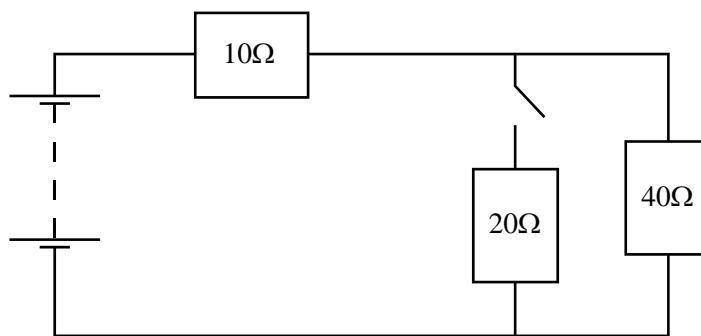


1. Three identical resistors are connected across a potential difference V so that one of them is in parallel with the other two which are connected in series. The power dissipated through the first one, compared to the power dissipated by each of the other two, is approximately
- A the same
 - B half as much
 - C twice as much
 - D four times as much

(Total 1 mark)

2. A circuit is set up as shown in the diagram.



When the switch is closed, the potential difference across the 20Ω resistor would

- A equal the potential difference across the 10Ω resistor
- B be twice the potential difference across the 10Ω resistor
- C equal the potential difference across the 40Ω resistor
- D be half the potential difference across the 40Ω resistor

(Total 1 mark)

3. How much electrical energy is required to move 4.00 mC of charge through a potential difference of 36.0 V?

A 1.11×10^{-4} J

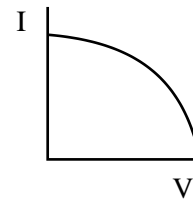
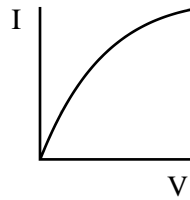
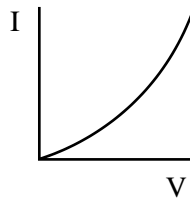
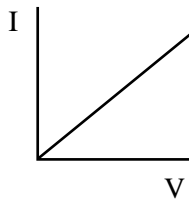
B 0.144 J

C 144 J

D 9000 J

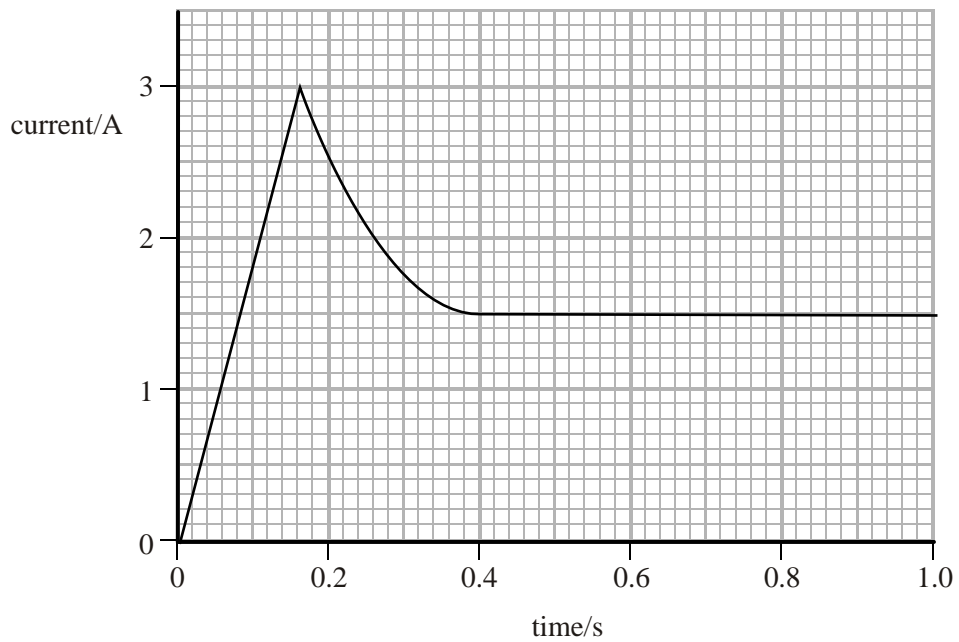
(Total 1 mark)

4. Which of the following graphs gives the current-potential difference characteristic of an NTC thermistor?



(Total 1 mark)

5. The graph shows how the current in a 9 V filament lamp varies during one second after it has been turned on.



- (a) A student wishes to carry out an experiment to verify these results. Explain why using a sensor and computer is a sensible option and suggest a suitable sampling rate.

.....

.....

.....

(2)

- (b) Explain the shape of the graph and why the filament is more likely to fail when being switched on rather than at other times.

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(4)
(Total 6 marks)

6. A group of students is discussing why the resistance of the metal filament of a lamp and the resistance of an NTC thermistor respond differently to changes in temperature.

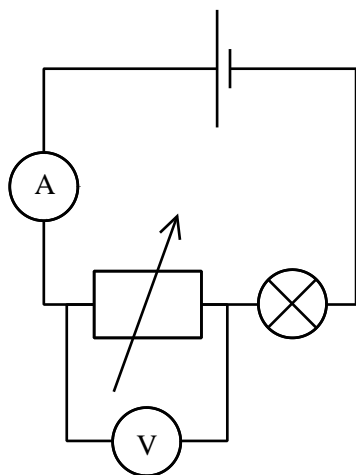
One student says that the increased vibrations of the atoms affect the conduction process. Another student says that as the temperature increases more electrons can break free of the atoms and take part in conduction.

Both students are correct. Explain how these **two** effects apply to the lamp and the thermistor.

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(Total 5 marks)

7. A student sets up the following circuit to measure the internal resistance of a cell.



(a) What is wrong with his circuit diagram?

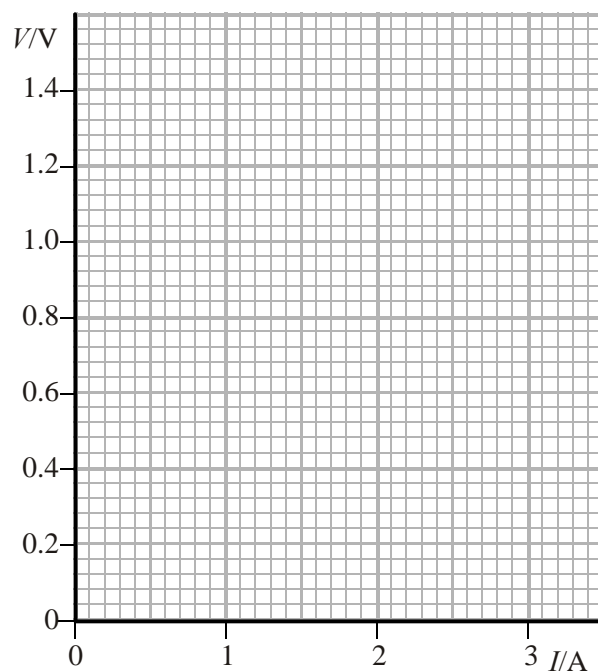
.....

(1)

(b) Using the correct circuit the student obtains the following results.

| Current in the cell I/A | Terminal potential difference across the cell V/V |
|------------------------------|--------------------------------------------------------|
| 0.5 | 1.2 |
| 0.9 | 1.0 |
| 1.5 | 0.8 |
| 1.9 | 0.6 |
| 2.5 | 0.4 |
| 2.9 | 0.2 |

- (i) On the grid below, plot these results and draw the line of best fit through your points.



(3)

- (ii) Use your graph to determine the e.m.f. of the cell.

e.m.f. =

(1)

- (iii) Use your graph to determine the internal resistance of the cell.

Internal resistance =

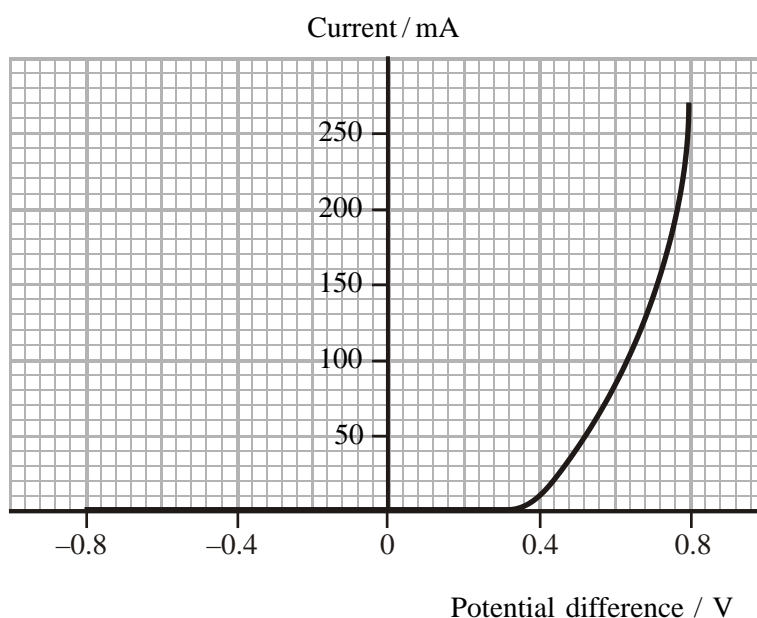
(2)

- (c) The experiment is repeated with two such cells connected in series. How does the graph differ?

.....

(2)
 (Total 9 marks)

8. The current–potential difference characteristics of an electrical component are shown below.



- (a) Name the component.

(1)

- (b) (i) Calculate the resistance of this component when the potential difference is +0.60 V.

.....

Resistance =

(2)

(ii) State its resistance when the potential difference is -0.80 V .

.....

(1)

(c) State a practical use for this component.

.....

(1)

(Total 5 marks)

9. (a) Define resistivity.

.....

.....

.....

(2)

(b) (i) The heating element used in a hairdryer consists of a long nichrome wire coiled around an insulator. The hairdryer operates at 230 V and has a power of 1.0 kW . Calculate the resistance of the heating element.

.....

.....

.....

.....

Resistance =

(3)

- (ii) The wire has a cross-sectional area of $1.3 \times 10^{-7} \text{ m}^2$. The resistivity of nichrome is $1.1 \times 10^{-6} \Omega \text{ m}$. Calculate the length of the nichrome wire.

.....
.....
.....
.....

Length =

(3)

- (iii) The nichrome wire in this heating element has a diameter of 0.41 mm.

A manufacturer wishes to make a hairdryer of the same resistance but using half the length of nichrome wire. What diameter wire must be used?

.....
.....
.....
.....

Diameter =

(2)

(Total 10 marks)

(3)

- (ii) Use your graph to determine the e.m.f. of the cell.

e.m.f. =

(1)

(iii) Use your graph to determine the internal resistance of the cell.

Internal resistance =

(2)

(c) The experiment is repeated with two such cells connected in series. How does the graph differ?

.....
.....
.....

(2)

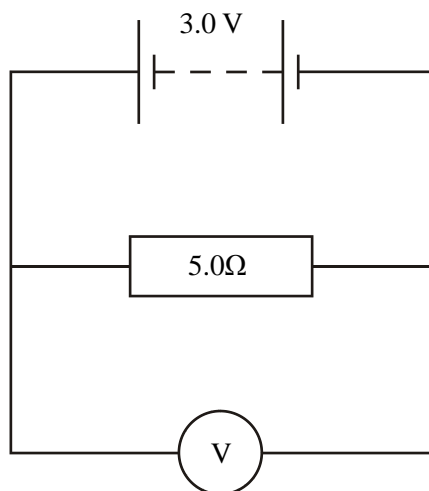
(Total 9 marks)

10. (a) Define the term electromotive force (e.m.f.).

.....
.....
.....

(2)

- (b) A battery of e.m.f. 3.0 V is connected to a 5.0 Ω resistor with a very high resistance voltmeter placed across the resistor.



- (i) The very high resistance voltmeter gives a reading of 2.8 V. Show that the internal resistance of the battery is about 0.4 Ω .

.....

.....

.....

.....

.....

(3)

- (ii) A voltmeter with a resistance of 10 Ω is used instead of the original one. Calculate the combined resistance of this voltmeter and the 5.0 Ω resistor.

.....

.....

.....

.....

Combined resistance =

(2)

(iii) Calculate the reading on this voltmeter.

.....
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.....
.....

Voltmeter reading =

(3)

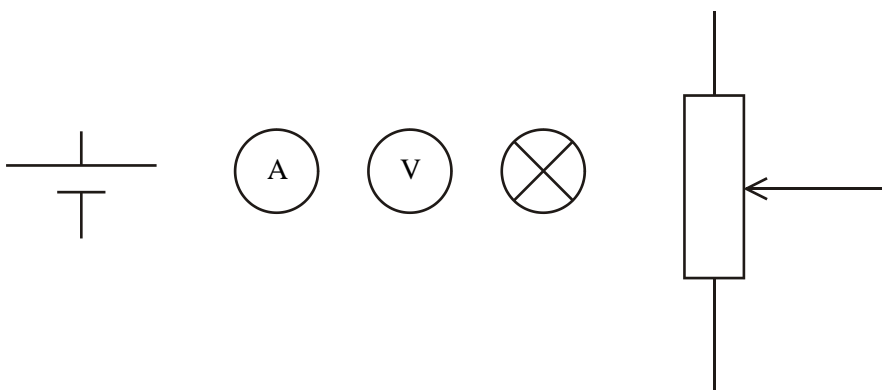
(c) State and explain what the resistance of an ideal voltmeter should be.

.....
.....
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.....

(2)

(Total 12 marks)

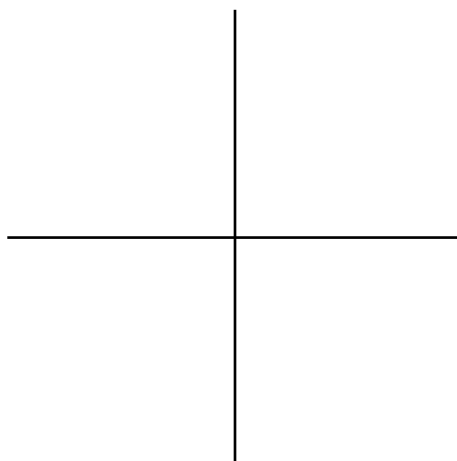
11. An experiment is set up to investigate how the current I in a filament lamp varies with the potential difference V across it. The components used are shown below.



- (a) Readings are taken over the full range from 0 V to the cell's maximum potential difference. In the space below, draw a circuit diagram for this experiment.

(2)

- (b) (i) Sketch on the axes below the shape of the graph you would expect the results to give.



(2)

- (ii) Explain the shape of your graph. You may be awarded a mark for the clarity of your answer.

.....
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.....

(4)
(Total 8 marks)

12. A portable games console has the option of using a rechargeable battery unit which is recharged by connecting it to a mains adaptor. The adaptor has an input power of 2.5W at a voltage of 230 V.

- (a) Calculate the adaptor's input current when it is in use.

.....
.....

Current =

(2)

- (b) The adaptor's output is marked as: 3 V 0.2 A 0.6 VA

- (i) Explain why V A is a unit of power.

.....
.....

(1)

(ii) Calculate the efficiency of the adaptor.

.....
.....
.....

Efficiency =

(2)

(iii) Suggest and explain a reason for the efficiency being less than 100%.

.....
.....
.....

(2)

(c) (i) The battery unit takes a time of 6 hours to charge fully. Assuming the adaptor's output current remains constant, calculate the amount of charge which flows from the adaptor.

.....
.....
.....

Charge =

(2)

(ii) Calculate the work done by the adaptor.

.....
.....
.....

Work done =

(3)

(Total 12 marks)

13. Modern technology makes wide use of light-emitting devices. For many years, however, their use was limited by the lack of materials that could emit blue light efficiently.

(a) State one property of blue light which is different from red light.

.....

(1)

(b) Physicists found that by adding indium to the semiconductor gallium nitride they could vary the band gap energy of the material from 2.0 to 3.4 eV and so produce a range of light from red to blue.

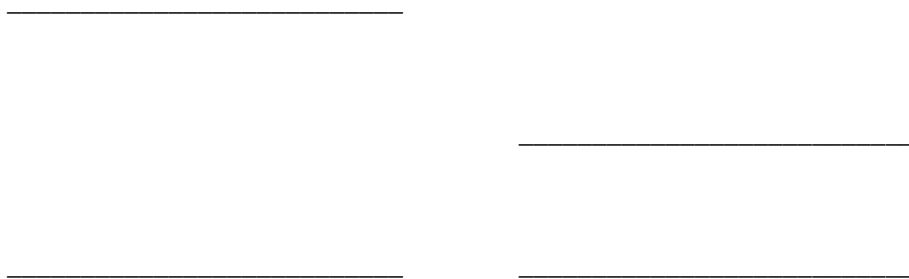
(i) Calculate the frequency range which corresponds to the above band gap energies.

.....
.....
.....
.....
.....

Frequency range =

(3)

(ii) The following diagrams show the ground state and one excited state for the semiconductor when it is being used to emit red and blue light. Decide which diagram is showing the band gap of the blue light emitter and add an arrow to show the electron transition that occurs during the emission of a blue light photon.



(2)

(c) The physicists also found that after this semiconductor material had been heated strongly in nitrogen its resistivity had dropped from $106 \Omega \text{ cm}$ to just $2 \Omega \text{ cm}$.

(i) State one advantage of this drop in resistivity when the semiconductor is in use.

.....

(1)

(ii) The length of a rectangular sample of the semiconductor is 0.5 cm . Its width is 0.3 cm and its thickness is 0.4 mm . Calculate the resistance across its length when the resistivity is $2 \Omega \text{ cm}$.

.....
.....
.....
.....
.....
.....

Resistance =

(3)

(Total 10 marks)

14. The current I in a conductor of cross-sectional area A is given by the formula

$$I = n A Q v$$

where Q is the charge on the charge carrier.

(a) State the meanings of n and v .

n :

v :

(2)

(b) Show that the equation is homogeneous with respect to units.

.....
.....
.....
.....
.....
.....

(3)

(c) Two pieces of wire A and B are made of the same material but have different diameters. They are connected in series with each other and a power supply.

(i) Which terms from the above equation will be the same for both wires?

.....

(1)

(ii) The diameter of A is twice that of B. Calculate the ratio $v_A : v_B$.

.....
.....
.....
.....

(2)

(Total 8 marks)

15. A and B are two lamps.

(a) Lamp A is rated at 12 V, 24W. Calculate the current in the lamp when it operates at its rated voltage.

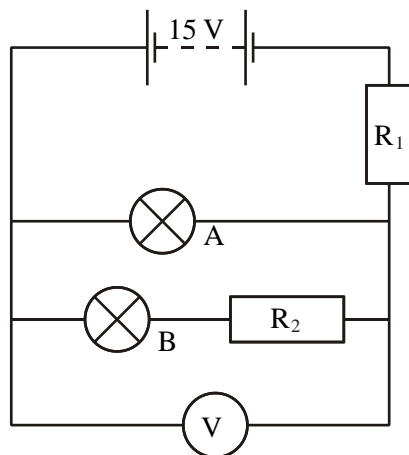
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Current in lamp A=

(2)

(b) Lamp B is rated at 6.0 V. When it operates at its rated voltage, the current in it is 3.0 A.

Lamps A and B are connected in a circuit as shown below. The values of R_1 and R_2 are chosen so that both lamps operate at their rated voltage.



(i) State the reading on the voltmeter.

.....

(1)

(ii) Calculate the resistance of R_2 .

.....

Resistance of $R_2 =$

(3)

(iii) Calculate the current in R_1 .

.....

Current in $R_1 =$

(1)

(iv) Calculate the potential difference across R_1 .

.....

Potential difference =

(1)

(v) Calculate the resistance of R_1 .

.....

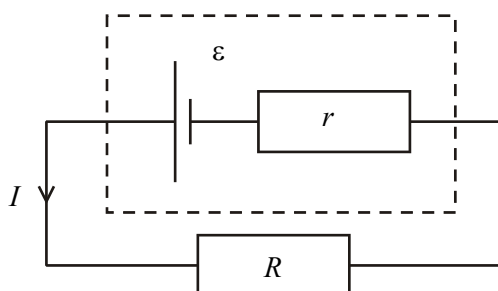
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Resistance of R_1 =

(1)

(Total 9 marks)

16. A cell of e.m.f. ε and internal resistance r is connected in a circuit with a resistor of resistance R . The current in the circuit is I .



(a) Using the symbols in the diagram, write down a formula for

(i) the rate of conversion of chemical energy in the cell,

.....

(ii) the power dissipated in the resistor of resistance R ,

.....

(iii) the power dissipated in r .

.....

(3)

(b) Use these formulae to write an equation based on conservation of energy in the circuit.

.....

(1)

(c) The current I in the above circuit is given by the formula $I = \varepsilon / (R + r)$. A laboratory E.H.T. supply is designed to produce a maximum potential difference of 5 kV. Give a typical value for the internal resistance of this supply and explain why it has this value.

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(3)

(Total 7 marks)

17. A gardener installs a solar powered fountain in a sunny part of his garden. He has the following data about the solar panel from the manufacturer.

Under best conditions:

| | |
|--------------------------|--------|
| voltage across terminals | 12.0 V |
| power available | 5.9 W |

The solar panel provides power to a water pump.

(a) (i) Calculate the maximum current in the pump. Assume that the resistance of the connecting cable is negligible.

.....
.....

Current =

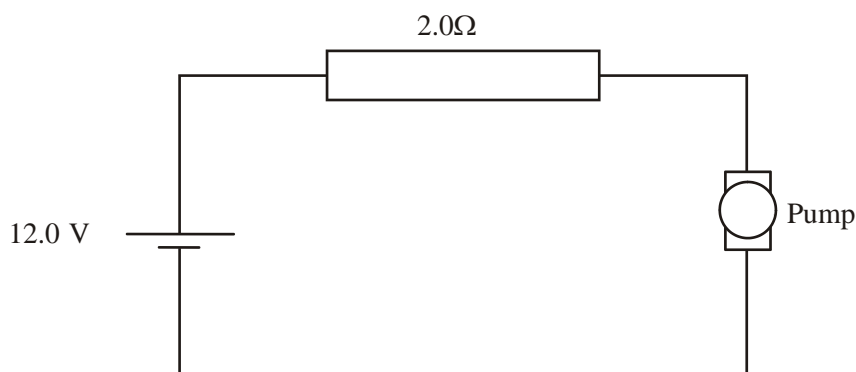
(2)

(ii) Show that the electrical resistance of the pump is about 24Ω .

.....
.....

(2)

(b) He decides to install another identical fountain in a shady area of the garden. He has to place the solar panel some distance away from the pump so that it is in the sunlight. He then uses a much longer connecting cable. The connecting cable to this pump has a total resistance of 2.0Ω . The circuit is equivalent to that shown below.



Calculate

(i) the current in this circuit

.....
.....

Current =

(2)

(ii) the power available to the pump.

.....
.....

Power =

(2)

- (c) State **one** way in which the power available to the pump in the shady area could be improved. The positions of solar panel and fountain cannot be changed.

.....
.....
.....
.....

(1)
(Total 9 marks)

18. Listed below are five physical quantities.

charge current potential difference resistance resistivity

Select from this list the quantity that fits each description below. You may use each quantity once, more than once or not at all.

- (i) A quantity which can be measured in joules per coulomb.

.....

- (ii) A quantity which equals the product of two other quantities in the list.

.....

