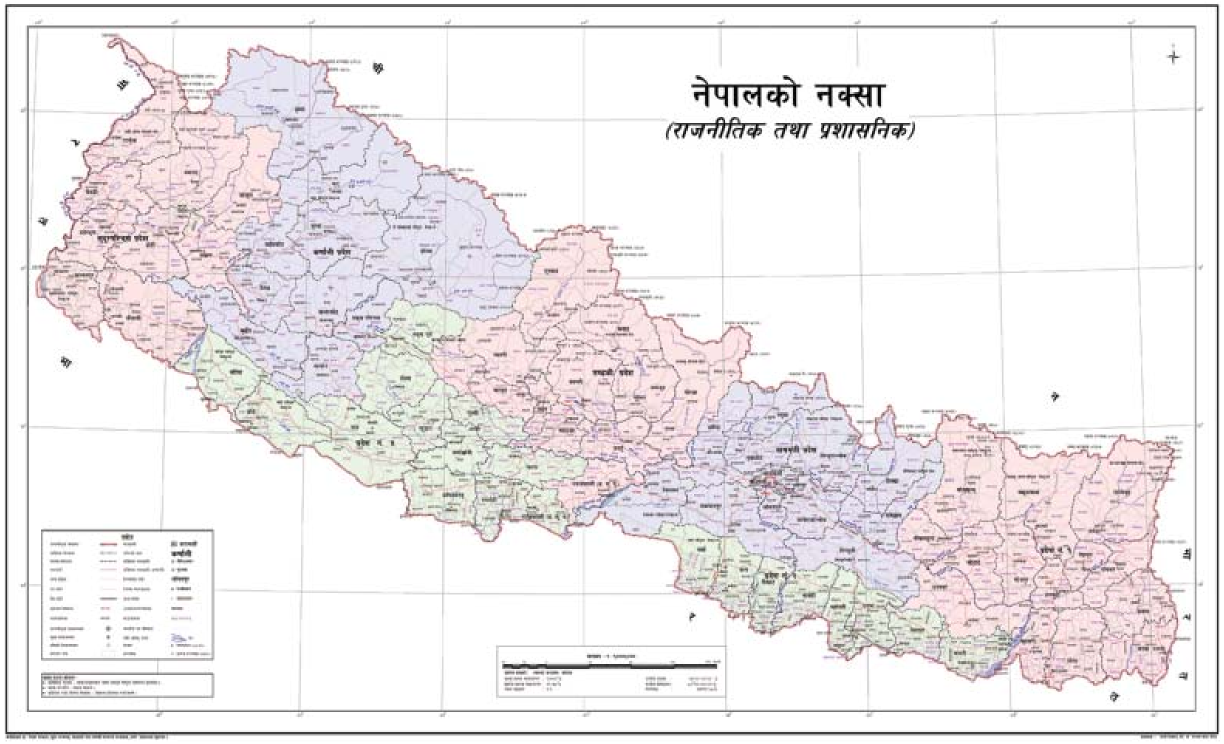
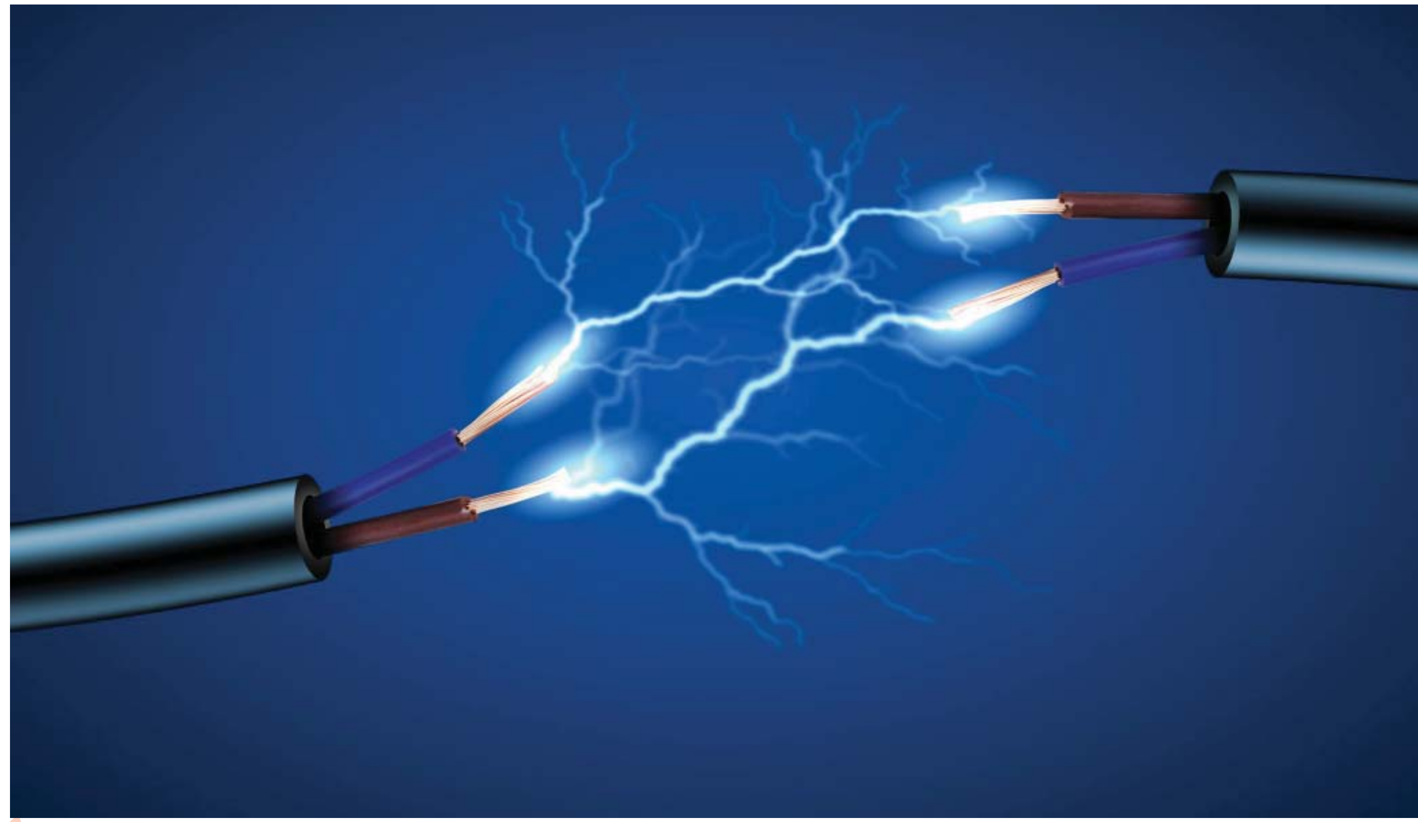


Government of Nepal
Ministry of Education, Science and Technology
Curriculum Development Centre
Sanothimi, Bhaktapur
Phone : 5639122/6634373/6635046/6630088
Website : www.moecdc.gov.np

Electrical Engineering



9

Feedback Copy

Technical and Vocational Stream
Learning Resource Material

Electrical Engineering
(Grade 9)

Secondary Level
Electrical Engineering

Government of Nepal
Ministry of Education, Science and Technology
Curriculum Development Centre
Sanothimi, Bhaktapur

Publisher : Government of Nepal
Ministry of Education, Science and Technology
Curriculum Development Centre
Sanothimi, Bhaktapur

Layout by Khados Sunuwar

Preface

The curriculum and curricular materials have been developed and revised on a regular basis with the aim of making education objective-oriented, practical, relevant and job oriented. It is necessary to instill the feelings of nationalism, national integrity and democratic spirit in students and equip them with morality, discipline and self-reliance, creativity and thoughtfulness. It is essential to develop in them the linguistic and mathematical skills, knowledge of science, information and communication technology, environment, health and population and life skills. it is also necessary to bring in them the feeling of preserving and promoting arts and aesthetics, humanistic norms, values and ideals. It has become the need of the present time to make them aware of respect for ethnicity, gender, disabilities, languages, religions, cultures, regional diversity, human rights and social values so as to make them capable of playing the role of responsible citizens with applied technical and vocational knowledge and skills. This Learning Resource Material for Electrical Engineering has been developed in line with the Secondary Level Electrical Engineering Curriculum with an aim to facilitate the students in their study and learning on the subject by incorporating the recommendations and feedback obtained from various schools, workshops and seminars, interaction programs attended by teachers, students and parents.

In bringing out the learning resource material in this form, the contribution of the Director General of CDC Dr. Lekhnath Poudel, Dr. Tankanath Sharma, Govinda Poudel, Sanju Shrestha, Suraj Dahal, Shisir Dahal, Shivaram Shrestha is highly acknowledged. The book is written by Rupesh Maharjan, Abin Maharjan and the subject matter of the book was edited by Badrinath Timalsina and Khilanath Dhamala. CDC extends sincere thanks to all those who have contributed in developing this book in this form.

This book is a supplimentary learning resource material for students and teachrs. In addition they have to make use of other relevnt materials to ensure all the learning outcomes set in the curriculum. The teachers, students and all other stakeholders are expected to make constructive comments and suggestions to make it a more useful learning resource material.

2076 BS

Ministry of Education, Science and Technology
Curriculum Development Centre

Table of Contents

UNIT-I

Electrostatics

Learning Outcomes

After completion of this chapter, the students will be able to

i) Know about the concept of charge
ii) Production of charge
iii) Force between two charges

Static Electricity:

Electrostatics is the branch of science that deals with the phenomena of electricity at rest.

The Greek philosopher Thales found that when a yellow fossilized resin (amber) is rubbed against wool, it develops ability to attract lighter objects like small pieces of paper. Later, Dr, Gilbert showed that many kinds of materials such as glass, plastic, nylon etc. behave also like amber. These substances can attract the lighter objects when rubbed with suitable materials. These were called electrics. In Greek the word 'electron' is for amber. So the word electricity has been derived from the word 'electron'.

Method of Electrification

When a plastic comb is brought near to the pieces of paper, it does not attract the papers. But when it is brought nearer after rubbing or combing the hair, it attracts the paper. Similarly when a glass rod rubbed with silk cloth is brought nearer to the pieces of paper, the glass rod will also attracts the pieces of paper. From these it can be said that the attracting capacity is developed on the body due to friction.

When the body produces a charge on it, it is said to be electrically charged or electrified. The process of producing the charge on a body is called electrification. Sometimes, a crackling sound is heard in the electrification caused by friction. It can be felt when we take out sweater in dark room. These crackling sounds are due to the electric sparks.

Note: *Charge is produced on a body due to movement of electrons from one to another. It is denoted by 'Q' and measured in terms of Coulombs (C).*

Some other smaller units of charge can be shown as,

1 micro coulombs (mC) = $\frac{1}{1000}$ C = 10^{-3} C

1micro coulombs (μ C) = $\frac{1}{1000000}$ C = 10^{-6} C

1 nano coulombs (nC) = $\frac{1}{10^9}$ C = 10^{-9} C

1 pico coulombs (pC) = $\frac{1}{10^{12}}$ C = 10^{-12} C

Negative charge is developed, when an atom or a substance gains or takes the electron.

Positive charge is developed, when an atom or a substance loses or gives the electros.

Activity:

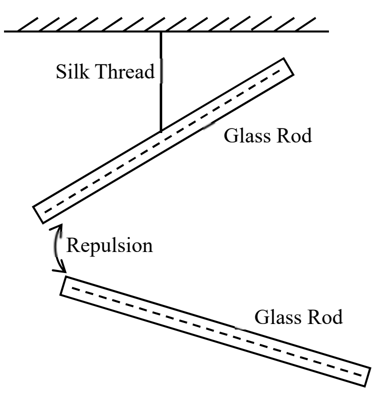


Fig (i)

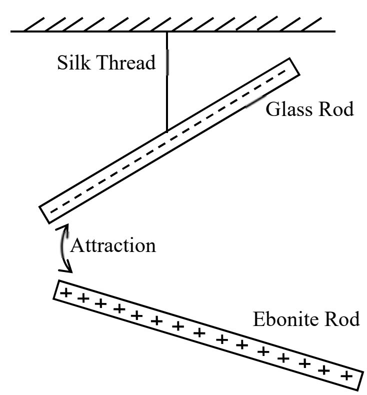


Fig (ii)

In figure (i), a glass rod is rubbed with silk cloth and is hanged with the help of silk thread. When another glass rod again rubbed with silk cloth is brought nearer to it, it is found that they repel each other.

Likewise, in figure (ii), a glass rod is rubbed with silk cloth and is hanged with the help of silk thread. Instead as in figure (i), when an ebonite rod rubbed with fur is brought nearer to the glass rod, it is found that the two glass rods attract each other.

From the above activity, it is cleared that same charges (like charges) repel each other and opposite charges (unlike charges) attract each other.

Modern theory of electrification

Matter is composed of very smallest particle called atoms, which can further be classified into electrons, protons and neutrons. It consists of central nucleus which contains protons and neutrons and a suitable number of electrons revolving around the nucleus.

Sub-atomic particles:

Atom is made up of three sub-atomic particles namely electron, proton and neutron.

Sub-atomic particles	Charge	Symbol	Location	Weight
Electron	-ve	e^-	Orbit	1/1837 a.m.u. 9.1×10^{-31} kg
Proton	+ve	p^+	Nucleus	1 a.m.u.
Neutron	No charge	n^o	Nucleus	1 a.m.u.

In general, atoms are electrically neutral due to having the number of equal number of protons and electrons in an atom. But if some electrons are removed or added to an atom, then the number of electrons and protons in that condition becomes unequal.

Thus an atom then develops charge in it. It develops a positive charge on lose of electron and negative charge on gain of electron.

In brief, it can be said that a body develops a positive charge on deficiency of electron and develops a negative charge on excess of electrons in it. And this deficiency or excess of electrons in a body is known as a charge.

Terms related to atom

Atomic number:

The number of protons or number of electrons contained in an atom is known as its atomic number.

i.e Atomic number = No. of protons or No. of electrons contained in an atom

For eg, the number of protons and electrons in oxygen is 8, hence its atomic number is 8.

Atomic Weight:

The sum of total number of protons and number of neutrons contained in an atom is known as its atomic weight.

i.e. Atomic weight = No. of protons + No. of neutrons

For eg, the number of protons and neutrons contained in oxygen is 8 and 8 resp., hence its atomic weight is 16.

Electronic Configuration:

The scientific and systematic arrangement of electrons in different orbits of an atom is known as electronic configuration.

Orbit:

The imaginary path through which the electrons move around the nucleus is known as orbit.

Valence Orbit and Valence Electrons:

The outermost orbit of an atom is known as valence orbit and the total number of electrons contained in the outermost shell or orbit is known as valence electrons. The valence electrons are also called free electrons.

$2n^2$ rule:

The rule to determine the maximum number of electrons that can exist in different orbits of an atom is known as $2n^2$ rule. For eg,

K-shell	n=1	No. of electrons= $2 X 1^2 = 2$
L-shell	n=2	No. of electrons= $2 X 2^2 = 8$
M-shell	n=3	No. of electrons= $2 X 3^2 = 18$
N-shell	n=4	No. of electrons= $2 X 4^2 = 32$

Duplet and Duplet Rule:

The atoms having two electrons in the outermost orbit is known as duplet. For eg, He. And the process of making two electrons in the outermost orbit of an atom by gaining, losing or mutual sharing of electrons is known as duplet rule.

Octet and Octet Rule:

The atoms having eight electrons in the outermost orbit is known as duplet. For eg, Ne, Ar. And the process of making eight electrons in the outermost orbit of an atom by gaining, losing or mutual sharing of electrons is known as octet rule.

And this process of being duplet or octet is the main reason for the atoms to react with each other.

Note: *An atom consists of equal number of protons and electrons in it. So the positive charge of proton is cancelled by negative charge of electrons, hence resulting the net charge to be zero. So the atoms are always electrically neutral or chargeless.*

Electric Current:

All the substances contain electrons which are free to move within the different atoms. When the electrons move from one atom to another, it results in the flow of charge. If there is no voltage applied across the two ends of the conductor, the electrons contained in it will be moving freely within the different atoms in random direction as shown in the figure (1) below, as there is no electric field applied in the conductor. So the electrons won't move in a fixed direction in the conductor.

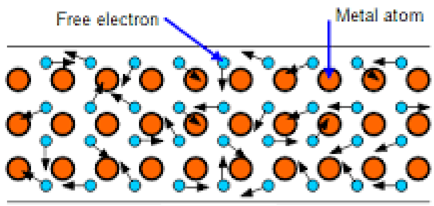


Fig 1

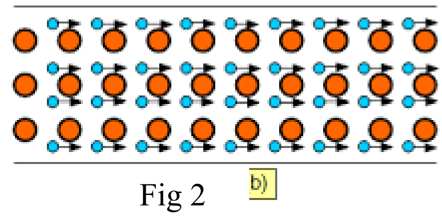


Fig 2

But when the voltage is applied across the ends of the conductor, the electrons will be confined in fixed direction as the electrons will be attracted towards the positive side of the applied voltage as shown in the figure (2) above. As a result there is movement of electrons in a fixed direction.

And this movement of electrons through a conductor along fixed direction results in the electric current. And it can be defined as the rate of flow of electric charge through a conductor.

i.e Electric current = $\frac{Charge}{Time}$

$$= \frac{q}{t} = \frac{C}{s} = Ampere\ (\text{A})$$

Types of electricity:

1. **Static Electricity**
2. **Dynamic Electricity (current electricity)**

When a glass rod is rubbed with silk cloth, the charge is produced in it. Similarly, if an ebonite rod is rubbed with woolen cloth or with fur, it also develops charge in it. These charges developed in glass rod and ebonite rod are termed as static electricity, as the charges produced remains at rest i.e the charges developed do not move. The lightning that we see in the sky during rainy season also involves static electricity.

In current electricity, the electric charges are in motion i.e the charges move from one point to another point in a circuit. Due to this, an electric current is produced. The electricity that we use in our home is an example of current electricity. Similarly, the electricity that is produced due to the different sources in a circuit can also be said as current electricity.

Conductor and Insulator

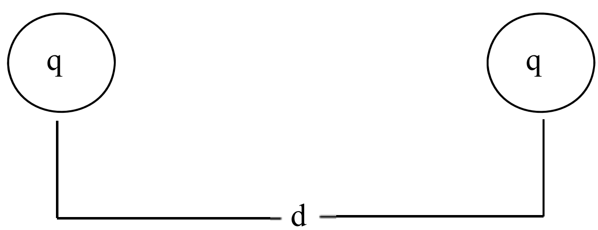
In an atom, electrons revolve around the nucleus within different orbits. There exist an attractive force of attraction between the nucleus and electrons. The electrons closer to the nucleus are strongly attracted by the nucleus. But when the atomic size or distance of electrons form the nucleus increases, the force of attraction goes on decreasing. So the electrons will be less attracted by the nucleus. And these weakly attracted electrons are called free electrons and are responsible for conductor and insulator.

The substances which have larger number of free electrons act as conductor and can conduct heat and electricity easily whereas the substances having very less number of free electrons act as insulator and cannot conduct heat and electricity through them.

Electrical Force:

The force of attraction between any two charges is known as electrical force.

Coulumb's Law:



It states that the force of attraction between any two charges is directly proportional to product of the charges and inversely proportional to square of distance between them.

i.e. $F \alpha\ q_1 q_2$ ……….(i)

$F\ \alpha \frac{1}{d^2}$ ………(ii)

Where F = force of attraction between them

q_1, q_2 = two charges

d = centre to centre distance between two charges

Combining (i) and (ii)

$$F \ \alpha \frac{q_1 q_2}{d^2}$$

$$F = k\frac{q_1 q_2}{d^2}$$

Where k= proportionality constant (Coulumb's constant) whose value is 9 X 10^{19} Nm^2/C^2

Numerical:

1. Two balloons are charged equally with 1 Coulomb of charge. If they are kept at a distance of 1m, find the force of attraction between them.

   Soln,

   Charge of first balloon (q1) = 1C

   Charge of second balloon (q2) = 1C

   Distance (d) = 1m

   Force of attraction (F) = ?

   Now,

   $$F = k\frac{q_1 q_2}{d^2}$$

   $$= 9 \times 10^{19} \times \frac{1 \times 1}{1^2}$$

   $$= 9 \times 10^{19} N$$

2. Two charged objects with charge -6.25 nC each are separated by a distance of 61.7cm. Find the electrical force produced.

   Sol^n,

   Charge of first balloon (q1) = -6.25 nC = -6.25 X 10^{-9} C

   Charge of second balloon (q2) = - 6.25 nC = -6.25 X 10^{-9} C

   Distance (d) = 61.7 cm = 0.617 m

   Force of attraction (F) = ?

   Now,

$$F = k\frac{q_1 q_2}{d^2}$$

$$= 9\times 10^{19} \times \frac{-6.25\times 10^{-19} \times -6.25\times 10^{-19}}{0.617^2}$$

$$= \frac{351.5625\times 10}{0.380689}$$

$$= 9234.9N$$

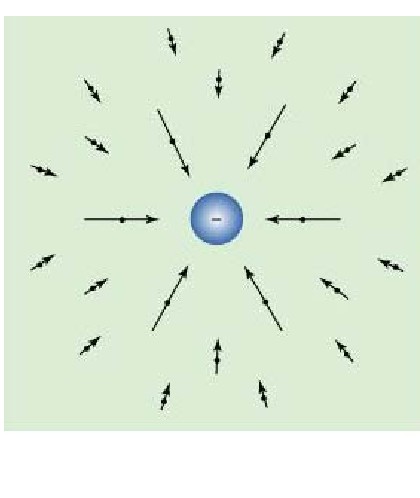
Electric Field:

The area around the charged object up to which it can attract other charged materials or substances is known as electric field of that object. Electric field can also be defined as the electric force per unit charge. The direction of the field is taken to be the direction of the force it would exert on a positive test charge. The electric field is radially outwards from a positive charge and radially in towards a negative point charge.

The magnitude and direction of the electric field are expressed by the value of *E*, called electric field strength or electric field intensity or simply the electric field. The strength of an electric field *E* at any point may be defined as the electric, or Coulomb, force *F* exerted per unit positive electric charge *q* at that point.

i.e.

$$\text{Electric field (Electric force)} = \frac{Force}{Charge} = \frac{F}{q}$$



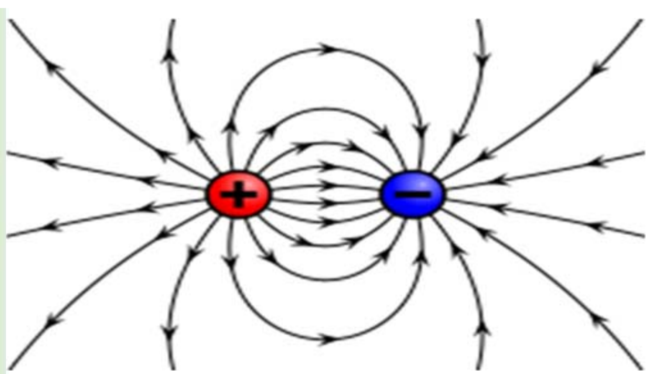


Fig: Electric field for positive and negative charge

Electric Potential:

An electric potential (also called the electric field potential or the electrostatic potential) is the amount of electric potential energy that a unit charge would have at any point in space, and is equal to the work done by an external agent in carrying a unit of positive charge from the arbitrarily chosen reference point (usually infinity) to that point without any acceleration.

Electric Flux:

If there is the production of certain amount of charge in a conducting object by the influence of charged object within its electric field, then it is called electric flux.

When a conducting material is placed in an electric field of a certain charged object, then the charge is produced in conducting material. The total charge produced in conducting material when placed in electric field is known as electric flux. It's SI unit is Coulumb and is represented by 'ψ' (psi).

Electric Flux Density:

The charge inducing capacity of a charged particle on another conducting material within its electric field is known as electric flux density.

It ψ coulomb is produced in an surface area of A m2, then the electric flux density is given by,

$$D = \frac{\psi}{A} C/m^2$$

Permitivity:

The property of medium to focus the electric field is known as permityvity of that medium. It is denoted by ε (Epsilon).

Note Point:

There is certain factor, permittivity of a medium that effects the electric field strength and the electric flux density.

And the relation between them is given by,

$\varepsilon = \frac{D}{E}$ where ε = permittivity of a medium

D = Electric flux density

E = Electric field strength

Tutorials:

1. Two bodies with charges +3.37μC and -8.21μC are being attracted by a force of 0.0626 N,find the distance between two bodies. [Ans:1.994 x 10^5m]
2. Two charges 160μC and -250μC are placed together at a distance of 150cm apart. Find the force of attraction between each other. Also explain the nature of the force.
   [Repulsing force = +ve , Attraction force = -ve]
3. A positive charge of 40μC is placed at a distance of 5cm from a negative charge of 100μC. Find the force of attraction between the two charges. [Ans: $-1.44 \times 10^{14} N$]
4. A flux of 100 μC penetrates vertically through an area of 10mm X 10mm. Find the flux density. [Ans: 1 C/m^2]
5. At a certain point in a medium, the flux density is 0.09 C/m^2 and electric field intensity is 1.2 X 10^9 V/m. Find the relative permittivity of medium. [Ans: 7.5 X 10^{-11}]

Teaching tips / Instruction to the teachers

- Provide the concept of generation of charge
- Explain the concept of Static and current electricity
- Give examples of static electricity.
- Show the movement of electrons in video. (slides) (youtube)

References:

A text book of electrical engineering, B.L Thereja, A.K. Thereja
A handbook of electrical engineering, S.L.Bhatia
A textbook of electrical engineering, J.B.Gupta
Basics on electrical engineering, P.S.Dhogal
www.fixit.com
www.allibaba.com
www.electricalkit.com

UNIT-2

DC Electric circuit

Learning Outcomes

After completion of this chapter, the students will be able to

1) Know about the different types and parameters of circuit.
2) Know about the different types of combinations in circuit.
3) Interpret and analyze the circuit.
4) Know about the laws related to circuit.
5) Calculate the electrical energy consumption.

Introduction

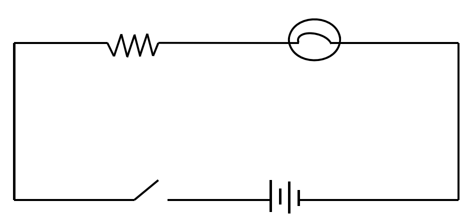
When the different components such as source, bulb, switch, connecting wires etc are joined together in a particular form, the bulb will glow. It is because through these components, we have made a path for the electrons to flow. And this flow of electrons is current. Actually, when the two ends of the cell are joined with various components through connecting wires, it forms a conduction path for the electrons (charge) to flow from one end of the source to another end. This conducting path is known as electric circuit.

Hence, the conducting path made for the flow of electrons when two ends of the cells are joined with the help of connecting materials and electrical components is known as electric circuit.

Types of circuit:

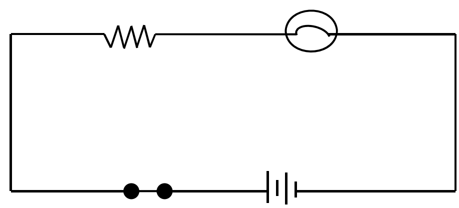
i) Open circuit:

The circuit where there is no flow of current is known as open circuit. There is a gap or discontinuity in the circuit. So the load connected to the circuit won't work.



ii) Closed Circuit:

The circuit where there is flow of electric current is known as closed circuit. There is no gap or discontinuity in the circuit. So the load connected to the circuit will work.



iii) Short Circuit:

Sometimes the two terminals of the source get connected to each other by mistakenly or accidently. Such circuit so formed has very less resistance, so much higher amount of current may flow through it. This may cause damages to the circuit and may cause other electrical hazards as well. Such circuit is known as short circuit.

iv) Series Circuit:

A circuit consisting of components connected only in series is known as a series circuit. In a series circuit, the current through each of the components is the same, and the voltage across the circuit is the sum of the voltages across each component. For a series circuit to be complete, every device or components must function. If one device or component burns out in a series circuit, the whole circuit will stop functioning.

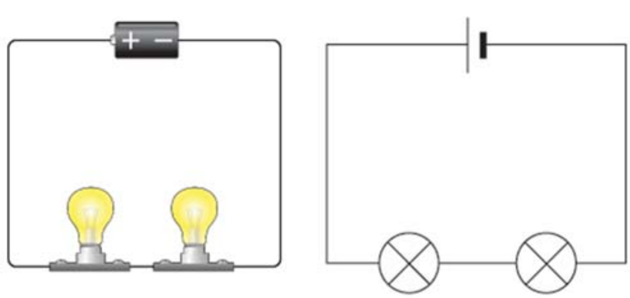


Fig: Series Circuit

v) Parallel Circuit:

The circuit in which all the components are connected completely in parallel is known as a parallel circuit. In a parallel circuit, the voltage across each of the components is the same, and the total current is the sum of the currents through each component. In parallel circuits, each device or component has its own circuit, so even one of the devices or components get damaged, the other will still function.

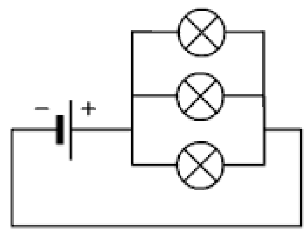
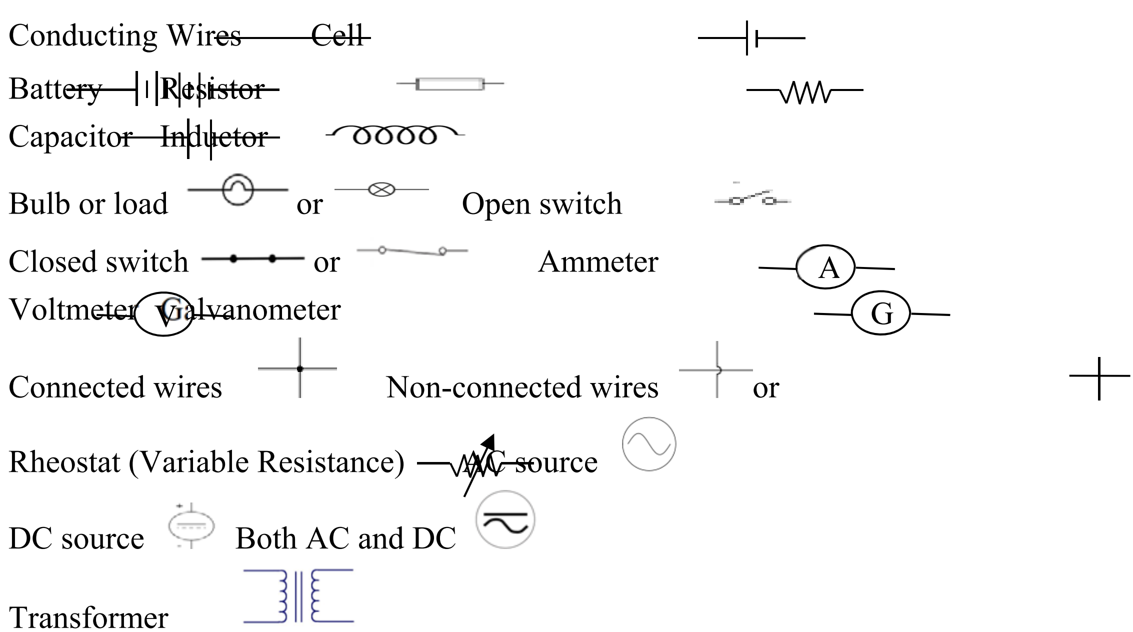


Fig: Parallel Circuit

vi) Mix Circuit:

The circuit in which all the components are connected both in series and parallel is known as mix circuit.

Symbols used in circuit.



Conventional Current:

At the time when the cell was discovered, the direction of flow of current was unknown. So they assumed that the flow of current through a conductor is from positive terminal to negative terminal of the battery. But later, when electron was discovered, it was proved that the actual flow of current means the flow of negative charge and is from negative terminal of the battery to positive terminal.

Even though the old concept of flow of positive charge is incorrect, we do accept it for solving various numerical. And this traditional concept of flow of electrons from positive to negative terminal of cell is known as conventional current.

Electric Current:

In previous chapter, we learnt that the body can be charged by friction. And when these charges move through the circuit, it gives rise to electric current.

So, the rate of flow of electrons (charge) through a conductor is known as current. It is represented by 'I' and Its SI unit is Ampere 'A'.

Mathematically,

$$\text{Current} = \frac{Charge}{time} = \frac{Q}{t} = \frac{C}{s}$$

The smaller amount of current are measured in terms of milliampere and microampere,

1 mili-ampere (mA) = 10^{-3} Ampere (A)

1 micro-ampere (µA) = 10^{-6} Ampere (A)

Since, an electron has charge of 1.6 X 10^{-19} C, 1 coulumb charge carries $\frac{1}{1.6\times10^{-19}} = 6.25\times10^{18}$ electrons. Hence to have 1 Ampere current flowing through a conductor, 6.25×10^{18} electrons must flow through it in 1 second.

1Ampere Current:

If 1 Coulumb of charge is flowing through a conductor in 1 second, then the current flowing through the conductor is said to be 1 Ampere current.

If 6.25 X 10^{18} electrons are flowing through a conductor in 1 second, then the current flowing is said to be 1 Ampere current.

Type of substances:

The electric charges (electrons) can flow more easily in some of the substances whereas it cannot flow in others. So the substances can be divided into following electrical categories.

Conductor:

The substances through which electric charges can flow are said to be conductor. But the flow of electric charges can be termed as electricity. Hence the conductors can also be defined as the substances through which electricity can flow are called conductors. For eg,metals like gold, copper, silver etc., alloys like nichrome, manganin, constantan etc, carbon (in form of graphite) etc.

Insulator:

The substances through which electric charges can't flow are known as insulators. In other words, the substances through which the electricity cannot flow are called insulators. For eg, wood, paper, plastics, bakelite, glass etc. In case of charged glass, plastics or ebonite etc the charges remain bound to them and do not move them.

Semi-conductor:

The substances through which the electric charge can partially pass are known as semi-conductors. In other words, the substances the electricity can partially flow are known as semi-conductors. For eg, silicon, germanium etc.

