

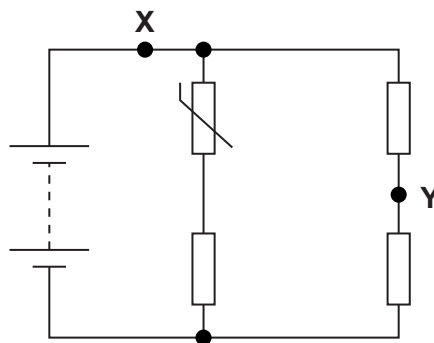
3 Which is **not** a unit of energy?

- A kWh
- B eV
- C J
- D W

Your answer

[1]

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]

2
SECTION A

You should spend a maximum of 30 minutes on this section.

Write your answer to each question in the box provided.

Answer **all** the questions.

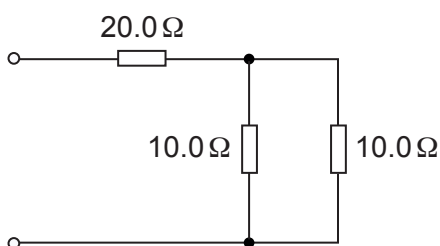
- 1** Which electrical quantity has S.I. units ampere-second (As)?

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

Your answer

[1]

- 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?

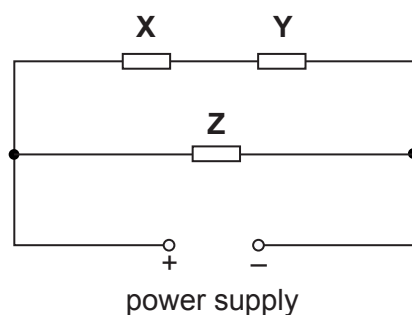
- A** $10.0\ \Omega$
- B** $20.2\ \Omega$
- C** $25.0\ \Omega$
- D** $40.0\ \Omega$

Your answer

[1]

4

- 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]

- 6 Which is the **best** value for the elementary charge e in terms of both accuracy and precision?

- A $(1.5 \pm 0.5) \times 10^{-19} \text{ C}$
- B $(1.5 \pm 0.4) \times 10^{-19} \text{ C}$
- C $(1.7 \pm 0.2) \times 10^{-19} \text{ C}$
- D $(1.8 \pm 0.2) \times 10^{-19} \text{ C}$

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.

