

WJEC A-LEVEL PHYSICS • UNIT 2

PHYSICS



EXAM QUESTION PACK

2.3 D.C. CIRCUITS

SCORE

/

PERCENTAGE

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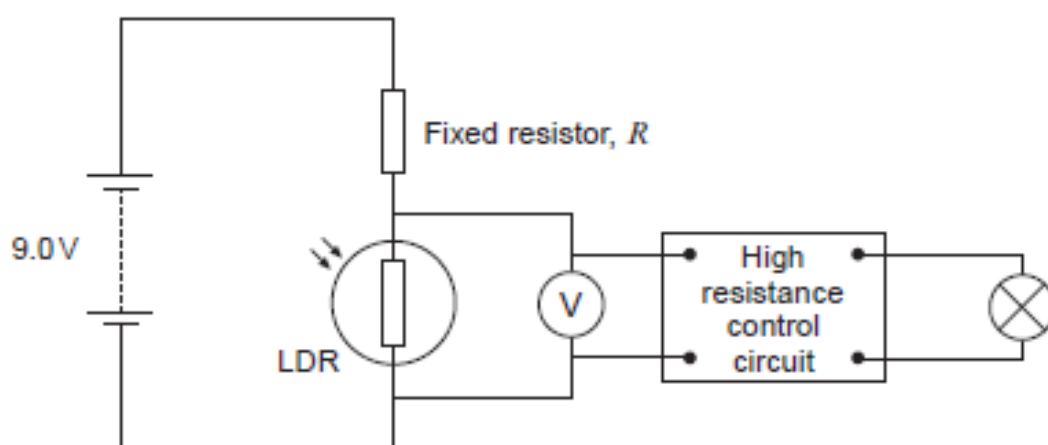
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1.

1. (a) An engineer investigates the use of a light dependent resistor (LDR) as a light sensor in a potential divider circuit. He designs the following sensing circuit to operate a 230 V lamp in the dark.



The control circuit draws a negligible current. During his research, the engineer determines the following facts:

The control circuit requires at least 4.0 V to activate.

The LDR the engineer intends to use has a resistance of $2.4 \text{ k}\Omega$ at the light intensity required to switch the lamp on.

- (i) Explain how the current in the LDR changes as the light intensity decreases. [2]

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- (ii) Determine a suitable value for the fixed resistor R , which would allow the lamp to be switched on. [3]

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- (b) When installing the circuit, the engineer made the mistake of placing the lamp near to the LDR. The engineer noted that, when in the dark, the lamp kept turning on and off repeatedly rather than staying on. Explain why this was the case. [2]

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2. (a) (i) State what is meant by *electric current*.

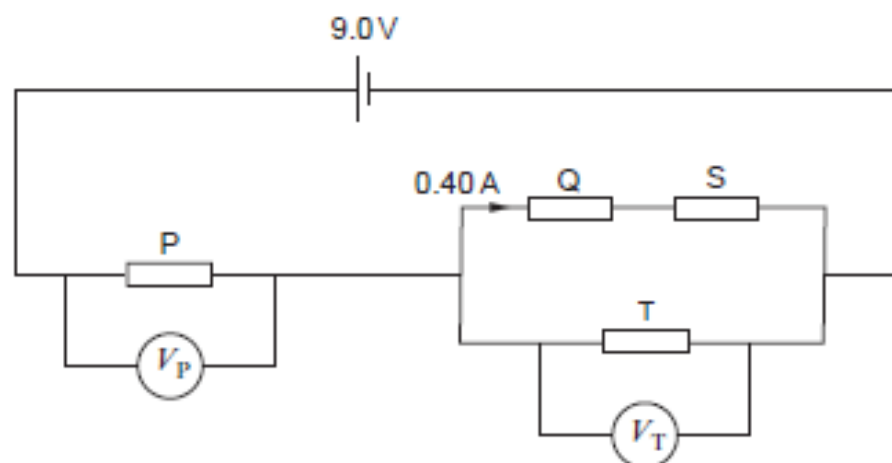
[1]

- (ii) Show that the unit of resistance, the ohm (Ω), can be expressed as:

[2]

$$\text{Js C}^{-2}$$

- (b) The following circuit shows an arrangement of identical resistors labelled P, Q, S and T connected to a fixed pd of 9.0 V. V_P and V_T are the pds across P and T respectively. There is a current of 0.40 A in Q and S.



- (i) Show that $V_P = 1.5 V_T$.

[2]

- (ii) Hence or otherwise show that the values given in the diagram are consistent with the resistance of each resistor being 4.5Ω .

[3]

- (c) Show that the total energy dissipated per second in the whole circuit is 15 times more than the energy dissipated per second in resistor Q. [3]

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- (d) Resistor T is now removed from the circuit. Explain the effect this will have on the ratio calculated in part (c). [3]

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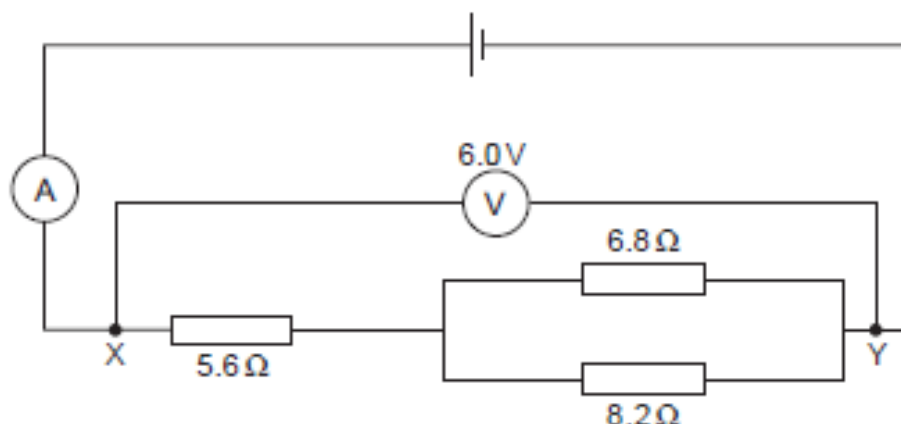
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3.

2. A circuit is set up as shown.



- (a) In the circuit shown, the potential difference between X and Y is 6.0 V . Explain what this statement means. [2]

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- (b) (i) Determine the reading on the ammeter if it has an instrument resolution of $\pm 0.01\text{ A}$. [4]

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- (ii) Calculate the potential difference across the $8.2\ \Omega$ resistor. [2]

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(iii) Calculate the power dissipated in the parallel resistor combination. [2]

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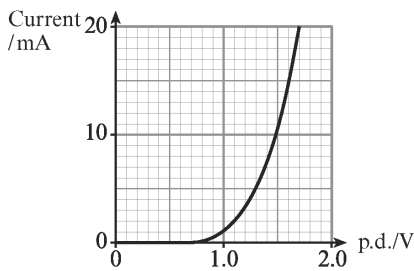
4. The current-voltage characteristics of a diode also apply to a light emitting diode (LED). A graph of current against potential difference for an LED is shown.

(a) (i) Calculate the resistance of the LED when the p.d. is 1.6 V. [2]

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(ii) Comment on the resistance of the LED at voltages below 1.0 V. Calculations are not required. [1]

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(b) (i) Explain how the graph shows that the LED does not obey Ohm's law. [1]

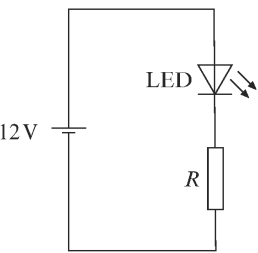
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(ii) Name one other device, other than a diode, to which Ohm's law does not apply. [1]

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(c) If the LED is connected across a supply of e.m.f. greater than 1.6 V, then the large current produced will destroy it. For this reason, LEDs usually have protective resistors in series with them to limit the current. The circuit shows this LED used as an indicator for a car alarm. The car battery supplies 12 V and the LED has an operating current of 15 mA. Determine the value, R , of the protective resistor needed. [3]



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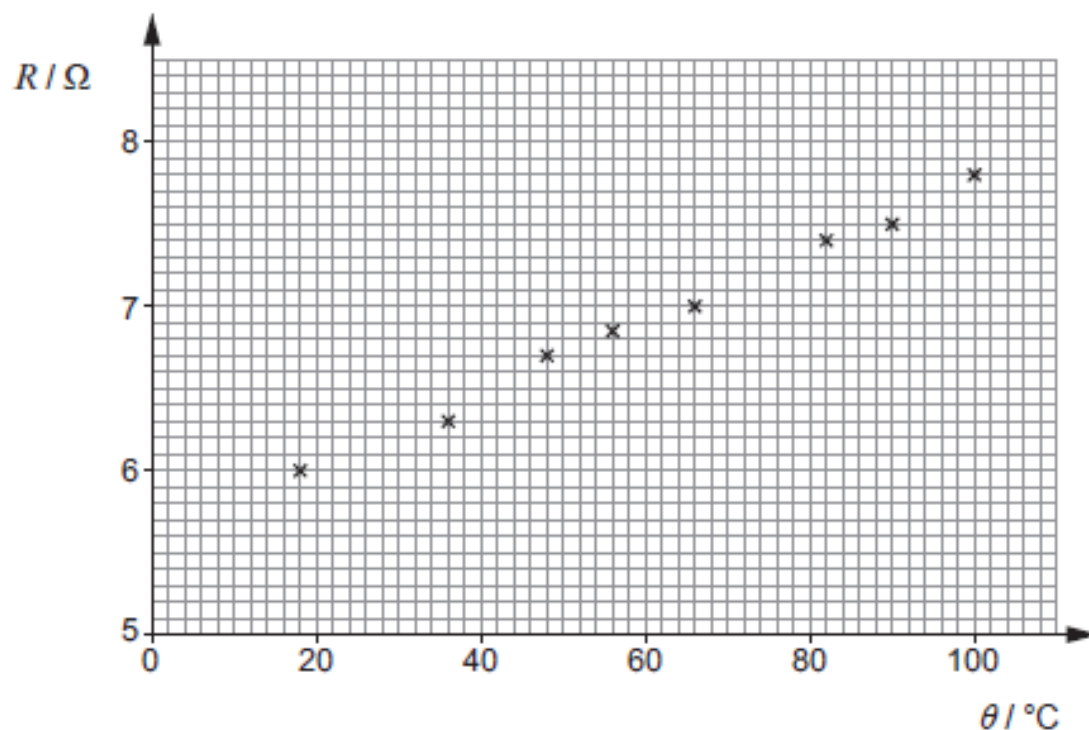
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5.

3. A student slowly heated a coil of insulated copper wire. He took readings of its temperature, θ , and resistance, R , at intervals. The readings are plotted below.



- (a) Bearing in mind the range of temperatures, suggest how the student heated the coil, and how he could have extended the range of temperatures down to just above 0°C . [2]

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- (b) Textbooks state that the resistance, R , of a metal wire is related to its celsius temperature, θ , by an equation of the form:

$$R = R_0 \alpha \theta + R_0$$

in which R_0 and α are positive constants.

- (i) Explain how the readings plotted support the equation. [3]

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(ii) Determine from the graph the values, with units, of:

I. R_0 ; [1]

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II. α . [3]

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6. (a) (i) Define resistance. [1]

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- (ii) The unit of resistance is the ohm (Ω). Show that it is possible to express the Ω as [3]

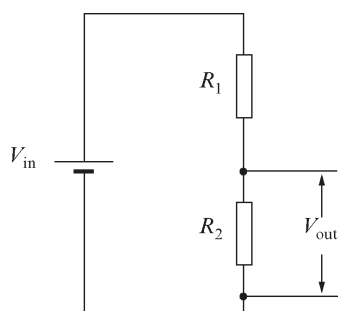
$$\text{J s C}^{-2}$$

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- (b) The diagram shows a potential divider.



- (i) Write down an equation for the current through resistors R_1 and R_2 when the input pd V_{in} is applied as shown. [1]

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- (ii) Hence show that the output pd V_{out} is given by the equation [2]

$$V_{\text{out}} = \frac{R_2}{R_1 + R_2} V_{\text{in}}$$

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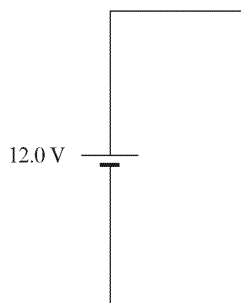
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- (c) Three resistors are available with values $40\ \Omega$, $40\ \Omega$ and $80\ \Omega$.

- (i) Draw a diagram showing how **two** of these resistors can be connected together to give a combined resistance of $20\ \Omega$. [2]

- (ii) Hence, using all three of the resistors, complete the following potential divider circuit for which $V_{\text{out}} = 2.4\ \text{V}$ when $V_{\text{in}} = 12.0\ \text{V}$. Clearly label the resistor values and V_{out} on your diagram. [2]



7.

