Electricity I

Fundamental of Electric

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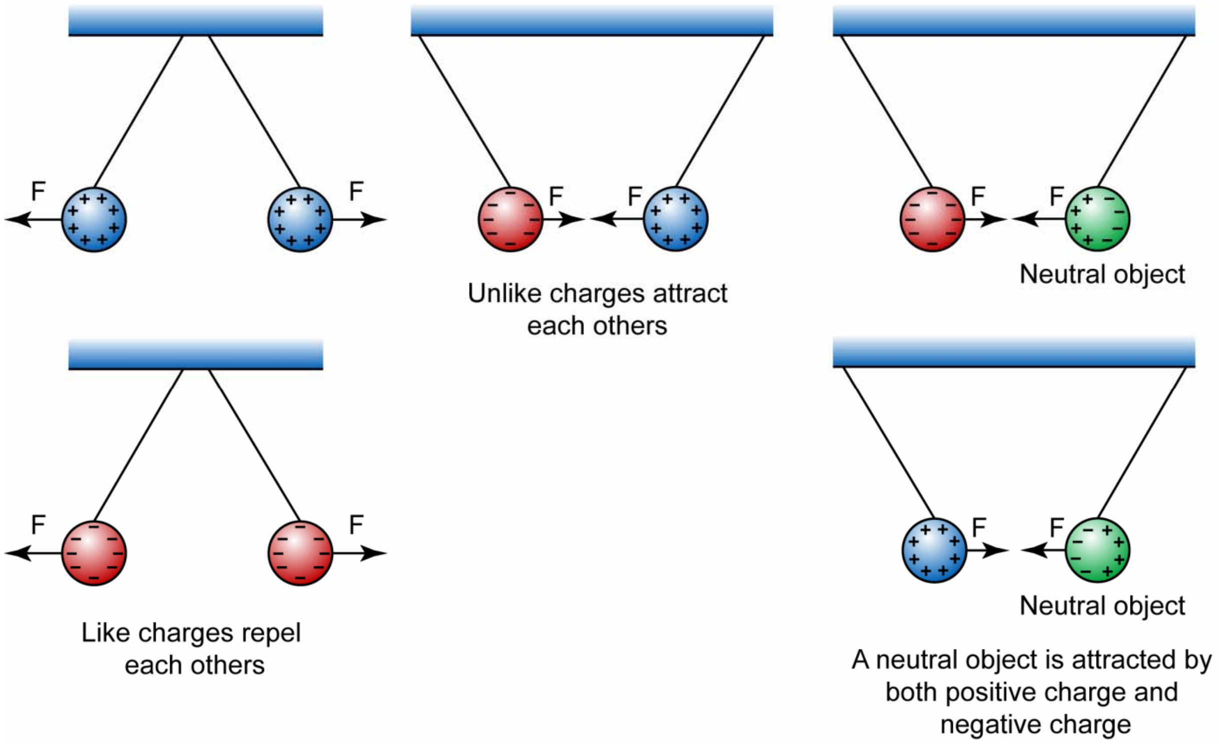


Electric Charge

1. There are two kind of electric charge, namely the positive charge and the negative charge.
2. Like charge repel each other.
3. Unlike charge attract each other.
4. A neutral body can be attracted by another body which has either positive or negative charge.

5. The SI unit of electric charge is Coulomb (C).
   Example
   Charge of 1 electron = -1.6×10^{-19} C
   Charge of 1 proton = $+1.6 \times 10^{-19}$ C

Unit of Charge
The SI unit of electric charge is Coulomb (C).

Equation:

Sum of charge

$$Q = ne$$

Charge and Relative Charge

Particle	Relative charge	Charge
Electron	**-1**	-1.6×10^{-19} C
Proton	**+1**	$+1.6 \times 10^{-19}$ C
Aluminium ion	**+3**	$3 \times +1.6 \times 10^{-19}$ C
Oxygen ion	**-2**	$2 \times -1.6 \times 10^{-19}$ C

Sum of Charge

Sum of charge
= number of charge particles × charge of 1 particle

$$Q = ne$$

Example 1

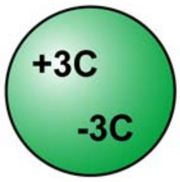
Find the charge of 2.5 x 10^{-19} electrons. (Charge of 1 electron is -1.6 x 10^{-19}C)

[-4C]

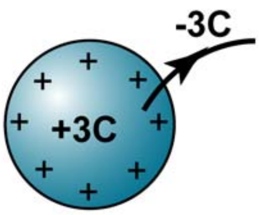
Example 2

How many protons are there in +2.5 Coulomb of charge? (Charge of 1 proton = +1.6 x 10^{-19} C)

[1.56 x 10^{19}]



A neutral object contain equal amount of positive and negative charge



If negative charge is removed from a neutral object, the object will become positively cearged.

