Resistivity

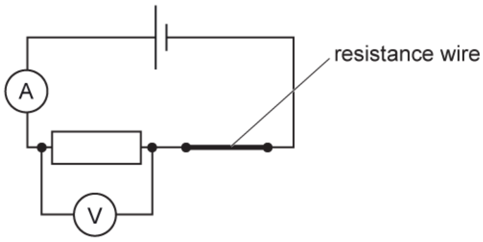
1. Wire **P** has length *L*, diameter *d* and a resistance of 1.00 Ω.
Another wire **Q** made from the same metal has length 3*L* and diameter 2*d*.

What is the resistance of wire **Q**?

A 0.750Ω
B 1.00Ω
C 1.33Ω
D 1.50Ω

Your answer [1]

2. A resistance wire is part of an electrical circuit, as shown below.



The resistance wire is pulled so that it becomes longer and thinner.

Which statement is correct?

A The ammeter reading increases.
B The resistance of the wire decreases.
C The total resistance of the circuit remains constant.
D The voltmeter reading decreases.

Your answer [1]

3. The intensity of light incident on a light–dependent resistor (LDR) is increased. Its resistance decreases.
Which statement gives the correct reason for this behaviour?

A The cross–sectional area of the LDR decreases.
B The mean drift velocity of the charge carriers decreases.
C The number density of the charge carriers increases.
D The magnitude of the charge on the charge carriers increases.

Your answer [1]

4. The resistance of a wire of length *L* is 3.00 Ω.
The wire is extended so that its length becomes 1.50*L*. Its volume remains the same.

What is the resistance of the extended wire?

A 2.00 Ω
B 3.00 Ω
C 4.50 Ω
D 6.75 Ω

Your answer ☐ **[1]**

5. A wire **X** has length *L* and radius *r*. Another wire **Y** made of the same material as **X** has length 2*L* and radius 3*r.* The wires are connected in **parallel** to a battery.

What is the correct ratio of

$$\frac{\text{power dissipated in } \mathbf{Y}}{\text{power dissipated in } \mathbf{X}} ?$$

A 0.22
B 1.0
C 4.5
D 6.2

Your answer ☐

[1]

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

The table shows some data.

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

Your answer ☐ **[1]**

7. A resistance wire is connected to a cell.
The length *L* of the wire is changed by pulling at the ends of the wire. The volume of the wire remains the same.

What is the correct relationship between the resistance *R* of the wire and its length *L*?

A R = constant
B $R \propto L$
C $R \propto L^2$
D $R \propto L^{-1}$

Your answer

[1]

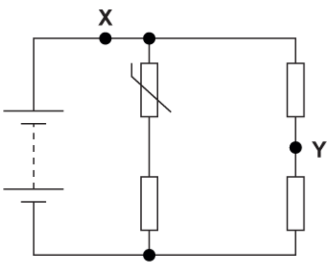
8. A cylinder of conducting material has length 6.0×10^{-2}m and diameter 2.0×10^{-2}m. It has resistance 24 Ω.

What is the resistivity of the material?

A 0.13 Ω m
B 0.50 Ω m
C 7.9 Ω m
D 25 Ω m

Your answer **[1]**

9. 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]**

10. Fig. 24 shows a circuit with a battery and two resistors.

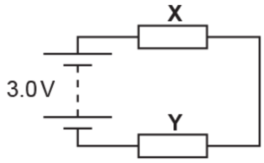


Fig. 24

The resistor **X** has length 8.0×10^{-3} m, cross–sectional area 1.2 mm^2 and is made of a material of resistivity 1.5×10^{-2} Ωm. The battery has e.m.f. 3.0 V and negligible internal resistance.
The resistor **Y** has resistance 68Ω.

Calculate the current I in the circuit.

I = A **[3]**

11. Nichrome is a metal. Silicon is a semiconductor.

State how the number density of charge carriers n and the resistivity ρ of silicon compare with that of nichrome.

n

ρ

[2]

12. The S.I. base units for the ohm (Ω) are kg m^2 s^{-3} 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]**

13 (a). Fig. 24 shows a square wafer of semiconductor of length *L* and thickness *t*.

