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OCR A LEVEL PHYSICS A (H556): QUESTIONS BY TOPIC

Electrical circuits (4.3)

A Level Physics A (H556) · Module 4: Electrons, waves and photons

46 questions · 313 marks · Mark schemes included

OCR A Level Physics A (H556), June 2017 – June 2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic and run from the lowest mark tariff to the highest within each one.

Click any row below to jump straight to that sub-topic or question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

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4. Q1 <i>also 6.3 & 6.2</i>	H556/02 Exploring physics June 2019	1	8
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42. Q18	<i>also 4.2</i>	H556/02 Exploring physics November 2020	6	94
43. Q2	<i>also 4.4 & 4.2</i>	H556/03 Unified physics November 2021	9	96
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46. Q23	<i>also 2.2 & 4.2</i>	H556/02 Exploring physics June 2025	13	105



QUESTIONS

46 questions · 313 marks · 3 sub-topics



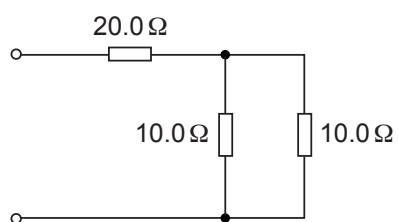
SUB-TOPIC 4.3.1

SERIES AND PARALLEL CIRCUITS

Sub-topic 4.3.1 · 30 questions · 211 marks · lowest tariff first



- 2 Three resistors are connected in a circuit.



The resistance of each resistor is shown in the circuit diagram.

What is the total resistance of this circuit?

- A $10.0\ \Omega$
- B $20.2\ \Omega$
- C $25.0\ \Omega$
- D $40.0\ \Omega$

Your answer

[1]

8 An isolated metal sphere is charged using a power supply.

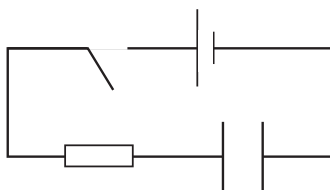
Which single quantity can be used to determine the capacitance of the sphere?

- A** The diameter of the sphere.
- B** The charge on the sphere.
- C** The resistance of the metal.
- D** The e.m.f. of the power supply.

Your answer

[1]

- 9 A capacitor is charged through a resistor.



The cell has e.m.f. 1.50 V and negligible internal resistance.
The capacitor is initially uncharged. The time constant of the circuit is 100 s .
The switch is closed at time $t = 0$.

What is the potential difference across the capacitor at time $t = 200\text{ s}$?

- A 0.20 V
- B 0.55 V
- C 0.95 V
- D 1.30 V

Your answer

[1]

1 Which law indicates that charge is conserved?

- A Lenz's law
- B Coulomb's law
- C Kirchhoff's first law
- D Faraday's law of electromagnetic induction

Your answer

[1]



- 6 Wires **P** and **Q**, made from the same metal, are connected in **parallel** across a cell of negligible internal resistance.
The table shows some data.

Wire	Length of wire	Diameter of wire	Mean drift velocity of electrons in the wire / mm s^{-1}
P	L	d	0.60
Q	$3L$	$2d$	v

What is the mean drift velocity v of the electrons in wire **Q**?

- A** 0.15 mm s^{-1}
B 0.20 mm s^{-1}
C 0.30 mm s^{-1}
D 0.60 mm s^{-1}

Your answer

[1]



- 10 A coil with 500 turns is placed in a uniform magnetic field.
The average cross-sectional area of the coil is $3.0 \times 10^{-4} \text{ m}^2$.
The magnetic flux through the plane of the coil is reduced from $1.8 \times 10^{-4} \text{ Wb}$ to zero in a time t .
The average electromotive force (e.m.f.) induced across the ends of the coil is 0.75 V .

What is the value of t ?

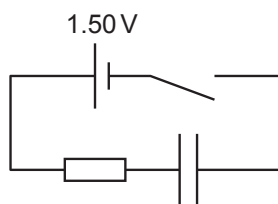
- A $3.6 \times 10^{-5} \text{ s}$
B $2.4 \times 10^{-4} \text{ s}$
C 0.12 s
D 8.3 s

Your answer

[1]

11 The diagram shows a circuit containing a variable resistor.

13 A capacitor is charged through a resistor.



The cell has electromotive force (e.m.f.) 1.50 V and negligible internal resistance. The time constant of the circuit is 10 s. The switch is closed at time $t = 0$. At time t , the potential difference across the resistor is 0.60 V.

Which expression is correct?

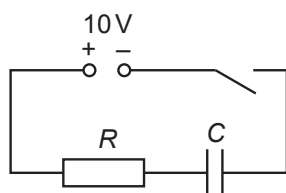
- A $0.60 = 1.50e^{-0.10t}$
- B $0.90 = 1.50e^{-0.10t}$
- C $0.60 = 1.50e^{-10t}$
- D $0.60 = 1.50(1 - e^{-10t})$

Your answer

[1]

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- 7 The diagram below shows a circuit used to charge a capacitor.



The power supply has electromotive force (e.m.f.) 10 V and negligible internal resistance.

The capacitor has capacitance C and the resistor has resistance R .

The switch is closed at time $t = 0$.

The table below shows potential difference V across the resistor at various values of time t .

V/V	10	6.3	5.0	3.7
t/s	0	2.8	4.2	6.0

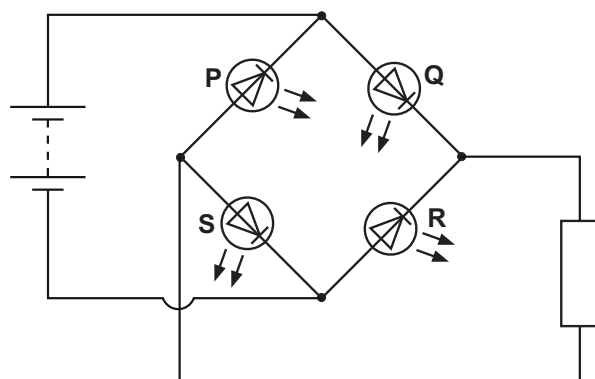
What is the product $C \times R$ for this circuit?

- A** 0 s
- B** 2.8 s
- C** 4.2 s
- D** 6.0 s

Your answer

[1]

- 5 A circuit with four light-emitting diodes (LEDs) **P**, **Q**, **R** and **S** is shown below.



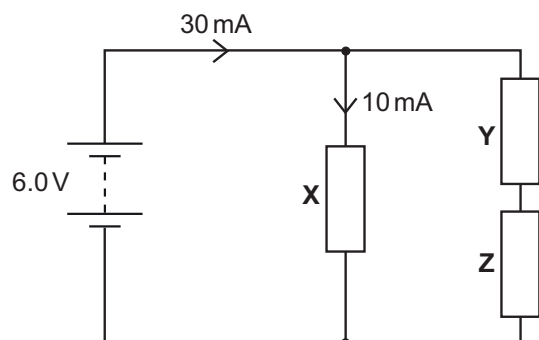
Two LEDs are lit in this circuit. Which **two** LEDs are lit?

- A P and Q
- B P and R
- C Q and R
- D Q and S

Your answer

[1]

- 10 A battery of electromotive force (e.m.f) 6.0V and of negligible internal resistance is used in the circuit below.



The current from the battery is 30 mA. The current in the resistor **X** is 10 mA.
The resistors **Y** and **Z** are identical.

What is the power dissipated in the resistor **Z**?

- A 30 mW
- B 60 mW
- C 120 mW
- D 180 mW

Your answer

[1]

15 Which statement is Faraday's law?

- A** The direction of electric current induced by a changing magnetic field is such that the magnetic field created by the induced current opposes changes in the initial magnetic field.
- B** The magnitude of the electrostatic force between two point charges is directly proportional to the product of the magnitudes of charges and inversely proportional to the square of the separation.
- C** The magnitude of induced EMF is proportional to the rate of change of the magnetic flux linkage.
- D** The total energy of an isolated system remains constant.

Your answer

[1]

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- 21 (a) A capacitor of capacitance 7.2 pF consists of two parallel metal plates separated by an insulator of thickness 1.2 mm . The area of overlap between the plates is $4.0 \times 10^{-4}\text{ m}^2$. Calculate the permittivity of the insulator between the capacitor plates.

permittivity = ... F m^{-1} [2]

- (b) Fig. 21 shows a circuit.

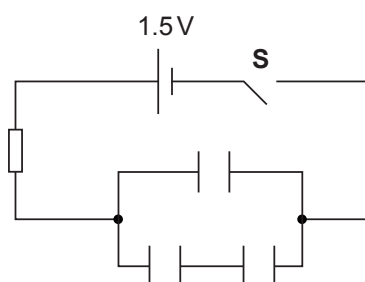


Fig. 21

The capacitance of each capacitor is $1000\text{ }\mu\text{F}$. The resistance of the resistor is $10\text{ k}\Omega$. The cell has e.m.f. 1.5 V and negligible internal resistance.

- (i) Calculate the total capacitance C in the circuit.

$C = \dots\dots\dots \mu\text{F}$ [2]

- (ii) The switch **S** is closed at time $t = 0$. There is zero potential difference across the capacitors at $t = 0$.
Calculate the potential difference V across the resistor at time $t = 12$ s.

$V =$ V [2]

- 17*** A metal circular plate is rotated at a constant frequency by an electric motor. The plate has a small hole close to its rim. Fig. 17.1 shows an arrangement used by a student to determine the frequency of the rotating plate.

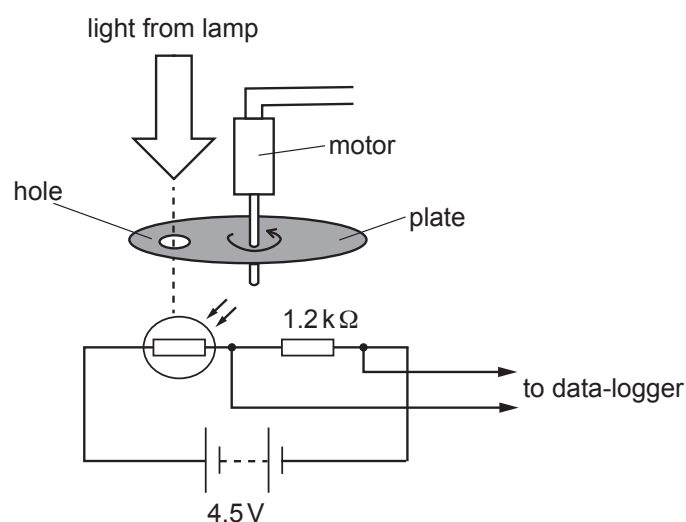


Fig. 17.1

A light-dependent resistor (LDR) and a fixed resistor of resistance $1.2\text{ k}\Omega$ are connected in series to a battery. The battery has e.m.f. 4.5 V and has negligible internal resistance. The potential difference V across the resistor is monitored using a data-logger.

Fig. 17.2 shows the variation of V with time t .

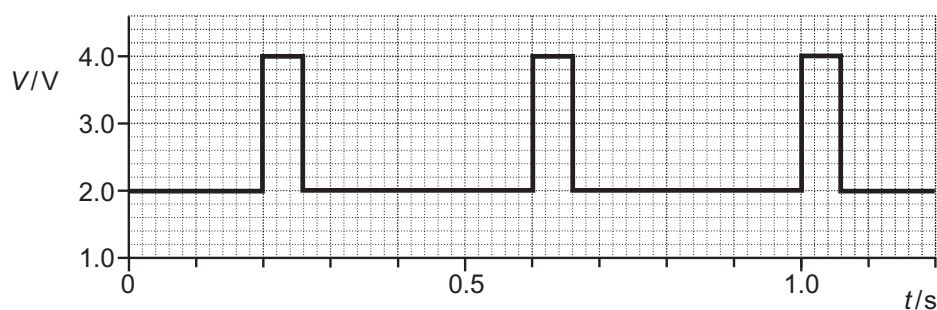


Fig. 17.2

Use your knowledge and understanding of potential divider circuits to explain the shape of the graph shown in Fig. 17.2. Include in your answer the maximum and minimum values of the resistance of the LDR.

Describe how the student can determine the frequency of the rotating plate.

[6]

[6]



21 Fig. 21.1 shows a coil of a simple generator rotating in a uniform magnetic field.

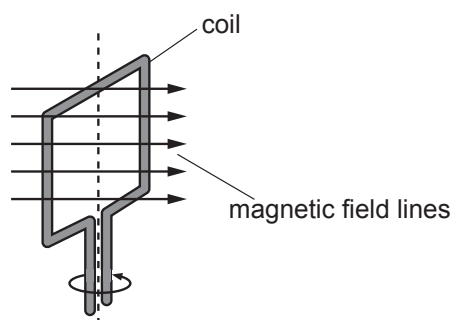


Fig. 21.1

The coil has 85 turns of insulated wire. The cross-sectional area of the coil is 14 cm^2 .

Fig. 21.2 shows the variation of magnetic flux density B through the plane of the coil with time t as it rotates.

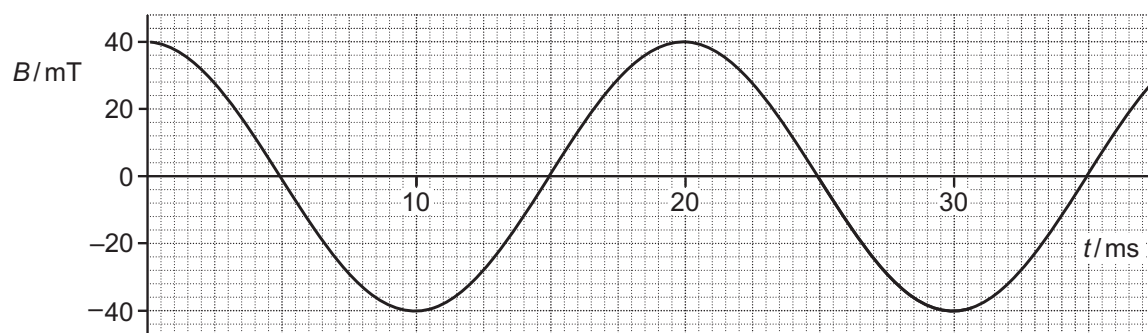


Fig. 21.2

- (a) (i) Explain why the electromotive force (e.m.f.) induced across the ends of the coil is a **maximum** at the times when $B = 0$.

.....

 [1]

- (ii) Draw a tangent to the curve in Fig. 21.2 when $B = 0$, and hence determine the **maximum** e.m.f. induced across the ends of the coil.

maximum e.m.f. = ... V [3]

- (b) Fig. 21.3 shows the variation of the e.m.f. induced across the ends of the coil with time t .

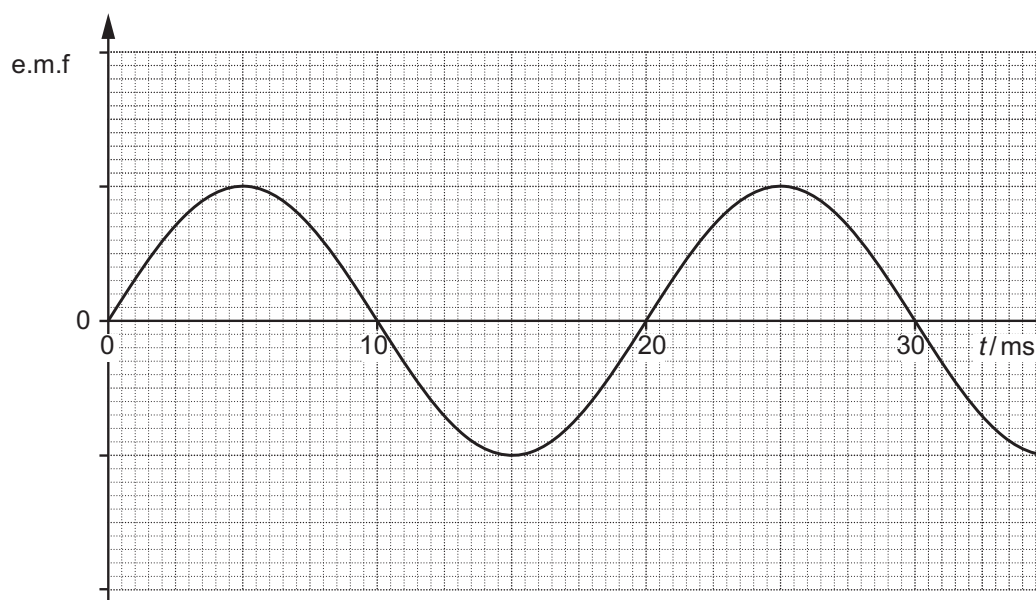


Fig. 21.3

The magnitude of the magnetic flux density of the uniform field is now halved and the coil is rotated at twice its previous frequency.

On Fig. 21.3 sketch the new variation of the e.m.f. induced with time t . [2]

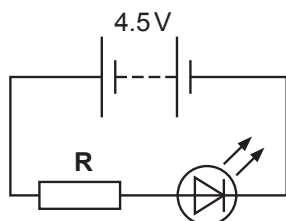
- 17 A light-emitting diode (LED) emits red light when it is positively biased and has a potential difference (p.d.) greater than about 1.8 V.

- (a) The energy of a photon of red light is about 1.8 eV.

Calculate the wavelength λ of this red light.

$$\lambda = \dots\dots\dots \text{ m [3]}$$

- (b) The LED is connected into a circuit, as shown below.

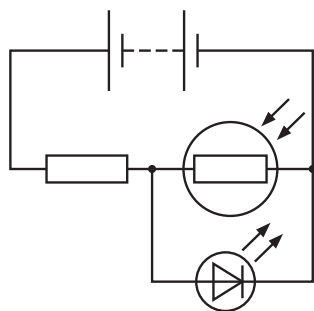


The battery has electromotive force (e.m.f.) 4.5 V and negligible internal resistance.
The resistor **R** has resistance 150 Ω .
Assume the p.d. across the LED is 1.8 V.

Calculate the ratio $\frac{\text{power dissipated by LED}}{\text{power dissipated by resistor}}$.

$$\text{ratio} = \dots\dots\dots \text{ [2]}$$

- (c) The diagram below shows a circuit designed by a student.



The LED is very close to, and facing the light dependent resistor (LDR).
The circuit is taken into a dark room.

- (i) The student thought that the LED would switch on.
Instead, the LED was found to repeatedly switch on and off.

Explain this behaviour of the LED in this potential divider circuit.

.....

 [2]

- (ii) Suggest a possible refinement so that the LED switches on permanently when taken into the dark room.

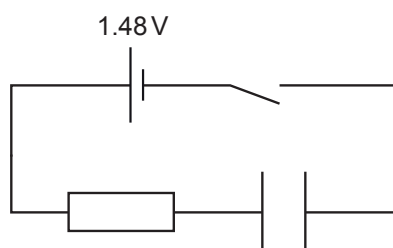
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20 (a) The diagram below shows a circuit to charge a capacitor.

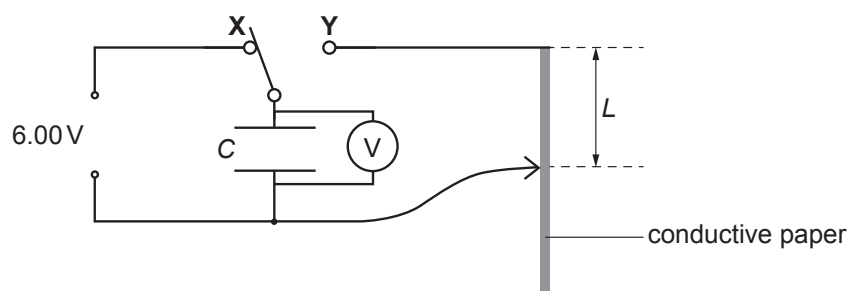


The electromotive force (e.m.f.) E of the cell is 1.48 V and it has negligible internal resistance. The resistance of the resistor is $120\text{ k}\Omega$ and the capacitance of the capacitor is $2000\text{ }\mu\text{F}$. At time $t = 0$ the capacitor is uncharged. The switch is closed at time $t = 0$.

Calculate the time t when the potential difference across the capacitor is 1.00 V .

$t = \dots\dots\dots\text{ s}$ [4]

(b) A capacitor of capacitance C is connected across a strip of conductive paper.



The switch is moved from **X** to **Y**, and the time t for the potential difference across the capacitor to halve is measured.