The difference in the behavior of the substances may be because of different reasons. The conductors have some electrons which are loosely attracted by the nuclei of their atoms, which are called free electrons. These electrons can move freely from one atom to another atom through out the conductor. And this presence of free electrons in a sunstance make it conductor of electricity.

But in case of insulators, the electrons present in the atoms are strongly attracted by the nucleus. So there is no presence of free electrons, which can move from one atom to another atom. Thus it doesn't allow the electric charges to flow through it.

Potential difference and electromotive force:

Generally, due to the potential difference between any two points, the charge flows from one point to another point. And the charge usually flows from higher potential to lower potential point. It can be compared to the flow of water i.e from higher level to lower level. When the potential difference between any two points becomes zero i.e both points at same potential, there is no flow of charge between them.

Due to the potential difference between two points, the charge moves from higher potential to lower potential doing certain amount of work against the force of attraction between them. This work done gives the measurement of potential difference between the two points.

The amount of work done in moving a unit charge from one point to another point in a circuit is known as potential difference across two points. It is measured by connecting volt meter parallel across two ends and its unit is volt (V). In general, it can be said as the difference in potential across any two points within the circuit.

$$\text{Potential difference} = \frac{\text{Work done`}}{\text{Quantity of charge moved}}$$

If W joules of work is done in moving Q coulombs of charge from one point to another point, then the potential difference, V is given by

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

And if 1 Joule of work is done in moving 1 Coulomb of charge from one point to another point within the circuit, then the potential difference between the points is said to be 1 volt.

Electromotive force (emf)

The flow of electrons results in the electric current. The continuous flow of electrons in the circuit is maintained by the cell. For this the cell has to do certain amount of work, by using the energy contained in it.

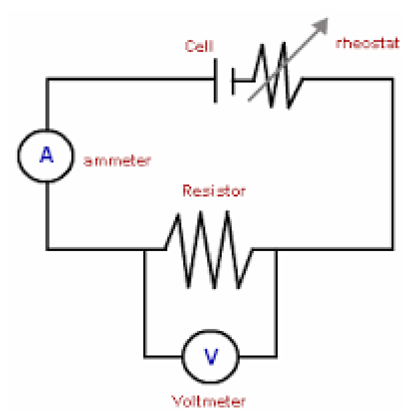
Hence, the amount of work done in moving a unit charge throughout the whole circuit is known as electromotive force (e.m.f.) Its SI unit is volt (V).

Differences between potential difference (p.d.) and electromotive force(e.m.f.)

Electromotive Force (e.m.f.)	Potential difference (p.d.)
It is the amount of work done in moving a unit charge throughout the whole circuit.	It is the amount of work done in moving a unit charge from one point to another point in a circuit.
It is a cause.	It is an effect.
It is measured in open circuit.	It is measured in closed circuit.
Its value is more.	Its value is less.

Ohm's Law:

In an electric circuit, the flow of electrons (charge) is maintained by the cell. The higher the potential difference between the two points, the higher is the flow of current. There exist a relation between the current flowing through a conductor and potential difference (p.d) between two ends of the conductor. This relation is explained by Ohm's law.



It states that "The current flowing through a conductor is directly proportional to voltage applied across its two ends assuming the physical condition and temperature of conductor to be constant."

i.e. $I \propto V$

or. $V \propto I$

or. $V = IR$

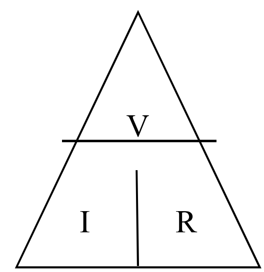
where, R = proportional constant, known as resistance of a conductor.

If V=1 volt and I = 1Ampere, then

R = 1 ohm

Hence, the resistance of conductor is said to be $1\,\Omega$. if 1 A current flows through a conductor under a potential difference between two ends of 1 V.

The three letters of Ohm's law can be arranged in the form of triangle as shown in the figure. The value of V or I or R can be found out by covering the letter meant for it and performing simple mathematical calculation as directed by uncovered two letters.



Thus, if we need to calculate V, we have to cover V, then V =IR. Similarly, if we need to calculate I, then $I=\frac{V}{R}$ and $R=\frac{V}{I}$.

Resistance:

The flow of electrons through a conductor is called electric current. When the electrons flow through a conductor, they collide with other electrons or atoms or ions contained in the conductor. Due to this there is some obstruction in the flow of electrons through a conductor. The property of a substance to oppose the flow of current through it is known as resistance. It is denoted by 'R' and its SI unit is ohm ' Ω '. The resistance of a conductor can be calculated using the mathematical relation,

$$\text{Resistance} = \frac{\text{Potential difference}}{Current}$$

$$\text{or, } R = \frac{V}{I}$$

Here, if the potential difference V= 1 volt and the current in the conductor is 1 ampere, then the resistance of the conductor becomes 1 ohm.

i.e. $1 \text{ ohm} = \frac{1volt}{1amp}$

Thus, 1 ohm is the resistance of the conductor, when 1 ampere of current flows through a conductor under a potential difference of 1 volts.

Factors Affecting Resistance:

The resistance of a conductor depends on the following factors.

i) length of the conductor
ii) Cross –sectional area of conductor
iii) Temperature of the conductor
iv) Nature of conducting material

i) Length of a conductor:

It is found that, the resistance of the conductor increases on increasing the length and decreases on decreasing the length of a conductor. So the resistance of a conductor is directly proportional to length of a conductor.

i.e. $R \ \alpha \ l$ ………(1)

Thus, when the length of wire is doubled, the resistance of the wire is also doubled and if the length of the conductor is made half, then the resistance is also halved. So we can conclude that, the resistance for a long wire is more and that for the shorter wire is less.

ii) Cross-Sectional Area of conductor:

The resistance of a conductor is inversely proportional to cross-sectional area of a conductor.

i.e. $R \ \alpha \ \frac{1}{A}$ ………(2)

Since the resistance of wire is inversely related to the cross-sectional area of the conductor, if the cross-sectional area of the wire is doubled, the resistance of the wire will be halved and if the cross-sectional area of the conductor is halved, then the resistance of the conductor will be doubled. So a thicker wire (large diameter) will have more cross-sectional area and thus will have less resistance and the thinner wire (less diameter) will have less cross-sectional area and thus will have more resistance in it.

Similarly, it can also be shown through the calculations that the resistance of the wire is inversely proportional to the square of its diameter. So if the diameter of the wire is doubled, its resistance will becomes one-fourth$\left(\frac{1}{4}\right)$ and if the diameter of wire is halved, the resistance of the wire will becomes 4 times.

iii) Temperature of the conductor.

It is found that the resistance of the conductors increases on increase of the temperature and decreases on lowering the temperature. Thus the resistance of a conductor is dependent on the temperature of conductor, which is given by,

$$R = R_o(1 + \alpha t)$$

Where R = resistance at a given temperature

R_o=Resistance at 0°C

α = temperature coefficient

t = given temperature

iv) Nature of conducting materials

The resistance of the conductor also depends upon the nature of material of which it is made. Some materials may have high resistance and some may have less resistance. For example, if we take two wires of same length and same cross section of copper and nichrome, then it can be found that the resistance of nichrome will be about 60 times more than that of copper. Thus we can conclude that the resistance of the conductors also depends upon the nature of materials of the conductor.

Combining (1) and (2)

$$R \; \alpha \; \frac{l}{A}$$

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

where ρ (rho) is proportionality constant known as resistivity of a conductor also known as specific resistance.

From this equation, it can be said that, for a given conductor having a specific length 'l' and cross-sectional area 'A', the resistance of the conductor 'R' is directly proportional to the resistivity of the material. So if the material of the conductor is changed with another material having double resistivity than the previous, then the resistance of the conductor will also be doubled. Similarly, if it is replaced with the conductor having resistivity half the previous, then the resistance will also be halved.

or, $\frac{RA}{l} = \rho$

If the cross-sectional area (A) = 1 m^2 and the length of the conductor is 1m, then the resistivity of the conductor will be equal to the resistance of the conductor. i.e $R = \rho$.

Thus, the resistivity of the substance can be defined as the resistance of the wire having unit length and unit cross-sectional area. And the SI unit of resistivity of the conductor is Ωm.

The resistivity of the material doesn't depend upon the length and cross-sectional area of the conductor. It only depends upon the temperature and nature of material used. The resistivity of some of the common materials is given below.

Resistivity of different materials

Category	Material	Resistivity
Conductor	Metals	
	1. Silver	$1.60 \times 10^{-8}\ \Omega$ m
	2. Copper	$1.69 \times 10^{-8}\ \Omega$ m
	3. Aluminium	$2.63 \times 10^{-8}\ \Omega$ m
	4. Tungsten	$5.20 \times 10^{-8}\ \Omega$ m
	5. Nickel	$6.84 \times 10^{-8}\ \Omega$ m

	6. Iron 7. Chromium 8. Mercury 9. Manganese Alloys: 1. Manganin (Cu-Mn-Ni) 2. Constantan (Cu-Ni) 3. Nichrome (Ni-Cr-Mn-Fe)	$10.0 \times 10^{-8}\ \Omega$ m $12.9 \times 10^{-8}\ \Omega$ m $94.0 \times 10^{-8}\ \Omega$ m $184.0 \times 10^{-8}\ \Omega$ m $44 \times 10^{-8}\ \Omega$ m $49 \times 10^{-8}\ \Omega$ m $110 \times 10^{-8}\ \Omega$ m
Semi-conductors	1. Germanium 2. Silicon	0.6 Ω m 2300 Ω m
Insulators	1. Glass 2. Paper 3. Diamond 4. Hard rubber 5. Ebonite	10^{10} to $10^{14}\ \Omega$ m $10^{12}\ \Omega$ m 10^{12} to $10^{13}\ \Omega$ m 10^{13} to $10^{16}\ \Omega$ m 10^{15} to $10^{17}\ \Omega$ m

From the above mentioned table, the resistivity if silver is 1.6 X 10-8 Ω m, which means that if we take a silver wire of length 1m and 1 m^2 in cross-section, then the resistance of the silver will be 1.6 X 10 -8 Ω. A good conductor of electricity should have low value of resistivity and an insulator will have very high resistivity.

Combination of resistors:

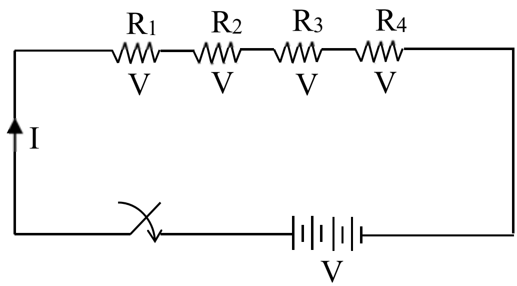
The resistors can be to a circuit in the following ways,

i) Series Combination of Resistor
ii) Parallel Combination of Resistor
iii) Mixed Combination of Resistor

i) Series Combination of resistor:

The combination in which the two or more resistors are connected end to end consecutively is known as series combination of resistor. In series combination, the equivalent resistance will be always greater than the maximum value of resistance connected to the circuit.

So in general, the resistors are connected in series in order to increase the value of resistance.



If the resistors R_1, R_2, R_3 and R_4 are connected in series, then the equivalent resistance is determined by,

Since in series combination, same current flows through all the resistor and voltage across them will be different and additive, so,

$V = V_1 + V_2 + V_3 + V_4$
or, $IReq = IR1 + IR2 + IR3 + IR4$
or, $IReq = I (R1 + R2 + R3 + R4)$
i.e. $Req= R1 + R2 + R3 + R4$

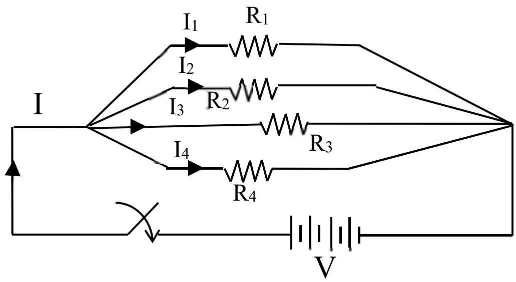
In series combination of resistor, the equivalent resistance is always greater than the maximum resistance connected to the circuit.

Characteristics:

- Resistance is added. i.e. $R_{eq} = R_1 + R_2 + R_3 + R_4$
- Same amount of current flows through all the resisitor
- Voltage drop across each resistor will be different.
- The total voltage drop will be additive. i.e. $V = V_1 + V_2 + V_3 + V_4$
- The power are also additive.

ii) Parallel Combination of resistor:

The combination in which two or more resistors are connected between the same two points is known as parallel combination of resistors. In other words, the combination of resistors in which all the positive terminals of resistor is connected to one point and all the negative terminals of resistor at another point is known as parallel combination of resistor.



If the resistors R_1, R_2, R_3 and R_4 are connected in parallel, then the equivalent resistance is determined by,

Since in parallel combination, there will be same voltage across all the resistor and current flowing them will be different and additive, so,

$$I = I_1 + I_2 + I_3 + I_4$$

or, $$\frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} + \frac{V}{R_4}$$

or, $$\frac{V}{R_{eq}} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right)$$

i.e. $$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

i.e. $G_{eq} = G_1 + G_2 + G_3 + G_4$ where G = Conductance

In parallel combination of resistors, the equivalent resistance is always less than the mimimum resistance connected to the circuit.

Characteristics:

- Conductance is added. i.e. $G_{eq} = G_1 + G_2 + G_3 + G_4$
- Voltage drop across each resistor will be same.
- Different current flows through different resistors.
- The total current is additive. i.e. $I = I_1 + I_2 + I_3 + I_4$

Advantages of parallel combinations in domestic wiring:

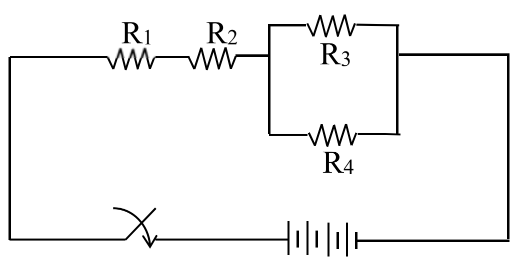
The arrangement of lights and various electrical appliances in parallel circuits or combinations is used in domestic wiring because of the following reasons:

1. In parallel circuits, if one of the appliance stop working, then all other appliances keep working normally. For eg, even one of the bulb connected to the parallel circuit get damaged, the other bulbs keep on glowing.
2. In parallel circuits, each of the appliances connected to the circuit has its own switch. So it can be turned on or off independently without affecting other appliances. For example, the bulbs are controlled through separate switches that are connected to parallel circuits. So they can be switched on or off as per required without affecting other bulbs in the house.

3. In parallel circuits, the voltage across each of the appliances remains the same as that of the supply line (220V). Due to this all the appliances will work at same voltage level.
4. In parallel combination of electrical appliances, the resultant resistance of the circuit is reduced. So more amount of current flows from the supply. Due to this, all the appliances connected to the circuit will get required amount of current. The high power rating devices, when connected to parallel circuits, can also draw required amount of current needed for their proper functioning.

iii) Mixed Combination of resistor:

The combination of resistors consisting of both series and parallel combination is known as mixed combination of resistors.



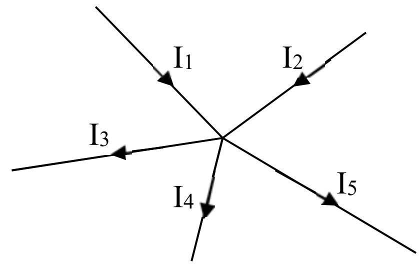
Kirchoff's Law:

Sometimes the resistors and the voltage source may be connected to the circuit in very complicated way. So the concept of combination of resistors and Ohm's law may not be sufficient to solve the problems. In such cases, we apply Kirchoff's law to analyze the circuit. And there are two laws of KIrchoff, namely,

1. Kirchoff's Current Law (KCL)
2. Kirchoff's Voltage Law (KVL)

1. Kirchoff's Current Law (KCL)

This law relates the current at the junction points of a circuit. It states that" the algebraic sum of current entering the node and leaving the node is always zero."



i.e $I_1 + I_2 = I_3 + I_4 + I_5$

2. Kirchoff's Voltage Law (KVL)

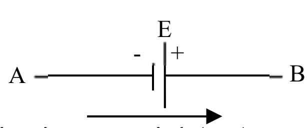
This law relates the emf and voltage drops in a circuit and it states that the algebraic sum of voltage drop across any loop in a circuit and emf is always equal to zero.

Sign Convention:

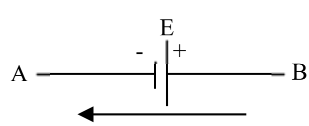
For applying KVL in a circuit, the sign convention is most important factor. The sign convention for KVL application is given by,

Voltage Source:

Move form positive to negative – drop in potential = -ve
Move from negative to positive – rise in potential = +ve



Rise in potential (+E)

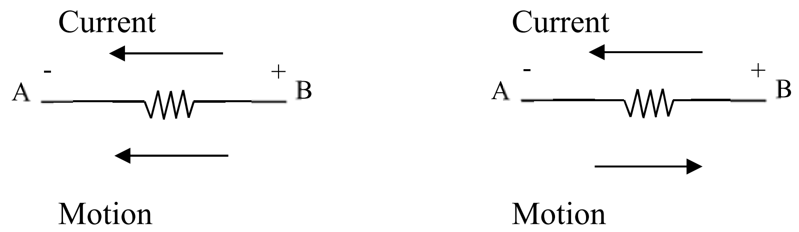


Fall in potential (-E)

Current Source:

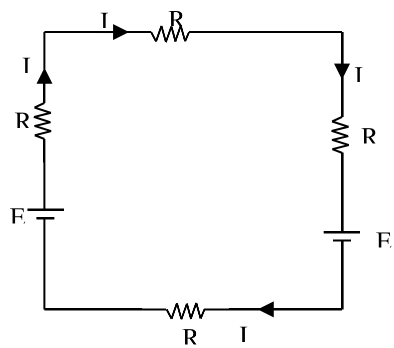
Same direction of current – Higher potential to lower potential (drop) = -ve

Opposite direction of current – lower potential to higher potential (rise) = +ve



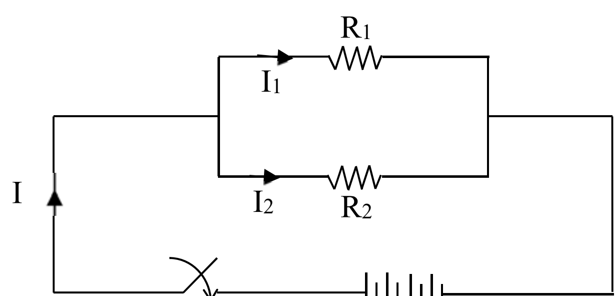
(Drop in potential-V=-IR) (Rise in potential +V =+IR)

Application:



i.e $-I_4R_4 - I_1R_1 - I_2R_2 - E_2 - I_3R_3 + E_1 = 0$

Current Dividing Rule:



As the resistors are connected in parallel, voltage across R_1 and R_2 will be same.

Now, $I = I1 + I2$

$$or, I = \frac{V}{R_1} + \frac{V}{R_2}$$

$$or, I = V\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$or, I = V\left(\frac{R_1 + R_2}{R_1 R_2}\right)$$

$$or, I\left(\frac{R_1 R_2}{R_1 + R_2}\right) = V$$

And, $$I_1 = \frac{V}{R_1} = \frac{I\left(\frac{R_1 R_2}{R_1 + R_2}\right)}{R_1} = \left(\frac{R_2}{R_1 + R_2}\right) \times I$$

$$I_2 = \frac{V}{R_2} = \frac{I\left(\frac{R_1 R_2}{R_1 + R_2}\right)}{R_2} = \left(\frac{R_1}{R_1 + R_2}\right) \times I$$

Voltage Dividing Rule:

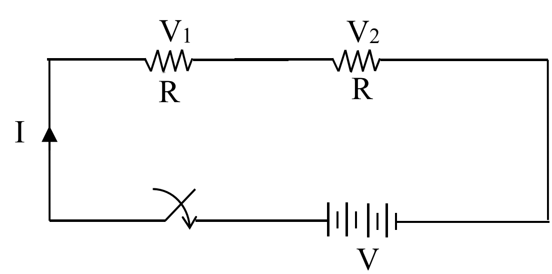
As the resistors are connected in series, current flowing through them is same.

Now, $V = V_1 + V_2$

$$or, V = IR_1 + IR_2$$

$$or, V = I(R_1 + R_2)$$

$$or, \frac{V}{(R_1 + R_2)} = I$$



And,

$$V_1 = I \times R_1 = \frac{V}{(R_1 + R_2)} \times R_1 = \left(\frac{R_1}{R_1 + R_2}\right) \times V$$

$$V_2 = I \times R_2 = \frac{V}{(R_1 + R_2)} \times R_2 = \left(\frac{R_2}{R_1 + R_2}\right) \times V$$

Numerical

1. A cell of e.m.f. 6V is connected across a resistor of resistance 15Ω. Find the current.

Solution:

Here, $V = 6V$

$R = 15\ \Omega$

$I = ?$

Now, we have

$V = IR$

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

or, $I = \frac{6}{15} = 0.4A$

2. If 6.25×10^{19} electrons are flowing through a conductor in 1 second, find the current flowing through it.

Solution:

No. of electrons $= 6.25 \times 10^{19}$

Now,

Current (I) $= \frac{\text{No. of electrons}}{6.25 \times 10^{18}} \quad (\because 1A = 6.25 \times 10^{18}\ electrons)$

$= \frac{6.25 \times 10^{19}}{6.25 \times 10^{18}}$

$= 10A$

3. In a circuit of resistance 6.2Ω, the current of 3.5A is flowing. Find the potential difference applied across the conductor.

Solution:

Here, $R = 6.2\Omega$

$I = 3.5A$

Now, we have

$V = IR$

or, $V = 6.2 \times 3.5$

$= 21.7\ V$

4. Find the current flowing through a conductor of resistance 25Ω, when the potential difference between the two terminals of conductor is 60V.

Solution:

Here, V = 60V

R = 25 Ω

I = ?

Now, we have

V =IR

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

or, $I = \frac{60}{25} = 2.4A$

5. The potential difference between two points of a conductor carrying a current of 4.2A is 6V. Find the resistance of the conductor.

Solution:

Here, V = 6V

I = 4.2 A

R = ?

Now, we have

V =IR

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

or, $R = \frac{6}{4.2} = 1.43\Omega$

6. The resistance of a conductor 1 mm^2 in cross-section and 20cm long is 0.346Ω. Determine the resistivity of the conductor.

Solution:

Cross sectional area (A) = $1mm^2 = 1 \times 10^{-6}\ m^2$

Length (l) = 20 cm = 0.2m

Resistance (R) = 0.346 Ω

Now, we have

$$\rho = \frac{RA}{l}$$

$$or, \rho = \frac{0.346 \times 1 \times 10^{-6}}{0.2}$$

$$or, \rho = 1.73 \times 10^{-6} \Omega - m$$

7. The resistances of 5Ω, 10Ω and 14Ω are connected in series and parallel. Find the equivalent resistance in each case.

Solution:

$R_1 = 5\Omega$

$R_2 = 10\Omega$

$R_3 = 14\Omega$

Now, for series combination

Equivalent Resistance (R_{eq}) $= R_1 + R_2 + R_3$

$= 5 + 10 + 14$

$= 29\Omega$

For parallel combination

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$or, \frac{1}{R_{eq}} = \frac{1}{5} + \frac{1}{10} + \frac{1}{14}$$

$$or, \frac{1}{R_{eq}} = \frac{14 + 7 + 5}{70}$$

$$or, R_{eq} = \frac{70}{26} = 2.69\Omega$$

8. Two resistors of resistances 10Ω and 25Ω are connected in (a) series and (b) parallel, with a battery of 12V. Calculate the current flowing in each case.

Solution;

$R_1 = 5\Omega$

$R_2 = 10\Omega$

Now, for series combination

Equivalent Resistance (R_{eq}) $= R_1 + R_2$

$= 10 + 25$

$= 35\Omega$

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

$$or, I = \frac{12}{35} = 0.343A$$

For parallel combination

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$or, \frac{1}{R_{eq}} = \frac{1}{10} + \frac{1}{25}$$

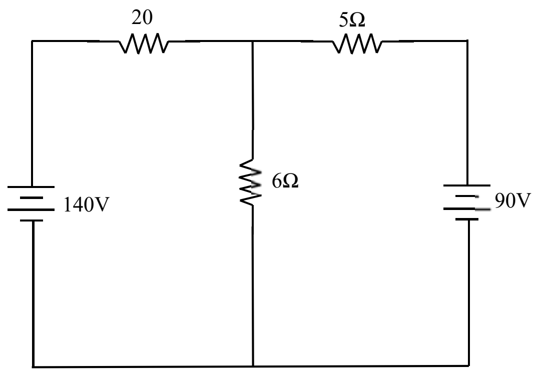
$$or, \frac{1}{R_{eq}} = \frac{5+2}{50}$$

$$or, R_{eq} = \frac{50}{7} = 7.143\Omega$$

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

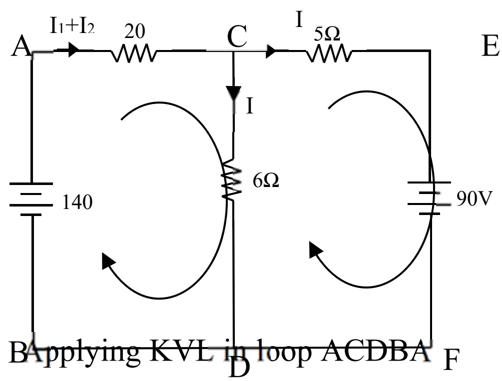
$$or, I = \frac{12}{7.143} = 1.68A$$

9. In the given circuit, find the current and power in 6Ω resistor.



Solution:

The direction of flow of current in different branches of the circuit is shown in the figure below.



Applying KVL in loop ACDBA

$-20(I_1 + I_2) - 6I_2 + 140 = 0$

or, $-20I_1 - 26I_2 + 140 = 0$

or, $10I_1 + 13I_2 = 70$………………(i)

Again, applying KVL in CEFDC

$-5I_1 - 90 + 6I_2 = 0$

or, $-5I_1 + 6I_2 = 90$………………(ii)

Solving (i) and (ii), we get

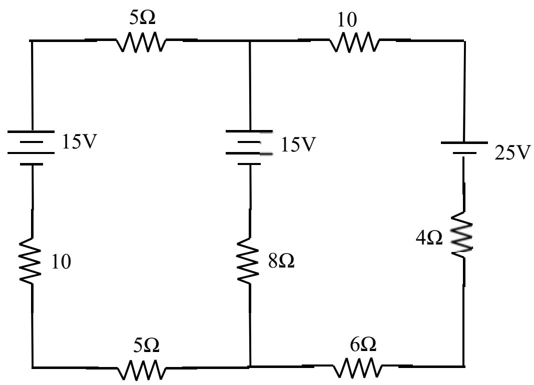
$I_1 = -6A$

$I_2 = 10A$

And,

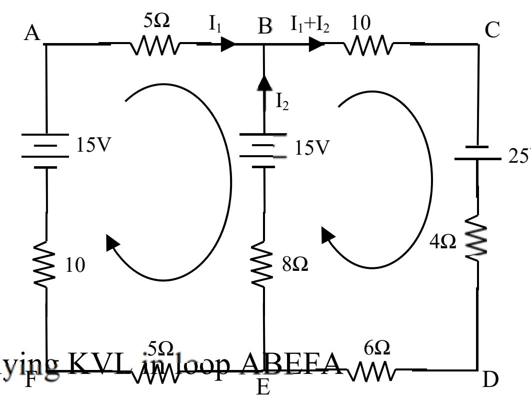
Power in 6Ω resistance $= I_2^2 R = (10)^2 \times 6 = 600 watt$

10. Find the current flowing through each branch in the given circuit.



Solution:

The direction of flow of current in different branches of the circuit along with the name of points is shown in the figure below.



Applying KVL in loop ABEFA

$-5I_1 - 15 + 8I_2 - 5I_1 - 10I_1 + 15 = 0$

or, $20I_1 = 8I_2$

or, $I_1 = 0.4\ I_2$

Again, applying KVL in loop

$-10\ (I_1 + I_2\ ) + 25 - 4\ (I_1 + I_2) - 6\ (I_1 + I_2) - 8I_2 + 15 = 0$

or, $-20I_1 - 28I_2 + 40 = 0$

or, $-20(0.4I_2) – 28I_2 + 40 = 0$

or, $36I_2 = 40$

or, $I_2 = 1.11A$

And, $I_1 = 0.4\ X\ 1.11 = 0.44\ A$

Ability Questions:

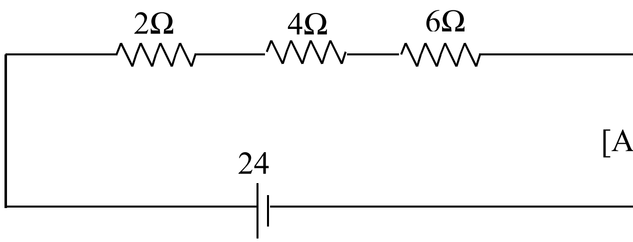
1. If the length of a conductor with fixed cross sectional area is doubled, what change can be seen in the resistance of it?
2. If the length of a conductor with fixed cross sectional area is made one third, what change can be seen in the resistance of it?
3. If the cross sectional area of a conductor with fixed length is doubled, what change can be seen in the resistance of it?
4. If the cross sectional area of a conductor with fixed length is halved, what change can be seen in the resistance of it?
5. If the wire of fixed resistance is made into two equal parts, and the two parts are connected in parallel to a circuit, then find the resulting resistance of it?

Tutorials

1. Calculate the amount of work done in moving a charge of 4 coulombs from a point at 220 volts to another point at 230 volts. [Ans: 40J]
2. What is the potential difference between the terminals of the battery if 250 joules of work is required to transfer 20 coulombs of charge from one terminal of battery to the other? [Ans: 12.5V]
3. In 10 seconds, a charge of 25 C leaves the battery and 200 J of energy are delivered to an outside circuit as a result.
   (a) What is the p.d. across the battery?
   (b) What current flows from the battery? [Ans: 8V, 2.5A]
4. A potential difference of 20 volts is applied across the ends of a resistance of 5 ohms. What current will flow in the resistance? [Ans: 4A]
5. A current of 5 amperes flows through a wire whose ends are at a potential difference of 3 volts. Calculate the resistance of the wire. [Ans: 0.6Ω]
6. What p.d will be needed to send a current of 6A through an electrical appliance having a resistance of 40 Ω ? [Ans: 240V]
7. Calculate the resistance of 100m length wire having a cross-sectional area of 0,1mm^2. (Given resistivity of wire = 50 X 10^{-8} Ω m)
8. A wire is 1.0 m long, 0.2mm in diameter and has a resistance of 10 Ω. Calculate the resistivity of the material.
9. What will be the resistance of the metal wire of length 2 meters and area of cross section 1.55 X 10^{-6} m^2, if the resistivity of the metal be 2.8 X 10^{-8} Ω m ?

10. Calculate the resistance of the copper wire 1.0 km long and 0.50mm diameter if the resistivity of copper is $1.7 \times 10^{-8}\ \Omega$ m.

11. Find the current flowing in the circuit.

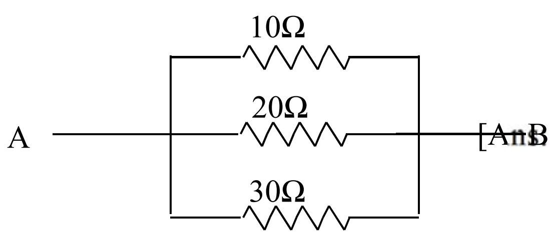


[Ans: 2A]

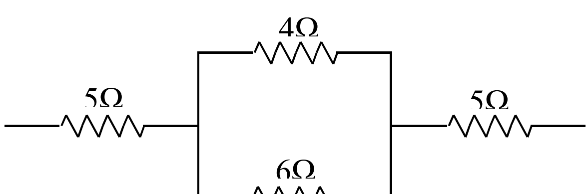
12. If the resistors 4Ω, 8Ω and 12Ω are connected in both series and parallel combination. Find the equivalent resistance in both cases. [Ans: 24Ω, 2.18Ω]

13. Two resistors of resistance 6Ω and 12Ω are connected in a) series and b) parallel combination, across a potential of 10V. Calculate the current flowing through the circuit in each case. [Ans: 0.56A, 2.5A]

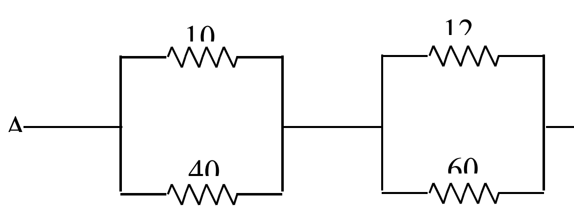
14. Find the equivalent resistance



[Ans: 5.45Ω]

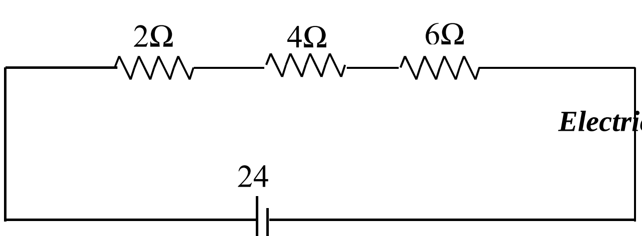


[Ans: 12.4Ω]



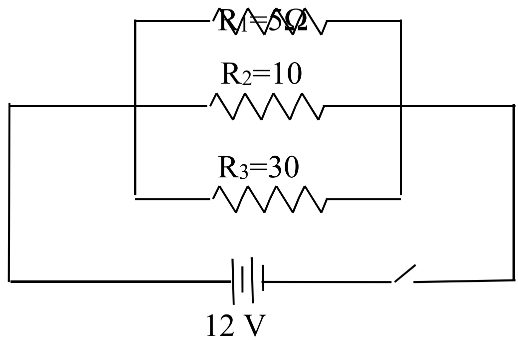
[Ans: 18Ω]

15. Find the voltage across each resistor.



[Ans: 4V, 8V and 12V]

16. In the circuit diagram given below, three resistors R1, R2 and R3 of 5Ω, 10Ω and 30Ω respectively are connected as shown:

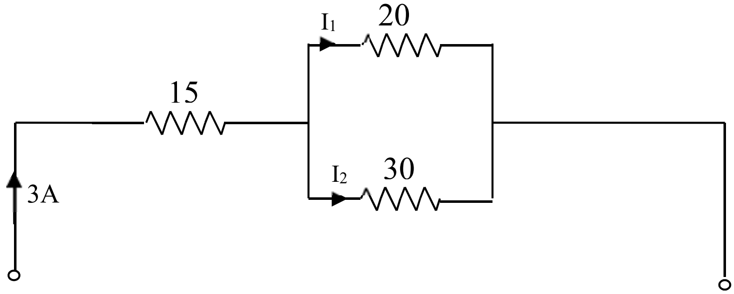


Calculate: a) current through the resistor. [Ans: 2.4A, 1.2A and 0.4A]

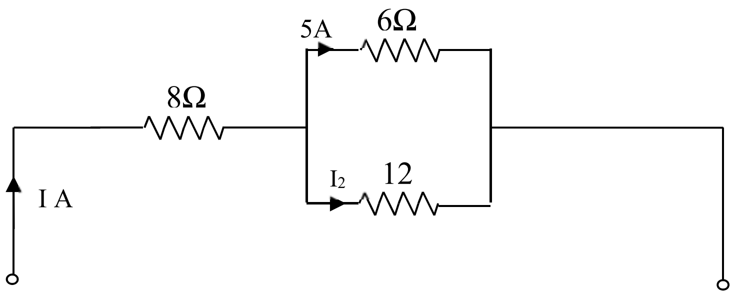
b) total current in the circuit. [Ans: 4A]

c) Total resistance in the circuit. [Ans: 3Ω]

17. In the given figure, find the current in 20Ω and 30Ω resistor. Also find the total voltage.



18.



