

1

When the temperature of a copper wire increases, its ability to conduct electricity

- A remains the same. ☐
- B increases. ☐
- C decreases. ☐
- D remains the same at first and then increases. ☐

(Total 1 mark)

2

A metal wire has a length l and a cross-sectional area A . When a potential difference V is applied to the wire, there is a current I in the wire.

What is the resistivity of the wire?

- A $\frac{IA}{VI}$ ☐
- B $\frac{VA}{Il}$ ☐
- C $\frac{Il}{VA}$ ☐
- D $\frac{VI}{IA}$ ☐

(Total 1 mark)

3

A cylindrical conductor of length l , diameter D , and resistivity ρ has a resistance R .

What is the resistance of another cylindrical conductor of length l , diameter $\frac{D}{2}$, and resistivity ρ ?

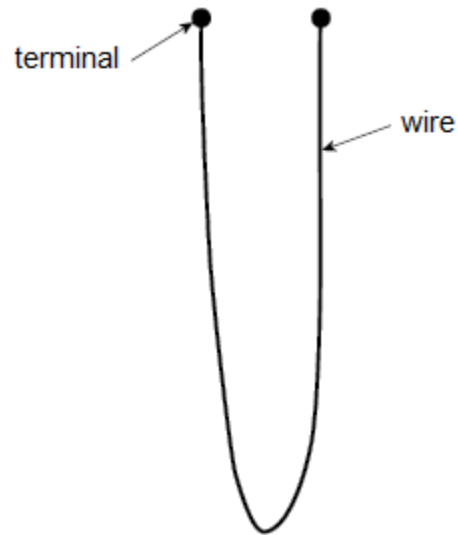
- A $8R$ ☐
- B $4R$ ☐
- C $2R$ ☐
- D R ☐

(Total 1 mark)

4

A wire probe is used to measure the rate of corrosion in a pipe carrying a corrosive liquid. The probe is made from the same metal as the pipe. **Figure 1** shows the probe. The rate of corrosion of the wire in the probe is the same as in the pipe.

Figure 1



- (a) The wire in an unused probe has a resistance of $0.070\ \Omega$ and a length of $0.50\ \text{m}$.

Calculate the diameter of the wire.

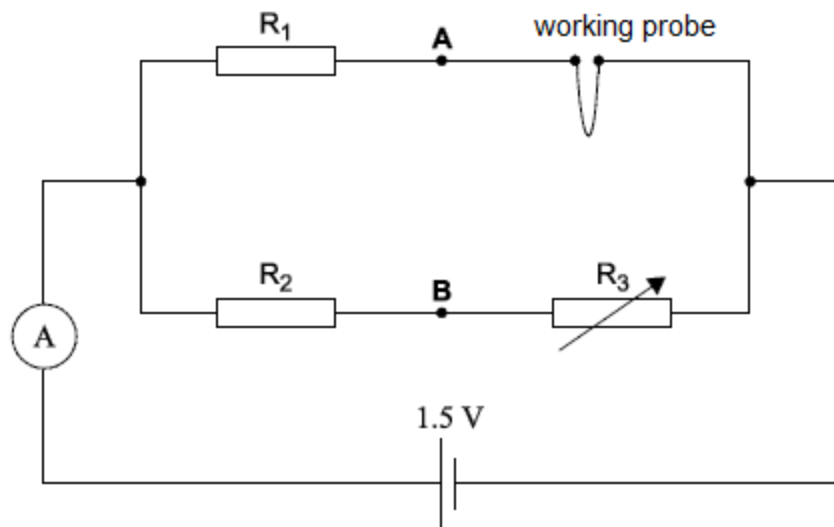
resistivity of metal in the wire = $9.7 \times 10^{-8}\ \Omega\ \text{m}$

diameter = _____ m

(3)

- (b) In order to measure the resistance of a used working probe, it is connected in the circuit shown in **Figure 2**.

Figure 2



When R_3 is adjusted to a particular value the current in the cell is 0.66 A.

Calculate the total resistance of the circuit.

You may assume that the cell has a negligible internal resistance.

resistance = _____ Ω

(1)

- (c) The resistance of R_2 is $22\ \Omega$ and the resistance of R_3 is $1.2\ \Omega$.

Calculate the current in R_3 .

current = _____ A

(1)

- (d) Calculate the resistance of the probe when the resistance of R_1 is $2.4\ \Omega$.

resistance = _____ Ω

(3)

- (e) Calculate the percentage change in the diameter of the probe when its resistance increases by 1.6 %.

percentage change = _____ %

(2)

- (f) A voltmeter is connected between points **A** and **B** in the circuit and R_3 stays at $1.2\ \Omega$.

