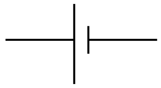
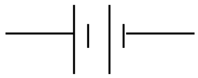
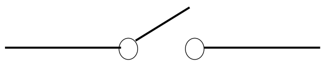
CURRENT ELECTRICITY

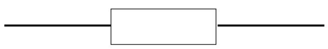
Common Circuit symbols for electric component

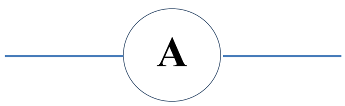
 Cell

 Two cells

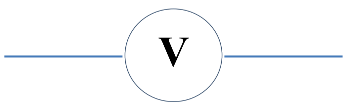
 battery

 switch

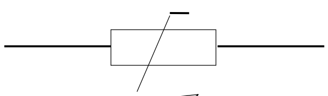
 Resistor

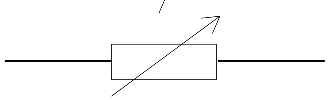


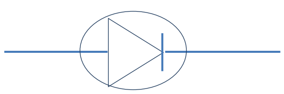
Ammeter

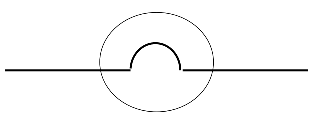
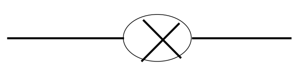


Voltmeter

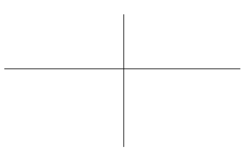
 Thermistor

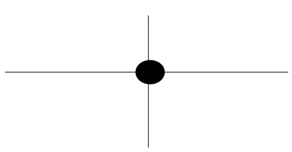
 Variable resistor

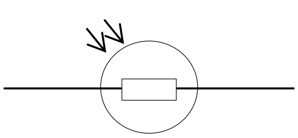
 Diode

 or  Lamp or bulb

 Connecting wire

 Crossing connecting wires

 Connecting wires with a junction

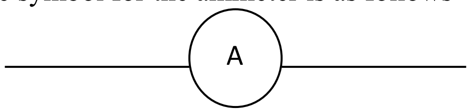
 Light Dependent Resistor

Electric Current

This is the rate of flow of the electric charges. The standard symbol for current is **I**. The electric charge is denoted by **Q** and its SI unit is Coulombs (C).

The SI unit for electric current is amperes and denoted by **A**. The instrument used to measure the electric current is called the **ammeter**.

The symbol for the ammeter is as follows



The other units for the electric current are:

- Milliamperes (**mA**): 1mA = 10^{-3}A
- Microamperes (**µA**): 1µA=10^{-6}A
- Kiloamperes (kA): 1kA = 10^{3}A

Relationship between charge andelectric current

The relationship between charge and electric current is given by the following equation:

Q = I × t where **Q** = charge measured in **Coulombs (C).**
I = electric current measured in **amperes (A).**
t= time measured in **seconds (s).**

Note: 1 A =1C /s

Examples

1. If a charge of 180C flows through a lamp every 2 minutes calculate the electric current passing through the lamp.
   Data: Q= 180C; t = 2minutes =2 × 60s = 120s; I-?
   Equation: Q = I × t
   Substitution: 180C = I × 120s
   180C ÷ 120s = I
   I= 1.5A
2. Calculate the quantity of charge passing through a lamp if current of 5A passes through a lamp for 30s.
   Data: I= 5A; t = 3s; Q-?
   Equation: Q = I × t
   Substitution: Q = 5A × 3s
   Q= 150C
3. Calculate the time taken by the battery to drive 300C of charges through a 15A bulb.
   Data: Q =300C; I =15A; t -?
   Equation: Q = I × t
   Substitution: 300C = 15A × t
   300C = 15A × t
   300C ÷ 15A = t
   t = 20s
4. Convert the following electric current to amperes.
   a) 500mA
   1A: 1000mA
   I : 500mA

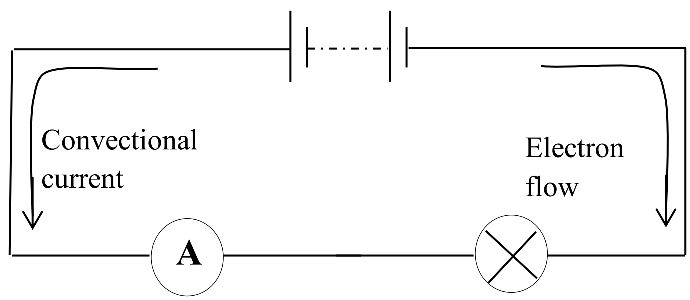
$I \times 1000mA = 500mA \times 1A$
$I = (500mA \times 1A) \div 1000mA$
$I = 0.5A$

b) $25000\mu A$
$1A: 10^6\mu A$
$I: 25000\mu A$
$I \times 10^6\mu A = 25000\mu A \times 1A$
$I = (25000\mu A \times 1A) \div 10^6\mu A$
$I = 2.5 \times 10^{-2}A$

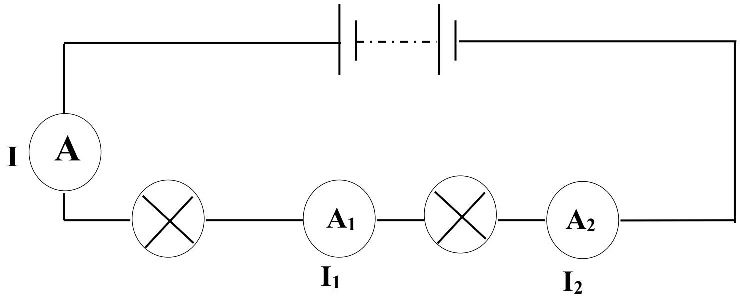
Electric current direction

The direction of electric current is represented by an arrow marked in a circuit. The two types of electric current direction are:

- Convectional current direction: the flow of positive charges from the positive terminal towards the negative terminal round the circuit.
- Electron flow: the flow of negative charges from the negative terminal towards the positive terminal round the circuit.



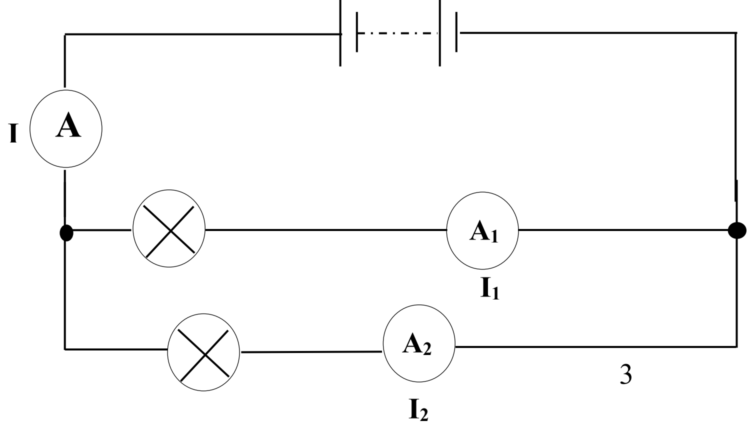
Electric current in a series circuit



In a series circuit the electric current is the same at every point i.e.

