WJEC EDUQAS A-LEVEL PHYSICS · COMPONENT 2

PHYSICS



EXAM QUESTION PACK

2.1 CONDUCTION OF ELECTRICITY

SCORE	PERCENTAGE
/78	%

STEMUP

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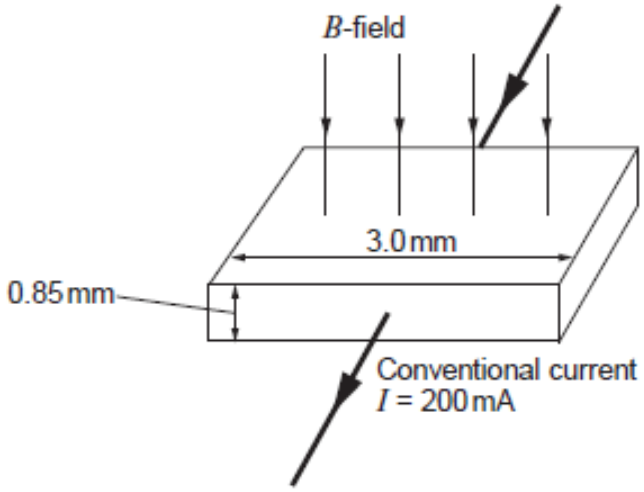
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#1

9. *(a)* The silicon chip shown in the diagram is used as a Hall probe with electrons as the charge carriers. Explain how the Hall voltage arises and which face of the chip becomes positively charged. [4]



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(b) The concentration of conduction electrons is $2.4 \times 10^{24}\,m^{-3}$. Calculate the mean drift velocity of the electrons. [2]

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(c) The Hall voltage, V_H, for this chip can be expressed as:

$$V_H = kB$$

where k is a constant and B is the magnetic flux density. Calculate a value for k and **state its unit.** [3]

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Question taken from Eduqas examination paper 842103, June 2019

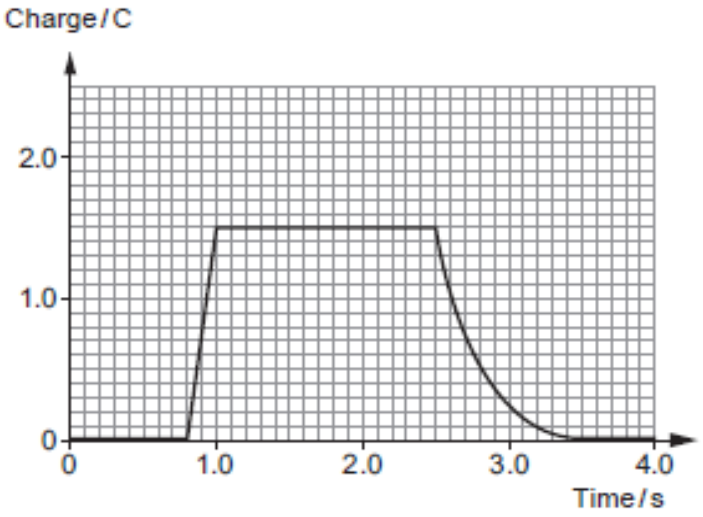
#2

4. *(a)* Define electric current. [1]

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(b) The following graph shows how the **charge** that has passed a point in an electrical circuit varies with time.



(i) Describe how the **current** varies from $t = 0$ to $t = 2.5\,s$ giving appropriate values. [4]

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(ii) Calculate the **current** when $t = 3.0\,s$. [3]

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Question taken from Eduqas examination paper 842002, June 2018

#3

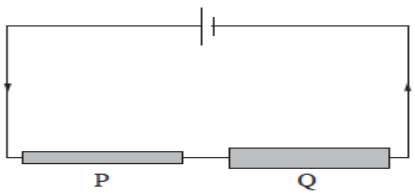
(a) Compare the movement of free electrons in a metal **before** and **after** a pd is applied to the metal. [3]

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

$$I = nAve$$

where n is the number of free electrons per unit volume and v is the drift velocity of these electrons. Derive the formula. Include a clearly labelled diagram. [4]

(ii) Wires P and Q are connected to a fixed voltage source. Wire Q is made of a different metal from wire P and has fewer free electrons per unit volume. [$n_P = 6.4 \times 10^{28}\,m^{-3}$ and $n_Q = 2.0 \times 10^{28}\,m^{-3}$]. The diameter of wire Q is twice the diameter of wire P.

