WJEC EDUQAS A-LEVEL PHYSICS · COMPONENT 2

PHYSICS



EXAM QUESTION PACK

2.2 RESISTANCE

SCORE	PERCENTAGE
/189	%

STEMUP

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#1

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]

(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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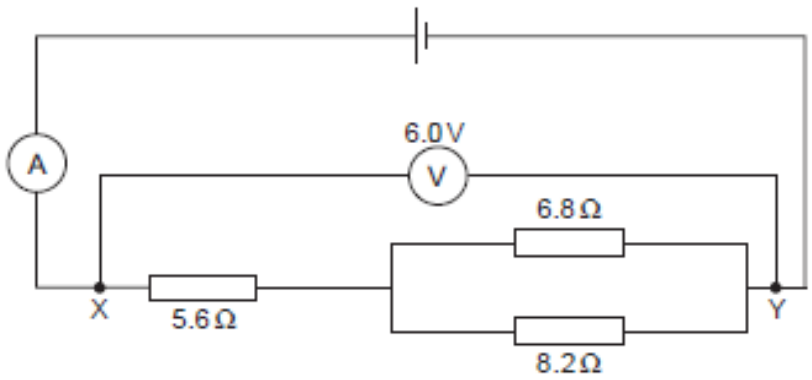
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Question taken from Eduqas examination paper 842102, June 2019

#2

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 ± 0.01 A. [4]

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(ii) Calculate the potential difference across the 8.2 Ω resistor. [2]

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

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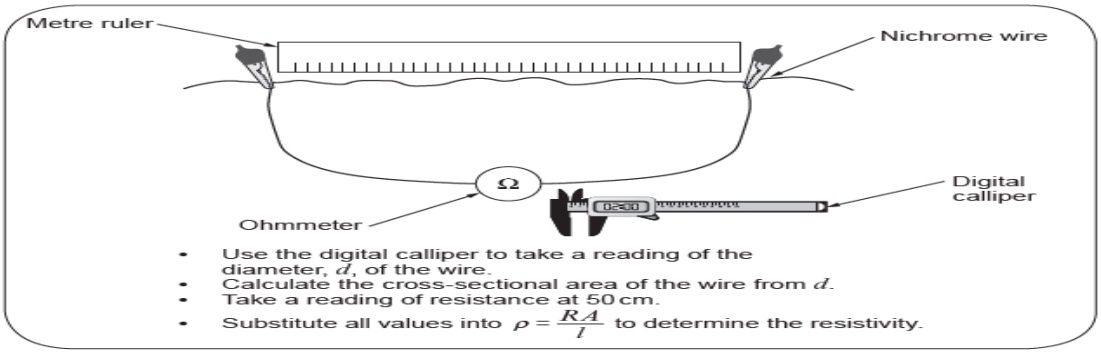
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#3

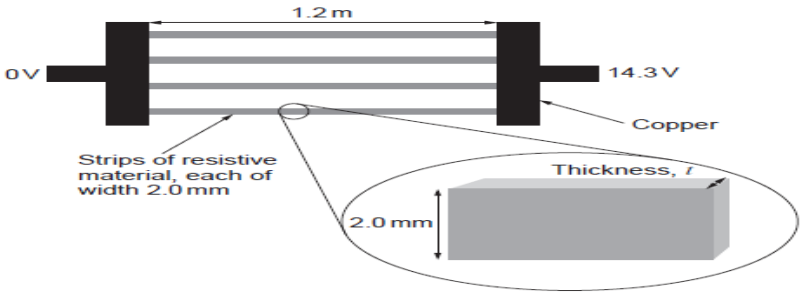
(a) Sally writes a plan for an experiment to determine the resistivity, ρ, of nichrome in a wire. Her outline plan, which includes a diagram of the apparatus is given below.



- Use the digital calliper to take a reading of the diameter, d, of the wire.
- Calculate the cross-sectional area of the wire from d.
- Take a reading of resistance at 50 cm.
- Substitute all values into $\rho = \frac{RA}{l}$ to determine the resistivity.

Sally's teacher believes the plan lacks detail, which might lead to an inaccurate value for ρ. Using the same apparatus, suggest improvements to the plan. You should include details of how to reduce the uncertainty in ρ using a graphical method. [6 QER]

(b) A heating unit proposed for the rear window of a car is to consist of four rectangular strips of resistive material, each of length 1.2 m and width 2.0 mm, joined at their ends by strips of copper of negligible resistance as shown. The unit must generate 45 W of heat when connected to a supply of 14.3 V.
Determine whether or not this can be done using a thickness, t, of approximately 0.2 mm for the metal strips.
[Resistivity of resistive material = $6.0 \times 10^{-6}\,\Omega\,m$] [4]



#4

10. A silver ring on a light rod swings as a pendulum with damped simple harmonic motion. The damping is caused by a stationary magnet as shown in the diagram.



(a) Explain why the motion of the pendulum is damped. [4]

(b) Explain what, if anything, would happen to the motion of the pendulum if the bar magnet were reversed. [2]

(c) The resistivity of silver is $1.59 \times 10^{-8}\,\Omega m$, the radius of the silver ring is 2.5 cm and the cross-sectional area of the silver wire of the ring is $2.4 \times 10^{-5}\,m^2$. Show clearly that the resistance of the silver ring is approximately $0.1 \times 10^{-3}\,\Omega$. [2]

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(d) The maximum current induced in the silver ring is 5.5 A. Calculate the maximum rate at which the magnetic flux density inside the ring changes. [3]

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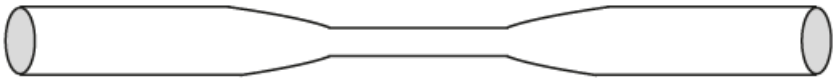
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Question taken from Eduqas examination paper 842103, June 2018

#5

(a) Calculate the mean drift velocity of the free electrons in a wire, which has a diameter of 0.50 mm and carries a current of 2.8 A. Assume each aluminium atom contributes 3 free electrons, and there are 6.0×10^{28} atoms per m^3 of aluminium. [4]

(b) The wire is thinner in a small section as shown below.



