A-level Physics
Summer Independent Learning
Y12-13

Welcome to Y13 A Level Physics, please complete the following tasks ready for your first day back at Sixth Form. You can either write on the document electronically, print the document out or write your notes and answers on paper to bring in for your first lesson in September.

You may have to research any knowledge or techniques you cannot immediately recall using common GCSE resources or other tutorials.

Please be aware that you will have an assessment on these topics shortly after the start of term and the knowledge covered is essential to understanding the subsequent content.

Part 1

Complete questions C1-C6 (C3 is not included) and fully mark and correct all questions using the solutions provided and in a different colour. Make sure you understand where you went wrong with questions you did not answer correctly.

Part 2

Complete the Circuit Questions sections and fully mark and correct the questions in a different colour. Make sure you understand where you went wrong with questions you did not answer correctly.

Part 3

Complete Physics AS Paper 1 and 2 from 2016 and fully mark and correct all questions. Again, make sure you understand where you went wrong with questions you did not answer correctly.

The papers can be found here:

Paper 1 question paper

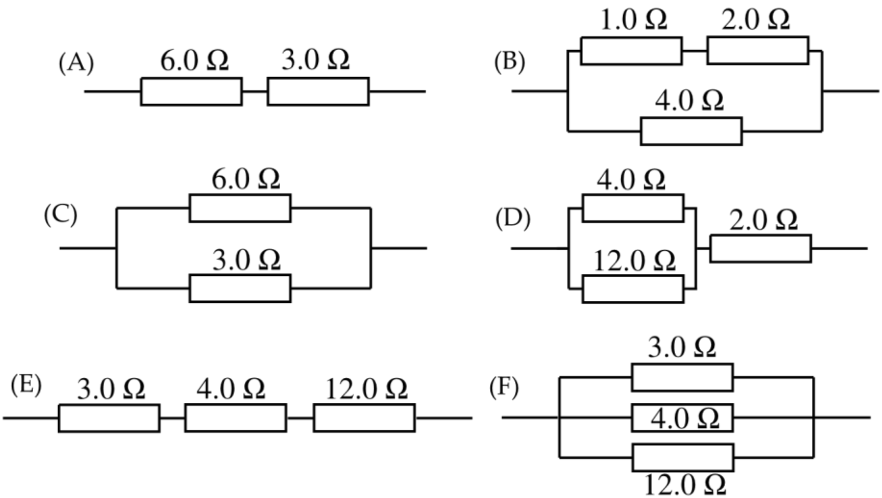
Paper 1 MS

Paper 2 question paper

Paper 2 MS

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: 0.50×10^{-6} m^2	4.9×10^{-7}	15
1.0	1.0 mm radius	4.9×10^{-7}	C1.6
15000	1.0 cm diameter	1.5×10^{-7}	C1.7

C1.8 Conventional domestic 13 A sockets are connected with copper cables with a cross sectional area of 2.5 mm^2. Copper has a resistivity of $1.5 \times 10^{-8}\ \Omega$ m. What is the resistance of 20 m of cable?

C1.9 A high voltage wire for transmission of electricity across the country is made of 10 aluminium wires (resistivity = $2.5 \times 10^{-8}\ \Omega$ m) wound together with 15 copper wires (resistivity of $1.5 \times 10^{-8}\ \Omega$ m). If all of the wires have a radius of 2.0 mm, calculate the overall resistance of 20 km of cable. (The aluminium is there to give strength to the cable.)

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:

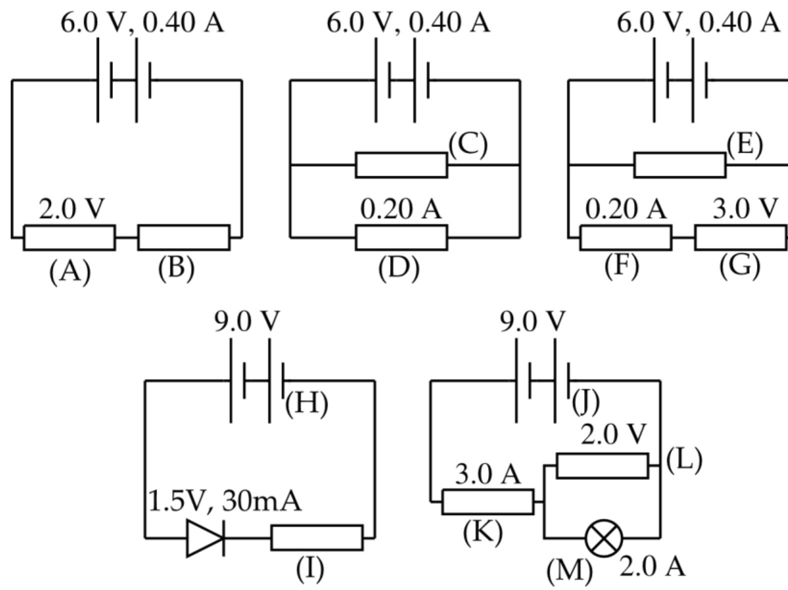
Diameter /mm	Cross Sectional Area /mm^2	Material	Current /A	Drift Velocity /m s^{-1}
	2.5	Copper	13	(a)
	0.75	Copper	6.0	(b)
1.0		Copper	(c)	0.005
	(d)	Copper	2.0	0.20
(e)		Germanium	2.0	0.20

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

13/17

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.

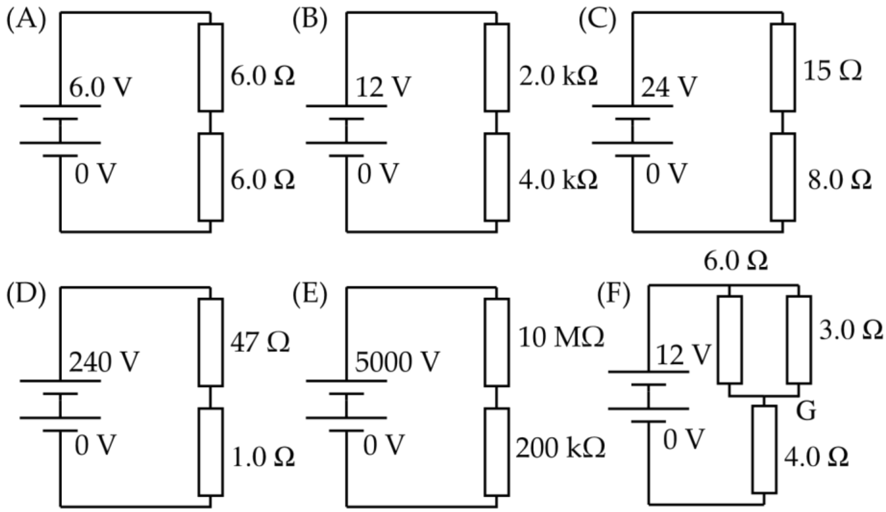
C4 Kirchhoff's Laws



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



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 $^{\circ}$C. It is wired in series with a fixed resistor and a 9.0 V battery. A highresistance 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 $^{\circ}$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.

