1. (a) A set of decorative lights consists of a string of lamps. Each lamp is rated at 5.0 V, 0.40 W and is connected in series to a 230 V supply.

Calculate

(i) the number of lamps in the set, so that each lamp operates at the correct rating,

Each lamp needs 5V across it – the mains supplies 230V – so you need 230/5 in series to share it out:

230/5 = 46 **(1 mark)**

(ii) the current in the circuit,

When the lamps have the correct voltage across them they let a current pass through that makes the lamp convert 0.40 J of electrical energy every second (the 0.40W rating indicates that)…

P=IV and 0.40 = I x 5

I = 0.40/5 = 0.080A **(1 mark)**

Note that you must NOT put 0.08A – that would be putting the answer to only 1SF

(iii) the resistance of each lamp,

V = IR so R = V/I

You can do it for an individual bulb straight off as you have the values:

R = 5.0/0.080 = 62.5Ω

OR you can do it for the whole circuit and then divide by the number of bulbs:

R = 230/(0.080 x 46) = 62.5Ω

OR you can do it from the power equation for a single bulb

P = IV but V = IR, so $P = V^2/R$

therefore $R = V^2/P = 5.0^2/0.40 = 62.5\Omega$

All of the methods give you the same answer. You should then quote the final answer to 2sf as that is the sensitivity of the figures in the question. 63 Ω **ANS (1 mark)**

(iv) the total electrical energy transferred by the set of lights in 2 hours.

The power rating tells you how much energy is transferred in each second, by each bulb.

So, in each second 46 bulbs will transfer 46 x 0.40 J of energy.

You are asked for the transfer in 2 hours – so you need to work out how many seconds that would be:

$2h = 2 \times 60^2$ s

Therefore we get: $46 \times 0.40 \times 2 \times 60^2$ J **(1 mark)** in 2 hours = 1.325×10^5 J

(This should be given to 2sf) = 1.3×10^5 J **(1 mark)**

(5)

(b) When assembled at the factory, one set of lights inadvertently contains 10 lamps too many. All are connected in series. Assume that the resistance of each lamp is the same as that calculated in part (a) (iii).

(i) Calculate the current in this set of lights when connected to a 230 V supply.

In series therefore add the resistances:

$62.5\Omega \times (10 + 46) = 3.5 \times 10^3\ \Omega$ **(1 mark)**

V= IR

$I = V/R = 230/(3.5 \times 10^3) = 0.0657$ A

= 0.066 A **(1 mark)**

(if you use 63Ω instead of 62.5 Ω you get 0.065A – either get you the mark)

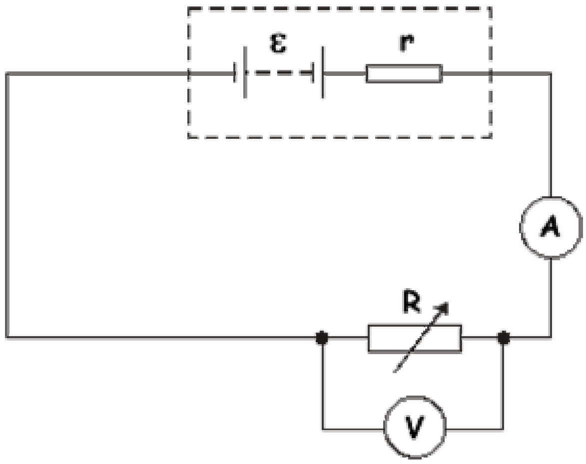
(ii) How would the brightness of each lamp in this set compare with the brightness of each lamp in the correct set?

Each lamp in this set would be dimmer that the corrrct set (as the current through each of them would be lower, due to a smaller p.d. being across them). **(1 mark)**

(3)

(Total 8 marks)

2. A battery of EMF ε and internal resistance *r* is connected in series to a variable resistor R and an ammeter of negligible resistance. A voltmeter is connected across R, as shown in the figure on the right.



(a) (i) State what is meant by the EMF of the battery.