Explain, without calculation, why the reading on the voltmeter does not change when the cell in the circuit is replaced with another cell of the same emf but a significant internal resistance.

(2)

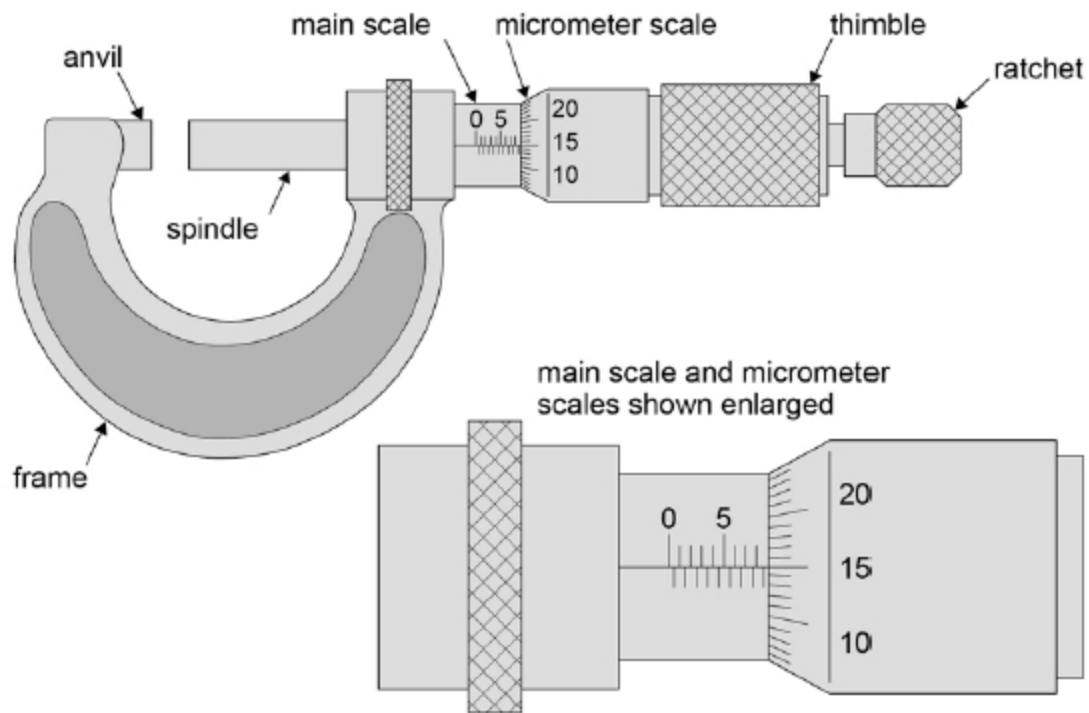
(Total 12 marks)

5

This question is about the determination of the resistivity of a wire.

Figure 1 shows a micrometer screw gauge that is used to measure the diameter of the wire.

Figure 1



(a) State the resolution of the **main scale** on the micrometer in **Figure 1**.

resolution = _____ mm

(1)

- (b) Determine the distance between the anvil and the spindle of the micrometer in **Figure 1**. State any assumption you make.

