

5. (a) A steady current of 0.25 A passes through a torch bulb for 6 minutes.
Calculate the charge which flows through the bulb in this time.

(From your data sheet)

$$\Delta Q = 0.25 \text{ A}$$

$$\Delta t = 6 \text{ mins} = 6 \times 60\text{s} = 360\text{s} \text{ (1 mark)}$$

$$\Delta Q = I \times \Delta t = 0.25 \times 360 = 90 \text{ C (1 mark)}$$

Common mistake not to change the time into seconds - extracting data onto the right hand side and checking it is in the correct unit avoids this pitfall!

(2)

- (b) The torch bulb is now connected to a battery of negligible internal resistance. The battery supplies a steady current of 0.25 A for 20 hours. In this time the energy transferred in the bulb is $9.0 \times 10^4 \text{ J}$. Calculate

- (i) the potential difference across the bulb,

$$\epsilon = \frac{E}{Q} \quad \epsilon = I(R + r)$$

From the data sheet we have the relationship between charge, energy and voltage - in this case it is V not ϵ we use, but the same relationship:

$$V = E/Q$$

The question gives us E - we have to calculate Q in the same way as above - but remember Δt MUST be in seconds

$$= (9.0 \times 10^4) / (0.25 \times (20 \times 60^2)) \text{ (1 mark)} = 5.0\text{V} \text{ (1 mark)}$$

(again you get a mark for converting the hours into seconds - it is important!)

- (ii) the power of the bulb.

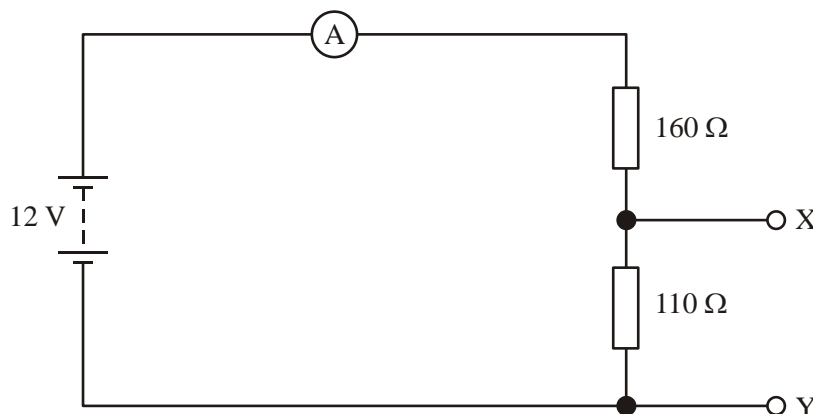
$$P = IV = 0.25 \times 5.0 = 1.3\text{W} \text{ (1.25W) (1 mark)}$$

(or you could use $P = E/\Delta t$)

(3)

(Total 5 marks)

6. In the circuit shown in the figure below, the battery, of negligible internal resistance (this means we just use $V=IR$), is connected to two resistors which form a potential divider.



$$I = \frac{\Delta Q}{\Delta t}$$

(a)

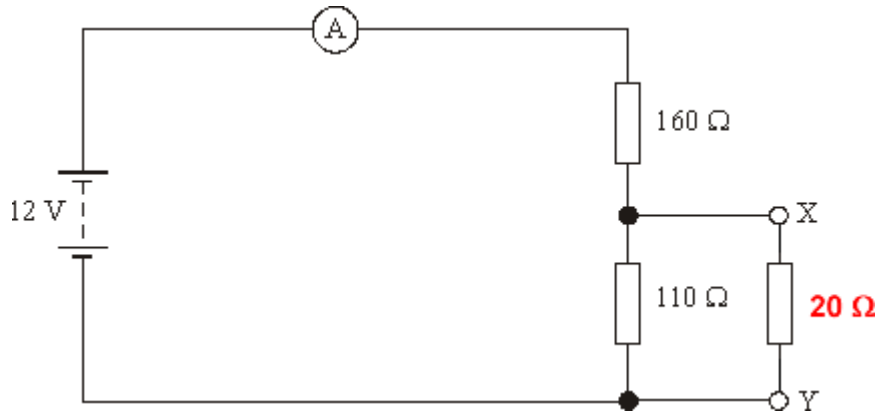
- (i) Calculate the current through the ammeter.

The resistors are in series so $R = (160 + 110) = 270\Omega$ (1 mark)

$$V = IR$$

$$\text{so, } I = V/R = 12/270 = 0.044 \text{ A (1 mark)}$$

- (ii) A $20\ \Omega$ resistor is now connected between X and Y.



State and explain, without further calculation, whether the current through the ammeter will increase or decrease.

The addition of the resistor in parallel decreases the overall resistance of the circuit (1 mark) because. Lower resistance will result in an increased current, so the value on the ammeter will increase. (1 mark)

(4)

- (b) The $20\ \Omega$ resistor is now removed and replaced with a voltmeter. Stating the assumption made, show that the reading on the voltmeter is $4.9\ \text{V}$.