Paula claims that within the thinner section the mean drift velocity of the free electrons will be greater. Evaluate whether she is correct. [3]

(c) (i) State what is meant by a superconductor. [1]

(ii) State and explain **one** advantage and **one** disadvantage of using superconductors to carry large currents. [4]

Advantage:

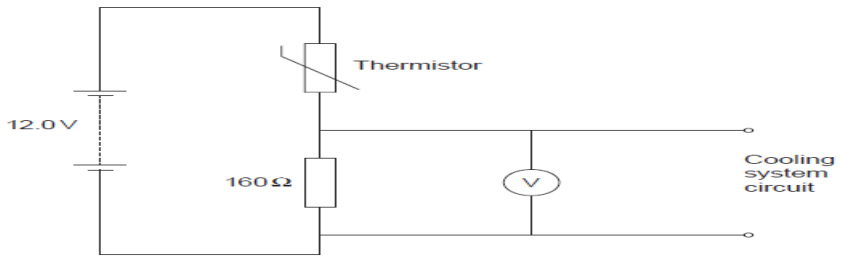
Disadvantage:

Question taken from Eduqas examination paper 842002, June 2017

#6

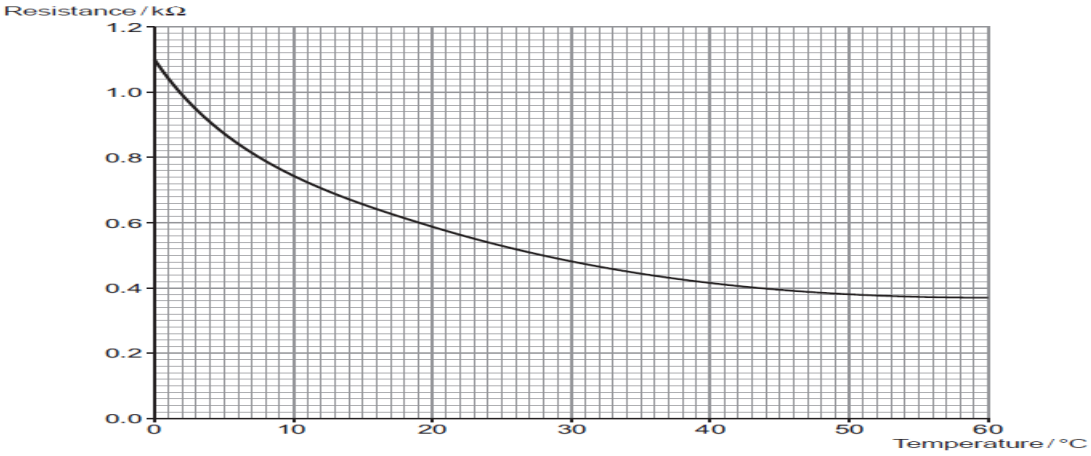
(a) Define the *potential difference* across two points in an electric circuit. [1]

(b) The diagram shows a possible control circuit for a cooling system. It consists of a battery of emf 12.0 V and negligible internal resistance connected in series with a thermistor and a 160 Ω fixed resistor. The voltmeter and cooling system circuit have very high resistances.



Calculate the resistance of the thermistor when the voltmeter reads 2.4 V. [3]

(c) The graph shows how resistance varies with temperature for this thermistor.



(i) The reading on the voltmeter increases when the temperature of the thermistor increases. Explain why this is the case. [2]

(ii) The cooling system can only be activated when the voltage across the 160 Ω resistor rises above 2.8 V. An engineer suggests that this thermistor and resistor combination is suitable to use in a car cooling system and should activate when the temperature reaches 30 °C. Check this claim. [4]

(d) The arrangement can also be used as a basis for a thermometer. By considering the shape of the graph on page 3 discuss whether this thermistor arrangement would be more effective at measuring changes in temperature between 0 °C and 10 °C or between 50 °C and 60 °C. [2]

Question taken from Eduqas examination paper 842102, June 2017

#7

An insulated wire is made into a long solenoid of length 4.00 m by winding it around a pipe of diameter 3.00 cm. The wire is 0.25 mm thick and is wound so that each loop just touches the next.

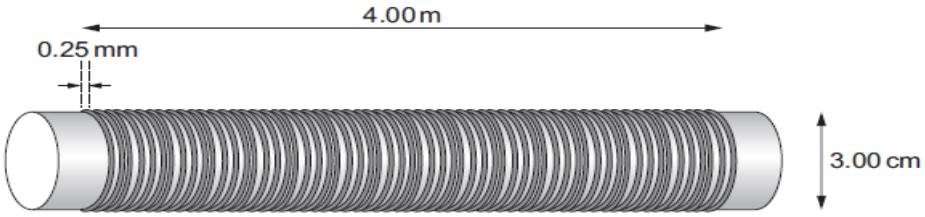


Diagram not to scale

(a) Show that the length of the wire is approximately 1.5 km. *You may assume that the insulation thickness is negligible.* [3]