(a) (i) State Ohm's law. [2]

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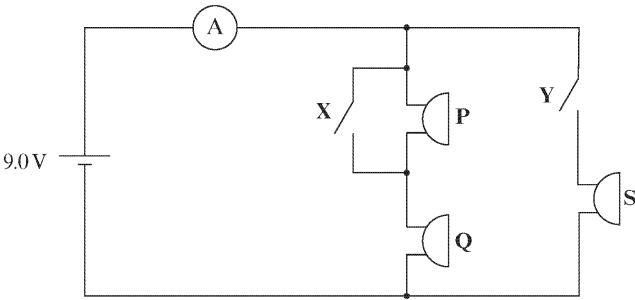
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(ii) The unit of resistance is the ohm (Ω). One of the following is a correct alternative unit to the ohm. Circle the correct one. [1]

VA^{-1} AV^{-1} JC^{-1} JS^{-1}

(b)



In the above circuit, buzzers **P**, **Q** and **S** are controlled using switches **X** and **Y**. **The buzzers are identical and their resistances remain constant.**

(i) The table shows the possible combinations of open and closed switches. When a switch is closed, charge can flow through it. Complete the table. The first row has been done for you. [3]

Switch combination	P	Q	S
X open, Y open	On	On	Off
X closed, Y open			
X open, Y closed			
X closed, Y closed			

- (ii) With **X** open and **Y** open, the ammeter reads 0.18 A. Calculate the resistance of **each** of the buzzers. [3]

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- (iii) Determine the reading on the ammeter when all three buzzers are on. [2]

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- (iv) When all three buzzers are on, show that
power used by **S** = $4 \times$ power used by **Q** [3]

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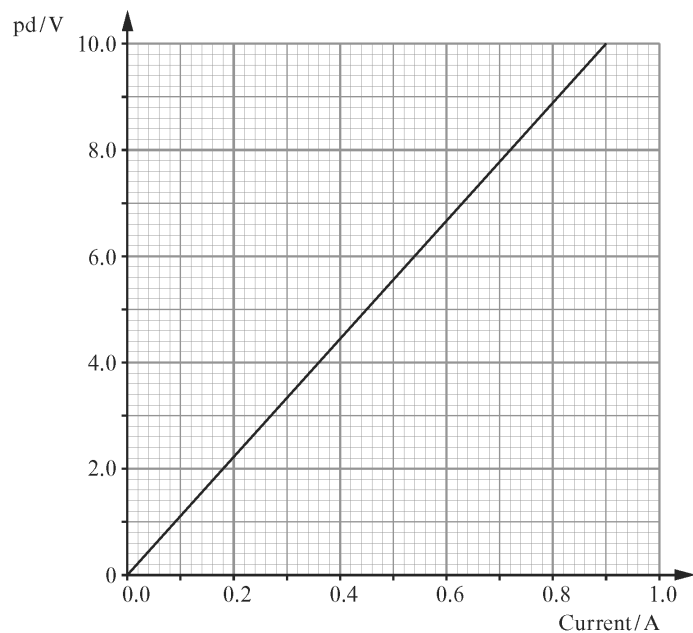
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8.

Experiments are carried out to determine the material from which a metal wire is made. Initially the resistivity of the metal is found. The wire's density is then determined and the results compared with known values of resistivity and density.

- (a) As a first step to finding the resistivity, an experiment investigates the relationship between pd and current for the wire. The results are shown in the graph.



- (i) Draw a circuit diagram to show how the above results could be obtained. The apparatus available includes a battery, a switch, a variable resistor, an ammeter and a voltmeter. [2]

(ii) The wire has length 3.2m and **diameter** 0.20mm. Use this information and the graph to calculate the resistivity of the material in the wire. [4]

(iii) Using the information in the table, write down **two** possible materials for the wire. [1]

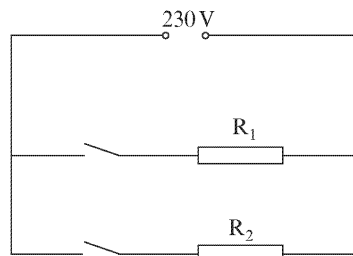
Material	Resistivity / $\Omega \text{ m}$	Density / kg m^{-3}
Iron	0.97×10^{-7}	7 850
Platinum	1.06×10^{-7}	21 400
Tin	1.12×10^{-7}	7 300
Nichrome	1.10×10^{-6}	8 400

The mass of the wire is found to be 0.74 grammes. Explaining how you obtain your answer, determine the material from which the wire is made. [3]

9. (a) (i) State Ohm's law. [2]

- (ii) What can be said about the resistance of a conductor that obeys Ohm's law? [1]

- (b) The heating circuit of a hairdryer consists of two heating elements R_1 and R_2 connected in parallel as shown. The elements are made from wire of the same material of resistivity $95 \times 10^{-8} \Omega \text{m}$ and diameter $1.4 \times 10^{-4} \text{m}$.



- (i) The length of wire used to make R_1 is 3.2m. Show that the resistance of R_1 is approximately 200Ω . [3]

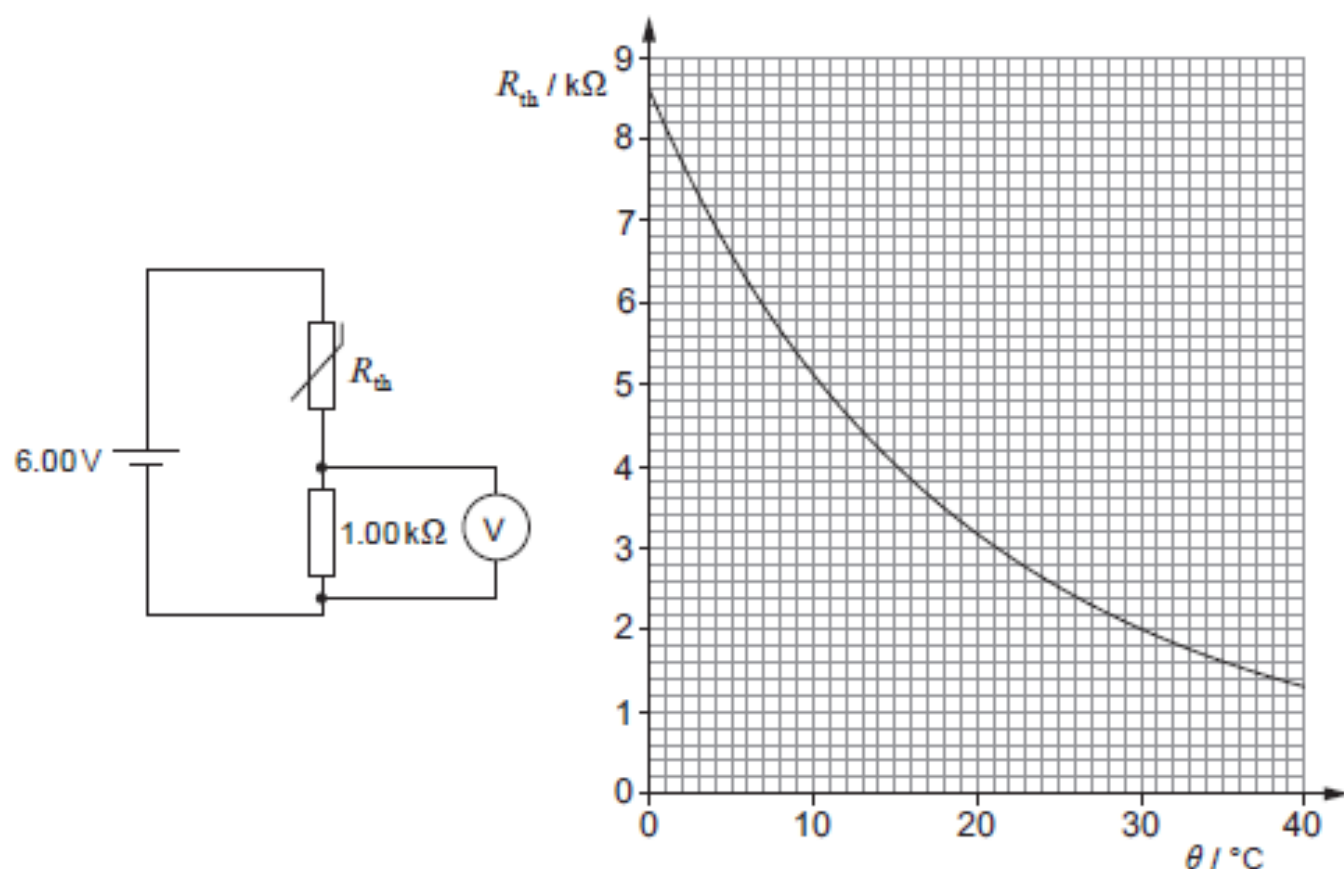
- (ii) Calculate the power output from the heating circuit with only R_1 switched on. [1]

- (iii) With both elements switched on the **total resistance** is only a third of the resistance of R_1 on its own. Calculate the resistance of R_2 . [3]

- (iv) Explain which element, R_1 or R_2 , would provide the greater power output from the heating circuit. [2]

- (v) Calculate the total current with both elements switched on. [1]

10. 2. The resistance, R_{th} , of the thermistor in the circuit varies with temperature as shown in the graph.



- (a) Determine the temperature of the thermistor when the voltmeter reads 1.20 V. [3]

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- (b) The set-up can be used as a thermometer, with the thermistor used as a temperature probe. David suggests that there must be a simple rule of the type "an increase of 0.10 V in the voltmeter reading corresponds to a temperature increase of $n^{\circ}\text{C}$ in which n is a constant." Without further calculation, discuss whether he is right. [2]

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- (c) Explain why the current through the thermistor must be very low, in order for it to work properly as a probe to measure the temperature of its surroundings. [2]

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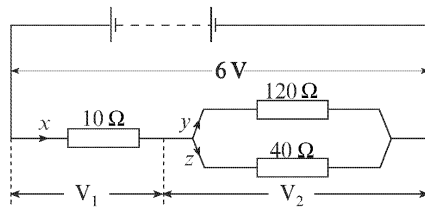
11.

- (a) (i) Using the idea of electric charge explain what is meant by *the electric current* in a conductor. [1]

- (ii) The unit of electric current is the ampère (A). One of the following is a correct alternative unit to the ampère. Circle the correct one. [1]

JC^{-1} Cs^{-1} Js^{-1} VA^{-1}

(b)



- (i) Write down the relationship between the currents x , y and z in the circuit. [1]

- (ii) The relationship you wrote down in (b)(i) is a consequence of which conservation law? [1]

(c) Calculate

- (i) the resistance of the combination of the three resistors, [3]

- (ii) the current x , [1]

- (iii) the potential differences, V_1 and V_2 , [2]

- (iv) the currents y and z . [2]

- (a) The unit of electrical resistance is the ohm (Ω). Two of the following are correct alternative units to the ohm. **Circle the correct two.** [2]

$$\text{VA}^{-1}$$

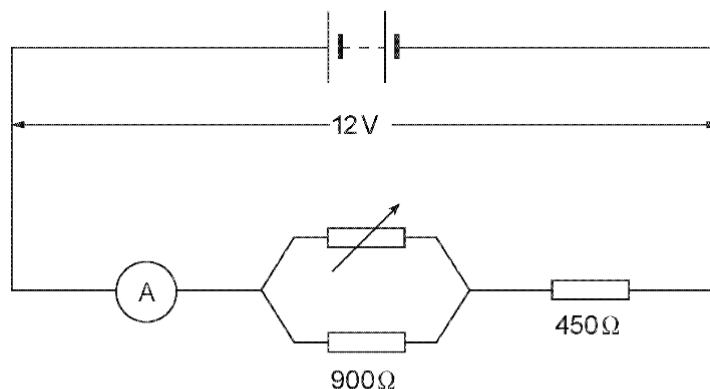
$$\text{V}^{-1}\text{A}$$

$$\text{WA}^{-2}$$

$$\text{Cs}^{-1}$$

Space for working if needed.

- (b) The circuit shows a variable resistor connected to two fixed resistors, an ammeter and a battery of emf 12 V. The battery has negligible internal resistance.



The variable resistor is adjusted so that the ammeter reads 0.01 A.

- (i) Calculate the potential difference across the 450Ω resistor. [1]

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- (ii) Calculate the potential difference across the 900Ω resistor. [1]

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- (iii) Calculate the resistance of the parallel combination of the 900Ω resistor and the variable resistor. [2]

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(iv) Calculate the resistance of the variable resistor.

[2]

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(c) The variable resistor is adjusted so that its resistance decreases. Explain in clear steps what happens to the potential difference across the 900Ω resistor. [3]

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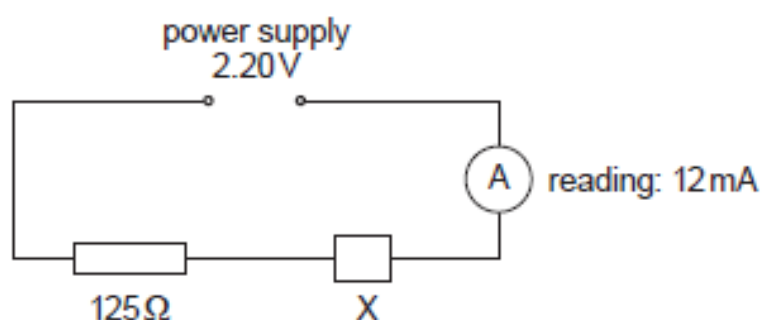
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1. (a) (i) State Ohm's law.

[1]

- (ii) What can be said about the *resistance* of a conductor that obeys Ohm's law? [1]

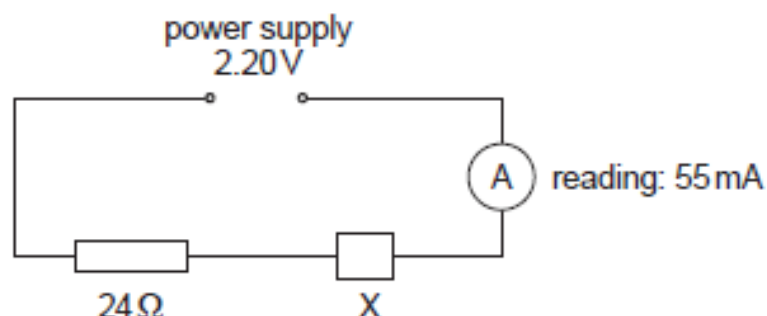
- (b) (i) An electrical component, X, is included in the circuit shown. The internal resistance of the power supply is negligible.



Show that the resistance of X in this circuit is approximately $60\,\Omega$.

[2]

- (ii) When the $125\,\Omega$ resistor in (b)(i) is replaced by a $24\,\Omega$ resistor, the reading on the ammeter increases, as shown below.



Evaluate whether or not X obeys Ohm's law, presenting your argument clearly. [2]

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- (iii) State, giving a reason, whether or not X could be a filament lamp. [1]

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- (c) A certain high temperature superconductor has a transition temperature of $-188\,^{\circ}\text{C}$. The boiling point of liquid nitrogen is $-196\,^{\circ}\text{C}$.

- (i) State what is meant by the *transition temperature* of a superconductor. [1]

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- (ii) Give one possible use for a high temperature superconductor and state why it would be an advantage for the transition temperature to be above the boiling point of liquid nitrogen. [2]

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4. (a) Describe how the resistance of a metal varies between 0K and 1000K. [Assume that the metal is superconducting below a certain temperature.] Account for this variation in resistance at higher temperatures.