Concept of Neutral

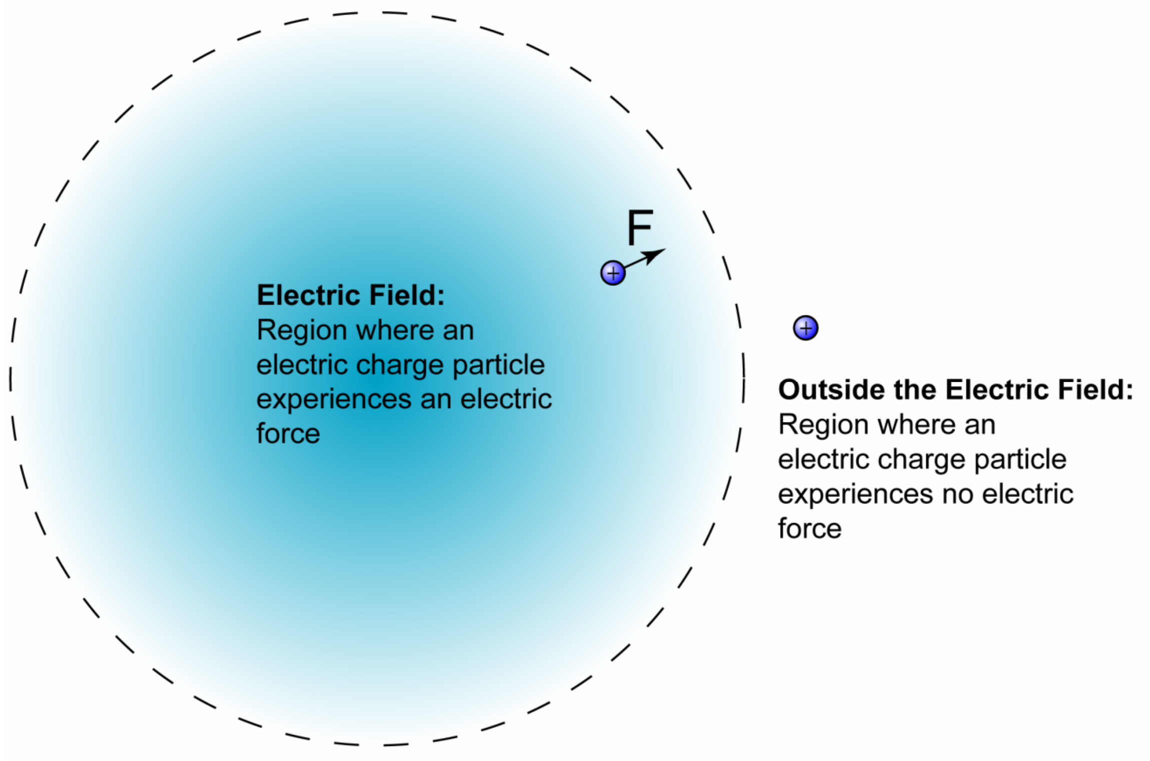
1. An object is neutral if the amount of positive charge is equal to the amount of negative charge.
2. When negative charge is removed from a neutral object, the object will come positively charged.

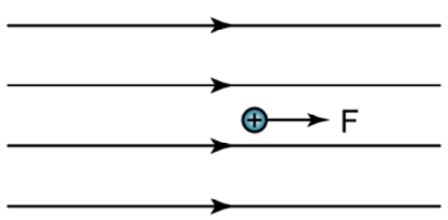
Example 3

1.25×10^{18} electrons are added into an object that carries +1C of charge. Calculate the nett charge of the object. (Charge of 1 electron is -1.6 x 10^{-19}C)

[+0.8 C]

[+3C]