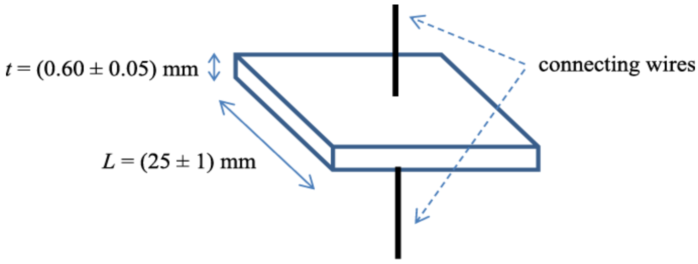


Fig. 24

The wafer is connected to a power supply. The current I in the wafer is 32 mA and the potential difference V across the wafer is 0.13 V.

i. Show that the resistivity ρ of the semiconductor is given by the expression

$$\rho = \frac{VL^2}{It}$$

[2]

ii. Calculate the resistivity ρ of the semiconductor.

ρ = ... Ω m **[2]**

(b). The ammeter reading increases when the circuit in **(b)** remains connected.

Use your knowledge of semiconductors to explain why.

---

[2]

14 (a). A student is investigating the resistance of a conducting putty.

The student rolls the putty into a cylinder shape and connects the ends of the cylinder to metal plates as shown in Fig. 5.1. The ohm-meter is used to measure the resistance *R* of the conducting putty.

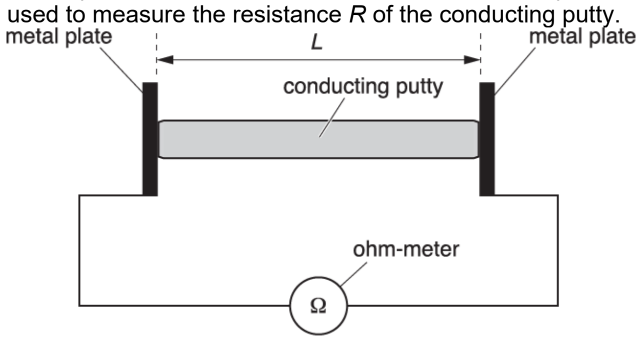


Fig. 5.1

i. Suggest why the student uses large metal plates at the ends of the conducting putty.

[1]

ii. Describe how the student can check that the diameter of the conducting putty is constant.

---

[2]

(b). The student measures the resistance *R* of the conducting putty for different length *L*.
The volume of the conducting putty is kept constant.

The student's results are shown in Table 5.2.

L / m	*R* / Ω	L^2 / 10^{-3} m^2
0.049	14	2.4
0.060	21	3.6
0.069	28	4.8
0.081	37	
0.090	46	8.1
0.099	57	9.8

Table 5.2

i. Complete the table for the missing value of L^2.

[1]

ii. Each length is measured to the nearest millimetre using a ruler.
Determine the percentage uncertainty in L^2 for L = 0.049 m.

percentage uncertainty = ...% **[1]**

(c). Fig. 5.3 shows the graph of R (y-axis) against L^2 (x-axis).

i. Plot the missing data point and draw the straight line of best fit.

[2]

ii. Determine the gradient of the line of best fit.

