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

Energy, power and resistance (4.2)

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

62 questions · 405 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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QUESTIONS

62 questions · 405 marks · 4 sub-topics



SUB-TOPIC 4.2.2

CIRCUIT SYMBOLS, E.M.F. AND P.D.

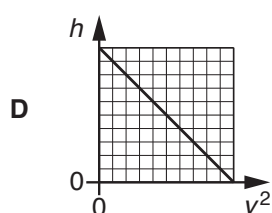
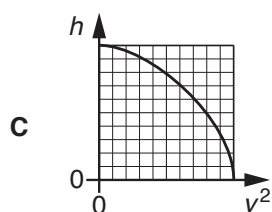
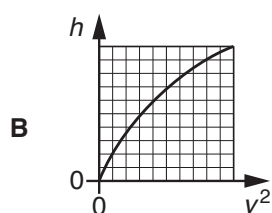
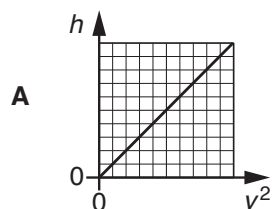
Sub-topic 4.2.2 · 29 questions · 183 marks · lowest tariff first



- 4 A ball is dropped from rest above the ground. Air resistance has negligible effect on the motion of the ball.

The speed of the ball is v after it has fallen a distance h from its point of release.

Which graph is correct for this falling ball?



Your answer

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[1]

Turn over

12 An object above the ground is released from rest at time $t = 0$.

Air resistance is negligible.

What is the distance travelled by the object between $t = 0.20\text{ s}$ and $t = 0.30\text{ s}$?

A 0.20 m

B 0.25 m

C 0.44 m

D 0.49 m

Your answer

[1]

12. An object above the ground is released from rest at time $t = 0$. Air resistance is negligible. What is the distance travelled by the object between $t = 0.20\text{ s}$ and $t = 0.30\text{ s}$?



1 Which electrical quantity has S.I. units ampere-second (As)?

- A charge
- B current
- C resistance
- D potential difference

Your answer

[1]



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

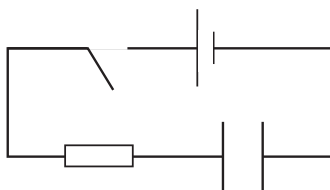
Which single quantity can be used to determine the capacitance of the sphere?

- 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 $t = 200$ s?

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

Your answer

[1]

- 8 An object is falling.
The weight of the object is 4.5 N.
The wind provides a horizontal force of magnitude F on the object.
The **resultant** force on the object is 5.8 N.
Air resistance and upthrust on the object are negligible.

What is the value of F ?

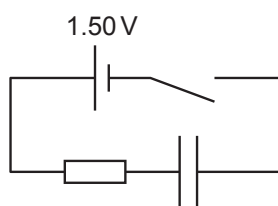
- A 1.3 N
B 3.7 N
C 7.3 N
D 13 N

Your answer

[1]



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?

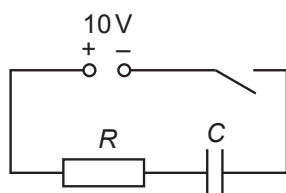
- A $0.60 = 1.50e^{-0.10t}$
- B $0.90 = 1.50e^{-0.10t}$
- C $0.60 = 1.50e^{-10t}$
- D $0.60 = 1.50(1 - e^{-10t})$

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

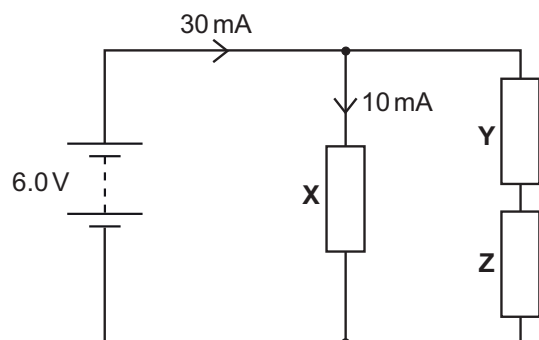
What is the product $C \times R$ for this circuit?

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

Your answer

[1]

- 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

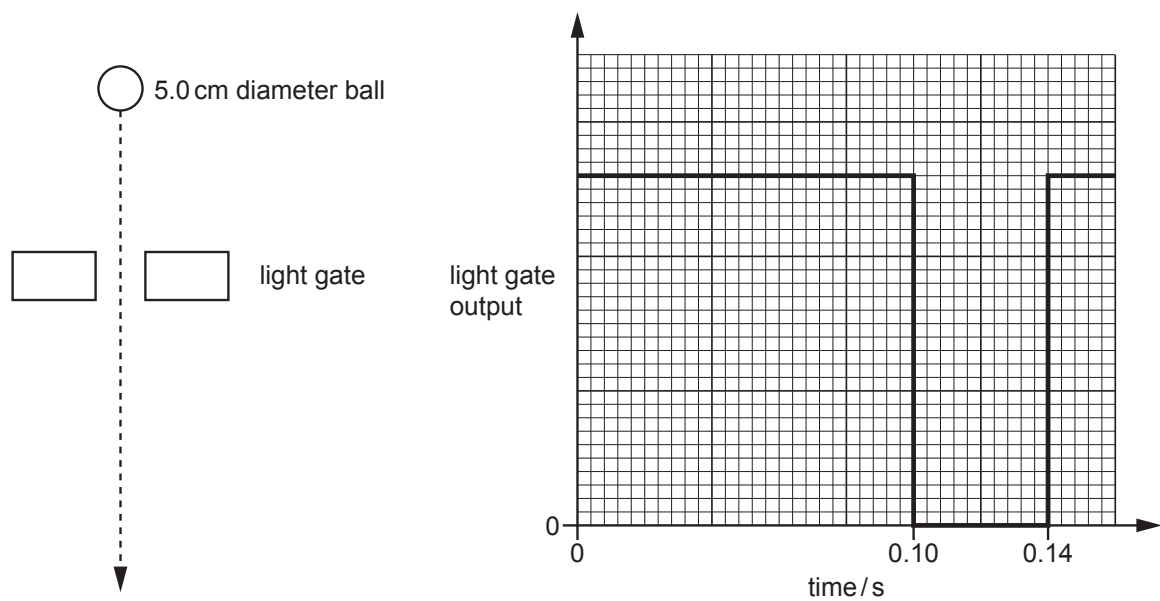
[1]

- 4 To determine the acceleration of free fall g , a ball is dropped from rest from a point vertically above a light gate.

The ball has a diameter of 5.0 cm. It is dropped at time $t = 0$.

The light gate output shows that the ball passes through the gate between times $t = 0.10$ s and $t = 0.14$ s.

The graph shows the output from the light gate.



Air resistance has negligible effect on the motion of the ball.

What is the value of g in ms^{-2} from these measurements?

- A 8.93
- B 9.81
- C 10.4
- D 12.5

Your answer

[1]

1 What are the base units of a kilowatt-hour?

A J

B $\text{kg m}^2 \text{s}^{-1}$

C $\text{kg m}^2 \text{s}^{-2}$

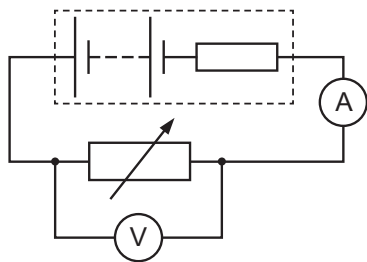
D Ws

Your answer

[1]



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.

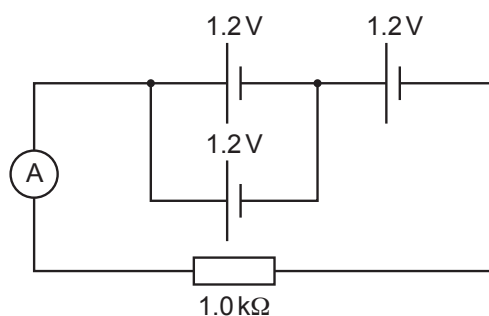
Which row is correct for calculating the e.m.f. and the internal resistance of the battery?

	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?

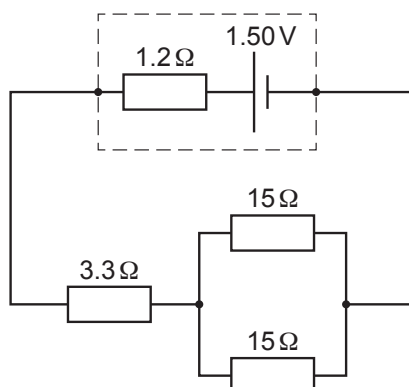
- A 1.2 mA
- B 1.8 mA
- C 2.4 mA
- D 3.6 mA

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]

- 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.

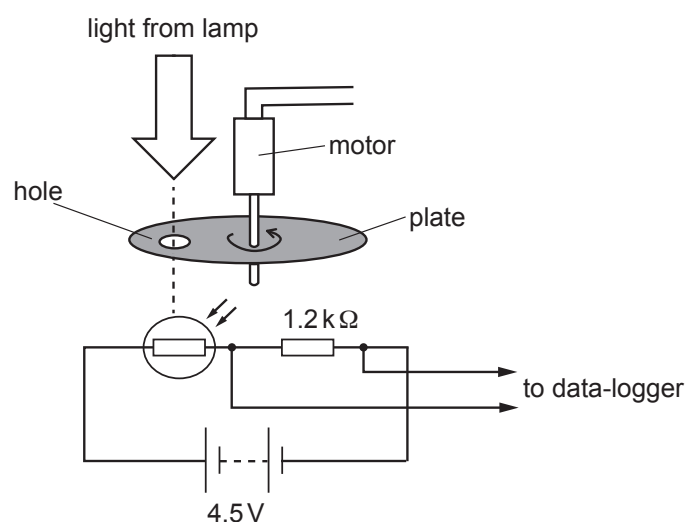


Fig. 17.1

A light-dependent resistor (LDR) and a fixed resistor of resistance 1.2 kΩ are connected in series to a battery. The battery has e.m.f. 4.5V 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 .

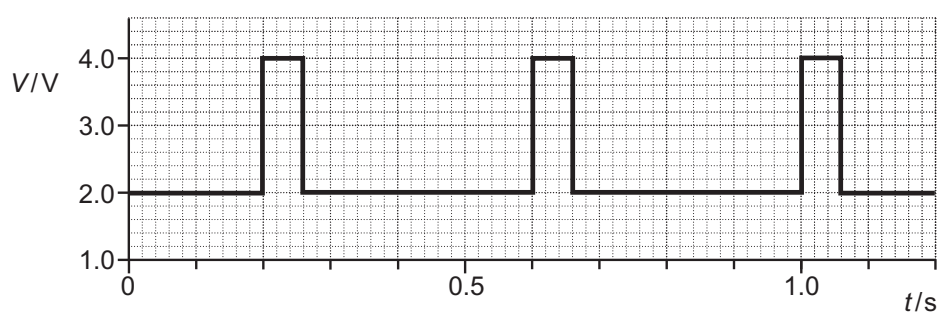


Fig. 17.2

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.

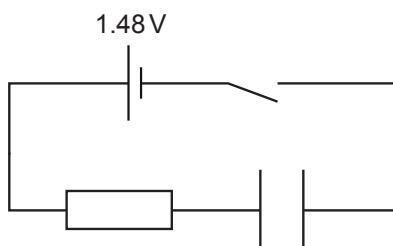
Describe how the student can determine the frequency of the rotating plate.

[6]

. [6]



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

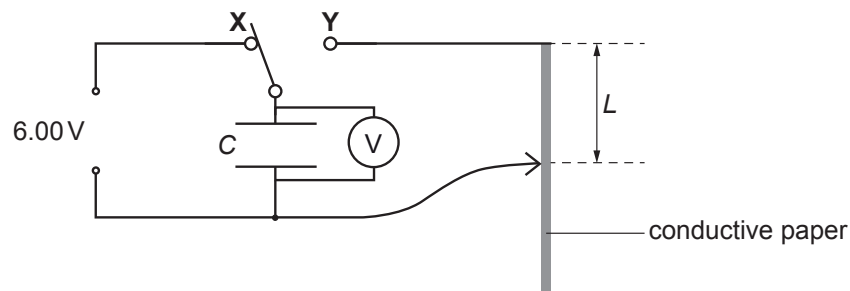


The electromotive force (e.m.f.) E of the cell is 1.48 V and it has negligible internal resistance. The resistance of the resistor is $120\text{ k}\Omega$ and the capacitance of the capacitor is $2000\text{ }\mu\text{F}$. At time $t = 0$ the capacitor is uncharged. The switch is closed at time $t = 0$.

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

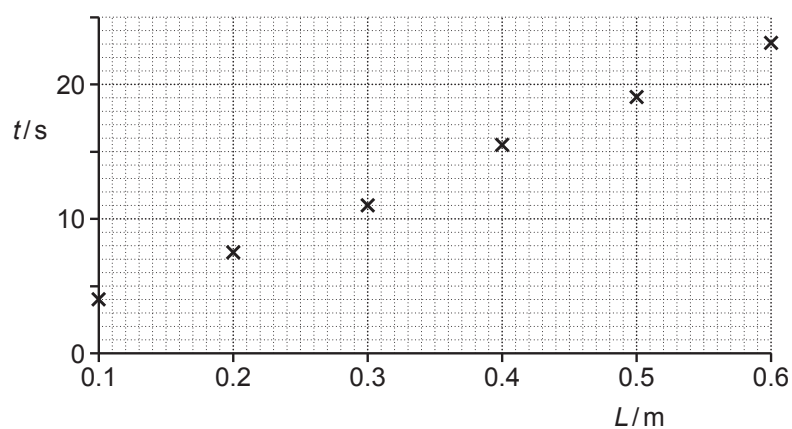
$$t = (Ck \ln 2) \times L$$

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.

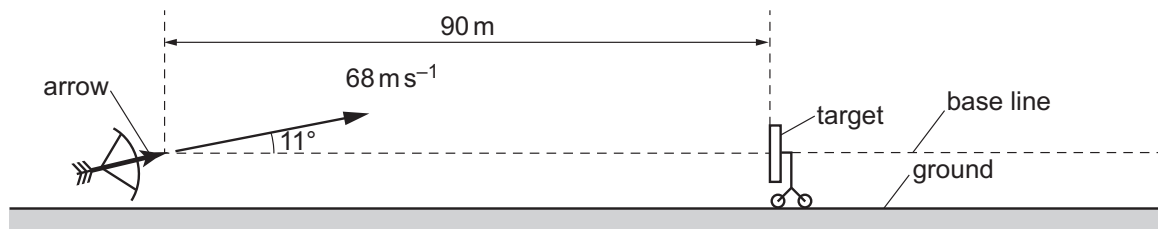
The data points are plotted on a t against L grid as shown below.



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

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

- 18 An archer fires an arrow towards a target as shown below.



The diagram is **not** drawn to scale.

The centre of the target is at the same height as the initial position of the arrow.

The target is a distance of 90 m from the arrow.

The arrow has an initial velocity of 68 m s^{-1} and is fired at an angle of 11° to the horizontal.

Air resistance has negligible effect on the motion of the arrow.

- (a) Describe how the kinetic energy of the arrow changes during its journey from when it is fired until it reaches its maximum height.

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

- (b) Show that the time taken for the arrow to reach its maximum height is about 1.3 s .

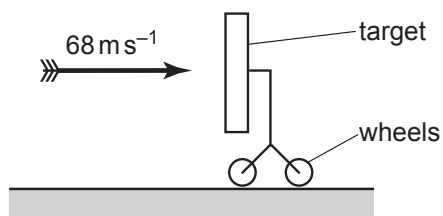
[2]

- (c) The arrow misses the target.

Calculate the horizontal distance, measured along the base line, by which the arrow misses the target.

horizontal distance = ... m [3]

- (d) The arrow is now fired horizontally at 68 m s^{-1} into the target at very close range.



The arrow sticks into the target. The collision between the arrow and the target is inelastic.

- (i) Explain what is meant by an **inelastic collision**.

.....
 [1]

- (ii) The target is mounted on wheels. The target has a much larger mass than the mass of the arrow.

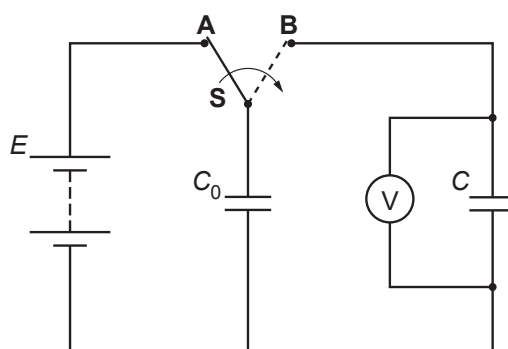
Using ideas of momentum, explain the velocity of the target immediately after the arrow sticks into the target.

.....

 [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 .