C1 Electric circuits

1. $6+3 = 9\,\Omega$
$= 9.0\,\Omega$

2. $\left((1+2)^{-1}+4^{-1}\right)^{-1} = \left(\tfrac{1}{3}+\tfrac{1}{4}\right)^{-1} = \left(\tfrac{7}{12}\right)^{-1} = \tfrac{12}{7} = 1.714$
$= 1.7\,\Omega$

3. $(6^{-1}+3^{-1})^{-1} = R_{\parallel} = \left(\tfrac{1}{6}+\tfrac{2}{6}\right)^{-1}$
$= \left(\tfrac{3}{6}\right)^{-1} = \tfrac{6}{3} = 2\,\Omega$
$= 2.0\,\Omega$

4. $R_T = 2 + (4^{-1}+12^{-1})^{-1}$
$= 2 + \left(\tfrac{1}{4}+\tfrac{1}{12}\right)^{-1} = 2 + \left(\tfrac{3}{12}+\tfrac{1}{12}\right)^{-1}$
$= 2 + \tfrac{12}{4} = 5.0\,\Omega$

5. $3+4+12 = 19.0\,\Omega$.
$= 19\,\Omega$

6. $R_{\parallel} = (3^{-1}+4^{-1}+12^{-1})^{-1} = \left(\tfrac{4}{12}+\tfrac{3}{12}+\tfrac{1}{12}\right)^{-1}$
$= \left(\tfrac{8}{12}\right)^{-1} = \tfrac{3}{2} = 1.5\,\Omega$

7. $R = \rho \frac{l}{A} = \frac{1.5\times10^{-8}\times 68}{2.1\times10^{-6}} = 0.4857\,\Omega = 0.49\,\Omega$

8. $R = \rho \frac{l}{A}$, $l = \frac{RA}{\rho} = \frac{15\times 0.5\times10^{-6}}{4.9\times10^{-7}} = 15.31 = 15\,\text{m}$

9. $R = \rho \frac{l}{A} = \frac{\rho l}{\pi r^2} = \frac{4.9\times10^{-7}\times 1}{\pi(10^{-3})^2} = 0.15597 = \cancel{140\,\Omega}\ 0.16\,\Omega$.

10. $R = \rho \frac{l}{A} = \rho \frac{l}{\pi d^2/4} = \frac{4\rho l}{\pi d^2} = \frac{4\times1.5\times10^{-7}\times1.5\times10^{4}}{\pi\times(10^{-2})^2} = 28.6 = 29\,\Omega$

11. $R = \rho \frac{l}{A} = \frac{1.5\times10^{-8}\times 20}{2.5\times(10^{-3})^2} = 0.12\,\Omega$

12. $R_m = \frac{\rho l}{A} = \frac{\rho l}{\pi r^2} = \frac{2.5\times10^{-8}\times20\times10^{3}}{10\times\pi\times(2\times10^{-3})^2} = \cancel{39.788\,\Omega}$
$3.9788 = 4.0\,\Omega$.

$R_a = \rho \frac{l}{A} = \rho \frac{l}{\pi r^2} = \frac{1.5\times10^{-8}\times 20\times10^{3}}{15\times\pi\times(2\times10^{-3})^2} = \cancel{23.873\,\Omega}$.
$1.5915 = 1.6\,\Omega$

$R_T \approx (R_a^{-1}+R_m^{-1})^{-1} = \cancel{(23.87^{-1}+39.79^{-1})^{-1} = 14.92 = 15\,\Omega}$
$= (1.592^{-1}+3.979^{-1})^{-1} = 1.137 = 1.1\,\Omega$

C2. CHARGE CARRIERS I

1. $n = Q/e = \dfrac{-6.00}{1.6\times10^{-19}} = \underline{\underline{3.75\times10^{19}}}$

2. $\dfrac{5\times10^{-3}}{1.6\times10^{-19}} = 3.125\times10^{16} = \underline{\underline{3.1\times10^{16}\ s^{-1}}}$

3. $I = \dfrac{\Delta Q}{\Delta t} = \dfrac{\Delta(nq)}{\Delta t} = \dfrac{\Delta n}{\Delta t} q = 3000\times(2\times1.6\times10^{-19})$
$= \underline{\underline{+9.60\times10^{-16}\ A}}$

4. $I = \dfrac{\Delta Q}{\Delta t} = \dfrac{\Delta(nq)}{\Delta t} = \dfrac{-3\times10^{21}\times1.6\times10^{-19}}{60\times2} = \underline{\underline{4.0A}}$

ChQ. ✓ **NOTE** current density, $j = I/A = nqv_d$ ← drift vel.
charge.
free e^- density.

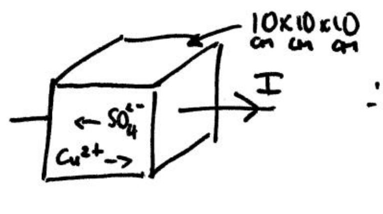
5. $I = nAqv_d$
$v_d = \dfrac{I}{n_{Cu}Aq} = \dfrac{13}{10^{29}\times2.5\times10^{-6}\times1.6\times10^{-19}} = 3.25\times10^{-4}$
$= \underline{\underline{3.3\times10^{-4}\ ms^{-1}}}$ (ie $0.33\ mms^{-1}$).

