ELECTRICAL APPLIANCES

SEMESTER – I

◆ **AUTHOURS** ◆

Sri M. Sudhadhar
Lecturer in Physics, GDC, Tuni

Dr. G. Pakardin
Lecturer in Physics, SCNR GDC, Proddatur

Sri B. Nageswara Rao
Lecturer in Physics, VSK GDC, Visakhapatnam

Sri G. Ameer Basha
Lecturer in Physics, SJGC, Kurnool

Dr. D. Chandra Sekhar
Lecturer in Physics, GDC, Kalyandurg

Sri K.V. Ganesh Kumar
Lecturer in Physics, GDC, Tadepalligudem

Dr. G. Manikya Rao
Lecturer in Physics,Andhra University, Visakhapatnam

Sri Y. Gishnu Nag Vijay
Lecturer in Physics, PSC & KVSC GC, Nandyal

Dr. B. Gowri Naidu
Lecturer in Physics, Govt. College, Rajahmundry

Smt. B. Durga Lakshmi
Lecturer in Physics, Govt. College, Rajahmundry

◆ EDITORS ◆

Sri M. Sudhadhar
Lecturer in Physics, GDC Tuni

Dr. D. Chandra Sekhar
Lecturer in Physics, GDC Kalyandurg

Sri Y. Gishnu Nag Vijay
Lecturer in Physics, PSC & KVSC GC, Nandyal

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Foreword

Electrical Appliances is a Skill Development Course that is offered in the first semester of the first-year undergraduate study. An Electric Appliance is a device or apparatus that uses to perform a function in our personal life, other than industrial, with the help of electrical energy. It makes our life easier, bring comfort, and saves time. Electric Appliance may utilize one or more different engineering branches of technology to perform its intended function. The technologies mainly involved in Electric Appliances are mechanical, electrical, electronics, instrumentation, etc. Electric Appliance may interchangeably call as a tool or equipment or a device when performing some kind of works or tasks in our personal life.

Choice Based Credit System (CBCS) in all colleges across all undergraduate courses in Andhra Pradesh as per the revised curriculum framework:2020. CBCS has brought a paradigm shift from teacher centered learning approach to student centric learning which offers more flexibility to the student in choosing interdisciplinary, intra-disciplinary and skill-based courses depending on his interest. In brief, it offers opportunities and avenues to learn core subjects but also allows for exploring additional avenues of learning beyond the core subjects for holistic development.

Such additional avenues of learning are covered under non-core subjects as two skill sets of courses. They are

I. Life Skill Courses

II. Skill Development Courses

The LSCs and SDCs are offered in the first three semesters. As there are no specified Text Books for these courses, the Department of Collegiate Education has come up with the initiative of “Content Generation for Skill Courses” in a phased manner. In the second phase, the content is proposed to be prepared for the benefit of students in their first semester. Accordingly, it was decided to bring out a textbook, prepare e-content in four quadrants video, text, self-assessment & additional information) along with a podcast in the assigned topic.

I congratulate & appreciate the content developers for bringing a concise yet resourceful material for the benefit of UG students that shall make them more knowledgeable and employable.

Dr. Pola Bhaskar, IAS
Commissioner of Collegiate Education

SKILL DEVELOPMENT COURSES
SCIENCE STREAM

Syllabus of

ELECTRICAL APPLIANCES

Total 30 hrs (02h/wk), 02 Credits & Max Marks :50

Learning Outcomes:

By successful completion of the course, students will be able to:

1. Acquire necessary skills/hand on experience/ working knowledge on multimeters, galvanometers, ammeters, voltmeters, ac/dc generators, motors, transformers, single phase and three phase connections, basics of electrical wiring with electrical protection devices.

2. Understand the working principles of different household domestic appliances.

3. Check the electrical connections at house-hold but will also learn the skill to repair the electrical appliances for the general troubleshoots and wiring faults.

SYLLABUS:

UNIT-I (6 hrs)

Voltage, Current, Resistance, Capacitance, Inductance, Electrical conductors and Insulators, Ohm's law, Series and parallel combinations of resistors, Galvanometer, Ammeter, Voltmeter, Multimeter, Transformers, Electrical energy, Power, Kilowatt hour (kWh), consumption of electrical power

UNIT-II (10 hrs)

Direct current and alternating current,RMS and peak values, Power factor, Single phase and three phase connections , Basics of House wiring , Star and delta connection , Electric shock, First aid for electric shock, Overloading , Earthing and its necessity, Short circuiting , Fuses , MCB , ELCB, Insulation, Inverter, UPS

UNIT-III (10 hrs)

Principles of working, parts and servicing of Electric fan, Electric Iron box, Water heater; Induction heater, Microwave oven; Refrigerator, Concept of illumination, Electric bulbs, CFL, LED lights, Energy efficiency in electrical appliances, IS codes & IE codes.

Co-curricular Activities (Hands on Exercises): (04 hrs)

[Any four of the following may be taken up]

1. Studying the electrical performance and power consumption of a given number of bulbs connected in series and parallel circuits.
2. Measuring parameters in combinational DC circuits by applying Ohm’s Law for different resistor values and voltage sources
3. Awareness of electrical safety tools and rescue of person in contact with live wire.
4. Checking the specific gravity of lead acid batteries in home UPS and topping-up with distilled water.
5. Identifying Phase, Neutral and Earth on power sockets.
6. Identifying primary and secondary windings and measuring primary and secondary voltages in various types of transformers.
7. Observing the working of transformer under no-load and full load conditions.
8. Observing the response of inductor and capacitor with DC and AC sources.
9. Observing the connections of elements and identify current flow and voltage drops.
10. Studying electrical circuit protection using MCBs, ELCBs
11. Assignments, Model exam etc.

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Co Curricular Activities

Brief introduction to Electrical Appliances

Appliance means it is an electrical or mechanical device which can perform a particular function.

Electrical Appliance means it is an equipment which uses Current or Electrical Energy for its functioning. Electrical appliances are used for Domestic purpose, Commercial purpose and Industrial purpose.

Electrical appliances are broadly divided into three types:

1) Small appliances: Mixers, Juicers, Blender, Electric kettle, Rice cooker etc.,

2) Large Appliances: Air conditioner, Dishwasher, Refrigerator, Microwave oven, Washing machine etc.,

3) Consumer electronics: Television, DVD player, Telephone, Digital cameras etc.,

Most of the electrical appliances are connected to power supply with the help of plug and socket arrangement. **As a safety measure Electrical appliances are regularly inspected for long life span of the appliance.**

Unit I

Learning Objectives

- Fundamental Concepts of Electricity like Voltage, Current etc.,
- Classification of Materials depending upon Current conduction.
- Ohms Law and Combination of Resistances.
- Working of various Meters and Transformer.
- Electric Power and its measurement.

Learning Outcomes

- Get familiar with the Fundamental quantities of Electricity.
- Can easily distinguish between the Conductors and Insulators.
- Gains knowledge on Resistance and its combination.
- Understand the working principles of Various Meters and Transformer.
- Acquire knowledge on Measurement of utilized Domestic Power.

George Simon Ohm from Germany, initially served as a School Teacher. He was a famous Physicist and Mathematician. Famous for his OHMS law which relates the Potential difference between the ends of a conductor and current passed through it. Unit of Electrical Resistance is named after him.

Introduction

Anything that occupies space and has mass is called as Matter. When Matter is divided into small fragments, the last piece which it cannot be divided further is called Atom. This name “Atom” was specified by John Dalton in his Atomic Theory in the year 1800AD. According to him, the atom is indivisible.

After Dalton, Thomson proved that the matter is divisible and he discovered the first elementary particle. Later it is named as Electron. Electron is a negatively charged particle and has negligible mass. Later Goldstein discovered the second elementary particle “Proton” which is a positively charged particle. After that Chadwick discovered Neutron which is a Neutral particle.

Thus every atom was made up of these three particles called Electron, Proton and Neutron. Out of these, Electron is a negatively charged particle, Proton is a positively charged particle and Neutron is a neutrally charged. Another important point to mention is that the magnitude of charges of both proton and electron are equal but they are of opposite sign.

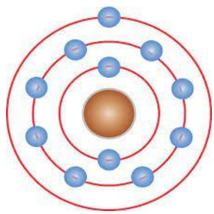


Figure 1: Atom

In an atom, the entire positive charge and mass of the atom is concentrated at the centre called Nucleus. Around this nucleus, the electrons rotate in different orbits just like the planets revolve around the sun in the solar system. The electrons present inside the atom are bound to the nucleus. When an electron comes out of the atom, the electron is free to move. Hence it is termed as Free Electron. The energy of an electron with which it is bind to the nucleus is called the Ionization potential of that Electron. It can also be defined as the minimum energy that must be supplied to an atomic electron to become free. Ionization potential depends upon the substance.

Charge

Charge is an intrinsic property of the particle. Hence every particle posses charge. Charge can be classified into two types: Negative and Positive. Note that Neutral is not a separate type of charge. Neutral means coexisting of equal amounts of Positive and Negative charges.

SI Unit of Charge: Coulomb (C)

Any charge is expressed in terms of the magnitude of charge of an electron. The magnitude of charge of an electron is represented by "e" and its value is 1.6×10^{-19} C. There is no charge that can be less than the magnitude of charge of electron. This is called as "Atomicity of Charge".

If "Q" is the charge then its magnitude can be expressed as $Q = ne$ where $n=1,2,3,4,5,6\ldots$..

This is called as Quantization of Charge.

As atom consists of equal amounts of Positive charge (because of Protons) and Negative charge (due to electrons) so it electrically Neutral. When an electron is removed from it then protons number will be more thereby becoming positive charge. When an electron is added to a neutral atom, then it will get negative charge due to more number of electrons. Thus we can simply say that Addition of electrons results Negative Charge while removal of electrons result Positive Charge.

Similar to Energy, Charge can neither be created nor destroyed. It can be transformed from one form to another. Thus the total charge of a system remains constant. This is called as Conservation of Charge.

1.1.1 Voltage

It is explained in two ways:

1. Potential Difference or Potential

2. Electromotive Force.

1. Potential Difference or Potential

Liquids always flow from higher altitude regions to lower altitude regions. Altitude determines the liquid flow. Heat always flow from high temperature regions to low temperature regions. In this case the property temperature determines the heat flow.

In the same way, for specifying the charge flow a physical property is needed. This property is termed as Potential. **Potential** is the property which specifies the direction of flow of charge.

Consider a charge +q is moved from infinity to a particular point A in an electric field. For moving this charge to point A some work has to be done against the Electric Field. Let this work done be W. The amount of work done for moving unit charge to point A is given by

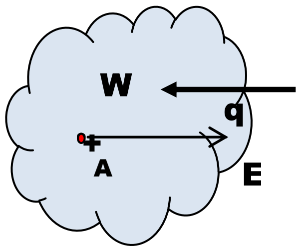


Figure 1.1.1 1: Electric Potential

$$V = W/q$$

This is called as potential.

Thus, the amount of work done in moving a unit positive test charge from infinity to a particular point in an electric field is termed as the Potential at that point.

Similarly, the amount of work done in moving a unit positive charge between two points in an electric field is called as Potential Difference between those two points.

It is important to note that Potential is defined at a particular point whereas Potential Difference is defined between two points.

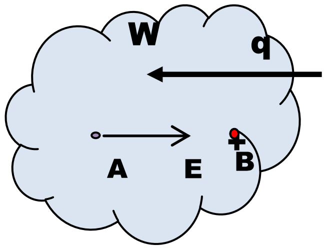


Figure 1.1.1 2: Potential Difference

If the two points are A and B where the potential Differences are V_A and V_B and the charge is moved from A to B then potential difference is given by

$$dV = V_B - V_A = W/q$$

SI Units:**Joule/ Coulomb or Volt**

2. Electromotive Force

Electromotive force is corresponding to a voltage source. Consider a Lamp which is connected to the two terminals of

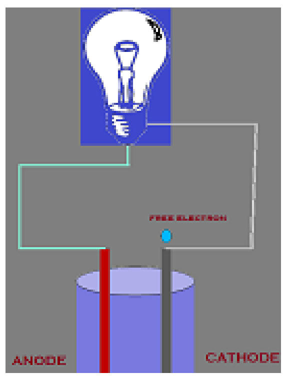


Figure 1.1.1 3: Battery

the battery B by two wires. The terminal which is at higher potential is called as Anode while at the lower potential is called cathode. In metals, current flow by the motion of electrons. When the battery is in ON state, current starts flowing through the circuit and the lamp glows. The current is due to the motion of electrons from the negative terminal of the battery to the positive terminal of the battery through the wires. Thus, this negative charge dumps at the anode of the battery. In order to maintain the same potential difference between the two terminals of the battery, this dumped negative charge at Anode must be again passed to cathode in the internal region of the battery. The work done in moving a unit negative charge from the anode to the cathode in the internal section of the battery is defined as the Electromotive force of the battery. It is denoted by E or emf. The emf can be thought as a charge pump.

When the two terminals of the battery are kept open then it is equal to the potential difference between the two terminals.

It is a characteristic feature of the source. It can be considered as pressure pump. As the pressure of the water flow varies with its height, the current flow varies with the series combination of batteries. Thus, a pile of batteries is similar to pressure pump.

1.1.2 Resistance

The property of a substance by virtue of which it opposes the current flow through it is called as its Resistance. It is denoted by R.

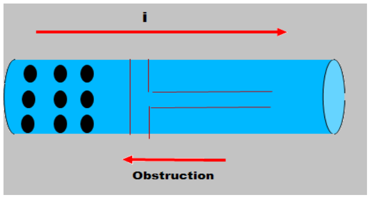


Figure 1.1.2. 1: Resistance

Units: **Ohm or Ω**

Every substance has resistance. It varies from substance to substance. Some will have more resistance and some other will have less resistance. When the resistance is more, then current cannot

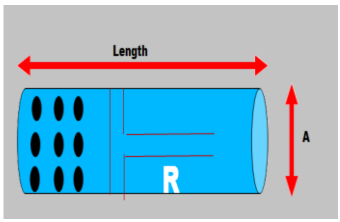


Figure 1.1.2. 2: Factors on which R depends

easily pass through it. When it is less, the current can easily pass through that substance.

The resistance of a substance depends on the following four parameters:

1. Length of that substance

2. Area of cross-section

3. Nature of that material and

4. Temperature

The resistance R of a substance is

1. Directly proportional to its length (l).

2. Inversely proportional to its area of cross-section(A).

Thus $R \propto \frac{l}{A}$

Hence $R = \frac{\rho l}{A}$ where ρ is called as Specific Resistance or Resistivity of that material.

If R_1 is the resistance of body at temperature T_1 of a substance and its resistance R_2 at the temperature T_2 is given by $R_2 = R_1[1 + \alpha(T_2 - T_1)]$

where α is called as the temperature coefficient of Resistance. It may be either Positive or Negative.

If α is Positive then the Resistance increases with increase of temperature and if it is Negative then Resistance decreases with increase of temperature.

The inverse of Resistance is called as Conductance. It is denoted by G

Units: mho or Ω^{-1} or Siemen

The device which offers resistance in the electrical circuit is called as Resistor.

Depending upon their Resistances, Resistors are divided into two types:

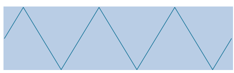


Figure 1.1.2. 3: Symbol

1.Fixed Resistor in which resistance does not change

2.Variable Resistor in which resistance

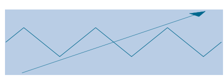


Figure 1.1.2. 4: Symbol

can be adjusted to any desired value.

1.1.3 Current

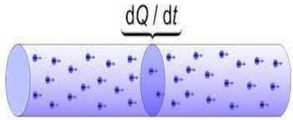


Figure 1.1.3. 1: Charge flow

When there is a potential difference between the ends of a material then charge flow from one end to the other. The amount of charge flowed per unit time is called as electric current. It is denoted by I.

It can also be defined as the rate of flow of charge.

If Q charge flows in a conductor per time T then the current I is given by I = Q/T.

Units: **Coulomb/sec or Ampere**

Current is produced by either flow of positive charge or negative charge.

During ionization process, the anions will move towards the cathode while the cations will move towards the anode. Thus both these constitute the ionization current.

Figure 1.1.3. 2: +ve Charge flow

Positive charge always flows from higher potential region to lower potential region while Negative charge flows from Lower potential side to higher potential side. Both these charges constitute current. Even though there are two directions, as per convention the direction of the current is taken as the direction in which the positive charge flows. Hence current direction will be always from higher potential to Lower potential or opposite to the flow of negative charge.

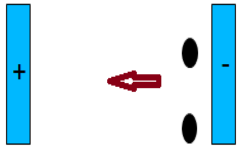


Figure 1.1.3. 3:-ve Charge flow

Even though the current has direction but it is a Scalar quantity. It will not be categorized as vector because it does not follow the Vector Law of Addition.

In Metals, the current conduction is mainly due to the free electrons. These free electrons flow from –ve side to +ve side, so the current will be taken opposite to this direction i.e. from +ve to –ve side.

1.2.1 Capacitance: The ability to store the electric charge in a conductor is defined as its capacitance. When the capacitance is more, the conductor stores more charge and if it is less, it stores less charge.

The charge that can be stored on a capacitor is directly proportional to the potential of the conductor. If Q is the charge stored on the conductor and V is the potential of the conductor then $Q \propto V$

It can be written as $Q = CV$

where C is called as the capacitance of the conductor

Thus $C = Q/V$

If V=1Volt then C=Q.

Hence it is defined as the charge stored on the conductor per unit change in electric potential.

Units: Coulomb/Volt or Farad (F)

For all practical purposes Farad is a very large unit. Practically it is expressed in micro-farad (μF) or pico-farad (pF)

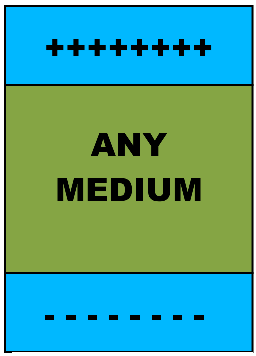


Figure 1.2.1.1: Parallel Plate Capacitor

Here 1 μF $=10^{-6}$ F and

1 pF =1 μμF $=10^{-12}$ F

Hence the capacitance of a conductor can be increased by decreasing the Potential difference.

In electrical circuits, capacitance is introduced by the device called Capacitor.

Capacitor is device which stores the charge. It is also called as condenser. It is also defined as the device used for storing the energy in the form of an electric field.

The Energy stored per unit volume in a capacitor is given by $U = \frac{1}{2}CV^2$

where C is its Capacitance and V is the Potential difference between the plates.

In terms of the Electric Field it is $U = \frac{1}{2}\varepsilon E^2$

where E is the electric field between the two plates and ε is the permittivity of the medium between the two conductors.

Generally it consists of two conductors separated by some distance. The space between these conductors is filled with air or with any other dielectric medium.

The capacitance of a capacitor depends upon the geometry of the conductors and the medium between them.

Depending upon their Capacitances, capacitors are divided into two types:

1. Fixed Capacitor in which capacitance does not change.

Figure 1.2.1. 2: Symbol

2. Variable Capacitor in which capacitance can be adjusted to any desired value.

Figure 1.2.1. 3: Symbol

1.2.2 Inductance

It is similar to Capacitance and Resistance in the electrical circuits.

The ability to store the energy in a device in the form of magnetic field which is produced to flow of electric current through it is called Inductance.

Oersted proved that the magnetic field is produced in the neighbouring regions of a current carrying conductor. This field is directly proportional to the electric current flowing. When the current changes the magnetic field also changes. When the magnetic field changes because of the change in the flow of current through an element, then by the phenomenon of Electromagnetic Induction, an emf is generated in that element which opposes the change in the electric current. This emf is called as back emf. The property by which this back emf is generated in an element due to the change in the flow of the electric current through it is called as Inductance.

Inductance is of two types:

1. Self Induction:

The ability of generation of back emf in an element due to the changes in the current flowing through the same element is called as Self Induction.

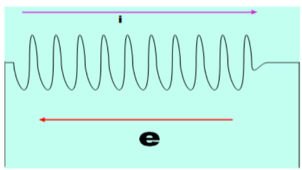


Figure 1.2.2 1: Self Induction

The magnetic flux (ϕ_B) produced in an element is directly proportional to the flow of current (i) through it.

Thus $\emptyset_B \propto i$. This can be re-written as $\emptyset_B = Li$

where L is called as coefficient of Self Induction.

If i=1 A then $\emptyset_B = L$

Hence the coefficient of Self Induction of an element is defined as the magnetic flux produced when unit current flows through it.

If e is the back emf generated in an element, due to the changes in the electric current flowing through it then this back emf will be directly proportional to the rate of change of current passing through it.

Thus $e \propto \frac{di}{dt}$ This can be re-written as $e = -L.\frac{di}{dt}$

where L is called as coefficient of Self Induction.

If di/dt =1 A/s then $e = -L$

Hence the coefficient of Self Induction of an element is defined as the back emf produced when the rate of change of current flowing through it is unity.

2. Mutual Induction:

The ability of generation of back emf in an element due to the changes in the current flowing through the other element which is nearer to the first one is called as Mutual Induction.

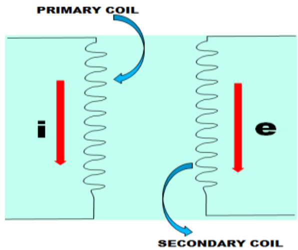


Figure 1.2.2 2:Mutual Induction

The magnetic flux (ϕ_B) produced in an element is directly proportional to the flow of current (i) through the other element.

Thus

$\emptyset_B \propto i$. This can be re-written as $\emptyset_B \propto Mi$

where M is called as coefficient of Mutual Induction.

If i=1 A then $\emptyset_B = M$

Hence the coefficient of Mutual Induction of an element is defined as the magnetic flux produced when unit current flows through the other element.

If e is the back emf generated in an element, due to the changes in the electric current flowing through the other element, then this back emf will be directly proportional to the rate of change of current passing through the other element.

Thus $e \propto \frac{di}{dt}$ This can be re-written as $e = -M.\frac{di}{dt}$

where M is called as coefficient of Mutual Induction.

If di/dt =1 A/s then $e = -M$

Hence the coefficient of Mutual Induction of an element is defined as the back emf produced in the second element when the rate of change of current flowing through the first one is unity.

1.3 Electrical conductors and Insulators

Depending upon the current conduction, the materials are broadly classified into two types. Those are:

1. Conductors and

2. Insulators

Conductors

The substances through which current flows freely are called as Conductors.

Examples: Copper, Silver, Lithium, Mercury, Saline water, Graphite etc.

All metals come under the class of conductors.

Properties:

1. They will offer less obstruction to the current flow.
2. They have Low resistivity of the order of $10^{-2} – 10^{-8}$ Ωm.
3. They have High conductivity which is of the order of $10^{2} – 10^{8}$ Sm.
4. They have free charge carriers (free ions or electrons).
5. The valence electrons are loosely bounded to the atom.
6. The electric field inside the conductor is always zero.
7. They have low melting and boiling points.
8. They have positive temperature coefficient of resistance.

Insulators: The substances through which no current flows freely are called as Insulators.

Examples: Paper, Mica, Wood, Rubber etc.

Most of the non-metals come under the class of Insulators.

Properties:

1. They will offer High obstruction to the current flow.

2. They have High resistivity of the order of $10^{11} – 10^{19}$ Ωm.

3. They have Low conductivity which is of the order of $10^{-11} – 10^{-19}$ Sm.

4. They have no free charge carriers (free ions or electrons).

5. The valence electrons are tightly bounded to the atom.

6. The electric field inside the insulator is always non-zero

7. They have high melting and boiling points

8. They have negative temperature coefficient of resistance

Note: There are intermediate materials between the Conductors and Insulators. These materials have Negative temperature coefficient of Resistance. Hence, they behave as Insulators at low temperatures and Conductors at High temperatures. These are called Semi-conductors.

Eg: Germanium, Silicon etc.

1.4 Ohm's Law

The Ohm's Law is proposed by the scientist George Simon Ohm after the number of experiments with thermocouples and published in 1827. It is an empirical Law. This tells that there is a linear relationship between potential difference (voltage) and electric current. As weknow that heat flows from a hot point to a cold point and water flows from top to bottom similarly electric current flows from high potential point

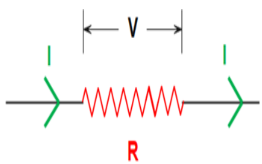


Figure 1.4. 1: Current through a conductor

to a low potential point.

Statement:- “At a constant temperature the electric current flowing through a conductor isproportional to the potential difference between the ends of the conductor.”

