10. (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.

$E = IVt,\ P = IV,\ P = I^2R$

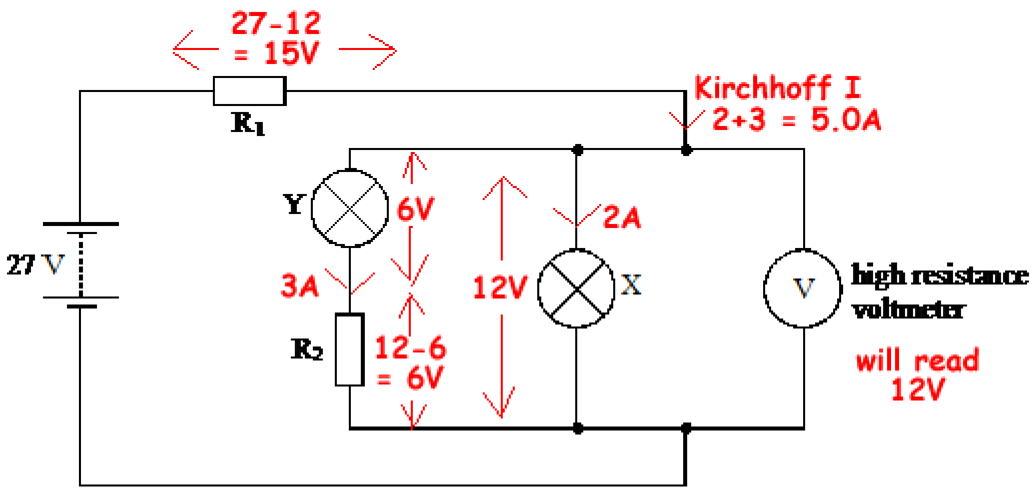
P =IV so I = P/V – Note this will only give the correct current if the lamp is plugged into the correct voltage – it will only have that power rating if it is connected to the correct voltage supply.

Lamp X: I = P/V = 24/12 = 2.0 A **(1 mark)**
Lamp Y: I = P/V = 18/6.0 = 3.0 A **(1 mark)**

(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.

You can therefore put in the currents and voltages you worked out in part 'a' onto the diagram – as soon as you do so you can work out the other voltages and currents – see below.



(i) What is the reading on the voltmeter? 12V **(1 mark)**

(ii) Calculate the resistance of R_2.

V=IR R=V/I = 6 **(1 mark)**/3**(1 mark)** = 2.0Ω **(1 mark)**

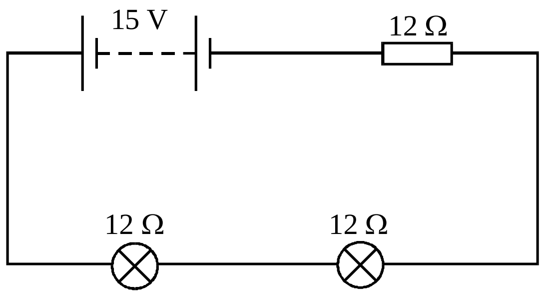
(iii) Calculate the current through R_1. Kirchhoff I 2.0A + 3.0 A = 5.0A **(1 mark)**

(iv) Calculate the voltage across R_1. 27V – 12V = 15V **(1 mark)**

(v) Calculate the resistance of R_1. V=IR R=V/I = 15/5.0 = 3.0 A **(1 mark)**

(7)
(Total 9 marks)

11. (a) In the circuit shown on the right, the battery, of EMF 15 V and the negligible internal resistance, is connected in series with two lamps and a resistor. The three components each have a resistance of 12Ω.



(i) What is the voltage across each lamp?

