Electricity Questions
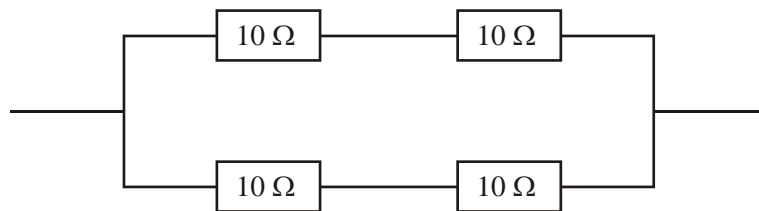
Current, Potential Difference, Resistor Networks, Resistance and Resistivity

1. Four 10 Ω resistors are connected as shown in the diagram.

Calculate the total resistance of the combination.

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Total resistance = ...

(3)

Comment on your answer and suggest why such a combination of resistors might be used.

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(2)
(Total 5 marks)

2. Tick whether the following statements are true or false. In each case explain your reasoning.

Statement 1

When a battery is connected across a thick wire in series with a thin wire of the same material, the electrons move faster through the thick wire.

True ☐   False ☐

Explanation

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(3)

Statement 2

When a battery is connected across a high resistance in parallel with a low resistance, more power is dissipated in the low resistance.

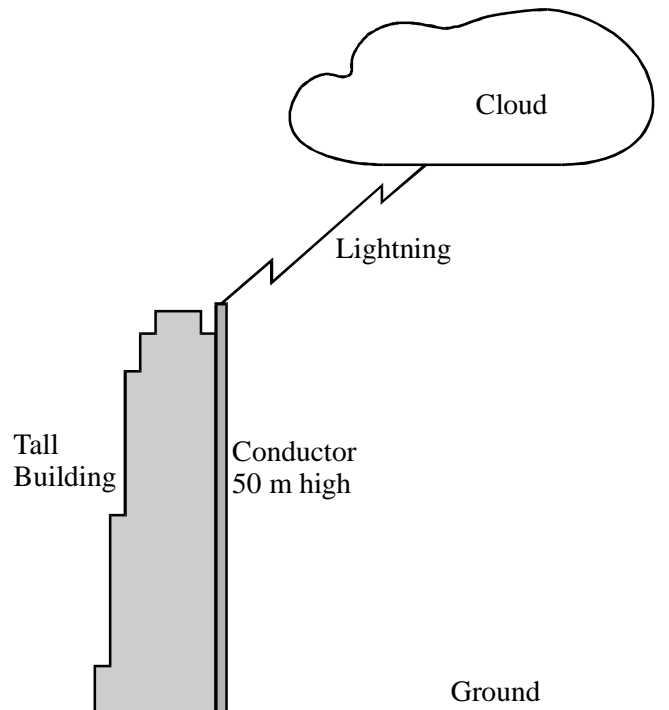True ☐   False ☐

Explanation

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(3)
(Total 6 marks)

3. A lightning stroke passes between a cloud and a lightning conductor attached to a tall building. A very large current of 20 000 A passes for 4.0×10^{-4} s.

Calculate the charge flowing to the ground in this time.

....

....

Charge = ...

(2)

The lightning conductor is 50 m high and has a cross-sectional area of 1.0×10^{-3} m^2.
It is made from copper which has a resistivity of 1.7×10^{-8} Ω m.

Calculate the resistance of the lightning conductor.

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Resistance = ...

(3)

Hence calculate the potential difference between the top and bottom of the current-carrying lightning conductor.

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Potential difference = ...

If lightning strikes a tree such that there is the same current through it as there was through the conductor, then a much larger potential difference exists between the top and bottom of the tree. Explain why this is so.

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4. A student is asked to carry out an experiment to find the resistivity of the material of a length of resistance wire. Draw an appropriate circuit diagram.

List all the measurements the student should take to find the resistivity.

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How should these measurements be used to find the resistivity?

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Suggest two precautions the student should take to ensure an accurate result.