If ‘V’ is the potential difference between the ends of a conductor, then the current flowing through the conductor ‘I’ as in Figure 1.4.1, then according to Ohm’s law,

I α V at a constant temperature

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

Here ‘R’ is the proportionality constant and is known as the resistance of the conductor. The SI Unit of resistance is ohm (Ω) after the scientist G.S. Ohm. When one ampere is flowing through a conductor having potential difference between its ends then the resistance offeredby the conductor is said to be 1Ω. This law can be shown in diagram as in Figure 1.4.2

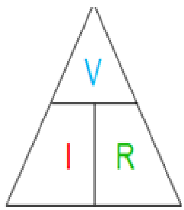


Figure 1.4.2 : Ohms Law Triangle

All materials do not obey Ohm’s law.

The materials which obey Ohm’s law are called ohmic materials.

Ex: All conductors (metals) and resistors like Copper, Silver, Carbon resistors etc. For these ohmic materials, the current and voltage graph is linear.

The materials which do not obey Ohm’s law are called non-ohmic conductors.

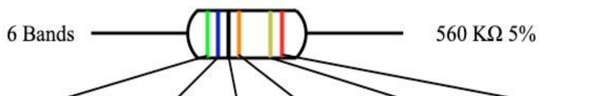
Ex: Incandescent bulb (Electric bulb), Semiconductors, p-n junction diodes etc.

For these non-ohmic materials, the current and voltage graph is non-linear.

Resistor Colour Coding

The resistance (R) which opposes flow of current is similar to that of friction in solids and viscosity in fluids. There are different types of resistors in which the resistance of the carbon resistors can be assessed with colour code using the Figure 1.4.3.

Example: In the below six band resistors, the first colour green having number 5 which represents first digit, second colour blue having number 6 which represents second digit and third colour black having number 0 which represents to be kept after the two digits in right side. The fourth colour orange having number 3 which represents (multiplier) number of zeros to be kept after two digits in right side. The fifth colour gold shows tolerance of 5%. Hence the resistance of the resistor is (560000 ±5%) Ω = (560±5%)kΩ.



Colour	1st digit	2nd digit	3rd digit	Multiplier	Tolerance	Temperature coefficient
Black	0	0	0	1		
Brown	1	1	1	10	1%	100ppm
Red	2	2	2	100	2%	50ppm
Orange	3	3	3	1k		15ppm
Yellow	4	4	4	10k		25ppm
Green	5	5	5	100k	0.5%	
Blue	6	6	6	1M	0.25%	
Violet	7	7	7	10M	0.1%	
Gray	8	8	8		0.05%	
White	9	9	9			
Gold				0.1	5%	
Silver				0.01	10%	

Figure 1.4.3: Resistance Colour Code

Similarly for any carbon resistor, its resistance can be known using colour code. Now a days some companies are giving resistance value in digits on the resistor.

1.5 Series and Parallel Combination of resistors

The resistors (resistances) can be connected in two ways according to the requirement in order to increase or decrease the effective resistance in the circuit between two points. They are

a). Series combination of resistors and

b). Parallel combination of resistors.

Series combination of resistors

When two or more resistances are connected end to end such that the electric current flowing through all the resistances is same then the combination is called series combinationof resistors.

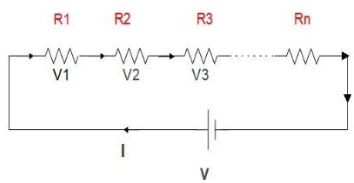


Figure 1.5. 1:Series Combination

Let us consider 'n' resistors

having resistances R_1, R_2, R_3, … R_n connected in series.

A battery of voltage 'V' volt connected across this series combination is as shown in the Figure 1.5.1.

Let 'R' be the effective resistance between A and B points. Let 'I' be the current in the circuit. Now as the resistors are in series, the same current 'I' flows through all resistors.

According to the Ohm's Law, **V = I R ------ (1)**

But due to the difference in resistances, different potential differences (voltages) drop across different resistors. Let V_1, V_2, V_3, …V_n be the voltages across the resistors R_1, R_2, R_3, … R_n respectively.

According to the Ohm's Law,

$V_1 = IR_1$, $V_2 = IR_2$, $V_3 = IR_3$ … $V_n = IR_n$ ------------**(2)**

According to the Kirchhoff's voltage Law,

$$\mathbf{V = V_1 + V_2 + V_3 + \ldots + V_n}$$

$$\mathbf{I\,R = I\,R_1 + I\,R_2 + I\,R_3 + \ldots + I\,R_n}$$

From eqns. (1) & (2) $\mathbf{I\,R = I\,(R_1 + R_2 + R_3 + \ldots + R_n)}$

On cancellation of ‘I’ on both sides, we get

Resultant resistance $\mathbf{R=R_1+R_2+R_3+\ldots+R_n}$ --------**(3)**

This is the effective resistance or resultant resistance in the case of series combination of resistors. If there are ‘n’ number of equal resistors each of resistance ‘r’, connected in series then the resultant resistance will be ‘nr’.

Note: - In the case of series combination of resistances, the resultant resistance is more than the highest resistance in the combination.

Applications

1. The decorated lights are connected in series, if anyone of the lights is burned out then all will go out (switch off), but it would not take much time to find out.

2.The series combination is useful for current controlling devices.Electric Fuses are connected in series.

3. Electric Switches or circuit breakers are connected in series.

4. Resistors are connected in series to limit current

through LEDs.

Parallel combination of resistors: -

When two or more number of resistors are connected such that all their one side ends are joined at one point and other side ends are joined at another point, then the combination is called parallel combination. Now when a battery is connected then the voltage (PD) across all resistors is same as that of battery voltage. But current through each resistance is different.

Let us consider 'n' resistors of resistances R_1, R_2, R_3, … R_n connected in parallel as shown in the Fig.1.5.2. and this combination is connected to a battery of voltage 'V'.

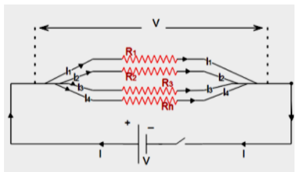


Figure 1.5. 2 : Parallel Combination

If 'R' is the resultant or effective resistance in the circuit, then according to Ohm's Law, the current in the circuit,

$$I = \frac{V}{R} \quad \text{----- (1)}$$

The voltage (PD) across all resistors is same but current ‘I’ is distributed through resistors depending on the resistances. Let I_1, I_2, I_3, … In be the currents through resistors R_1, R_2, R_3, …Rn respectively, then

$$I_1 = \frac{V}{R_1}, I_2 = \frac{V}{R_2}, I_3 = \frac{V}{R_3}, \qquad \text{-----(2)}$$

According to Kirchhoff’s Current law

Total current **$I = I_1 + I_2 + I_3 + \ldots I_n$**

Substituting equations (1) and (2) we get

$$\boldsymbol{I = \frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \ldots\ldots\ldots. + \frac{V}{R_n}}$$

$$\boldsymbol{\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots\ldots. + \frac{1}{R_n}}$$

In parallel combination of resistors, the reciprocal of the resultant or effective resistance is equal to the sum of reciprocals of the individual resistances connected in parallel.

If there are ‘n’ number of equal resistors each of resistance ‘r’, connected in parallel then the resultant resistance is r/n.

Note: - In the case of parallel combination of resistances, the resultant resistance is less than the least resistance in the combination.

Applications:

1. Parallel electrical circuits are used in every house wiring. If any of the electrical appliance like bulb is burn out , the remaining will not be affected.
2. Parallel combination is useful for dc power supply.
3. Generally, computer hardware i.e., circuits in printed circuit boards are in parallel combination.
4. Automobile electrical circuits are also in parallel form

Disadvantages:

1. Voltage cannot be increased across a particular component.
2. Short circuit may occur easily as parallel design is complicated.

****

1.6 Basic electric meters:

The electricity cannot be seen directly but its effects can be observed. Hence to measure electric current, voltage, resistance, electrical energy etc. Basic meters are used. Some of the basic meters are galvanometer, ammeter, voltmeter, ohmmeter, wattmeter etc.

1.6.1 Galvanometer

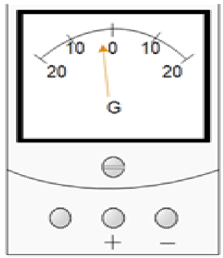


Figure 1.6.1.1 : DC Galvanometer

Galvanometer is an electromechanical instrument used to detect whether electric current is flowing in a circuit or not, to measure small amount of electric current and voltage. It is developed merely by observation that a magnetic needle placed nearby deflects due to flow of current in a conductor. It was first observed by Hans Cristian Oersted in 1820.

It works on the relation between electric current flowing in a conductor and magnetic field. Either coil or magnet moves due to arise of the torque between the current and the magnetic field. The movement of the coil or magnet can be calibrated so that current or voltage is measured and hence the galvanometer works as an ammeter or voltmeter depending on the resistance used. The galvanometer can be used to detect or measure voltage and current of ac and dc values. There are different types of galvanometers based on the requirement and methods used. They are

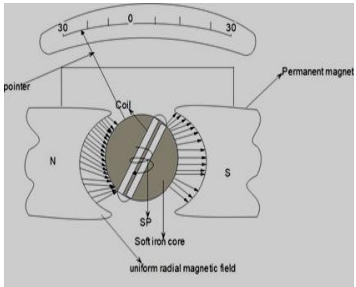


Figure 1.6.1.2: Main parts of a Galvanometer

1) Moving coil

2) Moving magnet

3) Moving iron

4) Electro dynamic

5) Hot- wire etc.,

The dc galvanometer is as shown in the Fig.1.6.1.1. The main parts of the galvanometer are shown in the Figure1.6.1.2.

Galvanometer consists of divisions either side of the middle ‘0’ reading i.e., it is a zero centred meter. It has different ranges 0 to 30 or 0 to 60. It shows zero deflection when no current flows through it. If current flows in a circuit in one direction, then the galvanometer shows deflection in one direction (say right) and if the current flows in opposite direction, then the galvanometer shows deflection in another direction (say left). That is the galvanometer shows the direction of flow of current.

A galvanometer can be converted into an ammeter by connecting a small resistance in parallel to it. This small resistance is called shunt resistance. The shunt resistance can be calculated as below:

Shunt Resistance

$$R_s = \frac{I_m G}{I - I_m}$$

where I is the maximum current to be measured

I_m is the maximum current that can flow through the galvanometer for full deflection and

G is the resistance of the galvanometer or internal resistance of the galvanometer

Example: Let us calculate shunt resistance to be connected to a galvanometer of resistance 30Ω and 5mA current is required for full deflection (say 30 divisions) to convert into an ammeter of range 0 to 30mA.

Solution: Given,

I = maximum current to be measured = 30mA

I_m = maximum current that can flow through the galvanometer for full deflection =5mA

G = resistance of the galvanometer or internal resistance of the galvanometer = 30Ω

Shunt Resistance

$$\boldsymbol{R_s = \frac{I_m G}{I - I_m}}$$

R_s = 6 **Ω**

This 6Ω is to be connected to the galvanometer to convert it into an ammeter of range 0 to 30mA.

Similarly, a galvanometer can be converted into voltmeter by connecting a high resistance in series to it. The large resistance can be calculated as below:

$$R = \frac{V}{I_m} - G$$

where V is the maximum voltage to be measured

I_m is the maximum current that can flow through the galvanometer for full deflection and

G is the resistance of the galvanometer or internal resistance of the galvanometer.

Example: Let us calculate large resistance to be connected to a galvanometer of resistance 30Ω and 5mA current is required for full deflection (say 30 divisions) to convert into a voltmeter of range 0 to 3V

Solution: Given,

V = maximum voltage to be measured = 3V

I_m = maximum current that can flow through the galvanometer for full deflection = 3mA

G = resistance of the galvanometer or internal resistance of the galvanometer = 30Ω

Resistance to be connected to the galvanometer is given by

$$R = \frac{V}{I_m} - G = 970\ \Omega$$

This 970Ω is to be connected to the galvanometer in series to convert it into a voltmeter of range 0 to 3V.

Applications:

There are number of applications of galvanometer. Some of the applications are given below

1. Electric currents and voltages can be detected whether they are present or not

2. Small amounts of ac and dc currents and voltages can be measured

3. In electrical bridges like Wheatstone bridge, Meter bridge, Carey foster bridge, etc.,

4. In beam steering and positioning elements in laser technology

5. In detection of errors in telecommunications

6. In Stereo lithography, Optical coherence tomography, Retinal scanning etc.,

Advantages:

1. Galvanometers are highly sensitive
2. These are not easily affected by stray magnetic fields.
3. These have high accuracy

Disadvantages:

1. The galvanometers act as permanent magnets.
2. The galvanometers only show deflections.

1.6.2 Ammeter

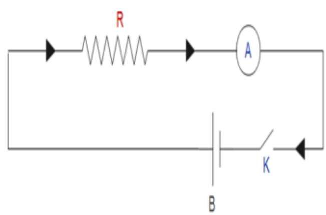


Figure 1.6.2. 1: Ammeter connected in Series

An Ammeter is an electrical instrument used to measure electric ac and dc currents flowing in an electrical circuit. Ammeter is the abbreviation of ampere meter. It is also a special type of galvanometer. It is simply a calibrated galvanometer. Generally, the ammeters have zero reading at one end unlike galvanometers, but there are some ammeters having zero reading at the middle in order to find the direction of flow of electrical current. The basis for this also is same as that of galvanometer i.e., deflection of magnetic needle near current carrying conductor observed by H.C Oersted in 1820. The ammeter is to be connected in series in a circuit to measure the current flowing through the circuit as in Figure 1.6.2.1. Ammeters usually have low resistances so that they do not cause for voltage drop. The ideal ammeter resistance (impedance) is zero. There are different types of ammeters based on the requirement and methods used. They are

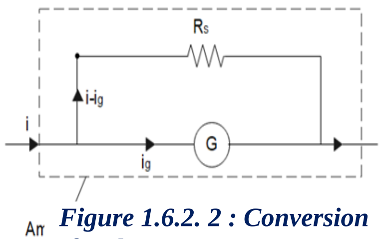


Figure 1.6.2. 2 : Conversion of Galvanometer to Ammeter

1) Moving coil

2) Moving magnet

3) Moving iron

4) Electrodynamic

5)Hot-wire

6) Integrating etc.,

Based on the type of measurement the ammeters can be classified as ac ammeters and dc ammeters. The dc ammeter measures peak value of dc current but the ac ammeter measures rms value of ac ammeter. The basic conversion of galvanometer in to ammeter is as shown in the Figure.1.6.2.2. The diagram of an ammeter is shown in the Figure 1.6.2.3.

Figure 1.6.2. 3: DC Milli Ammeter

Analog ammeters move a pointer on a scale to show deflection, the deflection is proportional to the current measured. These can be constructed and calibrated by connecting a small resistance (shunt resistance) to a galvanometer in parallel. This fulfils the principle of ammeter i.e., the resistance and inductive reactance should be very small. Depending on the amount of current to be measured Pico ammeter, micro ammeter, milli ammeter are also available.

1.6.3 Voltmeter

A voltmeter is an electrical instrument used to measure electric ac and dc voltages (potential differences) between two ends (across) of an electrical circuit. It is also a special type of galvanometer. It is simply a calibrated galvanometer. Generally, the voltmeters have zero reading at one end unlike galvanometers. The basis for this also is same as that of galvanometer i.e., deflection of magnetic needle near current carrying conductor observed by H.C. Oersted in 1820. The voltmeter is to be connected in parallel between the ends of a component (resistor or electrical appliance) in a circuit to measure the potential drop across the component as shown in Figure 1.6.3.1.

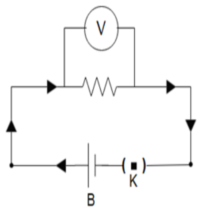


Figure 1.6.3. 1: Voltmeter in Parallel

Voltmeters usually have high resistances so that they do not cause for drawing of more current. The ideal voltmeter resistance (impedance) is infinity. There are different types of voltmeters based on the method of construction.

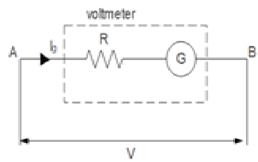


Figure 1.6.3. 2 : Conversion of Galvanometer into Voltmeter

They are

1) Permanent Magnet Moving coil Voltmeter

2) Moving iron

3) Electrodynamometer

4)Rectifier type

5) Induction type

6) Electro static type

7) Digital etc.,

Based on the type of measurement the voltmeters can be classified as ac voltmeter and dc voltmeters. The dc voltmeter measures peak value of dc voltage but the ac voltmeter measures rms value of ac voltage. The basic conversion of galvanometer in to voltmeter is as shown in the Figure 1.6.3.2. The diagram of a voltmeter is shown in the Figure 1.6.3.3.

Analog voltmeters move a pointer on a scale to show the deflection, the deflection is proportional to the voltage measured. These can be constructed and calibrated by connecting a high resistance to a galvanometer in series.

Figure 1.6.3. 3: DC Voltmeter

1.6.4 Multi-meter

Multi-meter is an electrical and as well as electronic instrument used for multifunction. It is a very useful handy instrument for those who work on electrical and electronic works. It can be used for measuring characteristic electrical signal apart from ac & dc current and voltages of different ranges, resistance, checking continuity of a circuit. It is powered by a rechargeable battery.

The multi-meters can be divided in two types on the basis of reading taking.

They are 1) Analog multi-meters and 2) Digital multi-meters.

Figure 1.6.4.2 :Analog Multimeter

Figure 1.6.4. 1: Digital Multimeter

The analog and digital multi-meters are as shown in Figure 1.6.4.1 and Figure 1.6.4.2 respectively. In order to measure required quantities like voltage, current, resistance etc., first of all some adjustments are to be made to the multi-meters. First switch on and adjust to zero position in the case of analog multi-meter. Place the test probe black (negative terminal) in common socket and red test probe (positive terminal) in the appropriate socket either in ac voltage/current, dc voltage/current, resistance socket in the multi-meter. Later turn the switch knob to resistance measurement mode and test probes are to be connected to each other, if it shows 0**Ω**, then it is right and the multi-meter can be used for our measurements.

Now for continuity checking the other ends the probes are to be contacted between the points in our circuit where continuity testing is required, if sound comes in digital multi-meter (zero reading in analog), then it is inference that there is continuity between the points in the circuit. Similarly, for required physical quantity (voltage, current etc.) the switch knob is to be adjusted to the appropriate measurement quantity and range in the multi-meter. Later the test probes are placed across the component or appliance and required quantity is noted either in digital display or in analog multi meter using pointer.

Advantages of Digital multi-meter

Digital multi-meters have some advantages over analog multi-meters. They are

1. It is easy to take readings as it shows numerical values.
2. It gives accurate values without parallax error.
3. Easy to operate and available in wide range

Disadvantages of digital multi-meter

Digital multi-meters have some disadvantages apart from advantages. Some of them are

1. It is ambiguity due to many functions.
2. It is difficult to read fluctuating values.
3. It is not possible to use without battery.

Advantages of analog multi-meter

Analog multi-meters have some advantages over digital multi-meters. Some of them are

1. It is easy to understand by sense.

2. It is easy to recognize fluctuating values.

3. Voltages and currents can be measured without batteries.

Disadvantages of analog multi-meter:

Analog multi-meters have some disadvantages. Some of them are

1. There is a variation in the measured values as there is internal resistance.

2. It is necessary to read the scale and there is a possibility of parallax error.

****

1.7 Transformer

The main reason for preferred use of alternating current (A.C.) over direct current (D.C.) is that the alternating current can be easily transferred over long distances.

The AC voltages can be easily and efficiently converted from high voltage to low voltage and viceversa at various stages of generation, transmission, distribution and utilization of power.

This conversion of ac voltage is possible only by means of transformers.

Definition

A transformer is defined as a static electrical device that transfers electrical energy from one electric circuit to another circuit or multiple circuits, through the process of electromagnetic induction.

The transformer is basically a voltage control device and is most widely used to decrease (step down) or increase (step up) the supply voltage without any change in frequency of alternating current between electric circuits. It is also commonly used in the transmission and distribution of alternating current signals between circuits. Transformer has highest possible efficiency out of all the electrical appliances, since it has no moving parts and it requires almost negligible amount of maintenance and supervision.

Construction

In its basic form, a transformer essentially consists of two inductive windings or coils that are electrically insulated from each other but are magnetically linked through a common soft iron laminated core as shown in Figure 1.7.1

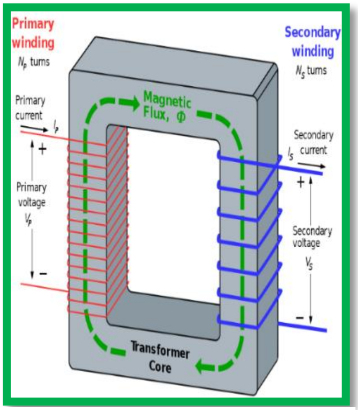


Figure 1.7.1: Construction of a Transformer

Source: https://shorturl.at /anq15

The first coil, also known as primary coil is connected to alternating voltage source called primary voltage (V_P) while the second set of the coil, also known as secondary coil is connected to the load called secondary voltage (V_S). This load delivers the resulting output (Step-up alternating voltage or step-down alternating voltage). The number of turns in the primary coil and secondary coil are indicated with N_P and N_S, while the circulating current in the primary coil and secondary coil is indicated with I_P and I_S, respectively.

Principle

Transformer works on the basic principles of Faraday's law of electromagnetic induction and mutual induction between the two circuits (coils).

Working

When an alternating voltage is applied to input, an alternating current will circulate in the primary winding (coil). The alternating current results a changing magnetic flux (Φ_B) while passing through the iron core. As the secondary winding (coil) is also connected to the varying magnetic flux, according to Faraday's Law, this change in magnetic flux induces an electromotive force (E.M.F.) in the secondary winding. This is known as mutual induction. The amount of the alternating voltage at the secondary coil depends on the number of windings.

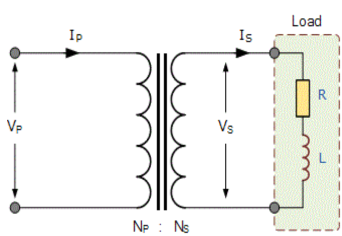


Figure 1.7.2: Symbolic representation of a transformer

Thus, the electric power is transferred from one coil to the other without making an electrical contact via change in magnetic flux. The symbolic representation of a two winding transformer is shown in Figure 1.7.2.

Parts of a transformer

Following are the basic components of a power transformer. They are

1. Laminated core
2. Windings
3. Insulating material
4. Tap changer
5. Terminals and bushings
6. Transformer oil
7. Cooling tubes
8. Buchholz relay
9. Conservator tank
10. Explosion vent
11. Breather
12. Radiators

13. Temperature Gauge

The primary parts including laminated iron core, windings and insulating material are present in all transformers whereas the remaining are present in only in transformers with a capacity of more than 100 kVA.

Types of Transformers

Different types of transformers are used in the electrical power sector for several purposes including in power generation, distribution & transmission, and dissipation of electrical energy. The transformers are classified depending upon turns ratio, shape of the core, number of phases, type of services offered, core medium used, and winding arrangements, etc.

- Based on turns ratio/ transformation ratio
    - Step up transformer
    - Step down transformer
    - Isolation transformer
- Based on construction/ shape of core
    - Core type transformer
    - Shell type transformer

    - Berry type transformer
- Based on the number of phases
    - Single phase transformer
    - Three phase transformer
    - Auto transformer
- Based on the type of services offered
    - Power transformer
    - Distribution transformer
    - Instrument transformer
- Based on the type of cooling method
    - Oil filled air cooled transformer
    - Oil filled water cooled transformer
    - Air blast type transformer
- Based on the type of material used
    - Air core transformer
    - Iron core transformer
    - Ferrite core transformer
- Based on the type of winding connection
    - Star – Star transformer
    - Delta – Delta transformer
    - Delta – Star transformer

Ideal Transformer equations

From the Faraday's laws of electromagnetic induction, "the rate of change of magnetic flux is directly proportional to the induced emf in a coil of N identical turns".

That is, $V = - N \frac{d\Phi_B}{dt}$ (3)

where, V – induced emf in the coil

$\frac{d\Phi_B}{dt}$ – change in the magnetic flux over time (t)

N – the number of turns in the coil

and the direction of induced emf is given by Lenz's law.

So, for the primary and secondary coils, the above equation can be expressed as:

$$V_P = - N_P \frac{d\Phi_B}{dt} \quad (4)$$

$$V_S = - N_S \frac{d\Phi_B}{dt} \quad (5)$$

where V_P – the instantaneous voltage of primary winding

V_S – the instantaneous voltage of secondary winding

N_P – number of turns of the primary winding

N_S – number of turns of the secondary winding

From these two equations,

Turns ratio (n) = $\frac{V_P}{V_S} = \frac{N_P}{N_S}$ (6)

For a Step-down transformer n > 1 and for a Step-up transformer n < 1 and for an Isolation transformer n = 1.