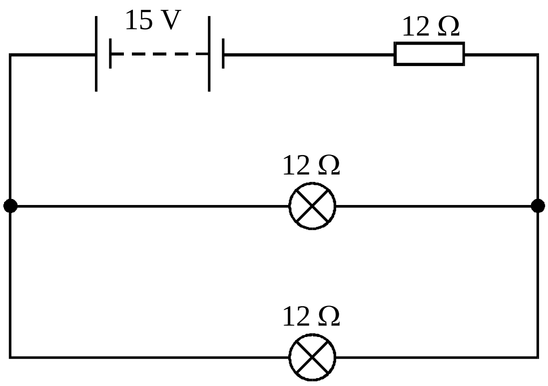
15V shared by three equal resistances
5V each – so the lamp gets 5V **(1 mark)**

(ii) Calculate the current through the lamps.

V = IR
so I = V/R = 5/12 **(1 mark)** = 0.42A **(1 mark)**

(3)

(b) The two lamps are now disconnected and reconnected in parallel.



(i) Show that the current supplied by the battery is 0.83 A.

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

= 1/12 + 1/12 = 1/12 = 1/6

Two lamps in parallel – resistance 6.0Ω **(1 mark)** in series with a 12Ω resistor = 18Ω **(1 mark)**
V = IR so I = V/R = 15/18 = 0.83A **(QED)**

(ii) Hence show that the current in each lamp is the same as the current in the lamps in the circuit in part '**a**'.

This current splits equally **(1 mark)** to go through the parallel section = 0.83/2 = 0.42A – so each lamp gets 0.42 A in this circuit too

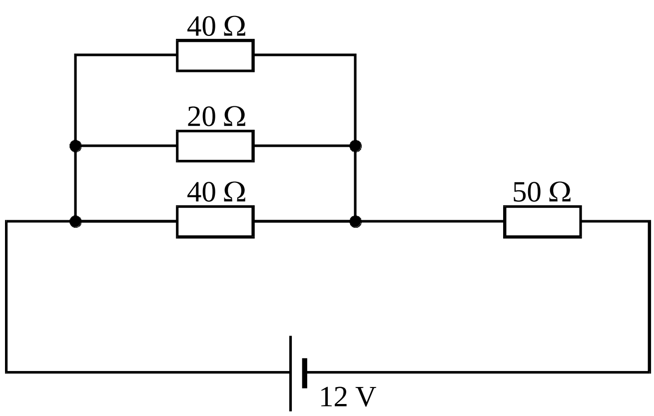
(3)

(c) How does the brightness of the lamps in the series circuit compare with the brightness of the lamps in the parallel circuit? Explain your answer.

Each lamp has the same current flowing through it **(1 mark)** (and has the potential difference across it. P=IV therefore they all are changing electrical energy into heat and light at the same rate). They will therefore be of equal brightness. **(1 mark)**

(2)
(Total 8 marks)

12. A battery of e.m.f 12 V and negligible internal resistance is connected to a resistor network as shown in the circuit diagram.



(a) Calculate the total resistance of the circuit.

Parallel section

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

= 1/40 + 1/20 + 1/40 = 4/40 **(1 mark)**

R_T = 10Ω **(1 mark)**

This arrangement is in series with the 50Ω resistor

$R_T = R_1 + R_2 + R_3 + \ldots$ = 10 + 50 = 60Ω **(1 mark)**

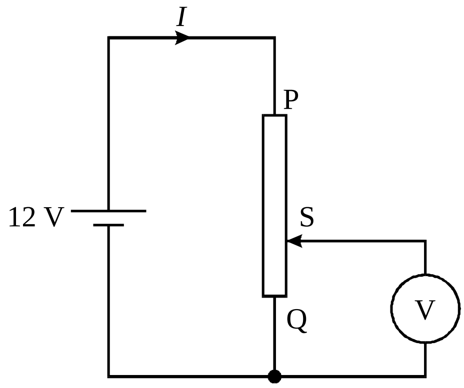
(3)

(b) Calculate the current through the 50Ω resistor.

As r is negligible ε = V.
ε =V=IR
I=ε/R = 12/60 = 0.20A **(1 mark)** (remember 2sf!)

(1)
(Total 4 marks)

13. (a) In the circuit shown on the right, the battery has an EMF of 12 V and negligible internal resistance.



PQ is a potential divider, S being the position of the sliding contact. In the position shown, the resistance between P and S is 180 Ω and the resistance between S and Q is 60Ω.