In the circuit given above, find

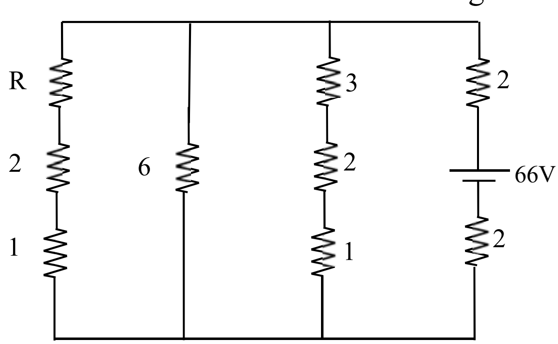
i) The total current

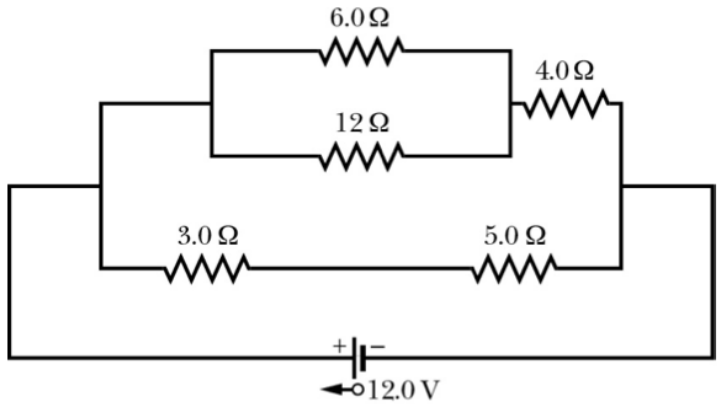
ii) Current flowing through 12Ω resistor

iii) Total voltage in the circuit.

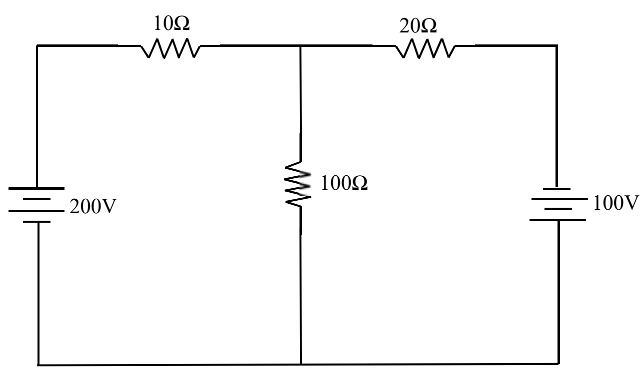
19. If current flowing through the given circuit is 6A, find the value of unknown resistance R.

19. Find the equivalent resistance and current flowing through the circuit.

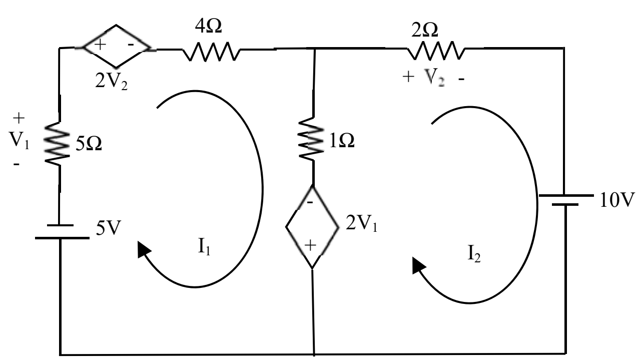




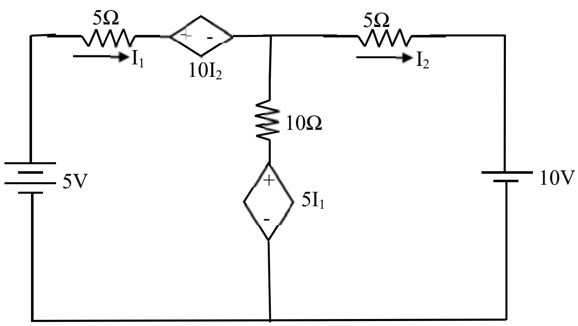
20. Use node and loop analysis, find current through 100Ω resistor and the potential difference across 10Ω resistor.



21. Find the branch current in the following circuit.



22. Find the branch current in the following circuit.



Electrical Energy

The energy produced due to the flow of electrons is known as electrical energy. It's SI unit is Joule.

If 'I' current is flowing through a circuit for a time of 't' seconds, then from the definition of potential difference,

$$\text{Potential difference} = \frac{\text{Work done}}{\text{Quantity of charge moved}}$$

Work done = charge X potential difference

= Q X V

i.e W=Q X V ....(i)

1. **J electrical work:**

   We have,

   W = Q X V

   = 1C X 1V

   = 1 J

It is defined as the amount of work done when 1 coulomb of charge is moved under a potential difference of 1 volt.

Similarly,

$$I = \frac{Q}{t}$$

$$\therefore Q = I \times t$$

………..(ii)

Substituting the value of 'Q' in (i), we get

W = I X t X V

Thus we can say, electrical energy depends on current, voltage and time of flow of current.

Similarly, from Ohm's law,

We have,

V= I X R

$\therefore$ W = I X t (I X R)

= I^2 R t

Thus, the electrical energy will be converted into heat energy and the electrical energy is said to be consumed by the electric circuit. This is known as heating effect of current and the heat developed in a circuit is given by the relation,

H = I^2Rt

This relation is known as Joules law of heating. According to it, the heat produced on the conductor is directly proportional to:

i) Square of magnitude of current flowing through the conductor.
ii) Resistance of conductor
iii) Time for which the current is passed over to the conductor.

Electric Power:

The amount of electrical work done per unit time is called the electric power. Its SI unit is watt.

$$\text{Electric power} = \frac{\text{Electric work done}}{\text{Time taken}}$$

$$or, P = \frac{W}{t}$$

$$or, P = \frac{ItV}{t}$$

$$or, P = IV$$

$$or, P = I^2 R$$

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

Similarly, the electric power can also be expressed as,

$$\text{Electric power} = \frac{\text{Electric energy consumed}}{\text{Time taken}}$$

$$\therefore \text{Electric power (P)} = \frac{\text{Q}}{\text{t}}$$

Electrical Energy Consumption:

We have

$$\text{Electric power} = \frac{\text{Electric energy consumed}}{\text{Time taken}}$$

Or, Electric energy consumed = Electrical power X time taken

Now, if P = 1 watt, t = 1 sec

Electric energy = 1 watt X 1 sec

= 1 watt-sec

Hence watt-sec is very smaller unit of electrical energy. So in home and for commercial purposes, we use higher units of it. i.e watt-hour, kilowatt-hour(kwh).

watt-hour

1 watt-hour = 1 X 60 X 60 watt-sec

= 3600 watt-sec

= 3600J

Kilowatt - hour

1 kilowatt-hour = 1000 X 60 X 60 watt-sec

= 3600000 J

This 1 kilowatt-hour simply can be said as 1 unit electrical energy consumption.

Kilowatt- hour (kwh):

When an electrical appliances of 1000 watt (1 kw) is used for 1 hour, then the electrical energy consumed is said to be 1 kilowatt-hour (kwh). Simply it is called 1 unit electrical energy consumption.

1. watt electrical power

We have,

P = I X V

= 1A X 1V

= 1 watt

If 1 A current is flowing through a conductor under a potential difference of 1 volt, then the power consumed is said to be 1 watt electrical power.

Similarly,

$$\text{Electric power} = \frac{\text{Electric work done}}{\text{Time taken}}$$

$$or, P = \frac{W}{t}$$

If W = 1 joule and t = 1 sec, then

$$or, P = \frac{1}{1} = 1watt$$

Thus, if 1 joule of work is done in moving the charge from one point to another within the circuit in 1 second, then the power consumed is said to be 1 watt power.

Note: *If a bulb is rated with 100 watt, it means the bulb can convert 100 J of electrical energy into heat and light energy in 1 second.*

Numerical

1. The resistance of the element of heater is 900Ω and current of 1.5A is flowing through the circuit. Find the power dissipated in the circuit.

   Sol^n. Here,
   Resistance (R) = 900Ω
   Current (I) = 1.5 A
   Now.
   Power (P) = I^2R
   = $(1.5)^2$ X 900
   = 2025 watt

2. An electric heater operates on 220 V and draws a current of 6 A. Calculate the power consumption.

   Sol^n. Here,
   Volatge (V) = 220V
   Current (I) = 6 A
   Now.
   Power (P) = IV
   = 6 X 220
   = 1320 watt

3. The current passing through a filament lamp is 2A. If it is connected to a 12 V power supply. Calculate the resistance of filament and power consumed by the lamp.

   Soln. Here,
   Voltage supply (V) = 12 V
   Current (I) = 2 A
   Now. From Ohms law, we have

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

   or, R = $\frac{12}{2}$
   or, R = 6Ω
   And,
   Power (P) = IV
   = 2 X 12 = 24 watt.

4. A student is using an electrical bulb of 100 watt for 6 hours daily. Find the electrical energy consumed in a month of 30 days.

Sol^n.

Power of bulb = 100 watt

$$= \frac{100}{1000} kw = 0.1 kw$$

Time = 6 hrs

Now,

Electrical energy consumed = 0.1 kw X 6 hrs

= 0.6 kw-hrs

And. Total energy consumed in 30 days = 0.6 X 30

= 16 kw-hrs (units)

5. An electric heater of 220V is used on 8A. Find the power consumed by it. Also find the cost of using the heater for one hour if the rate of electricity is Rs. 6 per unit.

Sol^n. Here,

Volatge(V) = 220V

Current (I) = 8A

Time used = 1 hr

Now.

Power (P) = IV

= 8 X 220

=1760 watt

= 1.76 kw

And,

Electrial energy consumed = 1.76 X 1

= 1.76 kw-hr

∴ Cost = Rs. 1.76 X 6

= Rs. 10.56

6. In a house, 5 bulbs of 60 watt glows for 4 hours a day, an electric press of 750 watt for an hour everyday and 3 electric fans of 150 watt is used for 8 hours a day. Find the total electrical energy consumed in 15 days. Also calculate the cost of electricity at Rs. 12 per unit.

Sol^n.

Power of bulb = 60 watt

$$= \frac{60}{1000} kw = 0.06 kw$$

No. of bulbs = 5

Time = 4 hrs

Now,

Electrical energy consumed = 0.06 kw X 5 X 4 hrs

= 1.2 kw-hrs

Similarly

Power of press = 750 watt

$$= \frac{750}{1000} kw$$

$= 0.75 kw$

No. of press = 1

Time = 1 hrs

Now,

Electrical energy consumed = 0.75 kw X 1 X 1 hrs

= 0.75 kw-hrs

And

Power of fan = 150 watt

$$= \frac{150}{1000} kw = 0.15 kw$$

No. of fans = 3

Time = 8 hrs

Now,

Electrical energy consumed = 0.15 kw X 3 X 8 hrs

= 3.6 kw-hrs

∴ Total energy consumed in 1 day = 1.2 + 0.75 + 3.6

= 5.55 kw-hrs (units)

And Total energy consumed in 15 days = 5.55 X 15

= 83.25 units

Cost of electricity = Rs. 12 X 83.25

= Rs. 999

7. In a house, 8 bulbs of 100 watts glows for 5 hrs a day, an electric iron of 800 watt for an hour everyday and 2 electric heaters of 1000 watt for 6 hours a day. Find the cost of electricity for a month of 30 days if the rate of electricity is Rs. 4 per unit.

Sol^{n}.

Power of bulb = 100 watt

$$= \frac{100}{1000} kw = 0.1 kw$$

No. of bulbs = 8

Time = 5 hrs

Now,

Electrical energy consumed = 0.1 kw X 8 X 5 hrs

= 4 kw-hrs

Similarly

Power of press = 800 watt

$$= \frac{800}{1000} kw = 0.8 kw$$

No. of press = 1

Time = 1 hrs

Now,

Electrical energy consumed = 0.8 kw X 1 X 1 hrs

= 0.8 kw-hrs

And

Power of heater = 1000 watt

$$= \frac{1000}{1000} kw$$

$= 1kw$

No. of heater = 2

Time = 6 hrs

Now,

Electrical energy consumed = 1 kw X 2 X 6 hrs

= 12 kw-hrs

$\therefore$ Total energy consumed in 1 day = 4 + 0.8 + 12

= 16.8 kw-hrs (units)

And Total energy consumed in 30 days = 16.8 X 30

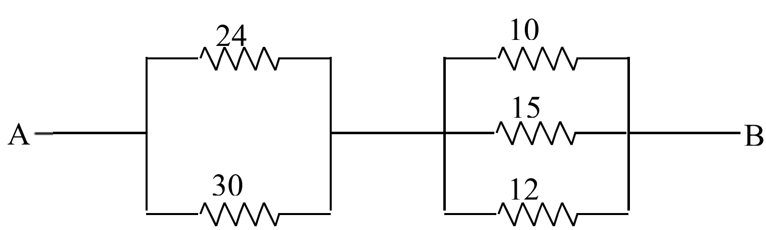
= 504 units

Cost of electricity = Rs. 4 X 504

= Rs. 2016

Tutorials

- A 75Ω resistor is connected to a voltage source of 220 V. Calculate the current flowing through the resistor and power consumed by it.



- Calculate the equivalent resistance of the following circuit in between A and B.

- An electric motor takes 5 amperes of current from a 220 volt supply line. Calculate the power of the motor and the electrical energy consumed by it in 2 hours.
- An electric kettle connected to the 230 V mains supply draws a current of 10A. Calculate: a) the power of the kettle.
  b) the energy transferred in a minute.
- A 2 kw heater, a 200 watt TV and three 100 watt lamps are all switched on from 6 p.m. to 9 p.m. What is the total cost of energy consumed at Rs. 7.30 per kWh ?
- In a house 8 bulbs of 75 watts glows for 8 hours a day. An electric iron of 750 watt is used for 3 hours a day. There are 2 fans of 80 watts which are used for 8 hours a day and electric heaters of 1000 watts is used for 4 hours every day. Find the consumption of electric energy in a month of 30 days. Also find the total cost, if the cost of electricity is Rs. 11 per unit.
- In a house, 15 bulbs each of 23 watts are used for 8 hours a day, 2 T.Vs each of 180 watts are used for 10 hours a day, a laptop of 65 watt is used for 5 hours a day, a rice cooker of 800 watt for 2 hours a day and a fridge of 60 watt for 24 hours a days. Find the total electrical energy consumed in that house in a day and in a month of 29 days. Also calculate the bill of electricity at Rs. 12 per unit.

Teaching tips/ Instruction to the teachers

- Provide the concept of circuit and its components and types.
- Show the chart of electric symbols along with the instruments.
- Give the application of the related laws.
- Make them to calculate the energy consumed at school, homes etc.
- Audio/video classes. (Videos from youtube)
- Slide shows.

References:

1. A text book of electrical engineering, B.L Thereja, A.K. Thereja
2. A text book of electrical engineering, J.B.Gupta

3. A handbook of electrical engineering, S.L.Bhatia
4. A textbook of Electrical Engineering, P.S.Dhogal
5. www.fixit.com
6. www.allibaba.com
7. www.electricalkit.com

UNIT-3

Capacitors

Learning Outcomes

After completion of this chapter, the students will be able to

1) Know about the basics of capacitor and its properties.
2) Know about the different types of combinations of capacitor.
3) Understand the charging and discharging of capacitor.

Capacitor

It is an electrical device which can store charge within it electric field. It consists of two conducting surfaces separated by a layer of insulating medium called dielectric. The conducting surfaces may be in the form of circular or rectangular plates or be in the form of spherical or cylindrical shape.

The property of a capacitor to store charge within its electric field is known as capacitance. Its SI unit is Farad (F).

The smaller units of capacitance are:

1mF (mili)= 10^{-3} F

1 μ F(micro) = 10^{-6} F

1 nF(nano) = 10^{-9} F

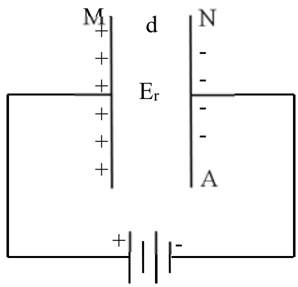
1 pF (pico)= 10^{-12} F

Capacitance can also be defined as the charge required to produced a unit potential difference between the plates. If 'Q' charge is stored in the plates to produce a potential difference of 'V' volts, then

$$\text{Capacitance (C)} = \frac{Q}{V}$$

1 F Capacitance:

It can be defined as the capacitance of the capacitor when 1 coulumb of charge is stored producing a potential difference of 1 V between the plates.



Calculation of capacitance of a parallel plate capacitor

The parallel plate capacitor with plates 'M' and 'N' each having an area of A is separated by a distance 'd'.

When the charge +Q is applied to the plate M, the charge starts to store in the dielectric and the electric flux (ψ) is produced in it.

Now,

$$\text{Electric Flux density } (\Delta) = \frac{\text{Electric Flux}}{Area}$$

$$\text{or, } \Delta = \frac{\psi}{A}$$

$$\text{or, } \Delta = \frac{Q}{A} \text{ …………(i)}$$

Again

$$\text{Electric Field Intesity (E)} = \frac{Voltage}{\text{Distance of separation}}$$

$$= \frac{V}{d}$$

Similarly,

$$\Delta = \in E$$

$$\text{or, } \Delta = \in \frac{V}{d} \text{ ....(ii)}$$

Equating (i) and (ii), we get

$$\frac{Q}{A} = \in \frac{V}{d}$$

or, $\frac{Q}{V} = \in \frac{A}{d}$

or, $C = \in \frac{A}{d}$, where C is the capacitance of parallel plate capacitor.

Note:

The capacitance of a parallel plate capacitor can be increased by the following ways,

i) Increasing the area of plates.
ii) Decreasing the distance between the plates.
iii) Using dielectrics with more dielectric values.

Values of dielectric constants for some medium

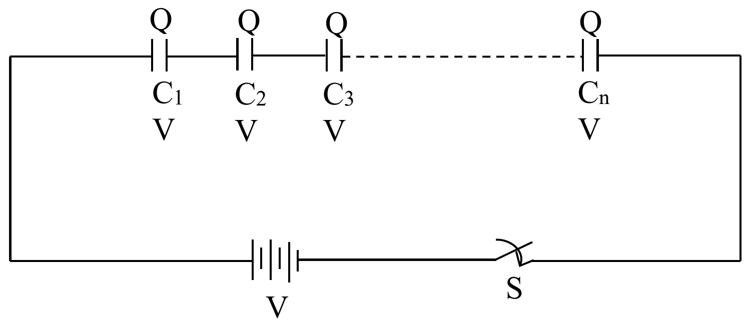
i) Vacuum – 1 F/m
ii) Air – 1.004 F/m
iii) Mylar – 3 F/m
iv) Paper – 5 F/m
v) Mica – 6 F/m
vi) Glass – (4-18) F/m
vii) Barium Titanate ($BaTiO_3$) – (1500-2000) F/m
viii) Other formulated ceramics – (8000-20000) F/m

Combination of capacitors

The capacitors can be connected to a circuit in different ways.

1. Series combination
2. Parallel Combination

1) Series combination of capacitors:



Let C_1, C_2, C_3............. and C_n be capacitances of the capacitors connected in series to a voltage source of 'V' volts. And C_{eq} be the equivalent capacitance of the capacitors connected to the above series circuit. Since same charge flows through all of them and potential difference will be different and additive.

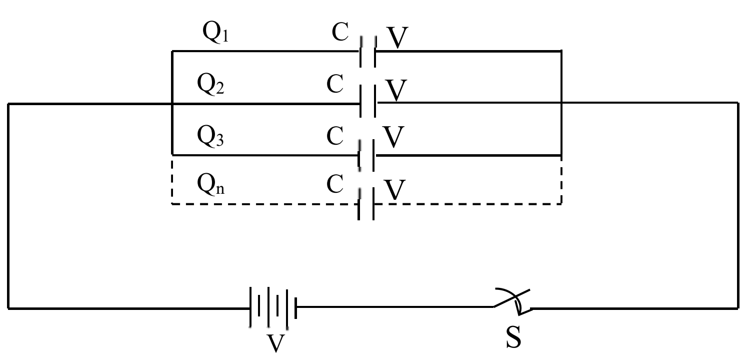
i.e. $V = V_1 + V_2 + V_3 + \ldots\ldots\ldots + V_n$

or, $$\frac{Q}{C_{eq}} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3} + \ldots\ldots\ldots\ldots\ldots\ldots + \frac{Q}{C_n}$$

or, $$\frac{Q}{C_{eq}} = \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots\ldots\ldots\ldots + \frac{1}{C_n}\right)Q$$

or, $$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots\ldots\ldots\ldots\ldots + \frac{1}{C_n}$$

2) Parallel combination of capacitor



Let C_1, C_2, C_3 .... and C_n be capacitances of the capacitors connected in parallel across a voltage source of 'V' volts. And C_{eq} be the equivalent capacitance of the capacitors connected to the above parallel circuit. Since in parallel combination, potential difference across each capacitor will be same and the charge stored in each of the capacitor will be different and additive.

i.e. $Q = Q_1 + Q_2 + Q_3 + \ldots\ldots + Q_n$

or, $C_{eq}V = C_1V + C_2V + C_3V + \ldots\ldots + C_nV$

or, $C_{eq}V = (C_1 + C_2 + C_3 + \ldots\ldots + C_n)\, V$

or $C_{eq} = C_1 + C_2 + C_3 + \ldots\ldots + C_n$

Tutorials

1. If the capacitors with capacitances 1.5μF, 2 μF and 3 μF are connected to a circuit, find the maximum and minimum that you can get using these three capacitors.

Sol[n]. Here

C1 = 1.5 μF

C2 = 2 μF

C3 = 3 μF

Now, if they are connected in series combination

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$\text{or, } \frac{1}{C} = \frac{1}{1.5} + \frac{1}{2} + \frac{1}{3}$$

$$= \frac{4+3+2}{6}$$

$$= \frac{9}{6}$$

$$\therefore C = 0.67\mu F$$

And, if they are connected in parallel combination,

$C = C_1 + C_2 + C_3$

or, $C = 1.5 + 2 + 3$

$\therefore C = 5.5 \mu F$

2. Three of the capacitors of capacitances 4 μF, 6 μF and 8 μF are connected in series across a potential difference of 220 V. Calculate the equivalent capacitance and the charge.

Sol^n. Here

C1 = 4 μF

C2 = 6 μF

C3 = 8 μF

Now, if they are connected in series combination

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

or, $\frac{1}{C} = \frac{1}{4} + \frac{1}{6} + \frac{1}{8}$

$$= \frac{6+4+3}{24}$$

$$= \frac{13}{24}$$

$$\therefore C = \frac{24}{13} = 1.85 \mu F$$

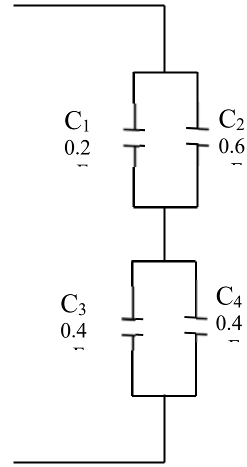
Again, we have

Q = CV

or, Q = 1.85 X 10-6 X 220

or, Q = 4.07 X 10-4 C

3. Find the equivalent capacitance in the given circuit.



Here,

The capacitors C_1 and C_2 are connected in parallel, so the equivalent capacitance C_{12} is given by

$C_{12} = C_1 + C_2$

or, $C_{12} = 0.2 + 0.6$

$= 0.8\ \mu F$

Similarly,

The capacitors C_3 and C_4 are also connected in parallel, so the equivalent capacitance C_{34} is given by

$C_{34} = C_3 + C_4$

or, $C_{34} = 0.4 + 0.4$

$= 0.8\ \mu F$

And, the equivalent capacitances C12 and C34 will be in series, so the equivalent capacitance between them can be calculated as,

$$\frac{1}{C} = \frac{1}{C_{12}} + \frac{1}{C_{34}}$$

$$\text{or, } \frac{1}{C} = \frac{1}{0.8} + \frac{1}{0.8}$$

$$\text{or, } \frac{1}{C} = \frac{2}{0.8}$$

$$\therefore C = 0.4\mu F$$

Hence the equivalent capacitance is 0.4μF.

4. The capacitors 10μF, 20μF and 30μF are connected in parallel across a potential difference (p.d) of 6V. Calculate the total charge across the capacitors.

Here,

C1 = 10μF

C2 = 20μF

C3 = 30μF

∴ Equivalent capacitance (C) = C1 + C2 + C3

= 10 + 20 +30

= 60 μF

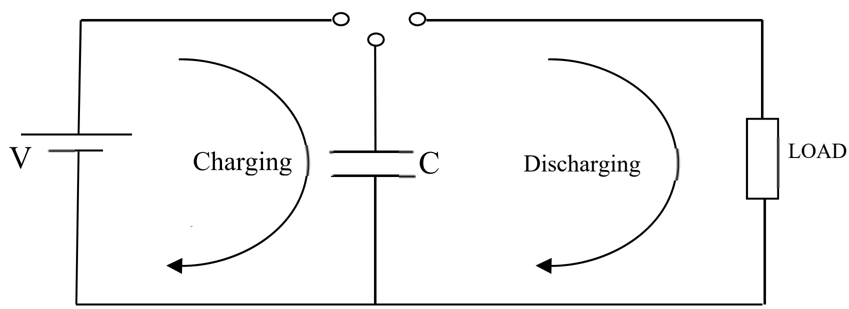
And, Total charge (Q) = CV

= 60 X 10-6 X 6

= 360 μC

Capacitor charge discharge cycle

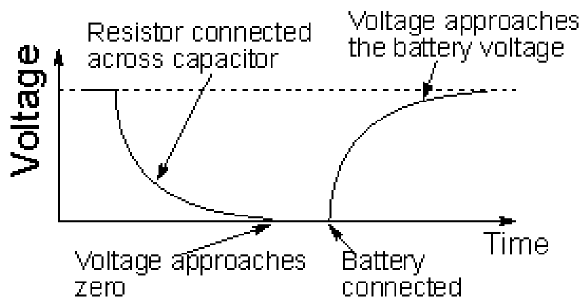
It is also possible to look at the voltage across the capacitor as well as looking at the charge. After all it is easier to measure the voltage on it using a simple meter. When the capacitor is discharged there is no voltage across it. Similarly, one it is fully charged no current is flowing from the voltage source and therefore it has the same voltage across it as the source.



In reality there will always be some resistance in the circuit, and therefore the capacitor will be connected to the voltage source through a resistor. This means that it will take a finite time for the capacitor to charge up, and the rise in voltage does not take place instantly. It is found that the rate at which the voltage rises is much faster at first than after it has been charging for some while. Eventually it reaches a point when it is virtually fully charged and almost no current flows. In theory the capacitor never becomes fully charged as the curve is asymptotic. However in reality it reaches a point where it can be considered to be fully charged or discharged and no current flows.

Similarly the capacitor will always discharge through a resistance. As the charge on the capacitor falls, so the voltage across the plates is reduced. This means that the current will be reduced, and in turn the rate at which the charge is reduced falls. This means that the voltage across the capacitor falls in an exponential fashion, gradually approaching zero.

The rate at which the voltage rises or decays is dependent upon the resistance in the circuit. The greater the resistance the smaller the amount of charge which is transferred and the longer it takes for the capacitor to charge or discharge.



Voltage on a capacitor charging and discharging

So far the case when a battery has been connected to charge the capacitor and disconnected and a resistor applied to charge it up have been considered. If an alternating waveform, which by its nature is continually changing is applied to the capacitor, then it will be in a continual state of charging and discharging. For this to happen, a current must be flowing in the circuit. In this way a capacitor will allow an alternating current to flow, but it will block a direct current. As such capacitors are used for coupling an AC signal between two circuits which are at different steady state potentials

Teaching tips/ Instruction to the teachers

- Demonstrate different types of capacitors.
- Demonstrate the parts of capacitor (Making if possible) (Videos)
- Explain the applications of capacitor in circuits.
- Show the charging and discharging process of capacitor,
- Show audio visual classes or slides.
- Show related videos from internet.

References:

1. A text book of electrical engineering, B.L Thereja, A.K. Thereja
2. A handbook of electrical engineering, S.L.Bhatia
3. A textbook of Electrical Engineering, P.S.Dhogal
4. A text book of electrical engineering , J.B.Gupta
5. www.fixit.com
6. www.allibaba.com

7. www.electricalkit.com

UNIT 4

Magnetism and Electromagnetism

Learning Outcomes

After completion of this chapter, the students will be able to

i) Know about the fundamentals related to magnetism.
ii) Know about electromagnetism and its laws and applications.
iii) Know about the basics of inductor and its properties.

Magnet

The substance that can attract the magnetic materials towards it is known as magnet.

Properties

1) It can attract magnetic materials when brought nearer to it.
2) When a magnet is freely suspended, it always rest pointing north south direction.
3) It consists of two poles namely north pole and south pole.
4) The poles of magnet cannot be separated.
5) It has maximum attracting capacity at the poles.
6) Like poles repel and unlike poles attract each other.

Types of magnet:

1. Temporary magnet
2. Permanent magnet

A permanent magnet is a magnet that maintains its magnetism or magnetic property for long periods of time once after it is magnetized. Usually, permanent magnets are made from hard magnetic materials such as iron, nickel, cobalt and some rare earth alloys. Permanent magnets have higher coercivity i.e. the magnetic field necessary to demagnetize it is very high.

A temporary magnet is a magnet that stays magnetized only for a relatively short period of time. Usually, soft magnetic materials are used to make temporary magnets and consist of materials like annealed iron. Temporary magnet has a low coercivity, meaning the magnetic field necessary to demagnetize it is relatively small.

For example, iron filings that have been recently affected by a magnetic field. While still magnetized, the filings have a very weak magnetic field and are demagnetized with very little effort. Similarly, another temporary magnet is the electromagnet, in which a strong magnetic field is produced by running electricity through a coil of wire but the magnetic field exists till when the current is running through the coil of wire.

Test for a magnet

- By using compass needle
- By using magnetic materials
- By freely suspending

Magnetic Induction

When a magnet is brought nearer to a box containing smaller magnetic materials(say nails), we can see that the nails will attach to another nails making a chain form arrangement. Even though the nails are not themselves magnet, till they remain in contact with the magent, they also develop an attracting capacity like a magnet. And this property will disappear when the contact between nails and magnet is removed.

This property by which a magnetic material behaves as a magnet till it remains in contact with a magnet is known as magnetic induction. And thus produced magnet is known as induced magnet.

Classification of materials

On the basis of attraction by the magnet, the substances can be classified into two different types,

1) **Magnetic Substances:**

The substances that are attracted by the magnet when placed inside its magnetic field is known as magnetic substances. For eg, iron, steel, nickel etc

Non-magnetic substances

The substances that are not attracted by the magnet when placed within its magnetic field are known as non-magnetic substances. For eg, plastic, wood, paper etc

Furthermore the magnetic substances may also be classified into different types as,

1) **Di-magnetic substances**

The substances that are repelled by the magnet are known as di-magnetic substances. For eg. Gold, silver etc.

2) **Para-magnetic substances**

The substances that are weakly attracted by the magnet are known as para-magnetic substances. For eg, Aluminium, platinium etc

3) **Ferro-magnetic substances**

The substances that are strongly attracted by the magnets are known as ferro-magnetic materials. For eg, iron, nickel, cobalt, steel etc.

Magnetization

The process of making magnet from magnetic materials is known as magnetization. The ways for making the magnet are as follows,

I. **By rubbing**

When magnetic materials are rubbed with magnet for certain time, the molecular magnets of the materials will be aligned in a fixed direction like that in magnet, thus producing certain attracting capacity. But this lasts for short period of time only.

II. **By passing DC current over a solenoid.**

When a DC current is passed through a magnetic materials placed inside the solenoid (a long wire in the form of coil), the magnetic materials behaves as a magnet and can attract the other magnetic materials towards it. It is also a temporary magnet because the attracting capacity of the material last till the current is passed through the solenoid.

And thus formed magnet is known as electromagnet.