- (iii) A quantity which equals the rate of change of another quantity in the list.

.....

- (iv) A base quantity in the SI system.

.....

(Total 4 marks)

19. (a) A thermistor has a negative temperature coefficient. Explain with reference to the equation $I = nAQv$ what happens to its resistance when its temperature increases.

.....

.....

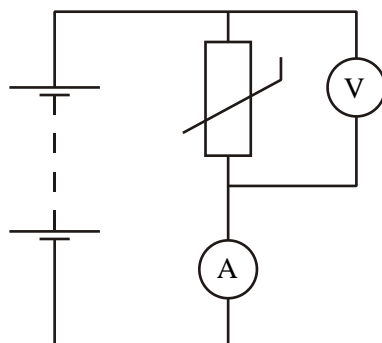
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.....

.....

(3)

- (b) This thermistor is connected as shown in the diagram. Assume the battery has negligible internal resistance.



This circuit can be used as an electrical thermometer to monitor the temperature of a water bath.

- (i) State how each meter responds when the temperature of the water is decreased.

Ammeter:

Voltmeter:

(2)

- (ii) Which meter is used to indicate temperature?

.....

(1)

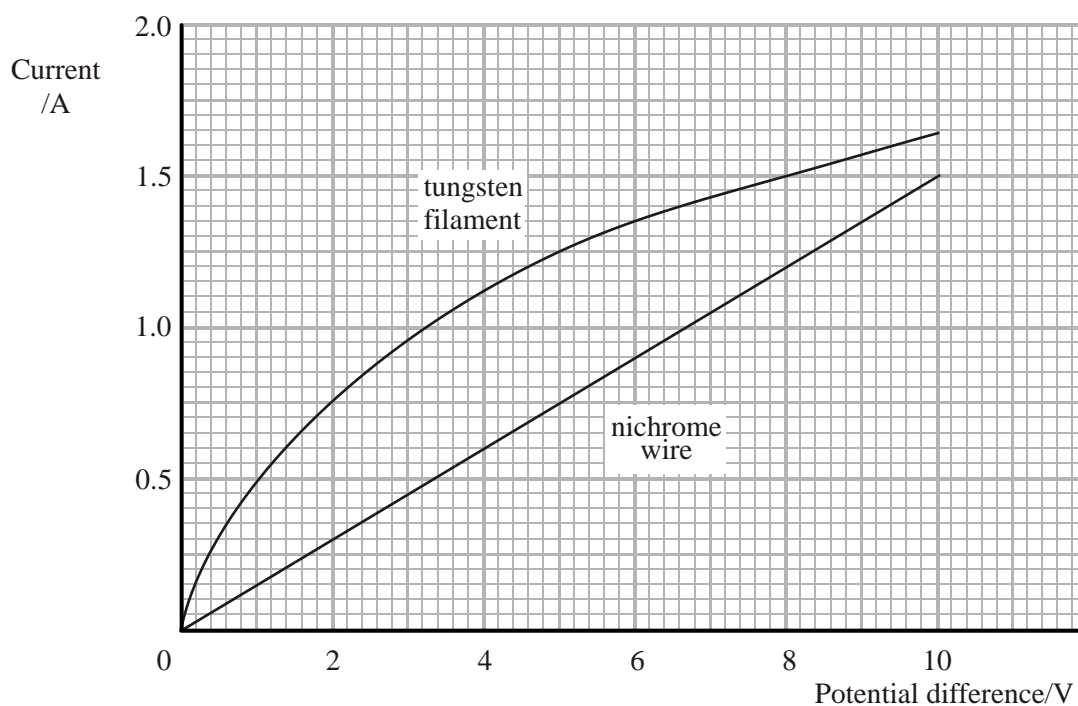
(iii) State another assumption that you made.

.....

(1)

(Total 7 marks)

20. The graph shows the I - V characteristics for two conductors. One is a length of nichrome wire and the other is the tungsten filament of a lamp.



- (a) Making reference to Ohm's law, explain the shape of the tungsten filament graph. You may be awarded a mark for the clarity of your answer.

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.....

(4)

- (b) (i) Calculate the resistance of the tungsten filament when the potential difference across it is 8.0 V.

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.....
.....

Resistance =

(2)

- (ii) Both conductors are connected in parallel with an 8.0 V supply. Calculate the current that will be drawn from the supply.

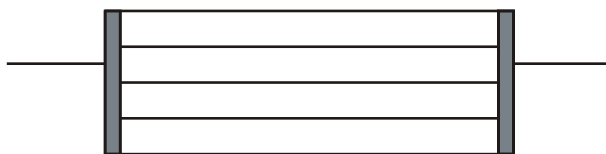
.....
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.....

Current =

(2)

(Total 8 marks)

21. A heater used on the rear window of a car consists of five strips of a resistive material joined as shown in the diagram.



When it is in use, the potential difference applied to the heater is 12 V and the heater generates 32 J of energy each second.

- (a) (i) Calculate the total resistance of the heater.

.....

Total resistance =

(2)

- (ii) Calculate the resistance of a single strip.

.....

Resistance =

(2)

- (b) Each strip has a cross-sectional area of $4.0 \times 10^{-8} \text{ m}^2$ and is made from a material of resistivity $1.1 \times 10^{-6} \Omega \text{ m}$. Calculate the length of each strip.

.....

Length =

(3)

- (c) The car manufacturer wants the rear window heater to be more powerful. Explain how this could be achieved without altering the dimensions of the individual strips or the potential difference across them.

.....

.....

.....

.....

.....

(2)
(Total 9 marks)

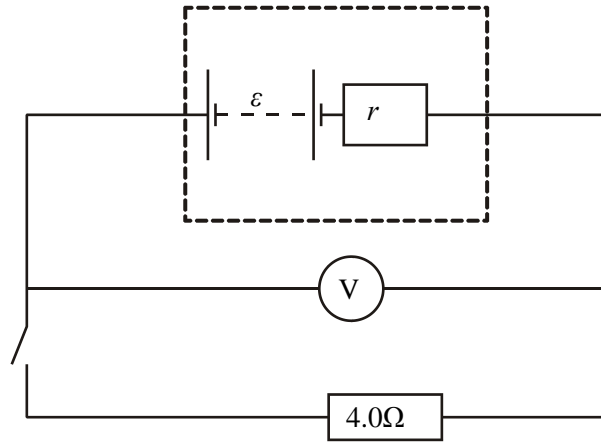
22. (a) Define the e.m.f. of a battery.

.....

.....

(1)

- (b) (i) A battery of e.m.f. ε and internal resistance r is connected into a circuit as shown below.



When the switch is open the voltmeter reads 12.0 V and when the switch is closed it reads 8.0 V. Calculate the current in the circuit when the switch is closed.

.....

Current =

(2)

- (ii) Determine the value of r .

.....

$r = \dots\dots\dots$

(2)

- (iii) The switch remains closed. Calculate the power dissipated in the 4.0Ω resistor.

.....

Power =

(2)

(iv) Calculate the energy wasted in the battery in five minutes.

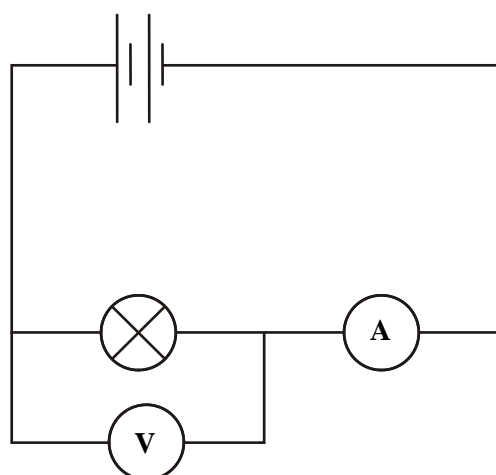
.....
.....
.....

Energy =

(3)
(Total 10 marks)

23. A student investigates the use of rechargeable cells in a torch.

The diagram shows the circuit used to obtain readings of voltage and current for the torch bulb.



The results obtained are voltage = 2.68 V, current = 0.31 A.

(a) (i) Calculate the resistance of the torch bulb.

.....
.....
.....

Resistance =

(2)

- (ii) The cells form a battery with an emf of 2.80 V.

Show that the internal resistance of the battery is about 0.4 Ω .

.....
.....
.....

(2)

- (iii) Comment on how well these values match the necessary condition for maximum power transfer between the battery of cells and the torch bulb.

.....
.....
.....

(2)

- (b) Each cell is labelled: 'capacity 2 A h'. (A h is amp hours).

- (i) Show that this corresponds to a total stored charge of about 14 000 C for the battery of two cells.

.....
.....
.....

(2)

- (ii) Calculate the time for which the battery could maintain a current of 0.31 A in the torch bulb.

.....
.....
.....

Time =

(2)

- (c) The internal resistance of the cells increases as they are used. Explain what effect this will have on the efficiency of the system.

.....

.....

.....

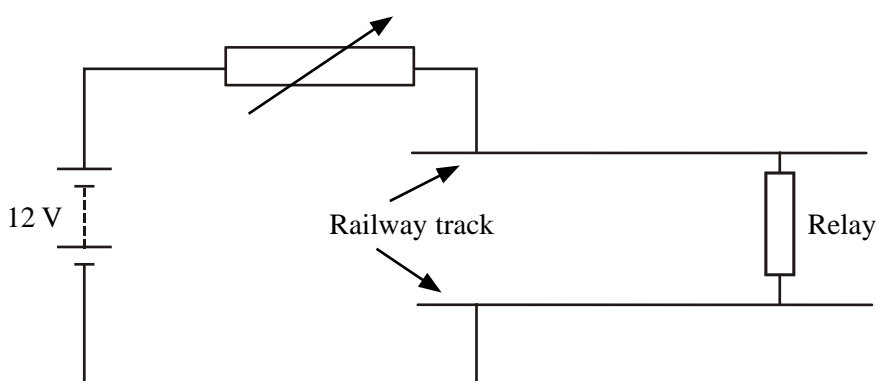
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(2)
(Total 12 marks)

24. Railway signals rely on a combination of resistors to trigger the correct colour of light. Figure 1 shows a simplified version of the circuit used. The relay can be considered to be equivalent to a resistor. When the potential difference across the relay is above 3 V it switches on the green signal. The signal is red when the relay potential difference is less than this value.

Figure 1



- (a) The ratio of potential differences across the resistors in this circuit varies as the resistances change. What name is given to a circuit such as this which makes use of multiple resistors in this way?

.....

(1)

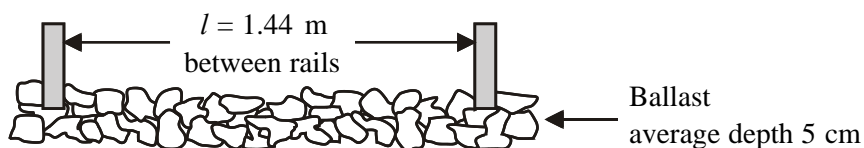
- (b) The variable resistor is set to $10\ \Omega$. The relay resistance is $5.0\ \Omega$. Calculate the potential difference across the relay. Assume the railway track has negligible resistance.

.....
 Potential difference =

(1)

- (c) The track is laid in sections of $100\ \text{m}$, with a length l between the rails. Each section of track is insulated from the next section. Ballast, usually made of broken up rock, is used to support the track as shown in Figure 2.

Figure 2



- (i) The ballast has a depth of $5.0\ \text{cm}$ and a resistivity of $3.4 \times 10^2\ \Omega\ \text{m}$. Show that the resistance of this $100\ \text{m}$ section of ballast between the rails is about $100\ \Omega$.

.....

(3)

- (ii) The ballast resistance is in parallel with the relay. Calculate the combined resistance due to the above section of ballast and the $5.0\ \Omega$ relay.

.....

Resistance =

(2)

(iii) How does the value of the potential difference across the relay and ballast compare with the potential difference across the relay alone?

.....
.....

(1)

(iv) When a train is on the track the current flows through the wheel axle from rail to rail causing a short-circuit in parallel with the relay. What would the effect be on the potential difference across the relay?

.....

(1)

(v) When wet the ballast resistance drops considerably and may become as small as 0.5Ω . Explain the consequence of this drop in resistance in terms of the signal lights.

.....
.....
.....
.....

(2)

(Total 11 marks)

25. A 240 V 60 W light bulb has a tungsten filament which has a working temperature of 2600°C .

(a) Calculate the resistance of the tungsten filament at this temperature.

.....
.....

Resistance =

(2)

- (b) The filament has a cross-sectional area of $3.1 \times 10^{-10} \text{ m}^2$. Tungsten contains 3.4×10^{28} free electrons per cubic metre. Determine the drift speed of the electrons in the filament when the current is 0.25 A.

.....

Drift speed =

(3)

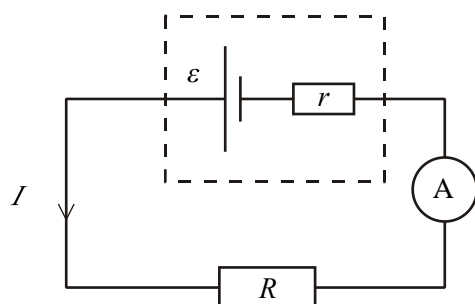
- (c) Explain fully why the resistance of a tungsten filament increases with temperature. You may be awarded a mark for the clarity of your answer.

.....

(4)

(Total 9 marks)

26. A student sets up the following circuit using a cell of e.m.f. ϵ and internal resistance r .

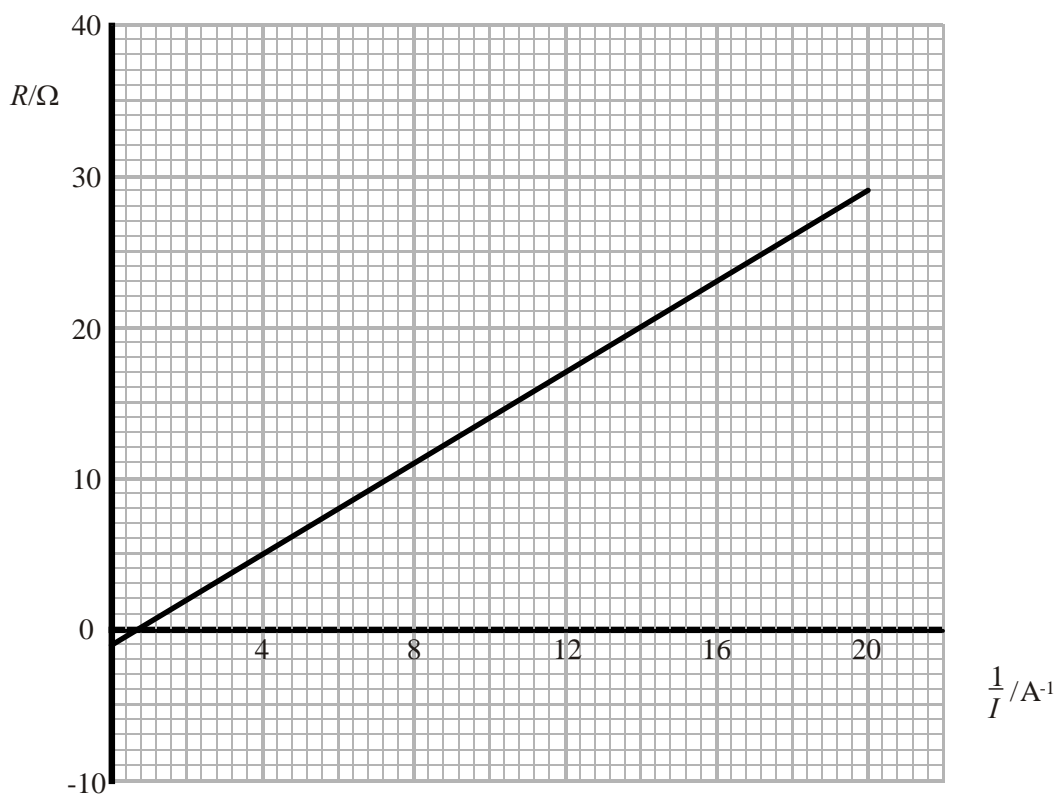


- (a) Complete the equation for the total e.m.f. \mathcal{E} in terms of the other quantities given in the diagram.

$$\mathcal{E} =$$

(1)

- (b) He measures the current I for different values of resistance R . He then plots a graph of R against $1/I$.



The equation for this graph is \mathcal{E}

$$R = \frac{\mathcal{E}}{I} - r$$

- (i) Show how this equation is derived from the one you have stated above.

.....

(1)

- (ii) Use the graph to determine the value for the e.m.f. of the cell. Show all your working.

.....
.....

E.m.f. =

(2)

- (iii) Show that when the external resistance is 5Ω the power dissipated in that resistance is about 0.3 W .

.....
.....
.....

(3)

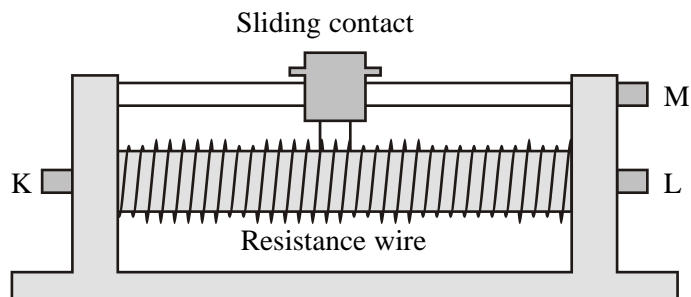
- (c) The student repeats the experiment adding an identical cell in series. Draw on the graph the result of this experiment.

(3)

(Total 10 marks)

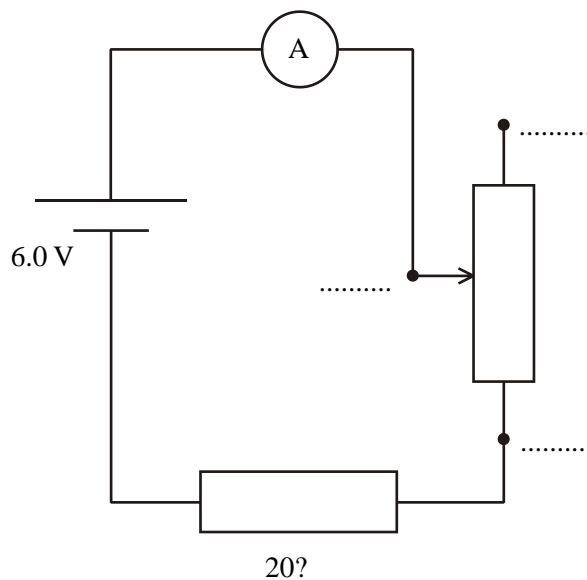
27. A variable resistor consisting of a wire and sliding contact has three terminals labelled K, L and M.

Figure 1



The variable resistor is connected in series with a 6.0 V supply of negligible internal resistance, an ammeter and a 20 Ω fixed resistor.

Figure 2



- (a) Label the terminals K, L and M on Figure 2.

(1)

- (b) (i) The variable resistor has a maximum resistance of $10\ \Omega$. The resistance of the fixed resistor is $20\ \Omega$. Determine the potential difference across the resistor when the sliding contact is at the mid-point of the variable resistor.

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.....
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.....
.....

Potential difference =

(3)

- (ii) What assumption have you made about the ammeter?

.....

(1)

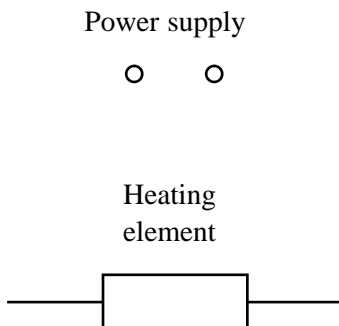
- (c) The same components can be used in a second circuit to vary the potential difference across the fixed resistor fully from $0\ \text{V}$ to $6.0\ \text{V}$. Draw the circuit diagram for this potential divider arrangement.

(3)

(Total 8 marks)

28. A student connects a circuit to find the resistance of a washing machine heating element.

(a) Complete the circuit diagram below and explain how he uses it to obtain the necessary measurements to calculate resistance.



.....

.....

.....

(2)

(b) The following results are obtained.

Voltage = 3.00 V

Current = 0.12 A

Calculate the resistance of the element from these values.

.....

.....

.....

Resistance =

(2)

- (c) The element is marked “1800 W, 230 V”.

Calculate the resistance of the element in normal use.

.....
.....
.....

Resistance =

(2)

- (d) Explain why the two values of resistance you have calculated are different.

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(2)

(Total 8 marks)

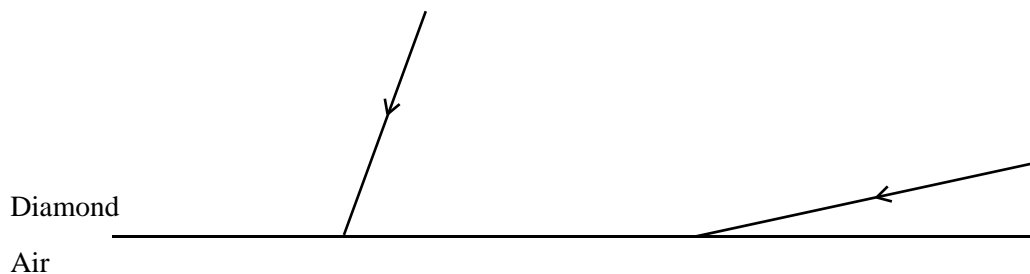
29. Diamonds are one of the most beautiful but expensive jewels available today. Their beauty is due largely to the way in which they sparkle when light falls on them. The way a jewel sparkles is related to how light is reflected inside the jewel which depends upon its refractive index.

- (a) (i) Diamond has a refractive index of 2.42. Show that the critical angle C for light passing from diamond into air is about 24° .

.....
.....
.....

(2)

- (ii) Add appropriate normals to the following diagram at the diamond-air interface and then sketch the paths that the two light rays would follow. One of them hits the interface at an angle smaller than C , and the other at an angle greater than C .



(2)

- (iii) On the above diagram label
1. an incident angle i ,
 2. an angle of refraction r .

(2)

- (iv) Explain how the amount of light reflected inside the jewel depends on the refractive index, using the terms **critical angle** and **total internal reflection**.

.....

.....

.....

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.....

.....

(3)

- (b) There have been many attempts to make imitation diamonds but they have always lacked the sparkle of the real thing. Recently, however, a semiconductor company has manufactured a mineral called moissanite. This has similar properties to diamond, but is much cheaper.

The refractive index of moissanite is about 2.67. Comment on the critical angle and hence the sparkle of this mineral compared with diamond.

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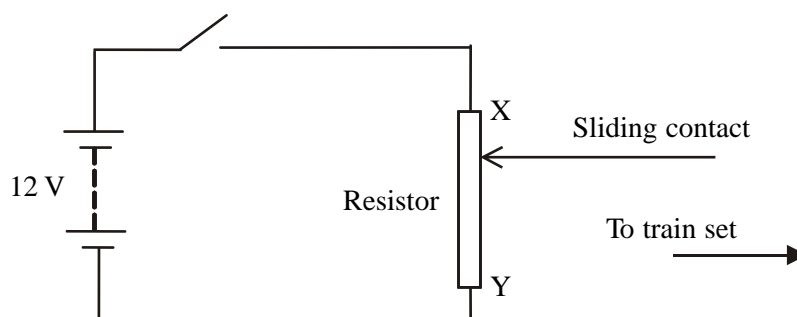
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(1)
(Total 10 marks)

30. A child wants to power his model train set from a 12 V battery. He also wants to be able to control the speed of his trains.