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(2)
(Total 10 marks)

5. Io is one of Jupiter's moons. Some of the electrons released from the volcanic surface of Io have an average velocity of $2.9 \times 10^7 \text{m s}^{-1}$ towards Jupiter. The distance between Jupiter and Io is 4.2×10^5 km.

(a) Show that the time taken for these electrons to reach Jupiter is about 14 s.

....

....

(2)

(b) In this way a current of 3.0×10^6 A is created between Io and Jupiter. Calculate the number of electrons that arrive at Jupiter every second.

....

....

....

Number of electrons = ...

(2)

(c) State the direction of the current.

....

(1)
(Total 5 marks)

6. State the word equation that is used to define charge.

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(1)

Define potential difference.

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(1)

A 9.0 V battery of negligible internal resistance is connected to a light bulb.
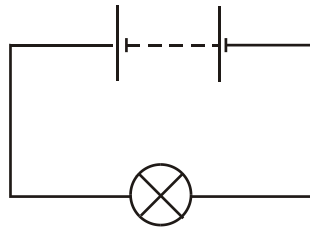
Calculate the energy transferred in the light bulb when 20 C of charge flows through it.

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Energy = ...

(2)
(Total 4 marks)

7. The circuit diagram shows a 12 V d.c. supply of negligible internal resistance connected to an arrangement of resistors. The current at three places in the circuit and the resistance of two of the resistors are given on the diagram.
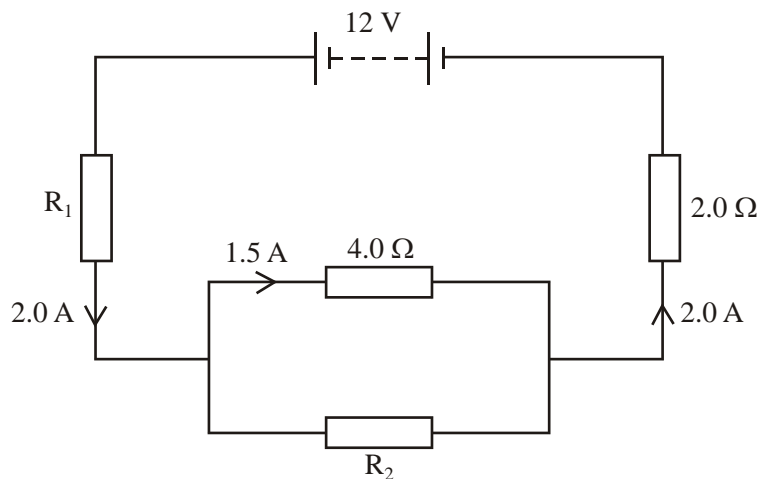
(a)   Calculate the potential difference across the 4.0 Ω resistor.

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....

Potential difference = ...

(1)

(b)   Calculate the resistance of resistor R_2.

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Resistance of R_2 = ...

(2)

(c)   Calculate the resistance of resistor R_1.

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Resistance of R_1 = ...

(3)
(Total 6 marks)

8.   The current I through a metal wire of cross-sectional area A is given by the formula

$$I = nAve$$

where e is the electronic charge on the electron.   Define the symbols n and v.

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(2)

Two pieces of copper wire, X and Y, are joined end-to-end and connected to a battery by wires which are shown as dotted lines in the diagram. The cross-sectional area of X is double that of Y.
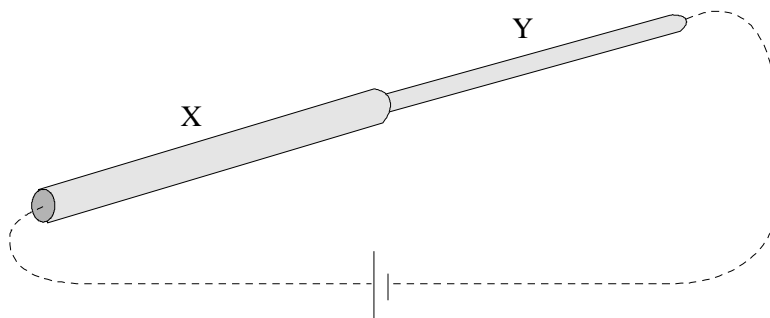
In the table below, n_x and n_y denote the values of n in X and Y, and similarly for the other quantities. Write in the table the value of each ratio, and alongside it explain your answer.