$\varepsilon = \frac{E}{Q}$ $\varepsilon = I\,(R + r)$

On the data sheet you have the equation that you use to formulate the definition.

The EMF of the battery is the electrical energy produced per unit charge **(1 mark)** [- it is equal to the potential difference/voltage across terminals of the battery when there is no current being drawn from it – or the reading on the voltmeter when connected on open circuit]

(ii) The reading on the voltmeter is less than the EMF. Explain why this is so.

The reading on the voltmeter gives the potential difference across the external circuit. When a current flows some of the EMF is used to drive that current through the battery **(1 mark)**. This results in voltage being 'lost' across the **internal resistance (1 mark)** as this is not measured on the instrument.

(3)

(b) A student wishes to measure ε and *r*. Using the circuit shown in the figure above the value of R is decreased in steps and at each step the readings *V* and *I* on the voltmeter and ammeter respectively are recorded. These are shown in the table.

reading on voltmeter/V	**reading on ammeter/A**
8.3	0.07
6.8	0.17
4.6	0.33
2.9	0.44
0.3	0.63

(i) Give an expression relating *V, I,* ε and *r.*

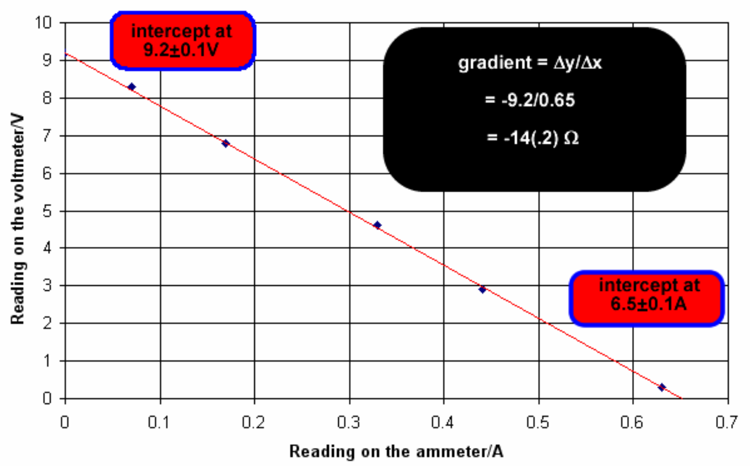
$\varepsilon = \frac{E}{Q}$ $\varepsilon = I\,(R + r)$

On the data sheet you have an equation that is one tiny step from the answer… just use V = IR to obtain it in the terms you want…

ε = V + Ir **(1)**

(ii) Draw a graph of *V* (on the *y*-axis) against *I* (on the *x*-axis) on graph paper.

labelled scales **(1)**
correct plotting **(1)**
best straight line **(1)**



(iii) Determine the values of ε and *r* from the graph, explaining your method.

V + Ir can be rearranged to be the equation of a straight line **(1 mark)**

$V = -rI + \varepsilon$

$Y = mx + c$

V is the reading on the voltmeter (external potential difference)

I is the ammeter reading – the current

-r is the gradient of the graph **(1 mark)** = -14 Ω so r = 14 Ω **(1 mark)**

ε is the intercept on the y axis **(1 mark)** = 9.2 V **(1 mark)**

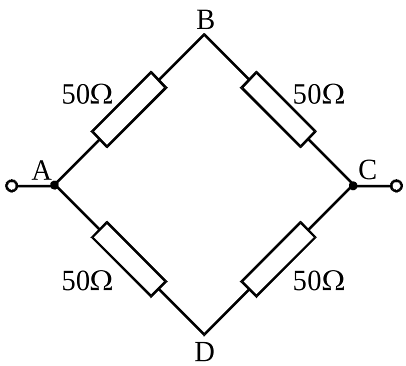
(9)

(Total 12 marks)

3. Four resistors, each having resistance of 50 Ω, are connected to form a square. A resistance meter measured the resistance between different corners of the square. Determine the resistance the meter records when connected between the following corners.

