CURRENT ELECTRICITY

Electric Currents

Charges that produce repulsion and attraction between objects can also produce an electric current if the charge can flow though it. An electric current is actually the flow of electric charge moving a particular direction. To maintain an electric current, the charge needs a continuous path to travel around (closed circuit)

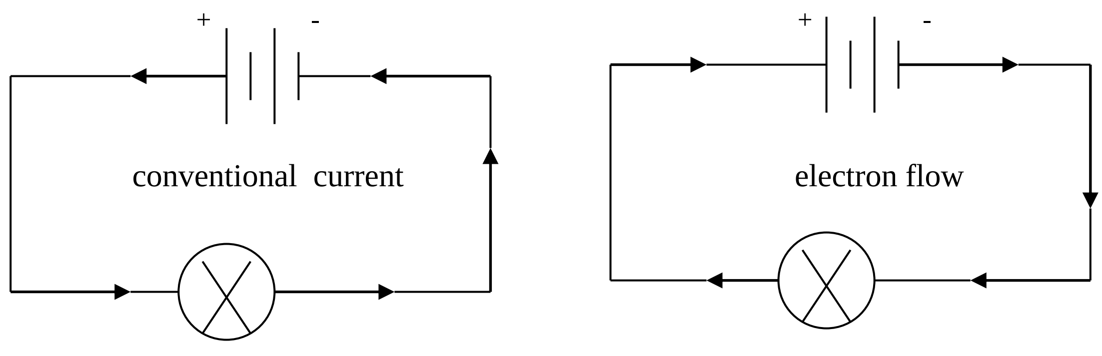
Convectional Current and Electron Flow

Electron Flow

When electric currents pass through a circuit the electrons in the conductor go through the conductor to produce a flow of negative charge in the direction they travel. The negative charge flows from the negative points to positive points. This is the opposite to the direction of conventional current flow.

Conventional Currents

Early experiments believe that electricity is the flow of positive charge around the circuit. We therefore represent the flow of electric current as from a positively charged point to a negatively charged point. We use arrows to indicate the direction of the current flow and we call this direction conventional current direction.



Closed Circuit
A closed circuit is one which there is an unbroken charge in which the charge can continuously flow.

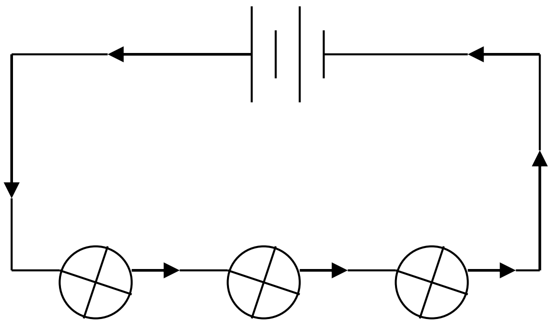
An Open Circuit
An open circuit is one which has a break at one or more points of the path so that no current can flow in the circuit.

A Short Circuit
A short circuit acts as a by pass for the electric current by providing an easier path for the current to flow.

Series and Parallel Connections

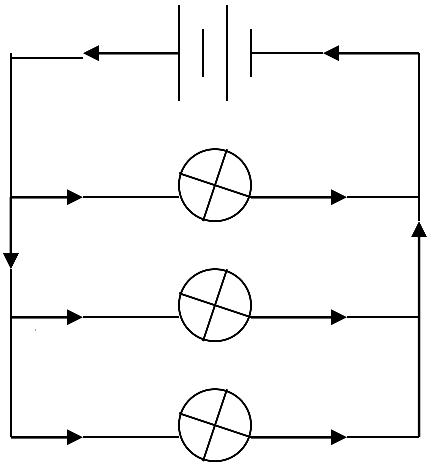
There are basically two ways in which conductors can be joined together in a circuit. These are:

a) **Series Connections**



The lamps in the diagram above are connected in series. When lit they shine at equal brightness. That means that the same current flows through all the lamps. If one lamp fails or is loose the circuit is broken, hence no current flows and all the lamps go off.

b) **Parallel Connections**



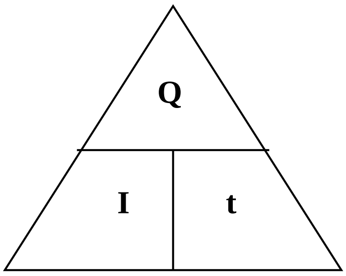
The lamps in the diagram above are in parallel connection. In parallel connection the current splits up and only part of the current flows through each lamp. If one of the lamp fails it does not affect the other lamps in the circuit.