(i) Calculate the current, *I*, in the circuit, assuming that there is no current through the voltmeter V.

As r is negligible ε = V=IR
I=V/R = 12/(60+180) **(1 mark)** = 12/240 = 0.05A**(1 mark)**

(ii) What property of the voltmeter allows us to assume that no current flows through it?

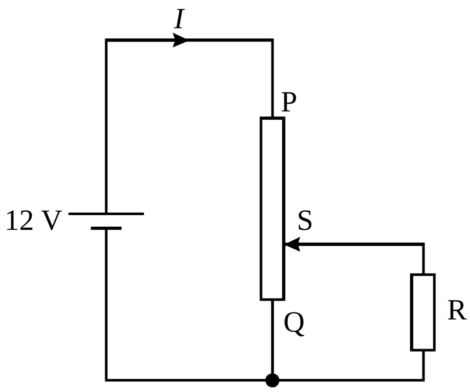
It has very high resistance *compared to the resistance in the circuit* **(1 mark)** if the resistance of the circuit was of the same order as the resistance of the voltmeter it would not be possible to ignore its presence

(iii) What is the reading on the voltmeter?

The voltmeter is connected across SQ – which has a quarter of the resistance of the circuit – it will therefore get a quarter of the voltage from the battery = 3V **(1 mark)**

(4)

(b) The circuit from part 'a' is modified as shown on the right, by exchanging the voltmeter for a load R, whose resistance is about the same as the resistance of section SQ of the potential divider.

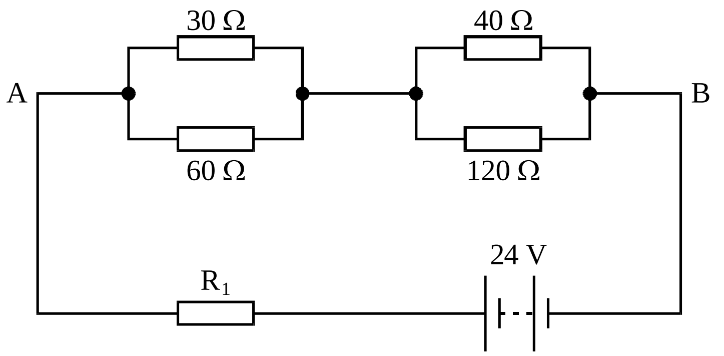


Explain, without calculation, why the current through the battery increases in value from that in part (a).

The parallel arrangement of SQ and R would have a lower resistance **(1 mark)** than SQ on its own (which is effectively what it is when in parallel with the voltmeter). The reduction of resistance to current flow will result in an increase of current flow. **(1 mark)**

(2)
(Total 6 marks)

14. A battery of EMF 24 V and negligible internal resistance is connected to a resistor network as shown in the circuit diagram in the diagram on the right.



(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.

First Arrangement

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

= 1/30 + 1/60 = 3/60 **(1 mark)**

R_1 = 60/3 = 20 Ω **(1 mark)**

Second arrangement

$1/R_2$ = 1/40 + 1/120 = 4/120

R_2 = 120/4 = 30 Ω **(1 mark)**

$$R_T = R_1 + R_2 + R_3 + \ldots$$

These two arrangements are in series

= 20 + 30 = 50Ω QED **(1 mark)**

(4)

(b) If R_1 is 50 Ω, calculate

(i) the current in R_1,

Total resistance of the circuit = resistance between AB and R_1 = 50 + 50 = 100Ω**(1 mark)**

V = IR I = V/R = 24/100 = 0.24A**(1 mark)**

(ii) the current in the 60 Ω resistor.

The current splits to go through the parallel arrangement – twice as much will go through the 30W one than the 60W – therefore a third of the current goes through the 60W resistor

= 0.24/3 **(1 mark)** = 0.080A **(1 mark)**

(4)

(Total 8 marks)

15. Two resistors, A and B, have different resistances but otherwise have identical physical properties. E is a cell of negligible internal resistance.