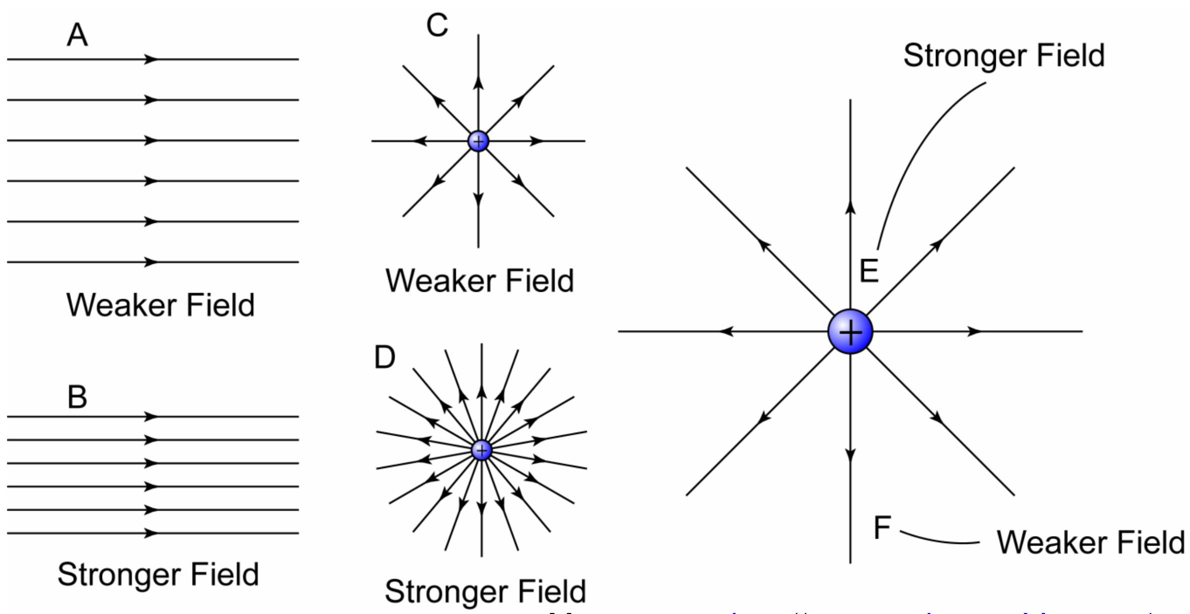


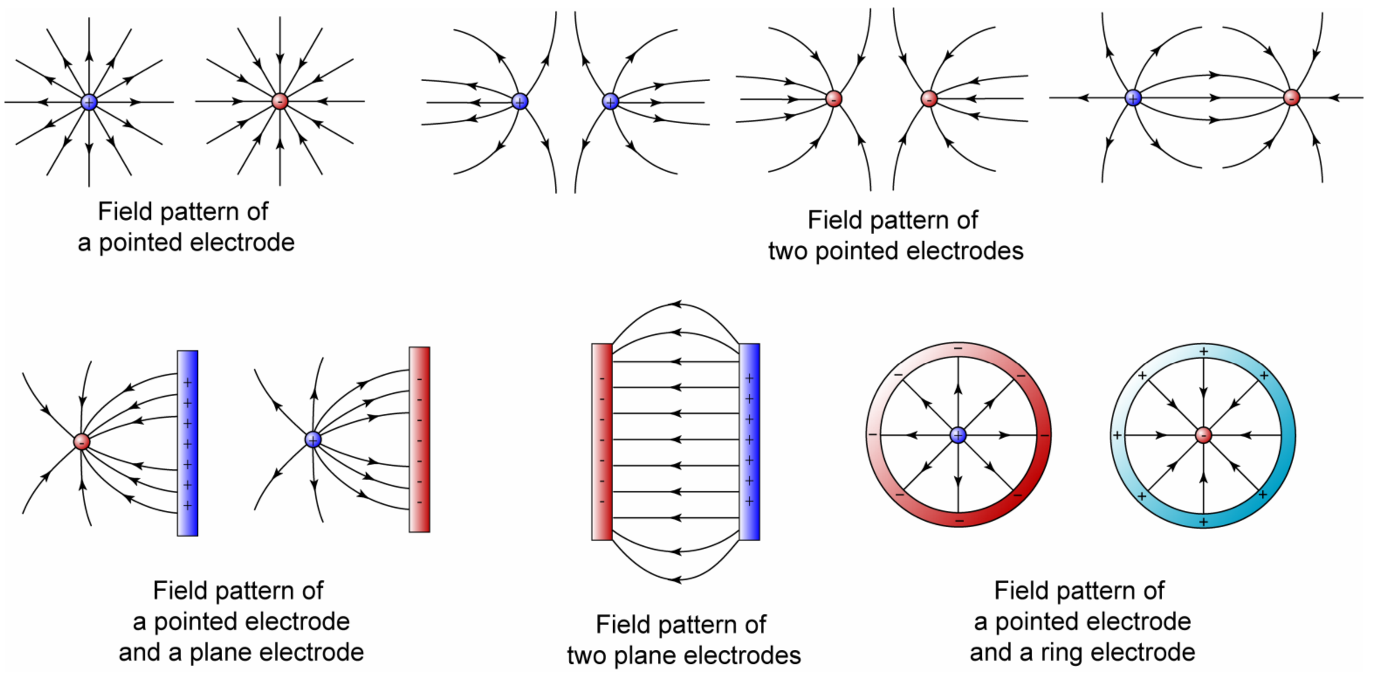


The direction of the field at a point is defined by the direction of the electric force exerted on a positive test charge placed at that point.

Electric Field

1. An **electric field** is a region in which an electric charged particle experiences an electric force.
2. Electric field is represented by a number of lines with arrows, called **electric lines of force** or electric field lines.
3. The direction of the field at a point is defined by the direction of the electric force exerted on a positive test charge placed at that point.
4. The strength of the electric field is indicated by how close the field lines are to each other. The closer the field lines, the stronger the electric field in that region.
   Example





5. The lines of force are directed **outwards for a positive** charge and **inwards for a negative** charge.
6. The electric line of force will never cross each other.
7. The figure shows a few examples of the field pattern that you need to know in the SPM syllabus.

Direction of the field
The direction of the field at a point is defined by the direction of the electric force exerted on a positive test charge placed at that point.

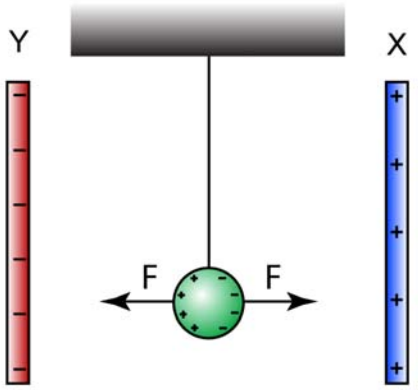
The lines of force are directed **outwards for a positive** charge and **inwards for a negative** charge.