Definitions

Current (I) ***Units: Amperes (A)***
A current of one (1) ampere is the flow of charge at a rate of one (1) coulomb per second. Current is the force between the current carrying conductors. We can use the ammeter to measure the current. One of the formulas we can use to measure the current is:

$$\textbf{current} = \frac{\textbf{charge}}{\textbf{time}}$$

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



Charge (Q) ***Units: Coulombs (C)***
A Coulomb is the quantity of electric charge, which passes a point in the conductor at a steady current of one (1) ampere for one (1) second.

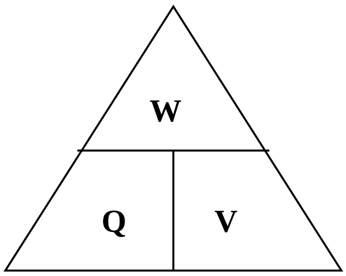
charge = current × time

$$Q = I \times t$$

Potential Difference (p.d.) ***Units: Volts (V)***
The potential difference between two points is the work done per coulomb when electrical energy is converted to another form of energy when current flows through a circuit.

$$\textbf{potential difference} = \frac{\textbf{energy}}{\textbf{charge}}$$

$$V = \frac{W}{Q}$$



Electromotive Force (e.m.f.) ***Units: Volts (V)***
An electromotive force is the work done per coulomb when another form of energy is converted to electrical energy at a cell or generator. The e.m.f. is the total amount of energy a cell or a generator can produce and it is the sum of all the p.d. inserted.

Both the electromotive force and the potential difference can be measured by using the voltmeter.

N.B. one (1) volt = one (1) joule / coulomb [1 J/C]

Examples

1. A battery circulates a charge around a circuit of one (1) minute. If the current in the circuit is five (5) amperes, what quantity of charge passes through the battery?

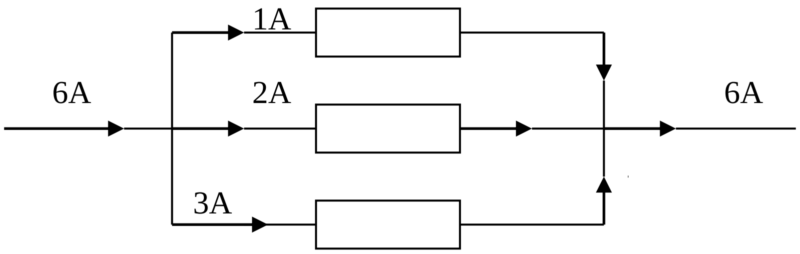
2. A charge of 120 coulombs goes through a lamp every two minutes. Calculate the electric current.

3. A current of 20 amps flows through a heater for one (1) hour converts 8.6×10^6 joules of electrical energy into heat energy. Calculate:
   (a) the total charge flowing through the heater.
   (b) p.d. across the heater.

4. A battery circulates 80 C of charge around a circuit. If the p.d. across a lamp in the circuit is 12 volts. How much energy is converted into heat and the light by the lamp? If the charge flows at a constant rate for 40 seconds, what is the current during this time?

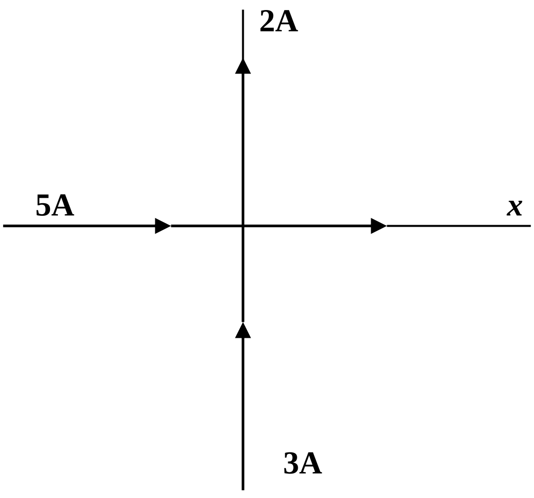
Kirchhoff 1st Law

This law states that the total current entering the junction in a circuit must equal to the total current leaving it. (As shown in the diagram below).