Demagnetization:

The process of removing the magnetic property of a magnet is known as demagnetization. The ways for demagnetizing a magnet are as follows,

- By heating
- By rough handling
- By passing AC current over a solenoid

In all these methods of demagnetizing a magnet, the properly arranged molecular magnets of a magnet will be disturbed. So they will not be aligned in a fixed direction, hence loses their magnetic property.

Classification of materials on basis of magnetization and demagnetization

1. **Soft Magnetic materials**

   The magnetic materials that can be easily magnetized and lose their magnetic property readily as the magnetizing force is removed are called soft magnetic materials. These materials are used in making electric bells, transformers etc. For example, silicon steel, nickel-iron alloy, alloys of iron, nickel & cobalt etc.

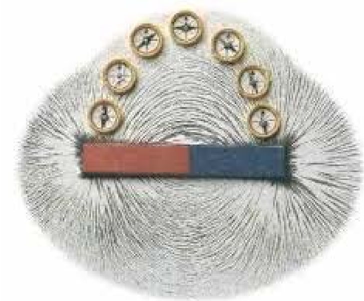
   They have high permeability, low coercivity and small hysteresis loop.

2. **Hard magnetic materials**

   The magnetic materials that are difficult to magnetize but once magnetized they retain their property even the magnetizing force is removed are called hard magnetic materials. These materials are used in the making of electric motor, telephone, ear-piece, dynamo, current measuring instruments, radio, speakers etc. For eg, cobalt steel, alloys like ALNI (Aluminium Nickel Iron), AlNICO (Aluminium Nickel Iron Cobalt)

They have low permeability, high coercivity and large hysteresis.

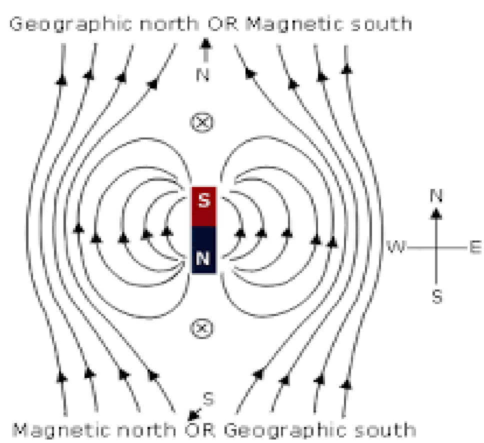
Magnetic field



When a magnetic material is placed near to a magnet, it will be strongly attracted by the magnet. But as the magnetic materials is moved far from the magnet, the attracting property gradually goes on decreasing. And a point will come, where there is no attraction to the magnetic material from the magnet. So the attracting capacity of a magnet is limited to specific space only. And that space is known as magnetic field.

The space around the magnet up to which it can attract magnetic materials is known as magnetic field. If an object goes beyond the magnetic field of a magnet, it is not affected or attracted by the magnet.

Magnetic lines of force



Within the magnetic field of a magnetic, there exists large number of imaginary lines, known as magnetic lines of force. The strength of magnet can be determined on the basis of number of magnetic lines of force. The properties of magnetic lines of force are:

i) They always originate from N-pole and terminate at S-pole.
ii) They are always closed, continuous and curved in nature.

iii) The magnetic lines of force come closer to one another near to the poles of magnet and will be widely separated at other places.

iv) A magnetic compass (north magnetic pole) experiences a stronger force as it comes nearer to the poles of magnet. This shows that the magnetic field is stronger at the poles. Thus, we can say that there exists a stronger magnetic field where the magnetic lines of force are closer to each other than the place where they are widely separated.

v) They never intersect each other.

vi) This is because the resultant force on a north pole at any point can be only in one direction.

Neutral point:

Within the magnetic field of a magnet, there exist a point where the force of attraction of a magnet and that of earth's magnetic field will be equal and opposite. So the magnetic compass cannot show a fixed direction at that point. And that point is known as neutral point.

Magnetic effect of current

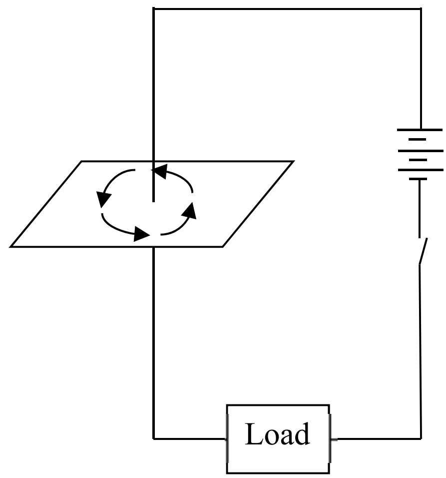
In 1820, Orested discovered that when a magnetic compass was brought nearer to a current carrying conductor, it got deflected. He also found that, when the direction of current was reversed, the direction of deflection of magnetic compass also got reversed. And there was no deflection in the magnetic compass when the current passing through the conductor was stopped.

This shows that a magnetic field is produced across a conducting wire, when the current is flowing through it.

Magnetic field due to straight current carrying conductor

A card board on which the iron-filings are spread is kept on which a straight conducting wire connected to the battery is passed through its centre.

When the switch is made closed or current is passed through the conductor, it was observed that the iron-filings arrange themselves in the form of concentric circles with the wire as its centre.



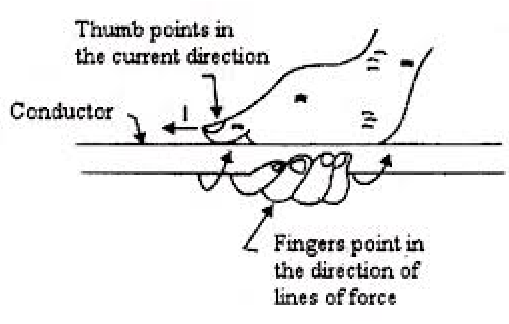
When the magnetic compass is kept on the magnetic field, the needle also shows the circular direction. This shows that the magnetic lines of force are also circular in nature.

And when the direction of current flowing through the wire is reversed, the direction of magnetic lines of force is also reversed.

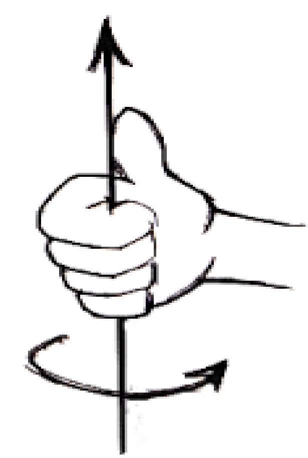
In order to determine the direction of the magnetic lines of force in a straight current carrying conductor, the following methods can be implemented.

i) Right hand thumb rule
ii) Maxwell's screw rule

Right hand thumb rule



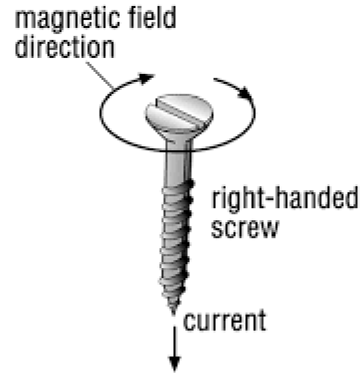
Right hand rule



According to this rule, when the current carrying conductor is hold in right hand in such a way that the thumb points the direction of current in a conductor, then the remaining four fingers will show the direction of magnetic lines of force in a straight current carrying conductor.

Maxwell's Screw rule

According to this rule, when we tie or open a screw on a board, if the direction of advancement of screw is taken as the direction of current in a straight current carrying conductor, then the direction in which the screw is rotated shows the direction of magnetic lines of force in a straight current carrying conductor.



Electromagnetism

Electromagnetism is the phenomenon of interaction of electric current with the magnetic field, as when the electric current generates magnetic field or when a changing magnetic field generates the electric field. The production of magnetic property (magnetism) in a current carrying conductor is known as electromagnetism and the magnetic field developed around is known as electromagnetic field.

Electromagnet

When an electric current is passed through a magnetic material placed inside a solenoid (a long wire in the form of coil), the magnetic materials behaves as a magnet and can attract the other magnetic materials towards it. It is a temporary magnet because the attracting capacity of the material last till the current is passed through the solenoid. Thus formed magnet is known as electromagnet. It works on the principle of magnetic effect of current.

The strength of thus formed electromagnet can be increased by following methods.

- By increasing the number of turns of a solenoid.
- By increasing the amount of current passing through a conductor
- By using soft magnetic materials inside a solenoid.

Applications:

- In electric bells
- For lifting heavy loads
- In motors and generators

- In transformers
- In electromagnetic deflections like radar and electro-dynamic speakers.

Electromagnetic Induction

When a conducting wire is placed in the magnetic field and is moved up and down, it will crosses the magnetic lines of force. Due to this the opposite charges are developed at the two ends of the conductor. Hence the electrons starts to flow through the wire, when its ends are connected to a galvanometer. This deflects the needle of galvanometer and shows the current in the circuit.

The production of electromotive force (emf) or voltage across a conductor due to relative motion between the conductor and the magnetic field is known as electromagnetic induction. This process was first discovered by Michael Faraday in 1831 A.D. And the current produced is known as induced current. This principle of electromagnetic induction is used in different equipments like generator, dynamo etc.

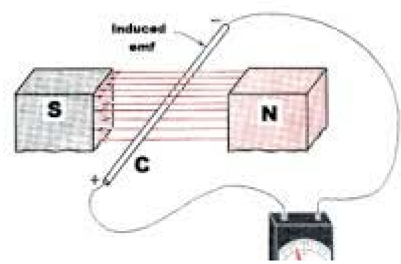


Fig: Electromagnetic Induction

Faraday's Law of electromagnetic induction

It states that

i) When the magnetic flux linked with the closed circuit changes, an electromotive force (emf) is induced in the circuit.
ii) The magnitude of induced emf is directly propotional to the rate of change of magnetic flux.
iii) The induced emf lasts in the circuit as long as the change in the magnetic flux continues.

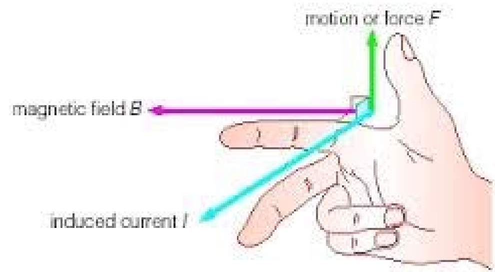
Note:

The magnitude of induced emf can be increased by the following methods

i) By increasing the strength of magnet
ii) By decreasing the distance between the poles of magnet
iii) By increasing the speed of moving conductor.

Flemming's Right Hand Rule

As per Faraday's law of electromagnetic induction, whenever a conductor moves inside a magnetic field, there will be an induced current in it. If this conductor gets forcefully moved inside the magnetic field, there will be a relation between the direction of applied force, magnetic field and the current. This relation among these three directions is determined by Fleming Right Hand Rule.



According to this rule, if three fingers of right hand thumb, fore and middle finger are kept mutually perpendicular to each other in such a way that the thumb shows the direction of motion of conductor or applied force, fore finger the direction of magnetic lines of force, then the middle finger will show the direction of induced current in a conductor.

Types of induced emf

1. Statically Induced emf
2. Dynamically induced emf

1. Statically Induced emf

When a conductor is moved in a fixed magnetic field, an emf is induced in the conductor due to the change in magnetic flux. And thus produced emf by keeping the magnetic field constant is known as statically induced emf.

2. Dynamically Induced emf

When a magnet is moved around a fixed conductor, an emf is induced in the conductor due to the change in magnetic flux. And thus produced emf by keeping the conductor constant is known as dynamically induced emf.

Lenz's Law:

Lenz's law states that when an emf is generated by a change in magnetic flux according to Faraday's law, the polarity of the induced emf is such that it produces an current that's magnetic field opposes the change which produces it.

According to Faraday's law of electromagnetic induction,

$$\varepsilon \;\alpha\; \frac{d\phi}{dt}$$

$$\text{or, } \varepsilon = -N \frac{d\phi}{dt}$$

The negative sign used in Faraday's law of electromagnetic induction indicates that the induced emf (ε) and the change in magnetic flux ($d\phi$) have opposite signs.

Where ε = Induced emf,

$d\phi$ = Change in magnetic flux

N = No. of turns of coil

Force due to current carrying conductor

When a current is passed through a conductor place in a magnetic field, the force is induced in it due to attraction between the magnetic field of magnet and magnetic field due to current carrying conductor.

The magnitude of force produced is given by,

$F = BIl$ Newton

where, F – magnitude of force produced

B – magnetic flux density

I – Current

l – length of conductor

In terms of magnetic parameters,

$F = \mu_o \mu_r HIl$

where, B - $\mu_o \mu_r H$

μ_o - Absolute permittivity

μ_r - Relative permittivity

H – magnetic field intensity

The direction of force produced can be determined by using Flemming's left hand rule.

Flemming's left hand rule:

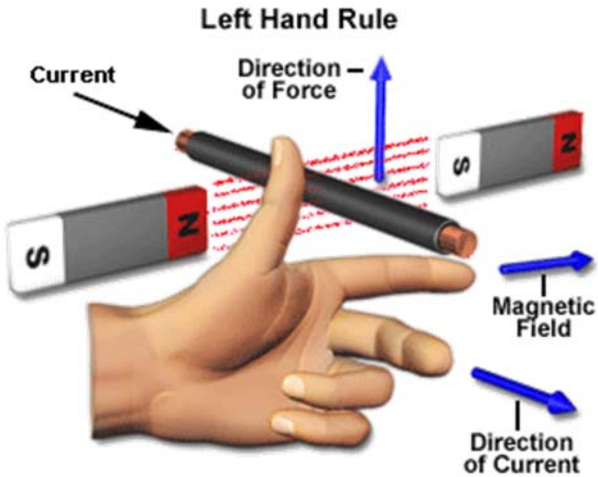


Fig: Fleming's left hand rule

According to this rule, if three fingers of left hand namely thumb, fore and middle finger are kept mutually perpendicular to each other in such a way that the fore finger shows the direction of magnetic lines of force, the middle finger shows the direction of current then thumb will show the direction of force.

Magnetic Circuit

The closed path through which magnetic flux passes is known as magnetic circuit.

Terms:

Magnetic flux:

The total number of magnetic lines of force produced in a magnetic field is known as magnetic flux. It is denoted by 'ϕ' and its SI unit is Weber (Wb).

If the magnetic lines of force of a magnet is more, the magnetic flux will also be more and hence the stronger magnetic field and vice-versa.

Magnetic flux density (B)

The total number of magnetic lines of force passing through unit surface of area 'A' normally (being perpendicular) is known as magnetic flux density. It is denoted by 'B' and its SI unit is Tesla.

Magnetic flux density = $\frac{\text{magnetic flux}}{Area}$

$$i.e B = \frac{\varphi}{A} = \frac{Wb}{m^2} (Tesla)$$

Magnetomotive force (mmf)

Magnetomotive force is any physical cause or a phenomenon that produces magnetic flux. The magnetomotive force (mmf) depends upon the value of current passing through the turns of the coil.

If the mmf will be more, the magnetic flux will also be more

Mathematically,

Magnetomotive force(mmf) = Current X No. of turns (Ampere X turns)

or, mmf = I X N = NI

Magnetic Field Intensity(H)

The magnetizing force that produces magnetic flux in a magnetic circuit is known as magnetic field strength.

In other words, it can also be defined as mmf per unit length of magnetic circuit.

Magnetic field strength $= \frac{mmf}{length} = \frac{mmf}{l}$

$$= \frac{NI}{l}$$

$$= \frac{Ampere-turns}{m}$$

$$\therefore H = \frac{NI}{l}$$

Reluctance(S)

The property of the coil to oppose the passage of flux through the magnetic circuit is known as reluctance.

Mathematically,

$$\text{Reluctance} = \frac{mmf}{flux}$$

$$\therefore S = \frac{NI}{\phi}$$

$$= \frac{Ampere-turns}{Weber}$$

$$= {}^{At}\!/\!_{Wb}$$

Also,

$$\text{Reluctance} = \frac{l}{\mu_o \mu_r A}$$ where l =length of conductor

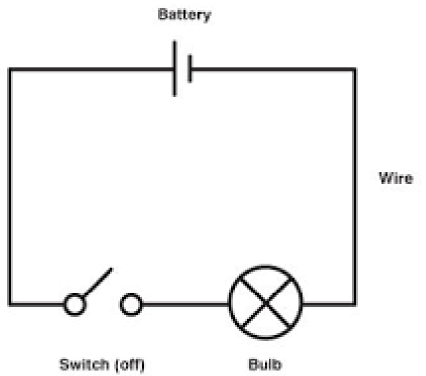
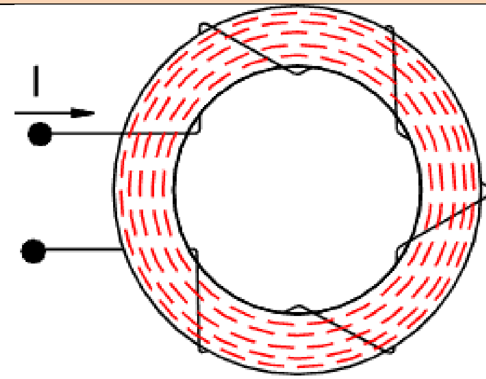
A = cross-sectional area

Permeance

It is the reciprocal of reluctance. i.e. the property to pass the flow of magnetic flux through the circuit. Its SI unit is Wb/At or henry.

Comparison between electric circuit and magnetic circuit

Similarities in analogue terms used in both circuits

Electric circuit	Magnetic Circuit
	
Current = $\frac{emf}{resistance}$	Flux = $\frac{mmf}{reluctance}$
Current (Ampere)	Flux (Weber)
emf (V)	mmf (Ampere-turns)
Resistance (R) (Ω)	Reluctance (S) (At/Wb)
Conductance (G) (Siemens)	Permeance (Wb/At)
Resistivity (ρ) (Ω -m)	Reluctivity (At-m/Wb)
Conductivity (1/ Ω -m)	Permeability(Wb/At-m)
Electric field strength $= \frac{emf}{length} = \frac{V}{m}$	Magnetic field strength $= \frac{mmf}{length} = \frac{At}{m}$
Current density $= \frac{current}{area} = \frac{I}{A} = \frac{A}{m^2}$	Flux density $= \frac{flux}{area} = \frac{\phi}{A} = \frac{Wb}{m^2}$

Differences:

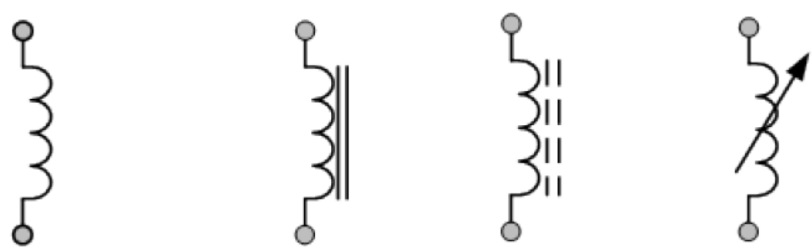
1. In an electric circuit, there is movement (flow) of current whereas in magnetic circuit, the flux is just generated but it doesn't flow through the circuit.
2. In an electric circuit, the current can be defined or assigned in a particular path but the flux in magnetic circuit cannot be fixed so accurately.

3. In an electric circuit, when a current is passed through the circuit, energy is continuously lost in the form of heat whereas in magnetic circuit, the energy supplied is just required for creating the flux but not for maintaining the flux.

Inductance:

An inductor is a passive electronic component which is capable of storing electrical energy in magnetic field. Basically, it uses a conductor that is wound into a coil, and when electricity flows into the coil from the left to the right, this will generate a magnetic field in the clockwise direction.

An inductor can be represented in terms of circuit diagram as,



Air Iron core Ferrite core Variable

The property of the coil that opposes any change in current or flux through it is known as inductance. It is denoted by 'L' and its SI unit is Henry (H).

The smaller value of inductance is calculated in terms of milihenry and microhenry.

1 milihenry = 10^{-3}H
1 micro-henry = 10^{-6}H

The numerical value of inductance is calculated in terms of coefficient of self inductance and is given by weber turns per ampere in the coil.

$$\text{i.e. } L = \frac{\text{flux linkage`}}{current} = \frac{\phi N}{I}$$

$$or, L = \frac{Weber - turns}{Ampere}$$

1 Henry:

If 1 weber-turn flux linkage has been induced by flow of 1A current in the coil, then the inductance of the coil is said to be 1H inducatance.

Factors affecting inductance of the coil

We have

$$L = \frac{\phi N}{I} \ldots\ldots\ldots\ldots\ldots(i)$$

Similarly

$$\phi = \frac{NI}{\mathrm{Re}luc\tan ce}$$

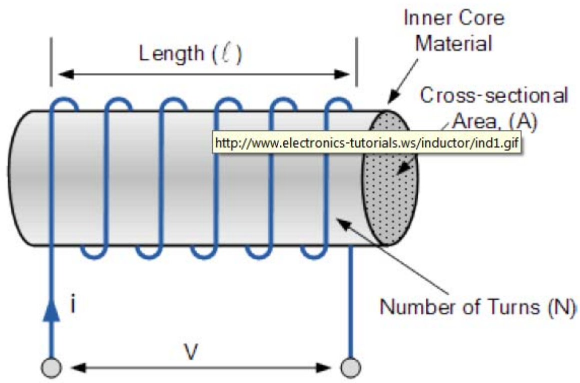
$$\phi = \frac{NI}{\frac{l}{\mu_o \mu_r A}}$$

$$\phi = \frac{NI\mu_0\mu_r A}{l} \ldots\ldots\ldots\ldots\ldots(ii)$$

From (i) and (ii)

$$L = \frac{N^2 \mu_0 \mu_r A}{l}$$

$$or, L = \frac{N^2 \mu_0 \mu_r \pi d^2}{4l}$$



From the above equation, we can find that the inductance of the coil depends on the following factors.

1. Number of turns of a coil

The inductance of a coil is directly proportional to the square of number of turns of a coil. i.e the coil having more number of turns will have higher value of inductance and the coil with lesser number of turns will have smaller value of inductance.

i.e $L \alpha N^2$

2. Diameter of the coil

The inductance of a coil is directly proportional to the square of diameter of coil. i.e The coil that has more diameter has greater value for inductance and that with less diameter has smaller value of inductance.

i.e $L \alpha d^2$

3. Length of the inductor

The inductance of a coil is inversly proportional to the length of coil. i.e The coil that has more length has smaller value for inductance and that with more diameter has greater value of inductance.

i.e $L \alpha \frac{1}{l}$

4. Number of layers of coil

The inductance of a coil is directly proportional to the number of layers of coil. i.e The coil that has more layers has greater value for inductance and that with less layers has smaller value of inductance.

5. Nature of material

The inductance of a coil depends on permittivity of the material and is directly proportional to it.

i.e $L \; \alpha \; \mu_o \mu_r$

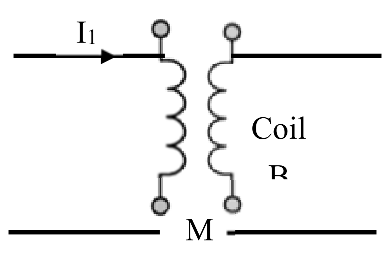
Self Inductance and mutual inductance

The emf produced in the coil when there is change in magnetic flux within the same coil is known as self inductance.

The value for self inductance can be calculated as,

$$L = \frac{\phi N}{I}$$

And the emf produced in the coil due to flux linkage of the second coil placed within its field is known as mutual inductance.



The value for mutual inductance can be calculated as,

Mutual Inductance (M) = $k\sqrt{L_1 L_2}$

where, k = coupling coefficient

L_1, L_2 – Inductance of coils

Two conductors of 10H and 20H are placed nearer to each other. If the coupling coefficient between them is 0.5, calculate mutual inductance between them.

Solution:

L1 = 10H

L2 = 20H

k =0.5

Now, we have

M = $k\sqrt{L_1 L_2}$

$= 0.5\sqrt{10 \times 20}$

$= 0.5\sqrt{200}$

$= 5\sqrt{2}$

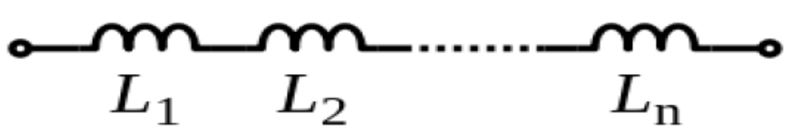
= 7.07H

Combination of inductors

The inductors can be connected to a circuit in two different ways,

1. Series combination
2. Parallel Combination

1. Series Combination



If the inductors having inductances L_1, L_2, L_3……….L_n are connected in series in such a way that there is no linkage between each other, then the equivalent inductance is given by,

Equivalent inductance (L_{eq}) = $L_1 + L_2 + L_3 + \ldots\ldots + L_n$

When inductors are connected together in series so that the magnetic field of one links with the other; this is referred to as mutual inductance. The effect of mutual inductance either increases or decreases the total inductance depending upon the amount of magnetic coupling. The effect of this mutual inductance depends upon the distance apart of the coils and their orientation to each other.

Mutually connected inductors in series can be classed as either "Aiding" or "Opposing" the total inductance. If the magnetic flux produced by the current flows through the coils in the same direction then the coils are said to be Cumulatively Coupled. If the current flows through the coils in opposite directions then the coils are said to be Differentially Coupled.

Case I (Aiding in same direction)

$L_{eq} = L_1 + L_2 + 2M$

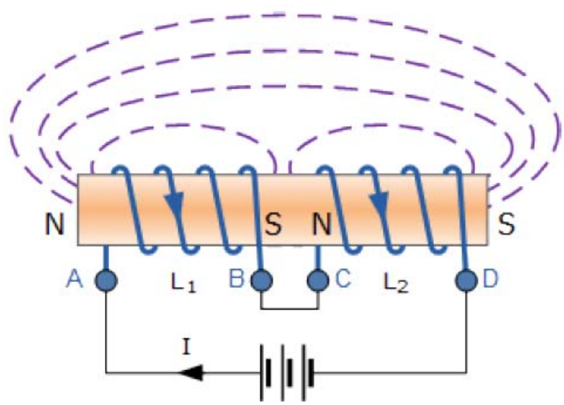


fig: Series combination of inductors aiding in same direction

Case II (Aiding in opposite direction) (Opposing)

$L_{eq} = L_1 + L_2 - 2M$

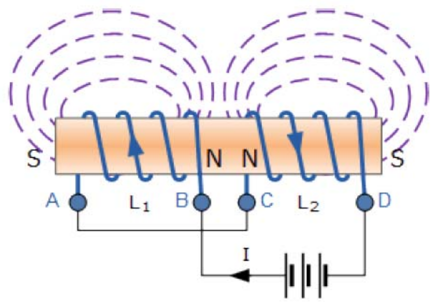


fig: Series combination of inductors aiding in opposite direction

2. Parallel Combination

Inductors are said to be connected together in parallel when both of their terminals are respectively connected to each terminal of the other inductor or inductors. The voltage drop across all of the inductors in parallel will be the same. Then, inductors in parallel have a common voltage across them, which can be shown as:

$V_{L1} = V_{L2} = V_{L3} = V_{AB}$ ...etc

In the following circuit the inductors L1, L2 and L3 are all connected together in parallel between the two points A and B.

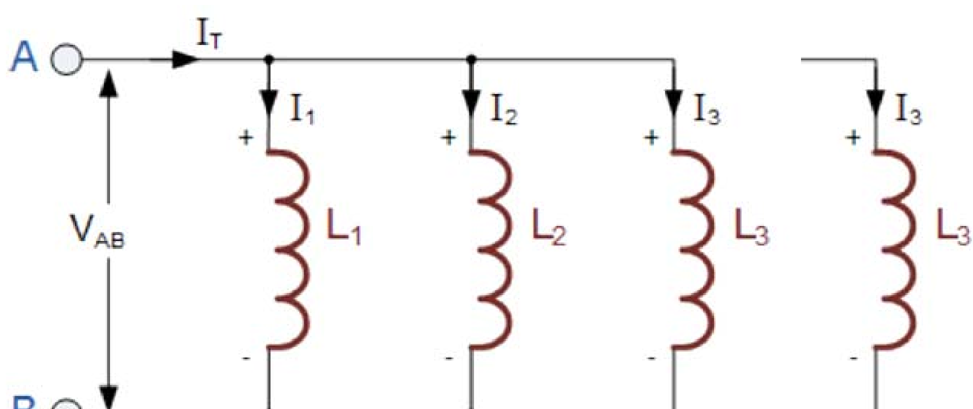


fig: Parallel combination of inductors

If the inductors having inductances L_1, L_2, L_3..........L_n are connected in parallel in such a way that there is no linkage between each other, then the equivalent inductance is given by, Equivalent inductance $(\frac{1}{L_{eq}}) = \frac{1}{L_1} + \frac{1}{L_2} = \frac{1}{L_3} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + \frac{1}{L_n}$

Numericals:

1. Two inductors of inductances 10H and 5H are connected in series. If the mutual inductance of 2H is adding towards them in same direction, find the equivalent inductance.

Solution:

$L_1 = 10H$

$L_2 = 5H$

$M = 2H$

Now, we have

$L_{eq} = L_1 + L_2 + 2M$

or, $L_{eq} = 10 + 5 + 2 \times 2$

or, $L_{eq} = 19$ H

2. **Two similar coils connected in series give a total inductance of 600mH and whent the coils are reversed, the total inductance is 300mH. Determine the mutual inductance between the coils and the coupling coefficient.**

Solution:

Let the inductance of each coil be L and mutual inductance be M.

Now, According to question

$L_{eq} = L_1 + L_2 + 2M$

or, $600 = L + L + 2M$

or, $600 = 2L + 2M$

or, $300 = L + M$……………..(i)

Similarly

$L_{eq} = L_1 + L_2 - 2M$

or, $300 = L + L - 2M$

or, $300 = 2L - 2M$

or, $150 = L - M$……………..(ii)

Adding (i) and (ii),

$300 + 150 = L + M + L – M$

or, $450 = 2L$

or, $L = 225$ mH

And, substituting the value of L in (i),

$300 = 225 + M$

or, M = 75 mH

And, we have,

$M = k\sqrt{L_1 L_2}$

or, $75 = k\sqrt{225 \times 225}$

or, 75 = k X 225

or, k = 0.333

3. **The combined inductance of two coils connected in series is 1.2H or 0.2H depending on relative direction of current in the coil. If one the coil has self inductance of 0.4H, calculate.**

   a. Mutual Inductance
   b. Inductance of second coil
   c. Coupling coefficient

Solution:

Let the inductance of coils be L_1 and L_2 and mutual inductance be M.

Now, According to question

$L_{eq} = L_1 + L_2 + 2M$

or, $1.2 = L_1 + L_2 + 2M$……………..(i)

Similarly

$L_{eq} = L_1 + L_2 - 2M$

or, $0.2 = L_1 + L_2 - 2M$……………..(ii)

Suntracting (ii) from (i),

$– 0.2 = L_1 + L_2 + 2M - L_1 - L_2 + 2M$

or, 1 = 4M

or, M = 0.25 mH

And, substituting the value of M in (i),

$1.2 = L_1 + L_2 + 2 X 0.25$

or,$1.2 = 0.4 + L_2 + 0.5$

or, $L_2 = 0.3$ H

And, we have,

M = k $\sqrt{L_1 L_2}$

or, 0.25 = k $\sqrt{0.4 \times 0.3}$

or, 0.25 = k $\sqrt{0.12}$

or, 0.25 = k X 0.346

or, k = 0.72

4. Two similar coils connected in series give a total equivalent inductance of 450mH when directing in same direction and when the coils are reversed, the total inductance is 120mH. Determine the mutual inductance between the coils and the coupling coefficient.

Teaching tips/ Instruction to the teachers

- Explain about the magnet and its properties.
- Show the magnetic lines of force.
- Clarify the laws of electromagnetic induction.
- Give clarification of magnetic circuits. (Terminologies)
- Show different types of inductors and its combinations.
- Show different terms and terminologies in visual form. (Youtube and slides)
- Explain other necessary topics using internet.

References:

1. A text book of electrical technology, B.L.Thereja, A.K.Thereja
2. A text book of electrical engineering, J.B.Gupta
3. A handbook of electrical engineering, S.L.Bhatia
4. A textbook of Electrical Engineering, P.S.Dhogal
5. www.fixit.com
6. www.allibaba.com
7. www.electricalkit.com

UNIT-5

Fundamentals of alternating current and single phase circuits

Objectives:

After completion of this chapter, the students will be able to

1. Understand the different terms and parameters related with AC signal.
2. Compare AC with DC signal
3. Calculate different parameters related with AC circuits
4. Analyze different AC circuits
5. Understand the response of AC in various types of circuits.

Introduction

DC Current:

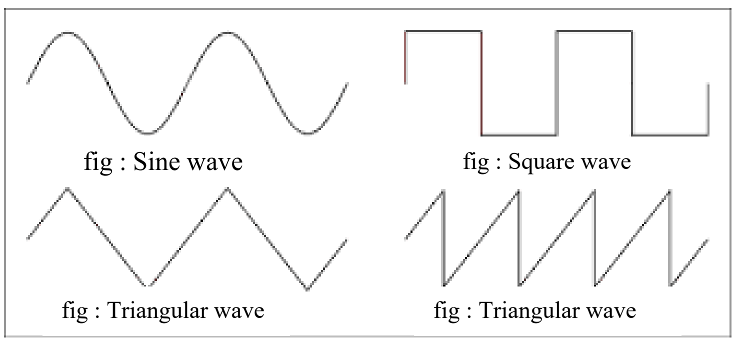
DC refers to power systems that use only one polarity of voltage or current, and refer to the constant, zero-frequency, or slowly varying local mean value of a voltage or current. i.e The voltage across a DC voltage source is constant as is the current through a DC current source.

Direct current (DC) is the unidirectional flow of electric charge. Direct current is produced by sources such as batteries, thermocouples, power supplies, solar cells etc. The electric current flows in a constant direction, distinguishing it from alternating current (AC). Direct current can also be obtained from an alternating current supply by using a rectifier circuit. Likewise, direct current can be converted into alternating current with an inverter or a motor-generator set.