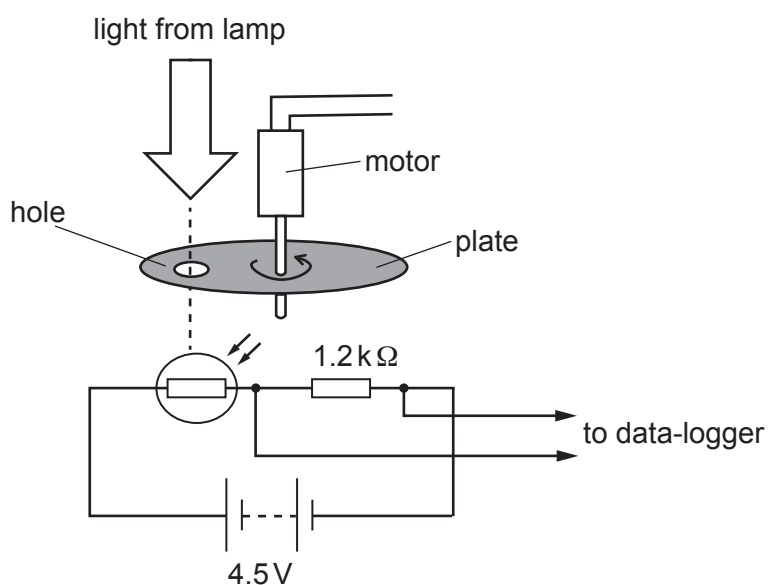


Fig. 17.1

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

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

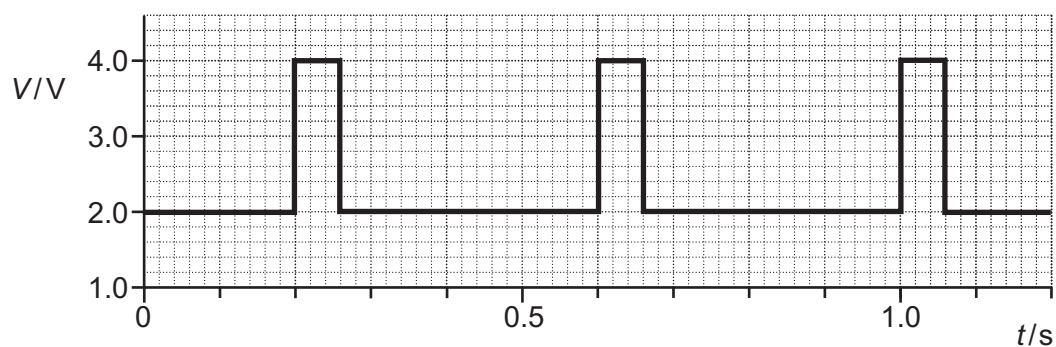


Fig. 17.2

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

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

[6]

- 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.

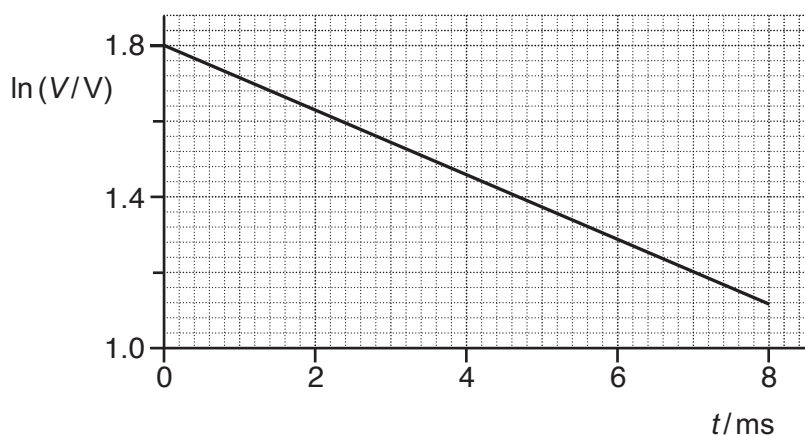


Fig. 22

- (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

2
SECTION A

You should spend a maximum of 30 minutes on this section.

Write your answer to each question in the box provided.

Answer **all** the questions.

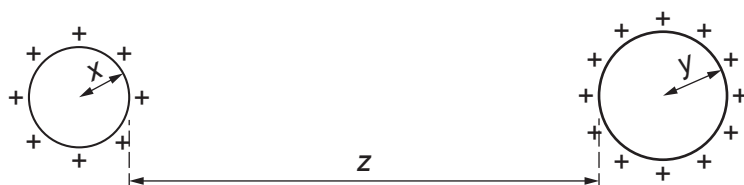
1 Which law indicates that charge is conserved?

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

Your answer

[1]

2 The diagram below shows two uniformly charged spheres separated by a large distance z .



The radius of the small sphere is x and the radius of the large sphere is y .

Which is the correct distance to use when determining the electric force between the charged spheres?

- A** z
- B** $x + z$
- C** $y + z$
- D** $x + y + z$

Your answer

[1]

SECTION B

Answer **all** the questions.

16 This question is about waves.

- (a) The **period** of a progressive wave can be determined from Fig. 16.1. Add a correct label to the horizontal axis so that the period can be found. [1]

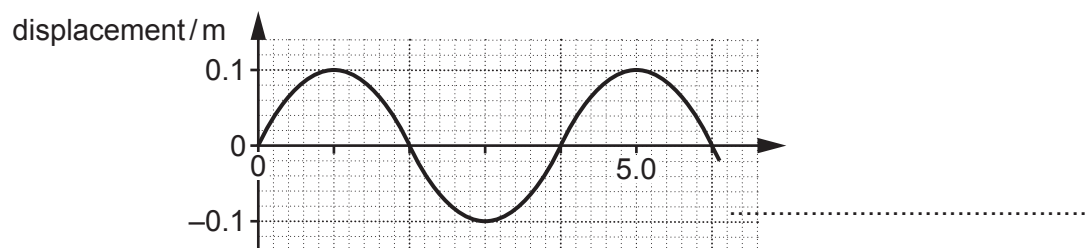


Fig. 16.1

- (b) A progressive wave has wavelength λ , frequency f and period T .