Example

The figure below shows the currents of 5A and 3A entering a junction in a circuit and a current of 2A leaving. Find the size and the direction of the current of ***x***.



Read only:
PFC Page 214 – 216

- Conductors and insulators

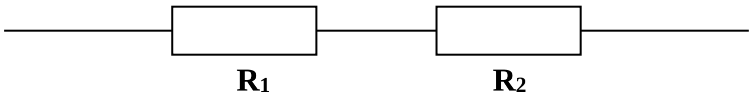
Read and make notes on
PFC Page 223 – 225

- How do objects become charge?
- Figure 12.17: types of resistors

Resistors

Resistors are small devices, which oppose the flow of current in the circuit.

Resistors in Series



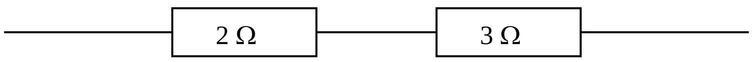
We can calculate the total resistance for resistors in series by using:

$$R_T = R_1 + R_2$$ ***Units: ohms (Ω)***

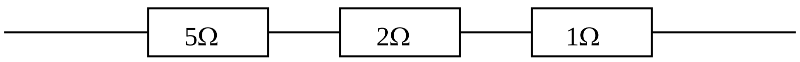
Examples

Find the equivalent resistor for the following circuit diagrams.

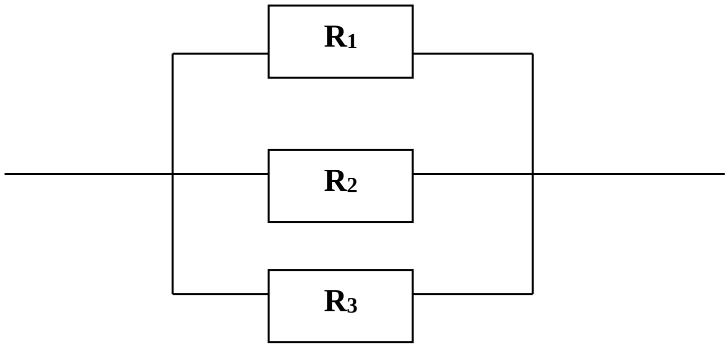
a)



b)



Resistors in Parallel



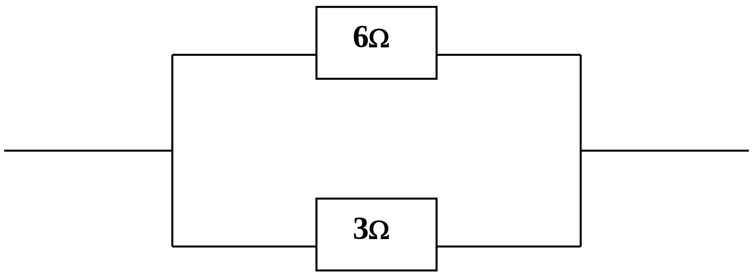
We can calculate the total resistance for resistors in parallel by using:

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

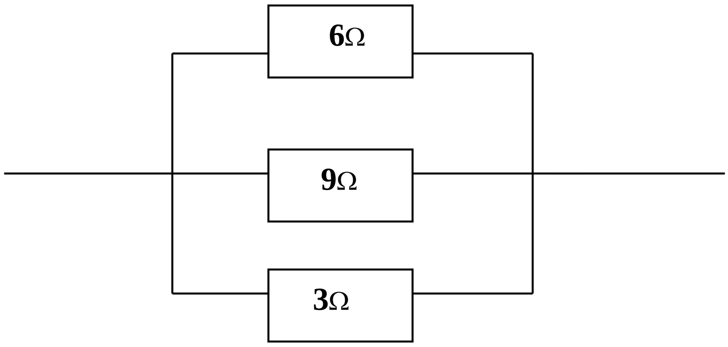
Examples

Find the equivalent resistor for the following circuit diagrams.

