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Electricity

ELECTRIC NATURE OF MATTER:

The electric nature of matter means the ability of a matter to produce charge on it. The addition or the removal of electrons from any atom produces charge on it. Therefore, charge is defined as: “The access or the deficiency of electrons.”

There are two types of charge.

i. Positive charge

ii. Negative charge

I POSITIVE CHARGE:

The efficiency or the loss of electrons from any atom creates positive charge on it.

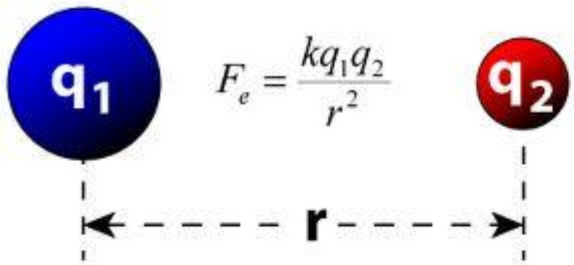
II NEGATIVE CHARGE:

The excess or the addition of electrons in an atom creates negative charge on it. Amount of electron lost by one atom is equal to the number of electrons gained by another atom. It means that total amount of charge always remains conserved.

COULOMB'S LAW:

STATEMENT:

" Every two like charges repel each other while unlike charges attract each other with a force called coulombs force. This force is directly proportional to the product of the magnitude of the charges and inversely proportional to the square of the distance between them."



MATHEMATICAL FORM:

Consider two charges of magnitudes "q1 " and " q2 " at a distance " r " from each other. According to the first part of the law, "Coulomb's force is directly proportional to the produce of the magnitude of the charges."

$$\text{i.e. } F \propto q_1\, q_2 \text{ ....1}$$

According to the second part of the law, "Coulomb's force is inversely proportional to the square of the distance between them."

$$\text{i.e. } F \propto \frac{1}{r^2} \text{ ....2}$$

Combining 1 and 2

$$\text{i.e. } F \propto \frac{q_1 q_2}{r^2}$$

$$\text{i.e. } F = K\frac{q_1 q_2}{r^2}$$

When K = coulomb's constant.

$$K = 9 \times 109\ Nm^2 / C^2$$

Which is the required mathematical form of coulomb's force. But coulomb's constant is given as

$$K = \frac{1}{4\pi\epsilon_0}$$

Substitute above relation in the expression of coulomb's force.

$$F = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$$

Where, ϵ_0 = permittivity of free space. = $8.85 \times 10^{-12}\ C^2 / Nm^2$

The tendency of a medium to allow the electric effect to pairs through it is called permitivity.

UNIT OF CHARGE:

The unit of charge is coulomb(c)

$$F = K\frac{q_1 q_2}{r^2}$$

$$F = 9 \times 109\ Nm^2 / C^2$$

$$\frac{1C\ 1C}{m^2}$$

When two identical charges separated by 1m repel each other with a force of 9×10^9 N, than it is said that there is a charge of IC on each.

POTENTIAL DIFFERENCE:

Amount of work required to move IC charge is called potential difference.

OR

Work done per unit charge is called potential difference.

OR

The difference of the potential at the terminals of the battery is called potential difference. It is denoted by "V" and its unit is volt.

ELECTRIC POTENTIAL (v):

Work done per unit charge against the electric field is called electric potential.

OR

Amount of work required to move IC charge against the electric field is called electric potential.

MATHEMATICALLY:

$$V = W / -q$$

Its unit is volt (v) $V = W / q$

$$IV = IJ/1C$$

It shows that, If IJ of work is required to displace IC charge than it is said that there is an electric potential of IV.

ELECTRIC FIELD:

The area or space around a charge (source charge) in which it can produce effect on any another charge (test charge) is called electric field. If the charges are of same nature than effect will be repulsive and if the charges are of opposite nature than effect will be attractive.

ELECTRIC INTENSITY:

The strength of electric field is called electric intensity.

OR

The force exerted by the same charge on a unit test charge is called electric intensity.

MATHEMATICALLY FORM:

Mathematically it is given as:

$$E = F / q$$

Its unit is N/C

$$E = F / q$$

$$I\ N/C = 1N/1e$$

If one neutron force acting on a charge of 1e than it is said that there is N/C.

CURRENT:

The amount of charge flows through a conductor in a unit time is called electric current.

OR

The rate of flow of charge is called electric current.

MATHEMATICAL FORM:

Mathematically it is given as:

$$\text{Current} = \text{charge}/\text{Time}$$

$$\mathbf{I = Q/t}$$

UNIT:

Its unit is ampere (A)

$$\therefore I = Q / t$$

$$1A = IC/1s$$

It shows that:

" It one coulomb charge flows through a conductor in 1 sec than it is said that there is a current of 1A."