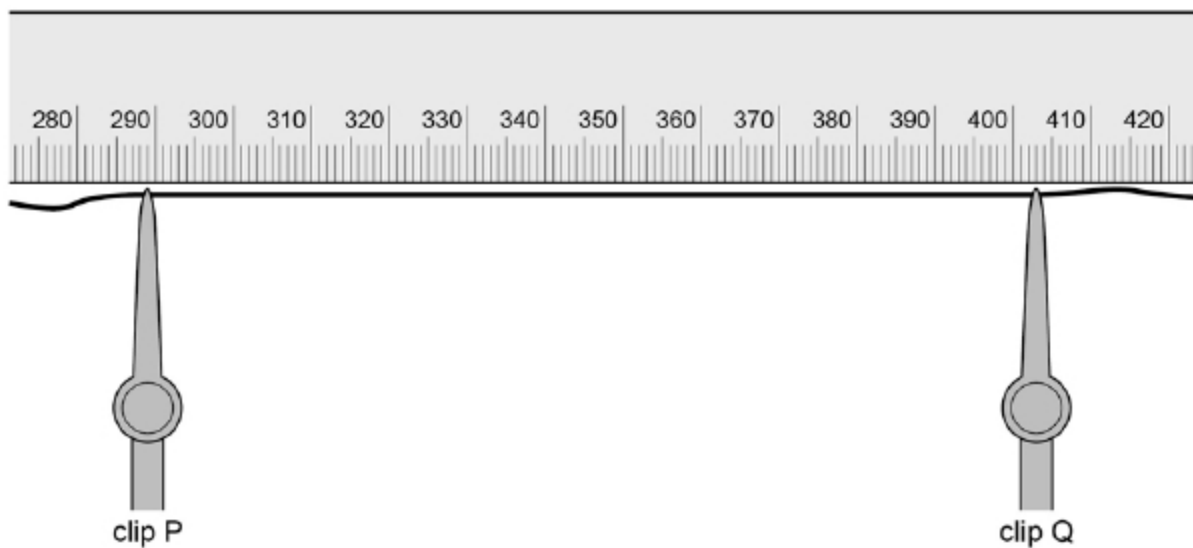
distance = _____ mm

(2)

- (c) A student must also determine the length L of the wire between clips P and Q that will be connected into a circuit.

Figure 2 shows the metre ruler being used to measure L .

Figure 2



Determine L

L = _____ mm

(1)

- (d) Calculate the percentage uncertainty in your result for L .

percentage uncertainty = _____ %

(2)

- (e) State and explain what the student could have done to reduce uncertainty in the reading for L .

(1)

- (f) The student intends to make measurements that will allow her to determine the resistance of one metre of the wire. She uses an ohm-meter to measure the resistance R for different lengths L of the wire. The student's measurements are shown in the table below.

L/cm	R/Ω	
81.6	8.10	
72.2	7.19	
63.7	6.31	
58.7	5.85	
44.1	4.70	

Determine the value that the student should record for the resistance per metre of the wire.

Use the additional column in the table above to show how you arrived at your answer.

resistance of one metre of wire = _____ Ω

(2)

(g) Determine the resistivity of the wire. Give a suitable unit for your answer.

mean diameter of the wire = 0.376 mm

resistivity = _____ unit = _____

(4)

(Total 13 marks)

6

State what is meant by a superconductor.

(Total 1 mark)

7

At room temperature a metal has a resistivity of $4.5 \times 10^{-7} \Omega\text{m}$. A wire made from this metal has a radius of 0.70 mm.

- (a) (i) Calculate the resistance of a 2.5 m length of the wire at room temperature.

resistance _____ Ω

(3)

- (ii) Calculate the power dissipated in this length of wire when it carries a current of 20 mA. Assume the resistance of the wire is constant.

power _____ W

(2)

- (b) The wire becomes superconducting as it is cooled. Draw a sketch graph on the axes below to show how the wire's resistivity would vary with temperature as it is cooled from room temperature θ_r .



(3)

- (c) Explain why the efficiency of electrical power transmission is improved when conventional wires are replaced with superconducting wires.

(1)

(Total 9 marks)

8

The critical temperature of tin is $-269\text{ }^{\circ}\text{C}$. The resistivity of tin increases as its temperature rises from $-269\text{ }^{\circ}\text{C}$.

- (a) (i) Define resistivity.

(2)

- (ii) State the significance of the critical temperature of a material.

(2)

- (b) A sample of tin in the form of a cylinder of diameter 1.0 mm and length 4.8 m has a resistance of $0.70\text{ }\Omega$.

Use these data to calculate a value of the resistivity of tin.
State an appropriate unit for your answer.

resistivity _____ unit _____

(4)

(Total 8 marks)

9

- (a) State what is meant by a superconducting material.

(2)

- (b) State an application of a superconductor and explain why it is useful in this application.

(2)

(Total 4 marks)

10

- (a) A sample of conducting putty is rolled into a cylinder which is 6.0×10^{-2} m long and has a radius of 1.2×10^{-2} m.

resistivity of the putty = $4.0 \times 10^{-3} \Omega\text{m}$.

Calculate the resistance between the ends of the cylinder of conducting putty.
Your answer should be given to an appropriate number of significant figures.

answer = _____ Ω

(4)

- (b) Given the original cylinder of the conducting putty described in part (a), describe how you would use a voltmeter, ammeter and other standard laboratory equipment to determine a value for the resistivity of the putty.

Your description should include

- a labelled circuit diagram,
- details of the measurements you would make,
- an account of how you would use your measurements to determine the result,
- details of how to improve the precision of your measurements.

The quality of your written communication will be assessed in this question.