$\mathbf{I = I_1 = I_2}$

Electric current in a parallel circuit

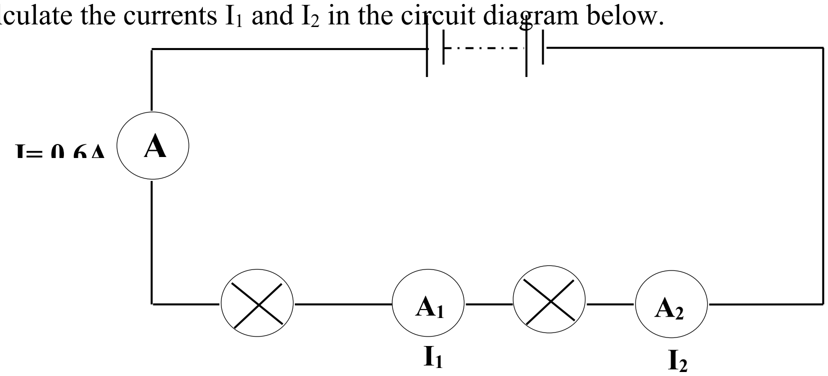


In a parallel circuit the electric current divides at the junction such as the total current provided by the power supply is equal to the sum of individual current in the paths i.e.

$\mathbf{I = I_1 + I_2}$

Examples

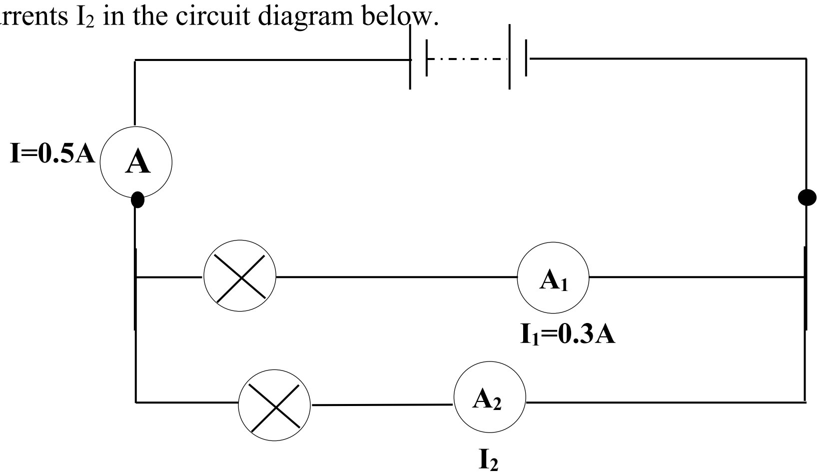
1. Calculate the currents I_1 and I_2 in the circuit diagram below.



Since this is a series circuit i.e.$\mathbf{I = I_1 = I_2}$and I= 0.6A then

I_1 =0.6A and I_2= 0.6A.

2. Calculate the currents I_2 in the circuit diagram below.



$\mathbf{I = I_1 + I_2}$

$0.5A = 0.3A + I_2$

$I_2 = 0.5A - 0.3A$

$I_2 = 0.2A$

Voltage

Two types of voltage are:

(a) Electromotive force

(b) Potential difference

(a) Electromotive force (emf)

This is the energy (work done) required to drive a unit charge around the circuit (from one terminal of the power supply to the other opposite terminal).It is measured in volts (**V**) using a voltmeter.It is calculated using the equation:

$\mathbf{V = E / Q}$ where **V** = electromotive force in **Volts(V)**

E = energy transferred (work done) in **Joules (J)**

Q = charge in **Coulombs (C).**

But **Q = I × t**hence substituting Q, we get;

V = E ÷ (I × t)

Therefore **E = V × I × t**

Note: the voltmeter must always be connected across (parallel to) the electric component e.g. battery or lamp etc.

(b) Potential difference (pd)

This is the energy (work done) required to drive a unit charge across a conductor e.g. a bulb. It is measured in volts (**V**) using a voltmeter. It is measured in volts (**V**) using a voltmeter. It is calculated using the equation:

V = E ÷ Q where **V** = potential difference in **Volts (V)**

E = energy transferred (work done) in **Joules (J)**

Q = charge in **Coulombs (C).**

But **Q = I × t** hence substituting Q, we get;

V = E ÷ (I × t)

Therefore **E = V × I × t**

Examples

1. Calculate the total energy transferred to 100 C of charge when they pass through a battery of emf 12 V.

   Data: Q= 100 C; V = 12 V; E-?

   Equation: V = E÷ Q or E = V×Q

   Substitution: 12 V = E ÷ 100 C

   12 V ×100 C = E

   E = 1200 J or 1.2×10^3 J

2. A cell supplies 9 J of energy to 6 C of charge. Calculate the voltage of the cell.

   Data: E = 9 J; Q = 6 C; V-?

   Equation: V= E÷ Q

   Substitution: V = 9 J ÷ 6 C

   V = 1.5 J / C

   V = 1.5V

3. Determine the amount of charge passing through a 240 V heaterconverting 24 000 J of electrical energy to heat energy.

   Data: E = 24 000 J; V = 240 V;Q -?