DIRECTION:

Since, current is due to the flow of electrons therefore, it has direction from negative to positive but in order to produce similarity in the direction of all electrical quantities the direction of current is conventionally consider from **"Positive To Negative ".**

CONVENTIONAL CURRENT:

The current having the same magnitude as that of the electric current but has direction from positive to negative is called conventional current.

OHM'S LAW:

Statement:

Amount of current laws through the conductor is directly proportional to the potential difference applied at the end of the circuit. Keeping the physical state of the conductor remains same.

MATHEMATICAL FORM:

If current " I " is flowing through the conductor due to potential difference (v) then Mathematically Ohm's law is given as:

$$\mathbf{I \propto V}$$

$$\mathbf{I = KV \ldots\ldots\ldots.1}$$

Where, K = conductance,

It is defined as, " Conductance is an expression of the ease with which electric current flows through a substance".

But conductance is reciprocal of the resistance.

i.e. **K = L/R ………….2**

Where "R" is the resistance and it is defined as, "The opposition offered by the conductor to resist the flow of current. "

Substituting (2) in (1)

$$\mathbf{I = \frac{L}{R}.V}$$

$$\mathbf{IR = V}$$

Which is the required mathematical form of Ohm's law.

COMBINATION OF RESISTOR IN SERIES CIRCUIT:

The combination of resistors in which path for the flow of current is only one is called series combination.

CHARACTERISTICS:

i. Path of the flow of current is only one.

ii. Current remain same in each resistor.

iii. Potential difference is divided among all resistors.

iv. Sum of all potential difference across each resistor is equal to the potential difference of battery i.e.

$$V = V_1 + V_2 + V_3$$

v. Equivalent resistor is equal to the sum of all resistance connecting series i.e.

$$R = R_1 + R_2 + R_3$$

PROOF:

Consider three resistance R_1, R_2 and R_3 connected in series using Ohm's law.

$$V = IR$$

Apply to all resistance

$$\text{At } R_1 = V_1 = IR_1$$

$$\text{At } R_2 = V_2 = IR_2$$

$$\text{At } R_3 = V_3 = IR_3$$

Replace all three resistance by a single resistance "R" keeping the potential difference remains same.

From the characteristics of series combination. $V = V_1 + V_2 + V_3$

Substituting the value:

$$IR = IR_1 + IR_2 + IR_3$$

$$IR = I(R_1 + R_2 + R_3)$$

$$R = R_1 + R_2 + R_3$$

This is the required expression.

COMBINATION OF RESISTOR IN PARALLEL CIRCUIT:

The combination of resistors in which path for the flow of current is more than one is called parallel combination.

CHARACTERISTICS:

i. Path for the flow of current is more than one.

ii. Current is divided among all resistors resistor.

iii. Sum of all currents is equal to the total current supplied from the main source.

$$I = I_1 + I_2 + I_3$$

iv. Potential difference remains same across each resistor.

v. The reciprocal of the Equivalent resistance is equal to the sum of reciprocal individual resistance.

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

PROOF:

Consider three resistances R_1, R_2 and R_3 connected in parallel.

Using Ohm's law.

$$\mathbf{V = I\,R}$$

Apply it to all resistance:

At R_1

$$\mathbf{V = I_1\,R_1}$$

$$I_1 = \frac{V}{R_1}$$

At R_2

$$\mathbf{V = I_2R_2}$$

$$I_2 = \frac{V}{R_2}$$

At R_3

$$\mathbf{V = I_3R_3}$$

$$I_3 = \frac{V}{R_3}$$

Replace all three resistance by a single resistance "R" keeping the potential difference remains same.

Using Ohm's law.

$$\mathbf{V = I\,R}$$

$$\mathbf{I=V/R}$$

From the character sticks of parallel combination:

$$\mathbf{I = I_1 + I_2 + I_3}$$

Substituting the values:

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\frac{V}{R} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

This is the required expression.

