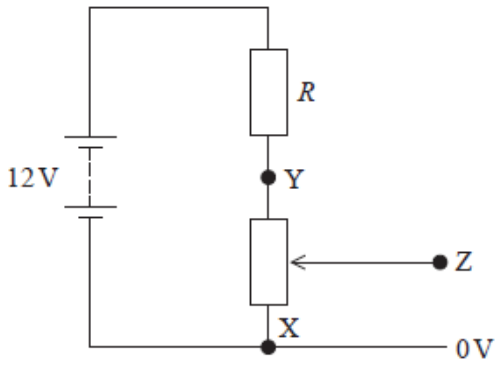
A potential divider circuit may contain a component known as a potentiometer. One type of potentiometer consists of a track with terminals X and Y at either end. There is a sliding contact that can move along the track connected to a terminal Z as shown.



The length of the track is 115 mm and the width is 5.0 mm.

The potentiometer is used to monitor the displacement of a moving tool on a machine in a production line. The tool is attached to the sliding contact. The potentiometer is connected to a resistor of resistance *R* and a potential difference is applied as shown. The tool moves through a maximum displacement of 60 mm from end X, producing a maximum potential difference of 5.0

V between Z and X.



(i) Show that the potential difference between X and Y is about 10 V.

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(ii) Calculate the value of *R*.

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R = ...

(iii) When the circuit is assembled, using the correctly calculated resistance value and a battery of e.m.f. 12 V, it is found that the maximum output from the potentiometer is slightly less than 5.0 V.

Explain why the maximum output is slightly less than predicted.

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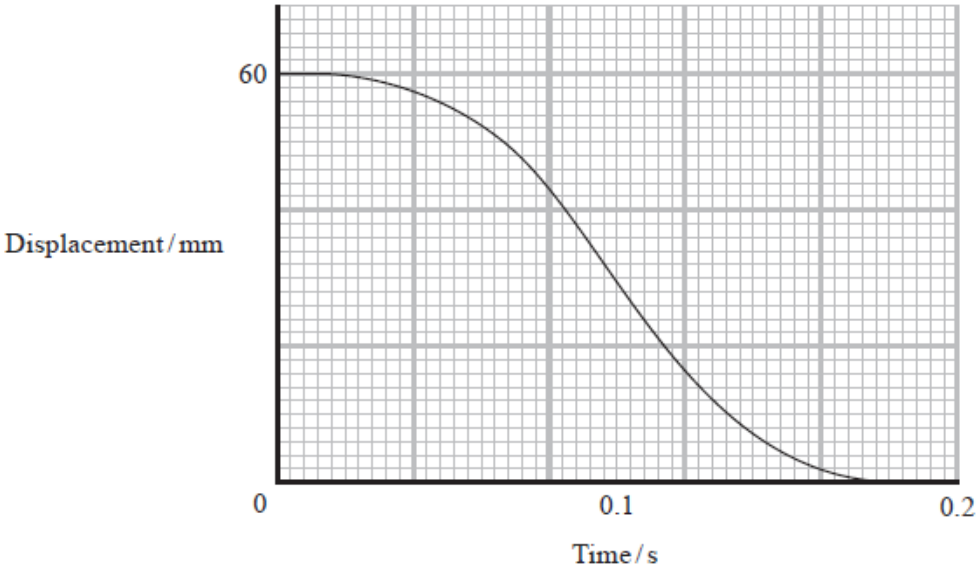
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(iv) The tool on the machine should not travel with a speed any larger than 0.8 m s^{-1} .

The graph shows how the displacement varies with time for the downward stroke of the moving tool.



Deduce whether this speed is exceeded by the moving tool.

(4)

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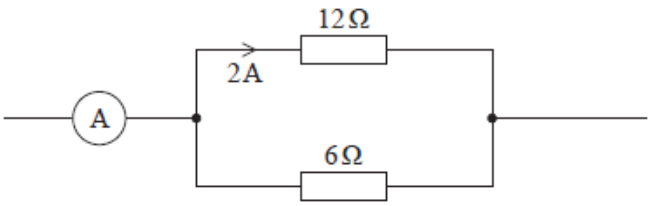
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(Total for question = 12 marks)

Q3.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

Part of an electric circuit is shown.



What is the current shown by the ammeter?

☒ **A** 3 A

☒ **B** 4 A

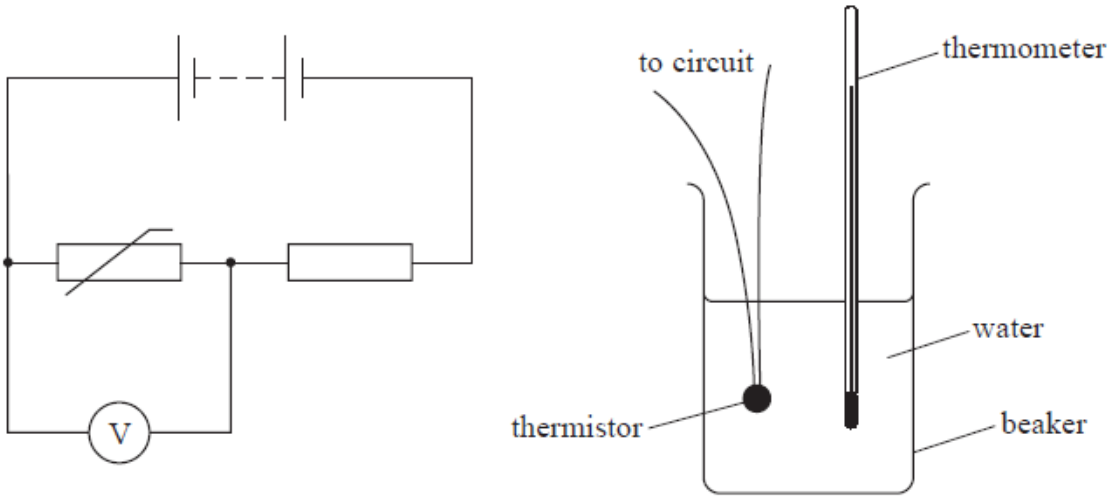
☒ **C** 5 A

☒ **D** 6 A

(Total for question = 1 mark)

Q4.

A student carried out an experiment to calibrate a thermistor. She connected the thermistor in series with a resistor and a power supply as shown. Then she placed the thermistor in a beaker of hot water and used a thermometer to record the temperature θ of the water.



The student recorded θ and corresponding values of the reading V on the voltmeter as the water cooled.

Explain, making reference to charge carriers, why V increased as the water cooled.

(3)

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(Total for question = 3 marks)

Q5.

Analogue ammeters were used before digital meters became widely available.

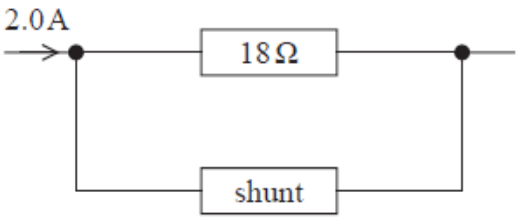
The analogue ammeter shown will measure a maximum current of 1.0 mA and has a resistance of 18 Ω.



(Source: © David J. Green/Alamy Stock Photo)

The analogue ammeter can be adapted to measure a larger current by adding a resistor, known as a shunt, in parallel with the ammeter. The arrangement is shown below.

The analogue ammeter is represented by the 18 Ω resistor.



The maximum current through the 18 Ω resistor remains as 1.0 mA.

Show that the shunt would need to have a resistance of about 0.01 Ω to adapt this ammeter to read up to a maximum current of 2.0 A.

(3)

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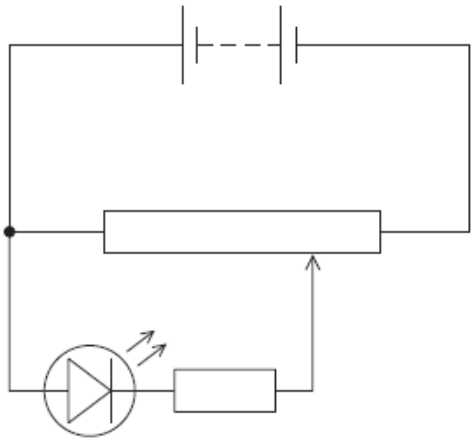
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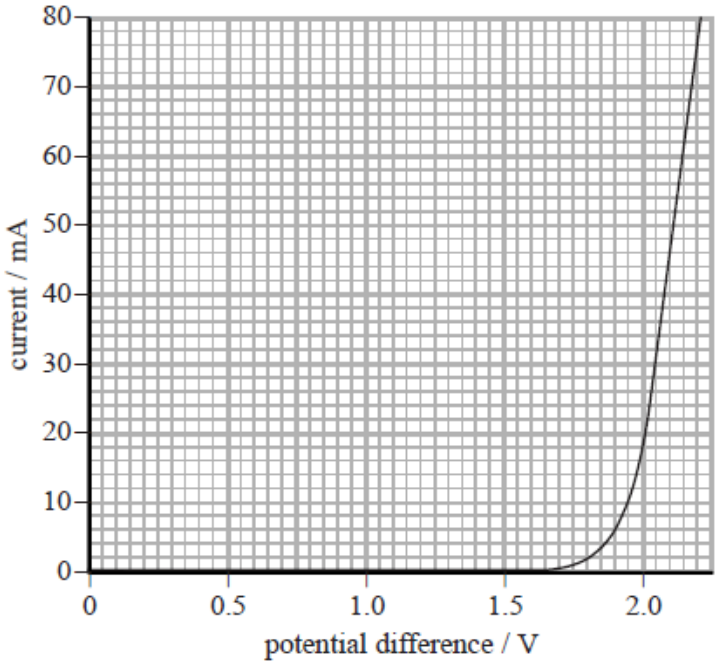
(Total for question = 3 marks)

Q6.

A student wanted to plot a graph of current against potential difference for a light emitting diode (LED). He used the circuit shown.



The graph of current against potential difference obtained by the student is shown.



(i) The student wrote the following conclusion.

"The graph shows that in general the LED is not an ohmic conductor. However, for potential differences greater than +2 V, Ohm's law is obeyed since the graph is linear in this region."

Criticise the student's conclusion.

(2)

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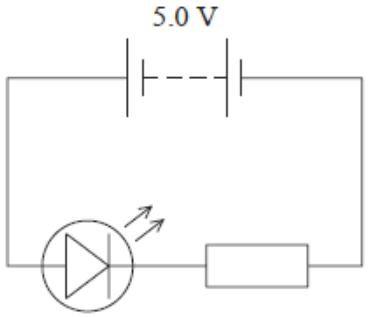
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(ii) The student used the LED with a 5.0 V power supply as shown in the circuit.



To be lit to normal brightness the current through the LED must be 18 mA.

Calculate the resistance of the resistor needed in the circuit.

(4)

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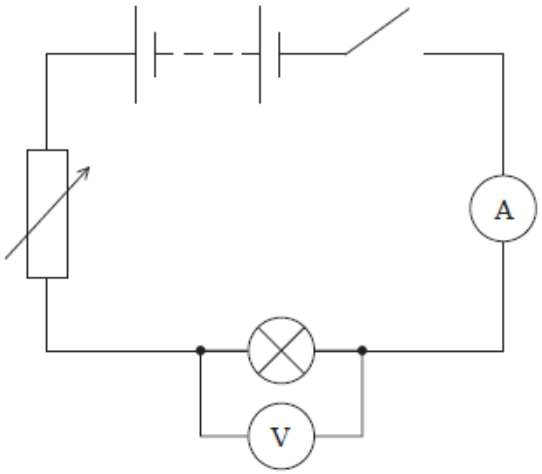
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Resistance = ...

(Total for question = 6 marks)

Q7.

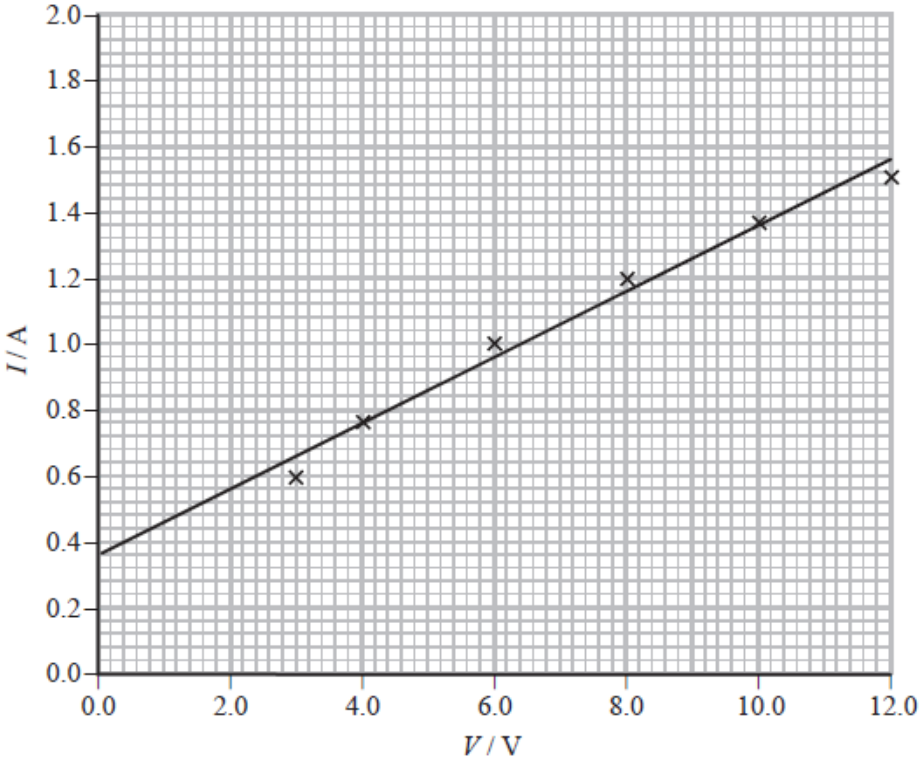
A student set up the circuit shown and measured the current *I* through the filament lamp for a range of values of potential difference (p.d.) *V*.



The student's data is shown in the table.

V / V	*I* / A
3.0	0.6
4.0	0.75
6.0	1.00
8.0	1.20
10.0	1.35
12.0	1.5

The student drew a graph of how current varies with p.d. She drew a straight line on the graph and claimed that the data demonstrates that the filament lamp obeys Ohm's law because the graph is linear.



Assess the validity of the student's statement.

(4)

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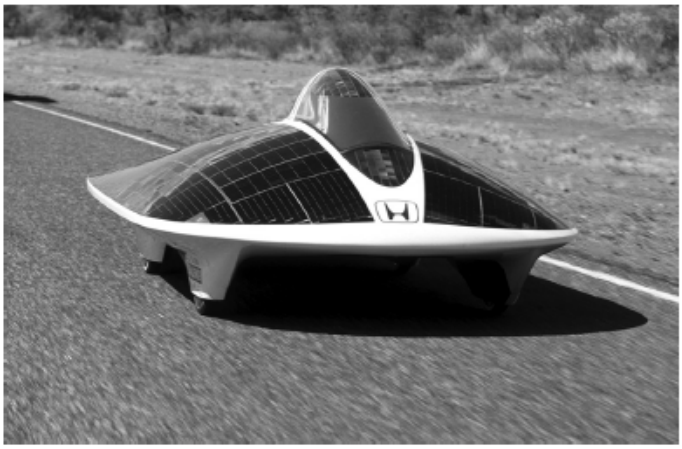
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(Total for question = 4 marks)

Q8.

The world solar challenge is set every two years, in Australia. The challenge is to complete a three thousand kilometre route with a vehicle powered only by the Sun.

Vehicles have their surfaces fitted with solar panels, as shown in the photograph.



(Source: © LAURENT DOUEK/LOOK AT SCIENCES/SCIENCE PHOTO LIBRARY)

One of the solar panels has an e.m.f. of 8.2 V when in sunlight. The terminal potential difference is 5.5 V when a current of 0.45 A is drawn from the solar panel.

Calculate the internal resistance of the solar panel in these conditions.

(3)

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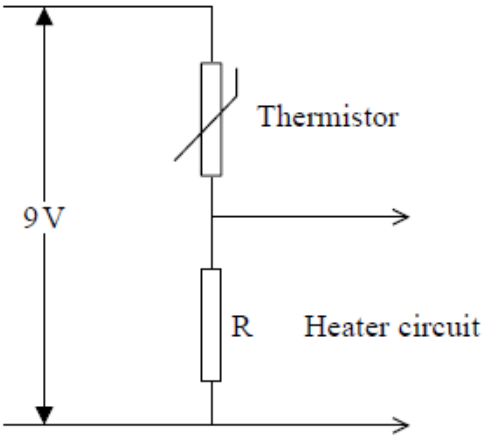
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Internal resistance = ...

(Total for question = 3 marks)

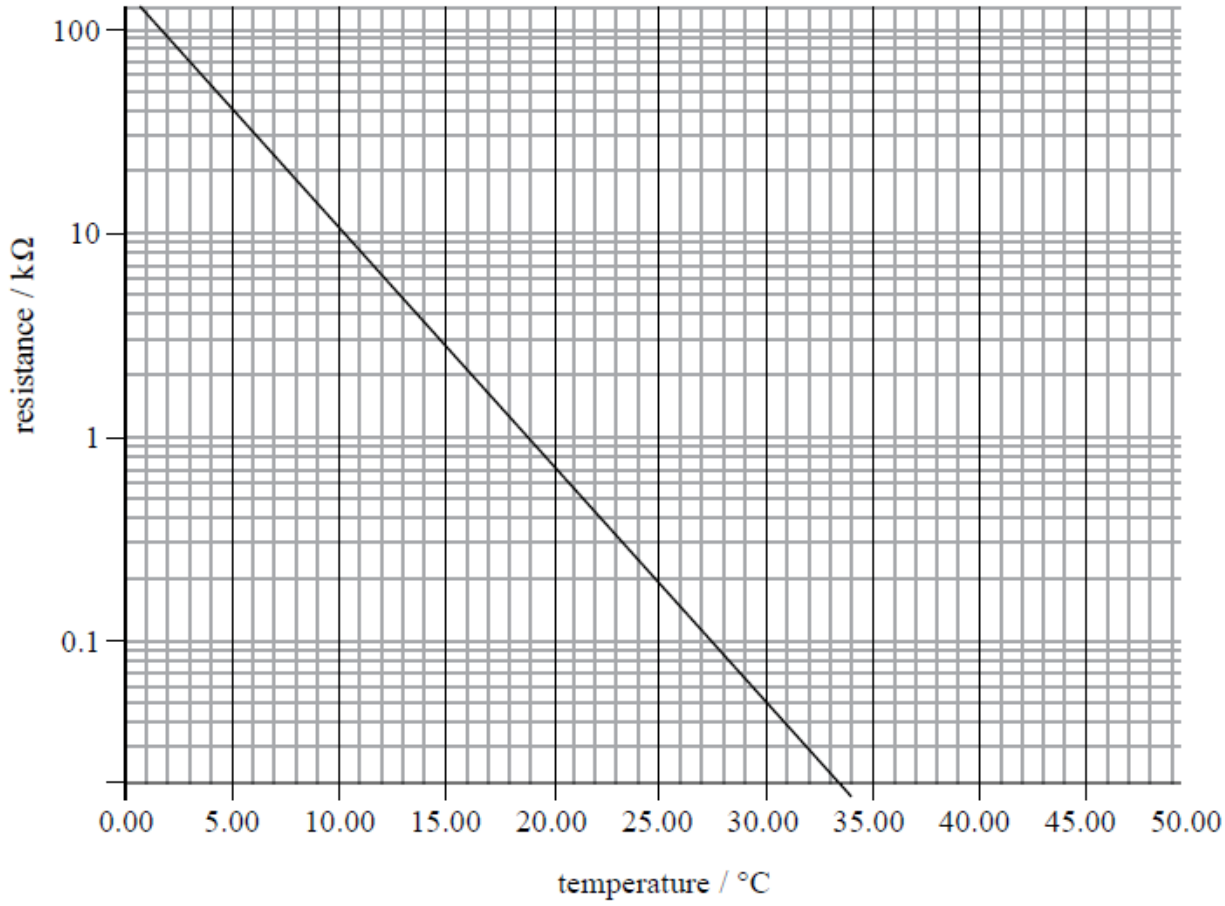
Q9.

A thermistor can be used to control a heater. When the temperature falls below a certain value the heater is switched on. The thermistor is connected in series with a fixed resistor R in a potential divider circuit as shown.



The heater circuit is connected across R and will switch on when the potential difference across it is above 5.5 V.

The variation of resistance of the thermistor R_T with temperature is shown on the graph.



(Source: http://reviseomatic.org/help/e-resistors/ThermistorLogGraph.gif)

The heater switches on when the temperature falls below 20 °C.

Calculate the resistance of the fixed resistor R.

(3)

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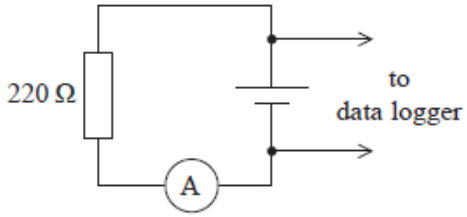
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Resistance= .....

(Total for question = 3 marks)

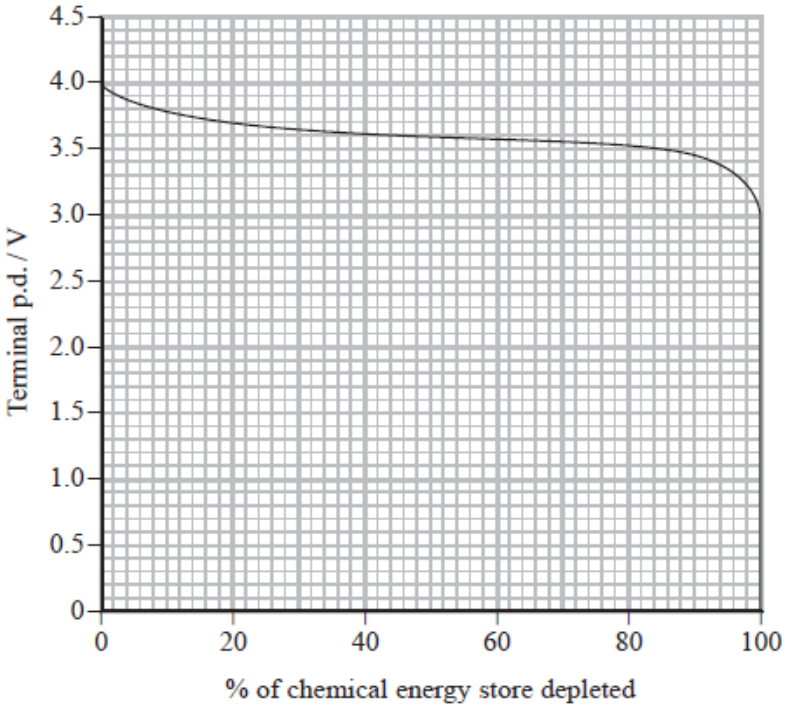
Q10.

A student is investigating how the internal resistance of a dry cell varies over time. She sets up the circuit shown to draw current from the cell.



The student proposes to use a data logger to monitor the terminal potential difference (p.d.) of the cell over a period of time.

The graph shows how the terminal p.d. varies as the chemical energy store in the cell is depleted.



(i) Explain, using the graph, why the current drawn from the cell decreases as the chemical energy store in the cell is depleted.

(2)

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(ii) Determine the internal resistance of the cell when its chemical energy store is 80% depleted. Assume that the e.m.f. of the cell remains constant at 4.0 V.

(3)

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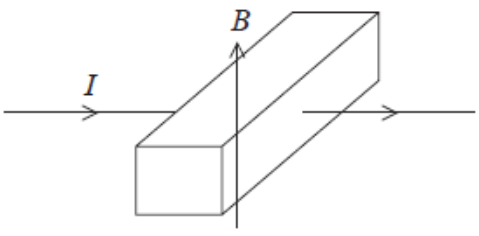
Internal resistance = ...

(Total for question = 5 marks)

Q11.

Some liquids conduct electricity. This property can be used to pump these liquids through pipes.

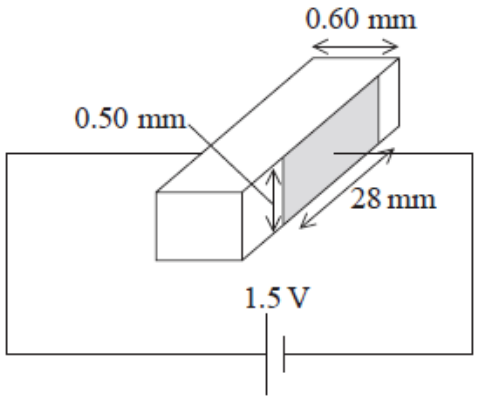
A short section of a rectangular pipe containing a liquid is shown in the diagram. The pipe is placed in a magnetic field of flux density *B* and a current *I* is passed through the liquid as shown.



A practical demonstration of this principle used two rectangular electrodes, opposite each other on either side of the pipe, a distance of 0.60 mm apart. The dimensions of the electrodes are

shown in the diagram.

The electrodes were connected to a 1.5 V cell.
Salt water was pumped using a magnetic field of magnetic flux density 0.40 T.



(i) Show that the current through the salt water is about 20 mA.

resistivity of salt water = 1.6 Ω m

(4)

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(ii) Hence calculate the force on the salt water.

(2)

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Force = ...

(Total for question = 6 marks)

Q12.

Resistance can also be affected by temperature.

Explain why the resistance of a metal sample increases with an increase of temperature.

(3)

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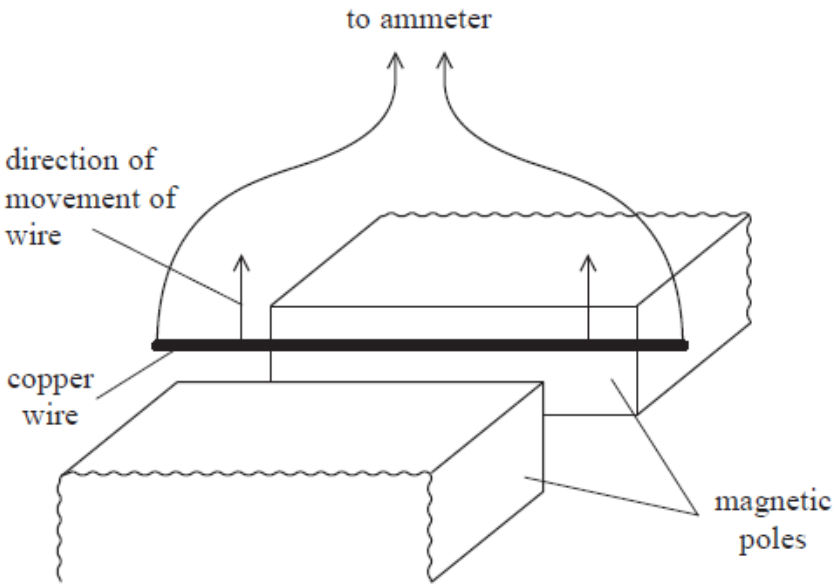
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(Total for question = 3 marks)

Q13.

A student is investigating electromagnetic induction using a U-shaped magnet. The magnetic flux density between the poles of the magnet is 74 mT. The magnetic field outside the region of the poles is negligible.
She places a stiff copper wire between the poles of the magnet as shown in the diagram.
The wire is connected to an ammeter of resistance 0.25 Ω



(a) The rectangular poles measure 6.0 cm × 2.4 cm.

Show that the magnetic flux between the poles of the magnet is about 1×10^{-4} Wb.

(3)

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(b) The student holds the wire as shown in the diagram and moves it vertically upwards at a constant speed of 1.2 m s^{-1}
Calculate the e.m.f. induced in the wire when it is moving.

(3)

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Induced e.m.f. = ...

(c) According to Lenz's law, a force will act on the wire to oppose the motion of the wire.

Calculate the magnitude of the force that opposes the motion and comment on this value.

(4)

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Magnitude of force = ...

Comment

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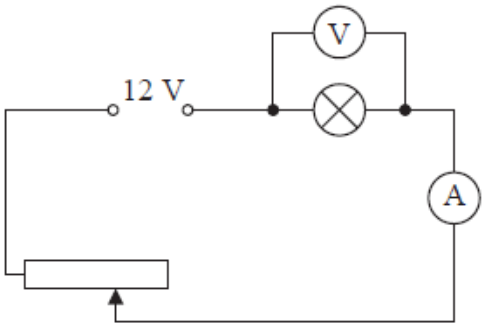
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(Total for question = 10 marks)

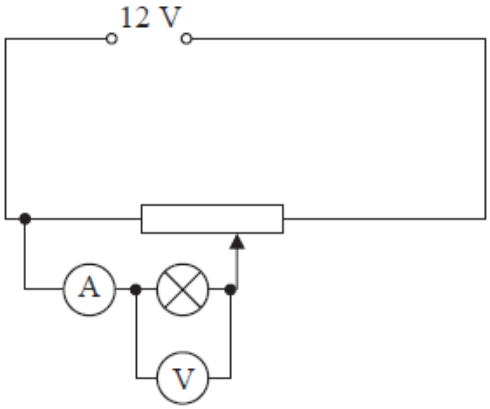
Q14.