His sister is studying Physics and suggests using the following circuit.



She has the following materials to choose from to make the resistor.

| Material | Resistivity / $\Omega \text{ m}$ |
|------------|----------------------------------|
| Copper | 1.8×10^{-8} |
| Iron | 1.2×10^{-7} |
| Constantan | 4.9×10^{-7} |
| Carbon | 1.4×10^{-5} |

- (a) The resistivity of the materials varies greatly. What type of scale could be used to plot them most easily on a graph?

.....

(1)

(b) (i) She chooses a carbon rod. Explain why this is a good choice.

.....
.....
.....
.....

(2)

(ii) The carbon rod she uses has a cross-sectional area of $3.0 \times 10^{-6} \text{ m}^2$ and a length of 40 cm. Show that the total resistance of the carbon rod is about 2Ω .

.....
.....
.....

(3)

(iii) Assuming that the internal resistance of the battery and the resistance of the connecting wires is negligible, state the potential difference available to the train set when the sliding contact is at:

X Y

(1)

(iv) The total resistance of the wires connecting the battery to the resistor is about 0.5Ω . Explain whether this would have a significant effect on the potential difference available for the train set.

.....
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.....
.....
.....

(2)

(Total 9 marks)

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

.....

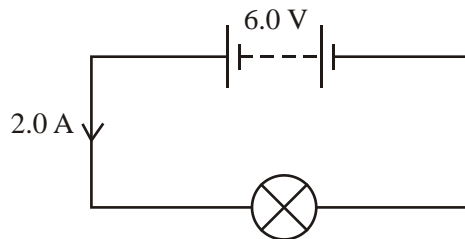
(1)

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

.....
.....
.....
.....
.....

(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.



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

.....
.....
.....
.....

Energy transferred =

(3)

(Total 7 marks)

32. The current I in a conductor of cross-sectional area A is given by the formula

$$I = nAQv$$

where Q is the charge on a charge carrier.

(a) What quantities do n and v represent?

n

v

(2)

(b) A student has a metal conductor and a plastic insulator of the same dimensions. He applies the same potential difference across each. Explain how the relative values of n for the metal conductor and plastic insulator affect the current in each.

.....

.....

.....

.....

(2)

(c) The student connects two pieces of copper wire, A and B, in series with each other and a battery. The diameter of wire A is twice that of wire B. Calculate the ratio of the drift velocity in wire A to the drift velocity in wire B and explain your answer.

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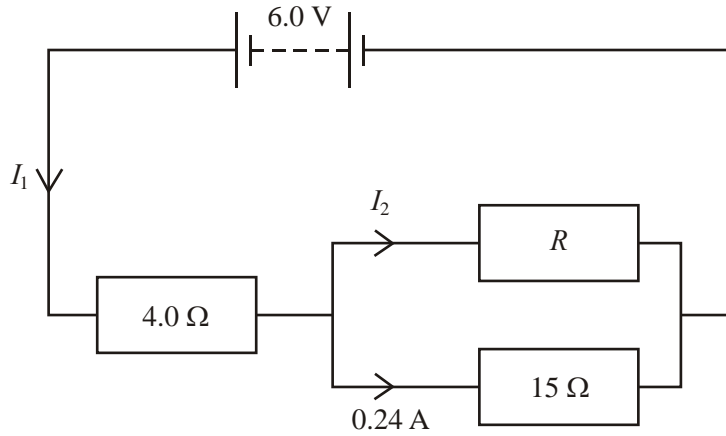
.....

.....

(3)

(Total 7 marks)

33. The circuit shows a battery of negligible internal resistance connected to three resistors.



(a) Calculate the potential difference across the 15Ω resistor.

.....

Potential difference =

(1)

(b) Calculate the current I_1 in the 4.0Ω resistor.

.....

.....

.....

$I_1 = \dots\dots\dots$

(3)

(c) Calculate the current I_2 and the resistance R .

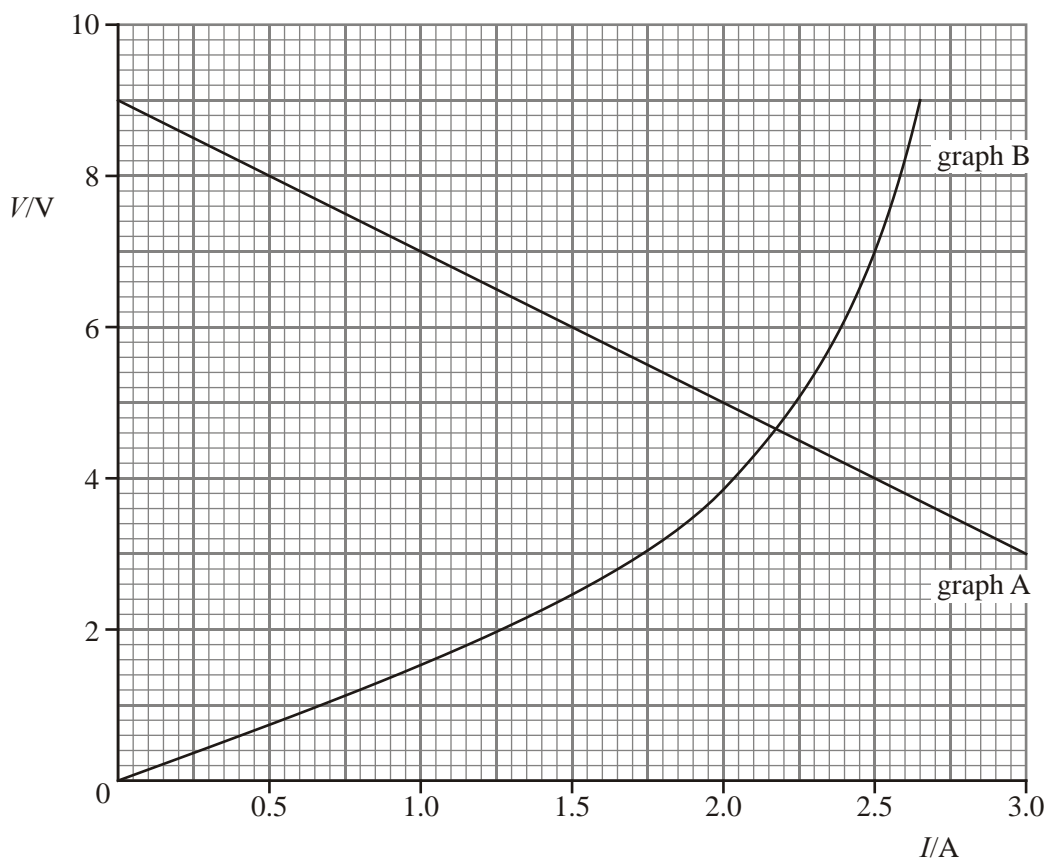
.....

$I_2 =$

$R =$

(3)
 (Total 7 marks)

34. Graph A shows how the potential difference across a battery varies with the current supplied. Graph B shows how the current in a filament lamp varies with the p.d. across it.



(a) (i) Use graph A to determine the internal resistance and the e.m.f. of the battery.

.....
.....

Internal resistance =

e.m.f =

(2)

(ii) The lamp is connected to the battery. Determine the current in the lamp.

.....

(1)

(iii) Calculate the resistance of the filament lamp when it is connected to the battery.

.....
.....
.....

Resistance =

(2)

(b) (i) Draw a diagram of a circuit that would enable graph A to be plotted.

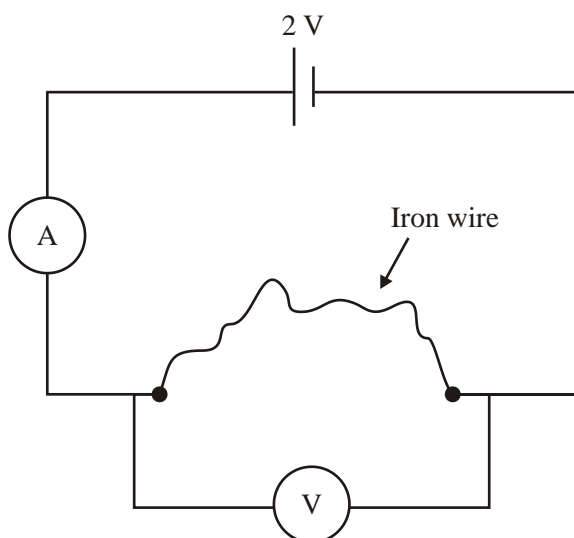
(2)

(ii) Describe how you would use this circuit to obtain the data for the graph.

.....
.....
.....
.....

(2)
(Total 9 marks)

35. A student carries out an experiment to determine the resistivity of iron using the circuit shown below.



He uses iron wire with a diameter of 0.50 mm.

Show that the cross-sectional area of this wire is about $2 \times 10^{-7} \text{ m}^2$.

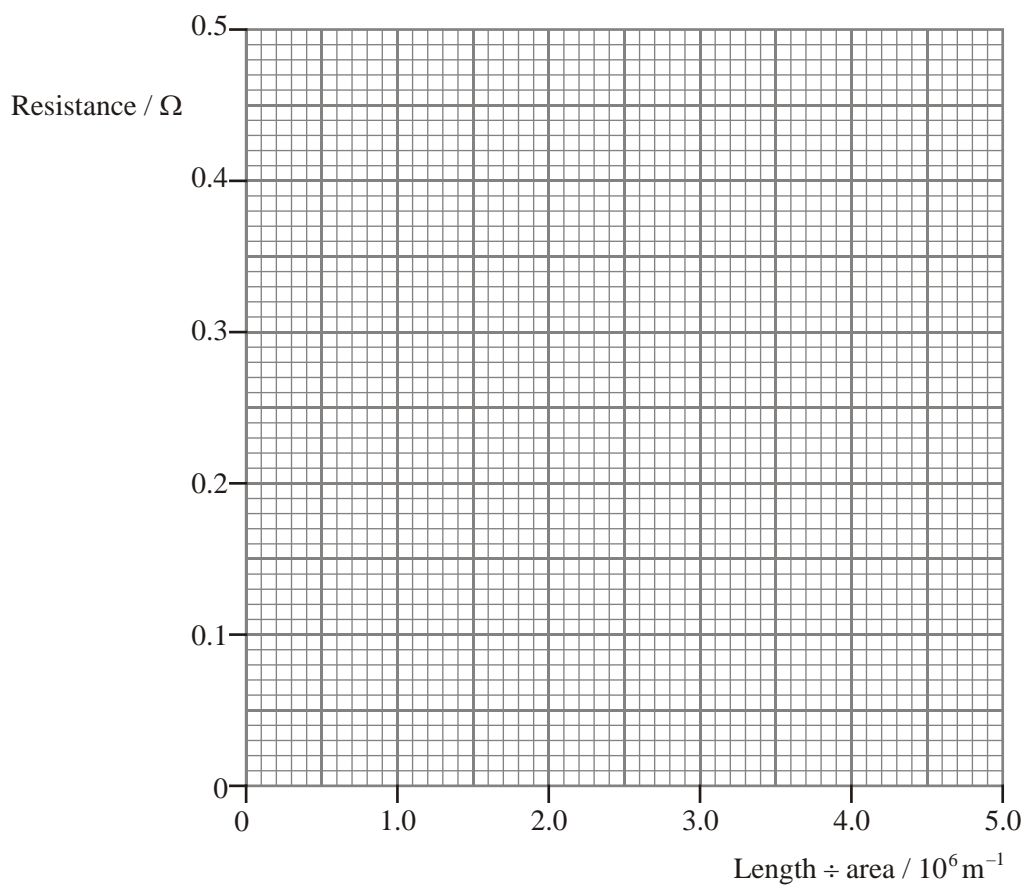
.....
.....

(2)

The table shows the results he obtained.

| Resistance / Ω | Length / m | Length \div area / 10^6 m^{-1} |
|-----------------------|------------|--------------------------------------------|
| 0.00 | 0.00 | |
| 0.10 | 0.10 | |
| 0.14 | 0.20 | |
| 0.18 | 0.30 | |
| 0.24 | 0.40 | |
| 0.30 | 0.50 | |
| 0.36 | 0.60 | |
| 0.42 | 0.70 | |
| 0.48 | 0.80 | |

Complete the third column and use the data to plot a graph of resistance against length \div area on the grid below.



(3)

Draw the line of best fit and use this to calculate the resistivity of iron.

.....

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.....

Resistivity =

(4)

Suggest an explanation for the anomalous results obtained in this experiment.

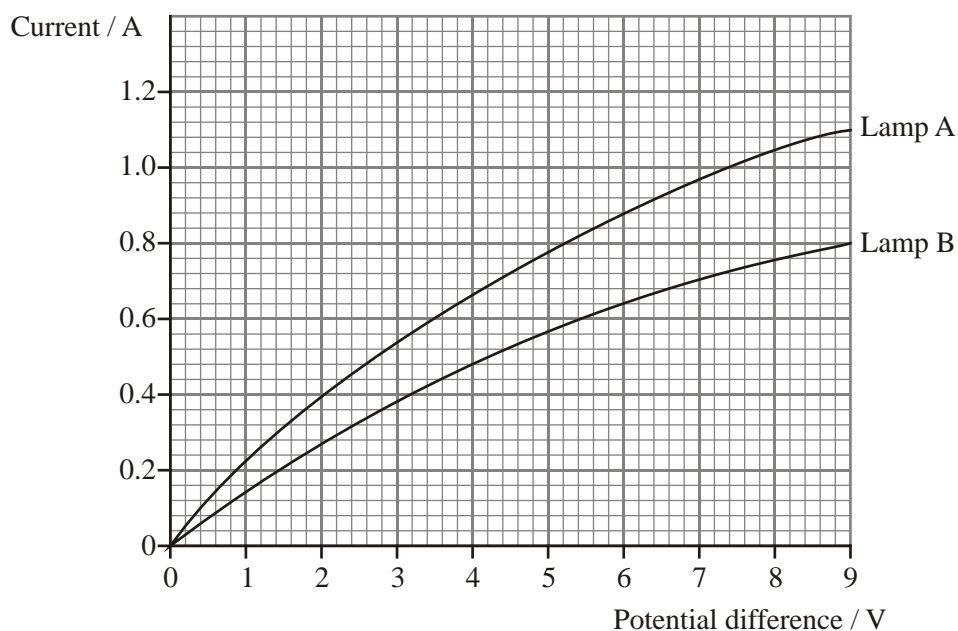
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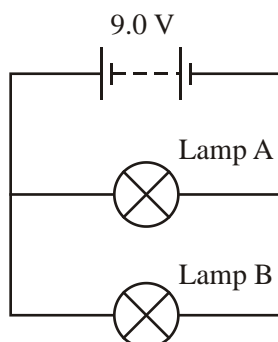
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(2)
(Total 11 marks)

36. Two filament lamps are designed to work from a 9.0 V supply but they have different characteristics. The graph shows the current-potential difference relationship for each lamp.



- (a) The lamps are connected in parallel with a 9.0 V supply as shown.



(i) Which lamp is brighter? Give a reason for your answer.

.....
.....

(2)

(ii) Determine the current in the supply.

.....
.....

Current =

(2)

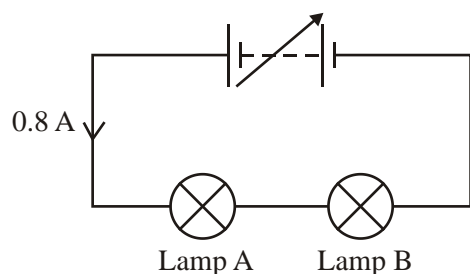
(iii) Calculate the total resistance of the two lamps when they are connected in parallel.

.....
.....
.....
.....
.....
.....

Total resistance =

(2)

- (b) The lamps are now connected in **series** to a variable supply which is adjusted until the current is 0.8 A.



Compare and comment on the brightness of the lamps in this circuit.

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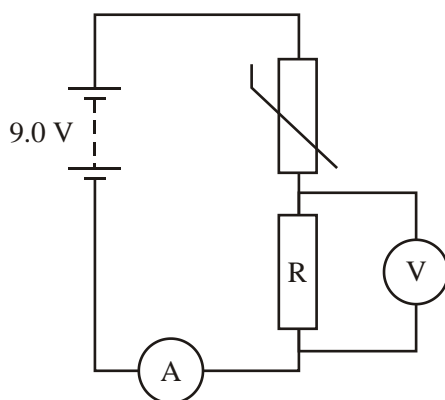
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(3)
(Total 9 marks)

37. A student connects a 9.0 V battery in series with a resistor R, a thermistor and a milliammeter. He connects a voltmeter in parallel with the resistor. The reading on the voltmeter is 2.8 V and the reading on the milliammeter is 0.74 mA.



- (a) (i) Show that the resistance of R is approximately 4000 Ω .

.....

.....

(2)

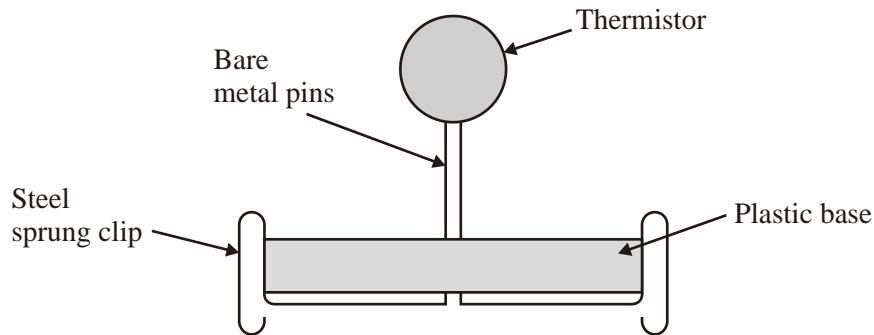
(ii) Calculate the resistance of the thermistor.

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.....
.....

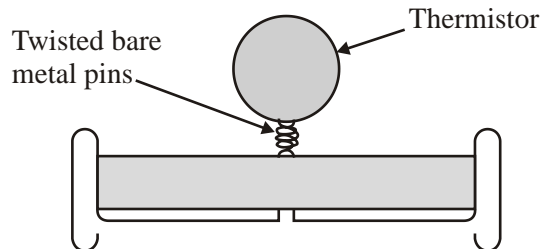
Resistance =

(2)

(b) The thermistor is mounted on a plastic base that has steel sprung clips for secure connection in a circuit board.



Another student is using an identical circuit except that the bare metal pins of his thermistor are twisted together.

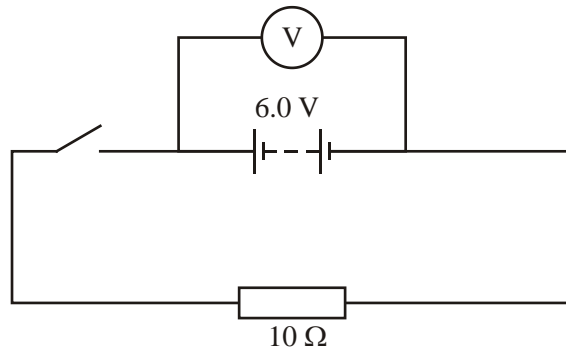


Suggest an explanation for how the reading on this student's milliammeter will compare with that of the first student.

.....
.....
.....

(3)
(Total 7 marks)

38. A battery of e.m.f. 6.0 V is connected to a 10 Ω resistor as shown in the circuit diagram.



(a) Define the e.m.f. of the battery.

.....

(2)

(b) When the switch is open the voltmeter reading is 6.0 V. The internal resistance of the battery is 0.40 Ω. Calculate the reading on the voltmeter when the switch is closed.

.....

Voltmeter reading =

(3)

- (c) A second identical battery is connected in parallel with the first one. Describe and explain qualitatively what would happen to the voltmeter reading if the switch remains closed.

.....

.....

.....

.....

.....

(3)
(Total 8 marks)

39. A student finds the following information in the instructions for an electric iron.

| Setting | Fabric | Temperature |
|---------|--------------|-------------|
| • | Synthetics | 110 °C |
| •• | Silk/wool | 150 °C |
| ••• | Cotton/linen | 200 °C |

He knows that the iron is heated by a wire filament controlled by a thermostat. The thermostat switches the current off when the required temperature is reached.

The student suggests that the filament will have a higher resistance at higher temperatures. Explain why the resistance of a metal wire would be expected to increase with temperature.

.....

.....

.....

.....

.....

(2)

The student investigates this for each setting by plugging the iron in until it reaches the required temperature and then unplugging it from the mains power. He then uses a laboratory d.c. power supply, ammeter and voltmeter to obtain the following results:

| Setting | Temperature/°C | Voltage/V | Current/A | Resistance/Ω |
|---------|----------------|-----------|-----------|--------------|
| • | 110 | 5.1 | 0.13 | 39 |
| •• | 150 | 6.2 | 0.15 | 41 |
| ••• | 200 | 7.4 | 0.19 | |

The resistances at 110 °C and 150 °C have been calculated.

Calculate the resistance of the filament at 200 °C.

.....

Resistance =

(2)

Discuss whether the results support the student’s suggestion that the filament has a higher resistance at higher temperatures.

.....

(1)

The student has a power meter to find the power when the iron is plugged into the mains supply and the setting is •• (silk/wool).

The reading is 1200 W.

Calculate the voltage of the mains supply.

.....

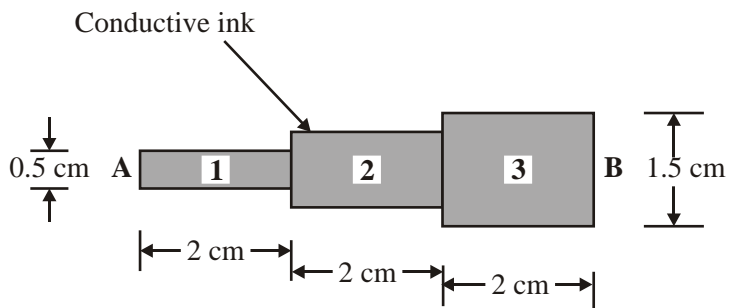
Voltage =

(3)

(Total 8 marks)

40. Disposable battery testers are sometimes placed on the packaging of battery packs. When placed across the battery terminals, the tester changes colour, depending on the amount of current that the battery provides.

To make a battery tester, you start with a layer of conductive ink that gets wider from one side to the other. The battery terminals are placed at **A** and **B**.



This ink is 0.02 mm thick on one such tester. Show that the resistance of section 1 above is about 30Ω . The resistivity ρ of the ink is $1.6 \times 10^{-4} \Omega \text{ m}$.

.....

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.....

(3)

Section 2 is 1.0 cm wide. Determine the total resistance between points **A** and **B**.

.....

.....

.....

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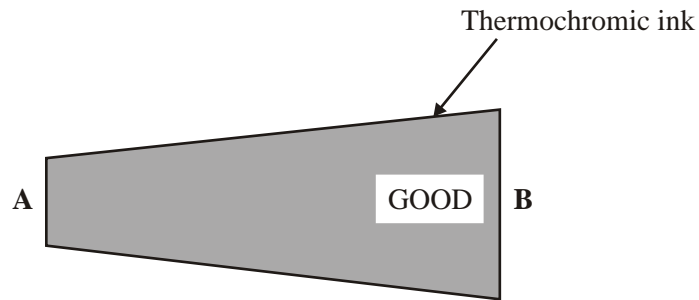
.....

.....