Show that the speed v of the wave is given by the equation $v = f\lambda$.

[2]

- (c) A scientist is investigating the interference of light using very thin transparent material. A sample of the transparent material is placed in a vacuum. Fig. 16.2 shows the path of two identical rays of light **L** and **M** from a laser.

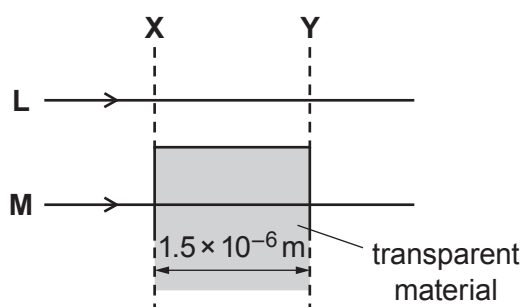


Fig. 16.2

The refractive index of the material is 1.20. The thickness of the material is $1.5 \times 10^{-6} \text{ m}$. The wavelength of the light in vacuum is $6.0 \times 10^{-7} \text{ m}$.

- (i) Show that the difference in time t for the two rays to travel between the dashed lines **X** and **Y** is 1.0×10^{-15} s.

$$t = \dots\dots\dots \text{ s [3]}$$

- (ii) Calculate the period T of the light wave.

$$T = \dots\dots\dots \text{ s [2]}$$

- (iii) The rays of light are in phase at the dashed line **X**.

Use your two answers above to state the phase difference ϕ in degrees between the light rays at **Y**.

$$\phi = \dots\dots\dots^\circ \text{ [1]}$$

Question 16 continues on page 12

- (d)*** The speed v of surface water waves in shallow water of depth d is given by the equation $v = \sqrt{gd}$, where g is the acceleration of free fall.

The speed v is about 1 m s^{-1} for a depth of about 10 cm.

You are provided with a rectangular plastic tray, supply of water and other equipment available in the laboratory.

Describe how an experiment can be conducted in the laboratory to test the validity of the equation above and how the data can be analysed to determine a value for g . [6]

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Additional answer space if required.

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

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..... [2]

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

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

base units for ρ [2]