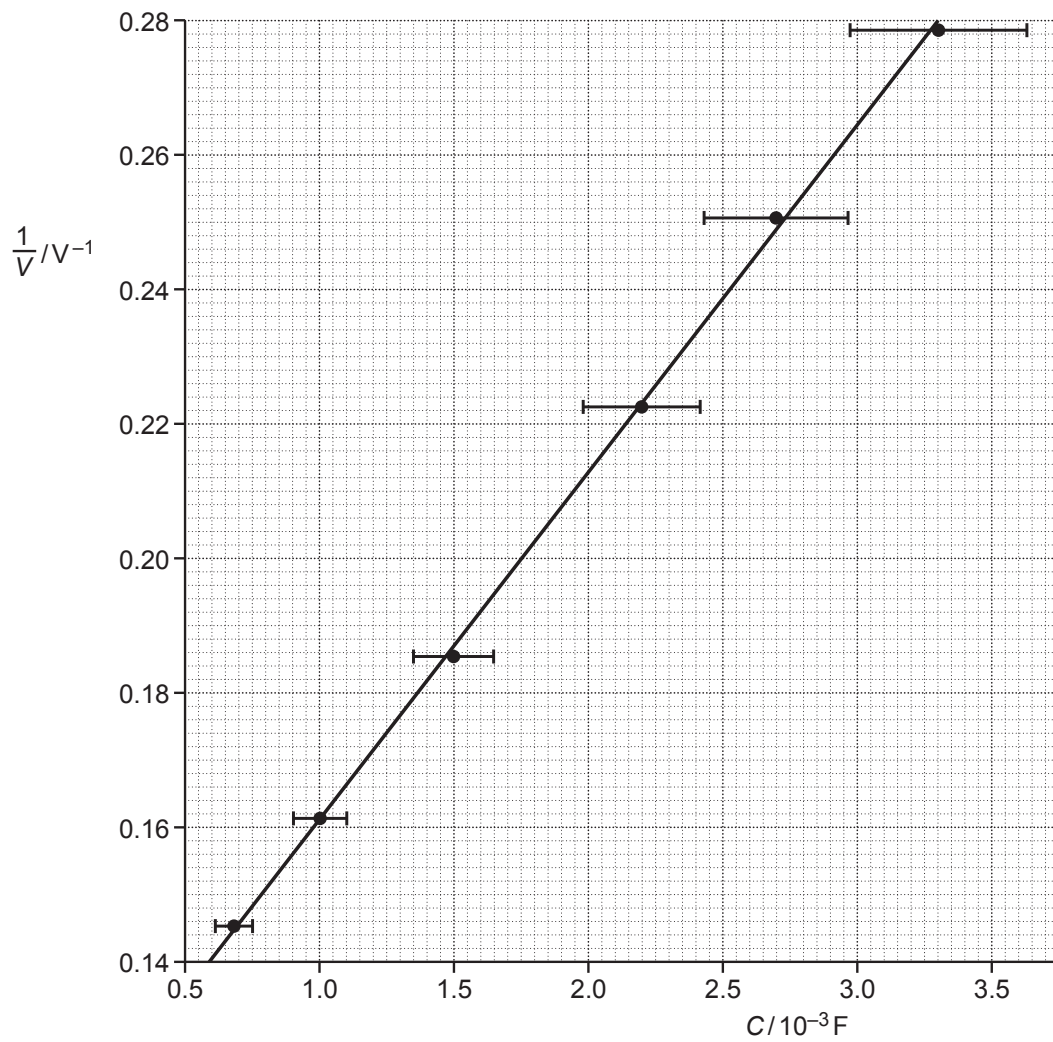
The student decides to plot a graph of $\frac{1}{V}$ against C .

- (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.

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

- 6 (a) Define the **time constant** of a circuit containing a capacitor of capacitance C and a resistor of resistance R .

.....
 [1]

- (b) The capacitor circuit shown in **Fig. 6.1** can be used to smooth oscillating electrical signals.

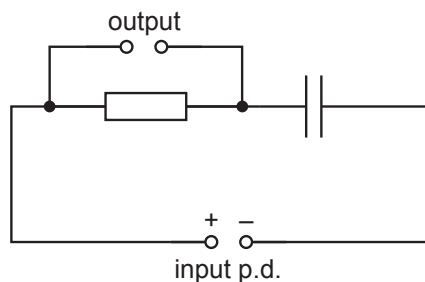


Fig. 6.1

- (i) **Fig. 6.2** shows the input signal of potential difference (p.d.) V against time t .

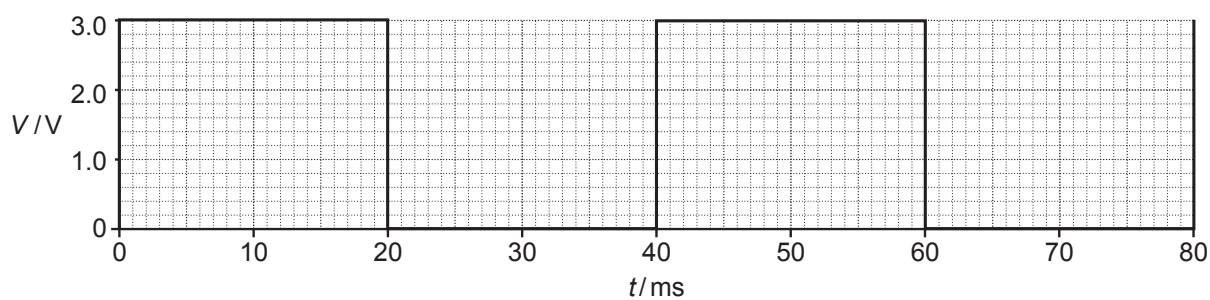


Fig. 6.2

Calculate the frequency f of this input signal.

$f =$ Hz [2]

- (ii) Fig. 6.3 shows the variation of the charge Q on the positive plate of the capacitor with time t .

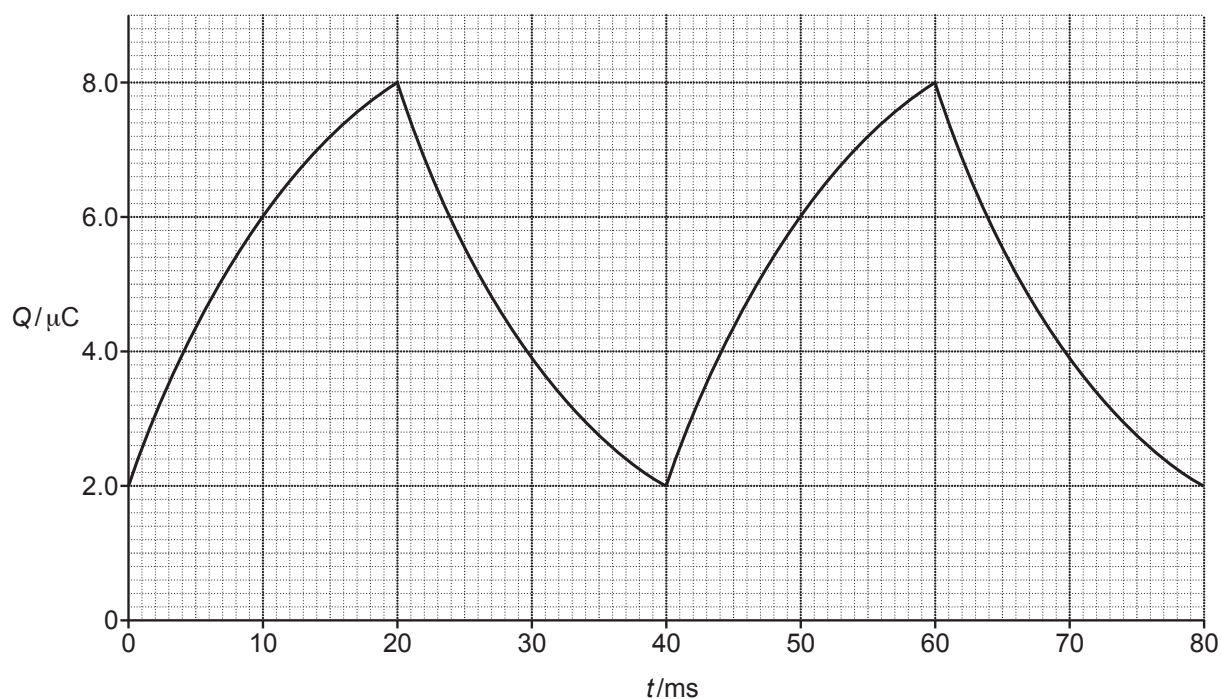


Fig. 6.3

Use a discharging section of the graph in Fig. 6.3 to determine the time constant of the circuit. Give your answer in ms.

time constant = ... ms [2]

- (iii) By drawing a suitable tangent to the graph in Fig. 6.3, calculate the maximum current in the resistor.

maximum current = ... A [2]

- (iv) On Fig. 6.4 below, sketch the variation of the current I in the resistor with time t . Include an appropriate label and scale on the vertical axis.

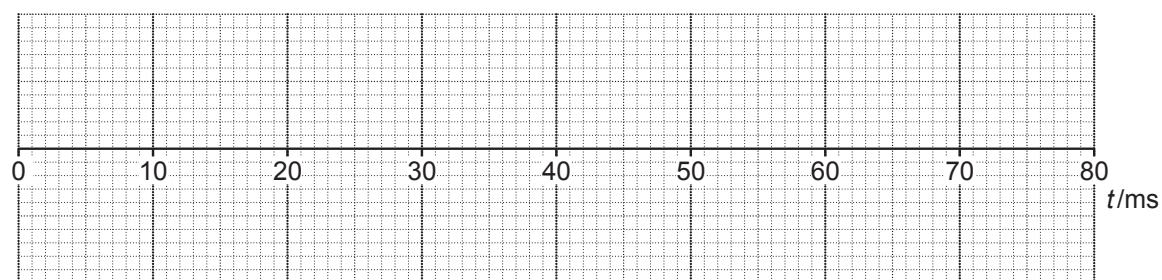


Fig. 6.4

[3]



- 3 A student is investigating how the discharge of a capacitor through a resistor depends on the resistance of the resistor.
The equipment is set up as shown in Fig. 3.1.

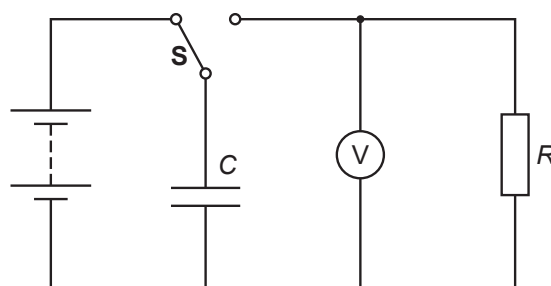


Fig. 3.1

The student charges the capacitor of capacitance C and then discharges it through a resistor of resistance R using switch **S**. After a time $t = 15.0\text{ s}$ the student records the potential difference V across the capacitor. The student repeats this procedure for different values of R .

It is suggested that V and R are related by the equation

$$V = V_0 e^{-\frac{t}{CR}}$$

where V_0 is the initial potential difference across the capacitor and t is the time over which the capacitor has discharged.

- (a) The student decides to plot a graph of $\ln(V/V_0)$ on the y -axis against $\frac{1}{R}$ on the x -axis to obtain a straight line graph. Show that the magnitude of the gradient is equal to $\frac{15}{C}$.

[2]

- (b) Values of R and V at $t = 15.0\text{ s}$ are given in the table below.

$R/\text{k}\Omega$	V/V_0	$\left(\frac{1}{R}\right)/10^{-6}\ \Omega^{-1}$	$\ln(V/V_0)$
56	3.0 ± 0.2	18	
68	3.7 ± 0.2	15	1.31 ± 0.06
100	5.0 ± 0.2	10	1.61 ± 0.04
150	6.4 ± 0.2	6.7	1.86 ± 0.03
220	7.3 ± 0.2	4.5	1.99 ± 0.03
330	8.1 ± 0.2	3.0	2.09 ± 0.03

- (i) Complete the missing value of $\ln(V/V_0)$ and its absolute uncertainty in the table above.

[1]

- (ii) Use the data to complete the graph of Fig. 3.2. Four of the six points have been plotted for you. [2]

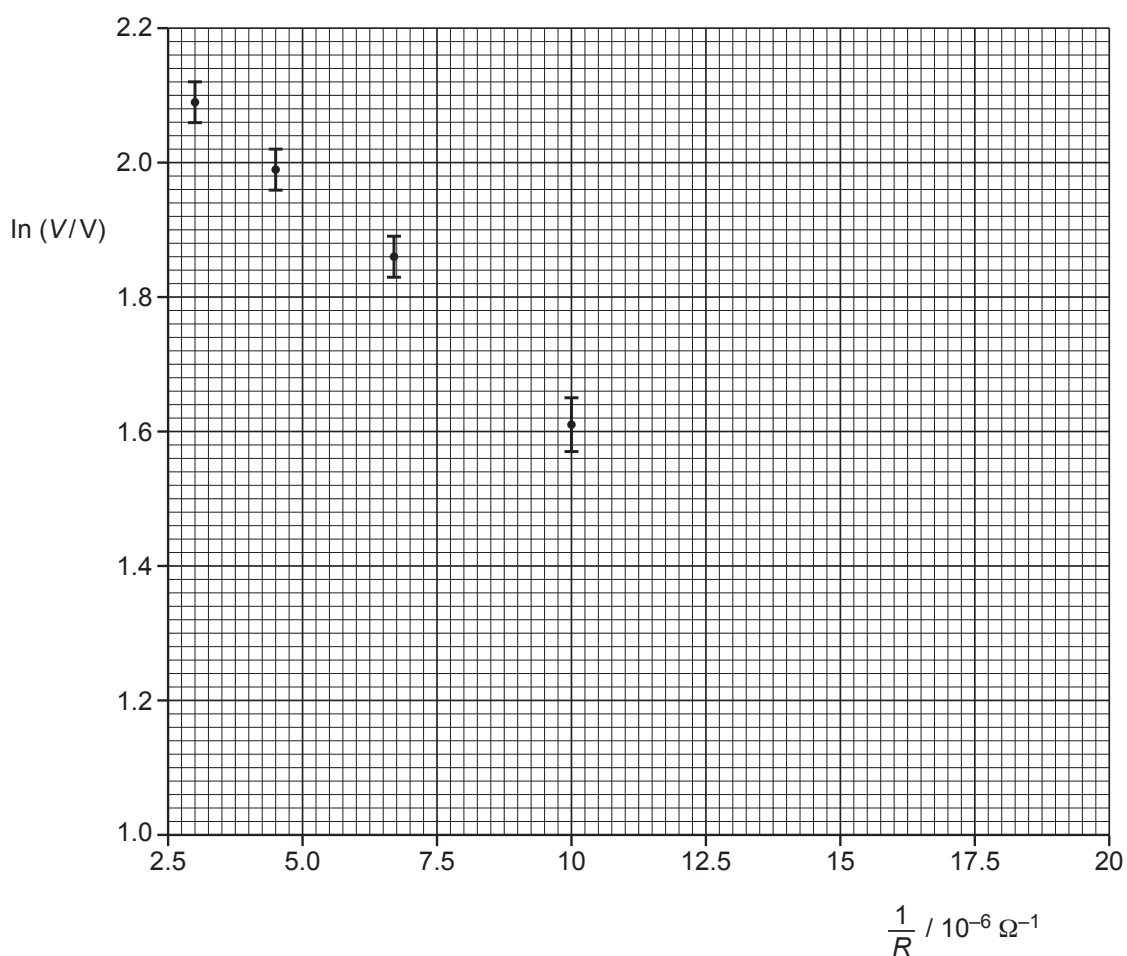


Fig. 3.2

- (iii) Use the graph to determine a value for C . Include the absolute uncertainty and an appropriate unit in your answer.

$C = \dots \pm \dots$ unit $\dots$ [4]

Turn over

- (c) Determine the value of R , in $\text{k}\Omega$, for which the capacitor discharges to 10% of its original potential difference in 15.0 s. Show your working.

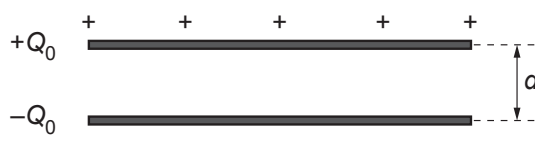
$R = \dots\dots\dots \text{k}\Omega$ [2]

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Question 4 begins on page 10.



22 (a) The diagram below shows a simple capacitor.



The capacitor consists of two horizontal metal plates in a vacuum. The magnitude of the charge on each plate is Q_0 . The potential difference (p.d.) between the plates is V_0 . The capacitor plates have capacitance C_0 . The separation between the plates is d . The energy stored by the capacitor is E_0 .

The top plate is moved vertically upwards. The new separation between the plates is $2d$. The charge on each plate remains the **same**. The energy stored by the capacitor **increases**.

(i) Determine the new:

1 capacitance in terms of C_0

capacitance = ... C_0 [1]

2 p.d. between the plates in terms of V_0

p.d. = ... V_0 [1]

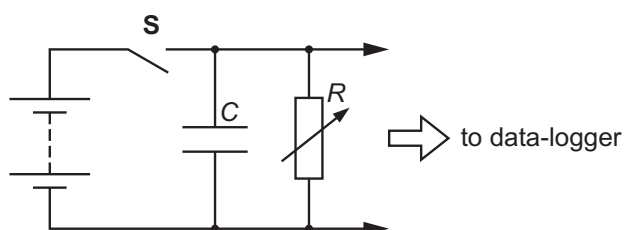
3 energy stored in terms of E_0 .

energy = ... E_0 [1]

(ii) Explain, in terms of forces between the plates, why the energy stored increases.

.....
 [1]

(b) A student discharges a capacitor of capacitance C through a variable resistor of resistance R using the arrangement below.



The capacitor is made from two parallel metal plates separated by a sheet of paper of thickness $8.0 \times 10^{-5} \text{ m}$. The area of overlap between the plates is $3.1 \times 10^{-2} \text{ m}^2$.

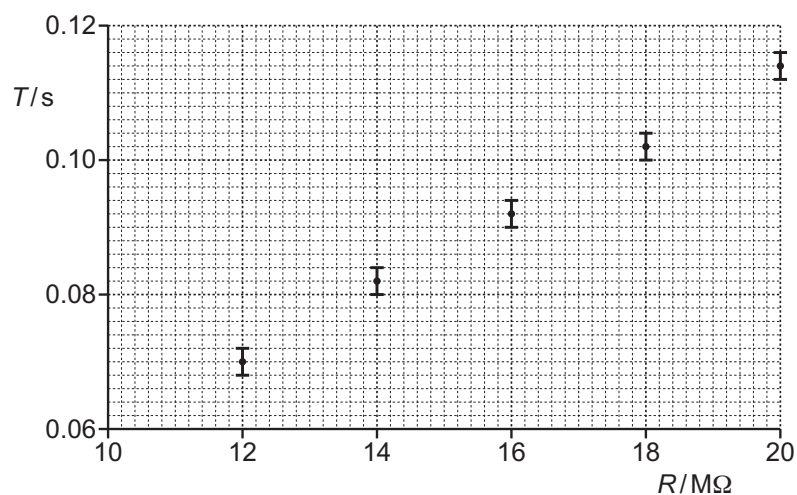
The capacitor is charged fully by closing switch **S**. At time $t = 0$, **S** is opened and the capacitor discharges through the resistor. After $t = T$, the potential difference across the capacitor is halved. The student repeats this for several values of R .

- (i) The student decides to plot T against R to obtain a straight-line graph.

Show that the line has gradient = $C \ln 2$.

