Electrical terms

Objectives: At the end of this lesson you shall be able to
- **describe electrical charge, potential difference, voltage, current, resistance**
- **explain DC and AC circuit**
- **explain single phase and 3 phase A.C. system.**

Electric charge

Charge is the basic property of elementary particles of matter. Charge is taken as the basic electrical quantity to define other electrical quantities such as voltage, current etc.

According to modern atomic theory, the nucleus of an atom has positive charge because of protons. Generally, when the word charge is used in electricity, it means excess or deficiency of electrons.

Charges may be stationary or in motion. Stationary charges are called static charge. The analysis of static charges and their forces is called electrostatics.

Example: If a hard rubber pen or a comb is rubbed on a sheet of paper, the rubber will attract paper pieces. The work of rubbing, resulted in separating electrons and protons to produce a charge of excess electrons on the surface of the rubber and a charge of excess protons on the paper. The paper and rubber give evidence of a static electric charge having electrons or protons in a static state i.e. not in motion or stationary charges.

The motion of charged particles in any medium is called current. The net transfer of charge per unit time is called current measured in ampere.

Charge of billions of electrons or protons is necessary for common applications of electricity. Therefore, it is convenient to define a practical unit called the coulomb (C) as equal to the charge of 6.25×10^{18} electrons or protons stored in a dielectric.

The symbol for electric charge is Q or q. A charge of 6.25×10^{18} electrons is stated as Q = 1 Coulomb = 1C. This unit is named after Charles A. Coulomb (1736-1806), a French physicist, who measured the force between charges.

Negative and positive polarities

Negative polarity has been assigned to the static charge produced on rubber, amber, and resinous materials in general. Positive polarity refers to the static charge produced on glass and other vitreous materials. On this basis, the electrons in all atoms are the basic particles of negative charge because their polarity is the same as the charge on rubber. Protons have positive charge because the polarity is the same as the charge on glass.

Positive charge is denoted by +Q (deficiency of electrons) and Negative charge is denoted by -Q (excess of electrons). A neutral condition is considered zero charge.

Opposite polarity/charges attract each other

If two small charged bodies of light weight are mounted so that they are free to move easily and are placed close to each other, they get attracted to each other when the two charges have opposite polarity. In terms of electrons and protons, they tend to be attracted to each other by the force of attraction between opposite charges. Furthermore, the weight of an electron is only about 1/1840 of the weight of a proton. As a result, the force of attraction tends to make electrons move towards protons.

Same polarity/charges repel each other

When the two bodies have an equal amount of charge with the same polarity, they repel each other. The two negative charges repel, while two positive charges of the same value also repel each other.

Neutralising a charge

After glass and silk are rubbed together, they become charged with electricity. But, if the glass rod and silk are brought together again, the attraction of the positive charges in the rod pulls the electrons back out of the silk until both materials become electrically neutral.

A wire can also be connected between the charged bodies for discharging. If the charges on both materials are strong enough, they could discharge through an arc, like the lightning.

Electrostatic fields

The attracting and repelling forces on charged materials occur because of the electrostatic lines of force that exist around the charged materials.

In a negatively charged object, the lines of force of the excess electrons add to produce an electrostatic field that has lines of force coming into the object from all directions.

In a positively charged object, the lack of electrons causes the lines of force on the excess protons to add to produce an electrostatic field that has lines of force going out of the object in all directions.

These electrostatic fields either aid or oppose each other.

The strength of attraction or repulsion force depends on two factors,

1) the amount of charge on each object, and
2) the distance between the objects.

The greater the amount electric charges on the objects, the greater will be the electrostatic force. The closer the charged objects are to each other, the greater the electrostatic force.

Static electric charge cannot usually perform any useful function. In order to use electrical charges to do some kind of work, say, to light up an electric bulb, the charges must be set in motion. Thus electric current is said to flow when negative charges/free electrons are moved in the same direction in a medium, for example a copper wire.

Electron movement

In order to produce an electric current, the free electrons in a copper wire must be made to move in the same direction. This can be done by putting electrical charges at the ends of the copper wire more precisely, a negative charge at one end and a positive charge at the other end of a copper wire.

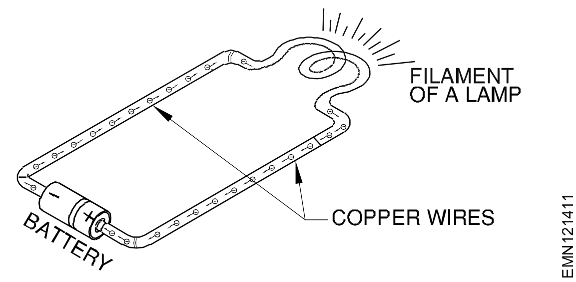
Since the free electrons in copper are negatively charged, they are repelled by the negative charge put at one end of the wire. At the same time these free electrons are attracted by the positive charge, put at the other end of the wire. Hence the free electrons in copper drift towards the positive charge, causing a flow of electric current.