(b) Show that a steady current of approximately 25 mA is carried in the wire when a pd of 12.0 V is applied across its ends. The resistivity of the wire is $1.59 \times 10^{-8}\ \Omega\,m$. [3]

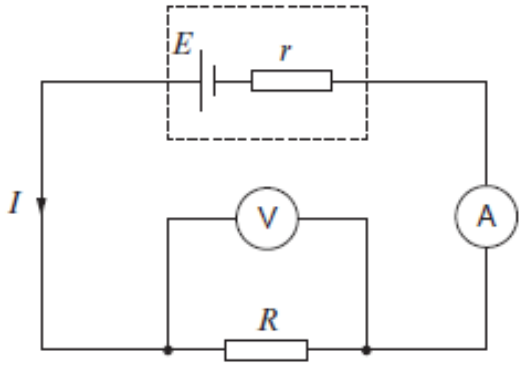
(c) Calculate the magnetic field strength, B, inside the solenoid. [2]

(d) Explain whether or not the solenoid could produce a magnetic field of 2 T. You should include a calculation to reinforce your answer. [3]

Question taken from Eduqas examination paper 842103, June 2017

#8

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 1050mW 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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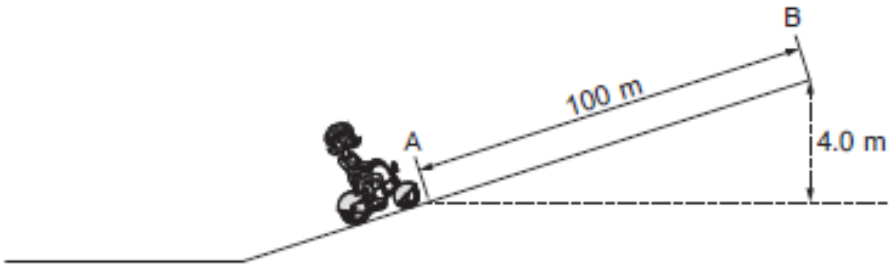
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Question taken from Eduqas examination paper 842102, June 2019

#9

3. Helen is riding an electric bike (a bike that is assisted by an electric motor) up a hill at a speed of 4.5 m s^{-1}. At point A she starts the electric motor and accelerates uniformly reaching a speed of 9.2 m s^{-1} at B. Whilst accelerating she also gains a height of 4.0 m as shown in the diagram below.



(a) Show that the time taken for Helen's journey between A and B is approximately 15 s. [2]

(b) Helen and the bike have a combined mass of 95 kg. Determine the gain in total energy between A and B. [3]

(c) (i) If the bike's electric motor operates at 36 V and 7.0 A calculate the electrical energy used by the motor between A and B. [2]

(ii) Helen, by pedalling, also provides 5 500 J of work between A and B. Determine the efficiency of the electric motor. *Ignore all resistive forces on Helen and the bike.* [2]

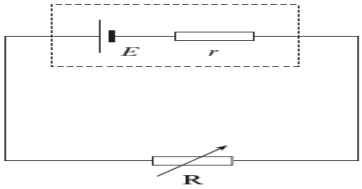
(iii) In practice resistive forces will act. Identify these forces and where they act. [2]

(d) Helen believes that by riding an electrically powered bike to the shops rather than using her car she is benefiting the environment. Explain whether or not Helen is correct. [2]

Question taken from Eduqas examination paper 842001, June 2018

#10

Abigail investigates how the power dissipated in a variable resistor varies as its resistance is altered. The diagram shows the circuit that Abigail uses (meters not shown). The variable resistor is connected to a battery of emf, E, and internal resistance, r.



Abigail obtains the following data as the resistance is varied from 0.5 Ω to 6.0 Ω.

Resistance, R / Ω	Power dissipated in R / W
0.5	2.5
1.0	3.3
2.0	3.8
3.0	3.8
4.0	3.7
5.0	3.6
6.0	3.5

(a) Plot a graph of power dissipated in R (on the y-axis) against resistance (on the x-axis) and draw a smooth curve through the data. [3]

(b) The emf of the battery is 6.0 V and the resistance, R, is now set at **4.5** Ω.

(i) State what is meant by an *emf* of 6.0 V. [2]

(ii) Calculate the current through the battery using data from your graph. [3]

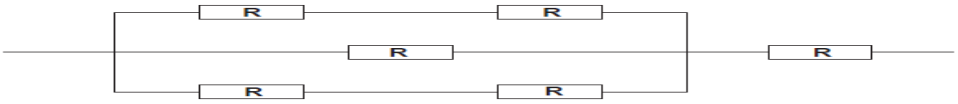
(iii) Calculate the internal resistance, r, of the battery. [3]

(c) Abigail repeats the experiment but with a battery of the same emf but smaller internal resistance. Explain how the graph would change. [2]

Question taken from Eduqas examination paper 842002, June 2017

#11

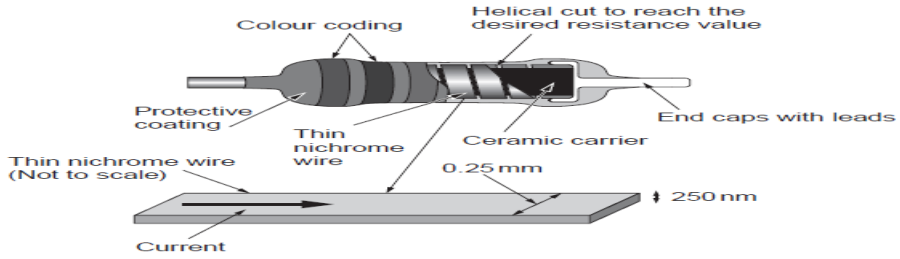
(a) The resistor network shown consists of six identical resistors, each of value **R Ω**.



