A-level Physics

Summer Independent Learning

Y12-13

9–12

C1 Combinations of Resistors

What is the resistance of labelled combination?

C1.1 a) A b) B

C1.2 a) C b) D

C1.3 a) E b) F

Resistivity

Complete the questions in the table:

Length /m	Wire thickness	Resistivity /Ω m	Resistance /Ω
68	cross sectional area: 2:1 10^{6} m^2	1:5 10^{8}	C1.4
C1.5	cross sectional area:		

8–10

C2 Charge Carriers

Data: Magnitude of the charge on an electron = 1:60 10 ^{19} C
Free electron density of copper [Cu] = 10^{29} m ^{3}
Free electron density of germanium [Ge] = 10^{20} m ^{3}

C2.1 How many electrons are needed to carry a charge of 6:00 C?

C2.2 How many electrons flow past a point each second in a 5:0 mA electron beam?

C2.3 Alpha particles have twice the charge of an electron. What is the current caused by a radioactive source which emits 3000 alpha particles per second?

C2.4 An electron gun emits 3:0 10^{21} electrons in two minutes. What is the beam current?

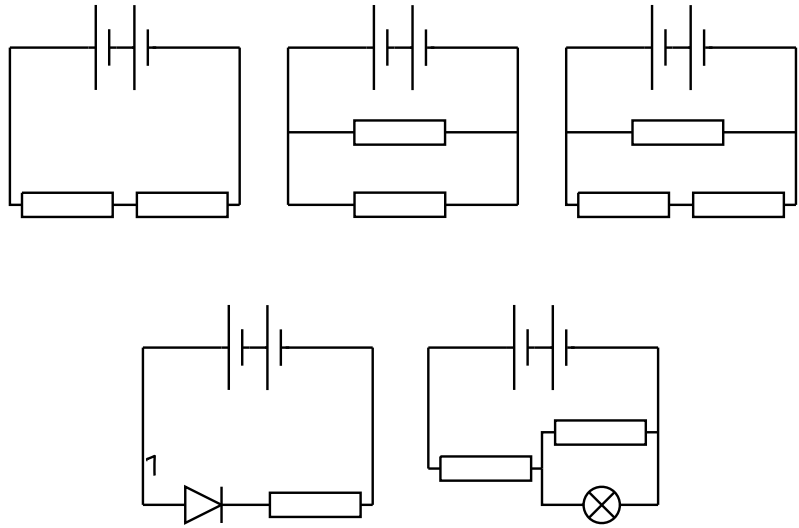
C2.5 Assume all wires have a circular cross section. Calculate the values to complete the gaps in the table:

Diameter /mm	Cross Sectional Area /mm^2	Material	Current /A	Drift Velocity /m s ^{1}
	2.5	Copper	13	(a)
	0.75	Copper	6.0	(b)
1.0		Copper	(c)	0.005
	(d)	Copper	2.0	0.20
(e)		Germanium	2.0	0.20

C2.6 In an experiment, a current of 3:5 A is being passed through a copper sulphate solution in a 10 cm cubical container, with the electrical terminals being opposite faces. This contains equal numbers of Cu^{2+} and SO_4^{2-} ions which have respectively +2 and 2 electron charge units. Assuming that the two ions have equal speed in the solution, and that there are 6:0 10^{26} of each per cubic metre of the solution, work out their mean speed.

13–17

C4 Kirchho 's Laws

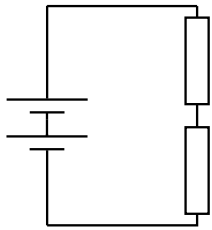


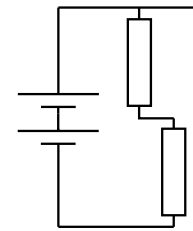
If they are not given, fill out the currents and voltages for the question parts below:

	Current /A	Voltage /V
C4.1	(A) (a); (B) (b)	(A); (2.0) (B) (c)
C4.2	(C) (a); (D) (0.20)	(C) (b); (D) (c)
C4.3	(E) (a); (F) (0.20); (G) (d)	(E) (b); (F) (c); (G) (3.0)
C4.4	(H) (a); (I) (b)	(H) (3.0); (I) (c)
C4.5	(J) (a); (K) (3.0); (L) (c); (M) (2.0)	(J) (9.0); (K) (b); (L) (2.0); (M) (d)

C5 Potential Dividers

10–13





C5.1 What is the voltage across the bottom resistor in circuit (A)?