The electric line of force will never cross each other.

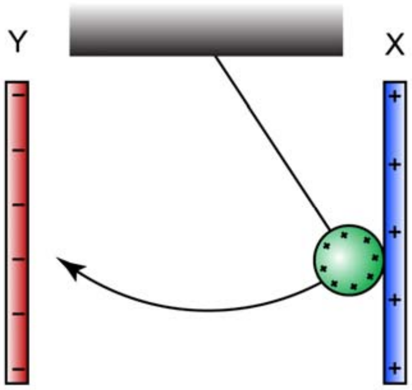
Effect of Electric Field

Effect of Electric Field on a Ping Pong Ball Coated with Conducting Material

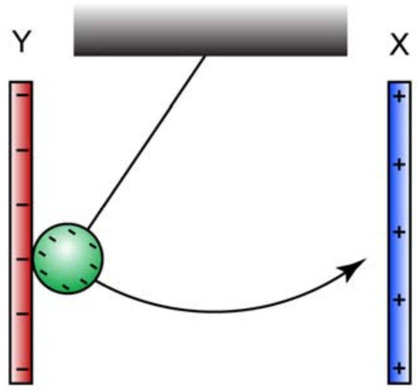
1. A ping ball coated with conducting material is hung by a nylon thread.
2. When the ping pong ball is placed in between 2 plates connected to a Extra High Tension (E.H.T.) power supply, opposite charges are induced on the surface of the ball. The ball will still remain stationary. This is because the force exert on the ball by the positive plate is equal to the force exerted on it by the negative plate.
3. If the ping pong ball is displaced to the right to touch the positive plate, it will then be charged with positive charge. Since like charges repel, the ball will be pushed towards the negative plate.
4. When the ping pong ball touches the negative plate, it will be charged with negative charge. Again, like charge repel, the ball will be pushed towards the positive plate. This process repeats again and again, causes the ping pong ball oscillates to and fro continuously between the two plates.



The ball will still remain stationary. This is because the force exert on the ball by the positive plate is equal to the force exerted on it by the negative plate.