Ratio	Value	Explanation
$\dfrac{n_Y}{n_X}$		
$\dfrac{I_Y}{I_X}$		
$\dfrac{\upsilon_Y}{\upsilon_X}$		

(6)
(Total 8 marks)

9. Use the axes below to sketch and label two graphs to show how the current varies with potential difference for (i) a metal wire, and (ii) a semiconductor diode, both at constant temperature.

Metal wire   Semiconductor diode

(3)

A semiconductor diode carries a current of 20 mA in normal operation.   The potential difference across it should be 1.9 V.   Complete the diagram below to show how, with the addition of a single component, the semiconducting diode may be powered from a 4.5 V supply.

Show that the resistance of the additional component is 130 Ω.

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(3)
(Total 6 marks)

10. Lord Kelvin discovered that the electrical resistance of iron wire changed when the wire was stretched or compressed. This is the principle on which a resistance strain gauge is based. Such a gauge consists of a length of very fine iron wire cemented between two very thin sheets of paper.

Gauge length = 2.4×10^{-2} m

Thin paper

Strain gauge

Fine iron wire
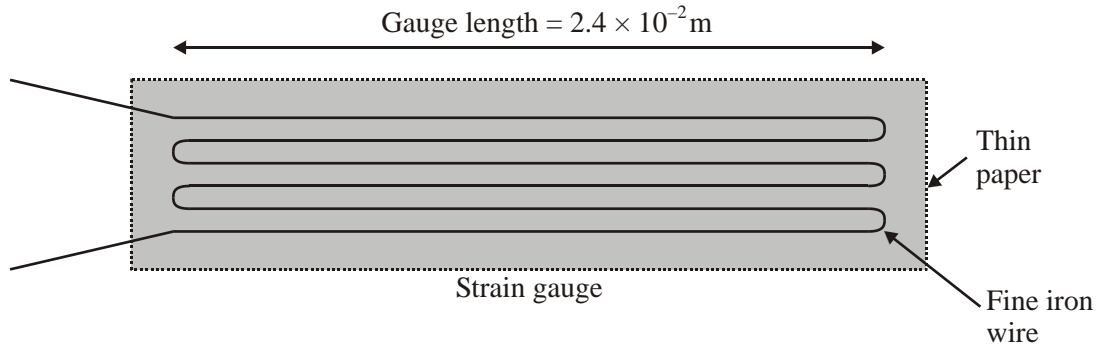
The cross-sectional area of the wire is 1.1×10^{-7} m^2 and the gauge length as shown in the diagram is 2.4×10^{-2} m. The resistivity of iron is 9.9×10^{-8} Ω m. Calculate the resistance of the strain gauge.

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....

....

....

Resistance of strain gauge = ...

(4)

When this gauge is stretched its length is increased by 0.1% but its cross-sectional area remains the same. What is the change in the resistance of the gauge?

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Change in resistance = ...

(2)

Explain the effect that stretching the wire will have on the drift velocity of electrons in the wire. Assume that the other physical dimensions of the wire remain unchanged and that there is a constant potential difference across the wire.

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(3)
(Total 9 marks)

11. Define the term **e.m.f. of a cell**.

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(2)

A student wants to use a graphical method to determine the internal resistance r of a cell of known e.m.f. $\mathcal{E}$.

Complete the diagram below showing how the cell should be connected in a circuit to allow the student to do this.
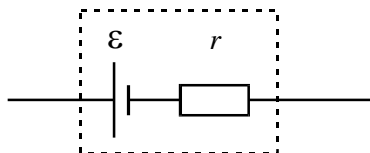
(2)

Sketch the graph the student should plot and state how she could determine *r* from the graph.