Question 18 continues on page 16

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

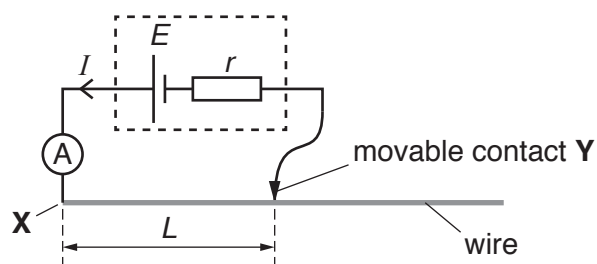


Fig. 18.1

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

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

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

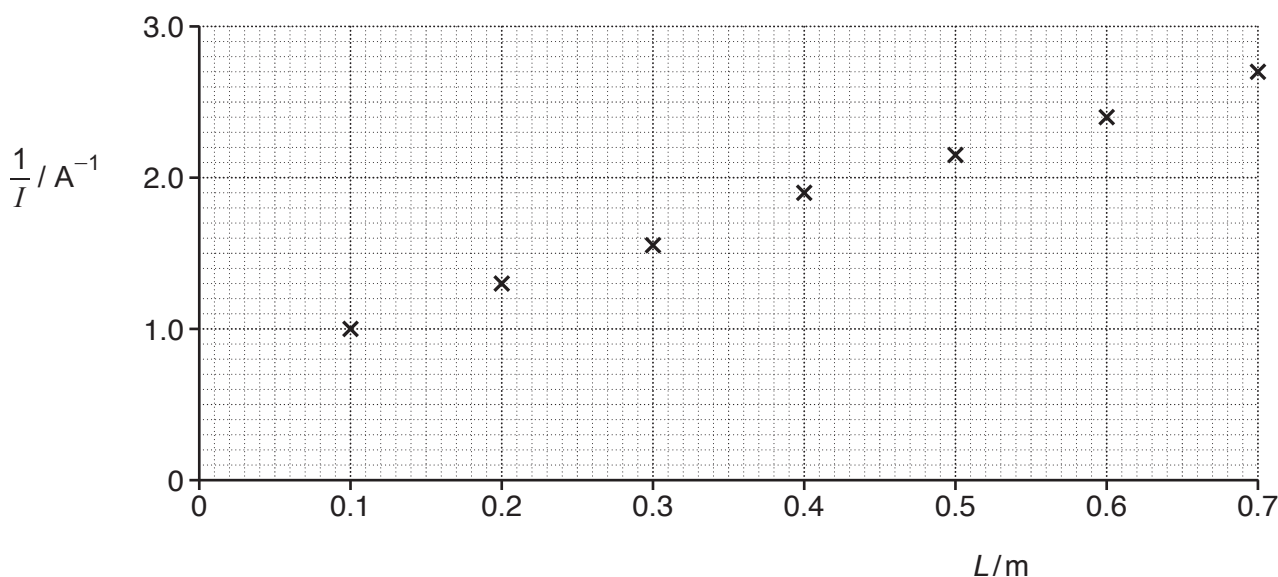


Fig. 18.2

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

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

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

[2]

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

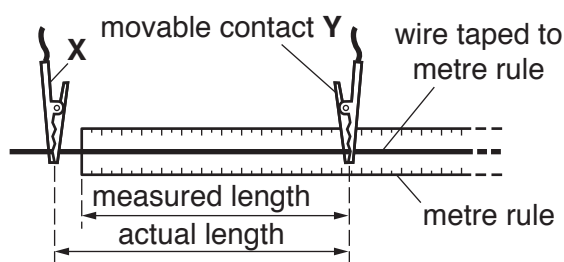


Fig. 18.3

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.

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..... [2]

- 22 (a) Fig. 22.1 shows two horizontal metal plates in a vacuum.

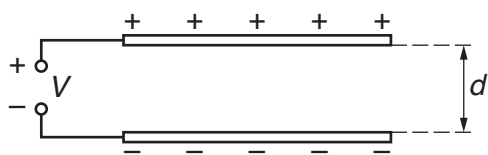


Fig. 22.1

The plates are connected to a power supply. The potential difference V between the plates is constant. The magnitude of the charge on each plate is Q . The separation between the plates is d .

Fig. 22.2 shows the variation with d of the charge Q on the positive plate.