If the resistance of the voltmeter is very high compared to the resistors in the circuit (1 mark), very little current will flow through it and it will not interfere with the effective resistances in the circuit.

12V is therefore shared across $270\ \Omega$.

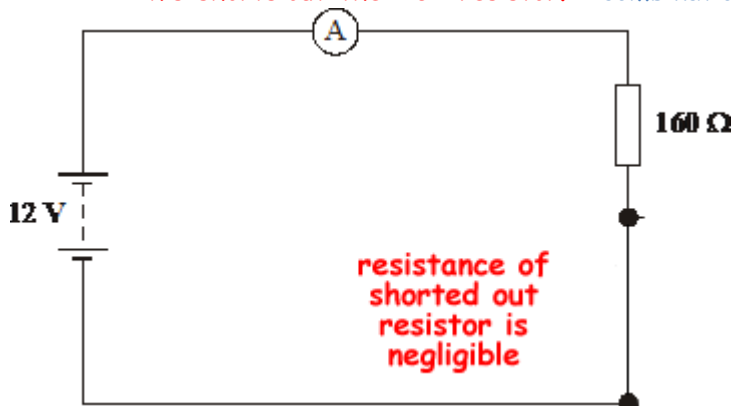
Each ohm gets $12/270\ \text{V}$ and the $110\ \Omega$ resistor (the voltage drop read by the voltmeter) will get

$$110 \times 12/270\ \text{V} = 4.9\text{V} \text{ (1 mark)}$$

(2)

- (c) The voltmeter is now removed and the terminals X and Y joined together with a wire. Calculate the reading on the ammeter.

This 'shorts out' the $110\ \Omega$ resistor. A combination of resistors in parallel has a resistance



of less than the smallest resistor. In the case of the 'shorting wire' we have a resistor (the wire) of negligible resistance in parallel with the $110\ \Omega$ resistor - the combination therefore has an even more negligible value! We can therefore redraw the circuit without the $110\ \Omega$ resistor - replace it with connecting wire.

We now have a very simple circuit to find the current in...

$R = 160 \Omega$ (1 mark)

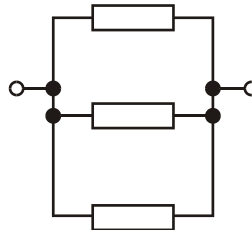
$V = IR$

So $I = V/R$

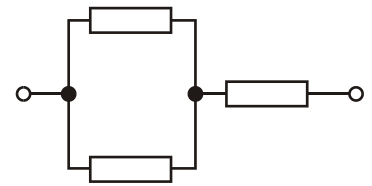
$= 12/160$

$= 0.075 \text{ A}$ (1 mark)

7. (a) On the right there are two possible arrangements of connecting three resistors, each resistor having a resistance of 40Ω .



(3)



(2)

(Total 8 marks)

Calculate the equivalent resistance in each case.

You can do this by inspection but you need to get all of the marks - so show some working! Looking at (i) we know that n resistors in parallel have the resistance of one of them divided by ' n '. In this case the resistance will be $40\Omega/3 = 13.3\Omega$. Looking at (ii) we have two in parallel - 20Ω in series with one 40Ω , giving a total resistance of 60Ω . But we need to show this using the equations from the data sheet to get the marks.

(i)

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots = 1/40 + 1/40 + 1/40 = 3/40 \text{ (1 mark)}$$

Therefore $R = 40/3 = 13.3\Omega$ (1 mark)

(ii) Parallel arrangement

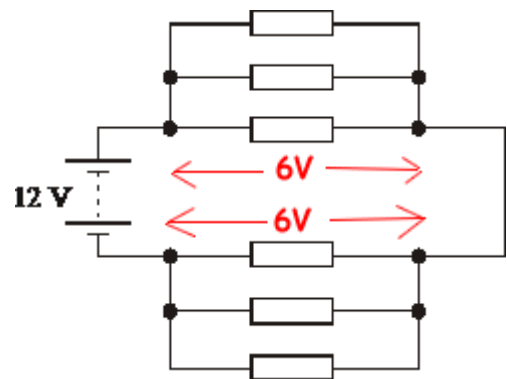
$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots = 1/40 + 1/40 = 2/40 \quad \text{Therefore } R = 40/2 = 20 \Omega \text{ (1 mark)}$$

This is in series with a single resistor so

$$R_T = R_1 + R_2 + R_3 + \dots = 20 + 40 = 60\Omega \text{ (1 mark)}$$

(MAX 3)

- (b) The designer of a heating element for the rear window of a car decides to connect six separate heating elements together as shown below. Each element has a resistance of 6.0Ω and the unit is connected to a 12 V dc supply having zero internal resistance.



- (i) Calculate the current in each single element.