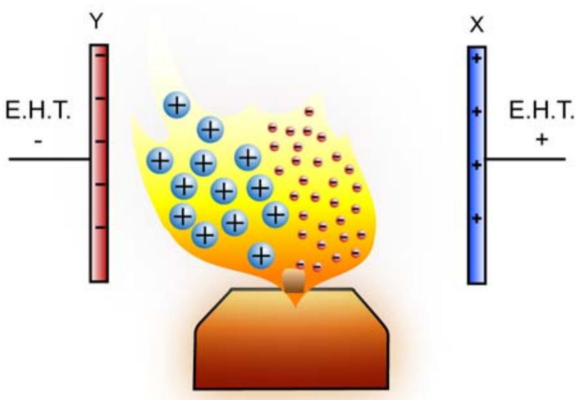


If the ping pong ball is displaced to the right to touch the positive plate, it will then be charged with positive charge and will be pushed towards the negative plate.



When the ping pong ball touches the negative plate, it will be charged with negative charge and will be pushed towards the positive plate. This process repeats again and again, causes the ping pong ball oscillates to and fro continuously between the two plates.

The heat of the candle flame removes electrons from the air molecules around it, and therefore ionised the molecule.



If the candle is placed in between 2 plates connected to a Extra High Tension (E.H.T.) power supply, the positive ions will be attracted to the negative plate while the negative ions will be attracted to the positive plate.

A Candle Flame in an Electric Field

1. Normally, with absent of wind, the flame of a candle is symmetry.
2. The heat of the candle flame removes electrons from the air molecules around it, and therefore ionised the molecule. As a result, the flame is surrounded by a large number of positive and negative ions.
3. If the candle is placed in between 2 plates connected to a Extra High Tension (E.H.T.) power supply, the positive ions will be attracted to the negative plate while the negative ions will be attracted to the positive plate.
4. The spreading of the flame is not symmetry. This is because the positive ions are much bigger than the negative ions; it will collide with the other air molecule and bring more air molecule towards the negative plate.

Current and Potential Difference

Current
Current is the rate of flow of electric charge flow in conductor.

Current

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

Current

1. An electric current I is a measure of the rate of flow of electric charge Q through a given cross-section of a conductor.
2. In other words, current is the measure of how fast the charge flow through a cross section of a conductor.

Equation

$$\text{Current} = \frac{\text{The Amount of Charge Flow}}{\text{Time Taken}}$$

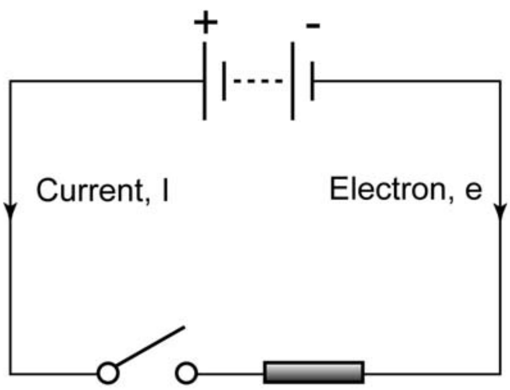
or

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

Direction of Current
In a circuit, current flow from the positive terminal to the negative terminal.

Direction of Current

1. Conventionally, the direction of the electric current is taken to be the flow of positive charge.
2. The electron flow is in the opposite direction to that of the conventional current.
3. In a circuit, current flow from the positive terminal to the negative terminal.
4. In a circuit, electrons flow from the negative terminal to the positive terminal.

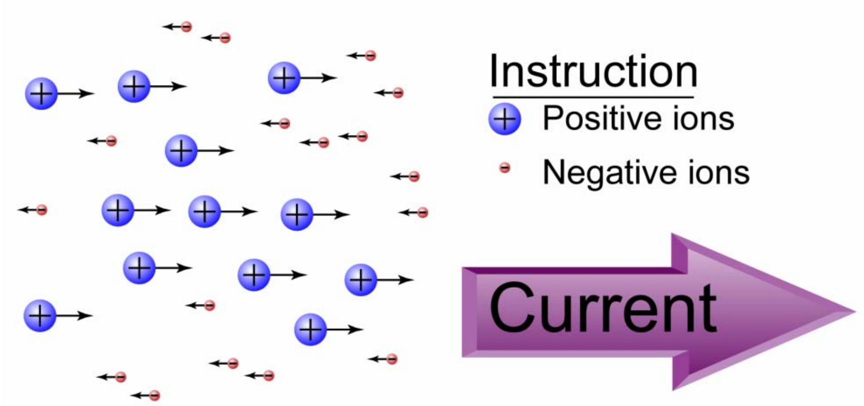


Unit of Current

1. The SI unit for current is the ampere (A).
2. The current at a point is 1 ampere if 1 Coulomb of electric charge flows through that point in 1 second. Therefore, 1 A = 1C/s.