(8)
(Total 12 marks)

11

A teacher wishes to construct a $2.0\ \Omega$ resistor from a metal wire of length $0.94\ \text{m}$. The metal wire has an electrical resistivity of $4.9 \times 10^{-7}\ \Omega\ \text{m}$.

Calculate the required diameter of the wire.

diameter _____ mm

(Total 4 marks)

12

(i) State what is meant by a superconductor.

(2)

(ii) With reference to **two** uses for superconductors in today's world, explain the advantage of their use compared with conventional conductors such as copper.

(3)

(Total 5 marks)

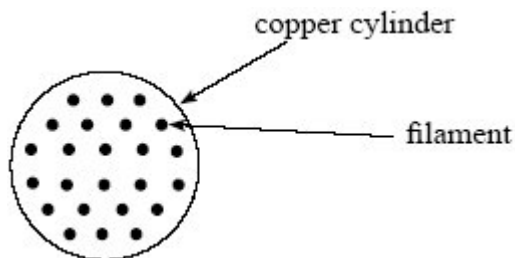
13

(a) Some materials exhibit the property of *superconductivity* under certain conditions.

- State what is meant by superconductivity.
- Explain the required conditions for the material to become superconducting.

(3)

- (b) The diagram below shows the cross-section of a cable consisting of parallel filaments that can be made superconducting, embedded in a cylinder of copper.



- (i) The cross-sectional area of the copper in the cable is $2.28 \times 10^{-7} \text{ m}^2$. The resistance of the copper in a 1.0 m length of the cable is 0.075Ω . Calculate the resistivity of the copper, stating an appropriate unit.

answer = _____

(3)

- (ii) State and explain what happens to the resistance of the cable when the embedded filaments of wire are made superconducting.

(3)

(Total 9 marks)

14

The wire in an electric heater has a resistance of 75Ω . It is 9.5 m long and has a cross-sectional area of $1.4 \times 10^{-7} \text{ m}^2$.

Calculate the resistivity of the material from which the wire is made.

Give an appropriate unit for your answer.

resistivity _____

(Total 3 marks)

15

- (a) A student wishes to measure the resistivity of the material of a uniform resistance wire. The available apparatus includes a battery, a switch, a variable resistor, an ammeter and a voltmeter.
- (i) Draw a circuit diagram which incorporates some or all of this apparatus and which enables the student to determine the resistivity of the material.

- (ii) State the measurements which must be made to ensure that a reliable value of the resistivity is obtained.

- (iii) Explain how a value of the resistivity would be obtained from the measurements.

- (b) A wire made from tin with cross-sectional area $7.8 \times 10^{-9} \text{ m}^2$, has a pd of 2.0 V across it. Calculate the minimum length of wire needed so that the current through it does not exceed 4.0 A.

resistivity of tin = $1.1 \times 10^{-7} \Omega \text{ m}$

(2)

(Total 12 marks)

16

- (a) For a conductor in the form of a wire of uniform cross-sectional area, give an equation which relates its resistance to the resistivity of the material of the conductor. Define the symbols used in the equation.

(2)

- (b) (i) An electrical heating element, made from uniform nichrome wire, is required to dissipate 500 W when connected to the 230 V mains supply. The cross-sectional area of the wire is $8.0 \times 10^{-8} \text{ m}^2$. Calculate the length of nichrome wire required.

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

- (ii) Two heating elements, each rated at 230 V, 500 W are connected to the 230 mains supply

(A) in series,
(B) in parallel.

Explain why only one of the circuits will provide an output of 1 kW.

(6)

(Total 8 marks)

17

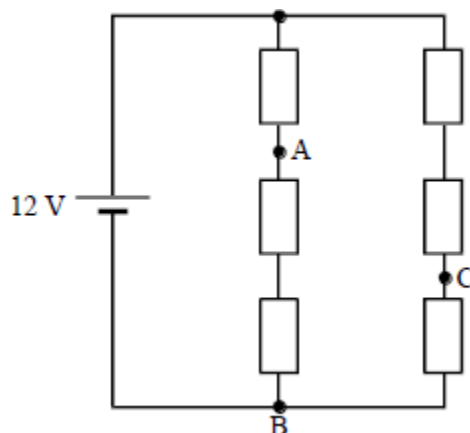
- (a) (i) Give the equation which relates the *electrical resistivity* of a conducting material to its *resistance*. Define the symbols in the equation.

- (ii) A potential difference of 1.5 V exists across the ends of a copper wire of length 2.0 m and uniform radius 0.40 mm. Calculate the current in the wire.