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(2)
(Total 6 marks)

12. (a) (i) Write the word equation that defines potential difference.

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(1)

(ii)   The unit of potential difference is the volt. Express the volt in terms of base units only.

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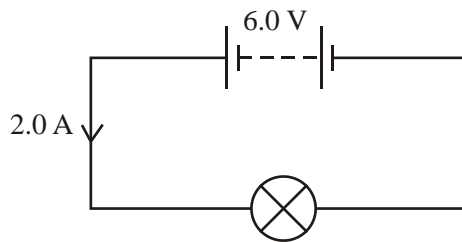...

(3)

(b)   A 6.0 V battery of negligible internal resistance is connected to a filament lamp. The current in the lamp is 2.0 A.

6.0 V

2.0 A

Calculate how much energy is transferred in the filament when the battery is connected for 2.0 minutes.

....

....

....

....

Energy transferred = ……………………………………

(3)
(Total 7 marks)

13.   A 500 W electric toaster operates from the 230 V mains. Calculate the current in the heating element of the toaster.

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Current = ...

(3)

The heating element of the toaster is made of much thinner wire than the wire in its supply cable. In which of these two wires do the electrons have the greater drift velocity?

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(1)

Explain your answer. You may be awarded a mark for the clarity of your answer.

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(4)
(Total 8 marks)

14. A copper wire has a cross-sectional area of 0.20×10^{-6} m^2. Copper has 1.0×10^{29} free electrons per cubic metre.

Calculate the current through the wire when the drift speed of the electrons is 0.94 mm s^{-1}.

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Current = ...

(3)

The wire is 4.0 m long. Copper has a resistivity of 1.7×10^{-8} Ω m. Calculate the resistance of the wire.

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....

....

Resistance = ...

(3)

Calculate the potential difference across the wire.

....

Potential difference = ...

(1)

A second wire with the same dimensions is made from a material that has a greater resistivity than copper. Explain how, if at all, the current will differ from that in the copper wire when the same p.d. is applied across it.

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(2)

The number of free electrons per cubic metre in this wire is the same as that in the copper wire. Compare the drift velocities of the free electrons in the two wires.
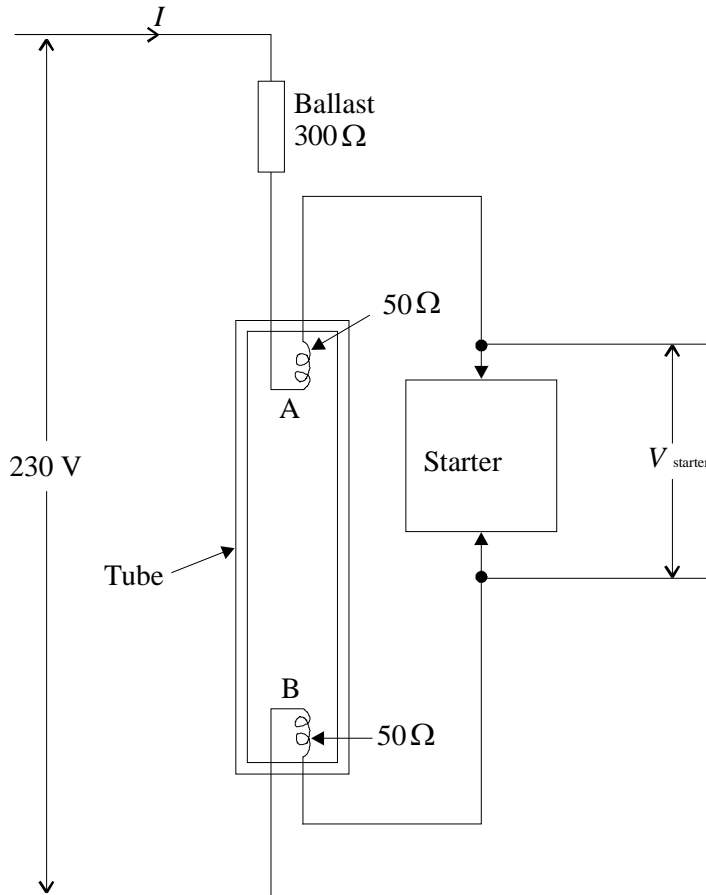
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(1)
(Total 10 marks)

15. The diagram shows the circuit of a fluorescent light fitting. It consists of a tube, a starter and a ballast resistance of 300 Ω.