Example 4
If 30 C of electric charge flows past a point in a wire in 2 minutes, what is the current in the wire?

[0.25A]



Example 5

Current of 0.5A flowed through a bulb. How many electrons had flowed through the bulb in 5 minute? (The charge of 1 electron is equal to -1.6×10^{-19} C)

[9.375×10^{20}]

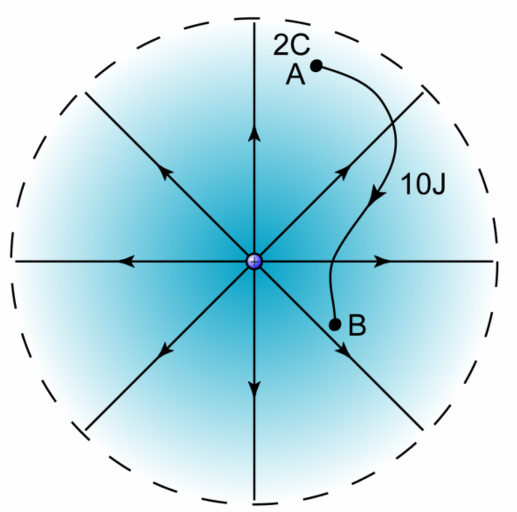
Potential and Potential Difference

1. The **electric potential** V at a point in an electric field is the work done to bring a unit (1 Coulomb) positive charge from **infinity to the point**.
2. The **potential difference** (p.d.) between two points is defined as the work done in moving 1 Coulomb of positive charge from 1 point in an electric field to another point.
3. In mathematics form

$$\text{Potential Difference} = \frac{\text{Work Done}}{\text{Amount of Charge Flow}}$$

or

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



The potential difference between A and B is 5J/C or 5V.

4. Example, the diagram on the left, if the work done to move a charge of 2C from point A to point is 10J, the potential difference between A and B,

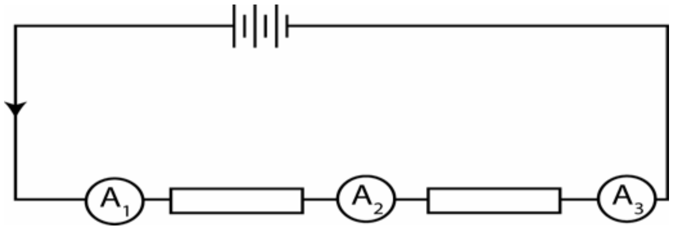
$$V_{AB} = \frac{10J}{2C} = 5J/C = 5V$$

Example 6

During an occasion of lightning, 200C of charge was transferred from the cloud to the surface of the earth and 1.25×10^{10}J of energy was produced. Find the potential difference between the cloud and the surface of the earth.

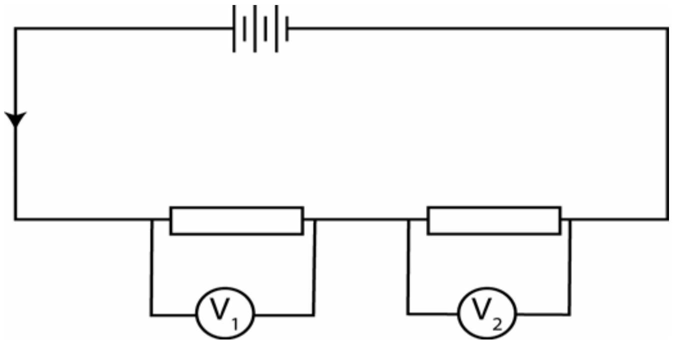
[6.25×10^{7} V]

Arrangement of Ammeter



To use the ammeter in the measurement of an electric current, the ammeter must be connected in series to the circuit.

Arrangement of Voltmeter



To use the voltmeter in the measurement of potential difference across an object, the voltmeter must be connected in parallel to the circuit.

Ohm's Law
the current flowing in the metallic conductor is directly proportional to the potential difference applied across it's ends, provided that the physical conditions (such as temperature) are constant.

Resistance
The resistance R of a material is defined as the ratio $V : I$, where V is the potential difference across the material and I is the current flowing in it.