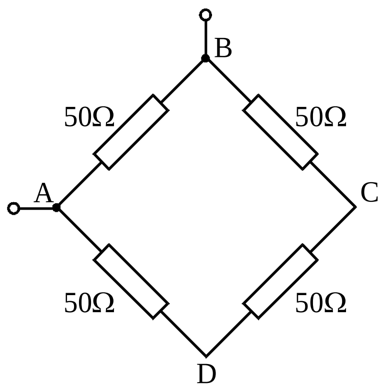
(a) Between A and C, as in Figure 1 ***(2)***

Figure 1

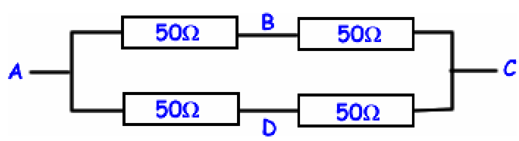


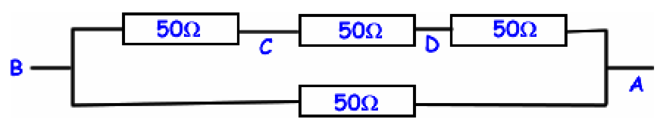
(b) Between A and B, as in Figure 2 ***(3)***

Figure 2



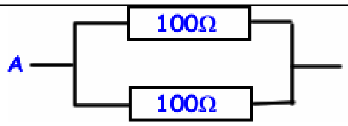
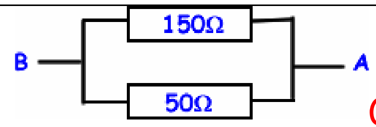
This always confuses students – let's redraw the circuits in a way we can recognize…





Now simplify… resistors in series can be replaced by a single resistor by adding the values…

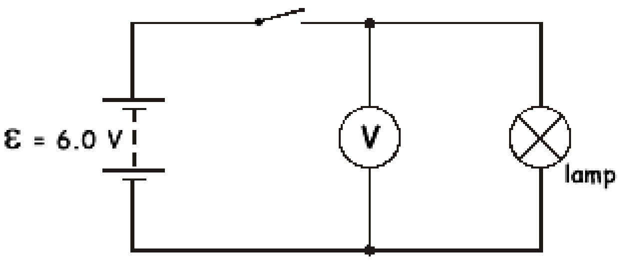
$R_T = R_1 + R_2 + R_3 + \dots$ (from your data sheet)

**(1 mark)** **Easy to solve – for n identical resistors (R) in parallel a single equivalent resistor is R/n so you can do it 'by inspection' but show some working – otherwise you may not get any marks!** R_{AC} = 50Ω **(1 mark)**	**(1 mark)** $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$ $= {}^{1}/_{150} + {}^{1}/_{50} = {}^{4}/_{150}$ **(1 mark)** $R_{AB} = {}^{150}/_{4} = 37.5$ =38Ω **(1 mark)**

(Total 5 marks)

4. (a) In the circuit shown on the right, the battery has an EMF of 6.0 V. With the switch closed and the lamp lit, the reading on the voltmeter is 5.4 V.

Explain without calculation, why the voltmeter reading is less than the EMF of the battery. **(3)**

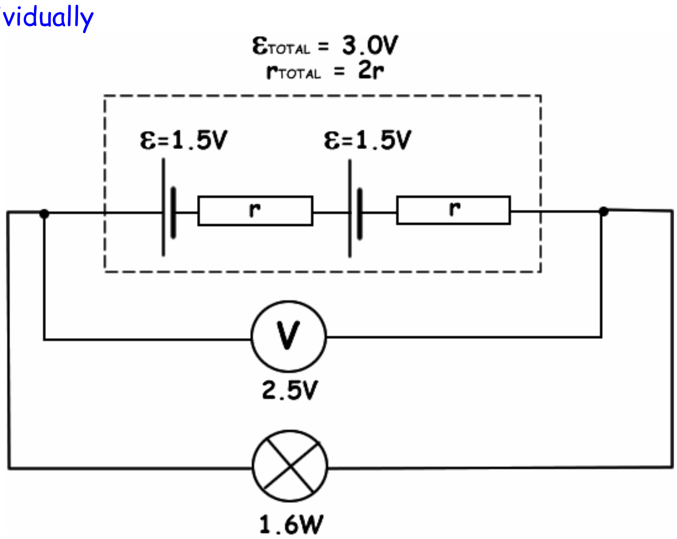


The battery has internal resistance **(1 mark)**. When the current passes through (this resistance) **(1 mark)** work is done (or voltage is used) to drive the current through the battery itself, which reduces the value of the EMF **(1 mark)**.

