ELECTRICAL QUANTITIES

Friction And Charge

When two materials rub together the contact between their surfaces may cause:

a) the surfaces to become hot and show wear and tear.

b) the surfaces to become attracted to other materials. (e.g. When we rub a plastic comb with a fabric it can attract small pieces of paper.

In this example we can say that the plastic comb was electrified or charged by the rubbing and this process is called charging.

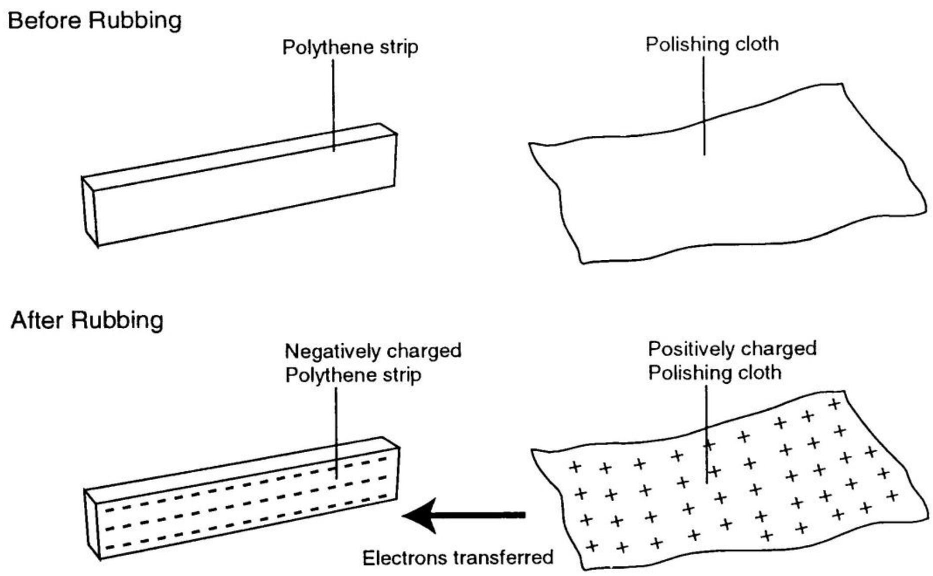
Either adding electrons or removing electrons from an object can charge it.
Adding electrons to an object causes the object to be negatively charged. Removing electrons from an object causes the object to be positively charged.

We can use simple experiments involving cellulose acetate rods and polythene rods to demonstrate that there are only two kinds of electric charge and that they are opposite because they have the ability to neutralise each other.

Polythene Rod and Cellulose Acetate Rod

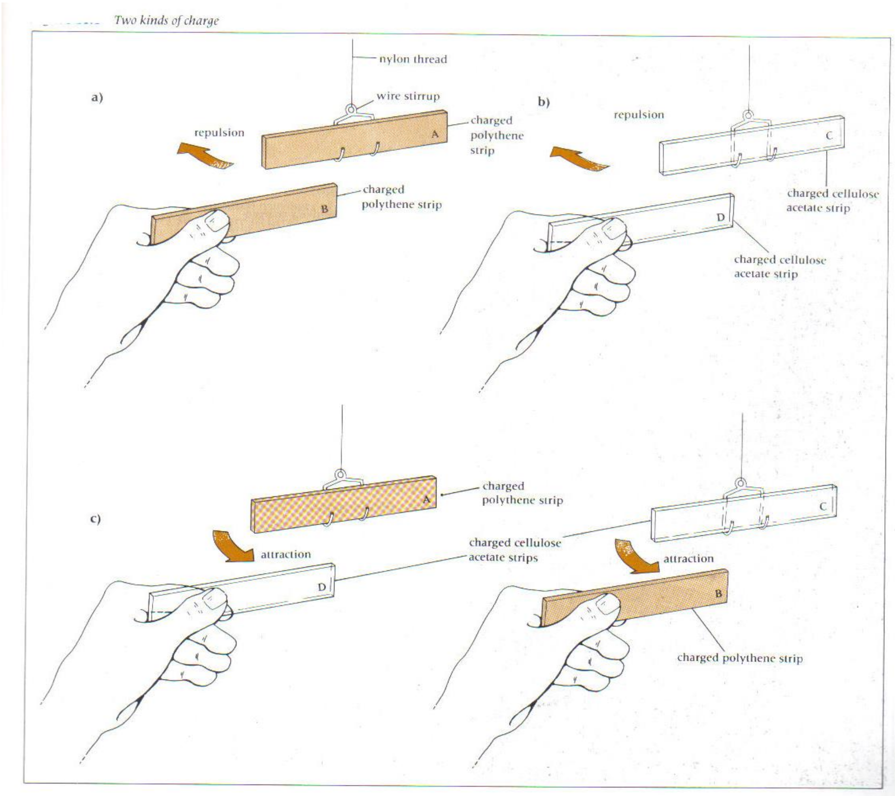
When we rub the polythene rod with a cloth, it gains electrons from the cloth and becomes negatively charged. This leaves a deficiency in the cloth and hence it becomes positively charged.