C5.2 In circuit (B):

a) What is the voltage across the bottom resistor?

b) What would the potential of the point between the resistors be if the 2:0 kΩ resistor were removed, leaving a gap in its place?

c) What would the potential of the point between the resistors be if the 4:0 kΩ resistor were removed, leaving a gap in its place?

d) What would the potential of the point between the resistors be if the 2:0 kΩ resistor were removed and a wire was attached in its place to complete the circuit?

e) A voltmeter with resistance 10 kΩ is used to measure the voltage across the 4:0 kΩ resistor. What would it read?

C5.3 What is the voltage across the bottom resistor in circuit (C)?

C5.4 What is the voltage across the bottom resistor in circuit (D)?

C5.5 What is the voltage across the bottom resistor in circuit (E)?

C5.6 What is the potential at G, the junction between the two resistors in parallel and the one in series, in circuit (F)?

C5.7 The 8:0 Ω resistance in circuit (C) is a loudspeaker (the battery represents the amplifier). The other resistor is replaced with a variable resistor which can take all values between 0 Ω and 30 Ω, and is used as a volume control. This volume control changes the voltage across the speaker. What is the range of speaker voltages which are possible? (Give the minimum and maximum.)

C5.8 A thermistor has a resistance of 800 Ω at a temperature of 16 C. It is wired in series with a fixed resistor and a 9:0 V battery. A high-resistance voltmeter is connected to give a 'temperature' reading.

a) If the voltage reading is to go up when the temperature increases, should the voltmeter be connected in parallel with the thermistor or the fixed resistor?

b) If the voltmeter needs to read 3:0 V when the temperature is 16 C, what is the resistance of the fixed resistor?

C6 Internal Resistance

8–10

C6.1 Give the missing values in the table:

e.m.f /V	Internal Resistance /Ω	Current /A	Terminal p.d. /V	Load Resistance /Ω
12.0	(a)	20	10.2	
12.0	0.12	72	(b)	
230.0	0.53	(c)	227.5	
6.0	(d)		4.2	4.3
(e)	3.2		21.3	12.0

C6.2 A school high voltage power supply unit has an e.m.f. of 5:0 kV. If short circuited, the current must be no more than 5:0 mA. Calculate the internal resistance of the supply needed in order to achieve this.

C6.3 A small battery is powering a powerful lamp. The terminal p.d. is 11:3 V, and the current flowing is 10:2 A. Assuming that the battery has an internal resistance of 2:4 Ω, calculate the e.m.f. of the battery.

C6.4 A high-resistance voltmeter is connected in parallel with a portable battery used to start cars. Before the car is connected, the meter reads 12:4 V. When the car is connected, and a 64 A current is flowing, the meter reads 11:5 V.

a) What is the e.m.f. of the battery?

b) What is the internal resistance of the battery?

C6.5 You are building a power supply which needs to be able to handle currents of zero to 10 A. Assume that you build it to have a terminal p.d. of 13:5 V when disconnected, and 10:5 V when supplying 10 A. (a) State the e.m.f. (b) Calculate the internal resistance of the supply.

3. $(6^{-1}+3^{-1})^{-1} = R_{11} = (1/6 + 2/6)^{-1}$

$= (3/6)^{-1} = 6/3 = 2\Omega$

$= 2.0\Omega$

4. $R_T = 2 + (4^{-1}+12^{-1})^{-1}$

$= 2 + (1/4 + 1/12)^{-1} = 2 + (3/12 + 1/12)^{-1}$

$= 2 + 12/4 = 5.0\Omega$

C2 CHARGE CARRIERS I

1. $n = Q/q = \frac{-6.00}{\quad} = 3.75 \times 10^{19}$

2. $\frac{5 \times 10^{-3}}{1.6 \times 10^{-19}} = 3.125 \times 10^{16} = \underline{3.1 \times 10^{16}\ s^{-1}}$