A complete or closed circuit

In order to have continuous electric current, the free electrons must continue to flow. For this to happen, an electrical energy source must be used, to keep applying opposite charges at the ends of the wire. Then, the negative charge would repel the electrons through the wire. At the positive side, electrons would be attracted into the source; but for each electron attracted into the source, an electron would be supplied by the negative side into the wire. Current would, therefore, continue to flow through the wire as long as the energy source continues to apply its electrical charges. This is called a **closed circuit**. Battery is a typical source of electrical charges.

A complete or closed circuit as shown in Fig 1 is needed for current to flow.

Fig 1



Electrical Units of Measurements

Electromotive force (voltage)

The electromotive force (EMF) is a measure of the strength of a source of electrical energy. EMF is not a force in the usual mechanical sense, but it is a convenient term used for the energy which drives current through an electrical circuit.

When two charges have a difference in potential, the electric force that exists between them can be called the electromotive force (EMF). The unit of measure used to indicate the strength of emf is **volt (V)**.

Definition of Volt

When a difference of potential causes 1 coulomb of charge to do 1 joule of work, the emf is 1 volt.

Some typical voltage sources and voltage levels that we come across in day to day life are:

– 1.5 volts from dry cells for pocket torch, digital clocks etc.,

– 9/12/24 volts from batteries for portable radios, emergency lamps motor cycles, automobiles etc.

– 220/240 volts from hydro/hydel or thermal generating stations for lighting and heating of homes

– 440 volts for industrial applications to run motors etc.,

The terms **potential, electromotive force (emf)**, and **voltage** are often interchangeably used.

Quantity of current

The quantity of current flowing through a wire or a circuit is determined by the number of electrons that pass a given point in one second. The unit of measure for the amount of current flowing through a wire or a circuit is **ampere** (A).

Definition of ampere

If 1 coulomb of charge passes a point in 1 second, then a current of 1 ampere is said to be flowing.

NOTE: One coulomb is 6.28×10^{18} electrons.

The term ampere came from the name of a scientist A. M. Ampere(18th century). A quantity of current smaller than one ampere is measured in milliampere and micro-ampere.

1 Milliampere = $\frac{1}{1000}$ of an ampere.

1 Microampere = $\frac{1}{1000000}$ of an ampere.

Types of electricity

Irrespective of how the electricity is generated or produced, electricity can be classified into two types,

1 Alternating current supply, generally known as **AC supply**

2 Direct current supply, generally known as **DC supply**.

AC supply

The term alternating current supply is given to a supply source that makes current to flow through a circuit which reverses or alternates its direction periodically. The number of times that the current alternates in a period of one second is called the **frequency** of alternation. The unit of frequency is **Hertz** denoted as Hz. In India and Europe the frequency is standardised as 50 Hz. In United States and the rest of North America the frequency is standardised to 60 Hz.

In India the electricity generated in hydro/thermal/nuclear power stations is AC.

AC supply has the following advantages over dc supply

1 Reduced transmission loss over very long distances.
2 Voltage levels can be changed using simple devices called transformers.
3 Reduced severity of electrical shock.
4 Generating equipments are simple and cheaper.
5 Can be easily converted to dc supply.

Alternating current is dealt in detail in further lessons.

DC supply

The term direct current supply is given to a supply source that makes current to flow through a circuit in one direction only. This is in contrast to the alternating current supply.

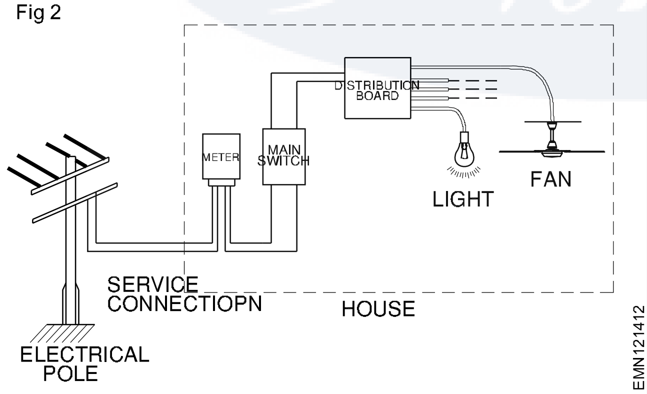
Batteries and some types of generators give DC supply of constant voltage.