Total resistance =

(3)

The conductive ink is red. This is covered by a layer of thermochromic ink, which gradually changes from black to transparent when warmed.



In use, the tester is placed across the battery terminals. Current then flows in the conductive ink. The thermochromic ink becomes transparent, allowing the colour underneath to become visible.

Why does the thermochromic ink become warm?

.....
.....

(1)

If the battery is low on charge, the thermochromic ink becomes transparent only in section 1 of the tester. Explain why.

.....
.....
.....

(2)

(Total 9 marks)

41. Below is a list of words associated with circuits.

| | | |
|---------|--------|------------|
| Current | Volt | Resistance |
| Ohm | Charge | Ampere |

For each of the following choose **one** example from the above list.

Base unit

Derived quantity

Derived unit.....

Base quantity

(Total 4 marks)

42. 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 $4.2 \times 10^5 \text{ km}$.

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

.....
.....

(2)

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

.....
.....
.....

Number of electrons =

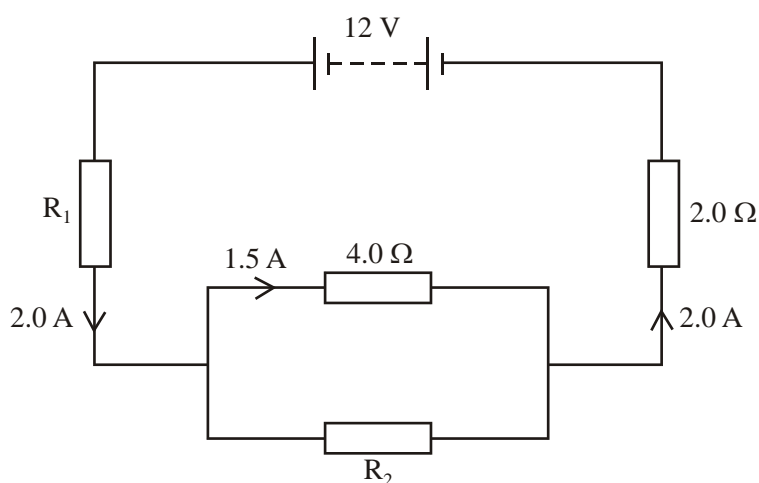
(2)

(c) State the direction of the current.

.....

(1)
(Total 5 marks)

43. 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.

.....
.....

Potential difference =

(1)

(b) Calculate the resistance of resistor R_2 .

.....
.....
.....

Resistance of R_2 =

(2)

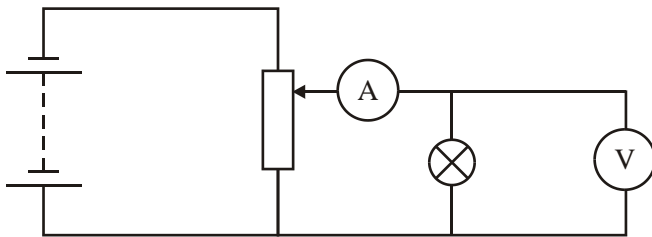
(c) Calculate the resistance of resistor R_1 .

.....
.....
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.....
.....

Resistance of $R_1 =$

(3)
(Total 6 marks)

44. The circuit shown is used to produce a current-potential difference graph for a 12 V, 24 W filament lamp.



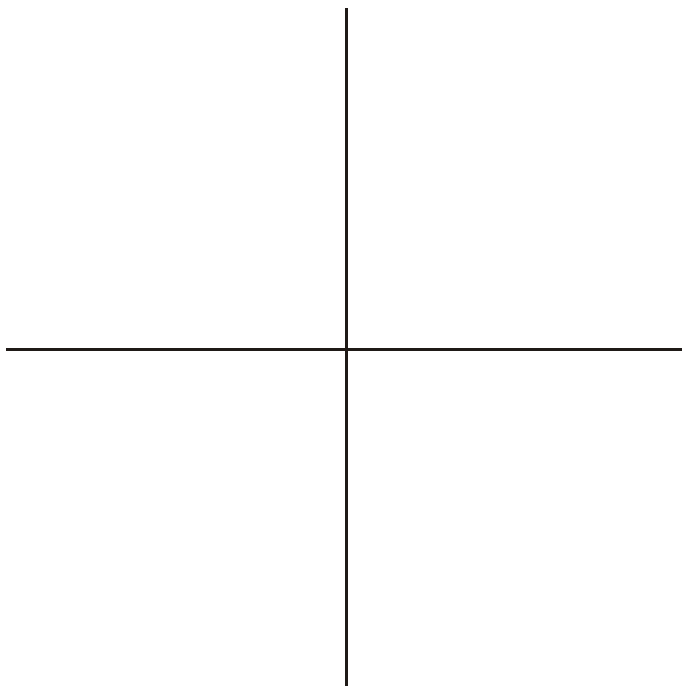
(a) Calculate the current in the filament lamp when the potential difference across it is 12 V.

.....
.....

Current =

(2)

(b) (i) Sketch a graph of current against potential difference for this filament lamp.



(2)

(ii) Explain, with reference to the filament, the shape of your graph, as the potential difference across the filament increases from 0 V to 12 V.

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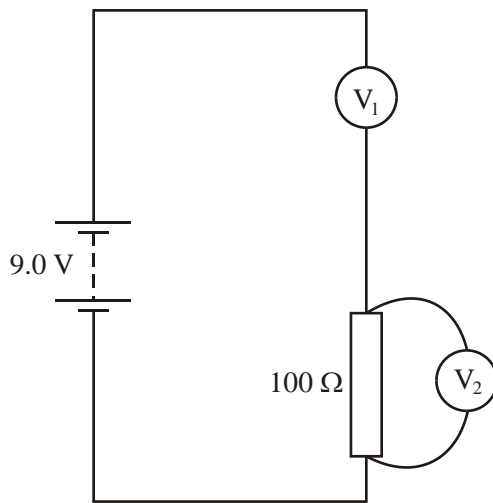
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(4)

(Total 8 marks)

45. (a) A student sets up a circuit and accidentally uses two voltmeters V_1 and V_2 instead of an ammeter and a voltmeter. The circuit is shown below.



- (i) Circle the voltmeter which should be an ammeter.

(1)

- (ii) Both voltmeters have a resistance of $10\text{ M}\Omega$. The student sees that the reading on V_2 is 0 V . Explain why the potential difference across the $100\ \Omega$ resistor is effectively zero.

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.....

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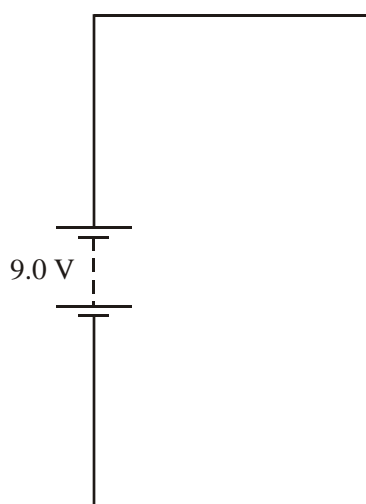
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(2)

(b) The student replaces the $100\ \Omega$ resistor with another resistor of resistance R . The reading on V_2 then becomes $3.0\ \text{V}$.

(i) Complete the circuit diagram below to show the equivalent resistor network following this change.

Label the resistor R .



(2)

(ii) Calculate the value of R .

.....

.....

.....

.....

.....

$R =$

(3)

(Total 8 marks)

46. The following notes are taken from some laboratory instructions for using an ohmmeter to measure resistance.

- Ohmmeters should be zeroed. To do this, touch the leads together and adjust the meter to read zero ohms.
- The ohmmeter works by placing a small voltage across the resistor. The current that flows in response to this voltage determines the ohmmeter reading.
- Do not measure the resistance of a resistor while it is in a circuit.

Explain why touching the leads together allows the meter to be zeroed.

.....
.....

(1)

An ohmmeter is connected across a resistor. The ohmmeter applies a voltage of 0.54 V. The current through the meter is 0.0081 A. Show that the resistance being measured is about 70 Ω .

.....
.....

(2)

Explain why, when using an ohmmeter, the resistance of the resistor should not be measured while it is in a circuit.

.....
.....
.....
.....

(2)

By connecting the ohmmeter across a coil of thin copper wire, temperature changes can be detected.

Explain how, as the temperature rises, changes in the copper lead to changes in the meter reading.

.....

.....

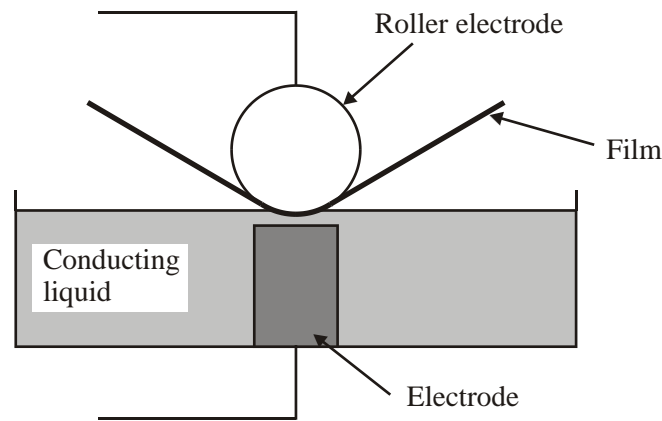
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(3)
(Total 8 marks)

47. To preserve food effectively, packaging film must isolate food from bacteria in the environment. The film is thoroughly inspected for holes, but many inspection techniques can damage it.

A new technique has been developed to check the film. The film is passed between a roller electrode and a conducting liquid, in which a second electrode is placed, as shown below. The resistance between the two electrodes is measured; even a pinhole in the film can greatly reduce this resistance by filling with the liquid and creating a conducting path.



Complete the diagram above showing a circuit you could use to measure this resistance.

(2)

For undamaged film the resistance measured between the electrodes is very high. Show that when a circular hole of diameter 1.0×10^{-4} m is present and fills with the conducting liquid the resistance measured is about 170Ω . Assume that the resistance through the liquid between the lower electrode and the film is so small it can be ignored.

Resistivity of conducting liquid = $2.7 \times 10^{-3} \Omega \text{ m}$, film thickness = 5.0×10^{-4} m.

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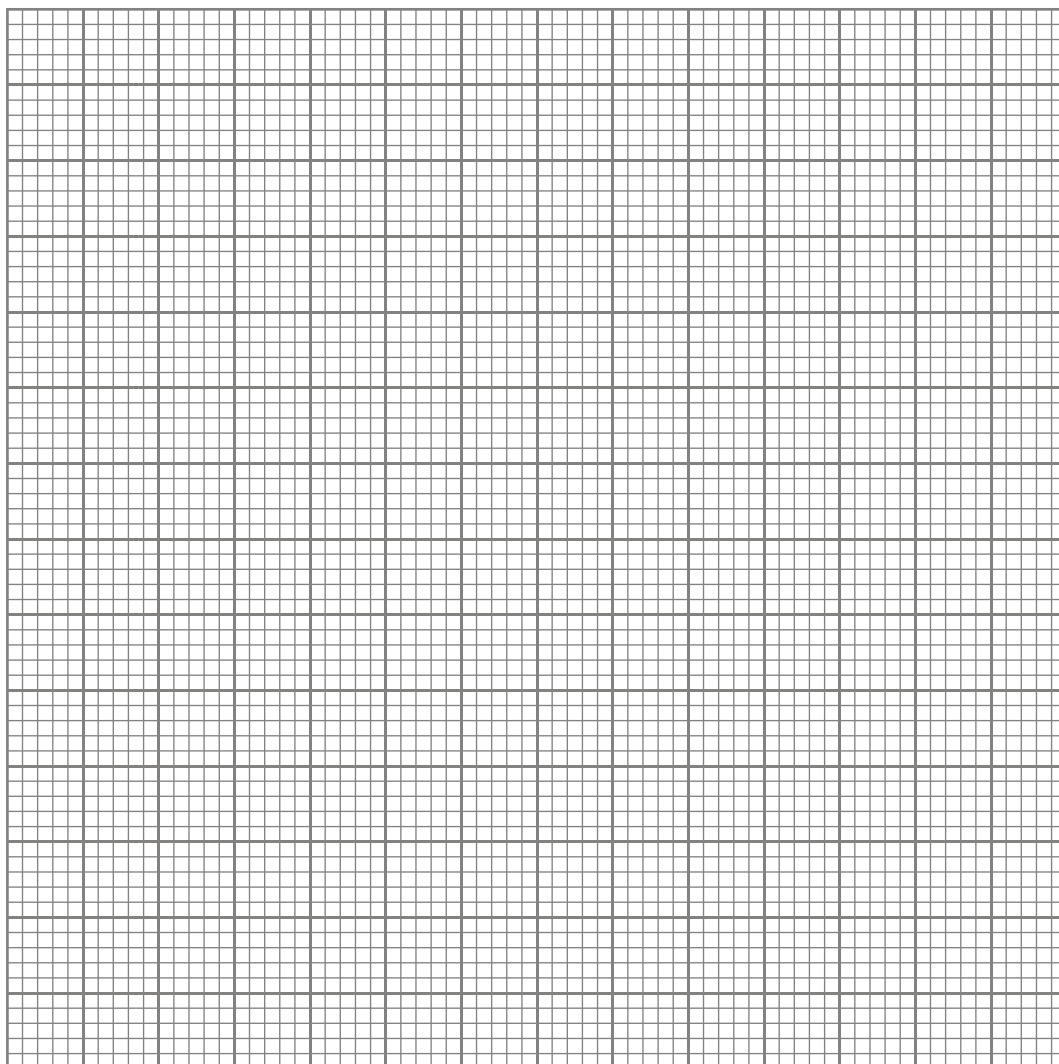
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(3)

Using this technique, the following values of resistance were obtained.

| Diameter of hole / mm | Resistance / Ω |
|-----------------------|-----------------------|
| 0.2 | 43.0 |
| 0.4 | 10.7 |
| 0.6 | 4.8 |
| 0.8 | 2.7 |
| 1.0 | 1.7 |

Plot a graph of resistance against diameter from these results on the grid below.



(4)

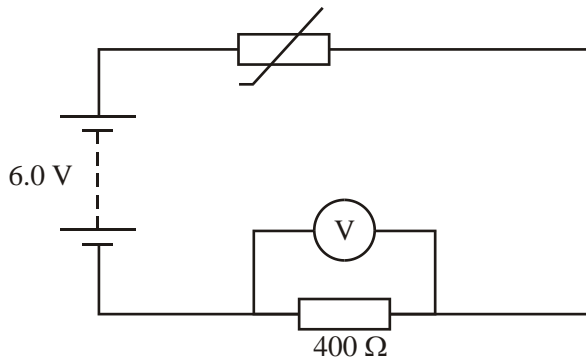
Use the graph to determine the diameter of the hole which gives a resistance of 30Ω .

.....

(1)

(Total 10 marks)

48. A student connects the circuit as shown in the diagram.



The reading on the voltmeter is 1.8 V. Calculate the current in the resistor.

.....
.....

Current =

(1)

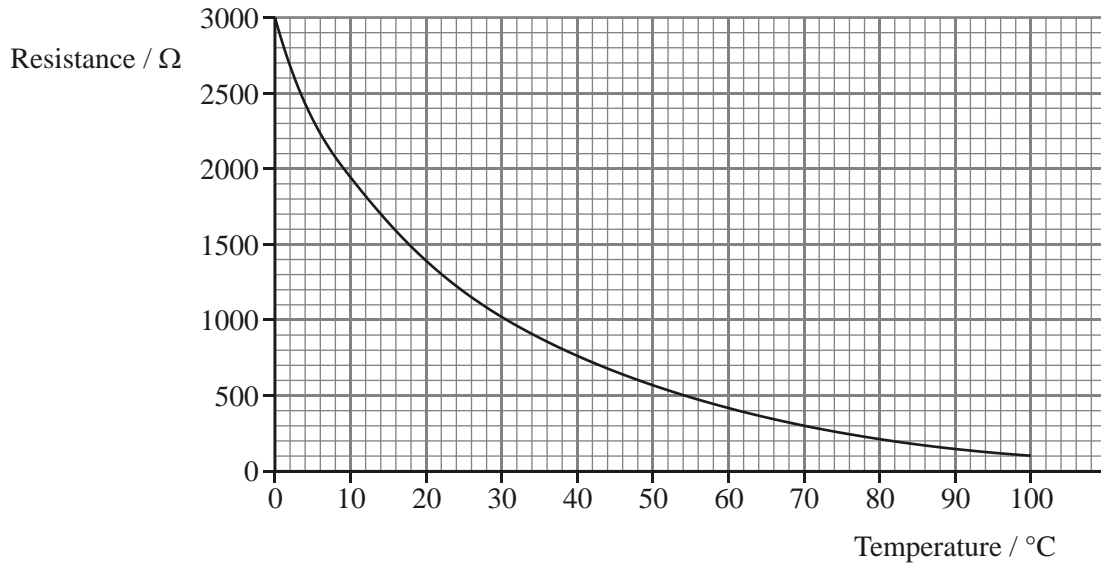
Calculate the resistance of the thermistor.

.....
.....
.....

Resistance =

(2)

The graph shows how the resistance of the thermistor depends on its temperature.



Determine the temperature of the thermistor.

Temperature =

(1)

If the e.m.f. of the supply were doubled, would the reading on the voltmeter double?

Explain your answer.

.....

.....

.....

.....

(3)

(Total 7 marks)

49. 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.

(2)

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

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.....
.....
.....

(3)

How should these measurements be used to find the resistivity?

.....
.....
.....
.....

(3)

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

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.....
.....
.....

(2)

(Total 10 marks)

50. Modern electric showers need to be very powerful because they are required to heat the water flowing through them very quickly.

The shower is connected to the electrical supply by a copper cable 15 m long. A conductor inside the cable has a cross-sectional area of $6.0 \times 10^{-6} \text{ m}^2$. The resistivity of copper is $1.7 \times 10^{-8} \Omega \text{ m}$. Find the resistance of the conductor.

.....
.....

Resistance =

(3)

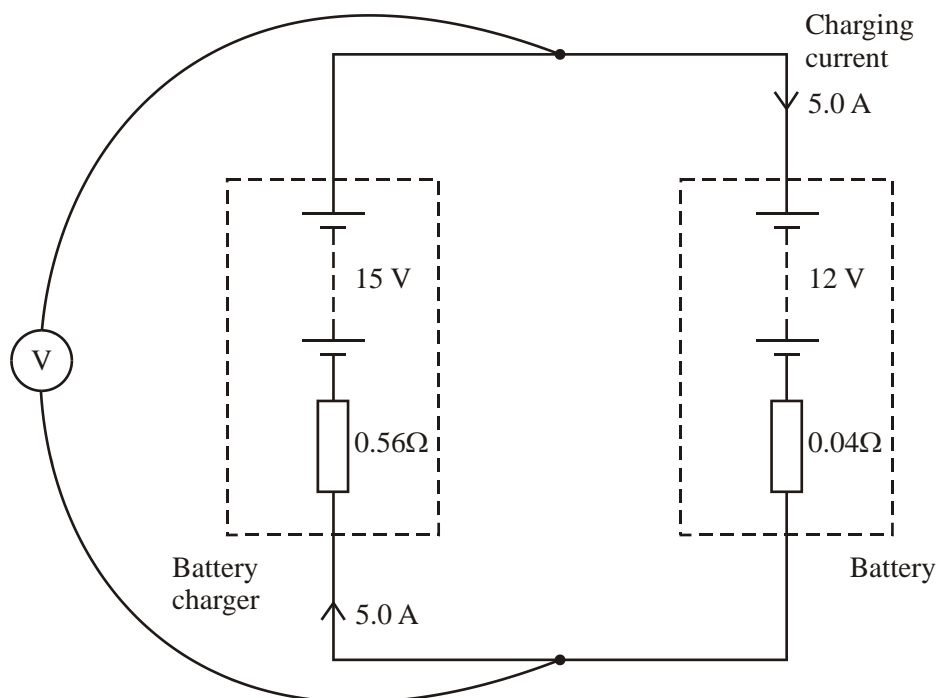
The conductors used for most electrical circuits in homes are copper but they have a smaller cross-sectional area. Suggest why the manufacturer of the shower recommends that the thicker wire is used in the shower cable.

.....
.....

(2)

(Total 5 marks)

51. A 12 V car battery is recharged by passing a current of 5.0 A through it in the reverse direction using a 15 V battery charger. The internal resistance of the charger and the battery are 0.56 Ω and 0.04 Ω respectively. The circuit used is shown below.



The terminal p.d. across the battery charger is found by solving the following equation:

$$\text{Terminal p.d.} = 15 \text{ V} - (5.0 \text{ A} \times 0.56 \Omega)$$

Determine the reading on the voltmeter.

.....

(1)

Write an equivalent equation for the terminal p.d. across the battery.

.....

.....

(3)

Calculate the rate at which energy is being wasted during the recharging process.

.....
.....

Rate =

(2)

Hence determine the efficiency of the recharging process.

.....
.....
.....

Efficiency =

(2)

The internal resistance of this car battery is 0.04Ω . Explain why a car battery is designed to have a very low internal resistance.

.....
.....
.....
.....

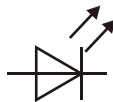
(2)

(Total 10 marks)

52. A student does some measurements on two light-emitting diodes (LEDs). She measures the current I through them at a series of voltages V . Her results are shown in the table.

| V/V | Green LED I/mA | Red LED I/mA |
|-------|------------------|----------------|
| 1.1 | 0 | 0 |
| 1.2 | 0 | 0 |
| 1.3 | 0 | 0 |
| 1.4 | 0 | 0.01 |
| 1.5 | 0 | 0.05 |
| 1.6 | 0 | 0.33 |
| 1.7 | 0.02 | 3.89 |
| 1.8 | 0.20 | |
| 1.9 | 1.46 | |
| 2.0 | 5.12 | |

Complete the circuit diagram below to show a circuit that she could have used to obtain these results.



(3)

For both LEDs, the current varies in a similar way. Describe in words this variation.

.....
.....
.....
.....
.....

(3)

Discuss whether the LEDs obey Ohm's law.

.....
.....
.....
.....

(2)

Calculate the resistance of the green LED when it has 1.9 V across it.

.....
.....

Resistance =

(2)

Calculate the power dissipated by the red LED when it has 1.7 V across it.

.....
.....
.....

Power =

(2)

(Total 12 marks)

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

.....
.....

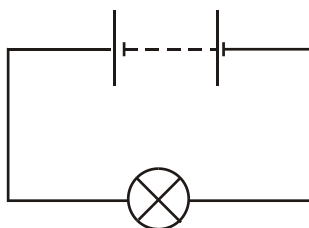
(1)

Define potential difference.

.....
.....

(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.

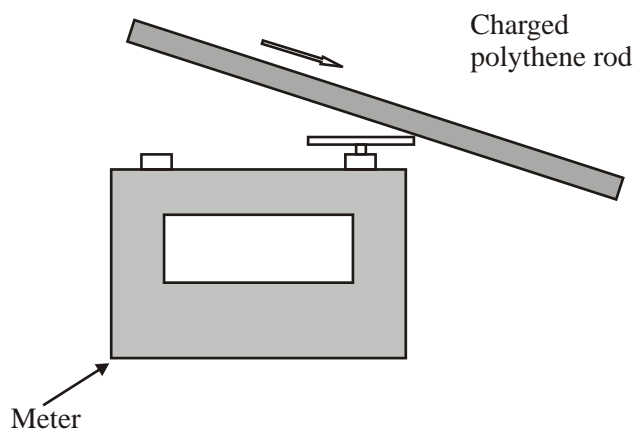
.....
.....
.....