Students are investigating how the current through a filament lamp depends upon the potential difference across the lamp. They are provided with a power supply of 12 V and a variable resistor.

Two students set up different circuits as shown.



Circuit A



Circuit B

Evaluate the effectiveness of the circuit used by each student in obtaining data for a current-potential difference characteristic graph. Assume that the voltmeters have infinite resistance.

(5)

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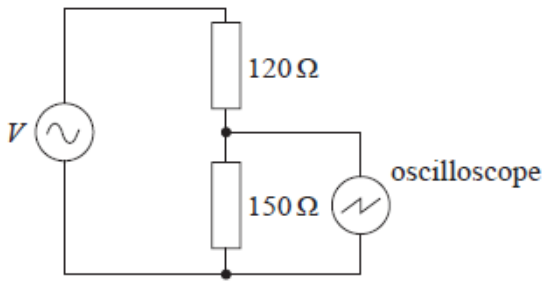
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(Total for question = 5 marks)

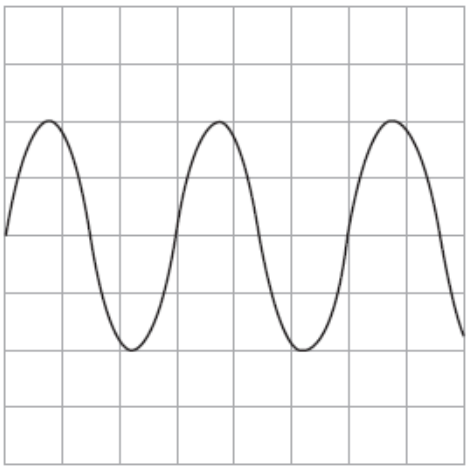
Q15.

A student connected the output from a source of alternating potential difference (p.d.) to a series resistor combination.

She connected an oscilloscope across the 150 Ω resistor as shown.



The trace obtained on the oscilloscope is shown below.



(i) Determine the peak p.d. across the 150 Ω resistor.

y-sensitivity of oscilloscope = 2.0 V per division

(2)

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Peak p.d. across 150 Ω resistor = ...

(ii) Calculate the root mean square (r.m.s.) value of the current in the circuit.

(3)

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r.m.s. value of current = ...

(iii) Calculate the power dissipated in the circuit.

(3)

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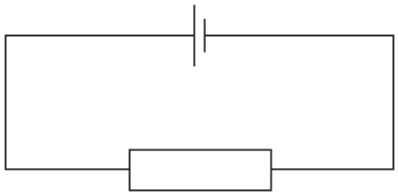
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Power dissipated in circuit = ...

(Total for question = 8 marks)

Q16.

A cell of e.m.f. 1.5 V is connected to a 5.0 Ω resistor. The terminal potential difference across the cell is 1.0 V.



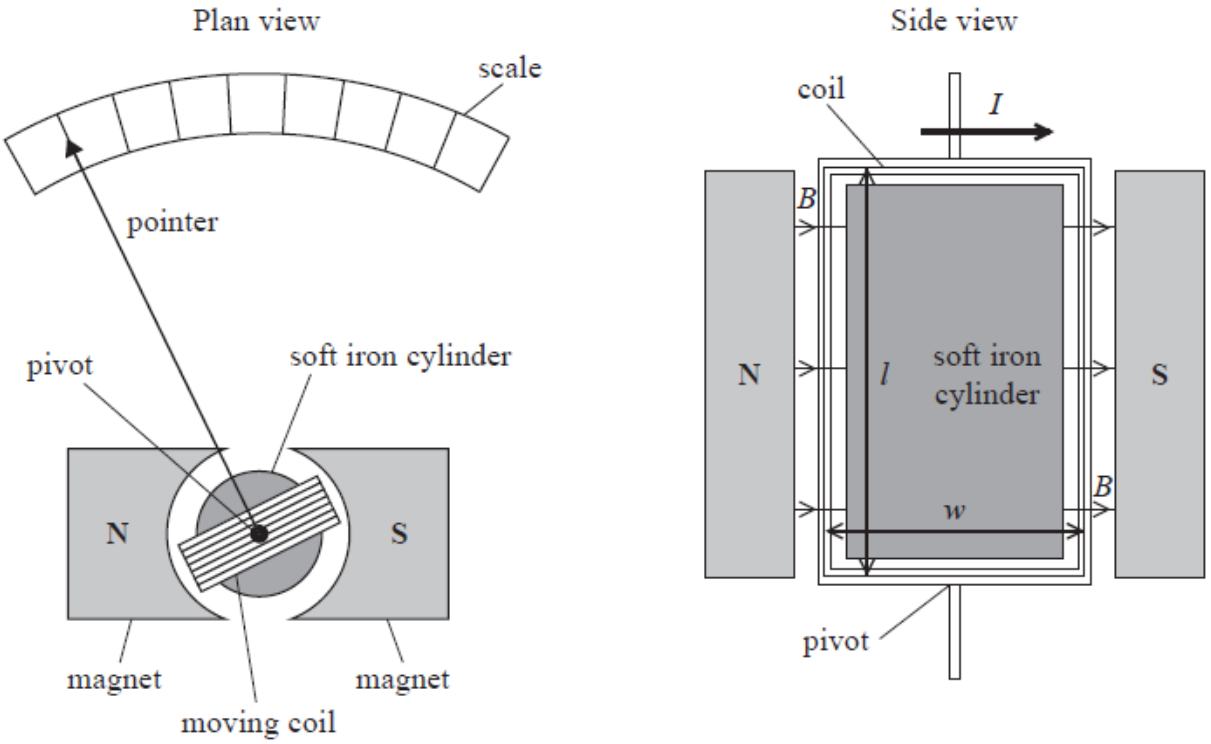
Which of the following is the current in the circuit?

- ☒ **A** 0.1 A
- ☒ **B** 0.2 A
- ☒ **C** 0.3 A
- ☒ **D** 0.5 A

(Total for question = 1 mark)

Q17.

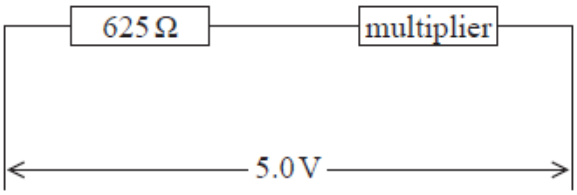
The diagrams show the plan view and side view of a moving coil ammeter.



An ammeter of this type has a resistance of 625 Ω and will measure a maximum current of 1.6 mA.

The ammeter can be adapted to measure potential difference by adding a resistor in series with the ammeter. This resistor is known as a multiplier.

The ammeter is adapted so that it can measure potential differences up to 5.0 V as shown.



The following multipliers are available:

200 Ω 2500 Ω 3125 Ω 3750 Ω

Deduce which multiplier should be used.

(3)

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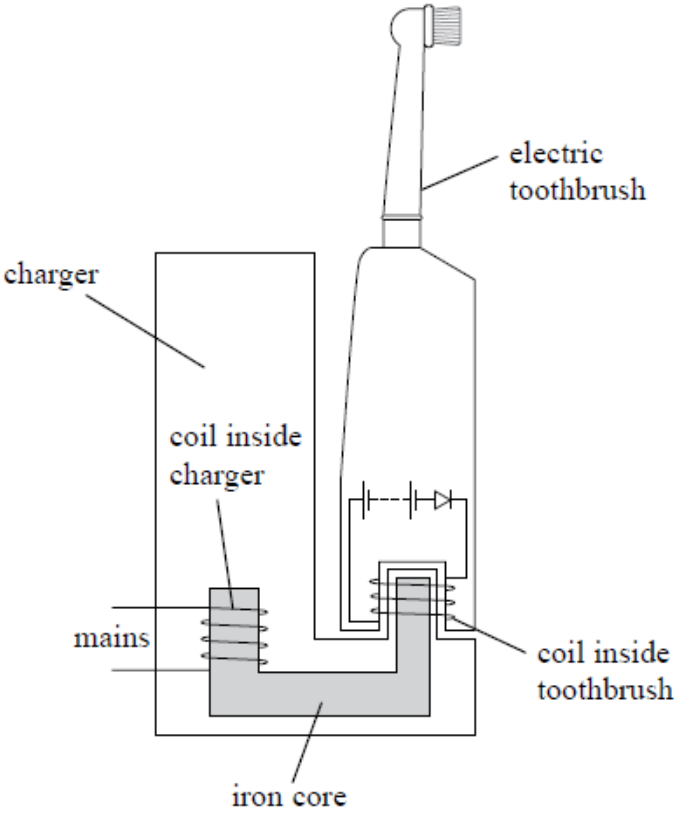
(Total for question = 3 marks)

Q18.

The diagram shows the inside of an electric toothbrush and a charger.

The charger contains a coil wrapped around an iron core. The coil is plugged into the mains a.c. supply.

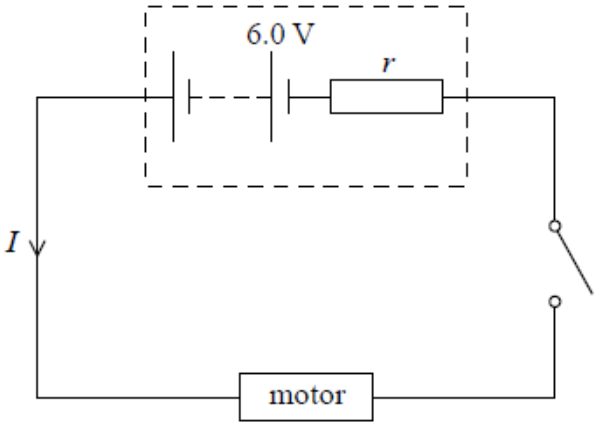
The toothbrush also contains a coil that sits around the iron core when the toothbrush is placed on the charger to recharge the battery of the toothbrush.





When fully charged the battery has an e.m.f. of 6 V.

When the toothbrush is in use, the battery supplies a current of 57 mA with a terminal p.d. of 2.7 V to a motor.



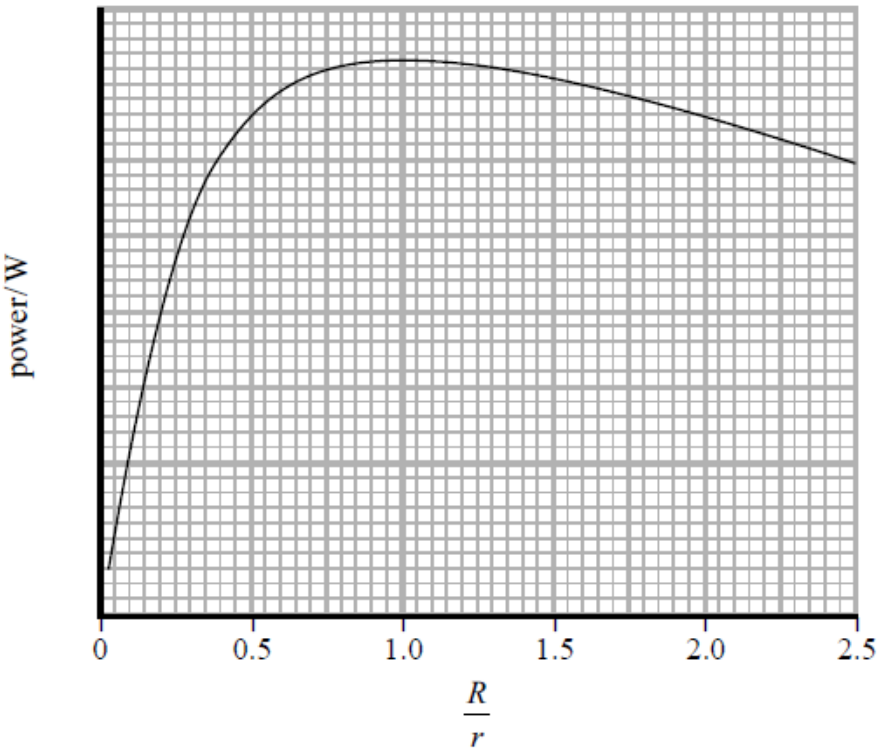
(i) Show that the resistance of the motor R is about 50 Ω.

(1)

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(ii) The power transferred from the battery to the motor depends on the ratio $\frac{R}{r}$ as shown in the graph below.



Determine whether maximum power is transferred to the motor.

(3)

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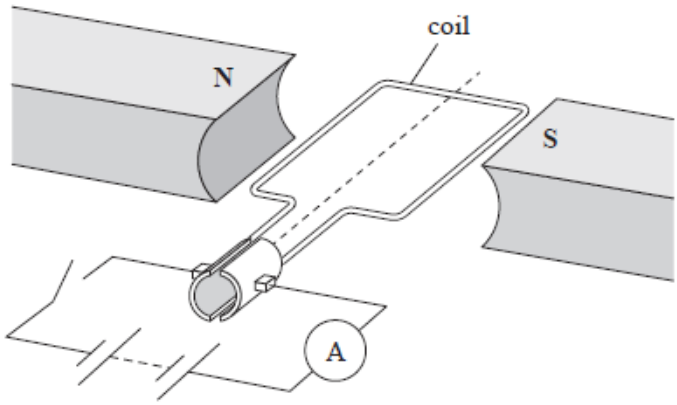
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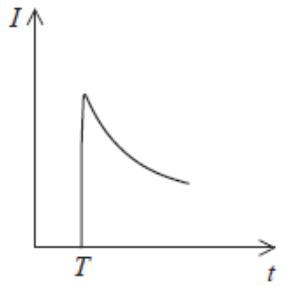
Q19.

* A simple electric motor consists of a coil that is free to rotate in a magnetic field.

A student connects the motor to an ammeter and a battery.



The graph shows how the current *I* in the coil varies with time *t*. The switch is closed at time *T*.



Explain why the current rises to a maximum then decreases.
Your answer should include a reference to Faraday and Lenz's laws.

(6)

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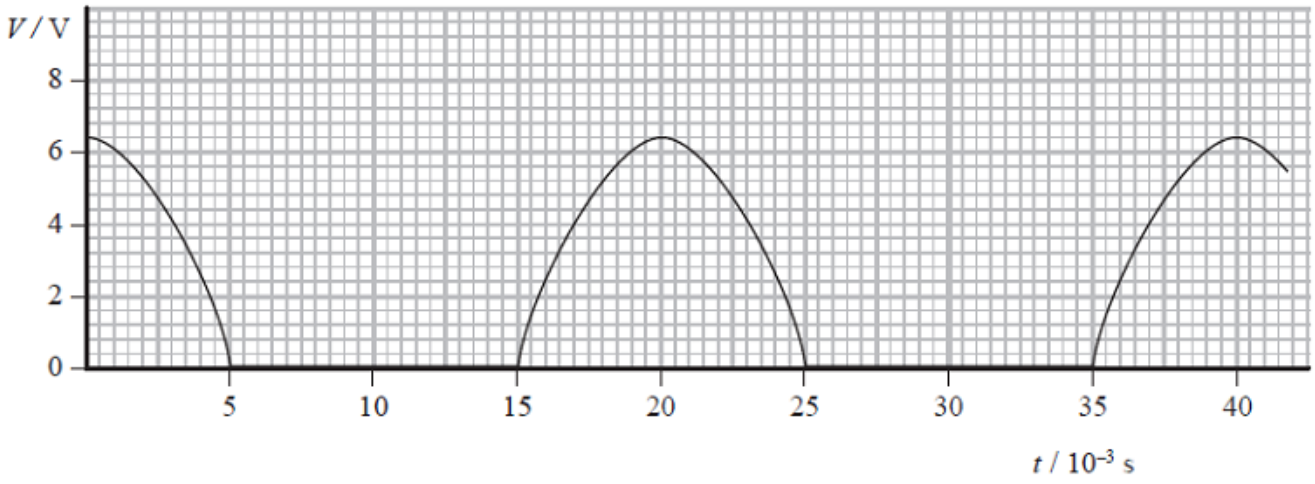
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(Total for question = 6 marks)

Q20.

The graph shows how the output *V* from the terminals of a power supply labelled d.c. (direct current) varies with time *t*. This type of supply will not allow current to flow backwards through it.



(a) A student connects a capacitor across the terminals of this power supply in order to try to produce a constant voltage.

Suggest how this produces a constant voltage.

(2)

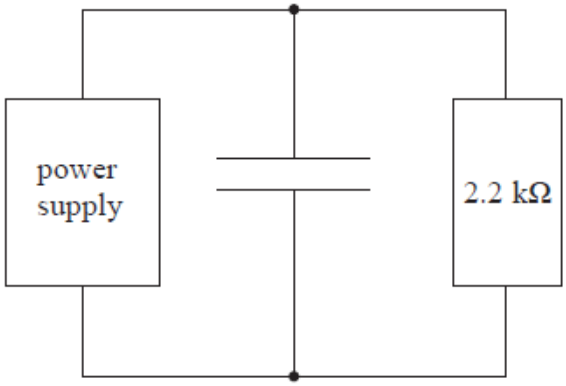
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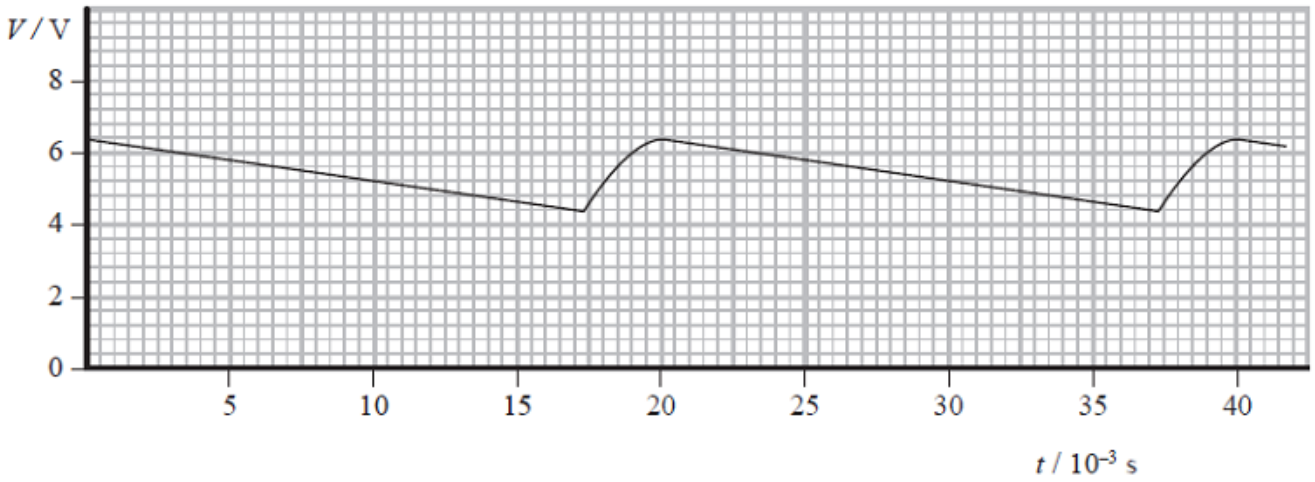
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(b) The student then connects a resistor across the capacitor as shown.



The graph shows the variation of the potential difference V across the resistor with time t.



(i) Estimate the average potential difference across the resistor.

(1)

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Average potential difference = ...

(ii) Calculate the average current in the resistor.

(2)

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Average current = ...

(iii) Determine the time in each cycle for which the capacitor discharges through the resistor.

(1)

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Discharge time = ...

(iv) Calculate the charge passing through the resistor during one discharge of the capacitor and hence determine the capacitance of the capacitor.

(4)

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Charge = ...

Capacitance = ...

(c) The student wants to produce a potential difference across the same resistor that has less variation in magnitude.
State, with a reason, what the student could do to achieve this.

(2)

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(Total for question = 12 marks)

Q1.

Aluminium is one of the most widely recycled metals. Aluminium cans are heated from room temperature until all the aluminium has melted. The molten aluminium is then used to make new cans. This process uses only 5% of the energy needed to extract aluminium from raw materials.

On a website it is claimed that recycling one aluminium can of mass 14 g saves enough energy to listen to music on a mobile phone continuously for 7 days.

Assess the validity of this claim.

melting point of aluminium = 660 K
specific heat capacity of aluminium = 902 J kg^{-1} K^{-1}
specific latent heat of aluminium = 396 kJ kg^{-1}
room temperature = 293 K
mobile phone p.d. = 3.7 V
mobile phone current = 120 mA

(6)

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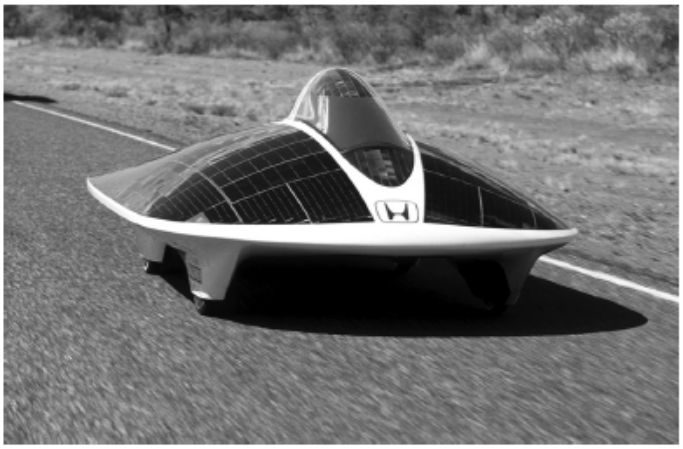
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(Total for question = 6 marks)

Q2.

The world solar challenge is set every two years, in Australia. The challenge is to complete a three thousand kilometre route with a vehicle powered only by the Sun.

Vehicles have their surfaces fitted with solar panels, as shown in the photograph.



(Source: © LAURENT DOUEK/LOOK AT SCIENCES/SCIENCE PHOTO LIBRARY)

A bank of 380 of these solar panels is used to charge the battery in a vehicle.
The panels are connected in parallel and the current provided by each panel is 0.45 A.
When fully charged, the energy stored in the battery is 12 kW h.

Calculate the time, in hours, to fully charge this battery if the solar panels are in sunlight.
Assume the efficiency of charging this battery is 100%.

(3)

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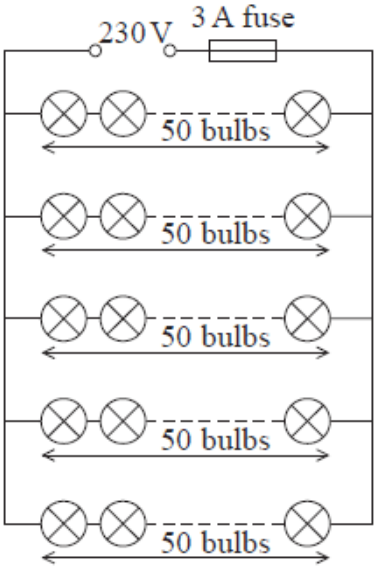
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Time = ... hours

(Total for question = 3 marks)

Q3.

A set of festive lights is made up of five parallel strands of filament bulbs. Each strand contains 50 bulbs in series as shown.



(a) When a bulb is working normally its resistance is 8.0 Ω. If the filament of the bulb breaks, the lamp is designed to still conduct and its resistance becomes 3.0 Ω.

(i) The filament of one bulb on a strand breaks.
By considering the effect this has on the remaining bulbs in that strand, explain why it is recommended that broken bulbs are replaced as soon as possible.

(3)

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(ii) The set of festive lights are fitted with a 3 A fuse. Five bulbs in one strand break.

Determine whether the fuse blows.

(3)

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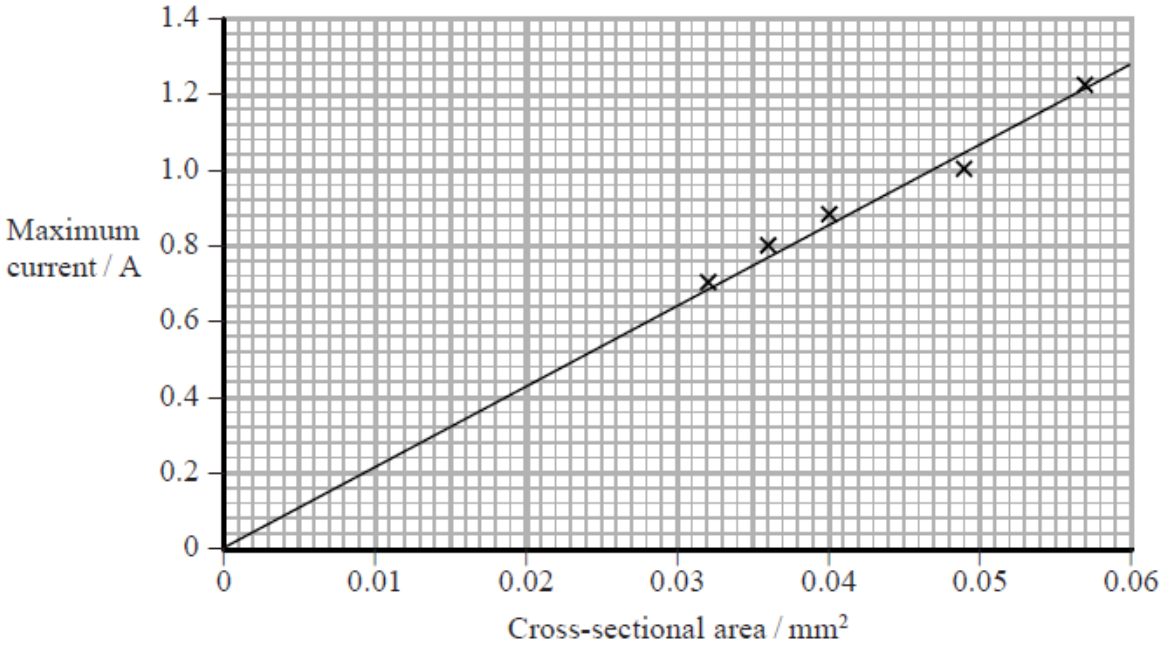
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(b) A student investigates how the cross-sectional area of a fuse wire affects the current at

which the fuse blows. She uses pieces of wire of the same material and length, but different cross-sectional areas. She steadily increases the current through each piece of wire and records the maximum current through the wire before it breaks.

She then plots a graph of maximum current against cross-sectional area.



(i) Describe how the student should determine the cross-sectional area of the wire.

(3)

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(ii) State the relationship between the maximum current and the cross-sectional area of the wire.

(1)

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(iii) The student chooses a piece of wire, of the same material and length as used in the investigation. The piece of wire has a diameter of 0.40 mm.

Use the graph to determine whether the piece of wire is suitable to use as the 3A fuse wire for the set of festive lights.

(4)

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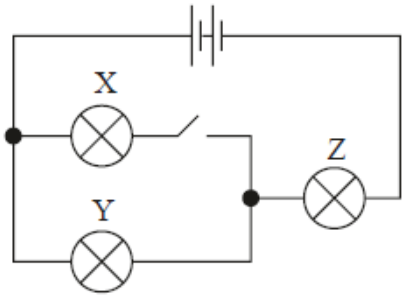
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(Total for question = 14 marks)

Q4.

A circuit consists of three identical 1.5 V bulbs connected to two 1.5 V cells.



The switch is closed.
Which row describes the change in brightness of bulb Y and bulb Z?

	Y	Z
☒ A	brighter	brighter
☒ B	brighter	dimmer
☒ C	dimmer	brighter
☒ D	dimmer	dimmer

(Total for question = 1 mark)

Q5.

An electric kettle is used to heat water from room temperature to boiling point.

(a) (i) Calculate the electrical power used by the kettle.

potential difference = 230 V

current = 12.5 A

(2)

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Electrical power = ...

(ii) The kettle is switched on for 140 s.

Calculate the total energy supplied to the kettle.

(2)

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Total energy supplied = ...

(iii) The amount of thermal energy transferred to the water is calculated to be 351 000 J.

Calculate the efficiency of the kettle at heating the water.

(2)

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Efficiency = ...

(b) A student suggests that the useful energy required is thermal and the kettle only produces thermal energy, so it should be 100 % efficient.

Discuss this suggestion.

(2)

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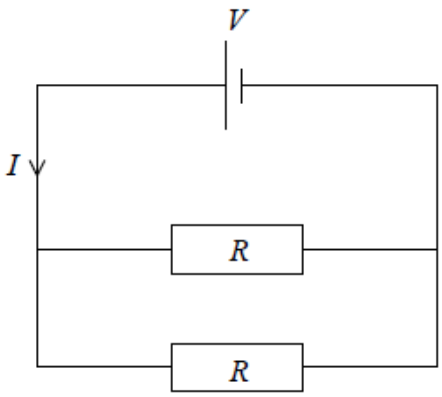
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(Total for question = 8 marks)

Q6.