a)



b)

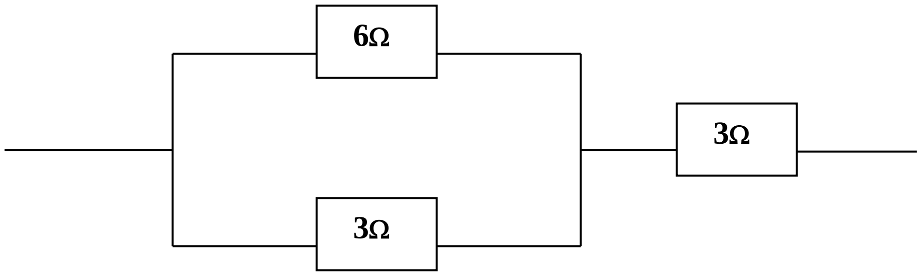


Mixed Series and Parallel Combinations of Resistors

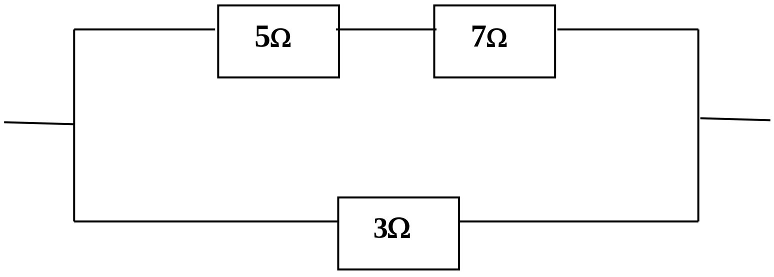
Examples

Find the equivalent resistors for the following circuit diagrams.

a)



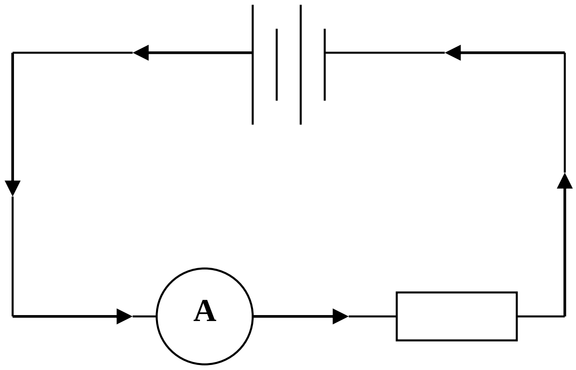
b)



Ammeters

We use the ammeters to measure the current in a circuit; therefore it should not change the amount of current that is flowing. If the ammeter has any resistance it would increase the total resistance in the circuit and reduce the amount of current flowing. Hence the ideal ammeter should have zero resistance.

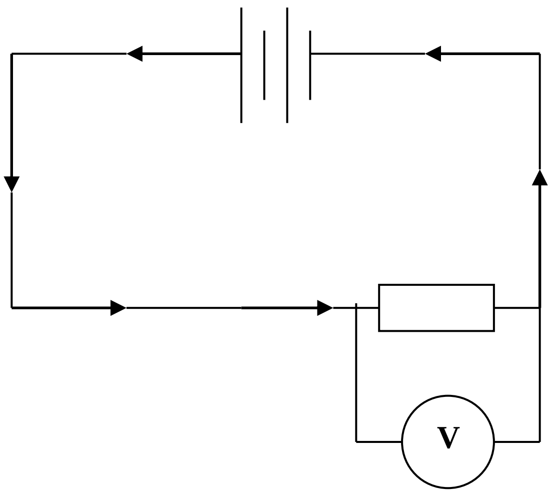
Ammeters are connected in series with the current to be measured.



Voltmeters

The voltmeter is used to measure the voltage across a given part of the circuit. The resistance of the voltmeter is very high to prevent any current flowing through it. Any current flowing through the voltmeter means an increase in the current in the circuit hence affecting the reading of the voltmeter. Hence the ideal voltmeter has an infinite resistance and zero current passing through it.

The voltmeter is connected in parallel width or across the voltage to be measured.