The fluorescent tube is filled with gas. It contains two filaments at A and B of resistance 50 Ω that heat the gas.

When the light is first turned on, the tube does not conduct but the starter does, drawing a current of 0.50 A from the 230 V supply.

Calculate the voltages across the ballast resistor and each filament when this current flows.

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Voltage across ballast =..

Voltage across each filament =...

(3)

Mark these voltages on the diagram, and hence calculate the voltage across the starter when the starting current is flowing.   Mark your answer on the diagram.

(2)

The starting current heats the filaments and the gas in the tube but the voltage across the tube is not large enough to make it conduct.   However, after a few seconds the starter stops conducting. The voltage across the tube rises and the gas conducts.   A current now flows from A to B and the tube lights up.

What fundamental change is necessary for a gas, which was an insulator, to be able to conduct?

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(1)

Now that the tube is conducting, the voltage across AB is 110 V. Calculate the power dissipated in the whole circuit.

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Power dissipated =................................

(3)

In a faulty fluorescent lamp the filaments at both ends of the tube glow steadily but the tube does not light up.   Identify, with a reason, the faulty component.

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(1)
(Total 10 marks)

16. The table gives four word equations. Complete the table with the quantity defined by each word equation.

Word Equation	Quantity Defined
Voltage ÷ Current	
Voltage × Current	
Charge ÷ Time	
Work Done ÷ Charge	

(Total 4 marks)

17. An electric shower is connected to the mains supply by a copper cable 20 m long. The two conductors inside the cable each have a cross-sectional area of 4.0 mm^2. The resistivity of copper is 1.7×10^{-8} Ω. Show that the resistance of each of the conductors is 0.085 Ω.

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(2)

The operating current of the shower is 37 A. Calculate the total voltage drop caused by the cable supplying the shower.

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Voltage =...

(2)

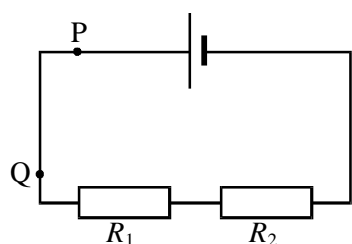Explain why cable with 6.0 mm^2 conductors would have been more suitable for this shower installation.
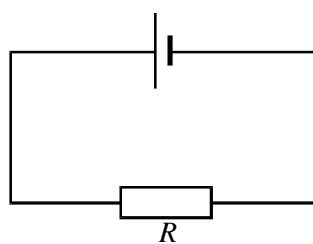
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(2)
(Total 6 marks)

18. The resistors R_1 and R_2 in circuit (i) are equivalent to a single resistor R in circuit (ii).

(i)   (ii)

Prove that $R = R_1 + R_2$

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(3)

In a real circuit it is usually assumed that there is no potential difference between two points, such as P and Q in diagram (i), which are on the same connecting lead. Explain why this is usually a good approximation.

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(2)

In what circumstances might the approximation break down?

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....

(1)

A laboratory lead consists of 16 strands of fine copper wire twisted together. Each strand is 30 cm long with a diameter of 0.15 mm. Calculate the potential difference across the lead when it is carrying a current of 2.0 A.

(The resistivity of copper = 1.7×10^{-8} Ωm)

....

....

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....

Potential difference =...................................

(4)

(Total 10 marks)

19.   The current *I* flowing through a conductor of cross-sectional area *A* is given by the formula

$$I = nAQv$$

where Q is the charge on a charge carrier. Give the meanings of *n* and v.

n ....

v ....