Energy =

(2)

(Total 4 marks)

54. A polythene rod was negatively charged by rubbing it with a cloth. The rod was then stroked several times across the metal cap of a meter used for measuring charge.



The initial reading on the meter was zero.

After 3.8 s the final reading was -6.4×10^{-8} C.

Calculate the number of electrons that were transferred to the metal cap.

.....

Number of electrons =

(3)

Calculate the average rate in C s^{-1} at which charge was transferred to the metal cap.

.....

Rate = C s^{-1}

(2)

State the base unit for the rate of flow of charge.

.....

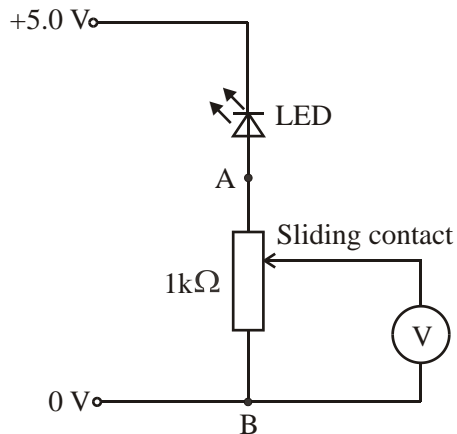
(1)

(Total 6 marks)

55. A light-emitting diode (LED) is a diode that emits light when it conducts. Its circuit symbol is



A student connects the circuit shown below.



She notices that the reading on the high resistance voltmeter remains at 0 V as she slides the contact between terminals A and B.

Explain this observation as fully as you can.

.....

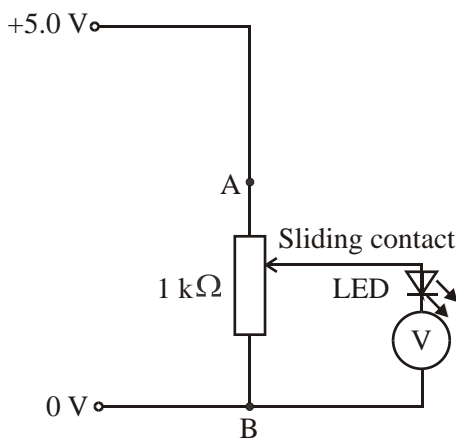
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.....

.....

(2)

The student then disconnects the LED and reconnects the circuit as shown below. She intends to vary the intensity of the light emitted by the LED by sliding the contact between terminals A and B.



The student cannot detect any light emitted by the LED. Briefly explain why the LED is so dim.

.....

.....

.....

.....

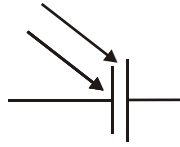
(2)

Draw the circuit that the student should have connected using this apparatus in order to vary the brightness of the LED and measure the potential difference across it.

(3)
(Total 7 marks)

56. A solar cell is a device that generates a potential difference when certain wavelengths of the electromagnetic spectrum are incident on it.

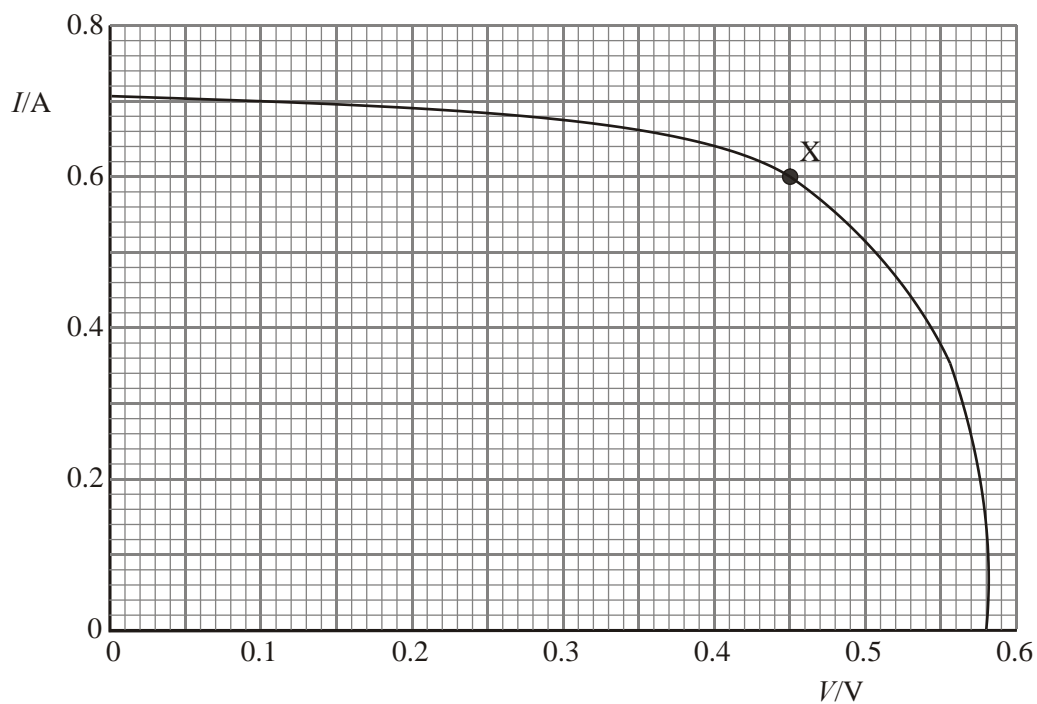
The circuit symbol for a solar cell is



The solar cell is used in a circuit with a variable resistor, an ammeter and a voltmeter. Readings of current I in the circuit and the terminal potential difference V across the solar cell are used to plot a graph of I against V . Draw a suitable circuit diagram.

(2)

The graph shows a set of results obtained in this way. The intensity of the light incident on the cell remained constant while the readings were obtained.



Calculate the power output of the cell at the point marked X on the graph.

.....
.....

Power =

(2)

Describe the variation of the power output of the cell as the current increases from zero to its maximum value.

.....
.....
.....
.....
.....
.....

(3)

State the e.m.f. of the cell.

.....

(1)

Calculate the internal resistance of the cell when it is operating under the conditions represented by point X.

.....
.....
.....
.....
.....

Internal resistance =

(2)

(Total 10 marks)

57. 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

.....
.....
.....
.....
.....
.....

(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

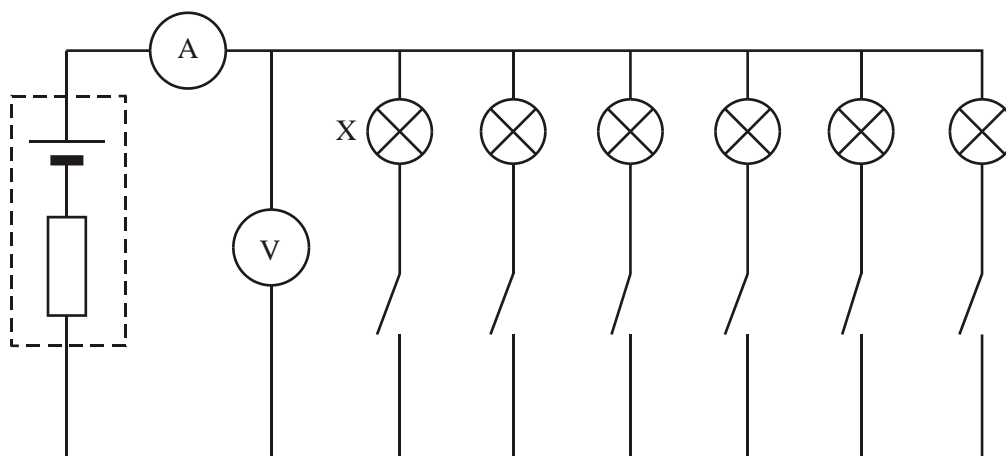
Explanation

.....
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.....
.....
.....
.....

(3)

(Total 6 marks)

58. A student models a stage lighting system using a circuit-drawing computer package and a spreadsheet. He starts with a power supply of e.m.f. 120 V, and internal resistance 15 Ω . He assumes that each lamp has fixed resistance 60 Ω . He is interested in the effect of turning on the lamps one at a time, so that the number of lamps switched on increases from one to six. His circuit and part of his spreadsheet are shown below.



| | A | B | C | D | E |
|---|-----------------------------|-----------------------------------|-----------------------------|---------------------|----------------------|
| 1 | Number of lamps switched on | Net resistance of lamps/ Ω | Total current from supply/A | p.d. across lamps/V | Power to all lamps/W |
| 2 | | | | | |
| 3 | 1 | 60 | 1.6 | 96 | 154 |
| 4 | 2 | 30 | 2.7 | 80 | 213 |
| 5 | 3 | 20 | 3.4 | 69 | 235 |
| 6 | 4 | 15 | 4.0 | 60 | 240 |
| 7 | 5 | 12 | 4.4 | 53 | |
| 8 | 6 | 10 | 4.8 | 48 | 230 |

The student has assumed that the voltmeter would have no effect on any of the values he has calculated. Explain why this is an appropriate assumption.

.....

.....

.....

(1)

When 6 lamps are on (row 8), how much current flows through lamp X?

.....
.....

Current through X =

(1)

Calculate the value missing from cell E7.

.....
.....

Value =

(1)

The lamp marked X is the first to be switched on. Explain how lamp X would appear as successive lamps are switched on.

.....
.....
.....
.....
.....
.....

(3)

What would be a suitable formula for calculating cell C6?

.....
.....

(2)

Comment on how the internal resistance of the power supply affects the way in which the values in column E vary.

.....

.....

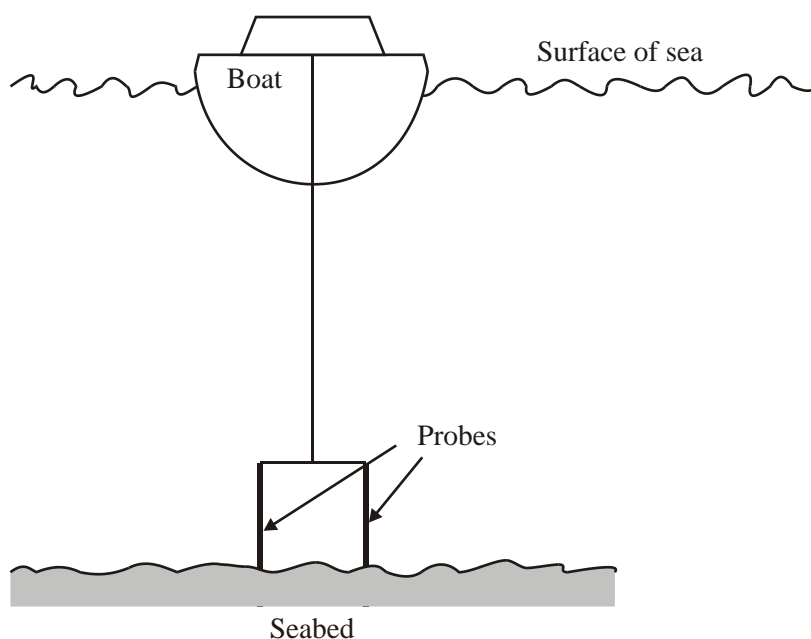
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(2)
(Total 10 marks)

59. Resistivity measurements under the sea have been used to find new sources of fresh water.

Two probes are towed along the seabed behind a small boat.



Taking measurements using these probes, resistivity can be calculated at various depths below the seabed.

What measurements are needed to calculate resistivity?

.....

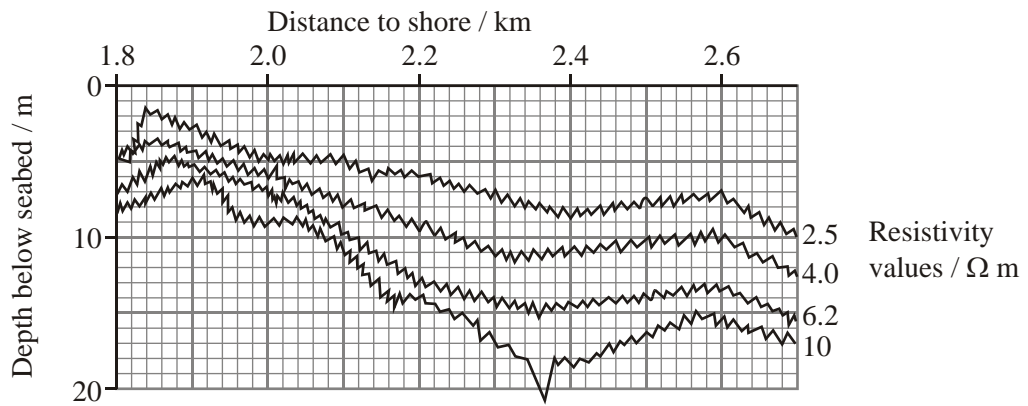
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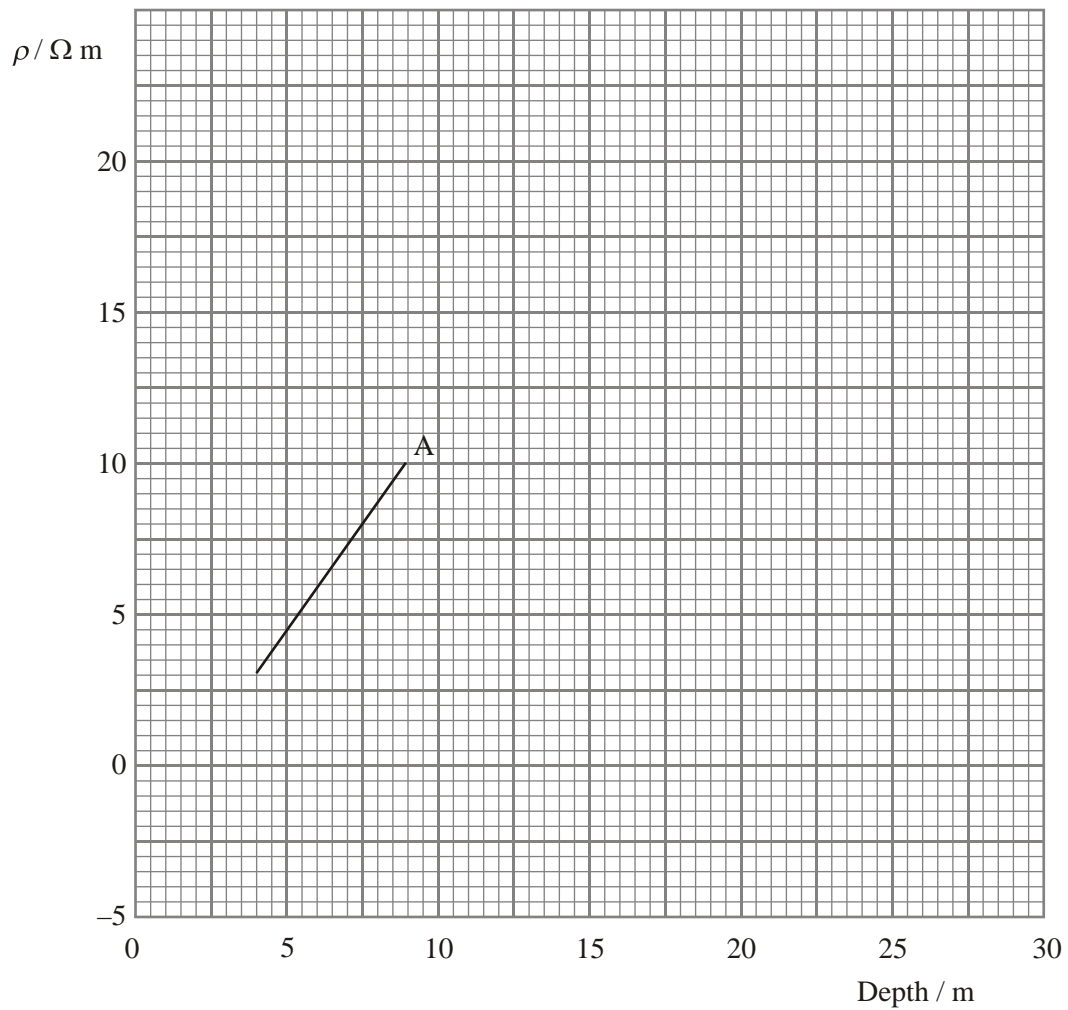
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(3)

The diagram below displays the resistivities measured in a survey.



Line A below has been plotted using some of this data. It shows how resistivity ρ varies with depth below the seabed 2.0 km from the shore.



Make measurements from this graph to determine the equation of line A.

.....

.....

.....

(3)

Use the survey results to add another line to show how resistivity varies with depth 2.4 km from the shore.

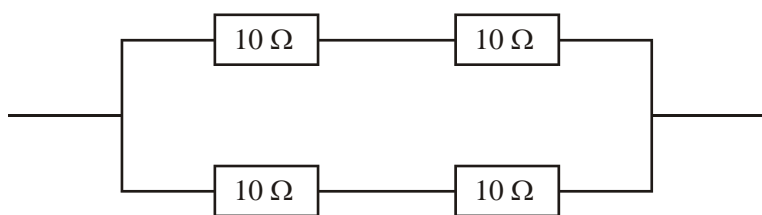
(3)

The resistivity gradient (the variation of resistivity with depth) is greater in areas where there is fresh water below the seabed. Suggest the best distance from the shore to drill for fresh water.

.....

(1)
(Total 10 marks)

60. Four $10\ \Omega$ resistors are connected as shown in the diagram.



Calculate the total resistance of the combination.

.....
.....
.....
.....

Total resistance =

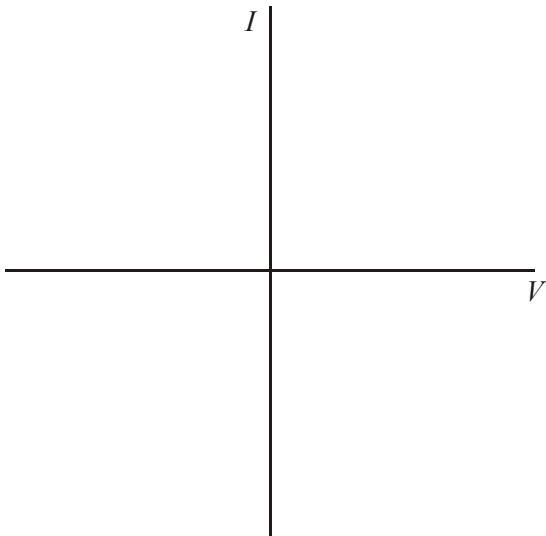
(3)

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

.....
.....
.....

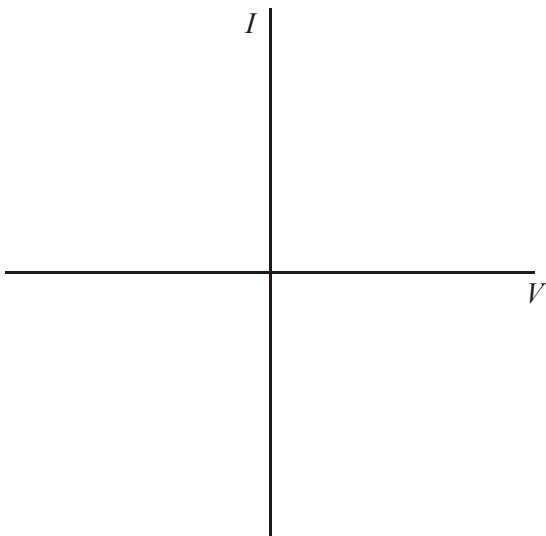
(2)
(Total 5 marks)

61. Use the axes to draw the current-voltage characteristic of a diode.



(3)

Use the axes to draw the current-voltage characteristic of a filament lamp.



(3)
(Total 6 marks)

62. A cell of negligible internal resistance is connected in series with a microammeter of negligible resistance and two resistors of value $15\text{ k}\Omega$ and $25\text{ k}\Omega$. The current is $150\text{ }\mu\text{A}$. Draw a circuit diagram of the arrangement.

(1)

Show that the e.m.f. of the cell is 6.0 V .

.....
.....
.....

(2)

A voltmeter is now connected in parallel with the $25\text{ k}\Omega$ resistor. Draw a diagram of the new circuit.

(1)

When the voltmeter is connected the reading on the microammeter increases to $170 \mu\text{A}$. Calculate the resistance of the voltmeter.

.....

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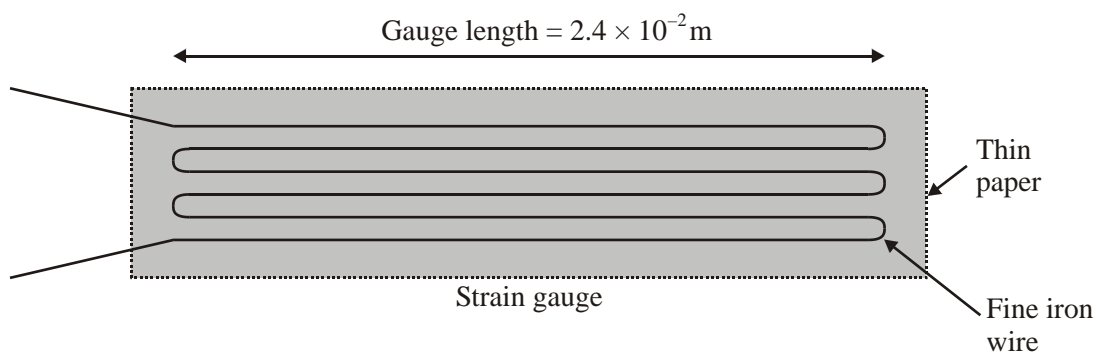
.....

.....

Resistance =

(3)
(Total 7 marks)

63. 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.



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

.....
.....
.....
.....

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?

.....
.....

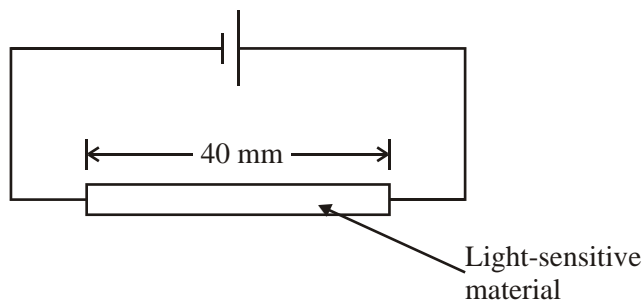
Change in resistance = (2)

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.