A potential difference, V, is applied to two resistors in parallel, each of resistance R.
A current, I, flows through the whole circuit.



The correct expression for the power developed in each resistor is given by

☒ **A** $P = IV$

☒ **B** $P = IV/4$

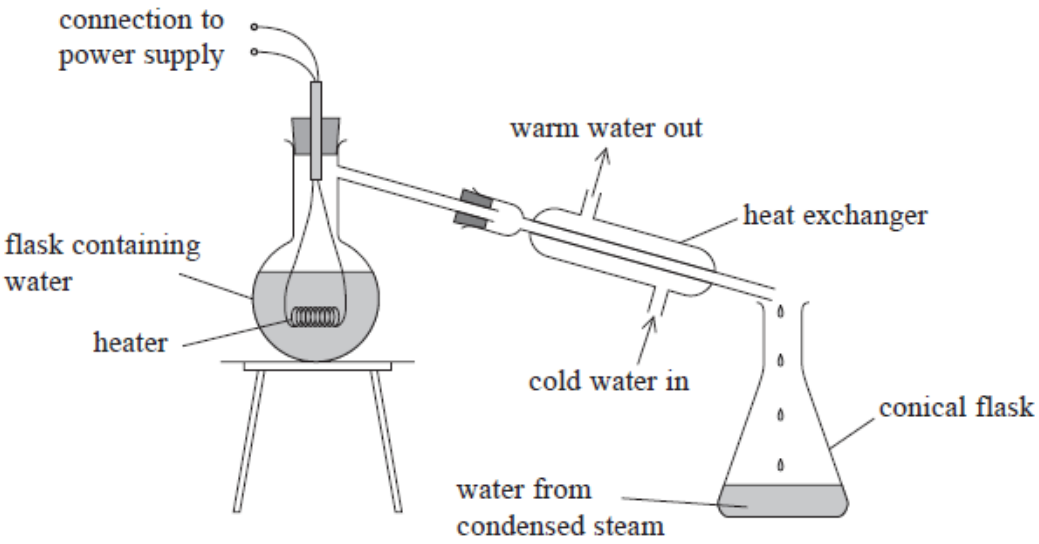
☒ **C** $P = V^2/2R$

☒ **D** $P = I^2R/4$

(Total for question = 1 mark)

Q7.

The apparatus shown can be used to determine a value for the specific latent heat of vaporisation of water.



(a) In one experiment the current in the heater was 8.20 A, and the potential difference across the heater was 230 V.

(i) Show that the power of the heater was about 2 kW.

(2)

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(ii) There was 0.655 kg of water in the flask at an initial temperature of 22.5 °C.
The heater was switched on, and the water in the flask was heated to boiling point.

Calculate the minimum time taken for the water to be heated to 100.0 °C.

specific heat capacity of water = 4190 J kg^{-1} K^{-1}

(3)

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Minimum time taken for water to be heated = ...

(b) The heater was left on and water continued to boil in the flask. The water was allowed to boil for a few minutes. The conical flask was then placed under the heat exchanger and water was collected in it.

(i) Give a reason why the water was left boiling for a few minutes before the conical flask was put in place.

(1)

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(ii) Water with a mass of 95.0 g was collected in a time of 125 s.

Calculate the rate of energy transfer in the heat exchanger.

specific latent heat of vaporisation of water = 2.26×10^6 J kg^{-1}

(3)

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Rate of energy transfer in the heat exchanger = ...

(iii) Discuss your answers to (a)(i) and (b)(ii).

(3)

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(Total for question = 12 marks)

Q8.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

A light dependent resistor is connected across a cell of negligible internal resistance. The light intensity is increased.

Which of the following statements about the current is correct?

☒ **A** It decreases because there is an increase in the number of conduction electrons.

☒ **B** It increases because there is an increase in the number of conduction electrons.

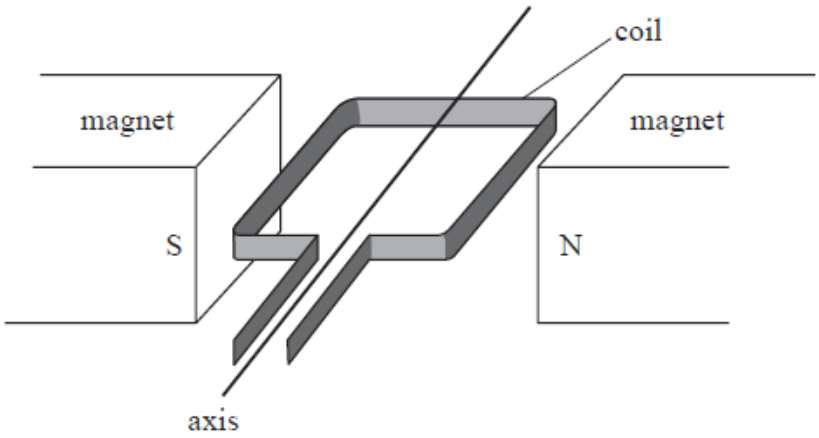
☒ **C** It decreases because the amplitude of lattice vibrations decreases.

☒ **D** It increases because the amplitude of lattice vibrations increases.

(Total for question = 1 mark)

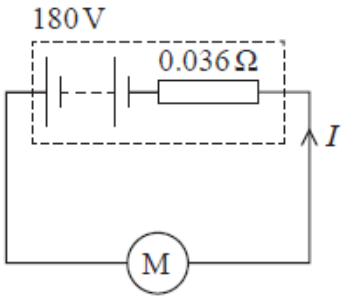
Q9.

Hybrid electric vehicles (HEV) use the same device both as a generator to charge the car battery and as an electric motor to support the propulsion system. A simplified diagram of the device is shown. The coil can rotate freely around the axis.



The circuit diagram shows a car battery connected to an electric motor for a HEV.

The battery has an electromotive force (e.m.f.) 180 V and internal resistance 0.036 Ω.



The motor has a maximum power of 88 kW.

(i) Show that the current I drawn by the electric motor when operating at this power would be given by the equation

$$0.036I^2 - 180I + 88\,000 = 0$$

(3)

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(ii) Solving the equation above produces an answer of $I = 550$ A. At maximum power, the car can accelerate from rest to sixty miles per hour in under 7 s.

The maximum charge capacity of the battery within this HEV is 6.1 amp-hour.

Deduce whether the battery could maintain this current for up to 7 s.

(2)

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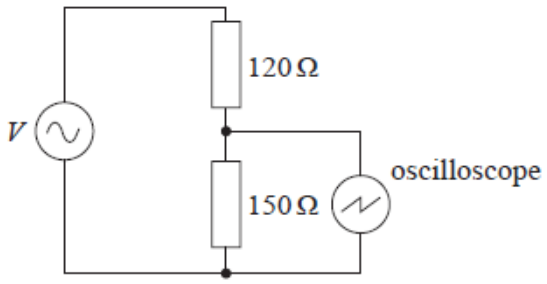
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(Total for question = 5 marks)

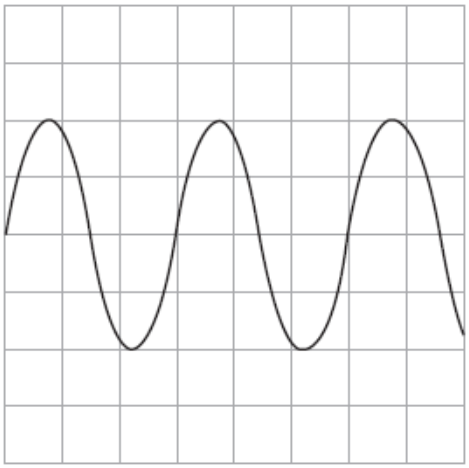
Q10.

A student connected the output from a source of alternating potential difference (p.d.) to a series resistor combination.

She connected an oscilloscope across the 150 Ω resistor as shown.



The trace obtained on the oscilloscope is shown below.



(i) Determine the peak p.d. across the 150 Ω resistor.

y-sensitivity of oscilloscope = 2.0 V per division

(2)

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Peak p.d. across 150 Ω resistor = ...

(ii) Calculate the root mean square (r.m.s.) value of the current in the circuit.

(3)

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r.m.s. value of current = ...

(iii) Calculate the power dissipated in the circuit.

(3)

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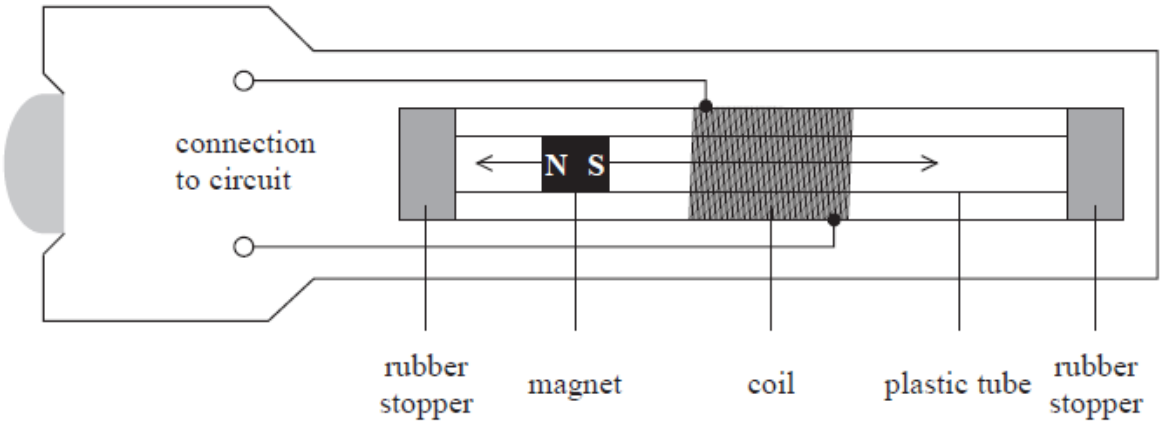
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Power dissipated in circuit = ...

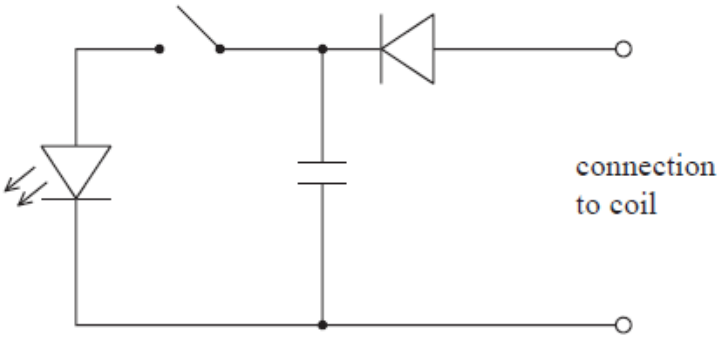
(Total for question = 8 marks)

Q1.

*The diagram shows a 'shaker torch'. When the torch is shaken, a strong magnet moves forwards and backwards through a copper coil, powering a light-emitting diode (LED).



Each time the magnet moves through the coil a current pulse is generated. The coil is connected to a capacitor via a diode, as shown.



Explain how the shaker torch is able to light the LED.

(6)

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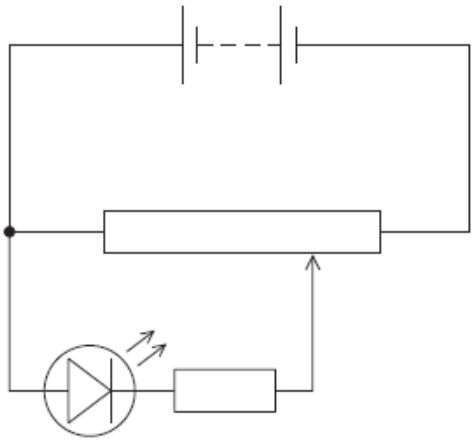
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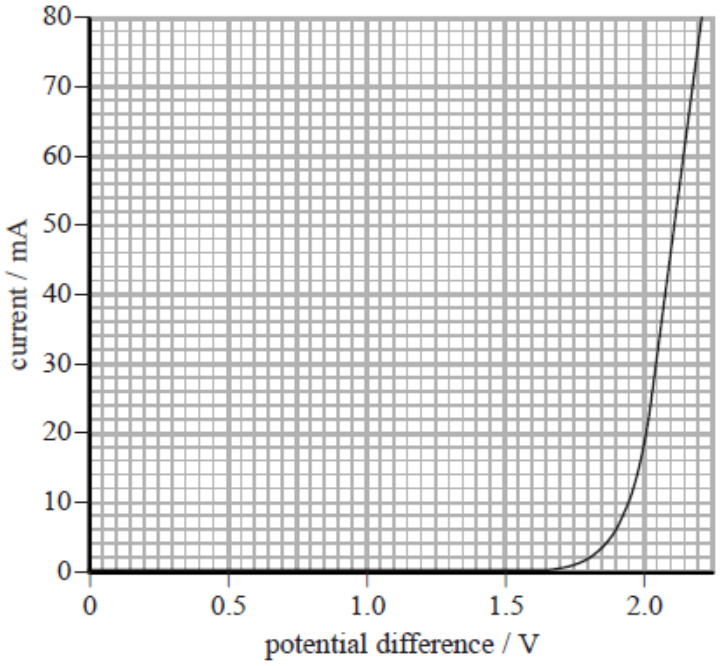
(Total for question = 6 marks)

Q2.

A student wanted to plot a graph of current against potential difference for a light emitting diode (LED). He used the circuit shown.



The graph of current against potential difference obtained by the student is shown.



(i) The student wrote the following conclusion.

"The graph shows that in general the LED is not an ohmic conductor. However, for potential differences greater than +2 V, Ohm's law is obeyed since the graph is linear in this region."

Criticise the student's conclusion.

(2)

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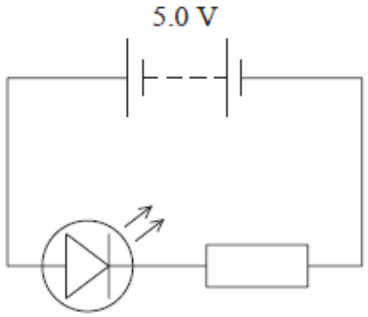
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(ii) The student used the LED with a 5.0 V power supply as shown in the circuit.



To be lit to normal brightness the current through the LED must be 18 mA.

Calculate the resistance of the resistor needed in the circuit.

(4)

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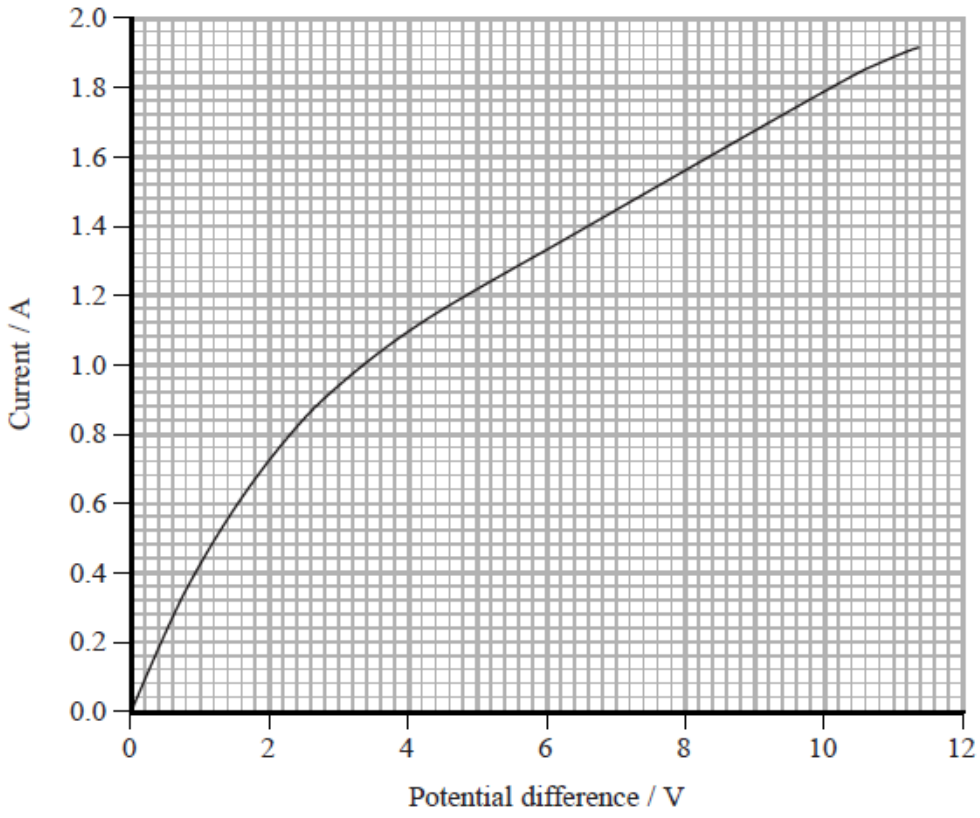
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Resistance = ...

(Total for question = 6 marks)

Q3.

The graph shows how the current through a filament bulb varies with the potential difference across the bulb.



(a) Determine the resistance of the filament bulb when the potential difference is 7.0 V.

(2)

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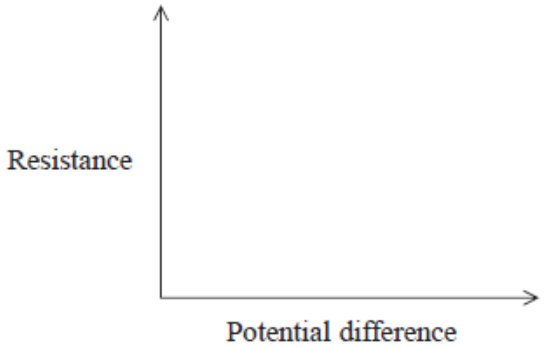
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Resistance = ...

(b) Sketch a graph of resistance against potential difference for the filament bulb over the range 0 V to 7 V.

(3)



* (c) Explain the variation of resistance with potential difference for the filament bulb in terms of particle behaviour.

(6)

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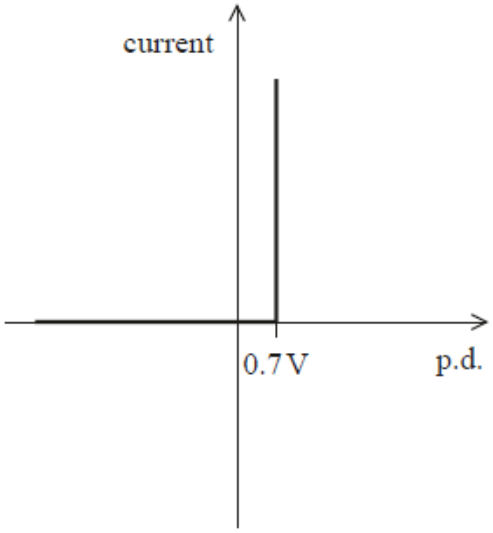
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(Total for question = 11 marks)

Q4.

The graph shows how current varies with potential difference (p.d.) for an ideal diode.



An alternating p.d. V_{IN} has a peak value of 3.4 V.

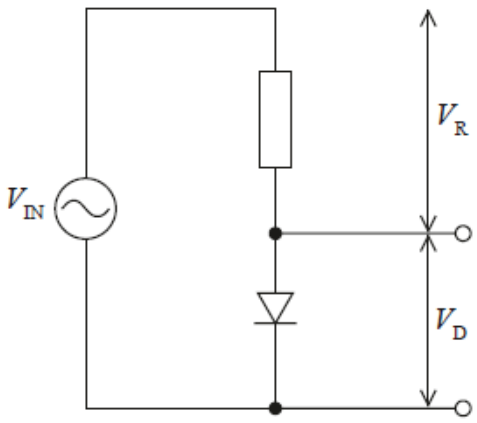
(i) Calculate the r.m.s. value.

(2)

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r.m.s. value = ...

(ii) V_{IN} is applied to a diode and resistor as shown.



The p.d. across the resistor is V_R and the p.d. across the diode is V_D. V_D is the output.

Explain why $V_{IN} = V_R + V_D$ at any given time.

(2)

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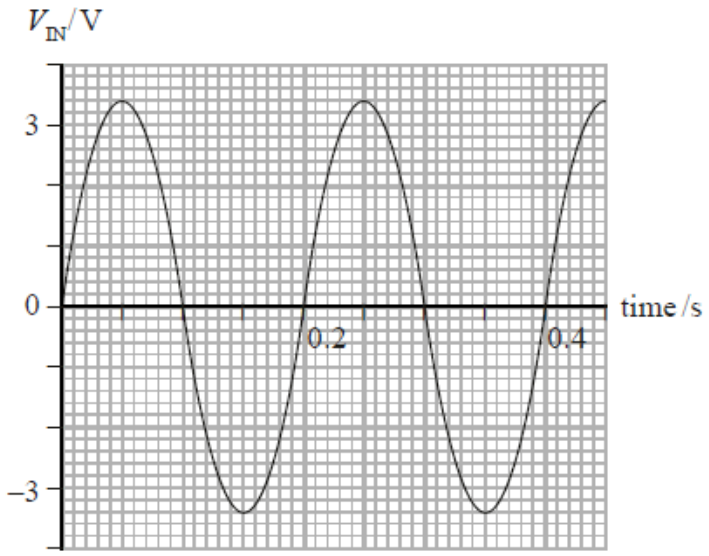
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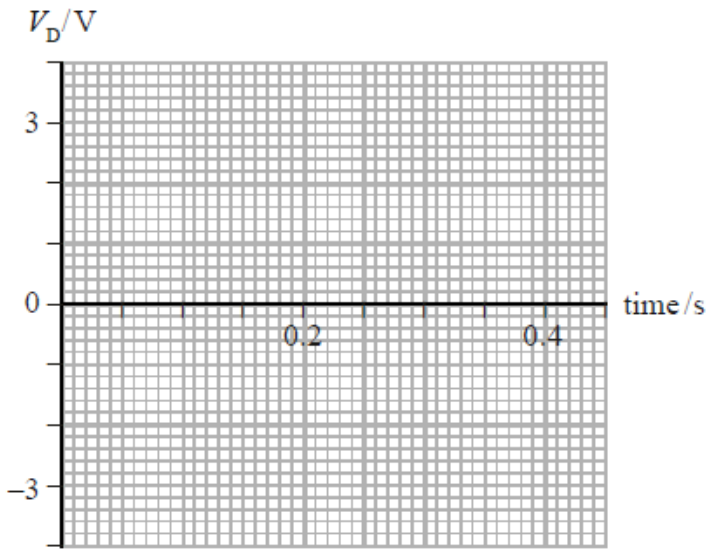
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(iii) The graph shows how V_{IN} varies with time.

Sketch a graph of V_D against time using the axes provided below.

(3)



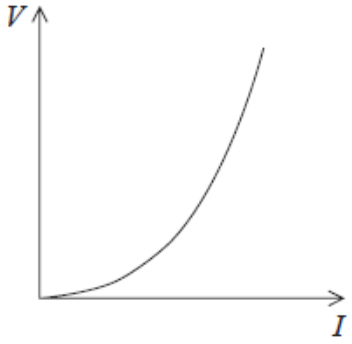


(Total for question = 7 marks)

Q5.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

The graph shows how the potential difference *V* varies with the current *I* for a circuit component.



Which of the following could be the circuit component?

☒ **A** diode

☒ **B** filament bulb

☒ **C** ohmic resistor

☒ **D** thermistor

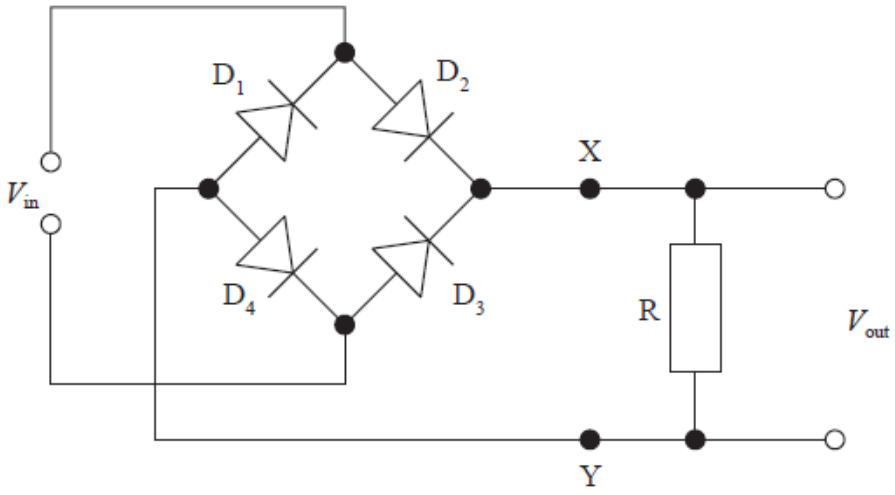
(Total for question = 1 mark)

Q6.

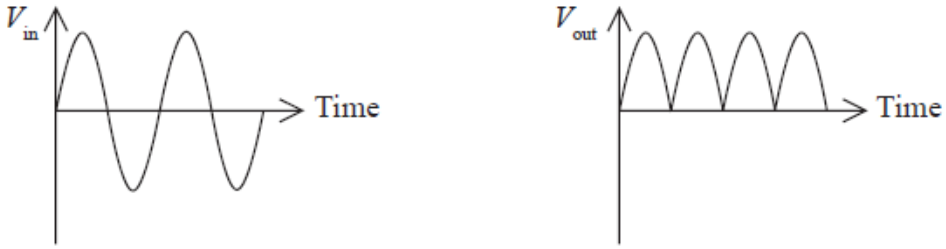
Power supplies provide either alternating or direct currents and potential differences.

It is possible to convert alternating currents and p.d.s, to direct currents and p.d.s using diodes.

The power supply provides an input V_{in} to the circuit shown. The circuit includes four diodes D_1, D_2, D_3 and D_4 and a resistor R. The circuit produces an output potential difference V_{out} .



A graph of V_{in} against time and a corresponding graph of V_{out} against time are shown below.



(i) Explain the operation of this circuit. Your answer should refer to D_1, D_2, D_3 and D_4.

(3)

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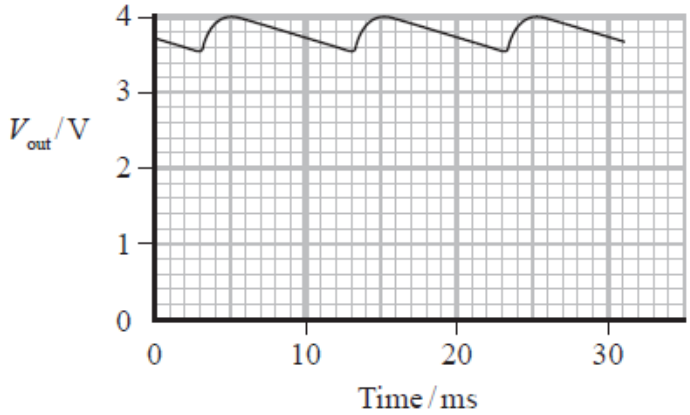
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(ii) A capacitor is added between points X and Y in the circuit.

The new graph of V_{out} against time is shown below.



Determine a value for the capacitance of the capacitor.

resistance of R = 2.2 kΩ

(3)

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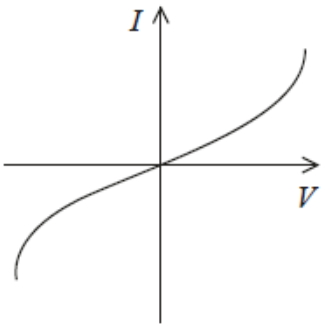
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Capacitance = ...

(Total for question = 6 marks)

Q7.

The diagram shows a graph of current *I* against potential difference *V* for an electrical component.



Which of the following components would produce a graph of this shape?

☒ **A** filament bulb

☒ **B** metallic conductor

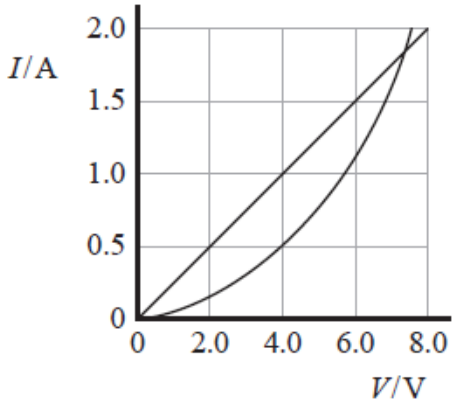
☒ **C** negative temperature coefficient thermistor

☒ **D** ohmic conductor

(Total for question = 1 mark)

Q8.

The current-potential difference graphs for a resistor and a thermistor are shown.