(2)

Show that the equation is homogeneous with respect to units.

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(3)

With reference to the equation, explain the difference between a metal conductor and a plastic insulator.

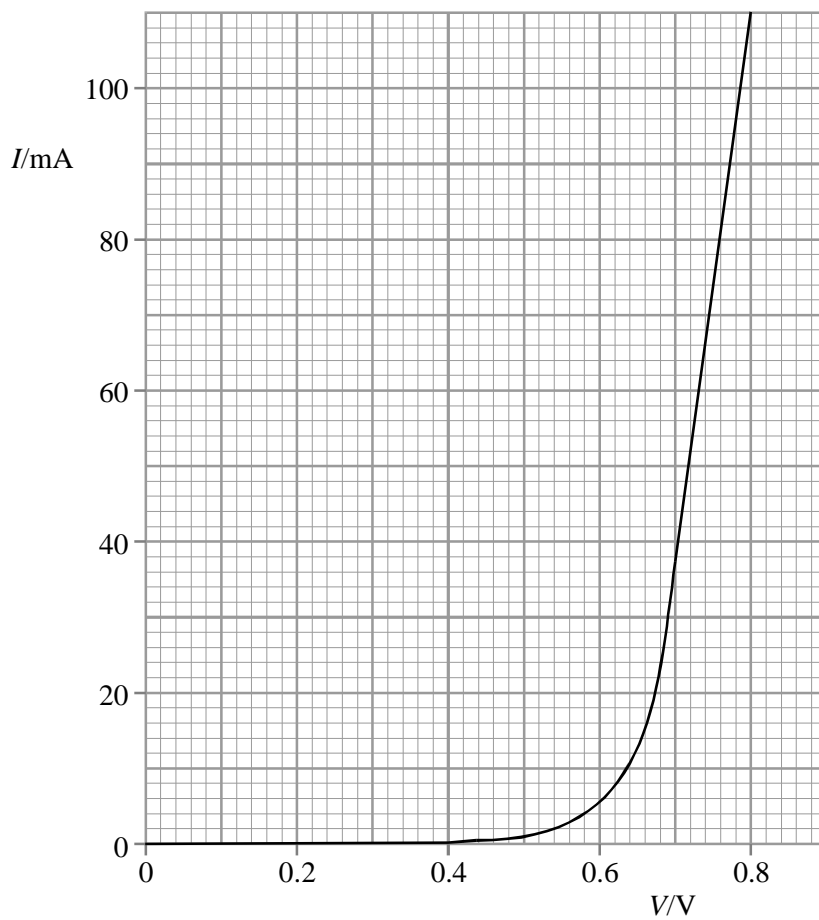...

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(2)
(Total 7 marks)

20. The graph shows the current-voltage characteristic of a semiconductor diode.

State, with a reason, whether the diode obeys Ohm's law.
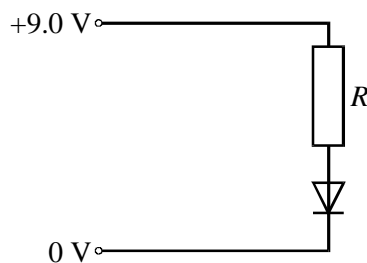
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(1)

Show that when the voltage across the diode is 0.74 V its resistance is about 9 Ω.

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(2)

When the diode is connected in the following circuit, the voltage across it is 0.74 V.

$+9.0$ V○─────────┐
                           │
                        ┌─┴─┐
                        │   │ R
                        └─┬─┘
                          ▽
0 V○─────────┘

Calculate the value of the resistance R.

....

....

....

R = ...

(3)

Electronic circuit designers often use a simple model of this type of diode. This "model diode" has the following properties:

(i)   For any voltage below +0.7 V it does not conduct at all.

(ii)   Once the voltage reaches +0.7 V the diode can pass any size of current with no further increase in voltage.