[2]

- (ii) The data points plotted by the student are shown below.



- 1 Draw a best-fit straight line through the data points and use the gradient of this line to determine C .

$C = \dots\dots\dots F$ [3]

- 2 Use your answer in (ii)1 to calculate the permittivity ϵ of the paper.

$\epsilon = \dots\dots\dots F m^{-1}$ [2]

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5

(a) Explain what is meant by

(i) internal resistance of a cell

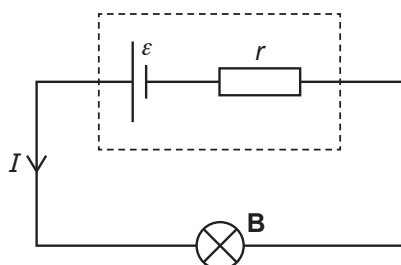
.....
 [1]

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

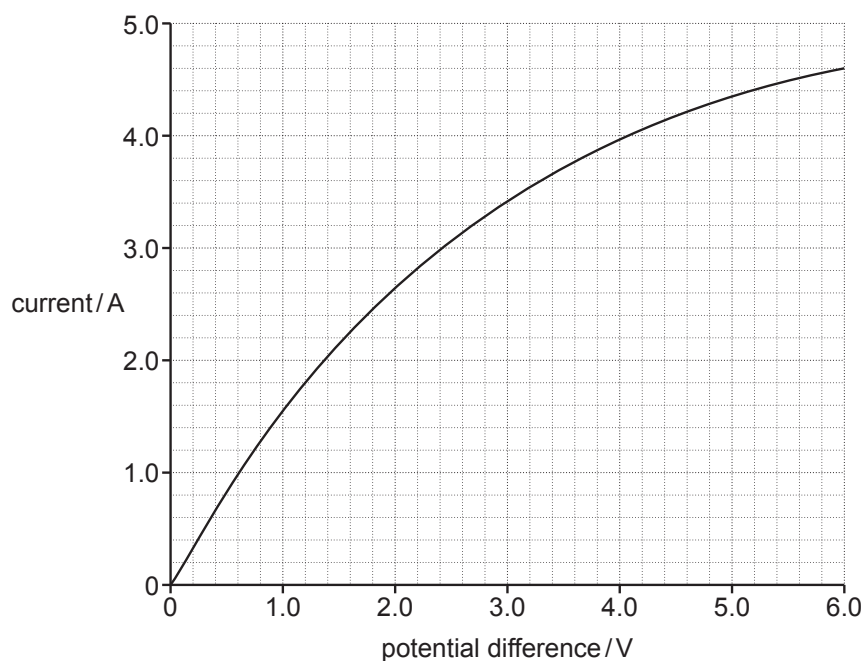
.....
 [1]

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

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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Additional answer space if required

[6]



- 6 This question is about the motion of a ball suspended by an elastic string above a bench. The mass of the string is negligible compared to that of the ball. Ignore air resistance.



Fig. 6.1

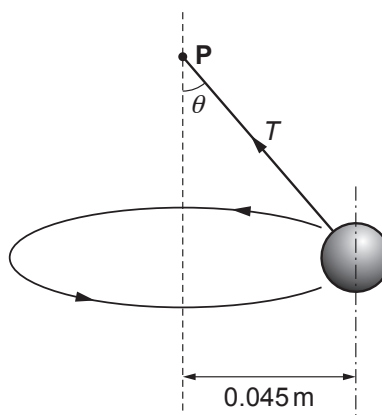


Fig. 6.2 (not to scale)

In Fig. 6.1 the ball of weight 1.2 N hangs vertically at rest from a point P. The extension of the string is 0.050 m. The string obeys Hooke's law.

In Fig. 6.2 the ball is moving in a horizontal circle of radius 0.045 m around a vertical axis through P with a period of 0.67 s. The string is at an angle θ to the vertical. The tension in the string is T.

- (a) On Fig. 6.2 draw and label one other force acting on the ball. [1]

- (b) (i) Resolve the tension T horizontally and vertically and show that the angle θ is 22° . [2]

- (ii) Calculate the extension x of the string shown in Fig. 6.2.

x = ... m [3]

- (c) Whilst rotating in the horizontal plane the ball suddenly becomes detached from the string. The bottom of the ball is 0.18 m above the bench at this instant. The ball falls as a projectile towards the bench beneath. Fig. 6.3 shows the view from above.

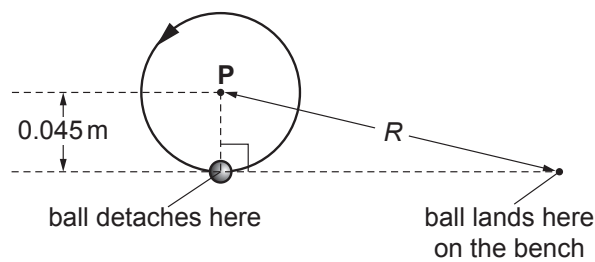


Fig. 6.3

Calculate the horizontal distance R from the point on the bench vertically below the point **P** to the point where the ball lands on the bench.

$R = \dots\dots\dots$ m [4]

- (d) Returning to the situation shown in Fig. 6.2, state and explain what happens when the rate of rotation of the ball is increased.

.....

 [2]

- 16 (a)** A tennis ball is struck with a racket.
The initial velocity v of the ball leaving the racket is 30.0 m s^{-1} and it makes an angle of 70° to the horizontal as shown in Fig. 16.
Air resistance is negligible

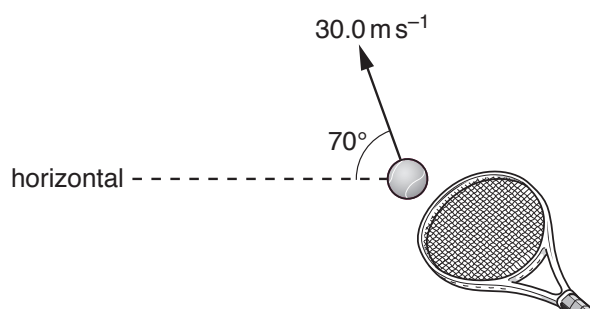


Fig. 16

- (i)** Calculate the vertical component of the initial velocity of the ball.

vertical component = ... m s^{-1} [1]

- (ii)** Use your answer in **(i)** to show that the ball reaches a maximum height h of about 40 m.

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

Turn over

- 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.

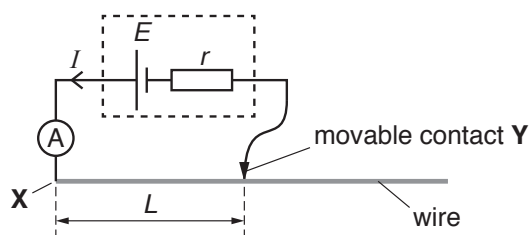


Fig. 18.1

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.

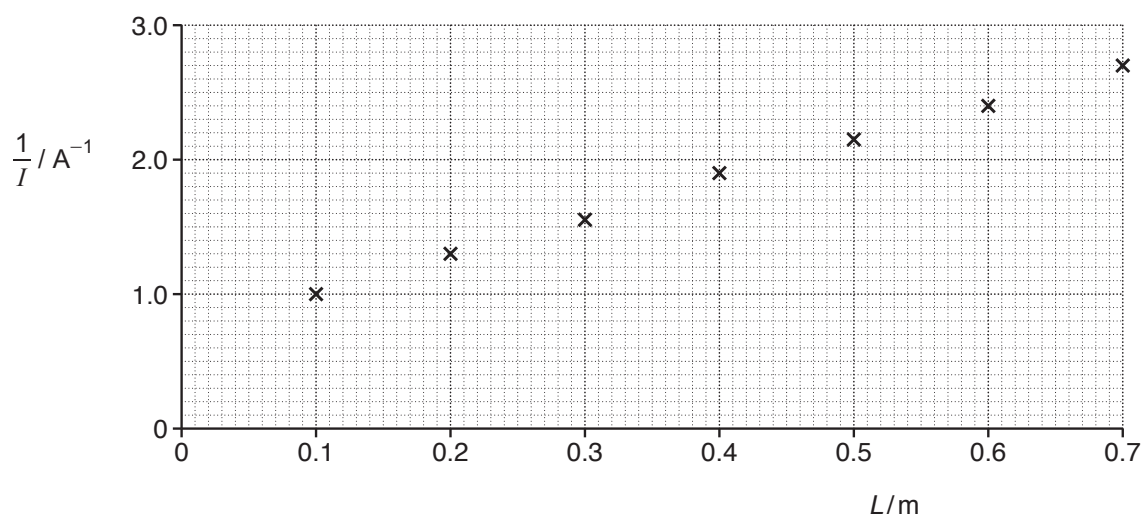


Fig. 18.2

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

gradient = ... $A^{-1} m^{-1}$ [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 1.5V. 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.

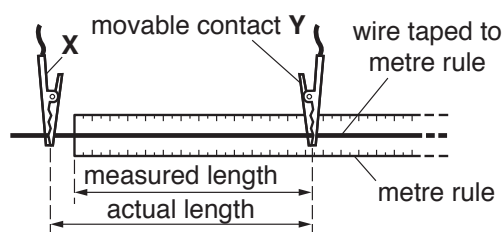


Fig. 18.3

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]

- 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]

20

(a)

- (i) Define the internal energy of an ideal gas.

.....

.....

..... [1]

- (ii) Use the formulae below to show that the average kinetic energy of a particle of an ideal gas is directly proportional to the absolute temperature of the gas.

$$pV = \frac{1}{3}Nm\overline{c^2} \quad pV = NkT$$

[2]

- (b) The velocities of four gas particles at 290 K are given below in
- ms^{-1}
- .

310 370 440 550

- (i) Show that the root-mean-square (r.m.s.) speed of the sample is about
- 430 ms^{-1}
- .

[2]

- (ii) Calculate the molar mass of the gas assuming an absolute temperature of 290 K and r.m.s. speed of
- 430 ms^{-1}
- .

molar mass = ... kg mol^{-1} [3]

- (c) Spherical filament lamps are manufactured by a process where they are filled with a gas at 290 K and low pressure.

When the filament lamp is switched on, the filament reaches a constant temperature of 2400 K. At this temperature, the pressure inside the filament lamp is 120 kPa.

- (i) Explain, in terms of energy transfers, why the temperature of the filament does **not** increase beyond 2400 K. You are **not** expected to refer to the electrical characteristics of the filament lamp.

.....

.....

.....

.....

..... [3]

- (ii) Calculate the pressure of the gas within the filament lamp during manufacture.

pressure = ... kPa [2]



- 18 A swimming pool designer investigates the depth d below a water surface reached by a diver when diving from a height h above the water surface. The designer models the diver as a uniform wooden cylinder. The experimental arrangement is shown in Fig. 18.1.

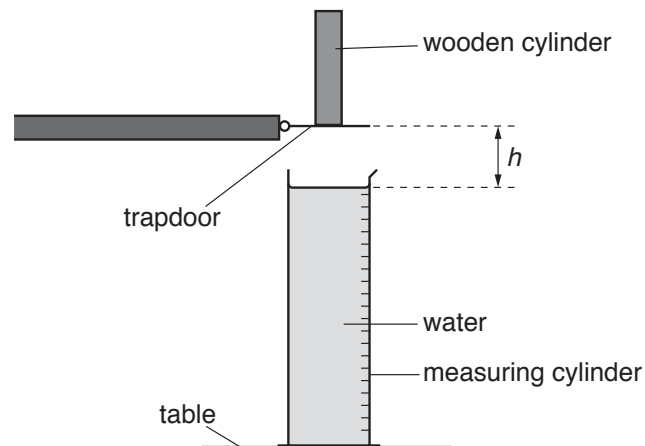


Fig. 18.1

- (a) The wooden cylinder has mass $5.0 \times 10^{-3} \text{ kg}$, diameter $1.0 \times 10^{-2} \text{ m}$ and length $7.0 \times 10^{-2} \text{ m}$.
- (i) Calculate the density of the wood.

density = ... kg m^{-3} [2]

- (ii) Suggest why wood is an appropriate material to model the depth reached by a diver.

.....

.....

.....

..... [2]

- (b) The cylinder is released from **rest** from a trapdoor. The base of the cylinder is at a height $h = 0.30\text{ m}$ above the water surface. Calculate the speed of the cylinder just before the base hits the water. Ignore air resistance.

speed = ... ms^{-1} [2]

- (c) Fig. 18.2 shows the cylinder fully submerged under the water surface before it has come to rest. The cylinder is moving vertically **down**.

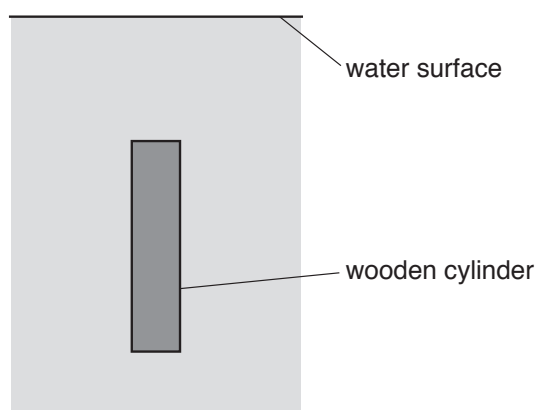


Fig. 18.2

- (i) Add arrows to Fig. 18.2 to show the **three** forces acting on the wooden cylinder. Label the arrows. [3]
- (ii) Describe and explain how the **resultant** force on the wooden cylinder varies from the moment the cylinder is fully submerged until it reaches its deepest point.

.....

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..... [3]

(d) The graph of Fig. 18.3 shows the depth d reached for different initial drop height h .

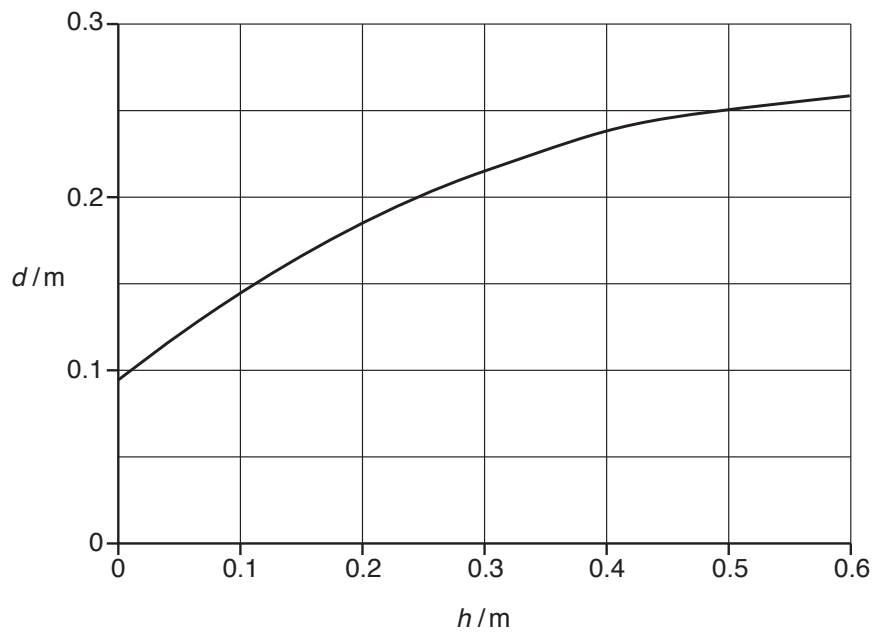
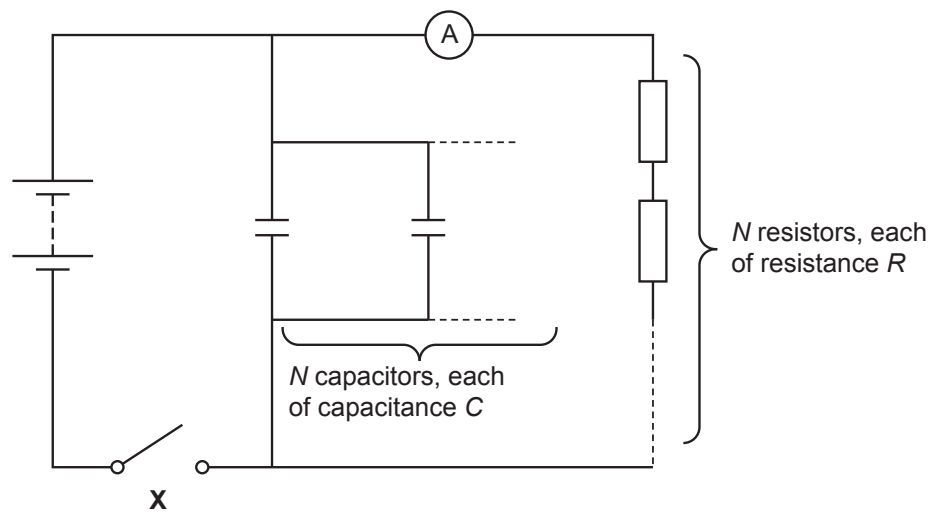


Fig. 18.3

The designer is required to double the height of a diving board for an existing swimming pool. He suggests that the depth of the pool also needs to be doubled. Use Fig. 18.3 to explain whether you agree with this suggestion.

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

2 A group of students investigate the circuit shown in the figure below.



There are N capacitors, each of capacitance C , connected in parallel.

There are N resistors, each of resistance R , connected in series.

Initially, the students close the switch **X**. They then note the reading on the ammeter.

The students then open the switch. They record the time T for the reading on the ammeter to fall to half of its initial value.

The table below shows the students' results.

N	T/s			
	1	2	3	Mean
1	14.7	14.1	14.3	
2	50.3	49.6	50.1	
3	126.6	126.3	125.2	126.0
4	224.4	224.3	225.9	224.9
5	356.1	354.3	345.6	352.0
6	500.4	512.7	499.5	504.2

(a) Show that $T = (\ln 2)N^2RC$.

[2]

(b) The students write in their lab books, "Our data is precise".

Evaluate this statement.

.....

.....

.....

.....

.....

..... [2]

Question 2 continues on page 6

(c) The results table is repeated below.

Complete the last column for $N = 1$ and $N = 2$ in the table below.