Ohm’s Law

Ohm’s law states that the current through a conductor at a constant temperature is directly proportional to the potential difference between its ends.

$$I \propto V$$

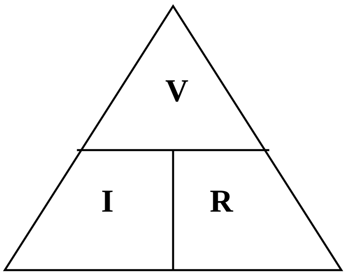
$$\frac{V}{I} = \text{constant}$$

where the constant the is the resistance of the conductor

$$R = \frac{V}{I}$$

or

$$V = IR$$



Examples

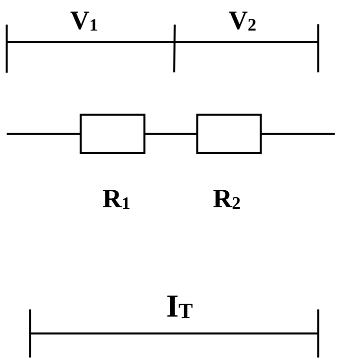
a) A current of 4A flows through a headlamp when it is connected to a car battery providing that a voltage of 12 V flows across the headlamp. Calculate the resistance of the headlamp.

b) What is the resistance needed to drive a current of 0.2 A through a torchlight lamp of resistance 25 Ω?

c) What is the potential difference required to produce a current of 2.5A through a conductor of resistance 12.5 Ω?

<table>
<tr><th>RESISTORS</th><th>CURRENT</th><th>VOLTAGE</th></tr>
<tr>
<td>

SERIES:



</td>
<td>

The current is the same in each resistor.

$$I_1 = I_2 = I_T$$

</td>
<td>

The voltage divides up directly according to the each resistance.

$$V_T = V_1 + V_2$$

$$V_1 = I_1 R_1 = I_T R_1$$

$$V_2 = I_2 R_2 = I_T R_2$$

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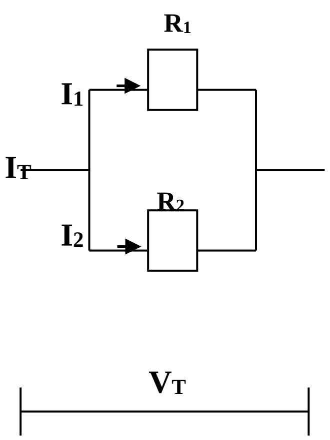
PARALLEL:



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<td>

The current divides according to the inverse ratio of each resistance.

$$I_T = I_1 + I_2$$

$$I_1 = \frac{V_1}{R_1} = \frac{V_T}{R_1}$$

$$I_2 = \frac{V_2}{R_2} = \frac{V_T}{R_2}$$

</td>
<td>

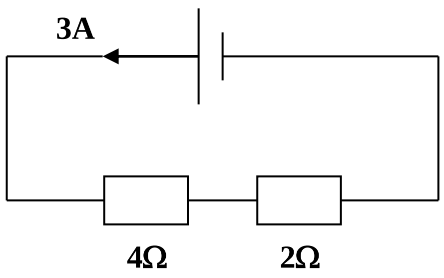
The voltage is the same in each resistor.

$$V_1 = V_2 = V_T$$

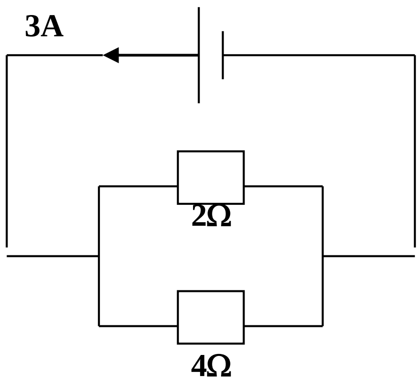
</td>
</tr>
</table>

Examples

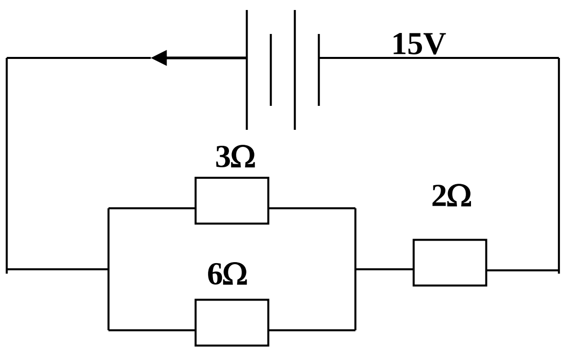
1. Calculate
   a) total resistance
   b) total voltage
   c) voltage across
      (i) 4Ω
      (ii) 2Ω resistors