Add a second graph to the grid above to show the current-voltage characteristic of this model diode.

(2)
(Total 8 marks)

21. A student is planning an experiment to measure the resistivity of aluminium. She plans to use an ohmmeter to measure the resistance of a rectangular strip of aluminium foil fastened between two bulldog clips.
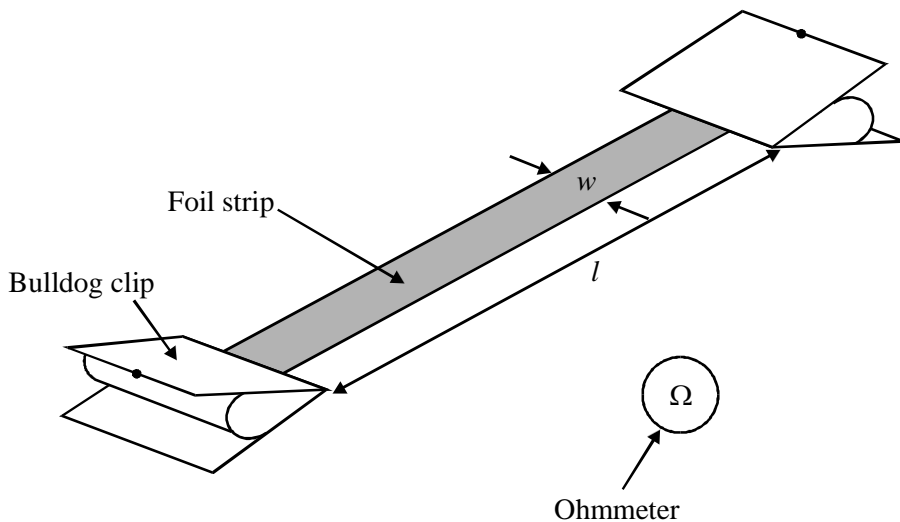
She also intends to measure the thickness t of the foil and the length l and width w of the strip.

Explain how she should calculate the resistivity from her measurements.

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(2)

The student decides that for sufficient accuracy the resistance of the strip must be at least $1.0\ \Omega$. To see what dimensions would be suitable, she does some preliminary experiments using strips 20 mm wide cut from foil 0.15 mm thick. She finds that for strips of a convenient length the resistance is far too small.

Calculate the length of strip, 20 mm wide and 0.15 mm thick, which would have a resistance of $1.0\ \Omega$ (Resistivity of aluminium $= 2.7 \times 10^{-8}\Omega$ m)

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Length =...

(3)

Suggest a way, other than increasing its length, by which she could increase the resistance of her strip. Comment on whether this change would lead to a more precise measurement of the resistivity.
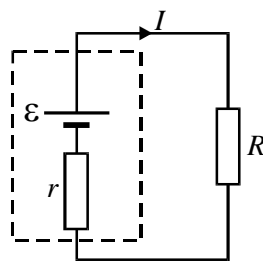
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(2)
(Total 7 marks)

22. The diagram below shows a cell, of e.m.f. ε and internal resistance r, driving a current I through an external resistance R.

Using these symbols, write down a formula for

    (i)   the power dissipated in the external resistance

    ....

    (ii)   the power dissipated in the internal resistance

    ....

    (iii)   the rate of conversion of chemical energy in the cell

    ....

Using these formulae, write down an equation expressing conservation of energy in the circuit, and hence show that $I = \dfrac{\varepsilon}{(R + r)}$

....

....

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(5)

The equation $I = \mathcal{E} / (R + r)$ shows that the internal resistance of a power supply limits the current which can be drawn from it. Explain this.

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(2)

A 5 kV laboratory supply can be made safe for student use by connecting an internal series resistor. The following resistors are available:

$$1\,k\Omega \quad 10\,k\Omega \quad 100\,k\Omega \quad 1\,M\Omega$$

Explain which resistor should be used to make the supply as safe as possible.

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(2)
(Total 9 marks)