The apparent power is conserved in the input and output of the transformer according to the law of conservation of energy. So,

$$S = I_P V_P = I_S V_S \quad (7)$$

Hence $\frac{I_S}{I_P} = \frac{V_P}{V_S}$ (8)

Therefore, Turns ratio (n) = $\frac{V_P}{V_S} = \frac{N_P}{N_S} = \frac{I_S}{I_P}$ (9)

Turns ratio (n): The ratio of the number of turns in the primary winding to the number of turns in the secondary winding in a transformer is defined as turns ratio. It is denoted by n.

Efficiency of the Transformer (η)

The ratio of the output power to the input power is called the efficiency of a transformer. It is indicated with **η.**

$$\therefore \text{Efficiency of a transformer } (\eta) = \frac{\text{Output power}}{\text{Input power}} \times 100$$

$$= \frac{V_S I_S}{V_P I_P} \times 100$$

The efficiency (η) of an ideal transformer is 1 or 100% due to the power loss is zero. But practically the efficiency is always less than 1 due to various factors such as, copper losses, Eddy current losses, hysteresis losses and flux leakage losses in a transformer.

Applications

The most common uses of transformers are:

1. Transformers are widely used in the power generation grid system.
2. They are also useful in electric power distribution and transmission sectors.

3. They are widely used in electrical energy consumption.

4. Transformers are usually used to decrease or increase alternating current (AC) in the electrical system.

5. They are used to stop the flow of electricity and interrupt an electric current in a circuit.

6. Transformers are also useful in controlling the voltage level in an AC circuit.

7. They are useful in stopping DC from flowing from one electric circuit to another circuit.

Example 1. A transformer primary coil is powered by a 120V AC source. Find the voltage in secondary coil, if the turn ratio is 2?

Solution:

Given that,

turns ratio (n) = 2 and

voltage of the primary coil, V_P = 120 V

Now, according to the definition of turns ratio:

turns ratio (n) = $\frac{V_P}{V_S}$

Substituting the above values,

$$n = \frac{V_P}{V_S}$$

$$\Rightarrow \qquad V_S = \frac{V_P}{n} = \frac{120}{2} = 60 \text{ V}$$

Example 2. A transformer has 1000 turns in the primary winding, and 8 A current flows through it. When the secondary coil has 500 turns, determine the current flowing in it?

Solution:

Given that, $N_P = 1000$, $N_S = 500$ and $I_P = 8$ A

Now, according to the transformer's equation:

$$\frac{N_P}{N_S} = \frac{I_S}{I_P}$$

Therefore, $\qquad I_S = I_P \frac{N_P}{N_S}$

$$\Rightarrow \qquad I_S = 8 \times \frac{1000}{500} = 16 \text{ A.}$$

1.8.1 Electrical energy

Electrical energy is a form of energy that involves the flow of electrons and it is one of the most widely used forms of energy in the world. Electrical energy is a basic component of nature and is used in our daily lives more than any other energy source.

The electrical energy carried by electrical charges is important because this form of energy can be easily converted into other energy forms such as, light, sound, heat, mechanical and chemical energy by using various electrical appliances and it can be safely and effectively transported over long distances.

Definition

Electrical Energy is defined as the energy caused by the movement of electrically charged particles from one point to another. It is also defined as the energy derived from the work done by the moving charges or electrons in the electric field.

Formula

If a current (**I)** flows through the wire for a time (**t)** sec, then total work done by the charge (Q) will be is given by

$$W = E = V.\ I.\ t \text{ joules}$$

$$E = I^2 R\ t \text{ joules} \qquad (\because V = IR)$$

$$E = Pt \text{ joules} \qquad (\because P = VI = I^2R)$$

where, V - Potential difference (volts)

I - Current (amperes)

R - Resistance (ohms)

P - Electric power (watts)

Units

The SI unit of electrical energy is **joule (J) or watt-sec. (Ws), whereas kilowatt-hour (kWh**) is the practical unit of electrical energy. The other best-known unit is **electron volt (eV)**.

Dimensions

Electrical energy = Electrical power * time

$E = M^1L^2T^{-3} * T^1 = M^1L^2T^{-2}$

where, M – Mass

L – Length

T – Time

Examples

Some examples of electrical energy, including:

Electric eels deliver a shock to predators for their defence by generating electrical energy due to its electrolyte cell (Fig. 1.8.1.1).

Figure 1.8.1.1: Electric Eel

Lightning is the discharge of electric charges in the atmosphere is an example of electrical energy (Fig. 1.8.1.2)

Figure 1.8.1.2: Lightening during thunderstorm.

Electrical energy Conversion

The electrical energy is converted into other forms of energy including light, heat, sound etc. Some examples are:

- Electric Fan: The electrical energy is converted into mechanical energy.
- Electronic Bulb: The electrical energy is converted into light energy.
- Loudspeaker: The electrical energy is converted into sound energy.
- Microwave Oven: The electrical energy is converted into heat energy.
- Electrolytic cell: The electrical energy is converted into chemical energy.

Energy meter

The amount of electrical energy consumed is evaluated by a device called Energy meter in kilowatt-hours (kWh). The energy meter is often referred to as an electrical meter or electric meter or electricity meter or kilowatt-hour meter (Fig. 1.8.1.3).

The number of revolutions per kilowatt-hour of an energy meter is defined as the meter constant.

Source: https://shorturl.at/aefpr

Figure 1.8.1.3: Energy Meter

Meter constant (K) =

$$\frac{\text{No. of revolutions made by the energy meter}}{\text{Electrical energy consumed}}$$

Unit of meter constant = revolutions per kilowatt-hour (rev / kWh)

The consumption of electrical energy in domestic or residential application is measured in kilowatt-hours (kWh), while in commercial and industrial application it is measured in kVAh. The kVAh reading consumption is higher than the reading of kWh due to power factor (P.F.).

Power factor is defined as the ratio of actual power to the apparent power.

1.8.2 Electric Power

Definition:

Electric power is defined as the rate at which the electrical energy is transferred by an electrical appliance per unit of time. It is denoted by P. Electric power is commonly produced by electric generators and supplied by sources like electric batteries. Figure 1.8.2.1 shows the relationship between electric power (P), electric current (I), voltage (V) and resistance (R).

The rate of work done by the electric current is also known as electric power. It is usually supplied to residential and industrial applications by the electric power industry through an electric power grid. Some household electrical appliances with power ratings are given in **Table 1.1.**

Formula

Electric Power = $\frac{\text{Electrical energy}}{\text{time}}$

$$P = \frac{E}{t}$$

$$P = \frac{I^2Rt}{t} \qquad (\because E = I^2Rt)$$

$$P = I^2R$$

$$P = VI$$

($\because$ According to Ohm's law, V = IR)

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

where, V is the potential difference across the resistance

R is the resistance in the circuit

I is the electric current flowing through the circuit

Units

Electric Power = $\frac{\text{Electrical energy}}{\text{time}}$

$$= \frac{J}{s}$$

= watt

The symbol for watt is **W**. It is the SI unit of electric power.

The electrical energy consumption rate of 1 joule per second is known as 1 watt.

Therefore, watt (W) = $\frac{J}{s}$

$$W = \frac{N.m}{s}$$

$$W = \frac{kg.m.s^{-2}.m}{s}$$

$$W = kg.m^2.s^{-3}$$

Also, $P = VI \Rightarrow W = VA$

and $P = \frac{V^2}{R} \Rightarrow W = \frac{V^2}{\Omega}$

and $P = I^2R \Rightarrow W = A^2\Omega$

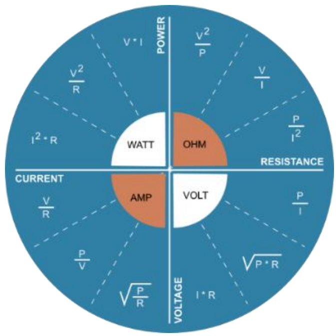


Figure 1.8.2.1: Relationships between P, I, V and R.

Source:

https://freesvg.org/img/1384

Dimensions

$$\text{Electric Power} = \frac{\text{Electrical energy}}{\text{time}}$$

$$= \frac{M^1L^2T^{-2}}{T}$$

$= M^1L^2T^{-3}$.

Horsepower (hp)

Horsepower is often used to measure engine power of some electrical and mechanical devices. It can be also used to measure the quantum of work done by generators and pumps etc., and is used to describe the quantity of power that is generated by electric motor.

Here, 1 horsepower (hp) = 746 watts (W)

or 1 hp = 0.746 kW

Table 1.1: Power ratings of some household electrical appliances.

Electrical appliance	**Abbreviation**	**Power rating (W)**
Electric shower	ES	7000
Dishwasher	Dw	1500
Washing machine	WM	1500
Iron	Ir	1600

Smart phone	SP	5
Broadband router	BR	10
Plasma TV	TV	400
Vacuum cleaner	VC	1000
Oven	Ov	2000
Toaster	Ts	1000
Hair dryer	Hd	1000
Desktop computer	PC	150
Fridge-freezer	FF	400

Conversion of KW to kVA

Both kilowatts (kW) and kilovolt-amperes (kVA) are a measure of power but in different sense. The kVA is a measure of the apparent power, whereas kW is a measure of the real power or active power in an electrical circuit.

In some electrical devices like a generator or transformer, the real power and apparent power are often not equal due to power factor, which represents the quantity of energy efficiency in the circuit. The conversion of kW to kVA requires power factor.

Therefore, **kVA =** $\mathbf{\frac{kW}{P.F.}}$

where, kVA is the apparent power, kW is the real power and P.F. is the power factor.

1.8.3 Kilowatt hour (kWh)

We all know that most of the electrical appliances operate on electricity. This consumption of electricity or electrical energy are practically measured in kilo-watt hours (kWh). A kilowatt-hour (kWh) is a commercial unit of electrical energy. It measures the amount of electrical energy being used per hour by a device. The kWh is also called as the Board of trade unit (B.O.T. unit).

Definition

A kWh is defined as the amount of electrical energy dissipated or consumed when an electrical appliance of 1 kilowatt power is sustained for one hour.

Therefore, one kilowatt hour = 1*1000 watts* 1 hour

$$1\ kWh = 1*1000\ \frac{J}{s}*3600\ s\ (\because \text{watt} = \frac{J}{s})$$

$$1\ kWh = 3.6 * 10^6\ J$$

$$1\ kWh = 3.6\ MJ$$

$$1\ kWh = 3600\ kJ\ (\because 1\ \text{million} = 10^3\ \text{kilo})$$

Generally, **1 kWh** is known as **1 unit** of electricity.

When a 1000-watt load is used for 1 hour then the electrical energy consumed is called 1 unit of electrical energy or 1 unit of electricity.

Therefore, **1 unit (**of electricity consumption) **= 1 kWh.**

Formula

Electrical energy = Electrical power * time

$$\therefore \mathbf{kWh} = \frac{\mathbf{watts} * \mathbf{time\ (in\ hours)}}{\mathbf{1000}}$$

Note: 1 kWh = 1000 Wh = 3.6 * 10^6 J

1 kWh = 860420.65 cal ($\because$ 1 cal = 4.184 J)

Examples

- A 75-watt Fan used for 13:20 hours will consume 1 unit of electricity.
- A 15-watt CFL used for 66:40 hours will consume 1 unit of electricity.

Kilo-watt hours (kWh) to Amp-hours (Ah) conversion

Kilo-watt hours (kWh) is the unit of electrical energy. One kWh is equal to 1000 watts consumed for one hour of time. One Ah is equal to one ampere of electrical current supplied for one hour.

Amp-hours (Ah) is the unit of electrical charge. It is commonly used to measure the charge of electric battery.

Electrical energy to electrical charge conversion requires supply voltage in volts. The conversion formula is given by

$$\therefore \mathbf{Ah} = \frac{\mathbf{kWh} * \mathbf{1000}}{\mathbf{V}}$$

where V - the supply voltage in volts.

Example 1. Convert 5 kWh to Ah at 120 V?

Solution: $$\text{Ah} = \frac{\text{kWh} * 1000}{\text{V}}$$

$$\text{Ah} = \frac{5\ \text{kWh} * 1000}{120\ \text{V}}$$

$$\text{Ah} = \frac{5000\ \text{kWh}}{120\ \text{V}} = 41.667\ \text{Ah}$$

1.8.4 Consumption of Electric Power

Consumption of electricity is an essential part of the modern life. It can provide clean and safe light throughout the day, refreshes homes in hot summer, and warms them on winter days. Use of electricity is essential to run electrical and electronic equipment for their proper functioning. The total electric power consumption can be divided into several categories, such as heating, lighting, driving, communication, information, and others. Although hundreds of millions of Indians associate to the power grid every day, most of them do not know about how the electricity consumed, and how much it costs. Annual consumption of electricity per capita measures the development of power sector in a country. Electrical energy and electric power are closely related to each other. The total consumption of electricity by an electrical appliance depends on three important factors. They are

1. The wattage or capacity of the electrical appliance (watt)
2. The total number of electrical appliances are in use
3. The no. of hours an electrical appliance is used per day

The consumption of electrical energy is calculated by

1. [total number of electrical appliances]x[wattage of the appliance]x[number of hours used per day] = number of Wh (consumption)
2. $\frac{\text{[total no.of appliances]x[wattage of appliance]x[no.of hours used per day]}}{1000}$

   = number of kWh
3. = number of **units** (of electricity consumption)
4. number of kWh x number of days used per month

   = Monthly energy consumption
5. number of kWh x number of days used per year

   = Annual energy consumption
6. Monthly energy consumption x utility price per kWh (or unit) = Monthly maintenance cost

The electrical energy consumption amount by an electrical appliance in a given period of time can be estimated by the formula

$$E = P \times t$$

where E – Electrical energy consumed (kWh)

P – Electric power (watt)

t – Time (hour)

The electrical energy consumption of some household appliances is given in **Table 1.2.**

Table 1.2: Power consumption chart of Home electrical appliances

S. No	Electrical Appliance	Power (W)	Avg usage time / Day	Consumption of Electricity (kWh)/ Day	Consumption (kWh)/ Month	Consumption (kWh)/ Year
1	Mobile Phone Charger	5	1 h	0.005	0.15	1.825
2	Refrigerator	200	All day	4.8	144	1752

3	Dish Washer	1200	1 h	1.2	36	438
4	Electrical Stove	1500	1.5 h	2.25	67.5	821.25
5	Water boiler	1500	1 h	1.5	45	547.5
6	Coffee Maker	1000	15 min	0.25	7.5	91.25
7	Electric Oven	2150	30 min	1.075	32.25	392.375
8	Food Processor	800	30 min	0.4	12	146
9	Pressure Cooker	1000	1 h	1	30	365
10	Toaster	1200	15 min	0.3	9	109.5
11	Water Dispenser	100	2h 15 min	0.225	6.75	82.125
12	Iron Box	1200	30 min	0.6	18	219
13	Washing machine	2000	1 h	2	60	730
14	Laptop	50	10 h	0.5	15	182.5

15	Desktop computer	170	5 h	0.85	25.5	310.25
16	LED TV	50	4 h	0.2	6	73
17	CFL Bulb	15	8 h	0.12	3.6	43.8
18	LED bulb	10	8 h	0.08	2.4	29.2
19	Incandescent bulb	60	8 h	0.48	14.4	175.2
20	Ceiling Fan	75	10 h	0.75	22.5	273.75
21	Split AC	1000	3 h	3	90	1095
22	Mixer Grinder	500	15 min	0.125	3.75	45.625
23	Geyser	2000	30 min	1	30	365
24	Electric Kettle	1500	15 min	0.375	11.25	136.875
25	Vacuum cleaner	1400	10 min	0.234	7	85.16

Illustration of electrical energy consumption

A consumer uses a 200 W refrigerator for 24 hours, a 2 kW electric oven for 1 hour, a 2 kW geyser for 2 hours, a 1.2 kW Iron box for 5 hours, a 2.5 kW washing machine for 2 hours and five 15 W CFL bulbs for 10 hours per day. How many units of electrical energy have been used. Calculate electricity consumption and tariff charges per month?

Explanation:

The consumption of electrical energy is calculated by

[total number of electrical appliances]x[wattage of the appliance]x[number of hours used per day] = number of Wh (consumption)

[(1 x 200 W x 24 h) + (1 x 2 kW x 1 h) + (1 x 2 kW x 2 h) + (1 x 1.2 kW x 5 h) + (1 x 2.5 kW x 2 h) + (5 x 15 W x 10 h)]

= 4800 Wh + 2 kWh + 4 kWh + 6 kWh + 5 kWh + 750 Wh

= 4.8 kWh + 2 kWh + 4 kWh + 6 kWh + 5 kWh + 0.75 kWh = 22.55 kWh

Therefore, the electrical energy consumed per day = 22.55 kWh = 22.55 units of electricity.

And monthly electrical energy consumption, on an average = 22.55 units x 30 = 676.5 units.

For above electricity consumption, the tariff can be calculated as follows:

If the cost per unit is Rs. 1.90 for 0 – 30 units,

Rs. 3.00 for 31 – 75 units,

Rs. 4.50 for 76 – 125 units,

Rs. 6.00 for 126 – 225 units,

Rs. 8.75 for 226 – 400 units and

Rs. 9.75 for above 400 units as per Andhra Pradesh Electricity Regulatory Commission (APERC), then the total tariff cost of energy consumption

= 30 units x Rs. 1.90 + 45 units x Rs. 3.00 + 50 units x Rs. 4.50 + 100 units x Rs. 6.00 + 175 units x Rs. 8.75 + 276.5 units x Rs. 9.75

= Rs. 57 + Rs. 135 + Rs. 225 + Rs. 600 + Rs. 1531.25 + Rs. 2695.875

= **Rs. 5244.125/-**

The amount calculated above are only electrical energy charges and not inclusive of other statutory charges; therefore, they do not match with the actual bill total. The domestic tariff rates as per APERC are given in **Table 1.3.Domestic tariff rates**

Table 1.3: The slab-wise electricity charges from April, 2022 for domestic consumers as per APERC (Andhra Pradesh Electricity Regulatory Commission) is as follows:

Slab (Units)	**Tariff rate (₹/unit)**
0 – 30	1.90
31 – 75	3.00
76 – 125	4.50
126 - 225	6.00
226 - 400	8.75
Above 400	9.75

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Question Bank

Essay answer type

1. What is a series combination of resistances? Derive the result of resistances of a series combination of n resistors.
2. What is a Parallel combination of resistances? Derive the result of resistances of a Parallel combination of n resistors.
3. What is a Transformer? Explain the working principle and derive ideal transformer equations.
4. Explain the construction of a transformer. Define its efficiency and what are the types of transformers.

Short answer type

1. What is Ohm's law? Explain.
2. What are ohmic and non ohmic materials? Give examples.
3. What is a Galvanometer? Explain
4. What is an Ammeter? Explain
5. What is a Voltmeter? Explain
6. What is a Multimeter? Explain
7. What are the advantages and disadvantages of a Digital Multimeter?
8. What is electrical energy? Explain.
9. What is electric power? Explain.
10. Discuss the unit of electricity?
11. Explain the calculation procedure of energy consumption with a suitable example.

Unit II

Learning Objectives:

- To understand the difference between D.C & A.C
- To understand Single phase and three phase connections.
- To understand Star and Delta connections.
- Awareness on electric shock and the first aid for it.
- Know the importance of EARTHING in electrical systems.
- Explore the safety devices and procedures like Fuses, Circuit breakers.

Learning Outcomes:

- Get the knowledge of AC and DC currents
- Understand the basics of House wiring connections.
- Understand the earthing and overloading.
- Understand the Inverter and UPS working

Andre-Marie Ampere. from France, was a famous Physicist and Mathematician,was known as "Father of Electrodynamics". Famous for his Amperes law which gives Magnetic Induction in the surrounding region of a current carrying conductor. Calculated the force between two parallel straight current carrying conductors which enables current as fundamental quantity . Unit of Electrical Current is named after him

VOLTAGE/EMF SOURCES

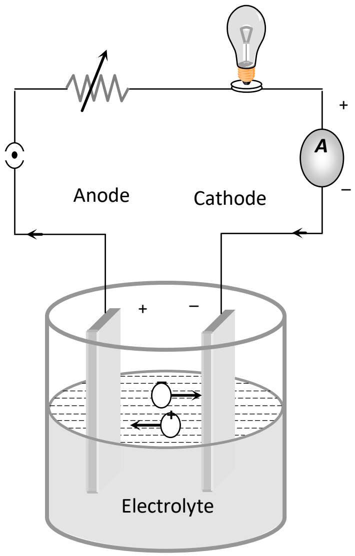
The device which provides electrical energy to electrical systems generally called as source.

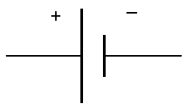
(I) Time Independent Sources

The EMF/Potential difference is constant with respect to time. The best example is CELL. The device which converts chemical energy into electrical energy is known as electric cell. Cell is a source of constant EMF/potential difference. Group of cells is called a battery.

(II) Time dependent Sources: The EMF/Potential difference is varying with respect to time.

The best example is GENERATOR. The GENERATOR converts Mechanical energy into Electrical energy. According to Faraday's law of electromagnetic induction, the induced EMF in a conducting loop is given by





Symbol of cell

Basic inner structure of cell

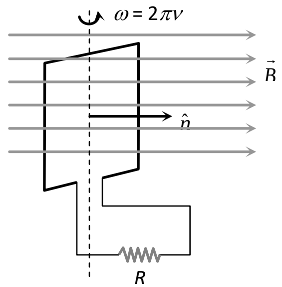
External appearance of cell and Battery

$$e = -\frac{d\varphi}{dt}$$

Negative sign indicates that induced emf (e) opposes the change of flux.

Where net flux through the conducting loop

$$\varphi = \oint \vec{B} \cdot d\vec{A} = BA\cos\theta$$



Rotating Coil in magnetic field

Consider a loop in the form of rectangle having N turns and placed in a uniform and constant magnetic field such that magnetic field is perpendicular to its plane as shown. The coil can rotate with some angular speed.

Suppose ω is Angular speed, ν is Frequency of rotation of coil and R is Resistance of coil then, for uniform rotational motion with ω, the flux linked with coil at any time t ($\theta = \omega t$)

$$\varphi = NBA\,cos\,\theta = NBA\,cos\,\omega\,t$$

$$\varphi = \varphi_0\,cos\,\omega\,t$$

Where $\phi_0 = NBA$ = maximum flux

Induced emf also changes in periodic manner that's why this phenomenon called periodic EMI

$$e = -\frac{d\varphi}{dt} = NBA\omega\,sin\,\omega\,t \Rightarrow e = e_0\,sin\,\omega\,t$$

where e_0 = maximum emf $= NBA\omega = \varphi_0\omega$

2.1.1 Direct and Alternating Current

The time rate of flow of charge through any cross-section is called current.

$$I = \lim_{\Delta t \to 0} \frac{\Delta Q}{\Delta t} = \frac{dQ}{dt}.$$

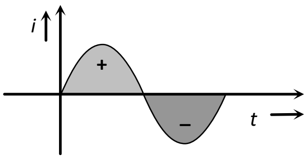
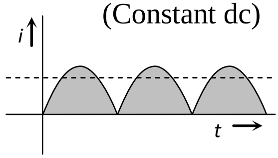
If flow is uniform then $I = \frac{Q}{t} = \frac{Charge}{time}$.

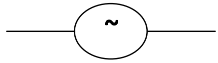
Current is a scalar quantity. Its S.I. unit is *ampere* (*A*)

Types of Currents

Depending upon the voltage sources, we have two types of electric currents. The first one is Direct current (DC)/Time independent current and second one is Alternating Current (Periodic variation of current with time).

Types of currents

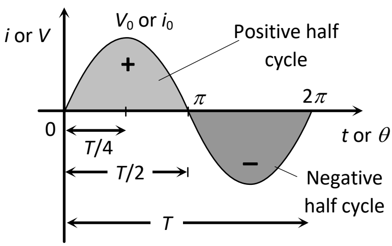
Alternating current (ac)	**Direct current (dc)**
(i) Magnitude and direction both varies with time 	(i) (Pulsating dc) (Constant dc) 
(ii) Conversion from AC to DC ac → Rectifier → dc	(ii) Conversion from DC to AC dc → Inverter → ac
(iii) Shows heating effect only	(ii) Shows heating effect, chemical effect and magnetic effect of current

(iv) It's symbol is	(iii) It's symbol is 

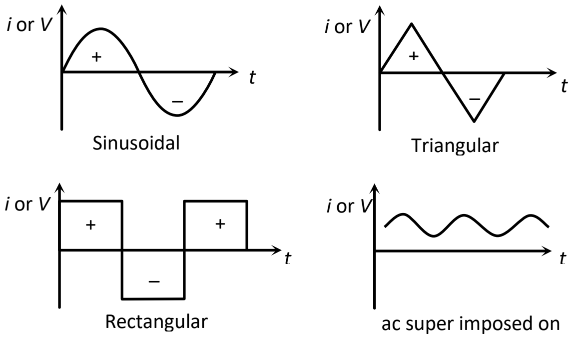
ALTERNATING CURRENT (AC)

Definition:

In an alternating physical quantity (current I or voltage *V*), magnitude changes continuously with time between zero and a maximum/minimum value and also direction changes/reverses periodically. Some graphical representation for alternating quantities as shown in figure 2.4.