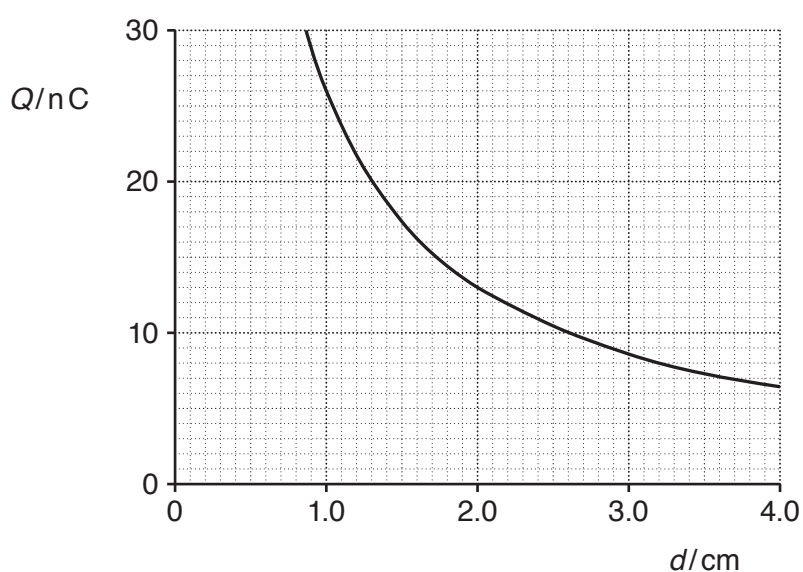


Fig. 22.2

- (i) Use Fig. 22.2 to propose and carry out a test to show that Q is inversely proportional to d .

Test proposed:

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Working:

- (ii) Use capacitor equations to show that Q is inversely proportional to d .

[2]

- (b) Fig. 22.3 shows a negatively charged oil drop between two oppositely charged horizontal plates in a vacuum.

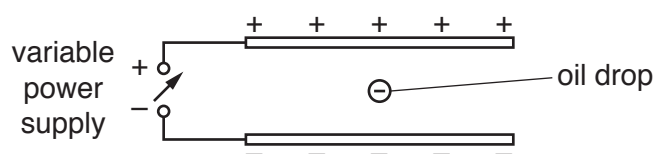


Fig. 22.3

The plates are fixed and connected to a variable power supply. The weight of the oil drop is $1.8 \times 10^{-14} \text{ N}$.

- (i) The power supply is adjusted so that the potential difference between the plates is 200 V when the oil drop becomes **stationary**.

State the magnitude of the vertical electric force F_E acting on the charged oil drop.

$$F_E = \dots\dots\dots \text{ N [1]}$$

- (ii) The potential difference between the plates is now increased to 600 V. The oil drop accelerates upwards.

Calculate the acceleration a of the oil drop.

$$a = \dots\dots\dots \text{ ms}^{-2} [3]$$

Question 22 continues on page 26

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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- 19 (a) The Planck constant h is an important fundamental constant in quantum physics.

Determine the S.I. base units for h .

base units = [2]

- (b) A researcher is investigating the de Broglie wavelength of charged particles.

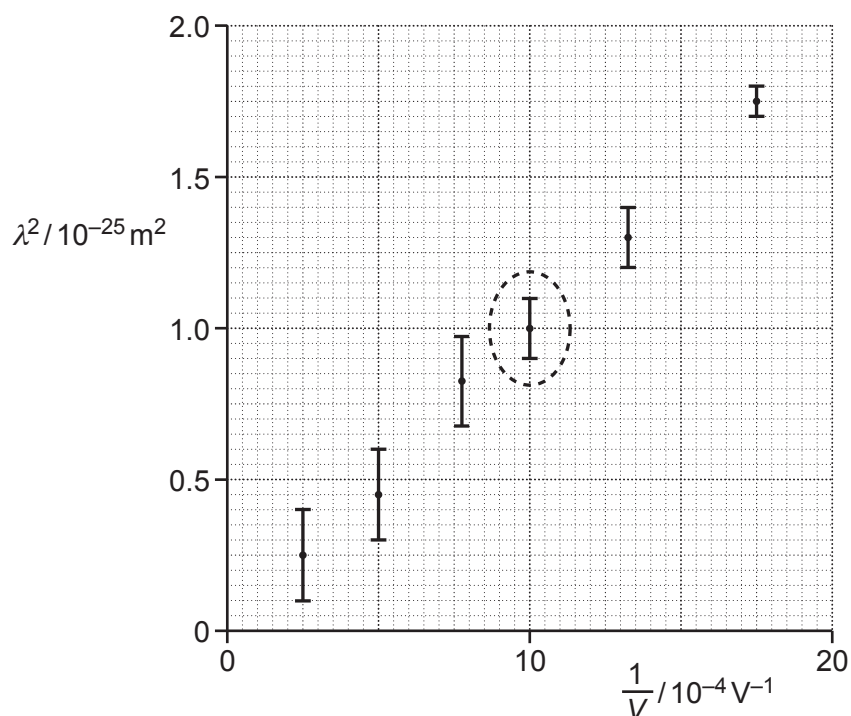
The charged particles are accelerated through a potential difference V . The de Broglie wavelength λ of these particles is then determined by the researcher.