(i) Determine, **in terms of R**, the total resistance of the network. [3]

(ii) **Draw a circle** around the resistor which dissipates the greatest power when a pd is applied across the arrangement. Explain your answer. [2]

(b) The alloy nichrome is commonly used to make 'Metal Film Resistors'. A cross-section through such a resistor is shown. The value of the resistor is determined by the length of the nichrome wire used in it.



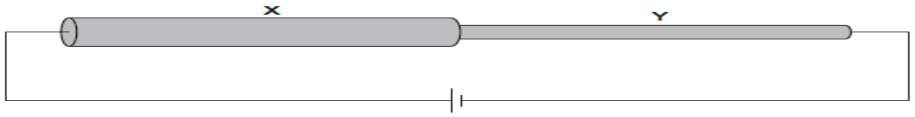
The wire used in such a resistor has a rectangular cross-section as shown. Determine the length of nichrome wire required to make a 2.0 kΩ resistor.
[Resistivity of nichrome = 1.20×10^{-6} Ω m] [2]

(c) The current I through a wire is related to the drift velocity, v, of free electrons through the wire by the equation:

$$I = nAve$$

(i) State the meaning of n. [1]

(ii) Two pieces of nichrome wire, **X** and **Y**, are joined end to end and connected to a battery as shown. The wires are of the same length but the diameter of **X** is **double** that of **Y**.



The table below shows the ratios of the values of n, I and v in the two wires. Write in the table the value of each ratio, giving an explanation for each of your answers.
Space is provided for calculations. [3]

Ratio	Value	Explanation
$\frac{n_X}{n_Y}$		
$\frac{I_X}{I_Y}$		
$\frac{v_X}{v_Y}$		

(iii) Wire **Y** is replaced with another wire **Z** of the same cross-sectional area as **Y** but double the length and made of a material with resistivity half that of **X**. Calculate the ratio:

$$\frac{\text{Power dissipated in wire Z}}{\text{Power dissipated in wire X}}$$

[3]

Question taken from Eduqas examination paper 842102, June 2017

2. *(a)* (i) State what is meant by *electric current*. [1]

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(ii) Show that the unit of resistance, the ohm (Ω), can be expressed as: [2]

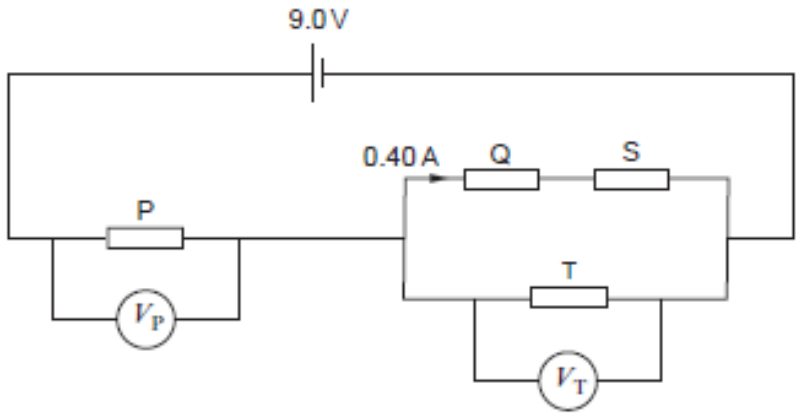
$$J\,s\,C^{-2}$$

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(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]

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(ii) Hence or otherwise show that the values given in the diagram are consistent with the resistance of each resistor being 4.5 Ω. [3]

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(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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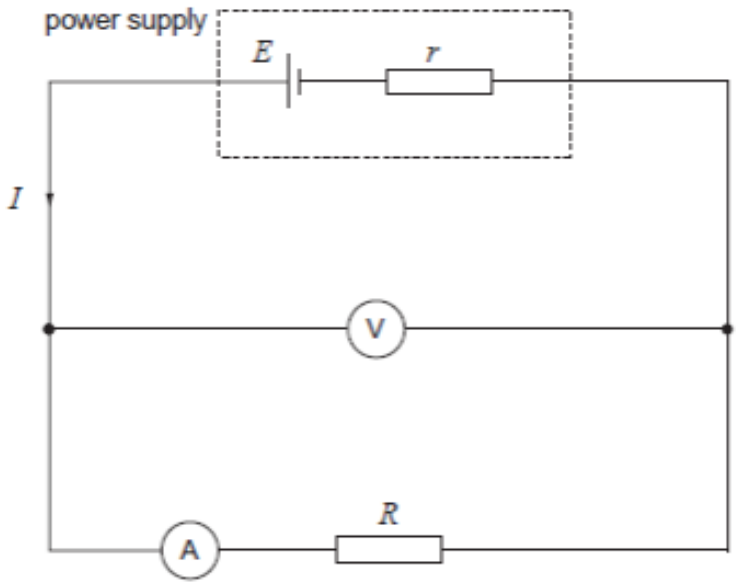
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Question taken from Eduqas examination paper 842102, June 2018

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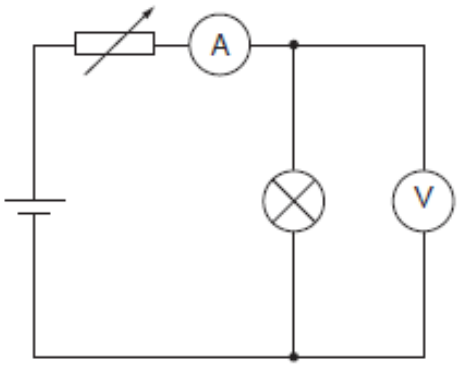
(b) (i) Zhang Li uses the spreadsheet formula = $\frac{A4 - E4}{D4}$ to determine the internal resistance in cell F4. Explain in terms of energy why this is a valid method. [6]