6. $v_d = \dfrac{I}{n_{Cu}Aq} = \dfrac{6}{10^{29}\times0.75\times10^{-6}\times1.6\times10^{-19}} = \underline{\underline{5.0\times10^{-4}\ ms^{-1}}}$

7. $I = nAqv_d = n\dfrac{\pi d^2}{4}qv_d = 10^{29}\times\dfrac{\pi\times(10^{-3})^2}{4}\times1.6\times10^{-19}\times0.005$
$= 62.83 = \underline{\underline{60A}}$

8. $I = nAqv_d$, $A = \dfrac{I}{n_{Cu}qv_d} = \dfrac{2}{10^{29}\times1.6\times10^{-19}\times0.2} = 6.25\times10^{-10}\ m^2 = \underline{\underline{6.3\times10^{-4}\ mm^2}}$

9. $\pi d^2/4 = \dfrac{I}{n_{Ge}qv_d} \Rightarrow d = \sqrt{\dfrac{4I}{\pi n_{Ge}qv_d}} = \sqrt{\dfrac{4\times2.0}{\pi\times10^{20}\times1.6\times10^{-19}\times0.2}} = 0.892\ m$
$= 892 = \underline{\underline{890mm}}$

10.


$\therefore v_d = \dfrac{I}{nAq} = \dfrac{3.5}{6\times10^{26}\times(10^{-1})^2\times4\times1.6\times10^{-19}} = 9.115\times10^{-7}$
$= \underline{\underline{9.1\times10^{-7}\ ms^{-1}}}$

C3. CHARGE CARRIERS II

1. $\dfrac{0.035\times10^{-12}}{3\times1.6\times10^{-19}} = 7.29\times10^{4} = \underline{\underline{7.3\times10^{4}}}$

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

$\Delta n = \dfrac{I\Delta t}{q} = \dfrac{50\times10^{-6}\times60}{1.6\times10^{-19}} = 1.875\times10^{16}$

$= \underline{\underline{1.9\times10^{16}}}$

3. $\cancel{I = \frac{\Delta Q}{\Delta t} = \frac{\Delta(nq)}{\Delta t}}$ $I = \dfrac{\Delta Q}{\Delta t} = \dfrac{45\times10^{-9}}{25\times10^{-3}} = 1.8\times10^{-6}\,A$

$\Delta n/\Delta t = I/q = \dfrac{1.8\times10^{-6}}{1.6\times10^{-19}} = 1.125\times10^{13} = \underline{\underline{1.1\times10^{13}\,s^{-1}}}$

4. $I = \dfrac{\Delta Q}{\Delta t} = \dfrac{\Delta(nq)}{\Delta t} = \dfrac{56\times10^{16}\times1.6\times10^{-19}}{0.035\times10^{-6}} = 2.56\times10^{6}\,A = \underline{\underline{2.6\,MA}}$

5. $I = \Delta Q/\Delta t$, $\Delta t = \dfrac{\Delta Q}{I} = \dfrac{\Delta(nq)}{I} = \dfrac{1.5\times10^{17}\times2\times1.6\times10^{-19}}{6} = \underline{\underline{80\times10^{-3}\,s}} = 8.0\,ms$

6. $I = \dfrac{\Delta Q}{\Delta t} = \dfrac{\Delta(nq)}{\Delta t}$, $\cancel{\Delta n_{SO_4} = \frac{q}{I\Delta t} = \frac{2\times1.6\times10^{-19}}{(36\times10^{-6}/2)\times15}} =$

$\Delta n_{SO_4^{2-}} = \dfrac{I\Delta t}{q} = \dfrac{(36\times10^{-6}/2)\times15}{2\times1.6\times10^{-19}} = 8.438\times10^{14} = \underline{\underline{8.4\times10^{14}}}$

<u>ChQ</u>

7. $j = I/A = nqv_d$, $v_d = \dfrac{I}{nqA} = \dfrac{7}{10^{20}\times1.6\times10^{-19}\times3.8\times10^{-6}} = 1.15\times10^{5}\,ms^{-1}$

$= \underline{\underline{1.2\times10^{5}\,ms^{-1}}}$

8. $v_d = \dfrac{I}{nqA} = \dfrac{I}{nq\pi d^2/4} = \dfrac{4I}{nq\pi d^2} = \dfrac{4\times4}{10^{29}\times1.6\times10^{-19}\times\pi\times(2.5\times10^{-3})^2} = 5.093\times10^{-5}\,ms^{-1}$

$= \underline{\underline{5.1\times10^{-2}\,mms^{-1}}}$

9. $I = nqv_dA = nqv_d\dfrac{\pi d^2}{4} = 10^{20}\times1.6\times10^{-19}\times5\times10^{-3}\times\dfrac{\pi\times(10^{-3})^2}{4} = 6.28\times10^{-8}$

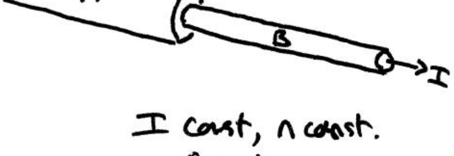
$= \underline{\underline{6.3\times10^{-8}\,A}}$

10. $A = \dfrac{I}{nqv_d} = \dfrac{6}{10^{29}\times1.6\times10^{-19}\times40\times10^{-3}} = 9.375\times10^{-9}\,m^2$

$= \underline{\underline{9.4\times10^{-3}\,mm^2}}$

11. $I = nqv_d\,\pi d^2/4 \therefore d = \sqrt{\dfrac{4I}{\pi nqv_d}} = \sqrt{\dfrac{4\times2}{\pi\times10^{20}\times1.6\times10^{-19}\times75\times10^{-3}}} = 1.46\,m = \underline{\underline{1.5\times10^{3}\,mm}}$

12.



$v_d = \dfrac{4I}{\pi nqd^2}$ $\therefore v_d d^2 = \text{const.}$

$v_{dA}d_A^2 = v_{dB}d_B^2$

$\therefore \dfrac{v_{dA}}{v_{dB}} = \left(\dfrac{d_A}{d_B}\right)^2 = \left(\dfrac{0.9}{2\times0.15}\right)^2 = (9/3)^2 = 3^2 = \underline{\underline{9}}$

I const, n const.
q const.

C4 KIRCHHOFF'S LAWS.