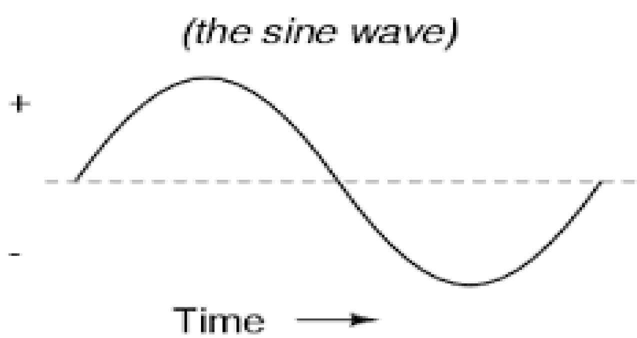
Direct current is used to charge batteries and as power supply for electronic systems. Very large quantities of direct-current power are used in production of aluminum and other electrochemical processes. It is also used for some railways, especially in urban areas. High-voltage direct current is used to transmit large amounts of power from remote generation sites or to interconnect alternating current power grids.

AC Current:

An alternating current can be defined as the one that changes the direction and magnitude continuously and periodically. The ac current is produced by generators. Alternating currents can be controlled, transmitted and utilized more easily than direct current, hence are more commonly used. AC current is not only the alternating quantity, the voltage can also be alternating as well. These signals are more generally represented in the form of sinusoidal waveform or sine wave but it can also be shown in the form of square or triangular wave.



Sine wave:



It is a very common form of representing an ac signal either current or voltage. It is also termed as sinusoidal wave. In sine wave, the value of current or voltage varies with time or angle.

The value of an alternating current or e.m.f. rises from zero, goes to positive maximum value, comes back to zero then decreases to negative maximum and again returns to zero. Doing this, the wave is said to have completed one cycle.

The power generating companies use sine wave to generate and transmit ac current due to the advantages of it which can be listed as below.

1) It is very easy to generate.
2) It is easy to distribute.
3) It is easy to use in different general equipments.
4) It can be combined to form complex harmonics. Eg. Harmonics

Terms related to ac signal

a. Cycle

When the waves moves through one positive half cycle and one negative half cycle, then the wave is said to have completed one complete cycle.

b. Time period

The time taken by a wave to complete one cycle is known as time period. It is represented by 'T' and is measured in terms of seconds.

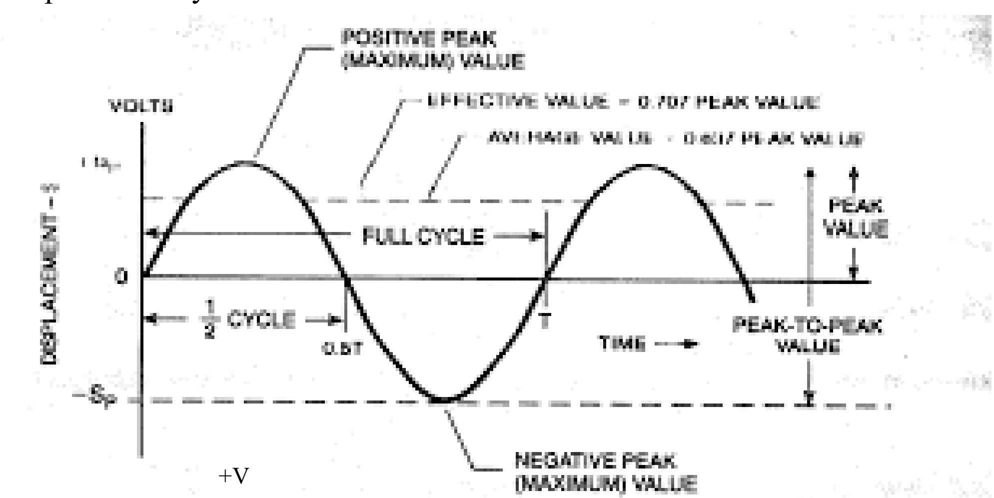


fig: AC signal showing different parameters

c. Frequency

The total number of complete cycles made by a wave in one second is known as frequency. It is represented by 'f' and measured in terms of Hertz (Hz).

The common power frequency in Nepal is 50 Hz i.e the wave completed 50 complete cycles in 1 second. Likewise in electronics, the frequencies of the signals may vary from zero (DC signal) to kilohertz (kHz), megahertz(MHz) to gigahertz(GHz).

Note:

The relation between time period and frequency of the wave is given by,

Frequency (f) $= \frac{1}{T} Hz$ where T – time period of the wave.

d. Wavelength

The distance covered by a wave while completing one cycle is known as wavelength of wave. It is represented by 'λ' and its SI unit is meter. It depends on the velocity of the wave and the relation can be expressed as,

$c = f\lambda$ where c = speed of the wave (m/s)

f = frequency of wave (Hz)

and λ = wavelength of wave (m)

In case of radio waves transmitting at a speed of 3 X 10^8 m/s, the wavelength of a 60 Hz alternating wave is ,

$$\lambda = \frac{c}{f} = \frac{3\times10^8}{60} = 5\times10^6 m$$

e. Amplitude (peak value)

The maximum positive or negative value attained by a wave from its mean position or zero value is known as amplitude. It is denoted by 'A'.

f. Phase

It is given by the amount of time (or angle) that has elapsed, sine the wave last passed through the positive zero value.

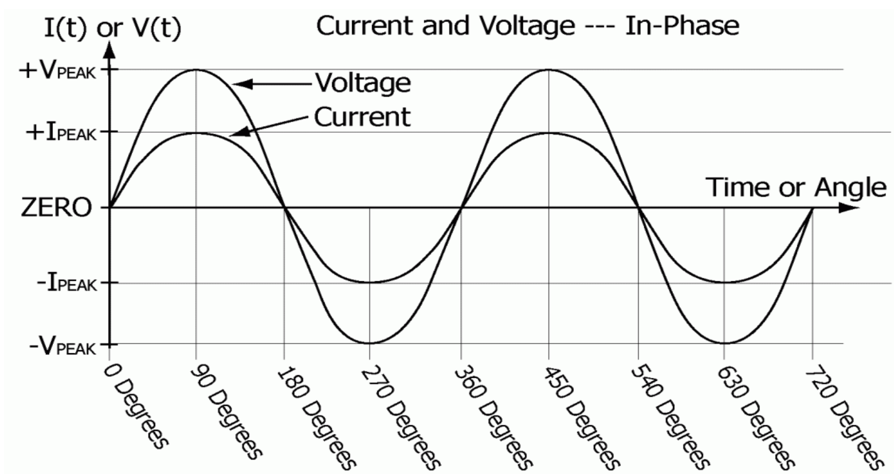
In figure, the phase angle of sine wave at point A is $\frac{T}{4}$ seconds or $\frac{\pi}{2}^c$.

g. Phase difference

The difference in time or angle between the two sine waves sine they last passed through their zero values is called phase difference between two waves.

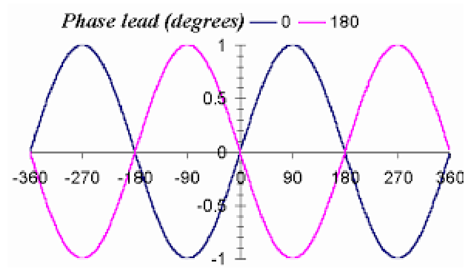
h. In phase

When we compare the two sine waves, if they reach the zero value or maximum (either positive or negative) at the same time or phase, then the two waves are said to be in phase. Under this condition the phase difference between the two waves is 0.



i. Anti-phase or Out-phase

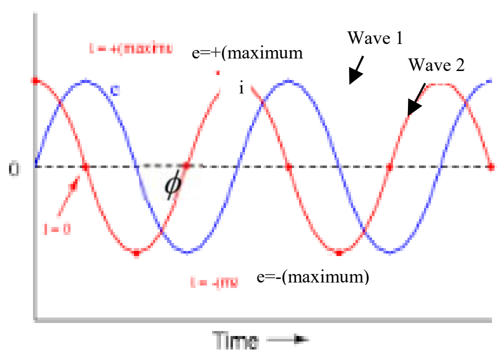
In comparing the two waves, if they reach the zero value at the same time but when one of the wave reaches the positive maximum, the other wave reach the negative maximum, then the waves are said to be in anti-phase or out-phase. During this condition, the phase difference between the waves is 180°.



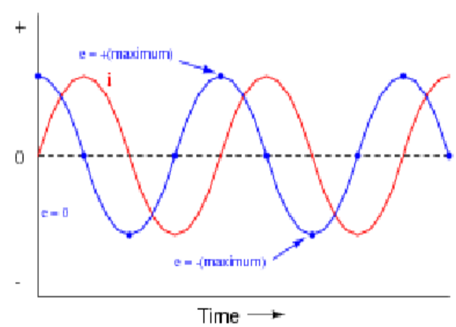
j. Leading and lagging waveform

The term leading and lagging are determined on the comparison of two waves on the basis of which wave reaches the zero value or maximum value earlier or lately than the other.

A wave is said to be lagging, if it reaches the zero value or maximum value lately than the other wave. Similarly, a wave is said to be leading, if it reaches the zero value or maximum value earlier than the other wave.



Fig(i)



Fig(ii)

In figure (i), the wave1 reaches the zero value later than the wave2. So the wave1 is said to be lagging than the wave2 by a phase angle of 'ϕ' (say)

If figure (ii), the wave1 reaches the zero value earlier than the wave2. So the wave1 is said to be leading than the wave2 by a phase angle of 'ϕ' (say)

k. Peak to peak value

The gap between maximum positive to maximum negative value attained by a wave is known as peak to peak value.

The peak to peak value can be seen in the given waveform.

l. Instantaneous value of AC signal

It is given by the value of current or voltage at a particular place in the signal waveform.

$i(t) = I_m \sin \omega t$

$i(t) = I_m \sin 2\pi f t$

where, $i(t)$ = instantaneous value of ac signal

I_m = peak value

w = angular frequency = $2\pi f t$

f = frequency of signal

t = time

Similarly, the instantaneous value for a voltage can be expressed as

$v(t) = V_m \sin \omega t$

$v(t) = V_m \sin 2\pi f t$

In case of lagging and leading

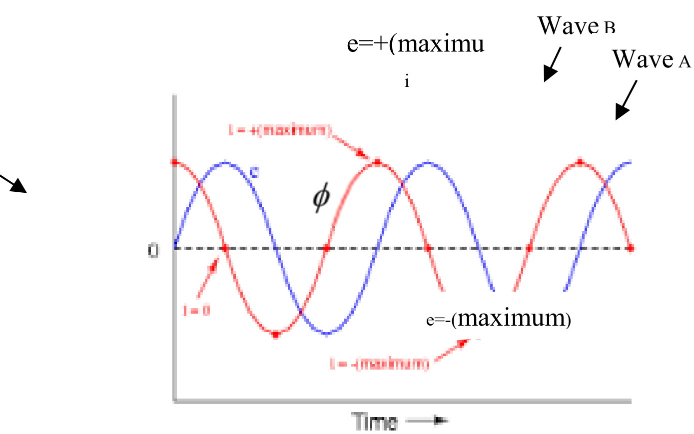
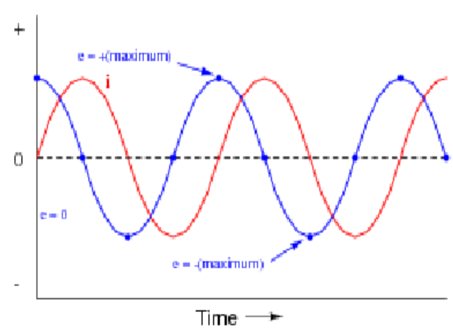


fig (i)



fig(ii)

In figure (i), if a wave A is represented by

$E = E_m \sin \omega t$

Then, lagging wave B can be expressed as

$$E' = E_m \sin\left(\omega t - \frac{\pi}{2}\right)$$

In general, $e(t) = E_m \sin(\omega t - \phi)$

And the leading wave B in figure (ii) can be expressed as,

$$E' = E_m \sin\left(\omega t + \frac{\pi}{2}\right)$$

In general, $e(t) = E_m \sin(\omega t + \phi)$

Numerical

If an AC signal is given by, $i(t) = 300 \sin\left(157t + \frac{\pi}{3}\right)$

Calculate: a) maximum value of current

b) frequency c) time period

Solution:

Here, the given expression for AC current is

$$i(t) = 300 \sin\left(157t + \frac{\pi}{3}\right)$$

Comparing with $i(t) = I_m \sin(\omega t + \phi)$, we get

(i) $I_m = 300$ A

$ii)\omega = 157$

$or, 2\pi f = 157$

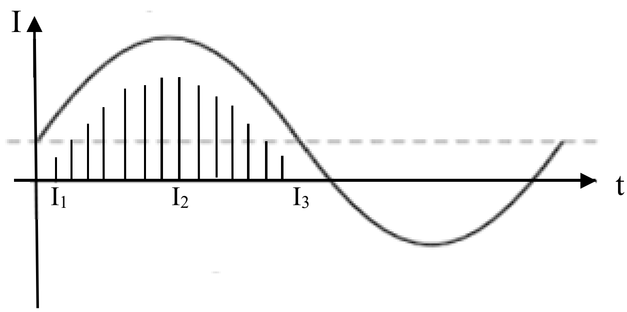
$$or, f = \frac{157}{2 \times 3.14} = 25 Hz$$

(iii) Time period (t) = $\frac{1}{f} = \frac{1}{25} = 0.04 \sec$

m. RMS value of an ac signal (Root Mean Square)

The rms value of an alternating current is given by the DC current that can produce equal amount of heat as the AC current at a given time in a given resistor.

RMS value actually means square root of mean of square of instantaneous current/voltage value s.



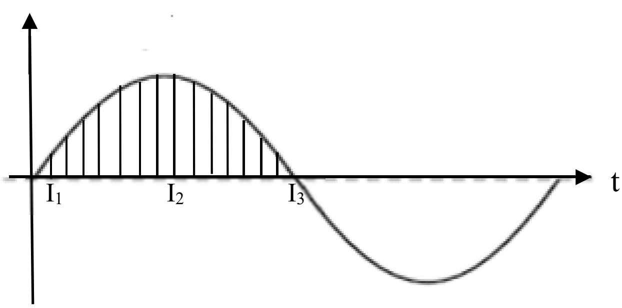
Mathematically,

RMS value of current (I_{rms}) = $\sqrt{\dfrac{I_1^2 + I_2^2 + I_3^2 + \ldots\ldots\ldots\ldots + I_n^2}{n}}$

i.e I_{rms} = $\dfrac{I_m}{\sqrt{2}} = 0.707 I_m$ where I_m = peak current

n. Average value of an ac current

The average value of an alternating signal is expressed by the steady current which transfers the same charge across the circuit as transferred by that alternating current during the same time. Mathematically, the average value of a waveform is given by the mean of instantaneous currents in a positive half or negative half cycle.



i.e. Average current (I_{avg}) = $\dfrac{I_1 + I_2 + I_3 + \ldots\ldots\ldots\ldots + I_n}{n}$

$I_{avg} = \dfrac{2I_m}{\pi} = 0.637 I_m$

o. Form Factor

It is the ratio of RMS value of AC current to average value of an AC current

i.e Form factor (K_f) = $\dfrac{\text{RMS value of ac signal}}{\text{Average value of ac signal}} = \dfrac{I_{rms}}{I_{avg}}$

$$or, K_f = \frac{0.707 I_m}{0.637 I_m} = 1.11$$

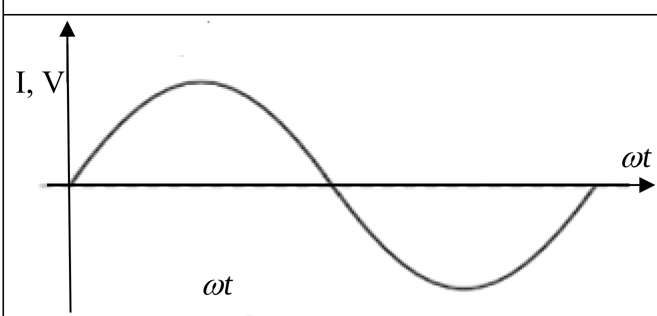
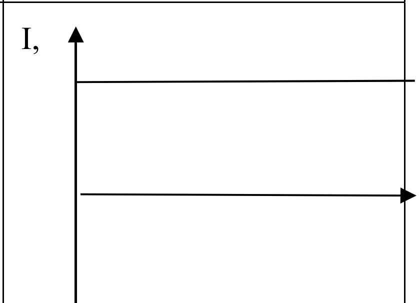
p. Peak Factor

It is the ratio of maximum value of AC current to RMS value of an AC current

$$\text{i.e Peak factor } (K_a) = \frac{\text{Maximum value of ac signal}}{\text{RMS value of ac signal}} = \frac{I_{max}}{I_{rms}}$$

$$or, K_a = \frac{I_m}{0.707 I_m} = 1.414$$

Comparison of AC and DC signal

AC	DC
1. The magnitude changes continuously.	1. The magnitude remains constant.
2. The direction of ac signal changes periodically	2. The direction of DC is fixed.
3. It is produced by AC generators.	3. It is produced by cells.
4. It has certain value of frequency.	4. The frequency of DC is 0.
5. AC signals can be easily converted into DC.	5. Conversion of DC into AC is not simple.
6. Transmission of AC signal over higher distances is easier.	6. Transmission of DC signal over higher distances is difficult.
7. With same rating, AC is less dangerous than DC.	7. With same rating DC is more dangerous than AC.
	

Active, Reactive and Apparent Power

Generally, the three different powers drawn by the circuit can be written as:

a) Apparent power (S)
b) Active power (P)
c) Reactive power (Q)

a) Apparent power(S)

It is given by the product of r.m.s. values of the applied voltage and circuit current.

$$i.e. S = IV = I \times IZ = I^2 Z \text{ volt ampere (VA)}$$

b) Active power(P)

It is the power that is actually dissipated in the circuit resistance.

$$i.e. P = I^2 R = VI \cos\phi \text{ watts}$$

c) Reactive power (Q)

It is the power developed in the reactance component of the circuit.

$$i.e. R = I^2 X = I^2 Z \sin\phi = IV \sin\phi \text{ volt ampere reactive (VAR)}$$

The three powers mentioned above can be related to each other by the relation

$$S = \sqrt{P^2 + Q^2}$$

Power Factor:

It is defined as the cosine of angle of lead or lag between the current and voltage.

$$i.e. p.f. = \cos\phi$$

It can also be defined as the ratio of resistance to impedance of the circuit.

$$i.e. p.f. = \cos\phi = \frac{\text{Resistance}}{\text{Impedance}} = \frac{R}{Z}$$

Again, It can also be defined as the ratio of true power to apparent power.

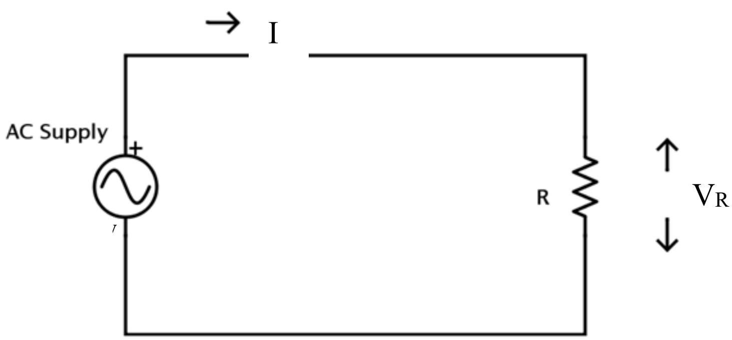
$$i..e. \text{power factor } (p.f.) = \frac{\text{true power } (P)}{\text{apparent power (S)}} = \frac{w}{VA} = \frac{kw}{kVA}$$

(S) = Apparent power = I_{rms} X V_{rms}

(P) = Active power = Power dissipated in the circuit (resistor)

$$i.e. P = IV\cos\phi$$

AC through a pure resistive circuit. (Resistor only)



Let the instantaneous value of supply voltage be,

$$v(t) = V_m \sin\theta$$

$$or. v(t) = V_m \sin\omega t........(i)$$

And, from ohm's law

V = iR

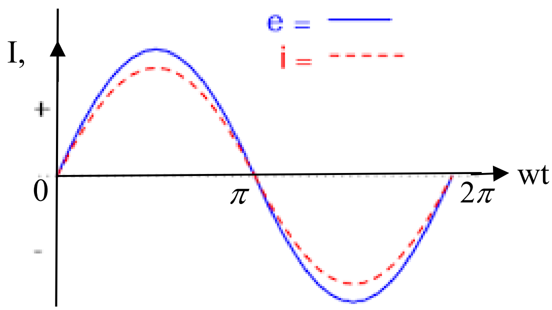
$$or, V_m \sin\omega t = iR$$

$$or, \frac{V_m}{R}\sin\omega t = i$$

$$\therefore i = I_m \sin\omega t.........(ii)$$

where, I_m = maximum current $= \frac{V_m}{R}$

From eqns (i) and (ii), we can say that when ac is passed through a pure resistive circuit, there is no phase difference between current and voltage. i.e phase difference = 0.



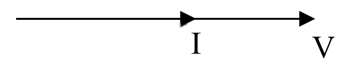


Fig: waveform showing current and voltage

fig: phasor diagram

Similarly, the power in the circuit can be calculated as

$$P = IV$$

$$or, P = I_m \sin \omega t \times V_m \sin \omega t$$

$$\therefore P = I_m V_m \sin^2 \omega t$$

$$or, P = \frac{I_m V_m}{2}(1 - \cos 2\omega t)$$

$$or, P = \frac{I_m V_m}{2} - \frac{I_m V_m}{2}\cos 2\omega t$$

Hence the power consists of two parts, a constant part $\frac{I_m V_m}{2}$ and a fluctuating part $\frac{I_m V_m}{2}\cos \omega t$ .For a complete cycle the average value of $\frac{I_m V_m}{2}\cos \omega t$ is zero.

Therefore, the total power for whole cycle is

$$P = \frac{I_m V_m}{2} = \frac{I_m}{\sqrt{2}} \times \frac{V_m}{\sqrt{2}} = I \times V \text{ watts}$$

In a pure resistive circuit, the instantaneous values of current and voltage are both either positive or negative, so the power will always be positive.

Numerical

The instantaneous voltage of an ac waveform is given by v=150sin314t, when applied over a resistance of 20Ω. Calculate:

i) Maximum voltage ii) Maximum current
iii) RMS value iv) Average value
v) Form factor vi) Peak Factor

Solution:

The given AC waveform is v=150sin314t

Comparing with v= $V_m \sin \omega t$, we get

$V_m = 150$ V

Similarly, we have

$V_m = I_m X R$

or , 150 = I_m X 20

or, $I_m = 7.5A$

Now, for RMS value

$$V_{rms} = \frac{V_m}{\sqrt{2}} = \frac{150}{\sqrt{2}}$$

$$\therefore V_{rms} = 106.05V$$

$$I_{rms} = \frac{I_m}{\sqrt{2}} = \frac{7.5}{\sqrt{2}}$$

$$\therefore I_{rms} = 5.303A$$

Again, for average value

$$V_{avg} = \frac{2V_m}{\pi} = \frac{2 \times 150}{3.14}$$

$$\therefore V_{avg} = 95.55V$$

$$I_{avg} = \frac{2I_m}{\pi} = \frac{2 \times 7.5}{3.14}$$

$$\therefore I_{avg} = 4.77 A$$

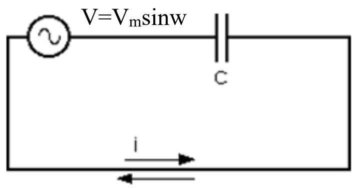
And, Form factor(K_f) $= \frac{V_{rms}}{V_{avg}} = \frac{106.05}{95.55}$

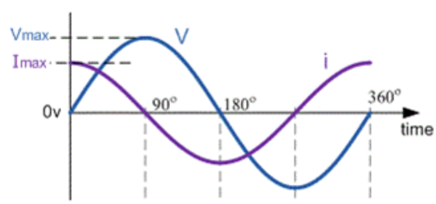
$$\therefore K_f = 1.1$$

Peak factor(K_a) $= \frac{V_m}{V_{rms}} = \frac{150}{106.05}$

$$\therefore K_a = 1.414$$

AC through a pure capacitive circuit. (Capacitor only)





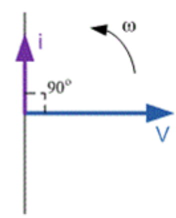


Fig: Circuit Diagram **Fig:** waveform of I and V **fig:**phasor diagram

Let the instantaneous value of supply voltage be,

$$v(t) = V_m \sin\theta$$

$$or.v(t) = V_m \sin\omega t........(i)$$

And, from the definition of capacitor

Q = C V

$$q = Cv$$

$$or, q = CV_m \sin\omega t$$

Now, we have

$$i = \frac{dq}{dt}$$

$$or, i = \frac{d}{dt}(CV_m \sin \omega t)$$

$$or, i = wCV_m \cos \omega t$$

$$or, i = wCV_m \sin(\omega t + 90^o)$$

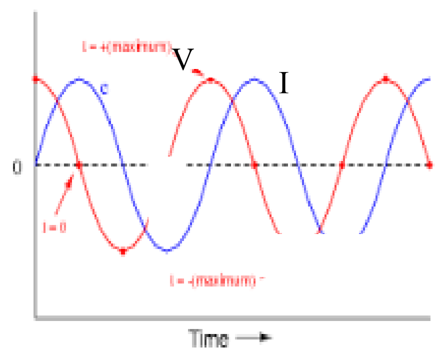
$$or, i = \frac{V_m}{\frac{1}{wC}} \sin\left(\omega t + \frac{\pi}{2}\right)$$

$$or, i = \frac{V_m}{X_c} \sin\left(\omega t + \frac{\pi}{2}\right)$$

where X_c = capcitive reactance = $\frac{1}{\omega C}$ measured in terms of ohms(Ω)

$$\therefore i = I_m \sin\left(\omega t + \frac{\pi}{2}\right) \ldots\ldots\ldots\ldots\ldots(ii)$$

where $I_m = \frac{V_m}{X_c}$ = maximum current



From eqns (i) and (ii), we can say that when ac is passed through a pure capacitive circuit, the current leads the voltage by a phase angle of 90° or $\left(\frac{\pi}{2}\right)^c$.

Again, Active power = I_{rms} X V_{rms} X $\cos\phi$ = 0 watt

Reactive power = I_{rms} X V_{rms} X $\sin\phi$ = I_{rms} X V_{rms} VAR

Total power or Apparent power $(S) = \sqrt{P^2 + Q^2}$

And, Power factor = $\cos\phi$

Numerical:

Find the capacitive reactance of a 8μF filter capacitor at a frequency of 120 Hz.

Solution:

Capacitance (C) = 0.8μF = 8 X 10^{-6} F

Frequency (f) = 120Hz

Now, we have

Capacitive reactance (X_c) = $\dfrac{1}{\omega C} = \dfrac{1}{2\pi f C}$

$$or, X_c = \frac{1}{2 \times 3.14 \times 120 \times 8 \times 10^{-6}}$$

$$\therefore X_c = 165.87\Omega$$

AC through a pure inductive circuit. (Inductor only)

Let the instantaneous value of supply voltage be,

$$v(t) = V_m \sin\theta$$

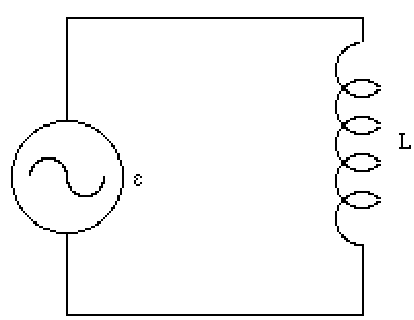
$$or. v(t) = V_m \sin\omega t........(i)$$

And, we have, from the definition of inductance

$$v = L\frac{di}{dt}$$

$$or, V_m \sin\omega t = L\frac{di}{dt}$$

$$or, \frac{V_m}{L}\sin\omega t = \frac{di}{dt}$$



v(t)=$V_m$sinw

Integrating both sides,

$$or, \int \frac{V_m}{L}\sin\omega t = i$$

$$or, \frac{V_m}{wL}(-\cos\omega t) = i$$

$$or, \frac{V_m}{wL}(-\sin(90^0 - \omega t)) = i$$

$$or, \frac{V_m}{X_L}\sin(-(90^0 - \omega t)) = i$$

where, X_L = inductive reactance = wL measured in terms of ohms(Ω)

$$or, I_m \sin(\omega t - 90^0) = i$$

$$\therefore i = I_m \sin\left(\omega t - \frac{\pi}{2}\right)..........(ii)$$

where, I_m = maximum current = $\frac{V_m}{X_L}$

From eq^{n}s (i) and (ii), we can say that when ac is passed through a pure inductive circuit, the current lags the voltage by a phase angle of 90^o or $\left(\frac{\pi}{2}\right)^c$.

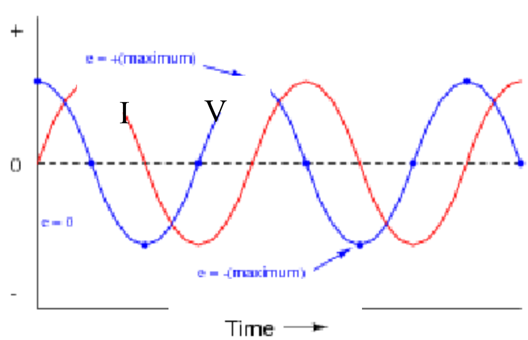


fig: waveform of I and V

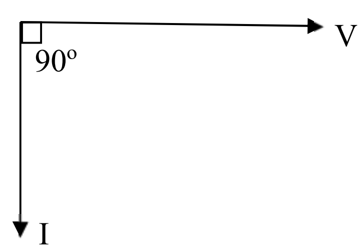


fig: phasor diagram

Again, Active power = I_{rms} X V_{rms} X $\cos\phi$ = 0 watt

Reactive power = I_{rms} X V_{rms} X $\sin\phi$ = I_{rms} X V_{rms} VAR

Total power or Apparent power $(S) = \sqrt{P^2 + Q^2}$

And, Power factor = $\cos\phi$

Alternatively,

Let the instantaneous value of supply current be,

$$i(t) = I_m \sin\theta$$

$$or.i(t) = I_m \sin\omega t........(i)$$

And, we have, from the definition of inductance

$$v = L\frac{di}{dt}$$

$$or, v = L\frac{dI_m \sin\omega t}{dt}$$

$$or, v = L\omega I_m \cos wt$$

$$or, v = \omega L I_m \sin\left(\omega t + 90^0\right)$$

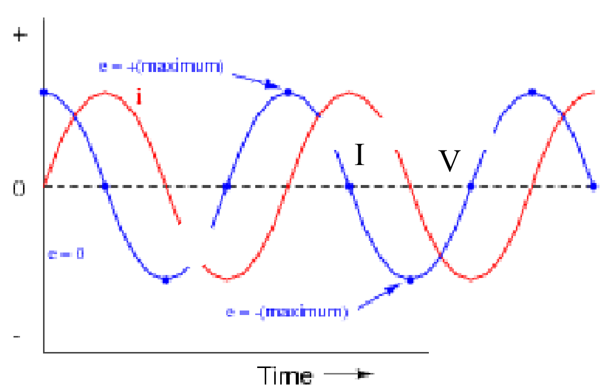
$$or, v = X_L I_m \sin\left(\omega t + \frac{\pi}{2}\right)$$

where, X_L = Inductive reactance = ωL measure in terms of ohms(Ω)

$$\therefore v = V_m \sin\left(\omega t + \frac{\pi}{2}\right)...........(ii)$$

where, V_m= maximum voltage = $I_m X_L$

From eqns (i) and (ii), we can say that when ac is passed through a pure inductive circuit, the voltage leads the current by a phase angle of 90o or $\left(\frac{\pi}{2}\right)^c$. i.e the current



lags the voltage by a phase angle of 90^o or $\left(\frac{\pi}{2}\right)^c$.