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

(5)

- (b) In the circuit shown, each resistor has the same resistance. The battery has an e.m.f. of 12 V and negligible internal resistance.



- (i) Calculate the potential difference between A and B.

- (ii) Calculate the potential difference between B and C.

- (iii) A high resistance voltmeter is connected between A and C. What is the reading on the voltmeter?

(5)

(Total 10 marks)

18

- (a) A metal wire of length 1.4 m has a uniform cross-sectional area = $7.8 \times 10^{-7} \text{ m}^2$. Calculate the resistance, R , of the wire.
resistivity of the metal = $1.7 \times 10^{-8} \Omega\text{m}$

(2)

- (b) The wire is now stretched to twice its original length by a process that keeps its volume constant. If the resistivity of the metal of the wire remains constant, show that the resistance increases to $4R$.

(2)

(Total 4 marks)

19

Scientists have suggested that carbon dioxide emissions produced by power stations in the European Union could be reduced considerably if high temperature superconductors were used instead of ordinary conductors to improve the efficiency of power plants.

- (a) Explain what is meant by a superconductor.

(2)

- (b) Explain why the use of superconductors would improve the efficiency of power stations and hence reduce carbon dioxide emissions.

(2)

(Total 4 marks)

20

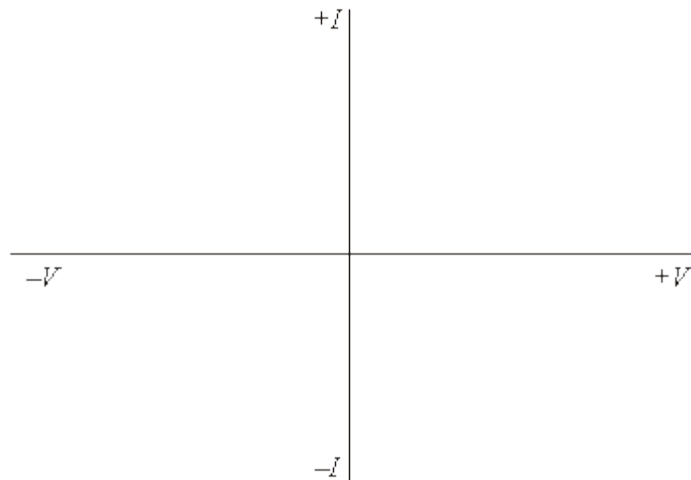
A resistance wire has a diameter 2.0×10^{-4} m and a resistivity of $4.5 \times 10^{-7} \Omega \text{ m}$.

- (a) Calculate the length of this wire that has a resistance of 25Ω .

length of wire _____

(3)

- (b) The resistivity of the wire increases as the current increases. Sketch, on the axes below, the variation of current, I , with potential difference, V , across the wire for both positive and negative potential differences.



(2)

(Total 5 marks)

21

- (a) (i) What is a *superconductor*?

- (ii) With the aid of a sketch graph, explain the term *transition temperature*.

(3)

- (b) Explain why superconductors are very useful for applications which require very large electric currents and name **two** such applications.

(3)

(Total 6 marks)

[illegible]

- (f) ANY TWO FROM
 correct reference to lost volts OR terminal pd OR reduced current ✓
 reference to resistors not changing OR resistors constant ratio ✓
 reference to voltmeter having high/infinite resistance (so not affecting circuit) ✓
 reference to pd between AB being (very) small (due to closeness of
 resistance ratios in each arm) ✓
 voltmeter (may not be) sensitive enough ✓

1
 1
 [12]

5

- (a) 0.5 mm [0.05 cm, 0.0005 m] ✓
only acceptable answers

1

- (b) 8.65 mm [0.865 cm, 0.00865 m] ₁✓

the micrometer reads zero when the jaws are closed ₂✓
only 3sf answers are acceptable for ₁✓
accept no zero error for ₂✓

2

- (c) $L = (403 - 289 =) 114 \text{ mm}$ ✓

1

- (d) absolute uncertainty = 1 mm ₁✓

$$\text{percentage uncertainty} = \frac{1}{114} \times 100 = 0.88\% \substack{2}{\checkmark}$$

accept 2 mm for ab. uncertainty ₁✓
allow ecf for wrong L and / or wrong ΔL
accept 1.75%

2

- (e) should move wire directly over / closer to scale on the ruler to avoid parallax error ✓
both statement and explanation required for this mark