   Equation: V= E÷ Q

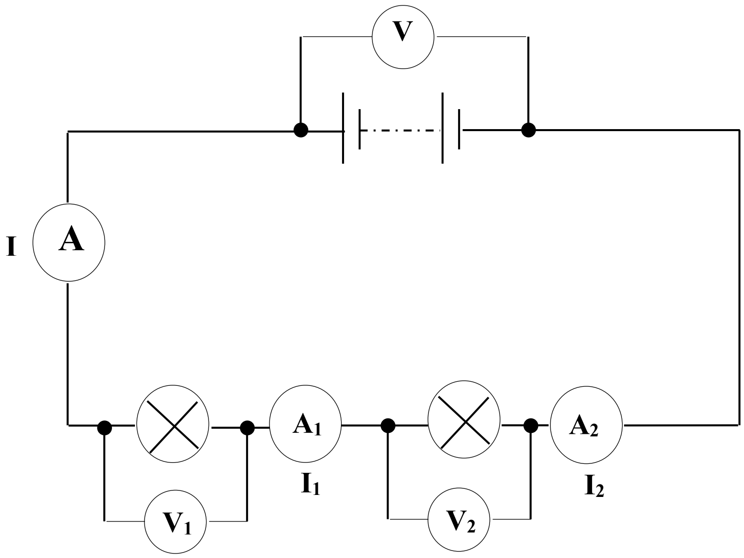
   Substitution:240 V = 24 000 J ÷ Q

   Q = 24 000 J ÷ 240 V

   Q = 100 J / V

   Q =100 C

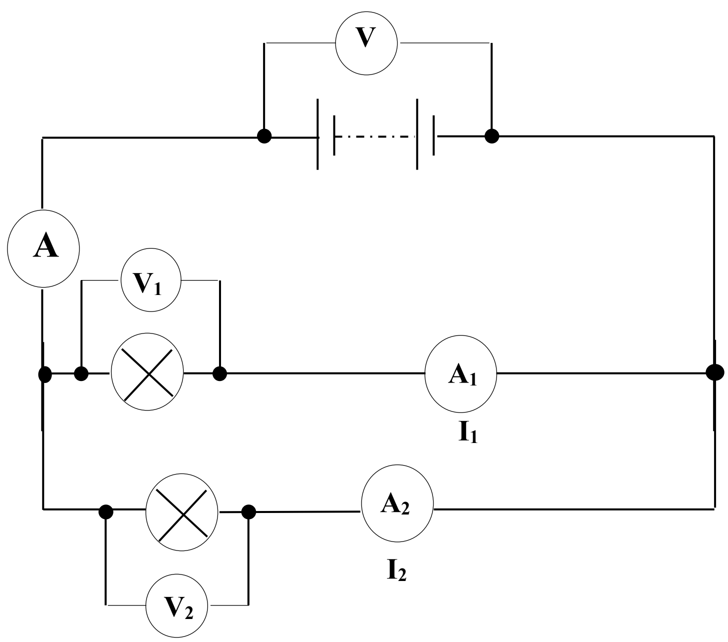
Potential difference (p.d) in a series circuit



In a series circuit the potential difference (p.d) or voltage at the terminals of power supply is equal to the sum of the potential differences (p.ds) or voltages across the devices in the external circuit from one terminal of power supply to the other i.e.

$\mathbf{V = V_1 + V_2}$

Potential difference (p.d) in a parallel circuit

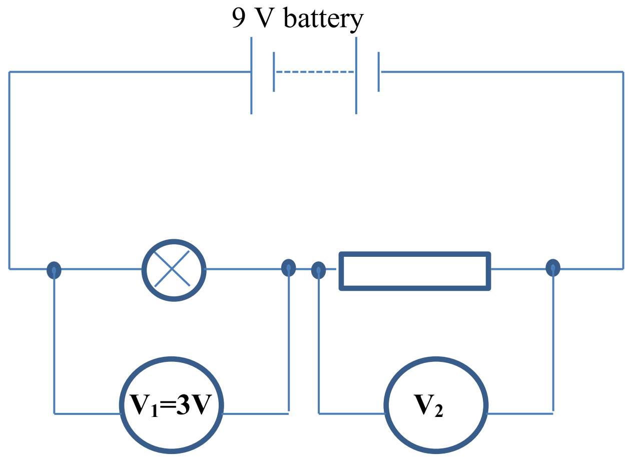


In a parallel circuit: Potential differences (p.ds) or voltages across the devices in parallel are the same i.e.

$\mathbf{V = V_1 = V_2}$

Examples

1. A 9 V battery is connected to a bulb and resistor as shown below.



Determine the p.d , V_2 across the resistor

Data: V = 9 V; V_1 = 3 V; V_2-?

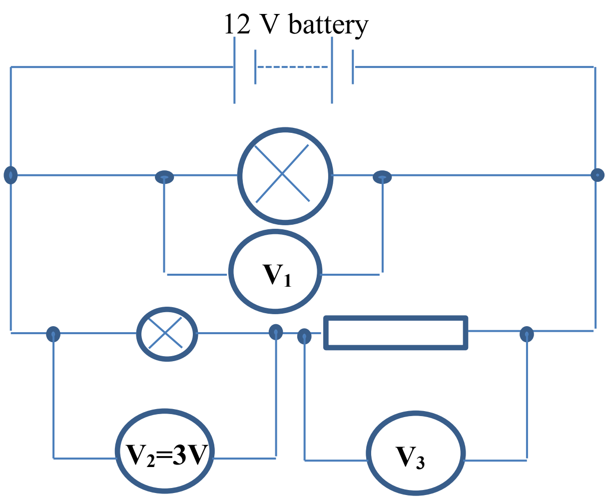
Equation: $V = V_1 + V_2$

Substitution: $9\ V = 3\ V + V_2$

$9\ V - 3\ V = V_2$

$V_2 = 6\ V$

2. A12 V battery is connected to two un-identical lamps bulbs and resistor as shown below



Determine the following

(a) potential difference, $\mathbf{V_1}$ across the first bulb

thep.d across devices in a parallelcircuit are equal therefore

V_1= 12 V

(b) potential difference, $\mathbf{V_3}$ across the resistor

$V = V_2 + V_3$

$12\ V = 3\ V + V_3$

$V_3 = 12\ V - 3\ V$

$V_3 = 9\ V$

Resistance

This is the opposition of current flow through a conductor.

Good conductors of electricity have low resistance while poor conductors of electricity have high resistance.

The SI unit for resistance is ohms (Ω).

The resistance of an electric device is calculated using the equation:

R = V / I where **R** = resistance in ohms (Ω).

V = Potential difference (p.d) in volts (V).

I = Current in amperes (A).

Ohm's Law states that the current through a conductor is directly proportional to the potential difference across it provided the temperature of the conductor remains constant.

Examples

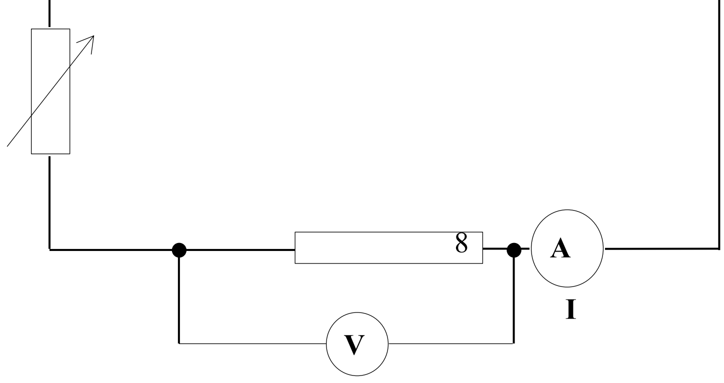
1. A current of 4A flows through a car headlamp when connected to a 12V car battery, providing a voltage of 12V across the lamp.
   Calculate its resistance.
   Solution:
   Data: I = 4A; V = 12V; R-?
   Equation: R = V / I
   Substitution: R = 12V ÷ 4A
   R = 3Ω.
2. Calculate the potential difference (p.d) needed to drive a current of 0.2A through a torch lamp of resistance 22.5Ω.
   Solution:
   Data: I = 0.2A; R = 22.5Ω; V-?
   Equation: R = V / I
   Substitution: 22.5Ω = V ÷ 0.2A
   22.5Ω × 0.2A = V
   V = 4.5V

Experimental determination of the resistance of a conductor

Apparatus:

- Ammeter
- Voltmeter
- Variable resistor (rheostat)
- Fixed resistor
- Connecting wires
- Battery

Set up:



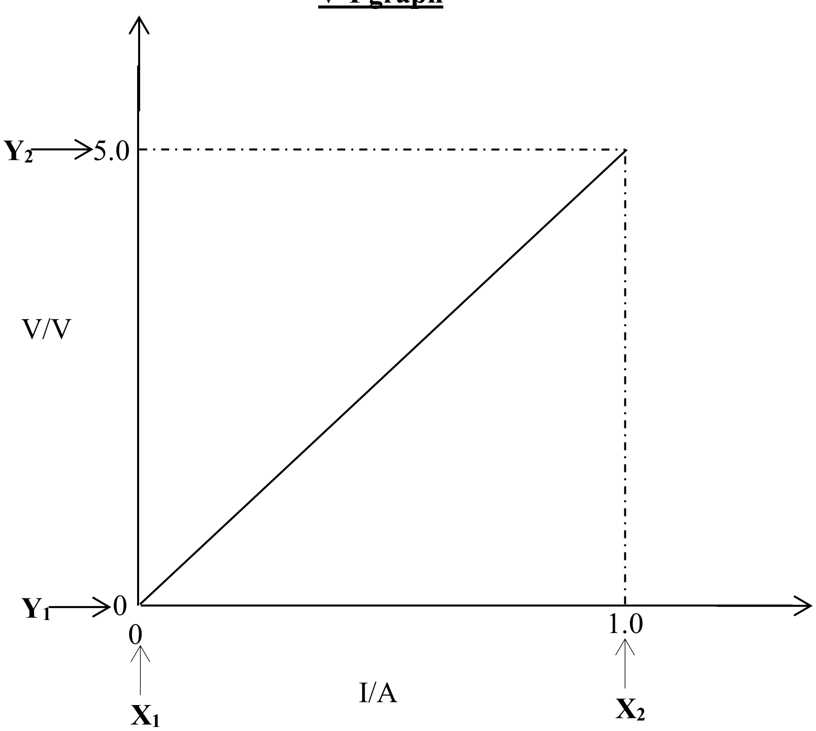
Procedure:

- Arrange the apparatus as shown above.
- Close the switch, adjust the rheostat until a suitable current, I, is recorded on the ammeter.
- Record the readings of current, I and potential difference, V to get at least five sets of suitable readings (0.0A < I < 1.0A).
- Tabulate the results and calculate the values of R, using **R = V /I**.
- Plot a graph of V against I.
- Draw the conclusion.

Results and Analysis:

Current, I / A	**Potential difference, V /V**	**Resistance, R /Ω**
0.2	1.0	5.0
0.4	2.0	5.0
0.6	3.0	5.0
0.8	4.0	5.0
1.0	5.0	5.0

<u>V-I graph</u>



Gradient calculation

Gradient = $(Y_2 - Y_1) \div (X_2 - X_1)$

= (5.0V – 0.0V) ÷ (1.0 A– 0.0A)

= 5.0V – 1.0 A

= 5.0Ω (resistance)

Note:

- The resistance of a conductor is equivalent to the gradient of a V-I graph.
- The steeper the gradient of a V-I graph, the greater the resistance a conductor have.

Factors affecting the resistance of a conductor (wire)

The resistance of a wire (conductor) depends on the following:

- **Length of a wire:** The longer the wire the greater the resistance and the shorter the wire the less the resistance.
- **Cross sectional area:** the bigger the cross sectional area of the wire (or the thicker the wire) the less the resistance and vice versa.
- **Resistivity of a material:** The greater the resistivity of the wire the greater the resistance and vice versa.
- **Temperature:**
  - i. For metal conductors, the resistance increases as temperature increases.
  - ii. For semiconductors, the resistance decreases as temperature increases.

Note:

(i) **Resistance** is directly proportional to the length, ***l*** of a wire i.e.

$R \alpha l$

(ii) **Resistance** is indirectly proportional to the cross sectional area, **A** of a wire i.e.

$R \alpha (1/A)$

Combining (i) and (ii) we get $R \alpha (l / A)$ **i.e.**

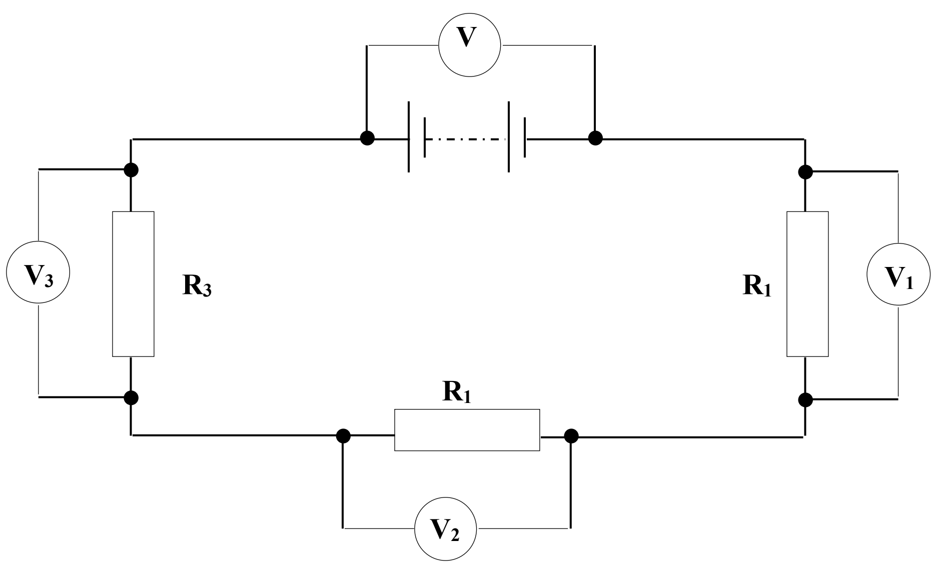
$R = \frac{\rho l}{A}$ where R = resistance in Ω

ρ = resistivity in Ωm

l= length in m.

A = cross sectional area in m^2

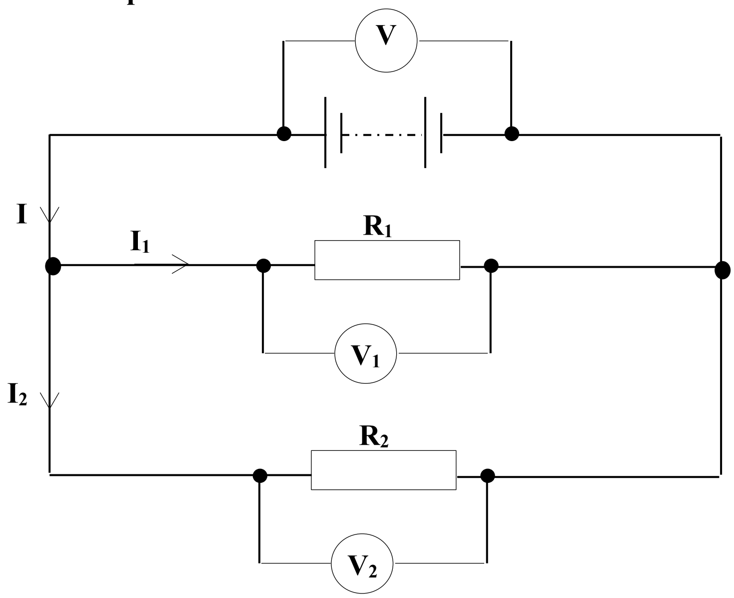
Resistance in a series circuit



In a series circuit: the total resistance, R_T of two or more resistors in series is simply the sum of the individual resistances of the resistors i.e.