The resistor and thermistor are connected in series to a 6 V battery.

What is the current, in amps, in the resistor?

(1)

☒ **A** 0.5

☒ **B** 1.0

☒ **C** 1.5

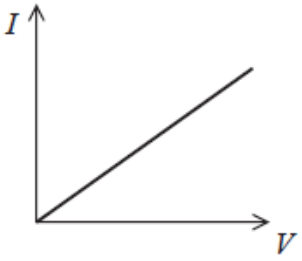
☒ **D** 2.0

(Total for question = 1 mark)

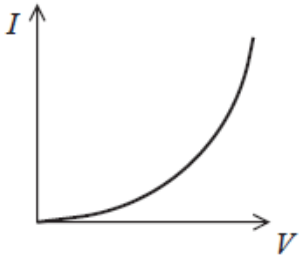
Q9.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

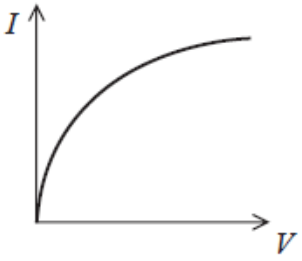
Which of the following graphs shows how the current *I* through a thermistor varies with the potential difference *V* across the thermistor?



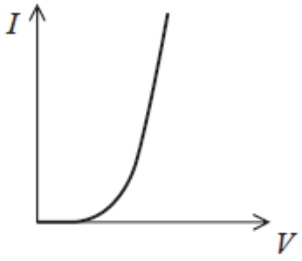
A



B



C



D

☒ **A**

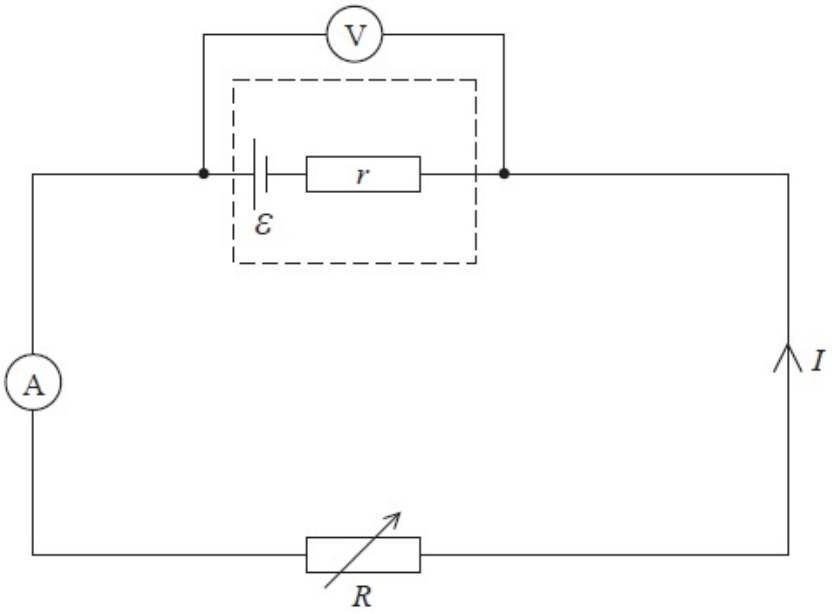
☒ **B**

☒ **C**

☒ **D**

(Total for question = 1 mark)

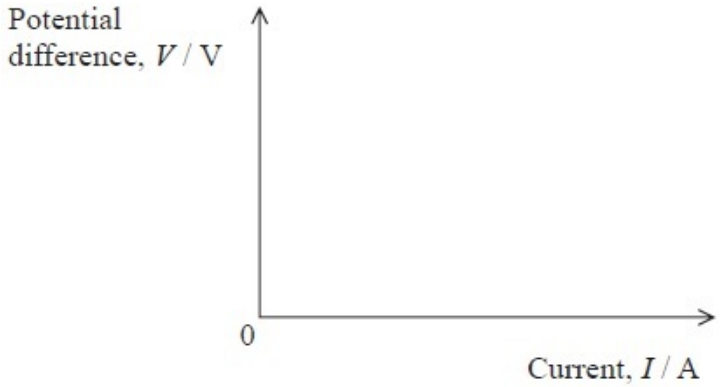
Q10. The diagram shows a circuit which may be used to find the emf ε and internal resistance r of a cell.



(a) As the resistance *R* of the variable resistor is varied, values of the current *I* in the circuit and the terminal potential difference *V* across the cell are recorded.

Sketch the graph of *V* against *I* and explain how it may be used to determine *ε* and *r*.

(5)



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*(b) We usually assume that ammeters have negligible resistance and voltmeters have infinite resistance.

The determination of *ε* and *r* is not affected by using an ammeter with non-negligible resistance but is affected by using a voltmeter with a low resistance.

Explain why.

(4)

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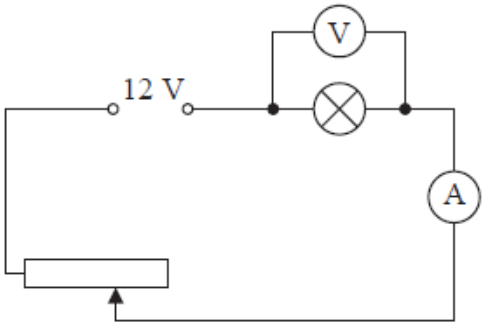
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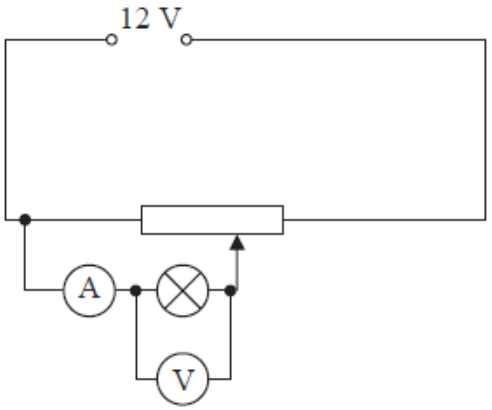
Q11.

Students are investigating how the current through a filament lamp depends upon the potential difference across the lamp. They are provided with a power supply of 12 V and a variable resistor.

Two students set up different circuits as shown.



Circuit A



Circuit B

Evaluate the effectiveness of the circuit used by each student in obtaining data for a current-potential difference characteristic graph. Assume that the voltmeters have infinite resistance.

(5)

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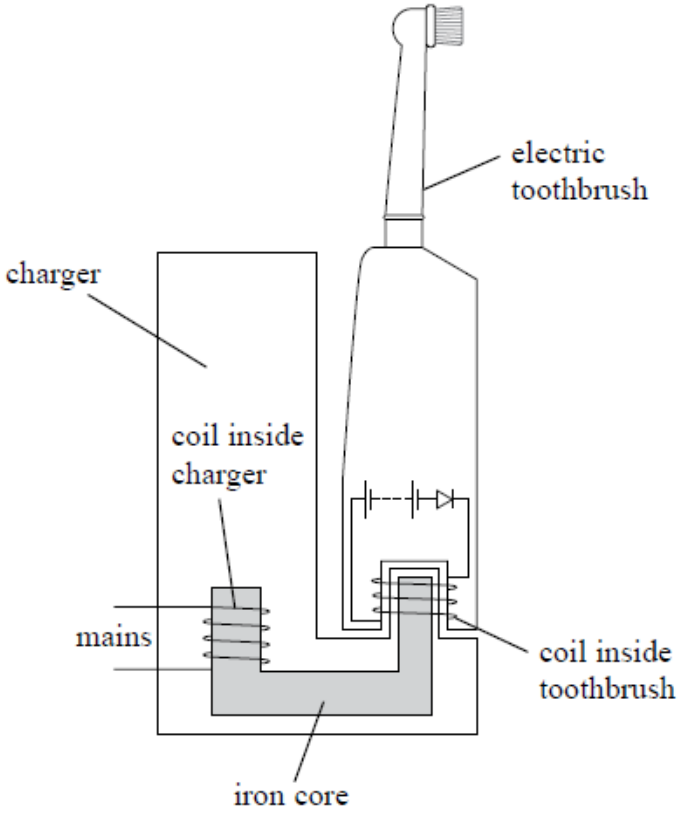
(Total for question = 5 marks)

Q12.

The diagram shows the inside of an electric toothbrush and a charger.

The charger contains a coil wrapped around an iron core. The coil is plugged into the mains a.c. supply.

The toothbrush also contains a coil that sits around the iron core when the toothbrush is placed on the charger to recharge the battery of the toothbrush.





* Describe how the charger is able to charge the low-voltage battery.

(6)

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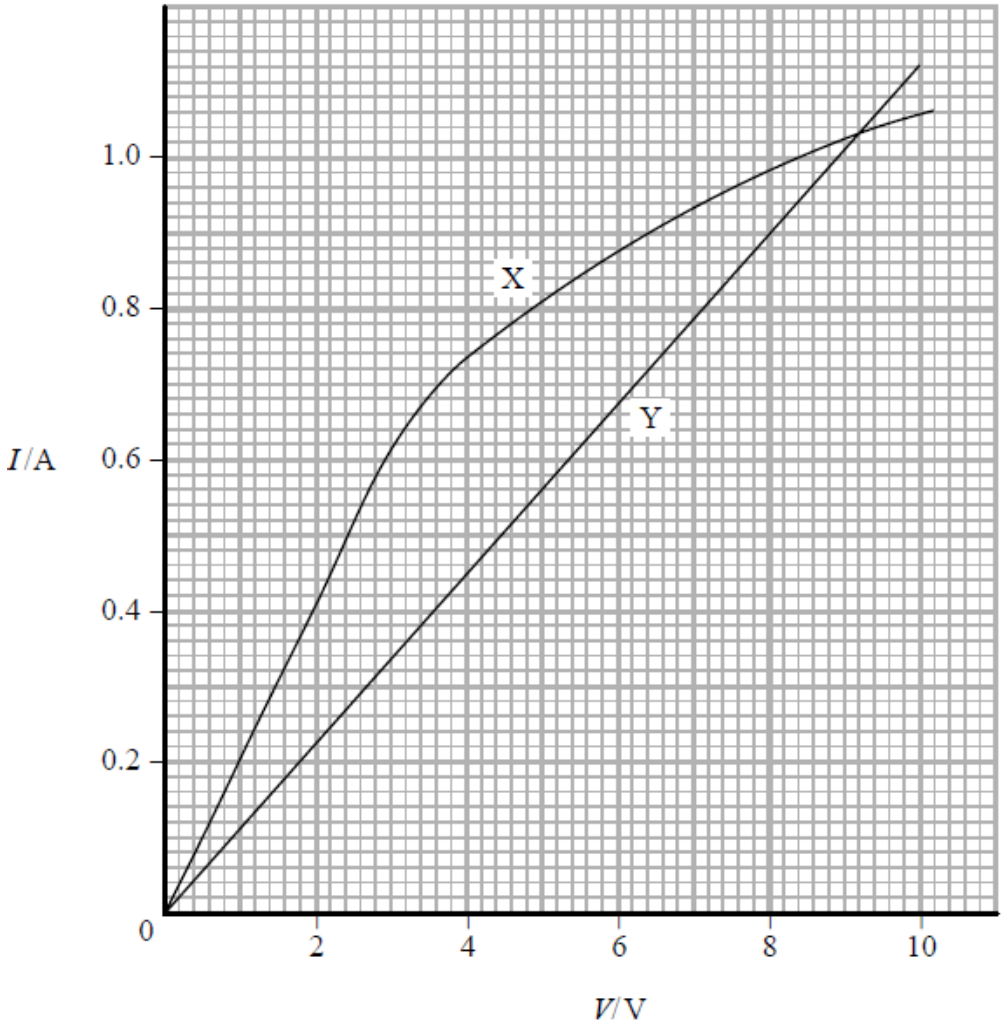
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(Total for question = 6 marks)

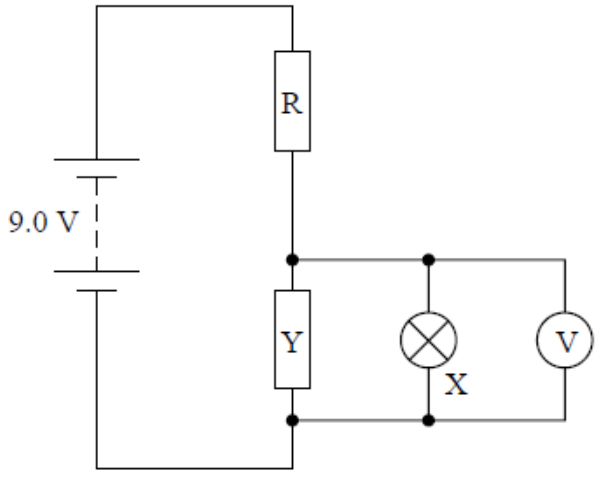
Q13.

The graph shows the variation of current *I* with potential difference *V* for two electrical components X and Y.

X is a filament bulb and Y is a fixed resistor.



A potential divider circuit consisting of components X and Y is connected to a 9.0 V supply in series with a fixed resistor R as shown. The supply has a negligible internal resistance.



The reading on the voltmeter is 3.0 V.

(i) Determine the current in the fixed resistor R.

(2)

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Current in the fixed resistor R = ...

(ii) Component X is removed from the circuit.

Explain, without further calculation, how this would change the voltmeter reading.

(3)

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(Total for question = 5 marks)

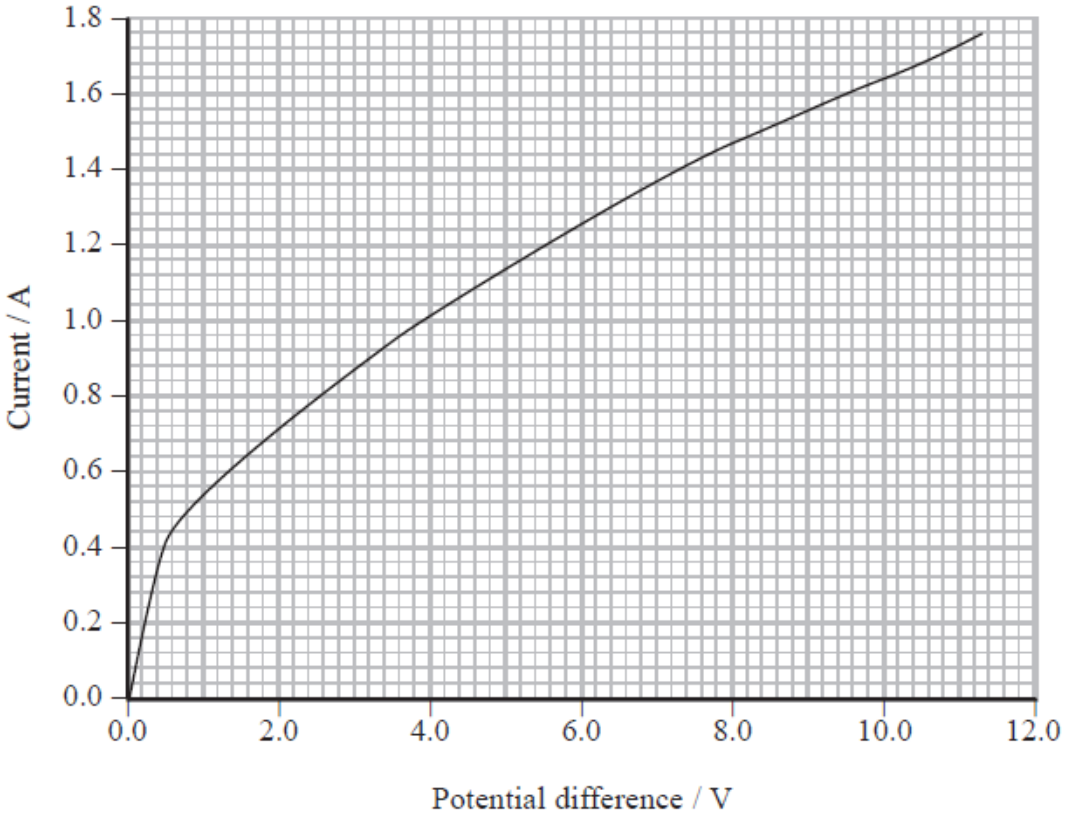
Q14.

A student investigates how the current through a filament light bulb varies with the potential difference across it.

(a) Draw a diagram of a circuit the student could use to obtain suitable measurements for a range of potential difference from 0 V to 12 V.

(3)

(b) The student's results are shown on the graph.



The student decides to draw a tangent to the curve at a potential difference of 6 V and use the gradient of the tangent to determine the resistance of the bulb.

(i) Explain why this is **not** a correct method to determine the resistance.

(2)

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(ii) Calculate the resistance of the bulb when the potential difference across it is 6 V.

(2)

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Resistance = ...

*(c) Describe and explain the change in the resistance of the bulb as the potential difference across it is increased.

(4)

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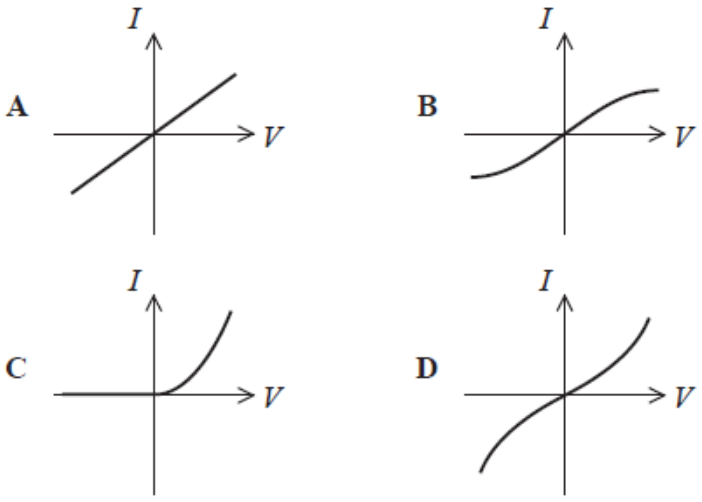
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(Total for question = 11 marks)

Q15.

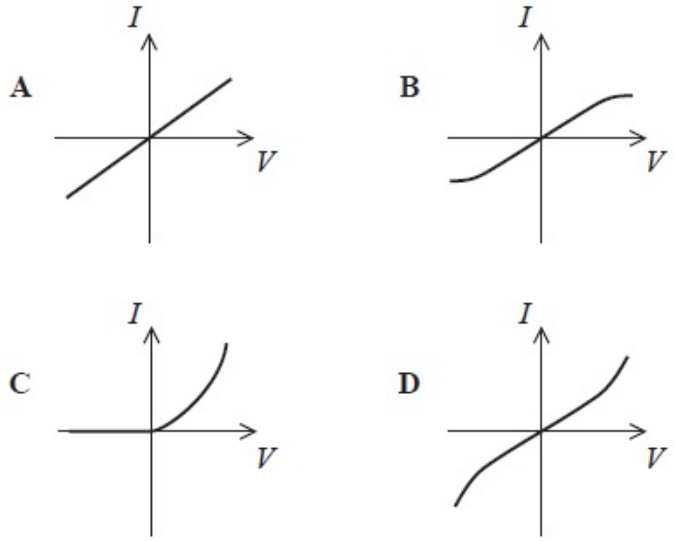
Which of the following current-potential difference (*I*-*V*) graphs correctly shows the behaviour of a diode?



- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for question = 1 mark)

Q16. Which of the following current – potential difference (*I*–*V*) graphs shows the correct behaviour for a filament bulb?



☒ **A**

☒ **B**

☒ **C**

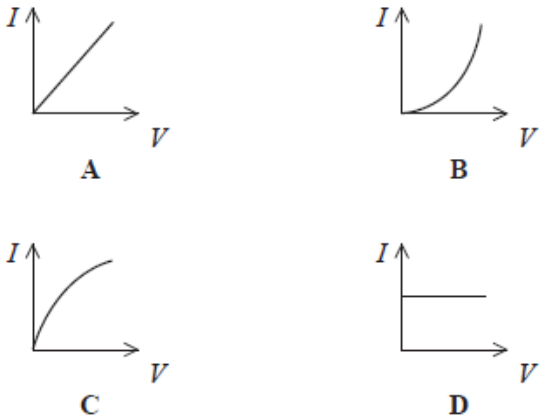
☒ **D**

(Total for Question = 1 mark)

Q17.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

Which of the following graphs shows how the current varies with potential difference for a filament lamp?



☒ **A**

☒ **B**

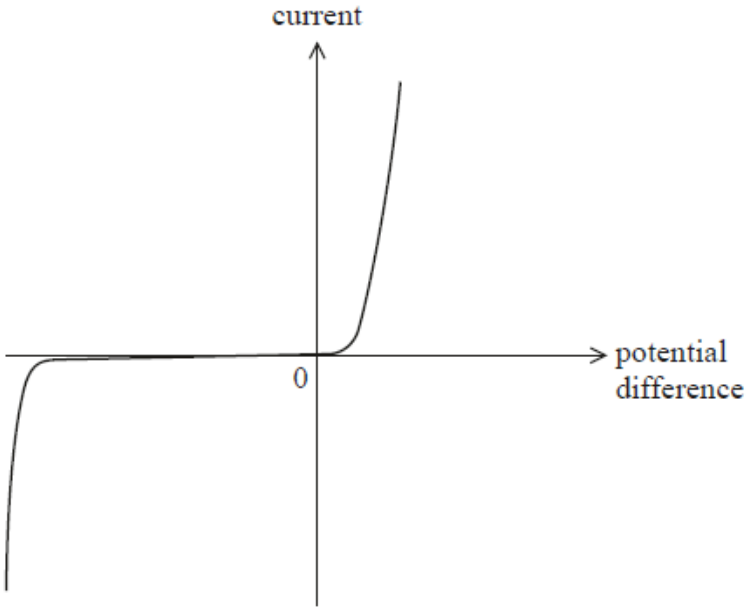
☒ **C**

☒ **D**

(Total for question = 1 mark)

Q18.

The graph shows how current varies with potential difference for a component in a circuit.



Explain how the graph shows what the component is.

(3)

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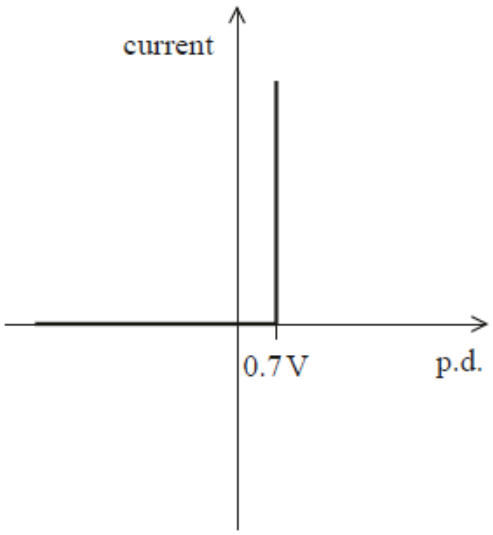
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(Total for question = 3 marks)

Q19.

The graph shows how current varies with potential difference (p.d.) for an ideal diode.



Describe how the current through this diode varies for positive p.d.s and negative p.d.s.

(2)

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(Total for question = 2 marks)

Q20.

A thermistor has a negative temperature coefficient. With reference to the equation $I = nqvA$, explain what happens to the resistance of the thermistor when its temperature increases.

(3)

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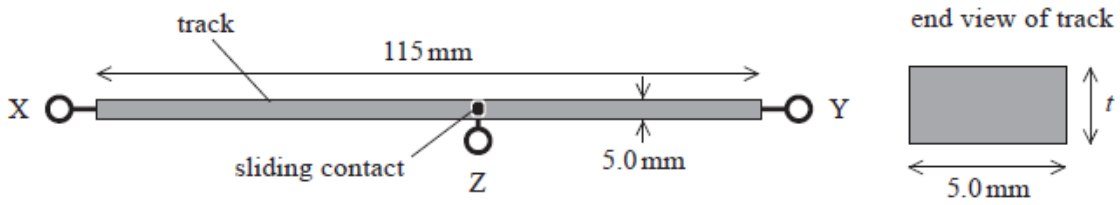
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(Total for question = 3 marks)

Q1.

A potential divider circuit may contain a component known as a potentiometer. One type of potentiometer consists of a track with terminals X and Y at either end. There is a sliding contact that can move along the track connected to a terminal Z as shown.



The length of the track is 115 mm and the width is 5.0 mm.

The resistance of the track between terminal X and terminal Y is 12.0 kΩ.

Calculate the thickness *t* of the track.

Resistivity of track material = 0.49 Ω m

(3)

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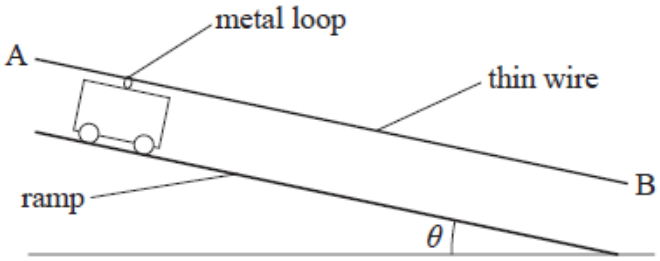
t = ...

(Total for question = 3 marks)

Q2.

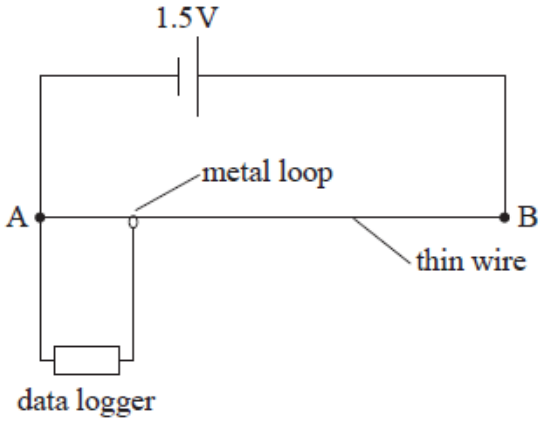
A student investigates the motion of a friction-free trolley down a ramp. On the top of the trolley there is a metal loop which makes contact with a length of thin resistance wire, AB, fixed above the ramp. The resistance wire has a uniform diameter.

The trolley accelerates down the ramp and the metal loop stays in contact with the wire along the full length of the ramp.



The student uses a protractor to measure the angle θ between the ramp and the horizontal and records a value of 4° with an uncertainty of ±1°.

(a) The two ends of the wire are connected to a 1.5 V cell. A data logger, set to measure potential difference, is connected to the metal loop and to the negative terminal of the cell.



Explain how the potential difference recorded by the data logger will vary as the loop moves along the length of the
wire AB.

(3)

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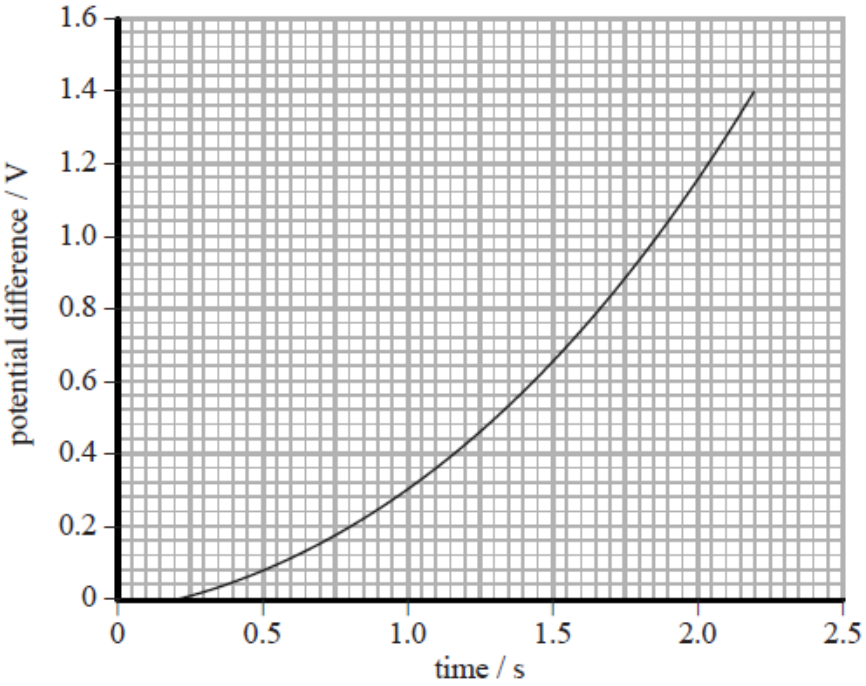
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(b) The graph shows the data obtained from the data logger.



Determine the velocity of the trolley at 1.5 s.

1.5 V represents a distance of 2.00 m.

(4)

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Velocity = ...

(c) The student calculated the velocity of the trolley at 2.0 s to be 1.5 m s^{-1}.

By considering the acceleration of the trolley, determine whether the student's measurement of θ was within the uncertainty quoted.