gradient = ... **[2]**

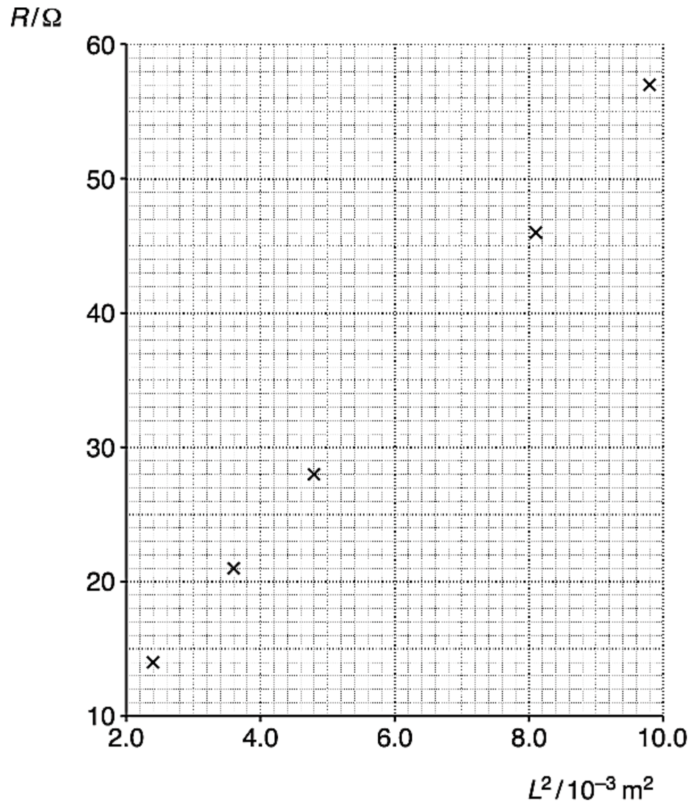


Fig. 5.3

(d). The relationship between R and L is

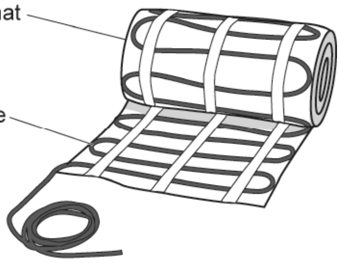
$$R = \frac{\rho}{V} L^2$$

where ρ is the resistivity of the conducting putty and V is the volume.

Use your answer to **(ii)** from the previous question and $V = 1.9 \times 10^{-5}\ \text{m}^3$ to determine a value for ρ. Include an appropriate unit.

ρ = ... unit: .... **[3]**

15. The diagram below shows a mat used for underfloor heating.



Each mat has resistance wire. The wire has cross-sectional area $6.7 \times 10^{-8}\ \text{m}^2$, total length 25 m and resistance 180 Ω. Each mat dissipates 300 W when connected to the mains supply.

i. A total output power 1.2 kW is required for a room.
Calculate the number of mats required.

number of mats =... **[1]**

ii. Calculate the resistivity ρ of the material of the wire.

ρ = ... Ωm **[2]**

16. A student conducts an experiment using two identical filament lamps and a variable power supply of negligible internal resistance. The lamps are connected in series to the supply. The current in the circuit is 0.030 A and the lamps are dimly lit.

The e.m.f. of the power supply is then doubled and the experiment repeated.
The student expected the current to double, but the current only increased to 0.040 A. The lamps are brightly lit.

Use your knowledge of physics to explain these observations.

----
[3]

17 (a). A student uses the circuit shown in **Fig. 16.1** to determine the resistivity of a metal in the form of a wire.

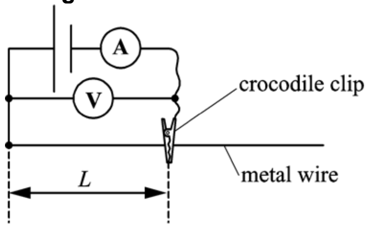


Fig. 16.1

The length *L* of the wire is changed with the help of a crocodile clip. The current in the wire is *I*, the p.d. across the wire is *V* and the wire has resistance *R*.
The table in **Fig. 16.2** shows the results recorded by the student from the experiment.

***L* / m**	***V* / V**	***I* / A**	***R* / Ω**
0.050	0.40	0.160	2.50
0.200	0.40	0.140	2.86
0.400	0.40	0.072	
0.800	0.40	0.036	11.1
1.000	0.40	0.029	13.8

Fig. 16.3 shows the graph of *R* against *L* for this wire.

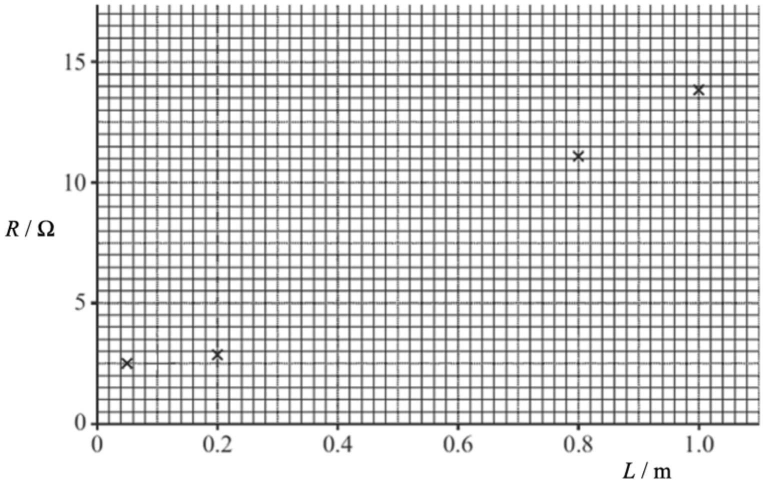


Fig. 16.3

The student observed that the wire was significantly hotter when the shortest length *L* = 0.050 m was used.
The cross-sectional area of the wire is 8.0×10^{-8} m^2.