The time t is given by the expression

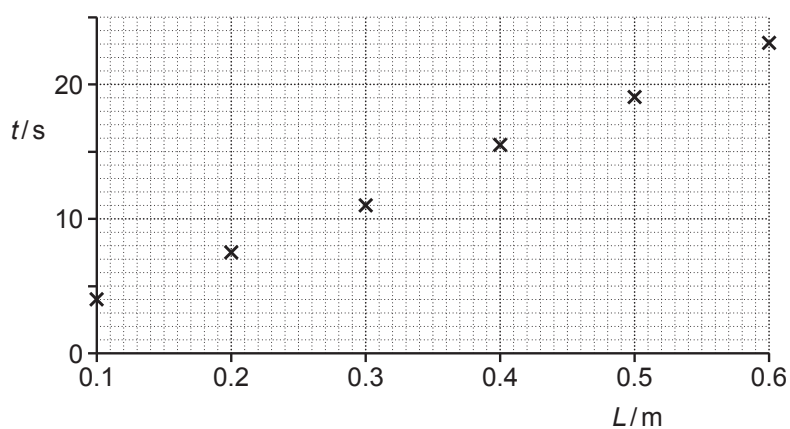
$$t = (Ck \ln 2) \times L$$

where k is the resistance of the conductive paper per unit length and L is the length of the conductive paper.

The value of C is $1.2 \times 10^{-3} \text{ F}$.

In an experiment, L is changed and t measured.

The data points are plotted on a t against L grid as shown below.



Draw a straight line of best fit through the data points, and use the gradient of this line to determine k .

$k = \dots\dots\dots \Omega \text{ m}^{-1}$ [4]

- 17 A light-emitting diode (LED) can be used to determine the Planck constant h . When the LED just starts to emit light, the equation below is valid

$$eV = \frac{hc}{\lambda}$$

where V is the potential difference (p.d.) across the LED, λ is the wavelength of the light emitted, c is the speed of light in vacuum and e is the elementary charge.

- (a) In the equation above, $\frac{hc}{\lambda}$ is the energy of a photon emitted from the LED.

Determine the S.I. base units for h .

base units = ... [2]

- (b)* Describe how an experiment can be carried out in the laboratory to determine h from a graph. Your description must include how V and λ are accurately determined. Assume that the values of e and c are known. [6]

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Additional answer space if required

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19 Fig. 19.1 shows an electric circuit.

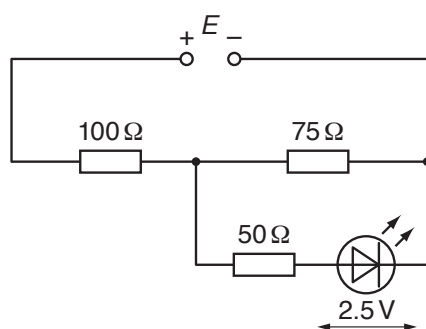


Fig. 19.1

The power supply has electromotive force (e.m.f.) E and negligible internal resistance.

The resistance values of the resistors are shown in Fig. 19.1. The I – V characteristic of the light-emitting diode (LED) is shown in Fig. 19.2.

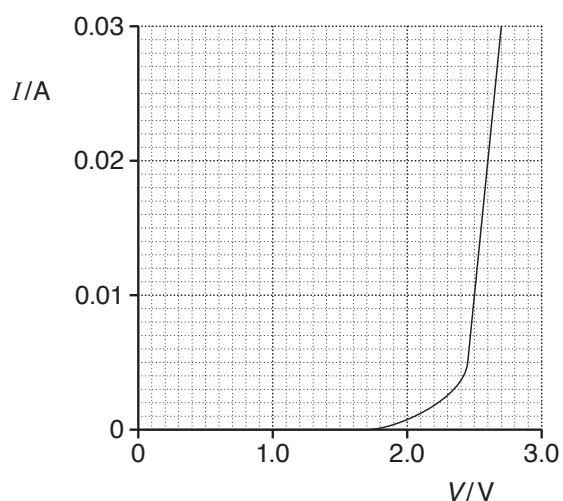


Fig. 19.2

The potential difference (p.d.) across the LED is 2.5 V.

(a) Use Fig. 19.2 to show that the p.d. across the $50\ \Omega$ resistor is 0.50 V.

- (b) Calculate the e.m.f. E of the power supply.

$E = \dots\dots\dots$ V [3]

- (c) The LED emits blue light of wavelength 4.7×10^{-7} m.

- (i) Estimate the number of blue light photons emitted from the LED per second.

number of photons per second = $\dots\dots\dots$ s⁻¹ [3]

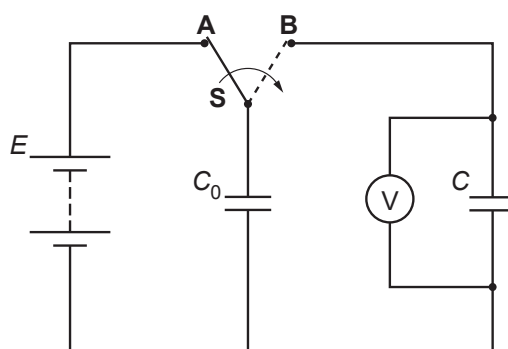
- (ii) The light from the LED is incident on a metal of work function 2.3 eV.

Explain, with the help of a calculation, whether or not photoelectrons will be emitted from the surface of the metal.

.....
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..... [2]

- 2 The diagram below shows a circuit containing two capacitors which are both initially uncharged. The battery has e.m.f. E and negligible internal resistance.

The switch **S** is first moved to position **A** until the capacitor of capacitance C_0 is fully charged.



The switch **S** is then moved to position **B**. The initial charge stored by the capacitor of capacitance C_0 is shared between the two capacitors. The final reading on the voltmeter is V .

- (a) Show that $V = \frac{C_0}{C + C_0} E$.

[2]

- (b) A student wants to determine the values of E and C_0 by repeating the experiment above and measuring the potential difference (p.d.) V for a selection of capacitors of capacitance C .

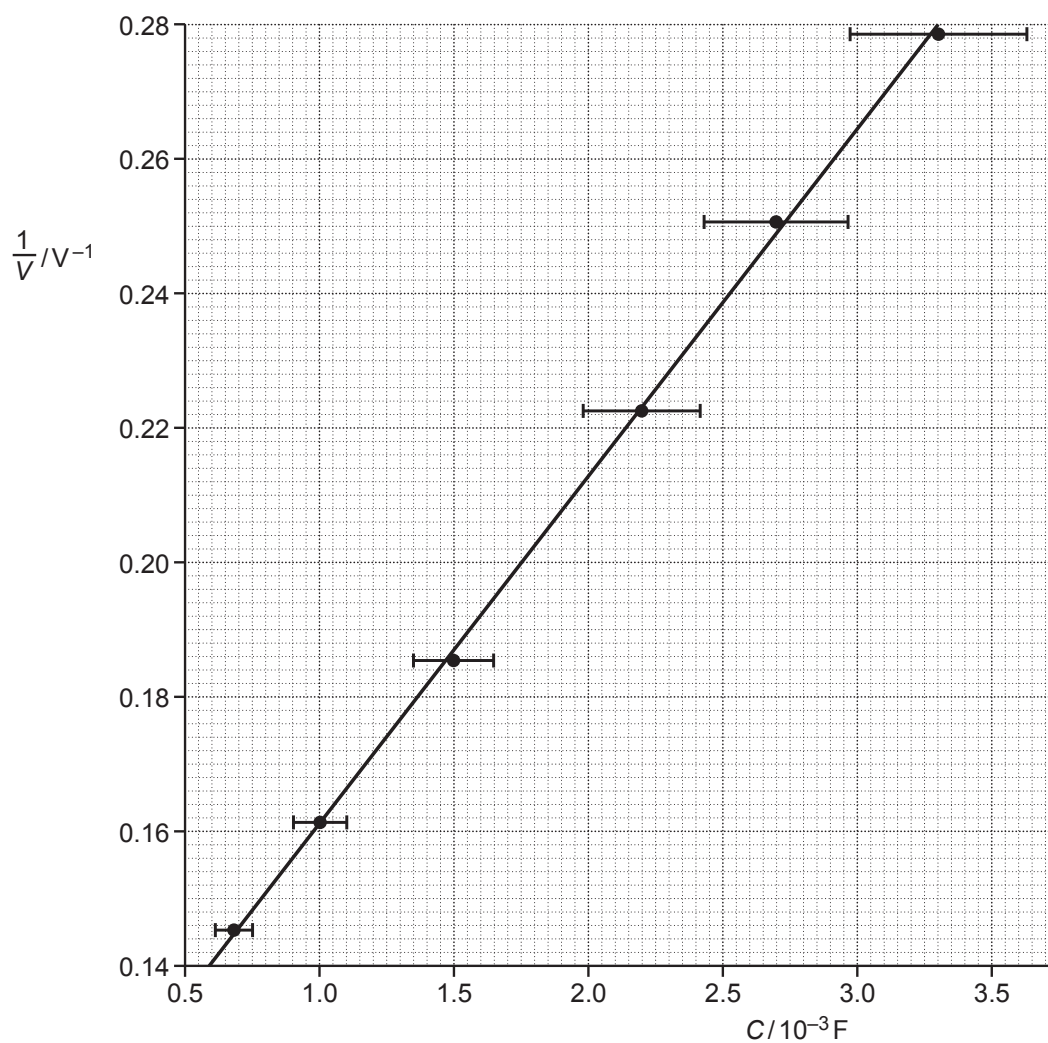
The student decides to plot a graph of $\frac{1}{V}$ against C .

- (i) Use the expression in (a) to show that the graph should be a straight line of gradient $\frac{1}{C_0 E}$ and y-intercept $\frac{1}{E}$.

[1]

Question 2 continues on page 6

- (ii) The data points, error bars and the line of best fit drawn by the student are shown in the graph below.



The gradient of the line of best fit is $51 \text{ V}^{-1} \text{ F}^{-1}$. The value of E is 9.1 V .

Determine the value of C_0 in millifarads (mF). Write your answer to 2 significant figures.

$C_0 = \dots\dots\dots \text{ mF}$ [2]

- (iii) Draw on the graph a straight line of worst fit.

Use this line to determine the absolute uncertainty in your value of C_0 . Write your answer to an appropriate number of significant figures.

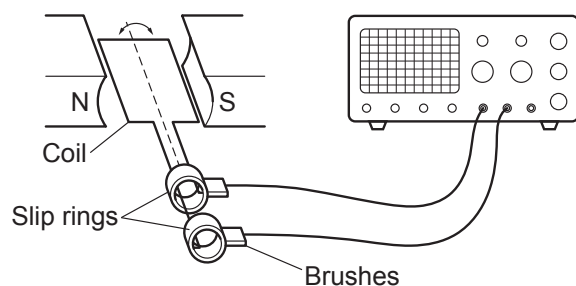
absolute uncertainty = ... mF [4]

- (c) The experiment is repeated with a resistor of resistance $10\text{ k}\Omega$ placed in series between **S** and the capacitor of capacitance C_0 .

State with a reason what effect, if any, this would have on the experiment.

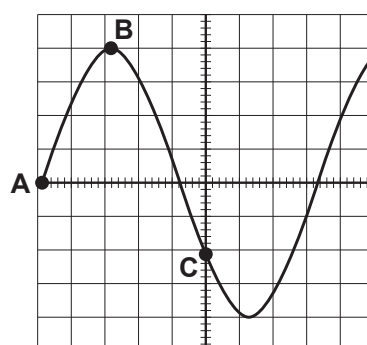
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.....
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..... [1]

- 21 The diagram shows a simple a.c. generator connected to an oscilloscope (CRO).

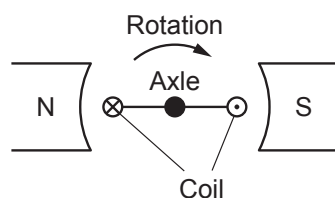


Students turn the coil at a steady rate and an a.c. signal is displayed on the oscilloscope screen, as shown in **Fig. 21.1**.

Fig. 21.1



- (a) Which position on the signal, **A**, **B** or **C**, corresponds to the generator position shown below?



view from end of coil

Tick **one** box.

A	☐
B	☐
C	☐

[1]

- (b) Draw on **Fig. 21.1** to show how the signal would change if the coil is rotated at a steady, faster rate.

[2]

- (c) The coil is rotated 45° clockwise from the position shown in (a) in a time of 0.13 s.
 The magnetic field between the poles of the magnet is uniform and is 25 mT.
 The coil has 120 turns.
 The coil is 8.0×10^{-2} m long and 4.0×10^{-2} m wide.

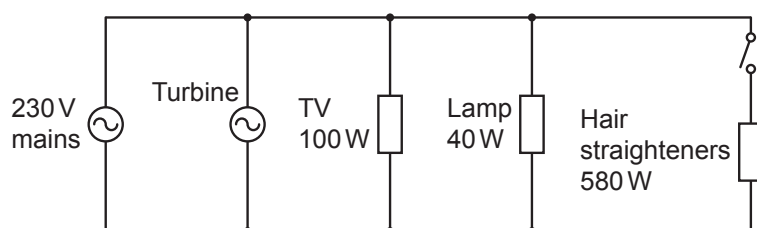
- (i) Calculate the change in flux linkage.

Change in flux linkage = ... Wb [2]

- (ii) Calculate the average induced electromotive force (e.m.f.) $\mathcal{E}$ across the contacts of the coil.

$\mathcal{E}$ = ... V [2]

- (d) A larger generator is used in a wind turbine to supply electricity to a house. The house is also connected to the 230 V mains supply.



The TV and lamp are switched on.

When the turbine is providing a steady 400 W, the hair straighteners are switched on.

Calculate the current, I , drawn from the mains supply.

I = ... A [2]

- (e) State the unit used to measure the electrical energy supplied to homes in the UK.

..... [1]

18 (a) Fig. 18.1 shows a circuit.

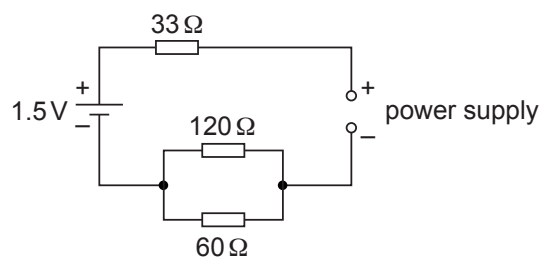


Fig. 18.1

The cell has e.m.f. 1.5V. The cell and the variable power supply both have negligible internal resistance.

- (i) The e.m.f. of the power supply is set at 4.2V.
Calculate the current I in the 33Ω resistor.

$I =$ A [3]

- (ii) The e.m.f. of the variable supply is now slowly decreased from 4.2V to 0V.
Describe the effect on the current I in the 33Ω resistor.

.....

 [2]

- (b)* A group of students are investigating the power dissipated in a variable resistor connected across the terminals of a cell. The cell has e.m.f. 1.5 V.
The students determine the power P dissipated in the variable resistor of resistance R .

Fig. 18.2 shows the data points plotted by the students on a graph of P (y -axis) against R (x -axis).

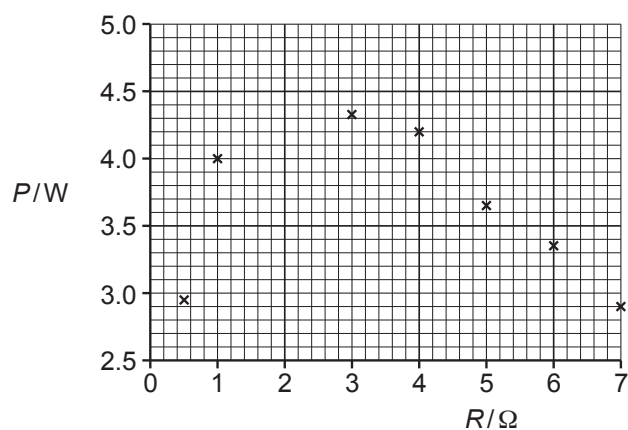


Fig. 18.2

The group of students know that **maximum power** is dissipated in the variable resistor when R is equal to the internal resistance r of the cell.

Describe, with the help of a suitable circuit diagram, how the students may have determined P and R . Use Fig. 18.2 to estimate the internal resistance r of the cell and discuss any limitations of the data plotted by the group.

[6]

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Turn over



16 (a) Derive the S.I. base units for resistance.

base units: [2]

(b) Fig. 16.1 shows the I - V characteristics of two electrical components **L** and **R**.

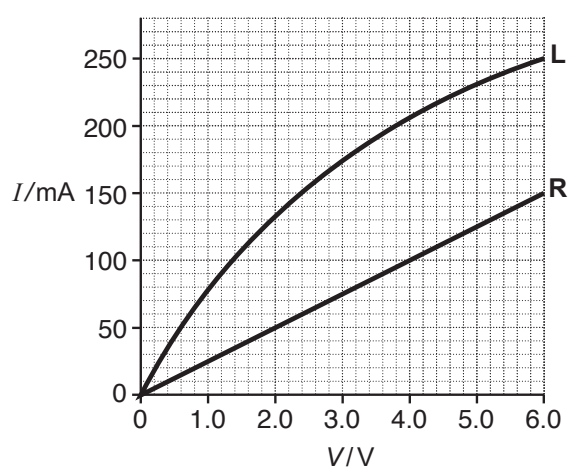


Fig. 16.1

The component **L** is a filament lamp and the component **R** is a resistor.

(i) Show that the resistance of **R** is $40\ \Omega$.

- (ii) Fig. 16.2 shows the components **L** and **R** connected in series to a battery of e.m.f. 6.0V.

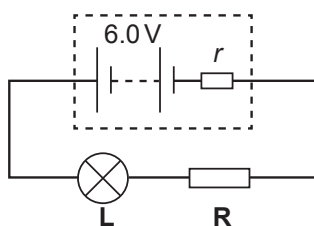


Fig. 16.2

The resistor **R** is a cylindrical rod of length 8.0 mm and cross-sectional area $2.4 \times 10^{-6} \text{ m}^2$. The current in the circuit is 100 mA.

- 1 Use Fig. 16.1 to determine the internal resistance r of the battery.

$$r = \dots\dots\dots \Omega \text{ [3]}$$

- 2 Calculate the resistivity ρ of the material of the resistor **R**.

$$\rho = \dots\dots\dots \Omega \text{ m [2]}$$

- 3 There are 6.5×10^{17} charge carriers within the volume of **R**.

Calculate the mean drift velocity v of the charge carriers within the resistor **R**.

$$v = \dots\dots\dots \text{ ms}^{-1} \text{ [3]}$$

Turn over

- 5 (a) A magnet rotates inside a shaped soft iron core. A coil is wrapped around the iron core as shown in Fig. 5.1. The coil is connected to an oscilloscope.

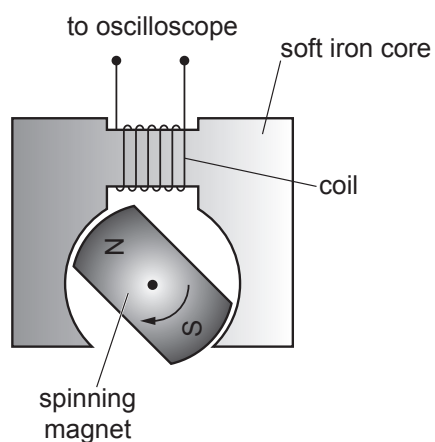


Fig. 5.1

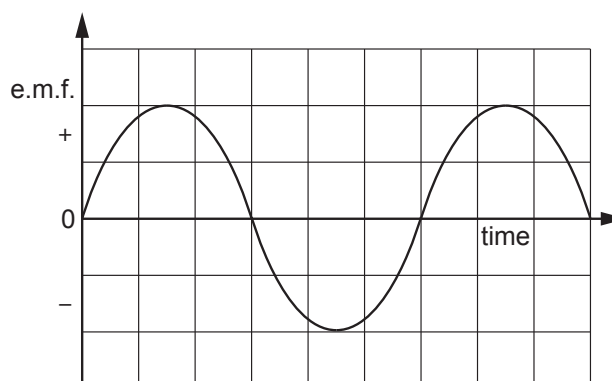


Fig. 5.2

The spinning magnet induces an e.m.f. in the coil. A graph of the e.m.f. displayed on the oscilloscope screen is shown in Fig. 5.2.

- (i) Explain the shape of the graph in terms of the magnetic flux linking the coil.

.....

 [2]

- (ii) On Fig. 5.3 sketch a graph of the magnetic flux linkage of the coil against time. The variation of the induced e.m.f. across the coil is shown as a dotted line. [1]

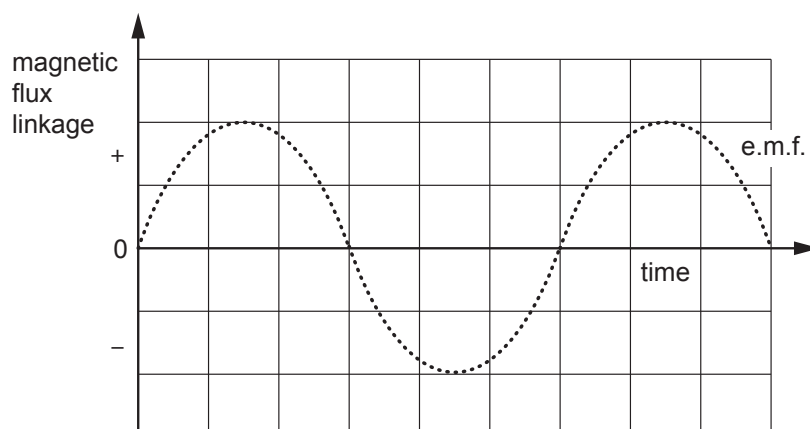


Fig. 5.3

Question 5 is continued on page 14.