(4)

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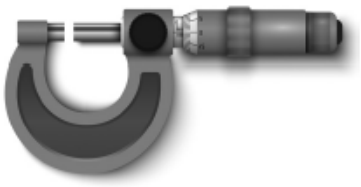
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(Total for question = 11 marks)

Q3.

The resistivity of a metal is an important property of wire used in an electric circuit.

A student carried out an experiment to determine the resistivity of a type of wire.
He used a micrometer to measure the diameter *d* of the wire.



(Source: © Viktor Chursin/Shutterstock)

He recorded the following values.

d_1 / mm	d_2 / mm	d_3 / mm	d_4 / mm
1.40	1.44	1.42	1.41

(i) Calculate the percentage uncertainty in the mean diameter of the wire.

(3)

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% uncertainty in mean diameter of wire = ...

(ii) The student used an ohmmeter to measure the resistance *R* of a 1.65 m length of the wire.

He looked up the resistivity values of some materials.

Material	Titanium	Constantan	Stainless Steel
Resistivity / $10^{-7}\,\Omega\,m$	4.2	4.7	6.9

Identify the material of the wire.

R = 0.72 Ω

(3)

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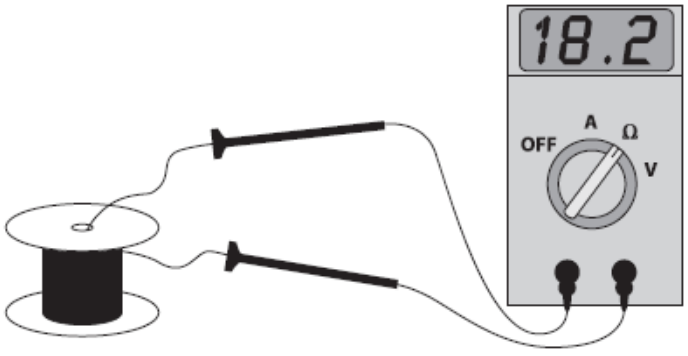
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(Total for question = 6 marks)

Q4.

A student carried out an experiment to determine the resistivity of nichrome wire.

He used an ohmmeter to measure the resistance of a length of nichrome wire as shown.



The diameter of the wire was measured as 0.27 mm ± 0.01 mm.
The length of the wire was measured as 1.25 m ± 0.05 m.

Calculate the minimum value of resistivity possible from the student's data.

(4)

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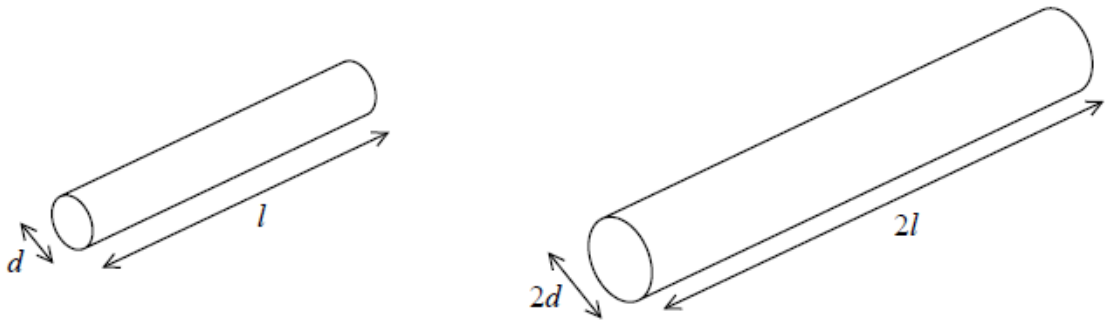
Minimum resistivity = ...

(Total for question = 4 marks)

Q5.

Pencil lead is a mixture of graphite and clay. The proportions of graphite and clay in the sample determine the hardness of the pencil lead, as well as the resistivity.

(a) The diagram shows two samples of pencil lead made from the same mixture of graphite and clay.



Sample A has a resistance R_A. Sample B has a resistance R_B and is twice the length and twice the diameter of sample A.

Calculate the ratio R_B/R_A.

(2)

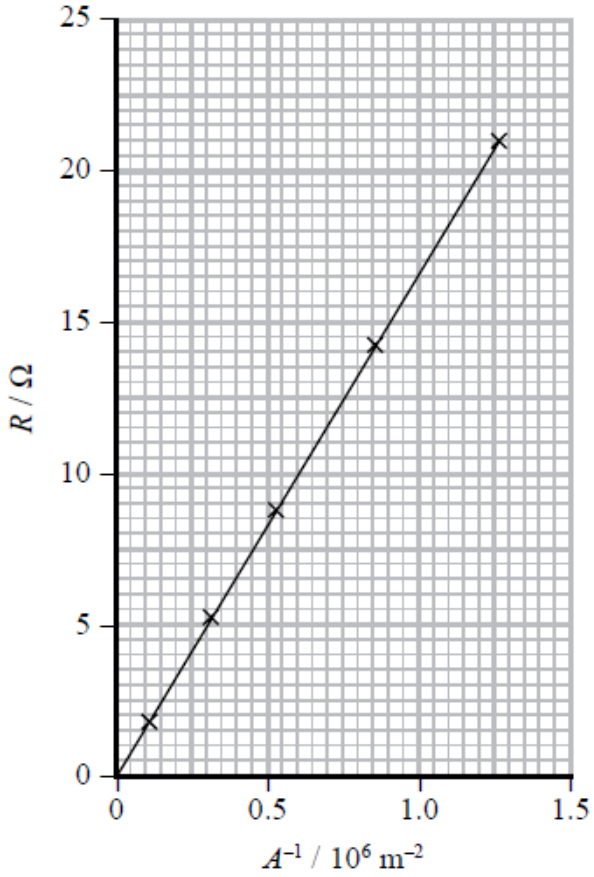
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R_B/R_A = ...

(b) A graph supplied by the manufacturer shows that the resistance R of a pencil lead is inversely proportional to its cross-sectional area A.



The resistivity of graphite is 3×10^{-5} Ω m. Use the graph to draw a conclusion about the effect of adding clay to graphite.

Length of pencil lead = 15.0 cm.

(4)

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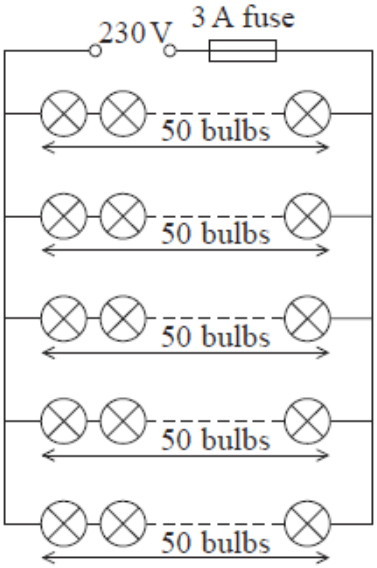
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(Total for question = 6 marks)

Q6.

A set of festive lights is made up of five parallel strands of filament bulbs. Each strand contains 50 bulbs in series as shown.



(a) When a bulb is working normally its resistance is 8.0 Ω. If the filament of the bulb breaks, the lamp is designed to still conduct and its resistance becomes 3.0 Ω.

(i) The filament of one bulb on a strand breaks.
By considering the effect this has on the remaining bulbs in that strand, explain why it is recommended that broken bulbs are replaced as soon as possible.

(3)

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(ii) The set of festive lights are fitted with a 3 A fuse. Five bulbs in one strand break.

Determine whether the fuse blows.

(3)

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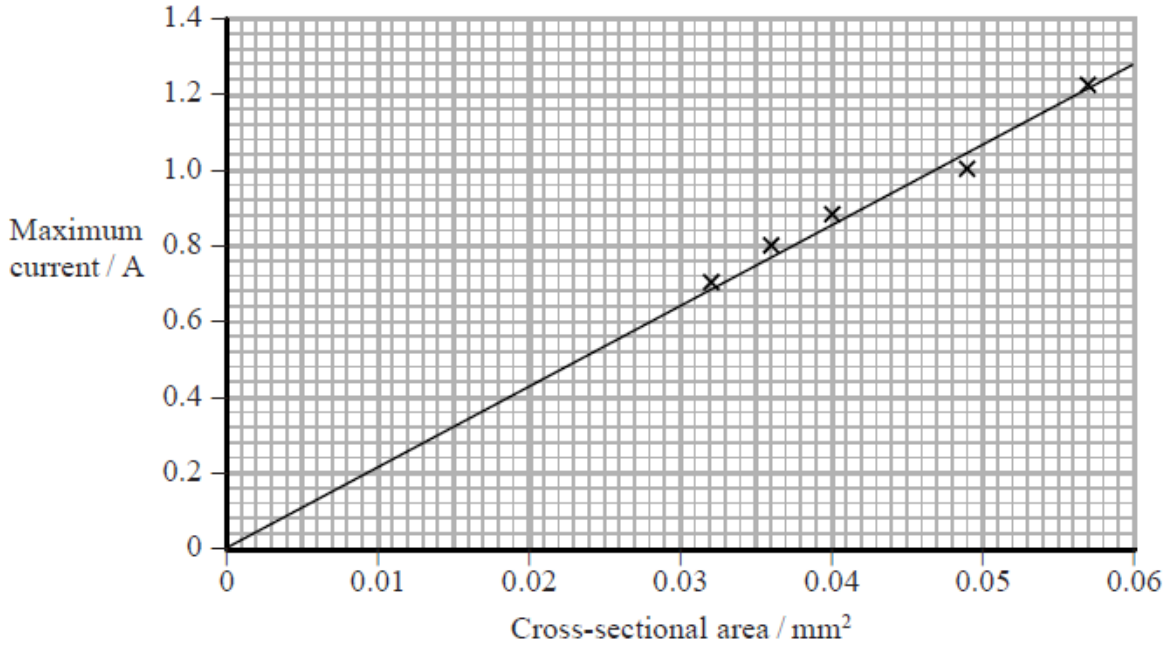
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(b) A student investigates how the cross-sectional area of a fuse wire affects the current at

which the fuse blows. She uses pieces of wire of the same material and length, but different cross-sectional areas. She steadily increases the current through each piece of wire and records the maximum current through the wire before it breaks.

She then plots a graph of maximum current against cross-sectional area.



(i) Describe how the student should determine the cross-sectional area of the wire.

(3)

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(ii) State the relationship between the maximum current and the cross-sectional area of the wire.

(1)

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(iii) The student chooses a piece of wire, of the same material and length as used in the investigation. The piece of wire has a diameter of 0.40 mm.

Use the graph to determine whether the piece of wire is suitable to use as the 3A fuse wire for the set of festive lights.

(4)

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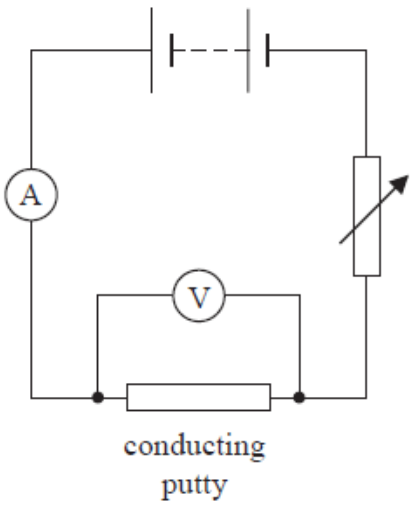
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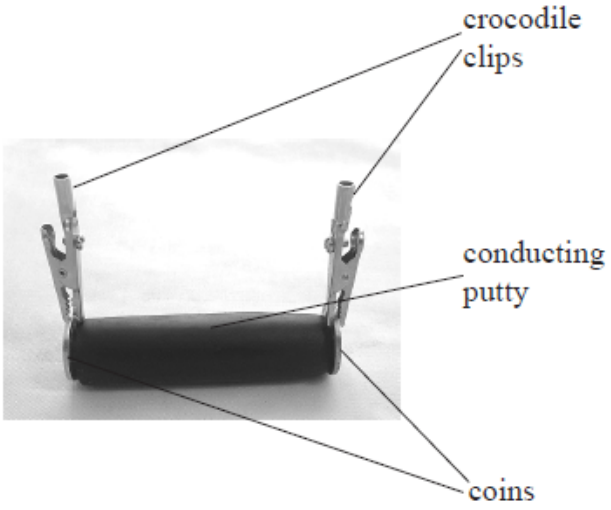
Q7.

Conducting putty is a material that is a relatively good conductor and can be easily moulded into different shapes.

A student decides to investigate how the resistance *R* of a cylinder of conducting putty depends upon the cross-sectional area *A* of the cylinder.

(a) She sets up the circuit shown and keeps the length *l* of the cylinder constant at 7.5 cm. She uses the ammeter and voltmeter readings to determine the resistance of cylinders of different cross-sectional areas.



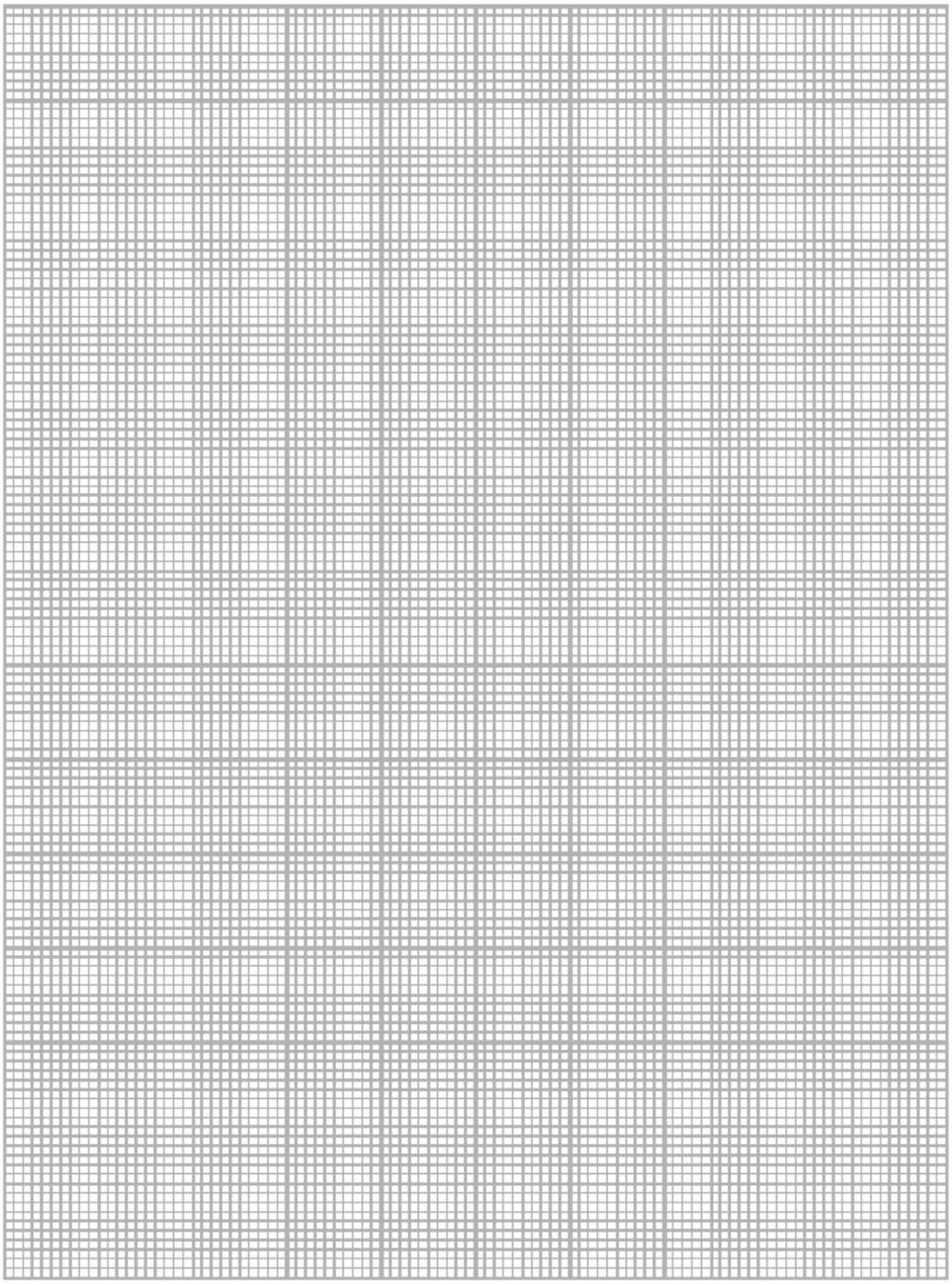


The student's results are shown in the table.

Diameter / cm	Resistance / Ω	(l / A) / m^{-1}
0.4	56.0	1490
1.0	37.5	968
1.5	16.7	430
2.0	9.44	242
2.5	6.00	155

(i) Plot a graph of R against l/A.

(4)



(ii) Use your graph to determine a value for the resistivity of the putty.

(2)

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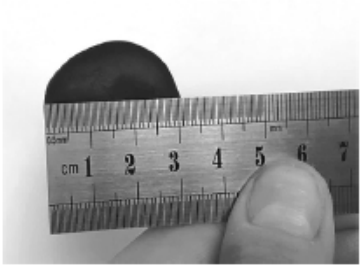
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Resistivity = ...

(b) The photographs show how the student obtained measurements for the length and diameter of a cylinder.





The student records the following readings:

length = 90 mm; diameter = 31 mm

Identify two problems with this method of determining the dimensions of the cylinder and for each problem identify a solution.

(4)

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(Total for question = 10 marks)

Q8.

Resistivity can be described correctly as

☒ **A** resistance of a unit length.

☒ **B** resistance per unit area.

☒ **C** resistance per unit volume.

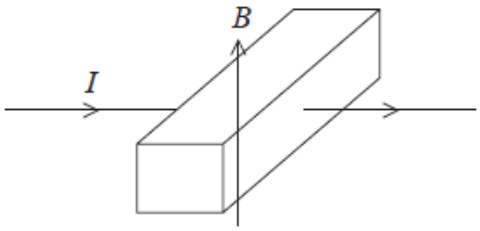
☒ **D** resistance of a unit cube.

(Total for question = 1 mark)

Q9.

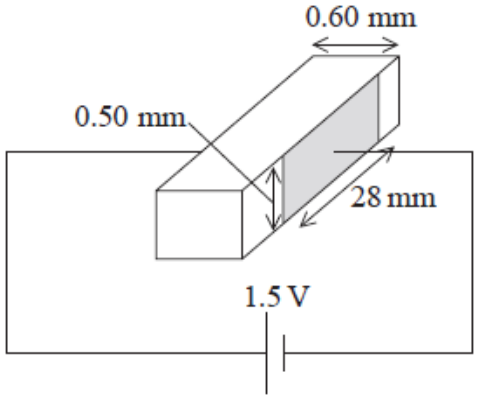
Some liquids conduct electricity. This property can be used to pump these liquids through pipes.

A short section of a rectangular pipe containing a liquid is shown in the diagram. The pipe is placed in a magnetic field of flux density *B* and a current *I* is passed through the liquid as shown.



A practical demonstration of this principle used two rectangular electrodes, opposite each other on either side of the pipe, a distance of 0.60 mm apart. The dimensions of the electrodes are shown in the diagram.

The electrodes were connected to a 1.5 V cell.
Salt water was pumped using a magnetic field of magnetic flux density 0.40 T.



(i) Show that the current through the salt water is about 20 mA.

resistivity of salt water = 1.6 Ω m

(4)

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(ii) Hence calculate the force on the salt water.

(2)

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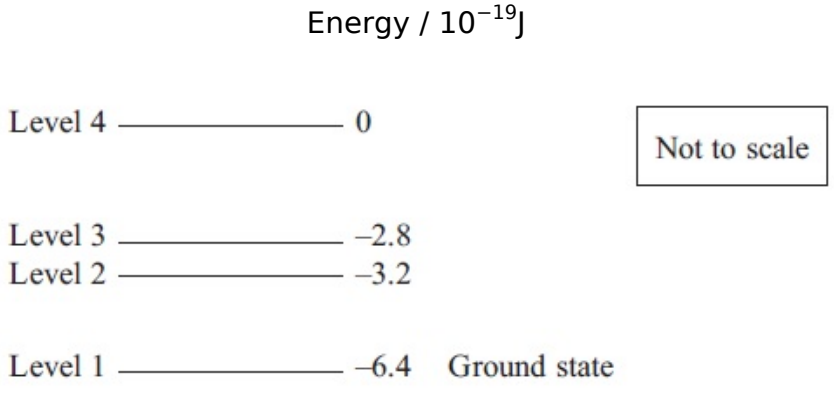
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Force = ...

(Total for question = 6 marks)

Q10.

The diagram shows four energy levels for an electron in a particular atom.



(a) State what is meant by an energy level.

(1)

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(b) Draw on the diagram **two** arrows to indicate two different transitions that would result in emitted radiation of the same frequency.

(2)

(c) A gas consisting of these atoms can emit a line spectrum.

Explain how this happens.

(3)

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(d) One of these atoms in its ground state absorbs 3.6×10^{-19} J of energy from a collision with an electron.

Calculate the smallest frequency of radiation that the atom may subsequently emit.

(3)

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Smallest frequency = ...

(e) Calculate how much energy in eV would be required to ionise the atom in its ground state.

(2)

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Energy = ...

(Total for question = 11 marks)

Q11.

A laboratory technician found a reel of resistance wire, without a label.

(a) In order to determine the type of wire on the reel she recorded the following measurements.

Length of wire l = 70.7 cm ± 0.2 cm
Diameter of wire d = 1.82 mm ± 0.02 mm
Potential difference across wire V = 1.50 V
Current through wire I = 4.11 A
The uncertainty in the measurements of V and I is negligible.

Calculate the resistivity of the wire.

(3)

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Resistivity = ...

(b) The technician used the internet to find values for the resistivity of the different wires available in the laboratory. She recorded these values in a table.

Wire	Resistivity / × 10^{-8} Ωm
Constantan	49.0
Nichrome	125
Kanthal	139

Use the uncertainties in the measurements to explain whether the technician could conclude which type of wire was on the reel.

(4)

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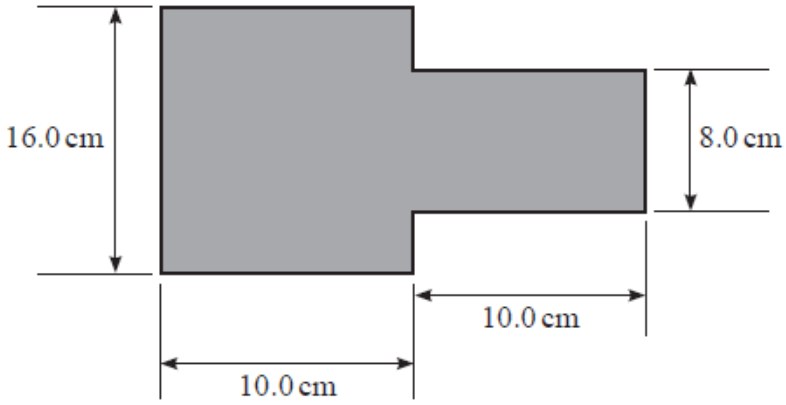
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(Total for question = 7 marks)

Q12.

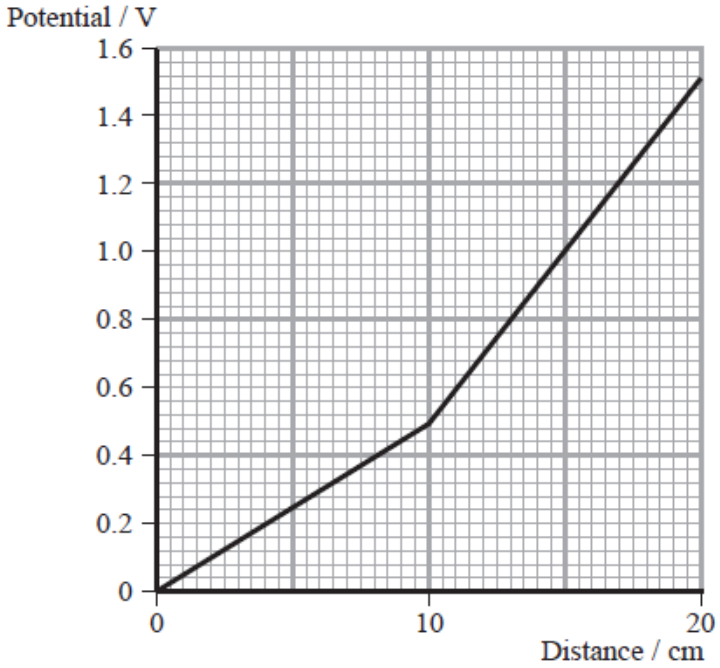
*****Carbon paper is an electrically conducting paper. A student cut a sheet of this paper into the shape shown, to carry out an investigation.



The student followed the procedure below to set up a potential divider circuit:

- connect the 16 cm and 8 cm wide ends to a 1.5 V cell
- connect the 16 cm wide end to the negative (0 V) terminal of the cell
- connect a voltmeter so that it measures the potential at a point 15 cm from the 16 cm wide end.

The following graph was plotted from an investigation in which the potential was measured at various distances from the 16.0 cm wide end of the shape.



Explain the shape of this graph.

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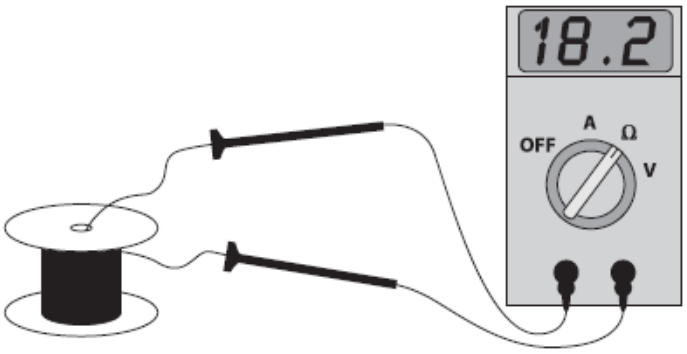
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(Total for question = 6 marks)

Q13.

A student carried out an experiment to determine the resistivity of nichrome wire.

He used an ohmmeter to measure the resistance of a length of nichrome wire as shown.



The diameter of the wire was measured as 0.27 mm ± 0.01 mm.
The length of the wire was measured as 1.25 m ± 0.05 m.

Determine which of the three measurements introduces the greatest uncertainty into the value for the resistivity.

Your answer should include calculations.

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(Total for question = 4 marks)

Q14.

Analogue ammeters were used before digital meters became widely available.

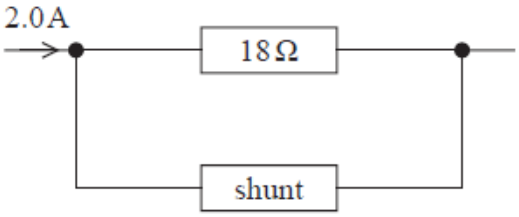
The analogue ammeter shown will measure a maximum current of 1.0 mA and has a resistance of 18 Ω.



(Source: © David J. Green/Alamy Stock Photo)

The analogue ammeter can be adapted to measure a larger current by adding a resistor, known as a shunt, in parallel with the ammeter.

The arrangement is shown below. The analogue ammeter is represented by the 18 Ω resistor.



The maximum current through the 18 Ω resistor remains as 1.0 mA.

A shunt of this resistance was usually made from Manganin wire.

Calculate the length of Manganin wire of radius 0.95 mm required to make this shunt.

resistivity of Manganin = 4.55×10^{-7} Ω m

(3)

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Length = ...

(Total for question = 3 marks)

Q15.

The photograph shows a statue of Buddha in Sri Lanka, which is protected by a lightning conductor.



© Valery Shanin/123RF

The lightning conductor is a length of copper wire with a diameter of 1.2×10^{-2} m and a resistance of $4.3 \times 10^{-3}\,\Omega$. It runs along the back of the statue from the base to a height of 1.5 m above the top of the statue.

A guidebook claims that the statue is over 30 m high.

Assess the validity of this claim.

resistivity of copper = $1.7 \times 10^{-8}\,\Omega\,\text{m}$

(4)

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(Total for question = 4 marks)

Q16.

In 2010, Andre Geim and Konstantin Novoselov were awarded the Nobel Prize in Physics for producing, identifying and studying graphene.

Graphene is a form of carbon which exists only as a single atomic layer of graphite. It has a breaking stress of 130 GPa compared to 0.5 GPa for steel. Some scientists claim that graphene is the strongest material ever measured.

(a) Explain why graphene, despite its greater strength, is unlikely to replace steel in many applications.

(2)

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(b) Graphite used in pencils consists of many layers of carbon. It can be assumed that a pencil deposits approximately 100 layers of carbon atoms when drawn across a piece of paper.

A student carried out an experiment to determine the resistivity of the graphite in a pencil.

