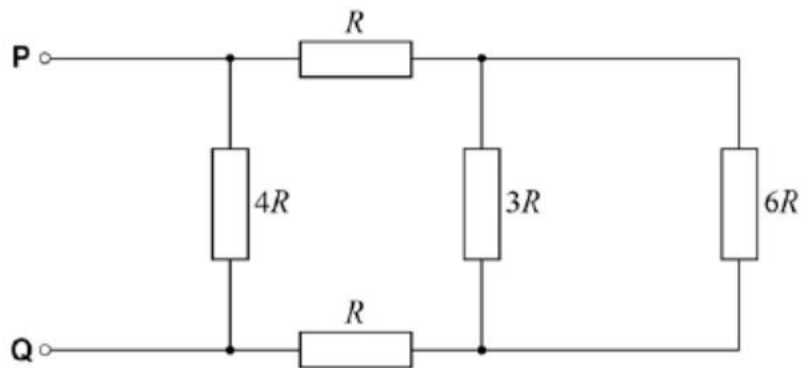


1 The diagram shows a network of resistors connected between the terminals **P** and **Q**.

The resistance of each resistor is shown.

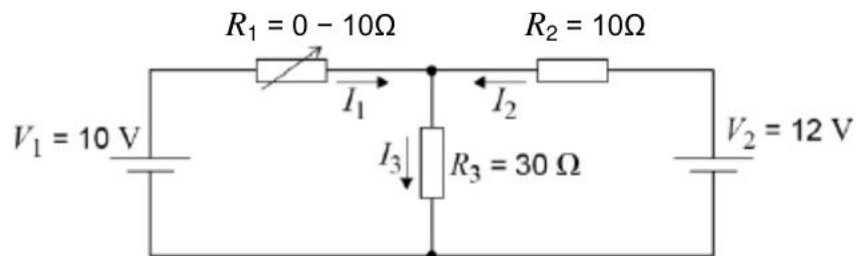


What is the effective resistance between **P** and **Q**?

- A R ☐
- B $2R$ ☐
- C $3R$ ☐
- D $4R$ ☐

(Total 1 mark)

2 The cells in the circuit shown in the figure below have zero internal resistance. Currents are in the directions shown by the arrows.



R_1 is a variable resistor with a resistance that varies between 0 and $10\ \Omega$.

(a) Write down the relationship between currents I_1 , I_2 and I_3 .

(1)

- (b) R_1 is adjusted until it has a value of $0\ \Omega$.

State the potential difference across R_3 .

potential difference = _____ V

(1)

- (c) Determine the current I_2 .

current = _____ J

(2)

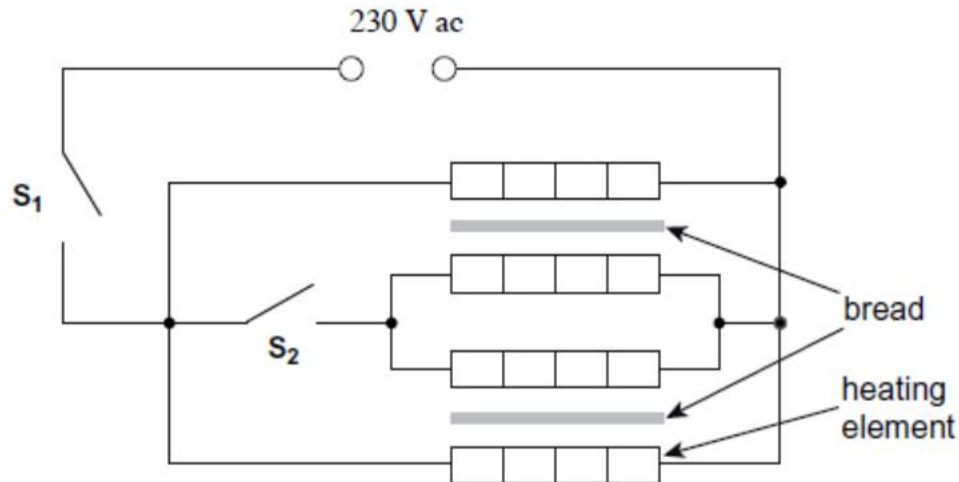
- (d) State and explain what happens to the potential difference across R_2 as the resistance of R_1 is gradually increased from zero.

(3)

(Total 7 marks)

3

The diagram shows the circuit diagram for a two-slice electric toaster that is operated at a mains voltage of 230 V.



The toaster has four identical heating elements and has two settings: normal and low. On the normal setting both sides of the bread are toasted. On the low setting, only one side of the bread is toasted. The setting is controlled by switches S_1 and S_2 .

The table shows the position of each switch and the power for each setting.