[6 QER]

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- (b) Superconductors are used in MRI scanners and particle accelerators. Consider which of these two applications has been of greater benefit to society. [3]

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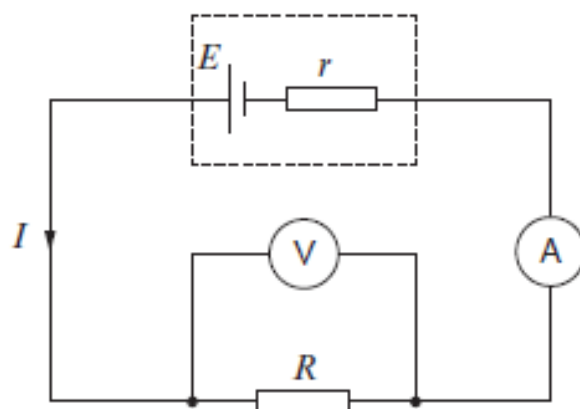
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1. The following circuit shows a cell of emf, E , and internal resistance, r , connected to a resistor of resistance, R .



- (a) An equation which can be applied to the above circuit is:

$$V = E - Ir$$

Explain this equation in terms of energy.

[4]

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- (b) Two students, Kiera and Tom, set up a circuit using two identical cells in series, each with an emf of 1.5V, to power a small heating coil. The heating coil dissipates power at the rate of 1050 mW and the pd across the coil is 2.5V.

Calculate:

- (i) the internal resistance of each cell;

[3]

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(ii) the energy dissipated in each cell in one minute.

[2]

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- (c) The students note that the cells get hot when the heater is switched on for long periods. Tom believes that adding an identical heating coil in parallel with the original would halve the energy dissipated in each cell. Kiera disagrees. She believes that the energy dissipated would increase by a factor of 3 if a coil is added in parallel. Investigate whether Kiera or Tom or neither of them is correct. [4]

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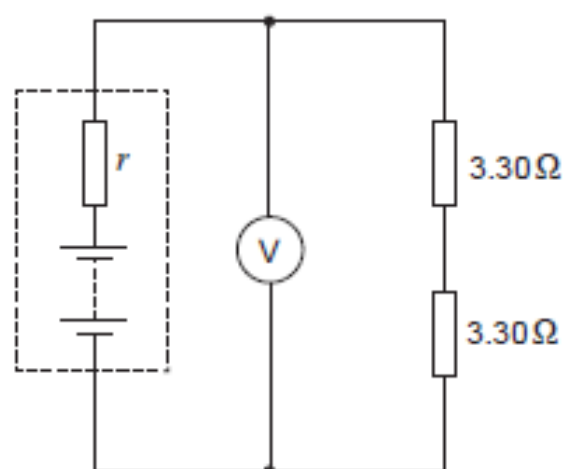
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16. 1. (a) Two $3.30\,\Omega$ resistors are connected in series across a battery of emf $4.80\,\text{V}$ as shown. The voltmeter reads $4.33\,\text{V}$.

Diagram 1



- (i) State in terms of work or energy what is meant by the emf of a battery. [2]

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- (ii) Show that the internal resistance, r , of the battery is approximately $0.7\,\Omega$. [2]

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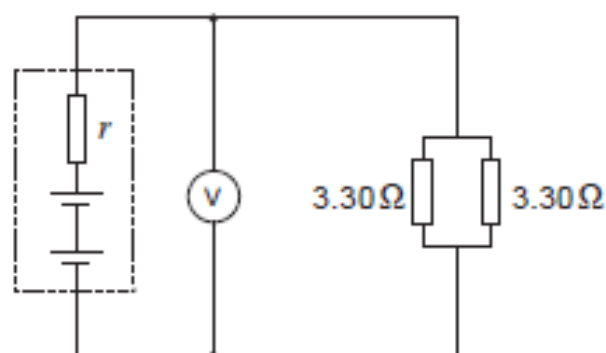
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- (iii) When the resistors are connected in parallel as shown below, the voltmeter reads $3.35\,\text{V}$.

Diagram 2



- (I) Without further calculation explain why you would expect the reading to be lower, now that there is a lower resistance across the cell terminals. [2]

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- (II) Calculate the number of electrons entering either of the resistors (shown in Diagram 2) per minute. [3]

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- (b) The heating element (a coil of wire) in an electric heater dissipates energy at a rate of 1.00 kW, when connected across the 230 V mains supply. Calculate:

- (i) the resistance of the coil; [2]

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- (ii) the energy dissipated per hour, giving your answer in megajoules (MJ). [1]

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- (c) For each megajoule of heat from an electric heater, approximately 0.08 m^3 of gas would have to be burned in a gas-fired electricity power station. For each megajoule of heat from a domestic gas fire or boiler, approximately 0.03 m^3 of gas is burned. Discuss whether the use of electric heaters in houses should be discouraged. Calculations are not required. [3]

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4. A length of wire of an unknown material is found at a crime scene. The diameter of the wire is measured as 0.28 ± 0.01 mm and its length 32.4 ± 0.1 cm. The resistance of the wire is measured as $0.085 \Omega \pm 5\%$.

(a) (i) Calculate the resistivity of the material of the wire.

[3]

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(ii) Calculate the absolute uncertainty in the resistivity.

[4]

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(iii) Evaluate whether it is possible to identify the unknown material from the table below.

[2]

Material	Resistivity ($10^{-8} \Omega \text{m}$)
Aluminium	2.65
Copper	1.68
Silver	1.59
Iron	9.71
Tungsten	5.60

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- (b) Anika applies a fixed potential difference of 6.0 V across a different piece of metal wire. At a temperature of 0 °C the current is found to be 0.30 A. At 50 °C the current is 0.24 A.

(i) Explain in terms of electrons why the current is smaller at 50 °C than at 0 °C. [4]

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(ii) Anika states that the resistance of the wire can be considered to be directly proportional to temperature in °C. Use the following table of data to determine whether Anika is correct. [3]

Temperature (°C)	Current (A)
10	0.29
30	0.26
50	0.24

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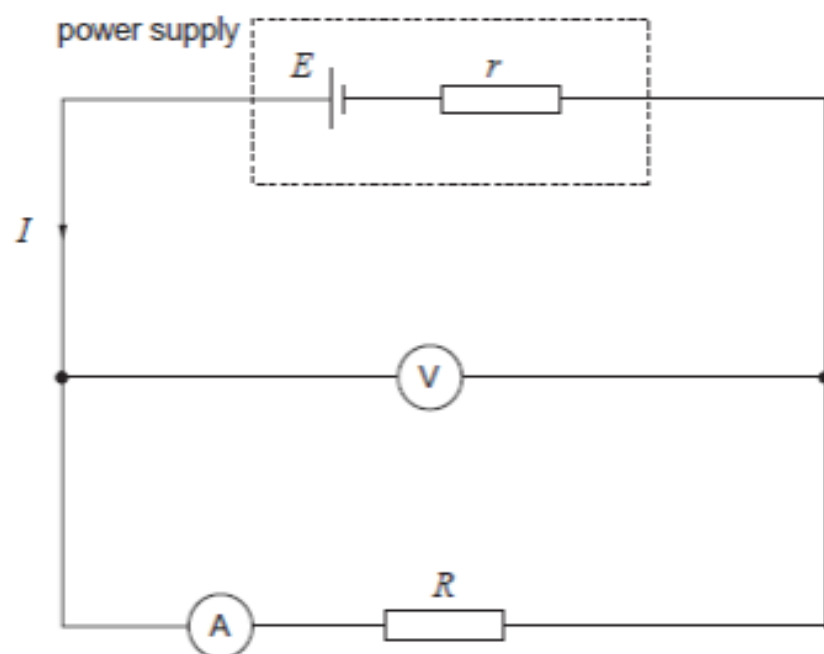
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5. Zhang Li sets up the following circuit and uses a spreadsheet to analyse her data as the load resistance, R , is varied.



	A	C	D	E	F
1					
2	Emf, E	Load resistance, R	Current, I	pd across R , V	Internal resistance, r
3	V	Ω	A	V	Ω
4	1.5	1.4	0.94	1.32	0.19
5	1.5	3.3	0.43	1.42	0.19
6	1.5	4.7	0.31	1.46	0.13
7	1.5	5.6	0.26	1.46	
8	1.5	8.0	0.19	1.49	0.17

- (a) Zhang Li uses 3 resistors of values 3.3Ω , 4.7Ω and 5.6Ω , to create various load resistance values. Show clearly how the value in cell C4 (column C and row 4) is obtained. [3]

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- (b) (i) Zhang Li uses the spreadsheet formula = $\frac{A4 - E4}{D4}$ to determine the internal resistance in cell F4. Explain in terms of energy why this is a valid method. [6]

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- (ii) Determine the internal resistance value for cell F7. [2]

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- (iii) Zhang Li can choose between $4.7\ \Omega$ resistors with power ratings of 0.25 W or 0.50 W. Justify, numerically, which resistor power rating she should use in the circuit. [3]

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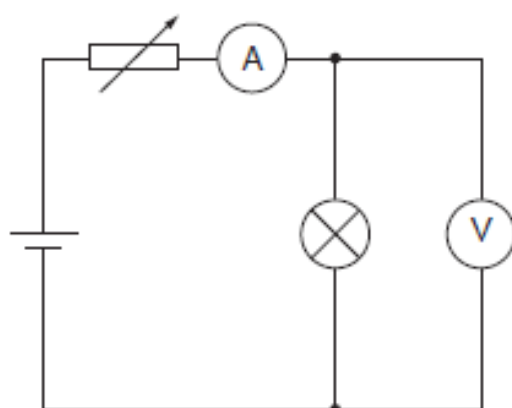
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2. Jasmine uses the following circuit to investigate how the resistance, R , of a filament lamp varies with the potential difference, V , across it.



- (a) Jasmine obtains a range of values for V and I . Describe briefly how she does this. [1]

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- (b) The relationship between R and V can be expressed as:

$$R = kV^n$$

where k and n are unknown constants. By taking logs of both sides of the equation, show how it can be written in the form $y = mx + c$. [2]

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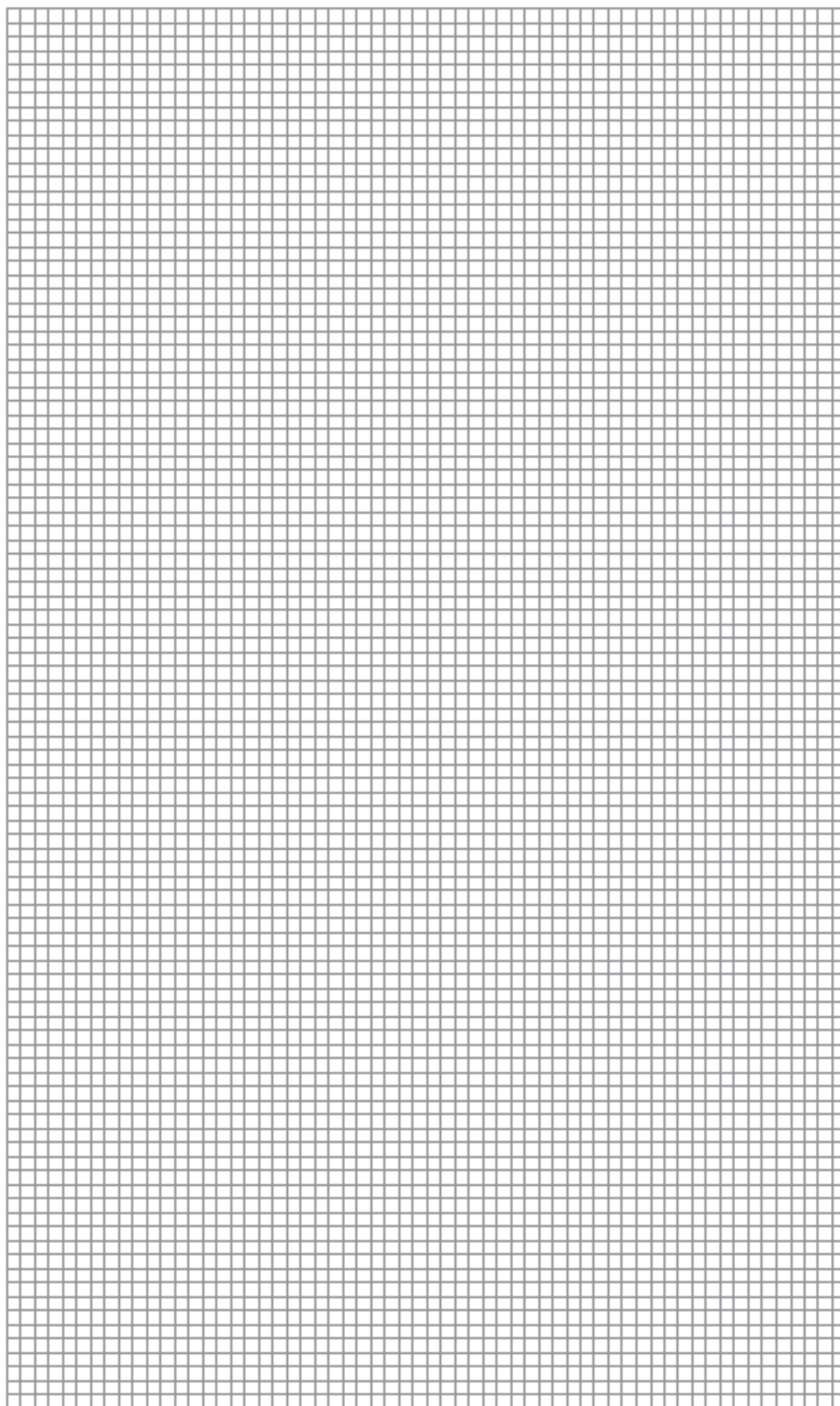
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- (c) Jasmine records the following data. Complete the table using an appropriate number of significant figures. [3]

V/V	I/A	R/Ω	$\log(V/V)$	$\log(R/\Omega)$
1.00	0.52			
2.00	0.72			
4.00	0.98			
6.00	1.20			
8.00	1.40			
10.00	1.54			

- (d) Draw a graph of $\log R$ (vertical axis) against $\log V$ (horizontal axis) and draw a line of best fit. Error bars are not required. [5]



- (e) (i) Use your graph to determine suitable values for k and n . [4]

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- (ii) Hence, write down an equation showing the relationship between R and V for this filament lamp. [1]

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- (f) Comment on the quality of Jasmine's results. [1]

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2. (a) A battery does not *store* charge. State what a battery *does* do in relation to charge in an electric circuit. [1]

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- (b) A battery consists of three cells, each of emf 1.60 V and internal resistance $0.10\ \Omega$, connected in series. The battery is connected to an electromagnet of resistance $1.20\ \Omega$.