$R_T = R_1 + R_2 + R_3$

Resistance in a parallel circuit



In a parallel circuit: the total resistance, $\mathbf{R_T}$ of two or more resistors in parallel is given by the following equation:

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$ OR $R_T = \frac{R_1 \times R_2}{R_1 + R_2}$

V-I graphs

These are obtained by plotting values of current, I (in y-axis) against potential differences (p.d), V (x-axis).

Types of V-I graphs

- **(i) V-I graphs for ohmic conductors**
- **(ii) V-I graphs for non-ohmic conductors**

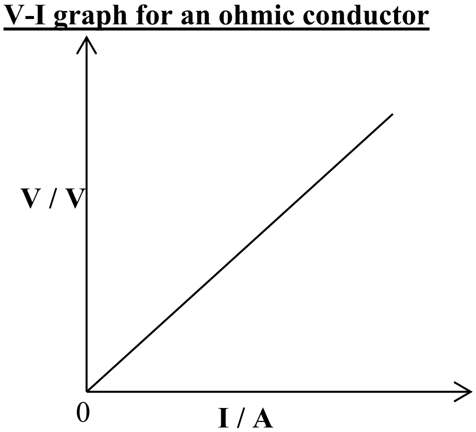
V-I graphs for ohmic conductors

Ohmic conductors: These are conductors which obey Ohm's law i.e.

The current through the conductor is directly proportional to the potential differences (p.d) across is ends provided its temperature remains the same. I α V.

V-I graphs for ohmic conductors are straight lines passing through the origin (0, 0).

<u>V-I graph for an ohmic conductor</u>



Non-ohmic conductors

These are conductors which do not obey Ohm's law i.e.

The current through the conductor is not directly proportional to the potential differences (p.d) across is ends i.e. they have non-linear I α V relationship.

Examples of non-ohmic conductors are:

- **Filament bulb:** V-I graph bends up as V and I increase as shown in Fig. a) below. That is the resistance (V/I) increases as I increases hence make the filament hotter.**Explanation:** the steepness (gradient) of V-I graph as I increases.
- **Thermistor:** The resistance of a thermistor decreases if its temperature increases i.e. its V-I graph bends down as V and I increase as shown in Fig. b) below.
- **Diode:** The resistance is very low for p.d is applied in one direction and very high when p.d is reversed as shown in Fig. c) below.

V-I graphs for non-ohmic conductors

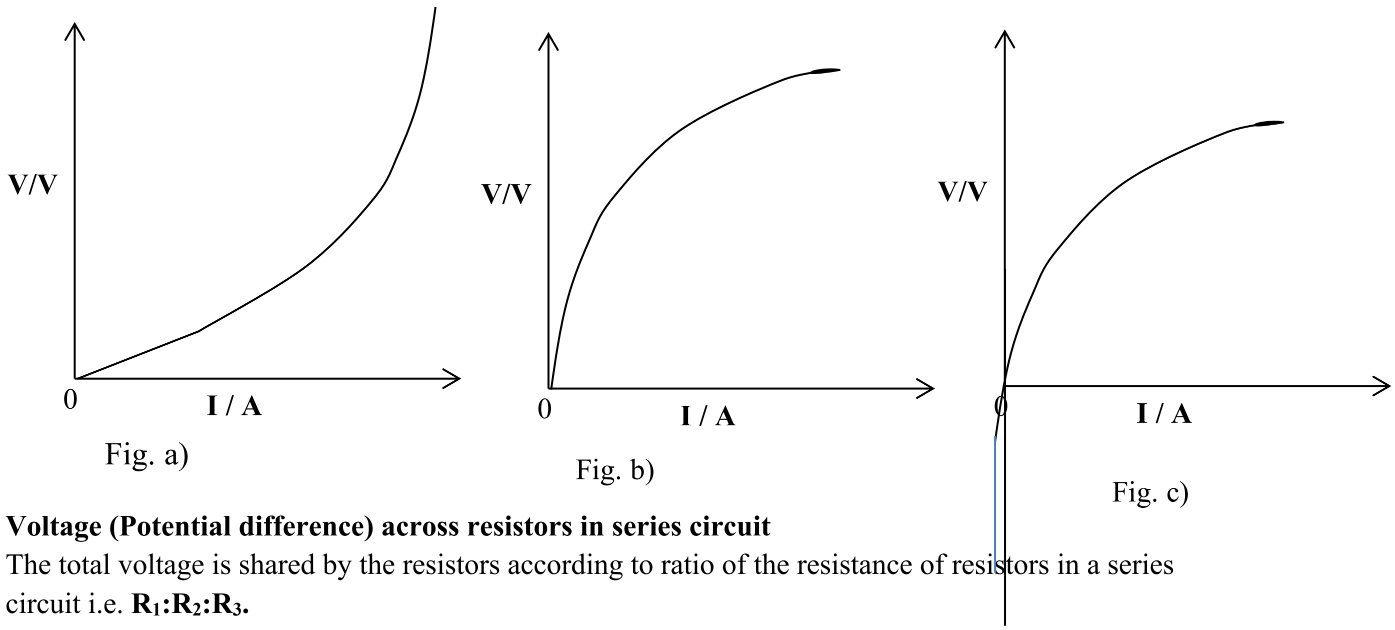
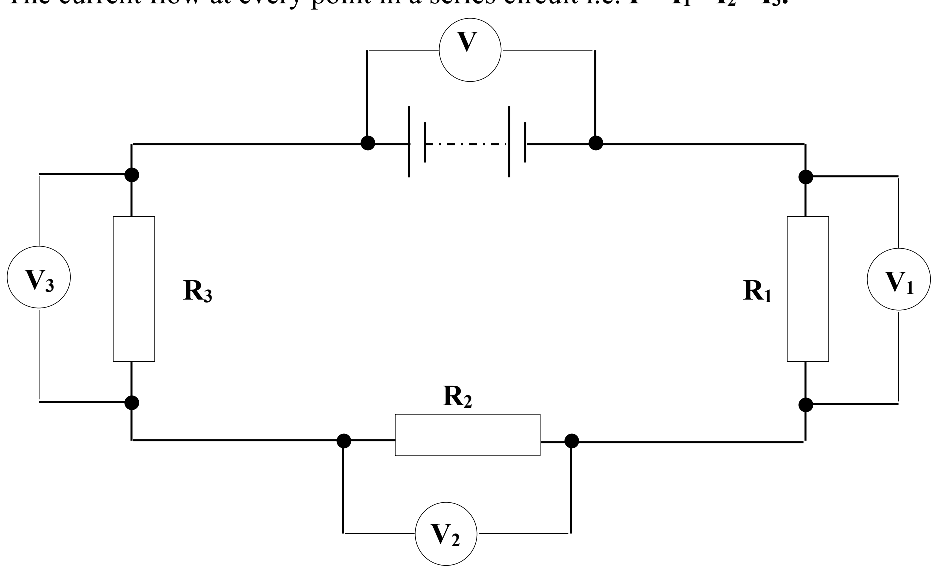


Fig. a) Fig. b) Fig. c)

Voltage (Potential difference) across resistors in series circuit

The total voltage is shared by the resistors according to ratio of the resistance of resistors in a series circuit i.e. $\mathbf{R_1:R_2:R_3}$.