Setting	S_1	S_2	Power / W
Low	closed	open	400
Normal	closed	closed	800

- (a) Calculate the current in **S**₂ when the normal setting is selected.

current _____ A

(2)

- (b) (i) Show that the resistance of **one** heating element is approximately 260 Ω when the toaster is operating at its working temperature.

(2)

- (ii) Calculate the total resistance when the normal setting is selected.

resistance _____ Ω

(2)

- (iii) Each heating element is made of nichrome wire of diameter 0.15 mm.
The nichrome wire is wrapped around an insulating board.

Determine the length of nichrome wire needed to provide a resistance of 260 Ω .

resistivity of nichrome at the working temperature = $1.1 \times 10^{-6} \Omega \text{ m}$

length of wire _____ m

(3)

- (c) Explain why the resistivity of the nichrome wire changes with temperature.

(3)

- (d) The nichrome wire has an equilibrium temperature of 174°C when the toaster is operating.

Calculate the peak wavelength of the electromagnetic radiation emitted by the wire.

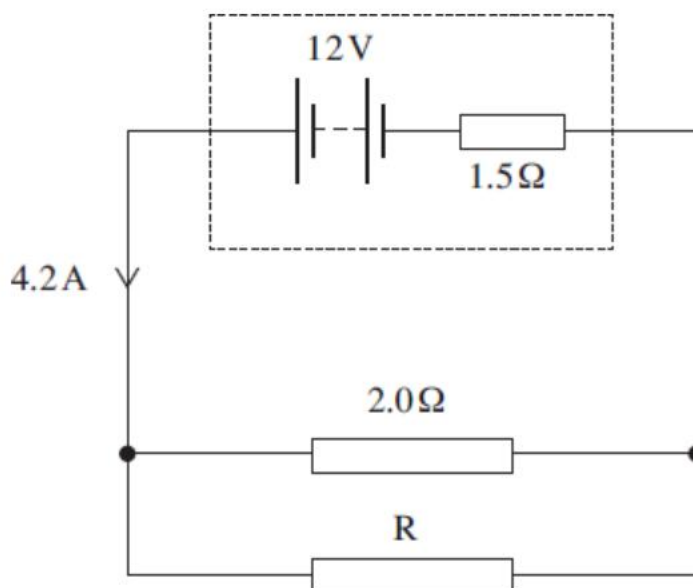
Give your answer to an appropriate number of significant figures.

peak wavelength _____ m

(3)

(Total 15 marks)

- 4 The circuit diagram below shows a battery of electromotive force (emf) 12 V and internal resistance $1.5\ \Omega$ connected to a $2.0\ \Omega$ resistor in parallel with an unknown resistor, R . The battery supplies a current of 4.2 A .



- (a) (i) Show that the potential difference (pd) across the internal resistance is 6.3 V .

(1)

- (ii) Calculate the pd across the $2.0\ \Omega$ resistor.

pd _____ V

(iii) Calculate the current in the $2.0\ \Omega$ resistor.

current _____ A

(1)

(iv) Determine the current in R.

current _____ A

(1)

(v) Calculate the resistance of R.

R _____ Ω

(1)

(vi) Calculate the total resistance of the circuit.

circuit resistance _____ Ω

(2)

(b) The battery converts chemical energy into electrical energy that is then dissipated in the internal resistance and the two external resistors.

(i) Using appropriate data values that you have calculated, complete the following table by calculating the rate of energy dissipation in each resistor.

resistor	rate of energy dissipation / W
internal resistance	
$2.0\ \Omega$	
R	

(3)

- (ii) Hence show that energy is conserved in the circuit.

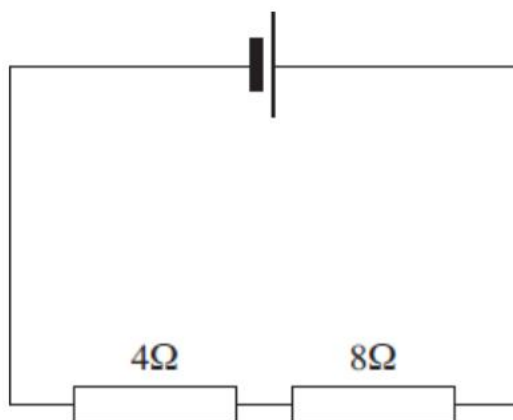
(2)

(Total 12 marks)

5

- (a) The cell in **Figure 1** has an emf of 3.0 V and negligible internal resistance.