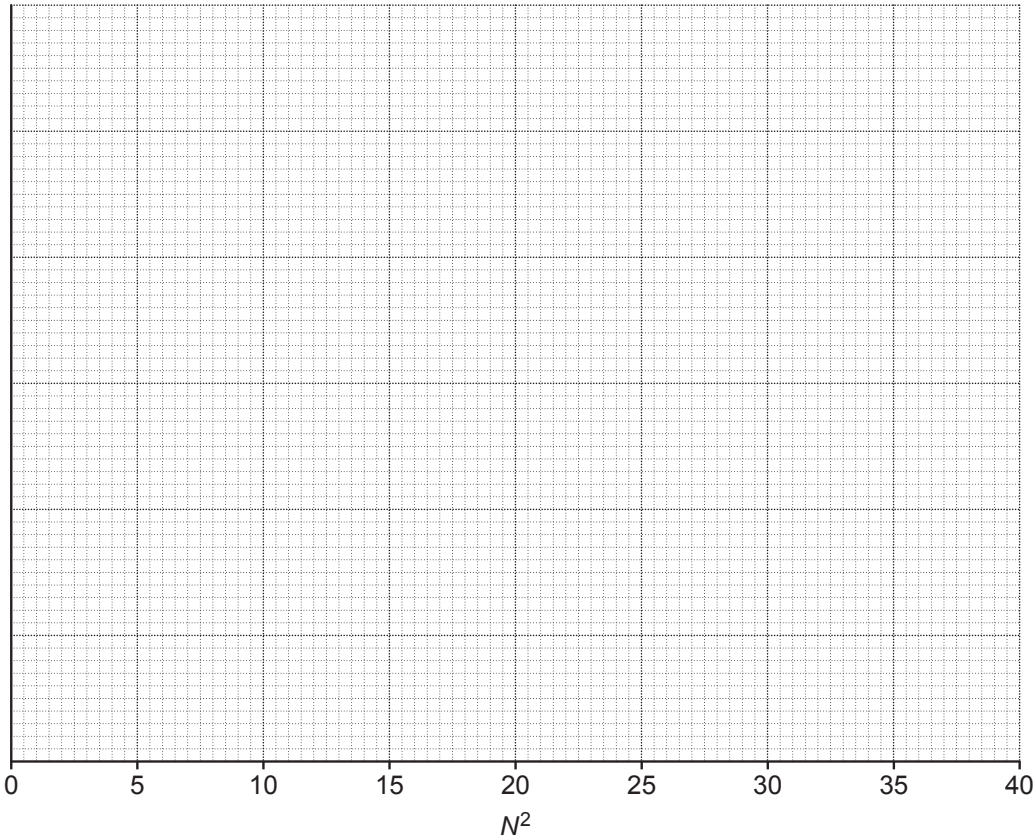
N	T/s			
	1	2	3	Mean
1	14.7	14.1	14.3	
2	50.3	49.6	50.1	
3	126.6	126.3	125.2	126.0
4	224.4	224.3	225.9	224.9
5	356.1	354.3	345.6	352.0
6	500.4	512.7	499.5	504.2

[1]

(d) The students begin to plot a graph of T (y -axis) against N^2 (x -axis).

(i) Complete the graph below and plot the 6 results from the table. You are **not** expected to include error bars.

[4]



(ii) Draw a straight line of best fit on the graph. [1]

(iii) Calculate the gradient of the straight line of best fit.

gradient = ... s [2]

(iv) The value of C is known to be $1000\ \mu\text{F} \pm 5\%$.

Use your gradient value from (iii) to find a value for R , in units of $\text{k}\Omega$, including an **absolute** uncertainty.

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

(e) Following the investigation, the students discovered that the sixth $1000\ \mu\text{F}$ capacitor connected to the circuit was actually two $470\ \mu\text{F}$ capacitors connected in parallel.

(i) State the type of error caused by this mistake.

..... [1]

(ii) Explain the effect that this error would have had on the calculated value of R .

.....

 [1]

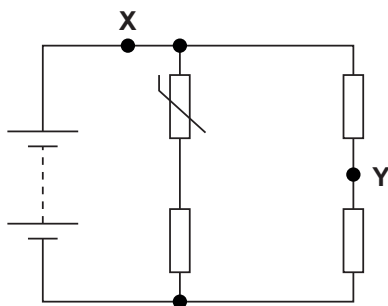
SUB-TOPIC 4.2.3

RESISTANCE AND I-V CHARACTERISTICS

Sub-topic 4.2.3 · 13 questions · 80 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

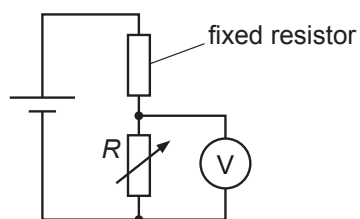
C Only 3

D Only 2

Your answer

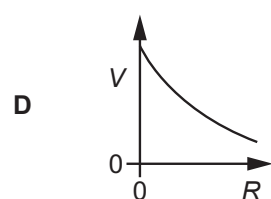
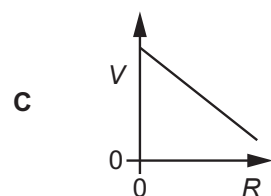
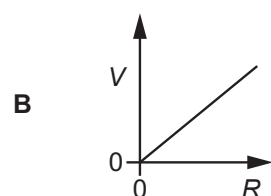
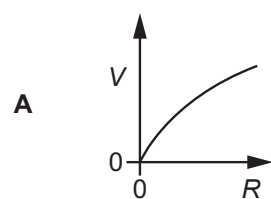
[1]

- 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 .

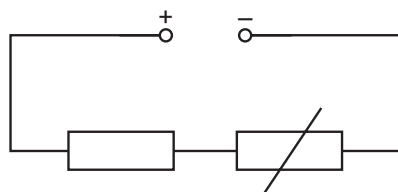
Which graph shows the correct variation with R of V ?



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 .

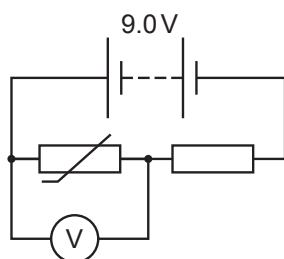
What is the total p.d. across both components?

- 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]

14 A wire in a circuit obeys Ohm's law.

Which statement about the wire is linked to this law?

- A** The current in the wire is directly proportional to the potential difference across it.
- B** The current in the wire is inversely proportional to its resistance.
- C** The resistance of the wire is directly proportional to its length.
- D** The resistance of the wire is inversely proportional to its cross-sectional area.

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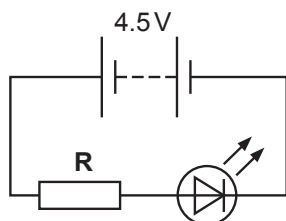
- 17 A light-emitting diode (LED) emits red light when it is positively biased and has a potential difference (p.d.) greater than about 1.8 V.

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

Calculate the wavelength λ of this red light.

$\lambda = \dots\dots\dots$ m [3]

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

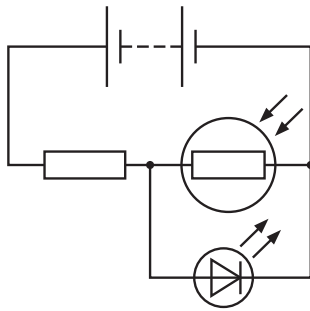


The battery has electromotive force (e.m.f.) 4.5 V and negligible internal resistance.
 The resistor **R** has resistance 150 Ω .
 Assume the p.d. across the LED is 1.8 V.

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

ratio = $\dots\dots\dots$ [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.

.....
 [1]

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- 17 (a) State **one** S.I. base quantity other than length, mass and time.

..... [1]

- (b) Fig. 17 shows two resistors **X** and **Y** connected in series.

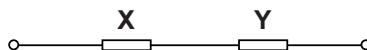


Fig. 17

The resistors are wires. Both wires have the same length L and diameter d . The material of **X** has resistivity ρ and the material of **Y** has resistivity 2ρ .

- (i) Show that the total resistance R of the wires is given by the equation

$$R = \frac{12\rho L}{\pi d^2}.$$

[2]

- (ii) A student uses the equation in (i) to determine R .
The table below shows the data recorded by the student in her lab book.

Quantity	Value
ρ	$4.7 \times 10^{-7} \Omega \text{ m}$
L	$9.5 \pm 0.1 \text{ cm}$
d	$0.270 \pm 0.003 \text{ mm}$

1. Name the likely instruments used by the student to measure L and d .

L :

d : [1]

2. Use the data in the table and the equation in (i) to determine R and the absolute uncertainty. Write your answer to the correct number of significant figures.

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

3. The instrument used to measure d has a zero-error. The measured d is much **larger** than the actual value.
Discuss how the actual value of R compares with the value calculated above.

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..... [1]

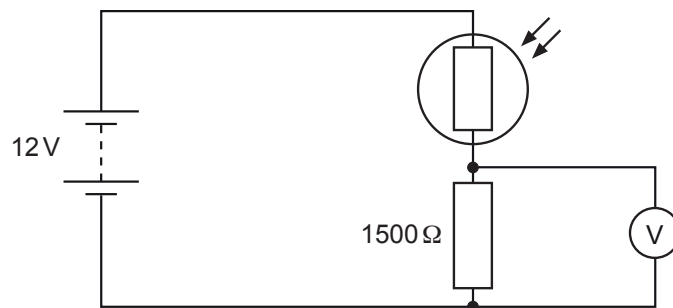
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2 This question is about a light-dependent resistor (LDR).

(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 .

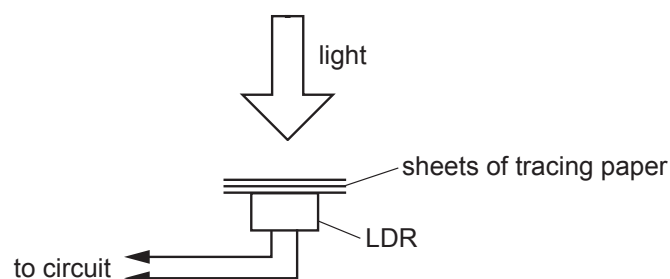
[1]

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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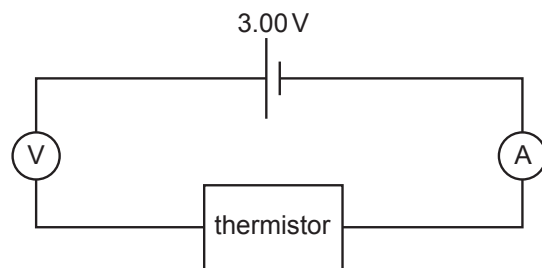


16 Thermistors are circuit components whose resistance varies with temperature.

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.

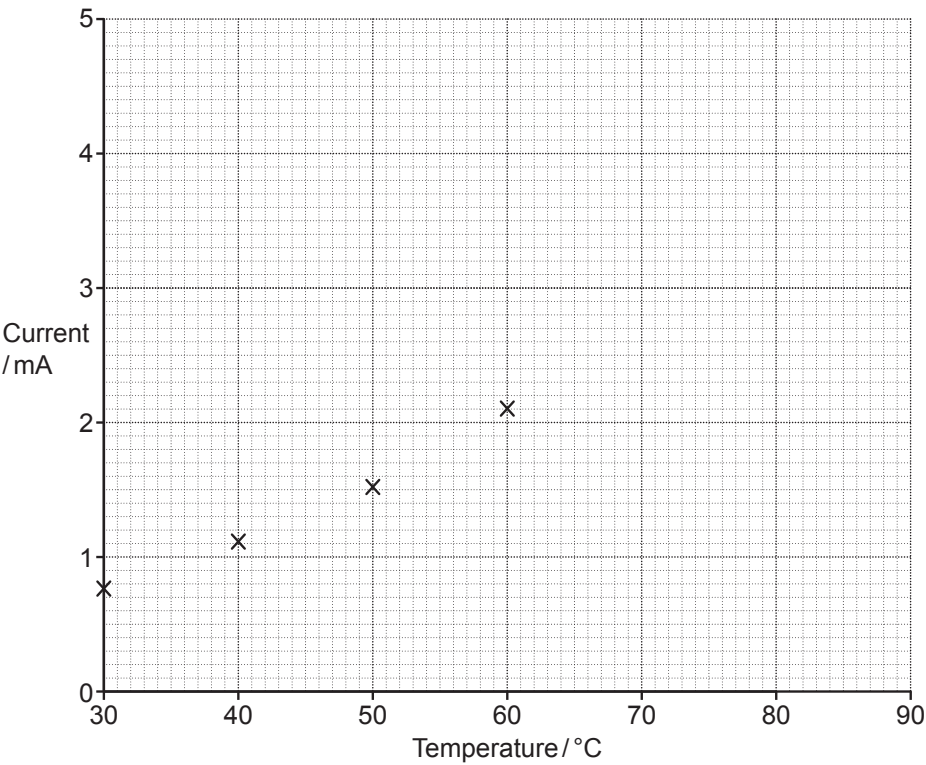
Temperature/°C	Current/mA	Voltage/V
30	0.75	3.00
40	1.10	3.00
50	1.51	3.00
60	2.10	3.00
70	2.80	3.00
80	3.66	3.00
90	4.76	3.00

(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]

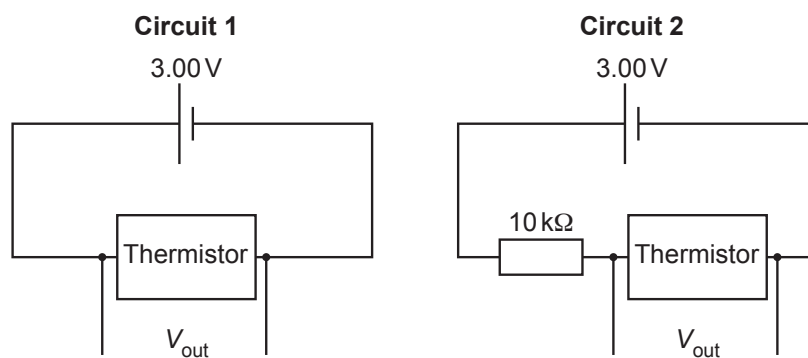


- (c) Describe, using the graph and calculations using data from the table, how the resistance of the thermistor varies for increasing temperature.
Hence determine whether the thermistor the student used was an NTC or a PTC thermistor.

[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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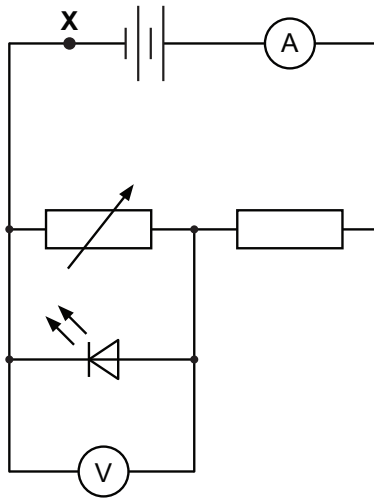
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..... [4]

- 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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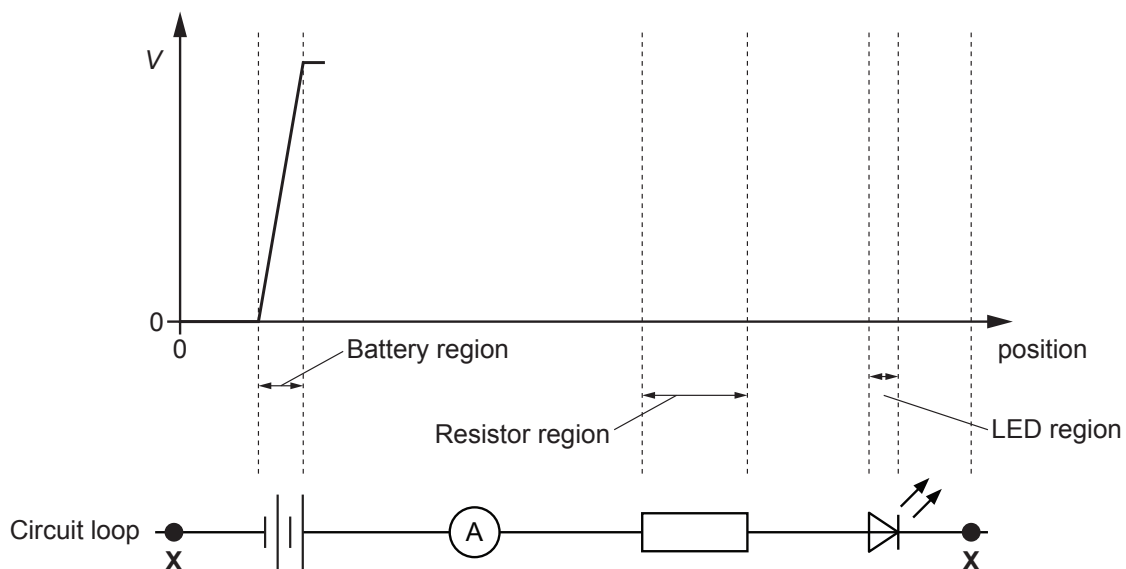
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..... [2]

(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]**

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**.

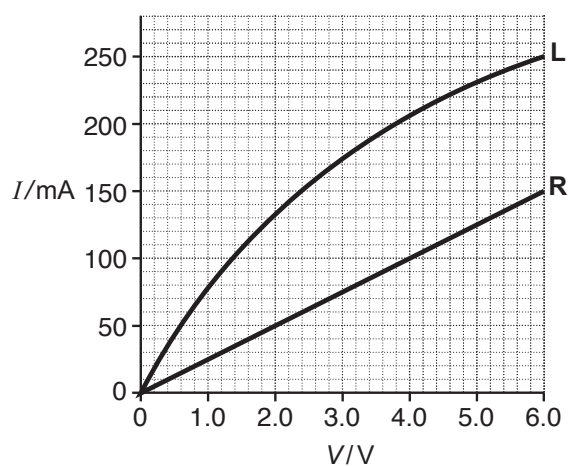


Fig. 16.1

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.

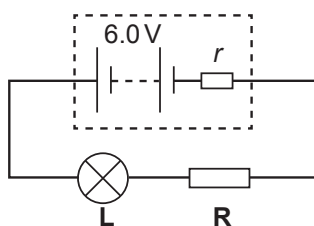


Fig. 16.2

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

- 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**.

