System Of Units:→

The International system of units, known as SI are commonly used by all engineering professional societies.

The SI is based on the measures of six physical quantities as follows:

Quantity	Unit	Symbol
Length	Meter	m
Mass	Kilogram	kg
Time	second	s.
Electric Current	Ampere	A
Temperature	Kelvin	K.
Luminous Intensity	Candela	cd.

Fundamentals Of Electric Circuits

Electric Charge:→

An electrical system generally transmits energy due to the movement of electric charge.

Electricity appears in one of two forms which, by convention, are called negative and positive electricity. Electric charge is the excess of negative or positive electricity on a body or in space. If the excess is negative, the body is said to have a negative charge and vice versa.

An electron is an elementary particle charged with a small and constant quantity of negative electricity. A proton is similarly defined but charged with positive electricity while the neutron is uncharged and is therefore neutral.

An atom is electrically neutral. If the atom has excess electrons, it is said to be negatively charged. A charged atom is called an ion. oppositely charged bodies are mutually attracted to one another while similarly charged bodies

The fundamental electric quantity is charge, and the smallest amount of charge that exists is the charge carried by an electron, equal to

$$q_e = -1.602 \times 10^{-19} C.$$

The other charge-carrying particle in an atom, the proton, is assigned a plus sign and the same magnitude. Thus, the charge of a proton is

$$q_p = +1.602 \times 10^{-19} C.$$

Electrons & protons are referred to as elementary charges.

ELECTRIC CURRENT :→

Electric current is defined as the time rate of change of charge passing through a predetermined area. If Δq units of charge flowing through the cross-sectional area A in Δt units of time, then, the resulting current i is then given by

$$i = \frac{\Delta q}{\Delta t} \quad C/s$$

In differential form, this relationship is written as

$$i = \frac{dq}{dt} \quad C/s.$$

The units of current are called Amperes, where 1 ampere (A) = 1 Coulomb/second (C/s).

The current is carried by negative charges, these charges are the free electrons in the conduction band, which are only weakly attracted to the atomic structure in conductors and are therefore easily displaced in the presence of electric fields.

Conventionally it is said that the current flows from a point of high energy level to a point of low energy level. These points are said to have ... respectively.

for convenience the point of high potential is termed as positive and the point of low potential is termed as negative, hence conventionally a current is said to flow from positive to negative.

This convention was in general use long before the nature of electric charge was discovered. Unfortunately it was found that electrons move in the other direction since the negatively charged electron is attracted to the positive potential. Thus conventional current flows in the opposite direction to that of electron current. Normally only conventional current is described by the term current and this will apply throughout the study.

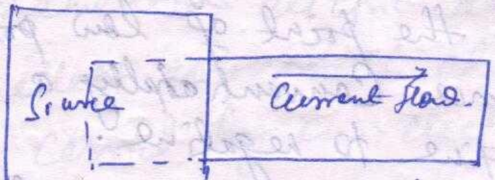
The transfer of electrons takes place more readily in a medium in which atoms can readily release electrons, i.e., copper, aluminium, silver etc. Such a material is termed a conductor. A material that does not readily permit electron flow is termed as an insulator, i.e. porcelain, nylon, rubber etc. There is also a family of materials termed semiconductors which have certain characteristics that belong to neither of the other groups.

CURRENT FLOW IN A CIRCUIT: →

The current flow continues only if the following conditions are fulfilled.

1. There must be a complete circuit around which the electrons may move. If the electrons cannot return to the point of starting, then eventually they will all congregate and the flow will cease.

2. There must be a driving influence to cause the continuous flow. This influence is provided by the source which causes the current to leave at a high potential and to move round the circuit, ... the source at a low potential as



Circuit.
(Elementary circuit).

The driving influence is termed the electromo force called as emf. Each time the charge passes throu the source, more energy is provided by the source to permit it to continue round once more. This is a continuous process since the current flow is continuous. The current is the rate of flow of charge through a section of the circuit.

ELECTROMOTIVE FORCE AND POTENTIAL DIFFERENCE

The emf represents the driving influence that causes a current to flow. The emf is not a force but represents the energy expended during the pass of a unit charge through the source, an emf is always connected with energy conversion.