- (iii) The coil shown in Fig. 5.1 has 150 turns. The maximum induced e.m.f. V_0 across the coil is 1.2 V when the magnet is rotating at 24 revolutions per second.

Calculate the maximum **magnetic flux** through the coil using the equation

$$V_0 = 2\pi \times (\text{frequency}) \times (\text{maximum magnetic flux linkage})$$

Give a unit with your answer.

maximum flux = ... unit [2]

- (b)* A student is given a transformer with coils **X** and **Y**, as shown in Fig. 5.4.

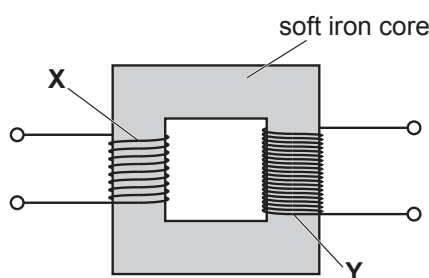


Fig. 5.4

The student is intending to investigate how the maximum induced e.m.f. V_0 in coil **Y** depends on the frequency f of the alternating current in coil **X**.

The changing magnetic flux density in coil **X** induces an e.m.f. in coil **Y**. Faraday's law indicates that the maximum induced e.m.f. V_0 should be directly proportional to f .

Describe how you would investigate the suggested relationship between V_0 and f in the laboratory using these coils. In your description include all of the equipment used and how you would analyse the data collected.

Use the space below to draw a suitable diagram.

- 4 (a)* You are given an unmarked sealed square box which has four identical terminals at each corner.

Fig 4.1 shows the circuit diagram for the contents of the box with the four terminals labelled **A**, **B**, **C** and **D**.

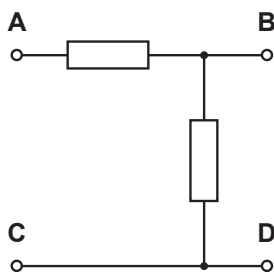


Fig. 4.1

One of the resistors in the box has resistance $220\,\Omega$. The other resistor has resistance $470\,\Omega$. Two of the terminals are connected by a wire.

The four terminals on your unmarked sealed box are **not** labelled.

You are given a 6.0 V d.c. supply, a $100\,\Omega$ resistor (labelled **R**) and a digital ammeter.

Plan an experiment to determine the arrangement of the components and identify which terminal of your unmarked sealed box is **A**, **B**, **C** and **D**.

A space has been left for you to draw circuit diagrams to illustrate your answer.

- (b) A light-dependent resistor (LDR) is connected between points **X** and **Y** in the circuit of Fig. 4.2. The circuit is used to switch on a lamp during the hours of darkness.

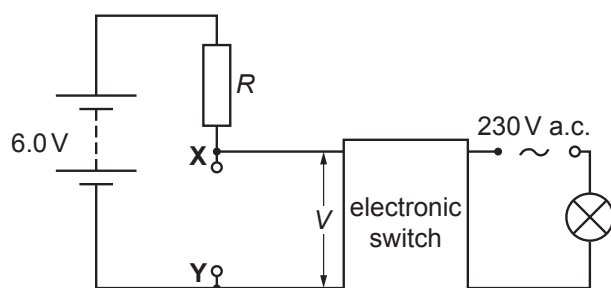


Fig. 4.2

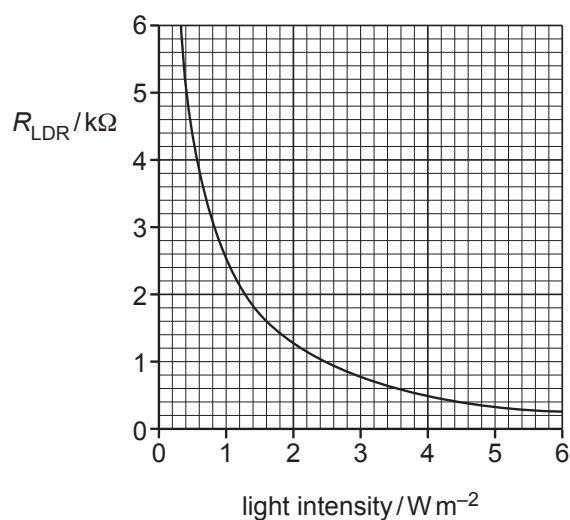


Fig. 4.3

- (i) Draw the symbol for an LDR on Fig. 4.2 between **X** and **Y**. [1]
- (ii) Fig. 4.3 shows how the resistance of the LDR varies with light intensity. The electronic switch closes when V across **XY** is 4.0 V and opens when V across **XY** is 2.4 V. The electronic switch draws a negligible current.

Calculate

- 1 the resistance R of the resistor for the lamp to switch on at a light intensity of 0.80 W m^{-2}

$$R = \dots\dots\dots \Omega \text{ [3]}$$

- 2 the light intensity of the surroundings at which the lamp switches off.

$$\text{light intensity} = \dots\dots\dots \text{ W m}^{-2} \text{ [2]}$$

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Question 5 begins on page 14.



- 18 (a) State Kirchhoff's second law **and** the physical quantity that is conserved according to this law.

.....

.....

.....

..... [2]

- (b) The S.I. base units for the ohm (Ω) are $\text{kg m}^2 \text{s}^{-3} \text{A}^{-2}$.

Use the equation $R = \frac{\rho L}{A}$ to determine the S.I. base units for resistivity ρ .

base units for ρ [2]

Question 18 continues on page 16



- (c) Fig. 18.1 shows a circuit used by a student to determine the resistivity of the material of a wire.

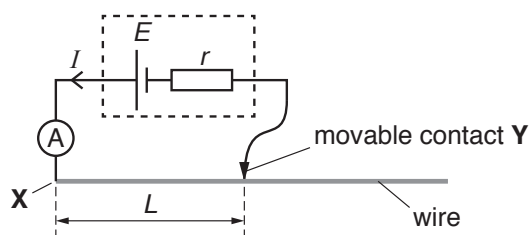


Fig. 18.1

The wire is uniform and has diameter 0.38 mm. The cell has electromotive force (e.m.f.) E and internal resistance r . The length of the wire between **X** and **Y** is L .

The student varies the length L and measures the current I in the circuit for each length.

Fig. 18.2 shows the data points plotted by the student.

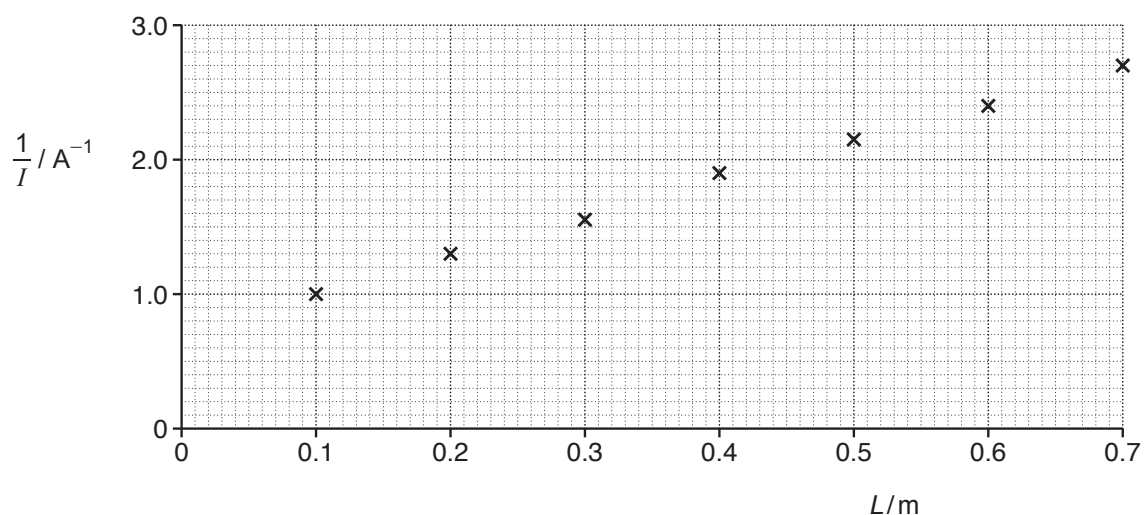


Fig. 18.2

- (i) On Fig. 18.2 draw the straight line of best fit. Determine the gradient of this line.

gradient = ... $\text{A}^{-1} \text{m}^{-1}$ [2]

- (ii) Show that the gradient of the line is $\frac{\rho}{AE}$, where ρ is the resistivity of the material of the wire, A is the area of cross-section of the wire and E is the e.m.f. of the cell.

[2]

- (iii) The e.m.f. E of the cell is 1.5 V. The diameter of the wire is 0.38 mm.

Use your answer to (i) and the equation given in (ii) to determine ρ .

$\rho = \dots\dots\dots \Omega \text{ m}$ [2]

- (iv) Fig. 18.3 illustrates how the student had incorrectly measured all the lengths L of the wire.

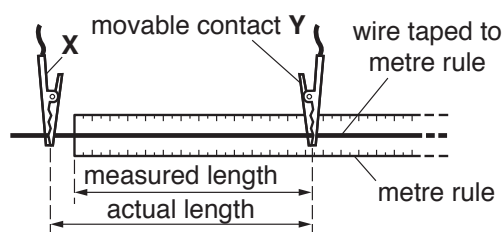


Fig. 18.3

According to the student, re-plotting the data points using the **actual** lengths of the wire will not affect the value of the resistivity obtained in (iii).

Explain why the student is correct.

.....

 [2]

- 3 Fig. 3.1 shows the design of a 'mechanical' torch.

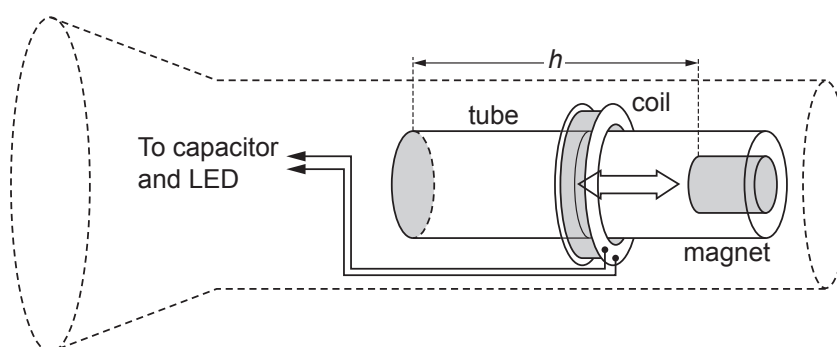


Fig. 3.1

There is no battery in the torch. Instead, when the torch is inverted, the magnet falls a short vertical distance h through the coil of wire, as shown in Fig. 3.2. This induces an electromotive force (e.m.f.) across the ends of the coil. The e.m.f. is used to store charge in a capacitor, which lights a light-emitting diode (LED) when it discharges.

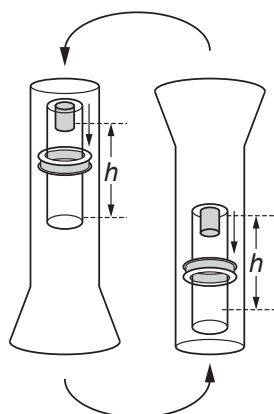


Fig. 3.2

Fig. 3.3 shows the variation with time of the e.m.f. generated as the magnet falls the distance h .

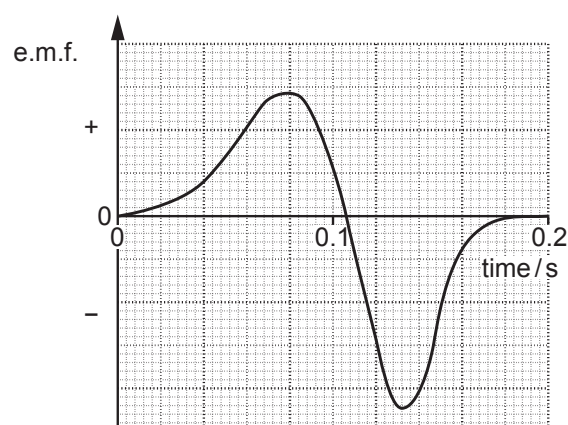


Fig. 3.3

- *(c)** In the torch, the gravitational potential energy of the magnet is converted into electrical energy supplied to the 50 mW LED.

You are asked to investigate whether the efficiency of this energy conversion depends on the number of inversions of the torch.

- Describe how you will make accurate measurements to collect your data. Assume that both the torch and the tube can be opened.
- Explain how you will use the data to reach a conclusion. **[6]**

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Additional answer space if required.

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- 20** In an experiment a circuit is set up so that a capacitor with a resistor in series can be charged and at some later time discharged through the same resistor without changing the positions of the components. This process can be repeated.

The supply has a potential difference (p.d.) 6.0 V d.c.

The capacitor has capacitance 1.0 μF .

The resistor has resistance 10 k Ω .

A voltmeter is used to measure the p.d. across the capacitor.

- (a)** Draw a circuit diagram for this experiment.

[2]

- (b)** Calculate the charge Q stored on the capacitor when it is fully charged.

$Q = \dots\dots\dots \text{ C}$ **[1]**

- (c)** Use a calculation to explain why it will not be possible to measure the variation of p.d. across the capacitor with time, using a stop watch.

.....
 **[4]**

- (d) State how this experiment can be modified to measure the variation of p.d. across the capacitor with time as the capacitor charges.

.....
..... [1]

- (e) The capacitor was completely charged and then discharged to 4.12 V.

- (i) Calculate the time t required for the p.d. across the capacitor to reach 4.12 V when discharging.

$t =$ s [2]

- (ii) Calculate the average rate at which energy is lost by the capacitor as it discharges from 6.0 V to 4.12 V.

average rate at which energy is lost = ... Js^{-1} [3]

18*

- (a) Describe how an experiment can be conducted to determine how the output current of a step-up transformer depends on the number of turns on the secondary coil.

Explain how the data collected can be analysed to establish the relationship between the output current and the number of turns on the secondary coil.

You are provided with wire and a suitable core on which to wind the wire, as well as any other normal laboratory equipment.

Use the space below to draw a labelled circuit diagram.

[6]

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Additional space if required

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- (b) A simple laminated iron-core transformer takes mains voltage 230 V, 50 Hz into the primary coil. The output voltage from the secondary coil is 5.0 V. The primary coil has 920 turns.

- (i) State *Faraday's law*.

.....

..... [1]

- (ii) Show that the number of turns on the secondary coil is 20.

[2]

- (iii) At one particular instant, the output voltage from the transformer is 3.4 V.

Calculate the change in magnetic flux experienced by the secondary coil in a short time interval of 1.2 ms and state its unit.

Assume that the output voltage from the transformer remains constant at 3.4 V over this time interval.

$\Delta\Phi =$ unit [4]



- 20 (a) An approximate value of the Planck constant h can be determined in the laboratory using light-emitting diodes (LEDs). An LED suddenly starts to conduct and emit monochromatic light when the potential difference across an LED exceeds a minimum value V_0 . The potential difference V_0 and the wavelength λ of the emitted light are related by the equation

$$V_0 = \left(\frac{hc}{e} \right) \times \frac{1}{\lambda}$$

where e is the elementary charge and c is the speed of light in a vacuum.

Fig. 20.1 shows some data points plotted by a student on a V_0 against $\frac{1}{\lambda}$ graph for five different LEDs.

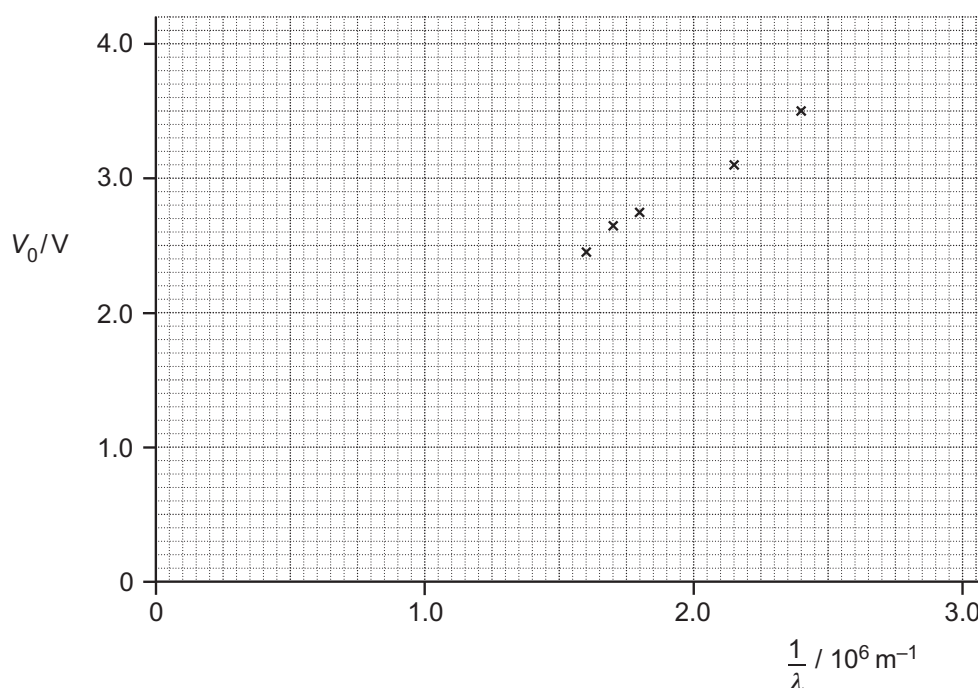


Fig. 20.1

The potential difference across each LED was measured using a digital voltmeter with divisions $\pm 0.01 \text{ V}$. The values for the wavelengths are accurate and were provided by the manufacturer of the LEDs.

The value of V_0 was determined by directly observing the state of the LED in the **brightly** lit laboratory.

- (i) Draw the straight line of best fit on Fig 20.1 and determine the gradient of the line.

- (ii) Use your answer in (i) and the equation on page 20 to determine a value for h to 2 significant figures. Show your working.

$h =$ Js [3]

- (iii) Calculate the percentage difference between your value in (ii) and the accepted value of the Planck constant.

difference = ... % [1]

- (iv) Identify the two types of errors shown by the data in Fig. 20.1 and suggest how you could have refined the experiment to reduce or eliminate these errors.

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..... [4]

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Question 21 is on page 24
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- 6 A 3D printer can manufacture small objects.

Some 3D printers use polylactic acid (PLA). PLA is supplied in the form of long filaments. The 3D printer melts the PLA and builds up the shape of the desired object in layers.

The electrical supply to the heater in the printer has an e.m.f., $\mathcal{E}$, of 12 V. The power of the heater is 40 W.

- (a) Calculate the resistance, R , of the heater.

$$R = \dots\dots\dots \Omega \text{ [2]}$$

- (b) The specific latent heat of fusion of PLA is $9.4 \times 10^4 \text{ J kg}^{-1}$ and its melting point is 160°C .

- (i) Define **specific latent heat of fusion**.

.....

 [1]

- (ii) Calculate the **maximum** mass m of PLA that the heater could melt in one minute.

$$m = \dots\dots\dots \text{ kg [2]}$$

- (iii) Explain why the printing process is slower in practice than your answer to (ii) suggests.

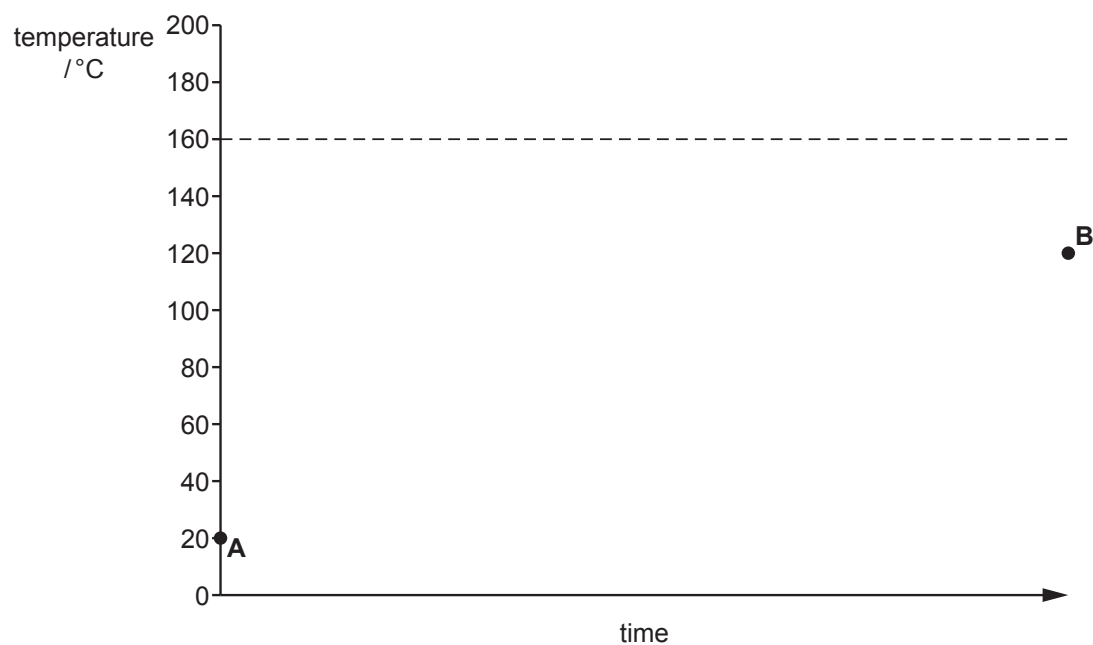
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 [2]

(iv) Fig. 6.1 shows the initial and final temperature of the PLA during the printing process.