Each particle has mass m and charge q .

- (i) Show that the de Broglie wavelength λ is given by the expression $\lambda^2 = \frac{h^2}{2mq} \times \frac{1}{V}$.

[2]

- (ii) The researcher plots data points on a λ^2 against $\frac{1}{V}$ grid, as shown below.



- 1 Calculate the percentage uncertainty in λ for the data point circled on the grid.

percentage uncertainty = % [2]

- 2 Draw a straight line of best fit through the data points. [1]

- 3 The charge q on the particle is $2e$, where e is the elementary charge.

Use your best fit straight line to show that the mass m of the particle is about 10^{-26} kg.

[4]

21

- 21 (a) In the 1800s, the atom was considered to be a fundamental particle. It was an indivisible particle of matter. Modern physics shows that this idea is not correct.

Describe the fundamental particles within an atom of carbon-14 ($^{14}_6\text{C}$).
In your answer state the composition of the hadrons.

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..... [4]

- (b) The half-life of the isotope carbon-14 is 5700 years (y).

(i) Show that the decay constant λ for this isotope is about $1.2 \times 10^{-4} \text{y}^{-1}$.

[1]

- (ii) Carbon-dating is a technique used to date an ancient wooden axe.
The ratio of carbon-14 to carbon-12 in the axe material is 78% of the current ratio of carbon-14 to carbon-12 in a living tree.

Calculate the age in years of the wooden axe.

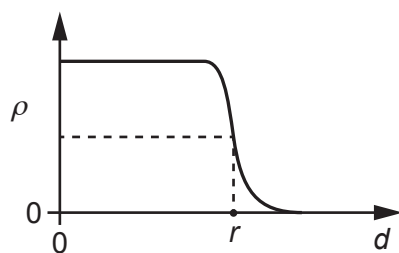
age = y [3]

- (iii) State **one** assumption made in the calculation in (ii).

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..... [1]

(c)* A graph of the density ρ of a nucleus against distance d from the centre of the nucleus is shown below.



The radius of the nucleus r is taken as the distance d where the density is half the maximum density.

Fig. 21.1 shows the density ρ variation for three different nuclei and **Table 21.1** shows the nucleon number A of each nucleus.

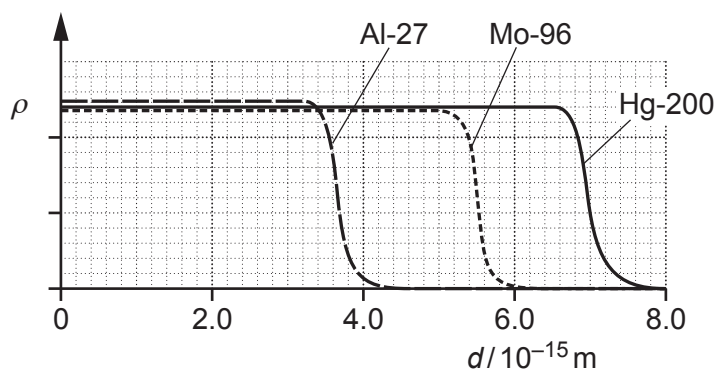


Fig. 21.1

Nucleus	Nucleon number A
Al-27	27
Mo-96	96
Hg-200	200

Table 21.1

Use the information provided opposite to

- describe how the density of a nucleus depends on its nucleon number A
- show numerically that $r \propto A^{1/3}$
- estimate the mean density of the nuclei.