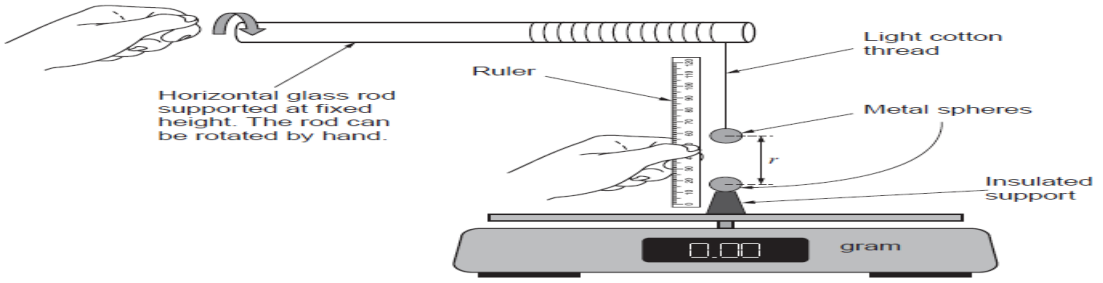


Determine the ratio $\frac{v_Q}{v_P}$. [3]

Question taken from Eduqas examination paper 842102, November 2020

#4

Two students, Ben and Sarah, use the following apparatus to investigate the 'inverse square' nature of Coulomb's law.



The **same** negative charge is placed on both spheres. The distance, r, between the centres of the spheres is varied and the reading on the top pan balance is noted. Sarah and Ben disagree on the best method to measure r.

Ben favours using a ruler with a resolution of 1 mm to measure it directly.

Sarah suggests measuring the diameter of the glass rod with Vernier calipers, with a resolution of 0.01 mm, to determine the circumference of the rod. The rod can then be rotated by hand, with each complete rotation corresponding to the calculated circumference.

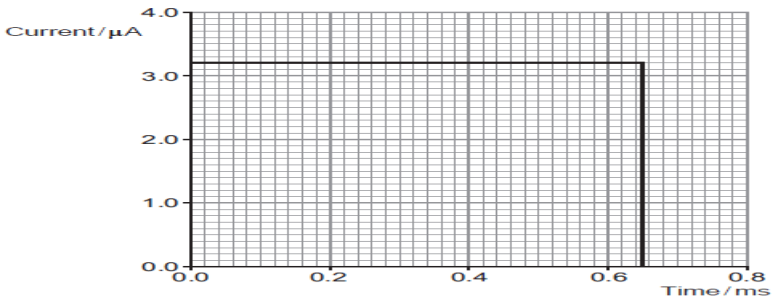
(a) (i) State an advantage and a disadvantage of each method. [4]

(ii) Suggest an improvement to **one** of the techniques which would increase the accuracy of measuring r. [1]

(b) When r = 20 mm, the reading on the top pan balance is 0.01 gram.

(i) Show that the value of Q_1Q_2, the product of the charges on the spheres, when r = 20 mm is approximately 4.4×10^{-18} C^2. [3]

(ii) One of the spheres is now discharged. The graph shows how the discharge current varies with time.



Show that the values given on the graph are consistent with the product Q_1Q_2 in *(b)*(i). [2]

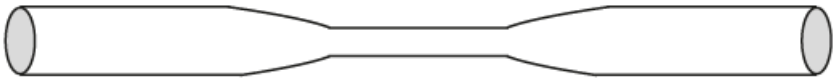
(iii) Hence, estimate the number of electrons on **one** sphere when the reading on the balance is 0.01 gram and r = 20 mm. [1]

Question taken from Eduqas examination paper 842102, June 2017

#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]