AC current



types of AC

Alternating current or voltage varying as sine function can be written as

$$I = I_0 \sin(\omega t) = I_0 \sin(2\pi\nu t) = I_0 \sin\left(\frac{2\pi}{T}t\right)$$

and $V = V_0 \, sin(\omega \, t) = V_0 \, sin(2\,\pi\nu t) = V_0 \, sin(\frac{2\pi}{T}t)$

where I and V are Instantaneous values of current and voltage,

I_0 and V_0 are peak values of current and voltage

ω = Angular frequency in *rad/sec*, ν = Frequency in *Hz* and T = time period

2.1.2 Peak value (I_0 or V_0):

The maximum value of alternating quantity (I or V) is defined as peak value or amplitude.

The maximum value of any function can be determined from the differentiation method.

At maximum First derivative is zero and second derivative is negative.

At minimum First derivative is zero and second derivative is positive.

$$For\ the\ function\ y = f(x) \quad at\ maximum\ \frac{dy}{dx} = 0\ \ and\ \frac{d^2y}{dx^2} < 0$$

$$For\ the\ function\ y = f(x) \quad at\ minimum\ \frac{dy}{dx} = 0\ \ and\ \frac{d^2y}{dx^2} > 0$$

$\boldsymbol{Example}$: $Max\ and\ Min\ values\ of\ f(x) = a\ sinx + b\ cosx\ are\ \sqrt{\boldsymbol{a^2 + b^2}}\ and\ -\sqrt{\boldsymbol{a^2 + b^2}}$

Mean value of any function:

The average or mean value of any function **y=f(x)** for the interval **a** to **b** is defined as

$$< f >= \frac{\int_a^b f(x)dx}{b-a}$$

Example: Mean value of sinx or cosx for one complete cycle(x=0 to 360 degree) is equal to zero.

$$<\sin x>=<\cos x>=0$$

Example: The average value of *ac* over half cycle (*t* = 0 to *T*/2) or (0 to 180 degree)

$$I_{av} = \frac{\int_0^{T/2} i dt}{\int_0^{T/2} dt} = \frac{2I_0}{\pi} = 0.637 I_0 = 63.7\% \text{ of } I_0,$$

Similarly, $V_{av} = \frac{2V_0}{\pi} = 0.637 V_0 = 63.7\%$ of V_0.

Mean square value ($\overline{V^2} or\ \overline{i^2}$) :

The average of square of instantaneous values in one cycle is called mean square value. It is always positive for one complete cycle.

$$\overline{V^2} = \frac{1}{T}\int_0^T V^2 dt = \frac{V_0^2}{2} \text{ or } \overline{I^2} = \frac{I_0^2}{2}$$

Root mean square (r.m.s.) value:

Root of mean of square of voltage or current in an *ac* circuit for one complete cycle is called *r.m.s.* value. It is denoted by V_{rms} or I_{rms}. *The r.m.s.* value of alternating current is also called virtual value or effective value.

$$I_{rms} = \sqrt{\frac{i_1^2 + i_2^2 + \ldots}{n}} = \sqrt{\overline{I^2}} = \sqrt{\frac{\int_0^T I^2 dt}{\int_0^T dt}} = \frac{I_0}{\sqrt{2}} = 0.707 I_0$$

$$70.7\%\ I_0$$

Similarly, $V_{rms} = \frac{V_0}{\sqrt{2}} = 0.707V_0 = 70.7\%$ of V_0

Here $\left[\langle sin^2(\omega t)\rangle = \langle cos^2(\omega t)\rangle = \frac{1}{2}\right]$

- AC ammeter and voltmeter are always measure *r.m.s.* value. Values printed on *ac* circuits are *r.m.s.* values.
- In our houses *ac* is supplied at 220 *V*, which is the *r.m.s.* value of voltage. Its peak value is $\sqrt{2} \times 200 = 311V$.

Peak to peak value:

It is equal to the sum of the magnitudes of positive and negative peak values.

PP Value = Maximum + Minimum

Example: For sinusoidal currents, Peak to peak value = $V_0 + V_0 = 2V_0 = 2\sqrt{2}V_{rms} = 2.828V_{rms}$

2.1.3 Form factor and peak factor:

The ratio of *r.m.s.* value of *ac* to its average during half cycle is defined as form factor. The ratio of peak value and *r.m.s.* value is called peak factor.

Phase: A physical quantity which represents both the instantaneous value and direction of alternating quantity at any instant is called its phase. It's a dimensionless quantity and its unit is radian.

If an alternating quantity is expressed as $Z = Z_0 \sin(\omega t \pm \varphi_0)$ then the argument of $\sin(\omega t + \varphi)$ is called its phase. Where ωt = instantaneous phase (changes with time) and φ_0= initial phase (constant *w.r.t.* time)

- **Phase difference** (Phase constant) : The difference between the phases of currents and voltage is called phase difference. If alternating voltage and current are given by $V = V_0 \sin(\omega t + \varphi_1)$ and $I = I_0 \sin(\omega t + \varphi_2)$ then phase difference $\phi = \phi_1 - \phi_2$ (relative to current) or $\varphi = \varphi_2 - \varphi_1$ (relative to voltage)
- **Phasor diagram:** A diagram representing alternating current and alternating voltage (of same frequency) as vectors (phasors) with the phase angle between them is called a phasor diagram. While drawing phasor diagram for a pure element (*e.g.* *R*, *L* or *C*) either of the current or voltage can be plotted along *X*-axis. But when phasor diagram for a combination of elements is drawn then quantity which remains constant for the combination must be plotted along *X*-axis so we observe that

(i) In series circuits current has to be plotted along *X*-axis.

(ii) In parallel circuits voltage has to be plotted along X-axis.

Some Important Definitions:

➢ **Impedance (Z) :** The opposition offered by ac circuits to the flow of ac through it is defined it's impedance. It's unit is *ohm*(Ω).

➢ **Reactance (X) :** The opposition offered by inductor or capacitor or both to the flow of ac through it is defined as reactance. It is of following two type

(i) Inductive reactance (X_L) : Offered by inductive circuit $\boldsymbol{X_L = \omega L = 2\pi\nu L}$ $\nu_{dc} = 0$ so for dc, $X_L = 0$.

(ii) Capacitive reactance (X_C) : Offered by capacitive circuit $\boldsymbol{X_C = \frac{1}{\omega C} = \frac{1}{2\pi\nu C}}$ **f**or dc $X_C = \infty$.

➢ **Admittance (Y) :** $Z = \frac{V_0}{i_0} = \frac{V_{rms}}{i_{rms}}$ Reciprocal of impedance is known as admittance $\left(Y = \frac{1}{Z}\right)$**.** It's unit is *mho*

➢ **Susceptance (S) :** the reciprocal of reactance is defined as susceptance $\left(S = \frac{1}{X}\right)$**.** It is of two type

(i) inductive susceptance $S_L = \frac{1}{X_L} = \frac{1}{\omega L}$ and

(ii) Capacitive susceptance, $S_C = \frac{1}{X_C} = \omega C = 2\pi\nu C.$

Measurement of Alternating Quantities:

Alternating current shows heating effect only, hence meters used for measuring ac are based on heating effect and are called hot wire meters (Hot wire ammeter and hot wire voltmeter). They measure RMS values. The deflection in AC ammeters is non-linear type.

But in case of Direct current, all the meters are based on magnetic effect of currents. They measure average values. The deflection in DC ammeters is linear type.

POWER IN AC CIRCUITS

In dc circuits power is given by $P = VI$. But in ac circuits, since there is some phase angle between voltage and current, therefore power is defined as the product of voltage and that component of the current which is in phase with the voltage.

Thus $P = VIcos\varphi$; where V and I are *r.m.s.* value of voltage and current.

- **Instantaneous power:** Suppose in a circuit

  $V = V_0 \sin \omega t$ and $I = I_0 \sin(\omega t + \varphi)$ then

  $P_{\text{instantaneous}} = VI = V_0 I_0 \sin \omega t \sin(\omega t + \varphi)$

- **Average power (True power):** The average of instantaneous power in an ac circuit over a full cycle is called average power. It's unit is *watt*.

$$P_{av} = V_{rms} i_{rms} \cos \varphi = \frac{V_0}{\sqrt{2}} . \frac{I_0}{\sqrt{2}} \cos \varphi = \frac{1}{2} V_0 I_0 \cos \varphi$$

$$= I_{rms}^2 R = \frac{V_{rms}^2 R}{Z^2}$$

- **Apparent or virtual power:** The product of apparent voltage and apparent current in an electric circuit is called apparent power. This is always positive

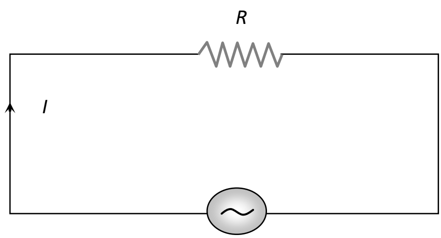
$$P_{app} = V_{rms} I_{rms} = \frac{V_0 I_0}{2}$$

- **Power Factor:** It may be defined as cosine of the angle of lag or lead ($\cos\phi$). It is also defined as the ratio of resistance and impedance ($\frac{R}{Z}$).

The ratio $\frac{\text{True power}}{\text{Apparent power}} = \frac{W}{VA} = \frac{kW}{kVA} = cos\,\varphi$

ALTERNATING CURRENT IN RESISTOR, CAPACITOR, INDUCTOR

In Pure Resistor- Resistive Circuit (*R*-Circuit)



$V = V_0 \sin \omega t$

Apply Kirchhoff's Voltage Law or Ohms law, then we have

V - IR = 0

That means I = V/R

(1) Current: $I = I_0\, sin\, \omega\, t$

(2) Peak current: $I_0 = \frac{V_0}{R}$

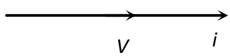
(3) Phase difference between voltage and current: $\phi = 0^o$

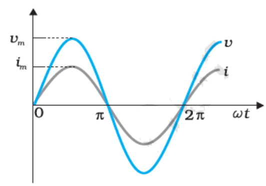
(4) Power factor: $\cos\varphi = 1$

(5) Power: $P = V_{rms}I_{rms} = \frac{V_0 i_0}{2}$

(6) Time difference: T.D. = 0

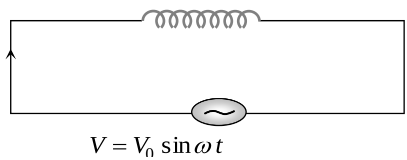
(7) Phasor diagram: Both are in same phase





Above figures visualizes the current and voltage phases clearly.

<u>In Pure Inductor-Inductive Circuit (*L*-Circuit)</u>



Apply Kirchhoff's Voltage Law or Ohms law, then we have

$$V - L\frac{dI}{dt} = 0$$

After solving this differential equation, we have

(1) Current: $I = I_0\, sin\left(\omega t - \frac{\pi}{2}\right)$

(2) Peak current: $I_0 = \frac{V_0}{X_L} = \frac{V_0}{\omega_L} = \frac{V_0}{2\pi\nu L}$

(3)Phase difference between voltage and current

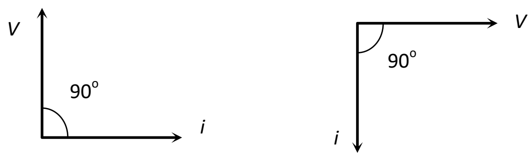
$$\varphi = 90^o \text{ (or } +\frac{\pi}{2})$$

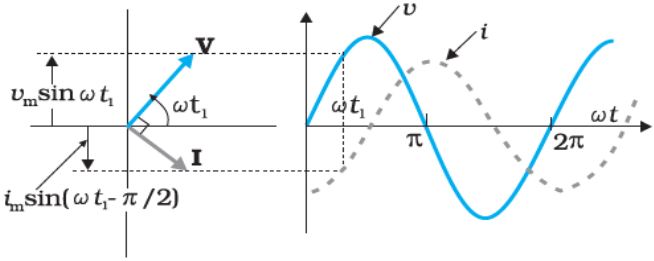
(4) Power factor: $cos\,\varphi = 0$

(5) Power: $P = 0$

(6) Time difference: T.D. $= \frac{T}{4}$

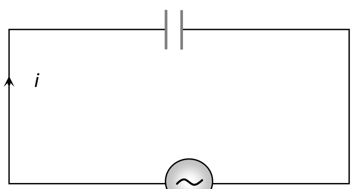
(7) Phasor diagram: Voltage leads the current by $\frac{\pi}{2}$





Above figure visualizes the current and voltage phases clearly. For step-by-step explanation you see the NCERT 12th class physics text book.

<u>In Pure Capacitor-Capacitive Circuit (*C*-Circuit)</u>



Apply Kirchhoff's Voltage Law or Ohms law, then we have

$$V - \frac{Q}{C} = 0 \quad but \;\; I = \frac{dQ}{dt}$$

After solving this differential equation, we have

(1) Current: $I = I_0 \, sin\left(\omega t + \frac{\pi}{2}\right)$

(2) Peak current: $I = \frac{V_0}{X_C} = V_0 \omega C = V_0 (2\pi \nu C)$

(3) Phase difference between voltage and current:

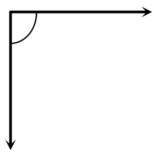
$$\varphi = 90^o \qquad \text{(or } -\frac{\pi}{2}\text{)}$$

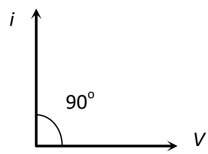
(4) Power factor: $cos\,\varphi = 0$

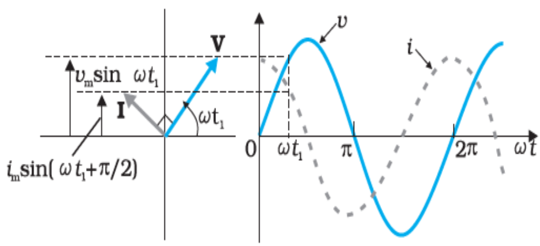
(5) Power: $P = 0$

(6) Time difference: $\text{TD} = \frac{T}{4}$

(7) Phasor diagram: Current leads the voltage by $\pi/2$



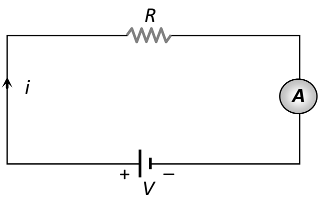




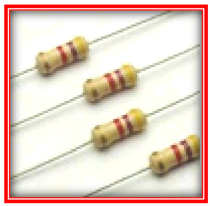
Above figure visualizes the current and voltage phases clearly. For step-by-step explanation you see the NCERT 12th class physics text book.

Direct Current in Resistor, Capacitor, Inductor

In Resistor



Current through resistor



It is just follows from Ohms law, the current in the circuit is given by

$$I = \frac{emf\ of\ source(V)}{resis\tan ce(R)}$$

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

The resistance of a conductor depends upon the geometry of conductor and material.

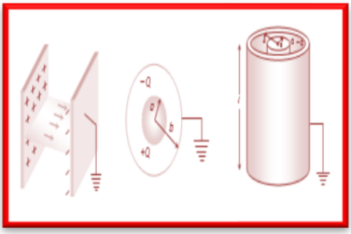
$$R = \frac{\rho l}{A}$$

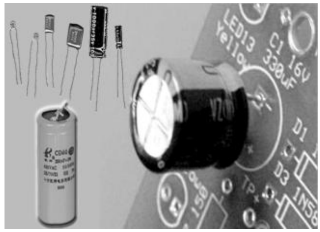
$\rho = resistivity\ of\ material\ of\ conductor$

$l = length\ of\ conductor$

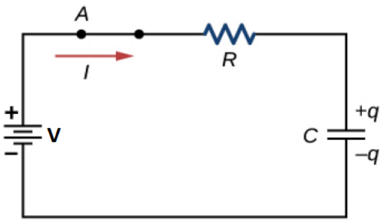
$A = area\ of\ conductor$

In Capacitor

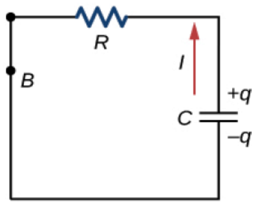




Different types of capacitors



Charging capacitor



Discharging capacitor

The charging and discharging circuits as shown in figures. When a battery is connected to a series resistor and capacitor, the initial current is high as the battery transports charge from one plate of the capacitor to the other. In charging circuit, current abruptly (in microseconds) approaches to zero once the capacitor charged up to the battery voltage. The charging capacitor stores energy in the form of electric fields between the capacitor plates. The rate of charging depends on the time constant RC. The maximum rate at which energy stored in the capacitor depends on source voltage(V) and resistor(R).

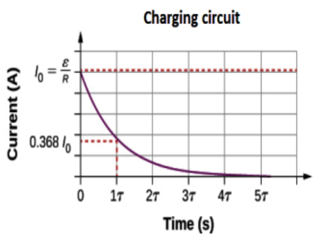
Current as a function of time in charging circuit is given by $I(t) = \frac{V}{R} e^{\frac{-t}{RC}} = \frac{V}{R} exp(\frac{-t}{RC})$

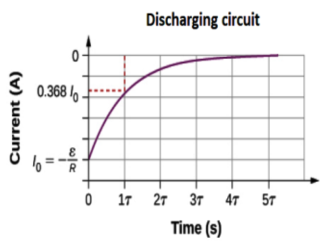
Current as a function of time in discharging circuit is given by

$$I(t) = \frac{-Q_0}{RC} e^{\frac{-t}{RC}} = \frac{-Q_0}{RC} exp(\frac{-t}{RC})$$

$$Where\ Q_0\ \ is\ initial\ charge\ on\ the\ capacitor$$

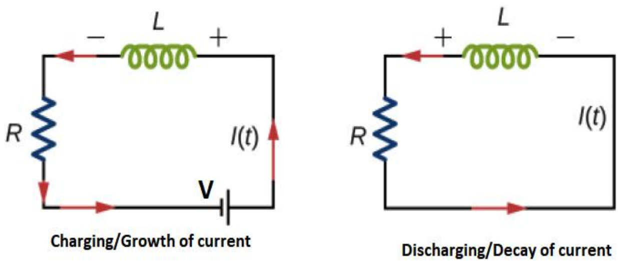
Energy stored in the capacitor in the form of Electric fields $U = \frac{Q^2}{2C} = \frac{\varepsilon_0 E^2}{2}(Volume)$





In Inductor: The current growing and decay circuits as shown in figures. As shown in figure a battery is connected to a series resistor and inductor. In accordance

with Faraday's law or Lenz’s law, inductor resists the change in current and so it grows up slowly. That means, the faster you try to make it change, the more it resists. The rate of growth of current is characterized by the time constant L/R. In inductor energy stored in the form of magnetic field.



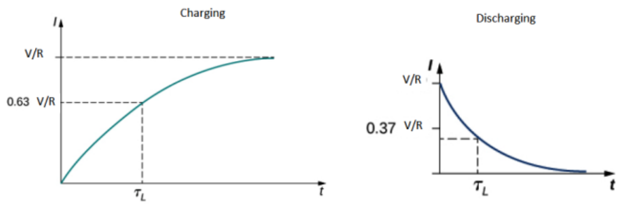
Current as a function of time in charging circuit is given by

$$I = \frac{V}{R}[1 - e\frac{-Rt}{L}] = \frac{V}{R}[1 - exp(\frac{-Rt}{L})]$$

Current as a function of time in discharging circuit is given by

$$I = \frac{V}{R} e \frac{-Rt}{L} = \frac{V}{R} exp(\frac{-Rt}{L})$$

Energy stored in the inductor in the form of Magnetic fields $U = \frac{Li^2}{2} = \frac{B^2}{2\mu_o}(Volume)$



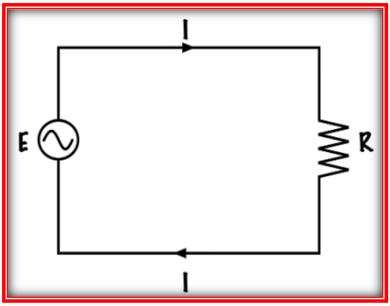
2.2 SINGLE-PHASE AND THREE-PHASE

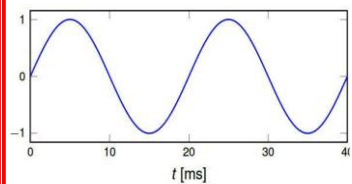
Control Circuit and Power circuit

The Control Circuit consists of inputs, in the form of switches, pushbuttons or pilot devices, which when activated, can either directly, or through a magnetic motor starter, energize a load. The Control Circuit often operates at a lower voltage than the Power Circuit for safety and ease of installation.

In contrast to the control circuit, the power circuit provides the large values of voltage and current used by the motor itself. Must be equipped with over current and overload protection, and horsepower-rated contacts in the control gear equal to the voltage and current ratings of the motor.

Single-Phase:



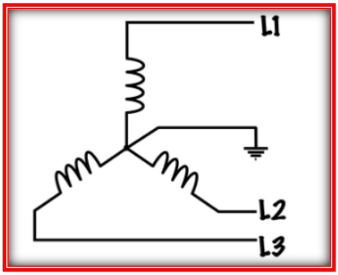


Single-phase electrical systems are the usual simple electrical circuits. They require only two lines: one for power to go in and the other is a return path for current. These are often called Line 1 and Line 2, or Line 1 and Neutral. Current only has one path to travel in a single-phase circuit, and all of the control circuits that we will be looking at are single-phase.

In a single-phase of voltage, in one cycle, the voltage rises to a maximum in one direction of flow, tends to zero, reverses, rises to a maximum in the opposite direction, tends to zero. This process occurs periodically. The cycle repeats itself 50 or 60 times for every one second, that we commonly named as 50-cycle or 50-hertz alternating current.(In India 50Hz and in US 60Hz)

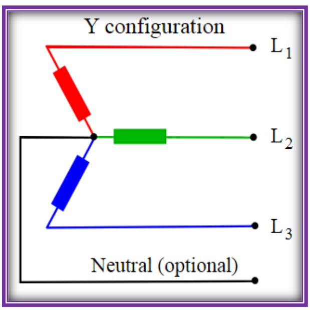
Single-phase power supply is very common for residential usage purpose. Single-phase power is known as "residential voltage," since it is what most homes use. It is used in home appliances like a fan, TV, computer, cooler, grinder, heater, etc. In a single-phase power supply system, only one transformer is used between the distribution line and the meter. Generally, there are three wires, two "hot" and one neutral are installed to provide 120V and 240V single-phase service. Single-phase power supply service, we may get it from three-phase service.

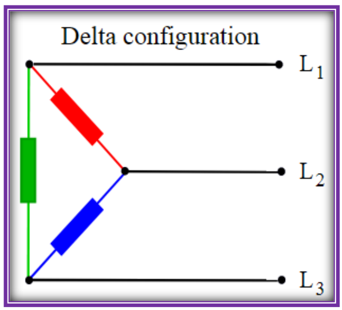
Three-Phase:



Three-phase systems are little bit more complex. They use three current carrying conductors, called Line 1, Line 2, and Line 3, which have a 120° phase shift in the voltage and current waveforms between them. Each of these conductors are connected to a three-phase load, like a three-phase motor.

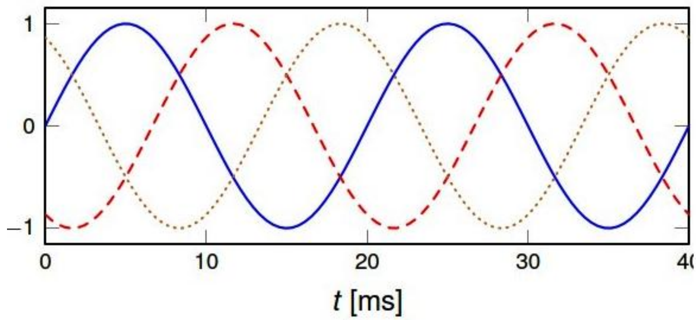
When in operation, a balanced three-phase load (such as a motor) has each of its three line's current values cancel each other out, and so it does not require a return conductor.





These loads can be connected in Wye(Y) or Delta configuration.