1. $\underline{\underline{0.40A}}$ 2. $\underline{\underline{30mA}}$ 3. $\underline{\underline{0.40A}}$ 4. $V = 6 - 2 = \underline{\underline{4.0V}}$

5. $\underline{\underline{30mA}}$ 6. $9.0 - 1.5 = \underline{\underline{7.5V}}$ 7. $0.4 - 0.2 = \underline{\underline{0.20A}}$

8. $\underline{\underline{6.0V}}$ 9. $\underline{\underline{3.0A}}$ 10. $\underline{\underline{6.0V}}$ 11. $9 - 2 = \underline{\underline{7.0V}}$

12. $0.4 - 0.2 = \underline{\underline{0.20A}}$ 13. $\underline{\underline{6.0V}}$ 14. $3 - 2 = \underline{\underline{1.0A}}$

15. $6 - 3 = \underline{\underline{3.0V}}$ 16. $\underline{\underline{2.0V}}$ 17. $\underline{\underline{0.20A}}$

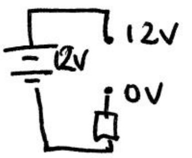
C5 POTENTIAL DIVIDERS

$\boxed{V_R = V_T \frac{R}{R_T}}$ ⇒ 1. $\underline{\underline{3.0V}}$ 2. $V = 12 \times \frac{4 \times \cancel{10^3}}{6 \times \cancel{10^3}} = \underline{\underline{8.0V}}$ 3. $V = 24 \times \frac{8}{23} = 8.348V$ $= \underline{\underline{8.3V}}$

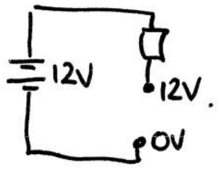
4. $V = 240 \times \frac{1}{48} = \underline{\underline{5.0V}}$ 5. $V = 5 \times 10^3 \times \frac{0.2 \times \cancel{10^6}}{10.2 \times \cancel{10^6}} = \frac{10^3}{10.2} = 98.04 = \underline{\underline{98V}}$

6. $R_{\parallel}^{-1} = (6^{-1} + 3^{-1})^{-1} = (\frac{1}{6} + \frac{2}{6})^{-1}$ $= 6/3 = 2.0\Omega$ ∴ $V = 12 \times \frac{4}{6} = \underline{\underline{8.0V}}$ (4.0V across ∥ combination)

7. ~~12-8=4.0V~~. $R \to \infty$ ∴ all pd emf dropped across gap (none across 4.0kΩ) ∴

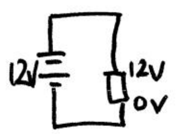


8.



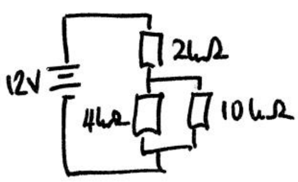
$V = \underline{\underline{12V}}$

9.



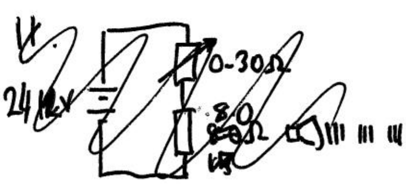
∴ $V = \underline{\underline{12V}}$.

10.



⇒ $R_{\parallel} = (4^{-1} + 10^{-1})^{-1}$ $= 2.857k\Omega$ $V = 12 \times \frac{2.857}{2 + 2.857} = 7.0588$ $= \underline{\underline{7.1V}}$

~~11.~~



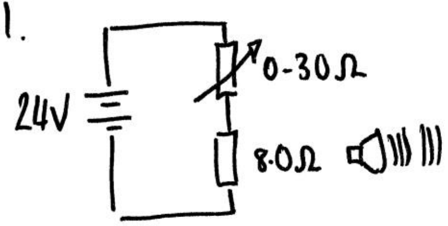
~~$R_v = 30\Omega$~~ ~~$R_v = 0\Omega$~~

~~$24 \times \frac{8}{38} \leq V_{out} \leq 24 \times \frac{8}{8}$~~

~~$5.05 \leq V_{out} \leq 24V$~~

~~$5.1 \leq V_{out} \leq 24V$~~

Q. 11.

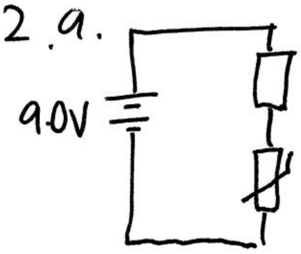


$R_v = 0\,\Omega$, $V = 24 \times 8/8 = \underline{\underline{24V}}$

$R_v = 30\,\Omega$, $V = 24 \times \frac{8}{38} = 5.053 = \underline{\underline{5.1V}}$

$5.1 \leq V_{sp} \leq 24\,V$

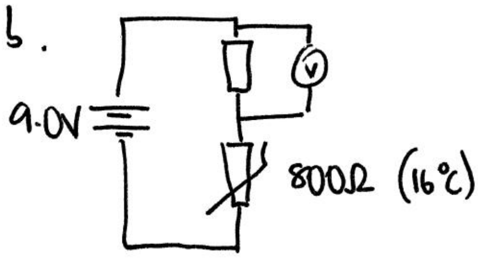
12. a.



if $\uparrow T$, $\downarrow R_{Th}$ want $\uparrow V$ $\quad V_{Th} = V\frac{R_{Th}}{R_T}$, $V_R = V\,R/R_T$

$\therefore$ Need across fixed resistor as $R/R_T \uparrow$

b.



$$V_R = V\frac{R}{R+R_{Th}}$$

$$V_R/V = R/(R+R_{Th})$$

$$V_R/V\,(R+R_{Th}) = R \quad [i]$$

$\therefore$ ~~$R(1-V_R/V) = R_{Th}$~~

~~$R = R_{Th}/(1 - V_R/V) = 800/(1-3/9)$~~

$\simeq$

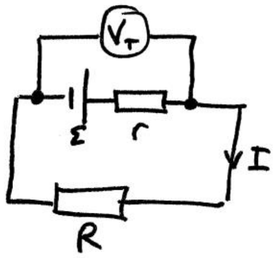
from [i].

$$R_{Th} + R = RV/V_R$$

$$R_{Th} = R(V/V_R - 1)$$

$$R = \frac{R_{Th}}{V/V_R - 1} = \frac{800}{9/3 - 1} = \underline{\underline{400\,\Omega}}$$

C6 INTERNAL RESISTANCE

1. 