The current flow at every point in a series circuit i.e. $\mathbf{I = I_1 = I_2 = I_3}$.



Voltage (potential difference, p.d), V_1 across R_1, is calculated by

$V_1=R_1/(R_1+R_2+R_3)\times V$ **OR** $V_1=(R_1/R_T)\times V$ where $R_T=R_1+R_2+R_3$

Voltage (potential difference, p.d), V_2 across R_2, is calculated by

$V_2=R_2/(R_1+R_2+R_3)\times V$ **OR** $V_2=(R_2/R_T)\times V$ where $R_T=R_1+R_2+R_3$

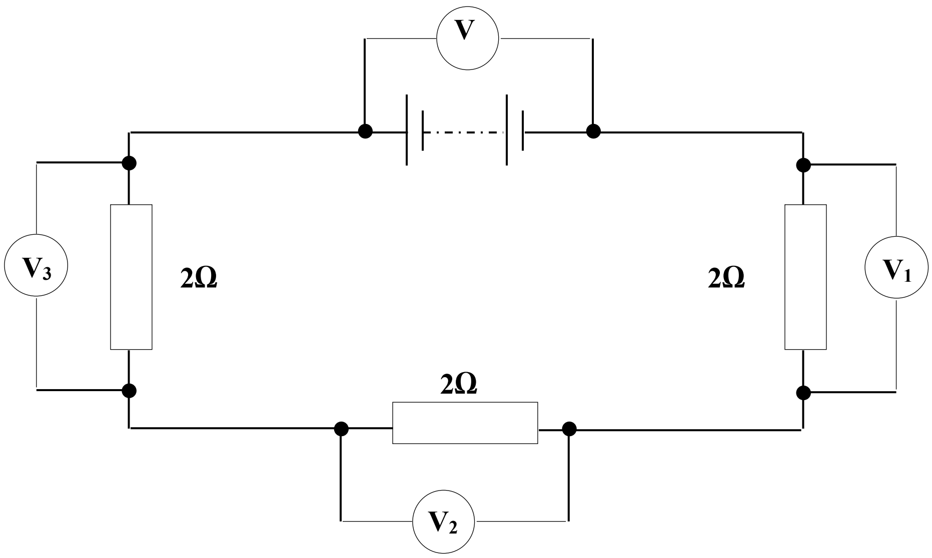
Voltage (potential difference, p.d), V_3 across R_3, is calculated by

$V_3=R_3/(R_1+R_2+R_3)\times V$ **OR** $V_3=(R_3/R_T)\times V$ where $R_T=R_1+R_2+R_3$

Note: $I=(V/R_T)=(V_1/R_1)=(V_2/R_2)=(V_3/R_3)$

Examples

1. Calculate the p.d (voltage) both resistors on circuit shown below if the voltmeter, **V** reads 12V.



i) P.d across the first 2Ω resistor is

$V_1=(R_1/R_T)\times V$
$=(2\Omega/6\Omega)\times 12V$
$=4V$

ii) P.d across the second 2Ω resistor is

$V_2=(R_2/R_T)\times V$
$=(2\Omega/6\Omega)\times 12V$
$=4V$

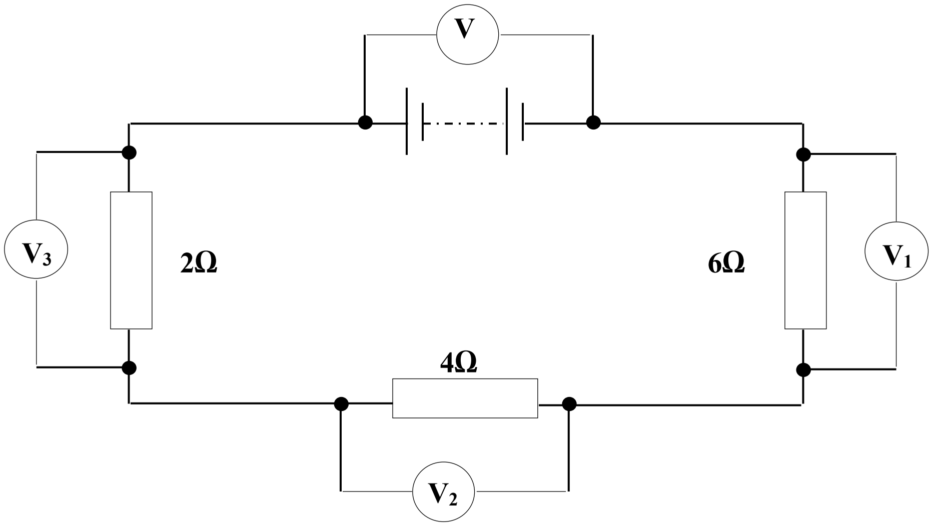
iii) P.d across the first 2Ω resistor is

$V_3=(R_3/R_T)\times V$
$=(2\Omega/6\Omega)\times 12V$
$=4V$

Note: the p.d across R_1, R_2 and R_3 are the same since the resistors have the equal resistance i.e.

$V_1=V_2=V_3$ **since** $R_1=R_2=R_3$

2. Calculate the p.d (voltage) both resistors on circuit shown below if the voltmeter, **V** reads 12V.



i) P.d across the first 2Ω resistor is

$V_1 = (R_1/R_T) \times V$

$= (2\Omega /12\Omega) \times 12 =$ **2V**

ii) P.d across the second 4Ω resistor is

$V_2 = (R_2/R_T) \times V$

$= (4\Omega /12\Omega) \times 12 =$ **4V**

iii) P.d across the first 6Ω resistor is

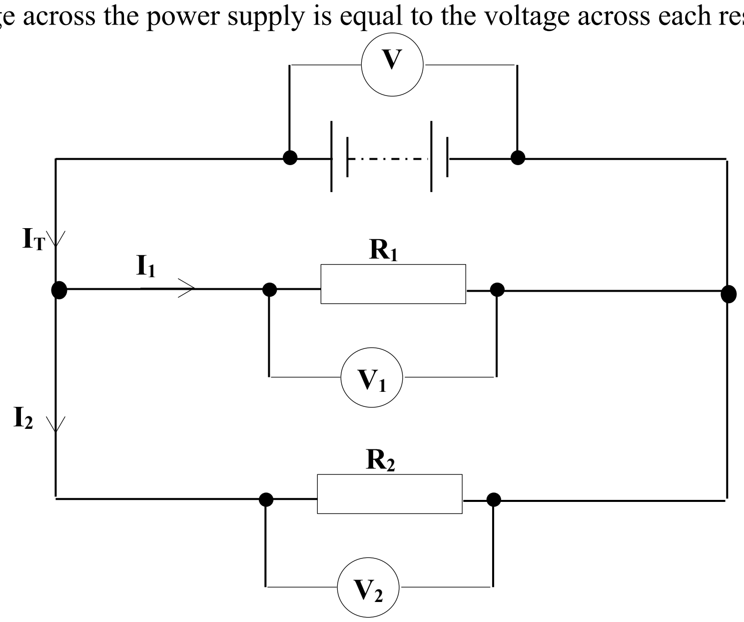
$V_3 = (R_3/R_T) \times V$

$= (6\Omega /12\Omega) \times 12V =$ **6V**

Note: the p.d across R_1 is less than that of R_2 and R_3 since the have the equal resistance of resistor, R_1 is less than that of R_2 and R_3 i.e.$\mathbf{V_1 < V_2 < V_3}$ **since** $\mathbf{R_1 < R_2 < R_3}$

Voltage (Potential difference) across resistors in a parallel circuit

The voltage across the power supply is equal to the voltage across each resistor in a parallel circuit i.e.