Equation:

$$V = IR$$

Relationship Between Current and Potential Difference

Ohm's Law

1. Ohm's Law states that the current flowing in the metallic conductor is directly proportional to the potential difference applied across it's ends, provided that the physical conditions (such as temperature) are constant.

$$\frac{V}{I} = \text{Resistance } (R)$$

2. The resistance R of a material is defined as the ratio $V : I$, where V is the potential difference across the material and I is the current flowing in it.
3. The SI unit of resistance is the ohm (Ω). One ohm is the resistance of a material through which a current of one ampere flows when a potential difference of one volt is maintained.

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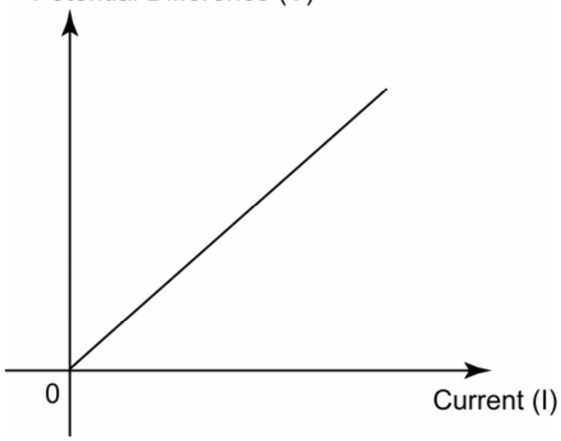
Example 7
What is the current flow through an 800Ω toaster when it is operating on 240V?

[0.3A]

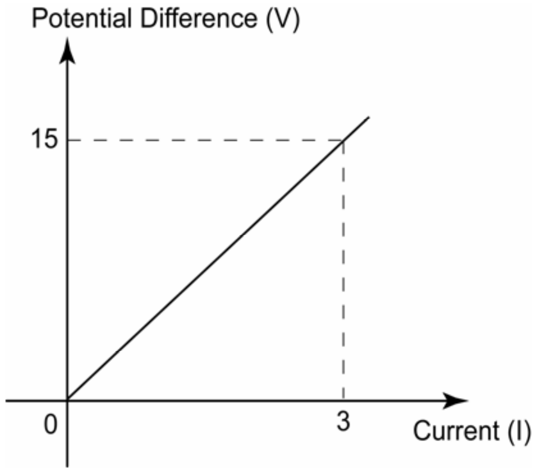
Ohm's Law - Graph

In the graph potential difference against current, the gradient of the graph is equal to the resistance of the resistor.



Resistance, R = Gradient of the Graph

Example 8
The diagram on the left shows the graph of potential difference across a wire against its current. Find the resistance of the wire.



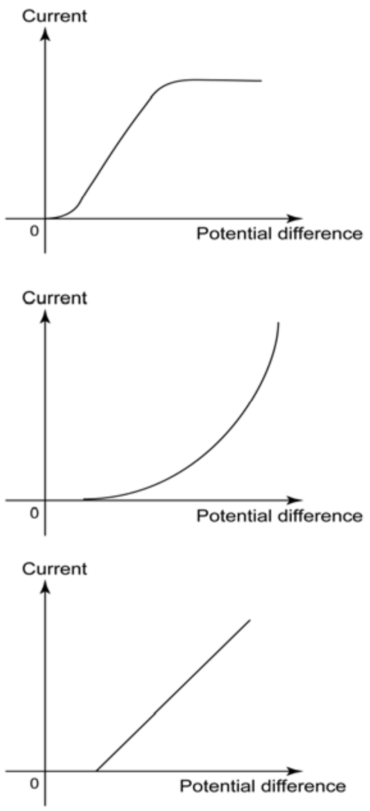
[5 Ω]

Ohmic Conductor

1. Conductors that obey Ohm's law are said to be ohmic conductor.
2. Examples of Ohmic conductor: Metal, Copper sulphate solution with copper electrodes

Non-Ohmic Conductor

1. Conductors which do not obey Ohm's law are called non-ohmic conductor.
2. Example: Semiconductor Diode, Vacuum tube diode