When we rub a cellulose acetate rod with a cloth, it loses electrons to the cloth and becomes positively charged. This causes an excess of electrons in the cloth, which makes it negatively charged.



Attraction and Repulsion

If we place two charged cellulose acetate rods together, they will repel each other. This situation also occurs if two charged polythene rods are used. However, if we place a charged cellulose acetate rod and a charged polythene rod next to each other they would attract to each other. We can therefore conclude that like charges always repel each other and unlike charges always attract each other.



Read and make notes (also include diagrams) on:

PFC Page 196

- charged and neutral objects
- where charge come from
- how do objects become charge?

Page 201

- charging by induction
- separating conductors
- earthing a conductor

Phenomena and Hazards Associated With Electrostatic Charging

- Overcoats worn by jumpers become charged as persons move around in it
- Collection of dust on television sets is caused by electrostatic charging
- Aircraft flying through the atmosphere
- Fuel tankers become charged as they travel. Tankers use metal chains to discharge static electricity
- Lightning – fork occurs between clouds and ground, sheet occurs between clouds

Research and make notes on (explanations and diagrams):

Uses of Electrostatics

- Crop Spraying
- Spray Painting
- Dust Collectors

Electric Currents

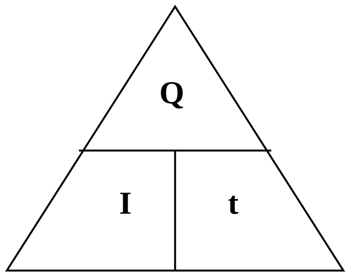
Charges that produce repulsion and attraction between objects can also produce an electric current if the charge can flow through it. An electric current is actually the flow of electric charge moving a particular direction. To maintain an electric current, the charge needs a continuous path to travel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

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

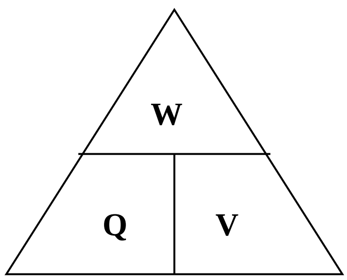
$$Q = I \times t$$

Potential
The potential at a point in an electric circuit is defined as the work done to bring one (1) unit positive charge from infinity to that point.

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.

Volt
The potential difference between two points in an electrical circuit is one (1) volt if 1 J of work is done to move 1 C of charge between two points.

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

Examples

1. A battery circulates a charge around a circuit of two (2) minutes. If the current in the circuit is five (5) amperes, what quantity of charge passes through the battery?

2. A charge of 170 coulombs goes through a lamp every five minutes. Calculate the electric current.

3. A current of 40 amps flows through a heater for three (3) hours 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 180 C of charge around a circuit. If the p.d. across a lamp in the circuit is 22 volts. How much energy is converted into heat and the light by the lamp? If the charge flows at a constant rate for 75 seconds, what is the current during this time?

Resistance
The ratio of the potential difference across a conductor compared to the current flowing through it

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.

$$I \alpha V$$

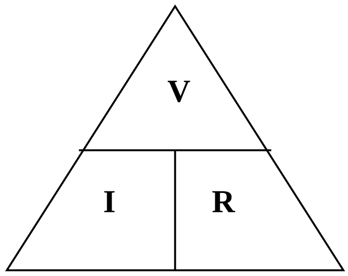
$$\frac{V}{I} = \text{constant}$$

where the constant the is the resistance of the conductor

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

or

$$V = IR$$



Ohm
The resistance of a conductor is 1Ω if a current of 1A exists in the conductor when the potential difference of 1V is placed across it.
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<u>Examples</u>

a) A current of 9A flows through a headlamp when it is connected to a car battery providing that a voltage of 14 V flows across the headlamp. Calculate the resistance of the headlamp.

b) What is the current passing through a torchlight lamp of resistance 35 Ω, given that the potential difference is 7 V?

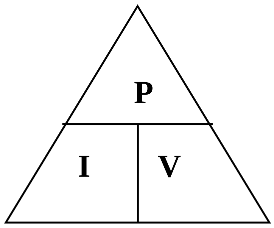
c) What is the potential difference required to produce a current of 5.5A through a conductor of resistance 8 Ω?