3. $I = \frac{\Delta Q}{\Delta t} = \frac{\Delta(nq)}{\Delta t} = 3000 \frac{\Delta n}{\Delta t} q = 3000 \times (2 \times 1.6 \times 10^{-19})$

$= \underline{+9.60 \times 10^{-16}\ A}$

4. $I = \frac{\Delta Q}{\Delta t} = \frac{\Delta(nq)}{\Delta t} = \frac{-3 \times 10^{21} \times 1.6 \times 10^{-19}}{60 \times 2} = \underline{4.0A}$

ChQ. Note current density, $j = I/A = nqv_d$ + drift vel.

$v_d = \frac{I}{\quad} = \frac{13}{\quad} = 3.25 \times 10^{-4}$

C3. CHARGE CARRIERS II

1. $\frac{0.035 \times 10^{-12}}{c} = 7.29 \times 10^{4} = 7.3 \times 10^{4}$

2. $I = \frac{\Delta Q}{\Delta t} = \frac{\Delta(nq)}{\Delta t}$

C4 KIRCHHOFF'S LAWS.

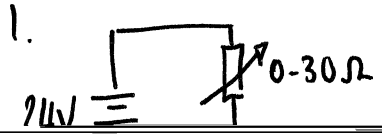
5. 30mA 6. 9.0-1.5=7.5V 7. 0.4-0.2=0.20A

8. 6.0V 9. 3.0A 10. 6.0V 11. 9-2=7.0V

12. 0.4-0.2=0.20A 13. 6.0V 14. 3-2=1.0A

15. 6-3=3.0V 16 2.0V 17 0.20A

Q. 11.



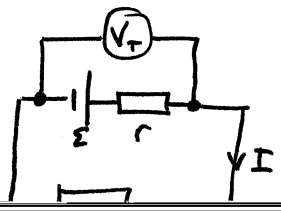
$R_v = 0\Omega$, $V = 24 \times \frac{8}{8} = \underline{24V}$

$R = 30\Omega$ $V = 24 \times \frac{8}{\quad} = 5.053 = \underline{5.1V}$

12.9.

C6 INTERNAL RESISTANCE

1.



1. $V_T = \varepsilon - V$, $V = \varepsilon - V_T = 12 - 10.2 = 1.8V$

$V = Ir$, $r = V/I = \frac{1.8}{\quad} = 0.090\Omega = 90m\Omega$

2. $V_T = \varepsilon - V = \varepsilon - Ir = 12 - 72 \times 0.12 = 3.36 = \underline{\underline{3.4V}}$

3. $V_T = \varepsilon - Ir$

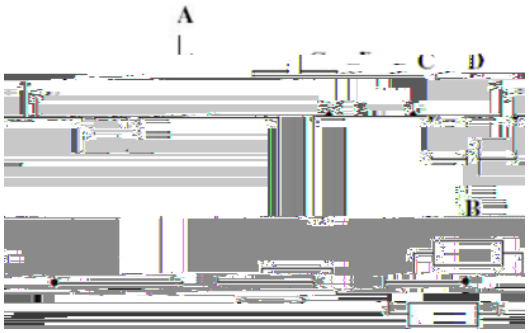
$r = V$ — $\varepsilon - V_T$ 230 − 227.5

Name _____ Class _____ Date __ /__ /__

Exam questions

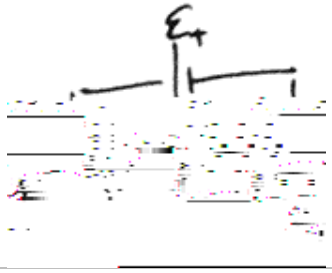
Worked example

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



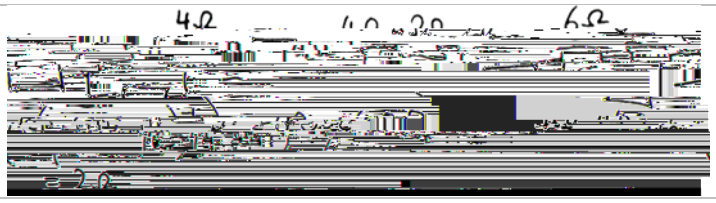
(NOTE: negligible only need to combine for cell)

Equivalent circuit



(a) The resistance of each resistor is 4.0 Ω.