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

$v = Ir$, $r = v/I = \frac{1.8}{20} = \underline{\underline{0.090\,\Omega}} = 90\,m\Omega$

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

3. $V_T = \varepsilon - Ir$

$Ir = \varepsilon - V_T$, $I = \frac{\varepsilon - V_T}{r} = \frac{230 - 227.5}{0.53} = 4.717 = \underline{\underline{4.7A}}$

4. $\varepsilon = I(R+r)$ $\Rightarrow$ $\cancel{V = IR}$ $I = V_T/R = \frac{4.2}{4.3} = 0.9767\,A$.

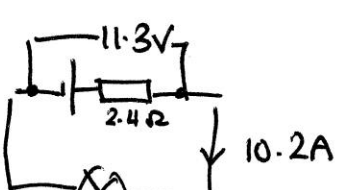
$\varepsilon = V_T + Ir \Rightarrow r = \frac{\varepsilon - V_T}{I} = \frac{6 - 4.2}{0.9767} = 1.843 = \underline{\underline{1.8\,\Omega}}$

5. $I = V_T/R = \frac{21.3}{12} = 1.775A$, $V_T = \varepsilon - Ir$

$\varepsilon = V_T + Ir = 21.3 + 1.775 \times 3.2$
$= 26.98 = \underline{\underline{27V}}$

6. $\varepsilon = I(R+r)$ if $R = 0$, $\varepsilon = Ir$.

$r = \varepsilon/I = \frac{5 \times 10^{3}}{5 \times 10^{-3}} = 1.0 \times 10^{6}\,\Omega = \underline{\underline{1.0\,M\Omega}}$

7. 

$V_T = \varepsilon - v$
$= \varepsilon - Ir$
$\varepsilon = V_T + Ir = 11.3 + 10.2 \times 2.4$
$= 35.78 = \underline{\underline{36\,V}}$

8. $\underline{\underline{12.4\,V}}$

as voltmeter has $R \to \infty$, $I \to 0\,A$
$\therefore v = Ir \to 0V$
& $\varepsilon = V_T$.

9. $V_T = \varepsilon - Ir$, $r = \frac{\varepsilon - V_T}{I} = \frac{12.4 - 11.5}{64} = 0.01406$
$= \underline{\underline{0.014\,\Omega}}$

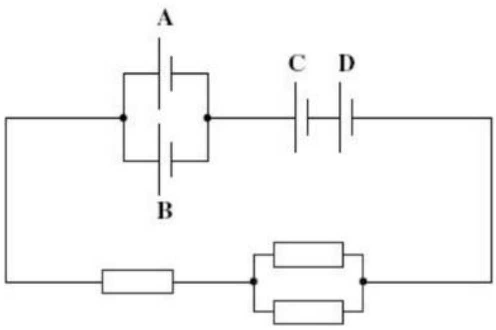
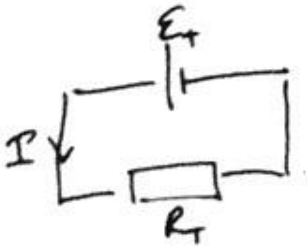
10. $0 \le I \le 10A$, $\varepsilon = 13.5V$ $V_T = \varepsilon - v$
$= \varepsilon - Ir$, $r = \frac{\varepsilon - V_T}{I} = \frac{13.5 - 10.5}{10} = 3/10 = \underline{\underline{0.20\,\Omega}}$

Name __________________________ Class _______ Date __/__/__

Exam questions

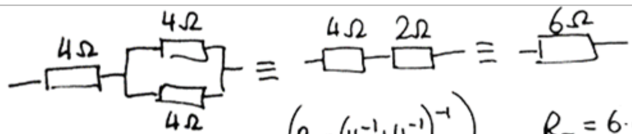
Worked example

Q1. 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.

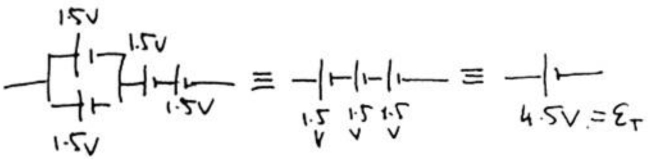
	(NOTE: negligible r ∴ only need to combine ε for cell)  Equivalent circuit

(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)	 $\left(R_T = (4^{-1}+4^{-1})^{-1}\right) = 2\Omega.$ $R_T = 6.0\Omega$

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

(NOTE: negligible r)	

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

(NOTE: cell A!)	$\varepsilon = I(R+\cancel{r})$, $I_T = \varepsilon_T/R_T = 4.5/6 = \underline{0.75A}$. $I_A = \frac{1}{2}I_T = 0.75/2 = 0.375 = \underline{0.38A}$

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

(NOTE: cell A!)	$I = \Delta Q/\Delta t$, $\Delta Q = I\Delta t = 0.375 \times (5\times 60) = 112.5 = \underline{110C}$

(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.

According to Kirchhoff's 1st law the current through cell would obey $I_C = I_D = I_A + I_B$. As cells A & B are identical $I_A = I_B$ and $I_A = I_B = \frac{1}{2}I_C = \frac{1}{2}I_D$. As $P = I\varepsilon$ if reduce the current for the same emf, less power is dissipated. Hence A & B will last longer and C & D will go flat first.	**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

(3)

(Total 9 marks)

Circuit questions

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

Figure 1

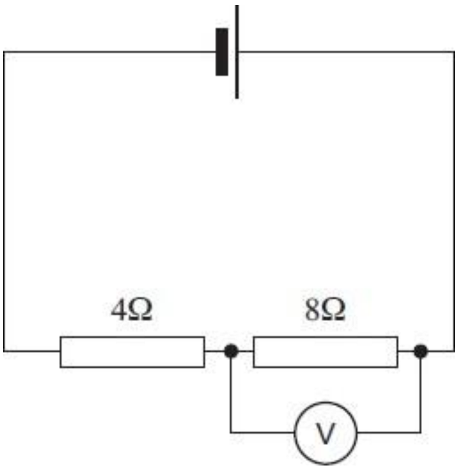
Calculate the potential difference across the 8 Ω resistor.

(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.