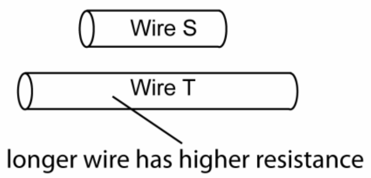


Graph of non-Ohmic conductor

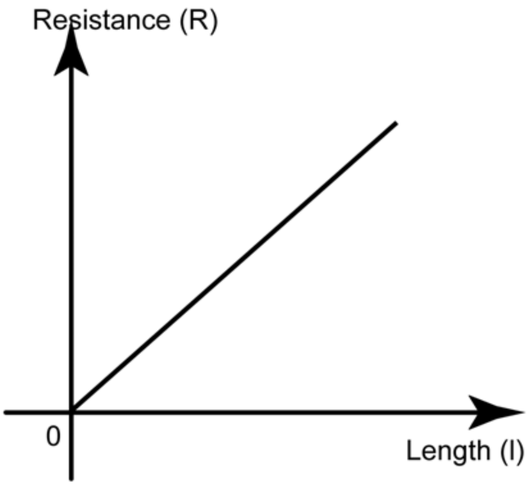
Factors Affecting the Resistance 1

1. The resistance R of a given conductor depends on:
   a. its length *l*,
   b. its cross-sectional area *A*
   c. its temperature and
   d. the type of material.

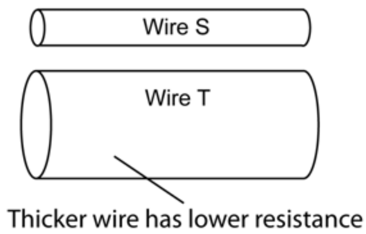
Length



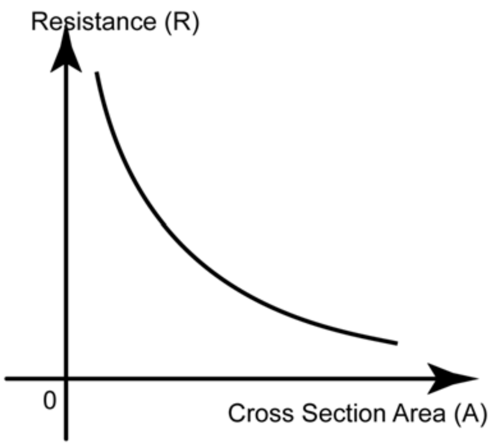
Resistance is directly proportional to the length of the conductor.



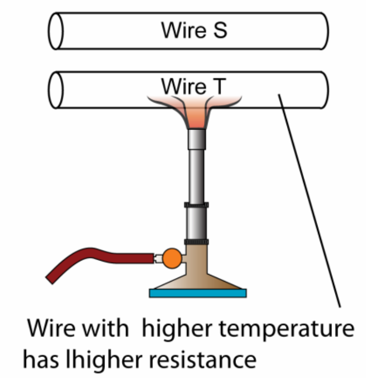
Cross Sectional Area



Resistance is inversely proportional to the cross sectional area of the conductor.

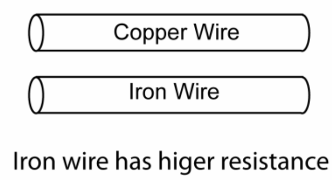


Temperature



A conductor with higher temperature has higher resistance.

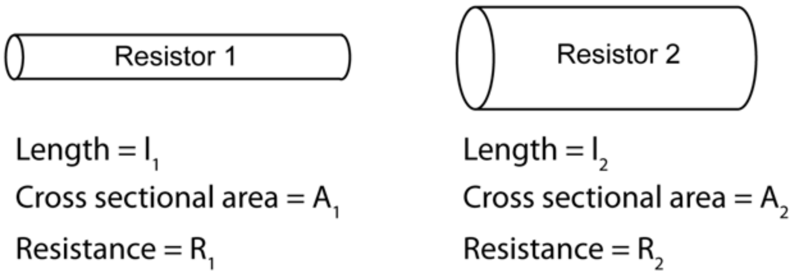
Material



Difference materials have difference resistivity. The resistance of copper wire is lower than iron wire.

Since resistance is directly proportional to the length and inversely proportional to the cross sectional area of the conductor. If two resistors of same material have same temperature, we can relate the resistance of the two resistors by the following equation.

$$\frac{R_1A_1}{l_1} = \frac{R_2A_2}{l_2}$$



Example 9
The resistance of a piece of copper wire of length 1m and cross sectional area $2mm^2$ is 0.2Ω. Find the he resistance of another piece of copper wire of length 2m and cross sectional area $1mm^2$.

[0.8 Ω]

Example 10
The resistance of a piece of copper wire of length 1m and diameter 2mm is 0.2Ω. Find the he resistance of another piece of copper wire of length 2m and diameter 1mm.

[1.6 Ω]