DC supply is not distributed by electric supply agencies in India.

Generating stations generate/produce electricity of the order of several hundreds to thousands of mega volts(1 mega = 10^6 volts). This large voltage level is reduced in stages by devices called transformers, and is finally available for the domestic user as a single phase 230 volts, 50Hz, AC. For industrial user three-phase, 440 volts, 50Hz, AC supply is made available.

The domestic voltage of **230 volts AC** is called the **Low tension (LT) voltage**. LT lines enters residential buildings from electricity poles called as service connection as shown in Fig 2.

Fig 2



Electric potential difference

The electrical potential difference is defined as the amount of work done to carrying a unit charge from one point to another in an electric field of the two charged bodies. In otherwords, the potential difference is defined as the difference in the electrica potential.

When a body is charged to a different electric potential as compared to the other charged body, the two bodies are said to be potential difference. Both the bodies are under stress and strain and try to attain minimum potential.

Unit : The unit of potential difference is **volt.**

Resistance

Resistance is the measure of opposition to electric current. A short circuit is an electric circuit offering little or no resistance to the flow of electrons. Short circuits are dangerous with high voltage power sources because the high currents encountered can cause large amounts of heat energy to be released.

A.C. Circuits

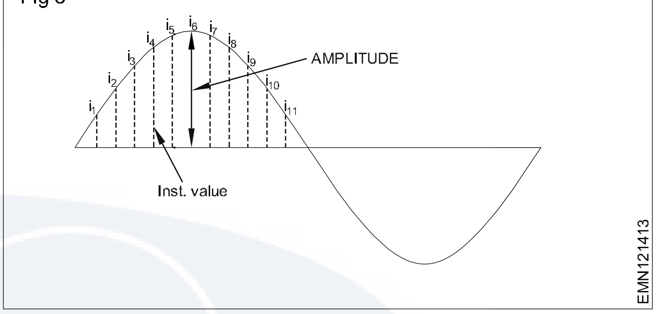
Cycle: A complete change in value and direction of alternating quantity is called cycle.

Period: Time taken to complete one cycle is called period.

Amplitude: It is the highest value attained by the current of voltage in a half cycle.

Instantaneous value: Value at any instant is called instantaneous value. Fig.3 shows this value by $i_{1,} i_2$....

Fig 3



Frequency: It is defined as the number of cycles per second. In India 50 c/s frequency is common.

Frequency $= \frac{NF}{120}$ where N is the speed in r.p.m and P is no.of poles of a machine.

R.M.S. Value: Root mean square value of an alternating current is given by that steady d.c. current which produces the same heat as that produced by the alternating current in a given time and given resistance. It is also called the virtual or effective value of A.C.

$$I_{r.m.s.} = 0.707\ I_{max}$$

$$V_{r.m.s} = 0.707\ V_{max}$$

All A.C. voltmeters and ampere meters read r.m.s. value of voltage and current.

Symmetrical Alternating Quantity: The ratio of the value to the mean period

Instantaneous value: The value of a variable quantity at a given instant.

Peak value: The maximum of the values of quantity during a given interval.

Basic of DC circuit

This flow of electrical charge is referred to as electric current. There are two types of current, direct current (DC) and alternating current (AC). DC is current that flows in one direction with a constant voltage polarity (fig.4) while AC is current that changes direction periodically along with its voltage polarity (fig 5). But as societies grew the use of DC over long transmission distances became too inefficient. With AC it is possible to produce the high voltages needed for long transmissions.Therefore today, most portable devices use DC power while power plants produce AC.

Fig 4

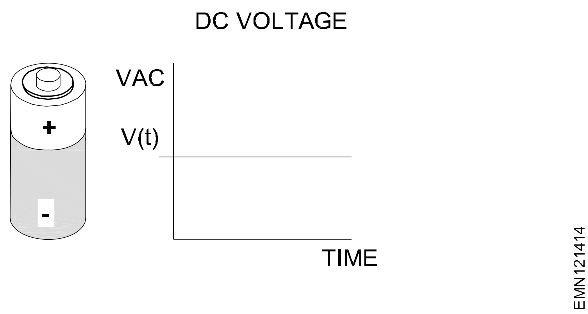
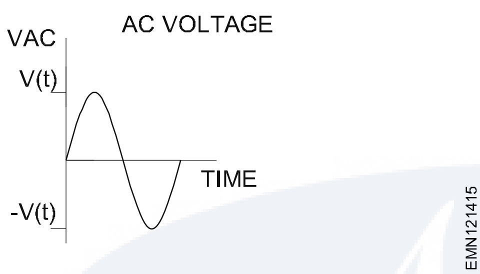