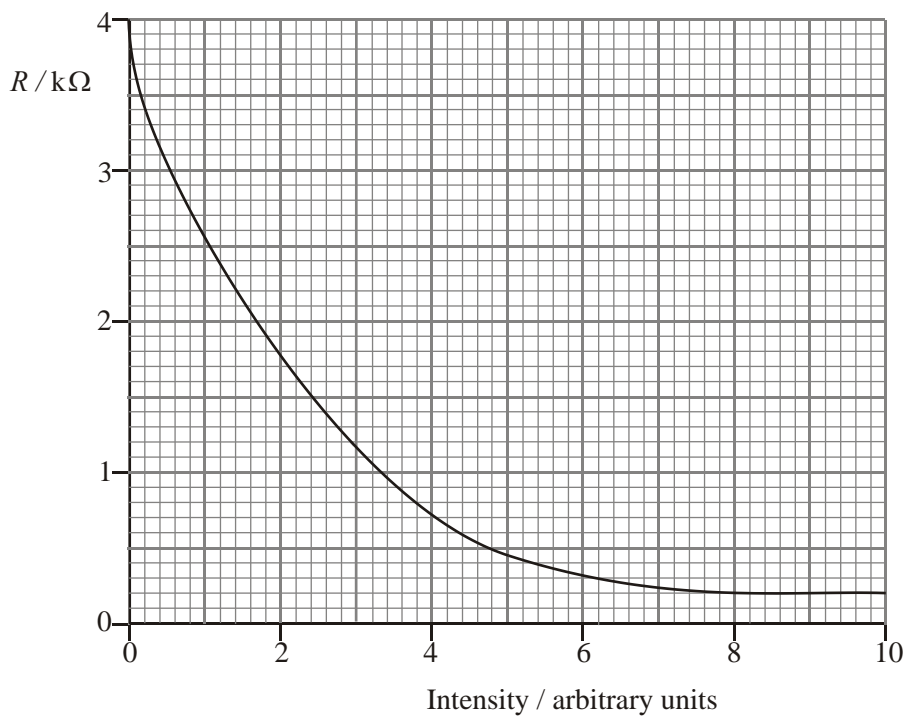
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.....
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(3)
(Total 9 marks)

64. A 40 mm strip of light-sensitive material is used in a camera with automatic focus.



The lens is moved automatically until light is sharply focused onto a very short length of this strip. The graph shows how the resistance R of the total length of the strip varies with light intensity.



Calculate the resistance per mm of the strip when it is in complete darkness.

.....

(2)

Bright light of intensity 10 units is focused on an 8 mm length of the strip.

Show that the resistance of the 8 mm length is 40Ω .

.....
.....
.....

(2)

The remainder of the strip is in the dark.

Calculate its resistance.

.....
.....

(1)

A cell of e.m.f. 1.2 V and negligible internal resistance is connected across the ends of the strip.
Calculate

(i) the current in the strip,

.....
.....

(ii) the p.d. across the 8 mm length.

.....
.....

(4)

Explain why this current decreases as the bright light is more sharply focused onto a smaller length of the strip.

.....
.....
.....

(2)

(Total 11 marks)

65. A student is provided with two filament lamps A and B. Each is rated 12 V 60 W, but lamp A has a carbon filament and lamp B a tungsten filament.

Calculate the resistance of each filament lamp under normal operating conditions.

.....

.....

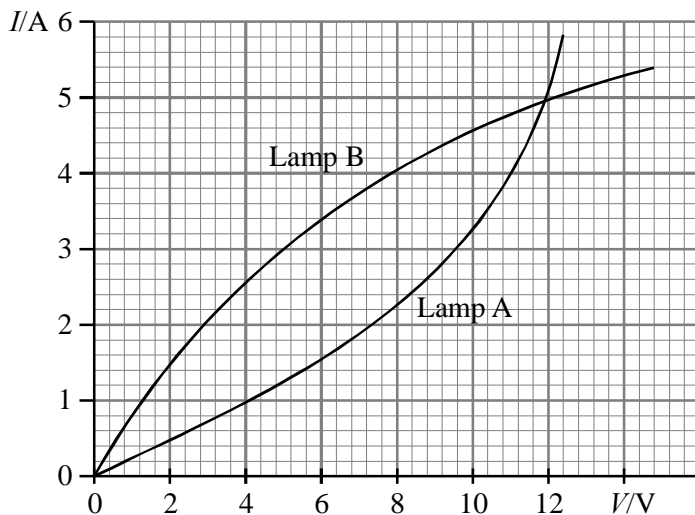
.....

.....

Resistance =

(3)

The graph shows the relationship between the current I and the potential difference V for the two filament lamps.



Describe how the resistances of lamp A and lamp B vary with current.

Lamp A:

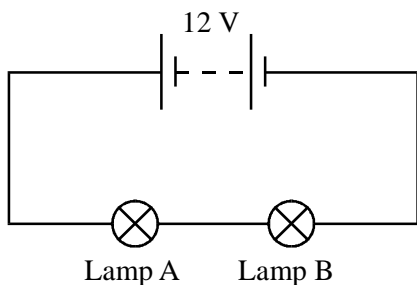
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Lamp B:

.....

(2)

The diagram shows the two filament lamps connected in series across a battery of e.m.f 12 V and negligible internal resistance. Both filaments glow dimly, but the *h*lank filament of lamp A is the brighter.



Why does each filament glow only dimly?

.....

(1)

Suggest why the filament of lamp A is the brighter.

.....

(2)

(Total 8 marks)

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

.....

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?

.....

(1)

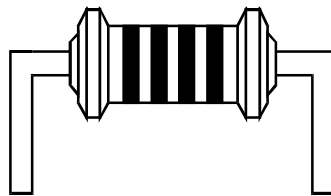
Explain your answer. You may be awarded a mark for the clarity of your answer.

.....

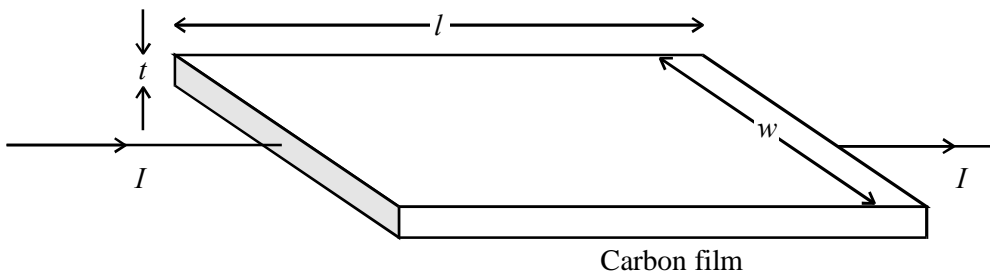
(4)

(Total 8 marks)

67. The diagram shows a type of resistor commonly used in electronic circuits.



It consists of a thin film of carbon wrapped around a cylindrical insulator. The diagram below (not to scale) shows a typical **film** of carbon, resistivity ρ , before it is wrapped round the insulator.



Show that the resistance R of the carbon film is given by

$$R = \frac{\rho l}{wt}$$

.....
.....
.....

(2)

This film has length $l = 8.0$ mm, width $w = 3.0$ mm and thickness $t = 0.0010$ mm (i.e. $t = 1.0 \times 10^{-6}$ m). If the resistivity of carbon is $6.0 \times 10^{-5} \Omega\text{m}$, calculate the resistance of the carbon film.

.....
.....
.....
.....
.....

Resistance =

(3)

Show that the resistance of a square piece of carbon film of uniform thickness is independent of the length of the sides of the square.

.....
.....
.....
.....

(2)

(Total 7 marks)

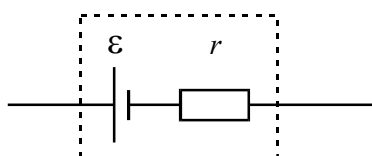
68. Define the term **e.m.f. of a cell**.

.....
.....
.....

(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)

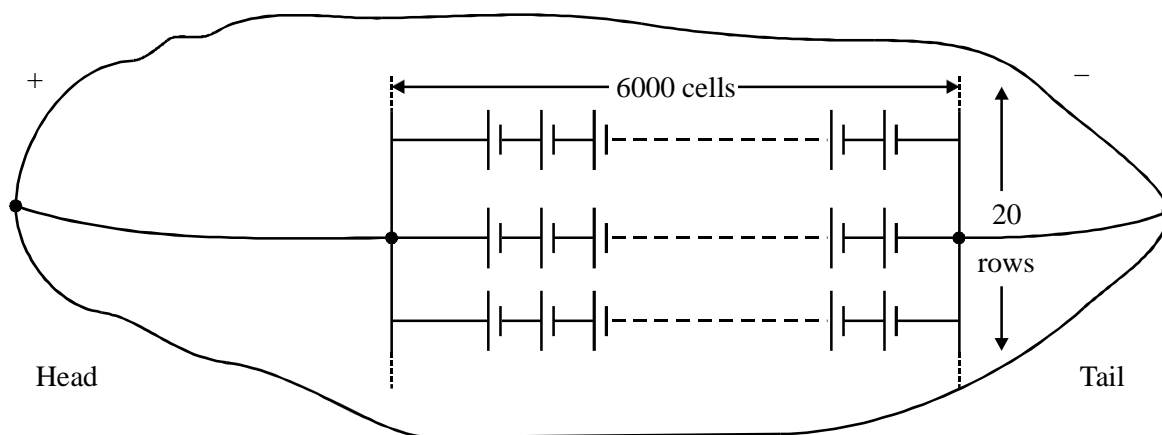
Sketch the graph the student should plot and state how she could determine r from the graph.

.....
.....

(2)

(Total 6 marks)

69. An electric eel has the ability to generate an e.m.f. and hence drive current through the surrounding water. Its body can be modelled as a battery containing a large number of cells. Such a battery has 20 parallel rows, each with 6000 cells connected in series. Each cell has an e.m.f of $40 \times 10^{-3} \text{ V}$ and an internal resistance of 0.70Ω .



When the eel is in the water, current can pass from its head to the tip of its tail through the water, stunning any other fish near it.

Calculate the total e.m.f. of **one row** of 6000 cells in series.

.....

e.m.f. =

(2)

Calculate the total internal resistance of this row of cells.

.....

Internal resistance =

(1)

Calculate the current which passes through the seawater if the eel is able to activate just **one** of its rows of 6000 cells. (Assume the resistance of seawater is zero.)

.....
.....

Current = (2)

In fact, all 20 rows of cells drive current at the same time. Calculate the total current which passes through the seawater.

.....
.....

Current = (1)

If you could connect a voltmeter across the eel from head to tail when it is delivering the total current, its reading, would not equal the total e.m.f. Explain why.

.....
.....
.....
.....
.....

(2)

State the voltmeter reading while the eel is delivering current through the seawater.

Voltmeter reading = (1)

(Total 9 marks)

70. The table gives the resistivities of five different materials:

| Material | Resistivity/ Ω m |
|----------|-------------------------|
| Copper | 1.8×10^{-8} |
| Iron | 1.2×10^{-7} |
| Carbon | 1.4×10^{-5} |
| Silicon | 2.3×10^3 |
| Glass | 1.0×10^{12} |

A student needs to make a 0.12Ω resistor. She has some copper wire of diameter 0.80 mm.

(i) Show that the cross-sectional area of the wire is about $5 \times 10^{-7} \text{ m}^2$

.....

(2)

(ii) Calculate the length of wire she needs for the 0.12Ω resistor.

.....

(3)

What would be the advantage of making the resistor from iron wire of the same diameter?

.....

(1)

(Total 6 marks)

71. State the unit of the base quantity **current**. 2.3×10^3

.....
.....
.....
.....
.....

(1)

Determine the base units of **potential difference**.

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.....
.....

(3)

(Total 4 marks)

Silicon

| | |
|-------|----------------------|
| Glass | 1.0×10^{12} |
|-------|----------------------|

A student needs to make a 0.12Ω resistor. She has some copper wire of diameter 0.80 mm .

(i) Show that the cross-sectional area of the wire is about $5 \times 10^{-7} \text{ m}^2$

.....
.....

(2)

(ii) Calculate the length of wire she needs for the 0.12Ω resistor.

.....
.....
.....
.....
.....

(3)

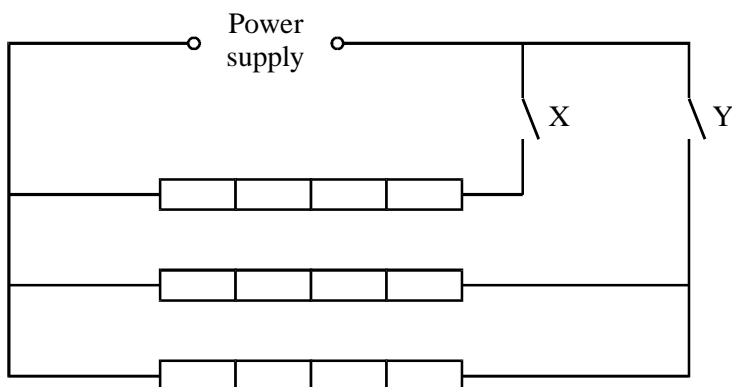
What would be the advantage of making the resistor from iron wire of the same diameter?

.....
.....

(1)

(Total 6 marks)

72. An electric room heater consists of three heating elements connected in parallel across a power supply.



Each element is made from a metal wire of resistivity $5.5 \times 10^{-5} \Omega \text{ m}$ at room temperature. The wire has a cross-sectional area $8.0 \times 10^{-7} \text{ m}^2$ and length 0.65 m.

The heater is controlled by two switches, X and Y.

Show that the resistance of one heating element at room temperature is approximately 45Ω .

.....

.....

.....

(3)

Calculate the total resistance of the heater for the following combinations of switches at the moment the switches are closed.

| Switch X | Switch Y | Resistance of heater / Ω |
|----------|----------|---------------------------------|
| Open | Closed | |
| Closed | Open | |
| Closed | Closed | |

(3)

Calculate the maximum power output from the heater immediately it is connected to a 230 V supply.

.....
.....

Maximum power =

(2)

After being connected to the supply for a few minutes the power output falls to a lower steady value. Explain why this happens.

.....
.....
.....
.....

(2)

(Total 10 marks)

73. A thick wire is connected **in series** with a thin wire of the same material and a battery.

In which wire do the electrons have the greater drift velocity? Explain your answer.

.....
.....
.....
.....
.....

(3)

A battery is connected across a large resistor and a small resistor is connected **in parallel**. The currents through the resistors are different.

Which resistor has the higher dissipation of power? Explain your answer.

.....

.....

.....

.....

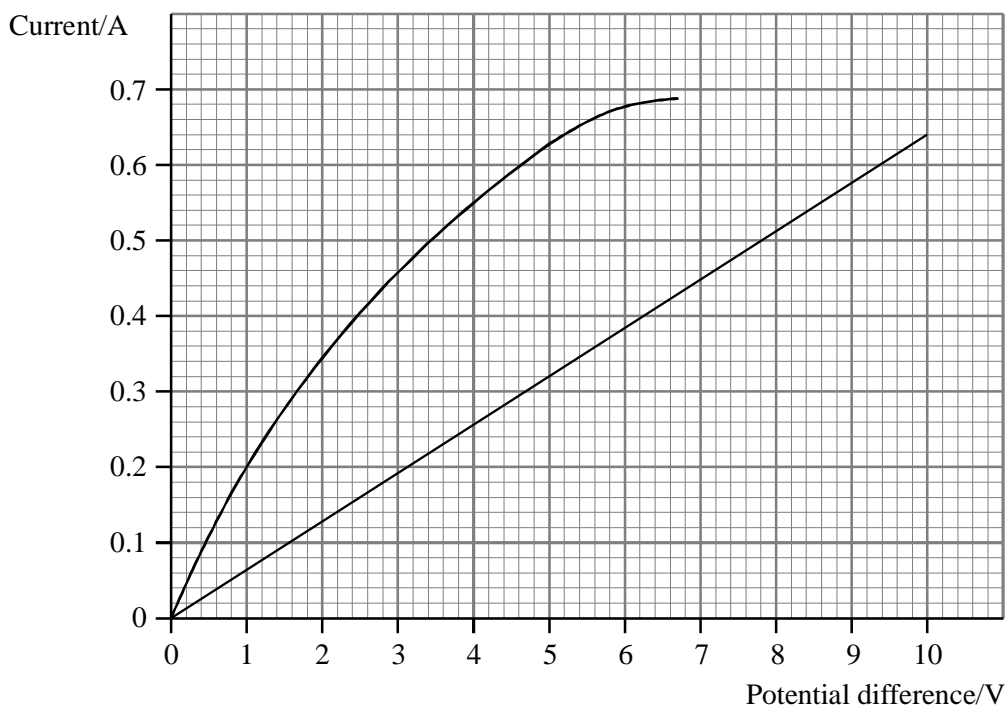
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(3)
(Total 6 marks)

74. A student investigates how the current in a resistor varies as the potential difference across the resistor is varied. Draw a suitable circuit diagram for the investigation.

(3)

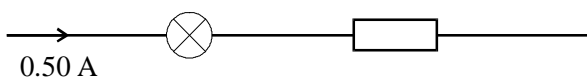
The graphs show the variation of current with potential difference for a filament lamp and for an ohmic resistor.



Label one graph **lamp** and the other graph **resistor**.

(1)

The lamp and resistor are connected in series as shown. There is a current of 0.50 A.



Use the graph to find the total potential difference across the combination.

.....

.....

.....

.....

Potential difference =

(2)

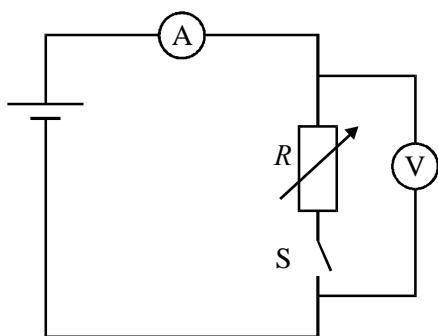
What is the resistance of the lamp under these conditions?

.....

Resistance =

(2)
(Total 8 marks)

75. A student read that a lemon could be used to power a clock. He made an electrical cell using a lemon and placed it in this circuit. The table shows the readings he obtained. The first reading was taken with switch S open. To obtain the others he closed S and varied the resistance R.



| Reading | Current/nA | Voltage/mV |
|---------|------------|------------|
| 1 | 0 | 110 |
| 2 | 90 | 83 |
| 3 | 150 | 74 |
| 4 | 210 | 57 |
| 5 | 310 | 35 |
| 6 | 350 | 20 |

The prefix n, as in nA, means “ $\times 10^{-9}$ ”.

What does the prefix m, as in mV, mean?

.....

(1)

Calculate the value of R for reading 3.

.....

Resistance =

(2)

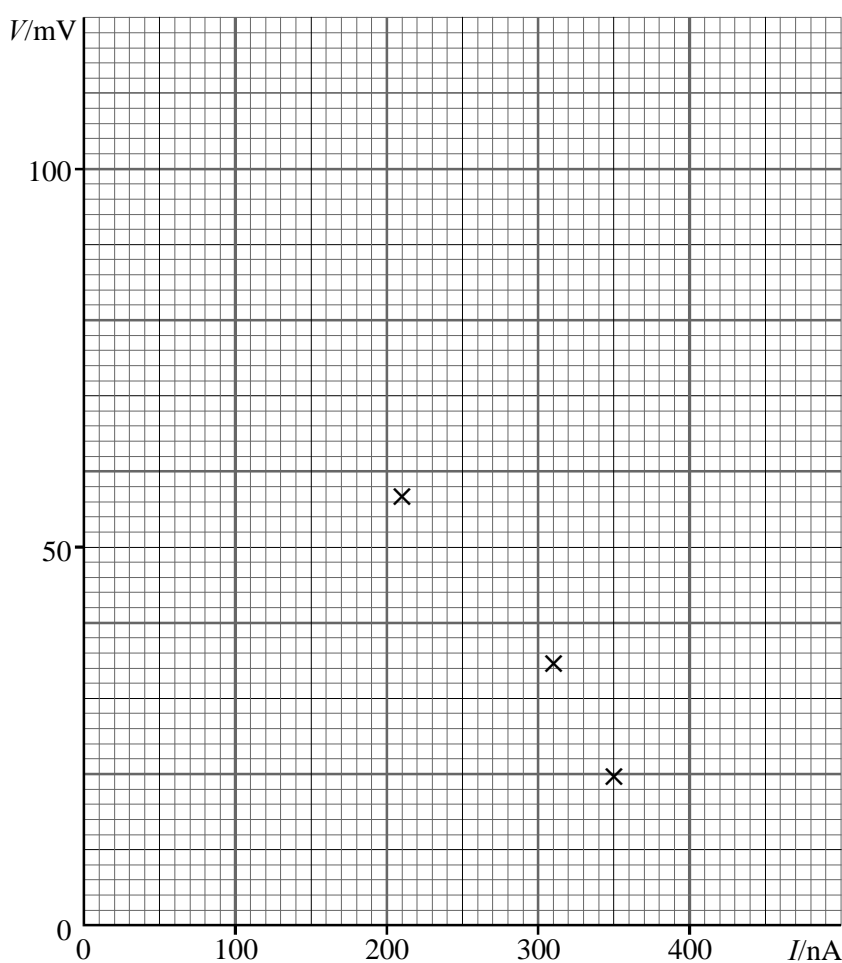
Calculate the power being supplied by the cell to resistance R for reading 4.

.....

Power =

(2)

The student plotted his results on a graph like the one shown. Points for readings 4, 5 and 6 have already been plotted. Complete the graph.



Predict the current that would flow from the cell if it were short-circuited, that is, if R were reduced to zero.

.....

(1)

State what the experiment suggests for the value of the e.m.f. of the cell.

.....

(1)

Explain why the voltage across the cell falls as R is reduced.

.....

.....

.....

(2)

(Total 12 marks)

76. A physics teacher was driving to work when she heard the following report on the radio.

“Scientists have been researching a method of judging people’s opinions of politicians. They have found that the more strongly opposed people are to a politician’s views, the more their hands sweat. This can be detected using a resistivity meter which has two probes resting on the palm of the hand.”

Write down an equation to define resistivity, stating what each symbol represents.

.....

.....

.....

.....

(3)

Why should the **resistivity meter** strictly be called a resistance meter?

.....

.....

.....

.....

(2)

The teacher decided to see if this idea would work. She used a multimeter to measure the resistance across her palm as shown in the picture below.



She obtained the following readings with the probes 2 cm apart:

| Radio Topic | Teacher's feelings | Approximate resistance/M Ω |
|-------------|--------------------|-----------------------------------|
| Comedy | Very relaxed | 3 |
| Music | Relaxed | 2 |
| Politics | Annoyed | 1 |

Do these results support the claims of the reporter? Give your reasoning.

.....

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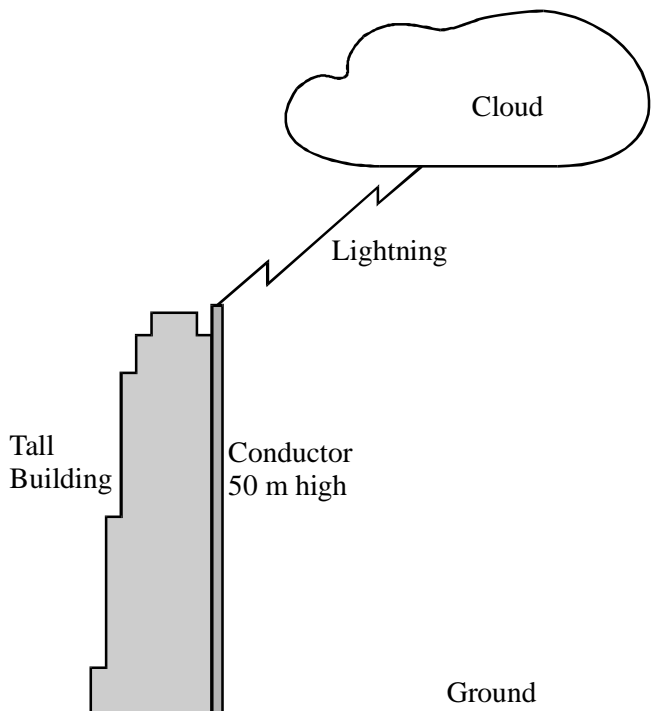
(3)
(Total 8 marks)

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

| Word Equation | Quantity Defined |
|--------------------------|------------------|
| Voltage \div Current | |
| Voltage \times Current | |
| Charge \div Time | |
| Work Done \div Charge | |

(Total 4 marks)

78. 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 $1.0 \times 10^{-3} \text{ m}^2$.
It is made from copper which has a resistivity of $1.7 \times 10^{-8} \Omega \text{ m}$.