- (i) Show clearly that the current is approximately 3 A . [The space is for a diagram if required.] [3]

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- (ii) Calculate the rate (in watts) at which:

- I. energy is dissipated by the electromagnet; [1]

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- II. the battery's chemical energy is being used. [1]

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- (iii) The answer to (b)(ii)II. is expected to be greater than the answer to (b)(ii)I. Explain where the missing energy goes. [2]

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- (c) A student wishes to maximise the current through the electromagnet. She has a spare cell of emf 1.50 V and internal resistance $0.50\ \Omega$. Evaluate whether or not she should put it in series with the battery, giving your calculations and conclusion clearly. [2]

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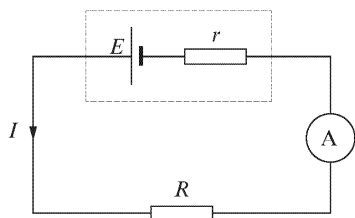
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21.

A student sets up the following circuit using a cell of emf E and internal resistance r .



(a) An equation which can be applied to the above circuit is

$$V = E - Ir$$

Explain, **in terms of energy**, the meanings of V , E and Ir .

[4]

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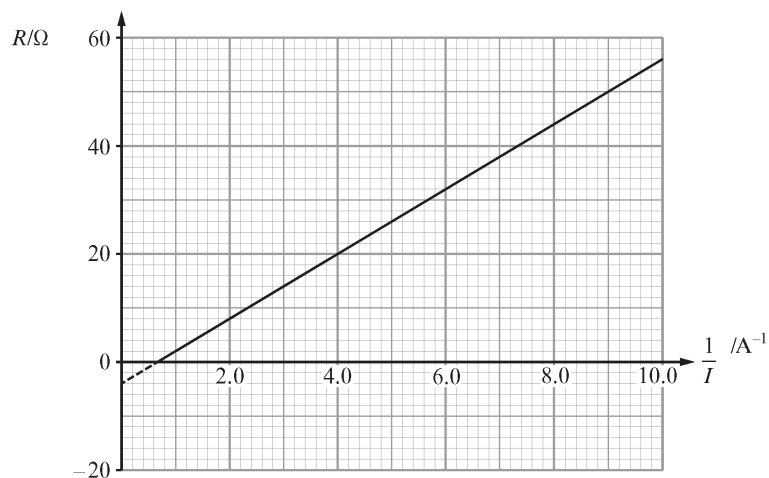
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- (b) The student measures the current I for different values of R . She then plots a graph of R against $\frac{1}{I}$.



The equation for this graph is

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

- (i) Use the graph to find the internal resistance, r , of the cell. [1]

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- (ii) Determine the emf of the cell. [2]

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- (iii) Referring to the graph, calculate the power dissipated in the resistor R when there is a current of 0.25 A. [4]

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- (c) A second identical cell is added in series with the original cell and the experiment is repeated.

- (i) Write down the emf and the internal resistance of the new combination of cells. [1]

emf = ... internal resistance = ...

- (ii) Hence, using the equation $R = \frac{E}{I} - r$, determine the value of R for this experiment when there is a current of 0.2 A. [1]

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- (iii) **Draw on the graph** the result of this experiment. [2]

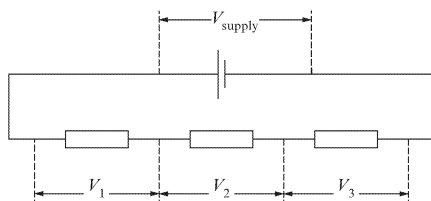
4. (a) Define the *potential difference* between two points in an electric circuit. [2]

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- (b) Three resistors are connected as shown.



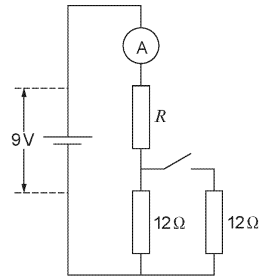
- (i) Complete the equation that relates **all** of the potential differences in the circuit: [1]

$V_{\text{supply}} = \dots\dots\dots$

- (ii) The equation you wrote down in (b)(i) is an example of which conservation law?[1]

.....

(c)



- (i) In the circuit shown, with the **switch open**, the ammeter reads 0.5A. Show that $R = 6\Omega$. [2]

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- (ii) The switch is now **closed**.

- (I) Calculate the (new) potential difference across R . [2]

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- (II) Calculate the (new) current through the ammeter. [2]

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- (III) More 12Ω resistors can be connected in parallel with the 12Ω resistors. Determine the **total** number of 12Ω resistors needed for the current through the ammeter to be 1.2A. [4]

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23. A power cable has a resistance of 11.2Ω and is made of an alloy of aluminium of resistivity $2.8 \times 10^{-8}\Omega\text{m}$. It is used to link a power station to a town 160 km away.

(a) (i) Show that the cross-sectional area of the cable is $4.0 \times 10^{-4}\text{m}^2$. [1]

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(ii) Calculate the current in the cable given that the pd across it is 2.0 kV. [1]

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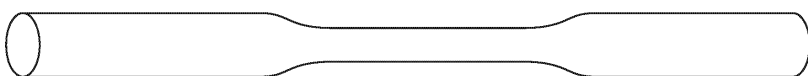
(iii) Calculate the mean drift velocity of the free electrons in the cable given that there are 6.0×10^{28} atoms per m^3 of aluminium and each atom contributes 3 free electrons. [3]

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(b) A small portion of the cable is damaged. As a result its cross-sectional area is less than that of the rest of the cable, as shown in the diagram.



(i) State how the current in the thinner portion compares with the current in the rest of the cable. [1]

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(ii) State how the mean drift velocity of free electrons in the thinner portion compares with that in the rest of the cable. Justify your answer. [2]

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(iii) Hence suggest, in terms of particles, why the damaged part of the cable will be prone to overheating. [2]

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24.

- (a) Derive, giving a labelled diagram, the relationship between the current I through a metal wire of cross sectional area A , the drift velocity, v , of the free electrons, each of charge e , and the number, n , of free electrons per unit volume of the metal. [4]
($I = nAve$).

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- (b) Calculate the drift velocity of free electrons in a copper wire of cross sectional area $1.7 \times 10^{-6} \text{ m}^2$ when a current of 2.0 A flows. [$n_{\text{copper}} = 1.0 \times 10^{29} \text{ m}^{-3}$]. [2]

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- (c) A potential difference is required across the copper wire in order for the current to flow. The size of the current depends on the wire's *resistance*. Explain in terms of free electrons, how this resistance arises. [2]

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(d) The copper wire in (b) is of length 2.5 m. When it carries a current of 2.0 A, it dissipates energy at the rate of 0.1 W. Calculate its resistivity. [4]

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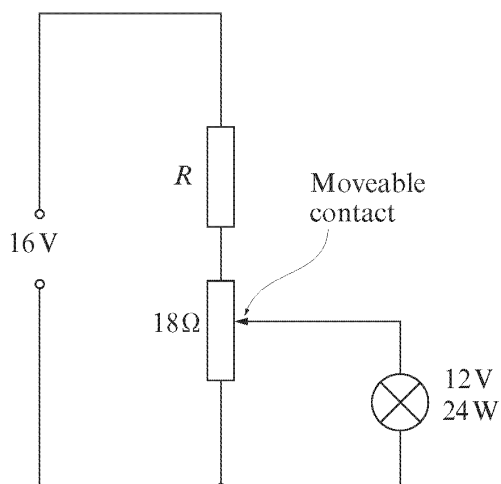
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(e) A second copper wire has the same volume as the wire in (d), but is longer. Complete the table below indicating whether the quantity given is **bigger**, **smaller** or **the same** for this longer wire. [3]

Quantity	For the longer wire this quantity is ...
Cross-sectional Area	
n , number of free electrons/unit volume	
Resistivity	

A student uses the circuit below to produce a current-voltage graph for a 12 V, 24 W filament lamp.



(a) Show clearly on the diagram the correct positions for the voltmeter and ammeter. [2]

(b) When the lamp is working normally, calculate

(i) the current flowing through it; [1]

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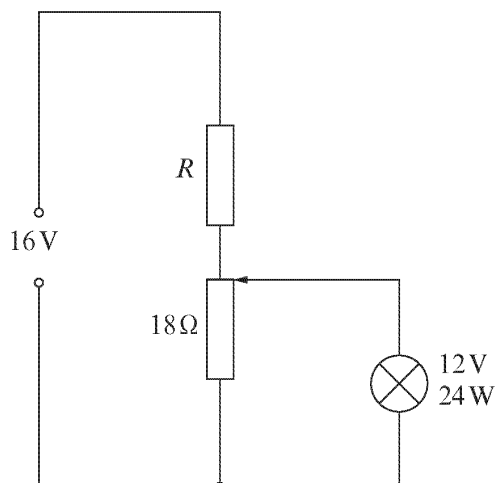
(ii) its resistance. [1]

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(c) The value of R is chosen so that the voltage across the lamp can be varied between 0 V and 12 V. The circuit below shows the position of the moveable contact when the lamp is operating normally (i.e. at 12 V).



Calculate the required value of R . [4]

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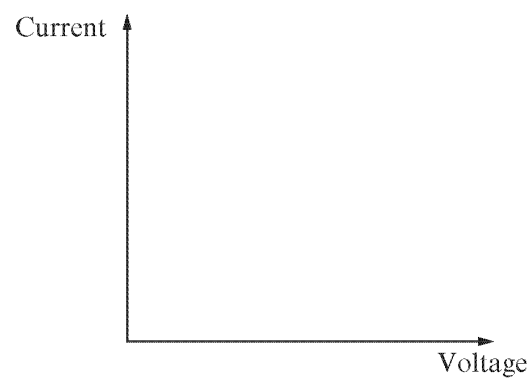
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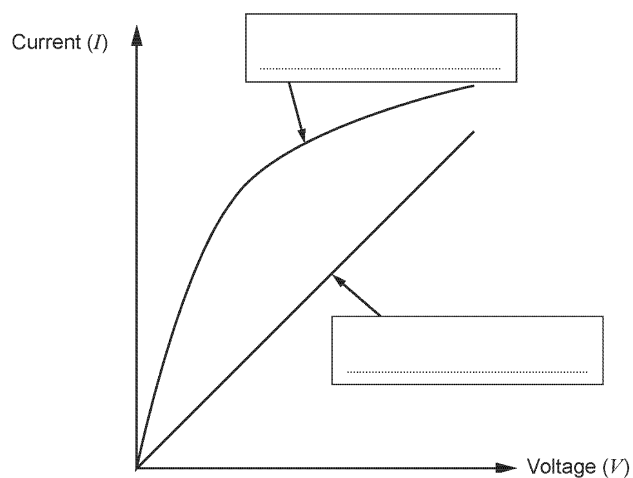
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(d) Sketch on the axes below the current-voltage graph expected for the filament lamp. [2]



- (a) Graphs are drawn for a metal wire at constant temperature and for the filament of a lamp.



- (i) Complete the boxes, labelling the graphs with the component they represent. [1]

- (ii) Suggest reasons for the different shapes of the two graphs. [5]

[illegible]

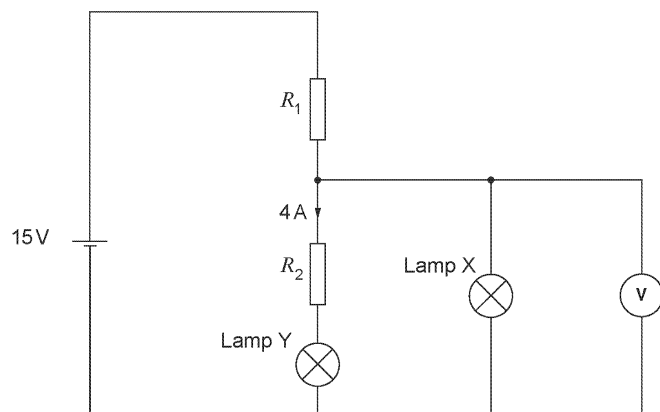
(b) X and Y are two lamps.

- (i) Lamp X is labelled at 12 V, 24 W. Calculate the current in the lamp when it operates at its rated voltage. [1]

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- (ii) Lamp Y is labelled at 6 V, 4 A. In the following circuit, the values of R_1 and R_2 are chosen so that **both lamps operate at their rated voltages**.



- (i) State the reading on the voltmeter. [1]

- (ii) Calculate the pd across R_2 . [1]

-
- (iii) Calculate R_2 . [1]

-
- (iv) Calculate R_1 . [3]

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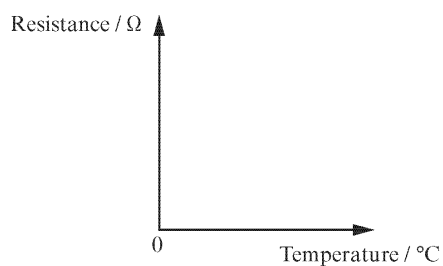
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27. (a) (i) Draw a labelled diagram of the apparatus you would use to determine the relationship between the resistance and temperature of a metal wire. [3]

- (ii) Sketch, on the axis below, a graph of the results you would expect from the experiment. [2]



- (b) (i) Explain in terms of particles how electrical resistance arises in metal conductors. [3]

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- (ii) Hence suggest an explanation for your results to the experiment in part (a). [2]

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- (a) (i) The current in a wire depends on its **resistance**. Explain, in terms of free electrons, how this resistance arises when a potential difference is applied across the wire.