Fig 5



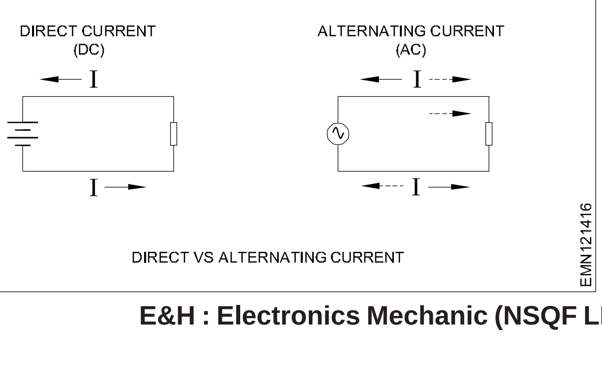
Voltage

We define voltage as the amount of potential energy between two point on a circuit. One point has more charge than another. This difference in charge between the two points is called voltage. It is measured in volts. Techinally, it is the potential energy difference between two points that will impart one joule of energy per coulomb of charge that passes through it. The unit "volt" is named after the Italian physicist Alessandro Volta who invented what is considered the first chemical battery. Voltage is represented in equations and schematics by the letter "V".

Basics of AC circuit

As useful and as easy to understand as DC is, it is not the only "kind" of electricity in use. Certain sources of electricity (most notably, rotary electro-mechanical generators) naturally produce voltages alternating in polarity reversing positive and negative over time. Either as a voltage switching polarity or as a current switching direction back and forth, this "kind" of electricity is known as Alternating Current (AC).

Fig 6



Whereas the familiar battery symbol is used as a generic symbol for any DC voltage source, the circle with the wavy line inside is the generic symbol for any AC voltage source.

One might wonder why anyone would bother with such a thing as AC. It is true that in some cases AC holds no practical advantage over DC. In applications where electricity is used to dissipate energy in the form of heat, the polarity or direction of current is irrelevant,so long as there is enough voltage and current to the load to produce the desired heat (power dissipation). However, with AC it is possible to build electric generators, motors, and power distribution systems that are far more efficient than DC, and so we find AC used predominately across the world in high power applications.

General overview of single phase and three phase AC system

Both single phase and three phase systems refer to units using alternating current (AC) electric power. With AC power, the flow of current is constantly in alternating directions. The primary difference between single phase and three phase AC power is the constancy of delivery.

In a single phase AC power system the voltage peaks at 90° and 270°, with a complete cycle at 360°. With these peaks and dips in voltage, power is not delivered at a constant rate. In a single phase system, there is one neutral wire and one power wire with current flowing between them. The cyclical changes in magnitude and direction usually change flow in current and voltage about 60 times per second, depending on the particular needs of a system.

Benefits and uses of a single phase AC power supply

Single phase power supply units have a broad array of applications. Units that have a limited power need up to 1000 watts typically make the most efficient use of a single phase AC power supply. Generally, benefits of selecting a single phase system include:

- Broad array of application uses
- Most efficient AC power supply for up to 1000 watts
- Fewer design costs
- Less complex design

In a 3 phase system there are three power wires, each 120° out of phase with each other. Delta and wye are the two types of circuits use to maintain equal load across a three phase system, each resulting in different wire configurations. In the delta configuration, no neutral wire is used. The wye configuration uses both a neutral and a ground wire. (Note: In high voltage system, the neutral wire is not usually present for a three phase system.) All three phases of power have entered the cycle by 120°. By the time a complete cycle of 360° has completed, three phases of power each peaked in voltage twice as shown in Fig 6. With a three phase power supply, a steady stream of power is delivered at a constant rate, making it possible to carry more load.

Fig 7

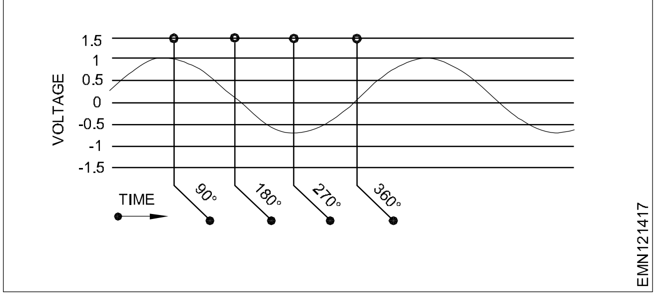
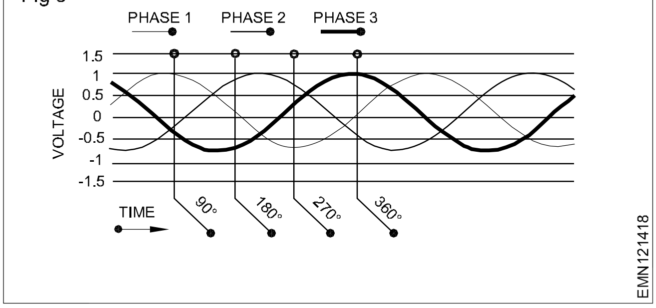