1

- (f) five values of R/L correct, recorded to 3 sf [last row to 3sf or 4sf]; accept values in $\Omega \text{ cm}^{-1}$ ✓
 mean based on first four rows only; result $9.94 \Omega \text{ m}^{-1}$ [$9.94 \times 10^{-2} \Omega \text{ cm}^{-1}$] ✓

L/cm	R/Ω	$(R/L)\Omega\text{m}^{-1}$
81.6	8.10	9.93
72.2	7.19	9.96
63.7	6.31	9.91
58.7	5.85	9.97
44.1	4.70	10.66 (10.7)

2

- (g) cross-sectional area = $\frac{\pi d^2}{4}$ 1✓

resistivity from $\frac{R}{L} \times A$, correct substitution of result from 01.6 2✓

$$1.10 \times 10^{-6} \text{ }_3 \text{ } \checkmark$$

$$\Omega \text{ m }_4 \checkmark$$

resistivity from $\frac{R}{L} \times \frac{\pi d^2}{4}$ earns 12✓✓

allow 2✓ if $\frac{R}{L}$ value is not based on mean or on a mean from all five rows of table in 01.6

condone 1.12×10^{-6} for 3✓ if fifth row in 01.6 was not rejected

withhold 3✓ for POT error

4

[13]

6

Resistance is zero at (or below) critical temperature
 "Negligible resistance" is insufficient

[1]

7

- (a) (i) calculated cross-sectional area = $1.54 \times 10^{-6} \text{ (m}^2\text{)}$ or *correct substitution*

C1

$$1.6 \times 10^{-3} \text{ (treating } r \text{ as } A\text{) gains 2}$$

into resistivity equation *with incorrect powers of ten correct substitution*

C1

into resistivity equation *with correct powers of ten*

$$0.73 \text{ (}\Omega\text{)}$$

A1

3

- (ii) Sub into $I^2 R$ irrespective of power of 10 [ecf from (a)(i)]

C1

$$2.96 \times 10^{-4} \text{ (W)}$$

A1

2

- (b) line with positive slope (linear or curve)

B1

knee and vertical line shown in first 2 / 3 on temperature axis

B1

resistivity falling to zero above 0 K

B1

3

- (c) (with no resistance there can be) no power loss

B1

1

[9]

8

- (a) (i) resistivity is defined as

$$\rho = \frac{RA}{l}$$

where R is the resistance of the material of length l ✓
and cross-sectional area A ✓

2

- (ii) below the critical temperature / maximum temperature which resistivity / resistance ✓
 is zero / becomes superconductor ✓
Any reference to negligible / small / very low resistance loses second mark

2

- (b) (use of $\rho = \frac{RA}{l}$)

$$\rho = 0.70 \times \pi \times 0.0005^2 / 4.8 \checkmark = 1.1(5) \times 10^{-7} (1.1 - 1.2) \checkmark \checkmark \Omega \text{ m } \checkmark$$

First mark for substitution R and l

Lose 1 mark if diameter used as radius and answer is 4 times too big (4.4 – 4.8) OR if power of ten error

4

[8]

9

- (a) no resistance

M1

(at or) below critical temperature

A1

alternative:

allow a labelled diagram which indicates features, allow T_c for transition temp in diagram

2

- (b) **Use**

eg mri scanner, transformer, generator, maglev train, particle accelerators, microchips, computers, energy storage with detail

B1

Reason

eg **strong** magnetic field, no energy dissipation (mri scanner / maglev/ particle accelerator)

higher (processing) speeds, smaller, no energy dissipation

(microchip / computer)

B1

smaller, no energy dissipation, no fire risk (transformer / generator)

no energy dissipation (power transmission / energy storage with detail)

2

[4]

10

(a)

(use of $R = \rho l/A$)

$$R = 4.0 \times 10^{-3} \times 0.060 \text{ (1)} / (\pi \times 0.012^2) \text{ (1)}$$

$$R = 0.53 \text{ (}\Omega\text{) (1)}$$

2 significant figures **(1)**

- (b) the mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication

circuit must include:

voltmeter and ammeter connected correctly **(1)**

power supply with means of varying current **(1)**

2

QWC	descriptor	mark range
good-excellent	(i) Uses accurately appropriate grammar, spelling, punctuation and legibility. (ii) Uses the most appropriate form and style of writing to give an explanation or to present an argument in a well structured piece of extended writing. [may include bullet points and/or formulae or equations] An excellent candidate will have a working circuit diagram with correct description of measurements (including range of results) and processing. An excellent candidate uses a range of results and finds a mean value or uses a graphical method, eg I-V characteristics. They also mention precision eg use of vernier callipers.	5-6
modest-adequate	(i) Only a few errors. (ii) Some structure to answer, style acceptable, arguments or explanations partially supported by evidence or examples. An adequate candidate will have a working circuit and a description with only a few errors, eg do not consider precision. They have not taken a range of results and fail to realise that the diameter needs to be measured in several places.	3-4
poor-limited	(i) Several significant errors. (ii) Answer lacking structure, arguments not supported by evidence and contains limited information. Several significant errors, eg important measurement missed, incorrect circuit, no awareness of how to calculate resistivity.	1-2
incorrect, inappropriate or no response		0