Figure 1



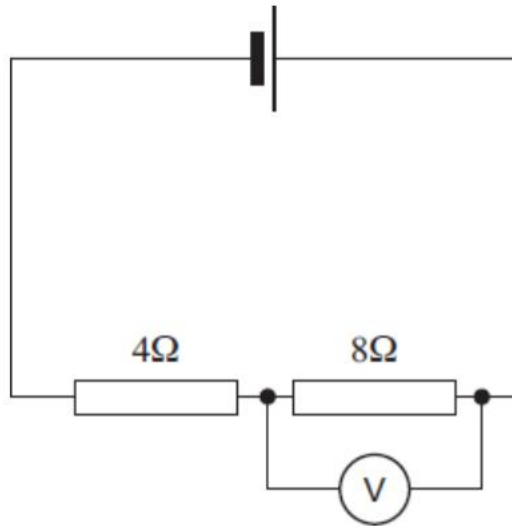
Calculate the potential difference across the 8Ω resistor.

potential difference _____ V

(2)

- (b) **Figure 2** shows the same circuit with a voltmeter connected across the $8\ \Omega$ resistor.

Figure 2



The voltmeter reads 1.8 V. Calculate the resistance of the voltmeter.

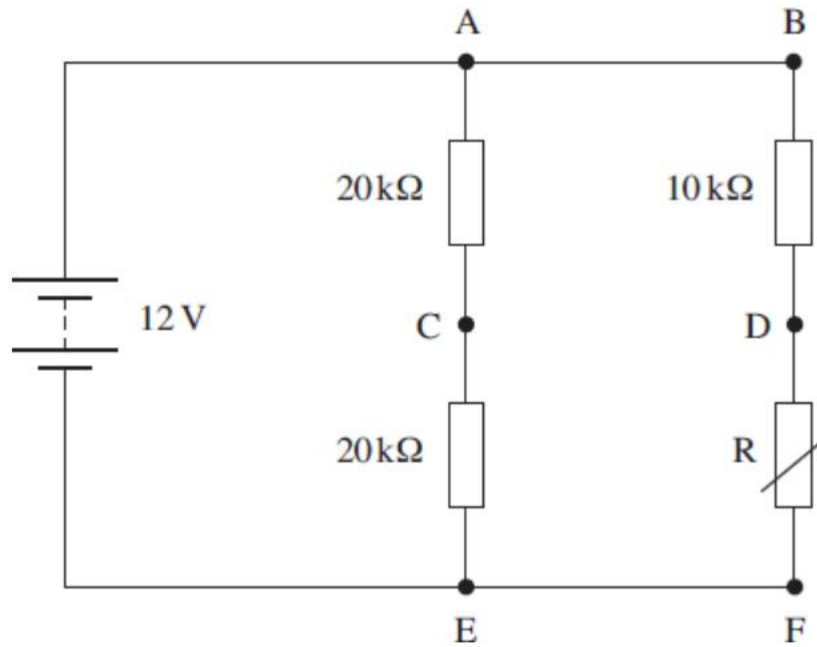
resistance _____ Ω

(3)

(Total 5 marks)

6

The circuit diagram below shows a 12 V battery of negligible internal resistance connected to a combination of three resistors and a thermistor.



(a) When the resistance of the thermistor is $5.0\text{ k}\Omega$

(i) calculate the total resistance of the circuit,

total resistance = _____ $\text{k}\Omega$

(3)

(ii) calculate the current in the battery.

current = _____ mA

(1)

- (b) A high-resistance voltmeter is used to measure the potential difference (pd) between points A-C, D-F and C-D in turn.
Complete the following table indicating the reading of the voltmeter at each of the three positions.

voltmeter position	pd / V
A-C	
D-F	
C-D	

(3)

- (c) The thermistor is heated so that its resistance decreases. State and explain the effect this has on the voltmeter reading in the following positions.

(i) A-C _____

(2)

(ii) D-F _____

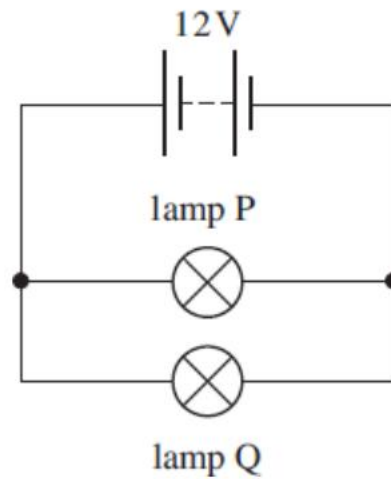
(2)

(Total 11 marks)

7

A battery of negligible internal resistance is connected to lamp P in parallel with lamp Q as shown in **Figure 1**. The emf of the battery is 12 V.

Figure 1



(a) Lamp P is rated at 12 V 36 W and lamp Q is rated at 12 V 6 W.

(i) Calculate the current in the battery.

answer = _____ A

(2)

(ii) Calculate the resistance of P.

answer = _____ Ω

(1)

(iii) Calculate the resistance of Q.

answer = _____ Ω

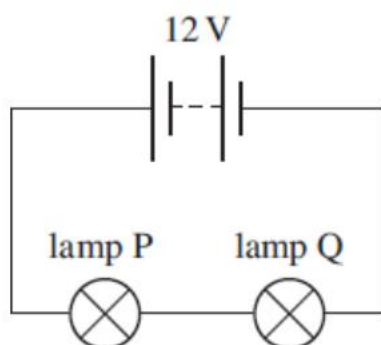
(1)

- (b) State and explain the effect on the brightness of the lamps in the circuit shown in **Figure 1** if the battery has a significant internal resistance.