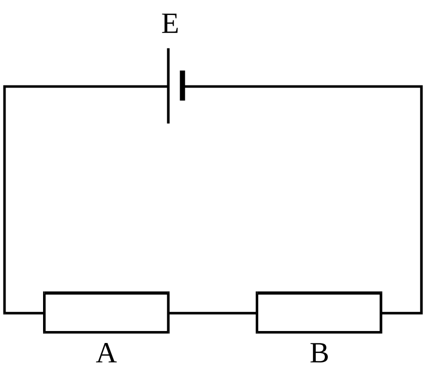


figure 1

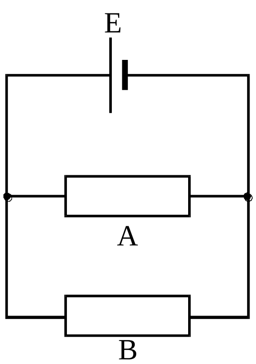


figure 2

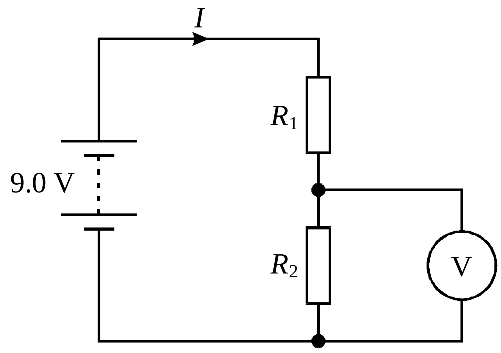
When the resistors are connected in the circuit shown in figure 1, A reaches a higher temperature than B. When connected in the circuit shown in figure 2, B reaches a higher temperature than A. Explain these observations fully, stating which resistance is greater.

$$E = IVt,\ P = IV,\ P = I^2R$$

When they are in series they both have the same current passing through them. **(1 mark)** The heat energy produced depends on the square of the current and the value of the resistance $P=I^2R$. **(1 mark)** The square of the current is the same – but the resistances differ. A gets hotter – therefore **A must have a higher resistance than B**. **(1 mark)**
When they are then connected in parallel they both get the same potential difference across them. **(1 mark)** P = IV but I = V/R so $P = V^2/R$ in this arrangement V is constant. **(1 mark)** The smallest power output will be from the largest resistance – therefore A must have the highest resistance. **(1 mark)**

(Total 6 marks)

16. In the circuit shown on the right, the battery has negligible internal resistance. (Therefore ε = V)



(a) (i) If the emf of the battery = 9.0 V, R_1 = 120 Ω and R_2 = 60 Ω, calculate the current I flowing in the circuit.

$$R_T = R_1 + R_2 + R_3 + \ldots$$

= 120 + 60 = 180Ω **(1 mark)**

V = IR I = V/R = 9.0/180 = 0.050A **(1 mark)**

(ii) Calculate the voltage reading on the voltmeter.

Ratio of total voltage/voltage across R_2 = ratio of total resistance/resistance of R_2

9.0/V = 180/60 **(1 mark)** V = 9.0 x 60/180 = 3.0 V **(1 mark)**

(Or just do by splitting the 9.0V across according to resistance or use V = IR = 0.050 x 60)

(4)

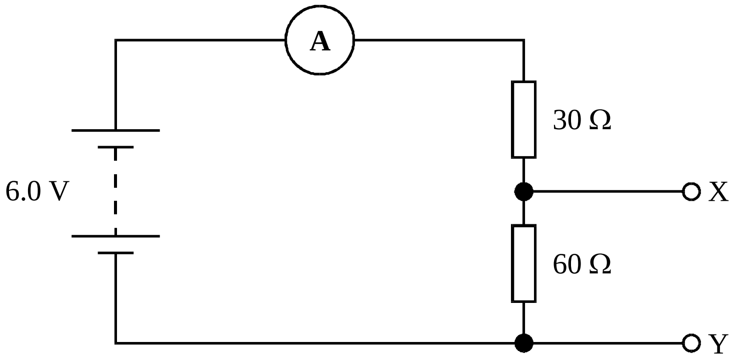
(b) The circuit shown in the diagram acts as a potential divider. The circuit is now modified by replacing R_1 with a temperature sensor, whose resistance decreases as the temperature increases.