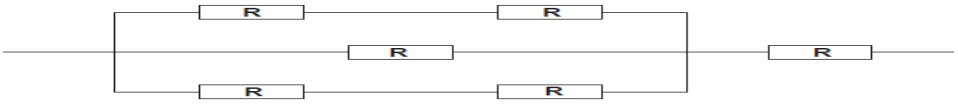
Advantage:

Disadvantage:

Question taken from Eduqas examination paper 842002, June 2017

#6

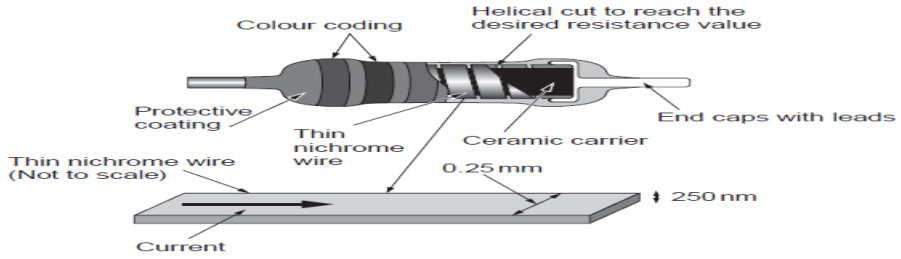
(a) The resistor network shown consists of six identical resistors, each of value **R** Ω.



(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.



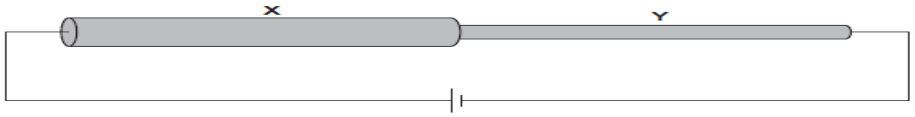
The wire used in such a resistor has a rectangular cross-section as shown. Determine the length of nichrome wire required to make a 2.0 kΩ resistor.
[Resistivity of nichrome = 1.20×10^{-6} Ω m] [2]

(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]

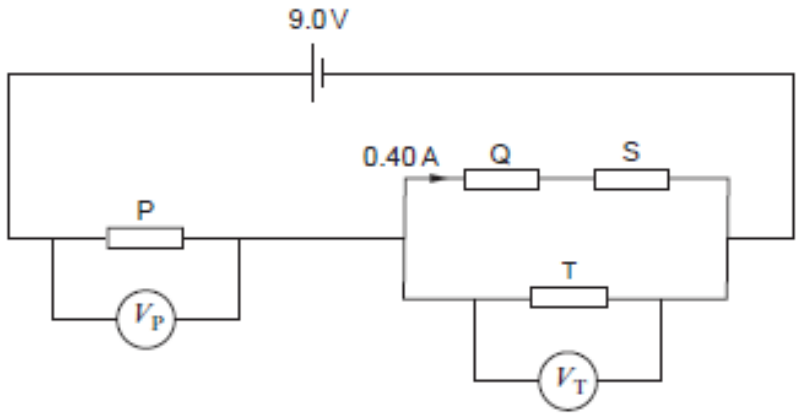
$$J\,s\,C^{-2}$$

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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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Question taken from Eduqas examination paper 842102, June 2018

Marking Scheme

#1

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
9	(a)		Force on charge carriers/electrons in mag field [1] [Force right] so left face becomes +ve [1] Electric field/voltage linked to charge movement [1] Electric force balances magnetic force / $V_H \propto B$ also constant I [1]	4			4		
	(b)		Correct application/substitution into equation $I = nAve$ [1] Answer = 0.204 [m s^{-1}] [1]		2		2	2	
	(c)		$eE = Bev$ used or equivalent e.g. $V = Bvd$ or $V = \frac{BI}{nte}$ [1] Correct comparison to get k e.g. $k = vd$ or $\frac{I}{nte}$ etc. [1] Correct answer = 6.13×10^{-4} V T^{-1} or m^2 s^{-1} or A m^2 C^{-1} unit mark, ecf on v [1]		3		3	3	
			Question 9 total	**4**	**5**	**0**	**9**	**5**	**0**