(3)

- (c) The lamps are now reconnected to the 12 V battery in series as shown in **Figure 2**.

Figure 2



- (i) Explain why the lamps will not be at their normal brightness in this circuit.

(2)

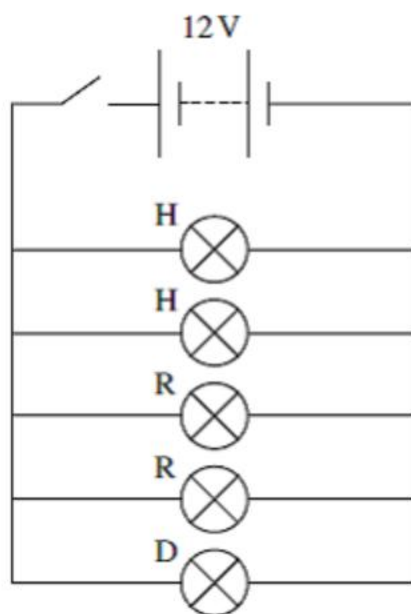
- (ii) State and explain which of the lamps will be brighter assuming that the resistance of the lamps does not change significantly with temperature.

(3)

(Total 12 marks)

8

The Figure below shows a simplified circuit for the main lights on a car. The battery has an emf of 12 V and no internal resistance.



The table below gives data about the lamps being used in the circuit. The resistances given are correct when the lamp is operating at its normal operating voltage.

LAMP	OPERATING VOLTAGE V	RESISTANCE Ω
H, headlight lamp	12	3.8
R, rear lamp	12	5.6
D, dashboard lamp	12	72

- (a) (i) Calculate the power of a single headlight lamp when operating at 12 V.

power _____ W

(2)

- (ii) Calculate the resistance of the combination of lamps when operating at 12 V.

resistance _____ Ω

(3)

- (iii) Calculate the total power of the combination of lamps when operating at 12 V.

power _____ W

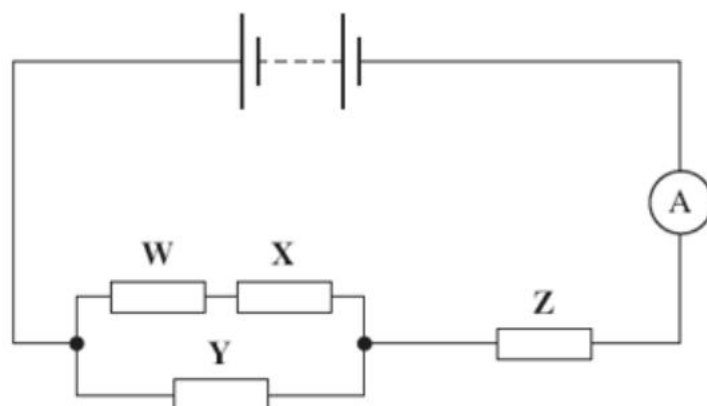
(2)

- (b) The battery is replaced with one of a lower emf. State and explain how the resistance of the lamps would have to change in order to achieve the same brightness.

(2)

(Total 9 marks)

- 9** The circuit shown in the figure below shows an arrangement of resistors, **W**, **X**, **Y**, **Z**, connected to a battery of negligible internal resistance.



The emf of the battery is 10V and the reading on the ammeter is 2.0 A.

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

answer = _____ Ω

(1)

- (ii) The resistors **W**, **X**, **Y**, and **Z** all have the same resistance. Show that your answer to part (a) (i) is consistent with the resistance of each resistor being $3.0\ \Omega$.

answer = _____ Ω

(3)

- (b) (i) Calculate the current through resistor **Y**.

answer = _____ A

(2)

- (ii) Calculate the pd across resistor **W**.

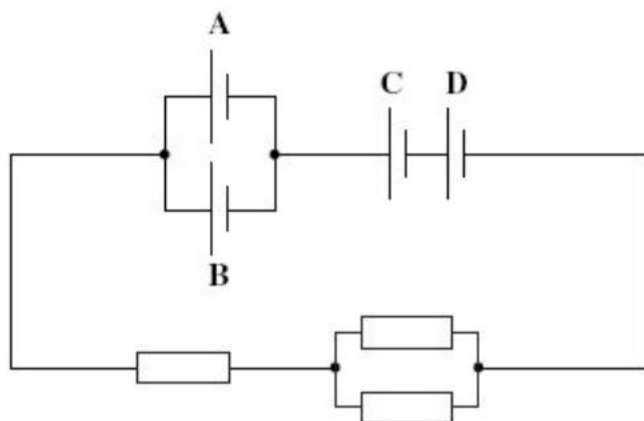
answer = _____ V

(2)

(Total 8 marks)

10

The circuit in the diagram below contains four identical new cells, **A**, **B**, **C** and **D**, each of emf 1.5V and negligible internal resistance.