Initially (point **A**), the solid PLA is at 20 °C and is just entering the heater. Later (point **B**), the PLA has been added to the object and is solid again.

Fig. 6.1



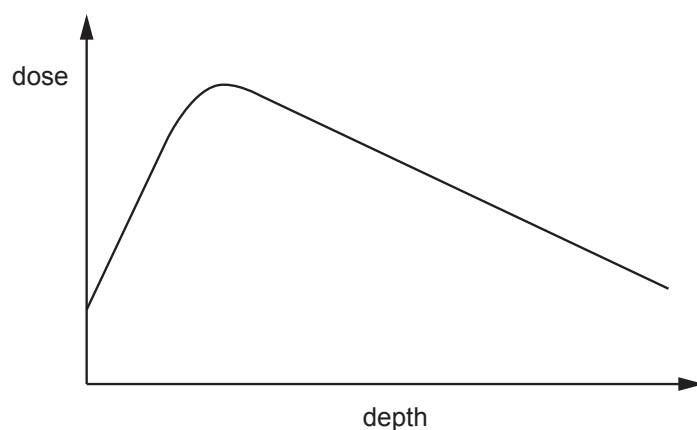
Complete Fig. 6.1 to show how the temperature of the PLA changes between **A** and **B**. You are **not** required to label the time axis. [3]

- (c) High-energy X-ray photons can destroy living cells. In radiotherapy, these photons are targeted at cancer cells.

The radiation **dose** is the amount of energy that a patient's body absorbs from the high-energy X-ray photons.

Fig. 6.2 shows how this dose changes with depth below the surface of the skin.

Fig. 6.2



The dose initially rises with depth because the high-energy X-ray photons produce electrons and positrons as they pass through the body. These electrons and positrons are quickly absorbed, increasing the dose.

- (i) Explain why high-energy X-ray photons produce electrons **and** positrons as they pass through the body.

.....

.....

.....

..... [2]

- *(ii) A 3D object called a **bolus** is used in radiotherapy for patients with skin cancer. A bolus targets the maximum radiation dose near the surface of the skin. So using a bolus makes the radiotherapy more effective.

A bolus can be made from PLA using a 3D printer. The bolus must fit the shape of the patient's body exactly. This shape is found beforehand by giving the patient either a CAT scan or a PET scan.

- Explain how CAT scans and PET scans work.
- Discuss the advantages and disadvantages of having a scan to produce a bolus for radiotherapy.

..... [6]

Additional answer space if required

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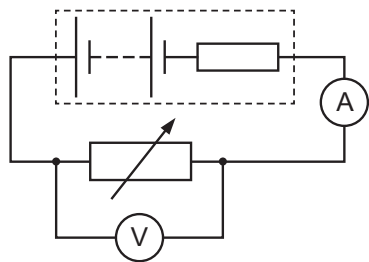
SUB-TOPIC 4.3.2

INTERNAL RESISTANCE

Sub-topic 4.3.2 · 7 questions · 50 marks · lowest tariff first



10 A student uses the circuit below to determine the electromotive force (e.m.f.) and internal resistance of a battery.



They measure the current and potential difference (p.d.) across the variable resistor for different resistor values.

A graph is drawn with p.d. on the y-axis and current on the x-axis.

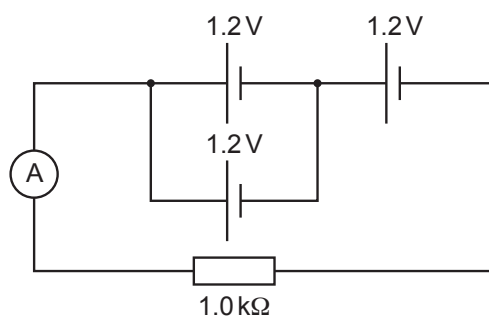
Which row is correct for calculating the e.m.f. and the internal resistance of the battery?

	e.m.f	internal resistance
A	magnitude of gradient	intercept on y-axis
B	magnitude of $\frac{1}{\text{gradient}}$	intercept on y-axis
C	intercept y-axis	magnitude of $\frac{1}{\text{gradient}}$
D	intercept y-axis	magnitude of gradient

Your answer

[1]

- 14 A $1.0\text{ k}\Omega$ resistor is connected in series to a battery made of three 1.2 V cells connected as shown. The cells have negligible internal resistance.



What is the reading on the ammeter?

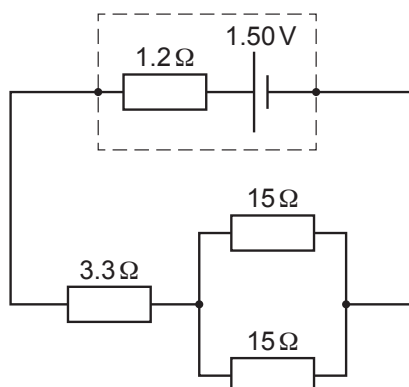
- A 1.2 mA
- B 1.8 mA
- C 2.4 mA
- D 3.6 mA

Your answer

[1]

- 7 A cell has electromotive force (e.m.f.) 1.50 V and internal resistance $1.2\ \Omega$. It is connected in a circuit as shown below.

What is the terminal potential difference (p.d.) of the cell in this circuit?

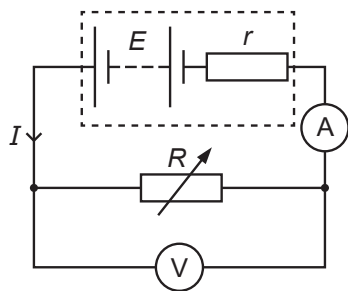


- A 0.15 V
- B 1.35 V
- C 1.50 V
- D 1.65 V

Your answer

[1]

- 18 A battery is connected to a variable resistor.



The variable resistor is made from a length of wire. The resistance of the variable resistor is R . The battery has electromotive force (e.m.f.) E and internal resistance r . The current in the circuit is I .

- (a) Compare the e.m.f. of the battery and the potential difference (p.d.) across the variable resistor in terms of energy transfers or changes.

.....
 [1]

- (b) State which physical quantity of the variable resistor is changed to alter its resistance.

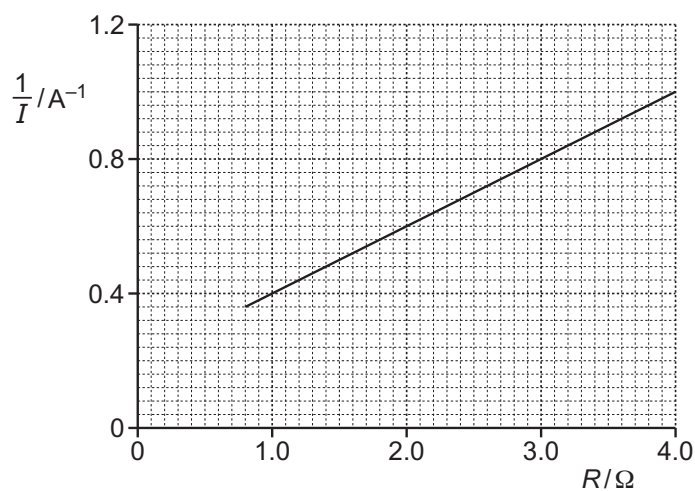
..... [1]

- (c) A student connects up the circuit above to determine r .

(i) Show that $\frac{1}{I} = \frac{R}{E} + \frac{r}{E}$.

[2]

- (ii) The student varies R and measures the current I .
The student plots a graph of $\frac{1}{I}$ against R .



- 1 Use the graph to determine the power dissipated in the variable resistor when $R = 3.0\ \Omega$.

power = ... W [2]

- 2 The e.m.f. E of the battery is 5.0 V.

Determine r from the intercept of the line with the vertical axis.

$r =$ Ω [2]

5

(a) Explain what is meant by

(i) internal resistance of a cell

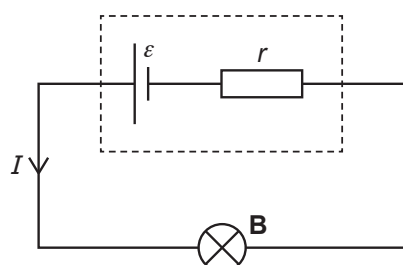
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 [1]

(ii) e.m.f. of a cell.

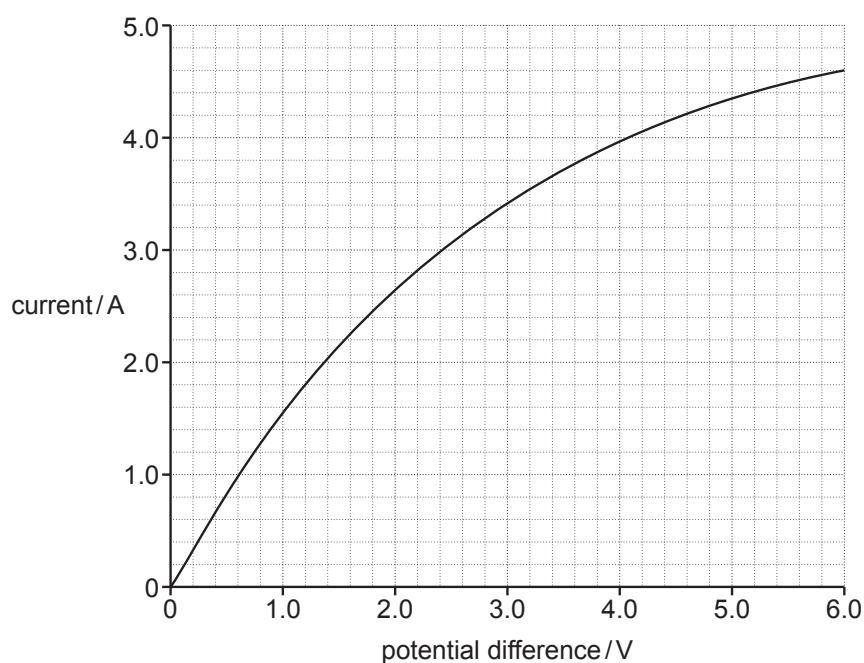
.....
 [1]

(b) A cell has internal resistance $r = 1.2\ \Omega$ and e.m.f. $\mathcal{E} = 5.6\text{ V}$.

When the cell is connected to a filament lamp **B**, as shown in the circuit diagram below, the current in the circuit is I .



The I - V characteristic for **B** is shown in the figure below.



Determine the current I in the circuit.

current = ... A [3]

Question 5 continues on page 16

*(c) A student wants to determine the internal resistance r and the e.m.f. $\mathcal{E}$ of a different cell.

The student knows that the internal resistance is approximately $0.1\ \Omega$.

The only other **electrical** equipment available is as follows:

- one voltmeter
- one ammeter
- one sensitive thermistor, known to have resistance of approximately $0.1\ \Omega$ at 20°C
- several connecting wires and crocodile clips.

Describe how the student can determine r and $\mathcal{E}$ for the cell.

Include how the student should:

- collect and analyse the data
- determine the uncertainties in the values of r and $\mathcal{E}$.

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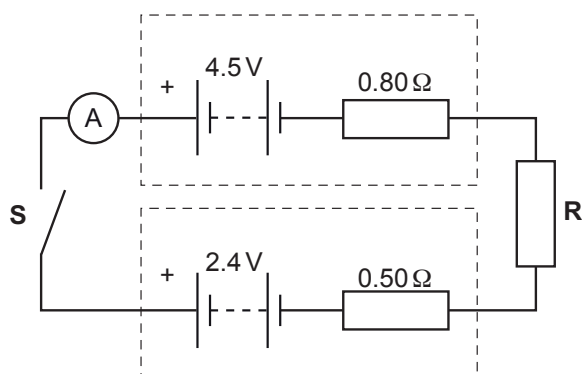
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18 (a) The circuit diagram of an electrical circuit is shown below.



The positive terminals of the batteries are connected together.

One battery has electromotive force (e.m.f.) 4.5 V and internal resistance 0.80 Ω.

The other battery has e.m.f. 2.4 V and internal resistance 0.50 Ω.

R is a coil of insulated wire of resistance 1.2 Ω at room temperature.

The switch **S** is closed.

(i) On the diagram, draw an arrow to show the direction of the conventional current. [1]

(ii) Calculate the current I shown by the ammeter.

$I =$ A [3]

- (iii) The insulated wire has diameter $4.6 \times 10^{-4} \text{ m}$.
The number density of charge carriers in **R** is $4.2 \times 10^{28} \text{ m}^{-3}$.

Calculate the mean drift velocity v of the charge carriers in **R**.

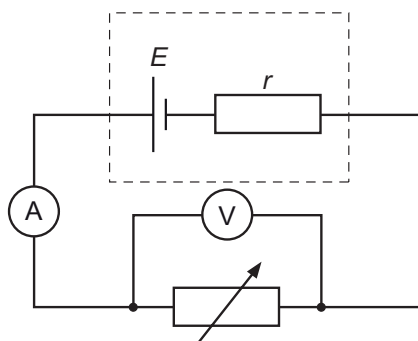
$$v = \dots\dots\dots \text{ ms}^{-1} \text{ [2]}$$

- (iv) The current measured by the ammeter is smaller than that calculated in (ii). This is because the temperature of **R** increased due to heating by the current.

Without any changes to the circuit itself, state and explain what practically can be done to make the measured current the same as the calculated current..

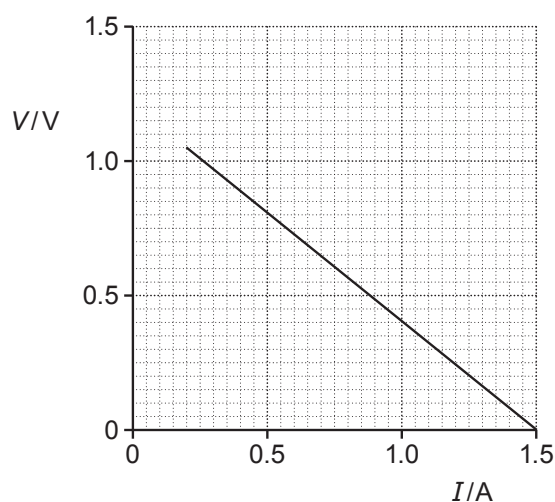
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..... [2]

- (b)* A student is doing an experiment to determine the e.m.f. E of a cell and its internal resistance r . The circuit diagram of the arrangement is shown below.



The student changes the resistance of the variable resistor. The potential difference V across the variable resistor and the current I in the circuit are measured.

The V against I graph plotted by the student is shown below.



V/V	I/A	R/Ω	P/W
0.20	1.25		
0.40	1.00		
0.60	0.75		
0.80	0.50		
1.00	0.25		

There is an incomplete table next to the graph.

R is the resistance of the variable resistor and P is the power dissipated by the variable resistor.

- Use the graph to determine E and r . Explain your reasoning.
- Calculate R and P to complete the table. Describe how P depends on R .

[6]

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Additional answer space if required

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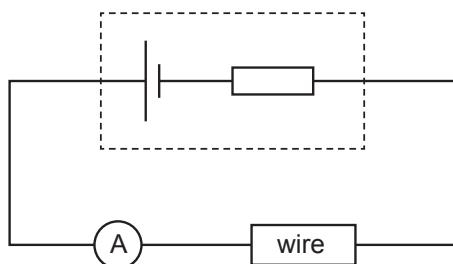
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- 2 A student uses the circuit below to investigate the resistivity of a wire.



The cell has e.m.f. ε and internal resistance r . The wire has resistivity ρ and diameter d .

- (a) The student takes five measurements of the diameter of the wire, which are shown in the table below.

Diameter / mm	0.460	0.450	0.455	0.495	0.455
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- (i) Suggest how the student made these measurements.

.....

 [2]

- (ii) The student calculates the value of the diameter as $d = 0.455 \pm 0.005$ mm.

Explain how the student calculated the value of the diameter, and its uncertainty, from the data in the table above.

.....

 [3]

(b) The student varies the length L of the wire in the circuit and records the current I using the ammeter.

(i) Show that

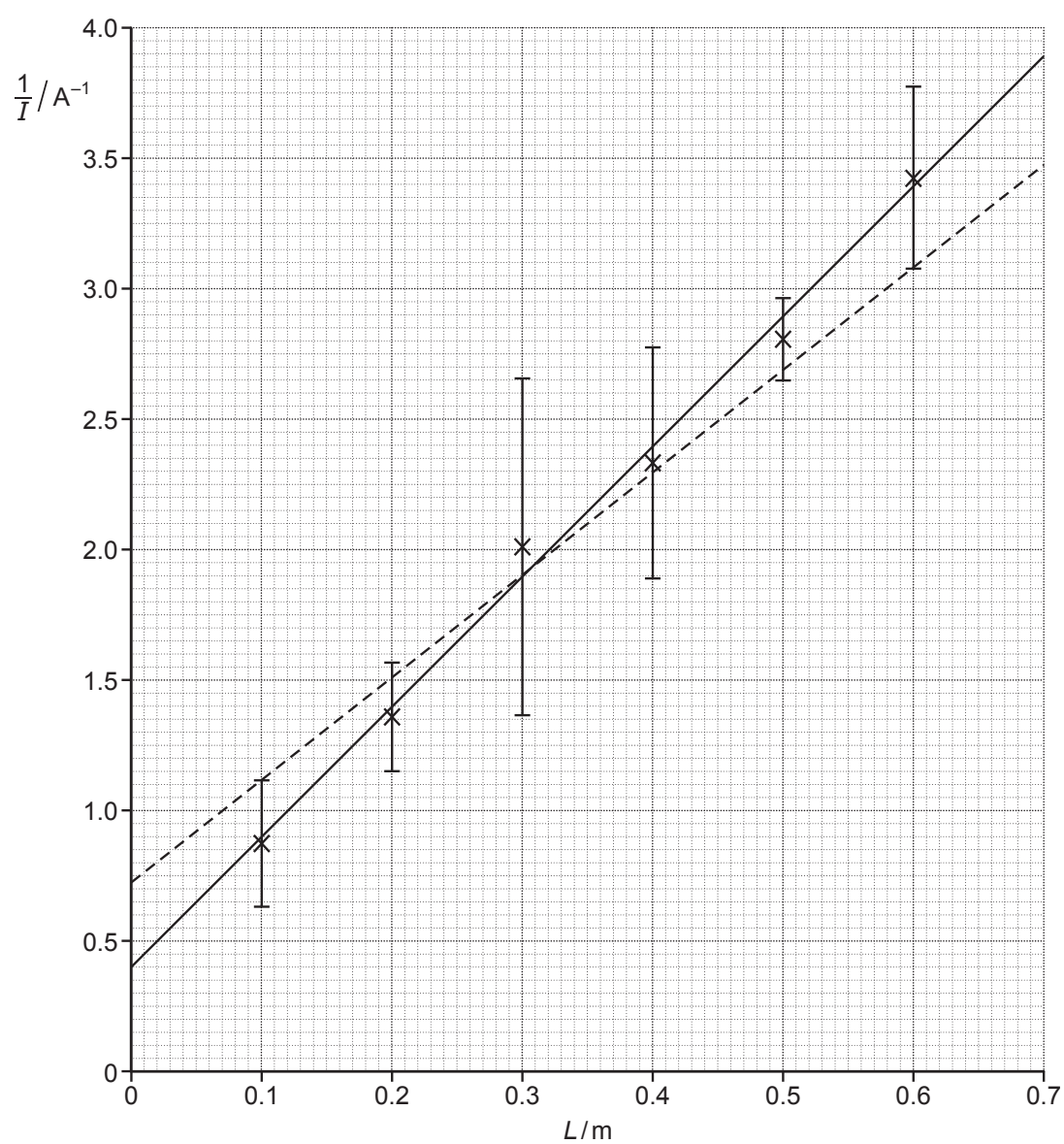
$$\frac{1}{I} = \left(\frac{4\rho}{\pi \epsilon d^2} \right) L + \frac{r}{\epsilon}$$

[3]

Question 2 continues on page 6



- (ii) The student plots a graph of $\frac{1}{I}$ against L . The data points, error bars, line of best fit and a line of worst fit are shown in the graph below.