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

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

Question taken from Eduqas examination paper 842002, June 2019

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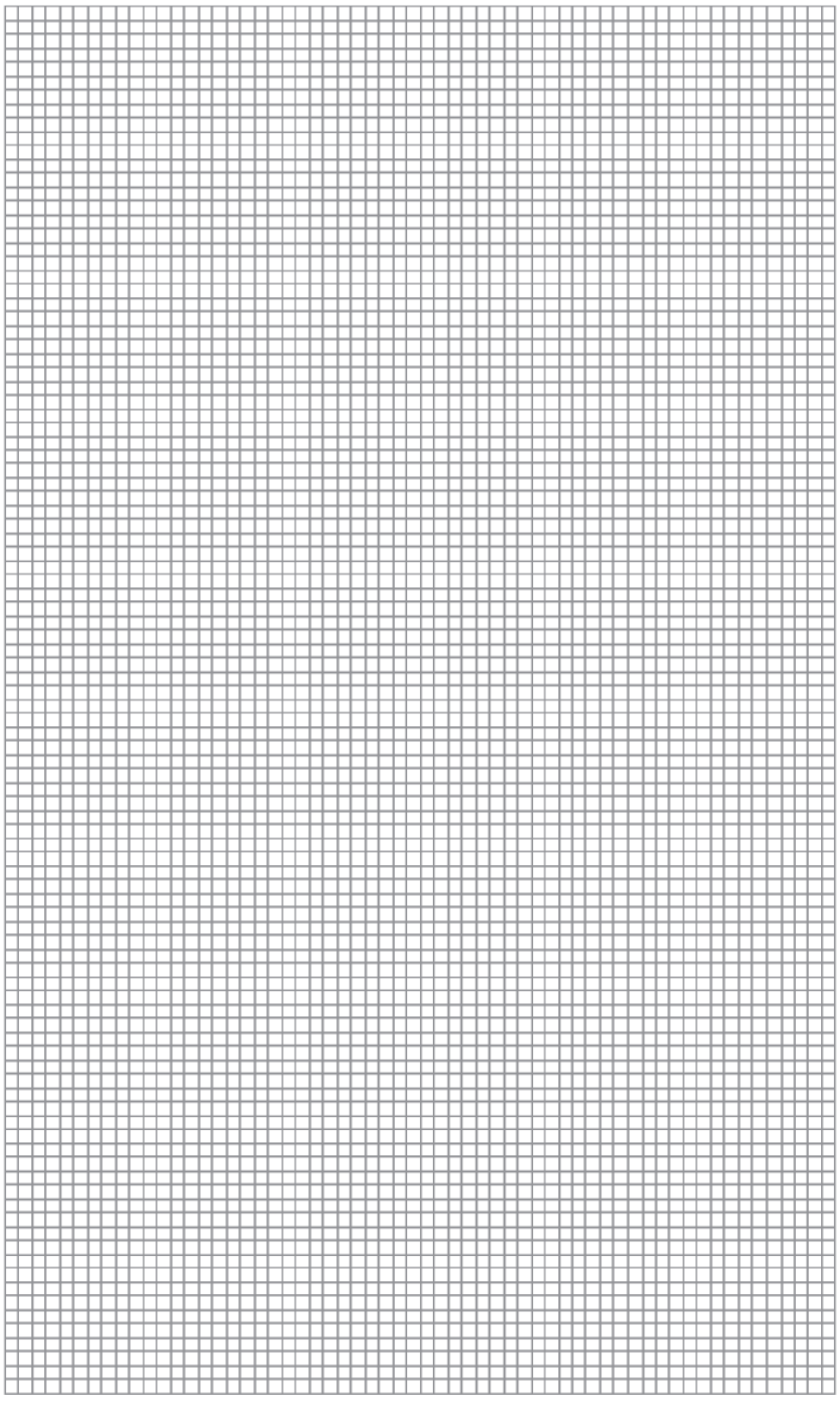
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(c) Jasmine records the following data. Complete the table using an appropriate number of significant figures. [3]

V / V	I / A	R / Ω	log(V / V)	log(R / Ω)
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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Question taken from Eduqas examination paper 842102, June 2019

#15

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 ($10^{-8}\Omega$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]

(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

Question taken from Eduqas examination paper 842002, June 2019

Marking Scheme

#1

Question			Marking details	Marks available					
				AO1	AO2	AO3	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. *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3-4 marks** Comprehensive description or explanation provided or limited attempt at both description and explanation. *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.* **1-2 marks** Limited attempt at description or explanation. *There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.* **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**

#2

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
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 × 3.7 ecf OR pd across 5.6 Ω = 0.65 × 5.6 = 3.6 V (1) Answer = 2.4 V (1)		2		2	1	
		(iii)	Substitute values into $P = I^2R$ [$P = 0.65^2 \times 3.7$] (1) P = 1.54 W – ecf (1)	1	1		2	2	
			Question 2 total	**4**	**6**	**0**	**10**	**6**	**0**