(i) Calculate the total resistance of the circuit.

(NOTE: two identical resistors in total to half of individual)	

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

(NOTE: negligible)	

(iii) Calculate the current passing through cell A.

(NOTE: cell A!)	$\mathcal{E} = I(R+r)$, $I_T = \mathcal{E}_T/R_T = 4.5/6 = 0.75A$, $I_A = \frac{1}{2}I_T = 0.75/2 = 0.375 = 0.38A$

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

(NOTE: cell A!)	[redacted]

(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.

According to Kirchhoff's 1st law the [redacted]	**Mark scheme** cells C and D will 90 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

Circuit questions

Q20.(a) The cell in **Figure 1** has an emf of 3.0 V and negligible internal resistance.

Calculate the potential difference across the 8 Ω resistor.

(2)

(b) **Figure 2** shows the same circuit with a voltmeter connected across the 8 Ω resistor.

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

resistance .....Ω

(3)
(Total 5 marks)

Q26. 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.

(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.

(2)

(ii) Calculate the resistance of P.

(1)

(iii) Calculate the resistance of Q.

(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.

[6 lines available]

(3)

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

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

[5 lines available]

(2)

(ii) State and explain which of the lamps will be bright

[5 lines available]

Circuit questions 2

Q31. **X** and **Y** are two lamps. **X** is rated at 12 V 36 W and **Y** at 4.5 V 2.0 W.

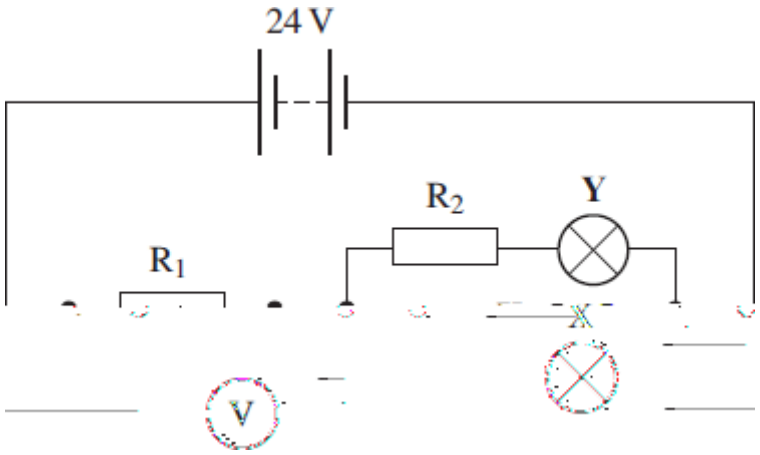
(a) Calculate the current in each lamp when it is operated at its correct working voltage.

X ..... A

Y ..... A

(2)

(b) The two lamps are connected in the circuit shown in the figure below. The battery has an emf of 24 V and negligible internal resistance. The resistors, R_1 and R_2 are chosen so that the lamps are operating at their correct working voltage.



(i) Calculate the pd across R_1.

answer V

(1)

(ii) Calculate the current in R_1.

answer ..... A

(1)

(iii) Calculate the resistance of R_1.

answer ..... Ω

(1)

(iv) Calculate the pd across R_2.

answer V

(1)

(v) Calculate the resistance of R_2.

answer ..... Ω

(1)

(c) The filament of the lamp in **X** breaks and the lamp no longer conducts. It is observed that the voltmeter reading decreases and lamp **Y** glows more brightly.

(i) Explain without calculation why the voltmeter reading decreases.

[3 lines available]

(2)

(ii) Explain without calculation why the lamp **Y** glows more brightly.

[3 lines available]

(2)

(Total 11 marks)

Q32. A battery of emf 9.0 V and internal resistance, *r*, is connected in the circuit shown in the figure below.