Again,

Active power = I_{rms} X V_{rms} X $\cos\phi$ = 0 watt

Reactive power = I_{rms} X V_{rms} X $\sin\phi$

= I_{rms} X V_{rms} VAR

Total power or Apparent power $(S) = \sqrt{P^2 + Q^2}$

And,

Power factor = $\cos\phi$

Numerical:

1. A small inductor of a TV receiver has a reactance of 50KΩ at 50 MHz. Find its inductance.

Solution:

Inductive reactance(X_L) = 50 KΩ = 50 X 10^3 Ω

Frequency (f) = 50 MHz = 50 X 10^6 Hz

Now, we have

Inductive reactance (X_L) = ωL

$$or, 50 \times 10^3 = 2 \times 3.14 \times 50 \times 10^6 \times L$$

$$or, L = \frac{50 \times 10^3}{314 \times 10^6}$$

$$or, L = 0.159 \times 10^{-3} H$$

$$\therefore L = 1.59 \times 10^{-4} H$$

2. A sinusoidal 50Hz current of maximum value 100 A flows through a capacitor of 318μF. Calculate:

i) The expression for instantaneous current

ii) Reactance of capacitor
iii) Expression for applied emf
iv) RMS value of current and voltage

Solution:

Frequency (f) =50 Hz

Angular frequency (ω) = $2\pi f = 2 \times 3.14 \times 50$

$$= 314 \, rad/\sec$$

Now, since the current leads the voltage by an angle of 90° in a capacitive circuit, the expression for instantaneous current can be expressed as

i = $I_m \sin(\omega t + 90^o)$

$$or, i = 100 \sin\left(314t + \frac{\pi}{2}\right)$$

Again,

Capacitive reactance (X_c) = $\frac{1}{\omega C} = \frac{1}{314 \times 318 \times 10^{-6}}$

$$or, X_c = \frac{1000000}{314 \times 318}$$

$$\therefore X_c = 10.015\Omega$$

Similarly

$V_m = I_m$ X X_c

or, Vm = 100 X 10.015

$$\therefore V_m = 1001.5V$$

And, expression for applied emf

v = $V_m \sin \omega t$

or, v=1001.5sin314t

And, for RMS value

$$V_{rms} = \frac{V_m}{\sqrt{2}} = \frac{1001.5}{\sqrt{2}}$$

$$\therefore V_{rms} = 708.17V$$

$$I_{rms} = \frac{I_m}{\sqrt{2}} = \frac{100}{\sqrt{2}}$$

$$\therefore I_{rms} = 70.71A$$

3. A sinusoidal 50Hz current of maximum value 20 A flows through a inductor of 40mH. Calculate:
   i) The expression for instantaneous current
   ii) Reactance of inductor
   iii) Expression for applied emf
   iv) RMS value of current and voltage
   v) Form factor and peak factor

Solution:

Inductance (L) = 40mH = 40×10^{-3} H

Frequency (f) =50 Hz

Angular frequency (ω) = $2\pi f = 2 \times 3.14 \times 50$

$$= 314 \, rad/\sec$$

Now, since the current lags the voltage by an angle of 90° in a inductive circuit, the expression for instantaneous current can be expressed as

$$i = I_m \sin(\omega t - 90^\circ)$$

$$or, i = 20 \sin\left(314t - \frac{\pi}{2}\right)$$

Again,

Inductive reactance (X_L) $= \omega L = 314 \times 40 \times 10^{-3}$

$$\therefore X_L = 12.56\Omega$$

Similarly

$V_m = I_m X X_L$

or, Vm = 20 X 12.56

$\therefore V_m = 251.2V$

And, expression for applied emf

$v = V_m \sin \omega t$

or, v=251.2sin314t

Similarly, for RMS value

$$V_{rms} = \frac{V_m}{\sqrt{2}} = \frac{251.2}{\sqrt{2}}$$

$$\therefore V_{rms} = 177.63V$$

$$I_{rms} = \frac{I_m}{\sqrt{2}} = \frac{20}{\sqrt{2}}$$

$$\therefore I_{rms} = 14.14A$$

And,

$$V_{avg} = \frac{2V_m}{\pi} = \frac{2 \times 251.2}{3.14}$$

$$\therefore V_{avg} = 160V$$

$$\text{Form factor}(K_f) = \frac{V_{rms}}{V_{avg}} = \frac{177.63}{160}$$

$$\therefore K_f = 1.1$$

$$\text{Peak factor}(K_a) = \frac{V_m}{V_{rms}} = \frac{251.2}{177.63}$$

$$\therefore K_a = 1.414$$

An inductive coil having negligible resistance and 0.2H inductance is connected across 300V, 50Hz supply. Find,

a) Inductive reactance
b) RMS value of current
c) Power and
d) Equation for current and voltage

Solution:

Inductance (L) = 0.2H
Frequency (f) =50 Hz
Angular frequency (ω) = $2\pi f = 2 \times 3.14 \times 50$

$$= 314 \, rad/\sec$$

Now,

Inductive reactance (X_L) $= \omega L = 314 \times 0.2$

$$\therefore X_L = 62.8\Omega$$

Similarly

$$I_{rms} = \frac{V}{X_L} = \frac{300}{62.8}$$

$$\therefore I_{rms} = 4.777\,A$$

Again, Power (P) = 0

And,

$V_m = \sqrt{2}V_{rms} = \sqrt{2} \times 300$

$$\therefore V_m = 424.264V$$

$I_m = \sqrt{2}I_{rms} = \sqrt{2} \times 4.777$

$$\therefore I_m = 6.756\,A$$

expression for applied emf

$v = V_m \sin \omega t$

or, $v = 424.264 \sin 314t$

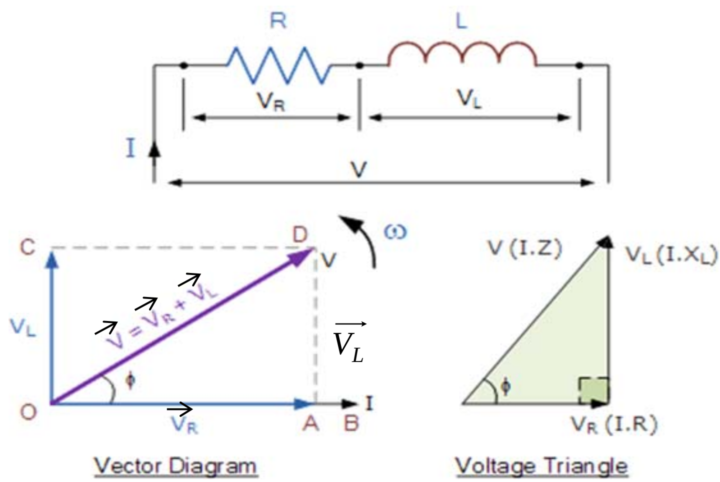
And, expression for current

$$i = I_m \sin(\omega t - \frac{\pi}{2}) \text{volts}$$

It is because the current lags the voltage by an angle of 90° in a pure inductive circuit.

$$\therefore i = 6.756\sin(314t - \frac{\pi}{2}) A$$

AC through a circuit containing resistor and inductor connected in series. (R and L in series)



Voltage drop across resistor (V_R) = iR

Voltage drop across inductor (V_L) = iX_L

When an ac signal is passed through a circuit containing resistor and inductor connected in series, it is found that the voltage is equal to the vector sum of voltage drop across resistor and inductor.

$$i.e. V = \vec{V_R} + \vec{V_L}$$

$$\therefore V = \sqrt{(V_R)^2 + (V_L)^2}$$

$$or, V = \sqrt{(iR)^2 + (iX_L)^2}$$

$$or, V = \sqrt{i^2R^2 + i^2X_L{}^2}$$

$$or, V = \sqrt{i^2(R^2 + X_L{}^2)}$$

$$or, V = i\sqrt{(R^2 + X_L{}^2)}$$

$$or, \frac{V}{i} = \sqrt{(R^2 + X_L{}^2)}$$

$$\therefore Z = \sqrt{(R^2 + X_L{}^2)}$$

where, Z = $\frac{V}{i}$ = impedance of the R-L circuit

Let the instantaneous value of supply voltage be,

$v(t) = V_m \sin\theta$ where $V_{rms} = \frac{V_m}{\sqrt{2}}$

$$or. v(t) = V_m \sin\omega t........(i)$$

Then,

$i = I_m \sin(\omega t - \phi)........(ii)$ where $I_{rms} = \frac{I_m}{\sqrt{2}}$

From the above relations, it is cleared that the current lags the voltage by an angle of 'ϕ'

where,

$$\tan\phi = \frac{reactance}{resistance} = \frac{X_L}{R}$$

$$or, \tan\phi = \frac{\omega L}{R}$$

$$\therefore \phi = \tan^{-1}\left(\frac{\omega L}{R}\right)$$

Now,

$$\text{Power factor} = \cos\phi = \left(\frac{R}{Z}\right)$$

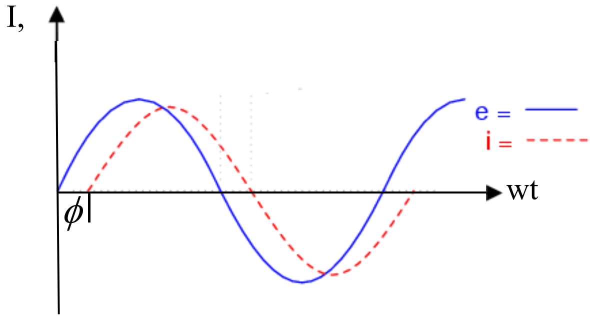


fig:waveform showing V and I

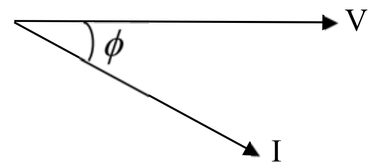


fig: phasor diagram

And,

Active Power = IVcosϕ

$$or, P = IV\left(\frac{R}{Z}\right)$$

$$or, P = IR\left(\frac{V}{Z}\right)$$

$$or, P = IR \times I$$

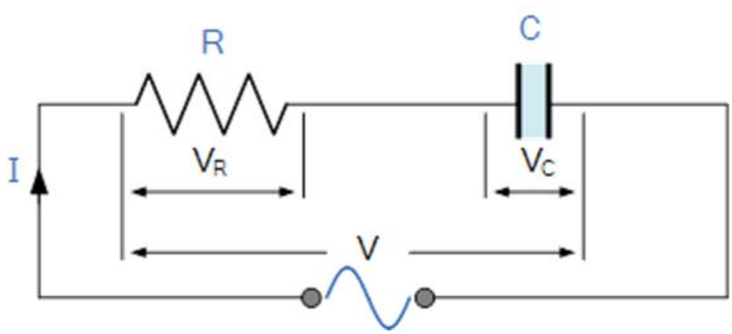
$$\therefore P = I^2R \text{ watt}$$

Hence the pure inductor doesn't consume the power, only the resistor consumes the power.

Again, Reactive power = I_{rms} X V_{rms} X $\sin\phi$ VAR

Total power or Apparent power $(S) = \sqrt{P^2 + Q^2}$

AC through a circuit containing resistor and capacitor connected in series. (R and C in series)



v(t)=$V_m \sin \omega$t

Voltage drop across resistor (V_R) = iR

Voltage drop across capacitor (V_c) = iX_c

When an ac signal is passed through a circuit containing resistor and inductor connected in series, it is found that the voltage is equal to the vector sum of voltage drop across resistor and inductor.

$$i.e. V = \overrightarrow{V_R} + \overrightarrow{V_C}$$

$$\therefore V = \sqrt{(V_R)^2 + (V_C)^2}$$

$$or, V = \sqrt{(iR)^2 + (iX_C)^2}$$

$$or, V = \sqrt{i^2R^2 + i^2X_C{}^2}$$

$$or, V = \sqrt{i^2(R^2 + X_C{}^2)}$$

$$or, V = i\sqrt{(R^2 + X_C{}^2)}$$

$$or, \frac{V}{i} = \sqrt{(R^2 + X_C{}^2)}$$

$$\therefore Z = \sqrt{(R^2 + X_C{}^2)}$$

where, $Z = \frac{V}{i}$ =impedance of the R-C circuit

Let the instantaneous value of supply voltage be,

$$v(t) = V_m \sin\theta \quad \text{where } V_{rms} = \frac{V_m}{\sqrt{2}}$$

$$or. v(t) = V_m \sin \omega t........(i)$$

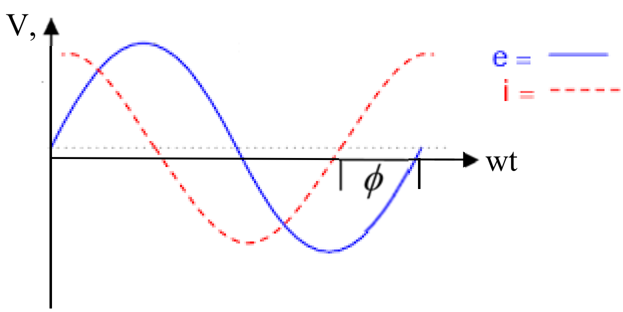
Then, $i = I_m \sin(\omega t + \phi)........(ii)$ where $I_{rms} = \frac{I_m}{\sqrt{2}}$

From the above relations, it is cleared that the current leads the voltage by an angle of 'ϕ' where,

$$\tan\phi = \frac{reactance}{resistance} = \frac{X_C}{R}$$

$$or, \tan\phi = \frac{\frac{1}{\omega C}}{R} = \frac{1}{\omega CR}$$

$$\therefore \phi = \tan^{-1}\left(\frac{1}{\omega CR}\right)$$



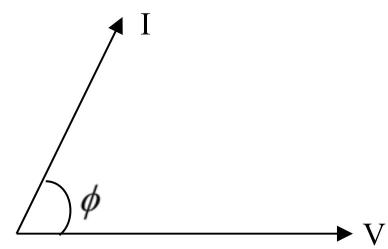


Fig: Waveform showing V and I

Fig: Phasor diagram

Again,

$$\text{Power factor} = \cos\phi = \left(\frac{R}{Z}\right)$$

And,

Power = IVcosϕ

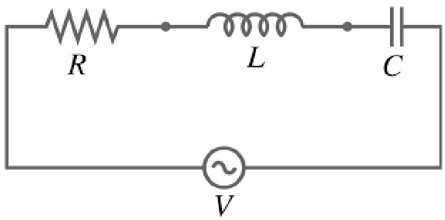
Hence the pure capacitor doesn't consume the power, only the resistor consumes the power.

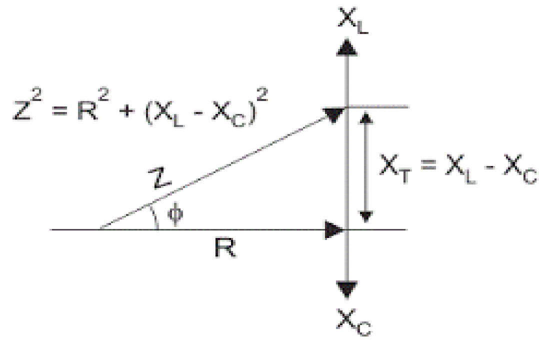
Again,

Reactive power = I_{rms} X V_{rms} X $\sin\phi$ VAR

Total power or Apparent power $(S) = \sqrt{P^2 + Q^2}$

AC through a circuit containing resistor, inductor and capacitor connected in series. (R, L and C in series)





VVoltage drop across resistor (V_R) = iR
Voltage drop across capacitor (V_c) = iX_c
Voltage drop across inductor (V_L) = iX_L

Since the voltage drop across inductor and capacitor are acting in opposite direction, so the resultant voltage drop is V_L-V_C (assuming V_L>V_C). And the applied voltage $(\overrightarrow{AC})$ is equal to the vector sum of $(\overrightarrow{AB})$ and $(\overrightarrow{BC})$.

$$i.e. \overrightarrow{AC} = \overrightarrow{AB} + \overrightarrow{BC}$$

Now, $AC = \sqrt{AB^2 + BC^2}$

$$or, V = \sqrt{V_R{}^2 + (V_L - V_C)^2}$$

$$or, V = \sqrt{(iR)^2 + (iX_L - iX_C)^2}$$

$$or, V = \sqrt{i^2R^2 + i^2(X_L - X_C)^2}$$

$$or, V = i\sqrt{R^2 + (X_L - X_C)^2}$$

$$or, V = i\sqrt{R^2 + X^2}$$

where, X = $(X_L - X_C)$ = net reactance

$$or, \frac{V}{i} = \sqrt{R^2 + X^2}$$

$$\therefore Z = \sqrt{R^2 + X^2}$$

where, Z = impedance of RLC circuit

Here,

If XL > XC, then it is called net inductive reactance and If Xc > Xl, then it is called net capacitive reactance

Also,

If the instantaneous value of supply voltage be,

$$v(t) = V_m \sin\theta \quad \text{where Vrms} = \frac{V_m}{\sqrt{2}}$$

$$or. v(t) = V_m \sin \omega t ....(i)$$

Then,

$$i = I_m \sin(\omega t + \phi), \text{when } X_C > X_L \quad \text{where Irms} = \frac{I_m}{\sqrt{2}}$$

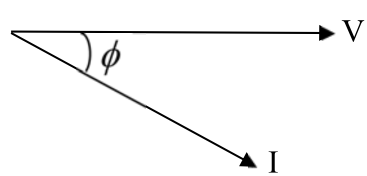
$$i = I_m \sin(\omega t - \phi), \text{when } X_L > X_C \quad \text{where Vrms} = \frac{I_m}{\sqrt{2}}$$

where,

$$\tan\phi = \frac{\text{net inductive reactance}}{resistance}$$

$$\therefore \tan\phi = \frac{X}{R}$$

$$i.e. \phi = \tan^{-1}\frac{X}{R}$$



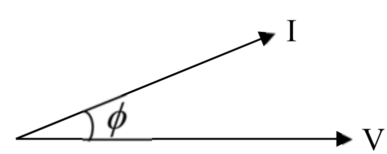


Fig: phasor digram for net inductive **Fig:** phasor digram for net capacitive

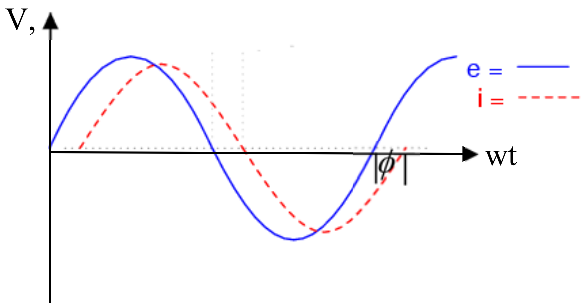


Fig: Waveform between I and V for net inductive circuit

Power factor of RLC circuit

$$p.f. = \cos\phi = \frac{Resistance}{Impedance} = \frac{R}{Z}$$

$$p.f. = \frac{R}{\sqrt{R^2 + X^2}}$$

Again,

Active power = = I_{rms} X V_{rms} X sinϕ watt

Reactive power = I_{rms} X V_{rms} X sinϕ VAR

Total power or Apparent power $(S) = \sqrt{P^2 + Q^2}$

Numerical:

1. A coil having a resistance of 7Ω and an inductance of 31.8mH is connected to 230V, 50Hz supply. Calculate
   a) Circuit current
   b) Phase angle
   c) Power factor
   d) Power consumed

Solution:

Resistance (R) = 7Ω

Frequency (f) = 50Hz

Angular frequency (ω) = $2\pi f = 2\times 3.14\times 50$

$$=314\, rad/\sec$$

Inductance (L) = 31.8 mH

$$\therefore \text{Inductive Reactance}(X_L) = \omega L$$

$$\text{or, } X_L = 314\times 31.8\times 10^{-3}$$

$$\therefore X_L = 9.9852\Omega$$

Now,

$$\text{Impedance of circuit (Z)} = \sqrt{R^2 + X_L^2}$$

$$\text{or, } Z = \sqrt{7^2 + 9.9852^2}$$

$$\text{or, } Z = \sqrt{148.7}$$

$$\therefore Z = 12.2\Omega$$

Again,

$$\text{Current (I)} = \frac{V}{Z}$$

$$\text{or, } I = \frac{230}{12.2} = 18.85A$$

Similarly,

$$\text{Tan}\phi = \frac{\text{Inductive Reactance}}{\text{Resistance}}$$

$$\text{or, } \tan\phi = \frac{X_L}{R} = \frac{9.9852}{7} = 1.43$$

$$\text{or, } \phi = \tan^{-1}(1.43)$$

$\therefore \phi = 55.035^{o}(lag)$

And,

$$\text{Power factor} = \cos\phi = \cos 55.035$$

$$\therefore \text{p.f.} = 0.573(lag)$$

Power = IV cosϕ

or, P = 18.85 X 230 X 0.573

$$\therefore P = 2484.24\text{watt}$$

3. A resistance of 70Ω and a capacitance of 50μF are connected in series across 220V, 50 Hz supply. Calculate
   (i) Capacitive reactance; (ii) current; (iii) power factor and (iv) voltage across resistance and capacitor.

Solution:

Resistance (R) = 70Ω

Frequency (f) = 50Hz

Angular frequency (ω) = $2\pi f = 2 \times 3.14 \times 50$

$$= 314 \, rad/\text{sec}$$

Capacitance (C) = 50 μF

$$\therefore \text{Capacitive Reactance}(X_C) = \frac{1}{\omega C}$$

$$\text{or, } X_c = \frac{1}{314 \times 50 \times 10^{-6}}$$

$$\therefore X_C = 63.694\,\Omega$$

Now,

$$\text{Impedance of circuit (Z)} = \sqrt{R^2 + X_C{}^2}$$

$$\text{or, } Z = \sqrt{70^2 + 63.694^2}$$

$$\text{or, } Z = \sqrt{8956.93}$$

$$\therefore Z = 94.64\Omega$$

Again,

$$\text{Current (I)} = \frac{V}{Z}$$

$$\text{or, } I = \frac{220}{94.64} = 2.325A$$

Similarly,

$$\text{Tan}\phi = \frac{\text{InductiveReactance}}{\text{Resistance}}$$

$$\text{or, } \tan\phi = \frac{X_c}{R} = \frac{63.694}{70} = 0.91$$

$$\text{or, } \phi = \tan^{-1}(0.91)$$

$$\therefore \phi = 42.3^{o}(lead)$$

And,

$$\text{Power factor} = \cos\phi = \cos 42.3^{o}$$

$$\therefore \text{p.f.} = 0.7396(lead)$$

And,Voltage across resistor (V_R) = I X R = 2.325 X 70 = 162.75 V

Voltage across capacitor (V_C) = I X X_c = 2.325 X 63.694 = 148.09 V

A coil of resistance 20Ω and inductance 0.2H is connected in series with a condenser of capacitance 200μF across a 200V, 50Hz supply. Calculate (i) impedance of the circuit; (ii) current; (iii) power factor; (iv) voltage across the coil and (v) voltage across the condenser.

Solution.

Resistance (R) = 20Ω

Frequency (f) = 50Hz

Angular frequency (ω) = $2\pi f = 2\times 3.14\times 50$

$$=314\ {rad}/{\sec}$$

Capacitance (C) = 200 μF

$$\therefore \text{Capacitive Reactance}(X_C) = \frac{1}{\omega C}$$

$$\text{or, } X_c = \frac{1}{314\times 200\times 10^{-6}}$$

$$\therefore X_C = 15.923\,\Omega$$

Inductance (L) = 0.2 H

$$\therefore \text{Inductive Reactance}(X_L) = \omega L$$

$$\text{or, } X_L = 314\times 0.2$$

$$\therefore X_L = 62.8\,\Omega$$

$$Since,\ X_L > X_c, \text{ net reactance}(X) = (62.8 - 15.923)\,\Omega$$

$$\therefore X = 46.877\,\Omega$$

Now,

$$\text{Impedance of circuit }(Z) = \sqrt{R^2 + X^2}$$

$$\text{or, } Z = \sqrt{20^2 + 46.877^2}$$

$$\text{or, } Z = \sqrt{2597.45}$$

$$\therefore Z = 50.97\,\Omega$$

Again,

$$\text{Current (I)} = \frac{V}{Z}$$

$$\text{or, } I = \frac{200}{50.97} = 3.92A$$

Similarly,

$$\text{Tan}\phi = \frac{\text{Net Reactance}}{\text{Resistance}}$$

$$\text{or, } \tan\phi = \frac{X}{R} = \frac{46.877}{20} = 2.34$$

$$\text{or, } \phi = \tan^{-1}(2.34)$$

$$\therefore \phi = 66.86^{\circ} (lag)$$

And,

$$\text{Power factor} = \cos\phi = \cos 66.86^{\circ}$$

$$\therefore \text{p.f.} = 0.393 (lag)$$

Similarly,

$$\text{Impedance of coil } (Z_1) = \sqrt{R^2 + X_L^2}$$

$$\text{or, } Z_1 = \sqrt{20^2 + 62.8^2}$$

$$\text{or, } Z_1 = \sqrt{4343.84}$$

$$\therefore Z_1 = 65.91\Omega$$

And, Voltage across coil (V_1) = I X Z_1 = 3.92 X 65.91 = 258.37 V

Voltage across capacitor (V_C) = I X X_c = 3.92X 15.923 = 62.42 V

Tutorials

1. An alternating voltage source is given by the relation

$$V = 200 \sin\left(200t + \frac{\pi}{4}\right), \text{ find}$$

a) maximum voltage

b) frequency

c) time period

2. The instantaneous voltage for an AC is given by v = 100sin(523.6t-150°), calculate:

a) Maximum voltage
b) Frequency
c) (iii) RMS voltage and average voltage
d) Time period

3. The current sinusoid of an AC element is i(t) = 10sin314t, calculate:

a. Maximum current
b. Frequency
c. RMS and average value of current
d. Form factor and peak factor

4. A sinusoidal 50Hz current of maximum value 80A flows through a resistor of 50Ω resistance. Calculate:

a) Expression for instantaneous current
b) Equation for applied emf
c) RMS value of current and voltage
d) Form factor

5. A sinusoidal 75Hz current of maximum value of 150A flows through a capacitor of 450µF capacitance, calculate,

a) The expression for instantaneous current
b) Reactance of capacitor
c) Equation for applied e.m.f.
d) RMS value of current and voltage
e) Form factor and peak factor

6. A coil with a resistance of 24Ω has a reactance of 32Ω when connected across a supply voltage, v= 566sin314t. Calculate,

a) frequency
b) RMS value of current
c) power factor
d) Equation for resultant current.

7. **A resistance of 10Ω is connected in series with an inductance of 0.524 H and a capacitor of 63.5µF to a 200V, 50 Hz supply. Determine the line current, power and power factor for the current.[Ans: 6.62A; 400W ; 0.316]**
   Also draw the necessary phasor diagram.
8. **A resistance of 100Ω is connected in series with a 56µF capacitor to a supply at 230V, 50Hz supply. Find,**
   a) Impedance
   b) Current
   c) Phase angle
   d) Power factor
   e) Voltage across resistance and capacitor.
      Also draw the necessary phasor diagram. [Ans: 115Ω; 2A; 29.6°; 0.87; 200V; 113.7V]
9. **A capacitor of capacitance 70µF is connected in series with a non-inductive resistance of 20Ω across 110V, 50 Hz supply. Find,**
   a) Impedance
   b) Current
   c) phase angle
   d) Equation for instantaneous value of current.
      [Ans: 49.7Ω; 2.213A; 66.27°(lead); 3.13sin(314t+66.27°)]

Teaching tips / Reference to the teacher

- Explain about the concept of alternating current. (Generation)
- Explain in detail about the parameters of ac.
- Explain the application of ac.
- Show the responses of ac in different circuits. (Lead or lag)
- Show the responses in the videos.
- Comparison between the different types of ac circuits.

Reference:

1. A text book of electrical technology, B.L.Thereja, A.K.Thereja
2. A textbook of electrical engineering, J.B.Gupta
3. A handbook of electrical engineering, S.L.Bhatia
4. A textbook of Electrical Engineering, P.S.Dhogal
5. www.fixit.com
6. www.allibaba.com
7. www.electricalkit.com

UNIT-6

Three Phase Circuits

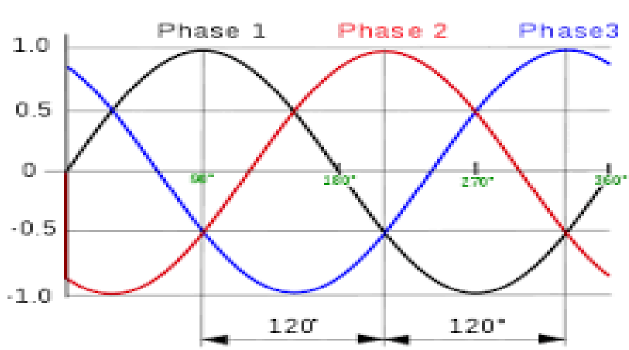
Objectives:

After completion of this chapter, the students will be able to

1. Understand the different terms and parameters related with three phase system.
2. Compare three phase system with other (advantages/disadvantages).
3. Understand about connections of three phase system.

Polyphase system

A polyphase system is a means of distributing alternating-current electrical power. Polyphase systems have three or more energized electrical conductors carrying alternating currents with a definite phase difference between the voltage waves in each conductor. Polyphase systems are particularly useful for transmitting power to electric motors. The most common example is the three-phase power system used for industrial applications and for power transmission. A major advantage of three phase power transmission (using three conductors, as opposed to a single phase power transmission, which uses two conductors), is that, since the remaining conductors act as the return path for any single conductor, the power transmitted by a balanced three phase system is three times that of a single phase transmission but only one extra conductor is used.



The single phase system is used for most of the application but in some cases it may not be applicable in some of the fields of electrical engineering such as power transmission, electro-mechanical energy conversion etc. In case of power transmission, the single phase ac circuit does not make use of the conduction system in appropriate condition and for energy conversion, the single phase machines provides a pulsating torque and operates at a very low power factor and it may often require additional apparatus for starting. Using three phase systems, these types of problems can be easily overcome. Hence three phase systems are mostly used in the field of power applications.

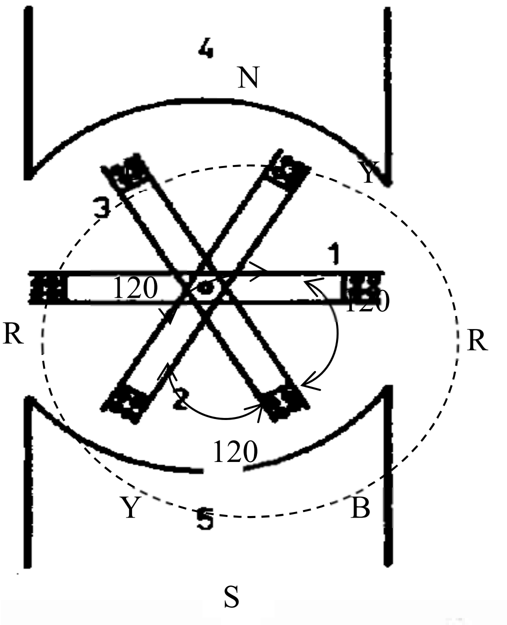
The advantages of three phase system over single phase system can be listed as follows.

1. Three phase power distribution requires lesser amount of copper or aluminium for transferring the same amount of power as compared to single phase power
2. The output of three phase machine is about 1.5 times the output of single phase machine of the same size. The 3-ϕ alternator occupies less space for a given size and voltage and costs less than the single phase machine of same ratings.
3. In three phase system, the power delivered is almost constant, when the loads are balanced but it is pulsating in single phase system.
4. The voltage regulation of three phase transmission line is better than that of single phase line. Similarly, single phase can be obtained from three phase but three phase cannot be obtained from single phase.
5. Higher power can be obtained from three phase system, hence can be used for running big and heavy motors.

Generation of three phase voltages

The three phase system contains three equal voltages of same frequency having a phase difference of 120^o. Three phase voltages are generated by three phase alternator. The armature of alternator contains the coils which are divided into three groups in such a way that they are displaced by 120^o from each other.

When these three windings are rotated in a stationary magnetic field as shown in the figure shown below or when the magnetic field is rotated by keeping the windings stationary as in figure below, an emf is induced in each winding according to the law of electromagnetic induction. Since the rotation is done at constant speed, so these emf has equal magnitude and frequency but they are displaced from one another by a phase angle of 120º.



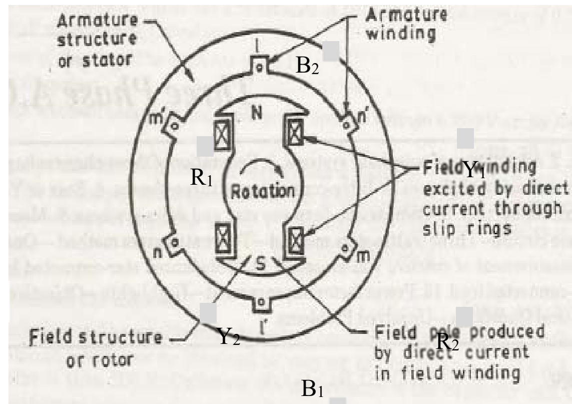
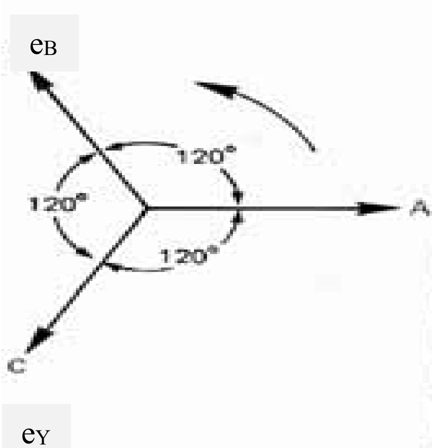


Fig. 1. Elementary 3-phase 2-pole generator.



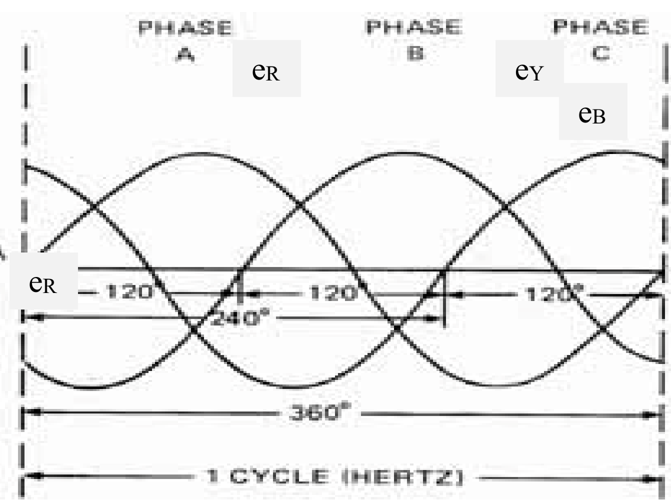


***Fig** source: Internet*

Let e_R, e_Y and e_B be the three voltages induced in the coils R_1-R_2, Y_1-Y_2 and B_1-B_2 respectively. All of these coils are displaced from one another by an angle of 120º.

Here, e_R is taken as the reference and is zero for the instant. At the same time, e_Y will be displaced by 120° from e_R. Similarly e_B will be ahead of e_Y by an angle of 120°. i.e if e_R is the reference, then e_Y will attain the maximum and minimum position 120° later than e_R and e_B will attain the maximum and minimum position 120° later than e_Y, i.e 120°+120° = 240° later with respect to e_R. All these coils together represent a three phase system.

The equation for the induced voltages are given by

$$e_R = E_m \sin \omega t$$

$$e_Y = E_m \sin(\omega t - 120^0)$$

$$e_B = E_m \sin(\omega t - 240^o)$$

$$= E_m \sin(\omega t + 120^o)$$

These emfs are called phase emfs. The corresponding emf waveforms and phasor diagrams are shown in the figure above.

The sum of these three phase voltages is zero.

$$i.e, e_R + e_Y + e_B = E_m \sin \omega t + E_m \sin(\omega t - 120^o) + E_m \sin(\omega t + 120^o)$$

$$= E_m(\sin \omega t + \sin \omega t \cos 120^o - \cos \omega t \sin 120^o + \sin \omega t \cos 120^o + \cos \omega t \sin 120^o)$$

$$= E_m(\sin \omega t + 2 \sin \omega t \cos 120^o)$$

$$= E_m\left[\sin \omega t + 2 \sin \omega t\left(-\frac{1}{2}\right)\right]$$

$$= E_m(\sin \omega t - \sin \omega t)$$

$$= 0$$

Phase sequence

The three voltages in three phase system have same magnitude and frequency and are displaced by an angle of 120° electrical. The voltages in the three phase system reach the maximum value on the basis of particular order, which is known as phase sequence.