(a) The resistance of each resistor is $4.0\ \Omega$.

(i) Calculate the total resistance of the circuit.

answer = _____ Ω

(1)

(ii) Calculate the total emf of the combination of cells.

answer = _____ V

(1)

(iii) Calculate the current passing through cell **A**.

answer = _____ A

(2)

- (iv) Calculate the charge passing through cell **A** in five minutes, stating an appropriate unit.

answer = _____

(2)

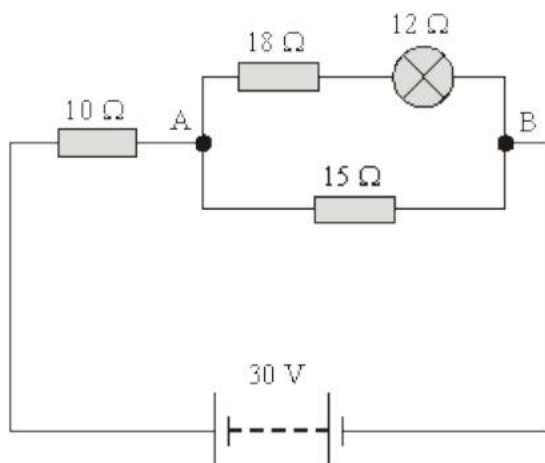
- (b) Each of the cells can provide the same amount of electrical energy before going flat. State and explain which two cells in this circuit you would expect to go flat first.

(3)

(Total 9 marks)

11

In the circuit shown in the figure below, the battery, of negligible internal resistance, has an emf of 30 V. The pd across the lamp is 6.0 V and its resistance is $12\ \Omega$.



- (a) Show that the total resistance of the circuit is $20\ \Omega$.

(3)

- (b) Calculate

- (i) the current supplied by the battery,

- (ii) the pd between the points A and B,

- (iii) the current in the lamp.

(4)

- (c) (i) What is the power of the lamp, in W?

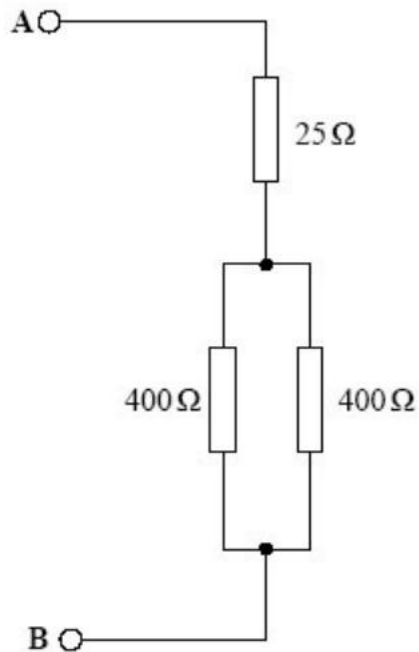
- (ii) What percentage of the power supplied by the battery is dissipated in the lamp?

(3)

(Total 10 marks)

12

The diagram below shows an arrangement of resistors.



- (a) Calculate the total resistance between terminals **A** and **B**.

answer = _____ Ω

(2)

- (b) A potential difference is applied between the two terminals, **A** and **B**, and the power dissipated in each of the $400\ \Omega$ resistors is $1.0\ \text{W}$.

- (i) Calculate the potential difference across the $400\ \Omega$ resistors.

answer = _____ V

- (ii) Calculate the current through the $25\ \Omega$ resistor.

answer = _____ A

- (iii) Calculate the potential difference applied to terminals **A** and **B**.

answer = _____ V

(6)

(Total 8 marks)

13

- (a) A student is given three resistors of resistance $3.0\ \Omega$, $4.0\ \Omega$ and $6.0\ \Omega$ respectively.

- (i) Draw the arrangement, using all three resistors, which will give the largest resistance.

- (ii) Calculate the resistance of the arrangement you have drawn.

- (iii) Draw the arrangement, using all three resistors, which will give the smallest resistance.

- (iv) Calculate the resistance of the arrangement you have drawn.

(5)

- (b) The three resistors are now connected to a battery of emf 12 V and negligible internal resistance, as shown in **Figure 1**.

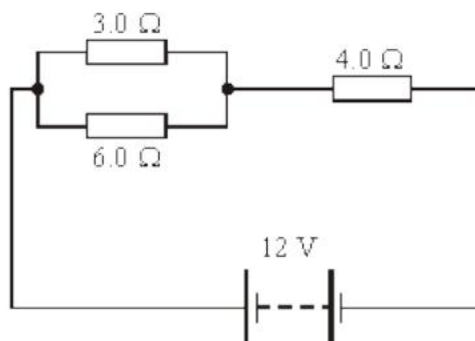


Figure 1

- (i) Calculate the total resistance in the circuit.