Use **Fig.16.3** to determine the resistivity of the metal.

resistivity = ... Ωm **[3]**

(b). The voltmeter used in the experiment had a zero error. The potential difference recorded in the experiment was smaller than it should have been.

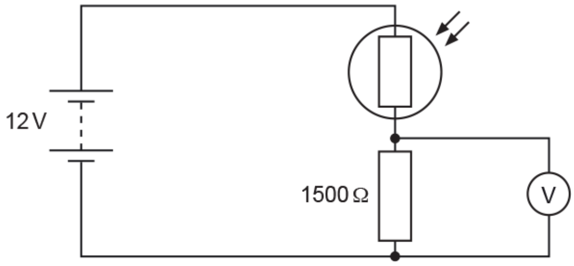
Discuss how the actual value of the resistivity of the metal would differ from the value calculated in **(b)**.

----

[3]

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

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



The fixed resistor has resistance 1500 Ω.
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 Ω.

Calculate the voltmeter reading.

= .... V**[2]**

ii. When fully illuminated, the resistance of the LDR is 100 Ω.
Show that the voltmeter reading **changes** by more than 7 V.

[1]

19. A student is investigating an unidentified component found in the laboratory.
The table shows the results from the lab book of the student.

V / V	**I / mA**
− 5.0	− 5.0
+ 5.0	+ 5.0
+ 10.0	+ 30.0

The potential difference across the component is *V* and the current through it is *I*.

i. Calculate the power dissipated by the component when *V* is +10.0 V.

power = W **[1]**

ii. Analyse the data in the table and hence identify the component.

-----

[3]

20. A researcher connects the circuit as shown in **Fig. 24.3** to determine the resistivity of a new metal designed from waste metals.

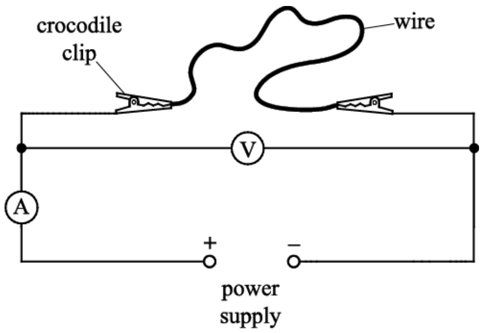


Fig. 24.3

The wire has length 0.75 m and cross-sectional area 1.3×10^{-7} m^2. The ammeter reading is 0.026 A and the voltmeter reading is 1.80 V.

i. Calculate the resistivity of the metal.

resistivity = ... Ω m **[2]**

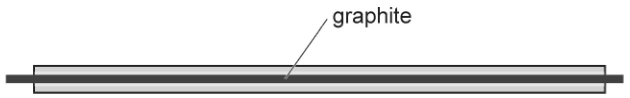
ii. The resistivity of the metal in **(c)(i)** is larger than the value predicted by the researcher.

Explain **one** possible limitation of the experiment.

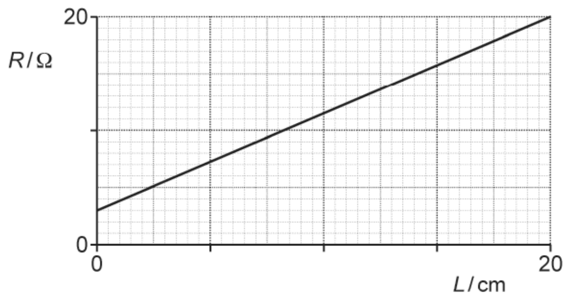
-----

[2]

21. The diagram below shows a pencil cut along its length exposing the graphite.



The resistance of a length *L* of the graphite is *R*. A student directly measures *R* using a multimeter (ohmmeter). The following graph is plotted by the student.



i. Suggest why the graph does not pass through the origin.

----

[1]

ii. The resistivity of graphite is *ρ*.

Describe how the student can use the graph above, and an additional measuring instrument, to accurately determine *ρ*.
No calculations are required.