In a three-phase power supply, the waveform has, three separate and distinct single-phase currents, which are combined and transmitted over three or four wires.



In a three-phase of voltage , in one cycle, the voltage rises to a maximum in one direction of flow, tends to zero, reverses, rises to a maximum in the opposite direction, tends to zero. This process occurs periodically, however, they do not peak at the same time. Each phase reaches its maximum or peak value 120 degrees apart from the others. In a three-phase power supply system, we need two or three transformers between the distribution line and the meter.

Three-phase power supply service is designed mainly for large electrical loads (Water pumping motors, Engines and mainly industrial machineries). It is more expensive due to the installation of three transformers and four wires. In four wires, three wires are “hot” and one is neutral.

Unbalanced three-phase loads are mainly connected in the Wye(Y) configuration where the central point is used as a neutral to carry any stray return currents. In practice a motor is always a balanced three-phase load.

All of the power circuits that we will be looking at will be three-phase. All of the control circuits that we will be looking at will be single-phase.

Color Coding in Three Phase Wire System

The color code is for identification of three phases, as a convention they are called as Red, Yellow and Blue, they are very practical used in our day to day working. These are useful in paralleling two transformers, Changing the direction of rotation of motor shaft.

In India we are using three phase wiring systems, in that we have three colors

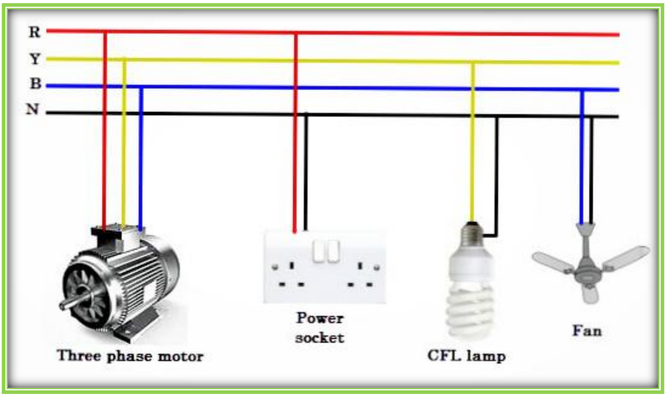
R - red color(L1)

Y - yellow color(L2)

B- Blue color(L3)

N- Black color (Neutral) and

PE=Protective Earth-Green with Yellow stripped



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2.3. Star Connection & Delta Connection:

The words star and delta connections, which are helpful in the driving of electric motors, were frequently used in three phase systems.

The three wires of either end or start terminals are connected in the three-phase system known as a star connection and it appears like a “Y” shape. The other end terminals are connected to the line wires. The common point is known as Star or Neutral point.

The star-connected three-phase systems supply two different voltages, i.e., 230 V and 440V. The voltage between the single phase and the neutral is 230V, and the voltage between the two phases is equal to 440V. This three-phase with the 4-wires system is used in power distribution, transformers and small-scale domestic and residential applications.

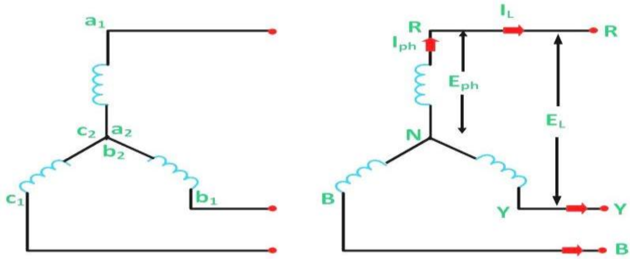


Fig shows the Star connection

As shown in the figure, the end terminals a_2, b_2, and c_2 of the three wires are connected to form a star or neutral point. As depicted in the figure, the three conductors R, Y, and B originate from the remaining three free terminals. The flow of current in each phase is known as **Phase current I_{ph}**, and the current flow in each line conductor is known as Line Current I_L. In the same way, the voltage between two line conductors is referred to as the Line Voltage E_L, and the voltage across each phase is referred to as the Phase Voltage Eph. Due to the three conductors' 120 degree phase difference, the line currents in a balanced star connection are equal to the phase currents.

Scan QR Codes see animated videos

In all three phase systems, Delta connection "Δ " is a closed loop or mesh circuit formed by connecting the starting end of the first wire to the finishing end of the second wire and so on (for three wires). This type of three-phase 3-wire system is used in transformers, power distribution and heavy industrial and commercial applications. No neutral point in the delta connection and it has three wires. The phase and line voltages are equal in delta connection.

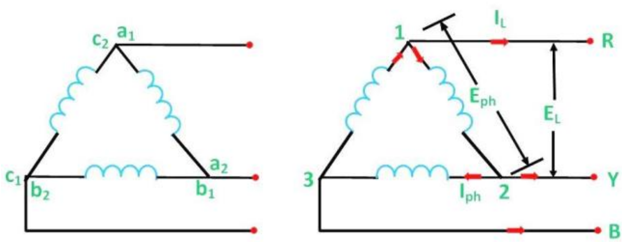


Fig shows the Delta connection

In order to obtain the **delta connections**, a_2 is connected with b_1, b_2 is connected with c_1 and c_2 is connected with a_1 as depicted in the image. The three coils R, Y and B are started from the common point of three junctions known as Line conductors. Phase Current

(Iph) and Line Current (Iph) are the terms used to describe the current flowing along each phase and each line conductor, respectively (I_L). The voltage across each phase is known as the phase voltage (Eph), while the voltage between two line conductors is known as the line voltage (E_L)**.**

Star and delta connections are made in different configurations which can be used in a three phase transformer. The configurations are (i) Star-star (ii) Delta-delta (iii) Star-delta (iv) Delta-star and (v) Open delta Star**-Star (Y-Y)**

- The Star - star connection is mostly used for low, high-voltage transformers. Due to the star connection, number of turns is reduced (as the phase voltage in star connection is 1/√3 times of line voltage only). Hence, the insulation required is less.
- The transformation ratio of the transformers is equal to the ratio of line voltages on the primary side to the secondary side.
- Line voltages on both sides are in phase with each other.

- This kind of connection used only if the connected load is balanced circuits.

Delta-Delta (Δ-Δ)

- This type of connection is commonly used for high, low-voltage transformers. Number of required turns is relatively larger than that for star-star connection.
- The ratio of line voltages of the primary to the secondary side is equal to the transformation ratio of the transformers.
- This type of configuration used even in unbalanced loading circuits.
- This type of configuration has advantages even if one transformer is disabled, the system can continue to run in open delta configuration but with availability of reduced capacity.

Star-Delta OR Wye-Delta (Y-Δ)

- The primary winding is star (Y) connected with grounded neutral and the secondary winding is delta connected.

- This connection is primarily used in the step transformer at the substation end of the transmission line.
- The ratio of secondary to primary line voltage is $1/\sqrt{3}$ times the transformation ratio.
- There is 30° phase shift between the primary and secondary line voltages.

Delta-Star OR Delta-Wye (Δ-Y)

- The primary winding is connected in delta and the secondary winding is connected in star with neutral grounded. Hence, it can be used to provide 3-phase 4-wire service.
- This type of connection is mainly used in step-up transformer at the beginning of transmission line.
- The ratio of secondary to primary line voltage is $\sqrt{3}$ times the transformation ratio.
- There is 30° phase shift between the primary and secondary line voltages.

Open Delta (V-V) Connection: Two transformers are used in open delta connection with the primary and secondary windings. It may be used when one of the Δ-Δ transformers is disabled and the service must be continued until the defective transformer is repaired or replaced. It can also be used for small three phase loads when the installation of a full three transformer bank is unnecessary. The total load transport capability of the open delta connection is 57.7% compared to the delta-delta connection.

Advantages of star connections:

- Used for high voltage loads
- Having Common neutral point
- Used in unbalanced loading
- Each phase is a different circuit
- Suitable for dual voltage applications
- The load is equally distributed in the Star connection.
- Low insulation is required for Star connection alternator.
- a small number of turns required in Star connection alternator

- Availability of single phase at even lower voltage
- The neutral point can be earthed easily.

Disadvantages of star connections:

- Provides less torque
- The construction involves combining 3 single phases into 1
- Secondary distribution, light-duty applications
- Construction cost is highly expensive

Advantages of delta connections:

- Provides More torque
- Works efficiently
- 3-phase motor design can be simple
- Operates in heavy-duty application
- Protection is easy and low cost.
- Used in rotatory conveyors
- Less current per winding is used with a delta connection to provide the same amount of power.

- Widely used for power production, transmission, and distribution
- The secondary of the transformer powers all three phases.
- Low Construction cost

Disadvantages of Delta connections:

- Does not have a common neutral point
- Difficulty in finding the earth ground faults.
- Low voltage connection

In case of three phase induction motor, we mostly used a star delta starter. Initially, the induction motor's star delta beginning is connected via a star connection for the duration of the starting process. Once the motor has reached the required speed after some time, it is plugged in using a delta design.

The table shows the difference between STAR and DELTA Connections

STAR Connection	DELTA Connection
A neutral point is created in the STAR connection by joining the beginning and ending ends of three conductors. This connection looks like 'Y" alphabet letter.	The Delta connections take the shape of the Greek alphabet "Δ" by joining the opposite ends of three conductors.
Star/Neutral point exists.	No Neutral Point
Four conductors required in case of the star connected system (3 live/phase Wires with one Neutral Wire).	Three conductors required for the delta connected system (3 live/phase Wires i.e. All are phases)
Line Current is same as the live or phase current. Line current = phase current $I_L = I_{PH}$	Line current =√3 phase Current $I_L = \sqrt{3}\ I_{PH}$
Line voltage = √3 phase Voltage $V_L = \sqrt{3}\ V_{PH}$	Line Voltage is same as the Phase Voltage. i.e. Line voltage=phase voltage $V_L = V_{PH}$

Total Power supplied through the 3Phases is derived in star connected system is $P= \sqrt{3}\ V_L\ I_L \cos\Phi$ … Or $P= 3\ V_{PH}\ I_{PH} \cos\Phi$ P= 3 VI	Total Power across 3 phases derived in delta connection is: $P= \sqrt{3}\ V_L I_L \cos\Phi$ … Or $P= 3 \times V_{PH} \times I_{PH} \cos\Phi$ P= 3 V I
The speed of the star-connected motor runs slow as they are supplied with 0.577 voltage	Because each phase receives the complete line voltage, the delta-connected motor operates at a high speed.
Less number of turns required.	Large number of turns required.
The star connection used in the transmission and distribution of electric power for longer distance. It is used in balance circuits due to having less insulation and Neutral.	Delta connection is used in the transmission and distribution of power for shorter distances. More insulation required for this connection to help in unbalanced currents.
Star connection applied for few appliances requires less amount current for starting period. like small loaded applications.	Delta connection is used in applications requiring a lot of starting torque, such as large electric motors used in industry, etc.

2.4 . Basics of house wiring

Electricity needs an electric path to flow and more conducting materials used for that purpose.

There are numerous semiconductor materials are used to reduce voltage and also decrease current flow. We will investigate how home wiring is made and which materials are essential for home wiring.

The most primary objective of the wiring system is to distribute electrical energy to the various load points at which it is required and secure the wiring with the given parameters.

1. **Electrical safety**: There must be no risk of leakage current or of electric shock to persons using the appliances which are connected to the power supply.

2. **Mechanical immunity**: A wiring system which is suitable for one type of building may not be suitable for another. The wiring selected for a particular type of building should be able to withstand climate change for an extended period of time and be protected from physical damage during use.

3. **Permanence**: Wiring should not be deteriorated due to humidity, fumes, weather conditions, etc.

4. **Appearance**: In certain cases appearance or invisibility is important.

5. **Cost**: the cost of wiring installation is a major factor. The system chosen should depend on the type of building and its purpose, taking into account the economy.

Service power lines and equipment were the primary stages of residential electrical wiring systems to provide electrical power to the home. The supplier's distribution system supplies electricity to customers via overhead lines to a location outside the customer's premises.

Service Entrance: The line bringing electrical power from the supplier`s low voltage distributor up to the energy meter installed at the consumer`s premises is called the service entrance. The service entrance connection may be achieved by means of overhead conductors or cables.

Energy meter: Once the power reaches the house viz. Service cables, it passes through the energy meter, which may be mounted on an exterior wall or may be located inside. The meter records all electricity used in the home, measured in Kilowatt hours or kWh. Meters may be analog or digital type.

Distribution Board

A Distribution panel board is a safeguard system designed for a home or building. To link the live, neutral, and earth wires to the sub circuits and final sub-circuits, it incorporates protective devices, circuit breakers. The distribution panel board is also called the "Consumer Unit". Below are the distribution Panel board types.

- **Main Distribution Panel(MDP)**
- **Sub Distribution Panel (SDP)**
- **Final Distribution Panel (FDP)**

MDP = Main Distribution Panel

A distribution panel board installed in the house premises which receives the incoming single phase electric power (**230V AC**) from transformer secondary via electric pole and energy meter or the supplier company’s electric service provider outlets is known as **Main Distribution Board**.

The protective devices installed in the distribution panel to provide phase in a safer mode for the various electrical appliances.

SDP = Sub Distribution Panel

A building's or home's distribution panel is used to distribute electrical wiring and circuits within a certain region.

According to the needs of the load, the Sub distribution board is now connected to and supplied by the Main Distribution Panel Board using various wires and cables.

FDP = Final Distribution Panel

The Final Distribution Board, also known as the Sub Final and Final Circuits, is powered by the Distribution Panel. The associated electrical equipment and appliances, such as lights, air conditioners, fans, etc., are operated by the final switches, which are directly connected to the FDP (Final Distribution panel) via the SDP (Sub Distribution panel).

Main Distribution panel contains on the following three important units in order to control and distribute the electric power supply to the different connected electrical appliances and devices via electrical wiring cables and wires.

The following three important components are found in the main distribution panel and are used to distribute and control the electric power supply to the many connected electrical appliances.

- ***DP = Double Pole MCB (The main controlling switch).***
- ***RCD = Residual Current Devices.***

- ***SP = Single Pole MCB (Circuit Breakers).***

We need to utilize the electrical wiring accessories and safety equipment mentioned above in order to regulate and distribute the electric power supplies to the connected various electrical loads/appliances around the house. The circuit diagram displays the wiring for the distribution panel board with RCD and the single-phase electrical supply.

As illustrated in the wiring diagram for single phase power supply, the secondary of the transformer provides the primary power supply that is connected to the energy meter.

The Double Pole MCB is wired using these two wires (Live and Neutral) from the energy meter. The phase wire is first connected to a common busbar segment of single pole MCBs, then to the RCD. The outlet wires come from single pole Miniature Circuit Breakers are connected to final electrical circuits and sub-final electrical circuits and electrical loads like light, fans, etc. through switches.

The Neutral wire from the Energy meter is connected through Double pole MCB, RCD and finally to the neutral link. The neutral link is connected to the sub-electrical circuits. All electrical devices must be connected to the earth link, which is directly connected with the earth electrode for earthing and grounding, in order to be on the safe side.

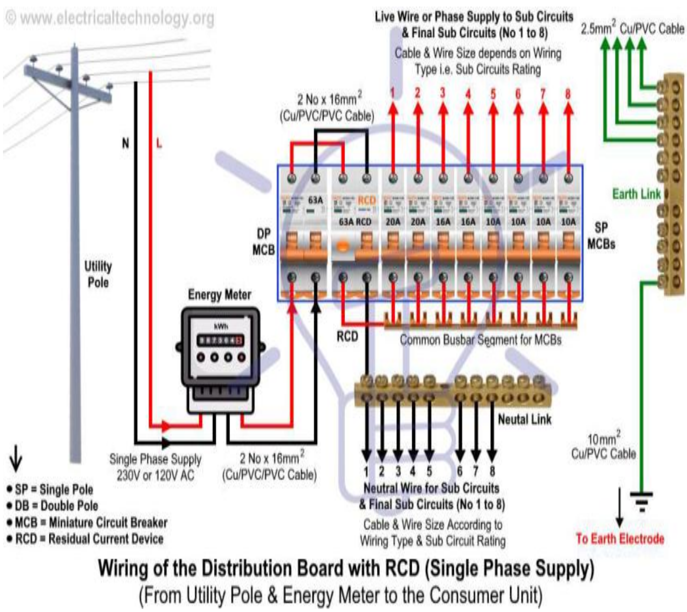


Fig shows the single phase wiring diagram

Image credit: shorturl.at/BHTZ9

Double Pole MCB

This device is a controlling or regulating switch used in order to control the home's electric power supply. If an emergency condition occurs like an electrical shock, short circuits, and fire, then the control switch can be used to immediately turn OFF the power to any connected electrical appliances and turn ON the supply while repairing/working on the main panel board, sub electrical circuit, and final sub electrical circuits. If more supply utilities, such as a storage heater, are installed in the wiring system, a different mains switchboard may be employed.

All the switches are connected through wire/s, MCB / fuse, etc. which makes a circuit. Parallel connections are made in the domestic electric wiring so that if any one electric appliance stops working due to fault, other appliances continue to work normally.

Common Loads are used at home are Tube lights, Fan, Lamp Point/s ,Sockets ,TV ,AC etc

RCD (Residual Current Devices)

The Residual Current Device (RCD) or Residual Current Circuit Breaker (RCCB) is an electrical device which disconnects a circuit if it detects an unbalanced electric current between the energized wire (L) and the return neutral wire (N) and finally stops the power supply in the connected electrical circuits by controlling in the safer mode to protect from the electrical hazards.

SP CB (Single Pole Circuit Breakers)

A Circuit Breaker is an electrical device which disconnects the electrical circuit. In the normal and abnormal conditions the electric supply immediately switches ON and OFF by the CB. An unwanted faulty condition is detected automatically in service panel board using CB. Types of circuit breakers are Single Pole **(**SP**),** DP- Double **Pole (**DP**) &** Triple Pole **(**TP**).**

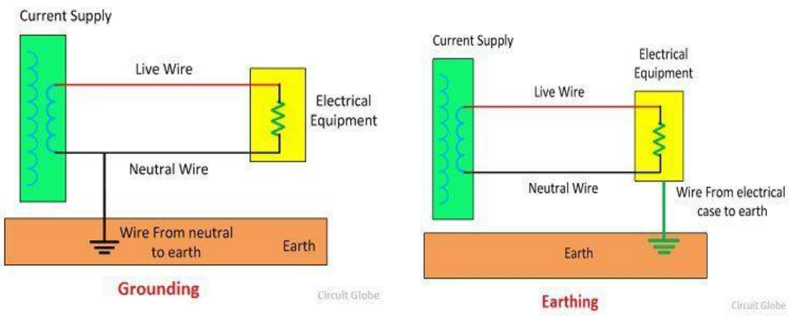
An electrical box is a plastic or metal box used to connect PVC insulated copper wires which are placed in the PVC conduit pipes. In the present days, households are preferred to go concealed conduit wiring means the PVC insulated copper wires are placed in the PVC pipes which are installed inside the wall. Further, the devices such as switches, outlets and fixtures are to be installed. Metal electrical boxes must be grounded to the home's grounding system.

Figure shows the concealed conduit wiring

Image credit: shorturl.at/gls23

Ground: In case of short circuit or fire hazard conditions electricity required a safe path which is provided by an electrical ground system. The current carried parts are directly grounded in the grounding system which allows the return path leakage current. In this way, the electrical power system equipment is protected from electrical hazards.

An electrical current in all three phases of the equipment becomes unbalanced when a fault condition occurred. Now, the grounding directly discharges the fault current to the ground and then the system secures a balanced condition.



(a) **(b)**

Figure (a) & (b) shows a grounding & earthing diagram

Image credit: shorturl.at/ekqr1

Earthing: All the non-current carrying part of the electrical device directly connected to the earth link is known as earthing. The human or stray animal gets an electrical shock when touches the electrical device due to leakage current.

The earthing system discharges the leakage current to the earth and hence protects the person from the electric shock and also protects devices from lighting strokes where it provides a discharge path for the gap, surge arrester and other devices. The earthing can be done by connecting the parts of the installation towards the earth with the help of the earth conductor in intimate contact with the soil placed with a short distance below the ground level.

Scan QR code to see the home wiring video

2.5.1 Electric shock: The current flowing through the human body when the person contact with the current source is known as electric shock. This can burn both internal and external parts of tissues and also damages the organs. Power cables, lightning, electric equipment, faulty home appliances, outlets etc are the general sources causing electric shock.

The following symptoms caused by the electric shock depending upon its intensity.

- Unconsciousness,
- Lack of sensation or tingling & muscle spasms,
- breathing problems,
- headache problems with the vision or hearing burns,
- Irregular heartbeats

2.5.2. First aid methods

Even if the person appears to be fine after receiving an electric shock, emergency medical care is always required. In order to provide the first aid follow the given steps below.

1. Separate the injured person from the source of current (Turn off power)

2. If you are unable turn off power, stand on dry and non-conducting object; try to separate the person from the current source by using non-conductive objects like wooden or plastic broom handles.

3. In case of high voltage lines, the entire power supply should be shut down by the local power supplier.

4. Apply cardiopulmonary Resuscitation (CPR) if the person does not have a pulse.

5. Call for local emergency services.

6. A doctor will give treatment for the injured person for burns, fractures, dislocations and other injuries.

Take a look at the following chart: EFFECTS OF ELECTRICAL CURRENT IN THE HUMAN BODY	
Current	Reaction
Below 1 Milliamp	Generally not perceptible
1 Milliamp	Faint Tingle
5 Milliamps	Slight shock felt. Not painful, but disturbing. Average individual can let go. Strong involuntary reactions can lead to other injuries.
6 to 25 Milliamps (women)	Painful shocks. Loss of muscle control.

9 to 30 Milliamps (men)	The freezing current or “let go” range. If the muscles are excited by the shock, the person may be thrown away from the power source. Individuals cannot let go. Strong involuntary reactions can lead to other injuries.
50 to 150 Milliamps	Extreme pain, respiratory arrest, severe muscle reactions. Death is possible.
1.0 to 4.3 Amps	The rhythmic pumping action of the heart ceases. Muscular contraction and nerve damage occur; death is likely.
10 Amps	Cardiac arrest, severe burns, death is probable.

Scan QR code to see the animated video for Electric shock and First aid treatment

2.6 OVER LOADING

The amount of current flowing in the circuit becomes higher than the capacity of electrical devices in the circuit to withstand the current is called Overloading.

All the electrical devices in the circuits have resistance to flow of current through it produces heat which is directly proportional to the square of current flowing.

The designed electrical appliances have a particular capacity only that much of heat as is generated by the maximum flow of current. When the current is beyond its level, or in other words, when the electrical circuit is overloaded the electrical devices get overheated, resulting in their damage i.e. the risk of fire.

OVERLOADING SIGNS:

1. Flickering, blinking of lights
2. Burning odor
3. Warm or discolored wall plates.
4. Mild shock or tingle from switches.

The overloading may continue from the defective electric motors, overloaded appliances or too much loads on single electrical circuit. Such kind of overloads become destructive and immediately disconnecting the power supply using protective devices as early before they can damage the circuit. Short circuit occurs when the neutral and the live wire come in contact with each other whereas overload takes place too many of appliances connected to single socket/outlet.

PRECAUTIONS SHOULD BE TAKEN FOR OVERLOADING IS GIVEN BELOW:

1.Avoid using too many appliances at the same time.

2.Make sure the appliance you are using must be within the safe limit of the electric circuit.

3.Avoid connecting too many appliances in one socket.

4.Electric fuse should be connected in series; it will protect the circuit from overloading and short circuiting.

5.Proper earthing of all electric circuits must be done.

Scan QR code to see the animated video Overloading and precautions

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2.7 Earthing and its necessity: Have you ever felt a mild electric shock when you touch a Refrigerator, T.V, Computer or any other electrical appliance in your house? (or) Have you ever heard that somebody was electrocuted due to a short circuit?

The reason for such electrical accidents is the lack of a safety system called '**EARTHING**'. According to National Crime Records Bureau (NCRB) report entitled "Accidental Deaths and Suicides in India 2020", 1812 people have died due to fire accidents caused by electrical short circuit in 2020. So let us try to understand what is **EARTHING** and how it can save your life from electrocution.

We know that electricity chooses a low resistance path. Imagine, there is an excess flow of current due to a faulty connection or short circuit in the house. If we can provide a safe low resistance path for the excess flow of current, it can save people from electrocution or fire accidents. It is done through EARTHING. Earthing means to connect all the electrical appliances in the house to earth (or) ground through a conducting material like Iron, Copper, Aluminium etc. Resistance of the conducting material is typically less than 1 ohm. Hence it provides a low resistance path to the circuit if there is a leakage of current.

Earthing of a railway track

Earthing for houses

Types of Earthing:

1. Pipe Earthing

A two-metre-long copper pipe is placed vertically in the ground to bypass the excess current. It is the most affordable and effective way of earthing.