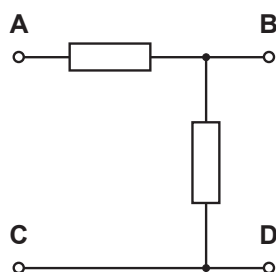


Fig. 4.1

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.

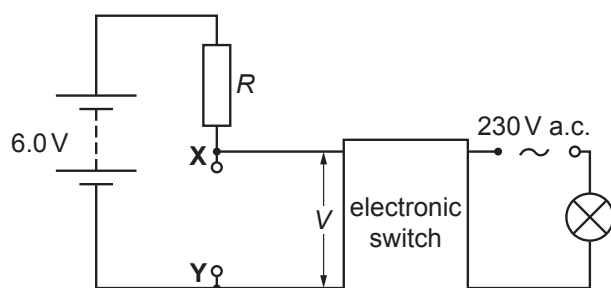


Fig. 4.2

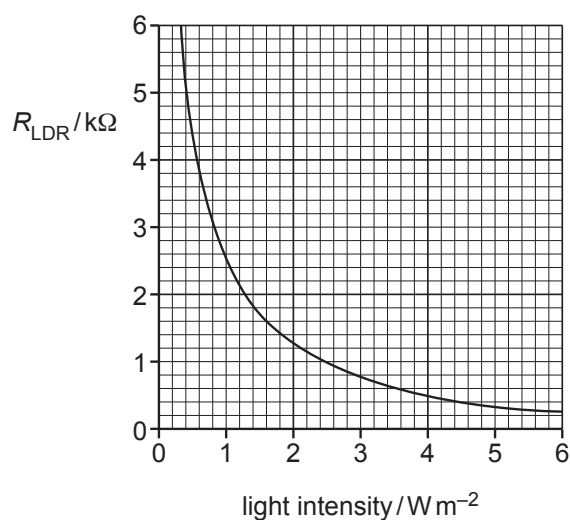


Fig. 4.3

- (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.



SUB-TOPIC 4.2.4

RESISTIVITY

Sub-topic 4.2.4 · 9 questions · 82 marks · lowest tariff first



- 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

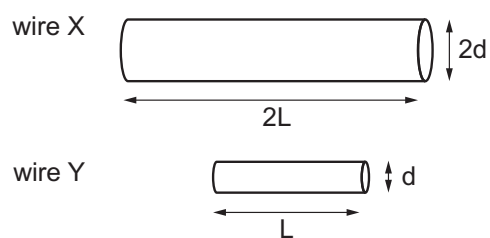
What is the mean drift velocity v of the electrons in wire **Q**?

- 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]

- 8 The diagram shows the relative lengths and diameters of two copper wires, labelled wire X and wire Y.



What is the ratio of the resistivity of wire Y to wire X?

- A** 1:1
B 1:2
C 1:4
D 1:8

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.

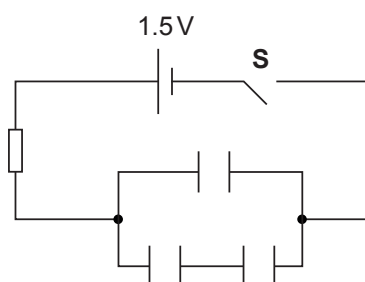


Fig. 21

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.

$C =$ μF [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]

- 22** A student wishes to determine the permittivity ϵ of paper using a capacitor made in the laboratory.

The capacitor consists of two large parallel aluminium plates separated by a very thin sheet of paper.

The capacitor is initially charged to a potential difference V_0 using a battery. The capacitor is then discharged through a fixed resistor of resistance $1.0\text{ M}\Omega$.

The potential difference V across the capacitor after a time t is recorded by a data-logger. The student uses the data to draw the $\ln V$ against t graph shown in Fig. 22.

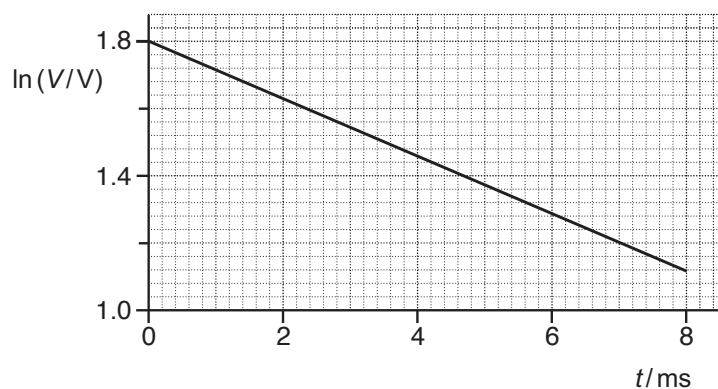


Fig. 22

- (a)** Show that the magnitude of the gradient of the line shown in Fig. 22 is equal to

$$\frac{1}{CR}$$

where C is the capacitance of the capacitor and R is the resistance of the resistor.

[2]

(b)* Use Fig. 22 to determine the capacitance C of the capacitor. Describe how the student can then use this value of C to determine a value for ϵ .
In your description, mention any additional measurements required on the capacitor.

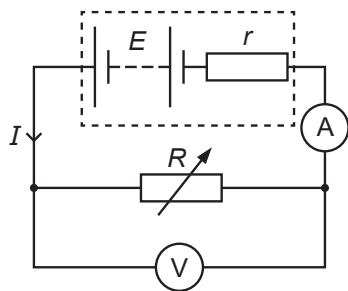
[6]

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Turn over



- 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.

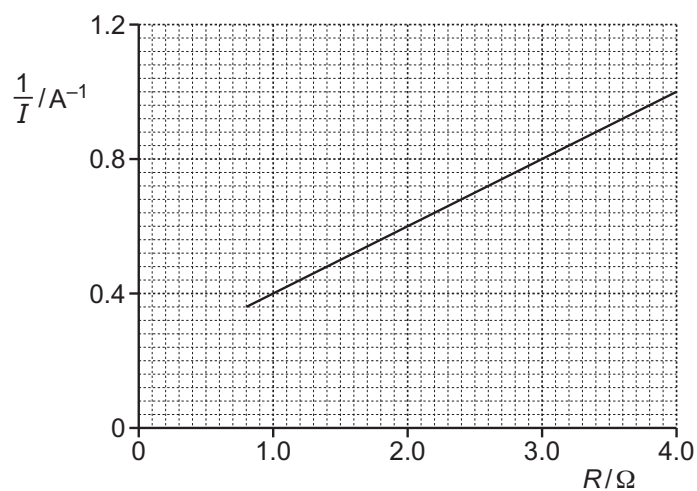
..... [1]

- (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]

1 This question is about a resistance wire made of nichrome.

(a)* It is suggested that the resistance R of a length of nichrome wire varies with temperature θ in $^{\circ}\text{C}$ according to the equation

$$R = R_0 (1 + k\theta)$$

where R_0 is the resistance of the wire at 0°C and k is a constant for the wire.

Fig. 1.1 shows a diagram of the arrangement of apparatus in an experiment to test the relationship between R and θ and to determine the value of k .

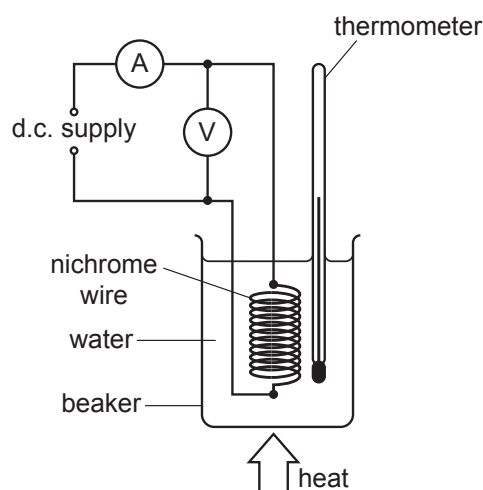


Fig. 1.1

The resistance wire is coiled and placed in a water bath.

Describe how you would carry out the experiment, analyse the data to verify the relationship between R and θ and determine a value for k .

In your description, state any precautions that you would take to improve the accuracy and precision of the measurements.

[6]

Question 1 is continued on page 4.

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Turn over



- (b) A student is investigating a 230 V, 1.0 kW heating element. The heating element is shown in Fig. 1.2.

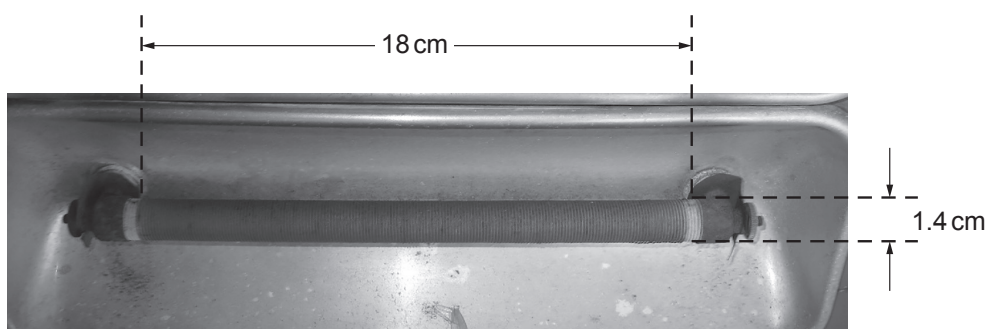


Fig. 1.2

A length of nichrome wire is wound in a spiral groove along 18 cm of a ceramic cylinder of diameter 1.4 cm. The distance between the centres of adjacent turns of the wire is 1.5 mm.

The numbers labelling the reels of loose wire on the laboratory shelf are the *imperial standard wire gauge* (swg). The student wishes to find out which reel holds the same wire as that wound on the heating element of Fig. 1.2.

The book of data gives the following information:

resistivity of nichrome at operating temperature = $1.1 \times 10^{-6} \Omega \text{ m}$

swg	24	26	28	30	32
diameter of wire / 10^{-3} m	0.56	0.46	0.38	0.32	0.27
cross-sectional area / 10^{-6} m^2	0.25	0.16	0.11	0.08	0.06

- (i) Show that the resistance of the nichrome wire wound on the ceramic cylinder is 53Ω .

[2]

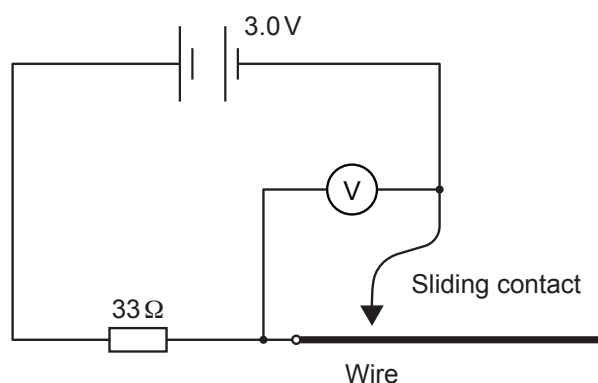
(ii) Show that the length of wire wound on the heating element is 5.3 m.

[2]

(iii) Use the information given in (i) and (ii) to determine the swg number of the wire used as the heating element.

swg number = ... [3]

- 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]

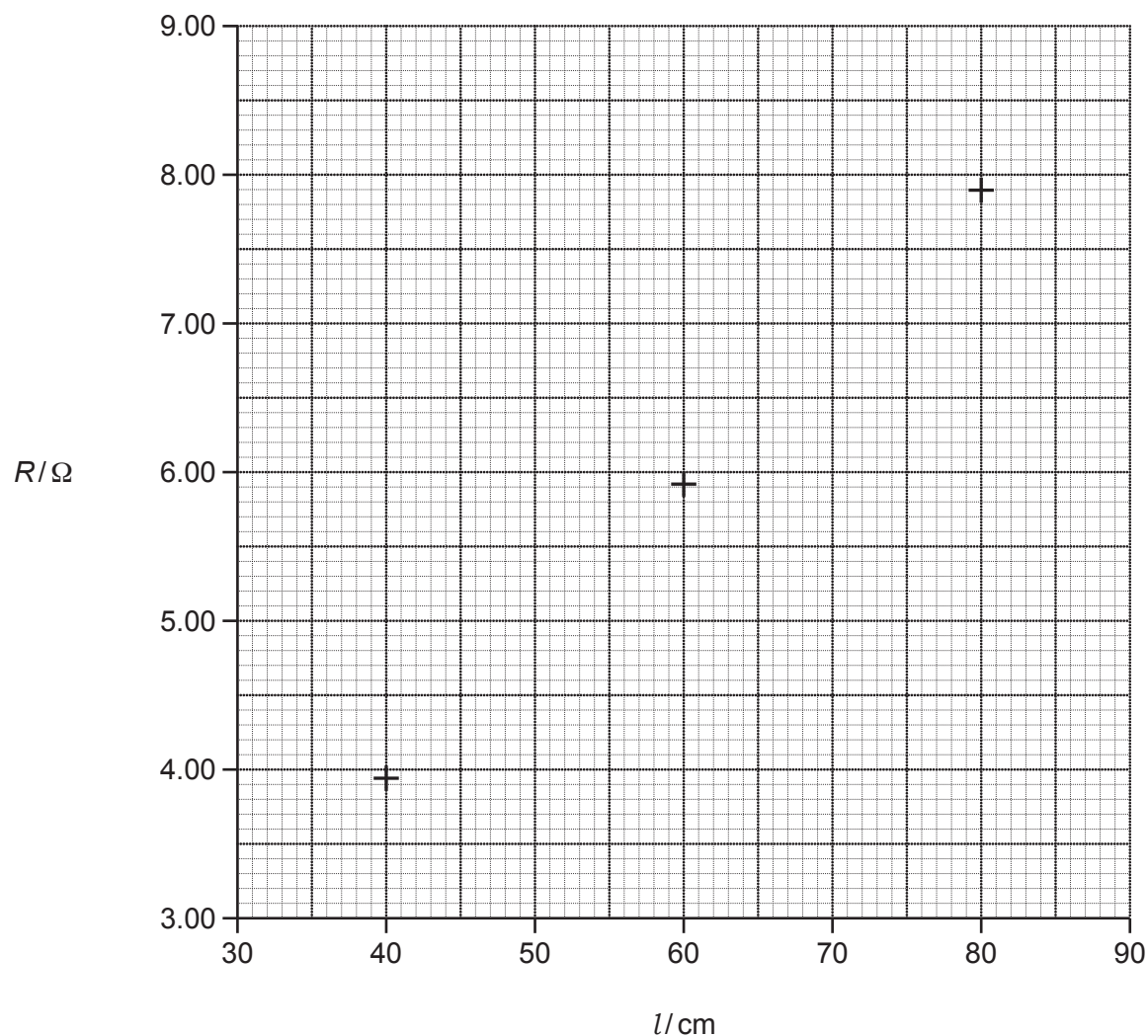
- (ii) The axes below show a plot of R against l .
Three points from the table have already been plotted.

Plot the remaining points.

[1]

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

[1]

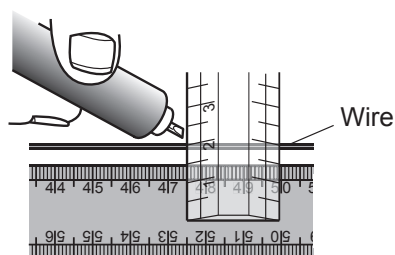


- (c) The wire is made of constantan which has a resistivity of $5.00 \times 10^{-7} \Omega \text{ m}$.

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.

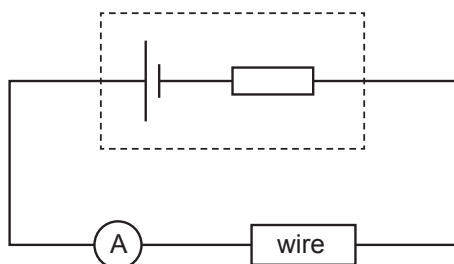


Explain how this arrangement helps the student to make high-quality measurements.

.....

 [3]

- 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.

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 [3]

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

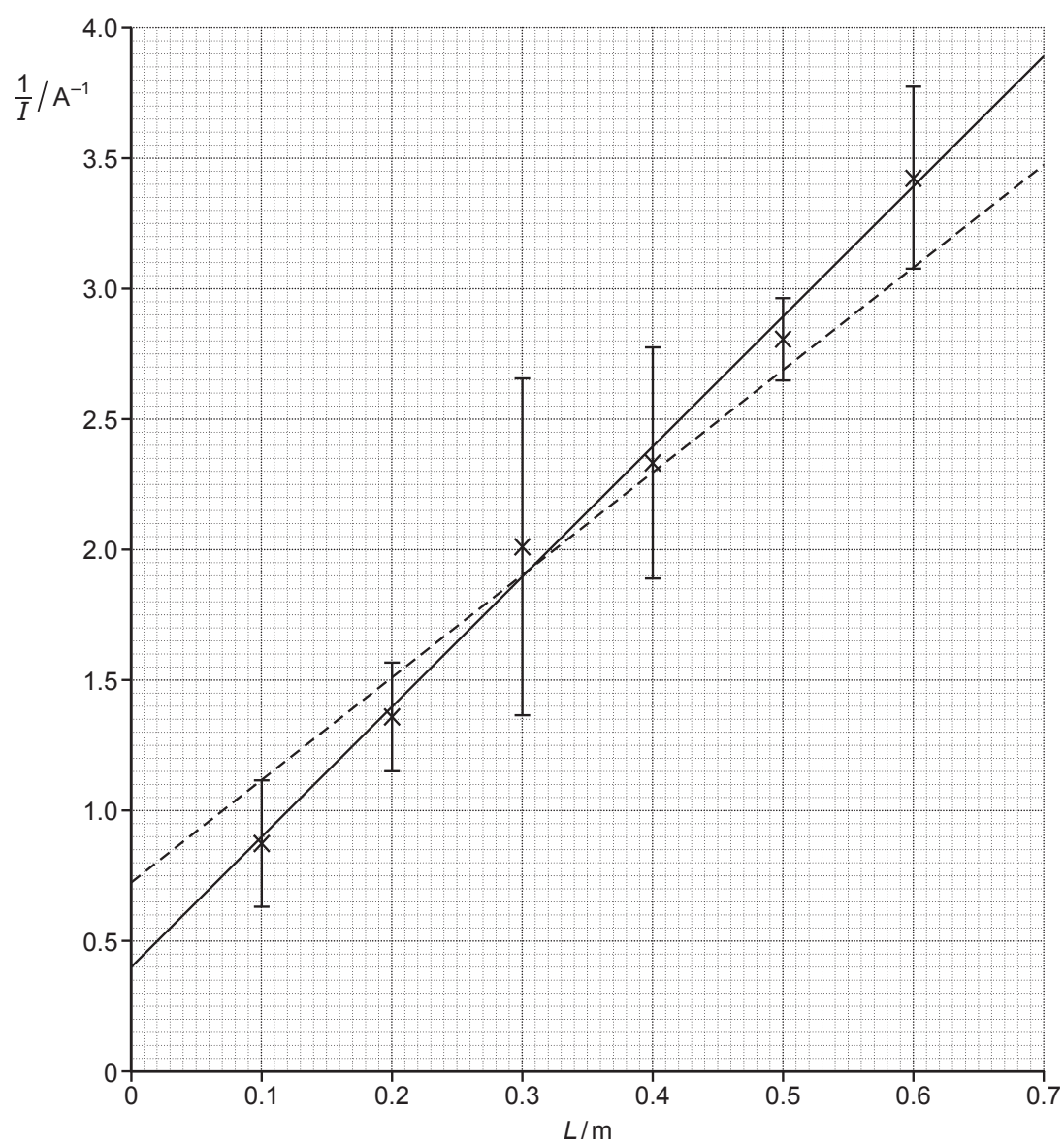
(i) Show that

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

[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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- 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.