(b) A torch is powered by two identical cells each having an EMF of 1.5 V and an internal resistance *r*. The cells are connected in series. The torch bulb is rated at 1.6 W and the voltage across it is 2.5 V.

(i) Draw the circuit described.

- encapsulate a battery in a dashed box
- show cells and their resistances individually
- above the box indicate the 'net' values (in case that is what the examiner wants) but within the box show individual values.
- incorporate ALL of the info they give you if they ask you to draw a circuit.
- if you had added a switch here you would have to put the value on the voltmeter as '3.0V when switch is open and 2.5V when the switch is closed'.



1 mark for correctly drawn cells in series and 1 mark for the resistances in series with them and each other.

(ii) Calculate the internal resistance of each cell.

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

ε = 3.0 V

V = 2.5 V (do you see the need for an italic 'V' here?)

(or write V = 2.5 volts)

r = 2r

R = ?

I = ?

We have three unknowns, so we need to first find I by some other means…

$P = IV$ (for the lamp)

P = 1.6W

V = 2.5V

$I = P/V = {}^{1.6}/_{2.5} = 0.64$ A **(1 mark)**

and then eliminate R by replacing IR with V

$\varepsilon = I(R + r) = V + Ir$ **(1 mark)**

3.0 = 2.5 + 0.64 (2r)

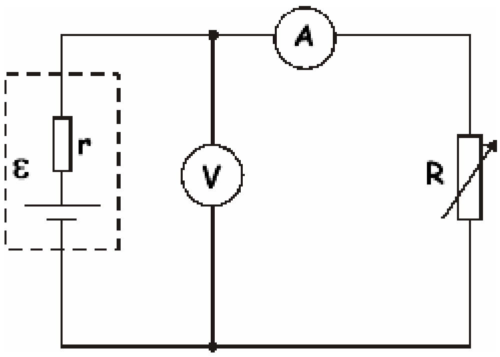
0.5 = 1.28r

r = 0.5/1.28 = **0.39Ω (1 mark)**

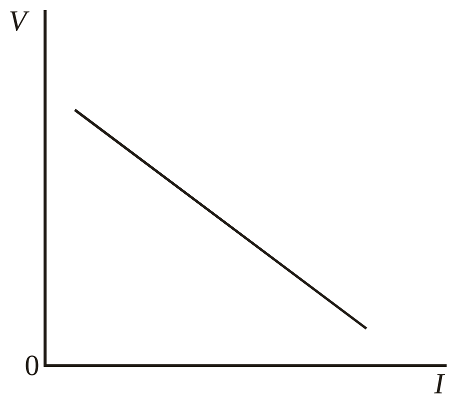
Or do it by:

'lost volts' = ε – V = Ir - same outcome!

(5)



(c) In the circuit on the left the cell has emf ε and internal resistance r. The voltage V across the cell is read on the voltmeter which has infinite resistance, and the current I through the variable resistor R is read on the ammeter. By altering the value of the variable resistor R, a set of values of V and I is obtained. These values, when plotted, give the graph shown on the right.



Show how the values of ε and r may be obtained from this graph. Explain your method.

$\varepsilon = I(R + r) = V + Ir$

Rearrange this into the form $Y = mx + c$ **(1 mark)**:

$V = -rI + \varepsilon$

The gradient of the line **(1 mark)** is the (negative) of the internal resistance and the intercept on the Y axis **(1 mark)** is the EMF of the cell.

(3)

(Total 11 marks)