The voltages in three phase system attain the maximum value in the order of R_1R_2, Y_1Y_2, B_1B_2 and are named as R, Y, B. This is termed as positive sequence. If these are considered in reverse way, that is from B to R as B, Y, R, then it is termed as negative sequence.

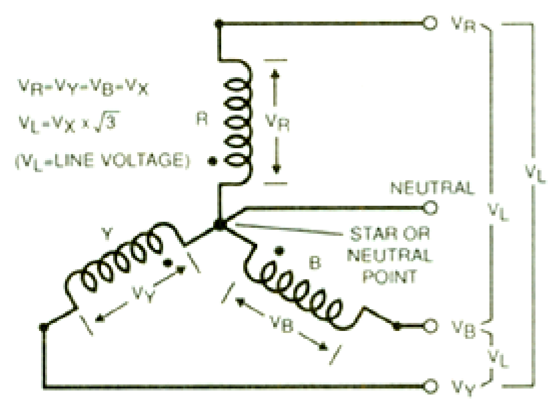
In case of three phase motors, it rotates in clockwise direction in the positive phase sequence and it rotates in anticlockwise direction, if the motor is connected to negative phase sequence.

Connection in three phase system

The three phase lines contained in three phase system can be connected to a circuit in two different ways, star or wye and mesh or delta connection. Both the type of connection derived its name from its appearance while connected to the circuit. The wye or star connection looks like capital letter 'Y' whereas the delta or mesh connection looks like a Greek letter 'Δ'.

Star or Wye(Y) connection

All of the three phases in three phase system have two ends i.e start and end. In this type of connection, one end of each of the three phases is connected to a common point known as neutral point. While connecting the ends, it should be noted that either start of all the three phases or end of all three phases is connected. It should not be connected at random. And the remaining three ends of the phases gives R, Y and B. These three line conductors run from the star connection are commonly called lines.



Generally, three wires are brought to the circuit giving a three phase three wire star connected system. However, sometimes a fourth wire can also be taken from the neutral point giving a three phase four wire star connected system.

As in figure, the current flowing through each of the phases is called phase current (I_{ph}) and the current flowing through each of the line conductor is known as line current (I_L).(i.e I_R, I_Y and I_B)

Similarly, the voltage across each phase or winding is called phase voltage(V_{ph}) or it can also be defined as the voltage between the line and neutral(i.e. V_{NR}, V_{NY}, V_{NB})

Likewise, the voltage across the two line conductors or two windings is known as line voltage(V_L) or can be said as line to line voltage. (i.e V_{RY}, V_{YB}, V_{BR})

In a wye or star connected three phase system, it is found that the line voltage is $\sqrt{3}$ times greater than the phase voltage.

i.e Line voltage = $\sqrt{3}$ X Phase voltage

$$\therefore V_{RY} = \sqrt{3} \times V_{ph}$$

$$V_{YB} = \sqrt{3} \times V_{ph}$$

$$V_{BR} = \sqrt{3} \times V_{ph}$$

As, the line conductor is connected in series with the phase winding, it is clear that the same current flows through the phase winding and the line conductor

i.e $I_R = I_{NR}$; $I_Y = I_{NY}$ and $I_B = I_{NB}$;
where, I_{ph} (phase current) = $I_{NR} = I_{NR} = I_{NR}$
and, $I_R = I_Y = I_B = I_L$(line current)

Hence in star conncetion,
Line current = phase current (i.e $I_L = I_{ph}$)

Mesh or Delta Connection

In delta connection, the three windings or phase lines are connected to each other forming a triangle. i.e the three windings are connected to each other in such a way that the starting end of one winding is connected to finishing end of another winding forming a closed mesh. In delta connection, there is absence of neutral point. So it is generally a three wired system. In a balance system, the sum of voltages in a circuit is zero.

i.e $V_{RY} + V_{YB} + V_{BR} = 0$

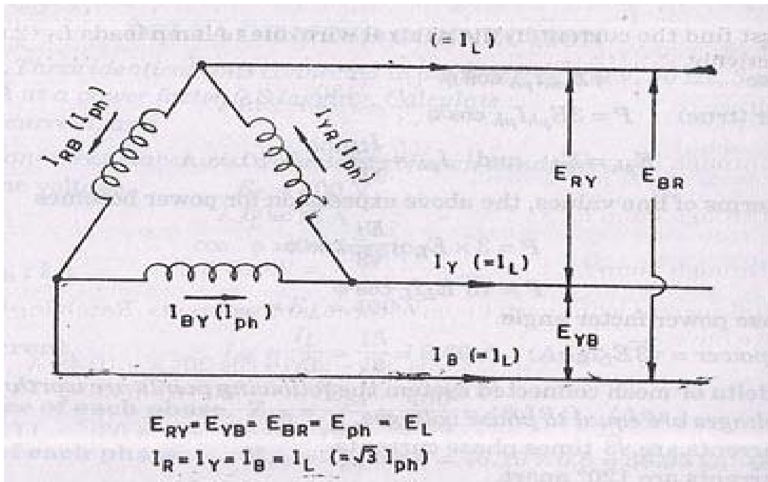


Figure Source: Internet

The three line conductors R, Y and B run from the three junctions called line conductors. The current flowing through each of the phases or windings is known as phase current (I_{ph}) and the current flowing through each of the line conductor is called line current (I_L).

In a delta connected three phase system, there is no presence of neutral point. So the line voltage is measured between any two windings and the phase voltage will have the same value as that of the line voltage.

i.e Line voltage = Phase voltage

$$\therefore E_{line} = E_{phase}$$

And in delta connected three phase system, it is found that the current flowing through each windings or phases is $\sqrt{3}$ times greater than the current through each load resistor.

$$\therefore I_{line} = \sqrt{3} I_{phase}$$

Power in three phase circuit

The power in a single phase circuit or system is given by,

$P = IV \cos\phi$

Where, P = power consumed

V = single phase voltage (V_{ph})

I = single phase current (I_{ph})

$\cos\phi$ = power factor of the circuit.

Now, the power in the three phase balance system or circuits, the power is the sum of powers in the three phases contained in it.

i.e. $P = 3\ I_{ph} \times V_{ph} \times \cos\phi$

For a star connected three phase system.

Since $I_{ph} = I_L; V_{ph} = \frac{V_L}{\sqrt{3}}$

$$P = 3 \times I_L \times \frac{V_L}{\sqrt{3}} \times \cos\phi$$

$$\therefore P = \sqrt{3} \times I_L \times V_L \times \cos\phi$$

Similarly, For a star connected three phase system.

Since $V_{ph} = V_L; I_{ph} = \frac{I_L}{\sqrt{3}}$

$$P = 3 \times \frac{I_L}{\sqrt{3}} \times V_L \times \cos\phi$$

$$\therefore P = \sqrt{3} \times I_L \times V_L \times \cos\phi$$

Therefore, the total power in a three phase balanced load is given by $P = \sqrt{3} \times I_L \times V_L \times \cos\phi$ for both the types of connection either star or delta connected three phase system. And its SI unit is watt (W) or kilowatt (kW).

Likewise,

Apparent power, $P_a = \sqrt{3} \times I_L \times V_L$

Its SI unit is volt ampere (VA) or kilovolt ampere (kVA).

And,

Reactive power, $P_r = \sqrt{3} \times I_L \times V_L \times \sin\phi$

Its SI unit is volt ampere reactive (VAR) or kilovolt ampere reactive (kVAR).

Teaching Tips / Reference to the teacher

- Give clear concept of polyphase and three phase system.
- Concept about the generation of three phase system.
- Explain the application of three phase system.
- Clarify about the advantages of three phase over single phase system.
- Explain about the types of connection in three phase system.
- Clarify about the parameters in three phase system in both connections.
- Show slides or vides or clips related to the topics.
- Internet surfing

Reference:

1. A text book of electrical technology, B.L.Thereja, A.K.Thereja
2. A handbook of electrical engineering, S.L.Bhatia
3. A text book of electrical engineering, J.B.Gupta
4. A textbook of Electrical Engineering, P.S.Dhogal
5. www.fixit.com
6. www.allibaba.com
7. www.electricalkit.com

LAB MANUAL

EXPERIMENT NO. 1

Title: Demonstrate the phenomenon of electrification

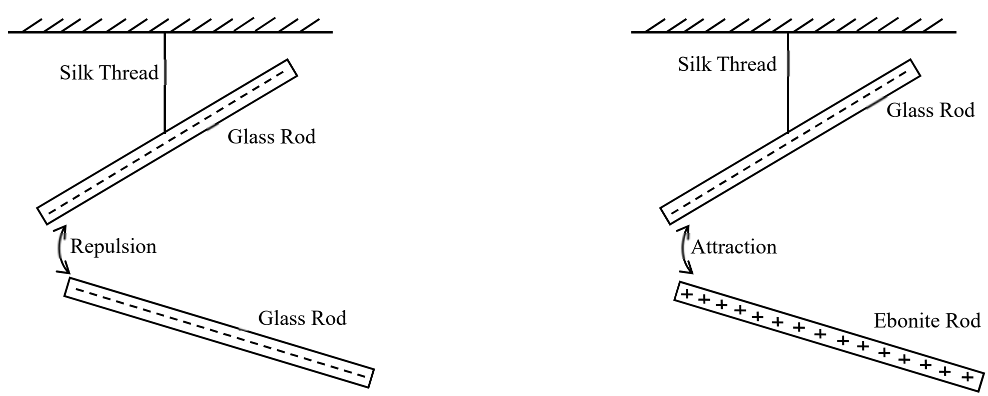
Objective: To demonstrate the phenomena of electrification. (static electricity)

Apparatus Required:

1. Glass rods – 2 nos
2. Ebonite rod – 1 no
3. Silk cloth
4. Fur
5. Thread

Theory:

When a plastic comb is brought near to the pieces of paper, it does not attract the papers. But when it is brought nearer after rubbing or combing the hair, it attracts the paper. Similarly when a glass rod rubbed with silk cloth is brought nearer to the pieces of paper, the glass rod will also attracts the pieces of paper. From these it can be said that the attracting capacity is developed on the body due to friction.



When the body produces a charge on it, it is said to be electrically charged or electrified. The process of producing the charge on a body is called electrification. Sometimes, a crackling sound is heard in the electrification caused by friction. It can be felt when we take out sweater in dark room. These crackling sounds are due to the electric sparks.

Procedure:

i. Rub a glass rod with silk cloth and hang it with the help of thread.
ii. Rub another glass rod with silk cloth again and bring it nearer to the first glass rod.
iii. Find the result.
iv. Rub an ebonite rod with fur and bring it nearer to the first glass rod.
v. Find the result.

Observations:

Precautions:

1) The glass rod must be rubbed in silk cloth.
2) The glass rods must be brought closer to next one as soon as possible after rubbing.
3) The rods should be rubbed with a particular material.

Conclusion:

……………………………………………………………………………………
……………………………………………………………………………………
…………………………………………………………………………………….

Viva-Voce

1. What do you mean by static electricity?
2. How does an object develop charge in it?
3. How does an object develop positive charge in it?
4. How does an object develop positive charge in it?
5. State laws of charge.

EXPERIMENT NO. 2

Title: **Familiarization with electrical equipments.**

Objective: To familiarize with different electrical equipments and their functions.

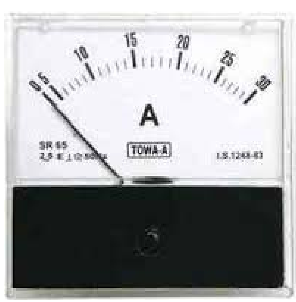
Apparatus Required:

1. Ammeter	2. Voltmeter	3. Galvanometer	4.Ohm-meter
5. Multimeter	6. Frequency meter	7. Watt meter	8. Energy meter

Theory:

Different types of equipment are needed to measure the value of different components and parameters of a circuit. They do have their own function and are connected in different configuration to the circuit.

1. Ammeter: It is an electrical equipment used to measure the current flowing through the circuit. It should be connected in series to circuit and has low resistance.



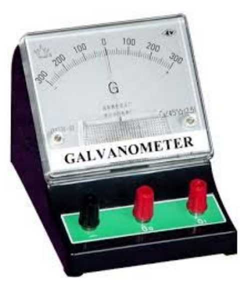


Fig: Ammeter **fig:** Volt meter **fig:** Galvanometer

2. Voltmeter: It is an electrical equipment used to measure the potential difference across any component in a circuit. It has high resistance and is connected in parallel to the circuit.
3. Galvanometer: It is used to detect the presence of current in a circuit. It also shows the direction of current flowing through the circuit.

fig: ohm meter **fig:** multi meter **fig:** frequency meter

4. Ohmmeter: It is used to measure the resistance of the substance. It is connected in parallel across a conductor of which the resistance need to be measured.
5. Multimeter: It is advance electrical equipment that can be used as ammeter, voltmeter, ohmmeter, continuity checker and so on. It can also be used to find the configuration of transistors.
6. Frequency meter: It is used to find the frequency of ac signal.

Fig: Energy meter **fig:** Watt meter

7. Energy meter: It is used to find the energy consumed by a load in a particular time period. It is connected in series with the supply line.
8. Watt meter: It is electrical equipment used to measure the power dissipated in the load.

Procedure:

1. Demonstrate the different electrical equipment used in lab.
2. Describe how to connect and the function of them.
3. Describe the methods of using them. (Selection of source, range)

Observation:

Different electrical equipment and their functions.

Precautions:

1. The instruments should be used for particular purpose only.
2. The range of the instruments should be kept in proper order.
3. The equipment should be properly connected.

Conclusion:

………………………………………………………………………………………
………………………………………………………………………………………
…………………………………………………………………………………….

Viva voce

1. Write the applications of different electrical appliances.
2. Define voltmeter. How is it connected to the circuit?
3. Define ammeter. How is it connected to the circuit?
4. Why ammeter is connected in series to the circuit?
5. Why should a voltmeter be connected in parallel to the circuit?
6. Discuss about the resistance of ammeter and voltmeter.
7. What is the function of galvanometer?
8. Write the applications of multi-meter.
9. Write the function of wattmeter and energy meter.
10. Write the application of ohm-meter.

EXPERIMENT NO. 3

Title: Demonstration of simple DC circuit and measurement of current and voltage across it.

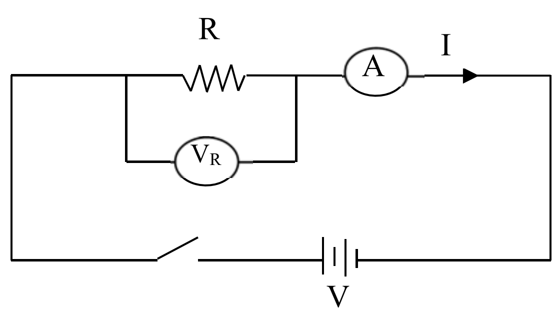
Objective: To make a simple DC circuit and measure voltage and current across it.

Apparatus Required:

1. Ammeter
2. Voltmeter
3. Multimeter
4. Voltage source (Cell, Battery)
5. Connecting wires

Theory:

The different electrical components such as cell, resistor, switches, wires etc can be connected to a circuit in different ways in different combinations. When the voltage is applied, the current start flowing through the circuit. The current flowing through the circuit, voltage applied to the circuit and the voltage drops across the components in the circuit can be easily calculated by connecting the electrical equipments in proper combination.



Procedure:

1. Connect the circuit as shown in the figure.
2. Observe the value in voltmeter and ammeter.
3. Repeat the process by changing the voltage source and value of resistor.

Observation:

S.N.	Supply Voltage	Resistance (R)	Voltmeter Reading (V_R)	Ammeter Reading (I)	Remarks
1					
2					
3					

Precautions:

1. Make the connections properly.
2. Connect the equipments in proper format.
3. Set the equipments in proper range.

Conclusion:

…………………………………………………………………………………………
…………………………………………………………………………………………
………………………………………………………………………………………

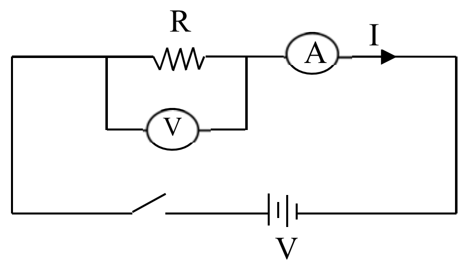
EXPERIMENT NO. 4

Title: Measurement of resistance of a resistor.

Objective: To measure the resistance of a resistor using voltmeter and ammeter.

Apparatus Required:

1. Ammeter
2. Voltmeter
3. Resisitor
4. Connecting wires
5. Bread board
6. DC Source



Theory

The flow of electrons through a conductor is called electric current. When the electrons flow through a conductor, they collide with other electrons or atoms or ions contained in the conductor. Due to this there is some obstruction in the flow of electrons through a conductor. The property of a substance to oppose the flow of current through it is known as resistance. It is denoted by 'R' and its SI unit is ohm ' Ω '. The resistance of a conductor can be calculated using the mathematical relation,

$$\text{Resistance} = \frac{\text{Potential difference across the reistor}}{\text{Current flowing through the reistor}}$$

$$\text{or, } R = \frac{V}{I}$$

Procedure:

1. Connect the circuit as shown in the figure.
2. Supply the voltage and observe the reading of ammeter and voltmer.
3. Calculate the value of resistance by using ohm's law.
4. Repeat the process by varying the supply voltage.

Observation Table:

S.N.	Voltmeter reading(V_R)	Ammeter reading (I)	R=$\frac{V_R}{I}$ (Ω)	Actual R(using ohmmeter)	Remarks
1					
2					
3					

Calculations:

$$\%Error = \left|\frac{R_{actual} - R}{R_{actual}}\right| \times 100\%$$

Precautions:

1. Make the connections properly.
2. Note the readings of voltmeters and ammeters properly.
3. Remove insulations from the connecting wire so as the current will flow properly.
4. Avoid loose connections and don't touch wire with wet hand.

Conclusion:

………………………………………………………………………………………
………………………………………………………………………………………
……………………………………………………………………………………

Viva-voce

1. Write the relation between resistance of a conductor, current flowing through it and the potential difference applied across its ends.
2. Define resistance.
3. Compare the resistance of conductor, heating element, semi-conductor and insulator.
4. List out the factors on which resistance of a conductor depends.

5. State Ohm's law.

EXPERIMENT NO. 5

Title: Verification of series and parallel combination of resistor.

Objective: To find the equivalent resistance of resistors connected in series and parallel combination.

Apparatus Required:

1. Resistors
2. Multi-meter
3. Connecting wires
4. Bread board

Theory:

Series Combination:

The combination in which the two or more resistors are connected end to end consecutively is known as series combination of resistor. In series combination, the equivalent resistance will be always greater than the maximum value of resistance connected to the circuit.

If the resistors R_1, R_2, R_3 and R_4 are connected in series, then the equivalent resistance is given by,

i.e. $R_{eq} = R_1 + R_2 + R_3 + R_4$

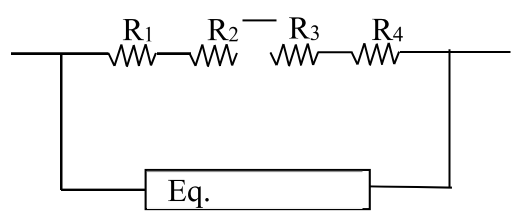


Fig: Series combination of resistor

Parallel Combination:

The combination in which two or more resistors are connected between the same two points is known as parallel combination of resistors.

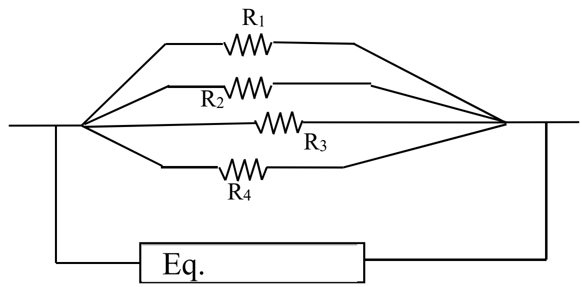


Fig: Parallel combination of resistor

If the resistors R_1, R_2, R_3 and R_4 are connected in series, then the equivalent resistance is given by,

$$\text{i.e. } \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

Procedure:

1. Measure the value of individual resistors.
2. Connect the two or more resistors in series and parallel respectively.
3. Measure equivalent resistance using ohmmeter.
4. Calculate the equivalent resistance by using formulae.
5. Compare the theoretical and observed value and calculate percentage error.
6. Repeat the same procedure for different observations.

Observation Table:

Series

S.N.	R_1(in ohm)	R_2(in ohms)	R_3(in ohms)	Observed $R_{eq.}$	Theoretical $R_{eq} = R_1 + R_2 + R_3$	% Error
1						
2						
3						

Parallel

S.N.	R_1(in ohm)	R_2(in ohms)	Observed R_{eq}	Theoretical $R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$	% Error
1					
2					
3					

Note: Try for three or more resistors

Calculations:

Series and Parallel

$$\%Error = \left| \frac{\text{Theoretical } R_{eq} - \text{Observed } R_{eq}}{\text{Theroetical } R_{eq}} \right| \times 100\%$$

Precautions:

1. Make the connections properly.
2. Note the readings of voltmeters and ammeters properly.
3. Remove insulations from the connecting wire so as the current will flow properly.
4. Avoid loose connections and don't touch wire with wet hand.

Conclusion:

……………………………………………………………………………………
……………………………………………………………………………………
………………………………………………………………………………….

Viva-voce

1. Define series combination of resistor.
2. List out the properties of series combination of resistor.
3. Write the applications of series combination of resistor.
4. Define parallel combination of resistor.

5. List out the properties of parallel combination of resistor.
6. Write the applications of parallel combination of resistor.
7. Write the advantages of series and parallel combination of resistor.
8. In which combination should the resistors be connected so that the resultant resistance will (a) increase (b) decrease ?

EXPERIMENT NO. 6

Title: Verification of Ohm's law.

Objective: To verify Ohms Law.

Apparatus Required:

1. Ammeter
2. Voltmeter
3. Resistor
4. Multimeter
5. Connecting wires
6. Bread Board

Theory:

It states that "The current flowing through a conductor is directly proportional to voltage applied across its two ends assuming the physical conditions of conductor to be constant."

i.e. $I \propto V$

or. $V \propto I$

or. $V = IR$

where, R = proportional constant, known as resistance of a conductor.

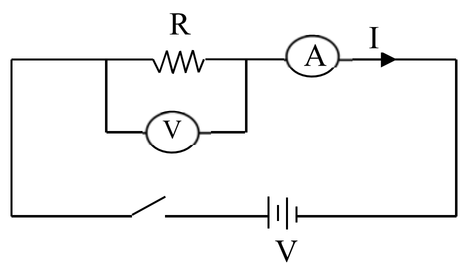
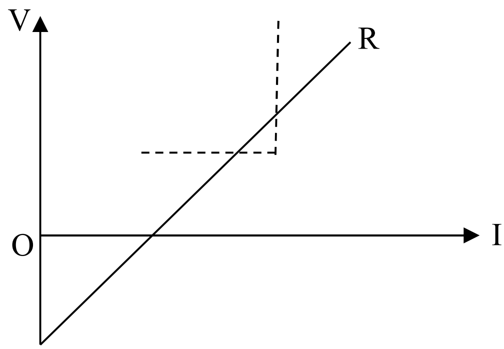


Fig: Ohm's law

The substances that follow Ohm's law are known as ohmic substances. If VI curve of such substances is drawn, then a straight line passing through origin is obtained.



Procedure:

1. Note the standard value of resistor.
2. Connect the circuit as shown in the diagram.
3. Now, vary source voltage uniformly & note readings of ammeter and voltmeter.
4. Repeat the same procedure for different observations.
5. Plot the graph between the reading of voltmeter and ammeter.
6. Find the slope of the curve which give the resistance of the resistor.
7. Compare with standard value and evaluate % error.

Observation Table:

S.N.	V(in volt)	I(in ampere)	$R = \frac{V}{I}$	Theoretical R (R_{th}) (Using ohmmeter)	% Error
1					
2					
3					
			R_{avg}=		

Drawing the VI curve,

Calculations:

$$\%Error = \left| \frac{R_{th} - R_{avg}}{R_{th}} \right| \times 100\%$$

Precautions:

1. Make the connections properly.
2. Note the readings of voltmeters and ammeters properly.
3. Remove insulations from connecting wire so as the current will flow properly.
4. Avoid loose connections and don't touch wire with wet hand.

Conclusion:

…………………………………………………………………………………………
…………………………………………………………………………………………
……………………………………………………………………………………….

Viva-voce

1. State Ohm's law.
2. Define ohmic substance.
3. Define non-ohmic substance.
4. Define resistance.
5. What are the applications and benefits of Ohm's law?

EXPERIMENT NO. 7

Title: Verification of Kirchoff's Laws

Objective: To verify Kirchhoff's Current Law (KCL) and Kirchhoff's Voltage Law (KVL)

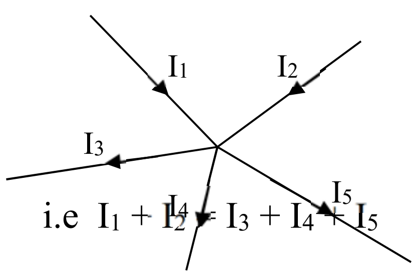
Apparatus Required:

1. Ammeter
2. Voltmeter
3. Resistors
4. Connecting wires
5. DC power supply unit

Theory:

Kirchoff's Current Law (KCL)

This law relates the current at the junction points of a circuit. It states that" the algebraic sum of current entering the node and leaving the node is always zero."



i.e $I_1 + I_2 = I_3 + I_4 + I_5$

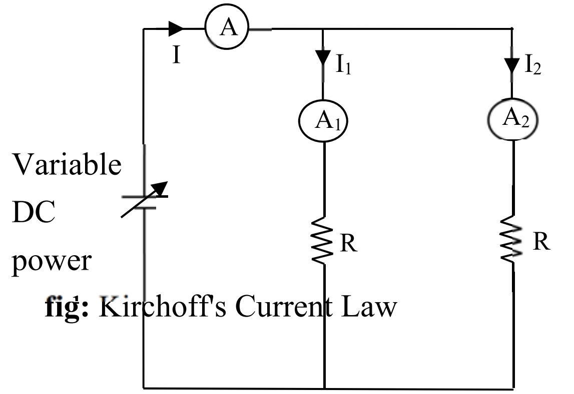


fig: Kirchoff's Current Law

Kirchoff's Voltage Law (KVL)

This law relates the emf and voltage drops in a circuit and it states that the algebraic sum of voltage drop across any loop in a circuit and emf is always equal to zero.

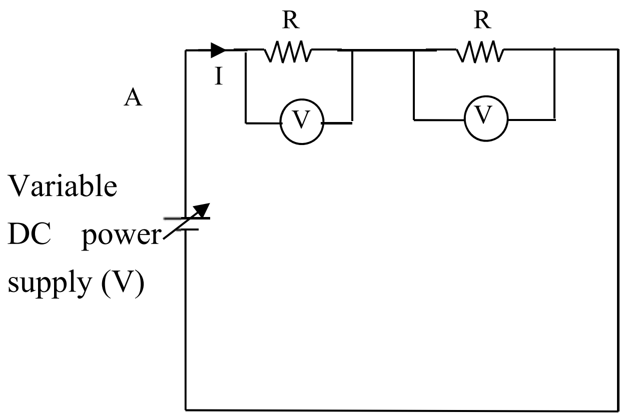


Fig: Kirchoff's voltage law

Procedure:

KCL:

1. Connect the circuit as shown in the diagram.
2. Now, vary the supply voltage or resistance to obtain different readings of ammeters A, A_1 and A_2.
3. Repeat the same procedure for different observations.

KVL:

1. Connect the circuit as shown in the diagram.
2. Now, vary the supply voltage or resistances to obtain different values of V_1, V_2 and V_3.
3. Repeat the same procedure for different observations.

Observation Table:

KVL

S.N.	Supply voltage,V(volts)	Voltmeter Reading V_1(volts)	Voltmeter Reading V_2(volts)	$V_{cal} = V_1 + V_2$	% Error
1					
2					

3					

KCL

S.N.	Supply Current, A(ampere)	Ammeter reading, A_1(Ampere)	Ammeter Reading, A_2(Ampere)	A_{calc} =A1+ A2	% Error
1					
2					
3					

Calculations:

KCL

$$\%Error = \left|\frac{A - A_{calc}}{A}\right| \times 100\%$$

KVL

$$\%Error = \left|\frac{V - V_{calc}}{V}\right| \times 100\%$$

Precautions:

1. Make the connections properly.
2. Note the readings of voltmeters and ammeters properly.
3. Remove insulations from the connecting wire so as the current will flow properly.
4. Avoid loose connections and don't touch wire with wet hand.

Conclusion:

………………………………………………………………………………………
………………………………………………………………………………………
……

………………………………………………………………………………………
………………………………………………………………………………………
…….

Viva-voce

1. Define node, mesh, loop.
2. State KCL.
3. State KVL.
4. Write the applications of KCL and KVL.

EXPERIMENT NO. 8

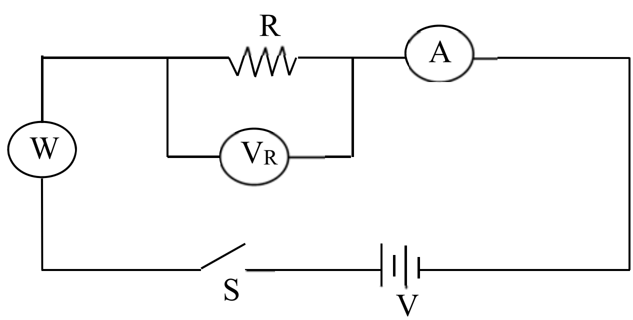
Title: Calculation of power in a resistive load.

Objective: To calculate the power in resistive circuit and verify it with watt meter reading.

Apparatus Required:

1. `Ammeter
2. `Voltmeter
3. `Watt meter
4. `Resistive load
5. `Connecting wires
6. `Power supply

Theory and circuit diagram:



The amount of electrical work done per unit time is called the electric power. Its SI unit is watt.

$$\text{Electric power} = \frac{\text{Electric work done}}{\text{Time taken}}$$

$$or, P = \frac{ItV}{t}$$

$$or, P = IV$$

$$or, P = I^2R$$

Procedure:

1. Connect the circuit as shown in the figure.
2. Provide the supply and observe the reading of ammeter, voltmeter and wattmeter.
3. Repeat the process varying the supply or the value of resistor and note the value of each meter separately.

Observation Table:

S.N.	Voltmeter Reading, V_R (volts)	Ammeter Reading, I (amps)	Power consumed $P = I \times V_R$ (watt)	Watt meter reading, P_{actual} (watt)	Remarks

Calculation:

$$\%Error = \left| \frac{P_{actual} - P}{P_{actual}} \right| \times 100\%$$

Precautions:

1. Make the connections properly.
2. Note the readings of voltmeters and ammeters properly.
3. Remove insulations from the connecting wire so as the current will flow properly.
4. Avoid loose connections and don't touch wire with wet hand.

Conclusion:

…………………………………………………………………………………………

…………………………………………………………………………………………

……………………………………………………………………………………

Viva-voce

1. Define power consumed by a circuit.

2. Write the relation between power consumed, current and potential difference across its ends.
3. Define 1 watt power.
4. Define electric power in terms of work done.

EXPERIMENT NO. 9

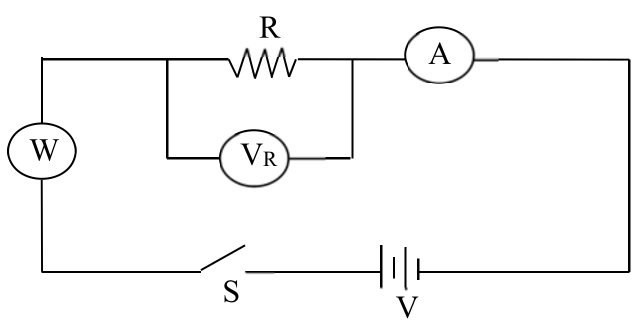
Title: Calculation of energy consumed by a resistive load.

Objective: To calculate the energy consumed by a resistive load using multi-meter.

Apparatus Required:

1. Ammeter
2. Voltmeter
3. Timer (Stop Watch)
4. Resistive Load
5. Connecting wires
6. Power supply

Theory:



Electrical Energy Consumption:

We have

$$\text{Electric power} = \frac{\text{Electric energy consumed}}{\text{Time taken}}$$

or, Electric energy = Electrical power X time taken

or, E = P X t

Now, if P = 1 watt, t = 1 sec

Electric energy = 1 watt X 1 sec

= 1 watt-sec

Hence watt-sec is very smaller unit of electrical energy. So in home, we use higher units of it. i.e watt-hour, kilowatt-hour(kwh).

watt-hour

1 watt-hour = 1 X 60 X 60 watt-sec

= 3600 watt-sec

= 3600J

1 kilowatt-hour = 1000 X 60 X 60 watt-sec

= 3600000 J

This 1 kilowatt-hour simply can be said as 1 unit electrical energy consumption.

Procedure:

1. Connect the circuit as shown in the figure.
2. Provide the supply for certain period of time and measure the readings of voltmeter, ammeter and watt meter.
3. Do necessary calculations.
4. Repeat the process by varying the parameters of the circuit.

Observation Table:

S.N.	Voltmeter reading (V volts)	Ammeter reading (I amps)	Time (t) (in hrs)	Calculated energy consumed (PXt)	Energy meter reading kWh	Remarks
1.						
2.						
3.						

Precautions:

1. Make the connections properly.
2. Note the readings of voltmeters and ammeters properly.
3. Remove insulations from connecting wire so as the current will flow properly.
4. Avoid loose connections and don’t touch wire with wet hand.