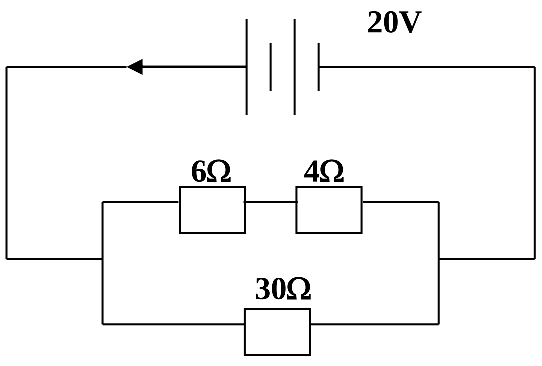
2. Calculate:
   a) total resistance
   b) total voltage
   c) voltage across
      (i) 4Ω
      (ii) 2Ω resistors



3. Calculate:
   a) total resistance
   b) total current
   c) voltage across
      (i) 2Ω
      (ii) 3Ω
      (iii) 6Ω



4. Calculate:
   a) total resistance
   b) total voltage
   c) voltage across
      (i) 4Ω
      (ii) 2Ω
      (iii) 30Ω resistors

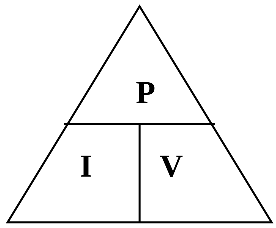


Power

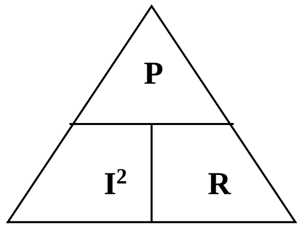
When the energy is converted from one form to another the rate of conversion is defined as power. ***Units of power: watts (W)***

They are three basic formulas we can use calculate the power of an electrical circuit.

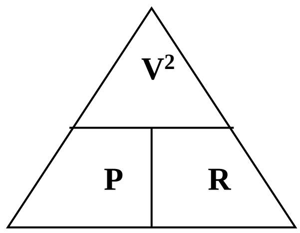
1. **$P = IV$**



2. **$P = I^2R$**



3. **$P = \frac{V^2}{R}$**



Examples

a) An electric fire has a power rating of 3 kW. Calculate the current that will flow through the fire when it is connected to the 240 V mains supply.

b) A torch bulb is labelled 2.5 V, 0.3 A. Calculate the power of the bulb and the energy converted in 10 minutes.

c) An electric kettle has a heating element rated 2 kW when connected to a 250 V electrical supply. Calculate:
   (i) the current that would flow when the element was connected to the 250 V supply.

   (ii) the resistance of the element.

   (iii) The heat produced by the element in one (1) minute.

Resistivity ***Units: ohm meter (Ωm)***

The resisitivity (ρ) of a material is the numerical value equal to the resistance (R) of the material 1m long with a cross section of 1 m^2.

$$R = \frac{\rho L}{A}$$

The resistance of a conductor depends on:

- The thickness of the conductor. (i.e. the resistance of the conductor is inversely proportional to is cross sectional area.)

$$R \ \alpha \ \frac{1}{A}$$

- The resistance of the conductor. The resistance of a conductor is directly proportional to the length.

$$R \ \alpha \ L$$

- The resistance depends on the material that makes up the conductor.

Read only:

PFC ***Page 229***

- Some important characteristics and graphs of resistors.

PFC ***Page 235 -243***

- Ammeters and voltmeters at work
- Resistivity
- Electrical energy and power

Read and make notes (include diagrams):

PFC ***Page 255***

- Simple cell and zinc carbon
- Dry cell

PFC ***Page 309***

- Electricity at home
- Connecting a cable to a power plug
- Fuses and breakers