2. Plate Earthing

In this method, a copper plate or Galvanised Iron is placed in the ground at a depth of approximately 6 feet.

3. Strip Earthing

Strip electrodes made of Galvanised Iron or Steel are buried in the ground at a depth of 2 feet.

Necessity of Earthing:

- ✓ Earthing provides an alternative way for the accidental leakage of current to flow towards earth.
- ✓ It protects humans from electric shock.
- ✓ It protects the electrical equipment from damage due to short circuits or high voltage.
- ✓ It protects tall buildings from lightning strikes.
- ✓ Earthing also provides voltage stabilisation in
- ✓ sensitive electronic equipment.

Scan the QR codes to see ANIMATIONS on EARTHING

Video Lecture on Necessity of Earthing

2.8 Short Circuiting

Imagine if MCB in your house trips and when you try to reset the MCB it trips again with sound and spark. It indicates a short circuit in one of the electrical appliances in your house. Short circuits are very dangerous as they can trigger a fire accident. Thanks to the MCBs in modern houses as they have prevented many potential fire accidents due to short circuits. Let's try to understand what a Short Circuit is, its causes and how we protect ourselves from it.

We know that electricity passes through a circuit in a well-designed network. But in case of faulty connections or insulation failure, current might pass through an unintended path with zero or very low resistance. This is called a short circuit. Since the resistance of this wrong path is very small, a large amount of current passes through the wire due to which the wire melts and may cause a fire, electric shock or appliance damage.

Let us try to understand Short Circuit with an analogy. Compare the current passing through a wire with a car moving on a road. Friction on the road is analogous to the resistance of the wire. Just as a car travelling on a road with zero friction meets with an accident, electricity passing through a wire of very low resistance can cause a fire accident due to abnormal heating.

Possible causes of short circuit:

- **Insulation failure**
- **Incorrect wiring**

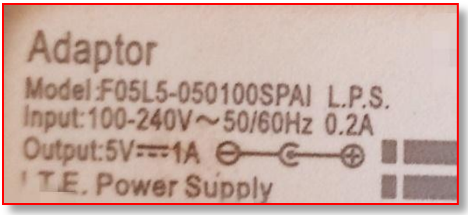
- **Loose connections**
- **Outdated wiring**
- **Liquids entering the appliances**

Scan the QR code to see
ANIMATION on SHORT CIRCUIT

Video Lecture on
Short Crcuitng

2.9 Fuses

We know that any electrical appliance has a certain limiting value of current and voltage depending on its design and utility. This is called rated current. For example, you can see the rated current values of a mobile charger in the below image.



Rated current, voltage and frequency of a mobile charger

In some cases, excess current can pass through electronic devices due to short circuits, overloading, load mismatch, device failure etc. which can damage the electrical appliance or even cause a fire accident. How can we avoid this? A solution to this problem is **‘FUSE’**

- **Fuse is a safety device that protects an electrical appliance from over current**

Let us try to understand, how ‘FUSE’ does this?

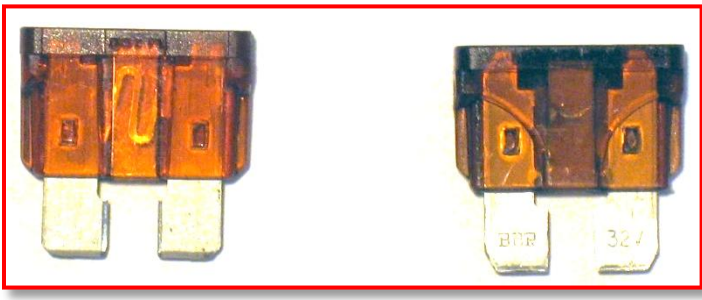
Any type of FUSE contains a thin metallic wire with low melting point. Under normal conditions, this wire does not affect the operation of the system since its resistance is small. We know that when current flows through a wire, it gets heated due to Joule’s heating. When excess current passes through the metallic wire in case of short circuit or overload, it melts and hence stops flow of current. The fuse is said to be blown and it needs to be replaced or reset for the device to function.

How to identify a blown fuse:

Remove the fuse from the holder. If there is a gap in the wire or any smear inside the glass the fuse is blown.

Normal Fuse

Blown Fuse



Normal Fuse

Blown Fuse

Some important types of fuses are shown below.

S.No	Type of fuse	Image	Application
1	Cartridge Fuse		High rated current appliances like Motors, A.Cs, Refrigerators
2	Rewireable Fuse		Domestic wiring
3	Drop Out Fuse		Transformers

4	Resettable Fuses		Consumer electronics, Telecom, Power line, Medical Equipment protection
5	Automotive Fuses		Automobiles
6	High Rupture Current (H.R.C) Fuse		Transformers, Motors, Automobiles, Backup protection

Scan the QR codes to see
VIDEO on FUSE

Video Lecture on
FUSES

2.10 MCB

We know that FUSE protects an electrical system in case of overcurrent caused by overload, short circuits etc. MCB is a modern alternative to Fuse especially in domestic applications.

Advantages of MCB over Fuse:

- Replacing or resetting the blown fuse may not be safe and takes time.
- Fuse offers thermal protection only. It does not offer magnetic protection like MCB

MCB means Miniature Circuit Breaker. It protects an electrical system in case of overload or short circuit by switching off or tripping the circuit automatically. The reason why it is termed ‘Miniature’ is because it is generally used for low voltage applications. Unlike a Fuse, MCB can be reset manually or automatically once the fault is identified. This is the reason why MCBs have replaced the conventional Fuses in domestic electrical systems.

MCB

-

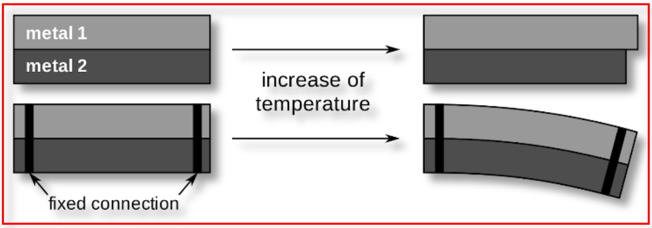
Main components of MCB:

1. **Actuator Lever**
2. **Actuator Mechanism**
3. **Contacts**
4. **Terminals**
5. **Bimetallic Strip**
6. **Calibration Screw**
7. **Solenoid**
8. **Arc extinguisher**

Principle and Working: To understand how MCB trips in case of overcurrent, we need to understand the functioning of two key components Bimetallic Strip and Solenoid.

- Bimetallic strip detects change in temperature. As shown in figure, it is formed by joining two strips of metals having different coefficients of thermal expansions. When there is a change in temperature, the strip bends and breaks the power supply

- Solenoid is simply a coil of wire. When current passes through a solenoid, it produces a magnetic field.



Overload Protection:

When an electrical circuit is overloaded, excessive current passes through the circuit. It causes the Bimetallic strip in the MCB to bend due to heating which releases a mechanical latch and trips the circuit.

Short Circuit Protection:

In case of a shot circuit, a large quantity of current suddenly flows through the circuit. It causes the

Solenoid in the MCB to produce a magnetic field which releases a mechanical latch and trips the circuit within milliseconds.

Types of MCBs:

MCBs ae classified in to 6 types A, B, C, D, K and Z depending on the range of tripping current.

S.No	Type	Tripping Current	Operating Time
1	Type A	2 to 3 times the rated current	0.04 to 13 Sec
2	Type B	3 to 5 times the rated current	0.04 to 13 Sec
3	Type C	5 to 10 times the rated current	0.04 to 5 Sec
4	Type D	10 to 20 times the rated current	0.04 to 3 Sec
5	Type K	8 to 12 times the rated current	<0.1 Sec
6	Type Z	3 to 5 times the rated current	<0.1 Sec

Scan the QR codes to see
ANIMATION on MCB

Video Lecture on
MCB

2.11 ELCB

To understand Earth Leakage Circuit Breaker, let us first try to understand what is Earth leakage current?

Imagine if the phase wire in an electrical appliance is accidentally cut and it touches the metal part of the device, then electricity passes through the metallic body of the appliance. If proper earthing is done, this dangerous electricity safely leaks to the Earth. This is called earth leakage current. The permissible limit of earth leakage current is 1 mA or 50 V. If proper earthing is not done, we might get electrocuted if we touch the metal parts of the device. So how do we protect ourselves from earth leakage current? The answer is ELCB.

ELCB means Earth Leakage Circuit Breaker. It detects the earth leakage current and switches off or trips the circuit to prevent electric shock to humans.

ELCBs are of two types.

- Voltage Earth Leakage Circuit Breaker
- Current Earth Leakage Circuit Breaker

Current Earth Leakage Circuit Breakers also known as Residual Current Circuit Breakers (RCCB) are widely used nowadays

Principle and Working:

- ELCB contains a relay coil or sensing coil.
- When Supply and Return currents pass through the relay coil, two magnetic fields are produced.
- When there is no earth leakage current, the two magnetic fields cancel each other since the supply and return currents are balanced.
- But when excessive earth leakage current passes through the relay coil, there will be an imbalance of currents and hence the magnetic fields do not cancel each other. The residual magnetic field releases a latch to trip the circuit preventing electric shock.

Scan the QR code to see ANIMATION on ELCB

Video Lecture on **ELCB**

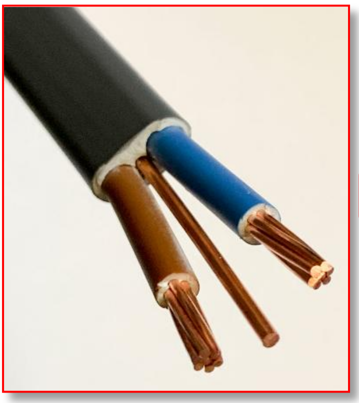
2.12 Insulation

Insulation in electrical appliances refers to the process of preventing flow of electricity through certain parts of the device to prevent short circuit or electrocution by using materials with high resistivity.

We know that the human body is a good conductor of electricity. Hence Insulation is very important in electrical appliances to avoid electrocution and fire accidents.

Insulators do not contain free electrons. Hence their resistivity is very large, of the order of 10^7 ohm-m.

Examples of insulators are:



Insulation in wires

- Plastic
- Wax
- Rubber
- Glass
- Ceramics
- Teflon
- Mica
- Polymers (PVC)

Materials used for insulation of wires:

1.Plastic: Characteristics of plastics which make them ideal for insulation are

- High electrical resistivity
- UV Resistance
- Fire Resistance

Ex: Polyvinyl Chloride (PVC), Polyethylene, Polypropylene, Nylon etc.

2.Rubber: In addition to high electrical resistivity, rubber materials are flexible. Hence, they can be drawn into any shape required for insulation.

Ex: Thermoplastic Rubber, Neoprene, Silicone, Fibreglass etc.,

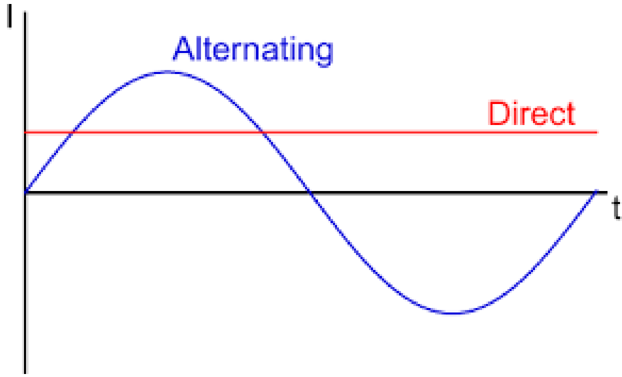
3.Fluoropolymer: Fluoropolymers are the most preferred materials for insulation because of their unique characteristics.

- Chemical resistance
- High temperature resistance
- Low coefficient of friction (Ideal for medical appliances)
- Low dielectric constant
- Highly flexible

Ex: Polytetrafluoroethylene (PTFE), Fluorinated Ethylene Propylene (FEP), Ethylene tetrafluoroethylene (ETFE) etc.

2.13.1 Inverter: We know that ELECTRICITY is a symbol of MODERNITY in the development of human civilization.

Use of electrical energy has spurred the socio-economic development of humanity. Electricity exists in two forms. Direct Current (D.C) and Alternating Current (A.C).



- If the polarity and magnitude of electric current changes periodically as shown in the above figure, it is known as Alternating Current (A.C).

- On the other hand, if the polarity of electric current remains the same, it is known as Direct Current. However, the magnitude of current may change in D.C.

Advantages of A.C over D.C:

- Easy to transmit over long distances

- Easy to change the voltage using a transformer

This is the reason why we receive A.C from the power grid.

- **Inverter is a device or a circuit which converts D.C to A.C.**

Solar panel with Inverter

What is the necessity of converting D.C into A.C:

Even though we receive A.C from power grid, sometimes there is a need for inverters to convert D.C into A.C. For example, solar panels and the batteries we use to store electrical energy produce D.C output. We must convert this D.C power into A.C power since most of the electrical appliances like Refrigerator, Electric Motor, Electric Fan, Dish Washer etc. operate with A.C.

Principle of Inverter:

Since periodic reversal of direction or polarity is the characteristic of A.C, to convert D.C into A.C we need to alternate the direction of D.C. This is done by the SWITCHING CIRCUITS.

Switching Circuits contain Transistors as the key components. Most commonly used transistors are Insulated Gate Bipolar Transistor (IGBT) and Metal Oxide Semiconductor Field Effect Transistor (MOSFET)

Types of Inverters:

➢ **Based on the output waveform**

- Square wave inverter
- Modified sine wave inverter
- Pure sine wave inverter

➢ **Based on the output phase**

- Single phase inverter
- Three phase inverter

- **Based on input source**

- Voltage source inverter
- Current source inverter

Video Lecture on
Inverter, UPS, Insulation

2.13.2 UPS

An Uninterruptible power supply (UPS) is an electrical apparatus that provides emergency power to a load when the input power source fails.

Basic Parts of a UPS System

1. Rectifier or charger, which produces DC power to charge a battery and supply to an inverter.
2. Inverter, which produces quality electrical power which is free from all disturbances, for sensitive electronic devices.
3. Battery, which provides sufficient backup time.

4. Static switch, a semi-conductor-based device which transfers the load from the inverter to the utility and back, without any interruption in the supply of power.

Types of UPS:

Stand by UPS: A standby UPS provides battery backup power in the instants such as a blackout, voltage sag, or voltage surge. This UPS switches to DC battery power and then inverts it to AC power to run connected equipment.

Line interactive UPS: It corrects minor power fluctuations (under-voltages and over voltages) without switching to battery. This type of UPS has an auto-transformer that regulates low voltages and over voltages without having to switch to battery.

Double-conversion (online) UPS: This UPS converts incoming AC power to DC, and then back to AC. These UPS systems have a zero-transfer time because they never need to switch DC power.

Applications of UPS

UPSs are used in any field that requires uninterruptible, high-quality power supply. These are Data Centres, Health care, Hospitals, clinics and retirement homes, Banks and insurance, Telecommunication, Industrials, Special projects (events).

****

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Question Bank

Essay answer type

1. What are the Direct current & Alternating currents? Explain them in detail.
2. Explain single and three phase connections.
3. What are Star, Delta connections? Explain them in detail.
4. Discuss the basic House wiring in detail?
5. Explain the working principle of Inverter.
6. Explain the different types of UPS

Short answer type

1. Write the differences between DC and AC currents
2. Define RMS Voltage and Power factor.
3. What is Electric shock? Write the first aid treatment for the electrical shock injured person
4. What is overloading? write the causes for it.
5. Explain the terms MCB & ELCB.
6. Write a short note on a short circuit.
7. Describe the necessity of earthing?
8. Discuss the importance of insulation.

Unit III

Learning Objectives:

- To understand the basic parts of Electric fan and iron box
- To understand the working of Water heater and Induction heater
- To understand the working of microwave oven and Refrigerator
- To understand the concept of illumination and different types of Bulbs
- To Understand the energy efficiency and codes

Learning Outcomes:

- Learn the basic principles of Electric fan, Iron box
- Learn the basic principles and working of Water heater, Induction heater, Microwave oven, Refrigerator.
- Learn the concept of illumination, Various Bulbs.
- Understand the concept of energy efficiency and codes.

Michael Faraday. from England, was a famous Physicist and Chemist, was known for his discovery of Electromagnetic Induction. Famous for his Electromagnetic laws and Electrolysis Laws and invented the Electromagnetic devices. He also discovered that magnetism will have effect on the path of light rays and explained diamagnetism. It was due to his efforts that electricity became practical for use in technology. Unit of Electrical Capacitance is named in honour of him

3.1 Working principle, Parts and Servicing of Electric Fan

The invention of Electric fan was a very significant contribution to mankind. An electric fan is an electrical appliance used to circulate the air-flow throughout the room and make the indoor environment more pleasant. It is used to regulate interior temperatures. The main purpose of electric fans is to enhance the comfort of people during hot and humid conditions.

Principle: When a current carrying conductor is placed in a magnetic field, it experiences a torque and this torque causes rotation. The direction of rotation can be found by Fleming's left-hand rule.

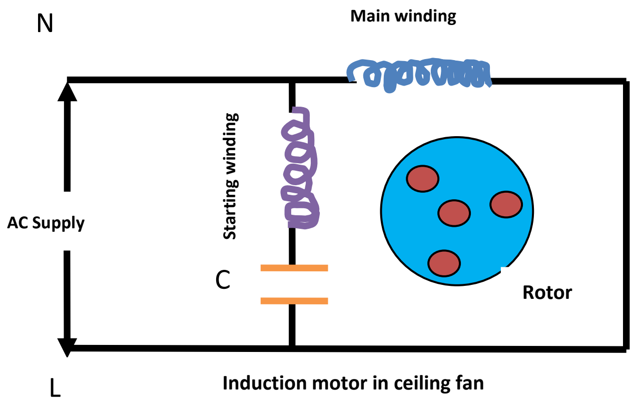
Parts of an electric fan: An electric fan has the following main components.

i) **Capacitor**: Start capacitor is used in electric fans. The capacitor stores electric energy and the stored energy utilized to rotate the electric fan. So, the capacitor allows the fan motor to rotate quickly.

ii) **Axle**: The metal rod made with mild steel is used as shaft or Axle.

iii) **Ball Bearings**: 2 bearings which are linked between housing and axle give rotatory motion to the housing.

iv) **Stator**: The stationary part of fan motor is called Stator. So, Stator is the stationary winding of motor and it has very low resistance. This winding produces a magnetic field when current passes through it.



Induction motor in ceiling fan

v) **Rotor**: The rotating part of fan motor is called Rotor. Rotor in the electric motor is the permanent magnet in the shape of half circles. Usually 2 pieces of Magnets are used in an Electric fan but this can change to 3 pieces or to a single piece depending upon size and capacity of electric fan.

vi) **Housing**: The outer part of the fan is called Housing.

vii) **Blades**: Wings or blades are bolted to the housing of fan. In general, three or four blades are used and their length depends on the capacity of fan motor.

<u>Working</u>: The working of electric fans is quite simple. An electric fan contains a single phase induction motor.

The fan capacitor allows the motor to start and rotate. When the electric current flows through the windings of motor, a strong magnetic field is developed and the resultant magnetic force drives the motor in clockwise direction. That means the electric energy is converted into mechanical energy. Then the blades slice the air and push it downward, causing the breeze. This whole process circulates the air throughout the room.

Servicing of an Electric Fan:

Servicing an electric fan is very important in our homes. In addition to extending life expectancy, maintaining a ceiling fan can help to avoid potential safety hazards of faulty fans.

Some of the servicing tasks are mentioned below.

i) **Cleaning the fan**: The cleaning of electric fan should be done at least once every 3 months. Clean the blades and housing with a brush and wet cloth. Later, let the fan to dry on its own before using it again.

ii) **Tightening the screws**: Ceiling fans contain different rotating parts which are connected together with the help of screws. When the fan is rotating, it produces small vibrations and as a result some of the screws will be loosen. Then we have to detect those loosen screws and they should be tightened with the help of a screwdriver.

iii) **Lubricating the fan**: The electric fans require frequent lubrication to run smoothly. So, apply any light oil to the oil hole for lubrication.

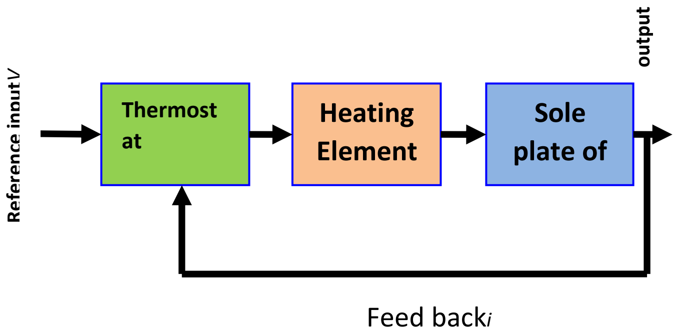
3.2 Electric Iron box

An electric iron is a household appliance used to remove creases or wrinkles of the clothes by the combination of heat and pressure.

Principle: Electric iron works basing on the heating effect of current. When the current passes through the coil inside the iron, it is heated. That means the electric energy is converted into heat energy. The heat energy is transferred to the soleplate due to the conduction principle.

For proper effective working, the electric iron box requires a certain range of temperatures. Generally, the operating temperature range of domestic irons is from 121 °C to 182 °C.

<u>The main parts of an electric iron box</u>: The electric iron box has following main parts.



Automatic Iron box

i) **Handle:** Generally, the handle of iron box is made with plastic or wood. Because current does not pass through those materials and the person who touches the handle while ironing would be saved from an electric shock. The handle is attached to the cover plate with the help of screws.

ii) **Sole plate:** This plate is also called as the hot plate. This plate is thick and flat triangular shaped surface made of aluminium. It is polished, layered with a nonstick material making it stainless. It is the base plate which comes in contact with clothes while ironing.

iii) **Cover Plate:** The cover plate is made of a thin sheet of iron and is placed on top of the sole plate. This plate covers all the internal parts of the iron box.

iv) **Pressure Plate:** This plate contains some holes through which the studs from the base plate passes through. The pressure plate and sole plate are connected tightly with the help of screws. In general, the pressure plate is heavy and made of cast iron but in some cases, it is a thin sheet of steel.

v) **Pilot Lamp:** It is an indicator lamp arranged on the cover plate of the iron box. Its one end is connected to the heating element and the second end is connected to power supply. Across the lamp a shunt resistance is connected which helps in providing a voltage drop.

vi) **Heating Element:** In general, the heating elements are made with a nickel-chromium wire, which has high resistance and tensile strength. The heating element is arranged between the pressure plate and sole plate in the iron box. The two ends of the nickel-chromium wire are connected to the contact strips and the contact strips are connected to the terminals of the iron box.

vii) **Thermostat:** In the iron box, a thermostat is used to regulate its temperature. The thermostat makes use of a bimetallic strip and this bimetallic strip is made up of two different types of metals with different coefficients of expansion. So, the bimetallic strip expands differently in the presence of heat energy. With the help of small pins, the metallic strip is connected to a contact spring.

At ordinary temperatures, the bimetallic strip remains straight and in contact with the contact point. When it is heated above a particular temperature, the strip tends to bend towards the metal, which has lower coefficient of expansion and as a result, the circuit breaks and no current flows through the circuit. When the temperature decreases, the strip goes back to its original position and circuit is closed. As a result, the current flows through the circuit again and this cycle continues until the plug is disconnected from the main power source.

viii) **Capacitor:** We know that the thermostat helps in regulating the temperature of iron box. But the frequent closing and opening of electric circuit damages the contact points. It may also cause radio interference with the circuit and to prevent this, across the two contact points, a capacitor is connected.

Working: When the current flows through the heating element, it gets heated up. This heat energy is transferred to the sole plate through conduction principle. As a result, the sole plate is also heated. When the iron box is rubbed on clothes, small strings of clothes stretch due to heat energy and the wrinkles are removed. A thermostat along with an indicator lamp is used for maintaining the optimum temperature.

Safety precautions while handling an Iron box:

i) Always use electric Iron on a proper ironing board.

ii) Never iron the clothing on the floor or bed.

iii) If the cord of iron box is damaged, then do not use the Iron

iv) Always keep your eye on children and pets while you are using the Iron.

3.3 Water Heater

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Edwin Ruud (9 June 1854 – 9 December 1932): He is a mechanical engineer and inventor of automatic storage water heater from Norway. Later he was immigrated to United States of America. He is popular for his design of first water heater in the year 1889. In 1904 he got Louisiana Purchase Exposition (St.Louis World's Fair) Gold Medal for his automatic water heater.

Definition: A device which is used to heat and store water for domestic purpose.