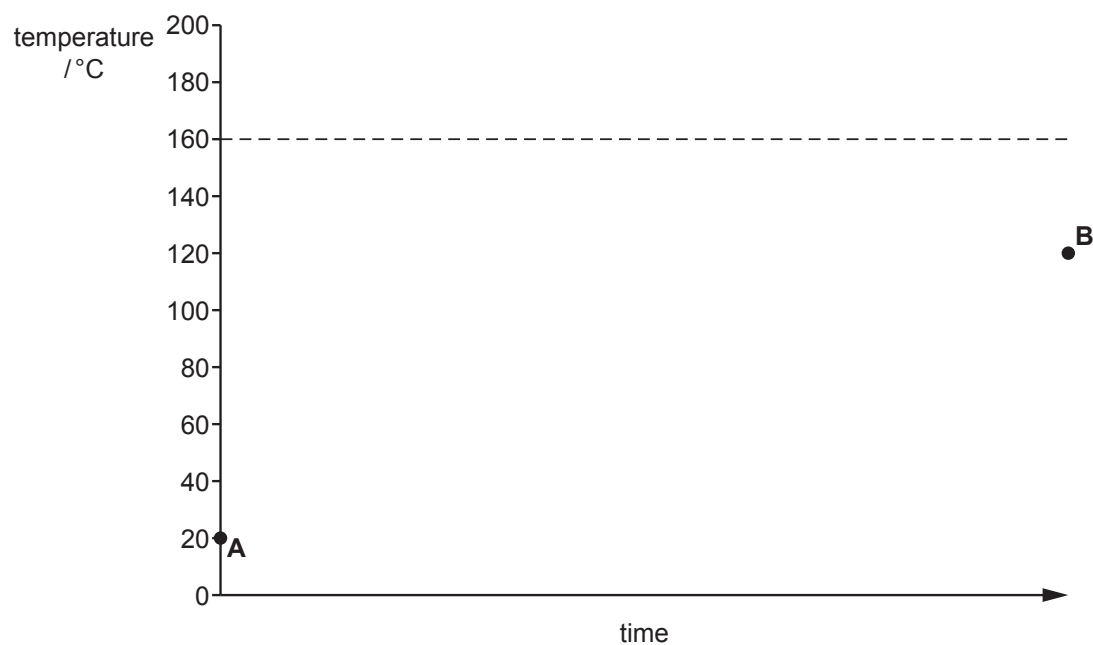
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 [2]

(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



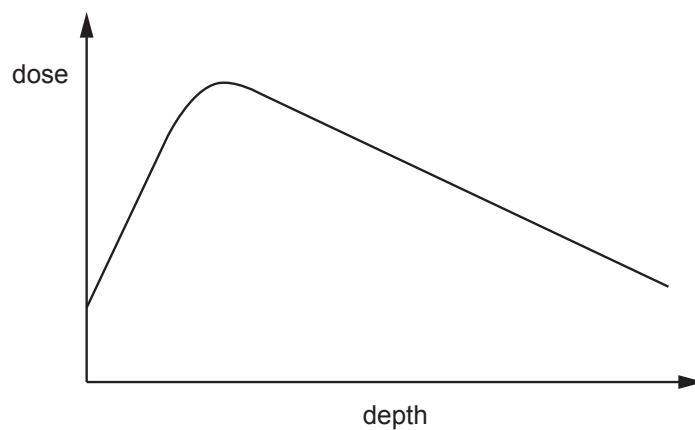
Complete Fig. 6.1 to show how the temperature of the PLA changes between **A** and **B**. You are **not** required to label the time axis. [3]

- (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.

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..... [2]

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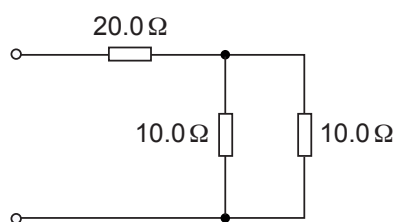
SUB-TOPIC 4.2.5

ELECTRICAL POWER AND ENERGY

Sub-topic 4.2.5 · 11 questions · 60 marks · lowest tariff first



- 2 Three resistors are connected in a circuit.



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

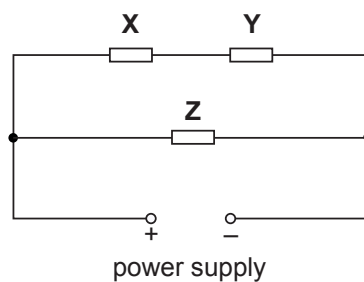
What is the total resistance of this circuit?

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

Your answer

[1]

- 5 Three identical resistors **X**, **Y** and **Z** are connected to a power supply.



The power dissipated in the resistor **Z** is 24 W.

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

- A** 6.0 W
- B** 12 W
- C** 24 W
- D** 48 W

Your answer

[1]

14 The potential difference across a lamp is 2.5 V. The current in the lamp is 20 mA.

What is the energy dissipated in the lamp in 3.0 hours?

A 0.050 J

B 0.15 J

C 9.0 J

D 540 J

Your answer

[1]

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- 3 The current in a lamp is 2.0 mA. The potential difference across the lamp is 6.0 V.

What is the energy transfer in the lamp over a period of 3.0 hours?

A 0.012 J

B 0.036 J

C 2.16 J

D 130 J

Your answer

[1]



- 4 A 200 W heater is used for 90 minutes. The cost per kWh is 13 pence.

How much did it cost to use the heater?

- A 3.9p
- B 39p
- C £2.34
- D £23.40

Your answer

[1]

- 7 The power dissipated across a $1\text{ k}\Omega$ resistor is 20 W .

What is the potential difference across the resistor?

- A 0.02 V
- B 50 V
- C 140 V
- D $20\,000\text{ V}$

Your answer

[1]

- 5** Large power stations generate an electrical power of about 1 GW.

Current methods of energy production that use nuclear fusion are unable to produce enough energy for large-scale energy production. A proposed method of controlling nuclear fusion is inertial confinement fusion (ICF). ICF uses a large number of powerful lasers to create the high temperatures required for nuclear fusion to occur.

One ICF experiment uses a network of capacitors to store the energy needed to power the lasers. When the network is fully charged:

- potential difference across the network = 24 kV
- total energy stored in the network = 400 MJ

- (a) (i)** Calculate the total capacitance, C , of the network.

$C = \dots\dots\dots$ F [2]

- (ii)** Explain why the individual capacitors in the network should be connected in parallel in order to produce this total capacitance.

.....
 [1]

- (b)** The total stored energy must be released in a time of less than 1 millisecond.

Explain, using a calculation, why the lasers are powered by the network of capacitors instead of being connected directly to the mains electricity supply.

.....

 [2]

(c) The fusion reaction in the ICF experiment is

deuterium + tritium $\rightarrow$ alpha particle + neutron

Calculate the number of fusion reactions that must occur for the energy released by fusion to be equal to the electrical energy stored in the network of capacitors.

- mass of deuterium = 2.014102 u
- mass of tritium = 3.016049 u
- mass of alpha particle = 4.002603 u
- mass of neutron = 1.008665 u

number of fusion reactions = ... [4]

19 Fig. 19.1 shows an electric circuit.

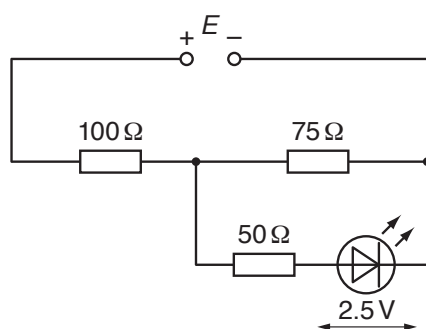


Fig. 19.1

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.

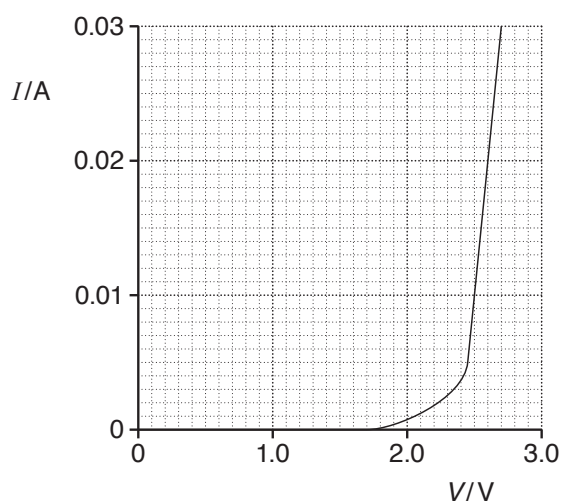


Fig. 19.2

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.

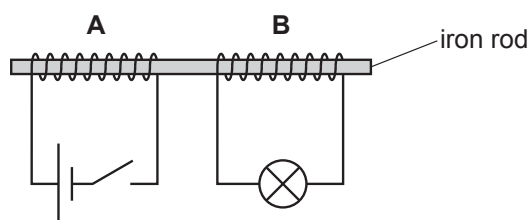
number of photons per second = $\dots\dots\dots$ s⁻¹ [3]

- (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.

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

- 21 (a) The diagram below shows two insulated-copper coils **A** and **B** connected in circuits.



Both coils are individually wrapped around the same iron rod.

Coil **A** is connected to a cell and a switch. Coil **B** is connected to a filament lamp.

The switch is initially closed and the lamp is off.

The switch is then opened. The lamp flashes on for a brief time, and then remains off.

Explain these observations in terms of magnetic flux.

.....

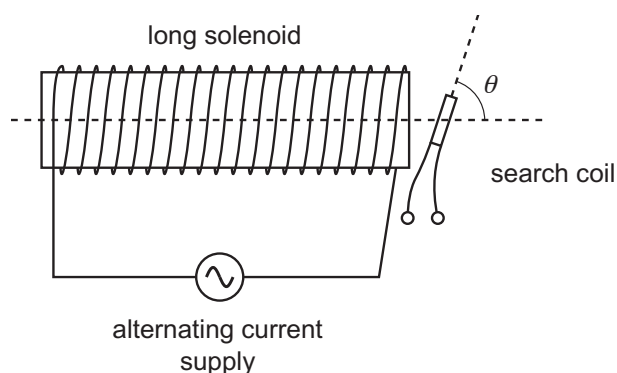
.....

.....

.....

..... [3]

- (b) A student is carrying out an experiment using a search coil.



A long solenoid is connected to an alternating current supply.

The search coil is placed at one end of the solenoid. The plane of the search coil is tilted such that it makes an angle θ with the central axis of the solenoid. The maximum alternating induced electromotive force (e.m.f.) across the ends of the search coil is E_0 .

- (i) Name an instrument that can be used to determine E_0 .

..... [1]

(ii) The equation for E_0 is:

$$E_0 = KI_0 ANf \sin \theta$$

where I_0 = maximum current in the solenoid, A = cross-sectional area of the search coil, N = number of turns of the search coil, f = frequency of the alternating current in the solenoid and $K = 4.0 \times 10^{-3} \text{ VA}^{-1} \text{ m}^{-2} \text{ s}$.

The magnitude of the induced e.m.f. in the search coil can be determined using Faraday's law of electromagnetic induction:

e.m.f. = rate of change of magnetic flux linkage

In the experiment, angle θ is changed and E_0 measured.

Suggest the quantity, or quantities, in the equation $E_0 = KI_0 ANf \sin \theta$ linked to

1 the 'rate' part of the law

..... [1]

2 the 'change of magnetic flux linkage' part of the law.

..... [1]

(iii) The student plots a straight-line graph of E_0 against $\sin \theta$.

Determine f , including the absolute uncertainty. Write your value of f to **2** significant figures.

$$I_0 = (8.0 \pm 0.2) \text{ A}$$

$$A = (7.8 \pm 0.1) \times 10^{-5} \text{ m}^2$$

$$N = 5000$$

$$\text{gradient of line} = KI_0 ANf = (0.62 \pm 0.03) \text{ V}$$

$$f = \dots \pm \dots \text{ Hz [4]}$$

18 (a) Fig. 18.1 shows a circuit.

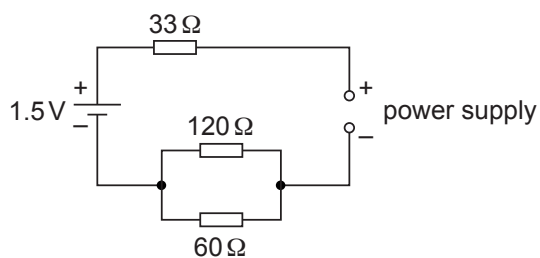


Fig. 18.1

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).

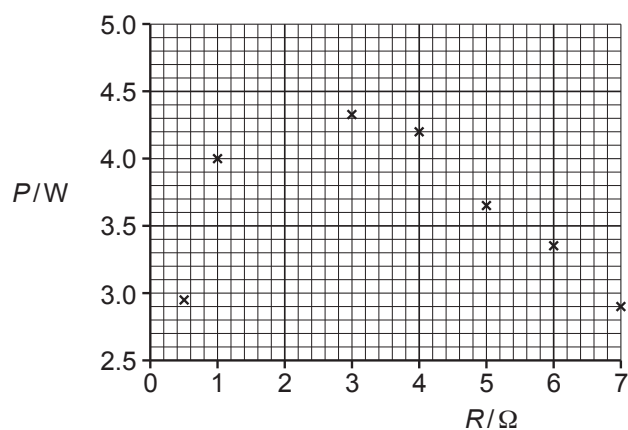


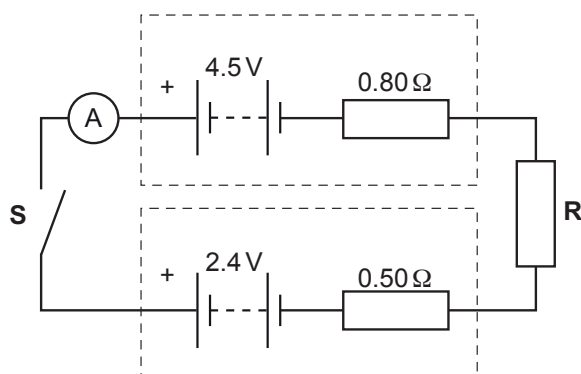
Fig. 18.2

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]

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**.

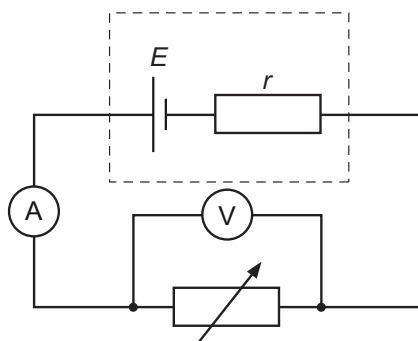
$v = \dots\dots\dots \text{ ms}^{-1}$ [2]

- (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..