Calculate the resistance of the lightning conductor.

.....
.....
.....

Resistance = (3)

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

.....
.....

Potential difference = (2)

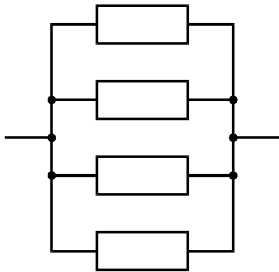
If lightning strikes a tree such that there is the same current through it as there was through the conductor, then a much larger potential difference exists between the top and bottom of the tree. Explain why this is so.

.....
.....

(1)
(Total 8 marks)

79. A student has four identical resistors each of resistance $10\ \Omega$. She connects them to form the different networks shown below.

Calculate the equivalent total resistance of each network.



First network

.....

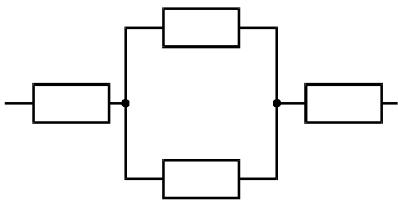
.....

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.....

.....

Total resistance = Ω



Second network

.....

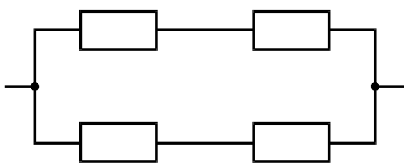
.....

.....

.....

.....

Total resistance = Ω



Third network

.....

.....

.....

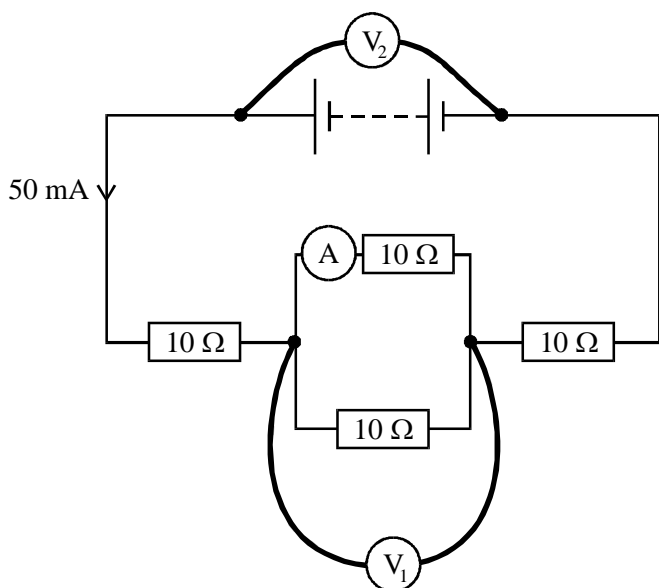
.....

.....

Total resistance = Ω

(3)

She then connects a battery across the second network and adds meters to make the circuit shown below. A current of 50 mA is drawn from the battery.



Determine the reading on each of the three meters.

Reading on ammeter A:

.....

Ammeter reading = mA

Reading on voltmeter V_1 :

.....

Voltmeter reading = V

Reading on voltmeter V_2 :

.....

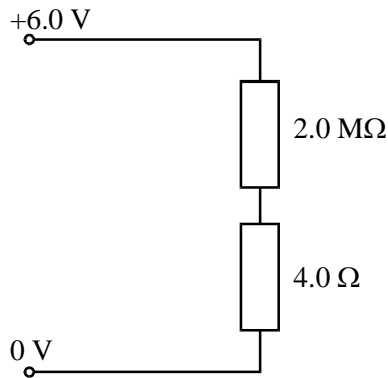
.....

Voltmeter reading = V

(5)
(Total 8 marks)

80. Two resistors of resistance $2.0\text{ M}\Omega$ and $4.0\ \Omega$ are connected in series across a supply voltage of 6.0 V . Together they form a simple potential divider circuit.

State the potential difference across each resistor.

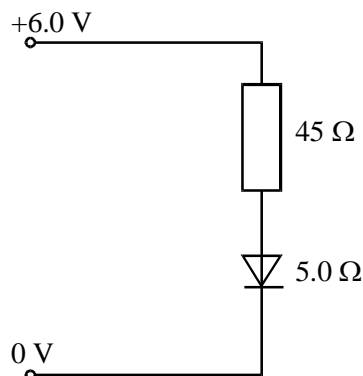


P.d. across the $2.0\text{ M}\Omega$ resistor =

P.d. across the $4.0\ \Omega$ resistor =

(2)

A second potential divider circuit uses a resistor and a diode connected in series with the same supply. Calculate the potential difference across each component when the resistance of the resistor and diode are $45\ \Omega$ and $5.0\ \Omega$ respectively.



.....

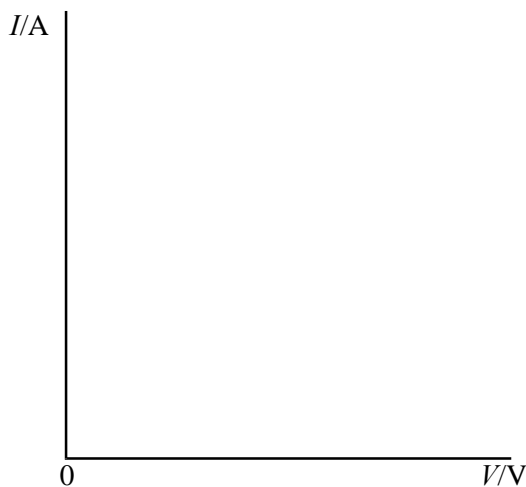
P.d. across the $45\ \Omega$ resistor =

.....

P.d. across the diode =

(2)

In this circuit the diode is in forward bias. Use the axes below to sketch a graph of current I against potential difference V for a diode in forward bias.



(1)
(Total 5 marks)

81. Sam bought a new set of Christmas tree lights. The box stated, “40 lamps, 6.0 V 0.78 W each”.

Calculate the working current of each lamp.

.....

Current =

(2)

Calculate the working resistance of each lamp.

.....

Resistance =

(2)

Explain how this set of lights can operate normally from a mains supply of 240 V.

.....
.....
.....

(2)

Sam thought the lamps at the top of the Christmas tree would light more faintly than the others because the current would have to flow further through the wires to reach them. Explain why all the lamps are lit equally brightly.

.....
.....
.....

(1)

Sam decides to check the lamps before connecting them to the mains. He measures the resistance of each lamp with an ohmmeter. This does not make the lamp light up. He discovers that the measured resistance is not the same as the working resistance.

State whether the measured resistance is higher or lower than the working resistance.

.....

Explain this observation.

.....
.....
.....
.....

(3)

(Total 10 marks)

82. A rechargeable battery for an electronic game is marked with the following information:

Output 3.0 V, capacity 1.5 amp hours

Explain why “amp hours” is a unit of charge.

.....
.....
.....

(2)

Show that the charge equivalent to 1.5 amp hours is about 5000 C.

.....
.....

(1)

Calculate the energy stored in the battery when it is fully charged, assuming the output voltage remains constant at 3.0 V.

.....
.....

Energy stored =

(2)

To recharge the battery a supply voltage of 3.1 V is used with a current of 0.30 A. The battery takes 6 hours to charge fully.

Show that the electrical energy supplied in charging the battery is about 20 000 J.

.....
.....

(2)

Calculate the overall efficiency of the process of charging the battery and then using it to play the game.

.....

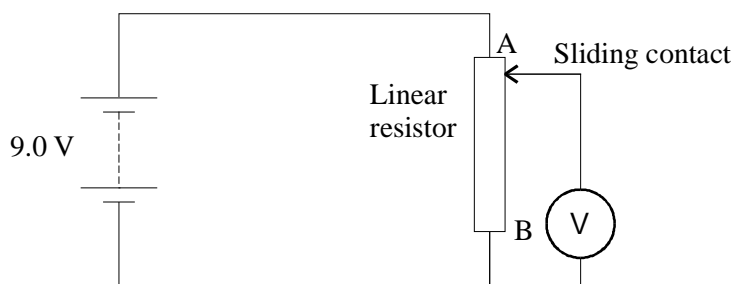
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.....

Efficiency =

(3)
(Total 10 marks)

83. A student wants to provide lighting for a model house which she has made. She needs 3.0 V for her lamps but only has a 9.0 V battery, so uses a linear resistor AB in the circuit below. The linear resistor is made from a high resistance uniform conductor.



What is the name of the device AB when it is used in this manner?

.....

(1)

State the voltmeter reading when the sliding contact is at:

A B

(2)

The student moves the sliding contact until the voltmeter reads 3.0 V.

Add an arrow labelled X to the diagram to show where the sliding contact must be placed.

(1)

The student replaces the voltmeter with a 3.0 V lamp but the lamp does not light. Explain why the lamp does not light.

.....

.....

.....

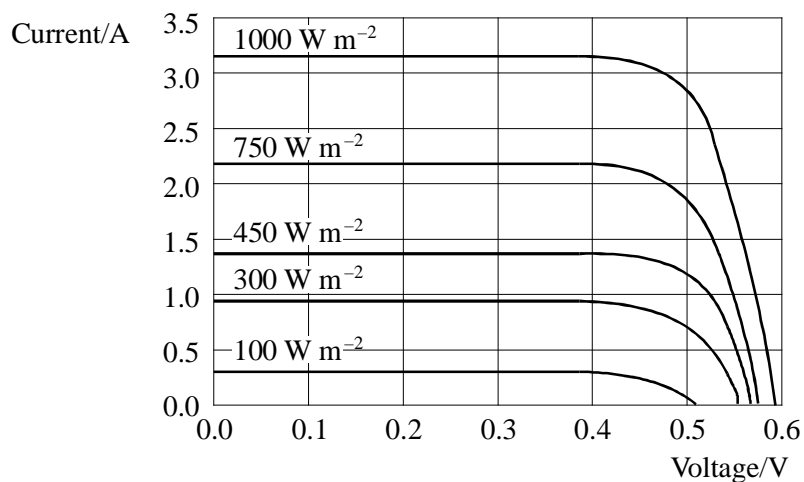
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(3)
(Total 7 marks)

84. The current in the tether would be provided by a solar cell array on MIR. The graph below shows a set of current-voltage ($I-V$) curves for a particular solar cell for different light intensities. The cell was kept at 25 °C.



Draw a circuit diagram to show how a range of measurements of V and I could be taken for the solar cell at a given light intensity.

(3)

Show that the maximum power available for an intensity of 1000 W m^{-2} is about 1.4 W .

.....
.....

(2)

It is suggested that maximum power is proportional to light intensity.
Without plotting any further graphs, analyse some of the data to comment on whether this suggestion is reasonable.

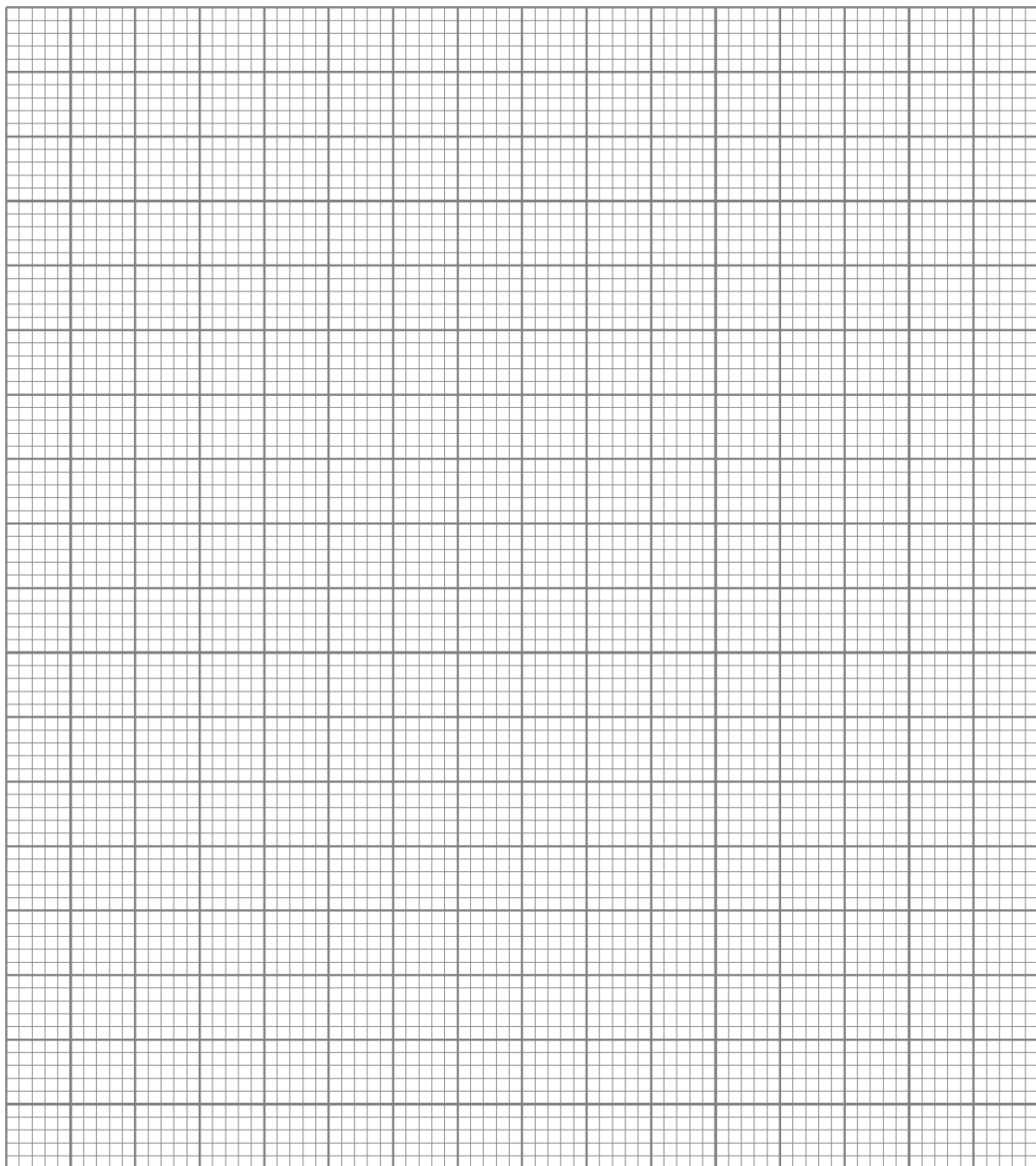
.....
.....
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(3)

Data showing how the e.m.f., ξ , of this cell depends on temperature t is provided in the table below.

| ξ/V | $t/^{\circ}C$ |
|---------|---------------|
| 0.62 | 12 |
| 0.59 | 25 |
| 0.54 | 50 |
| 0.51 | 63 |
| 0.48 | 75 |

Plot a graph of ξ against t on the grid below.



(4)

Use the graph to determine a mathematical relationship between ξ and t .

.....

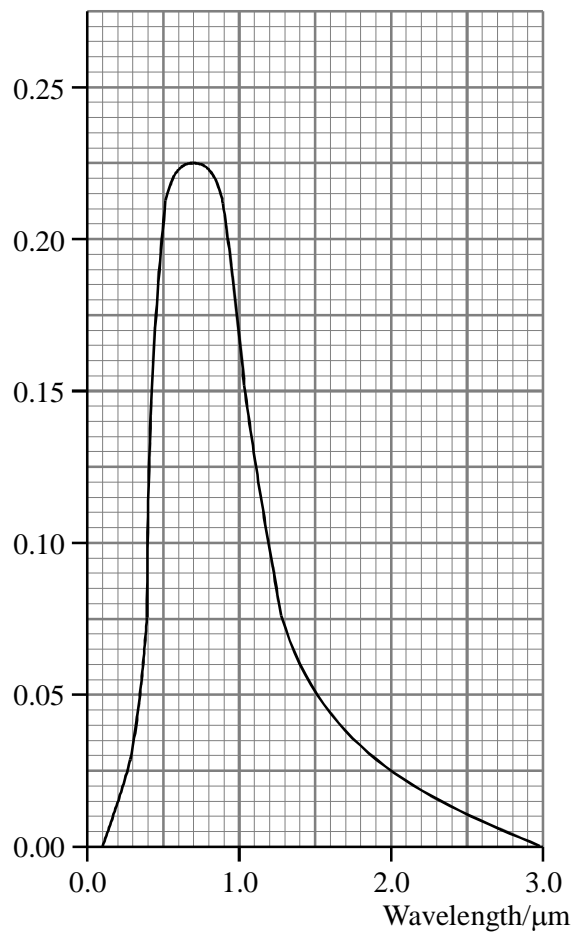
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(4)

The graph below shows the contribution of different wavelengths of light arriving from the Sun, to the total intensity at a point just above the Earth's atmosphere.

Intensity per unit
wavelength
 $/\text{W cm}^{-2} \mu\text{m}^{-1}$



This particular solar cell only produces current from light with a wavelength less than or equal to 1.1×10^{-6} m.

Use the graph to determine the light power from the sun that is available for conversion to electrical power in this satellite solar cell. The area of the solar cell is 4.0 cm^2 .

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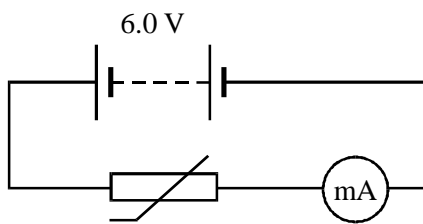
(4)
(Total 20 marks)

85. Classify each of the terms in the left-hand column by placing a tick in the relevant box.

| | Base unit | Derived unit | Base quantity | Derived quantity |
|--------|-----------|--------------|---------------|------------------|
| Mass | | | | |
| Charge | | | | |
| Joule | | | | |
| Ampere | | | | |
| Volt | | | | |

(Total 5 marks)

86. A negative temperature coefficient thermistor is used in the following circuit to make a temperature sensor.



Explain how the circuit works.

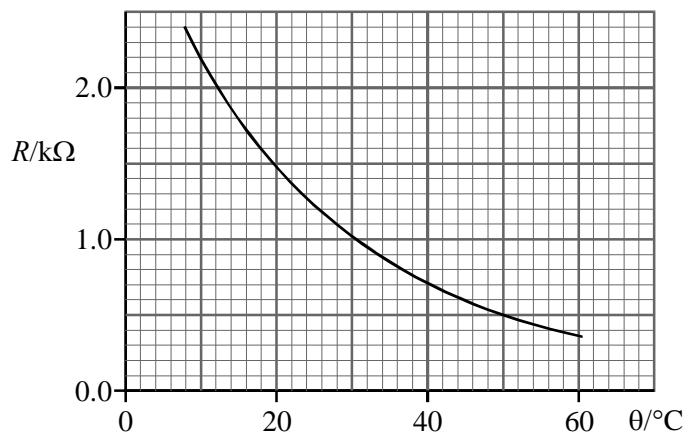
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(2)

The graph shows how the resistance of the thermistor varies with temperature.



What will the reading on the milliammeter be when the thermistor is at a temperature of $20^\circ C$?

.....

.....

.....

Milliammeter reading =

(3)

(Total 5 marks)

87. A copper wire has a cross-sectional area of $0.20 \times 10^{-6} \text{ m}^2$. 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} .

.....
.....
.....

Current = (3)

The wire is 4.0 m long. Copper has a resistivity of $1.7 \times 10^{-8} \Omega \text{ m}$. Calculate the resistance of the wire.

.....
.....
.....

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.

.....
.....

(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.

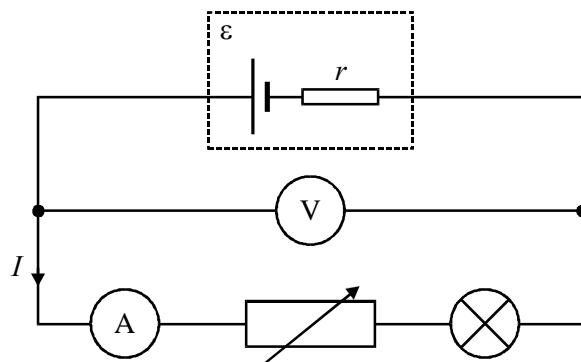
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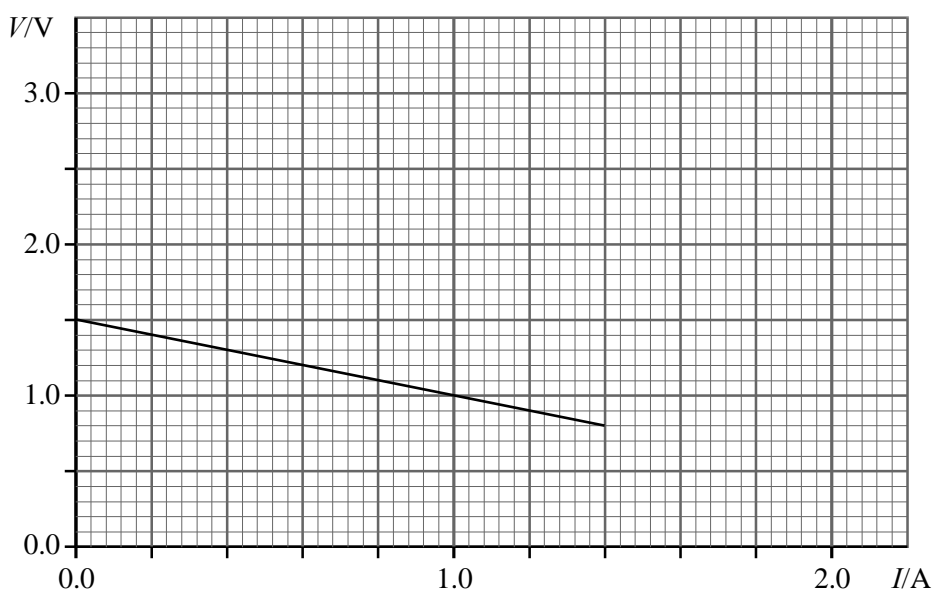
(1)
(Total 10 marks)

88. A student wants to determine the e.m.f. ϵ of a cell and its internal resistance r .

He uses the circuit shown and measures the terminal voltage V across the cell and the current I in the circuit for each setting of the variable resistor.



He plots the following graph of terminal voltage V against current I .



Show how the relationship $V = \mathcal{E} - Ir$ can be used with his graph to determine the e.m.f. \mathcal{E} of the cell. State its value.

.....
.....

E.m.f. = (2)

Show how the graph can be used to determine the internal resistance r of the cell. Calculate its value.

.....
.....
.....

Internal resistance = (2)

The student repeats the experiment using two of these cells in series. On the graph, draw the line that he obtains.

(3)

Suggest why the student includes the filament lamp in the circuit.

.....
.....

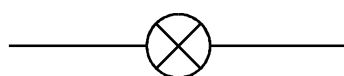
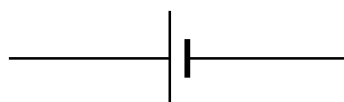
(2)

(Total 9 marks)

89. Edward notices that a bulb for a torch is marked “1.25 V, 0.40 A”.

Edward and Sarah set up a circuit using the cell and the bulb from the torch to check the values marked on the bulb.