- (ii) Calculate the voltage across the $6.0\ \Omega$ resistor.

(4)

(Total 9 marks)

14

- (a) For a conductor in the form of a wire of uniform cross-sectional area, give an equation which relates its resistance to the resistivity of the material of the conductor. Define the symbols used in the equation.

(2)

- (b) (i) An electrical heating element, made from uniform nichrome wire, is required to dissipate 500 W when connected to the 230 V mains supply. The cross-sectional area of the wire is $8.0 \times 10^{-8}\ \text{m}^2$. Calculate the length of nichrome wire required.

resistivity of nichrome = $1.1 \times 10^{-6}\ \Omega\ \text{m}$

- (ii) Two heating elements, each rated at 230 V, 500 W are connected to the 230 mains supply

(A) in series,

(B) in parallel.

Explain why only one of the circuits will provide an output of 1 kW.

(6)

(Total 8 marks)

Mark schemes

1	B	[1]
2	(a) $I_3 = I_1 + I_2$ ✓	
	(b) 10 V ✓	1
	(c) $I_2 = (12 - 10) / 10$ ✓ <i>Allow ce for 10 V</i>	1
	= 0.2 A ✓ <i>The first mark is for the pd</i> <i>The second is for the final answer</i>	1
	(d) pd across R_2 increases	1
	As R_1 increases, pd across R_1 increases as $pd = I_1 R_1$ ✓ <i>First mark is for identifying that pd across R_1 increases (from zero).</i>	1
	pd across $R_3 = 10$ V – pd across R_1	
	Therefore pd across R_3 decreases ✓ <i>Second mark is for identifying that pd across R_3 must decrease</i>	1
	pd across $R_2 = 12$ – pd across R_3	
	Therefore pd across R_2 increases ✓ <i>Third mark is for identifying that this means pd across R_2 must increase</i>	1
		[7]
3	(a) Correct substitution into $P=VI$ 1.74 (A)	2
	(b) (i) Correct substitution into $R=V/I$ or V^2/P or P/I^2 264 (Ω) <i>Allow correct use of parallel resistor equation</i>	2
	(ii) Use of $1/R_T = 1/R_1 + 1/R_2$ or $R = V^2/P$ 65 (66.1) (Ω)	

(iii) $A = \pi(1.5 \times 10^{-4})^2/4$ or $\pi(7.5 \times 10^{-5})^2$ or $1.767 \times 10^{-8} \text{ (m}^2\text{)}$

Substitution into $l=RA/\rho$ with their area

4.2 (4.18) (m)

2 marks for 17 (m), using of d instead of r

3

(c) Resistivity / resistance increases with increasing temperature

(Lattice) ions vibrate with greater amplitude

Rate of movement of charge carriers / electrons (along wire)

reduced (for given pd)

ORA

Condone atoms for ions.

Accept "vibrate more".

Accept more frequent collisions occur between electrons and ions

owtte

3

(d) $2.9 \times 10^{-3}/447$ or $2.9 \times 10^{-3}/174$ seen

$6.5 \text{ (6.49)} \times 10^{-6} \text{ (m)}$

Correct answer given to 2 sig fig

Condone use of 174 for T for C1 and B1 marks

Allow 3 sig fig answer if 2.90×10^{-3} used

3

[15]

4

(a) (i) *(use of $V=Ir$)*

$V = 4.2 \times 1.5 \checkmark = 6.3 \text{ (V)}$

1

(ii) $\text{pd} = 12 - 6.3 = 5.7 \text{ V} \checkmark$

NO CE from (i)

1

(iii) *(use of $I = V / R$)*

$I = 5.7 / 2.0 = 2.8(5) \text{ A} \checkmark$

CE from (ii)

(a(ii)/2.0)

accept 2.8 or 2.9

1

(iv) $I = 4.2 - 2.85 = 1.3(5) \text{ A} \checkmark$

CE from (iii)

(4.2 - (a)(iii))

accept 1.3 or 1.4

1

(v) $R = 5.7 / 1.35 = 4.2 \text{ } \Omega \checkmark$

CE from (iv)

(a(ii) / (a)(iv))

Accept range 4.4 to 4.1

1

$$(vi) \quad \frac{1}{R_{Parallel}} = \frac{1}{4.2} + \frac{1}{2.0} = 0.737 \checkmark$$