----

[3]

22. Fig. 17 shows a potential divider circuit consisting of a fixed resistor of resistance *R* and a negative temperature coefficient (NTC) thermistor.

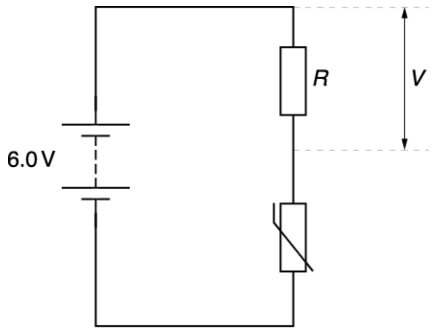


Fig. 17

The battery has electromotive force (e.m.f.) of 6.0 V and negligible internal resistance.
The thermistor is at room temperature. The resistance of the thermistor is 0.25 *R*.

The circuit shown in Fig. 17 is now placed in a cold fridge. The temperature of the thermistor slowly decreases to a constant value.

Describe and explain, in terms of current in the circuit, the variation of the potential difference *V* across the fixed resistor with time.

----

[4]

23. Fig. 1 shows a high-speed electric train.

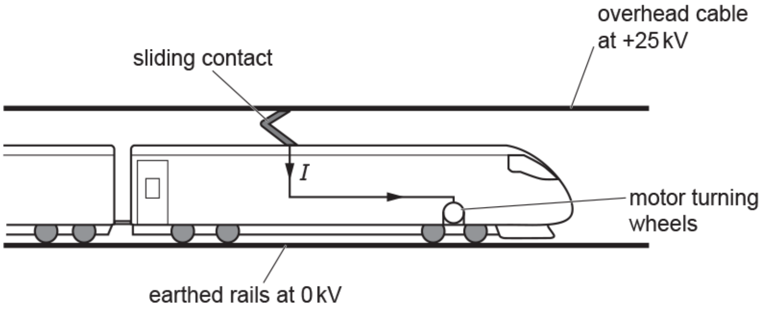


Fig. 1

The overhead cable in **Fig. 1** must be tensioned.
It is constructed from several equal lengths of wire.

Some data for one length of this wire are shown below.

- length = 1500 m
- area of cross-section = 1.1×10^{-4} m^2
- resistivity = 1.8×10^{-8} Ωm
- the Young modulus = 1.2×10^{10}Pa
- strain = 1.3%

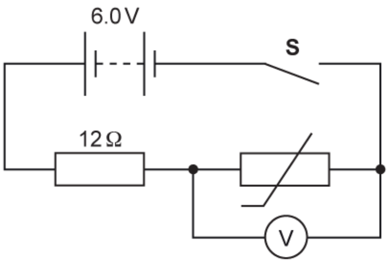
i. Calculate the resistance *R* of one length of wire.

R = ... Ω**[2]**

ii. Calculate the tension T in one length of wire.

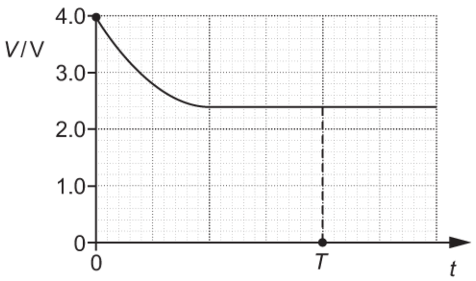
T = ... N**[3]**

24. A student connects a resistor and a thermistor in a circuit, as shown in the circuit diagram below.



The battery has electromotive force (e.m.f.) 6.0 V and negligible internal resistance.
The resistor has resistance 12 Ω.
The thermistor is at room temperature. The student closes the switch **S** at time $t = 0$.

The student draws the following graph which shows potential difference (p.d.) V across the thermistor against time t.



i. Explain why V decreases at the start.