Power

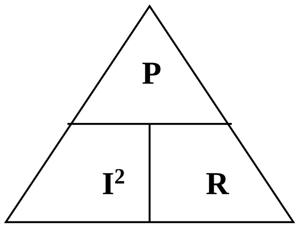
When the energy is converted from one form to another the rate of conversion is defined as power. ***Units of power: watts (W)***

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

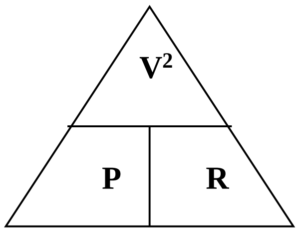
1. **$P = IV$**



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



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



(NB: Need to derive the power formulae listed above)

Examples

a) An electric wire has a power rating of 5 kW. Calculate the current that will flow through the fire when it is connected to the 210 V mains supply.

b) A torch bulb is labelled 4.5 V, 0.8 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 550 V electrical supply. Calculate:
   - (i) the current that would flow when the element was connected to the 550 V supply.
   - (ii) the resistance of the element.
   - (iii) The heat produced by the element in one (1) minute.

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

Resistivity is the unique resistance times the length of a particular substance and the values can vary from 1.6×10^{-8} *Ω*m for silver to 2300 *Ω*m for silicon

The resistivity (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 substance depends on the nature of the substance depends on the nature of the substance and the physical dimensions. 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.

Example

An electric hot plate has a coil of length 20m and a cross sectional area of 0.23 mm^2. A potential difference of 120V is placed across it. The resistivity of the wire material is 4.6×10^{-7} Ωm. Calculate:

(i) the resistance of the wire
(ii) the current through the coil
(iii) the charge which passes through it in half an hour
(iv) the power produced in the coil.

Conductance (G)

The electrical conductance of a conductor is the reciprocal of its resistance

$$G = \frac{1}{R}$$

where
G = electrical conductance (Siemens (S) = Ω^{-1})
R = electrical resistance (Ω)

Conductivity (σ)

The electrical conductivity of a material is the reciprocal of its resistivity

$$\sigma = \frac{1}{\rho}$$

where

σ = electrical conductivity ($Sm^{-1} = \Omega^{-1}m^{-1}$)

ρ = electrical resistivity (Ωm)

Current Density (*J*)

The current density at a point in a conductor is defined as the current per unit cross-sectional area at that point

$$J = \frac{I}{A}$$

where

J = current density (Am^{-2})
I = current (A)
A = cross-sectional area (m^2)

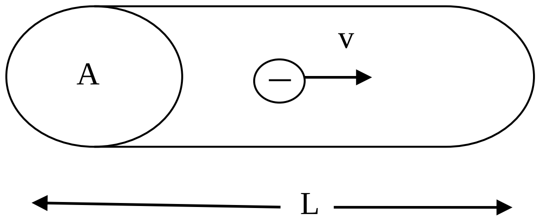
Read and make Notes on the Mechanism of Conduction in Metals. Muncaster Page 538, 36.2

Drift Velocity

Drift velocity is defined as the average velocity that electrons (ions) flow in a given conductor of circuit. For a circuit the direction of this drift velocity points from negative to positive of the battery and this resultant drift of charge constitutes an electric current.

<u>Deriving Drift Velocity (*I = nAve and J = nve*)</u>

Consider a conductor of length, ***L*** and cross sectional area, ***A***, having ***n*** free electrons per unit volume each carrying a charge, ***e***.



The volume of the section of a conductor can be calculated using

$$volume = L \times A$$

The number of electrons in this volume can be calculated

$$= nLA$$

The total amount of charge which is free to move $= (nLA)e$

We can calculate the time it takes by using the formula

$$time = \frac{length\ (L)}{velocity\ (v)}$$

Hence the rate of flow of charge (or current) pass a point X is

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

$$= (nLAe) \div \frac{L}{v}$$

$$\therefore I = nAve$$

Also since $J = \frac{I}{A}$

We can conclude that

$$J = nve$$

Temperature Coefficient of Resistance (α)

The temperature coefficient of resistance, α, is defined by

$$\alpha = \frac{increase\ in\ resistance\ per\ ℃}{Resistance\ at\ 0℃}$$

Hence the average value of α between two temperatures θ_1 and θ_2 is given by

$$\alpha = \frac{R_{\theta_2} - R_{\theta_1}}{R_0(\theta_2 - \theta_1)}$$

where R_{θ_2} – resistance of specimen at θ_2, R_{θ_1} – resistance of specimen at θ_1
R_0 – resistance of specimen at 0 °C

Classwork: Muncaster Page 538 Questions 36 A # 1 - 4