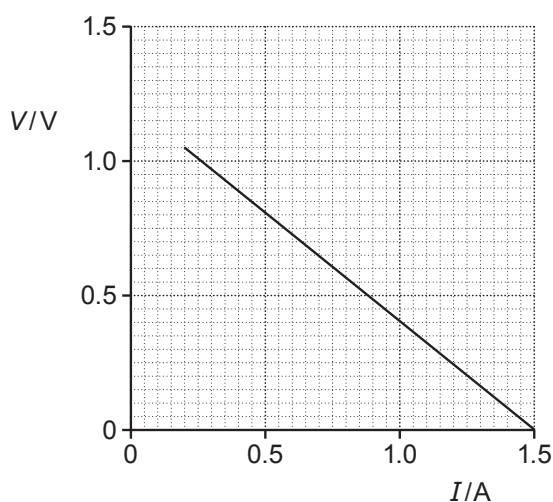
.....
.....
..... [2]

- (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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MARK SCHEMES

official mark schemes



4	A		1	
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12	B		1	
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1	A	1	
---	---	---	--



8	A		1	
---	---	--	---	--



9	D			1	
---	---	--	--	---	--



8	B	1	
---	---	---	--



13	A	1	
----	---	---	--



7	D	1	
---	---	---	--



10	B	1	
----	---	---	--



4	C		1	
---	---	--	---	--



1	C	1	
---	---	---	--



10	D	1	
----	---	---	--



14	C	1	
----	---	---	--



7	B	1	
-	-	-	



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	

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	

18	(a)		(Kinetic energy) reduces (with height) At maximum height, KE is minimum / non-zero	B1 B1	Allow idea that KE is transferred to GPE/KE store reduces and GPE store increases Not references to KE being a vector/having components for second mark
	(b)		$(u =) 68 \sin 11^\circ$ or $13.0 \text{ (m s}^{-1}\text{)}$ $t = 13.0 / 9.81$ and t correctly evaluated $t = 1.3(2) \text{ (s)}$	C1 C1 A0	Not $t = 90 / (68 \cos(11)) = 1.35$ for zero marks. Allow any subject
	(c)		$(t =) 2 \times 1.3$ or 2.6 (s) $(x =) 68 \cos 11^\circ \times 2.6$ or 174 (m) horizontal distance = $174 - 90$ horizontal distance = 84 (m)	C1 C1 A1	 Note answer is 86 (m) if 1.32 s is used Note answer is 87 (m) if $1.3226 \dots \text{ s}$ is used Allow $1.3 \times 68 \cos 11^\circ$ for 1 mark Allow 3 or -3 m for 2 marks
	(d)	(i)	A collision in which kinetic energy is lost	B1	Allow KE is not conserved
		(ii)	Conservation of momentum Idea that velocity is to the right and velocity is very small / much smaller than $68 \text{ (m s}^{-1}\text{)}$	B1 B1	 Not 'goes backwards'
			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 A1	At least one correct expression for Q for first mark 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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6	(a)		time taken for current (or charge or voltage) to fall to $1/e$ of <u>its initial value</u>	B1	Not capacitance Not to fall <u>by</u> (a factor of) $1/e$ Allow to decrease <u>to</u> 37% of its initial value Allow to decrease <u>by</u> 63% Ignore time constant = CR
	(b)	(i)	$f (= 1/T) = 1 / (40 \times 10^{-3})$ $f = 25$ (Hz)	B1 B1	Allow $f = 1/T$ and $T = 40 \times 10^{-3}$ (s)
		(ii)	EITHER Calculation of Q_0 / e time constant (read from graph) = 14 (ms) OR Use of $Q = Q_0 e^{-t/CR}$ time constant = 14 (ms)	C1 A1 (C1) (A1)	Allow any initial value of charge e.g. $8.0 / e = 2.9$ (μC) or $37\% \times 8.0 = 3.0$ (μC) Allow 14 ± 1 (ms) e.g. $2.0 = 8.0 e^{-0.02/CR}$ gives $CR = 0.02 / \ln 4$ Using the decay equation may incur two POT errors
		(iii)	tangent drawn to graph <u>at steepest part of curve</u> maximum current in range 5.0×10^{-4} to 7.0×10^{-4} (A)	M1 A1	Judge by eye, no daylight between curve and tangent Allow a negative answer Allow answer to 1sf

Question			Answer	Marks	Guidance
6	(b)	(iv)	vertical axis labelled as current with the correct unit and at least one positive and one negative scale marking and scale should allow for their maximum current to be plotted exponential decay of current in each section sign of current alternates at 20, 40, 60 and 80 ms	B1 M1 A1	For example I / mA , $I (\text{mA})$, $I / 10^{-4} \text{ A}$, current in mA etc All scale markings shown must be correct Allow any curve with a decreasing gradient in each section Ignore value of minimum current but not zero Ignore sign of current for this marking point All curves should start at the correct maximum current value. However, If B1 mark has not been scored, allow any value of maximum current as long as it remains consistent across all four sections
			Total	10	



Question	Answer	Mark	Guidance
3 (a)	Take $\ln$ to give $\ln V = -(t/C).1/R + \ln V_0$ gradient (m) = $(-t/C)$ where $t = 15$	M1 A1	allow $\ln(V/V_0) = -(t/C).1/R$
(b) (i)	1.10 ± 0.07	B1	value plus uncertainty required for the mark
(ii)	two points plotted correctly to within $\frac{1}{2}$ small square on x-axis; line of best fit	B1 B1	ignore accuracy of length of error bar; ecf bi value or both worst acceptable lines drawn
(iii)	gradient ($= 15/C$) = 6.6×10^4 ; $C = 15 / 6.6 \times 10^4 = 2.3 \times 10^{-4}$ (F) worst acceptable straight line drawn $(C) \pm 0.3 \times 10^{-4}$ F	C1 A1 B1 B1	accept 6.4 to 6.8 ignore power of 10 accept $2.3 \pm 0.1 \times 10^{-4}$ allow ecf for the point calculated incorrectly in b(ii) ; steepest or shallowest possible line that passes through <u>all</u> the error bars; should pass from top of top error bar to bottom of bottom error bar or bottom of top error bar to top of bottom error bar allow e.g. $(C) \pm 0.2 \times 10^{-4}$; allow value of C to 4 SF but N.B. the uncertainty and the value of C must be to the same number of decimal places allow $230 \pm 30 \mu\text{F}$ etc allow equivalent unit including $\text{s } \Omega^{-1}$, C V^{-1} , A s V^{-1}
(c)	$\ln(0.1) = -15/RC$ or $R = -15/C \ln(0.1)$ or $R = 0.65/C$ $R = 0.65/2.3 \times 10^{-4}$ giving $R = 28 \text{ k}\Omega$	C1 A1	$\ln(0.1) = -2.30$ ecf (b)(iii)
Total		11	

H556/03

Mark Scheme

June 2017

Question	Answer	Marks	Guidance
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22	(a)	(i)1	0.5 (C_0)	B1	Allow $\frac{1}{2}$
		(i)2	2 (V_0)	B1	Ignore working No ecf
		(i)3	2 (E_0)	B1	Ignore working No ecf
		(ii)	Work done against <u>attractive</u> forces	B1	Allow WD for work done
	(b)	(i)	Evidence of use of $V = V_0 e^{-t/CR}$ leading to $\ln(\frac{1}{2}) = -T/CR$ or $\ln 2 = T/CR$ $T = C \ln 2 \times R$ compared with $y = mx$ with gradient = $C \ln 2$	M1 A1	Must see exponential decay as starting point (allow Q for V) Allow t for T Allow x for V and x_0 for V_0 Not $T/R = \text{gradient}$
		(ii)1	Best-fit line drawn correctly gradient = $5.4 (\times 10^{-9})$ $C = (\text{gradient} / \ln 2) = 7.8 \times 10^{-9} \text{ (F)}$	B1 B1 B1	Note line must pass through all (vertical part of) error-bars. If more than one line drawn, all lines must pass through all error-bars (1/2 square tolerance). Allow $\pm 0.2 (\times 10^{-9})$ Ignore POT Ecf from incorrect gradient, but penalise POT error here
		(ii)2	$7.8 \times 10^{-9} = \frac{\epsilon \times 3.1 \times 10^{-2}}{8.0 \times 10^{-5}}$ $\epsilon = 2.0 \times 10^{-11} \text{ (F m}^{-1}\text{)}$	C1 A1	Possible ECF from (b)(ii)1 Allow 1 mark if final answer is relative permittivity correctly calculated (ϵ divided by 8.85×10^{-12})
			Total	11	



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; $r = -\text{gradient}$ • 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	

Question	Answer	Mark	Guidance
6	arrow down through centre of ball labelled weight or W or mg or 1.2 N	B1	zero if any other arrows or forces present
(b) (i)	(horizontally) mv^2/r (or $mr\omega^2$) = $T \sin \theta$ and (vertically) W or mg = $T \cos \theta$ ($\tan \theta = v^2/rg$ or $r\omega^2/g$) $\tan \theta = 0.045 \times 4 \times 9.87 \times 2.2/9.81$ or $0.48/1.2$ (= 0.40) $\theta = 22^\circ$	M1 A1 A0	accept figures in place of algebra, $r = 0.045$ m $v = 0.42$ m s ⁻¹ $\omega = 3\pi$ rad s ⁻¹ ; $r\omega^2 = 4.0$ m s ⁻² ; $W = 1.2$ N and $m = 0.12$ kg and $mr\omega^2 = 0.48$ N accept labelled triangle of forces diagram N.B. this is a <i>show that Q</i> ; sufficient calculation must be present to indicate that the candidate has not worked back from the answer
(ii)	$k = (mg/x_0 = 1.2 / 0.050) = 24$ (N m ⁻¹) ($T = mg / \cos \theta = kx$ giving) $x = 1.2 / 24 \cos 22$ $x = 0.054$ (m)	C1 C1 A1	or solution by ratios
(c)	($y = \frac{1}{2}gt^2 \Rightarrow 0.18 = 0.5 \times 9.81 \times t^2$ giving $t = 0.19$ (s) ($x = vt \Rightarrow 0.42 \times 0.19 = 0.08$ (m) distance = $\sqrt{r^2 + x^2} = \sqrt{0.0020 + 0.0064} = 0.092$ (m)	C1 C1 C1 A1	alt: projectile motion: $x = vt$, $y = \frac{1}{2}gt^2$ $y = \frac{1}{2}g(x/v)^2$ ecf (b)i for v ; $x^2 = 2yv^2/g = 2 \times 0.18 \times 0.42^2/9.81$
(d)	T increases or string stretches or angle θ increases to provide/create a larger centripetal force	M1 A1	allow mv^2/r or $mr\omega^2$ in place of <i>centripetal force</i> causality must be implied to gain the A mark
	Total	12	

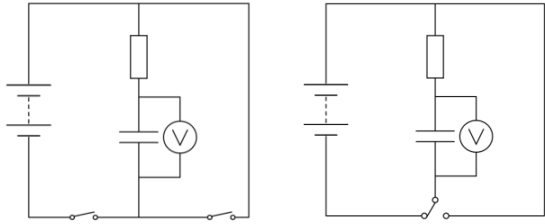
16	(a)	(i)	vertical component = $30.0 \sin(70^\circ)$ or $30.0 \cos(20^\circ)$ vertical component = $28.2 \text{ (m s}^{-1}\text{)}$	A1	Allow 2 SF answer of 28
		(ii)	Evidence of $v^2 = u^2 + 2as$ and $v = 0$ or $gh = \frac{1}{2} u^2$ $h = \frac{28.2^2}{2 \times 9.81}$ (Any subject) $h = 40.5 \text{ (m)}$	C1 M1 A0	Allow v and u interchanged; a and g interchanged Allow use of candidate's answer for (a)(i) at this point Ignore sign Allow $h = \frac{28^2}{2 \times 9.81}$ or $(30 \sin(70)) / (2 \times 9.81)$ No ECF from (a)(i) for the second mark
		(iii)	The ball has horizontal motion / velocity (AW)	B1	Allow idea of horizontal e.g. sideways, forwards Not: 'moving' unqualified
		(iv)	(horizontal velocity =) $30.0 \cos 70^\circ$ or $10.2 \text{ (m s}^{-1}\text{)}$ or $30.0 \sin 20^\circ$. $E_k = \frac{1}{2} \times 0.057 \times 10.26^2$ $E_k = 3.0 \text{ (J)}$	C1 A1	Allow 1 SF answer Not 22 (J), $v = 28$ used Not 23 (J), $v = 28.2$ used Not 140 (J), $v = 70$ used



Question	Answer	Marks	Guidance
(b)*	Level 3 (5–6 marks) Clear description and 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 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 limited analysis or 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 (NR) or no response worthy of credit (0).	B1× 6	Indicative scientific points may include: Description • Ruler used to determine x • Average readings to determine x • x recorded for various v • Suitable method for consistent v or varying v e.g. • Released from same point on a track • Ejected from a spring device with different compressions • Suitable method of determining point of impact e.g. • trial run to get eye in approximate correct position • carbon paper so that ball makes a mark on paper • scale in frame of video recording • tray of sand to catch ball • Suitable instrument used to determine v (light-gate / motion sensor / video techniques) or suitable description of inference of v from other measurements such as energy released from spring of known k and x • Ensuring the initial velocity of ball is horizontal Analysis • Horizontal velocity is constant • Time of fall is independent of v/horizontal velocity • Suggested relationship: e.g. $x \propto v$, x d.p. to v^2, etc • Plot a graph of x against v or graph consistent with candidate's suggested relationship • If relationship is correct, then a straight line through the origin. • Suggested relationship supported by correct physics or algebra. • Correct relationship supported by physics. Note: L1 is used to show 2 marks awarded and L1^ is used to show 1 mark awarded.
	Total	12	



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)	$L \rightarrow [m]$ and $A \rightarrow [m^2]$ or $L/A \rightarrow [m^{-1}]$ $kg\ m^3\ s^{-3}\ A^{-2}$	C1 A1	Allow $\frac{kg\ m^3}{s^3\ A^2}$ or $kg\ m^3/s^3\ A^2$
	(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)	$(\rho = \text{gradient} \times AE)$ $\rho = 2.8 \times \pi \times (0.19 \times 10^{-3})^2 \times 1.5$ $\rho = 4.8 \times 10^{-7}\ (\Omega\ m)$	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	

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 = $1.0 \times 10^{-6} \times 6.0 = 6.0 \times 10^{-6}$ (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 $0.9V_0$ (<5.4 V). 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 ($t < 0.1$ s). 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

20	a	i	Internal energy (of an ideal gas) is the sum of the (randomly distributed) kinetic energies of the particles	B1	Allow use of KE or E_k and atoms/molecules for particles. Ignore reference to PE (of particles)
		ii	evidence of $NkT = \frac{1}{3}Nm\overline{c^2}$ Manipulation to insert $\frac{1}{2}$ to give $\frac{1}{2}mc^2 = \frac{3}{2}kT$	M1 A1	
	b	i	(r.m.s. speed =) $\sqrt{\frac{310^2+370^2+440^2+550^2}{4}}$ r.m.s. speed evaluated as 427 (m s ⁻¹)	M1 A1	Not arithmetic mean 418. Treat as XP. Allow 729100 as evidence of summation of squares Allow mean squared speed = 182275 (m ² s ⁻²) Allow any candidate evaluation that rounds to or is 427 i.e. 426.93...
		ii	$\frac{1}{2}mc^2 = \frac{3}{2}kT$ $\frac{1}{2}m \times 430^2 = \frac{3}{2} \times 1.38 \times 10^{-23} \times 290$ (molar mass = $6.02 \times 10^{23} \times 6.49 \times 10^{-26}$) molar mass = 0.039 (kg mol ⁻¹)	C1 C1 A1	allow $\frac{1}{2}Mc^2 = \frac{3}{2}RT$ allow any valid rearrangement allow $\frac{1}{2}M \times 430^2 = \frac{3}{2} \times 8.31 \times 290$ allow $m = 6.5 \times 10^{-26}$ (kg) or $m = 6.7 \times 10^{-26}$ (kg) Using 427 m s ⁻¹ gives 0.0396 i.e. 0.040
	c	i	Energy transferred from electrical (energy) to internal (energy) or thermal (energy) of filament	B1	Allow power supply doing electrical work on filament



Question			Answer	Mark	Guidance
			Energy transferred from filament to internal energy of gas	B1	Allow heating of gas by conduction Allow description of Newton's Law of Cooling Allow heating of gas by radiation
			(because) the (rate of) energy lost to the surroundings = the (rate of) energy transfer gained (by filament)	B1	Allow reference to thermal equilibrium of any part or whole of lamp structure
		ii	$(P/T = \text{constant}) \frac{120}{2400} = \frac{p}{290}$	C1	
			pressure = 14.5 (kPa)	A1	Allow 15 Allow 14
			TOTAL	13	

Question	Answer	Mark	Comments
18 (a) (i)	$\text{volume} = 7.0 \times 10^{-2} \times \pi \times (0.5 \times 10^{-2})^2$ or $5.5 \times 10^{-6} \text{ (m}^3\text{)}$ $\rho = 5.0 \times 10^{-3} / (7.0 \times 10^{-2} \times \pi \times (0.5 \times 10^{-2})^2)$ density = 910 (kg m ⁻³)	C1 A1	No ecf for incorrect volume. Answer to 3 s.f. is 909 Allow 1 mark for 230 ($r = 1.0 \times 10^{-2} \text{ m}$ used)
(ii)	The density (of wood is) similar to human (AW) Less than density of water / it needs to float / otherwise it will sink	B1 B1	Allow 'greater upthrust than weight when fully submerged'
(b)	$(v^2 = 2as + u^2); v = (2 \times 9.81 \times 0.30)^{1/2}$ (Allow any subject) speed = 2.4 (m s ⁻¹)	C1 A1	Allow ($s = \frac{1}{2} a t^2$) to give $t = 0.247$ and ($v = at$) gives 2.42
(c) (i)	weight / W / mg and downward arrow upthrust / U and upward arrow drag / D / friction and upward arrow	B1 B1 B1	Allow labels used in (c)(i) throughout Ignore arrow sizes. Allow '(water) resistance' for drag
(ii)	Resultant force decreases (with time or as cylinder descends) Upthrust remains constant / drag decreases (as speed decreases) / resultant force is upwards / At lowest point, drag is zero At lowest point, resultant force is upwards	B1 B1 B1	Allow 'At lowest point, upthrust > weight' Note: Any incorrect answer from the list will not score this point Not 'resultant force = 0' Note: Resultant force is <u>always</u> upwards' scores B1x2
(d)	Doubling the depth is too much / d is not (directly) proportional to h Qualifying statement using evidence from graph e.g. decreasing gradient, use of numbers to show not proportional, comment about non-zero intercept etc	B1 B1	
	Total	14	