The explanation expected in a good answer should include a coherent account of the procedure and include most of the following points.

- length with a ruler
- thickness/diameter with vernier callipers/micrometer
- measure voltage
- measure current
- calculate resistance
- use of graph, eg I - V or resistance against length
- use of diameter to calculate cross-sectional area
- mention of precision, eg vernier callipers or full scale readings for V and I
- flat metal electrodes at each end to improve connection

6

[12]

11

$$A = 4.9 \times 10^{-7} \times 0.95 \div 2$$

C1

$$\text{area} = 2.30 \times 10^{-7}$$

C1

$$\text{radius} = \sqrt{(A/\pi)} = 2.7 \times 10^{-1} \text{ (mm)}$$

C1

$$\text{diameter} = 0.54 \text{ (mm)}$$

A1

4

[4]

12

(i) **zero** resistance

M1

at or below critical/transition temperature

A1

2

- (ii) one valid use mentioned or reason why important

B1

one valid use with reason why important or two significantly different valid uses

B1

two valid uses with reasons

B1

eg uses

electromagnet/magnets for accelerators/scanners

generators/transmission lines/electric cables/power

transmission

transformers

computers (reason: increased speed and heating problems)

amplifiers in radio astronomy (reason: low noise)

reasons

can produce very high magnetic field strengths

can produce low-energy (power) loss conductors

less energy/power wasted or lower energy loss

3

[5]

13

- (a) superconductivity means a material has zero resistivity/resistance **(1)**

resistivity decreases with temperature **or** idea of cooling **(1)**

becomes superconducting when you reach the critical/certain/transition temperature **(1)**

3

- (b) (i) (use of $R = \rho l/A$)

$$0.075 = \rho \times 1/(2.28 \times 10^{-7}) \text{ (1) (must see working or equation)}$$

$$R = 1.7 \times 10^{-8} \text{ (1) } \Omega\text{m (1)}$$

(ii) **max 3 from**

the resistance decreases (to zero) **(1)**

copper still has resistance **(1)**

but this is in parallel with filaments (which have zero resistance) **(1)**

hence **total** resistance is zero **(1)**

current goes through filaments **(1)**

6

[9]

14

correct substitution of data in resistivity formula

C1

$$1.1(1) \times 10^{-6} \text{ (1)}$$

A1

Ωm **(1)**

B1

[3]

15

(a) (i) circuit diagram to show:
wire, ammeter, battery, (variable resistor) and switch in series **(1)**
[or potentiometer with ammeter in correct position]
voltmeter across the wire **(1)**

(ii) (method: constant length of wire)
measure length (of wire) **(1)**
measure diameter (of wire) **(1)**
measure voltage (across) and current (through wire) **(1)**
vary resistor to obtain different voltage and current **(1)**
alternative
[(method: variable length of wire)
measure length (each time) **(1)**
measure diameter **(1)**
(for full length of wire) measure voltage and current **(1)**
voltmeter to shorter lengths, measure voltage (and current) **(1)**]

(iii) (use of) $\rho = \frac{RA}{l}$ (to calculate ρ) **(1)** (for either method)

calculate A from (πr^2) **(1)** (for either method)

(method: constant length of wire)

determine $R \left(= \frac{V}{I} \right)$ for (one) length **(1)**

repeat readings (for same length and) take mean of ρ or R **(1)**

[or plot graph of V vs I to give mean R **(1)**

or gradient = $\frac{\rho l}{A}$ **(1)]**

alternative

[(method: variable length of wire)

determine $R \left(= \frac{V}{I} \right)$ for each length **(1)**

calculate ρ for each length and take mean **(1)**

[or graph of R vs l **(1)** with correct gradient **(1)]**

10

(b) (use of $R = \frac{\rho l}{A}$ gives) $\frac{2.0}{4.0} = \frac{1.1 \times 10^{-7} l}{7.8 \times 10^{-9}}$ **(1)**