CE from (a)(v)

$$R_{parallel} = 1.35 \Omega$$

second mark for adding internal resistance

$$R_{total} = 1.35 + 1.5 \checkmark = 2.85 \Omega$$

OR

$$R = 12/4.2 \checkmark$$

$$R = 2.85 \Omega \checkmark$$

2

(b) (i)

resistor	Rate of energy dissipation (W)
1.5 Ω internal resistance	$4.2^2 \times 1.5 = 26.5 \checkmark$
2.0 Ω	$2.85^2 \times 2.0 = 16.2$ (15.68 – 16.82) $\checkmark$
R	$1.35^2 \times 4.2 = 7.7$ (7.1 – 8.2) $\checkmark$

CE from answers in (a) but not for first value

$$2.0: a(iii)^2 \times 2$$

$$R: a(iv)^2 \times a(v)$$

3

- (ii) energy provided by cell per second = $12 \times 4.2 = 50.4$ (W) $\checkmark$
 energy dissipated in resistors per second = $26.5 + 16.2 + 7.7 = 50.4 \checkmark$
 (hence energy input per second equals energy output)

if not equal can score second mark if an appropriate comment

2

[12]

5

(a) potential divider formula used or current found to be 0.25 A

C1

A1

allow 1 s.f.

2.0 V

1.0 V (with working) gains 1 mark

2

(b) $\text{main current} = 1.2 \text{ V} / 4 \Omega = 0.3 \text{ (A)}$

C1

$R_{\text{total}} = 1.8 \text{ V} / 0.3 \text{ A} = 6 \Omega$ or $I_g = 0.225 \text{ (A)}$

C1

$R_V = 24 \Omega$

A1

3

[5]

6

(a) (i) $1/R_{\text{total}} = 1/(40) + 1/(10+5) = 0.09167$
 $R_{\text{total}} = 10.9 \text{ k}\Omega$

3

(ii) $I = 12 / 10.9 \text{ k} = 1.1 \text{ mA}$

1

(b)

position	pd / V
AC	6.0
DF	4.0
CD	2.0

C.E. for CD

3

(c) (i) AC: no change
 constant pd across resistors / parallel branches
no CE from first mark

2

(ii) DF: decreases
 as greater proportion of voltage across fixed / 10 k Ω resistor
no CE from first mark

2

[11]

7

(a) (i) (use of $P=VI$)

$I = 36/12 + 6/12 = 3.5 \text{ (A)}$

2

(ii) (use of $V=IR$)

$R = 12/3 = 4 \text{ (}\Omega\text{)}$

1

(iii) $R = 12/0.50 = 24 \text{ (}\Omega\text{)}$

- (b) terminal pd/voltage across lamp is now less OR current is less ✓
 due to lost volts across internal resistance OR due to higher resistance ✓
 lamps less bright ✓

3

- (c) (i) current through lamps is reduced as resistance is increased **or**
 pd across lamps is reduced as voltage is shared ✓

hence power is less OR lamps dimmer ✓

2

- (ii) lamp Q is brighter ✓

lamp Q has the higher resistance hence pd/voltage across is greater ✓

current is the same for both ✓

hence power of Q greater ✓

3

[12]

8

- (a) (i) $P = V^2/R$ with substitution: 144/any resistance

C1

37.9 (W)

A1

2

- (ii) use of $1/R$ formula with substitution of some data
 even if not all five resistors

C1

correct calculation of $1/R$ (giving 0.897)

C1

1.11 (Ω)

A1

3

- (iii) 144/their aii

C1

129 to 131 (W) **ecf**

A1

- (b) lower resistance needed

B1

(to achieve) higher current (for I^2R to be the same)/
correct use of V^2/R

B1

2

[9]

9

- (a) (i) (use of $R = V/I$)

$$R = 10/2.0 = 5.0 \, \Omega \checkmark$$

1

(ii) $\frac{1}{R} = \frac{1}{3} + \frac{1}{3+3} = \frac{3}{6} \checkmark$

$$R = 2 \, (\Omega) \checkmark$$

$$R_{\text{total}} = 2 + 3 \checkmark (= 5 \, \Omega)$$

3

- (b) (i) voltage across Y = $10.0 - 2.0 \times 3.0 = 4.0 \, \text{V} \checkmark$

$$\text{current in Y} = 4.0/3.0 = 1.3 \, \text{A} \checkmark$$

2

- (ii) current through W = $0.67 \, \text{A} \checkmark$

$$\text{voltage} = 0.67 \times 3 = 2.0 \, \text{V} \checkmark$$

$$(\text{or } 4.0/2 = 2.0 \, \text{V} \checkmark)$$

2

[8]

10

- (a) (i) $6.0 \, (\Omega) \text{ (1)}$

1

- (ii) $4.5 \, (\text{V}) \text{ (1)}$

1

- (iii) (use of $I = V/R$)

$$I = 4.5/6.0 = 0.75 \, (\text{A}) \text{ (1)}$$

$$\text{current through cell A} = 0.75/2 = 0.375 \, (\text{A}) \text{ (1)}$$

2

- (iv) charge = $0.375 \times 300 = 112 \text{ (1) C (1)}$

2

- (b) cells C and D will go flat first or A and B last longer **(1)**

current/charge passing through cells C and D (per second) is double/more than that passing through A or B **(1)**

energy given to charge passing through cells **per second** is double or more than in cells C and D **(1)** or in terms of power