Fig 8



Benefits and uses of a three phase AC power supply

Typical applications for 3 phase systems include data centers, mobile towers, power grids, shipboard and aircraft, unmanned systems, and any other electronic with a load greater than 1000 watts. Three phase power supplies offer a superior carrying capacity for higher load systems. Some of the benefits include:

Reduction of copper consumption

Fewer safety risks for workers

Lower labor handling costs

Greater conductor efficiency

Ability to run higher power loads

Additionally, three phase systems in delta configuration with a 208 volt load requires less circuit breaker pole positions than that of a wye configuration. In these cases, a three phases system yields further savings in installation, maintenance, and cost of production materials due to the reduction of required wires. However, in most cases, the wye configuration is preferable. When is more flexible so that it can power devices that require 3 phase, 2 phase, or 1 phase power. For example, a data center's warehouse of servers may only require three phase power, however the technician monitory the series will likely need single phase power to operate his/her computer, tools and lights.

Line voltage and phase voltage

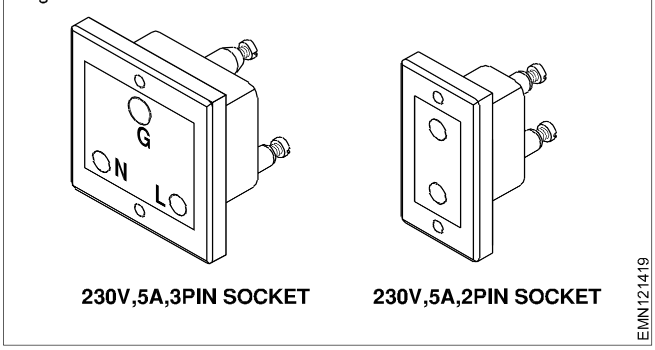
Line voltage is the voltage measured between any two lines in a three-phase circuit. Phase voltage is the voltage measured across a single component in a three-phase source or load.

Line current and Phase current

Line current is the current through any one line between a three- phase source and load. Phase current is the current through any one component comprising a three phase source or load. In balanced "Y" circuits, line voltage is equal to phase voltage times the square root of 3, while line current is equal to phase current.

This 230 volts is used to light up the lamps, fans etc., in homes. To connect electrical appliances at home, 230 V AC is available in either two-pin or three-pin sockets as shown in Fig 9.

Fig 9

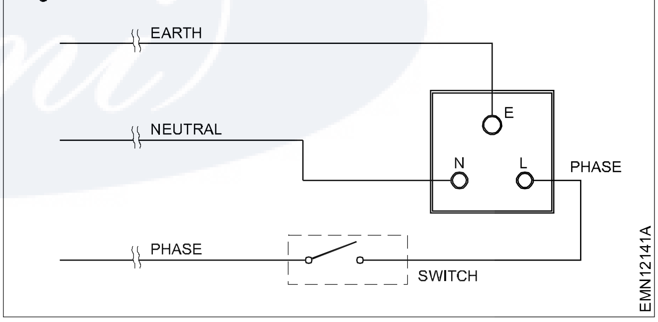


All the 3 pin outlets are generally connected through a single pole ON/OFF switch-as shown in Fig 10. While wiring a 3 pin socket, the following two important points are to be noted,

1 Phase should always be to the RIGHT side of the socket

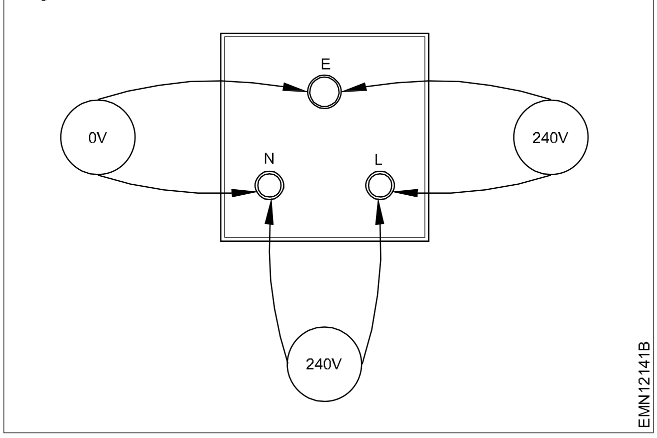
2 Phase should always be wired through the ON/OFF switch as shown in Fig 10. This is as per I.S & I.E rules.