A line of length 0.200m and width 0.50mm was drawn on a piece of paper. An ohmmeter was then used to measure the resistance of the graphite line.



Calculate the resistivity of graphite.

resistance = $1.029 \times 10^{6}\ \Omega$
diameter of carbon atom = 1.4×10^{-10} m

(4)

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Resistivity of graphite = ...

(c) Photocells traditionally use silicon to generate electricity using visible light. Research demonstrates that unlike silicon, graphene is able to respond at all wavelengths and releases multiple electrons as it absorbs one photon.

Deduce why it would be an advantage to use graphene in photocells to generate electricity.

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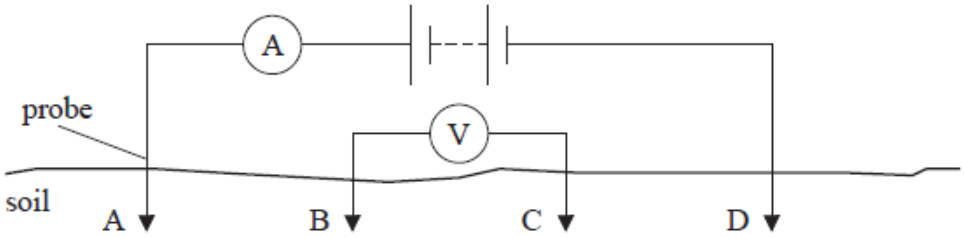
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(Total for question = 9 marks)

Q17.

Archaeologists use resistivity surveying of soil to search for the remains of buildings and settlements under the ground.

A basic arrangement that can be used to determine the resistivity of a region of soil is shown.



Probes are placed at positions A and D so that the length AD of soil forms part of the circuit. The ammeter measures the current through the soil.

A second pair of probes connected to a voltmeter is placed at positions B and C.
This measures the potential difference between positions B and C in the soil.

The table gives the resistivity of some different materials.

Material	Resistivity / Ω m
Undisturbed clay	4–20
Compacted clay	100–200
Limestone	500–1000
Sandstone	1500–10 000

The probes connected to the voltmeter are kept at a constant separation of 0.75 m and are moved along the soil between positions A and D.

The current is constant at 9.5 mA. The voltmeter reading varies between 1.8 V and 8.0 V.

It can be assumed that the sample of soil under investigation has a cross-sectional area of 0.65 m^2.

Deduce two possible materials that could be present in the soil between positions A and D.

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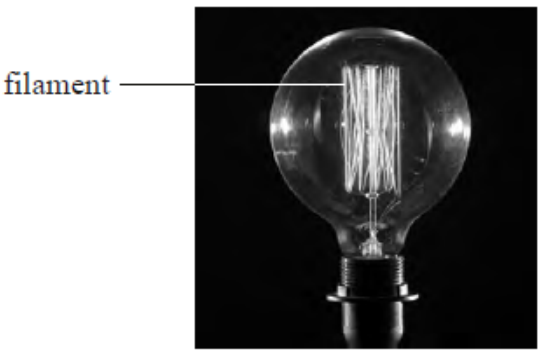
(Total for question = 4 marks)

Q18.

Filament and fluorescent are two types of light bulb.

Filament light bulbs contain a tightly coiled wire filament, surrounded by an inert gas and encased in a thin glass bulb. When the potential difference (p.d.) across the bulb is sufficient, the filament heats up, emitting visible light.

Fluorescent light bulbs use a long tube of glass containing a small amount of mercury. When a sufficient p.d. is applied across the ends of the tube, electrons moving through the tube cause the mercury to become a vapour and emit photons in the ultraviolet part of the electromagnetic spectrum. The collisions of these photons with the phosphor coating of the tube result in the emission of photons of visible light.



Filament bulb



Fluorescent bulb

A filament bulb contains a tungsten filament of diameter 3.8×10^{-5} m and uncoiled length 1.6 m. As the temperature of the filament increases, the resistance of the filament increases to a maximum which is 14 times greater than the initial resistance at room temperature.

(i) Determine the power of the filament at maximum brightness.

p.d. across filament = 240 V
resistivity of tungsten at room temperature = 5.6×10^{-8} Ω m

(5)

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Power = ...

(ii) Filament bulbs are designed to last for thousands of hours of use. Over time the filament may wear away, becoming thinner at one point. This can cause the filament to melt and break at that point.

Assess whether the filament is more likely to break as the bulb is switched on or when it is in use.

(4)

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(Total for question = 9 marks)

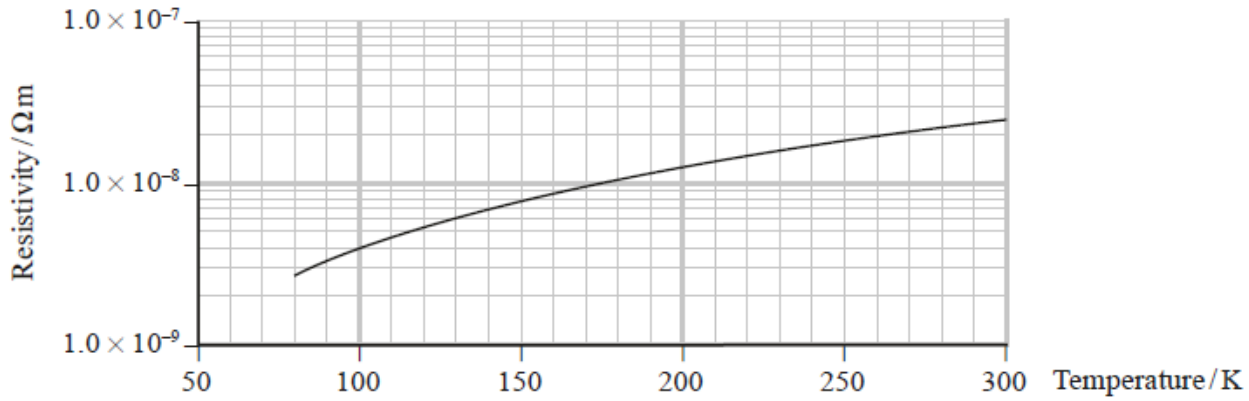
Q19.

Electrical transmission systems are used to transmit electrical power from place to place. Transformers are used to change potential differences (p.d.) and power transmission cables are used to transmit power.

Efficient electrical transmission systems are being developed using superconductors. Superconductors have zero resistance at low temperatures, and therefore no power is wasted by transfer to thermal energy unlike copper cable systems.

In one project a 1.05 km length of copper cable at a temperature of 270 K has been replaced by a superconductor. The superconductor has a cooling system which requires power.

The graph shows the variation of resistivity with temperature for copper.



Deduce whether the power requirement of the superconductor cooling system is less than the power losses in the copper cable.

transmission power = 40 MW

transmission potential difference = 110 kV

cross-sectional area of copper cable = 145 mm^2

power requirement of cooling system for the superconductor = 7 kW

(5)

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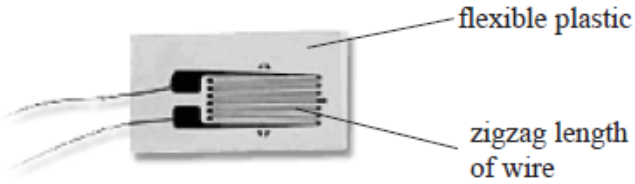
(Total for question = 5 marks)

Q20.

A medical scanner uses a moving table to position the patient. Strain gauges are used to monitor the shape of the table which enables a more precise positioning of the patient.



Strain gauges consist of a thin length of wire attached, in a zigzag pattern, to a small flexible piece of plastic. The strain gauge is attached to the table. When the table is subjected to forces, the dimensions of the plastic change. This causes a change in the length of the wire and hence a change in the resistance of the wire.



(a) Resistance can be measured directly using an ohmmeter or indirectly using measurements from a voltmeter and ammeter.

Describe **two** benefits of using an ohmmeter compared to using a voltmeter and an ammeter.

(2)

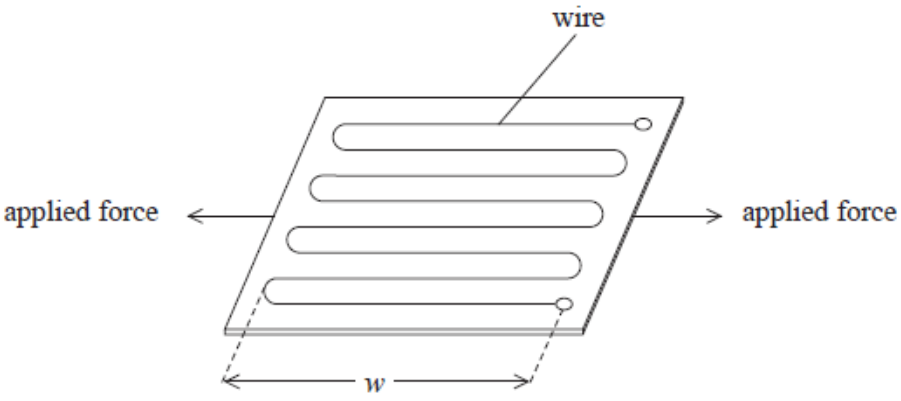
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(b) The diagram shows forces applied to a strain gauge. The 'width' of the strain gauge is defined by the distance *w*.



(i) State and justify how the applied forces change the resistance of the wire.

(2)

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(ii) The gauge factor *GF* of a strain gauge is given by

$$GF = \frac{\Delta R}{\varepsilon R}$$

where ε is the strain
R is the initial resistance
ΔR is the change in resistance

When forces are applied to the strain gauge, the resistance of the gauge changes by 0.10%.

Calculate the change in the width of the strain gauge.

w = 5.0 cm
GF = 2.0

(3)

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Change in width = ...

(c) Explain the benefit of arranging the wire in a zigzag pattern.

(2)

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(Total for question = 9 marks)

Q21.

A "metre bridge" is a circuit which can be used to measure an unknown resistance accurately. The metre bridge includes a metre length of nichrome wire.

Calculate the resistance of a 1.00 m length of the nichrome wire.

(3)

resistivity of nichrome = 1.12×10^{-6} Ωm
diameter of wire = 4.00×10^{-4} m

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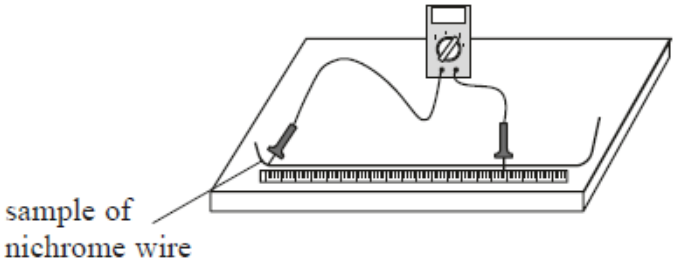
Resistance = ...

(Total for question = 3 marks)

Q22.

An ohmmeter was used to measure the resistance *R* of a length *l* of nichrome wire as shown.

This was then repeated for different values of *l*.



The diameter of the wire was measured and the cross-sectional area *A* of the wire calculated.

A graph was plotted. The gradient of the graph was equal to the resistivity of nichrome.

Which row of the table shows the quantities which were plotted on the *y*-axis and the *x*-axis?

	y-axis	*x*-axis
☒ **A**	l	RA
☒ **B**	lA	R
☒ **C**	R	Al
☒ **D**	RA	l

(Total for question = 1 mark)

Q23. A strain gauge measures changes in the resistance of a metal under strain to find the applied force. The kitchen balance in the photograph uses strain gauges to measure the weight of cooking ingredients.



A student tests this method by measuring the resistance of a wire before a force is applied and while it is under tension.

(a) Calculate the initial resistance of the wire.

length of wire = 1.0 m

cross sectional area of wire = 2.9×10^{-8} m^2

resistivity of wire = 4.9×10^{-7} Ω m

(2)

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Resistance of wire = ...

(b) The student applies a force to the wire and measures the new length. He calculates the increase in the resistance to be 0.035 Ω. He measures the increase in resistance and finds it to be 0.070 Ω.

The student suggests that the difference between these two values is because the cross-sectional area of the wire changes under strain.

Explain why a change in cross-sectional area would cause this difference.

(3)

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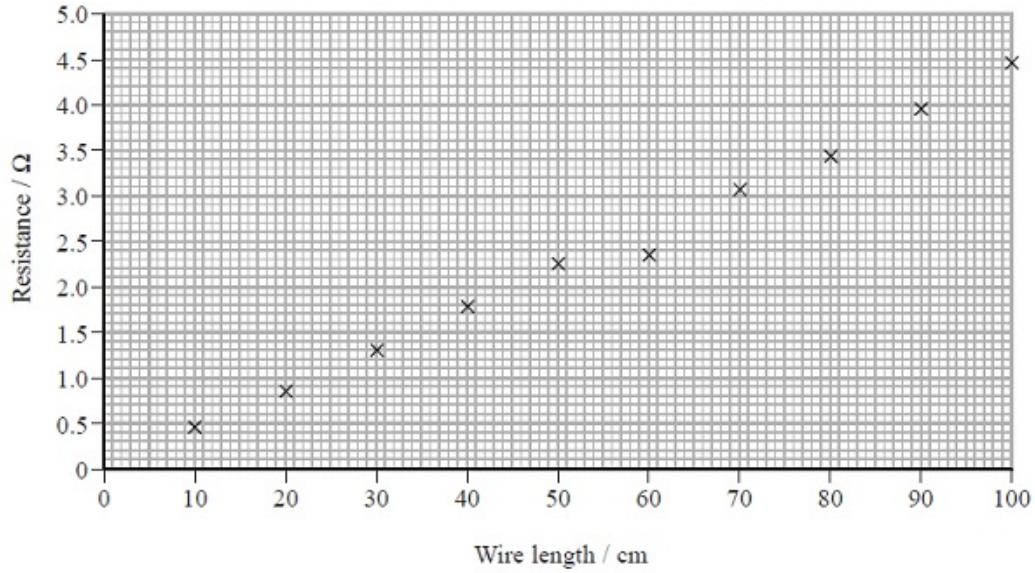
(Total for Question = 5 marks)

Q24. A student carried out a series of measurements to determine how the resistance of a wire varies with its length.

The student obtained the following results.

Wire length / cm	Current / A	Potential difference / V	Resistance / Ω
100	0.15	0.67	4.47
90	0.16	0.63	3.94
80	0.17	0.58	3.41
70	0.17	0.52	3.06
60	0.18	0.42	2.33
50	0.18	0.40	2.22
40	0.19	0.34	1.79
30	0.20	0.26	1.30
20	0.22	0.18	0.82
10	0.22	0.10	0.45

The student plotted the results on a graph.



(a) Calculate the resistivity of the wire used.

cross-sectional area of wire = 1.06×10^{-7} m^2

(4)

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Resistivity = ...

(b) One precaution taken by the student was to keep the current small.

Explain why this precaution was necessary.

(2)

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(c) Explain **one** other precaution which should be taken by the student to ensure the accuracy of the results in the table.

(2)

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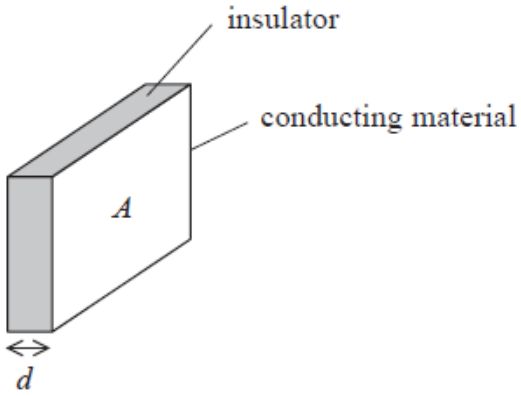
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(Total for Question = 8 marks)

Q25.

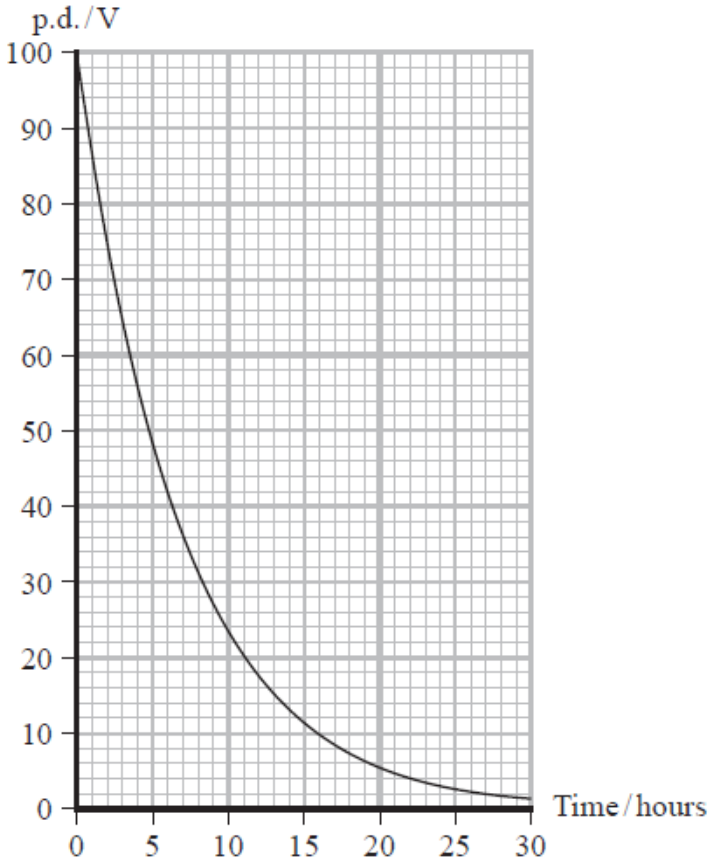
A parallel plate capacitor consists of a thin layer of insulator of thickness *d* between two plates of conducting material of area *A*.



The capacitor has a capacitance 0.1 μF and is charged to a p.d. of 100 V by connecting it to an electrical supply.

The capacitor is then disconnected from the supply and the p.d. between the two plates slowly decreases. This is because the insulator is not perfect and a small charge can flow through it.

The graph shows how the p.d. varies with time.



The insulator is a type of plastic and should have a resistivity greater than 10^{14} Ω m.

Deduce whether the plastic used in this capacitor has a resistivity greater than this value.

$A = 5.6 \times 10^{-3}$ m^2

$d = 0.6 \times 10^{-6}$ m

(5)

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(Total for question = 5 marks)

Q26.

The instruction booklet for an electric garden shredder includes the following advice.

When using an extension cable, the following dimensions should be observed:

Cross-sectional area of conductor / mm^2	Maximum cable length / m
1.00	40
1.50	60
2.50	100

(a) Describe the relationship between area and length in the table.

(1)

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(b) The cable for the shredder contains two conductors in series, the live wire and the neutral wire. A cable of length 40 m has a total conductor length of 80 m.

(i) Show that the resistance of a copper conductor of length 80 m and cross-sectional area 1.00 mm^2 is about 1.3 Ω.

resistivity of copper = 1.68×10^{-8} Ω m

(2)

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(ii) When in use the current for the shredder is 11 A.

Calculate the rate of energy dissipation by the 40 m, 1.00 mm^2 cable when it is used with the shredder.

(2)

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Rate of energy dissipation = ...

(iii) Calculate the total potential difference across the conductors in the 40 m cable when it is used with the shredder.

(2)

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Potential difference = ...

(c) Suggest why the advice in the instruction booklet is included.

(2)

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(Total for question = 9 marks)

Q27.

A student was given a block of conducting putty of mass 43 g.

The student then made a cylinder that had a larger resistance.

Explain how the student used the putty to make a larger resistance.

(2)

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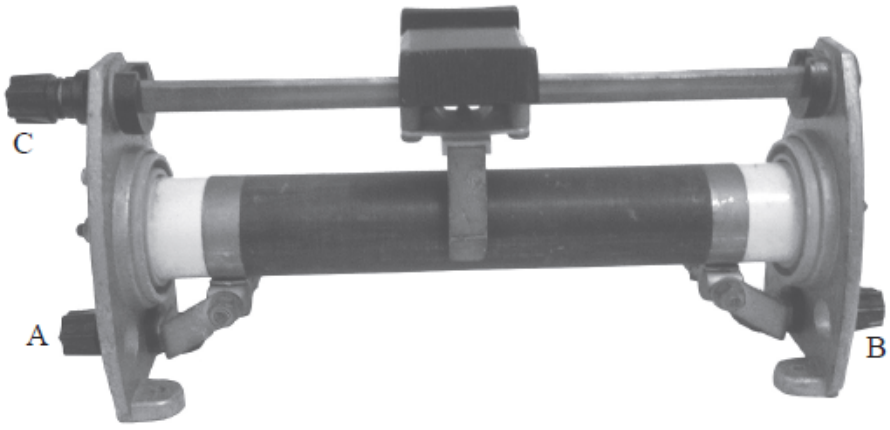
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(Total for question = 2 marks)

Q28.

Photograph 1 shows a rheostat (a variable resistor).

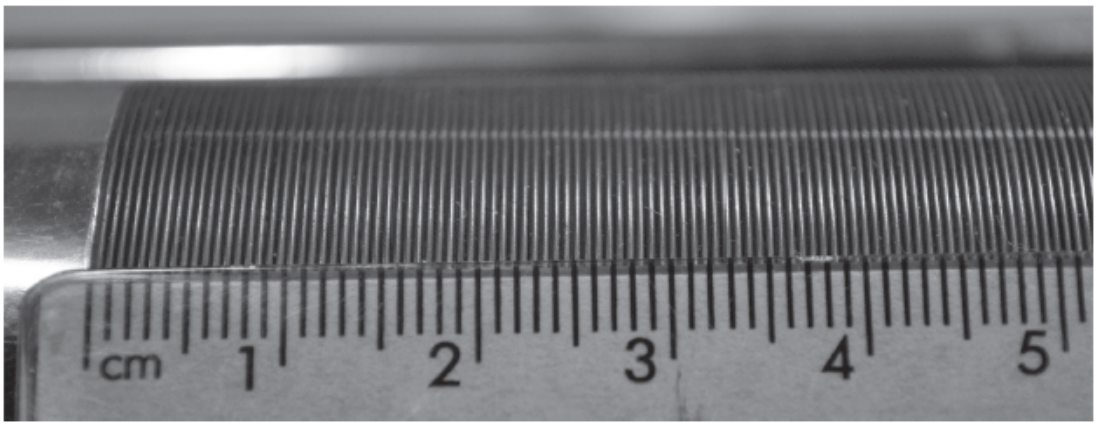


Photograph 1

The rheostat is made of a long resistance wire coiled around an insulating cylinder. The turns of wire are also separated from each other by insulation of negligible thickness. The ends of the wire are connected to the sockets A and B at either end and there is a sliding contact in the centre connected to the socket C. The resistance between A and C is varied by moving the sliding contact.

(a) A student decides to determine the resistivity of the material from which the wire is made by measuring the dimensions of the wire and its resistance.

Photograph 2 shows a section of the rheostat and a scale.



Photograph 2

(i) Take measurements from the photograph and use them to show that the cross-sectional area of the wire is about 2×10^{-7} m^2.

(3)

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(ii) Calculate the resistivity of the material from which the wire is made.

resistance of wire = 22 Ω

length of wire = 12 m

(3)

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Resistivity = ...

(iii) Suggest an advantage for the student of using a photograph rather than taking direct measurements.

(1)

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(b) The coil of the rheostat is 10.2 cm long. A potential difference of 12 V is applied across AB and the slider C is 7.0 cm from the end of the coil near A.

(2)

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Potential difference = ...

(Total for question = 9 marks)

Q29.

A physicist investigates how light intensity varies with distance from a light bulb. She sets up the apparatus as shown.



Explain why the resistance *R* of the LDR will increase as it gets further away from the bulb.

(2)

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(Total for question = 2 marks)

Q30.

A student was given a block of conducting putty of mass 43 g.

(i) Show that the volume of the block of conducting putty was about 8×10^{-6} m^3.

density of conducting putty = 5300 kg m^{-3}

(2)

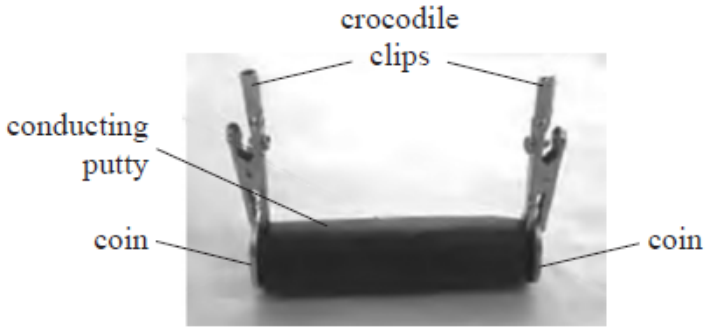
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(ii) The student formed the putty into a cylinder. Coins were pushed onto the ends of the cylinder as shown. The coins each had a crocodile clip attached and an ohmmeter was connected across the putty.



Determine the resistance of the cylinder of putty.

diameter of cylinder = 12 mm

resistivity of conducting putty = 4.0×10^{-3} Ω m

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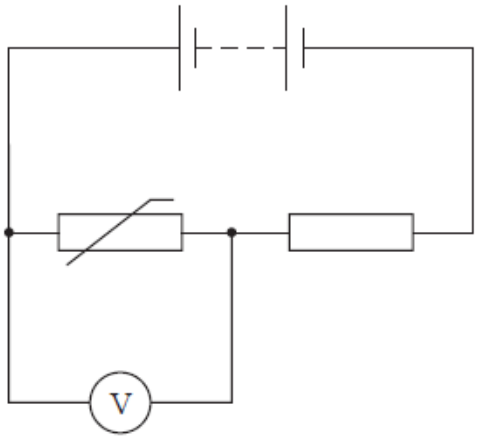
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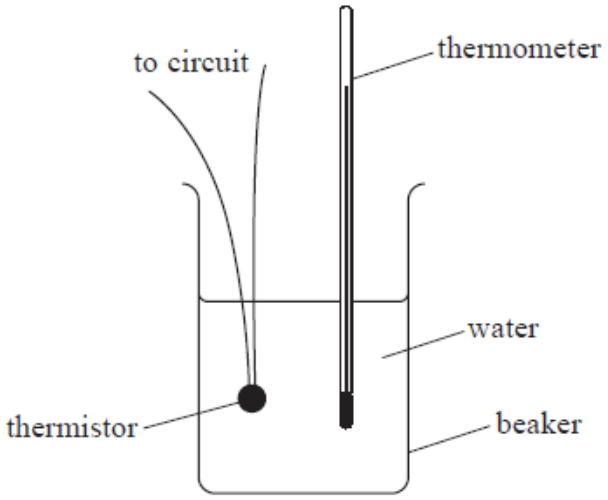
Resistance = ...

(Total for question = 5 marks)

Q1.

A student carried out an experiment to calibrate a thermistor. She connected the thermistor in series with a resistor and a power supply as shown. Then she placed the thermistor in a beaker of hot water and used a thermometer to record the temperature θ of the water.





The student recorded θ and corresponding values of the reading V on the voltmeter as the water cooled.

Explain, making reference to charge carriers, why V increased as the water cooled.

(3)

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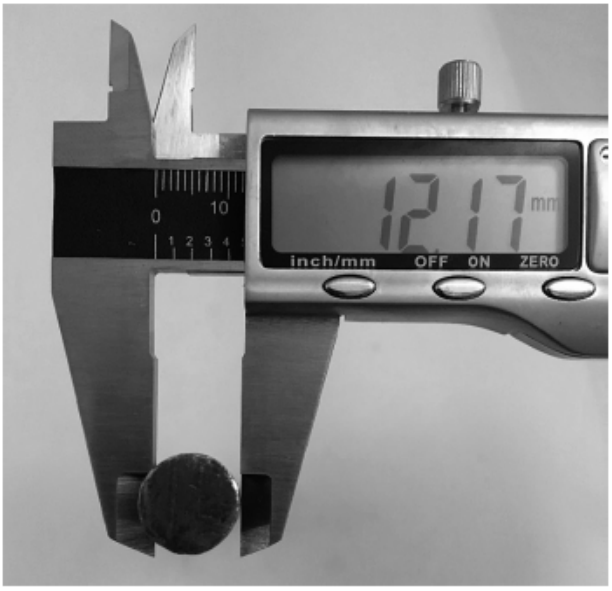
(Total for question = 3 marks)

Q2.