#3

Question	Marking details	Marks available					
		AO1	AO2	AO3	Total	Maths	Prac
(a)	**Methodology** • Take readings of diameter at more than one point and determine mean diameter. • Tape the wire to the ruler (or move wire close to the ruler) • Ensure wire is taut (kink free) • Obtain values for R for at least 5 different values for l • Most/all of the length of the wire used to take readings from. • Obtain value for resistance of crocodile clips and subtract from each reading of R. **Analysis** • Calculate CSA from $\frac{\pi d_{mean}^{\ 2}}{4}$ • Plot graph of R against l • Determine gradient of graph • ρ =gradient × A **Uncertainties** • Check zero error for micrometer (or state that 'any' zero error should be subtracted from each reading of diameter). Or close callipers and press 'zero' button. • Plot uncertainties on R-axis from repeat readings of R **Other possible answers** {Uncertainty in $\frac{R}{l}$ obtained from graph (no details)} {Total % uncertainty in ρ calculated from % unc in gradient + % unc in A.}	4		2	6		6
	5-6 marks At least 7 clear points made, but must include at least one statement from each of methodology, analysis and uncertainties *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3-4 marks** At least 5 clear points made and must include at least one statement from each of methodology and analysis. *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.* **1-2 marks** At least 3 clear points made. *There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.* **0 marks** *No attempt made or no response worthy of credit.*						
(b)	$R_{total} = \frac{V^2}{P} = \frac{14.3^2}{45}$ = 4.5[44 Ω] [1] R of each strip = 4 × 4.5[44] = 18[.176 Ω] [1] A calculated = $\frac{\rho l}{R} = \frac{6.0 \times 10^{-8} \times 1.2}{18}$ = 4.0 × 10^{-7} [m²] [1] (**ecf** on R, even if total R used) A = 3.96 × 10^{-7} if 18.176 Ω used. Thickness = $\frac{4.0 \times 10^{-7}}{2.0 \times 10^{-3}}$ = 2.0 × 10^{-4} [m] (0.2 mm) and appropriate statement e.g. can be achieved [1] (Thickness = 0.198 mm if A = 3.96 × 10^{-7} used) **Alternative:** Find power used for thickness of 0.2 mm: A = 2 × 10^{-3} × 0.2 × 10^{-3} = 4.0 × 10^{-7} [m²][1] $R = \frac{\rho l}{A}$ = 18 [Ω] [1] Total R = 4.5 [Ω] [1] $P = \frac{14.3^2}{4.5}$ = 45.4 [W] and appropriate statement [1] **Or alternative for final two marks above:** $P = \frac{14.3^2}{18}$ = 11.4 [W] for each strip [1] Total P = 11.4 × 4 = 45.4 [W] and appropriate statement [1]			4	4	4	
	Question total	**4**	**0**	**6**	**10**	**4**	**6**

#4

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
10	*(a)*		Flux changes in ring as it approaches [or recedes from] magnet (1) Emf induced (1) [or by implication by next marking point] Current induced (complete circuit) (1) [Motor effect force] opposes motion or energy lost or Lenz's law stated(1)		4		4		
	(b)		Nothing [or equiv](1) Always opposes motion (Lenz) / field in opposite direction / current in opposite [not: the force opposite] (1)		2		2		
	(c)		Length = $2\pi r$ used (1) [0.157 m] $R = \frac{1.59\times10^{-8}\times2\pi\times0.025}{2.4\times10^{-5}}$ seen (or 1.04×10^{-4} [Ω] seen) (1)	1	1		2	1	
	(d)		Ohm's law used (1) $\text{Emf} = \frac{BNA}{t}$ i.e. Faraday's used (1) [= 0.55 mV] [NB c.s.a of wire used → no credit and no ecf] Answer, $\frac{B}{t}$ = 0.29 T s^{-1} (or 0.28 depending on rounding)(1)	1	1 1		3	2	
			Question 10 total	**2**	**9**	**0**	**11**	**3**	**0**

#5

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)		Using $I = nAve$ (1) Area calculated correctly = 1.96×10^{-7} m^2 (1) $n = 18\times10^{28}$ [m^{-3}] (1) Drift velocity v = 0.000496 or 0.0005[0] m s^{-1} **unit mark** (1)	1	1 1 1		4	4	
	(b)		Current remains the same as do n and e (1) [Cross-sectional] area less in thinner portion (1) Correct conclusion needs to be qualified - drift velocity is <u>greater</u> in thinner portion (1)			3	3		
	(c)	(i)	Superconductor is when R = 0 accept negligible	1			1		
		(ii)	**Advantage** No power / energy loss [in the power lines] (1) power lines needs to be referenced if referring to 100% efficient As R = 0 [and $P = I^2R$] / no heat (1) **Or** Use in MRI scanners / particle accelerators (1) High currents / large magnetic fields (1) **Disadvantage** Operates at very low temperature (1) Extra energy/apparatus required to cool the wires (1) **Or** Due to cooling [the materials] (1) Cost is high (needs to be qualified) (1)		4		4		
			Question total	**2**	**7**	**3**	**12**	**4**	**0**