Fig 10



Referring to the Fig 10, when the switch is put ON, the voltages across the three points in a 3 pin socket should be as shown in Fig 11.

Fig 11



Any defect either in mains supply or in the wiring of the socket or in the equipment connected to any other 3 pin sockets in the same building may result in voltages other than that shown in Fig 15.

TESTING A 3 PIN SOCKET OUTLET

On wiring of a new 15 pin socket or if the equipment connected to an existing 3 pin socket is not working or giving a shock, it is necessary to test the socket for voltage across the phase, neutral and ground.

Testing a mains outlet can be done using any one or more of the following test instruments;

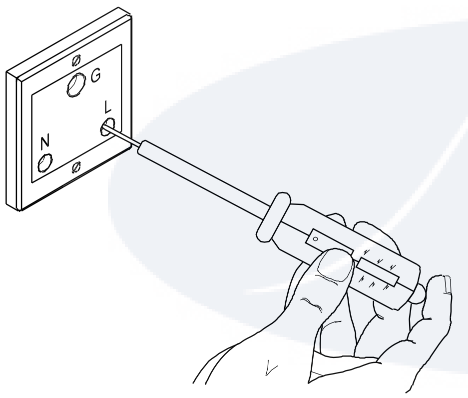
1 Neon tester

A neon tester or neon test lamp is an inexpensive device usually in the form of insulated shank screw driver used to indicate presence of voltage.

When a neon tester is placed at the phase point of a 3 pin socket and the other end of the tester is touched by the finger as shown in Fig 12, if voltage exists at the phase point of the socket, the neon lamp inside the tester glows indicating presence of voltage.

In a correct outlet the lamp should not glow when the neutral and ground points are tested.

Fig 12



2 Test lamp

It is an inexpensive test circuit consisting of an incandescent lamp with two lengthy wires connected across the terminals of the lamp. When the two free ends of the lamp are connected across phase-neutral points of a socket, if voltage exists across the points the lamp glows indicating presence of voltage. The test lamp can be connected across the three outlets of the socket as shown in Fig 11 to confirm condition of the outlet.

3 AC voltmeter/multimeter

Using a voltmeter or a multimeter put to AC 300V range, the voltage across all the 3 terminals of the socket as in Fig 11 is measured to confirm existence of voltage and their correct levels across the outlet points.

Conditions for certifying a 3 pin socket as GOOD or SAFE

1 Voltage across phase-neutral should be equal to mains supply of 230/240 volts. Due to voltage fluctuations, pohase-neutral voltage can sometimes be as low as 210 and as high as 250 V these voltage levels can also be accepted as "tolerable".

2 Voltage across phase - ground should be equal to mains supply of 230/240 V. This indicates that the ground wire to the socket and the local grounding is proper.

3 Voltage across NEUTRAL-GROUND should be zero volts or in the worst case less than 10V. This indicates that the neutral line is safe and there is no excessive leakage in the equipment(s) connected to other 3 pin sockets in the same building.

If the voltage across neutral-ground is higher than 10 volts or very high (of the order of hundreds of volts) the socket is not safe for use, especially when you want to power ON sensitive and delicate equipments/instruments like computers, CRO etc.

Conductor and Insulator

Objectives: At the end of this lesson you shall be able to

- **define conductor and insulator**
- **explain electrical cables**
- **explain the properties of insulating materials.**

Conductors: Materials that contain many free electrons and are capable of carrying an electric current are known as conductors.

Some materials are better conductors of electricity than others. The more free electrons in a material has the better it will conduct. Silver, copper, aluminium and most other metals are good conductors.

Insulators: Materials that have only a few free electrons (if any), and are capable of not allowing the current to pass through them are known as insulators.

Wood, rubber, PVC, porcelain, mica, dry paper, fibre glass are some examples of insulating materials.

Non-conducting materials (insulators) are also called DIELECTRIC.