The photographs show two types of caliper being used, in turn, to measure the diameter of an

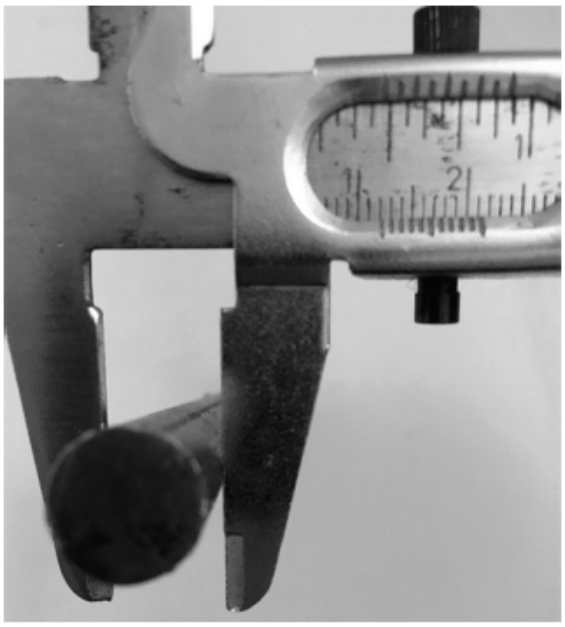
iron rod.

Caliper 1



diameter = 12.17 mm

Caliper 2



diameter = 12.2 mm

The value obtained from caliper 2 was used to determine the cross-sectional area of the rod and the electrical properties of the rod were investigated.

Calculate the drift velocity for the charge carriers in the rod when the current in the rod is 1.9 A.

diameter of rod = 12.2 mm
charge carrier density for iron = 1.7×10^{29} m^{-3}

(3)

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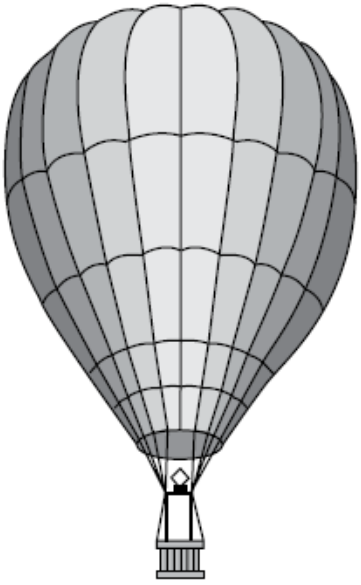
Drift velocity = ...

(Total for question = 3 marks)

Q3.

Newton's laws relate the changes in motion of an object to the forces acting on the object.

A hot-air balloon is made of an envelope, containing hot air, with a wicker basket suspended from it. The balloon rises upwards because the heated air in the envelope is less dense than the surrounding air.



The total volume of the hot-air balloon is 2880 m^3. The total mass of the hot-air balloon, including the envelope, is 3400 kg. The density of the surrounding air is 1.20 kg m^{-3}.

Calculate the initial upward acceleration of the balloon.

(4)

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Initial acceleration = ...

(Total for question = 4 marks)

Q4.

(a) State what is meant by drift velocity when applied to a metal conductor.

(1)

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(b) Two conductors of the same material and length carry the same current. Conductor X has twice the cross-sectional area of conductor Y.

(i) By referring to an appropriate equation, compare the drift velocities for conductor X and conductor Y.

(2)

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*(ii) Explain the difference in resistance of conductor X and conductor Y in terms of the difference in drift velocity.

(3)

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(Total for question = 6 marks)

Q5.

A potential difference is applied across the metal filament of a light bulb and charge flows.

By referring to the mean drift velocity of the electrons, explain what happens to the current in the metal filament if the potential difference is unchanged and the temperature of the metal increases.

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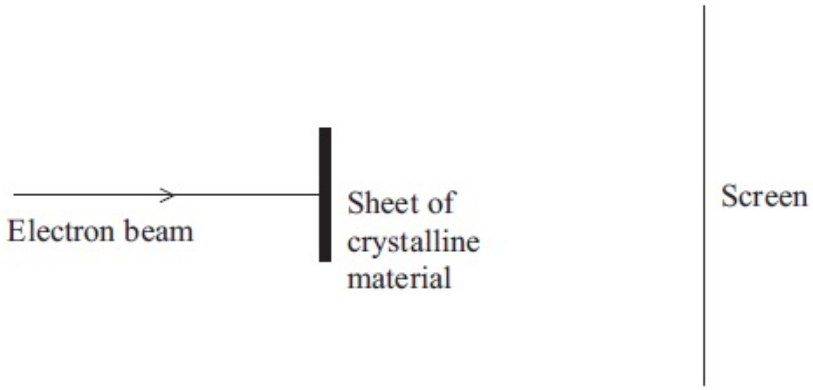
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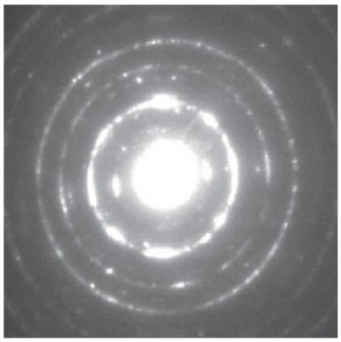
(Total for question = 3 marks)

Q6.

The diagram shows a beam of electrons being fired towards a thin sheet of crystalline material. The screen detects electrons after they have passed through the sheet.



The photograph shows the positions at which electrons strike the screen.



Explain what can be deduced about the behaviour of electrons from the formation of this pattern.

(3)

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(Total for question = 3 marks)

Q7.

The current through a wire of cross-sectional area A is I when the drift velocity of the electrons in the wire is v and the charge carrier density is n.

The wire is replaced with a wire of a different metal with half the charge carrier density but the same cross-sectional area A.

If the current in the new wire is $2I$, the drift velocity is

☒ **A** $v/2$

☒ **B** v

☒ **C** $2v$

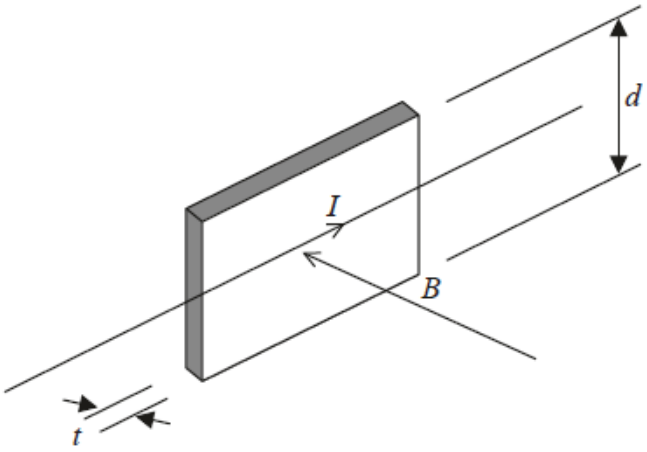
☒ **D** $4v$

(Total for question = 1 mark)

Q8.

Tiny sensors in smartphones could be used to determine the position of the phone on the Earth's surface by measuring the Earth's magnetic flux density.

A current I and a magnetic field of flux density B are applied to a slice of semiconductor as shown. The slice has thickness t and depth d.



Electrons collect at the top edge of the slice and the bottom edge becomes positively charged. As a result a potential difference known as a Hall voltage V_{HALL} develops.

Electrons continue to collect at the top edge of the slice, until the force on a moving electron due to the magnetic field is equal to the force on the electron due to the electric field.

Derive the following equation for V_{HALL}:

$$V_{HALL} = \frac{BI}{nte}$$

where n is the number of charge carriers per unit volume of the semiconductor.

(4)

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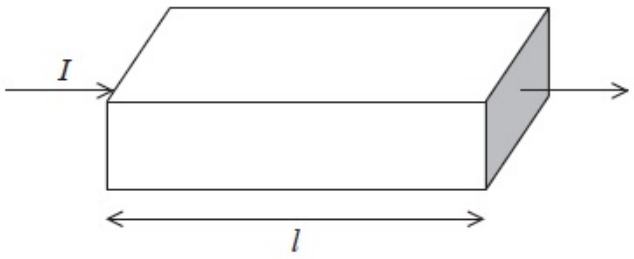
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(Total for question = 4 marks)

Q9. The diagram shows a current *I* flowing through a sample of material of length *l* and cross-sectional area *A*.



The drift velocity of the free electrons is *v*.

If the area and length are both doubled, but the current remains the same, the drift velocity will be

☒ **A** *v* / 4

☒ **B** *v* / 2

☒ **C** 2*v*

☒ **D** 4*v*

(Total for Question = 1 mark)

Q10.

Answer the question with a cross in the box you think is correct (☒). If you change

your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

A light dependent resistor is connected across a cell of negligible internal resistance. The light intensity is increased.

Which of the following statements about the current is correct?

☒ **A** It decreases because there is an increase in the number of conduction electrons.

☒ **B** It increases because there is an increase in the number of conduction electrons.

☒ **C** It decreases because the amplitude of lattice vibrations decreases.

☒ **D** It increases because the amplitude of lattice vibrations increases.

(Total for question = 1 mark)

Q11. Dolphins use ultrasound when hunting prey. They emit short pulses of ultrasound, known as clicks, and detect the ultrasound reflected from their prey.

(a) Describe how ultrasound travels through water.

(2)

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(b) Suggest why the dolphins emit a series of clicks rather than a continuous sound.

(1)

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(c) When searching for prey the dolphins emit 16 clicks per second.

(i) Show that the time between clicks when searching for prey is about 0.06 s.

(1)

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(ii) Calculate the maximum distance that can be determined by the dolphin when searching for prey.

speed of sound in seawater = 1530 m s^{-1}

(3)

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Maximum distance = ...

(iii) The dolphin increases the number of clicks per second to 125 when near to capturing its prey.

Suggest why.

(1)

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(d) Bats use ultrasound in air when hunting prey. The ultrasound frequency and the duration of the click is the same for both bats and dolphins.

Explain whether bats or dolphins would be able to locate their prey more precisely.

speed of sound in air = 330 m s^{-1}

(3)

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(Total for Question = 11 marks)

Q12.

Two copper wires are joined in series in a circuit. Wire A has twice the radius of wire B.

The drift velocity of the electrons in wire A is v_A and the drift velocity of the electrons in wire B is v_B.

The ratio $v_A : v_B$ is

☒ **A** 1 : 2

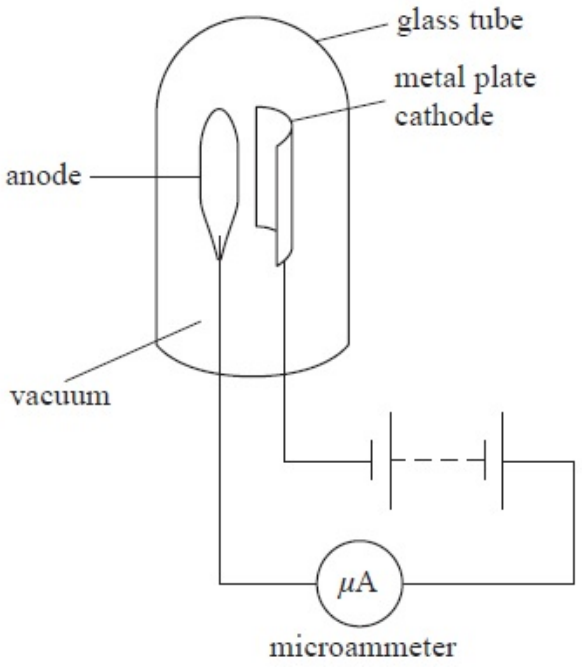
☒ **B** 1 : 4

☒ **C** 2 : 1

☒ **D** 4 : 1

(Total for question = 1 mark)

Q13. Phototubes are devices which make use of the photoelectric effect to detect light above a specific frequency.



(a) Explain why

- no current flows when the phototube is in darkness
- current flows in the circuit when the phototube is illuminated by light above a specific frequency.

(5)

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(b) Make an appropriate calculation to explain why caesium is used as the cathode for visible light but zinc is not.

work function of zinc = 3.63 eV

work function of caesium = 2.14 eV

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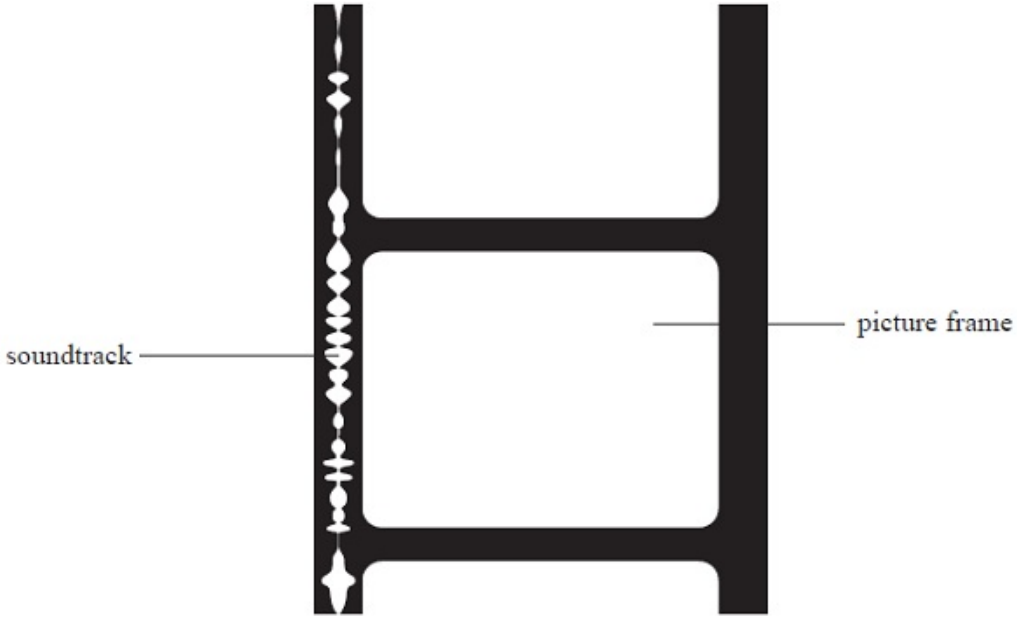
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(c) Before digital technology was used, the films used at the cinema had an optical soundtrack next to the picture frames.



The film, including the soundtrack as shown, moves through a projector past a source of light. Light is detected by a phototube on the other side of the soundtrack. The changing current produced by the phototube circuit is converted to a sound signal with the same variation in amplitude and frequency as the original sound.

(i) State what is meant by amplitude.

(1)

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(ii) Explain how the changing pattern of the soundtrack produces a changing current in the phototube circuit.

(3)

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(Total for Question = 13 marks)

Q14.

A potential difference V is applied across the ends of a conductor. The drift velocity of the charge carriers in the conductor is v.

Which of the following expressions gives the relationship between drift velocity and potential difference?

☒ **A** $v \propto \frac{1}{V}$

☒ **B** $v \propto \frac{1}{V^2}$

☒ **C** $v \propto V$

☒ **D** $v \propto V^2$

(Total for question = 1 mark)

Q15.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A conductor has a resistance R. A constant potential difference is applied across the conductor. The drift velocity of the charge carriers in the conductor is v.

Which of the following is the relationship between R and v ?

☒ **A** $v \propto R$

☒ **B** $v \propto \sqrt{R}$

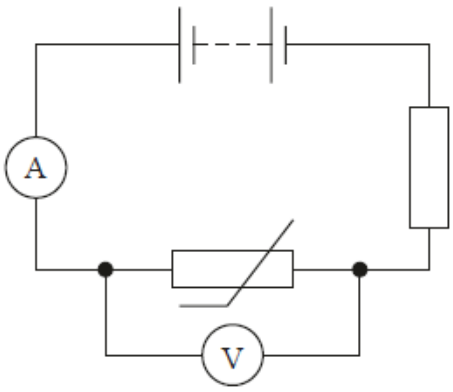
☒ **C** $v \propto {}^{1}/_{R}$

☒ **D** $v \propto {}^{1}/_{\sqrt{R}}$

(Total for question = 1 mark)

Q1.

A student investigated the effect of temperature on the resistance of a thermistor, using the circuit shown.



A negative temperature coefficient thermistor was used in this circuit.

With reference to the charge carriers in the thermistor, explain what happens to the p.d. across the thermistor as the temperature increases.

(3)

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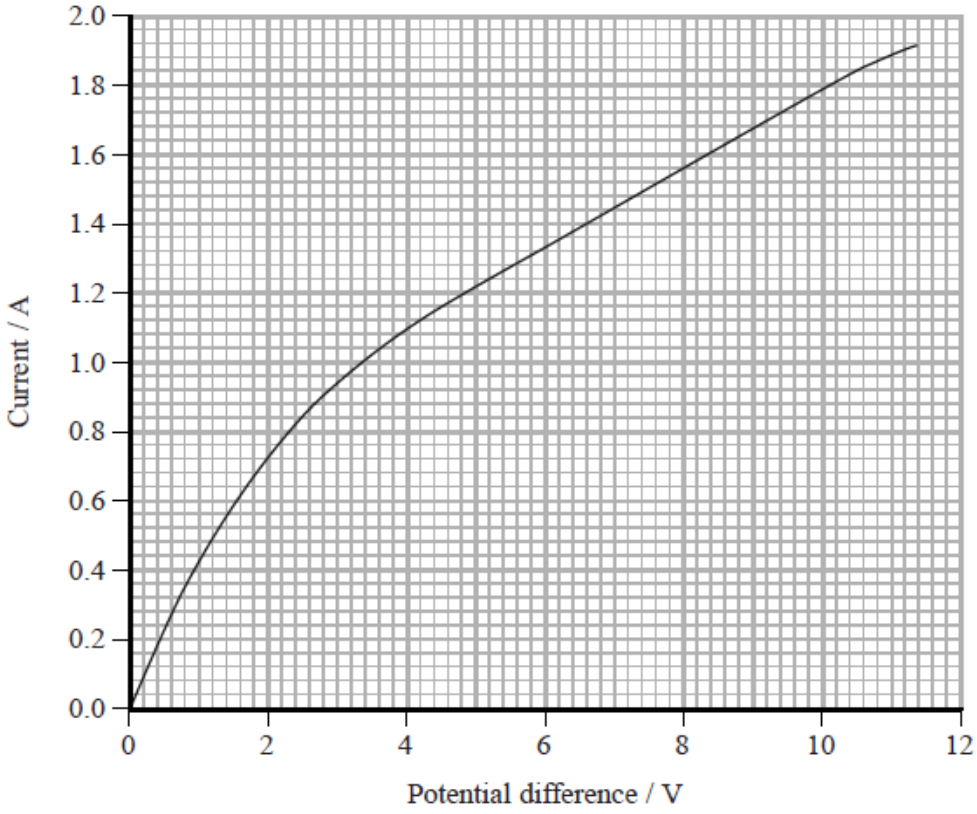
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(Total for question = 3 marks)

Q2.

The graph shows how the current through a filament bulb varies with the potential difference across the bulb.



(a) Determine the resistance of the filament bulb when the potential difference is 7.0 V.

(2)

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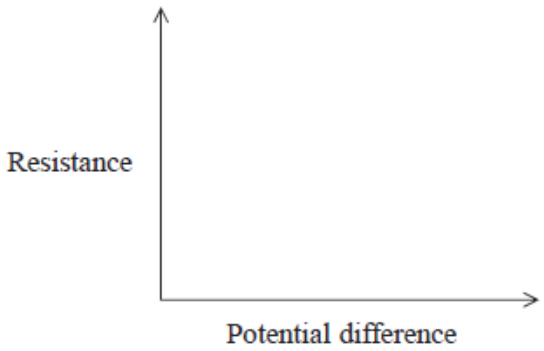
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Resistance = ...

(b) Sketch a graph of resistance against potential difference for the filament bulb over the range 0 V to 7 V.

(3)



* (c) Explain the variation of resistance with potential difference for the filament bulb in terms of particle behaviour.

(6)

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(Total for question = 11 marks)

Q3. When a semiconductor has its temperature increased from room temperature, its resistance usually decreases because

☒ **A** the electrons are moving faster.

☒ **B** the lattice atoms vibrate with greater amplitude.

☒ **C** the lattice atoms vibrate with smaller amplitude.

☒ **D** the number of charge carriers per unit volume increases.

(Total for Question = 1 mark)

Q4.

A light dependent resistor and a negative temperature coefficient thermistor are connected in series.

Which of the following combinations of illumination and temperature will result in the highest combined resistance?

(1)

☒ **A** dark and cold

☒ **B** dark and hot

☒ **C** light and cold

☒ **D** light and hot

(Total for question = 1 mark)

Q5.

(a) State what is meant by drift velocity when applied to a metal conductor.

(1)

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(b) Two conductors of the same material and length carry the same current. Conductor X has twice the cross-sectional area of conductor Y.

(i) By referring to an appropriate equation, compare the drift velocities for conductor X and conductor Y.

(2)

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*(ii) Explain the difference in resistance of conductor X and conductor Y in terms of the difference in drift velocity.

(3)

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(Total for question = 6 marks)

Q6.

A potential difference is applied across the metal filament of a light bulb and charge flows.

By referring to the mean drift velocity of the electrons, explain what happens to the current in the metal filament if the potential difference is unchanged and the temperature of the metal increases.

(3)

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(Total for question = 3 marks)

Q7.

Resistance can also be affected by temperature.

Explain why the resistance of a metal sample increases with an increase of temperature.

(3)

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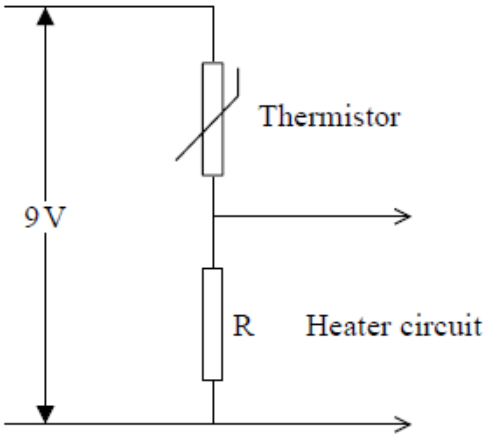
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(Total for question = 3 marks)

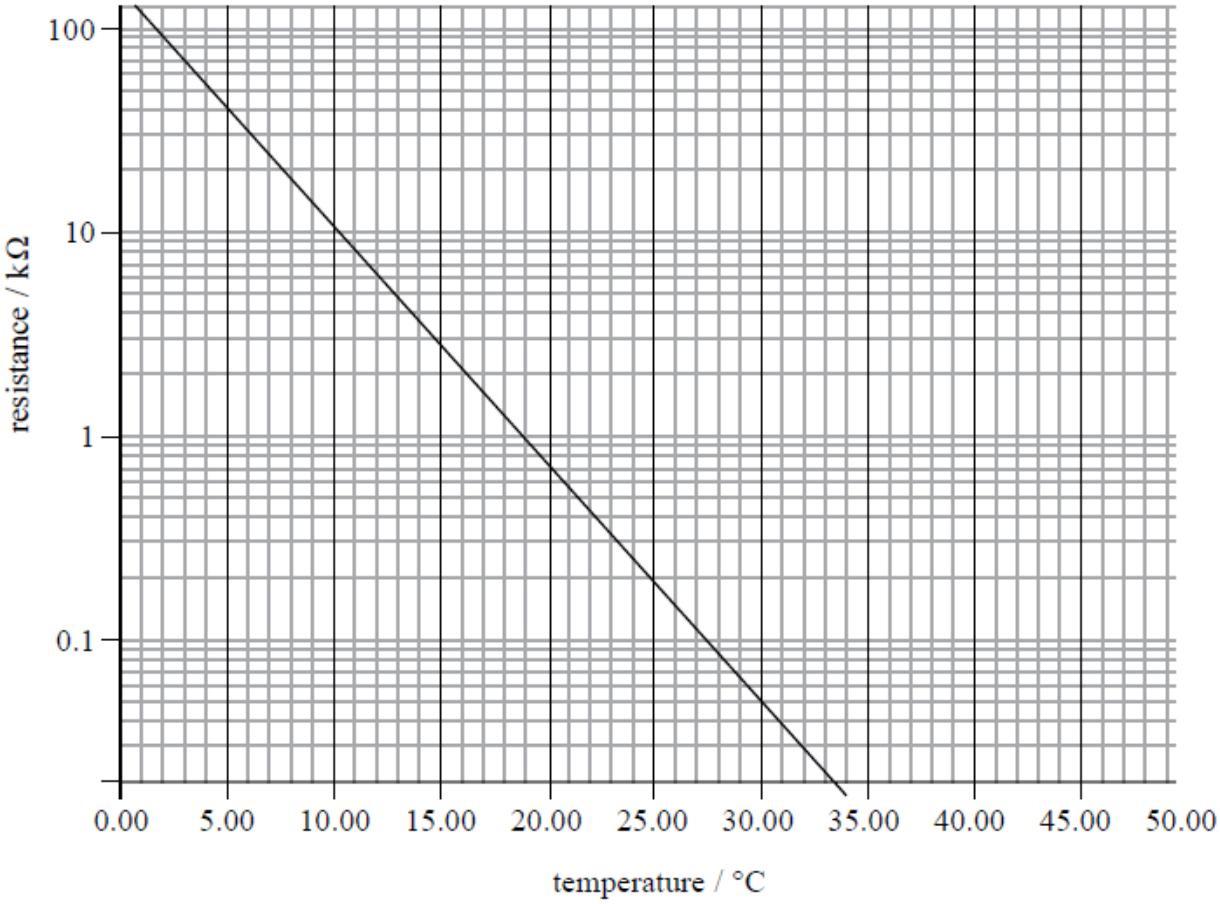
Q8.

A thermistor can be used to control a heater. When the temperature falls below a certain value the heater is switched on. The thermistor is connected in series with a fixed resistor R in a potential divider circuit as shown.



The heater circuit is connected across R and will switch on when the potential difference across it is above 5.5 V.

The variation of resistance of the thermistor R_T with temperature is shown on the graph.



(Source: http://reviseomatic.org/help/e-resistors/ThermistorLogGraph.gif)

With reference to charge carriers, explain why the resistance of the thermistor R_T, changes with temperature.

(2)

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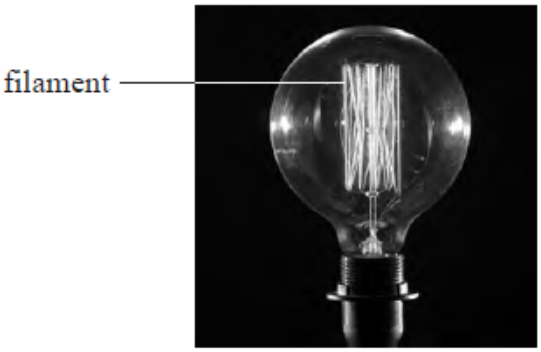
(Total for question = 2 marks)

Q9.

Filament and fluorescent are two types of light bulb.

Filament light bulbs contain a tightly coiled wire filament, surrounded by an inert gas and encased in a thin glass bulb. When the potential difference (p.d.) across the bulb is sufficient, the filament heats up, emitting visible light.

Fluorescent light bulbs use a long tube of glass containing a small amount of mercury. When a sufficient p.d. is applied across the ends of the tube, electrons moving through the tube cause the mercury to become a vapour and emit photons in the ultraviolet part of the electromagnetic spectrum. The collisions of these photons with the phosphor coating of the tube result in the emission of photons of visible light.



Filament bulb



Fluorescent bulb

(i) Explain how the wire in the filament lamp gets hot when a p.d. is applied.

(2)

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(ii) Explain how the fluorescent bulb emits photons when sufficient p.d is applied.

(2)

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(Total for question = 4 marks)

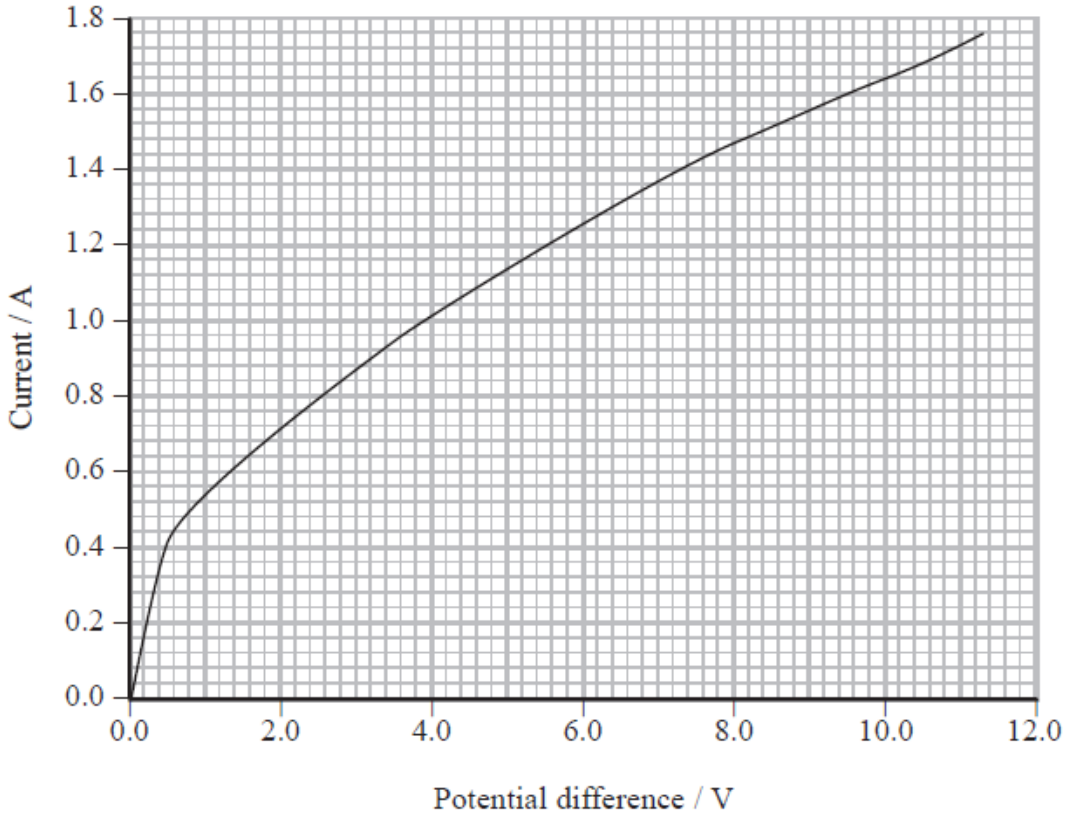
Q10.