(a) The current in the battery is 1.0 A.

(i) Calculate the pd between points **A** and **B** in the circuit.

answer = ... V

(2)

(ii) Calculate the internal resistance, *r*.

answer = ... Ω

(2)

(iii) Calculate the **total** energy transformed by the battery in 5.0 minutes.

answer = ... J

(2)

(iv) Calculate the percentage of the energy calculated in part (iii) that is dissipated in the battery in 5.0 minutes.

answer = ... %

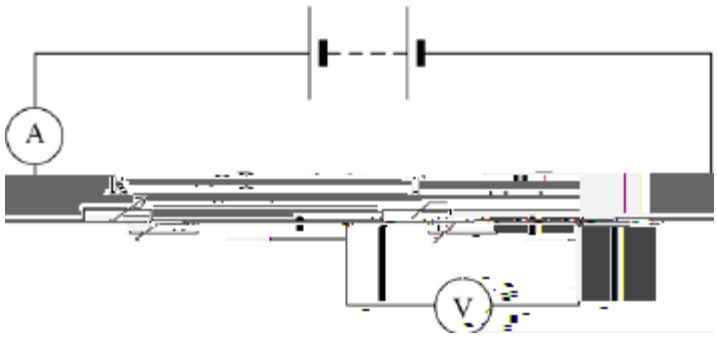
(2)

(b) State and explain

Circuit questions ChQ

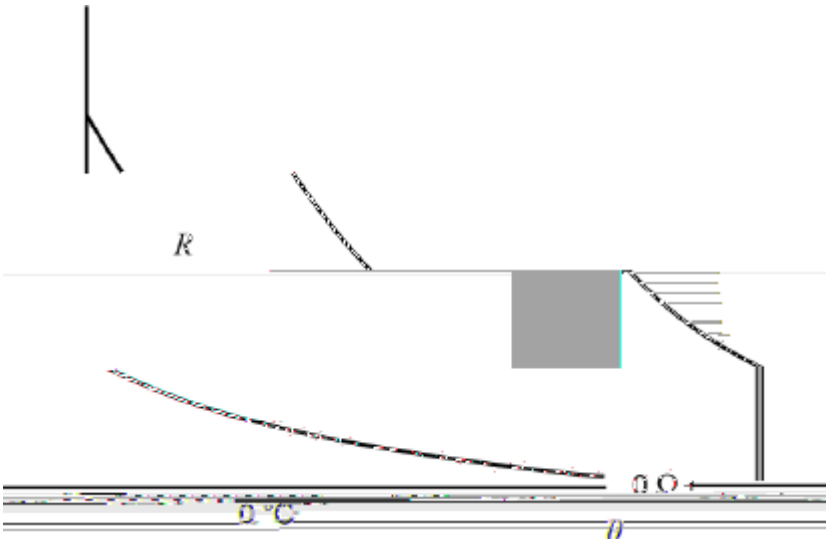
Q1.Figure 1 shows a circuit including a thermistor **T** in series with a variable resistor **R**. The battery has negligible internal resistance.

Figure 1



The resistance–temperature (R–θ) characteristic for **T** is shown in **Figure 2**.

Figure 2



(a) The resistor and thermistor in **Figure 1** make up a potential divider.

Explain what is meant by a potential divider.

[3 lines available]

(1)

(b) State and explain what happens to the voltmeter reading when the resistance of **R** is increased while the temperature is kept constant.

[6 lines available]

(3)

(c) State and explain what happens to the ammeter reading when the temperature of the thermistor increases.

[4 lines available]

(2)

(d) The battery has an emf of 12.0 V. At a temperature of 0 °C the resistance of the thermistor is 2.5 ×10^3 Ω.

The voltmeter is replaced by an alarm that sounds when the voltage across it exceeds 3.0 V.