Figure 2



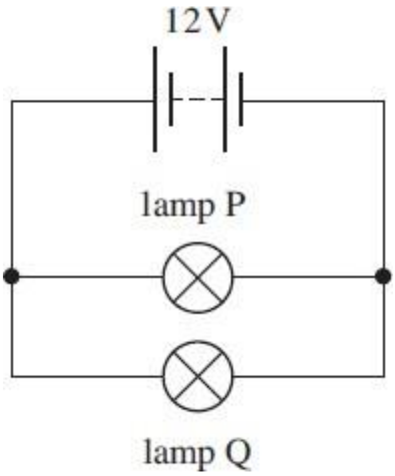
resistance ....Ω

(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.

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.

(2)

(ii) Calculate the resistance of P.

(1)

(iii) Calculate the resistance of Q.

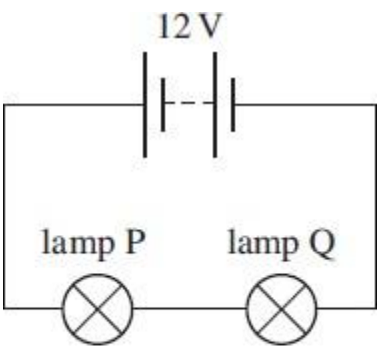
(1)

(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)

Figure 2



(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 brighter assuming that the resistance of the lamps does not change significantly with temperature.

[4 lines available]

(3) (Total 12 marks)

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.

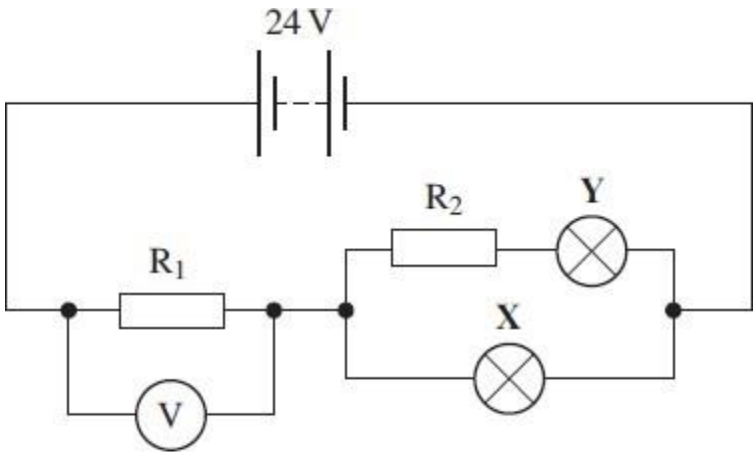
(a) Calculate the current in each lamp when it is operated at its correct working voltage.

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]

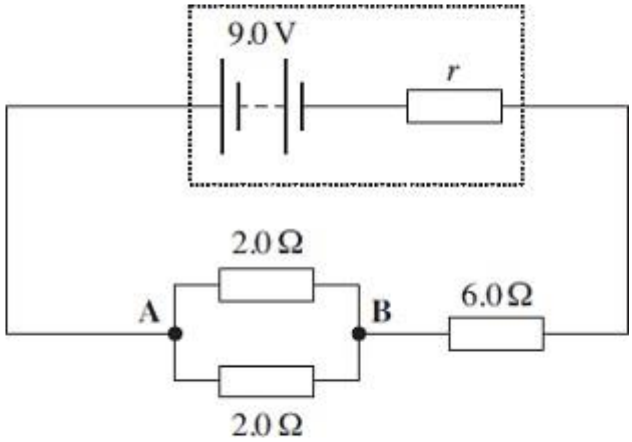
(2) (ii) Explain without calculation why the lamp **Y** glows more brightly.

[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 **one** reason why it is an advantage for a rechargeable battery to have a low internal resistance.

[4 lines available]

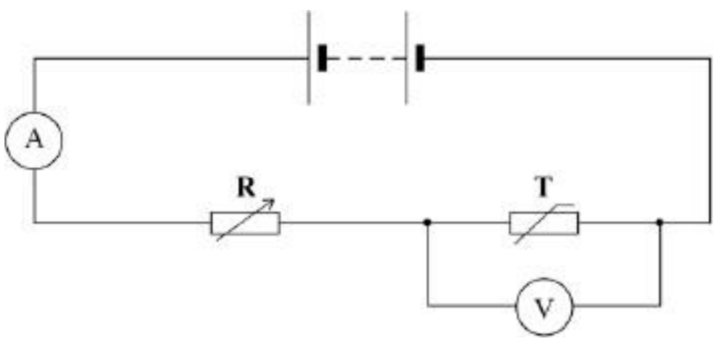
(2)

(Total 10 marks)

ChQ

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

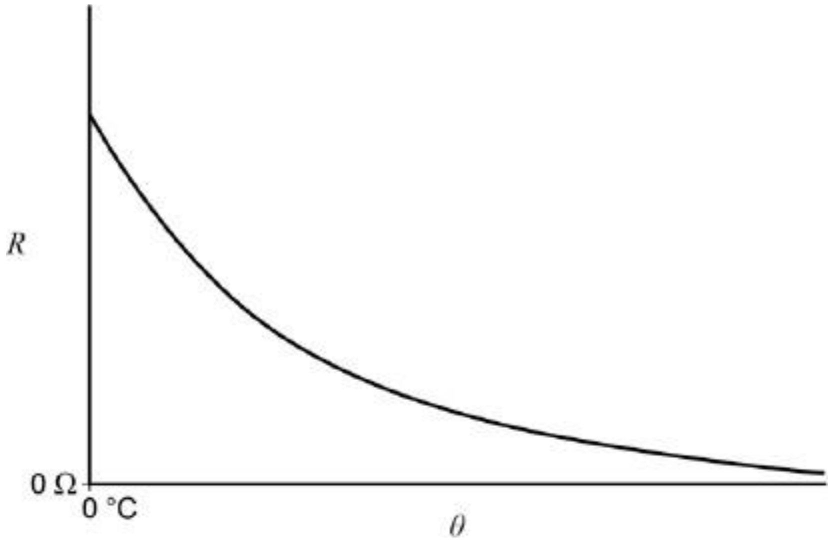
Figure 1



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

Figure 2

Circuit questions



(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)

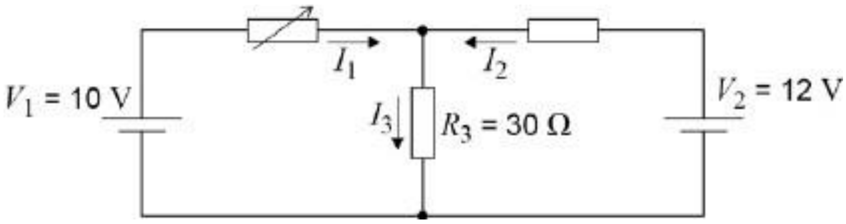
(e) State **one** change that you would make to the circuit so that instead of the alarm coming on when the temperature falls, it comes on when the temperature rises above a certain value.