[2]

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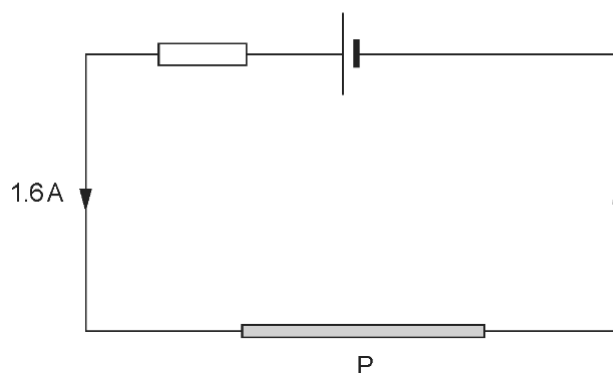
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- (ii) The wire (labelled P in the diagram) is connected to a fixed voltage source and a resistor to limit the current as shown. The wire is 0.4m long and has a cross-sectional area of $2.0 \times 10^{-6} \text{ m}^2$. When the current is 1.6A it dissipates 1.8J of energy in 1 minute. Calculate its resistivity.

[4]



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- (b) (i) The current, I , in a wire of cross-sectional area, A , is given by the formula:

$$I = nAve$$

Derive the formula. You may include a clearly labelled diagram.

[4]

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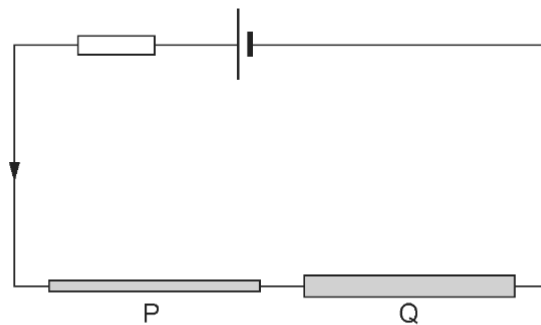
- (ii) Calculate the drift velocity of the free electrons in the wire in (a)(ii) when the current through it is 1.6 A. [$n = 6.4 \times 10^{28} \text{ m}^{-3}$] [2]

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- (iii) Wire P is now connected to another wire, Q, of the same material but with **twice** the cross-sectional area. The wires are connected to the same fixed voltage source and resistor.



Complete the following sentences by **circling the correct option** given in brackets.

- (I) The current in the circuit containing both wires is
[less than 1.6 A] [equal to 1.6 A] [more than 1.6 A]. [1]
- (II) The current in P is [less than] [the same as] [greater than] the current in Q. [1]
- (III) The electron drift velocity in Q is [half] [the same as] [twice] [four times] the electron drift velocity in P. [1]

29.

The current I in a metal conductor of cross-sectional area A is given by:

$$I = nAve$$

- (a) State the meanings of n and v . [2]

n

v

- (b) Show that the equation is correct in terms of units. [3]

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- (c) (i) The current in a copper wire is 2.0 A. The wire has a cross-sectional area of 1.2 mm^2 and is 5.0 m long. Calculate the time it takes a free electron in the wire to travel from one end to the other. [Take $n_{\text{copper}} = 8 \times 10^{28} \text{ m}^{-3}$.] [3]

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- (ii) The **same current** (2.0 A) is now passed through a **thinner** wire of the **same length and material**. Use the above equation to explain the effect this change would have on the time for an electron to travel from one end to the other. [3]

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30. (a) (i) Draw a labelled diagram of the apparatus you would use to determine the relationship between the resistance and length of a metal wire.

[3]

(ii) Sketch a graph of your expected results.

[1]



(iii) Explain how you would use an accurately drawn graph of resistance against length, as well as any other measurements, to obtain a value for the resistivity of the metal in the wire.

[3]

(b) (i) A simple heater is made of a metallic wire of resistivity $48 \times 10^{-8} \Omega \text{ m}$ and crosssectional area $4.0 \times 10^{-8} \text{ m}^2$. When it is in use the potential difference across the heater is 12.0 V and its power is 32 W. Calculate the length of the wire in the heater.

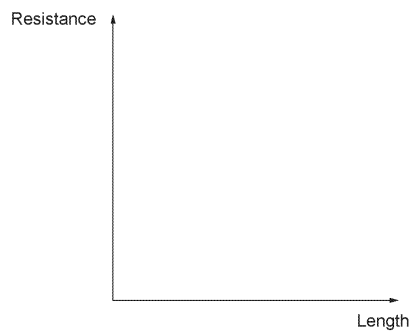
[3]

- (ii) Calculate the drift velocity of the electrons in the wire when the heater is in use.
[The number of free electrons per unit volume is $3.4 \times 10^{28} \text{ m}^{-3}$ for the material in the wire.]

[3]

5. (a) (i) Draw a **labelled** diagram of the apparatus you would use to determine the relationship between the resistance and length of a metal wire. [3]

- (ii) Sketch a graph of your expected results. [1]



- (iii) Explain how you would use an accurately drawn graph of resistance against length, as well as any other measurements, to obtain a value for the *resistivity* of the metal in the wire. [3]

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- (b) (i) A simple heater is made of a metallic wire of resistivity $48 \times 10^{-8} \Omega \text{m}$ and cross-sectional area $4.0 \times 10^{-8} \text{m}^2$. When it is in use the potential difference across the heater is 12.0V and its power is 32W . Calculate the length of the wire in the heater. [3]

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- (ii) Calculate the drift velocity of the electrons in the wire when the heater is in use. [The number of free electrons per unit volume is $3.4 \times 10^{28} \text{m}^{-3}$ for the material in the wire.] [3]

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Marking Scheme

1.	Question		Marking details	Marks available				Maths	Prac
				AO1	AO2	AO3	Total		
1	(a)	(i)	Resistance of LDR / circuit increases [as light intensity decreases] (1) [Hence] current decreases (1)	2			2		2
		(ii)	Either: $\text{Current in LDR} = \frac{4.0}{2.4 \times 10^3} = [1.67 \times 10^{-3} \text{ A}] \text{ (1)}$ $R = \frac{5.0(1)}{1.67 \times 10^{-3}}$ $R = 3.0 \text{ k}\Omega \text{ (1)}$ Alternative: $4.0 = \frac{2.4 \times 10^3 \times 9.0}{(2.4 \times 10^3 + R)} \text{ (1) [substitution into potential divider equation]}$ Correct algebra (1) $R = 3.0 \text{ k}\Omega \text{ (1)}$ Alternative: $\frac{4}{5} = \frac{2.4}{R} \text{ (1)}$ $R = 3.0 \text{ k}\Omega \text{ (1)}$	1	1 1		3	2	3
	(b)		Light from lamp will decrease [LDR resistance and hence] V across lamp low so lamp not activated (1) Hence reason for on/off, e.g. lamp off $\rightarrow$ LDR in dark $\rightarrow V_{\text{out}}$ high $\rightarrow$ lamp on		2		2		2
			Question 1 total	3	4	0	7	2	7

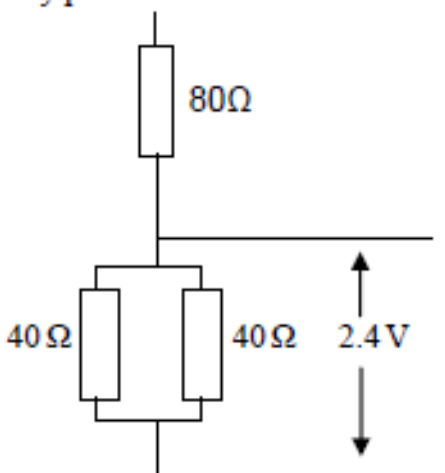
Question			Marking details	Marks available				Maths	Prac
				A01	A02	A03	Total		
2	(a)	(i)	Rate of charge flow Accept $I = \frac{\Delta Q}{\Delta t}$ only if ΔQ and Δt defined [accept Q and t]	1			1		
		(ii)	J C ⁻¹ and C s ⁻¹ as units of V and I respectively clearly shown (1) Correct division seen i.e. $\frac{JC^{-1}}{Cs^{-1}}$ seen (1) Or from alternative correct expression, e.g. $R = \frac{V^2}{P}$ ~~or $R = \frac{V}{I}$~~ Or equivalent in terms of quantities.	1	1		2	1	
	(b)	(i)	I through $R_P = 1.2$ A and I through $R_T = 0.8$ A (1) $\frac{V_P}{V_T} = \frac{1.2R_P}{0.8R_T}$ (=1.5) seen (1) Or Parallel combination calculated as $\frac{2}{3}R$ (1) Potential divider: $\frac{R}{R + \frac{2}{3}R} \times 9 = 1.5$ (1)		2		2	1	
		(ii)	$2.5V_T = 9.0$ or $\frac{5V_P}{3} = 9.0$ (1) $V_T = 3.6$ V or $V_P = 5.4$ V (1) Award 2 marks for either V_P or V_T calculated correctly. $R_T = \frac{3.6}{0.8} = 4.5 \Omega$ or $R_P = \frac{5.4}{1.2} = 4.5 \Omega$ or $\frac{1.8}{0.4} = 4.5 \Omega$ (1) Alternative: Total circuit $R = \frac{9.0}{1.2} = 7.5 \Omega$ (1) Parallel and series combination shown to be $= \frac{5R}{3}$ (1) $\frac{5R}{3} = 7.5$ and $R = 4.5 \Omega$ (1) Alternative: Understanding that $V_P + V_T = 9$ (1) $1.2R_P + 0.8R_T = 9$ (1) (award 2 marks for this only) $R_P = R_T = R$ and $R = \frac{9}{2} = 4.5 \Omega$ clearly shown (1) Accept reverse argument.		3		3	3	
	(c)		P (circuit) = 10.8 W (1) (either $\frac{81}{7.5}$ or $(1.2)^2 \times 7.5$ or 1.2×9) P in $R_Q = (0.4)^2 \times 4.5 = 0.72$ W (1) $\frac{10.8}{0.72} = 15$ seen (1) Alternative: $P_s = P_Q$ since $I_s = I_Q$ $P_T = 4 \times P_Q$ since $I_T = 2 \times I_Q$ $P_P = 9 \times P_Q$ since $I_P = 3 \times I_Q$ Hence total circuit power = $P_Q + P_Q + 4P_Q + 9P_Q$ $= 15P_Q$ Award (1) for correct individual power analysis Award (1) for correct reason linked to currents Award (1) for showing correct total P		3		3	2	
	(d)		Circuit resistance increases, leading to total current decreasing. Power dissipated in circuit decreases (1) V across R_Q has increased (from 1.8 V to 3.0 V), so P_Q increases / I through R_Q has increased (from 0.4 A to 0.67 A) so P_Q increases (1) Hence ratio decreases (1) [only award from correct explanation] Accept numerical explanation: e.g. Circuit resistance is now 13.5 Ω and circuit current = 0.67 A (1) circuit power shown to be 6 W and P_Q shown to be 2 W (1) Hence ratio decreases or is now 3 (1) Alternative: With T removed, I through all remaining resistors is the same or V across each is the same (1) Use of VI or I^2R or V^2/R or power / energy dissipated in all three resistors equal (1) So total $P = 3 \times P_Q$ or which is less than $15P_Q$ (1)		3		3		
			Question 2 total	2	12	0	14	7	0

3.

Question			Marking details	Marks available				Maths	Prac
				AO1	AO2	AO3	Total		
2	(a)		There are 6 J of energy/work done (converted from electrical to other forms) (1) Per coulomb of charge between X and Y (1)	2			2		
	(b)	(i)	Attempt to use equation to determine resistors in parallel (1) Resistance of parallel combination = 3.7[2] Ω (1) Total circuit resistance = 9.3 Ω ecf on parallel (1) Current = $\frac{V}{R}$ = 0.64 A [accept 0.65 A] answer to 2 d.p. (1)	1	1 1 1		4	3	
		(ii)	Apply ecf from part (b) (i) PD across parallel = 0.65 $\times$ 3.7 ecf OR pd across 5.6 Ω = 0.65 $\times$ 5.6 = 3.6 V (1) Answer = 2.4 V (1)		2		2	1	
		(iii)	Substitute values into $P = I^2 R$ [$P = 0.65^2 \times 3.7$] (1) $P = 1.54$ W – ecf (1)	1	1		2	2	
			Question 2 total	4	6	0	10	6	0

4.	(a)	(i)	$R = \frac{1.6}{15 \times 10^{-3}(1)}$ (reading from graph, accept 14×10^{-3}) $R = 107 \Omega$ [answers in range 107 – 114 Ω]	2
		(ii)	[Very] high [accept infinite]	1
	(b)	(i)	V not proportion to I / not a straight line [through the origin] [“Not through origin” insufficient on its own]	1
		(ii)	Bulb / thermistor [Not wire or superconductor, but accept superconducting device, e.g. superconducting electromagnet coil]	1
	(c)		$R = \frac{V}{I} (1); R = \frac{10.4(1)}{15 \times 10^{-3}} = 693 \Omega (1)$ Alt 1: $10.4 = \frac{R}{R + 107} \times 12$ [or equiv.] (1) manipulation e.g. $10.4R + 112.8 = 12(1); R = 696 \Omega (1)$ Alt 2: $R_T = \frac{V}{I}$ or $\frac{12}{1.5 \times 10^{-3}} (1) = 800 \Omega (1); R = 800 - 107 = 693 \Omega (1)$	3
				[8]

Question				Marking details	Marks available					
					A01	A02	A03	Total	Maths	Prac
3.	(a)			In a <u>water</u> bath or in a beaker of <u>water</u> must imply heading (1) Using ice cubes / taking water from fridge / in an ice bath or equivalent (1)	1		1	2		2
	(b)	(i)		Straight line of best fit drawn (from 18 – 100 °C) with points either side or reference to very little scatter in the readings (1) Reference to or comparison with $y = mx + c$ (1) Positive intercept or positive gradient (1)		1	1 1	3		3
		(ii)	I	5.5 Ω , 5.6 Ω or 5.7 Ω unit mark [Accept attempts at 3 sf]		1		1	1	1
			II	Either Readings from graph line inserted in $\frac{\Delta R}{\Delta \theta}$. Tolerate slips (1) Gradient = 0.023 [± 0.002] [$\Omega ^\circ\text{C}^{-1}$] or by implication (1) $\alpha = 3.9 [\pm 0.4] \times 10^{-3} ^\circ\text{C}^{-1}$ unit mark ecf on R_0 and gradient (1) Or Value of R_0 and (R , θ) values from another point on graph line inserted in equation. Tolerate slips (1) Correct algebra (1) $\alpha = 3.9 [\pm 0.4] \times 10^{-3} ^\circ\text{C}^{-1}$ unit mark ecf on R_0			1 1 1	3	3	3
				Question 3 total	1	2	6	9	4	9