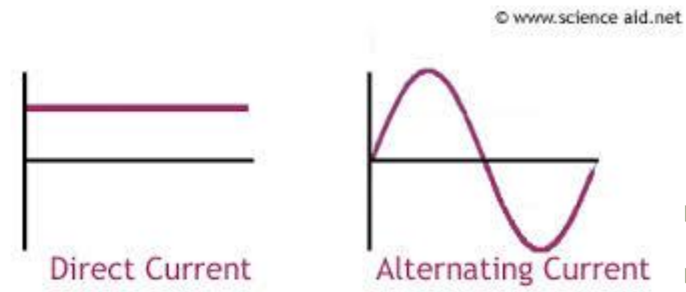
ALTERNATING CURRENT AND DIRECT CURENT:

ALTERNATING CURRENT:

A current which changes its direction many times in a second is called alternating current. Alternating current always flows in the form of cycle which is given as:

DIRECT CURRENT:

A current which does not changes its direction is called direct current. Direct current always flows in a straight line which is given as"



JOULE'S LAW:

Whenever current passes through any conductor it requires certain amount of energy to pass through the resistance of the conductor. Battery provides exactly the same amount of energy. When current cross the resistor it converts such amount of energy into heat as a result of collision between the vibrating molecules and the free electrons. "The amount of heat is directly proportional to the work done by the battery for the flow of current."

Potential difference is defined as:

Work done per unit charge.

∴ By the definition of potential difference ;

Amount of work required to move **IC = W = V.**

Amount of work required to move **qc = w = Vq.**

W = vq ………………….1

But: I = q/t

q = It ……………….2

Substituting 2 in 1

W = VIT

But: **V= IR**

W = (IR)IT

$$W = I^2RT$$

Which is the required mathematical form of Joule's law and it is expressed as, "Amount of heat produced is directly proportional to the work required for the flow of current, the time for which the current is passed and the resistance of the conductor.

POWER DISSIPATION:

"Amount of energy lost in a unit time due to the resistance of the conductor is called power dissipation."

OR

"Rate of energy lost is called power dissipation".

MATHEMATICALLY FORM:

$$P = W/T$$

But

$$W = I^2RT$$

$$P = I^2RT/T$$

$$P = I^2RT$$

Multiply & divide by "R"

$$P = \frac{I^2\ R\ x\ R}{R}$$

$$P = \frac{I^2\ R^2}{R}$$

$$P = \frac{(IR)^2}{R}$$

But:

$$V = IR$$

$$P = \frac{V^2}{R}$$

ELECTRO MOTIVE FORCE:

DEFINITION:

A force which is required to motivate the electrons to move through the conductor is called electromotive force. OR "Energy supplied by the battery per unit charge is called electromotive force".

MATHEMATICAL FORM:

$$EMF = \frac{\text{energy supplied}}{\text{Charge}}$$

$$E = \frac{W}{q}$$

Unit: Its unit is volt.

$$E = \frac{W}{q}$$

$$1V = \frac{1J}{1C}$$

It shows that: "If 1J of work is done i.e. 1J of energy is supplied to move 1C charge than it is said that there is an electromotive force of 1V."

CAPACITOR:

DEFINITION:

A storing device for the charges is called capacitor.

OR

An electrical device having ability to store the charges at its plates is called capacitor.

CONSTRUCTION:

It consists of two electric plates at a certain distance from each other. A battery of potential difference (V) is connected across the plates to store the charges (q) at the surface of the plates.

PRINCIPLE / WORKING:

It is based on the principle that: Amount of charges stored in the capacitor is directly proportional to the potential difference applied across the plates of the capacitor. If ‘q’ is the amount of charge stored in the capacitor due to potential difference ‘V’ than

$$q \propto V$$

$$q = CV$$

Where,

C = capacitance of the capacitor.

Capacitance is defined as. “ The tendency of a capacitor to store the charge on its plates.”

FACTORS:

Following are the factors effecting the capacitance of the capacitor.

1. AREA OF THE PLATES:

Capacitance increases with the increase of area of the plates.

2. DISTANCE OF THE PLATES:

Capacitance increases with the decrease of the distance between the plates.

3. NATURE OF THE PLATES:

Capacitance depends on the nature of the dielectric used between the plates and the use of dielectric increases the capacitance of the capacitor.

UNIT OF CAPACITANCE:

The unit of capacitance is farad.

$$\therefore q = CV$$

$$C = \frac{q}{V}$$

$$1f = \frac{1C}{1V}$$

It shows that,

“If 1C charge is stored in the capacitor due to 1V battery then the unit is said that there is capacitance of 1f.”

NUMBERS:

given:

$q = 2.5\ \mu c$

$= 2.5 \times 10^{-6} C$

$V_A = -60$ V

$V_B = +10V$

To find:

$$U = ?$$

Formula:

$$V = \frac{w}{q}$$

Solution:

∴ charge is displacement from A to B

$$\therefore V = V_B - V_A$$

$$V = 10 - (-60)$$

$$V = 10 + 60$$

$$V = 70$$