The energy introduced into a circuit is transferred to the load unit by the transmission system, and the energy transferred due to the passage of unit charge between two points in a circuit is termed as the potential difference (p.d.) If all the energy is transferred to the load unit the p.d. across the load is unit is equal to the source emf.

Both emf & p.d. are similar quantities. However, an emf is always active in that it tends to produce an electric current in a circuit while a p.d. may be either passive or active. A p.d. is passive whenever it has no tendency to create a current in a circuit.

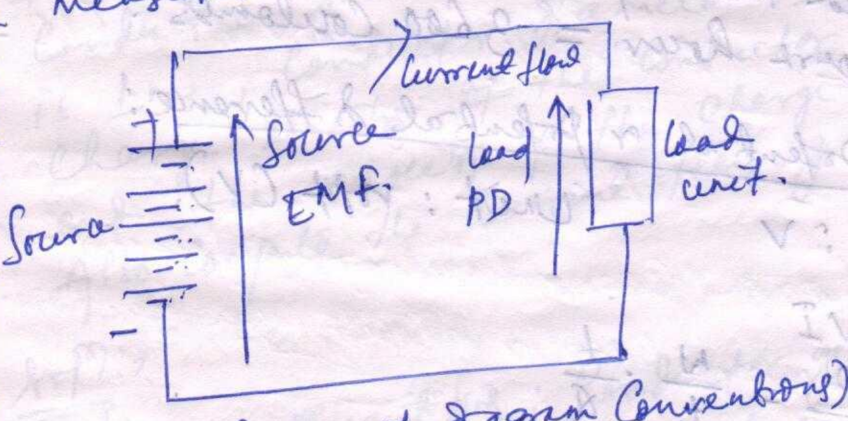
Considering the transmission system of a circuit ... all the energy from the source is transmitted

Charge moving in an electric circuit gives rise to a current: Naturally, it must take some work, or energy, for the charge to move between two points in a circuit, say from point a to point b. The total work per unit charge associated with the motion of charge between two points is called voltage. Thus the units of voltage are those of energy per unit charge. 1 volt (V) = 1 Joule(J)/coulomb(C). The voltage or p.d. between two points in a circuit indicates the energy required to move charge from one point to the other.

Certain Conventions of representing the emf and p.d. in a circuit diagram is given below in the fig.

Each is indicated by an arrows as shown in the fig. In each case, the arrowhead points towards the point of high potential. An arrowhead is drawn on the transmission system to indicate the corresponding direction of conventional current flow.

The current flow leaves the source at the positive terminal and therefore moves in the same direction as indicated by the source emf arrow. However, the current flow enters the load at the positive terminal, and therefore in the opposite direction to that indicated by the load p.d. arrow. Energy is converted within the load unit. The p.d. is considered as the change in energy level across the terminals of the load unit. This is termed a volt drop since the p.d. (and emf) are measured in volts.



(Circuit Diagram Conventions).

<u>Notes</u>:→ The rate of charge passing a point is the current but it has become common practice to describe a flow of charge as a current. Thus we find the term 'current' being used both to indicate a flow of charge and also the rate of flow of charge. It sounds confusing but fortunately it rarely gives rise

word potential is quite appropriate as a synonym of voltage, in that voltage represents the potential energy between two points in unit: If we remove the light bulb from its connections to the battery, there still exists a voltage across the terminals b and a. le the voltage across the battery represents the potential for providing energy to a circuit, the voltage across the light bulb indicates the ut of work done in dissipating energy. In the first case, energy is generated; in the second, it is consumed. We shall in general, refer to elements that provide energy as sources and to elements that dissipate energy as loads.

The principal source of emf are as follows:

1. The electrodes of dissimilar materials immersed in an electrolyte, as in primary and secondary cells, i.e. batteries.

2. The relative movement of a conductor and a magnetic flux, as in electric generators; this source can, alternatively be expressed as the variation of magnetic flux linked with a coil.

3. The difference of temperature between junction of dissimilar metals, as in thermo-junctions.

ELECTRICAL UNITS & SYMBOLS :→

a) Current : Symbol : I Unit : Ampere (A)

b) charge : Symbol : Q Unit : Coulomb (C)

Since, $Q = It$, the Coulomb is an ampere second. Batteries are used to hold charge but they are usually rated in ampere hours.