The cell has e.m.f. $\mathcal{E} = 1.45 \pm 0.05 \text{ V}$

The wire has diameter $d = 0.455 \pm 0.005 \text{ mm}$

- 1 Calculate the gradient of the best fit line and use this to determine a value for the resistivity ρ of the wire.

You are **not** required to determine an uncertainty.

$\rho = \dots\dots\dots \Omega \text{ m}$ [2]

- 2 Determine a value for the internal resistance r of the cell **and** its absolute uncertainty.

$r = \dots\dots\dots \pm \dots\dots\dots \Omega$ [4]

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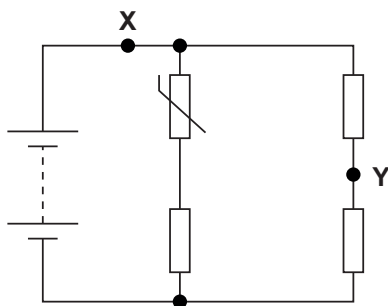
SUB-TOPIC 4.3.3

POTENTIAL DIVIDERS

Sub-topic 4.3.3 · 9 questions · 52 marks · lowest tariff first



4 A circuit is shown below.



The battery has negligible internal resistance. The temperature of the NTC thermistor is **decreased**.

Which of the following statements is/are correct?

- 1 The current at **X** increases.
- 2 The current at **Y** remains the same.
- 3 The potential difference across the thermistor increases.

A 1, 2 and 3

B Only 2 and 3

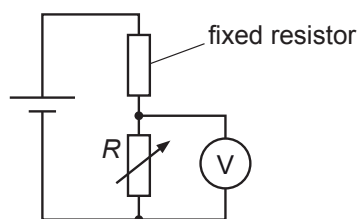
C Only 3

D Only 2

Your answer

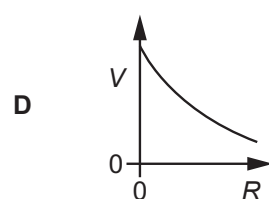
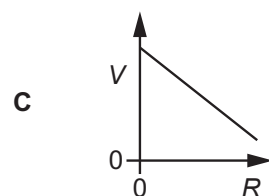
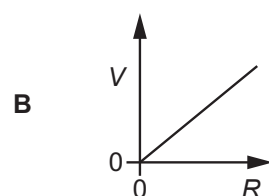
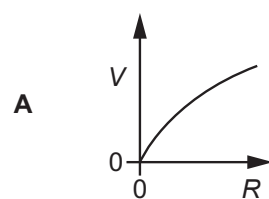
[1]

5 A potential divider circuit is shown below.



The resistance of the variable resistor is R . The potential difference across the variable resistor is V .

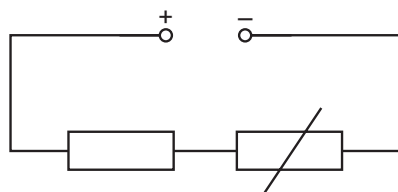
Which graph shows the correct variation with R of V ?



Your answer

[1]

- 7 A circuit with a thermistor is shown below.



The resistance of the resistor is R and the resistance of the thermistor is $2.5R$.
The potential difference (p.d.) across the thermistor is 5.0 V .

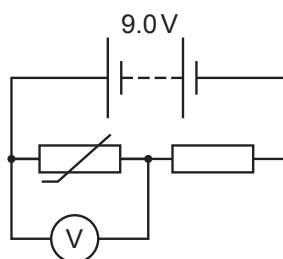
What is the total p.d. across both components?

- A 2.0 V
- B 7.0 V
- C 12.5 V
- D 17.5 V

Your answer

[1]

- 6 A potential divider circuit is shown below.



The battery has electromotive force (e.m.f.) 9.0V and negligible internal resistance.
At room temperature the potential difference (p.d.) across the thermistor is 4.5V.
The temperature of the thermistor is increased and its resistance decreases by 20% from its previous value.

What is the p.d. across the thermistor now?

- A 3.6V
- B 4.0V
- C 5.0V
- D 5.4V

Your answer

[1]

18* A resistance wire is coiled around a thermistor. The coil of wire will warm the thermistor.

It is suggested that the relationship between the power P dissipated in the coiled wire and the stable resistance R of the thermistor is given by the expression $P = kR^n$, where k and n are constants.

Describe how an experiment can be conducted to assess the validity of this expression and how the data collected can be analysed to determine k and n .

Use the space below for a circuit diagram.

[6]

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Additional answer space if required

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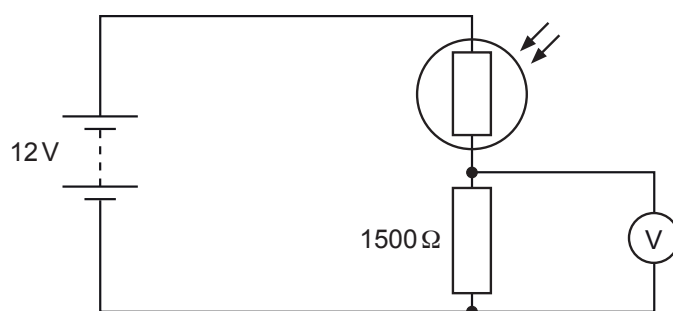
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2 This question is about a light-dependent resistor (LDR).

(a) A student connects a potential divider circuit as shown below. It contains an LDR.



The fixed resistor has resistance $1500\ \Omega$.

The battery has electromotive force (e.m.f.) 12 V and negligible internal resistance.

The voltmeter has extremely high resistance.

(i) When the LDR is covered, its resistance is $3000\ \Omega$.

Calculate the voltmeter reading.

voltmeter reading = ... V [2]

(ii) When fully illuminated, the resistance of the LDR is $100\ \Omega$.
Show that the voltmeter reading **changes** by more than 7 V .

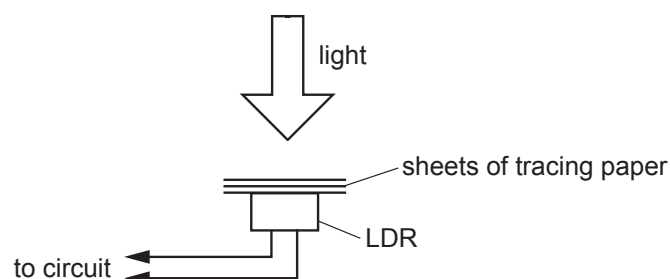
[1]

Question 2 is continued on page 6

***(b)** The current in an LDR depends on the intensity of light incident on it.

A student decides to alter the intensity of light incident on an LDR by using sheets of tracing paper and a light source.

The diagram below shows **part** of an arrangement suggested by the student.



It is suggested that the current I in the LDR is given by the expression

$$I = ke^{-nx}$$

where x is the **total** thickness of the sheets of tracing paper, and k and n are constants.

Describe how the student could carry out an experiment to verify the validity of this expression and determine k and n . Include in your answer

- a circuit diagram
- a possible table for the results, including the headings
- the graph plotted to determine k and n
- any precautions taken to improve the quality of the results.

[6]

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Additional answer space if required

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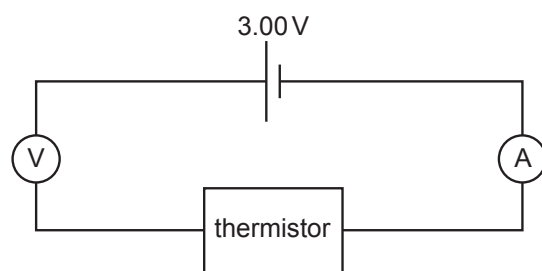
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16 Thermistors are circuit components whose resistance varies with temperature.

There are two major types; negative temperature coefficient (NTC) thermistors, whose resistance decreases with increasing temperature and positive temperature coefficient (PTC) thermistors, whose resistance increases with increasing temperature.

A student is investigating how the resistance of a thermistor varies with temperature by measuring current and voltage. The thermistor is placed in a water bath and the temperature of the water measured using a thermometer.

The diagram below shows how the student set up the experiment (water bath not shown). The circuit has been set up **incorrectly**.



(a) Describe how the student should change the circuit.

.....
..... [1]

(b) The circuit was corrected and then used to collect data.

The table shows data collected from the investigation.

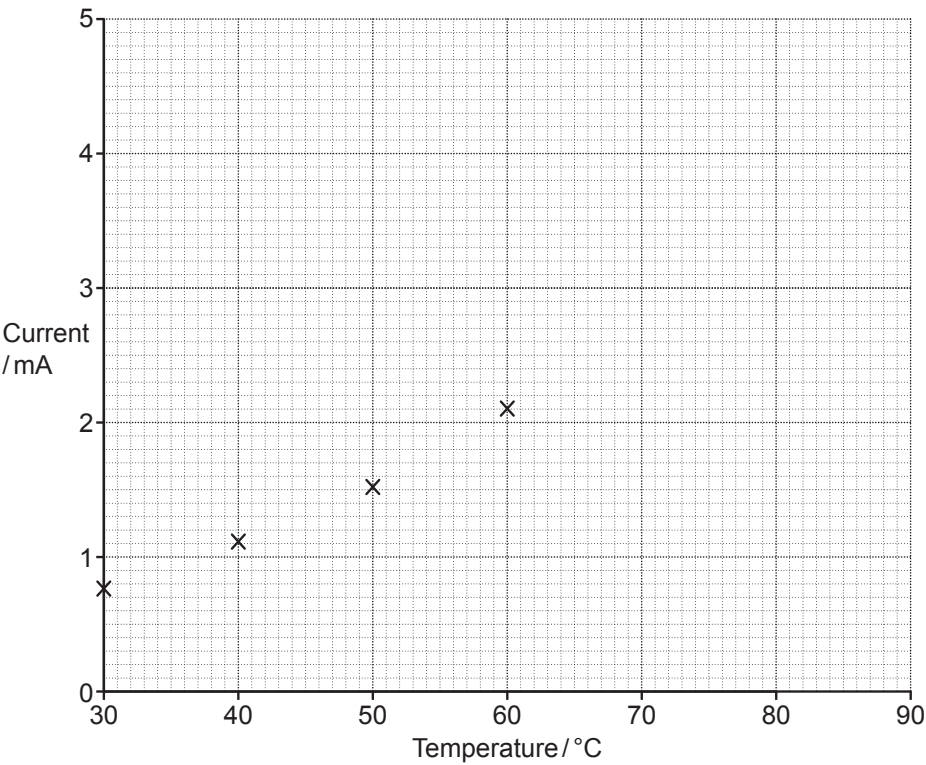
Temperature/°C	Current/mA	Voltage/V
30	0.75	3.00
40	1.10	3.00
50	1.51	3.00
60	2.10	3.00
70	2.80	3.00
80	3.66	3.00
90	4.76	3.00

(i) The axes below show a plot of current against temperature. The first four points from the table have been plotted. Plot the remaining points.

[1]

(ii) Draw a suitable line of best fit through the data points.

[1]

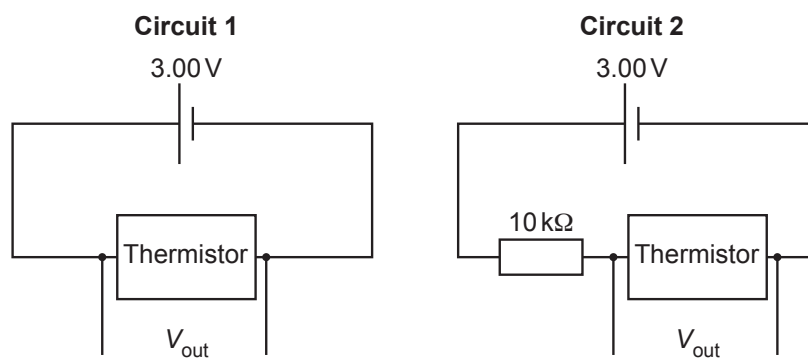


- (c) Describe, using the graph and calculations using data from the table, how the resistance of the thermistor varies for increasing temperature.
Hence determine whether the thermistor the student used was an NTC or a PTC thermistor.

[3]

- (d) The thermistor is used in a temperature-sensing circuit for a heating system to warm milk for a baby.

The student considers two possible designs for the circuit which are shown below.



In each circuit, the voltage V_{out} across the thermistor is connected to the heating system for warming the milk.

Discuss which circuit may be suitable for the heating system by considering the response of the circuit to changes in temperature.

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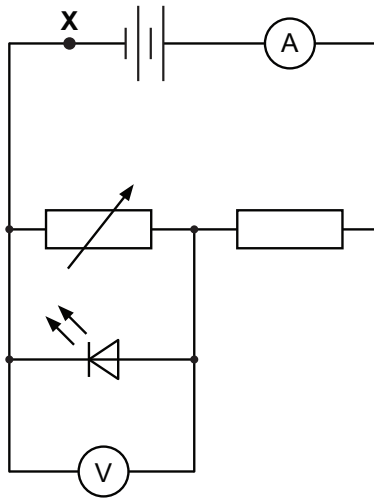
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..... [4]

- 16** A student is investigating the behaviour of a light-emitting diode (LED).

They use the circuit below to determine the lowest potential difference (p.d.) at which the LED lights.



- (a) State the name of the circuit arrangement of the battery, variable resistor and resistor in this circuit.

..... [1]

- (b) Draw an arrow on the circuit to show the direction of conventional current. [1]

- (c) State how the readings on the ammeter and the voltmeter change when the resistance of the variable resistor is increased.

Ammeter reading

Voltmeter reading

[2]

- (d) The LED is made from two semiconducting materials.

Compare the number density of charge carriers in semiconductors, metals and insulators.

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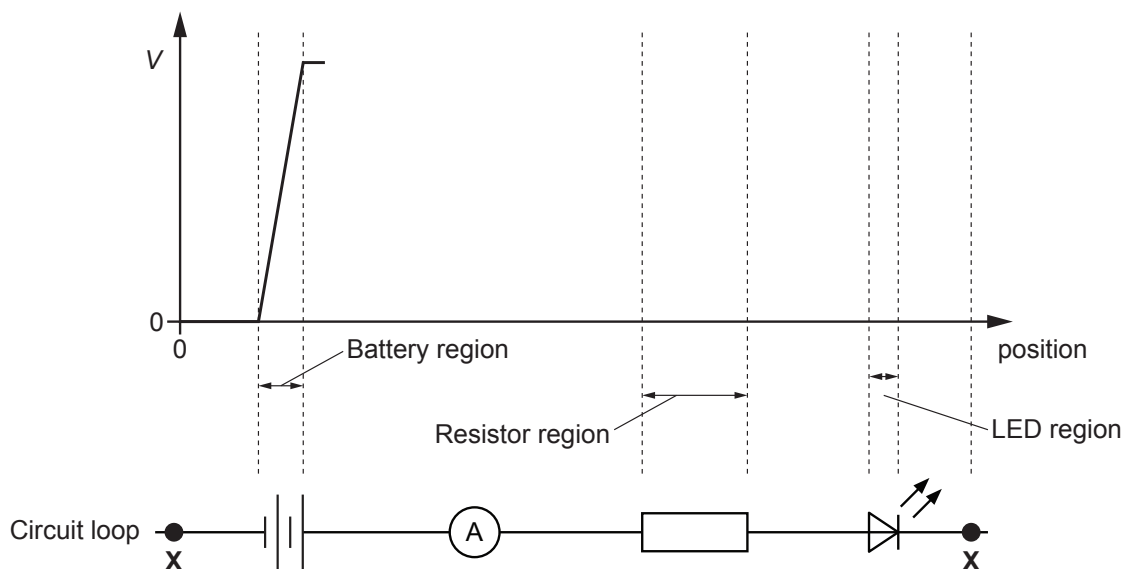
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..... [2]

(e) This question is about a clockwise circuit loop starting at **X**.

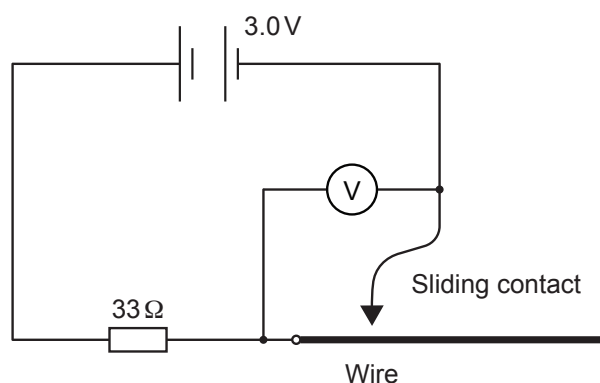
This loop is shown beneath the graph.

Assume the battery has negligible internal resistance. The resistance of the ammeter is also negligible.



On the axes above this loop, complete the graph to show the variation of the potential difference V relative to the point **X** with the position along this loop. **[4]**

- 23 A student is investigating the resistance of a metal wire using the circuit shown below.



The battery has electromotive force (e.m.f.) 3.0V and negligible internal resistance.

- (a) Show that the resistance, R , of a length of this wire in terms of the p.d. across it, V , is given by the expression $R = \frac{33 V}{3.0 - V}$.

[2]

- (b) The student records the voltmeter reading V for different lengths l of the wire. The resistance of the wire is R .

l/cm	V/mV	R/Ω
40	320	3.94
50	390	
60	456	5.92
70	519	
80	579	7.89

- (i) Use the expression given in (a) to complete the two missing R values in the table.

[2]

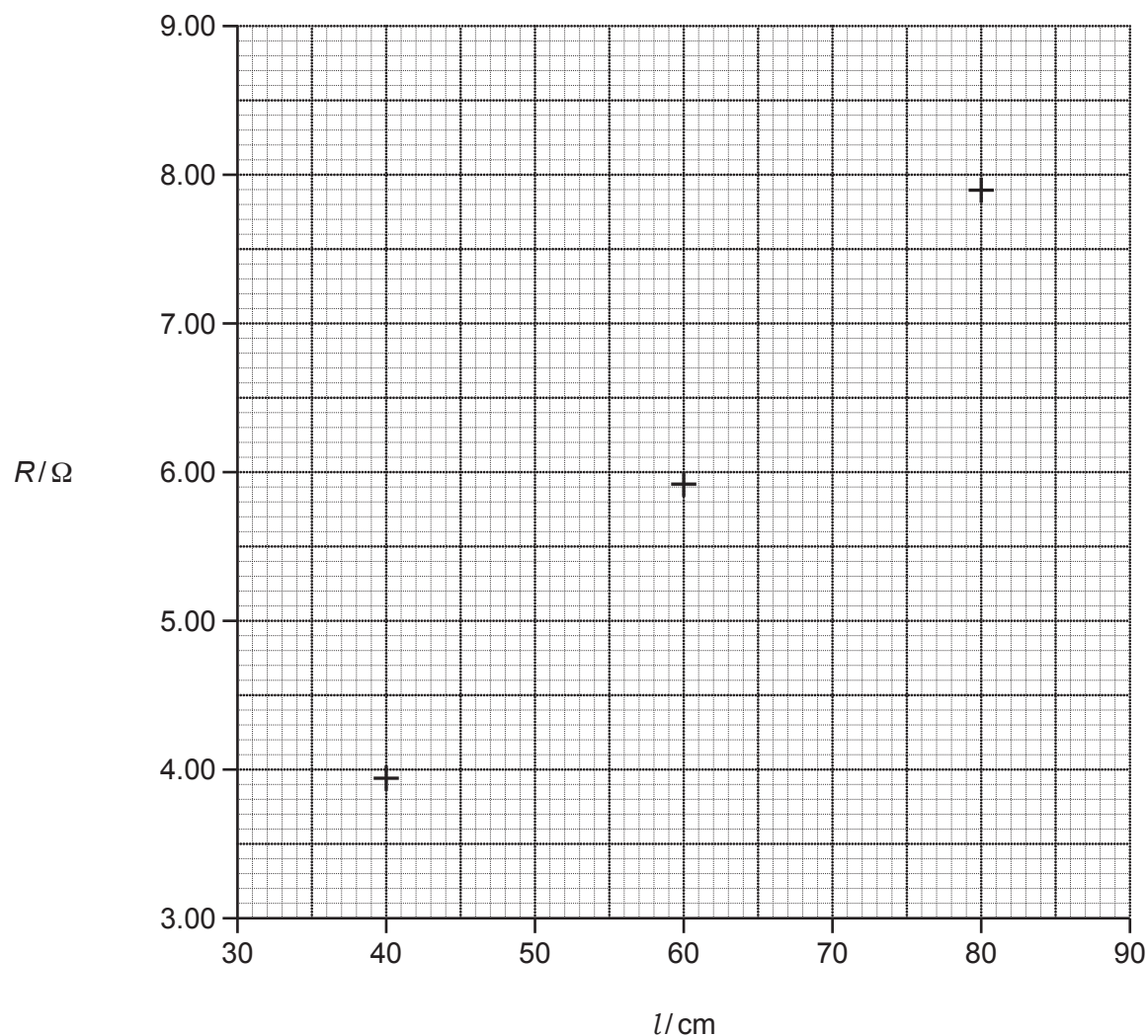
- (ii) The axes below show a plot of R against l .
Three points from the table have already been plotted.