$\mathbf{V = V_1 = V_2}$

But the total current from the power supply is equal to the sum of the individual current flow through each resistor i.e.

$I_T = I_1 + I_2$

Note:

- The current flow through individual resistors in a parallel circuit will equal if both resistors have equal resistance i.e.
  $I_1 = I_2$ since $R_1 = R_2$
- The current flow through individual resistors in a parallel circuit will different if the resistors have different resistances i.e.
  $I_1 < I_2$ since $R_1 > R_2$ or $I_1 > I_2$ since $R_1 < R_2$

Practical Electric Circuitry

Heating effects of electric current

This refers to changing electric energy to heat energy, for example in:

- Electric heaters
- Electric cookers
- Electric ovens
- Electric kettles
- Electric irons
- Electric lamps

How does this happen?

Heat is produced when current passes through a resistor, thus a wire must have a high resistance i.e. the greater the resistance the hotter the object becomes.

That's why the filament of bulbs or element of heaters etc. are made of thin wires that becomes red hot when the electric current is switched on.

Other uses of electric current

There are some of the many uses of electric current (electricity) such as for:

- Lighting
- Communication
- In operation of machines e.g. cars
- Security e.g. alarms etc.

Electrical Power and Energy

The electrical power of an electrical appliance is given by:

P = VI where P = power in watts (**W**)
V = potential difference in volts (**V**)
I = current in amperes (**A**)

The electrical energy converted to heat energy or other forms of energy by an appliance is given by:

$E = P \times t$

But $P = VI$

Therefore $E = VIt$

Since $Q = It$

Then $E = VQ$

Also since $V = IR$

Then $E = I^2Rt$

But also $I = V/R$

Hence $E = (V^2/R) \times t$

Examples

1. Which type of lamp in the table below has the greatest resistance?

	Type of lamp	Voltage across lamp	Current through iamp
A	Torch lamp	2.5V	0.5A
B	Car head lamp	12V	3.0 A
C	Projector lamp	110V	3.0 A
D	House lamp	240V	0.4 A

2. An electrical kettle has this information on its back cover; 3000W, 240V. How much much electrical energy is converted to heat energy when the kettle is operated for 30s.
   A. 8J
   B. 100J
   C. 7200J
   D. 90 000J

The Cost of Electricity Consumption

Electrical companies such as Botswana Power Cooperation (i.e. BPC) measure the electrical energy consumption using the SI unit kilowatt-hour (kWh), rather than Watts-second.

Note: 1 unit =1kWh = 1000W × 60mins/h × 60s/min
= 1000W × 3600s = 3 600 000Ws
= 3.6×10^6J

One kilowatt-hour (1kWh) is the energy supplied when an electrical appliance with a power rate of 1kW is used for one hour.

Energy transferred (in kWh) = power (in W) × time (in h)

The electrical energy cost is calculated as follows:

Energy cost = Energy transferred (in kWh) × Cost per kWh

Examples

1. A radio is labeled 240V, 60W. The cost of electricity is 50 thebe per kilowatt-hour. How much will it cost to use the radio 5 hours a day for 10 days?
   Solution:
   Data: Power = 60W = 60W × (1kW÷ 1000W) = 0.06kW; time = 10 days × 5h /day = 50h
   Energy transferred-?
   Equation: Energy transferred = power × time
   Substitution: Energy transferred = 0.06kW × 50h = 3.0kWh
   Therefore: Energy cost = Energy transferred × Energy cost per kWh
   = 3.0kWh × 50 thebe /kWh
   = 150 thebe = P1.50
2. The kettle has a power of 2000W (2kW). It is used to heat water for 900s (0.25h).
   a) Calculate the electrical energy supplied during this period in Joules.
      Solution:
      Data: P =2000W; t = 900s; E-?
      Equation: E = P × t
      Substitution: E = 2000W × 900s =1 800 000J
      = 1.8×10^6J
   b) How much units of electricity are used?
      Solution:
      Data: P =2kW; t = 0.25h; E-?

Electrical Hazards and Safe Use of Electricity

Electrical Hazards

These are conditions and situations that make the use of electricity unsafe or dangerous.

The main electrical hazards are:

i. **Damaged insulation:**
   The live wire may be in contact with the body of the electric appliances and cause electrical shock when the person touches the appliances.

ii. **Overheating of cables:**
   This can cause melting of insulation of cables. Excess heat can also cause fire.

iii. **Damp conditions:**
   Wet insulators conduct electricity since water is a good conductor of electricity. Hence touching switches with wet or damp hands or cloth can cause electric current flow through your body, therefore leading to severe burning or heart attack due to electric shock.

iv. **Overloading of sockets:**
   This is putting too many appliances in one main socket. If all appliances are used at once, there will a large current flow, which causes overheating of electric cables, leading to fire outbreak.

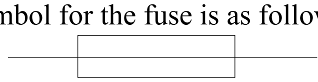
Electrical Safety

These are preventative measures that make the use of electricity safe such as:

- Fuse
- Double insulation
- Earth wire

Fuse

The symbol for the fuse is as follows:



Function of the fuse

It is used to protect the electrical appliance from excessive current.

How the fuse works?

A fuse is made of a wire (from a material with low melting point). The fuse melts and breaks the circuit when there is excess current flow in the circuit. Hence lead to no current flow to the appliance as the circuit will be incomplete.

Note: The fuses must be connected to the live wire. This ensures that when the fuse melts, the electrical appliance is isolated from the live terminal.

Fuse Ratings

The fuse rating indicates the maximum current that can pass through it without melting it.The common fuse ratings are: 1A, 3A, 5A and 13A fuses. A fuse rated 3A will melt when a current more than 3A flows through it.

Note: The value printed on the fuse should always be more than the actual current drawn by the appliance, but as close as possible.

Choosing the suitable fuse for an appliances

The suitable fuse rate for an appliance is the one with a current slightly larger than the normal current flow needed for an appliance e.g. if the normal current flow is 2A, then a 3A fuse is chosen.

Note: If the fuse selected has a;

- Too low fuse rating, it will melt (or blow) and create a short circuit even when there is no fault or when there is normal current flow through an appliance.
- Too high fuse rating, it will not protect an appliance when there is too large current flow through it.

Examples

1. Determine the suitable fuse rating for an electric fan rated at 240V, 3kW.
   Data: V=240V; P= 3kW= 3000W; I-?
   Equation:
   Substitution:
   Therefore the fuse rated 13A is needed.
2. Determine the suitable fuse rating for an electric hair drier rated at 230V, 1000W.
   Data: V=230V; P= 1000W; I-?
   Equation:
   Substitution:
   Therefore the fuse rated 5A is needed.