Calculate the resistance of R that would cause the alarm to sound when the temperature of the thermistor is lowered to 0 °C.

resistance = ... Ω

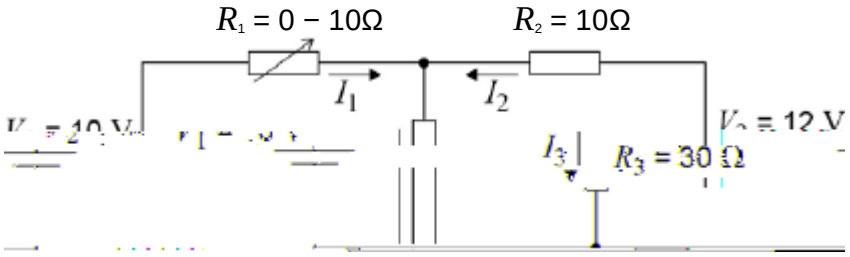
(2)

(e) State **one** change that you would make to the circuit so that instead of the alarm coming on when the temperature falls, it comes on when the temperature rises above a certain value.

[3 lines available]

(1)
(Total 9 marks)

Q9. 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 Ω.

(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 Ω.

State the potential difference across R_3.

potential difference = ... V

(1)

(c) Determine the current I_2.

current = ... A

(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.

[5 lines available]

(3)
(Total 7 marks)

Circuit questions: soutions

M20.(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) main current =1.2 V / 4 Ω = 0.3 (A) **C1**

R_{total} = 1.8 V / 0.3 A = 6 Ω or I_8 = 0.225 (A) **C1**

R_v = 24 Ω **A1**

3

[5]

M26. (a) (i) *(use of P=VI)*

I = 36/12 + 6/12 = 3.5 (A)

2

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

R = 12/3 = 4 (Ω)

1

(iii) *R* = 12/0.50 = 24 (Ω)

1

(b) terminal pd/voltage across lamp is now less OR current is less

Example calculation solutions:

Circuit questions

Q2. **X** and **Y** are two lamps. **X** is rated at 12 V 36 W and **Y** at 4.5 V 2.0 W.

(a) Calculate the current in each lamp when it is operated at its correct working voltage.

X ..... A
Y ..... A

(2)

(b) The two lamps are connected in the circuit shown in the figure below. The battery has an emf of 24 V and negligible internal resistance. The resistors, R_1 and R_2 are chosen so that the lamps are operating at their correct working voltage.

(i) Calculate the pd across R_1.

(1)

(ii) Calculate the current in R_1.

(1)

(iii) Calculate the resistance of R_1.

(1)

(iv) Calculate the pd across R_2.

(1)

(v) Calculate the resistance of R_2.

(1)

(c) The filament of the lamp in **X** breaks and the lamp no longer conducts. It is observed that the voltmeter reading decreases and lamp **Y** glows more brightly.

(i) Explain without calculation why the voltmeter reading decreases.
[3 lines]

(2)

(ii) Explain without calculation why the lamp **Y** glows more brightly.
[3 lines]

(2)

(Total 11 marks)

Q17. (a) X and Y are two lamps. X is rated at 12 V, 24 W and Y at 6.0 V, 18 W. Calculate the current through each lamp when it operates at its rated voltage.

X: .....
Y: .....

(2)

(b) The two lamps are connected in the circuit shown. The battery has an emf of 27 V and negligible internal resistance. The resistors R_1 and R_2 are chosen so that the lamps are operating at their rated voltage.

(i) What is the reading on the voltmeter?

(ii)

Circuit questions: solutions

M2. (a) (use of $P = V/I$)

$I = 36/12 = 3.0$ A

$I = 2.0/4.5 = 0.44$ A

2

(b) (i)

1

(ii) current = 3.0 + 0.44 = 3.44 A

1

(iii) R_1

1

(iv)

1

(v) R_2

1

(c) (i) (circuit) resistance increases

current is lower (reducing voltmeter reading)

or correct potential divider argument

2

(ii) pd across Y **or** current through Y increases

hence power/rate of energy dissipation greater **or** temperature of lamp increases

2

[11]

M17. (a) (i) for X: ($P = VI$ gives) $24 = 12I$ and $I = 2$ A **(1)**
for Y $18 = 6I$ and $I = 3$ A **(1)**

2

(b) (5/Lang (en)SB 0.00000887 0 59.25 842 reW*nBT/F 11 Tf1 0 0 1 64.275 a