Explain whether the reading on the voltmeter increases or decreases as the temperature increases from a low value.

As the temperature increases the resistance of the thermistor decreases. The total voltage remains the same but it is shared out across the resistors according to their relative values **(1 mark).** It therefore gets a smaller share of the total voltage **(1 mark).** The reading on the voltmeter will therefore decrease. **(1 mark)**

(3)
(Total 7 marks)

17. In the circuit shown, the battery has negligible internal resistance.
Calculate the current in the ammeter when



(a) the terminals X and Y are short-circuited i.e. connected together,

When they are short circuited the 60W resistor is in parallel with a piece of connecting wire. The resistance of a parallel arrangement is always less than the lowest resistance strand. The shorted resistor is therefore effectively removed from the circuit and the total resistance in the circuit is then 30Ω.

V = ε as r=0 and R = 30Ω **(1 mark)**

V = IR so I = V/R = 6.0/30 = 0.50 A **(1 mark)** **Care with sig figs!!!**

(2)

(b) the terminals X and Y are connected to a 30 Ω resistor.

Parallel arrangement

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

= 1/30 + 1/60 = 3/60 **(1 mark)**

So, R_T = 60/3 = 20Ω**(1 mark)**

This is in series with the 30W resistor

$$R_T = R_1 + R_2 + R_3 + \ldots$$

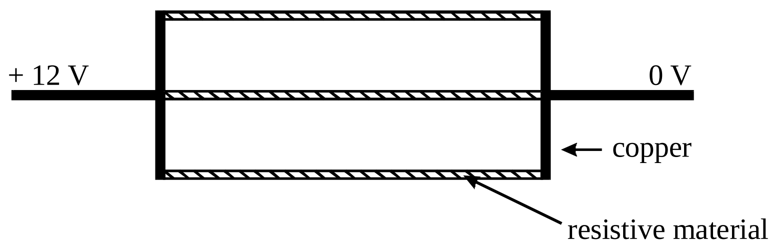
= 20 + 30 = 50Ω **(1 mark)**

V = IR so I = V/R = 6.0/50 = 0.12 A **(1 mark)**

(4)

(Total 6 marks)

18. A heating element, as used on the rear window of a car, consists of three strips of a resistive material, joined, as shown in the diagram, by strips of copper of negligible resistance. The voltage applied to the unit is 12 V and heat is generated at a rate of 40 W.



(a) (i) Calculate the total resistance of the element.

$$E = IVt,\ P = IV,\ P = I^2R$$

P = IV and I = V/R so P = V^2/R **(1 mark)**

and R = V^2/P = 12^2/40 = 144/40 = 3.6Ω **(1 mark)**

(ii) Hence show that the resistance of a single strip is about 11 Ω.

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

- for n identical resistors = n/R

Therefore the resistance of an arrangement of n identical resistors of resistance R in parallel is = R/n **(1 mark)**

In this case there are 3 resistor strips of resistance R in parallel with each other **(1 mark)**

$R/3 = 3.6\Omega$ so $R = 3 \times 3.6 = 10.8\Omega$ (which to 2sf is 11Ω) QED **(1 mark)**

(5)

(b) If each strip is 2.6 mm wide and 1.1 mm thick, determine the length of each strip.

(resistivity of the resistive material = 4.0×10^{-5} Ω m)

$R = 10.8\Omega$

$A = (2.6 \times 10^{-3}) \times (1.1 \times 10^{-3})$ m^2 **(1 mark)**

$$\rho = \frac{RA}{L}$$

rearrange to give $L = (RA)/\rho$ **(1 mark)**

$= 10.8 \times (2.6 \times 10^{-3}) \times (1.1 \times 10^{-3}) / 4.0 \times 10^{-5}$ m

= 0.77 m **(1 mark)**

(3)

(Total 8 marks)