$l = 0.035 \text{ m}$ **(1)**

2

[12]

16

(a) $R = \frac{\rho l}{A}$ **(1)**

ρ is resistivity, l is the length of the wire, A is the cross-sectional area **(1)**

2

(b) (i) $P = \frac{V^2}{R}$ **(1)**

$R = \frac{230^2}{500} = 106(\Omega)$ **(1)** (105.8 Ω)

$l = \left(\frac{RA}{\rho} \right) = \frac{105.8 \times 8.0 \times 10^{-8}}{1.1 \times 10^{-6}} = 7.7 \text{ m}$ **(1)** (7.69 m)

(allow C.E. for incorrect value of R)

(ii) in series, voltage across each < 230 V or pd shared **(1)**

∴ power ($= V^2/R$) is less than 500 W in each **(1)**

in parallel, voltage across each = 230 V **(1)**

∴ correct rating, ∴ conclusion **(1)**

[or, in series, high resistance or combined resistance **(1)**

∴ low current **(1)**

in parallel, resistance is lower, ∴ higher current **(1)**

more power, justified **(1)**]

max 6

[8]

17

(a) (i) resistivity defined by $\rho = \frac{RA}{l}$ **(1)**

symbols defined $\frac{RA}{l}$

$$(ii) \quad R = \frac{\rho l}{A} = \frac{1.7 \times 10^{-8} \times 2}{\pi (0.4 \times 10^{-3})^2} \quad \mathbf{(1)}$$
$$= 0.068 \, (\Omega) \quad \mathbf{(1)} \quad (0.0676 \, \Omega)$$

$$I = \frac{1.5}{0.068} = 22 \, \text{A} \quad \mathbf{(1)} \quad (22.2 \, \text{A})$$

(allow e.c.f. from value of R)

(5)

$$(b) \quad (i) \quad \text{pd}_{AB} = \frac{2}{3} \times 12 = 8 \, \text{V} \quad \mathbf{(1)} \quad \mathbf{(1)}$$

$$(ii) \quad \text{pd}_{BC} = \left(\frac{1}{3} \times 12\right) = 4 \, \text{V} \quad \mathbf{(1)}$$

$$(iii) \quad \text{pd}_{AC} = \text{potential at A} - \text{potential at C} \quad \mathbf{(1)}$$
$$= (8 - 4) = 4 \, \text{V} \quad \mathbf{(1)}$$

(allow e.c.f. from (i) and (ii))

(5)

[10]

18

$$(a) \quad R = \frac{\rho l}{A} \quad \mathbf{(1)}$$

$$= \frac{1.7 \times 10^{-8} \times 1.4}{7.8 \times 10^{-7}} = 0.031 \, \Omega \quad \mathbf{(1)} \quad (0.0305 \, \Omega)$$

(b) constant volume gives $l_1 A_1 = l_2 A_2$

[or $l_2 = 2l_1$ and $A_2 = A_1/2$] **(1)**

$$R = \frac{\rho 2l}{A/2} = 4R \text{ **(1)**}$$

[or calculation with $l_2 = 2.8$ (m) and $A_2 = 3.9$ (m²) **(1)**]

gives $R = 0.124 \Omega$ **(1)**

2

[4]

19

(a) superconductor has zero resistance/resistivity (**not** very little)

B1

when at (condone below) the **transition temperature**
(not critical or low)

B1

2

(b) no/less/lower **power/energy lost** (in conducting wires)

B1

less fuel needed (so less CO₂ emitted to produce the
required power)

B1

2

[4]

20

(a) $R = \rho L/A$

C1

area = $3.14 \times 10^{-8} \text{ m}^2$ or 12.6×10^{-8} or $\pi(1 \times 10^{-4})^2$
or $\pi(2 \times 10^{-4})^2$

A1

1.7 (1.74 or 1.75) m (not 1.8 m)

A1

3

(b) correct curvature for positive V (decreasing gradient)

B1

consistent graph for negative V through origin

B1

2

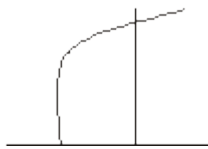
[5]

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(a) (i) (a substance/component/...with) no (electrical) resistance

B1

(ii)



graph showing transition temperature

B1

temperature below which/at which a material is superconducting

B1

3

(b) (no resistance) means no energy/heat/power loss

B1

any two from:

power/electrical cables, generators, transformers, motors,
electromagnets, MRI scanners, monorail trains, particle
accelerators, fusion reactors

not supercomputers

B2

3

[6]