#6

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)		Electrical energy (or work) transferred [to other forms] per unit [accept coulomb] of charge [passing between the two points]	1			1		
	(b)		**Either:** I in circuit = $\frac{2.4}{160}$ (1) [= 15.0 mA] $R_{Thermistor} = \frac{(12.0-2.4)(1)}{15.0 \times 10^{-3}}$ [**ecf** on I] = 640 [Ω] (1) **Or:** $R_T = \frac{9.6(1)}{2.4} \times 160$ (1) **or** $2.4 = \frac{12 \times 160}{160 + R_T}$ (2) = 640 [Ω] (1)	1	1 1		3	3	
	(c)	(i)	[Resistance of thermistor decreases as temp increases] pd across thermistor decreases (1) So pd across fixed resistor increases **because**: **Either** - ratio of pds across potential divider changes **Or** - total pd must = 12.0 V (or equivalent) (1) **Alternative:** [Resistance of thermistor decreases as temp increases] so circuit current increases (1) So pd across fixed resistor increases **because** $V = IR$ and R is constant or $V \propto I$ (1)		2		2		
		(ii)	At 30 °C, $R_{thermistor}$ = 480 Ω from graph (1) $V_{cooling\ system} = \frac{160}{(480+160)} \times 12.0$ (1) [**ecf** on $R_{Thermistor}$] = 3.0 [V] (1) **Alternative:** $2.8 = \frac{160}{(R_{Thermistor}+160)} \times 12.0$ (1) $R_{Thermistor}$ = 526 [Ω] (1) Corresponds to 25 °C from graph (1) **Alternative:** $I_R = \frac{2.8}{160} = 0.0175$ [A] (1) $R_T = \frac{9.2}{0.0175} = 526$ [Ω] (1) Corresponds to 25 °C from graph (1) **Alternative:** $I_R = \frac{2.8}{160} = 0.0175$ [A] (1) At 30 °C, $R_{thermistor}$ = 480 Ω from graph (1) $I_T = \frac{9.2}{480} = 0.0192$ [A] (1) **Alternative:** At 30 °C, $R_{thermistor}$ = 480 Ω from graph (1) $I = \frac{V}{R} = \frac{12}{(480+160)} = 0.01875$ [A] (1) $V = IR = 0.01875 \times 160 = 3$ [V] (1) **Final mark for all methods - Valid conclusion consistent with answer:** i.e. Claim incorrect - system activated at $\theta < 30$ °C (1)			4	4	3	
	(d)		More effective at 0 °C – 10 °C (no mark) Because: Steeper gradient / larger change in resistance (1) Greater sensitivity in this range / greater [fractional] change in R per °C change in temperature or over the same temperature range) (1)			2	2		2
			Question total	**2**	**4**	**6**	**12**	**6**	**2**

#7

Question	Marking details	Marks available					
		AO1	AO2	AO3	Total	Maths	Prac
(a)	Method for obtaining N e.g. $\frac{4\,000}{0.25 \times 10^{-3}}$ (1) Use of πd or $2\pi r$ (1) 1 508 m or $16\,000 \times \pi \times 0.03$ seen or equivalent (1)	1	1 1		3	3	
(b)	$R = \frac{\rho l}{A}$ used and $I = \frac{V}{R}$ used (1) 0.25 mm used as diameter for area or (0.125 mm as radius) (1) 24.6 mA seen or $\frac{12}{488}$ or $\frac{12}{486}$ seen or equivalent evidence (1)	1	1 1		3	3	
(c)	$n = \frac{N}{\text{length}}$ (1) Answer = 1.23×10^{-4} [T] (1) Award 1 mark only for answer of 3.35×10^{-7} [T]	1	1		2	2	
(d)	$B = \mu_0 nI$ used to calculate I **ecf** (1) Correct conclusion stated and consistent with calculation (1) Wires would melt / damaged / burnt / become hot / use superconductor / use cooling (1)			3	3	1	
	Question total	**3**	**5**	**3**	**11**	**9**	**0**

#8

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
1	*(a)*		*V*- 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] $r_{cell} = 0.6$ [Ω] [1]		3		3	2	
		(ii)	Substitution into I^2rt i.e. $(0.42)^2 \times 0.6 \times 60$ (**ecf** on *I*, *r*) [1] **Alternative:** Substitution into $\frac{V^2t}{r}$ i.e. $\frac{(0.25)^2 \times 60}{0.6}$ (**ecf** on *V*, *r*) **Alternative:** Substitution into IVt i.e. $0.42 \times 0.25 \times 60$ (**ecf** on *I*, *V*) Energy dissipated = 6.3 [J] [N.B. Alternative → 6.4 J] [1]	1	1		2	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**

#9

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
3	(a)		Use of $s = \frac{1}{2}(u+v)t$ (1) t = 14.6 [s] (1)	1	1		2	2	
	(b)		Gain in KE = 4 020 – 962 = 3 058 [J] (1) Gain in PE = 95 × 9.8 × 4 = 3 728 [J] (1) Total = 3 058 + 3 728 = 6 786 [J] ecf (1)		3		3	3	
	(c)	(i)	Use of $E = VIt$ (1) 3 679 or 3 680 [J] ecf (1)	1	1		2	2	
		(ii)	Useful energy of motor = *(b)* – 6 500 = 1 286 [J] (1) Efficiency $= \frac{1286}{3679} \times 100 = 35$ [%] (1) ecf from (c)(i)		2		2	2	
		(iii)	Friction within motor / between front tyre and road (not just 'friction') (1) Air resistance on bike and Helen (1) Do not accept just heat / sound loss	2			2		
	(d)		Yes compared to petrol vehicles no [direct] emissions (1) ..and power station emissions [of CO_2, PM2s etc] much less than petrol vehicles			2	2		
			Question 3 total	**4**	**7**	**2**	**13**	**9**	**0**