[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 = 0 − 10Ω R_2 = 10Ω



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)

Solutions

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) ✓

Circuit questions

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 ✓ 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 <u>higher resistance</u> hence <u>pd/voltage</u> across is greater ✓ current is the same for both ✓ hence power of Q greater ✓ 3

[12]

Circuit questions

2: solutions

M31. (a) (use of $P = V/I$) $I = 36/12 = 3.0$ A ✓ $I = 2.0/4.5 = 0.44$ A ✓

2

(b) (i) pd = 24 − 12 = 12 V ✓

1

(ii) current = 3.0 + 0.44 = 3.44 A ✓

1

(iii) $R_1 = 12/3.44 = 3.5\ \Omega$ ✓

1

(iv) pd = 12 − 4.5 − 7.5 V ✓

1

(v) $R_2 = 7.5/0.44 = 17\ \Omega$ ✓

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]

M32. (a) (i) (use of $V = IR$)

$R_{total} = 1$ (ohm) ✓

$V = 1 \times 1 = 1.0$ V ✓

2

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

$R = 9.0/1.0 = 9.0\ \Omega$ ✓ $r = 9.0 - 1.0 - 6.0 = 2.0\ \Omega$ ✓

or use of ($E = I(R + r)$)

$9.0 = 1(7 + r)$ ✓

$r = 9.0 - 7.0 = 2.0\ \Omega$ ✓

2

(iii) (use of $W = VIt$)

$W = 9.0 \times 1.0 \times 5 \times 60$ ✓

$W = 2700$ J ✓

2

(iv) energy dissipated in internal resistance = $1^2 \times 2.0 \times 5 \times 60 = 600$ (J) ✓
percentage = 100 × 600/2700 = 22% ✓ CE from part aii

2

(b) internal resistance limits current ✓ hence can provide higher current **or** ✓ energy wasted in internal resistance/battery less energy ✓ wasted (with lower internal resistance) **or** ✓ charges quicker ✓
as current higher or less energy wasted ✓ **or** (lower internal resistance) means higher terminal pd/voltage as less pd ✓ across internal resistance or mention of lost volts ✓

2

[10]

ChQ: solutions

M1.(a) A combination of resistors in series connected across a voltage source (to produce a required pd) ✓
Reference to splitting (not dividing) pd

Circuit questions

1

(b) When R increases, pd across R increases ✓ Pd across R + pd across T = supply pd ✓

So pd across T / voltmeter reading decreases ✓ *Alternative:*

Use of $V = V_{tot}\left(\frac{R}{R_1 + R_2}\right)$ ✓

V_{tot} and R_2 remain constant ✓

So V increases when R_1 increases ✓

3

(c) At higher temp, resistance of T is lower ✓

1

So circuit resistance is lower, so current / ammeter reading increases ✓

1

(d) Resistance of T = 2500 Ω

Current through T = V / R = 3 / 2500 = 1.2×10^{-3} A ✓

(Allow alternative using $V_1/R_1 = V_2/R_2$)

pd across R = 12 − 3 = 9 V

The first mark is working out the current

1

Resistance of R = V / I = 9 / 1.2×10^{-3} = 7500 Ω✓

The second mark is for the final answer

1

(e) Connect the alarm across R instead of across T ✓ *allow: use a thermistor with a ptc instead of ntc.*

1

[9]

M9.(a) $I_3 = I_1 + I_2$ ✓

1

(b) 10 V ✓

1

(c) I_2 = (12 – 10) / 10 ✓

Allow ce for 10 V

1

= 0.2 A ✓

The first mark is for the pd
The second is for the final answer

1

(d) pd across R_2 increases

As R_1 increases, pd across R_1 increases as pd = $I_1 R_1$ ✓

First mark is for identifying that pd across R_1 increases (from zero).

1 pd across R_3 = 10 V – pd across R_1

Therefore pd across R_3 decreases ✓

Second mark is for identifying that pd across R_3 must decrease

1 pd across R_2 = 12 – pd across R_3

Therefore pd across R_2 increases ✓

Third mark is for identifying that this means pd across R2 must increase

1

[7]

Example calculation solutions:

M10. (a) (i) 6.0 (Ω) **(1)**

1

(ii) 4.5 (V) **(1)**

1

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

$I = 4.5/6.0 = 0.75$ (A) **(1)**

current through cell A = 0.75/2 = 0.375 (A) **(1)**

2

(iv) charge = 0.375 × 300 = 112 **(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]

Circuit questions

Exam tips (worked example)

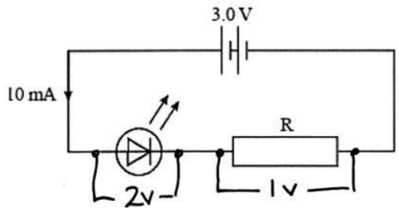
Some tips for solving circuit calculations

1. Familiarise yourself with key equations*.
2. Simplify problems (see example below):
   a. Identify phrases or assumptions in the question e.g. ‘the internal resistance is negligible’.

      The student observes that **two** of the lamps are at their normal brightness. Assume that any changes in resistance of the lamps are negligible. crucial.

   b. Annotate your circuit diagram with information from the question and from calculations you perform as you progress. It will be easier to solve with the following questions when you have all the information.

      The circuit diagram shows a light-emitting diode connected in series with a resistor R and a 3.0 V battery of negligible internal resistance. The potential difference across the terminals of the diode is 2.0 V and the current through it is 10 mA. The diode emits photons of wavelength 635 nm.



   c. Beware units with prefixes.