Plot the remaining points.

[1]

- (iii) Draw on your plot a line of best fit.

[1]

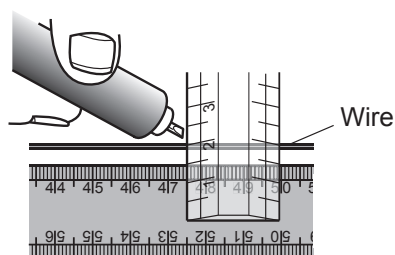


- (c) The wire is made of constantan which has a resistivity of $5.00 \times 10^{-7} \Omega \text{ m}$.

Use the gradient of the line of best fit to determine the diameter, d , of the wire.

$d = \dots\dots\dots \text{ m}$ [4]

- (d) The diagram below shows how the student uses the sliding contact to complete the circuit for a known length of wire.



Explain how this arrangement helps the student to make high-quality measurements.

.....

 [3]

MARK SCHEMES

official mark schemes



2	C		1	
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8	A		1	
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9	D			1	
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1	C	1	
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6	B	1	
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10	C	1	
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13	A	1	
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7	D	1	
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5	D	1	
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10	B	1	
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15	C	1	
	Total	15	

9

SECTION B

General rule: For substitution into an equation, allow any subject - unless stated otherwise in the guidance

Question	Answer	Mark	Guidance
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Question	Answer	Mark	Comments
21 (a)	$\epsilon = 7.2 \times 10^{-12} \times 1.2 \times 10^{-3} / 4.0 \times 10^{-4}$ permittivity = 2.2×10^{-11} (F m ⁻¹)	C1 A1	Allow any subject Allow ϵ_0 instead of ϵ Note answer to 3 sf is 2.16×10^{-11} (F m ⁻¹) Allow 1 mark for bald 2.4; relative permittivity calculated
(b) (i)	capacitance of two capacitors in series = 500 (μF) $C = 1000 + 500$ $C = 1500$ (μF)	C1 A1	
(ii)	$V = 1.5 \times e^{-12/15}$ $V = 0.67$ (V)	C1 A1	Possible ecf from (i) Allow 1 mark for 0.83 V, $V = 1.5[1 - e^{-12/15}]$ used
	Total	6	

17*		Level 3 (5–6 marks) Clear explanation, some description and both resistance values correct <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Some explanation, limited or no description and both resistance values correct OR Clear explanation, limited or no description and calculations mostly correct / one correct calculation OR Clear explanation, some description and no calculations <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Some explanation OR Some description OR Some calculation <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit	B1 × 6	Indicative scientific points may include: Explanation of trace - The 'trace' is because of light reaching and not reaching LDR - Resistance of LDR varies with (intensity) of light - In light - resistance of LDR is low - p.d. across LDR is low - p.d across resistor (or V) is high - current in circuit is large - In darkness - resistance of LDR is high - p.d. across LDR is high - p.d across resistor (or V) is low - current in circuit is small $V_{\max} = 4.0 \text{ V}$; $V_{\min} = 2.0 \text{ V}$ - Potential divider equation quoted - Substitution into potential divider equation Description of determining frequency - Time between pulses is constant because of constant speed - Time between pulses = 0.4 (s) $f = 1/T$ - frequency = 2.5 (Hz) Calculations - Resistance of LDR is 150 (Ω) in light - Resistance of LDR is 1500 (Ω) in darkness
		Total	6	

17	(a)	$(E =) 1.8 \times 1.6 \times 10^{-19} \text{ or } 2.88 \times 10^{-19} \text{ (J)}$ $1.8 \times 1.6 \times 10^{-19} = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{\lambda}$ $\lambda = 6.9 \times 10^{-7} \text{ (m)}$	C1 C1 A1	
	(b)	$(V_R =) 2.7 \text{ (V) or (current =) } 0.018 \text{ (A)}$ $(\text{ratio} = \frac{0.018 \times 1.8}{0.018 \times 2.7})$ ratio = 0.67	C1 A1	Note the mark can be scored on circuit diagram Note values of powers are: 0.0324 W and 0.0486 W Allow 2/3; Not 0.66 (rounding error)
	(c) (i)	In darkness LDR has more resistance / p.d. across LDR is large or In light LDR has less resistance / p.d. across LDR is small Clear idea that when the LED is on, this will force the p.d. across LED / LDR to decrease, forcing the LED to switch off (ORA) (The cycle of LED switching on and off is repeated)	B1 B1	 Note the explanation must be in terms of p.d. / potential divider. Ignore current
	(ii)	A sensible suggestion, e.g. Point the LED away from the LDR / increase distance (between LED and LDR) / insert a card between (LED and LDR)	B1	
		Total	8	

20	(a)	$(CR =) 2000 \times 10^{-6} \times 120 \times 10^3$ $1.00 = 1.48 \times [1 - e^{-t/240}]$ or $0.48 = 1.48e^{-t/240}$ $(t =) -240 \times \ln(0.48/1.48)$ $t = 270 \text{ (s)}$	C1 C1 C1 A1	$CR = 240 \text{ (s)}$ Special case: 94 (s) for use of discharging equation. Max 2 marks
	(b)	Line of best fit drawn through the data points Gradient = 38 $(Ck \ln 2 = \text{gradient})$ $1.2 \times 10^{-3} \times k \times \ln 2 = 38$ $k = 4.6 \times 10^4 \text{ (}\Omega \text{ m}^{-1}\text{)}$	B1 C1 C1 A1	Allow ± 2 . Not calculated through use of a single point. Possible ECF from incorrect gradient Note: gradient of 40 gives 4.8×10^4 and gradient of 36 gives 4.3×10^4
		Total	8	

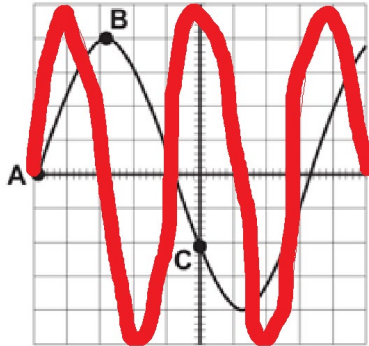
17	(a)	eV or J $\rightarrow$ $[\text{kg m}^2 \text{s}^{-2}]$ in base units by any method base units = $\text{kg m}^2 \text{s}^{-1}$	C1 A1	Allow $\text{kg (m s}^{-1})^2$ Allow base units in any order
	*(b)	Level 3 (5–6 marks) Clear description of method and analysis of data <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Some description of method and analysis of data or Clear description or Clear analysis <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited description or Limited analysis <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>	B1× 6	Indicative scientific points may include: Description • Circuit with LED connected to a variable supply (and series /current limiting resistor) / or use of variable resistor • p.d. across LED increased until LED emits light • Voltmeter (across LED) used to measure V • Use a range of LEDs • λ determined using diffraction grating / spectrometer / double-slit / use $n\lambda = d \sin \theta$ / $\lambda = ax/D$ OR λ determined from manufacturer's data / known wavelength • Darkroom used / tube placed over LED used to establish switching of LED / switch-on identified from finite ammeter reading Analysis of data • Plot of V against λ^{-1} / eV against λ^{-1} / eV against c/λ • Line of best-fit drawn through the points • Straight line (through origin) • Correct gradient for described graph hc/e or hc or h • Correct arrangement for determination of h $h = (\text{gradient} \times e) / c$ or $h = \text{gradient} / c$ (allow numerical values for e and/or c)
		Total	8	

19	(a)		current = 0.01 (A) p.d. = 0.01×50 (= 0.50 V)	M1 A1	
	(b)		$(V_{75} =) \mathbf{0.5 + 2.5}$ (V) or $(R_{LED} =) \mathbf{250}$ (Ω) or $(R_p =) \mathbf{60}$ (Ω) $(I_{100} =) \mathbf{0.05}$ (A) $(E = 3.0 + 0.05 \times 100)$ $E = 8.0$ (V)	C1 C1 A1	Allow other correct methods Note there is no ECF from (a) Allow 1 SF for the p.d. of 3 (V) There is no ECF here from wrong physics (XP) from the parallel network Allow 1 SF answer of 8
	(c)	(i)	$(P =) 0.01 \times 2.5$ or $0.01^2 \times 250$ or $2.5^2/250$ or 0.025 (W) $(E_{\text{photon}} =) \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{4.7 \times 10^{-7}}$ or 4.23×10^{-19} (J) (number per second = $\frac{0.025}{4.23 \times 10^{-19}}$) number per second = 5.9×10^{16} (s ⁻¹)	C1 C1 A1	Allow 4.0×10^{-19} (J); which is 2.5 eV Note using 4.0×10^{-19} (J) gives 6.25×10^{16} (s ⁻¹)
		(ii)	$(E_{\text{photon}} =) 2.64$ (eV) or $(\phi =) 3.68 \times 10^{-19}$ (J) or $(f_0 =) 5.55 \times 10^{14}$ (Hz) or $(\lambda_0 =) 5.40 \times 10^{-7}$ (m) Photoelectrons are emitted and $2.6(4) > 2.3$ or $4.23 \times 10^{-19} > 3.68 \times 10^{-19}$ or 6.38×10^{14} (Hz) $> 5.55 \times 10^{14}$ (Hz) or 4.7×10^{-7} (m) $< 5.40 \times 10^{-7}$ (m)	M1 A1	Possible ECF from (i) Allow 2.6 (eV) or 3.7×10^{-19} (J) Allow 2.5 (eV) as the energy of the photon Note the conclusion must be consistent with (i) Allow $hf > \phi$ Note this can be implied by calculating the KE of the emitted electron
			Total	10	

2	(a)		(initial charge) $Q = EC_0$ or (Q conserved so final) $Q = V(C + C_0)$ (as capacitors are in parallel) <u>so</u> $EC_0 = V(C + C_0)$ (and hence $V = C_0 E / (C + C_0)$)	M1	At least one correct expression for Q for first mark
				A1	The two correct expressions equated for the second mark
	(b)	(i)	$1/V = 1/E + C/EC_0$ (and compare to $y = c + mx$)	B1	Mark is for rearrangement into linear equation
		(ii)	$1/EC_0 = 51 = 1/(9.1 C_0)$ giving $C_0 = 1/(51 \times 9.1) \text{ F}$ $C_0 = 2.2 \text{ (mF)}$	B1 B1	$C_0 = 2.1547 \times 10^{-3} \text{ F}$ Answer must be correct, rounded correctly and given in mF Candidate's answer must be given to 2 SF
		(iii)	(at least) one correct worst fit line drawn gradient calculated correctly using a large triangle uncertainty = $C_0 - 1/(\text{wfl gradient} \times 9.1)$ uncertainty given is to the same number of decimal places as C_0	B1 B1 B1 B1	Top and bottom points chosen must be from opposite extremes of uncertainty limits, accurate to within half a small square $\Delta x \geq 1.5 \times 10^{-3}$; expect 59 ± 1 or 44 ± 1 (or 0.059 or 0.044); allow ECF from poorly drawn line; readings must be accurate to within half a small square ECF from b(ii) ; expect uncertainty of up to 0.4 (mF) ECF from b(ii) If no value for C_0 given in b(ii) , allow any answer given to 1dp
	(c)		Only effect is to slow the charging and/or discharging (of capacitor(s)) <u>and so</u> the final charges are unchanged / the values for V are unchanged / the graph is unchanged / the gradient is unchanged / there is no effect on the experiment (results)	B1	Allow and so the experiment takes longer
			Total	10	

Question	Answer	Marks	Guidance
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21	(a)	B	A1	
21	(b)	Amplitude drawn is larger Time period drawn is smaller	B1 B1	At least one complete cycle needs to be drawn for any credit Consider all cycles drawn. All peaks must be greater than amplitude of given wave and consistent within $\frac{1}{2}$ square of each other For T, only mark first complete cycle – do not insist on symmetry but such that the end of the first cycle is less than or equal to 8 squares e.g. 

Question	Answer	Mark	Guidance
21	(c) (i)	$\Phi = BA \cos \theta = 25 \times 10^{-3} \times (8.0 \times 10^{-2} \times 4.0 \times 10^{-2}) \times \cos 45 (= 5.66 \times 10^{-5} \text{ Wb})$ Change in flux linkage = $N \Phi = 120 \times 5.66 \times 10^{-5}$ $= 6.8 \times 10^{-3} \text{ (Wb)}$	C1 A1 ALLOW $\sin \theta$ for $\cos \theta$ Only apply POT error in coil dimensions once Calculation of area of circle using one of the given coil dimensions is XP Correct to at least 2 significant figures (6.79×10^{-3}) IGNORE sign
21	(c) (ii)	Induced emf ($E = - \Delta \Phi / \Delta t$) = (-) 0.0068 / 0.13 $\mathcal{E} = (-) 0.052 \text{ (V)}$	C1 A1 ALLOW ECF for flux linkage above but answer to (c)(i) $\times 120 \div 0.13$ scores zero marks for this question Correct to at least 2 significant figures IGNORE sign
21	(d)	Total power requirement = $580 + 40 + 100 = 720 \text{ W}$ Power required from mains = $720 - 400 = 320 \text{ (W)}$ Mains current drawn = $(P / V) = 320 / 230$ $= 1.4 \text{ (A)}$	C1 A1 ALLOW other methods e.g. total current required = $(40 + 100 + 580) / 230 = 3.13 \text{ (A)}$ Current supplied by mains = current required - current from turbine = $3.13 - (400/230) = 1.4 \text{ (A)}$ Correct to at least 2 significant figures

Question		Answer	Mark	Guidance
21	(e)	kWh or kilowatt-hour	B1	IGNORE case of letters

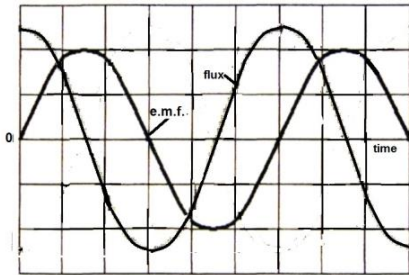


18	(a)	(i)	Resistance of parallel combination = 40 (Ω) $I = \frac{4.2 - 1.5}{40 + 33}$ $I = 0.037$ (A)	C1 C1 A1	Allow $(1/60 + 1/120)^{-1}$ Allow 2 marks for $I = \frac{4.2 + 1.5}{40 + 33} = 0.078$ (A)
		(ii)	Any <u>two</u> from: The current decreases up to 1.5 V The current is zero at 1.5 V The current changes direction / is negative when < 1.5 V The current increases below 1.5 V	B1×2	Allow 'current is zero when the e.m.f.s are the same'

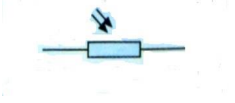
Question	Answer	Marks	Guidance
(b)*	Level 3 (5–6 marks) Clear description including a reasonable estimate of r and clear limitations <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Some description with an attempt to estimate r and some limitations <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited description <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>	B1×6	Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks, etc. Indicative scientific points may include: Description and estimation • Correct circuit with (variable) resistor, ammeter and voltmeter • Correct symbols used for all the components • R changed to get different values for P • $R = V/I$ (using ammeter and voltmeter readings) or R measured directly using an ohmmeter with the variable resistor isolated from the circuit or R read directly from a resistance box • Power calculated using $P = V^2/R$ or $P = VI$ or $P = I^2R$ • The value of r is between 1.0 to 3.0 Ω • A smooth curve drawn on Fig. 18.2 (to determine r) • A better approximation from sketched graph or r is between 1.5 and 2.7 Ω • Any <u>attempt</u> at using $E = V + Ir$, with or without the power equation(s) to determine r - even if the value is incorrect Limitations • 'More data' required • Data point necessary at $R = 2.0 \Omega$ / More data (points) needed between 1 to 3 Ω • No evidence of averaging / Error bars necessary (for both P and R values)
	Total	11	

16	(a)	$(R = \frac{V}{I} = \frac{W}{QI}; Q = It)$ charge $\rightarrow A\ s$ or energy $\rightarrow kg\ m\ s^{-2} \times m$ or $kg\ m^2\ s^{-2}$ (base units) $kg\ m^2\ A^{-2}\ s^{-3}$	C1 A1	Allow other correct methods Allow Q or C or coulomb for 'charge'; E or W or joule or J or work done for 'energy' Allow 1 mark for $J\ s^{-1}\ A^{-2}$ Allow $\frac{kg\ m^2}{A^2\ s^3}$ or $kg\ m^2 / (A^2\ s^3)$ Not $kg\ m^2 / A^2 / s^3$ or $kg\ m^2 / s^3 / A^2$
	(b) (i)	$(R =) \frac{6.0}{0.150}$ $R = 40\ \Omega$	M1 A0	Allow any correct value of V ($\pm 0.1\ V$) divided by the correct value of I ($\pm 10\ mA$) from the straight line for R
	(ii)1	$(V_L =) 1.4\ (V)$ or $(V_R =) 4.0\ (V)$ or $(R_T =) 6.0/0.1\ (\Omega)$ $(V_{terminal} =) 5.4\ (V)$ or $(V_r =) 0.6\ (V)$ or $(r =) 60 - 54\ (\Omega)$ $r = 6.0\ (\Omega)$	C1 C1 A1	Allow full credit for other correct methods Possible ECF from (i) Allow $\pm 0.1\ V$ for the value of p.d. from the graph Note getting to this stage will also secure the first C1 mark Allow 1 SF answer here without any SF penalty
	(ii)2	$\rho = \frac{40 \times 2.4 \times 10^{-6}}{8.0 \times 10^{-3}}$ (Any subject) $\rho = 0.012\ (\Omega\ m)$	C1 A1	Allow ECF Allow 1 mark for either 0.018 for using $60\ \Omega$, 0.016(2) for using $54\ \Omega$ or for 0.0018 for $6.0\ \Omega$
	(ii)3	$n = \frac{6.5 \times 10^{17}}{2.4 \times 10^{-6} \times 0.008}$ or $n = 3.385 \times 10^{25}\ (m^{-3})$ $v = \frac{0.100}{2.4 \times 10^{-6} \times 3.385 \times 10^{25} \times 1.60 \times 10^{-19}}$ (Any subject) $v = 7.7 \times 10^{-3}\ (m\ s^{-1})$	C1 C1 A1	Note do not penalise again for the same POT error Allow 1 mark for $4(.0) \times 10^5\ (m\ s^{-1})$; $n = 6.5 \times 10^{17}$ used
		Total	11	



Question	Answer	Mark	Guidance
5	(a) (i)		
	the <u>flux</u> in the coil <u>changes/ increases/ decreases/ varies</u> (caused by the spinning/rotating magnet) causing a sinusoidal/alternating e.m.f./AW	B1 B1	or e.m.f. is proportional to /equals rate of change of flux linkage/linking the coil or qualification, e.g. magnet vertical gives minimum flux through core or maximum rate of change of flux or vice versa with magnet horizontal or maximum flux is when emf is zero or minimum flux is when emf is maximum or vice versa
	(ii)		
		B1	allow $\pm \cos$ wave of correct period, constant amplitude at least one cycle N.B. quality: curve must look like a reasonable sine wave as one is present on the page to copy
	(iii)		
	$\phi = BA = V/2\pi fN = 1.2/(2 \times \pi \times 24 \times 150)$ $\phi = 5.3 \times 10^{-5}$ Wb / T m ²	B1 B1	allow no other unit combinations; NOT T m ⁻²
	(b)		
	see page 9	B1 x 6	
	Total	11	

Question	Answer	Marks	Guidance
5	Level 3 (5–6 marks) Clear description, some measurements and full analysis <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Some description, some measurements and some analysis. <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited description and/or limited measurements and/or limited analysis <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	B1 x 6	Indicative scientific points may include: Description - Signal generator/a.c. supply connected to coil X - Coil Y connected to voltmeter / oscilloscope (can be on diagram) - Use oscilloscope to determine period / frequency or read off signal generator - Adjust signal generator / use of rheostat to keep current constant in coil X Measurements - Vary f and measure V - Keep <u>current</u> in coil X <u>constant</u> - Detail on how to measure e.m.f. e.g. 'height x y-gain' - Detail on how to measure period on oscilloscope screen using time base and hence f Analysis - Determine f from period measurement, $f = 1/T$ - Plot a graph of V against f - Relationship valid if straight line through the origin