3

[9]

11

- (a) (for lamp and resistor) $18(\Omega) + 12(\Omega) = 30(\Omega)$ **(1)**

(in parallel) $\frac{1}{30} + \frac{1}{15} =$ **(1)** (gives $R = 10(\Omega)$)

(allow C.E. for wrong value in first step)

total resistance = $\frac{30}{3} + 10$ **(1)**

(= 20 Ω)

3

- (b) (i) (use of $V = IR$ gives) $I = \left(\frac{30}{20}\right) = 1.5 \text{ A}$ **(1)**

- (ii) $\text{pd}_{AB} = 30 - (10 \times 1.5)$ **(1)**
= 15V **(1)**

[or alternative method]

(allow C.E. for value of I from (i))

- (iii) $I_{\text{lamp}} = \frac{6}{12} = 0.5 \text{ A}$ **(1)**

[or alternative method] (allow C.E. for value of pd_{AB} from (ii))

4

- (c) (i) (lamp power) ($= I^2 R$) = $0.5^2 \times 12 = 3.0 \text{ (W)}$ **(1)**
(allow C.E. for value of I_{lamp} from (b) (iii))

- (ii) power from battery = $30 \times 1.5 = 45 \text{ (W)}$ **(1)**
(allow C.E. for value of I from (b) (i))

$$\% = \frac{3 \times 100}{45} = 6.7(\%)$$
 (1)

(allow C.E. for power in lamp and/or battery in (i))

3

[10]

12

- (a) (use of $1/R_{\text{total}} = 1/R_1 + 1/R_2$)

$$1/R_{\text{total}} = 1/400 + 1/400 = 2/400$$

$$R_{\text{total}} = 200 \, \Omega \text{ (1) (working does not need to be shown)}$$

$$\text{hence total resistance} = 25 + 200 = 225 \Omega \text{ (1)}$$

2

- (b) (i) (use of $P = V^2/R$)

$$1 = V^2/400 \text{ (1)}$$

$$V^2 = 400 \text{ (working does not need to be shown)}$$

$$V = 20 \text{ V (1)}$$

- (ii) (use of $I = V/R$)

$$I = 20/400 = 0.05 \text{ A (1) (working does not need to be shown)}$$

$$\text{hence current} = 2 \times 0.05 = 0.10 \text{ A (1)}$$

- (iii) (use of $V = IR$)

$$\text{pd across } 25 \Omega \text{ resistor} = 25 \times 0.10 = 2.5 \text{ V (1)}$$

(working does not need to be shown)

$$\text{hence maximum applied pd} = 20 + 2.5 = 22.5 \text{ V (1)}$$

6

[8]**13**

- (a) (i) three resistors in series (1)

$$(ii) R = 3.0 + 4.0 + 6.0 = 13 \, \Omega \text{ (1)}$$

- (iii) three resistors in parallel (1)

$$(iv) \frac{1}{R} = \frac{1}{3} + \frac{1}{4} + \frac{1}{6} = \frac{9}{12} \text{ (1)}$$

$$R = 1.3 \, \Omega \text{ (1)}$$

5

- (b) (i) two resistors in parallel give $\frac{1}{R'} = \frac{1}{3} + \frac{1}{6}$ and $R' = 2.0 \, \Omega$ (1)

$$\text{total resistance} = (2 + 4) = 6.0 \, \Omega \text{ (1)}$$

4

- (ii) divide the emf in the ratio of 2 : 4 (1)
to give 4.0 V (1)
[or any suitable method]

[9]

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(a) $R = \frac{\rho l}{A}$ (1)

ρ is resistivity, l is the length of the wire, A is the cross-sectional area (1)

2

(b) (i) $P = \frac{V^2}{R}$ (1)

$$R = \frac{230^2}{500} = 106(\Omega)(1) \quad (105.8 \Omega)$$

$$l = \left(\frac{RA}{\rho} \right) = \frac{105.8 \times 8.0 \times 10^{-8}}{1.1 \times 10^{-6}} = 7.7 \text{ m (1)} \quad (7.69 \text{ m})$$

(allow C.E. for incorrect value of R)

(ii) in series, voltage across each < 230 V or pd shared (1)

∴ power ($= V^2/R$) is less than 500 W in each (1)

in parallel, voltage across each = 230 V (1)

∴ correct rating, ∴ conclusion (1)

[or, in series, high resistance or combined resistance (1)

∴ low current (1)

in parallel, resistance is lower, ∴ higher current (1)

more power, justified (1)]

max 6

[8]