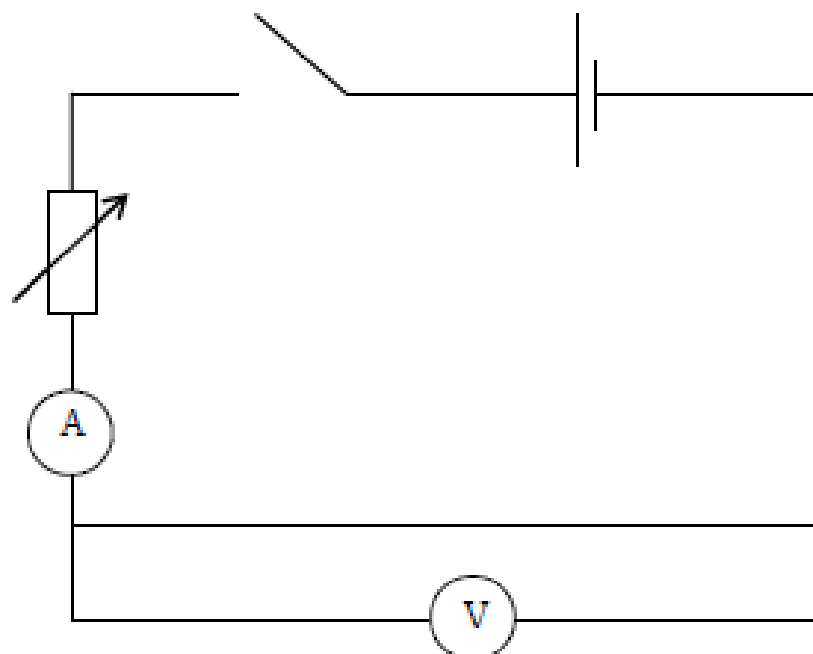
6.	(a)	(i)	$Resistance = \frac{pd}{current}$ (accept: voltage / if V and I written must be qualified)	[1]
		(ii)	$V = JC^{-1}$ (1); $I = C s^{-1}$ (1); Convincing working (1) Don't accept use of t -award ecf for 3 rd mark. Alternative route using power formulae is acceptable.	[3]
	(b)	(i)	$I = \frac{V_{in}}{R_1 + R_2}$	[1]
		(ii)	$V_{out} = IR_2$ (1); I (from (i)) used correctly (1)	[2]
	(c)	(i)	Any parallel combination shown (1); 40 [Ω] used correctly (1)	[2]
		(ii)	 Resistor combination shown (1) ecf from (c)(i) 2.4 [V] or V_{out} labelled correctly (1)	[2]

7. (a)	(i)	$I \propto V(1)$ Providing the temperature / physical conditions remain constant (1)	2																				
	(ii)	$V A^{-1}$ circled	1																				
(b)	(i)	<table border="1"> <thead> <tr> <th>Switch combination</th><th>P</th><th>Q</th><th>S</th></tr> </thead> <tbody> <tr> <td>X open, Y open</td><td>On</td><td>On</td><td>Off</td></tr> <tr> <td>X closed, Y open</td><td>Off</td><td>On</td><td>Off</td></tr> <tr> <td>X open, Y closed</td><td>On</td><td>On</td><td>On</td></tr> <tr> <td>X closed, Y closed</td><td>Off</td><td>On</td><td>On</td></tr> </tbody> </table> (1) (1) (1)	Switch combination	P	Q	S	X open, Y open	On	On	Off	X closed, Y open	Off	On	Off	X open, Y closed	On	On	On	X closed, Y closed	Off	On	On	3
Switch combination	P	Q	S																				
X open, Y open	On	On	Off																				
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X closed, Y closed	Off	On	On																				
	(ii)	Either $R = \frac{9}{0.18} (1) (= 50 \Omega) \rightarrow R_P + R_Q = 50 (1)$ $R_{\text{each buzzer}} = 25[\Omega] (1)$ ecf between 2 nd and 3 rd marks Or $R = \frac{4.5 (1)}{0.18} (1) = 25[\Omega] (1)$	3																				
	(iii)	$R_{\text{Total}} = 16\frac{2}{3} [\Omega] (1) \quad I = \frac{9}{16\frac{2}{3}} = 0.54 [A] (1)$ ecf from (b)(ii) / no ecf for R_{Total}	2																				
	(iv)	<u>Either</u> ecf from (b)(ii) or (b)(iii) or both $P_S = \left(\frac{2}{3} \times 0.54\right)^2 \times 25 (1) \quad P_S = 3.24 [W]$ $P_Q = \left(\frac{1}{3} \times 0.54\right)^2 \times 25 (1) \quad P_Q = 0.81 [W]$ <u>Or</u> $P_S = \frac{9^2}{25} (1) = 3.24 [W] \quad P_Q = \frac{4.5^2}{25} (1) = 0.81 [W]$ <u>Or</u> $P_S = \frac{2}{3} \times 0.54 \times 9 (1) = 3.24 [W] \quad P_Q = \frac{1}{3} \times 0.54 \times 4.5 (1) = 0.81 [W]$ $\rightarrow \frac{3.24}{0.81} = 4 (1) \quad \text{or any correct algebraic solution} = 3 \text{ marks}$	3																				

8.

(a)

(i)



Circuit (without voltmeter and ammeter) (1)

Voltmeter and Ammeter correctly positioned (1)

2

$$(ii) \quad R = \frac{10}{0.9} = 11.11 \, [\Omega] \quad (1)$$

$$A = 3.14 \times 10^{-8} \, [\text{m}^2] \quad (1)$$

$$\rho = \frac{11.11 \times 3.14 \times 10^{-8}}{3.2} \quad (1) \text{ substitution} \quad \rho = 1.09 \times 10^{-7} \, [\Omega \text{ m}] \quad (1)$$

ecf for R and A

4

(iii) Platinum and Tin

1

(b)

$$\rho = \frac{0.74 \times 10^{-3}}{(3.14 \times 10^{-8} \times 3.2)(1)} = 7365 \, [\text{kg m}^{-3}] \quad (1) \text{ ecf for A}$$

Tin (1) ecf from density value

3

9.	(a)	(i)	[For a metallic conductor] the potential difference and current are [directly] proportional/ $I \propto V$ (1), provided the temperature remains constant / all physical factors remain constant (1) $V = IR$ only no marks	2
		(ii)	It is constant / stays the same / increases as the temperature increases	1
	(b)	(i)	$A = 1.5(3) \times 10^{-8} \text{ [m}^2\text{]}(1)$ $R = \frac{\rho l}{A} = \frac{95 \times 10^{-8} \times 3.2}{1.5(3) \times 10^{-8}} (1) = 199 \text{ } [\Omega] (1)$	3
		(ii)	$\frac{230^2}{200} = 265 \text{ [W]}$ allow e.c.f. from (b)(i)	1
		(iii)	$\frac{1}{66.7(1)} = \frac{1}{200} + \frac{1}{R_2} (1)$ $R_2 = 100 \text{ } [\Omega] (1)$	3
		(iv)	R_2 (1) either reference to $\frac{V^2}{R}$ so lower R / same V across lower R or reference to $I^2 R$ so greater I or reference to IV so I increased [for constant V] or correct calculation of R_2 (1)	2
		(v)	$\frac{230}{66.7} = 3.5 \text{ [A]}$ allow e.c.f. from (b)(iii)	1

(a)	(i)	[For a metallic conductor] the potential difference and current are [directly] proportional/ $I \propto V$ (1), provided the temperature remains constant / all physical factors remain constant (1) $V = IR$ only no marks	2
	(ii)	It is constant / stays the same / increases as the temperature increases	1
(b)	(i)	$A = 1.5(3) \times 10^{-8} \text{ [m}^2\text{]}(1)$ $R = \frac{\rho l}{A} = \frac{95 \times 10^{-8} \times 3.2}{1.5(3) \times 10^{-8}} (1) = 199 \text{ } [\Omega] (1)$	3
	(ii)	$\frac{230^2}{200} = 265 \text{ [W]}$ allow e.c.f. from (b)(i)	1
	(iii)	$\frac{1}{66.7(1)} = \frac{1}{200} + \frac{1}{R_2} (1)$ $R_2 = 100 \text{ } [\Omega] (1)$	3
	(iv)	R_2 (1) either reference to $\frac{V^2}{R}$ so lower R / same V across lower R or reference to $I^2 R$ so greater I or reference to IV so I increased [for constant V] or correct calculation of R_2 (1)	2
	(v)	$\frac{230}{66.7} = 3.5 \text{ [A]}$ allow e.c.f. from (b)(iii)	1

10.

Question		Marking details	Marks available				Maths	Prac
			AO1	AO2	AO3	Total		
2	(a)	$I = 0.0012 \text{ A}$ and $R_{\text{int}} = 5000 \Omega$ or $V_{\text{therm}} = 4.80 \text{ V}$ or $\frac{R_{\text{th}}}{1000 \Omega} = \frac{4.8 \text{ V}}{1.2 \text{ V}}$ or any other correct and relevant potential divider equation or by implication (1) $R_{\text{therm}} = 4000 \Omega$ (1) $\theta = 15^\circ$ ecf on R_{therm} (1)		3		3	3	
	(b)	Graph gradient changes [with θ] or graph not straight [or voltmeter reading doesn't vary linearly with R_{therm}] or ΔV not proportional to ΔR (1) n not constant [with varying θ] / he is wrong [only award if backed up by reasonable argument] (1)			2	2	1	
	(c)	So thermistor [accept: 'it' doesn't heat up] (1) Reference to electrical heating [even of circuit or resistor] or masking response to surroundings (or equiv) (1)		2		2		
		Question 2 total	0	5	2	7	4	0

11.

(a)	(i)	[Rate of] flow of charge / $I = \frac{Q}{t}$ or $\frac{dQ}{dt}$ <u>with Q defined</u>	1
	(ii)	C s^{-1}	1
(b)	(i)	$x = y + z$	1
	(ii)	charge	1
(c)	(i)	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$ or $R = \frac{R_1 R_2}{R_1 + R_2}$ of by impl. (1) $R_{\parallel} = 30 \Omega$ (1); $R_{\text{Total}} = 40 \Omega$ (1) [no e.c.f.]	3
	(ii)	[Current $x =$] 0.15 A e.c.f. [Accept equiv., e.g. $\frac{6}{40}$, but not 0.2 A without working]	1
	(iii)	$V_1 = 0.15 \times 10 [= 1.5 \text{ V}]$ (1) [e.c.f.] $V_2 = 6 - 1.5 [= 4.5 \text{ V}]$ [or $30 \times 0.15 = 4.5 \text{ V}]$ (1) [e.c.f.]	2
	(iv)	$y = \frac{4.5}{120} [= 0.038 \text{ A}]$ (1) $z = 0.15 - 0.038 \text{ e.c.f.} [= 0.11 \text{ A}]$ $\left[\text{or } \frac{4.5}{40} [= 0.11 \text{ A}] \right]$ (1)	2
		[Accept solutions based upon ratios, e.g. $y = \frac{0.15}{4} \dots$]	[12]

13.

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
1.	(a)	(i)	The current [through a metal conductor at constant temperature] is proportional to the pd [across it] Accept $I \propto V$ with well-defined symbols.	1			1		
		(ii)	Constant [or independent of current [or pd]] (1)	1			1		
	(b)	(i)	pd across X = 0.70 [V] (1) or by impl so $R_X = 58 \text{ } \Omega$ (1) or total resistance = 183 Ω (1) or by impl so $R_X = 58 \text{ } \Omega$ (1)		2		2	2	
		(ii)	$R_X = 16 \text{ } \Omega$ or equivalent (1) So Ohm's law not obeyed (1) [not freestanding] no ecf or If R_X stayed at 58 Ω (or 58.3 Ω), then $I = 27$ (or 26) mA (1) Not so, therefore Ohm's law not obeyed (1) no ecf			2	2	1	
		(iii)	No. Filament resistance increases with increasing pd [or current] or equivalent ecf on calculated value of R_X in (b)(ii)			1	1		
	(c)	(i)	Temperature at which a material [that is classed as a superconductor] loses all its resistivity [accept resistance] [when cooled]. Accept "... below which a material [...] has no resistivity [accept resistance]"	1			1		
		(ii)	Coil for MRI machine, power cables, magnets / electromagnets or anything reasonable (1) Can be kept below transition temp [cheaply] by liquid nitrogen [accept: superconducts in liquid nitrogen] (1)	2			2		
			Question 1 total	5	2	3	10	3	0

Question		Marking details	Marks available					
			A01	A02	A03	Total	Maths	Prac
4	(a)	Indicative content: Description: D1: At very low temperatures resistance of superconductor is zero ohms D2: Reference to transition temperature or critical temperature..... D3: where resistance suddenly drops to zero as temperature drops (or jumps up from zero as temperature rises) D4: Above transition temperature resistance increases with temperature D5: This increase in resistance with temperature is [approximately] linear [Sketch graph can show some of these points] Explanation: No explanation required for superconducting state. Above transition temperature: E1: As temperature increases, the ions in the metal lattice vibrate more quickly E2: Which makes it more likely that an electron will interact (accept collide) with the ion.... E3: So electrons lose kinetic energy and the drift velocity decreases E4: and collisions will cause ions to gain kinetic energy making further collisions more likely 5-6 marks Comprehensive description and explanation provided. <i>There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.</i> 3-4 marks Comprehensive description or explanation provided or limited attempt at both description and explanation. <i>There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.</i> 1-2 marks Limited attempt at description or explanation. <i>There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.</i> 0 marks No attempt made or no response worthy of credit.	6			6		
	(b)	One benefit to society given for each application: Particle accelerator 1 × (1) from: • Improve understanding of the nature of particles, • Skilled workforce opportunities • Have led to more powerful computing • Particle discoveries used in everyday applications e.g. TV sets • Well-reasoned economic benefits MRI scanner 1 × (1) from: • Improved diagnoses and treatment of many ailments • Skilled workforce opportunities • Benefits more people Reasoned choice of application [1]			3	3		
		Question 4 total	6	0	3	9	0	0