Question	Answer	Mark	Guidance
4	see page 12	B1 x 6	
(b) (i)		B1	two arrows needed not across resistor; allow a surrounding circle with arrows outside circle
(ii)1	from graph $3.0 \text{ (k}\Omega\text{)}$ $I = 4.0/3.0 = 1.33 \times 10^{-3} \text{ A}$ or $R = 2.0/4.0 \times 3.0 \times 10^3$ $R = (6.0 - 4.0)/1.33 \times 10^{-3} = 1.5 \times 10^3 \text{ (}\Omega\text{)}$	B1 C1 A1	allow $3.1 \pm 0.1 \text{ (k}\Omega\text{)}$ accept 1.3 mA ; accept potential divider argument allow $1.5 \text{ k}\Omega$; special case: using 2.4 V in place of 4.0 V gives $R = 4.5 \text{ k}\Omega$; give 1 mark out of 2
(ii)2	at 2.4 V $R_{\text{LDR}} = 1.0 \text{ k}\Omega$ giving $2.5 \text{ (W m}^{-2}\text{)}$	M1 A1	ecf (b)(ii) ; allow potential divider or $I = 2.4 \text{ mA}$; for special case: $R_{\text{LDR}} = 9.0 \text{ k}\Omega$; give 1 mark out of 2 allow 2.4 to 2.6 W m^{-2} N.B. remember to record a mark out of 5 here
	Total	12	

H556/03

Mark Scheme

June 2017

Question		Answer	Marks	Guidance
4	(a)	Level 3 (5 - 6 marks) Clear planning and correct identification of terminals and position of components <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is clear relevant and substantiated.</i> Level 2 (3 – 4 marks) Clear planning and correct identification of some components / terminals <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) Some planning and/or an attempt at identifying component / terminals <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>	B1 x 6	Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks, etc. Indicative scientific points may include: Planning • suitable circuit arrangements/diagrams drawn between two points which could be connected to the box terminals • use of R to limit current, e.g. to find CD terminals • logical plan of connection across terminals e.g. connect circuit to each pair of terminals in turn • identify terminals C and D as the circuit with the largest current/smallest resistance • A and B identified because CD known or the circuit including terminals AC/D has the smallest current/largest resistance Identifying • $V = IR$ quoted or used in calculations • $R_T = \Sigma R$ used to determine the $220\ \Omega$ or the $470\ \Omega$ resistors • For $220\ \Omega$ resistor (between AB or BC/D) current is 27 (mA) A or 19 (mA) with R • For $470\ \Omega$ resistor (between AB or BC/D) current is 13 (mA) or 11 (mA) with R • For both resistors (between AC/D) current is 8.7 (mA) or 7.6 (mA) with R • For wire (between CD) current is 0.060 A



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Mark Scheme

June 2017

Question	Answer	Marks	Guidance
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18	(a)	Sum of e.m.f(s) is equal to the sum of p.d.(s) (in a loop of a circuit) Energy is conserved	B1 B1	Allow total / Σ instead of 'sum' Allow voltage instead of p.d. Not sum of IR, unless I and R are defined Expect 'sum' at least once in the statement Not $\Sigma E = \Sigma V$, unless V and E are defined
	(b)	$L \rightarrow [\text{m}]$ and $A \rightarrow [\text{m}^2]$ or $L/A \rightarrow [\text{m}^{-1}]$ $\text{kg m}^3 \text{s}^{-3} \text{A}^{-2}$	C1 A1	Allow $\frac{\text{kg m}^3}{\text{s}^3 \text{A}^2}$ or $\text{kg m}^3/\text{s}^3 \text{A}^2$
	(c) (i)	Line of best fit drawn gradient = 2.8	B1 B1	Expect the extrapolated line to have a y-intercept in the range 0.60 to 0.85 and at least one data point on each side of the line Allow gradient of line in the range 2.60 to 3.00
	(ii)	$E = I(r + R)$ and $R = \rho L/A$ $\frac{1}{I} = \frac{r}{E} + \frac{\rho}{AE} L$ (and comparison with $y = mx + c$ leads to gradient = $\frac{\rho}{AE}$)	C1 A1	Allow $E = V + IR$ and $R = \rho L/A$
	(iii)	$(\rho = \text{gradient} \times AE)$ $\rho = 2.8 \times \pi \times (0.19 \times 10^{-3})^2 \times 1.5$ $\rho = 4.8 \times 10^{-7} (\Omega \text{ m})$	C1 A1	Possible ECF from (i) Note not using $A = \pi r^2$ is wrong physics (XP) Allow 1 mark for 1.9×10^{-6} , diameter used instead of radius
	(iv)	The graph / points just shift horizontally (AW) The gradient is unchanged (and ρ will be the same)	B1 B1	Allow shifted to the right or left / 'systematic error' / zero error / change in length stays the same / 'no change in vertical values'
		Total	12	

3	(a)	• (Induced) e.m.f. is caused by a change in (magnetic) flux (linkage) / (Induced) e.m.f. is proportional (or equal to) the <u>rate</u> of change of (magnetic) flux (linkage) • The peaks are inverse / e.m.f. changes from positive to negative because: the rate of change of magnetic flux linking the coil changes sign or the flux (linkage) increases and then decreases or description in terms of Lenz's law as seen by coil to conserve energy • The e.m.f. becomes zero because: the (rate of) change of magnetic flux is zero when the magnet is in the middle of the coil • The second peak has a larger negative amplitude because: the <u>rate</u> of change of flux linkage is greater (when the magnet leaves the coil compared to when it enters) • The pulses have different widths because: the second Δt is shorter (since magnet accelerates) or areas under curves must be the same (because total change of flux linkage is the same on entering and leaving coil) / area under curve = $V\Delta t = N\Delta\phi$ (so bigger V leads to smaller Δt)	B1 x 3 Maximum 3 marks from 4 marking points. Not voltage or p.d. or current for e.m.f. Accept 'cutting of field lines by coil' for 'change in flux' <u>Answers to any of the last three points must link clearly to the correct graph characteristic</u> Allow the North (or South) pole first approaches then recedes Ignore magnet approaches then recedes / field increases then decreases Not torch is inverted Allow no field lines are being cut Allow the magnet is accelerating / is travelling faster when it exits the coil
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H556/03			Mark Scheme		June 2019
Question			Answer	Marks	Guidance
	(b)	(i)	$Q = 9.0 \times 10^{-3} \times 2 \times 80 = 1.44 \text{ (C)}$ $W = (Q^2/2C) = 1.44^2/2 \times 0.12$ $W = 8.6(4) \text{ (J)}$	C1 C1 A1	ECF for incorrect Q e.g. 2/3 for use of $Q = 0.72 \text{ (C)}$ giving $W = 2.2 \text{ (J)}$
		(ii)	$(W = Pt \text{ so } 8.6 = 0.050t)$ $t = 8.6/0.050 = 170 \text{ (s)}$	A1	ECF (b)(i) for incorrect W
	(c)		see page 14	B1 x 6	
			Total	13	



H556/03			Mark Scheme		June 2019
Question			Answer	Marks	Guidance
3	(c)		Level 3 (5 - 6 marks) Clear determination of input energy, procedure and analysis <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is clear, relevant and substantiated.</i> Level 2 (3 – 4 marks) Clear determination of input energy and procedure, but no analysis or Clear analysis but limited determination of input energy and/or limited procedure or Attempted determination of input energy, basic procedure, and an attempt at analysis <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) A limited selection from the scientific points worthy of credit. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>	B1 x 6	Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks, etc. Candidates can gain full credit for investigating the efficiency of either: Method 1(M1): GPE ($nmg h$) to energy conversion in LED ($P t$) or Method 2(M2): GPE ($nmg h$) to energy stored in capacitor ($\frac{1}{2} C V^2$ or $\frac{1}{2} Q^2 / C$) <u>L1 maximum for any answers which do not use GPE as input energy</u> Indicative scientific points may include: Determination of input energy - record the number of inversions, n (use electronic / top pan balance to) measure mass of magnet m (use mm ruler to) measure tube length l_t and magnet length l_m - calculate $h = l_t - l_m$ - calculate (GPE =) $nmg h$ Procedure - invert torch n times (with torch switched off) - make sure that the magnet falls the full height h between inversions - M1 switch torch on and (use stopwatch to 0.1 s to) measure time t taken until LED goes out (use video with timer for greater accuracy) - M1 use a darkened room or view LED through tube - M2 (use voltmeter across capacitor to) measure final p.d. V_f - M2 (with coulombmeter) measure final charge Q_f stored by capacitor - repeat experiment for different n Analysis of efficiency - M1 calculate $W = P t$ where $P = 50 \text{ mW}$ - M2 calculate $W = \frac{1}{2} C V_f^2$ or $\frac{1}{2} Q_f^2 / C$ - calculate efficiency = $W / nmg h$ - compare efficiency values for different n - plot suitable graph e.g. efficiency against n / W against $nmg h$ - plot t against n (M1) / V^2 or Q^2 against n (M2) with justification - discuss shape / gradient of graph



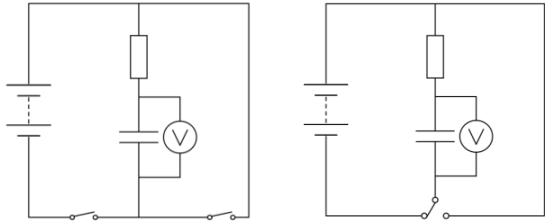
H556/03

Mark Scheme

June 2019

Question	Answer	Marks	Guidance
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20	(a)	Circuit showing (6V) supply in series with a capacitor and resistor, with a voltmeter in parallel with the capacitor. Switch/switches allowing discharging of the capacitor through the resistor.	B1 No labels required. ALLOW any suitable symbol for d.c. supply B1 ALLOW this mark if resistor and capacitor in parallel if switch will allow the discharge Examples of correct circuit for both marks e.g. 
	(b)	Charge = $1.0 \times 10^{-6} \times 6.0 = \mathbf{6.0 \times 10^{-6}}$ (C)	A1 ALLOW correct answer to 1 significant figure
	(c)	(CR =) $1 \times 10^{-6} \times 10 \times 10^3$ CR / Time constant / $\tau = 0.010$ (s) Time constant / τ is time taken to fall to 1/e (37%) of initial value The time it takes to record the variation of pd / the capacitor to discharge is far less than (human) <u>reaction time</u> OR	C1 ALLOW POT error for capacitance if same as in (b) A1 ALLOW 1sf ALLOW t for τ B1 NOT fallen <u>by</u> 37% B1

Question			Answer	Mark	Guidance
			$V = V_0 e^{-\left(\frac{t}{CR}\right)}$ to give $0.6 = 6.0 e^{-\left(\frac{t}{1.0 \times 10^{-6} \times 10 \times 10^3}\right)}$ $t = 0.023$ (s) 0.6 is the voltage when it has fallen to 10% of the initial voltage The time it takes to record the variation of pd / for the capacitor to discharge is far less than human <u>reaction time</u> OR $V = V_0 e^{-\left(\frac{t}{CR}\right)}$ to give $V = 6.0 e^{-\left(\frac{0.02}{1.0 \times 10^{-6} \times 10 \times 10^3}\right)}$ $V = 0.81$ V 0.02 s is a very short amount of time The time it takes to record the variation of pd / for the capacitor to discharge is far less than human <u>reaction time</u>	(C1) (A1) (B1) (B1) (C1) (A1) (B1) (B1)	Substitution into exponential decay equation to fall to a value of V less than $0.9V_0$ ($<5.4V$). ALLOW calculation in log form e.g $\ln 0.6 = \ln 6.0 - t/0.01$ Justification/explanation for using a given voltage Substitution into exponential decay equation with a time less than 0.1s ($t < 0.1s$). ALLOW calculation in log form $\ln V = \ln 6.0 - 0.02/0.01$ Justification/explanation for using a given time
	(d)		Use an oscilloscope / data logger with a voltmeter probe	B1	ALLOW connect a voltmeter to a datalogger
	(e)	(i)	$V = V_0 e^{-\left(\frac{t}{CR}\right)}$ to give $4.12 = 6.0 e^{-\left(\frac{t}{1.0 \times 10^{-6} \times 10 \times 10^3}\right)}$ $= 3.76 \times 10^{-3}$ (s)	C1 A1	ALLOW in terms of logs eg $\ln 4.12 = \ln 6.0 - \frac{t}{0.01}$ Correct to at least 2 significant figures IGNORE minus sign in final answer

Question			Answer	Mark	Guidance
		(ii)	Change in energy = $\frac{1}{2} CV_1^2 - \frac{1}{2} CV_2^2$ $= (\frac{1}{2} \times 1 \times 10^{-6} \times 6^2) - (\frac{1}{2} \times 1 \times 10^{-6} \times 4.12^2) = 9.5 \times 10^{-6} \text{ (J)}$ rate = $9.5 \times 10^{-6} / 3.76 \times 10^{-3}$ $= \mathbf{2.53 \times 10^{-3} \text{ (Js}^{-1}\text{)}}$	C1 C1 A1	 ALLOW POT error from (e)(i) Ecf from (e)(i) Correct to at least 2 significant figures

18	(a)	Level 3 (5–6 marks) Clear description and clear analysis <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Clear description or clear analysis or some description and some analysis	B1 x 6	Use level of response annotations in RM Assessor Indicative scientific points may include: Expect to see use of ac for clear description Description • labelled circuit diagram • smaller number of turns on primary • a.c. supply on primary
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13



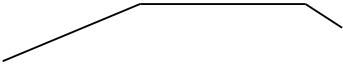
Question			Answer	Mark	Guidance
			<i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited description or limited analysis <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.		- load resistor on output - a.c. ammeter to measure current - measurement of number of turns on secondary - keep number of turns on primary constant - keep input ac voltage constant - increase number of turns on secondary each time Analysis - algebra to get to $N_s \propto 1/I_s$ - graph drawn $1/I_s$ against N_s / I_s against $1/N_s$ - expect straight line through origin or $\lg I_s$ against $\lg N_s$ - expect straight line to show gradient = -1 - therefore $N_s \propto 1/I_s$ or – if load resistor in circuit only - use of Ohm's law applied to load resistor to explain why presence of load resistor increases primary current - plotting graph drawn I_s against N_s - expect straight line through origin
	(b)(i)		The (magnitude of the induced) e.m.f. is (directly) proportional/equal to the rate of change of (magnetic) flux linkage	B1	Allow electromotive force for e.m.f Do not allow electromagnetic force for e.m.f. Allow change per unit time for rate of change Allow cutting flux for change of flux linkage Do not allow flux density for flux linkage

Question		Answer	Mark	Guidance
	(b)(ii)	Use of $N_s / N_p = V_s / V_p$	C1	Expect to see attempt at substitution following the equation
		$N_s / 920 = 5.0 / 230$ so $N_s = 20$	A1	Correct substitution and correct algebra into any arrangement
	(b)(iii)	Use of $N = 20$	C1	Expect to see factor of 20 correctly used
		$3.4 = 20 \times \Delta\phi / 1.2 \times 10^{-3}$	C1	
		$\Delta\phi = 2.0 \times 10^{-4}$	A1	Correctly calculated to 2sf (2.04)
		Unit: Wb / weber(s)	B1	Special cases: for two marks from the calculation Use of $N = 1$ gives 4.08×10^{-3} correct to 2sf Use of $N = 920$ gives 4.43×10^{-6} correct to 2sf Allow T m ² Ignore V s Allow correct base unit (kg m ² s ⁻² A ⁻¹)

20	(a)	(i)	A straight line with non-zero V_0 intercept gradient = 1.3×10^{-6}	B1 B1	Ignore spread of data points on either side of the line Allow Intercept > 0 and < 1.0 V Allow $(1.10 \text{ to } 1.60) \times 10^{-6}$; no need to check calculation
		(ii)	gradient = $\frac{hc}{e}$ (Any subject) $h = \frac{1.3 \times 10^{-6} \times 1.60 \times 10^{-19}}{3.00 \times 10^8}$ (Any subject) $h = 6.9 \times 10^{-34}$ (J s)	C1 C1 A1	Possible ECF from (i) Note the answer must be given 2 SF only
		(iii)	difference = $\frac{6.9 \times 10^{-34} - 6.6(3) \times 10^{-34}}{6.6(3) \times 10^{-34}} \times 100 \%$ difference = 4.1 %	B1	Possible ECF from (ii) Ignore sign Not division by value from (ii) Allow 1 SF answer
		(iv)	Random (error) / data points are spread about line Systematic (error) / line does not pass through origin Take (many) repeat readings (of V_0) and average Conduct the experiment in a darkroom / use (black) tube over the LED to view when it is lit / use a (digital) voltmeter with no zero error	B1 B1 B1 B1	Allow other sensible suggestion Not faulty voltmeter

Question		Answer	Marks	Guidance
	(b)	Any one from: Energy of visible light photon < work function (of zinc) (frequency of) visible (light/photon) < threshold frequency Any one from: Energy of UV photon > work function (of zinc) (frequency of) UV (radiation/photon) > threshold frequency Any two from: • Collapse of leaf linked to removal of electrons • One-to-one interaction of photon and (surface) electron • Photon energy is independent of intensity / Intensity linked to rate of photons (incident on the zinc plate)	B1 B1 B1 × 2	Allow f for frequency, λ for wavelength and ϕ for work function throughout Allow 'overcome' / 'met' / 'reached' when describing > or < Allow photons Not f_0 for threshold frequency Allow equivalent statement with wavelength Allow = instead of > or < throughout for UV Allow equivalent statement with wavelength Ignore stem / plate / leaf / electroscope becoming positive
		Total	14	

6	(a)		$P = V^2 / R$ $R = 12^2 \div 40 =$ 3.6 (Ω)	C1 A1	Allow $I = P/V$ ($= 3.3\text{A}$) and $R = V/I$ Correct to at least 2sf
	(b)	(i)	Either (thermal/heat) energy required per unit mass to change solid to liquid <u>at constant temperature</u> or (thermal/heat) energy released per unit mass when liquid changes to solid <u>at constant temperature</u>	B1 (B1)	Ignore $L = E/m$ unless letters are defined Allow energy per kg /energy of 1kg for energy per unit mass Allow energy required to melt unit mass at constant temperature Allow energy released when unit mass solidifies at constant temperature
		(ii)	(Energy =) $Pt = mL$ $m = \frac{40 \times 60}{9.4 \times 10^4} =$ 2.6×10^{-2} (kg)	C1 A1	Allow $E = Pt$ and $E = mL$ seen separately Formulae may be implied from subsequent calculation Correct to at least 2sf 2.553×10^{-2} to 4sf so annotate 2.5×10^{-2} as AE

Question			Answer	Mark	Guidance
6	(b)	(iii)	Any two from - not all the heat / energy is used to melt the PLA or some heat / energy is 'lost' (to environment / surroundings) - some heat / energy / time is used to raise temperature of PLA up to or above its melting point / 160°C (PLA not all applied to same spot so) PLA needs (time) to move from one place to another - PLA needs (time) to solidify	B1 × 2	For environment, allow printer or any named part of printer (e.g. nozzle, print head, print bed, build plate, hot-end, cables) Allow energy transfer is not 100% efficient Not energy is lost through sound or light Not PLA needs time to melt
		(iv)	a single line (or curve) starting at A which gradually and continuously rises to 160°C followed by an initial flat section at 160°C after a flat section at 160°, the line (or curve) rises and then falls back to 160°C a second flat section at 160°C followed by a single line (or curve) which gradually and continuously falls, ending at B	B1 B1 B1	Note: this flat-topped shape gains the first and third marks 

Question			Answer	Mark	Guidance
6	(c)	(i)	Any two points from the following: (high-energy X-ray) photon interacts with nucleus / travels close to nucleus / disappears - Positron is the antiparticle of an electron - energy (of X-ray photon) is transformed into matter and antimatter - particle and antiparticle pair produced / (mechanism known as) pair production occurs	B1 x 2	Ignore references to scattering, Compton effect and photoelectric effect Not - atom instead of nucleus - approaches instead of travels close to - two photons annihilate - photon annihilates - electron and positron annihilate Allow photon is absorbed by nucleus Allow electrons and positrons are antiparticles (of each other) Allow energy (of photon) is transformed into mass Ignore electron positron pair (this is a rewording of the stem which states that X-ray photons produce electrons and positrons) Allow pair creation