[6]

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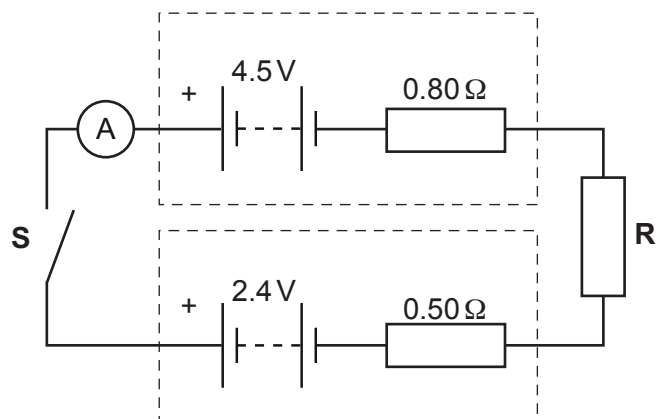
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- 18 (a) The circuit diagram of an electrical circuit is shown below.



The positive terminals of the batteries are connected together.
One battery has electromotive force (e.m.f.) 4.5 V and internal resistance 0.80 Ω.
The other battery has e.m.f. 2.4 V and internal resistance 0.50 Ω.
R is a coil of insulated wire of resistance 1.2 Ω at room temperature.

The switch **S** is closed.

- (i) On the diagram, draw an arrow to show the direction of the conventional current. [1]
(ii) Calculate the current I shown by the ammeter.

$I = \dots\dots\dots$ A [3]

16

- (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**.

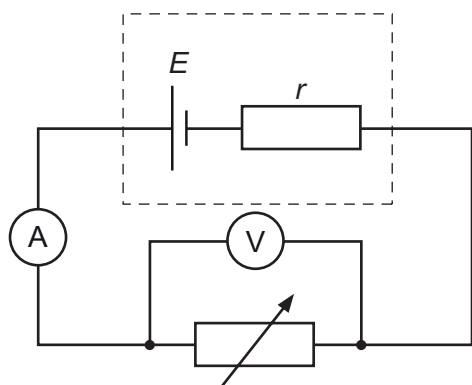
$$v = \dots\dots\dots \text{ m s}^{-1} \text{ [2]}$$

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

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

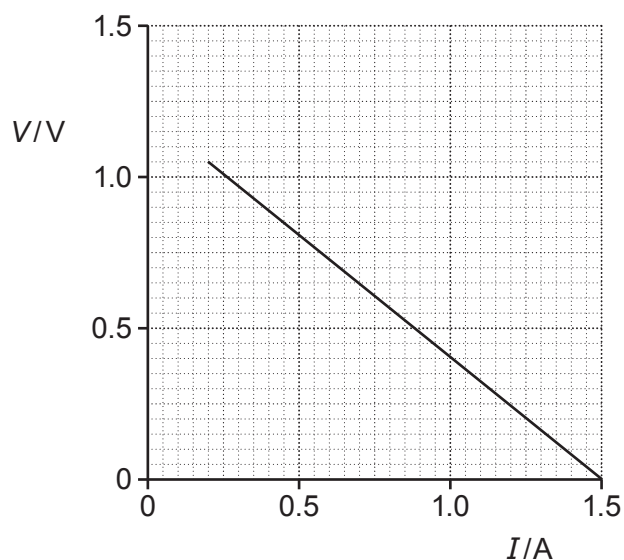
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..... [2]

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



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

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



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

There is an incomplete table next to the graph.

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

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

[6]

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Additional answer space if required

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Section A

You should spend a **maximum** of **30 minutes** on this section.

Write your answer to each question in the box provided.

1 Which of these units is a base unit?

A A

B J

C m^2

D N

Your answer

[1]

2 The accepted value of g is 9.81 ms^{-2} . In an experiment to verify the value of g , students obtained a value of 10.20 ms^{-2} .

What is the percentage difference between the students' value and the accepted value of g ?

A 1%

B 2%

C 4%

D 8%

Your answer

[1]

3 Which of these statements is/are true?

1 Antiprotons are hadrons so are subject to the strong nuclear and weak nuclear forces.

2 Neutrons are subject to the weak nuclear force only.

3 The weak nuclear force is the only force that causes a change of quark type.

A 1, 2 and 3

B Only 1 and 2

C Only 1 and 3

D Only 3

Your answer

[1]