#2

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	(a)		Rate of flow of electric charge/electrons (1)	1			1		
	(b)	(i)	During t = 0 to t = 0.8 s current (or I) = 0 (1) Then there is a sudden increase at 0.8 s (1) Value of current = $\frac{1.5}{0.2}$ = 7.5 A (1) Current = 0 from t = 1.0 to 2.5 s (1)		4		4		
		(ii)	Tangent drawn to the graph at t = 3.0 s (1) Gradient calculated correctly (ignore negative sign) (1) Current in the range 1.0 ± 0.1 A (1)			3	3	3	
			Question 4 total	**1**	**4**	**3**	**8**	**3**	**0**

#3

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(a)			**Before pd applied**: [Free] electrons move randomly/no overall velocity/mean velocity zero/vector average velocity zero [1] **After pd applied:** [Free] electrons accelerated by pd/drift velocity/overall velocity due to pd [1] **Reference to speed either before or after pd applied:** [1] **e.g. either** • [Free] electrons move very quickly/magnitude approx. 10^6 m s^{-1} before pd is applied **or** • Drift velocity is small/magnitude approx. 10^{-3} or 10^{-4} m s^{-1} after pd is applied.	3			3		
	(b)	(i)		Volume = vtA or lA [1] can be obtained from diagram No of free electrons = $vtAn$ or lAn [1] Total charge = $vtAne$ or $lAne$ [1] Current = $\frac{vtAne}{t}$ or $\frac{lAne}{t}$ [1]	4			4	1	
		(ii)		$I_P = I_Q$ seen or implied- e.g. $n_P A_P v_P = n_Q A_Q v_Q$ [1] Substitution e.g. $6.4 \times A \times v_P = 2.0 \times 4A \times v_Q$ [1] Algebra to show $\frac{v_Q}{v_P} = \frac{6.4}{8}$ (or $\frac{4}{5}$ or 0.8) [1]	1	1 1		3	3	
				Question total	**8**	**2**	**0**	**10**	**4**	**0**

#4

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)	(i)	<table><tr><th></th><th>Advantage</th><th>Disadvantage</th></tr><tr><td>Ben (ruler)</td><td>Easy to use/convenient / quicker</td><td>Inaccurate [only to ± 1 mm] / reference to parallax errors / difficulty in supporting ruler / may touch spheres</td></tr><tr><td>Sarah (rod)</td><td>Diameter measured accurately / greater accuracy</td><td>Diameter/radius of spheres need to be known beforehand / difficult to judge one complete rotation / difficult to measure angle [of rotation] / difficult to set-up / thread overlapping</td></tr></table>4 × 1 mark - one response required from each cell.		4		4		4
		(ii)	**Any ×(1) from:** • Pins/markers on ruler • Marker on cylinder • Measure diameter of spheres • Mark point at centre of each sphere and use a travelling microscope to measure the separation • Fix the ruler close to spheres • Smaller diameter rod • Use of Vernier calipers (for Ben) Don't accept repeat readings			1	1		1
	(b)	(i)	$F = 9.81 \times 10^{-5}$ N (1) Use of $F = \frac{9 \times 10^9 Q_1 Q_2}{r^2}$ (1) $Q_1Q_2 = 4.36 \times 10^{-18}$ [C^2] (1)	1	1 1		3	3	3
		(ii)	$Q = (4.36 \times 10^{-18})^{1/2}$ determined (or use of 4.4×10^{-18}) = 2.09×10^{-9} C (1) Area under graph calculated: $3.2 \times 10^{-6} \times 0.65 \times 10^{-3}$ = 2.08×10^{-9} C (1) **Alternative:** Area, $Q = 2.08 \times 10^{-9}$ (1) So $QQ = (2.08 \times 10^{-9})^2 = 4.3 \times 10^{-18}$ C^2 (1)			2	2	2	2
		(iii)	$n = \frac{2.09 \times 10^{-9}}{1.6 \times 10^{-19}} = 1.31 \times 10^{10}$ electrons **ecf** on Q		1		1	1	1
			Question total	**1**	**7**	**3**	**11**	**6**	**11**

#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) $n = 18 \times 10^{28}$ [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)	(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**

#7

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 Ω (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**