6	(c)	*(ii) Level 3 (5–6 marks) Clear explanation of both scans and Clear discussion (compares the risks of either having a scan to fit a bolus or not, to a patient undergoing radiotherapy for skin cancer) <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Limited explanations of both scans or clear explanation of one scan and Basic discussion (e.g. compares the risks of one scan to the other) <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited explanation for example • CAT scan only • PET scan only • both scans attempted but with several errors or Limited discussion (eg compares advantages and disadvantages of having a CAT scan) <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit	B1 × 6 Use the annotations (for example) L2 for 4 marks, L2^ for 3 marks etc. Place the appropriate number of ticks below the annotation. Indicative scientific points may include: Explanation <u>CAT scan</u> • Thin fan-shaped beam of X-rays • Ring of detectors rotate around patient • Images of slices produced • Instruments move along patient to take several 2D images • Software produces 3D image <u>PET scan</u> • Positron-emitting tracer injected • Positron annihilates electron producing two gamma photons • Gamma photons travel in opposite directions • Ring of gamma detectors around patient • Delay time between arrival of photons locates annihilation • Software produces 3D image Discussion - balance of benefits and risks of having the scan • Both types of scan deliver radiation dose to healthy tissue but • a bolus would mean a lower dose is needed during radiotherapy • Both types of scan are expensive / use NHS resources • but radiotherapy also costly and less would be needed with bolus • Scans can be long / scary / cause discomfort • but the same is true of radiotherapy and less would be needed • Both types of scan are risky but with a bolus the • improved effectiveness of radiotherapy may save a patient's life
		Total	18



10	D	1	
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14	C	1	
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7	B	1	
-	-	-	



18	(a)	e.m.f. → (chemical) to electrical and p.d. → from electrical (to thermal / heat) or e.m.f. → charges/electrons gain energy and p.d. → charges/electrons lose energy	B1	Allow e.m.f. is work done on charges and pd is work by charges Allow battery for e.m.f and resistor for p.d. Allow less p.d. (than e.m.f.) due to energy transferred in <u>internal</u> resistance (must be clear that it is internal or cell resistance and not any other circuit resistance). AW
	(b)	length (of wire)	B1	
	(c) (i)	$E = V + Ir$ / $E = IR + Ir$ / $E = I(R + r)$ Clear manipulation leading to $\frac{1}{I} = \frac{R}{E} + \frac{r}{E}$	M1 A1	Allow ε for E throughout Expect at least one line of intermediate correct algebra leading to correct expression, explicitly shown.
	(ii)1	$I^{-1} = 0.8 \text{ (A}^{-1}\text{)}$ / $I = 1.25 \text{ (A)}$ $P (= 1.25^2 \times 3.0) = 4.7 \text{ (W)}$	C1 A1	Allow $I = 1.3 \text{ (A)}$. Expect at least 2sf. No ecf from graph misread. Allow 5.1 (W) from use of 1.3 (A)
	(ii)2	(Intercept =) $0.20 \text{ (A}^{-1}\text{)}$ $r = (0.20 \times 5.0) = 1.0 \text{ (}\Omega\text{)}$	M1 A1	Value of 0.2 anywhere in calculation implies correct reading of intercept. Allow ± 0.02. Allow current = 5 (A) implies intercept correctly read Do not allow substitutions into $E = IR + Ir$ other than using the intercept. Allow 1 SF answer Alternative $r = (E / I = 5 / 5) = 1.0 \text{ (}\Omega\text{)}$
		Total	8	

5	(a)	(i)	Resistance (which causes a loss of energy) as charges pass through the cell	B1	Allow current passes for charges pass Allow resistance inside the cell or resistance produced by materials or chemicals in the cell Allow lost volts per (unit) current Allow resistance which leads to a drop in terminal p.d. when current is drawn from the cell Ignore resistance of the cell
		(ii)	energy transferred <u>per (unit) charge</u> (from chemical energy / some other form of energy) into <u>electrical</u> energy	B1	Allow work (done) for energy Allow energy transferred <u>per (unit) charge</u> to charge carriers Allow (maximum) p.d./voltage across a cell when no current is drawn
	(b)		$\epsilon = I(R + r)$ or $\epsilon = V + Ir$ Rearranging $V = 5.6 - 1.2I$ gives $I = 4.7 - 0.83 V$ drawn as a line on the graph $I = 2.8$ (A)	C1 C1 A1	Allow $V = 5.6 - 1.2I$ Allow evidence of a trial and improvement method (could be inferred from graph) Allow answer in the range 2.70 – 2.90 (A)

5	(c)	*	Level 3 (5–6 marks) Clear description and clear uncertainties <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Clear description (eg correct circuit, valid method for varying temperature, r found from graph) or clear uncertainties (eg adds error bars to graph and uses a wfl to find uncertainties) or Some description and limited uncertainties <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited description (eg thermistor symbol correct, range of temperatures used, V and I measured) or Limited uncertainties (eg uncertainties not related to graph, uncertainty in r found from Δintercepts rather than Δgradients) <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	B1 x 6	Use level of response annotations in RM Assessor Indicative scientific points may include: Description • correct circuit symbols and diagram • vary resistance of thermistor, record V and I • method to vary resistance of thermistor, e.g. water bath and thermometer, start from 0°C • Plot V (y-axis) against I (x-axis) • e.m.f. = y-intercept; $r = -$ gradient • alternatively, $P = IV$, $R = V/I$ • plot P (y-axis) against R (x-axis) • maximum power occurs when $r = R$ • e.m.f. found from $\epsilon = V + Ir$ Uncertainties • Gather repeat readings of V and I at each temperature if possible and estimate uncertainty in V and I from half the range of the repeated values • If no repeats, use accuracy (or (half) resolution) of ammeter and voltmeter for uncertainty in V and I • Add error bars to graph and draw a wfl • Find gradient and y-intercept of wfl • Uncertainty in r / e.m.f. is difference between gradients / y-intercepts of best and worst line • For alternative method, estimate width of peak to find uncertainty in r and find uncertainty in e.m.f. using $\epsilon = V + Ir$
			Total	11	



18	(a)	(i)	Arrow in anticlockwise direction	B1	Allow this mark for correct direction shown on diagram either on or off connecting wires
		(ii)	$(E =) 4.5 - 2.4$ or $(R_T =) 0.80 + 0.50 + 1.2$ $4.5 - 2.4 = I \times (0.80 + 0.50 + 1.2)$ $I = 0.84 \text{ (A)}$	C1 C1 A1	$E = 2.1 \text{ (V)}; R_T = 2.5 \text{ (}\Omega\text{)}$ Treat missing 1.2 resistance as TE Allow 2 marks for 2.8 (A); $E = 6.9 \text{ V}$ used
		(iii)	$(I = Anev)$ $0.84 = \pi \times (2.3 \times 10^{-4})^2 \times 4.2 \times 10^{28} \times 1.60 \times 10^{-19} \times v$ $v = 7.5 \times 10^{-4} \text{ (m s}^{-1}\text{)}$	C1 A1	Possible ECF from (ii) Note answer is $2.5 \times 10^{-3} \text{ (m s}^{-1}\text{)}$ for $I = 2.76 \text{ (A)}$ Allow 1 mark for 1.9×10^{-4} ; diameter used as radius
		(iv)	Sensible suggestion, e.g. use a water bath / fan / only switch on when taking readings Need to lower the temperature / reduce resistance of R	M1 A1	Allow keep the surroundings cold Allow to keep the temperature / resistance constant OR allow increase in temperature increases resistance

	(b)*	Level 3 (5–6 marks) <i>E and r calculated correctly and table completed correctly and clear description of P and R</i> <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Table completed correctly and some description of P and R /some attempt at E and r OR <i>E and r calculated correctly</i> OR Some attempt at calculating E and r and some description of P and R <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited calculation of E and r OR Table completed correctly OR Limited description of relationship between P and R <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit	B1×6	Indicative scientific points may include: Calculating E and r • $E = Ir + V$ • gradient = (-) r • y-intercept = E • Line extrapolated to y-axis • $E = 1.2 \text{ (V)}$ • $r = 0.8(0 \, \Omega)$ Table and description • Table completed (ignore SF) – see below • R increases as V increases (or I decreases) • P increases and decreases • Maximum power is when internal resistance is equal to R (0.8 Ω) <table><tr><th>V / V</th><th>I / A</th><th>R / Ω</th><th>P / W</th></tr><tr><td>0.20</td><td>1.25</td><td>0.16</td><td>0.25</td></tr><tr><td>0.40</td><td>1.00</td><td>0.40</td><td>0.40</td></tr><tr><td>0.60</td><td>0.75</td><td>0.80</td><td>0.45</td></tr><tr><td>0.80</td><td>0.50</td><td>1.60</td><td>0.40</td></tr><tr><td>1.00</td><td>0.25</td><td>4.00</td><td>0.25</td></tr></table>	V / V	I / A	R / Ω	P / W	0.20	1.25	0.16	0.25	0.40	1.00	0.40	0.40	0.60	0.75	0.80	0.45	0.80	0.50	1.60	0.40	1.00	0.25	4.00	0.25
V / V	I / A	R / Ω	P / W																									
0.20	1.25	0.16	0.25																									
0.40	1.00	0.40	0.40																									
0.60	0.75	0.80	0.45																									
0.80	0.50	1.60	0.40																									
1.00	0.25	4.00	0.25																									
		Total	14																									

2	(a)	(i)	use (vernier / digital / dial) calliper(s) or micrometer (taking readings) at different positions / orientations (along the wire)	B1 B1	 Ignore take multiple readings
		(ii)	exclude the 0.495 (mm) anomaly add the remaining 4 values and divide by 4 / calculate mean of the remaining values calculate half the range of the remaining values	M1 A1 A1	May be inferred from calculations Allow the correct calculation which leads to 0.455 Ignore references to median or mode or average Allow the correct calculation which leads to 0.005 Ignore difference between mean and highest (or lowest) value Ignore references to resolution of the measuring instrument
	(b)	(i)	$\varepsilon = I(R + r)$ $R = \rho L/A$ and $A = \pi d^2/4$ clear steps leading to given equation	M1 M1 A1	Allow $\varepsilon = V + Ir$ and $V = IR$ Allow $A = \pi r^2$ and $r = d/2$ Allow area formula by inference, if clear

Question			Answer	Mark	Guidance
2	(b)	(ii)1	(gradient = $\Delta y/\Delta x$ where $\Delta x \geq 0.35$) gradient = 5.0 (A⁻¹ m⁻¹) $\rho = \frac{\pi \times (0.455 \times 10^{-3})^2 \times 1.45 \times \text{gradient}}{4}$ $\rho = 1.2 \times 10^{-6}$ ($\Omega \text{ m}$)	C1 A1	Allow answer to 1sf Mark is either for the correct gradient or for working which would lead to 5.00 ± 0.10, seen anywhere in the question Correct to at least 2sf Allow the correct answer with no working shown for ρ if the gradient (or working for the gradient) is correct Allow ECF for gradient ($\rho = 2.358 \times 10^{-7} \times \text{gradient}$)

Question			Answer	Mark	Guidance
2	(b)	(ii)2	$r = \text{y-intercept} \times \varepsilon = 0.40 \times 1.45$ $r = \mathbf{0.58(\Omega)}$ $\text{y-intercept}_{\text{MAX}} = 0.73 \text{ (A}^{-1}\text{)}$ EITHER Fractional uncertainty in $r =$ $0.05/1.45 + 0.33/0.40 = 0.034 + 0.825$ $= 0.86$ $0.86 \times 0.58 = 0.5(\Omega)$ to 1sf so $r = \mathbf{0.6 \pm 0.5 (\Omega)}$ OR $r_{\text{MAX}} = \text{y-intercept}_{\text{MAX}} \times \varepsilon_{\text{MAX}} = 0.73 \times 1.5$ $= 1.1(\Omega)$ $1.1 - 0.58 = 0.5(\Omega)$ to 1sf so $r = \mathbf{0.6 \pm 0.5 (\Omega)}$	B1 M1 A1 A1 (A1) (A1)	Mark is for working leading to the correct value of r . $r = 0.58(\Omega)$ seen either in working or on answer line implies B1 Allow answers in the range 0.70 to 0.75 Ignore any attempt to calculate uncertainty in gradient Expect answers in the range 0.78 – 0.91 (or 78% to 91%) Ignore units if given Expect answers for absolute uncertainty in the range 0.45–0.53 Value and uncertainty <u>must</u> be given to same number of dp Expect answers in the range 1.05 - 1.13 Expect answers for absolute uncertainty in the range 0.45–0.55 Value and uncertainty <u>must</u> be given to same number of dp Special case: allow abs unc of 0.55 giving $r = 0.6 \pm 0.6 (\Omega)$
			Total	14	

4	B		1	
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5	A	1	
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7	B	1	
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6	B	1	
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18*		Level 3 (5–6 marks) Clear description and clear analysis of data <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Some description and some analysis of data OR Clear description OR Clear analysis of data <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited description and limited analysis OR Some description OR Some analysis of data <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit	B1×6	Indicative scientific points may include: Description • Circuit showing supply, ammeter, voltmeter and resistance wire /coil • Measure I (in coil) with ammeter • Measure V (across coil) with voltmeter • Power (for coil) calculated: $P = VI$ • Resistance of thermistor either calculated using $R = V/I$ or measured with ohmmeter • Change P / change V / use variable power supply / use variable resistor (to change I) • Keep the number of turns of coil constant throughout / no draughts / wait until the resistance stabilises Analysis • $\lg P = \lg k + n \lg R$ (or natural logs $\ln$) • Plot a graph of $\lg P$ against $\lg R$ • If expression is correct, then a straight line with non-zero intercept • gradient = n • intercept = $\lg k$ • $k = 10^{\text{intercept}}$ (or $k = e^{\text{intercept}}$ for natural logs)
		Total	6	

2	(a)	(i)	$R = 3000 + 1500$ $V = 12 \times 1500/4500 = 4.0 \text{ (V)}$	C1 A1	$R = 4500 \text{ (}\Omega\text{)}$ <i>or</i> $I = V/R = 12/4500 = 2.67 \text{ mA}$ $V_{1500} = 2.67 \text{ mA} \times 1.5 \text{ k}\Omega = 4.0 \text{ (V)}$
		(ii)	$V (= 12 \times 1500/1600) = 11.25 \text{ (V)}$ $\Delta V = 11.25 - 4.0 = 7.25 \text{ (V)}$	C1 A0	
	(b)		see next page		

H556/03			Mark Scheme	October 2021
Question	Answer	Marks	Guidance	
(b) *	Level 3 (5–6 marks) Clear description of a valid experiment which would lead to accurate results, sensible suggestions for table, graph and accuracy <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Reasonable description of experiment and sensible suggestion for table or graph or accuracy, or attempt at all three <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Attempt at experiment and attempt at table or graph or accuracy <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	B1 x 6	Indicative scientific points may include: Experiment • Diagram(s) to show electrical circuit and/or set-up of apparatus • Use ammeter in series to measure current I through LED • Use micrometer to measure thickness of (one sheet of) tracing paper • or use calliper with m sheets of thickness t; measure t and use $x = mt$ • Measure I for various x • Calculate $\ln I$ Results table • Need columns for total thickness x (or number of sheets m and $x = mt$), current I, $\ln(I)$ • Units if included should be appropriate and presented in an appropriate format e.g. $\ln(I/\text{mA})$ Graph • plot $\ln I$ against x • expect straight line graph with negative gradient and non-zero intercept • gradient = $-n$ and y-intercept $c = \ln k$ • $k = e^c$ (alternatively, k is the current when no sheets of paper are used) Accuracy • work in darkened room/constant low light conditions • keep distance between light-source and LDR constant • use same power light source and same LDR throughout • position yourself so as not to cast shadow on LDR • clamp equipment to bench to ensure distances do not change	
	Total	9		

H556/03

Mark Scheme

October 2021

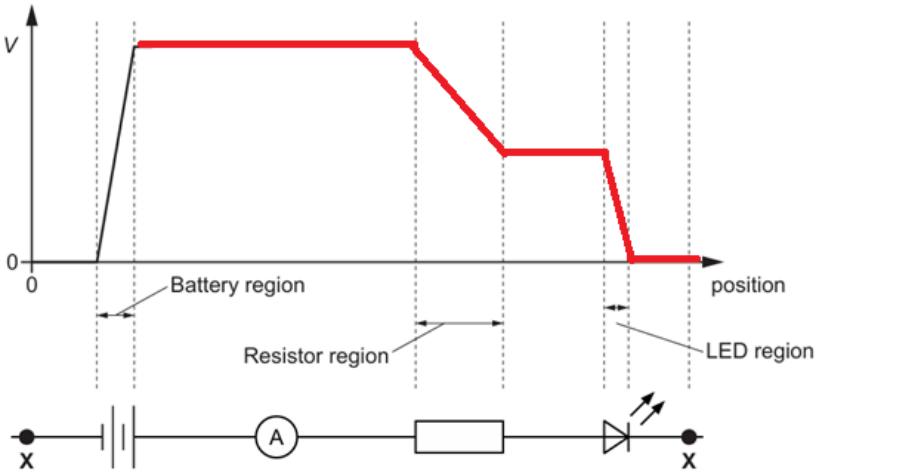
Question	Answer	Marks	Guidance
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16	(a)		Connect the <u>voltmeter</u> in parallel with the thermistor	B1	Allow correctly drawn on diagram Allow “across” for “in parallel with” Allow voltmeter in parallel with cell																
	(b)	(i)	Points plotted correctly, within ½ small square	B1																	
		(ii)	Smooth curve passing within 1 vertical small square of plotted points	C1	No credit for straight line If thick line drawn, all width of line must lie within 1 vertical small square																
	(c)		Current increases as temperature increases (and voltage is constant) Use of at least two sets of data to calculate resistance The resistance decreases, therefore it is ntc thermistor	B1 M1 A1	Accept standard symbols (T , I , θ etc) for variables in explanation <table><tr><td>Temp / °C</td><td>Resistance / kΩ</td></tr><tr><td>30</td><td>4.0</td></tr><tr><td>40</td><td>2.7</td></tr><tr><td>50</td><td>2.0</td></tr><tr><td>60</td><td>1.4</td></tr><tr><td>70</td><td>1.1</td></tr><tr><td>80</td><td>0.82</td></tr><tr><td>90</td><td>0.63</td></tr></table> Allow 1sf for resistance values from calculations Ignore POT error for M mark	Temp / °C	Resistance / kΩ	30	4.0	40	2.7	50	2.0	60	1.4	70	1.1	80	0.82	90	0.63
Temp / °C	Resistance / kΩ																				
30	4.0																				
40	2.7																				
50	2.0																				
60	1.4																				
70	1.1																				
80	0.82																				
90	0.63																				

Question		Answer	Mark	Guidance
16	(d)	In circuit 1, p.d. (across the thermistor) will remain (almost) constant (with varying temperature)	M1	Allow voltage for p.d.
		In circuit 2, p.d. (across the thermistor) will vary (with varying temperature)	M1	Allow variation of pd to be increase or decrease
		Hence, circuit 2 will be best to choose / circuit 1 is not suitable	A1	Both M marks required for A mark
		Correct potential divider argument OR explanation of operation of circuit	B1	e.g. Use of $V_{out} = V_{in} \times (R / R + 10\,000)$ / the ratio of the resistances will vary (with temperature) e.g. as the milk gets hotter, the rate of heating reduces B mark is for qualifying statement

16	(a)	Potential divider / Series (circuit)	B1	IGNORE potentiometer
16	(b)	An arrow pointing in the correct direction (clockwise)	B1	ALLOW any arrow indicating correct direction All arrows drawn must be in the correct direction
16	(c)	(Ammeter reading) decreases (Voltmeter reading) increases	B1 B1	
16	(d)	Number density is high(est) in metals / low(est) in insulators Number density in semiconductors is higher than in insulators and lower than metals	B1 B1	ALLOW for use of n for number density in both marking points ALLOW answers in terms of charge carriers ALLOW any numbers as method of comparison in both marking points 2 nd marking point is for idea that semiconductors lie in the correct position between metals and insulators and will score both B marks.

16	Question	Answer	Mark	Guidance
	(e)	Continuous line, not rising at any point and at least one decrease Non-zero horizontal line across ammeter AND lower non-zero horizontal line from RHS of resistor and to LHS of LED ALLOW very small decrease of voltage across either/both Any decrease shown across the resistor and any decrease shown across LED Zero at (and beyond) RHS of LED	B1 B1 B1 B1	

Question	Answer	Guidance
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Question	Answer	Mark	Guidance
23	(b) (i)	4.93 and 6.90	B1
		Both rounded to 2dp	
23	(b) (ii)	Two points within ½ square tolerance	B1
23	(b) (iii)	Line of best fit	B1
23	(c)	Evidence of use of at least half of the line in calculation of gradient	B1
		Evidence of calculation of gradient of their line using a pair of points	B1
		Identify that gradient = ρ / A	C1
		Area = $\pi d^2/4 = \rho / \text{gradient}$, so	
		$d = \sqrt{\frac{4 \times \rho}{\pi \times \text{gradient}}} = \sqrt{\frac{4 \times 5.00 \times 10^{-7}}{\pi \times 9.9}}$	
		$d = 2.5 \times 10^{-4} \text{ (m)}$	A1

[illegible]

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