There are several ways of doing this... the simplest is to think that the arrangements of three in parallel are equal so the 12V is split equally - each arrangement gets 6.0V (Mark this on the diagram as shown) (1 mark) - therefore the potential drop across each resistor is 6.0V . We can then use $V=IR$ to work out the current.

$I = V/R = 6.0/6.0 = 1.0A$ (1 mark)

OR - you could work out the resistance of the three in parallel = $6.0/3.0 = 2\Omega$ therefore the total resistance = 4.0Ω . Then total current = $V/R = 12/4.0 = 3.0 A$. This splits three ways as it goes through the parallel arrangement so each resistor gets $1.0A$ current - this is far more complicated and still only gets you 2 marks!

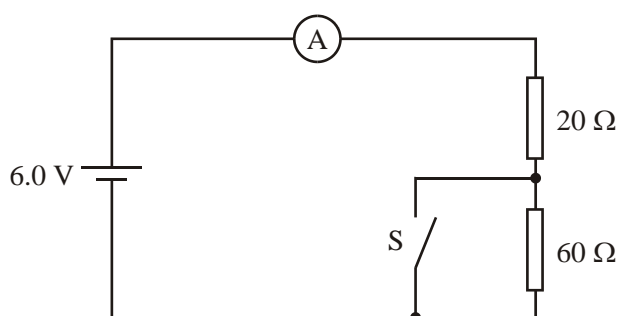
- (ii) With the aid of a similar calculation give a reason why the heater would not be as effective if all six were connected in series.

If they were all connected in series each resistor would get $12V/6 = 2.0V$ across it. (1 mark)

$I = V/R = 2.0/6.0 = 0.33A$ (1 mark) This is only a third of the current worked out in part (i). As the heating effect produced is given by I^2R (1 mark) the arrangement would result in a ninth of the heat output if arranged in this manner. (1 mark) (3 max)

(5)
(Total 8 marks)

8. In the circuit shown below, the battery, of EMF 6.0V, has negligible internal resistance.



- (a) Calculate the current through the ammeter when the switch S is

- (i) open, (ii) closed.

(i) When the switch is open the circuit resistance is 80Ω (1 mark).

$I = V/R = 6.0/80 = 0.075A$ (1 mark).

(ii) When the switch is closed the 60Ω resistance is in parallel with a piece of connecting wire - the resulting resistance is less than the resistance of the connecting wire - it is shorted out.

That means the circuit resistance is 20Ω . (1 mark).

$I = V/R = 6.0/20 = 0.30A$ (1 mark). (Max 3)

(3)

- (b) The switch S is now replaced with a voltmeter of infinite resistance. Determine the reading on the voltmeter.

The voltmeter reads the potential difference across the 60Ω resistor. The $6.0 V$ voltage is shared out across 80Ω . (1 mark)

Each ohm gets $6.0/80$ - so the 60Ω resistor would get $60 \times 6.0/80 = 360/80 = 4.5 V$ (1 mark)

(2)

(Total 5 marks)

9. (a) A student is given three resistors of resistance 3.0Ω , 4.0Ω and 6.0Ω respectively.
 (i) Draw the arrangement, using all three resistors, which will give the largest resistance.

The three in series (1 mark)

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

$$R_T = R_1 + R_2 + R_3 + \dots = 3.0 + 4.0 + 6.0 = 13\Omega \text{ (1 mark)}$$

- (iii) Draw the arrangement, using all three resistors, which will give the smallest resistance. The three in parallel. (1 mark)

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

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots = 1/3 + 1/4 + 1/6 = 9/12 \text{ (1 mark)}$$

So, $R_T = 12/9 = 1.3 \Omega$ (1 mark)

(5)

- (b) The three resistors are now connected to a battery of emf 12 V and negligible internal resistance, as shown on the right

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

Parallel Arrangement

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots = 1/3 + 1/6 = 3/6$$

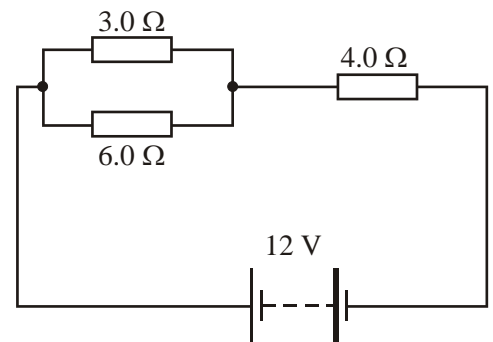
So, $R_T = 6/3 = 2.0 \Omega$ (1 mark)

This was in series with the 4.0Ω resistor.

$$R_T = R_1 + R_2 + R_3 + \dots = 2.0 + 4.0 = 6.0 \Omega \text{ (1 mark)}$$

- (ii) Calculate the voltage across the 6.0Ω resistor.

12V shares out across the 4.0Ω and the 2.0Ω arrangement - each ohm gets 2V - so the 2Ω arrangement gets 4.0V (1 mark) and the potential drop across the 6.0Ω resistor is 4.0V (1 mark)



(4)

(Total 9 marks)