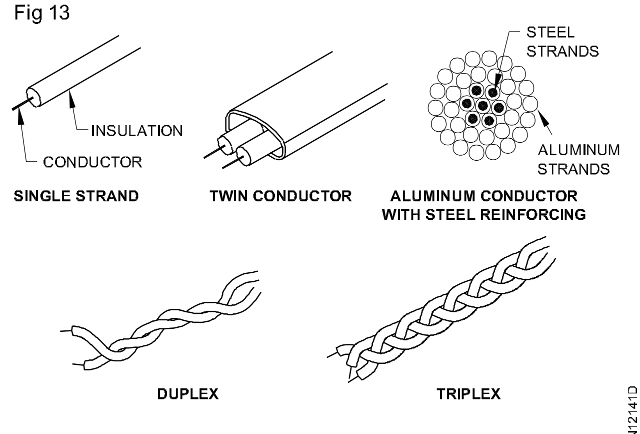
Conductors make up the main conducting path of electric current, and insulating materials prevent current flow through unwanted paths and minimises electrical hazards.

Conductors: The use of conductors and their insulation is regulated by I.E. regulations and I.S.Code of practice.

Regulations and I.S. code cover electrical conductors listing the minimum safety precautions needed to safeguard people, buildings and materials from the hazards of using electricity.

Wires and cables are the most common forms of conductors. They carry electric current through all kinds of circuits and systems. Wires and cables are made in a wide variety of forms suited to many different applications. (Fig.13).

Fig 13



VARIOUS FORMS OF CONDUCTOR

Conductors form an unbroken line carrying electricity from the generating plant to the point where it is used. Conductors are usually made of copper and aluminium.

A conductor is a wire or cable or other form of metal, suitable for carrying current.

All wires are conductors, but all conductors are not wires. For example copper bus bar are conductors but not wires. They are rigid rectangular bars.

Current passing through a conductor generates heat. The amount of heat depends on the value of current and the potential difference between its ends.

The rate of heat production in the conductor equals the amount of power lost by the electricity in passing through the conductor.

The cross-sectional area of the conductor must have a large enough area to give it a low resistance. But the cross-sectional area must also be small enough to keep the cost and weight as low as possible.

The best cross-sectional area depends on how much current the conductor must carry.

The rate of heat production in a conductor increases with the square of the current. As heat is produced the conductor gets hotter and the temperature rises until the rate at which the conductor releases heat to the surroundings equals the rate at which the heat is produced. The temperature of the conductor then remains steady. This steady temperature is called equilibrium temperature.

There is a limit to the temperature each kind of insulation can safely withstand. There is also a limit to the temperature the surroundings can withstand.

I.E. regulations specify the maximum current considered safe for conductors of different sizes, having different insulation and installed in different surroundings.

Size of conductors: The size is specified by the diameter or the cross-sectional area. Typical sizes are 1.5 sq mm, 2.5 sq mm, 6 sq mm etc.

A common measure of wire diameter is the standard wire gauge (SWG), commonly used in our country. The resistance of a material increases as the length of the conductor increases, and the resistance decreases as the cross-sectional area of the conductor increases. We can compare one material with another by measuring the resistance of samples.

Classification of Conductors

Wires and cables can be classified by the type of covering they have.

Bare conductors: They have no covering. The most common use of bare conductor is in overhead electrical transmission and distribution lines.

Insulated conductors: They have a coating of insulation over the metals. The insulation separates the conductor electrically from other conductors and from the surroundings. It allows conductors to be grouped without danger. Additional covering over the insulation adds mechanical strength and protection against weather, moisture and abrasion.

Stranded conductors: They consist of many strands of fine wires. The wires in stranded conductors are usually twisted together. Stranded conductors are more flexible and have better mechanical strength.

Cable: A length of insulated conductor. It may also be of two or more conductors inside a single covering. The conductors in a cable may either be insulated or bare. Cables are available in different types. There are single core, twin core, three core, four core and multi-core cables.

Properties of insulation materials

Two fundamental properties of insulation materials are insulation resistance and dielectric strength. They are entirely different from each other and measured in different ways.

Insulation resistance: It is the electrical resistance of the insulation against the flow of current. Mega-ohmmeter(Megger) is the instrument used to measure insulation resistance. It measures high resistance values in megaohms without causing damage to the insulation. The measurement serves as a guide to evaluate the condition of the insulation.

Dielectric strength: It is the measure of how much potential difference the insulation layer can withstand without breaking down. The potential difference that causes breakdown is called the breakdown voltage of the insulation.

Every electrical device is protected by some kind of insulation. The desirable characteristics of insulation are:

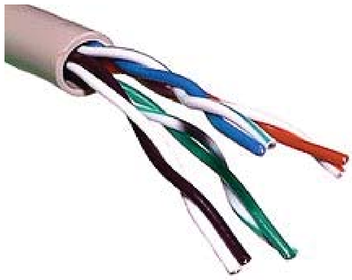
- high dielectric strength
- resistance to temperature
- flexibility
- mechanical strength
- Non hydroscopic.