1 Ampere hour = 3600 Coulombs.

c) Electric potential or potential difference:

Symbol : V Unit : volt (V).

$$P = VI$$

$$\Rightarrow V = \frac{P}{I} = \frac{W}{t} \cdot \frac{t}{Q}$$

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

That is, the p.d. is equal to the energy per unit c[harge]

d) Resistance : Resistance is the property of a material by which it opposes the flow of current through it.

Symbol : R Unit : ohm (Ω).

If V represents the p.d., in volts, across a circuit having resistance R, in Ω, carrying a current of I, in amperes, for time t, in seconds.

$$V = IR$$

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

Power $P = IV = I^2R = \frac{V^2}{R}$.

Energy dissipated is given by

$$W = Pt = I^2Rt = IVt.$$

e) <u>Power</u>: symbol: P Unit: watt (W).

f) <u>Electrical Energy</u>: symbol: W Unit: watt hour (Wh).

g) <u>Electromotive force</u>: symbol: E Unit: volt (V).

<u>Ex: 2.1</u> Charge and Current in a Conductor:

<u>Rizzoni-29.</u>

<u>Problem</u>: Find the total charge in a cylindrical conductor (solid wire) if the length of the conductor is 1 m, conductor diameter is 2×10^{-3} m, charge density of the conductor is 10^{29} carriers/m³ and the velocity of the charge carrier is $u = 19.9\times10^{-6}$ m/s. Also compute the current flowing ~~through~~ in the wire.

<u>Sol</u>:

<u>Known quantities</u>: Conductor geometry, charge density, charge carrier velocity.

<u>To determine</u>: Total charge (Q), current in the wire (I).

<u>Schematics, Diagrams, Circuits and Given Data</u>:

Conductor length: $L = 1$ m.

Conductor diameter: $d = 2r = 2\times10^{-3}$ m.

Charge density: $\eta = 10^{29}$ carriers/m³

Charge of one electron: $q_e = -1.602\times10^{-19}$ C.

... $u = 19.9\times10^{-6}$ m/s.

Assumptions: None.

Analysis:

$$\text{Volume} = \text{Length} \times \text{Cross-sectional area}$$
$$= L \times \pi r^2$$
$$= 1 \left[\pi \left(\frac{2\times10^{-3}}{2}\right)^2\right]$$
$$= \pi \times 10^{-6}\ m^3.$$

Number of Carriers (electrons) = volume × Carrier density

$$\Rightarrow N = V \times n = (\pi\times10^{-6})\times10^{29} = \pi\times10^{23}\ \text{Carriers}$$

Charge = Number of Carriers × charge/carrier.

$$\Rightarrow Q = N \times q_e = (\pi\times10^{23})\times(-1.602\times10^{-19})\ C$$
$$= -50.33\times10^{3}\ C.$$

$$\text{Current } (I) = \frac{Q}{t} = \frac{Q}{\left(\frac{L}{u}\right)} = \frac{Q}{L}\cdot u.$$

$$= \frac{-50.33\times10^{3}}{1}\cdot\times(19.9\times10^{-6})\ C/s.$$

$$= -1\ A.$$

<u>Comments</u>: Charge Carrier density is a function of material properties. Carrier velocity is a function of the applied electric field.

SUMMARY:→

Current:→ It is the rate of flow electric charge in a circuit. The term is often used to describe the flow of electric charge, i.e. 'a current is flowing in a circuit', this is ambiguous but is so common that we have to accept it.

Source:→ A source supplies energy to a system.

Load:→ A load accepts energy from a system.

Electric charge:→ Electric charge may be either positive or negative. Negative electrons are free to move around a circuit thus transporting energy from source to load.

Electromotive force:→ To maintain a current, the source must provide a driving force called the electromotive force (emf).

Potential Difference:→ The potential difference across a load indicates in volts the energy lost per coulomb of charge passing through the load.

Since the current is the rate of flow, its product with the voltage gives the rate of energy transmission, i.e. the power.

Resistance:→ Resistance is a measure of the opposition to the flow of charge through a load.

Ohm's law:→ It states that the ratio of voltage to current is constant, provided other physical factors such as temperature remain unchanged.

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