#10

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)		Label axis with units and suitable scale (1) Plot all points correctly ± ½ small square division (1) Draw a smooth curve with maximum between 2.3 and 2.6 Ω **no** straight lines present (no requirement to extend back to the origin) (1)	1	1 1		3	3	3
	(b)	(i)	6.0 [J] of [chemical] energy transferred/converted/work done to electrical [potential] energy (1) Per unit charge [or coulomb] [flowing through the cell/battery] (1)	2			2		2
		(ii)	Using $P = I^2R$ (1) Data point from graph when R = 4.5 Ω, P = 3.64 W (1) Need 2 dp and within ± ½ small square Calculation of current correctly i.e. = 0.90 [A] (1)	1	1 1		3	3	3
		(iii)	Using $E = V + Ir$ (1) Substituting correct values 6 = 0.90 × 4.5 + 0.90r **ecf** (1) Internal resistance = 2.2 [Ω] (1)	1	1 1		3	3	3
	(c)		Power is higher/greater/larger (1) Total resistance of circuit is less for all values of R (1) Accept peak of graph shifts to left			2	2		2
			Question total	**5**	**6**	**2**	**13**	**9**	**13**

#11

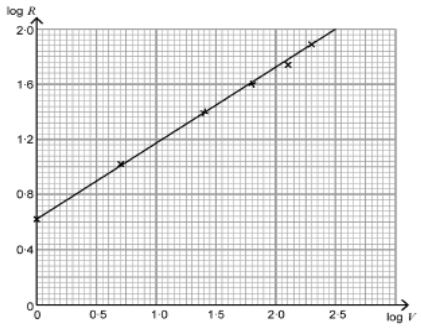
Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)	(i)	For Left Hand Combination: $\frac{1}{R_{parallel}} = \frac{1}{2R} + \frac{1}{R} + \frac{1}{2R}$ (RHS seen in any correct form e.g. $\frac{4}{2R}$)(1) $= \frac{R}{2}$ (1) Total $R = \frac{R}{2} + R$ or $\frac{3R}{2}$ seen (1) **Alternative solutions possible** e.g. Sum of top and bottom branch = R (1) Then parallel branch = $\frac{R}{2}$ (1) Total $R = \frac{R}{2} + R$ (1)		3		3	3	
		(ii)	Right hand resistor circled (1) Greatest current / greatest voltage (1)		2		2		
	(b)		Correct substitution into $l = \frac{RA}{\rho}$ i.e. $\frac{2.0 \times 10^{3} \times 250 \times 10^{-9} \times 0.25 \times 10^{-3}}{1.20 \times 10^{-6}}$ (1) l = 0.10 [m] (1) (**ecf** on slip in powers of 10)	1	1		2	2	
	(c)	(i)	n- free electron density. Accept- number of free electrons per unit volume or per m^3 (or equivalent)	1			1		
		(ii)	<table><tr><th>Ratio</th><th>Value</th><th>Explanation</th></tr><tr><td>$\frac{n_X}{n_Y}$</td><td>1</td><td>Wires made of the same material</td></tr><tr><td>$\frac{I_X}{I_Y}$</td><td>1</td><td>Wires in series</td></tr><tr><td>$\frac{v_X}{v_Y}$</td><td>0.25</td><td>Correct explanation based on $A_X v_X = A_Y v_Y$ e.g $(d)^2 v_x = \left(\frac{d}{2}\right)^2 v_y$</td></tr></table> Award 1 mark for each correct row	1 1	1		3		
		(iii)	$R = \frac{\rho l}{A}$ substituted into $P = I^2 R$ i.e. $P = \frac{I^2 \rho l}{A}$ (1) $P_x = \frac{I^2 \rho_x l_x}{A_x}$ and $P_z = \frac{I^2 \rho_z l_z}{A_z}$ (or equivalent) - can award 1st mark from one of these expressions $A_x = 4A_z$ and $l_x = \frac{l_z}{2}$ and $\rho_x = 2\rho_z$ to show: (1) $\frac{P_z}{P_x}$ = 4 (1)		3		3	3	
			Question total	**4**	**10**	**0**	**14**	**8**	**0**

#12

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
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 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**

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_{total} = 1.44 [Ω] (1)	1	 1 1		3	2	3
	(b)	(i)	(A4/emf) is the energy generated in the cell (1) per coloumb (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 1		6	1	
		(ii)	Substituting values in $\frac{\text{A7-E7}}{\text{D7}}$ (1) r = 0.15 [Ω] (1)	1	 1		2	2	
		(iii)	Using $P = I^2R$ (1) P = 0.45 [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**

#14

Question			Marking details	Marks available					
				AO1	AO2	AO3	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)		V / V | I / A | R / Ω | ln(V/V) | ln(R/Ω) 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** $\ln V$ 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] **$\log_{10}(V/V)$** | **$\log_{10}(R/\Omega)$** 0.00 | 0.28 0.30 | 0.45 0.60 | 0.61 0.78 | 0.70 0.90 | 0.76 1.00 | 0.81 Accept 2 or 3 sig figs in all cases. Accept 4 sig. Figs for ln V at 10.00 V (= 2.302) [1]		3		3	3	3
	(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 $\ln(V/\text{V})$ 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 ≥ half available space] [1] All points plotted correctly within ±< small square division [2] 5 points plotted correctly within ±< small square division [1] 4 or less points plotted correctly within ±< 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**

#15

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	*(a)*	(i)	Using $R = \frac{\rho l}{A}$ (1) Area = $\frac{\pi d^2}{4} = 6.16 \times 10^{-8}$ m² (1) Resistivity = $1.62 \times 10^{-8}\,\Omega$m **unit mark** (1)	1	1 1		3	2	
		(ii)	$p_l = \frac{0.1}{32.4} \times 100\% = 0.3\%$ or statement – negligible (1) $p_A = 2 \times p_d = 7.1\%$ (1) Total percentage uncertainty = 12% (ecf) (1) Abs unc (resistivity) = ± 0.2 × 10^{-8} [Ωm] 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 x 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**