Earth wire

Electrical appliances are earthed by connecting the earth wire from the metal casing (body) of the appliance to the ground.

Function: safety and prevention of electrical shocks.

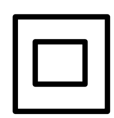
The symbolic representation of Earthing is 

How it works:

When there electric fault such as a live wire accidentally touching metal casing of the appliance, the earth wire will create a path of very large current flow from the appliance to the ground and lead to melting (blowing) of the fuse hence creating a short circuit.

Double insulation

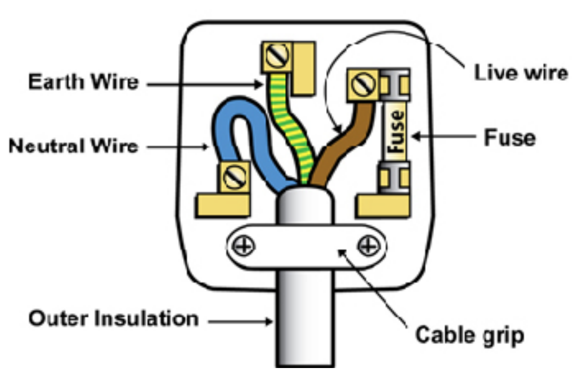
The double insulation substitutes for earth wire. Here connection to the power supply is by two wires only i.e. live and neutral only.

Symbol for double insulation: 

The appliances which use double insulation have non-metallic casing (body) such as radios, cellphones

Three Mains Plug

The diagram below shows a correctly wired three mains plug.

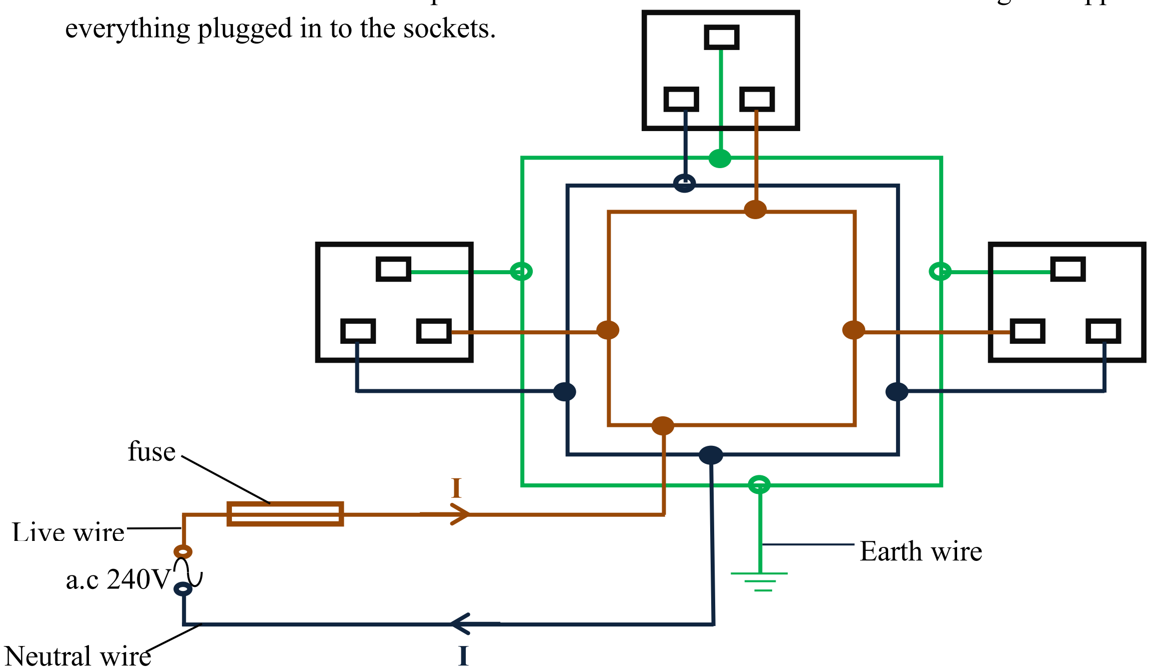


The three mains plug has three pins connected three wires namely:

- **Live wire (is brown):** This is most dangerous which wire carries alternating current (a.c) at a high voltage from the mains to the appliance.
- **Neutral wire (is blue):** This wire carries electric current from the appliance to the mains. The voltage is zero in the neutral wire. It completes a circuit.
- **Earth wire (is green or green with yellow stripes):** It carries leakage electric current from the metal casing of appliance to the ground when there is an electric fault.

Ring main circuit

In the house there are usually two or three ring main circuits, which supply all the wall sockets.
All wall sockets are connected parallel to each other so that the full mains voltage is supplied to everything plugged in to the sockets.



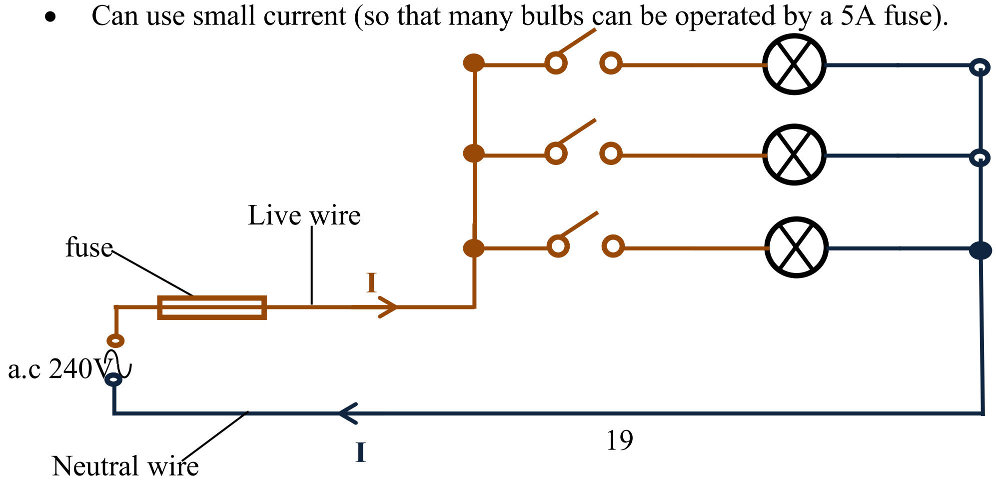
Advantage of using the ring main circuit

A ring main circuit allows current flow in two ways to a particular socket.
Cookers, immersion heater or electric shower heater use large current so they have their own circuits. That's why they have their own separate switches.

Lighting circuit

Lights for the house have their own circuit as shown in the diagram below.
Each lamp is connected in parallel so that it,

- Can receive maximum voltage.
- Can use small current (so that many bulbs can be operated by a 5A fuse).



Diagnostic steps to follow when there is an electric fault in an appliance

- Switch OFF, the power supply if the person is shocked is still touching the appliance.
- Ask for a qualified medical assistant.
- If breathing has stopped, apply the mouth to mouth respiration.
- If the heart has stopped, restart by pressing the chest three times over the heart.

Examples

1. In a main plug, which wire, live, neutral or earth
   a) Has a brown color code
   b) Is a safety wire
   c) Has a blue color code
   d) Has a yellow and green color code