Principle:- The main principle involved in electric water heaters is the electrical energy is converted into heat energy through a heating element. This heating element raises the temperature of water to a desired value.

Electric water heater is used to raise the temperature of water. That means it converts cold water into hot water.

Joule's law: If current is passed through a heating element having high resistance, heat is produced. It can be explained by using the equation

$$Q = Ri^2t$$

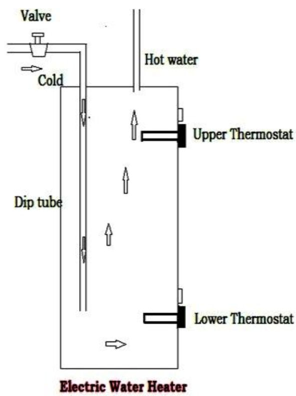
where

Q = Heat produced

R = Resistance of heating element

i = current passed through the heating element

t = time of flow of current



Types of water heaters:

There are hardly two types of water heaters

1. Tank/Storage water heaters

2. Tank less/Instant water heaters

1. Tank water heaters:

Today we commonly use tank water heaters for domestic purpose. Because they have the capacity to store hot water. In these heaters two electric resistance materials are used. One element is at the top and other at the bottom of the storage tank.

2. Tank less or instant water heaters:

They heat water instantly and does not store water the tank. Copper is used as heat exchanger in this type. Copper has high thermal conductivity and easy to fabricate.

Main parts of the Water Heater:

1. Storage Tank: It is a heavy metal tank. It can store water ranging from 10 litres to 50 litres of hot water. The inner layer of the tank is coated with water protection layer like enamel for reducing the corrosion. The exterior is coated with PUF.

2. Dip tube: It is used for cold water inlet.

3. Shut off valve: It is used to stop the water flow when tank fills completely.

4. Heating element: It is used to raise the temperature of water. Generally high resistance material like Nichrome is used as heating element.

5. Thermostat: It is a temperature control device. It contains a thermometer which controls the temperature of heating element using a bimetallic strip.

6. Heat out pipe: It is the hot water outlet.

7. Drain valve: It is used to empty the heater for cleaning or in case of replacing the components.

8. Pressure relief valve: It maintains the pressure in safe limits within the heater.

These components are arranged as in the following figure:

Working: When heater is ON current passes through heating element and this element gets heated. Through conduction heat is transferred to cold water in the tank. Thermostat controls the temperature of the process by using a bimetallic strip. This bimetallic strip consists of two metals iron and brass. As the water is heated it reaches the heat out pipe for exit from the tank.

For more info Scan QR code

3.3.1 INDUCTION HEATER

Induction heating involves Electromagnetic induction and Joule's heating.

It is a non contact process of heating. Induction heater operates in the range of medium frequency or radio frequency range.

Principle:

When an electric conductor is placed inside the alternating current carrying coil, induced current is generated due to electromagnetic induction.

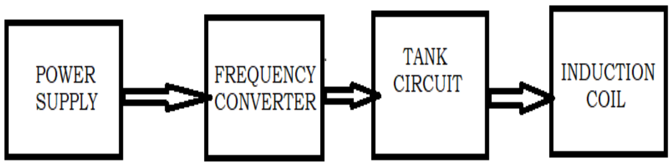
This induced current heats the conductor by Joules heating.

Parts of Induction heating:

1. Radio frequency Power supply: Most of the induction heaters contains Radio frequency power supply. It contains an electromagnet.

2. Induction coil: The induction coil is a part of tank circuit. The electric conductor is placed inside it.

3. Resonance tank circuit: It consists of parallel circuit of capacitors and Inductors. It is connected with RF power supply. It gives resonance frequency at a desired value.



INDUCTION HEATER BLOCK DIAGRAM

Working of Induction Heater:

Generally the induction coil is made up of copper like metals. If ac current is passed through it produces time varying magnetic field. If a metal rod is placed inside the coil without contact induced current is produced. This current causes heating effect in the conductor.

Applications of Induction heating:

1. Used in Heat treatment in metallurgy

2. Used for soldering, surface heating and melting

3. Used in Induction cook tops for cooking.

For more info Scan QR code

3.4 MICROWAVE OVEN

Percy Spencer(July 19, 1894 - September 8, 1970) is an American Physicist and the first inventor of Micro wave oven after the second world war. It is named as Radarange. Microwaves are the electromagnetic radiation of frequency range from 300MHz to 300GHz. Most of the microwave ovens use 2.24GHz frequency range.

Definition: A device used to heat and cook the food by using electromagnetic radiation of microwave range is called Microwave oven.

Principle: The main principle involved in Microwave oven is Dielectric heating.

Dielectric heating is a process in which electromagnetic energy is converted into heat energy.

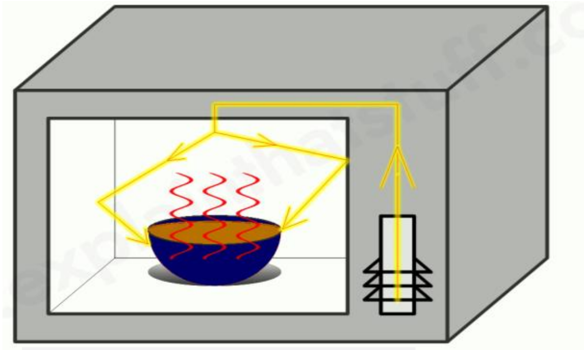
When a high frequency electromagnetic field is applied to a dielectric substance the temperature of the substance is raised.

Main parts of the Oven:

1. High voltage Transformer: Microwave oven requires high voltage for its operation. Hence a step up transformer is placed inside the oven for this purpose. 240V household supply voltage is raised to few thousand volts.

2. Cavity magnetron: It is a vacuum tube with high power and several cavities. In these cavities electrical energy is converted into electromagnetic radiation of micro wave frequency.

3. Wave guide: It guides the generated microwaves towards the food items.



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4. Cooking Cavity: The place where food materials is placed in the chamber. It has metallic walls and contains a turn table.

5. Stirrer: It is a cooling fan. It reduces the operating temperature of magnetron and increase its efficiency.

Working:

When power is switched ON current passes through high voltage transformer it increases the voltage into several thousand volts. The high voltage is converted into DC voltage by using Capacitor circuit. This DC Voltage enter into Magnetron to produce microwaves. Wave guide directs the microwaves towards the food items.

Water molecules(polar) in the food absorbs the micro wave radiation and starts oscillation to align the dipoles. In this process energy is lost by the dipole resulting in heating the substance. This phenomenon is called Dielectric heating. After reaching the required temperature the cooking stops automatically. For this a micro controller is used.

For more info Scan QR code

3.5 REFRIGERATOR

Definition:

A refrigerator is a household machine used for producing low temperatures below the surroundings and maintaining an enclosure at that temperature.

Principle: When a liquid of low boiling point is passed through objects which we want to cool, it absorbs heat from the objects and evaporates.

Main parts of Refrigerator:

1. Compressor:

Compressor increases the pressure of the gas by decreasing the volume. It is located at the lower backside of the refrigerator.

2. Condenser:

The condenser removes heat from the refrigerant by condensing it from gas to liquid. During this condensation the temperature of the refrigerant falls. It is located at the back side of the refrigerator.

3. Evaporator:

The evaporator coils present inside the refrigerator. In this process the liquid evaporates by absorbing the temperature of food items kept in the refrigerator. This heat is removed by the condenser.

4. Refrigerant: It is a liquid or gas of low boiling point. Hydroflurocarbons are generally used as refrigerants.

5. Thermostat: It controls the temperature of the refrigerator. When the temperature of refrigerator is reached to a desired value, the thermostat stops power supply to the compressor. If the temperature increases than the desired value then the thermostat starts power supply to the compressor.

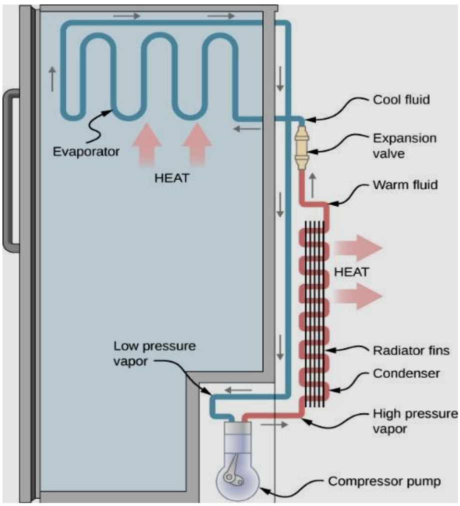


Fig: Refrigerator Block diagram

Source: shorturl.at/pvx49

6. Expansion valve: It controls flow of liquid refrigerant into the evaporator depending on the set temperature of refrigerator.

Working:

First of all the liquid refrigerant is passed through expansion valve. It is cooled due to expansion. The low boiling point cooled refrigerant passes through the evaporator coils and absorbs heat from the food items kept inside the refrigerator. Due to evaporation the pressure of the gas decreases and it is passed through compressor. At the Compressor the temperature and pressure of the gas raises. This hot gas passes through condenser coils and change into liquid phase due to condensation by losing heat to surroundings. The cooled liquid again enters into expansion valve and the cycle repeats.

For more info Scan QR code

3.6. Concept of Illumination:

The sensation of sight is immensely essential to us, as it facilitates us to see and gather a lot of information about the world. We can observe a body in one of two distinctive ways: (i) the body may be acts as a source of light, like a flame, a light bulb, or star, in this situation we can observe the light directly from the source (ii) we can observe a body by light reflected from it.

Light is an electromagnetic wave (EMW) consisting of several wavelengths ranging from X-rays to radio waves. Artificial light can be produced through the process of increasing the temperature of a certain solid body. If the increasing temperature of a body is above room temperature, then energy is radiated into the surrounding space of the body in the form of EMWs consisting of several wavelengths. The type of energy of emanated radiation depends on the body temperature.

Radiant energy of the body consists of different waveforms at different temperatures that are at low temperatures, it is as heat waves and at relatively high temperatures, along with heat waves light waves are also emitted and then the body in the state of luminous. The emission of light waves as well as heat waves goes on increasing if temperature goes on increasing, so that the color of visible or light waves suddenly changes as red to orange, to yellow and then into white if the temperature is very high. Wavelength of visible light decreases if the temperature is increased further. Except for the difference of wavelengths, heat waves are identical to light waves and because of consisting of longer wavelengths by heat waves, so that these are not viewed/recognized by the eye retina. As long as we are interested in light waves, the energy of heat waves is treated as waste.

Illumination:

Illumination is illustrated as the fraction of light energy (ε) incident onto a given unit surface area per unit time. This definition is mathematically represented as

$$\varepsilon = \frac{Icos\alpha}{d^2}$$

Where "*ε*" is the light energy (illumination) in lumens (L)/mm^2.

"I_s" is intensity of source in candlepower

"α" is the angle making between light rays of source and a unit vector normal to an illuminated surface.

"d" is the distance (in mm) from the source to the illuminated surface.

The process of illumination and luminance is shown in Figure 3.6.

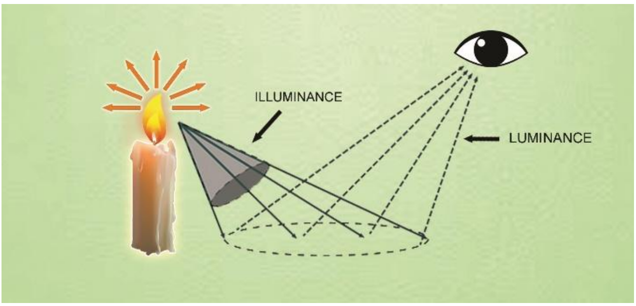


Figure 3.6: Illumination and luminance

Radiant efficiency (Light efficiency):

We are interested in only light rays/waves coming out of the body as far as luminance is concerned, so that we have to know that what is the fraction of light is being radiated out of the total radiations (consisting of heat radiation) emitted by a body kept at a certain temperature. Radiant efficiency is defined as

$$Radiant\ efficiency = \frac{the\ amount\ of\ radiation\ emitted\ in\ the\ form\ of\ light}{the\ total\ radiations\ emitted\ by\ the\ hot\ body}$$

There are certain terms required to understand the illumination and luminance properties which are summarized as below

Candela	Candela is SI unit of intensity of luminous, described as light rays emitted per unit area per second in a particular direction in space. It is defined as 1/60th of the luminous intensity per cm^2 of a black body radiator at the temperature of solidification of platinum (2045°K).
Luminous Flux (F):	It is the light energy radiated out per second from the body in the form of luminous light waves. It represents the rate of flow of energy. Lumen (lm) is the unit of luminous flux. It shows the amount luminous flux contained per unit solid angle of a source of one candela (Fig. 3.6(a))

Luminous Intensity(I):	It is defined as the amount of luminous flux emitted by a source into a particular solid angle in particular direction. If $d\phi$ is the amount of luminous flux emitted by a source and $d\omega$ is the solid angle through which flux is ejected out, then the Luminous Intensity (I) is defined as, $I = \frac{d\phi}{d\omega}$ (lumen/steradian) 1 lumen/steradian (lm/sr) = candela (cd).

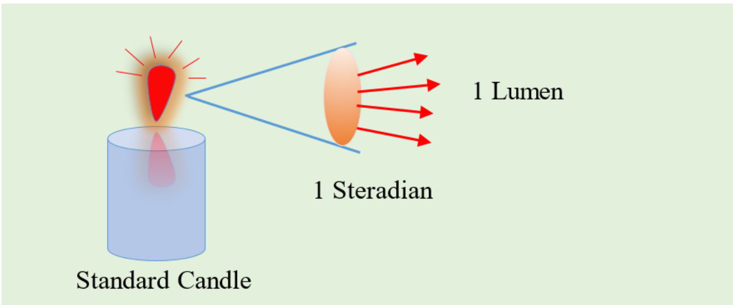


Figure 3.6 (a): Luminous flux

3.7. Electrical Bulbs

A device, which produces light when current passes through a certain material having a particular high resistance is called an Electric bulb/light. The material through which current passes is known as filament. Usually, tungsten filament is used in electric bulbs due to the fact that it has a high melting point and a high electric resistance. As current flows through this high resistance filament, which becomes hot and glows as white color brightness leading to emit light, which enables us to view objects.

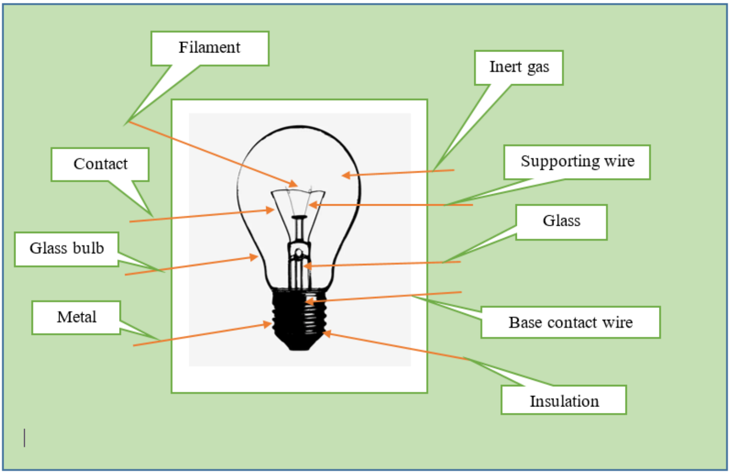
We know that filament is at high temperature after a certain amount of current passes through it. At this high temperature filament, if oxygen is present then it leads to combustion of filament and consequently it emits no light. In order to prevent this combustion, filament is usually placed in a vacuumed enclosure made up of glass casing. This glass casing consisting of the filament is filled with inert gases to prevent any further combustion. The typical electrical bulb is shown in Figure 3.7. The electrical bulb is contains several parts, which are

- Tungsten filament
- Glass bulb

- Inert gas
- Contact wires
- Supporting wires
- Glass mounting arrangement
- Base contact wire
- Metal
- Insulation
- Screw threads

There are three main distinct types of electrical light sources, which are

- ❖ Incandescent light source
- ❖ Fluorescent light source
- ❖ Light Emitting Diode (LED) light source



Source: (shorturl.at/jxYZ8)

Figure 3.7: Components of light bulb

Incandescent light source is one which produces light via the process of heating filament by passing electric current through it as discussed above.

Fluorescent light sources are those, which are working on the principle of fluorescence. Fluorescence is defined as emission of light ray (secondary light ray) when light ray (primary light ray) incident on substance of any state.

Light emitting diode (LED) produces light through the process of electron-hole recombination process. In LEDs, usually direct band gap compound semiconductors like GaAs, GaN, InGaAs, CdS, ZnS, PbS and CdTe are used.

3.8. Compact Fluorescent Light (CFL)

CFL's are those, which are working on the principle of fluorescence. Fluorescence is defined as emission of light ray (secondary light ray) when light ray (primary light ray) incident on substance of any state.

The CFL's are filled with mercury vapour/gas. When current passes through mercury vapour, then the electrons in mercury go to excited states. As we know that life-time of electron in an excited state is 10^{-8} sec, so that the electron comes back to the ground state by emitting light. The emitted light is in the region of ultra-violet (UV). In addition to mercury vapor, phosphor is coated inside CFL tube. As UV light is not recognized by the human eye, hence these UV light rays are allowed to fall in phosphor coating, then electrons in phosphor are excited and during the de-excitation process, emission of visible light takes place. This secondary emission of light is called as fluorescence. Hence, the whole process is taking place in compact enclosure. Therefore, it is known as Compact Fluorescent Light (CFL). Figure 3.6.2 shows various types of CFL bulbs.

(shorturl.at/br015) (shorturl.at/ciq35) (shorturl.at/brv57)

Figure 3.8: Various types of Compact Fluorescent Light bulbs

When compared to incandescent bulbs, CFL bulbs consume less power, they save electricity. During the process of converting input power into visible light, tungsten filament bulbs convert only 5 percent of its input power, whereas CFL bulbs convert 22 percent to visible light. Hence, CFL bulbs are more luminous than incandescent light bulbs. These bulbs are contributing to very less greenhouse gases emission due to the reason that they use less amount of mercury.

3.9. Light Emitting Diode (LED)

LED works in a similar way as that of p-n junction diode and produces light through the process of electron-hole recombination process. If we consider a normal p-n junction diode under no external voltage condition, a depletion region is formed due to recombination of electrons and holes from n-type semiconductor and p-type semiconductor respectively. In forward bias condition, electrons from n-side and hole from p-side move towards junction resulting in reducing the depletion region and as a result of this depletion region becomes thin. As increasing voltage in forward bias, charge carriers i.e., electrons will cross the barrier (depletion region) to move from hole to hole to constitute an electrical current.

Choosing a suitable semiconductor is very important for fabrication of a LED. Semiconductors can be classified into direct and indirect band gap semiconductors. During the electron-hole recombination process in the indirect band gap semiconductors (Ex. Si and Ge), heat energy is released and hence, these will not be used in production of light through LEDs.

We can convert an indirect band gap semiconductor into direct band gap by adding suitable materials (doping elements). LED emits light on the basis adding suitable doping materials. Usually, compound semiconducting materials such as GaAs, GaN, InGaN, SiC,..etc. are direct band gap semiconductors. When any of these are used as diodes and it is in forward bias condition, then electrons cross the depletion region and join with a hole (recombination process). During this process, the electron comes down to a lower energy state via emission of light as the photon. Photon is quantization of electromagnetic radiation/light. The wavelength/color of the emitted light/photon depends on the band gap of a semiconductor used when the diode is in forward bias condition. Further, this band gap depends upon the type of direct band gap semiconductor used. Figure 3.9 shows the working of LEDs.

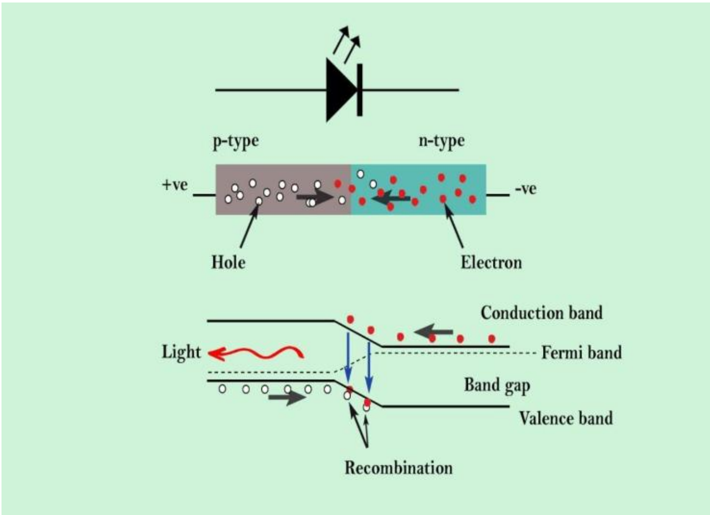


Figure 3.9: Working of LED

An LED with SiC generates a light which has the color of blue. A LED with GaAs emits light which is having the wavelength of infra-red color. Similarly, we can produce different types of colors of lights with the aid of different types of direct band gap compound semiconducting materials. Table 3.9 shows a list of

LEDs with different types of semiconductors and the colors produced by them.

Table 3.9: List of semiconductors and the colors emitted by respective LEDs

S. No.	Semiconductors	Color emitted by LED
1.	GaAs	Infra-red
2.	SiC	Blue
3.	ZnSe	Blue
4.	InGaN	Bluish geen, blue, near ultraviolet
5.	GaN	Green, emerald green
6.	GaP	Red, yellow, green
7.	GaAsP	Red, orange, red and yellow
8.	AlN	Near to far ultraviolet
9.	AlGaN	Near to far ultraviolet
10.	AlGaInP	Bright orange red, orange, yellow.
11.	AlGaP	Green
12.	AlGaAs	Red and infra-red

LEDs have several applications which include

- LEDs are used in different types of displays
- Used as photo sensors
- Due to their high switching rates, LEDs are used in communication technology
- Used in general lighting
- Used in Traffic signals
- Used in Medicine
- Used in smartphone and TV displays

❖ For more information related to concept of illumination, electric bulbs, CFL's and LED's can be found in following link or QR code https://drive.google.com/drive/u/1/folders/1MITvp95bXYBfLkboo1fdHb-apsuTOKpl

3.10 Energy Efficiency In Electrical Appliances

When you go to an electrical shop to buy any electrical appliance (fan, bulb, mixer, fridge, washing machine, air cooler, AC, Geyser, TV, electrical vehicles, and electrical cars etc.), we generally compare the cost and benefits. But we might forget to compare energy efficiency of the appliances which saves energy, environment and money. If you investigate money on more energy efficient appliances, you will be getting benefited in saving current bill as well as our environment. So in this section, we learn about the Energy efficiency of electrical appliances: Definition, energy efficiency awareness of various appliances and benefits of using energy efficient appliances.

Definition:

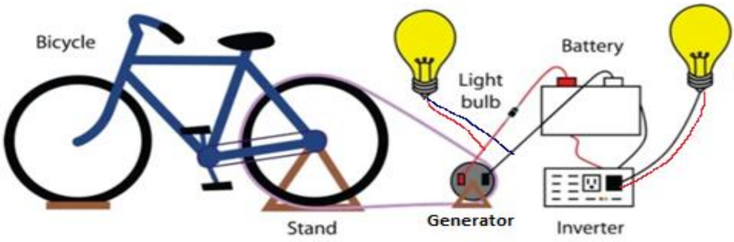
The efficiency of a system in electronics and electrical engineering is defined as useful power output divided by the total electrical power consumed (a fractional expression), typically denoted by the Greek small letter ‘η’

$$\eta = \frac{Useful\ Power\ output}{Total\ Power\ consumed}$$

In general efficiency has no units if both i/p and o/p are having units same.

Commonly, efficiencies are expressed as percentages, the right-hand side of the expressions being multiplied by 100.For example, the energy efficiency of a light bulb that gives of 40J of light from 200J of electrical Energy is $\eta = \frac{40\ J}{200\ J} = 0.2\ ie\ 20\%$. The efficiency of an amplifier that gives 10 watts of power to its speaker by drawing 20 watts of power from a source is $\eta = \frac{10\ W}{20W} =$ 0.5 ie 50%....