Complete the circuit diagram below adding any necessary additional components.



(2)

The results confirm the values marked on the bulb. Edward wonders why it needs a 1.5 V cell to operate correctly. Sarah says this is because of internal resistance, but can't say why.

Explain this apparent inconsistency between bulb voltage and cell e.m.f.

.....
.....
.....
.....
.....
.....

(2)

Show that the internal resistance of the cell is about 0.6 Ω .

.....
.....
.....

(2)

Calculate the resistance of this bulb when connected to the cell as above.

.....
.....
.....

Resistance =

(2)

Sarah and Edward then check their result using, an ohmmeter. The ohmmeter uses a very small current which does not light up the bulb. They obtain a resistance value of 0.7Ω .

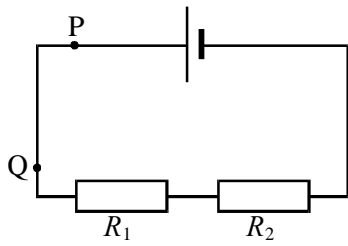
Explain why this value of resistance is much lower than the resistance obtained using the circuit above.

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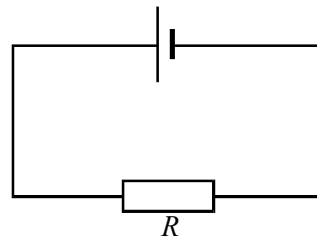
(2)

(Total 10 marks)

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



(i)



(ii)

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.

.....
.....
.....

(2)

In what circumstances might the approximation break down?

.....
.....

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

.....

.....

.....

.....

.....

Potential difference =.....

(4)

(Total 10 marks)

91. 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.

.....

.....

.....

.....

(3)

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

.....

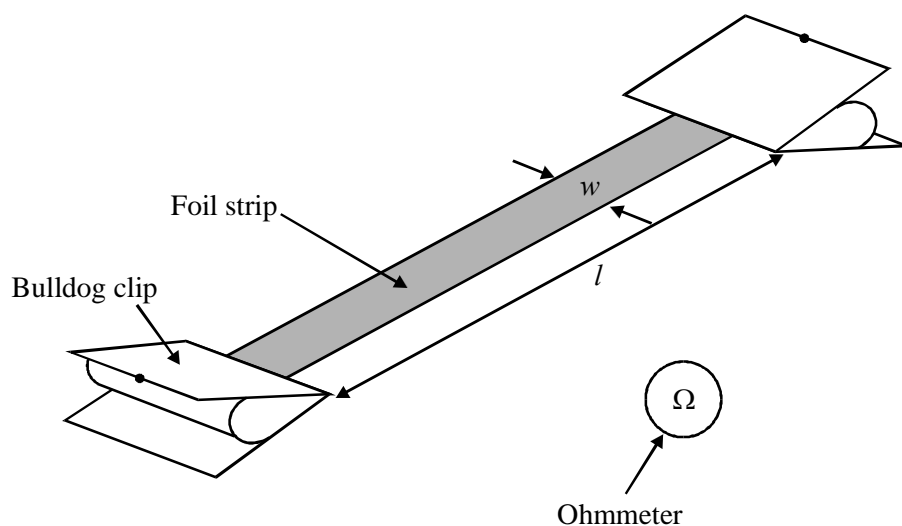
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(2)
(Total 7 marks)

92. 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.

.....

.....

.....

.....

(2)

The student decides that for sufficient accuracy the resistance of the strip must be at least 1.0Ω . 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 1.0Ω (Resistivity of aluminium = $2.7 \times 10^{-8} \Omega \text{ m}$)

.....

Length =.....

(3)

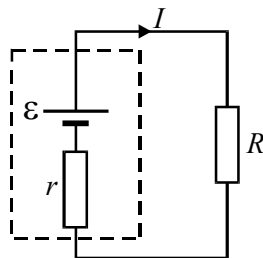
Suggest a way, other than increasing its length, by which she could increase the resistance of her strip. Comment on whether this change would lead to a more precise measurement of the resistivity.

.....

(2)

(Total 7 marks)

93. The diagram below shows a cell, of e.m.f. \mathcal{E} 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 $I = \frac{\mathcal{E}}{(R + r)}$

.....
.....
.....

(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.

.....
.....
.....
.....

(2)

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

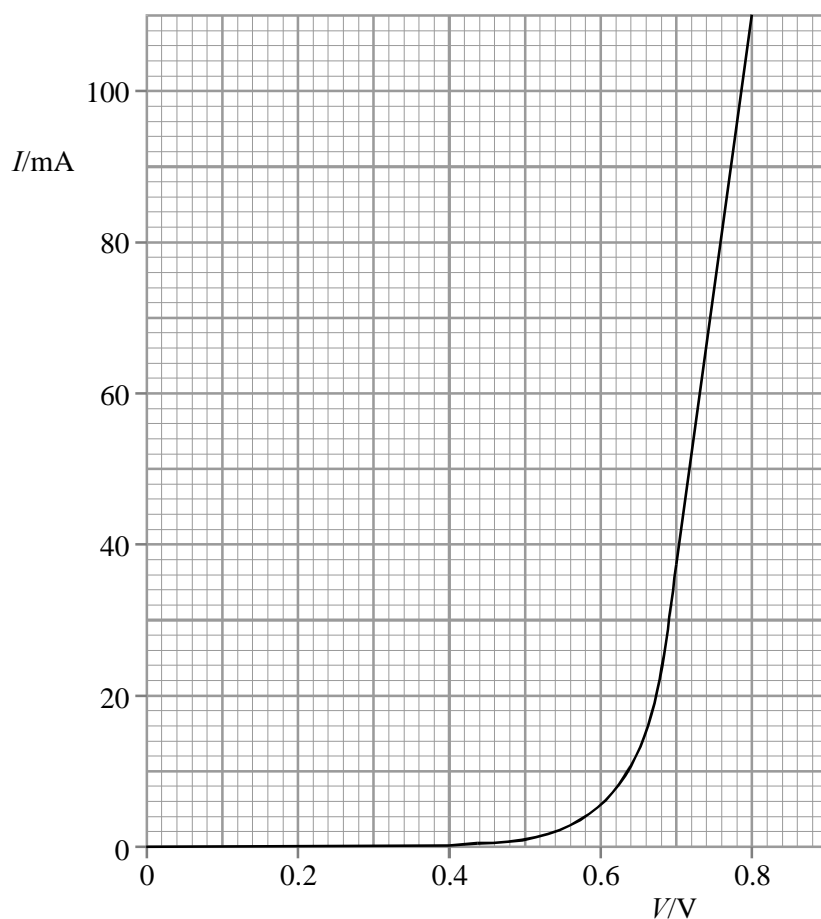
1 k Ω 10 k Ω 100 k Ω 1 M Ω

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

.....
.....
.....

(2)
(Total 9 marks)

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



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

.....
.....

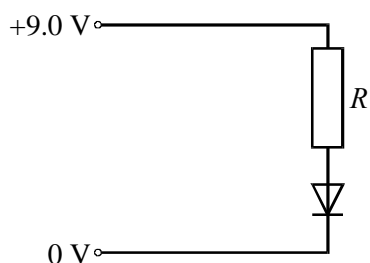
(1)

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

.....
.....

(2)

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



Calculate the value of the resistance R .

.....
.....
.....

$R = \dots\dots\dots$

(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)

95. Define electrical potential difference.

.....
.....

(1)

State an appropriate unit for potential difference.

.....

(1)

Express this unit in terms of base units.

.....
.....
.....

(2)

(Total 4 marks)

96. White Lightning is an electric car which held the world speed record for such a vehicle in 1999.



White Lightning on Bonneville Salt Flats

Some data about White Lightning:

| | |
|---------------------------------------------------|-----------------------|
| Maximum speed reached | = 107ms^{-1} |
| Mass of vehicle plus driver | = 1160kg |
| Voltage provided by battery when delivering power | = 420 V |
| Power input to main motor | = 300 kW |
| Time to reach maximum speed | = 100s |

Show that the current in the motor is about 700 A.

.....
.....

(1)

Suggest one problem that a current of this size might give the designer.

.....
.....

(1)

Explain why the e.m.f. of the battery would have to be more than 420 V.

.....
.....

(2)

Show that the overall efficiency of the vehicle is about 20% during a run up to full speed.

.....
.....
.....
.....
.....

(3)

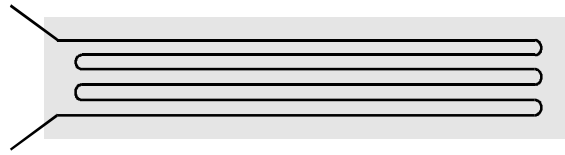
Suggest two reasons for the energy losses of about 80%.

.....
.....
.....
.....

(2)

(Total 9 marks)

97. The diagram shows a strain gauge. The resistance of this device changes when it is deformed. It is used on bridges to monitor any changes such as flexing at the joints or extension of the supporting cables.



The strain gauge consists of a length of very fine wire, looped as shown, which has been cemented between two sheets of very thin paper. It is firmly glued to the surface that is to be monitored.

Explain why the resistance of the strain gauge changes when it is stretched.

.....
.....
.....
.....

(2)

Explain an advantage of using the arrangement of wire shown in the diagram.

.....
.....
.....
.....

(1)

Draw a diagram showing a circuit you could use to measure the resistance of the strain gauge.

(2)

The wire used for the gauge is 0.20 m long and has a diameter of 2.0×10^{-4} m. Show that this wire has a resistance of about 3Ω .

Resistivity = $4.9 \times 10^{-7} \Omega \text{ m}$

.....

.....

.....

.....

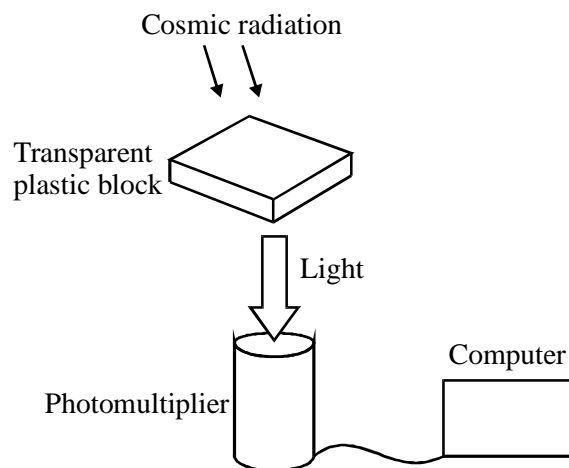
.....

.....

(3)
(Total 8 marks)

98. Scientists from Leeds University are involved in an experiment at the South Pole to look for cosmic radiation from a supernova observed in 1987. Cosmic radiation consists of high energy particles from space.

Their equipment involves the following:



Cosmic radiation causes this plastic block to emit light. If this light enters the photomultiplier, photoelectrons are released and the signal is sent to a computer which records the event.

A photomultiplier which has a photocathode made from antimony–caesium has a threshold wavelength of 700 nm. Explain why a photocathode has a threshold wavelength.

.....
.....
.....
.....
.....

(4)

Show that the work function of antimony-caesium is about 3×10^{-19} J.

.....
.....
.....
.....

(3)

The scientists' generator at the South Pole produces a voltage of 600 V and the photomultiplier needs potential differences of 200 V, 400 V and 600 V. Draw a circuit to show how a series of resistors could provide all of these potential differences from one 600 V supply.

(2)

Suggest why cosmic radiation from the supernova was not detected at the same time as the supernova was observed.

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(1)
(Total 10 marks)

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

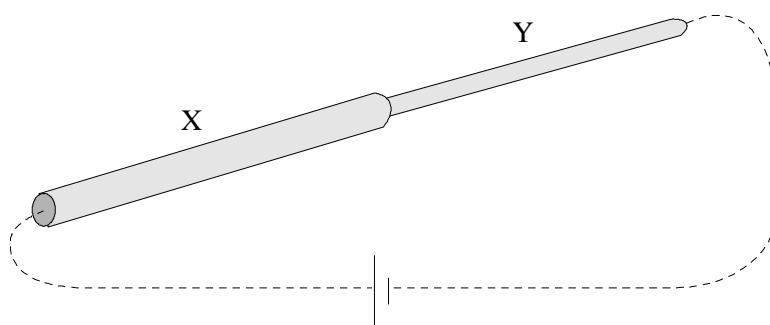
$$I = nAve$$

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 |
|-------------------|-------|-------------|
| $\frac{n_y}{n_x}$ | | |
| $\frac{I_y}{I_x}$ | | |
| $\frac{V_y}{V_x}$ | | |

(6)
(Total 8 marks)

100. 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 $1.7 \times 10^{-8} \Omega$. Show that the resistance of each of the conductors is 0.085Ω .

.....

(2)

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

.....

Voltage =.....

(2)

Explain why cable with 6.0 mm^2 conductors would have been more suitable for this shower installation.

.....

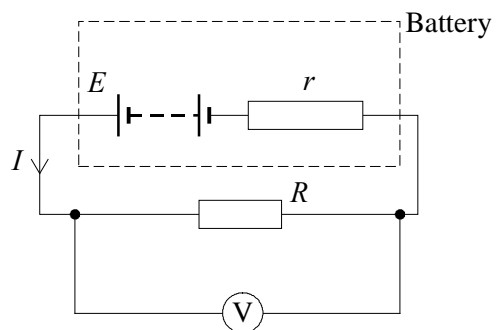
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(2)
(Total 6 marks)

101. Melanie is using a spreadsheet to model the behaviour of the circuit shown below.



| | A | B | C | D | E | F |
|----|---------------------------------------------|---------------------|---------------|----------|------------------|---------------|
| 1 | Calculations for a Battery Delivering Power | | | | | |
| 2 | | | | | | |
| 3 | e.m.f. | internal resistance | load resistor | current | p.d. across load | power in load |
| 4 | E | r | R | I | V | P |
| 5 | (volts) | (ohms) | (ohms) | (amps) | (volts) | (watts) |
| 6 | | | | | | |
| 7 | 12.0 | 2.00 | 0.00 | 6.00 | 0.00 | 0.0 |
| 8 | 12.0 | 2.00 | 0.50 | 4.80 | 2.40 | 11.5 |
| 9 | 12.0 | 2.00 | 1.00 | 4.00 | 4.00 | 16.0 |
| 10 | 12.0 | 2.00 | 1.50 | 3.43 | 5.14 | 17.6 |
| 11 | 12.0 | 2.00 | 2.00 | 3.00 | 6.00 | 18.0 |
| 12 | 12.0 | 2.00 | 2.50 | 2.67 | 6.67 | 17.8 |
| 13 | 12.0 | 2.00 | 3.00 | 2.40 | 7.20 | 17.3 |
| 14 | 12.0 | 2.00 | 3.50 | 2.18 | 7.64 | 16.7 |
| 15 | 12.0 | 2.00 | 4.00 | 2.00 | 8.00 | 16.0 |

To calculate a value for cell D7, Melanie entered this formula:

$$= A7/(B7 + C7)$$

Explain why this is correct.

.....

.....

(1)

What would be an appropriate formula for cell E9?

.....

(1)

What would be an appropriate formula for cell F11?

.....

(1)

What is the short-circuit current obtainable from this battery?

.....

(1)

Explain why the p.d. across the load resistor increases as the current falls.

.....

.....

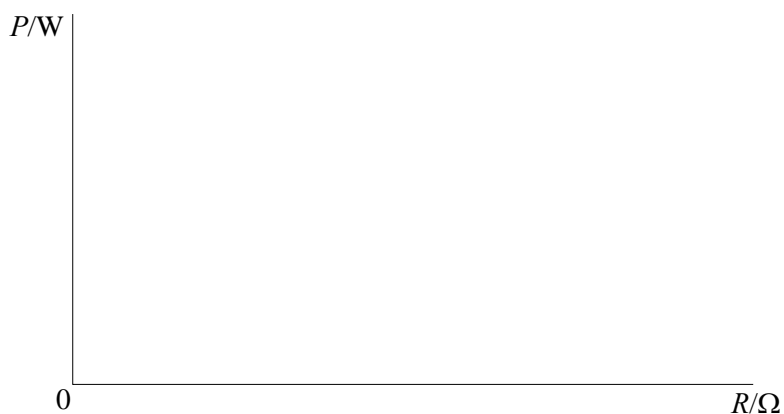
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(2)

Sketch a graph on the axes below to show how the power in the load would vary for load resistors in the range 0–9 Ω (marking values where appropriate).



(3)

Comment on *one* key feature of the graph.

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(2)
(Total 11 marks)

102. (a) Describe how you would determine by experiment approximate values for the e.m.f and internal resistance of a torch battery. Include a circuit diagram.

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(4)

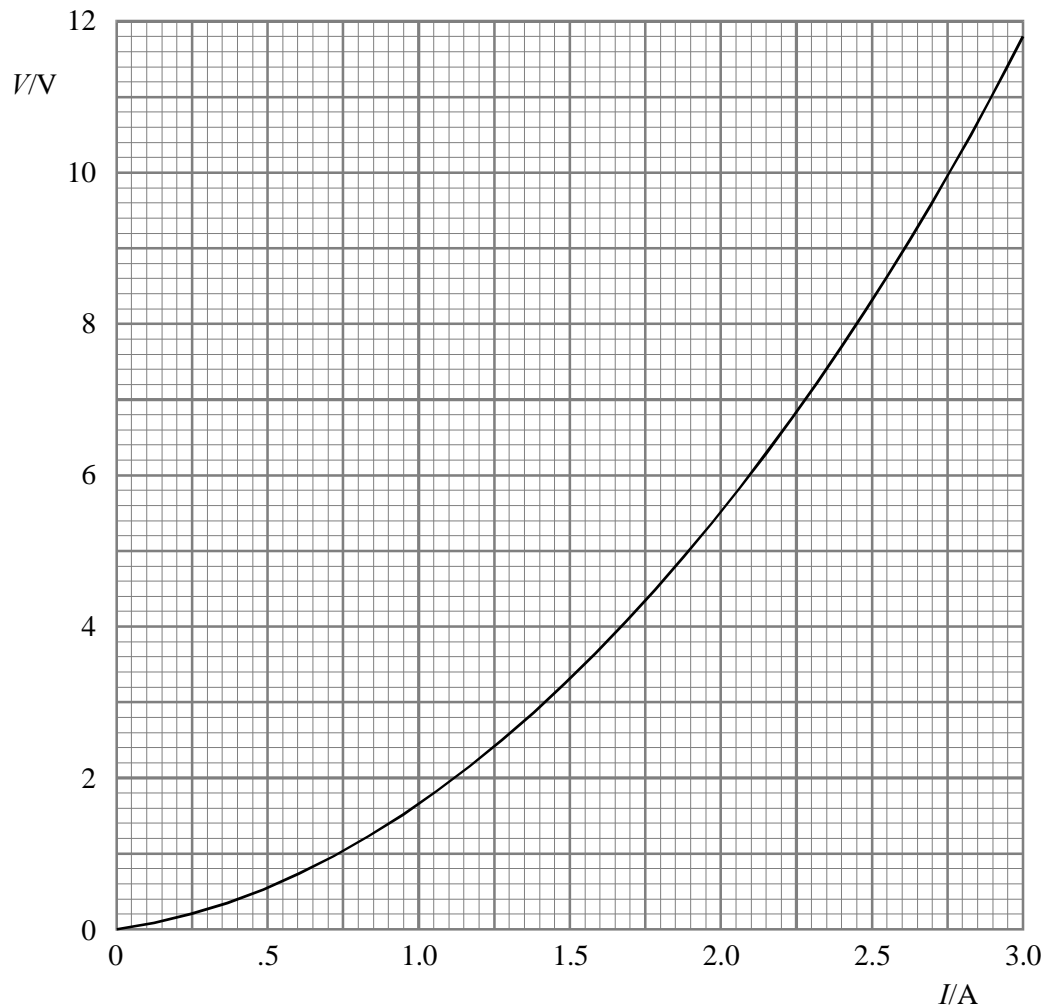
- (b) (i) A battery has an e.m.f. of 12.0 V and an internal resistance of 3.0Ω . Calculate the p.d. across the battery when it is delivering a current of 3.0 A.

.....

p.d. =

(2)

- (ii) The same battery is now connected to a filament lamp. The graph shows how the p.d. across the lamp would depend on the current through it.



Use your answer to part (i) to help you draw, on the same axes, a line showing how the p.d. across the battery would depend on the current through it.

(1)

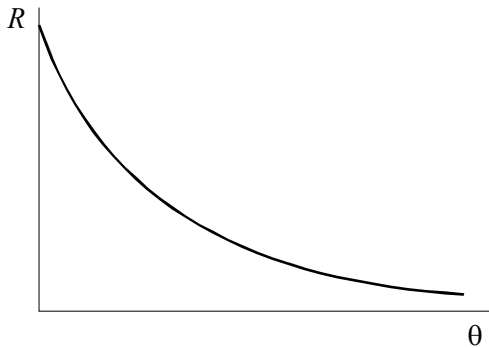
What current will the battery drive through the lamp?

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(1)

(Total 8 marks)

103. The graph shows how the resistance R of a thermistor depends on temperature θ .

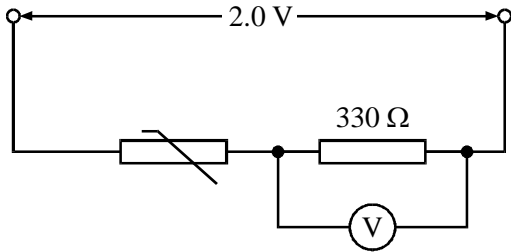


In terms of the behaviour of the material of the thermistor, explain qualitatively the variation shown on the graph.

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.....
.....

(2)

A student connects the thermistor in series with a $330\ \Omega$ resistor and applies a potential difference of $2.0\ \text{V}$. A high resistance voltmeter connected in parallel with the resistor reads $0.80\ \text{V}$.



Calculate the resistance of the thermistor.

.....

.....

.....

Resistance =

(3)

The student now increases the applied p.d. from $2.0\ \text{V}$ to $20\ \text{V}$. She expects the voltmeter reading to increase from $0.80\ \text{V}$ to $8.0\ \text{V}$ but is surprised to find that it is greater. Explain this.

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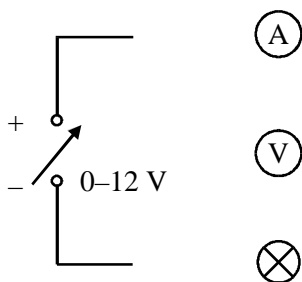
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(3)

(Total 8 marks)

- 104.** You are asked to set up a circuit to take some measurements and to draw a graph which shows how the current in a 12 V, 24 W electric filament lamp varies with the potential difference across it.

The diagram shows the electrical components you will need. Complete a suitable circuit diagram by drawing the connection wires.



(2)

What measurements would you make using this circuit?

.....

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.....

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.....

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(3)

Sketch and label the graph you would expect to obtain.



(3)
(Total 8 marks)

- 105.** A torch has three identical cells, each of e.m.f. 1.5 V, and a lamp which is labelled 3.5 V, 0.3 A.

Draw a circuit diagram for the torch.

(2)

Assume that the lamp is lit to normal brightness and that the connections have negligible resistance. Mark on your diagram the voltage across each circuit component and the current flowing in the lamp.

(3)

Calculate the internal resistance of one of these cells.

Resistance =

(3)

(Total 8 marks)