No single material has all the characteristics required for every application. Therefore, many kinds of insulating materials have been developed.

Semiconductors: A semiconductor is a material that has some of the characteristics of both the conductor and an insulator. Semiconductors have valence shells containing four electrons.

Common examples of pure semiconductor materials are silicon and germanium. Specially treated semiconductors are used to produce modern electronic components such as diodes, transistors and integrated circuit chips.

Fig 14



Twisted pair cable

A comparison of the most commonly used metals as conductors in wires is given below:

PROPERTIES	TYPES OF METALS USED AS CONDUCTORS			
	Silver	**Copper**	**Gold**	**Aluminium**
Ability to be drawn into thin wires	Very good	Very good	Very good	Not good
Flexibility (ability to bend without breaking).	Very good	Good	Very good	Not good
Conductivity.	Very good (100%)	Very good (94%)	Good (67%)	Good (56%)
Resistivity in W m at 20°C	$1.6x10^{-8}$	$1.7x10^{-8}$	$2.4x10^{-8}$	$2.85x10^{-8}$
Ability to withstand	Good	Good	Very good	
Cost	Expensive	Cheap	Very expensive	Very cheap

Conductors used in common types of wires are always drawn to thin circular forms (bare wires). A few reasons why the wires are drawn in circular form are given below.

1 Drawing a conductor in the circular shape is cheaper and easier than drawing in any other form.

2 Round shape of the conductor ensures uniform current flow through the conductor.

3 Uniform diameter of wire can be maintained.

4 Insulation can be uniformly covered.

Conductor(s) of wires are covered with insulating material or an insulating coating(enamel). Some of the reasons for covering the conductor of wires with an insulator are given below:

TYPES OF INSULATORS

PROPERTIES	Polyvinyl chloride (PVC)	Vulcanised insulated rubber(VIR)	Teflon
Ability to withstand physical strain	Good (Hard & rough)	Good (Hard & rough)	Good (Hard & rough)
Ability to withstand action of acids	Good	Good	Good

Ability to withstand atmospheric variations	Good	Good	Good
Flexibility	Very good	Not good	Bad
Ease of skinning	Easy	Difficult	Difficult
Ability to withstand high temperature (heat)	Not good	Good	Very good
Cost	Cheap	Expensive	Very expensive

CURRENT CARRYING CAPACITY OF WIRES

A wire is used to carry electric current. The amount of current that can flow through a wire depends on, how good is the conductivity of the conductor used (silver,copper,aluminum etc) physical dimension (diameter) of the conductor(s).

Larger the diameter of the conductor, higher is the current that can flow through it.

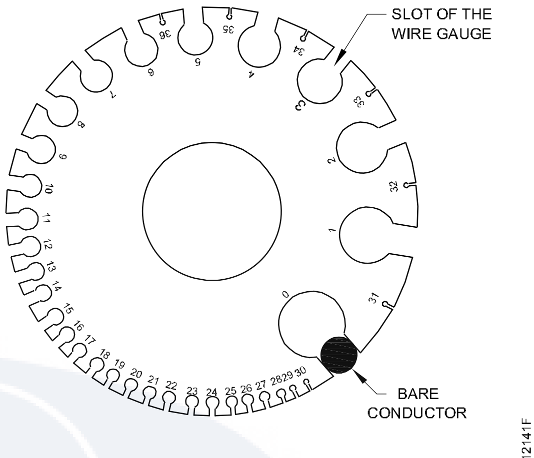
The maximum current that flows through a wire of a particular diameter without heating up the wire is called the maximum current carrying capacity or generally the **current carrying capacity** of a wire. Hence the current carrying capacity of a wire is directly proportional to the conductor's diameter.

STANDARD WIRE GAUGE

Size of a wire means the diameter of the conductor used in that wire. To measure the size of a wire, an instrument called **standard wire gauge (SWG)** is used as shown in Fig 14.

Standard wire gauge is a circular metal disk with varying slot sizes on its circumference. Each slot size corresponds to a gauge number which is written just below the hole. The gauge numbers specify the size of a round wire in terms of its diameter and cross-sectional area. The following points are to be noted while using/reading Standard Wire Gauge:

Fig 15



STANDARD WIRE GAUGE

– As the gauge numbers increase from 0 to 36, the diameter and circular area decrease. Higher gauge numbers indicate thinner wire sizes.

– The circular area doubles for every three gauge sizes. For example, No. 10 SWG has approximately twice the area of No. 13 SWG.