Let us take another example for comparison,



In this figure, we observe that mechanical energy through pedals is converted into rotational energy which turns the shaft of Generator. Generator converts shaft rotational energy into electrical energy. Part of this electrical energy can glow a bulb and excess energy can be stored in the battery. Now this DC is converted in to AC by Inverter which glows another bulb

The first bulb is more efficient than the second bulb, because its efficiency depends only on the generator Where as the second one's efficiency depends on both inverter and battery efficiency

Generally the efficiency of appliances like Refrigerator, Air Conditioner, Geyser , some domestic fans, Televisions can be showed by **energy efficiency labels** as shown

Fig :1 Labels on Refrigerator and Ac showing Energy rating [Source :https://rb.gy/py4n7l]

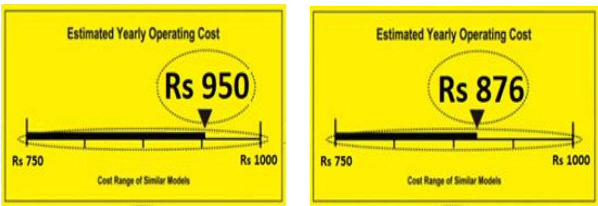


Fig :2 Labels on Televisions showing operating cost that gives efficiency indirectly(USA)

In these labels, they have given star rating and estimated yearly operating cost. This cost can be calculated as follows

Suppose the power rating of a 30 inches LED TV is 50 W and the average operating time per day is 5 hrs. So total energy consumption (Energy = Power*time) in a day is $50 \times 5 = 250\, WH = 0.25\, KWH.$ Hence yearly consumption is $365 \times 0.25 = 91.25$ KWH. Hence Estimated yearly cost is 91.25 X 2.6 = 237 Rs. This is what you might pay to run the appliance LED TV for a year. If we do similar calculations for Plasma TV of same size for same time period of usage, the pay for a year is (150 X 5 X 365 X 2.6)/ 1000 = 712 Rs. Less pay - less energy consumption - more efficiency. This cost appears on labels for almost all models and brands. So you can easily compare energy efficiency just like you would price or other features.

[Note : 1Unit of electricity is equal to 1Kilo watt hour.ie an amount of power required to use an appliance of 1000 watt power rating for an hour. The unit cost is around 2.6 Rs (for 50 to 75 slab)]

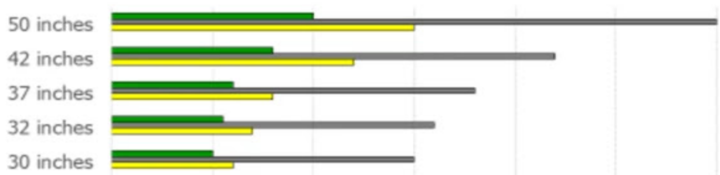


Fig 3: Input power consumption itself more and output(Quality) is less. So overall efficiency is less for Plasma and more for LED[Source: https://rb.gy/rr3inx] Yellow – LCD , Green- LED, Brown - Plasma

Conservation and efficient use of energy in India:

To increase the conservation and energy efficiency in India, the Government of India started an agency 'The Bureau of Energy Efficiency (BEE)' on **1st March 2002** under the Energy Conservation Act, 2001.In 2010, the government proposed that it is mandatory for certain appliances to be with energy rating by the BEE. The mission of BEE is to institutionalize energy efficiency services, enable delivery mechanisms in the country and provide leadership

The energy efficiency labels are issued by the Energy Commission to manufacturers of electrical appliances who comply with the standards and requirements of energy performance tests. Energy efficiency label shows us the estimated energy consumption of an electrical equipment based on a star rating system- 5 star means the most efficient, 1 star means least efficient. But in some appliances like TV, advanced technology needs higher power consumption.

In these cases where the technology is a priority the star rating may not be helpable.

In fig.1, we note that ISEER(Indian seasonal Energy Efficiency ratio) instead of BEE on some appliances like air conditioners whose power consumption depends on seasons. ISEER allows manufacturers to make more efficient air conditioners for the Indian climate conditions.

Appliances like bulbs, fans, TVs, fridges, Coolers, AC, and water heaters contribute about 50-55% of the total residential electricity consumption in India. Replacing traditional bulbs with a fluorescent or LED becomes a step towards energy efficiency.

Ceiling fans have a very high usage of 10-20 hours per day and cumulatively all fans can contribute up to 4-5 units per day in a household. Refrigerators and water heaters again can contribute up to 3-4 units per day in any house. Hence searching more efficient ones for such appliances make a lot of benefit.

Benefits of Energy Efficient Appliances

- Direct benefits are energy savings, money savings and Environmentally Friendly
- Minimizes the usage of natural resources, such as natural gas, oil, coal, and water.
- Controlling the pollution and achieving international goals for reduction of greenhouse emissions, fossil fuel usage, grid load strain, and a wide range of other benefits.

Energy efficiency awareness of various appliances:

How can an electrical appliance be more energy efficient? The voltage and current drawn from input source (power plug) is different for different appliances. Conversion of that drawn power in to useful power/output is mainly depends on two factors

- Working parts of appliances
- Proper utilization of Electrical energy manually

Here are some working parts of various electrical appliances that play a role in improving energy efficiency.

- **Fan:** Good condition of Ball bearings, blades should be in proper alignment, good condition of Capacitor, winding core without eddy losses
- **Water pump:** arresting all leakages in pipeline, conditioning motor bearings, use proper suction and delivery pipes
- **Air Conditioner :** Filters must to be cleaned regularly since the build-up of dust causes air conditioners to consume more energy, Cooling gas should be maintained at proper pressure
- **Inverter battery:** Distilled water level should be maintained, Inverter unit and battery connections should be tight, avoid to use after battery life (battery get charged but won't hold the charge)
- **Electric bike:** Main parts of ebike are battery, motor and wheel. The battery is the most vital part of an ebike. Use the batteries within its lifetime.

The belt/chain connecting motor and wheel should be in proper tension and alignment.

Also, proper utilization of energy with proper awareness leads to minimize the wastage

- **Refrigerators:** Keeping refrigerators a bit away from walls, defrosting freezing compartment before ice buildup become 1/4 inch thick, and avoiding hot foods in refrigerators lead to increase efficiency of a refrigerator
- **Heating appliances:** Heating loads like electric cookers, ovens, water heaters and iron boxes consume a lot of energy. Ironing in bulk instead of small parts, covering of the lids during cooking, not opening the oven doors until the time set**,** **Switch** OFF the geyser after the use, adjust proper setting of thermostat as per the required hot water **etc.**
- Air conditioners consume more energy when doors and windows are not properly closed or left open. Avoid simultaneous running of fan and AC in

room. Use daylight instead of electric bulbs. Replace traditional bulbs with a fluorescent or LED

- Nowadays lots of new appliances use the inverter technology to reduce power consumption.
- Mobile and laptop battery life depends on the number of charge and discharge cycles. So, avoid more plug ins and plug outs. Unplug electronics when not used. Avoid keeping electronic equipment on standby for long periods
- Creating an awareness program in educational institutions among students and staff makes the country free from lot of energy wastage. More energy is saved if the lights, fans and Ac etc. in classrooms and offices are switched off when they are empty

Skill learned

- The method of calculating energy efficiency is very much useful in harvesting many small businesses
- Can be able to adopt energy-efficient technology to get innovative profits

- Behavioral changes in energy usage amongst students will eventually affect energy use in homes, offices, and industries
- You also do research on how to increase energy efficiency using technology
- Also, for a business owner/individual, he needs to monitor, assess the energy expenses over time. The first step is in improving business's energy efficiency is to track overall energy usage. Next identify the devices and appliances that are contributing more to energy consumption. So, understanding of how energy is used can help him to improve efficiency.

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➢ For appliance calculator

https://bit.ly/3UbwzeB

➢ Energy efficiency awareness and preparedness in students.
https://bit.ly/3QwRdD6

➢ For CCE LMS(Notes,Self Assessments,video class,additional info)

https://bit.ly/3qzmbQ9

3.11 IS & IE Codes:

Indian Standard Codes

Electrical engineers and other professionals get exposed to electricity indirectly when they generate, install and transport it. In such areas, we should follow accurate safety methods, and some codes and code of conduct should be followed to avoid electrical accidents. Hence BIS has given standard codes for the promotion of safe and right usage of appliances. These are called Indian Standard codes. Main principle of IS codes is to get easy access, adaptability with simple technology and making environment green. Not only in electrical industries, BIS formulated the codes in all types of divisions like food industry, constructions, IT sector etc.

These codes are written by experts and are revised from time to time to bring them in line with current trends and research. Generally, these codes are written in the form of section number which made the code **unique** by prefixing with the corresponding title number and its parts

Example: There are many codes under the IS title 'Safety of household and similar electrical appliances' with different parts and sections

- IS 302 (Part 1): 2008 Reaffirmed In : 2016 (Active):Safety of household and similar electrical appliances: **Part 1 general requirements**

- IS 302 (Part 2/Sec 2): 1997 Reaffirmed In: 2019 (Active) - Safety of household and similar electrical appliances: **Part 2 particular requirements**: **Sec 2** vacuum cleaners and water suction cleaning appliances

- IS 302 (Part 2/Sec 3): 2007 Reaffirmed In : 2017 (Active): Safety of household and similar electrical appliances: Part 2 particular requirements: **Sec 3** electric iron (First Revision) etc

Also, some Codes are in Active and some others are withdrawn like

- IS 302 (Part 2/**Sec 205**): 1994 Reaffirmed In : 2009 (Withdrawn) :Safety of household and similar electrical appliances: Part 2 Particular requirements, Sec 205 Steam irons

Generally Indian standard codes have the following basic detailed information

- **IS number**
- **IS title**
- **Language**: The text on code representation is in English, Hindi or local language
- **Reaffirmation year**: The standard has been reapproved or reviewed periodically and says the document is still valid to use just as it is. If the review indicates that changes are needed, it is taken up for the revisions
- **Amendments:** Amendments are minor changes which are issued to the standards as the need arises based on comments
- **Technical departments and technical committees**:

Various departments and committees are

- ✓ Electro Technical Department (ETD),
- ✓ Transport Engineering Department (TED),

Aspects: Different aspects of standards are

- ✓ Code of conduct,
- ✓ Methods of tests,

- ✓ Product specifications
- ✓ Safety standards etc.

- **Degree of equivalence**: Most of the codes are Indigenous. Some International standards were adopted by the Bureau of Indian Standards on the recommendation of a technical committee. Hence the degree of equivalence of IS code with other codes should be given in basic details
- Ex: we can see basic details of IS number 2551 for Danger notice plates at high voltages

Basic Details

IS Number	:	IS 2551 : 1982 Reaffirmed In : 2020
IS Title	:	Danger notice plates (First Revision)
Degree of Equivalence	:	Indigenous
Number of Revisions	:	1
Number of Amendments	:	No amendment issued
Aspect	:	Product Specification
Language	:	English
Reaffirmation Year	:	March, 2015
Technical Department	:	ETD (Electrotechnical Department)
Technical Committee	:	ETD 20 (Electrical Installation Sectional Committee)
Member Secretary	:	RITWIK ANAND (SCIENTIST-D)

IS Codes of some House hold Appliances

Item	IS number	Item	IS number
Fluorescent Tube lights	IS 2418 (Part-1)	Water Heater	IS 8978
Table fan	IS 555	Electrical Iron Box	IS 6290
Pedestal fan	IS 1169	Refrigerators	IS 1476
Exhausted fan	IS 2312	Electric stove	IS 2994
Electronic Fan regulators	IS 11037	Desert Coolers	IS 3315
Ceiling fan including regulators	IS 374	Geysers	IS 2082
Food Mixers	IS 4250	Colour TV	IS 10662
Washing Machine	IS 14155	AC	IS 1391

Some other IS Codes of Practice published by BIS are

- IS:1646 It gives code of practice for fire safety during installation of electrical things in building

- IS:1882 Public Address System (PAS) installed at outdoor
- IS:1886 Installation and maintenance of Transformers
- IS:1913 General and safety requirements of electric lighting fittings
- IS:2032 It gives symbols graphically for electrical terminology
- IS 8716 Code of practice for packaging of household electrical appliances

Some Management System Certification related to electrical appliances under Indian Standards are

- ***Quality Management System Certification Scheme IS/ISO 9001***
- Environmental Management System Certification Scheme IS/ISO 14001
- Occupational Health and Safety Management System Certification Scheme IS 18001

- Hazard Analysis and Critical Control Scheme IS 15000
- Service Quality Management System Certification Scheme IS 15700
- Energy Management System Certification Scheme IS/ISO 50001

Advantages:

- These codes provide safety to the structure, make the work for designers very easy and they provide consistency among different designers.
- The codes also provide legal support.
- If a structure fails or collapses due to any external condition, the design codes protect the designer from any liability only if he/she follows the guidelines in the code.
- We can apply for eco mark certification for electrical appliances based on requirements of IS codes

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➔ The Govt.website of BIS where we find the IS codes and their basic details under 'Know your Standard' specification by typing IS code or a keyword https://www.bis.gov.in/

➔ BIS is offering mandatory standards free of cost through authorized BSB(Book Supply Bureau) Edge Private Limited. Users of Indian Standards should be aware of the latest amendments or editions . https://bit.ly/2MYuKQF

➔ For more information on IS codes of electrical appliances https://bit.ly/3DcPzDo

➔ For CCE LMS(Notes,Self Assessments,video class,additional info)https://bit.ly/3DeR7Nt

IE Rules - Indian Electricity Rules:

Indian Electricity Rules are the laws relating to generation, transmission, distribution, trading and use of electricity especially in terms of safety and development of the electricity industry in India . These rules were enacted in 1956 under sections 37 of Indian Electricity Act 1910. But in 2003, to include the participation of the private sector and to make competition, The Electricity Act 2003 was enacted. After enacting this Act, IE was redefined in 2003. Now Central Electricity Authority Regulation (CEAR)- 2010 came into effect after IE rules 1956.

General safety precautions Under Indian electricity rules, 1956:

- All electrical supply lines, apparatus shall be sufficient in power, size and in mechanical strength. They should follow Indian standard codes to prevent danger
- All electrical supply lines and wires etc. should be in a safe condition and well insulated

- The supplier should provide a suitable cut out in each conductor of service line
- Proper identification should be there for earthed and neutral conductors and also for the position of switches and cutouts
- Whenever AC, DC circuits are installed on the same support, they shall be arranged so that they will not come in contact during supply
- Proper caution notices should be affixed On or as near as possible to all motors, generators, Transformers and other electrical plant and equipment and also on all supporters of high and extra high voltage is overhead line

Advantages:

❖ These IE rules promote the competition and help in development of Electricity Industry

❖ Protects interest of consumers and supply of electricity to all areas

❖ Rationalize the electricity tariff

- ❖ Ensures the transparent policies regarding subsidies
- ❖ Promotes an efficient and environmentally harmless policies

These rules covers in totally 11 chapters: Find these chapters in

https://www.dgms.net/IErules1956.pdf

List of some Important IE Rules:

IE Rule 29 : This rule tells about Constructions, Installation, Protection, Operation and Maintenance of Electrical Supply Lines and Apparatus

IE Rule 30 : This rule gives the precautions to be taken to avoid accidents from supply lines, wires, fittings and apparatus on a consumer's premises

IE Rule 31 : Cut-out on consumer premises ie the supplier should provide a proper cut out in each conductor of a service line other than earthed and neutral conductor

IE Rule 32 : It gives the identification of conductors and position of switches and cut-out like

IE Rule 33 : It tells about the earthed terminals on consumer’s premises

IE Rule 34: Accessibility of bare conductors

IE Rule 35 : Danger notices

IE Rule 36 : handling of electric supply lines and apparatus

IE Rule 37 :Supply to vehicles, cranes etc.

IE Rule 38: Cables for portable or transportable apparatus

IE Rule 41: Distinction of different circuits

IE Rule 42: Accidental charges

IE Rule 43: Provision applicable to protective equipment

IE Rule 44: Instruction for restoration of persons suffering from electric shock

IE Rule 45: Precautions to be adopted by consumers, owners, occupiers, electrical contractors,electrical workmen and suppliers

IE Rule 46: Periodical Inspection and testing of consumer's Installation

IE Rule 48 : It gives the rules regarding voltage drop concept

IE Rule 63: Approval of Inspector is necessary before erecting any high voltage installations

IE Rule 65 : Passing of the prescribed testing before emerging the installation

IE Rule 67 : Connection with earth

IE Rule 70 :Condensers

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- https://indiankanoon.org/doc/160042451/ Description to IE rules
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- For CCE LMS https://bit.ly/3DeR7Nt

Learning Management System(LMS)

Notes for Examination,

Video lessons for self learning and

Self assessment

Scan this QR Code

OR Click on the Drive link: https://bit.ly/3xsYFbt

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58.https://electricallive.com/2015/05/electrical-energy.html

Question Bank

Essay answer type

1. Explain the instrumentation, working principle and servicing of an electric fan.
2. Discuss the principle, components and working of an electric iron box.
3. Describe the working and parts of electric water heater.
4. Describe the principle and working Refrigerator.
5. Discuss the concept of illumination and explain about the working of electric bulbs.
6. What is a light emitting diode? Discuss about its working
7. Define electrical energy efficiency with example. Discuss the various ways of increasing energy efficiency of electrical appliances.
8. Discuss about Indian Standard codes and explain the terminology in the codes.

Short answer type

1. Explain the principle and working of Induction heater
2. Explain the working principle of Microwave Oven
3. Discuss about the working of compact fluorescent lamps.
4. List out any five examples for compound semiconductors used as light emitting diodes.
5. Explain the working of LED bulb
6. Briefly explain Indian Electricity Rules with two examples

Electrical Appliances

CO - CURRICULAR ACTIVITIES

Activity - 1: Calculation of Power dissipation when bulbs connected in series and parallel combination

Activity - 2: Ohm's law - calculation of parameters in combinational DC circuit

Activity - 3: Find the Phase, Neutral and Earth points in power socket

Activity - 4: Test the condition of UPS Battery using Hydrometer.

Co - Curricular Activity - 1:

Studying of electrical performance and power consumption of a given number of bulbs connected in series and parallel combination

Apparatus: Bulbs of different rating 40W,220V and 60W,220V, Connecting wires.

Formula:

Power dissipated in heating filament $P = \frac{V^2}{R}$

Where

V = Voltage

R = Resistance

Observation: More power dissipated = More brightness of bulb

Hence find resistance of each bulb using given rating

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

For Bulb 1 40W, 220V $R_{40} = (220)^2/40 = 1210\ \Omega$

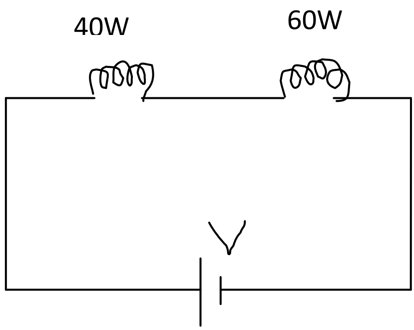
For Bulb 2 60W, 220V $R_{60} = (220)^2/60 = 806.6\ \Omega$

In series Combination:

Voltage is different and Current is same

Power dissipated $P = I^2R$

Power dissipated is directly proportional to resistance of the Bulb. That means the bulb which has more resistance dissipates more power and glows brighter in series combination.

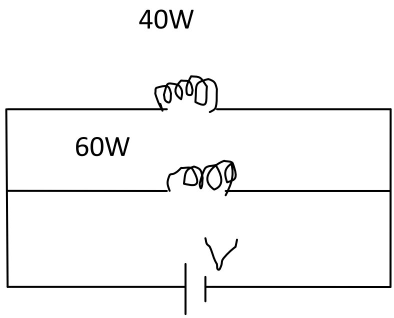


$R_{40} > R_{60} \longrightarrow P_{40} > P_{60}$

Hence 40W bulb has more brightness.

In Parallel Combination:

Voltage is same and Current is different



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

Power dissipated is inversely proportional to resistance of the Bulb. That means the bulb which has less resistance dissipates more power and glows brighter in parallel combination.

$R_{40} > R_{60} \longrightarrow P_{40} < P_{60}$

Hence 60W bulb has more brightness.

ACTIVITY:

Calculate the Resistance and Power Dissipation of Three bulbs connected in the Series and the Parallel Combination and also find which bulb is the brightest of the three in the Series and the Parallel Combination.

DO IT YOURSELF: Draw the circuit diagrams of series and parallel combination. Calculate the resistance of three bulbs

Bulb 1 - 100W, 220V

Bulb 2 - 50W, 220V

Bulb 3 - 40W, 220V

R_{100} = $(220)^2/100$ = ... Ω

R_{50} = $(220)^2/50$ = ... Ω

R_{40} = $(220)^2/40$ = ... Ω

In Series Combination:

Voltage is different and Current is same

Power dissipated $P = I^2R$

Which bulb has more glowness?

Ans...

In Parallel Combination:

Voltage is same and Current is different

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

Which bulb has more glowness?

Ans...

Observations:

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Co-Curricular Activity - 2:

Measuring the parameters in combinational DC Circuits by applying Ohm's law for different resistors and voltage sources.

Apparatus: Voltage Source, Resistors, Voltmeter, Ammeter

Formula:

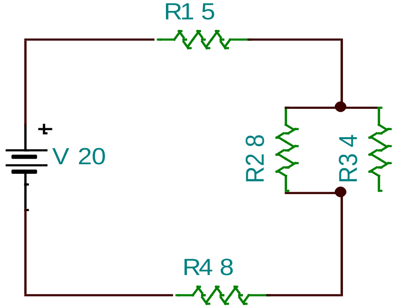
Ohm's law V = I R

where V = Voltage in Volt

I = Current in ampere

R = Resistance in ohm

Circuit diagram:



Calculations:

In the given circuit V = 20V

$R_1 = 5\ \Omega$, $R_2 = 8\ \Omega$, $R_3 = 4\ \Omega$, $R_4 = 8\ \Omega$

Here R_2 and R_3 are in parallel hence the resultant of R_2 and R_3 is equal to $\frac{R_2 R_3}{R_2 + R_3} = 2.7\ \Omega$

Now the resistances 5,2.7,8 are in series hence the total resistance in the circuit is

$R_T = 15.7\ \Omega$

Total Current $I_T = V/R_T$

$= 20/15.7 = 1.27$ A

ACTIVITY:

Calculate the following parameters in the circuit using Ohm's law

Current through R_1 = ...A

Current through R_2 = ...A

Current through R_3 = ...A

Current through R_4 = ...A

Voltage across R_1 = ...V

Voltage across R_2 = ...V

Voltage across R_3 = ...V

Voltage across R_4 = ...V

Comment your

observations..

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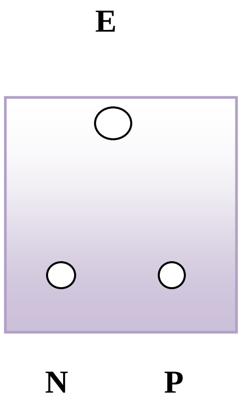
Co - Curricular Activity - 3:

Identifying Phase, Neutral and Earth on Power sockets

It can be done in two ways.

1. By using Multimeter

2. By using 100W Bulb with plug.



Using Multimeter:

1. SET Multimeter in Voltage AC

2. Now insert Red probe in Phase pin

Black probe in Neutral pin

Measure the voltage by switch ON it should be around 220Volts.

Observation: **Voltage is optimum**

3. Now insert Red probe in Phase pin

Black probe in Earthing pin

Measure the voltage by switch ON it should be around 220 Volts

Observation: **House has Earth connection. If voltage shows ZERO then NO EARTHING.**

4. Now insert Red Probe in Neutral pin

Black Probe in Earth pin

Measure the Voltage by switch ON it should be Zero volts.

Observation: **If Voltage is ZERO then there is proper Earthing in the House.**

If Voltage is not ZERO there is problem in Earthing connection.

By using 100W Bulb:

DO IT YOUR SELF

1. If the Bulb is connected to Phase - Neutral pins

Observation: **Bulb Glows or NOT**

2. If the Bulb is connected to Phase - Earth pins

Observation: **Bulb Glows or NOT**

3. If the Bulb is connected to Neutral - Earth pins

Observation: **Bulb Glows or NOT**

What are the conclusions you have drawn from the above observations

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Safety Precaution: The above experiment must be done under parental control or with help of your Teacher.

Co - Curricular Activity - 4:

Checking the Specific Gravity of lead acid batteries in home UPS

Apparatus: Hydrometer, Home UPS Battery

Hydrometer consists of Glass tube, Float, Rubber tube and Rubber Bulb.

The Float will find the pH value of the electrolyte like Sulphuric acid present in the batteries.

By using this we can find the condition of the Batteries.

Activity:

1. Open the caps of the Battery and insert the Hydrometer into it and drag the acid.

Observation	Condition of Battery
Float did not rise to even RED point	Battery is dead - Not able to store any charge
Float rises upto YELLOW point	Battery is Working - Fully charged.

The percentage of Charge is identified by the Specific gravity value of the electrolyte given in the table

Charge	Specific Gravity
100%	1.255 - 1.275
75%	1.215 - 1.235
50%	1.180 - 1.200
25%	1.155 - 1.165
0%	1.110 - 1.130

Now it's your turn Check the condition of home UPS Battery and find the Specific gravity of electrolyte.

Comment Your observations:...

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