----

[2]

ii. Use the graph to calculate the resistance of the thermistor at $t = T$.

resistance = ... Ω **[3]**

25. Fig. 24.1 shows a battery connected across a negative temperature coefficient (NTC) thermistor.

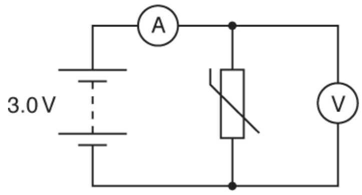


Fig. 24.1

The battery has electromotive force (e.m.f.) 3.0 V and negligible internal resistance. The ammeter has negligible resistance and the voltmeter has a very large resistance.
The thermistor has resistance 100 Ω at room temperature and a cross-sectional area of 3.8×10^{-6} m^2.
The number density of the free electrons within the thermistor is 5.0×10^{25} m^{-3}.

i. Calculate the mean drift velocity *v* of the free electrons in the thermistor.

v = ... m s^{-1} **[2]**

ii. The thermistor is now heated using a naked flame.
Describe and explain the effect on the ammeter and voltmeter readings.

----

[3]

26. * 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]

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

It is suggested that the resistance R of a length of nichrome wire varies with temperature θ in °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.

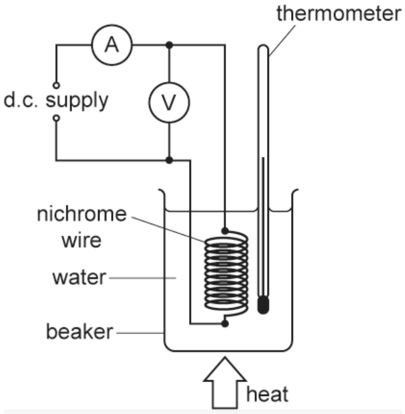


Fig. 1.1

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]

28. Fig. 24.2 shows a circuit designed by a student.

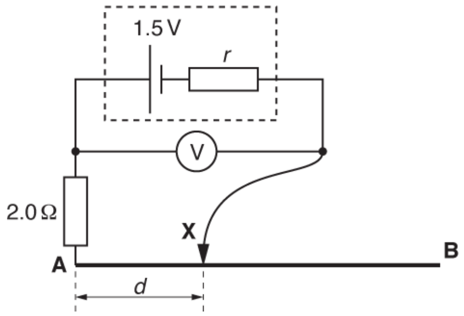


Fig. 24.2

The cell has e.m.f. 1.5 V and an internal resistance *r*.
The uniform wire **AB** has length 1.0 m and resistance 16 Ω.

i. When the contact **X** is in the **middle** of the wire, the voltmeter reading is 1.2 V.
   Calculate the internal resistance *r* of the cell.

r = ... Ω **[3]**

ii. The contact **X** is now moved along the wire from **A** to **B**.
The distance of the contact **X** from **A** is *d*.
Fig. 24.3 shows the variation of the potential difference *V* across the terminals of the cell.

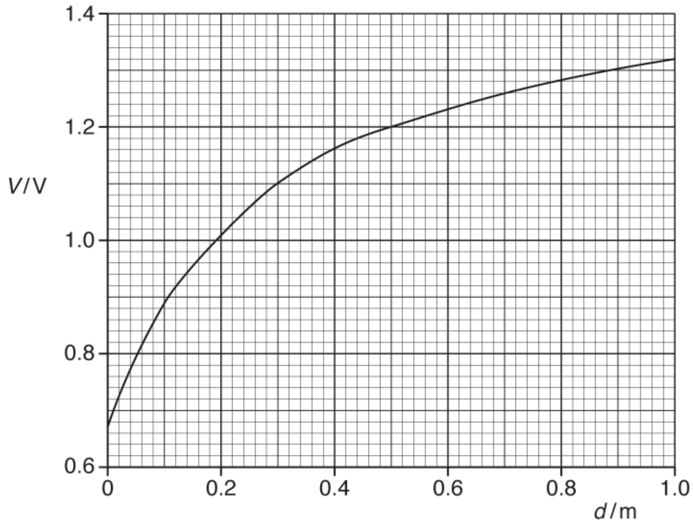


Fig. 24.3

Explain the variation of *V* with *d* in terms of the current in the circuit.

---

[3]

29 (a). Some houses are heated by “night storage heaters” which use cheap electricity between the hours of midnight and 7.00 am.

Fig. 4.1 shows a circuit diagram of three identical 230 V, 3.5 kW storage heaters connected to a 230 V mains power supply of negligible internal resistance.