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
1	(a)		I^2 - Energy (per coulomb or unit charge) used in external resistor/circuit [1] E - Energy (per coulomb/unit charge) transferred by source [or from chemical energy or from other forms] or used in whole circuit [1] Ir - energy (per coulomb/unit charge) wasted/lost in source or due to internal resistance [1] Use of 'per coulomb' or 'unit charge' at least once [1]	4			4		
	(b)	(i)	Circuit current = $\frac{1050 \times 10^{-3}}{2.5} = 0.42$ [A] [1] Total internal resistance = $\frac{0.5}{0.42} = 1.2$ [Ω] ecf on I [1] $r_{\text{cell}} = 0.6$ [Ω] [1]		3		3	2	
		(ii)	Substitution into $I^2 r t$ i.e. $(0.42)^2 \times 0.6 \times 60$ (ecf on I, r) [1] Alternative: Substitution into $\frac{I^2 r t}{r}$ i.e. $\frac{(0.25)^2 \times 60}{0.6}$ (ecf on I, r) Alternative: Substitution into It^2 i.e. $0.42 \times 0.25 \times 60$ (ecf on I, I) Energy dissipated = 6.3 [J] [N.B. Alternative $\rightarrow$ 6.4 J] [1]	1					
	(c)		Either: Total resistance of coils in parallel = 2.975 [Ω] [1] and total circuit resistance = 4.175 [Ω] ecf [1] New current in circuit = $\frac{3}{4.175} = 0.72$ [A] [1] For the 4th mark: Rate of energy dissipation in each cell = $(0.72)^2 \times 0.6 = 0.31$ [W] so Kiera correct (or ratio calculated to be approx. 3) Or Energy dissipated in each cell in one minute = $(0.72)^2 \times 0.6 \times 60 = 18.6$ [J] so Kiera correct (or ratio calculated to be approx. 3) [1] Alternative: Total resistance of coils in parallel = 2.975 [Ω] [1] and total circuit resistance = 4.175 [Ω] ecf [1] New current = 0.72 [A] and pd drop across internal resistance = $0.72 \times 1.2 = 0.86$ [V] [1] Rate of energy dissipation in each cell For the 4th mark: = $\frac{(0.43)^2}{0.6} = 0.31$ [W] so Kiera correct (or ratio calculated to be approx. 3) Or Energy dissipated in each cell in one minute = $\frac{(0.43)^2 \times 60}{0.6} = 18.6$ [J] so Kiera correct (or ratio calculated to be approx. 3) [1]			4	4		
			Question 1 total	5	4	4	13	3	0

16.	Question			Marking details	Marks available				Maths	Prac
					AO1	AO2	AO3	Total		
1	(a)	(i)		Energy (or work) /charge or energy (or work) per coulomb [accept joules per coulomb] (1) The above put correctly into context, e.g. Energy given by battery / energy transfer from chemical [or to electrical]. [Free standing mark] (1)	1 1			2		
		(ii)		Method 1 $I = \frac{4.33 \text{ V}}{6.60 \Omega} [= 0.656 \text{ A}]$ or by implication (1) $r = \frac{4.80 \text{ V} - 4.33 \text{ V}}{0.656 \text{ A}} = 0.71 / 0.72 / 0.7 \Omega$ (1) Method 2 Any correct and relevant pot div equation e.g. $\frac{r}{6.6 \Omega} = \frac{4.80 \text{ V} - 4.33 \text{ V}}{4.33 \text{ V}}$ or $4.33 = \frac{4.80 \times 6.60}{r + 6.60}$ (1) $r = 0.71 / 0.72 / 0.7 \Omega$ (1) See additional guidance for methods assuming 0.7 Ω	1	1		2	2	
		(iii)	i	More current (1) Therefore greater Ir [accept: greater lost volts] (1) NB $V = E - Ir$ on its own doesn't score. or Ratio (ext res)/ r lower (1) So ratio (ext pd)/(pd across r) less (1) or equivalents	1	1		2		
			ii	Current in either resistor = $\frac{3.35}{3.30} [= 1.02 / 1.015 \text{ A}]$ (1) Division by e at any stage (1) [e.g. $\rightarrow 61 \text{ C}$] Electrons in 1 minute = $3.8 \times 10^{20} \text{ C}$, ecf on I [NB electrons through parallel combination = $7.6 \times 10^{20} \rightarrow (2)$]		3		3	2	
	(b)	(i)		$R = \frac{V^2}{P}$ or $\left[I = \frac{1000 \text{ W}}{230 \text{ V}} \text{ and } R = \frac{V}{I} \right]$ (1) $R = 53 \Omega$ [accept early rounding] (1)	1	1		2	2	
		(ii)		3.6 [MJ]		1		1	1	
	(c)			If electric heating is used rather than gas, for a given heating effect more CO_2 produced [or more gas, a non-renewable resource [accept: fossil fuel] is used]. (1) Greater contribution to climate change/global warming [so use of electric heaters <i>should</i> be discouraged] (1) Any one of... • [But] higher cost of electricity [per kW] is discouragement enough • [But] not all power stations are gas-fired. [Some eg nuclear, wind, don't produce CO_2] • [But] not all homes have gas available • CO_2 absorbs long-wavelength infrared (or infrared emitted from Earth's surface) in context of climate change • Any other relevant and non-trivial point e.g. safety issue with naked flames / CO emission / gas leaks Example of point not worth credit: "it's none of anyone else's business how I heat my home" – the word in the question was "discouraged" / electric heaters more expensive to run			3	3		
				Question 1 total	5	7	3	15	7	0

Additional guidance for 1(a)(ii)

Method 3

[Assuming that] $r = 0.7 \Omega$:

Total resistance = 7.30Ω

$$\therefore \text{Current} = \frac{4.80 \text{ V}}{7.30 \Omega} = 0.658 \text{ A} \quad (1)$$

$$\text{Terminal pd, } V = E - Ir = 4.80 - 0.685 \times 0.7 = 4.34 \text{ V, which is approximately as expected} \quad (1)$$

So the initial assumption is correct

Method 4

[Assuming that] $r = 0.7 \Omega$:

[Total resistance = 7.30Ω]

Using the potential divider equation:

$$V = E \times \frac{R}{R+r} = 4.80 \text{ V} \times \frac{6.60 \Omega}{7.30 \Omega} \text{ equation used correctly} \quad (1)$$

$$= 4.34 \text{ V, which is approximately as expected} \quad (1)$$

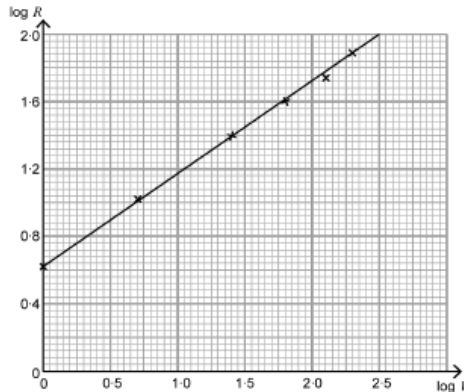
17.

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	(a)	(i)	Using $R = \frac{\rho l}{A}$ (1) Area = $\frac{\pi d^2}{4} = 6.16 \times 10^{-8} \text{ m}^2$ (1) Resistivity = $1.62 \times 10^{-8} \Omega \text{ m}$ unit mark (1)	1	1 1		3	2	
		(ii)	$p_i = \frac{0.1}{32.4} \times 100\% = 0.3\%$ or statement – negligible (1) $p_A = 2 \times p_d = 7.1\%$ (1) Total percentage uncertainty = 12% (ecf) (1) Abs unc (resistivity) = $\pm 0.2 \times 10^{-8} [\Omega \text{ m}]$ to 1 sf maximum (ecf) (1)		4		4	4	4
		(iii)	Silver and copper lie within range of values (ecf) (1) Material cannot be determined exactly from table (1)			2	2		
	(b)	(i)	Current is flow of (free) electrons (1) Flow is obstructed by collisions with ions (1) Collisions increase as temperature increases (1) Because of increased vibrations of ions/lattice or random speed of electrons increases (1)	4			4		
		(ii)	Using $R = \frac{V}{I}$ or proportional to $\frac{1}{I}$ OR temperature is inversely proportional to current (V constant) (1) Determining constant for at least 3 values dependent on method $k = \frac{R}{\text{Temperature}}$ or Temperature $\propto I$ (1) Conclusion – not constant (accept directly proportional if temperature in kelvin) (1)			3	3	2	3
			Question 4 total	5	6	5	16	8	7

18.

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5	(a)	(i)	All resistors connected in parallel (1) Using $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ [or equiv] (1) $R_{\text{total}} = 1.44 [\Omega]$ (1)	1	1 1		3	2	3
	(b)	(i)	(A4/emf) is the energy generated in the cell (1) per coulomb (1) Loss of energy in circuit in the load resistor (E4) (1) $E - V$ is the energy is lost in internal resistance (1) Energy is conserved (1) Re-arrange gives $r = \frac{E - V}{I}$ (1)	1 1	1 1 1		6	1	
		(ii)	Substituting values in $\frac{A7 - E7}{D7}$ (1) $r = 0.15 [\Omega]$ (1)	1	1		2	2	
		(iii)	Using $P = I^2 R$ (1) $P = 0.45 [\text{W}]$ (1) 0.50 W – has to be greater than the power dissipated (need reason) (1)	1	1 1		3	1	
			Question 5 total	5	9	0	14	6	3

19.

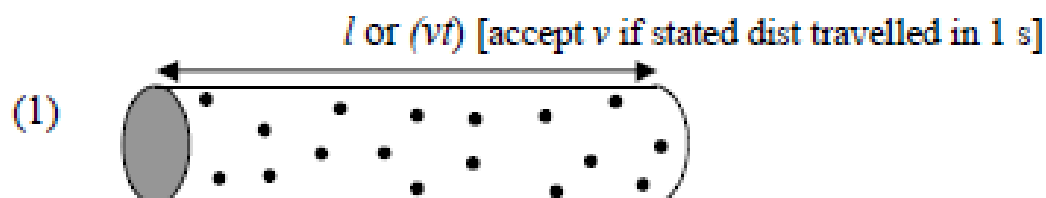
Question		Marking details	Marks available																																																						
			A01	A02	A03	Total	Maths	Prac																																																	
2	(a)	Varies value of variable resistor			1	1		1																																																	
	(b)	Correct attempt e.g. $\ln R = \ln(kV^n)$ or $\ln R = \ln k + \ln V^n$ [or using $\log_e$ or using $\log_{10}$] [1] Correct expression $\ln R = n \ln V + \ln k$ [or using $\log_e$ or using $\log_{10}$] [1]		2		2	2	2																																																	
	(c)	<table border="1"><thead><tr><th>V/V</th><th>I/A</th><th>R/Ω</th><th>$\ln(I/V)$</th><th>$\ln(R/\Omega)$</th></tr></thead><tbody><tr><td>1.00</td><td>0.52</td><td>1.9(2)</td><td>0.00</td><td>0.65</td></tr><tr><td>2.00</td><td>0.72</td><td>2.78 or 2.8</td><td>0.69</td><td>1.02</td></tr><tr><td>4.00</td><td>0.98</td><td>4.08 or 4.1</td><td>1.39</td><td>1.41</td></tr><tr><td>6.00</td><td>1.20</td><td>5.00</td><td>1.79</td><td>1.61</td></tr><tr><td>8.00</td><td>1.40</td><td>5.7(1)</td><td>2.08</td><td>1.74</td></tr><tr><td>10.00</td><td>1.54</td><td>6.49 or 6.5</td><td>2.30</td><td>1.87</td></tr></tbody></table> $\ln V$ values correct or accept $\log_{10} V$ values [1] Use of $R = \frac{V}{I}$ and all R and $\ln R$ values correct or accept $\log_{10} R$ values [1] <table border="1"><thead><tr><th>$\log_{10}(I/V)$</th><th>$\log_{10}(R/\Omega)$</th></tr></thead><tbody><tr><td>0.00</td><td>0.28</td></tr><tr><td>0.30</td><td>0.45</td></tr><tr><td>0.60</td><td>0.61</td></tr><tr><td>0.78</td><td>0.70</td></tr><tr><td>0.90</td><td>0.76</td></tr><tr><td>1.00</td><td>0.81</td></tr></tbody></table> Accept 2 or 3 sig figs in all cases. Accept 4 sig. Figs for $\ln V$ at 10.00 V (= 2.302) [1]	V/V	I/A	R/Ω	$\ln(I/V)$	$\ln(R/\Omega)$	1.00	0.52	1.9(2)	0.00	0.65	2.00	0.72	2.78 or 2.8	0.69	1.02	4.00	0.98	4.08 or 4.1	1.39	1.41	6.00	1.20	5.00	1.79	1.61	8.00	1.40	5.7(1)	2.08	1.74	10.00	1.54	6.49 or 6.5	2.30	1.87	$\log_{10}(I/V)$	$\log_{10}(R/\Omega)$	0.00	0.28	0.30	0.45	0.60	0.61	0.78	0.70	0.90	0.76	1.00	0.81		3		3	3	3
V/V	I/A	R/Ω	$\ln(I/V)$	$\ln(R/\Omega)$																																																					
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0.90	0.76																																																								
1.00	0.81																																																								
	(d)	Axes labelled either with no units i.e. $\ln R$ (or $\log_{10} R$) on y-axis and $\ln V$ (or $\log_{10} V$) on x-axis, or with $\ln(R/\Omega)$ and $\ln(V/V)$ respectively (or equivalent using) [1] Suitable scale e.g. large block – 0.2 on y-axis and 0.4 on x-axis for $\ln$ values and 0.2 on x-axis and 0.1 on y-axis on both axes for $\log_{10}$ values. [Linear, scales, with points occupying $\geq$ half available space] [1] All points plotted correctly within $\pm$ small square division [2] 5 points plotted correctly within $\pm$ small square division [1] 4 or less points plotted correctly within $\pm$ small square division [0] Straight line of best fit drawn [1] e.g. for $\ln$ graph: 		5		5	4	5																																																	
	(e)	(i) Attempt at taking gradient [1] $n = \frac{(2.0 - 0.65)}{2.5} = 0.5(4)$ [1] [answer gains both marks] $\ln k = 0.65$ or $k = e^{0.65}$ [1] $k = 1.9(2)$ [1] [answer gains both marks] N.B. ecf from graph for both values. Mark scheme to be applied as above for candidates using $\log_{10}$ values.	1 1	1 1		4	3	4																																																	
	(ii)	$R = 1.9 V^{0.5}$ (ecf on n and k)	1			1	1	1																																																	
	(f)	Required statement: Results lie close to line of best fit suggests good quality Accept: results fit with the expected theory Don't accept it's a straight line or reference to measuring instruments			1	1		1																																																	
		Question 2 total	3	12	2	17	13	17																																																	