***Key equations**

$$V = \frac{W}{Q}, \quad I = \frac{\Delta Q}{\Delta t}$$

$$V = IR$$

$$P = IV = I^2R = \frac{V^2}{R}$$

$$V = \frac{W}{Q}, \quad \varepsilon = \frac{E}{Q}$$

$$\frac{1}{R_{T\parallel}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$$

$$R_{T--} = R_1 + R_2 + \cdots$$

$$\varepsilon = I(R + r), v = Ir$$

3. If in doubt, go back to Kirchhoff’s laws:
   a. **Junction (1st):** At any junction in a circuit, the total current leaving the junction is equal to the total current entering the junction.
   b. **Loop (2nd):** The sum of all the emf, ε, around a given loop is equal to the sum of the p.d. dropped around the loop.

      (a) Calculate the resistance of R.

      $V_R = 3 - 2 = 1V$, $R = V/I = 1/10\times10^{-3} = 100\,\Omega$

4. Ensure you read the question and relate your equations to the correct components.

      (b) Calculate the electrical power supplied to the diode.

      $P = IV = 2\times10\times10^{-3} = 20\times10^{-3} = 0.020W = 20mW$

5. To find the current through the battery, find the total external resistance (load) of an equivalent resistor (c.f.

figure 1). This can often help to lead to the final answer in circuit problems.

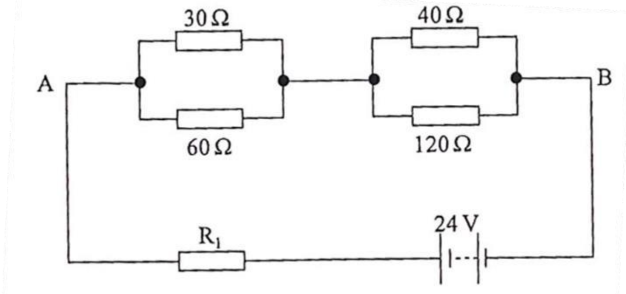


Figure 1

6. Use subscripts to keep track of all the different components, e.g. V_1,R_T, I_3 ....
7. If you know the current through a component and its resistance you can find the pd! $V = IR$
8. Most potential divider questions can be solved by combining [**5**] and [**7**] but ensure you know the potential divider equation for the exam (it can help):

$$V_1 = V_T\frac{R_1}{R_1 + R_2}$$

9. Standard operating conditions of bulbs are at a provided pd. and current (hence power).
10. If there is internal resistance then if you can you find the lost pd, $v = Ir$, then you can find the terminal pd, $V = \varepsilon - v$.
11. Ideal voltmeters have infinite resistance, ideal ammeters have zero resistance.
12. Keep going and be resilient! If the question gives you the answer then you can definitely try subsequent questions.

(a) Show that the resistance of the single equivalent resistor that could replace the four resistors between the points A and B is 50 Ω.

13. If can't work your way through, go back &logically apply Kirchhoff's laws (these help with **explain** questions too!).

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.

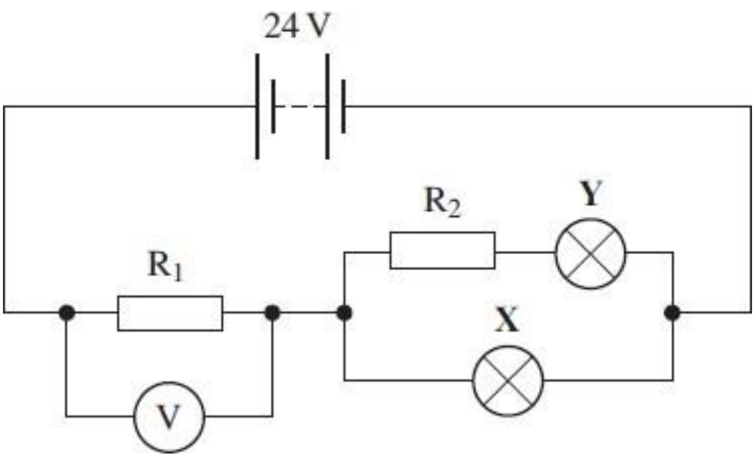
(a) Calculate the current in each lamp when it is operated at its correct working voltage.

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.

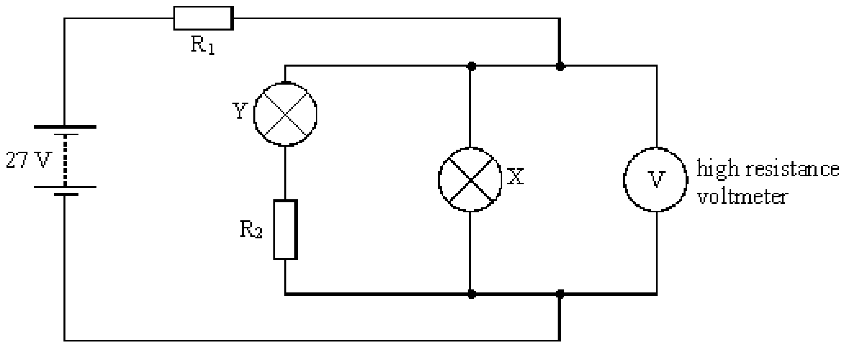
(i) What is the reading on the voltmeter?

(ii) Calculate the resistance of R_2.

(iii) Calculate the current through R_1.

(iv) Calculate the voltage across R_1.

(v) Calculate the resistance of R_1.



(7) (Total 9 marks)

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) pd = 24 − 12 = 12 V ✓

1

(ii) current = 3.0 + 0.44 = 3.44 A ✓

1

(iii) $R_1 = 12/3.44 = 3.5\ \Omega$ ✓

1

(iv) pd = 12 − 4.5 − 7.5 V ✓

1

(v) $R_2 = 7.5/0.44 = 17\ \Omega$ ✓

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) (i) 12 V **(1)**

(ii) voltage across R_2 (= 12 – 6) = 6 (V) **(1)** $I = 3$ (A) **(1)**
($V = IR$ gives) $6 = 3R_2$ and $R_2 = 2\Omega$ **(1)**
(allow C.E. for I and V from (a) and (b)(i))

[or $V = I(R_y + R_2)$ **(1)** $12 = 3(2 + R_2)$ **(1)** $R_2 = 2\Omega$ **(1)**]

(iii) current = 2 (A) + 3 (A) = 5 A **(1)**
(allow C.E. for values of the currents)

(iv) 27 (V)– 12 (V) = 15 V across R_1 **(1)**

(v) for R_1, $15 = 5\ R_1$ and $R_1 = 3\Omega$ **(1)**
(allow C.E. for values of I and V from (iii) and (iv)

7

[9]