2	(a)	$x = x_0 e^{-t/RC}$ or $\frac{x_0}{2} = x_0 e^{-T/RC}$ and (total) resistance = NR and (total) capacitance = NC $\frac{1}{2} = e^{-\frac{T}{NR \times NC}}$ with clear steps leading to $T = (\ln 2)N^2 RC$	M1 Allow $x = x_0 e^{-T/RC}$ Allow any letter for x except N Allow τ for RC Not $x = x_0 (1 - e^{-t/RC})$ Not $R_T C_T = N^2 CR$ alone but allow $R_T C_T = NR \times NC$																												
	(b)	a measurement is precise if repeat readings are closely clustered (or reverse argument) quantitative data used to support their conclusion	A1 Intermediate working must be shown in full e.g. $\ln^{1/2} = -\frac{T}{NR \times NC}$ so $\frac{T}{NR \times NC} = \ln 2$ Do not allow incorrect negative signs in working or in answer																												
			B1 Allow if there is a small spread (of results about the mean value) / small range / small uncertainties (or small error bars on graph) Ignore comments about number of sig figs																												
			B1 Either range, absolute or % error calculated correctly for at least one stated value of N <table border="1"> <thead> <tr> <th>N</th><th>Range /s</th><th>abs unc/s)</th><th>%unc</th></tr> </thead> <tbody> <tr> <td>1</td><td>0.6</td><td>+/- 0.3</td><td>2.1 or 4.2</td></tr> <tr> <td>2</td><td>0.7</td><td>+/- 0.4</td><td>0.8 1.6</td></tr> <tr> <td>3</td><td>1.4</td><td>+/- 0.7</td><td>0.6 1.2</td></tr> <tr> <td>4</td><td>1.6</td><td>+/- 0.8</td><td>0.4 0.8</td></tr> <tr> <td>5</td><td>10.5</td><td>+/- 5.3</td><td>1.5 3.0</td></tr> <tr> <td>6</td><td>13.2</td><td>+/- 6.6</td><td>1.3 2.6</td></tr> </tbody> </table>	N	Range /s	abs unc/s)	%unc	1	0.6	+/- 0.3	2.1 or 4.2	2	0.7	+/- 0.4	0.8 1.6	3	1.4	+/- 0.7	0.6 1.2	4	1.6	+/- 0.8	0.4 0.8	5	10.5	+/- 5.3	1.5 3.0	6	13.2	+/- 6.6	1.3 2.6
N	Range /s	abs unc/s)	%unc																												
1	0.6	+/- 0.3	2.1 or 4.2																												
2	0.7	+/- 0.4	0.8 1.6																												
3	1.4	+/- 0.7	0.6 1.2																												
4	1.6	+/- 0.8	0.4 0.8																												
5	10.5	+/- 5.3	1.5 3.0																												
6	13.2	+/- 6.6	1.3 2.6																												

Question		Answer	Mark	Guidance
2	(c)	14.4 <u>and</u> 50.0	B1	Both values given to 1dp Mark entries in first table (on page 4) only if second table (on page 6) is left blank
	(d)	(i)		
		y-axis labelled " T / s "	B1	Allow suitable equivalent e.g. T (s), Time in secs
		y-axis scale completed correctly	B1	Scales markings of 100, 200, 300, 400 and 500 every 2 cm
		all six x-co-ordinates correctly plotted	M1	Check at 1, 4, 9, 16, 25 and 36; $\pm\frac{1}{2}$ small square tolerance.
		all six data points plotted accurately	A1	Check visually by fit to bfl; $\pm\frac{1}{2}$ small square tolerance. ECF candidate's values for $N = 1$ and 2
		(ii)		
		suitable best fit line	B1	There must be an even scatter of points above and below the line
2	(d)	(iii)		
		evidence of use of at least half of the width of the drawn line	B1	Evidenced by triangle drawn on graph or by Δx in working for gradient

Question			Answer	Mark	Guidance
			Gradient =14 (s)	B1	Correct line should have $\Delta x \geq 17.5$ Allow any answer between 13 and 15(s) ECF candidate's own best fit line
		(iv)	$R = \frac{\text{gradient}}{C \ln 2}$ Value of R is in the range 19 – 22 (k Ω) uncertainty is 5% of R with value given to same number of dp as R	B1 B1	For reference, R in k Ω = $\frac{\text{gradient value in d(iii)}}{0.69}$ ECF candidate's gradient value in d(iii) Allow answer given in Ohms if unit clearly stated Allow answer given to 1sf i.e. 20 (k Ω) Expect 1 (k Ω) Allow to more than 1 s.f. but uncertainty <u>must</u> be given to same number of d.p. as candidate's value for R If answer given in Ohms, allow uncertainty also given in Ohms to same number of d.p. as R
	(e)	(i)	systematic	B1	
		(ii)	(smaller T value for N = 6 so) smaller gradient and therefore smaller R value	B1	Ignore references to smaller or bigger C
			Total	16	

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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14	A		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	

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	

17	(a)		Any <u>one</u> from: current, temperature, light intensity and amount of substance / matter	B1	Not: ampere, kelvin, candela and mole Not correct quantity with its unit, e.g. current in <u>A</u> or current (A)
	(b)	(i)	$R = \frac{\rho L}{A} \quad \text{and} \quad A = \pi \left(\frac{d}{2} \right)^2$ $R_x = \frac{4\rho L}{\pi d^2} \quad \text{and} \quad R_y = \frac{8\rho L}{\pi d^2}$ Clear steps leading to $R = \frac{12\rho L}{\pi d^2}$	M1 A1	
		(ii)1	Ruler / tape measure (for L) and micrometer (for d)	B1	Allow (vernier / digital) calipers or travelling microscope for micrometer
		(ii)2	$R = 2.3(4) (\Omega)$ $\frac{0.1}{9.5} \quad \text{or} \quad 2 \times \frac{0.003}{0.270}$ $\frac{0.1}{9.5} + 2 \times \frac{0.003}{0.270} \quad \text{or} \quad 0.0327 \quad \text{or} \quad 3.27\%$ absolute uncertainty in $R = 0.0327 \times 2.34 = 0.077$ $R = 2.3 \pm 0.1 (\Omega)$	C1 C1 C1 A1	Allow other correct methods for getting $2.3 \pm 0.1 (\Omega)$ Allow 2 or more sf for this C1 mark Note 0.0105 or 1.05% or 0.0222 or 2.22% scores this mark, allow 2sf or more Allow: $2.34 \pm 0.08 (\Omega)$ Note use of R_x or R_y instead of R can score the second and third C1 marks only
		(ii)3	(The actual) R is large(r) because (the actual) d is small(er) or (the actual) A is small(er) or $R \propto 1/d^2$	B1	Allow: The <u>calculated</u> R is small(er) because (the measured) A is large(r) or $R \propto 1/d^2$
			Total	9	

8

Question	Answer	Marks	Guidance
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2	(a)	(i)	$R = 3000 + 1500$ $V = 12 \times 1500/4500 = 4.0 \text{ (V)}$	C1	$R = 4500 \text{ (}\Omega\text{)}$
				A1	<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

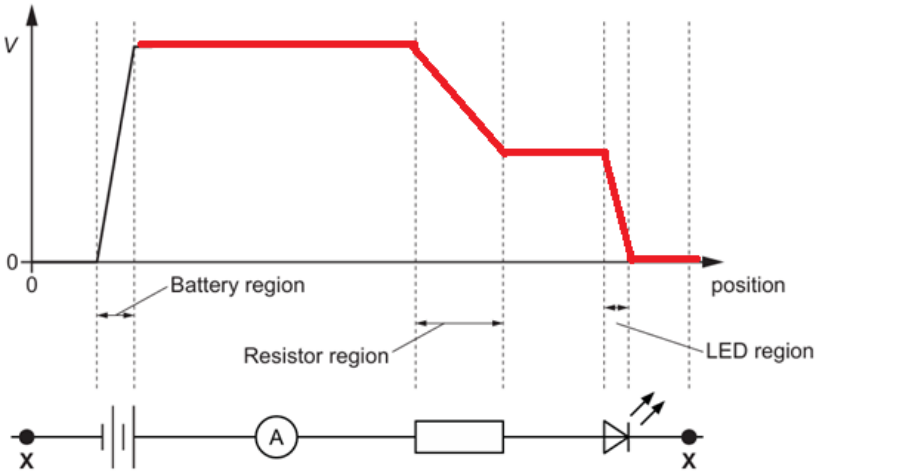
October 2021

Question	Answer	Marks	Guidance
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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

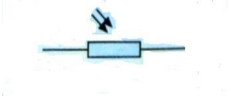
16	(a)	Potential divider / Series (circuit)	B1	IGNORE potentiometer
16	(b)	An arrow pointing in the correct direction (clockwise)	B1	ALLOW any arrow indicating correct direction All arrows drawn must be in the correct direction
16	(c)	(Ammeter reading) decreases (Voltmeter reading) increases	B1 B1	
16	(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.

Question		Answer	Mark	Guidance
16	(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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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
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 (kΩ) $I = 4.0/3.0 = 1.33 \times 10^{-3} \text{ A}$ or $R = 2.0/4.0 \times 3.0 \times 10^3$ $R = (6.0 - 4.0)/1.33 \times 10^{-3} = 1.5 \times 10^3 (\Omega)$	B1 C1 A1	allow $3.1 \pm 0.1 \text{ (k}\Omega\text{)}$ accept 1.3 mA; accept potential divider argument allow 1.5 kΩ; 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 (W m ⁻²)	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



H556/03

Mark Scheme

June 2017

Question	Answer	Marks	Guidance
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6	B	1	
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8	A	1	
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Question	Answer	Mark	Comments
21 (a)	$\varepsilon = 7.2 \times 10^{-12} \times 1.2 \times 10^{-3} / 4.0 \times 10^{-4}$ 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	

22	(a)	$(V = V_0 e^{-t/CR}) \quad \ln(V/V_0) = -t/CR \quad \text{or} \quad \ln V = \ln V_0 - t/CR$ $\ln V = \ln V_0 - t/CR \quad \text{and} \quad y = mx + c \quad / \quad \text{gradient} = -1/CR$	B1 B1	Note the minus sign is necessary
	(b)*	Level 3 (5–6 marks) Clear description and correct value of C <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 and some correct working OR Some description and correct value for C <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 description OR Some working <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 • $C = \epsilon A/d$ • A = area (of overlap) and d = separation. • Use ruler to measure the side / radius / diameter (and hence the area A) • Ensure total overlap of plates. • Measure the thickness / d of paper using micrometer / (vernier) caliper. • Take several readings of thickness and determine an average value for d Calculation of capacitance • gradient ≈ 85 • $C \approx 1.2 \times 10^{-8}$ (F)
		Total	8	

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	

Question	Answer	Marks	Guidance
1 *(a)	Level 3 (5–6 marks) Clear description and 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 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 or 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 - Determine R_0 using ice water mixture or* - Record V and I for various temperatures - If wire is not insulated some conduction through water/use insulated wire - Use small current to minimise heating effect or connect to supply for short time for readings - Stir the water - Wait for temperature to stabilise/bath to come to equilibrium - Avoid parallax errors when reading instruments - Comment about large scale increments on instruments/digital meters for precision of measurements/AW Analysis - Determine resistance from $R = V/I$ - Graph of R against θ is a straight line / Graph of R/R_0 against θ is a straight line - Correct interpretation of gradient m to find k; i.e. $k = m/R_0$ or $k = m$ *R_0 by extrapolation from linear graph *descriptors D1 and A4 are alternatives

Question			Answer	Marks	Guidance
	(b)	(i)	$R = V^2/P$ or $P = V^2/R$ $R = 230^2/1000 = 52.9$ or $53(\Omega)$	C1 A1	or $P = VI$ and $R = V/I$ with $I = 4.34$ (A) This is a 'show that' question so the A1 mark is for giving both the full substitution of values and the final answer. The final answer may be to 2 or more SF.
		(ii)	number of turns, $n = 180/1.5$ (= 120) length ($l = \pi dn$) = 3.14 (or π) $\times 0.014 \times 120 = 5.28$ (m)	C1 A1	This is a 'show that' question so the A1 mark is for giving both the full substitution of values and the final answer. The final answer may be to 2 or more SF.
		(iii)	$A = (\rho l/R) = 1.1 \times 10^{-6} \times 5.28/52.9$ $A = 0.11 \times 10^{-6} \text{ (m}^2\text{)}$ so swg = 28	M1 A1 A1	allow 53 allow solution which calculates diameter of wire using $\pi d^2/4$ rather than finding A give max 1/3 for using data from the table, i.e. finding $R = 53 \Omega$ using correct value of A or $d = 0.37$ (mm) the A marks cannot be awarded unless the M mark is awarded.
			Total	13	

Question	Answer	Marks	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

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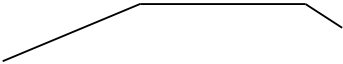
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2	(a)	(i)	use (vernier / digital / dial) calliper(s) or micrometer (taking readings) at different positions / orientations (along the wire)	B1 B1	 Ignore take multiple readings
		(ii)	exclude the 0.495 (mm) anomaly add the remaining 4 values and divide 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 ($\text{A}^{-1} \text{m}^{-1}$) $\rho = \frac{\pi \times (0.455 \times 10^{-3})^2 \times 1.45 \times \text{gradient}}{4}$ $\rho = 1.2 \times 10^{-6} \text{ } (\Omega \text{ m})$	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	$r = \text{y-intercept} \times \varepsilon = 0.40 \times 1.45$ $r = \mathbf{0.58(\Omega)}$ $\text{y-intercept}_{MAX} = 0.73 \text{ (A}^{-1}\text{)}$ EITHER Fractional uncertainty in $r =$ $0.05/1.45 + 0.33/0.40 = 0.034 + 0.825$ $= 0.86$ $0.86 \times 0.58 = 0.5(\Omega) \text{ to 1sf so}$ $r = \mathbf{0.6 \pm 0.5 (\Omega)}$ OR $r_{MAX} = \text{y-intercept}_{MAX} \times \varepsilon_{MAX} = 0.73 \times 1.5$ $= 1.1(\Omega)$ $1.1 - 0.58 = 0.5(\Omega) \text{ to 1sf so}$ $r = \mathbf{0.6 \pm 0.5 (\Omega)}$	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	

6	(a)		$P = V^2 / R$ $R = 12^2 \div 40 =$ 3.6 (Ω)	C1 A1	Allow $I = P/V$ ($= 3.3A$) 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



2	C		1	
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5	A		1	
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14	D	1	
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3	D	1	
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4	A	1	
---	---	---	--



7	C	1	
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5	(a)	(i)	$(W = \frac{1}{2} C V^2 \text{ so})$ $400 \times 10^6 = 0.5 \times C \times (24 \times 10^3)^2$ C = 1.4 (F)	C1 A1	Allow $W = \frac{1}{2} Q V$ and $C = Q / V$ $(Q = 3.3 \times 10^4 \text{ (C) so})$ $C = Q / V = 3.3 \times 10^4 / 24 \times 10^3$
		(ii)	(putting capacitors in parallel) increases the total capacitance ORA	B1	Allow $C_T = C_1 + C_2 + \dots$ or capacitors add together (in parallel) Ignore capacitors in parallel can store more charge/energy
	(b)		power $\approx 400 \times 10^6 / 10^{-3} = 4.0 \times 10^{11} \text{ (W)}$ power required is equivalent to output of ≈ 400 power stations or time taken for power station to release stored energy $= 400 \times 10^6 / 10^9 = 0.40 \text{ s}$ 0.4s is (much) longer than 1 ms	M1 A1 (M1) (A1)	Allow ECF (a)(i) for incorrect POT in 400GW Allow this is <u>much</u> more than could be provided by one power station or $4.0 \times 10^{11} \text{ (W)} \gg 1 \text{ GW}$ Ignore comments about household supply Allow ECF (a)(i) for incorrect POT in 400GW Allow it would take more time / too long

5	(c)	(mass defect in u =) $(2.014102 + 3.016049 - 4.002603 - 1.008665) \text{ u}$ $(= 0.018883 \text{ u})$ (mass defect in kg =) $0.018883 \times 1.661 \times 10^{-27}$ $(= 3.1365 \times 10^{-29})$ (energy per fusion reaction in J = mc^2 =) $3.1365 \times 10^{-29} \times (3.00 \times 10^8)^2$ $(= 2.82 \times 10^{-12})$ (number of fusion reactions = $\frac{\text{energy needed}}{\text{energy per fusion reaction}} =$ $400 \times 10^6 / 2.82 \times 10^{-12} =$) 1.4×10^{20}	Allow ECF for mass defect throughout unless XP C1 Mark is for correct working leading to the answer. Answer does not need to be calculated but 0.018883 u (not just 0.018883) implies C1 Allow negative answer C1 Mark is for substituting $u = 1.661 \times 10^{-27} \text{ (kg)}$, seen anywhere in the working Allow 1.66×10^{-27} or 1.67×10^{-27} for 1.661×10^{-27} Answer need not be calculated but 3.1365×10^{-29} implies first two C1 marks C1 Mark is for multiplying mass defect by $(3.00 \times 10^8)^2$, seen anywhere in the working Answer need not be calculated but 2.82×10^{-12} implies all three C1 marks A1 Ignore unit if given Allow ECF (a)(i) or (b) for incorrect POT in 400GW Note for markers: calculation in kg $3.34542 + 5.00966 - 6.64832 - 1.67539 (\times 10^{-27})$ $= (8.35508 - 8.32372) \times 10^{-27} (= 3.136 \times 10^{-29} \text{ kg})$ Note for markers: calculation in J $3.01088 + 4.50869 - 5.98349 - 1.50785 (\times 10^{-10})$ $= (7.51957 - 7.49134) \times 10^{-10} (= 2.82 \times 10^{-12} \text{ J})$
		Total	9

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	

21	(a)		When switch is opened, there is (rate of) change in (magnetic) flux (linkage) which induces an emf / current as the (magnetic) flux links to B which causes the lamp to light (Lamp off) at start / end there is constant flux / no change in (magnetic) flux (linkage for coil B)	B1 B1 B1	Not just a statement of Faraday's law Allow flux is cut by B
	(b)	(i)	Oscilloscope / CRO	B1	Allow a.c. voltmeter Ignore datalogger / multimeter
		(ii)1	f	B1	Not any other symbol. Only mark quantity letters – ignore any words, but allow frequency.
		(ii)2	θ or $\sin \theta$	B1	Allow θ or $\sin \theta$ with any or all of K , I_0 , A , N . Only mark quantity letters – ignore any words.
		(iii)	$f = \frac{0.62}{5000 \times 4.0 \times 10^{-3} \times 8.0 \times 7.8 \times 10^{-5}} \quad / \quad f = 49.67 \quad . \text{ (Hz)}$ $\frac{0.2}{8.0} \quad / \quad \frac{0.1}{7.8} \quad / \quad \frac{0.03}{0.62}$ $\text{abs uncertainty} = \left(\frac{0.2}{8.0} + \frac{0.1}{7.8} + \frac{0.03}{0.62} \right) \times 49.67 \dots \quad / \quad 4.28 \quad \text{(Hz)}$ $f = 50 \pm 4 \text{ (Hz)}$	C1 C1 C1 A1	Any individual raw uncertainty Max value = 54.11 (Hz) and min value = 45.54 (Hz) for f Allow 8.6% as evidence of this calculation For min / max method: difference / 2 = 4.29 (Hz) Allow ecf on abs uncertainty from incorrect f Any ecf on f must be given to 2sf and uncertainty sf consistent. Not the paper SF penalty
			Total	10	

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	

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																									