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
2.	(a)			Gives charge [electrical potential] energy Accept pumps charge around circuit / does work on charge. Accept electrons instead of charge	1			1		
	(b)	(i)		Total emf = 3×1.60 or 4.80 [V] (1) Total resistance = $(1.20 + (3 \times 0.10))$ or 1.50 [Ω] (1) Current $[= \frac{V}{R}] = 3.2$ [A] (1) N.B. If workings in reverse award a maximum of 2 marks		3		3	1	
		(ii)	I	12.3 [W] ecf (10.8 W if 3 A used) e.g. using $P = I^2 R = 3.2^2 \times 1.2 = 12.3$ [W]		1		1	1	
			II	15.4 [W] ecf (14.4 W if 3 A used) e.g. using $P = IE = 3.2 \times 4.8 = 15.4$ [W]		1		1	1	
		(iii)		Thermal or internal. Accept 'heat', 'dissipated' (1) in internal resistance (1)	2			2		
	(c)			3.15 A or 3.2 A [Accept: even on short-circuit, extra cell gives only 3.0 A] (1) No. Current less than [accept same as] before ecf on (b)(i) (1)			2	2	1	
				Question 2 total	3	5	2	10	4	0

21.	(a)		V - energy (per coulomb) used in [external] resistor / circuit. (1) E - energy (per coulomb) transferred / supplied by source / in the whole circuit (1) Ir - energy (per coulomb) wasted / lost in source / cell / internal resistance (1) Use of 'per coulomb / unit charge' once. (1)	[4]
	(b)	(i)	4 [Ω]	[1]
		(ii)	Gradient attempted e.g. $60/10$ (1) (or use of equation ecf from (b) (i)) $\text{emf} = 6$ [V] (1)	[2]
		(iii)	$1/I = 4$ [A^{-1}] or by implication (1) $R = 20$ [Ω] (1) Use of $I^2 R$ i.e. $(0.25)^2 \times 20$ (ecf) (1) or correct substitution into both $V = IR$ and $P = IV$ or V^2/R $P = 1.25$ [W] (1)	[4]
	(c)	(i)	$\text{emf} = 12.0$ [V] (ecf) <u>and</u> $r = 8.0$ [Ω] (ecf)	[1]
		(ii)	$R = 52.0$ [Ω] (ecf)	[1]
		(iii)	y intercept ($r \rightarrow 8.0 \Omega$ (ecf)) (1) Precise gradient e.g. through (5,52) (ecf) (1)	[2]

22.	(a)	<u>Electrical energy (or work done) transferred [to other forms passing] between two points (1) per coulomb of charge (1)</u> Definition of 1 V award 1 mark only	[2]
(b)	(i)	$V_{\text{supply}} = V_1 + V_2 + V_3$	[1]
	(ii)	Energy	[1]
(c)	(i)	$R_1 + 12 = \frac{9}{0.5} \quad (1)$ Clear manipulation seen to show $R_1 = 6 \, [\Omega] \quad (1)$	[2]
	(ii) (I)	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$ to show effective parallel combination = $6 \, \Omega \quad (1)$ this can be implied V across upper $6 \, \Omega$ resistor shown = $4.5 \, [\text{V}]$ (ecf on parallel combination) (1)	[2]
	(II)	Total resistance = $12 \, \Omega \quad (1)$ $I = \frac{9.0}{12} = 0.75 \, [\text{A}] \quad (1)$ (accept $\frac{4.5}{6} = 0.75 \, [\text{A}]$)	[2]
	(III)	$1.2 = \frac{9}{(6 + R_{\text{parallel}})} \quad (1)$ $R_{\text{parallel}} = 1.5 \, [\Omega] \quad (1)$ $n \times \left(\frac{1}{12}\right) = \frac{1}{1.5} \quad (1)$ ecf on $1.5 \, [\Omega]$ $n = 8 \quad (1)$ Full marks for correct answer based on trial and error Alternative solution: $\frac{9}{1.2} = 7.5 \, [\Omega] \quad (1)$ $7.5 - 6 = 1.5 \, [\Omega] \quad (1)$ $\frac{12}{n} = 1.5 \, [\Omega] \quad (1)$ $n = 8 \quad (1)$	[4]

(a)	(i) Correct and convincing use of $\rho = \frac{RA}{l}$ (including unit conversion)	[1]
	(ii) $\left(\frac{2000}{11.2}\right) = 179 \text{ A unit mark}$	[1]
	(iii) $v = \frac{I}{nAe}$ rearranged (or shown numerically) (1) $n = 6.0 \times 10^{28} \times 3$ (1) $v = 1.55 \times 10^{-5} [\text{m s}^{-1}]$ (ecf on I and n) (1)	[3]
(b)	(i) Same (or equivalent)	[1]
	(ii) v increased (1) because...; A decreased, I, n, e unchanged by implication (1)	[2]
	(iii) Increased frequency / more collisions <u>between electrons and lattice / atoms / ions</u> or electrons carry greater kinetic energy (1) leading to <u>increased vibrational / kinetic energy of lattice atoms</u> (1)	[2]



[NB free electrons not required to be labelled]

Number of free electrons = $nAvt$ [or nAl] (1)

Total charge = $nAvte$ [or $nAle$] (1)

$$I = \frac{nAvte}{t} \text{ with cancelling shown [or } \frac{nAle}{t}, \text{ where } \frac{l}{t} = v \text{ shown]} (1)$$

4

$$2.0 = 1.0 \times 10^{29} \times 1.7 \times 10^{-6} v \times 1.6 \times 10^{-19} (1) \text{ [substitution]}$$

$$v = 7.4 \times 10^{-5} \text{ m s}^{-1} ((\text{unit}))(1)$$

2

collisions [accept obstructions](1)

between free electrons and copper atoms / ions / lattice (1) [accept: delocalised / moving / conducting electrons]

2

$$R = \frac{P}{I^2} \text{ [or } P = I^2 R] (1); R = \frac{0.1}{4} [=0.025 \Omega] (1)$$

$$\rho = \frac{0.025[\text{e.c.f.}] \times 1.7 \times 10^{-6}}{2.5} (1) \text{ [manipulation i.e. } \rho = \frac{RA}{l} \text{ or with}$$

figures]

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

4

cross-sectional area

smaller (1)

n

the same (1)

resistivity

the same (1)

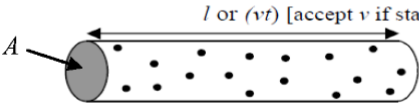
3

[15]

25.	2	(a)	Ammeter shown in series with bulb [or in series with bulb/voltmeter parallel combination] (1) Voltmeter shown in parallel with bulb [or across bulb/ammeter series combination] (1)	2
		(b)	(i) 2.0 A (ii) 6.0 Ω	1 1
		(c)	Either: $\frac{1}{18} + \frac{1}{6(\text{ecf})} = \frac{1}{R_{\text{p}}}$ (1); $R_{\text{p}} = 4.5 \Omega$ (1) Subst into pot div equations: $12 = \frac{4.5}{4.5 + R} \times 16$ (1) $R = 1.5 \Omega$ (1) Or: $I_{18\Omega} = \frac{12}{18}$ [=0.67 A] (1); So $I_{\text{total}} = 2.67 \text{ A}$ [ecf from (a)](1) $R = \frac{4(1)}{2.67(\text{ecf})} = 1.5 \Omega$ (1)	4
		(d)	Graph shown with positive gradient and linear through the origin for low values (1) and smoothly reducing gradient for higher values [NB – not negative gradients at end](1)	2
				[10]

26.	(a)	(i)	Metal wire at constant temperature - straight diagonal line. Filament of lamp - curved line.	[1]
		(ii)	Straight line: R constant throughout [or V/I constant] as... (1) I constant throughout (1) Curve: Initially R constant [or V/I constant] as....(1) Then I increases (1) so R increases - accept explanation in terms of particles (1)	[5]
	(b)	(i)	$I = 2 \text{ [A]}$	[1]
		(ii)	(I) Voltage across X = 12 [V]	[1]
			(II) $12 \text{ V} - 6 \text{ V} = 6 \text{ [V]}$ ecf from (I)	[1]
			(III) $R_2 = \frac{6}{4} = 1.5 [\Omega]$ ecf from (II)	[1]
			(IV) V across $R_1 = 3 \text{ [V]}$ (1) I through $R_1 = 6 \text{ [A]}$ (1) $R_1 = \frac{3}{6}$ (ecf on I and/or V) = 0.5 [Ω] (1)	[3]

(a)	(i) Diagram to include • Correct electric circuit with ohmmeter or power supply with ammeter + voltmeter with correct symbols and positioning (1) • Method of heating shown (1) • Method of recording temperature shown (1) (ii) Linear [or approximately linear] graph with positive gradient (1) and positive intercept on R axis (1).	3 2
(b)	(i) Conducting / delocalised / free electrons (1) collide (1) with metal lattice / atoms / ions (1) [not with other free electrons] (ii) The greater the temperature the greater the vibrational energy of the lattice / metal ions (1) producing a greater chance [or rate] of collisions/ collisions more often / greater frequency of collisions (1) [not harder] .	3 2

Question			Marking details	Marks Available
3	(a)	(i)	[Free] electrons forced to move by applied pd (Need a reference to drift velocity or electron flow but does not need to be explicitly stated) (1) They collide with atoms/nuclei/ions/lattice of the wire (1) don't accept particles or molecules	2
		(ii)	$\text{Power} = \frac{1.8}{60} = 0.03 \text{ [W]} (1)$ $R = \frac{0.03(\text{ecf})}{1.6^2} = 0.0117 \text{ [\Omega]} (1)$ Alternative solution possible for the first 2 marks using $V = \frac{W}{Q}$ and $R = \frac{V}{I}$ $\rho = \frac{0.0117 \times 2 \times 10^{-6}}{0.4} (1) \text{ [ecf on } R]$ $= 5.9 \times 10^{-8} \text{ [\Omega m]} (1)$	4
	(b)	(i)	 [NB free electrons not required to be labelled] Number of free electrons = $nAvt$ [or nAl] (1) Total charge = $nAvte$ [or $nAle$] (1) $I = \frac{nAvte}{t}$ with cancelling shown [or $\frac{nAle}{t}$, where $\frac{l}{t} = v$ shown] (1) Volume defined either from diagram [e.g. A and l labelled as shown] or in body of derivation [e.g. $\text{vol} = Al$] and n identified correctly– for the first mark	4
		(ii)	$1.6 = 6.4 \times 10^{28} \times 2 \times 10^{-6} \times v \times 1.6 \times 10^{-19} (1: \text{substitution})$ $v = 7.8 \times 10^{-5} \text{ [m s}^{-1}] (1)$	2
		(iii)	(I) less than 1.6 A identified/circled (1) (II) the same as identified/circled (1) (III) half identified/circled (1)	3
			Question 3 Total	[15]

29.

(a)		n - number of free/conducting electrons (charge carriers) per unit volume (1) accept free electron density v - drift velocity (1)	[2]
(b)		LHS: $C s^{-1}$ (1) RHS: $m^3 \times m^2 \times m s^{-1} \times C$ (1) Clear manipulation to show/state LHS = RHS (1)	[3]
(c)	(i)	$v = \frac{I}{nAe}$ (1) (or correct substitution) $v = 1.30 \times 10^{-4} m s^{-1}$ (1) (-1 for slips in powers of 10) $t = \frac{5.0}{1.30 \times 10^{-4}} = 3.85 \times 10^4 [s]$ (1) ecf for incorrect value of v	[3]
(ii)		Reduced CSA (or diameter) <u>and</u> n, e constant..... (1) Increased v (1) Hence reduced t (1)	[3]

30.

(a)	(i)	Ruler and wire shown and labelled (1) Moving pointer or jockey or crocodile clip indicated (1) Either: Correctly positioned ohmmeter with no power supply; or correctly positioned voltmeter and ammeter with power supply (1) [No labelling required for either method].	[3]
(ii)		Diagonal line through origin	[1]
(iii)		CSA from <u>diameter of wire</u> (1) Gradient from graph = (R/l) or (ρ/A) Or stated take a pair of R and l values from the graph (1) $\rho = \text{gradient} \times \text{CSA}$ or use of $\rho = RA/l$ (1)	[3]
(b)	(i)	$R = \frac{144}{32} = 4.5 [\Omega]$ (1) Correct substitution into $R = \rho l/A$ (1) $l = 0.375 [m]$ (1) (ecf on R)	[3]
(ii)		$I = 2.7 [A]$ (from V/R or P/V etc) (1) (ecf on l) Correct substitution into $I = nAve$ (1) $v = 1.24 \times 10^{-2} [m s^{-1}]$ (1) accept $0.01 m s^{-1}$	[3]
Question 5 Total			[13]

31. (a)	(i) Ruler and wire shown and labelled (1) Moving pointer or jockey or crocodile clip indicated (1) Either: Correctly positioned ohmmeter with no power supply; or correctly positioned voltmeter and ammeter with power supply (1) [No labelling required for either method].	[3]
	(ii) Diagonal line through origin	[1]
	(iii) CSA from <u>diameter of wire</u> (1) Gradient from graph = (R/l) or (ρ/A) Or stated take a pair of R and l values from the graph (1) $\rho = \text{gradient} \times \text{CSA}$ or use of $\rho = RA/l$ (1)	[3]
(b)	(i) $R = \frac{144}{32} = 4.5 [\Omega]$ (1) Correct substitution into $R = \rho l/A$ (1) $l = 0.375 [\text{m}]$ (1) (ecf on R)	[3]
	(ii) $I = 2.7 [\text{A}]$ (from V/R or P/V etc) (1) (ecf on l) Correct substitution into $I = nAve$ (1) $v = 1.24 \times 10^{-2} [\text{m s}^{-1}]$ (1) accept 0.01 m s^{-1}	[3]