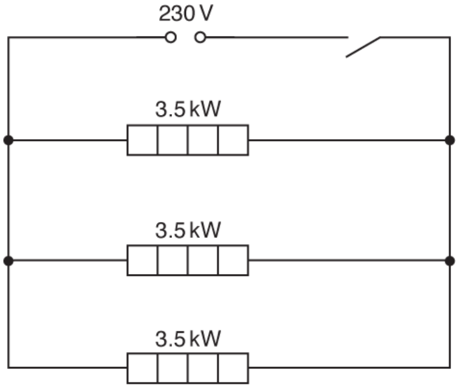


Fig. 4.1

i. Show that the resistance of each heating element is about 15 Ω when the heater is operating at 230 V.

[1]

ii. The heating element is constructed from a metallic wire of resistivity 1.6×10^{-6} Ω m.
The radius of the wire is 0.55 mm.
Determine the length *L* of the metallic wire in one heating element.

L = ... m **[3]**

iii. State and explain whether the heater obeys Ohm’s law.

---

[2]

(b). The cost of 1 kW h of energy is 7.6 pence.

Calculate the cost of using the three storage heaters between midnight and 7.00 am every night for one week.

cost = £ .... **[2]**

30. A student is investigating a 230 V, 1.0 kW heating element. The heating element is shown in Fig. 1.2.

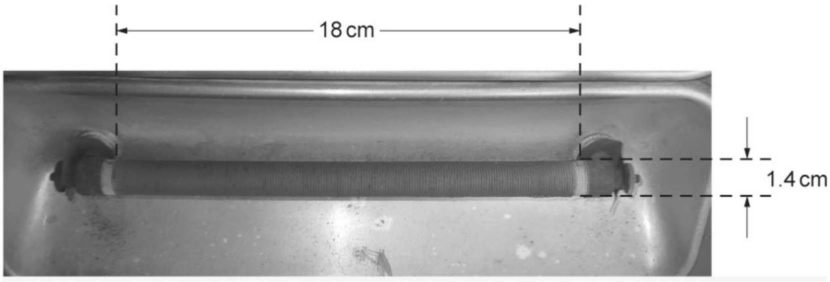


Fig. 1.2

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 = $1.1 \times 10^{-6}\ \Omega$ 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 53 Ω.

[2]

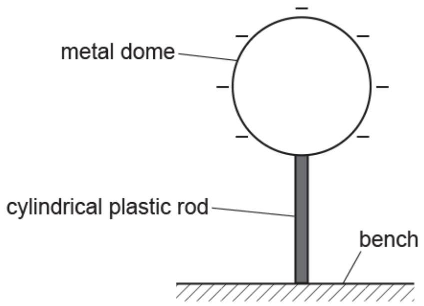
ii. Show that the length of wire wound on the heating element is 5.3 m.

[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]**

31. A spherical metal dome shown below is charged to a potential of −12 kV.



The dome is supported by a cylindrical plastic rod. The radius of the dome is 0.19 m.

i. Show that the magnitude of the total charge Q on the dome is 2.5×10^{-7} C.

[2]

ii. The dome discharges slowly through the plastic rod.
It takes 78 hours for the dome to completely discharge.

1 Show that the mean current I in the plastic rod is about 9×10^{-13} A.

[2]

2 The average potential difference across the plastic rod during discharge is 6000 V.
The rod has cross-sectional area 1.1×10^{-4} m^2 and length 0.38 m.

Calculate the resistivity ρ of the plastic.

ρ = ... Ωm **[3]**

32. A cable consists of 17 tightly packed copper wires, see Fig. 6.3.

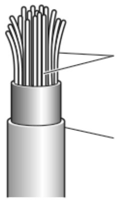


Fig. 6.3 (not to scale)

The student measures the diameter *d* of one of the copper wires as 0.12 ± 0.01 mm.

i. Explain how the student should measure precisely the diameter of the wire.

----

[2]

The student measures the resistance *R* of the whole **cable** as 1.86 ± 0.02 Ω.

The length *L* of the cable is 21.0 ± 0.1 m.

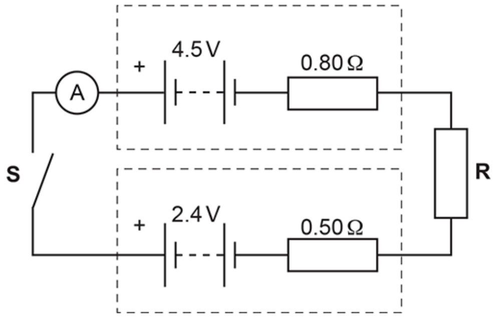
ii. Determine the resistivity *ρ* of copper.