A student investigates how the current through a filament light bulb varies with the potential difference across it.

(a) Draw a diagram of a circuit the student could use to obtain suitable measurements for a range of potential difference from 0 V to 12 V.

(3)

(b) The student's results are shown on the graph.



The student decides to draw a tangent to the curve at a potential difference of 6 V and use the gradient of the tangent to determine the resistance of the bulb.

(i) Explain why this is **not** a correct method to determine the resistance.

(2)

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(ii) Calculate the resistance of the bulb when the potential difference across it is 6 V.

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Resistance = ...

*(c) Describe and explain the change in the resistance of the bulb as the potential difference across it is increased.

(4)

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(Total for question = 11 marks)

Q11.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A constant current maintained in a copper wire causes the temperature of the wire to increase.

Which of the following does **not** increase?

☐ **A** amplitude of vibration of the lattice ions

☐ **B** number of conduction electrons per unit volume

☐ **C** rate of collision of conduction electrons with lattice ions

☐ **D** rate of energy transfer from conduction electrons to lattice ions

(Total for question = 1 mark)

Q12. Dolphins use ultrasound when hunting prey. They emit short pulses of ultrasound, known as clicks, and detect the ultrasound reflected from their prey.

(a) Describe how ultrasound travels through water.

(2)

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(b) Suggest why the dolphins emit a series of clicks rather than a continuous sound.

(1)

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(c) When searching for prey the dolphins emit 16 clicks per second.

(i) Show that the time between clicks when searching for prey is about 0.06 s.

(1)

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(ii) Calculate the maximum distance that can be determined by the dolphin when searching for prey.

speed of sound in seawater = 1530 m s^{-1}

(3)

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Maximum distance = ...

(iii) The dolphin increases the number of clicks per second to 125 when near to capturing its prey.

Suggest why.

(1)

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(d) Bats use ultrasound in air when hunting prey. The ultrasound frequency and the duration of the click is the same for both bats and dolphins.

Explain whether bats or dolphins would be able to locate their prey more precisely.

speed of sound in air = 330 m s^{-1}

(3)

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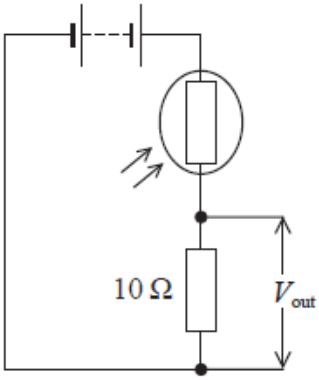
(Total for Question = 11 marks)

Q13.

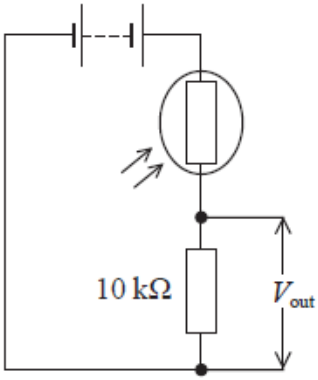
When a light dependent resistor is illuminated, its resistance falls from 1000 kΩ to 0.1kΩ.

The light dependent resistor is connected in series with a fixed resistor.

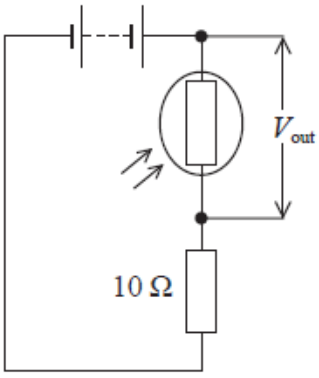
Which of the circuits shown would produce the greatest output potential difference V_{out} when illuminated?



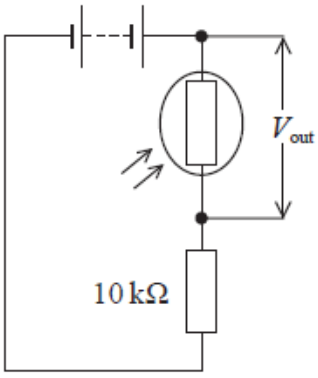
☒ **A**



☒ **B**



☒ **C**



☒ **D**

(Total for question = 1 mark)

Q14.

A constant potential difference is maintained across a negative temperature coefficient thermistor. The thermistor is heated and its resistance decreases.

Which of the following explains this decrease in resistance?

☒ **A** the collision rate of conduction electrons with lattice ions increases

☒ **B** the drift velocity of the conduction electrons decreases

☒ **C** the kinetic energy of the lattice ions decreases

☒ **D** the number density of the conduction electrons increases

(Total for question = 1 mark)

Q15.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

Which of the following increases as the temperature of a metallic conductor increases?

☒ **A** amplitude of the vibrations of the lattice ions

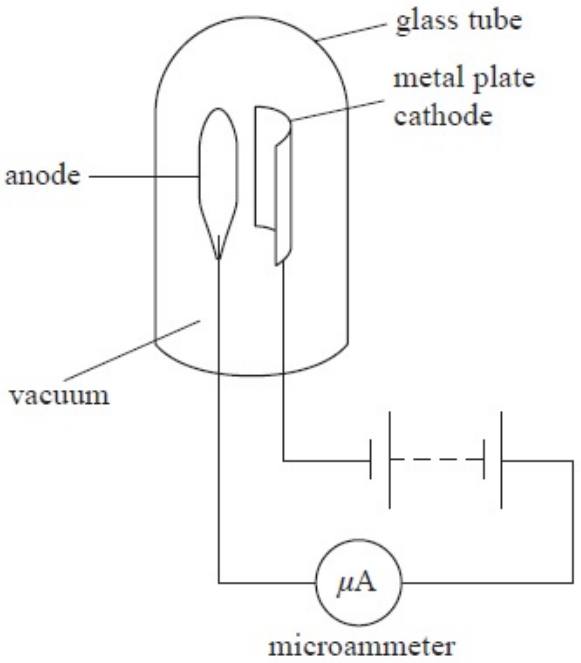
☒ **B** distance travelled by the charge carriers between collisions

☒ **C** drift velocity of the conduction electrons

☒ **D** number of conduction electrons per unit volume

(Total for question = 1 mark)

Q16. Phototubes are devices which make use of the photoelectric effect to detect light above a specific frequency.



(a) Explain why

- no current flows when the phototube is in darkness
- current flows in the circuit when the phototube is illuminated by light above a specific frequency.

(5)

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(b) Make an appropriate calculation to explain why caesium is used as the cathode for visible light but zinc is not.

work function of zinc = 3.63 eV

work function of caesium = 2.14 eV

(4)

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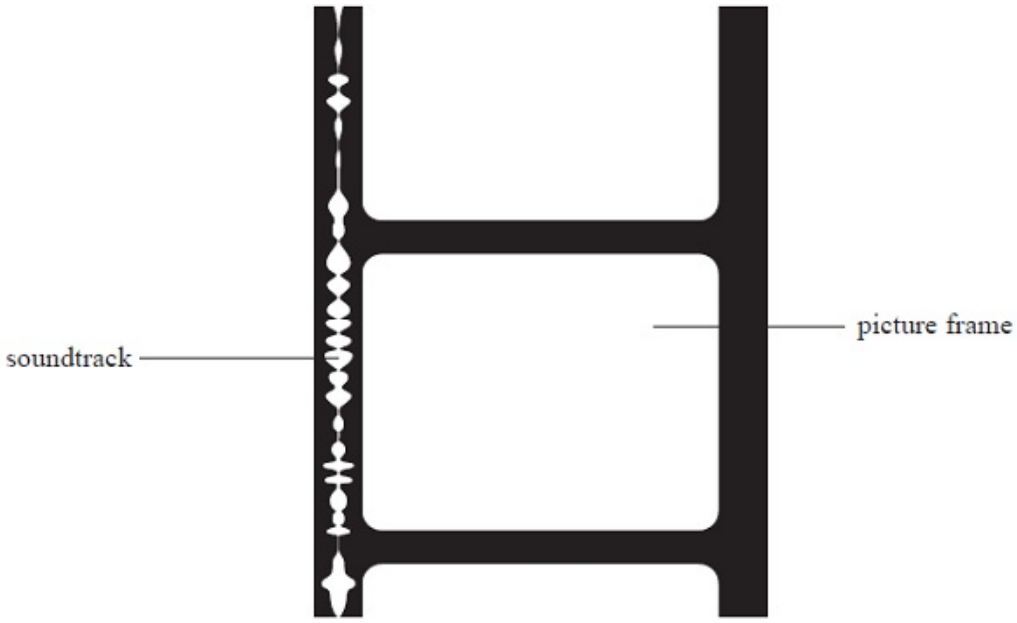
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(c) Before digital technology was used, the films used at the cinema had an optical soundtrack

next to the picture frames.



The film, including the soundtrack as shown, moves through a projector past a source of light. Light is detected by a phototube on the other side of the soundtrack. The changing current produced by the phototube circuit is converted to a sound signal with the same variation in amplitude and frequency as the original sound.

(i) State what is meant by amplitude.

(1)

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(ii) Explain how the changing pattern of the soundtrack produces a changing current in the phototube circuit.

(3)

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(Total for Question = 13 marks)

Q17.

All electrical components have resistance.

In which of the following situations would the resistance of the stated component **not** increase?

☒ **A** Increasing the current through a filament lamp.

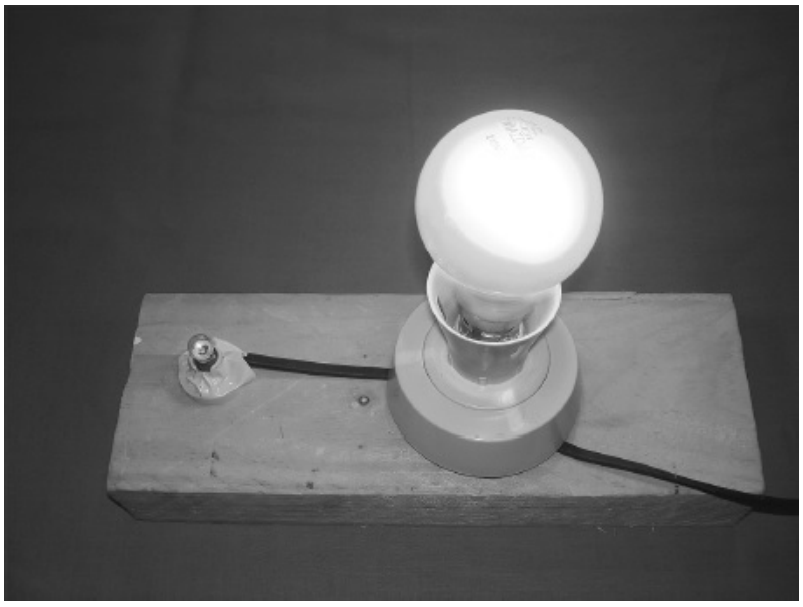
☒ **B** Increasing the temperature of a metal wire.

☒ **C** Increasing the temperature of a negative temperature coefficient thermistor.

☒ **D** Reversing the direction of a diode in forward bias in a circuit.

(Total for question = 1 mark)

Q18. The photograph shows a piece of apparatus in which a mains light bulb and a torch bulb are both connected to the mains.



Students were surprised to see both bulbs shining normally when the apparatus was switched on.

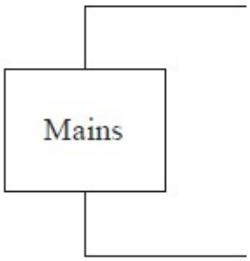
It is impossible to tell from looking at the apparatus whether the bulbs are connected in series or in parallel.

To test this, the apparatus was switched off and the mains bulb was removed. When it was switched on again the torch bulb did not light up. When this was repeated, removing the torch bulb, the mains bulb did not light up.

When the circuit was tried again with both bulbs, they still operated normally.

(a) Complete the circuit diagram to show how the bulbs are connected and explain why they must be connected in this way and not the alternative.

(3)



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(b) The mains bulb is marked 40 W, 230 V.

(i) Show that the current in the mains bulb is about 0.2 A when it is operating normally.

(2)

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(ii) Calculate the resistance of the mains bulb when it is operating normally.

(2)

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Resistance = ...

(iii) The torch bulb is marked 2.5 V, 0.20 A.

Calculate the resistance of the torch bulb when it is operating normally.

(2)

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Resistance = ...

(c) Explain, with reference to both current and potential difference, why it is possible to operate both bulbs at the same time from the same power supply.

(2)

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(d) Earlier in the question you were asked to calculate the resistances of the bulbs when operating normally.

Explain the effect on the resistances of the bulbs if they are operated at a much smaller current so that neither bulb lights up.

(4)

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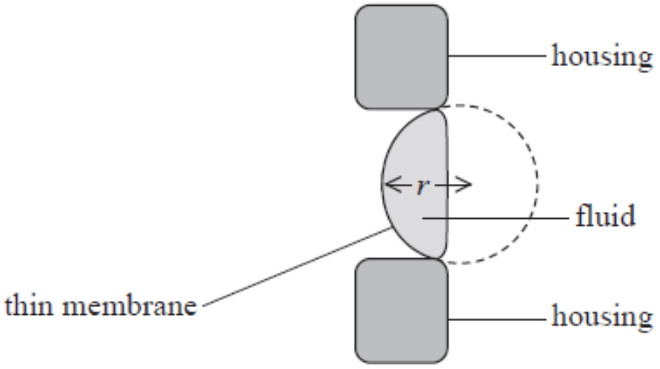
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(Total for Question = 15 marks)

Q19.

Bar code scanners scan objects at different distances and need a lens that changes shape and hence focal length, in order to produce a focused image. A fluid is sealed within a thin membrane and acts as the shape-changing lens.

A current in a coil of wire is used to change the radius of curvature of the lens. Increasing the current decreases the radius of curvature of the lens and increases the focal length of the lens.



The manufacturer states that the current in the coil should not exceed a maximum value.

Justify the manufacturer's statement.

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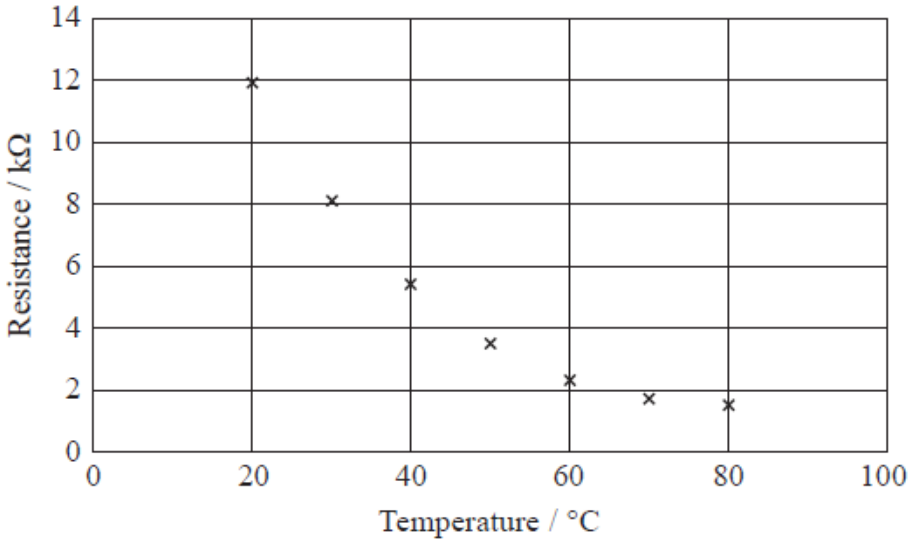
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Q20.

A student wants to investigate how the resistance *R* of a negative temperature coefficient thermistor varies with its temperature *T*.

The following graph was plotted from the results of another student's experiment for the same topic.



Explain, in terms of particle behaviour, why the resistance of the thermistor decreases as temperature increases.

(4)

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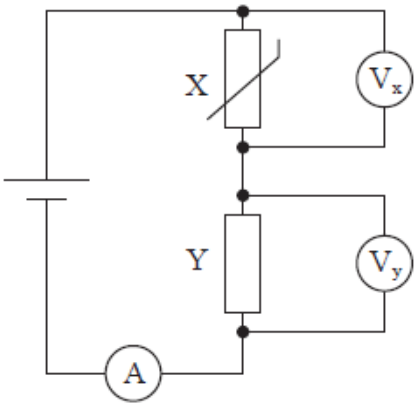
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(Total for question = 4 marks)

Q1.

The diagram shows a potential divider circuit that contains a negative temperature coefficient thermistor.



The temperature of the room containing the circuit increases.

Select the row of the table that correctly shows the changes in readings on the meters.

	V_x	V_y	A
☐ **A**	decrease	increase	decrease
☐ **B**	decrease	increase	increase
☐ **C**	increase	decrease	decrease
☐ **D**	increase	decrease	increase

(Total for question = 1 mark)

Q2.

A light dependent resistor and a negative temperature coefficient thermistor are connected in series.

Which of the following combinations of illumination and temperature will result in the highest combined resistance?

(1)

☒ **A** dark and cold

☒ **B** dark and hot

☒ **C** light and cold

☒ **D** light and hot

(Total for question = 1 mark)

Q3.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The intensity of light incident on a light dependent resistor (LDR) can vary both its electrical resistance *R* and the number of charge carriers per unit volume *n*. The light intensity on an LDR is increased.

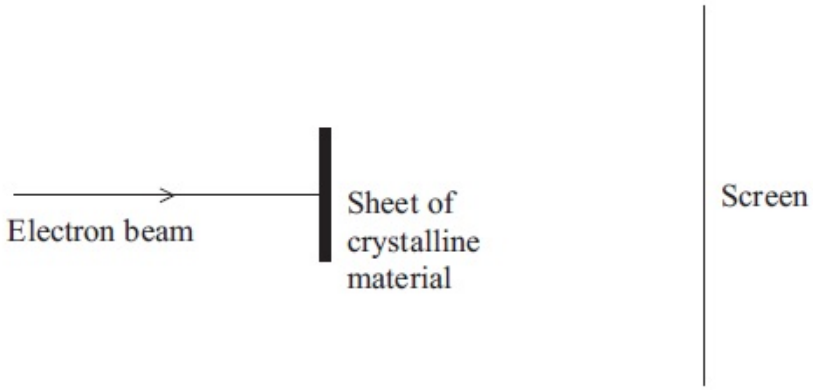
Which row of the table describes the effect on *R* and *n*?

	R	n
☒ **A**	decreases	decreases
☒ **B**	decreases	increases
☒ **C**	increases	decreases
☒ **D**	increases	increases

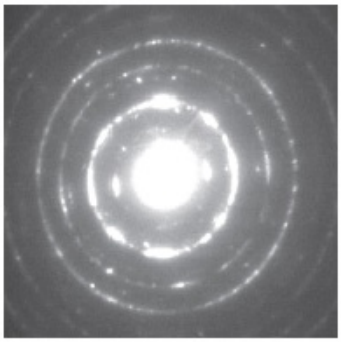
(Total for question = 1 mark)

Q4.

The diagram shows a beam of electrons being fired towards a thin sheet of crystalline material. The screen detects electrons after they have passed through the sheet.



The photograph shows the positions at which electrons strike the screen.



Explain what can be deduced about the behaviour of electrons from the formation of this pattern.

(3)

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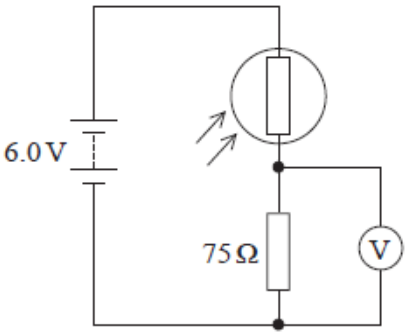
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(Total for question = 3 marks)

Q5.

A student set up a circuit containing a light dependent resistor (LDR) in series with a fixed resistor as shown.



As the student moved a lamp towards the circuit she observed the potential difference (p.d.) changing across the fixed resistor.

With reference to the electrons in the LDR explain this observation.

(5)

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(Total for question = 5 marks)

Q6.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

A light dependent resistor is connected across a cell of negligible internal resistance. The light intensity is increased.

Which of the following statements about the current is correct?

☒ **A** It decreases because there is an increase in the number of conduction electrons.

☒ **B** It increases because there is an increase in the number of conduction electrons.

☒ **C** It decreases because the amplitude of lattice vibrations decreases.

☒ **D** It increases because the amplitude of lattice vibrations increases.

(Total for question = 1 mark)

Q7.

A solar panel uses electromagnetic radiation from the Sun to generate electricity.
In one installation a sensor in the solar panel measures the intensity of radiation arriving from different directions. A motor rotates the solar panel so that it always faces the brightest part of the sky.

When light is incident on an LDR, electrons move to a higher energy level where they become conduction electrons. This causes the resistance of the LDR to decrease.

A student suggests that this is an example of the photoelectric effect. The student is not correct.

Compare and contrast the photoelectric effect with the effect of radiation incident on an LDR.

(6)

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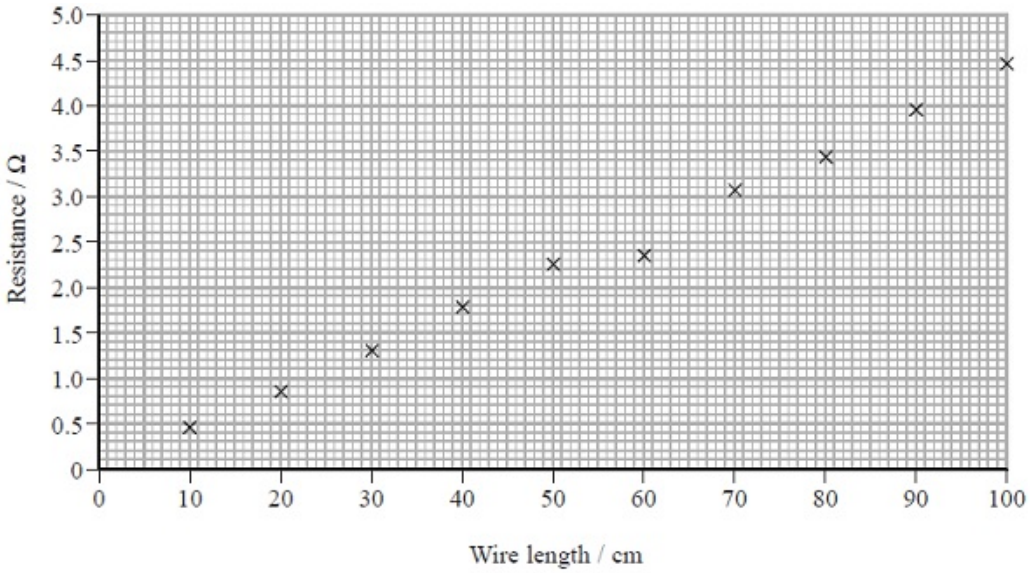
(Total for question = 6 marks)

Q8. A student carried out a series of measurements to determine how the resistance of a wire varies with its length.

The student obtained the following results.

Wire length / cm	Current / A	Potential difference / V	Resistance / Ω
100	0.15	0.67	4.47
90	0.16	0.63	3.94
80	0.17	0.58	3.41
70	0.17	0.52	3.06
60	0.18	0.42	2.33
50	0.18	0.40	2.22
40	0.19	0.34	1.79
30	0.20	0.26	1.30
20	0.22	0.18	0.82
10	0.22	0.10	0.45

The student plotted the results on a graph.



(a) Calculate the resistivity of the wire used.

cross-sectional area of wire = 1.06×10^{-7} m^2

(4)

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Resistivity = ...

(b) One precaution taken by the student was to keep the current small.

Explain why this precaution was necessary.

(2)

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(c) Explain **one** other precaution which should be taken by the student to ensure the accuracy of the results in the table.

(2)

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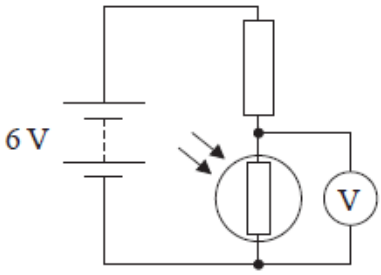
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(Total for Question = 8 marks)

Q9.

A light-dependent resistor (LDR) and resistor are connected in series with a 6V battery as shown. A voltmeter measures the potential difference across the LDR.



In daylight the voltmeter reads 3.0V.

Which reading is most likely if the circuit is now in total darkness?

(1)

☒ **A** a little above 0 V

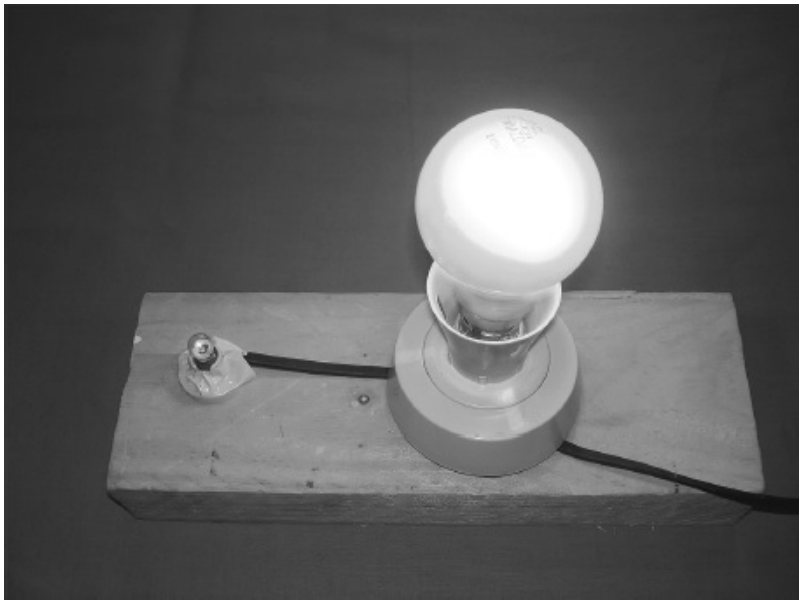
☒ **B** a little below 3 V

☒ **C** a little above 3 V

☒ **D** a little below 6 V

(Total for question = 1 mark)

Q10. The photograph shows a piece of apparatus in which a mains light bulb and a torch bulb are both connected to the mains.



Students were surprised to see both bulbs shining normally when the apparatus was switched on.

It is impossible to tell from looking at the apparatus whether the bulbs are connected in series or

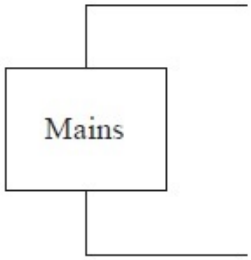
in parallel.

To test this, the apparatus was switched off and the mains bulb was removed. When it was switched on again the torch bulb did not light up. When this was repeated, removing the torch bulb, the mains bulb did not light up.

When the circuit was tried again with both bulbs, they still operated normally.

(a) Complete the circuit diagram to show how the bulbs are connected and explain why they must be connected in this way and not the alternative.

(3)



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(b) The mains bulb is marked 40 W, 230 V.

(i) Show that the current in the mains bulb is about 0.2 A when it is operating normally.

(2)

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(ii) Calculate the resistance of the mains bulb when it is operating normally.

(2)

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Resistance = ...

(iii) The torch bulb is marked 2.5 V, 0.20 A.

Calculate the resistance of the torch bulb when it is operating normally.

(2)

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Resistance = ...

(c) Explain, with reference to both current and potential difference, why it is possible to operate both bulbs at the same time from the same power supply.

(2)

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(d) Earlier in the question you were asked to calculate the resistances of the bulbs when operating normally.

Explain the effect on the resistances of the bulbs if they are operated at a much smaller current so that neither bulb lights up.

(4)

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(Total for Question = 15 marks)