ρ = -- Ω m **[3]**

iii. Determine the percentage uncertainty in *ρ*.

percentage uncertainty = -- % **[2]**

33. 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 4.6×10^{-4}m.
The number density of charge carriers in **R** is 4.2×10^{28} m^{-3}

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

v = ... m s^{-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]

34 (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 2*ρ*.

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	4.7×10^{-7} Ωm
L	9.5 ± 0.1 cm
d	0.270 ± 0.003 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 = ... ± .... Ω **[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.

----

[1]

35. Fig. 18.1 shows a circuit used by a student to determine the resistivity of the material of a wire.

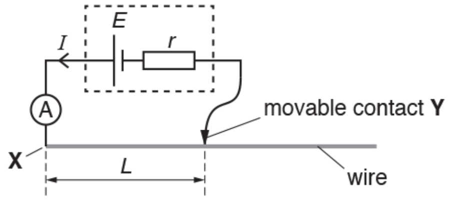


Fig. 18.1

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.

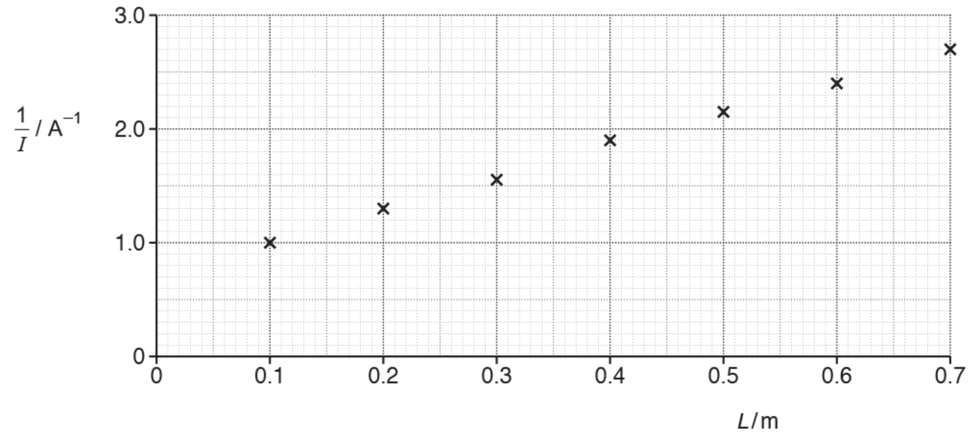


Fig. 18.2

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 1.5 V. The diameter of the wire is 0.38 mm.

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

ρ = ... Ωm **[2]**

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

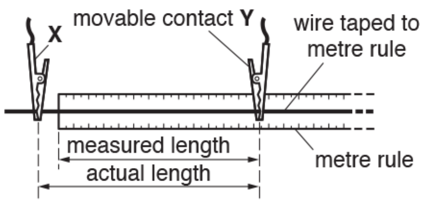


Fig. 18.3

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]

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

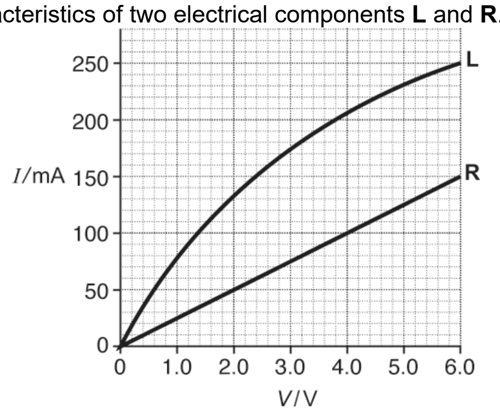

Fig. 16.1

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

i. Show that the resistance of **R** is 40 Ω.

[1]

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

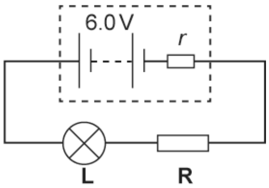

Fig. 16.2

The resistor **R** is a cylindrical rod of length 8.0 mm and cross-sectional area 2.4 × 10^{-6} 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 = ... Ω **[3]**

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

ρ = ______________________ Ω 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 = ______________________ m s^{-1} **[3]**

END OF QUESTION PAPER