Conclusion:

………………………………………………………………………

………………………………………………………………………

………………………………………………………………………

………………………………………………………………

Viva-voce

1. Define energy consumed by an equipment.
2. How can the energy consumed by an equipment determined?
3. Write the unit for electrical energy consumption.
4. Define watt-sec.
5. Define watt-hour.
6. Define kilowatt-hour (kWh).
7. How much electrical energy need to be consumed to have 1 unit consumed?

EXPERIMENT NO. 10

Title: Demonstration of capacitors.

Objective: To observe the different types of capacitors.

Apparatus Required:

1. Ceramic capacitors
2. Electrolytic capacitors

Theory:

Capacitor is an electrical device which can store charge within it electric field. It consists of two conducting surfaces separated by a layer of insulating medium called dielectric. The conducting surfaces may be in the form of circular or rectangular plates or be in the form of spherical or cylindrical shape.

The property of a capacitor to store charge within its electric field is known as capacitance. Its SI unit is Farad (F).

The smaller units of capacitance are:

1mF (mili)= 10^{-3} F

1 μ F(micro) = 10^{-6} F

1 nF(nano) = 10^{-9} F

1 pF (pico)= 10^{-12} F

Capacitance can also be defined as the charge required to produced a unit potential difference between the plates. If 'Q' charge is stored in the plates to produce a potential difference of 'V' volts, then

$$\text{Capacitance (C)} = \frac{Q}{V}$$

Procedure:

Demonstrate the different types and sizes of capacitors.

Observation:

Different types of capacitors

Conclusion:

………………………………………………………………………………………
………………………………………………………………………………………
……………………………………………………………………………………….

Viva-voce

1. Define capacitor.
2. On what unit is capacitance measured?
3. What are the applications of capacitor?
4. What are the factors on which the capacitance of capacitor depends?
5. What happens when the distance between the plates of capacitor is decreased?
6. If the area of plates of capacitor is increased, what happens to the value of capacitance of it?

EXPERIMENT NO. 11

Title: **Verification of series and parallel combination of capacitors.**

Objective: To find the equivalent capacitance in series and parallel combination of capacitors.

Apparatus Required:

1. Capacitors
2. Capacitive meter
5. Connecting wires

Theory:

Series combination of capacitors:

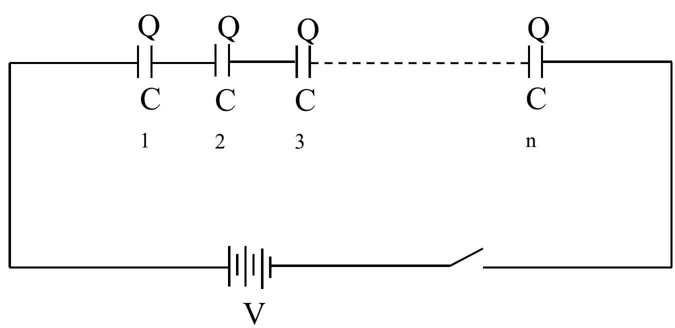


Fig: Series combination

The combination in which one terminal of one capacitor is connected to terminal of another capacitor, then the combination is called series combination of capacitor. If C_1, C_2, C_3............. and C_n be the capacitors connected in series to a voltage source of 'V' volts. Since same charge flows through all of them and potential difference will be different and additive.

i.e. $V = V_1 + V_2 + V_3 + ... + V_n$

or, $$\frac{Q}{C} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3} + ... + \frac{Q}{C_n}$$

$$\text{or, } \frac{Q}{C} = \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \text{.............} + \frac{1}{C_n} \right) Q$$

$$\text{or, } \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \text{................} + \frac{1}{C_n}$$

Parallel combination of capacitor

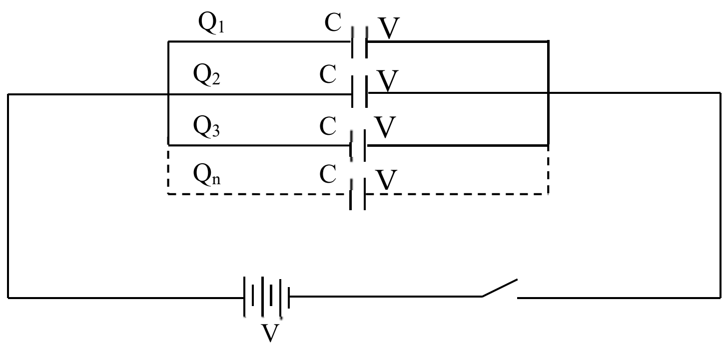


Fig: Parallel combination

The combination in which the all terminals of capacitors are connected in between any two points is called parallel combination of capacitor. If C_1, C_2, C_3, ... and C_n be the capacitors connected in parallel across a voltage source of 'V' volts. Since in parallel combination, potential difference across each capacitor will be same and the charge stored in each of the capacitor will be different and additive.

i.e. $Q = Q_1 + Q_2 + Q_3 + \ldots\ldots\ldots\ldots\ldots\ldots + Q_n$

or, $CV = C_1V + C_2V + C_3V + \ldots\ldots\ldots\ldots\ldots\ldots + C_nV$

or, $CV = (C_1 + C_2 + C_3 + \ldots\ldots\ldots\ldots\ldots\ldots + C_n)\, V$

or $C = C_1 + C_2 + C_3 + \ldots\ldots\ldots\ldots\ldots\ldots + C_n$

Procedure:

1. Connect the circuit as shown in the figure.
2. Obtain the capacitances of each and the equivalent capacitance.
3. Repeat the process by varying the value of capacitances. (By varying the number as well)

Observation Table:

Parallel

S.N.	C_1(in Farad)	C_2(in Farad)	C_3(in Farad)	Observed, C_{eq}	Calculated, C $(=C_1+C_2+C_3)$	Remarks
1						
2						
3						

Series

S.N.	C_1(in Farad)	C_2(in Farad)	Observed C_{eq}	Theoretical,C $=\frac{C_1C_2}{C_1+C_2}$	Remarks
1					
2					
3					

Note: *Try for three or more capacitors*

Calculations:

Series and Parallel

$$\%Error=\left|\frac{C_{calc}-C_{observed}}{C_{calc}}\right|\times 100\%$$

Precautions:

1. Make the connections properly.
2. Note the readings properly.
3. Remove insulations from connecting wire so as the current will flow properly.
4. Avoid loose connections and don't touch wire with wet hand.

Conclusion:

…………………………………………………………………………………
…………………………………………………………………………………
……………………………………………………………………………….

Viva-Voce

1. Define series combination of capacitor.
2. Define parallel combination of capacitor.
3. What are the applications of series and parallel combination of capacitors?
4. What are the advantages of parallel and series combination of capacitor?

EXPERIMENT NO. 12

Title: Demonstration of charging and discharging phenomena of capacitor

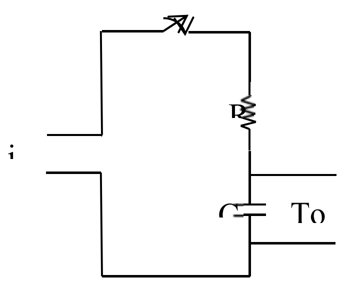
Objective: To demonstrate the phenomena of charging and discharging of capacitor in oscilloscope.

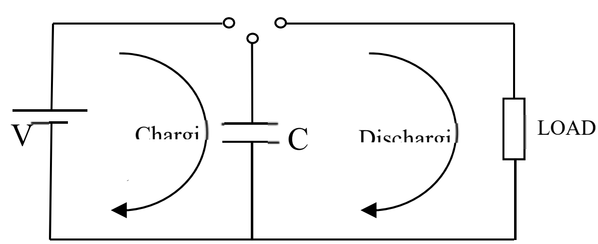
Apparatus Required:

1. Capacitor
2. Oscilloscope
3. Voltage source
4. Resistive load
5. Connecting wires

Theory:

It is also possible to look at the voltage across the capacitor as well as looking at the charge. After all it is easier to measure the voltage on it using a simple meter. When the capacitor is discharged there is no voltage across it. Similarly, one it is fully charged no current is flowing from the voltage source and therefore it has the same voltage across it as the source.





In reality there will always be some resistance in the circuit, and therefore the capacitor will be connected to the voltage source through a resistor. This means that it will take a finite time for the capacitor to charge up, and the rise in voltage does not take place instantly. It is found that the rate at which the voltage rises is much faster at first than after it has been charging for some while. Eventually it reaches a point when it is virtually fully charged and almost no current flows. In theory the capacitor never becomes fully charged as the curve is asymptotic. However in reality it reaches a point where it can be considered to be fully charged or discharged and no current flows.

Similarly the capacitor will always discharge through a resistance. As the charge on the capacitor falls, so the voltage across the plates is reduced. This means that the current will be reduced, and in turn the rate at which the charge is reduced falls. This means that the voltage across the capacitor falls in an exponential fashion, gradually approaching zero.

The rate at which the voltage rises or decays is dependent upon the resistance in the circuit. The greater the resistance the smaller the amount of charge which is transferred and the longer it takes for the capacitor to charge or discharge.

Procedure:

1. Connect the capacitor to the circuit connected with oscilloscope.
2. At first, without connecting it to the load, provide supply to the capacitor and observe the curve in oscilloscope. (Observe full charge condition)
3. Then, remove the source and connect the capacitor to the load.
4. Observe the curve in oscilloscope. (Note: Full discharge condition)

Observation:

Observe the charging and discharging curve of the capacitor and sketch it.

Precautions:

1. Make the connections properly.
2. Note the readings of voltmeters and ammeters properly.
3. Remove insulations from the connecting wire so as the current will flow properly.
4. Avoid loose connections and don't touch wire with wet hand.

Conclusion:

…………………………………………………………………………………………
…………………………………………………………………………………………
……………………………………………………………………………………….

Viva-voce

1. What do you mean by charging and discharging of capacitor?
2. How can we determine the capacitor is fully charged?
3. How can we determine the capacitor is fully discharged?
4. What are the factors on which the charging and discharging of capacitor depends on?
5. How can we make the charging faster and slower?
6. How can we make the discharging faster and slower?

EXPERIMENT NO. 13

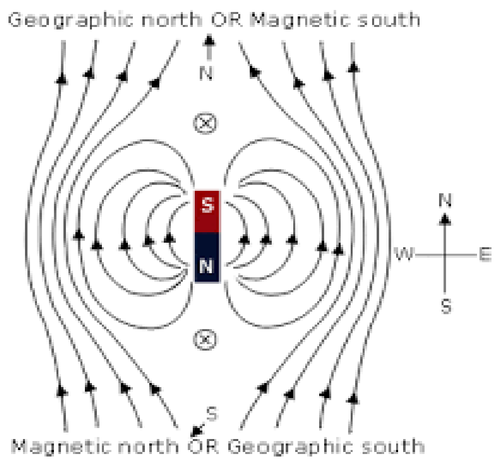
Title: Observation of magnetic lines of force.

Objective: To trace the magnetic lines of force of a magnet.

Apparatus Required:

1. Magnet (Bar magnet)
2. A sheet of paper
3. magnetic compass
4. Drawing board

Theory:



Within the magnetic field of a magnetic, there exists large number of imaginary lines, known as magnetic lines of force. The strength of magnet can be determined on the basis of number of magnetic lines of force. The properties of magnetic lines of force are:

i) They always originated from N-pole and end at S-pole.
ii) They are always closed, continuous and curve in nature.
iii) They never intersect each other.

Procedure:

1. Take a clean sheet of paper and attach it on to the board.
2. Take a magnet and trace the outlines of it at the centre of paper.
3. Put the magnetic compass near to the magnet and mark the point indicated by the compass. Then place the compass in such a way that the back side of needle is exactly points the previous one.
4. Repeat the process until curve is obtained between the poles.
5. Find more number of lines of force as mentioned above.

Observation:

magnetic lines of force for a bar magnet.

Precautions:

1. The points should be obtained accurately and precisely.
2. The compass should be kept exactly behind the previous point.
3. The curve should be drawn clearly.

Conclusion:

…………………………………………………………………………………………
…………………………………………………………………………………………
……………………………………………………………………………………….

Viva-voce

1. Define the magnetic lines of force.
2. Explain the properties of magnetic lines of force.
3. Why don't the magnetic lines of force intersect each other?
4. How does the magnetic lines of force determines the magnetic strength?
5. Define neutral point.

EXPERIMENT NO. 14

Title: Verification of presence of magnetic lines of force across a current carrying conductor.

Objective: To observe the presence of magnetic lines of force across a current carrying conductor and observe its direction.

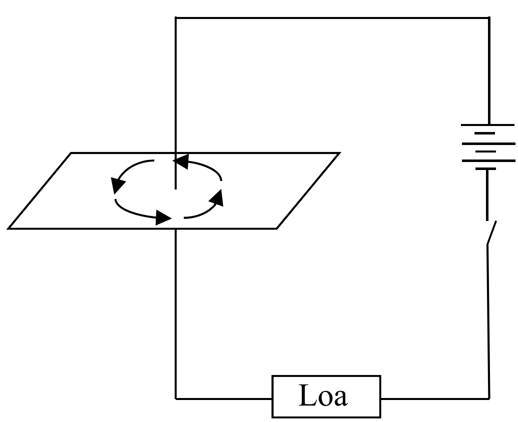
Apparatus Required:

1. Battery Source
2. Wires
3. Card board
4. Iron filings
5. Connecting wires

Theory and circuit Diagram:

In 1920, Orested discovered that when a magnetic compass was brought nearer to a current carrying conductor, it gets deflected. He also found that, when the direction of current was reversed, the direction of deflection of magnetic compass also gets reversed. And there was no deflection in the magnetic compass when the current passing through the conductor was stopped.

This shows that a magnetic field is produced across a conducting wire, when the current is flowing through it.



Procedure:

1. Connect the circuit with a straight conducting wire connected to the battery passing through its centre.
2. Place the iron-filings spread over the card board.
3. Pass the current through the conductor.
4. Observe the pattern formed in the card board. (slightly tap on the card board if necessary)
5. Also observe the result by reversing the direction of current.

Observation:

- patterns formed by the iron filings on the cardboard.

Precautions:

1. Make the connections properly.
2. Note the readings of voltmeters and ammeters properly.
3. Remove insulations from the connecting wire so as the current will flow properly.
4. Avoid loose connections and don't touch wire with wet hand.

Conclusion:

…………………………………………………………………………………………
…………………………………………………………………………………………

Viva-voce

1. Define the magnetic lines of force.
2. Explain the properties of magnetic lines of force.
3. Why don't the magnetic lines of force intersect each other?
4. How does the magnetic lines of force determines the magnetic strength?
5. How can the direction of magnetic lines of force be determined?
6. State Right hand thumb rule.
7. State Maxell's screw rule.

EXPERIMENT NO. 15

Title: Verification of motor effect of current.

Objective: To verify the force experience by a current carrying conductor when placed across a magnetic field and find its direction.

Apparatus Required:

1) A horse shoe magnet
2) A conductor or thick copper wire
3) Battery
4) Connecting wires
5) Key

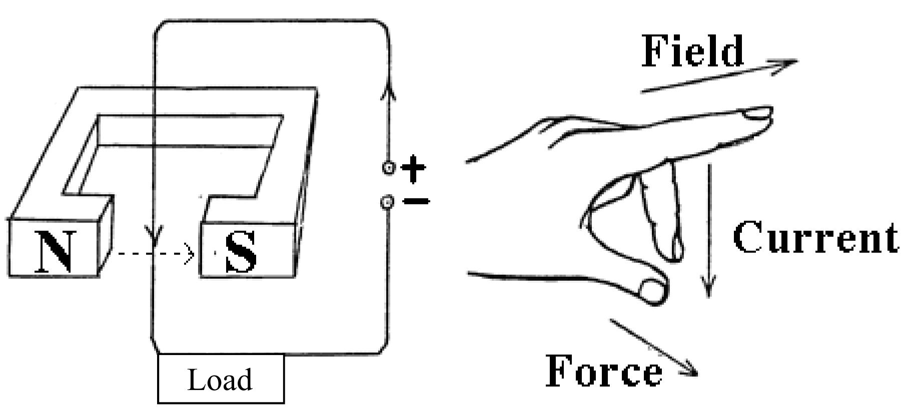
Theory:

When a current is passed through a conductor place in a magnetic field, the force is induced in it due to attraction between the magnetic field of magnet and magnetic field due to current carrying conductor.

The magnitude of force produced is given by,

$F = BIl$ Newton

where, F – magnitude of force produced
B – magnetic flux density
I – Current
l – length of conductor



The magnitude of the force on the wire can be increased by:

1) Increasing the strength of the magnetic field it experiences.
2) Increasing the current flowing through it.
3) Increasing the number of turns of wires.

Procedure:

1) Hang a straight conductor using insulated wires such that it may swing freely between the poles of a horse shoe magnet.
2) Pass a DC current through the conductor by closing the circuit and find the result.
3) Observe the result once by reversing the polarity of the magnet and once by reversing the polarity of the DC current.

Observation:

When the current is passed through the conductor placed between the two poles of the magnet, the conductor is pulled out or pushed in towards the centre of the horse shoe magnet. But by reversing the pole of DC or pole of the magnet, the direction of motion of conductor is seen reversed.

Precautions:

1. Make the connections properly.
2. Note the result of movement of conductor properly.
3. Avoid loose connections and don't touch wire with wet hand.

Conclusion:

……………………………………………………………………………………
……………………………………………………………………………………
……

Viva-voce

1. Define Lenz's law.
2. Explain motor effect.
3. How can the direction of force experience be determined?
4. State Flemming's Left hand rule.

5. How can the magnitude of force be changed?

EXPERIMENT NO. 16

Title: Verification of Faraday's law of electromagnetic induction.

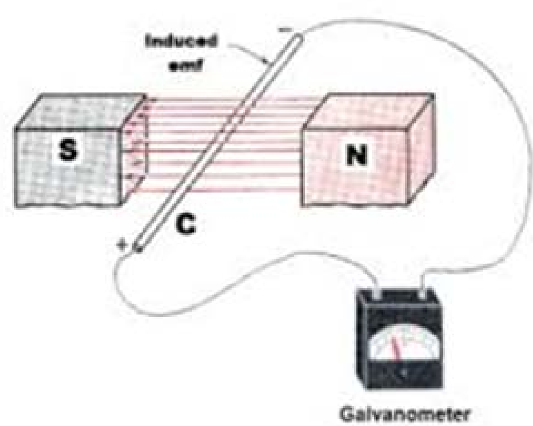
Objective: To verify laws of electromagnetic induction and hence find the magnitude and direction of induced emf.

Apparatus Required:

1) A powerful bar magnet
2) A plastic pipe
3) A 2-3 meter long and 0.2mm diameter enameled copper wire
4) A sensitive galvanometer

Theory:

When a conducting wire is placed in the magnetic field and is moved up and down, it will cross the magnetic lines of force. Due to this the opposite charges are developed at the two ends of the conductor. Hence the electrons starts to flow through the wire, when its ends are connected to a galvanometer. This deflects the needle of galvanometer and shows the current in the circuit.



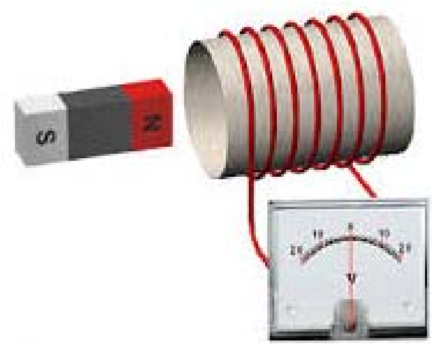
The induction of electric current in a conductor is due to the movement of conductor inside the magnetic field (as it crosses the magnetic lines of force). This process is known as electromagnetic induction. This process was first discovered by Michael Faraday in 1831 A.D. And the current produced is known as induced current.

This principle of electromagnetic induction is used in different equipments like generator, dynamo etc.

Faraday's Law of electromagnetic induction

It states that

- When the magnetic flux linked with the closed circuit changes, an electromotive force (emf) is induced in the circuit.
- The magnitude of induced emf is directly propotional to the rate of change of magnetic flux.
- The induced emf lasts in the circuit as long as the change in the magnetic flux continues.



Procedure:

- Take a plastic pipe of about 15cm long with about 3 cm diameter.
- Take a 2-3 meters long and 0.2mm diameter enameled(insulated) copper wire.
- Wind the pipe up with more than 40 turns of enameled copper wire.
- Strip about 2 cm of insulation off each end of the wire and connect them to the two terminals of a voltmeter for reading of magnitude of induced emf.
- Take a powerful bar magnet with its N-pole inwards.
- Move the magnet in and out of the pipe as quickly as possible.
- Observe the direction of deflection by connecting a galvanometer.
- Similarly, with its S-pole inward, move the magnet in and out as quickly as possible and observe the direction of deflection in galvanometer.
- Observe the direction of deflection when the speed of movement is decreased or stopped.

Observation:

The deflection in galvanometer is observed when the magnet is moved in and out in the pipe. When the pole of the magnet is reversed, the direction of deflection in the galvanometer is also reversed. The deflection of galvanometer is seemed more when the speed of magnet is more and when the speed is decreased the deflection is also decreased. Similarly, when the magnet is stopped to move, there is no deflection in the galvanometer.

Precautions:

1. Make the connections properly.
2. Note the deflection of galvanometer properly.
3. Avoid loose connections and don't touch wire with wet hand.

Conclusion:

……………………………………………………………………………………
……………………………………………………………………………………
…………………………………………………………………………………….

Viva-Voce

1. Define electromagnetic induction.
2. State Faraday's law of electromagnetic induction.
3. Define induced emf.
4. Define electromagnet.
5. Write the application of electromagnet.
6. How can the strength of electromagnet be increased?
7. How can the strength of induced emf be increased?
8. Explain about statically induced and dynamically induced emf.

EXPERIMENT NO. 17

Title: Observation of waveform of AC and DC signals.

Objective: To be familiar with operation of oscilloscope and demonstrate the waveform of dc and ac quantities.

Apparatus Required:

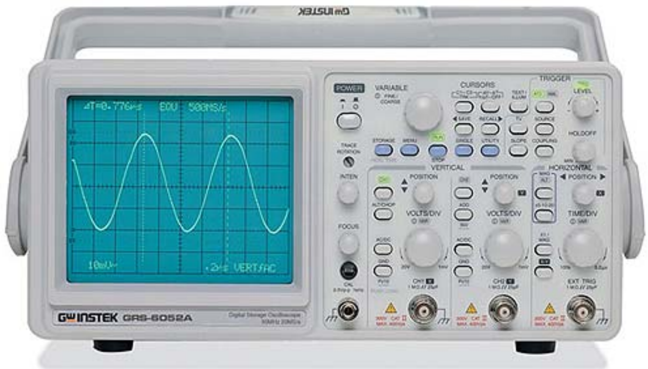
1) A.C. source
2) D.C source
3) Oscilloscope

Theory:

Oscilloscope:

An oscilloscope is a type of electronic test instrument that allows observation of constantly varying signal voltages, usually as a two-dimensional plot of one or more signals as a function of time. Oscilloscopes are used to observe the change of an electrical signal over time, such that voltage and time describe a shape which is continuously graphed against a calibrated scale. The observed waveform can be analyzed for such properties as amplitude, frequency, rise time, time interval, distortion and others. Modern digital instruments may calculate and display these properties directly. Originally, calculation of these values required manually measuring the waveform against the scales built into the screen of the instrument. The oscilloscope can be adjusted so that repetitive signals can be observed as a continuous shape on the screen

Oscilloscopes are used in the sciences, medicine, engineering, and the telecommunications industry. General-purpose instruments are used for maintenance of electronic equipment and laboratory work. Special-purpose oscilloscopes may be used for such purposes as analyzing an automotive ignition system or to display the waveform of the heartbeat as an electrocardiogram.



An alternating current can be defined as the one that changes the direction and magnitude continuously and periodically. The ac current is produced by generators. Alternating currents can be controlled, transmitted and utilized more easily than direct current, hence are more commonly used. AC current is not only the alternating quantity, the voltage can also be alternating as well. These signals are more generally represented in the form of sinusoidal waveform or sine wave but it can also be shown in the form of square or triangular wave.

Similarly, in DC signals, the magnitude is constant and the direction remains the same through out the period. These signals are usually produced by cells. Since the direction doesn't changes, the frequency of the dc signal is 0.

The waves of ac and dc signals can be easily observed by connecting the source with the oscilloscope. Similarly the parameters of the signals like amplitude, wavelength, time period, phase, instantaneous value etc can also be measured with the help of waveform formed in the oscilloscope.

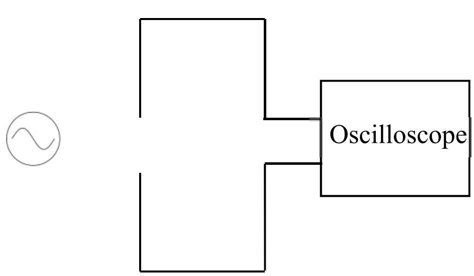


Fig: AC signal over oscilloscope

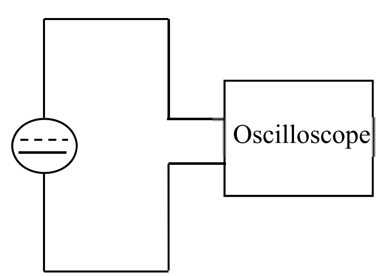


Fig: DC signal over oscilloscope

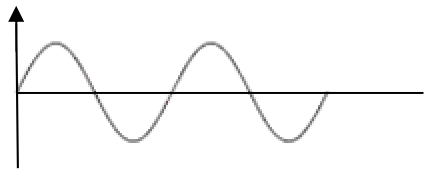


Fig: AC waveform

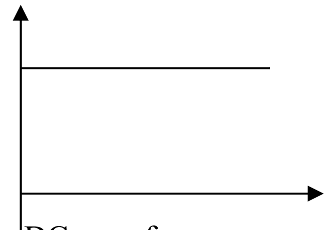


fig: DC waveform

Procedure:

1. Adjust the oscilloscope to the proper range.
2. Connect the ac signal to the oscilloscope.
3. Observe the waveform of the signal in different forms. (sinusoidal, triangular, square)
4. Do it for dc source as well.

Observation:

1. Observe the waveform for ac and dc source.
2. Handling and proper operation of the oscilloscope.

Precautions:

1. Adjust the range of oscilloscope properly.
2. Connect the probes of the oscilloscope properly.
3. Horizontal and vertical calibrations should be properly adjusted.

Conclusion:

…………………………………………………………………………………………
…………………………………………………………………………………………
……………………………………………………………………………………….

Viva-Voce

1. Define DC signal.
2. Define AC signal.
3. What are the sources of DC and AC signals.
4. What are the applications of AC and DC signals.
5. What is the frequency of DC signal?
6. Compare AC with DC.

7. What are the advantages of AC over DC?

EXPERIMENT NO. 18

Title: Measurement of parameters of AC signal

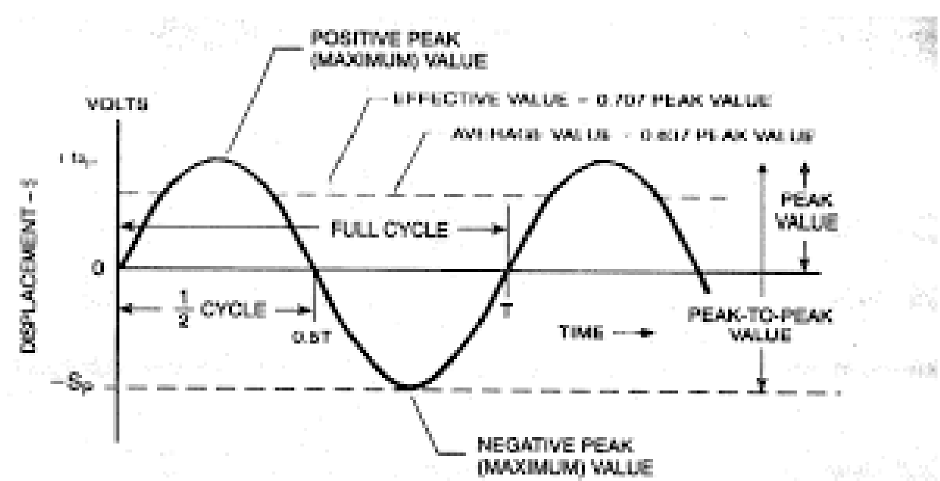
Objective: To measure the parameters of alternating current using oscilloscope.

Apparatus Required:

1. A .C. source
2. Oscilloscope
3. Transformer (if needed)
4. Function generator

Theory:

Terms related to ac signal



Cycle: When the waves moves through one positive half cycle and one negative half cycle, then the wave is said to have completed one complete cycle.

Time period: The time taken by a wave to complete one cycle is known as time period. It is represented by 'T' and is measured in terms of seconds.

Frequency: The total number of complete cycles made by a wave in one second is known as frequency. It is represented by 'f' and measured in terms of Hertz (Hz).

The common power frequency in Nepal is 50 Hz i.e the wave completed 50 complete cycles in 1 second. Likewise in electronics, the frequencies of the signals may vary from zero (DC signal) to kilohertz (kHz), megahertz(MHz) to gigahertz(GHz).

Wavelength

The distance covered by a wave while completing one cycle is known as wavelength of wave. It is represented by 'λ' and its SI unit is meter. It depends on the velocity of the wave and the relation can be expressed as,

$c = f\lambda$ where c = speed of the wave

f = frequency of wave

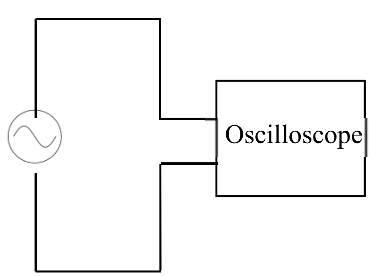
and λ = wavelength of wave

Amplitude (peak value)

The maximum positive or negative value attained by a wave from its mean position or zero value is known as amplitude. It is denoted by 'A'.

Phase: It is given by the amount of time (or angle) that has elapsed, sine the wave last passed through the positive zero value.

Phase difference: The difference in time or angle between the two sine waves sine they last passed through their zero values is called phase difference between two waves.



Procedure:

1. Connect the ac source with the terminals (probe) of the oscilloscope.
2. Arrange the proper range of the oscilloscope.
3. Observe the parameters of the ac signal.

Observation:

Observe the different parameters of the ac signal in the oscilloscope.

Precautions:

- Make the connections properly.
- Fix the oscilloscope in proper range.
- Note the readings of oscilloscope correctly.

Conclusion:

……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………

Viva-voce

- Define AC signal.
- Define the term frequency.
- Define wavelength.
- If the wave has a frequency of 50 Hz, what does it mean?
- What is the standard value of supply system in Nepal?

EXPERIMENT NO. 19

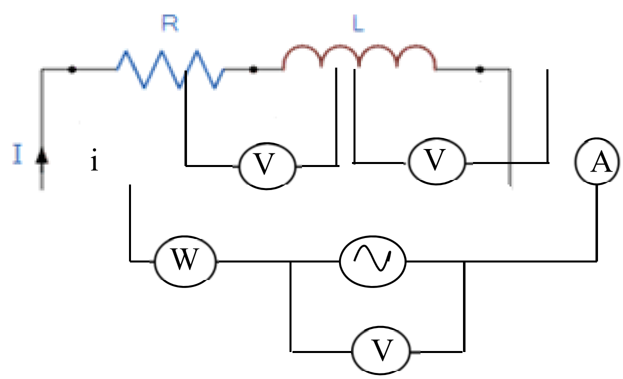
Title: Measurement of power factor of R-L load.

Objective: To measure the power factor of a R-L load.

Apparatus Required:

1. Ammeter
2. Voltmeter
3. Rheostat
4. Inductive Load
5. Wattmeter
6. Connecting wires

Theory:



Voltage drop across resistor (VR) = iR

Voltage drop across inductor (VL) = iXL

When an ac signal is passed through a circuit containing resistor and inductor connected in series, it is found that the voltage is equal to the vector sum of voltage drop across resistor and inductor.

$$i.e.V = \overrightarrow{V_R} + \overrightarrow{V_L}$$

$$\therefore V = \sqrt{(V_R)^2 + (V_L)^2}$$

$$or, V = \sqrt{(iR)^2 + (iX_L)^2}$$

$$or, V = \sqrt{i^2R^2 + i^2{X_L}^2}$$

$$or, V = \sqrt{i^2(R^2 + {X_L}^2)}$$

$$or, V = i\sqrt{(R^2 + {X_L}^2)}$$

$$or, \frac{V}{i} = \sqrt{(R^2 + {X_L}^2)}$$

$$\therefore Z = \sqrt{(R^2 + {X_L}^2)}$$

where, Z = $\frac{V}{i}$ = impedance of the R-L circuit

Let the instantaneous value of supply voltage be,

$$v(t) = V_m \sin\theta \quad \text{where Vrms} = \frac{V_m}{\sqrt{2}}$$

$$or. v(t) = V_m \sin wt........(i)$$

Then,

$$i = I_m \sin(wt - \phi)........(ii) \quad \text{where Irms} = \frac{I_m}{\sqrt{2}}$$

From the above relations, it is cleared that the current lags the voltage by an angle of 'ϕ', where,

$$\tan\phi = \frac{reactance}{resistance} = \frac{X_L}{R}$$

$$or, \tan\phi = \frac{wL}{R}$$

$$\therefore \phi = \tan^{-1}\left(\frac{wL}{R}\right)$$

Now,

$$\text{Power factor} = \cos\phi = \left(\frac{R}{Z}\right)$$

And,

Active Power = IVcosϕ

i.e Watt-meter reading = I X V X cosϕ

$$\text{or, } \cos\phi = \frac{\text{Watt - meter reading}}{\text{ammeter reading X voltmeter reading}}$$

Procedure:

- Connect the circuit as shown in the figure.
- Observe the ammeter, voltmeter and wattmeter reading.
- Calculate power factor using above formula.
- Compare it with theoretical value.
- Repeat the process varying the voltage.

Observation:

S.N.	Wattmeter Reading (W)	Voltmeter Reading (V)	Ammeter Reading (I)	Calculated p.f. $\cos\phi = \frac{W}{I X V}$	Theoritical p.f. $\cos\phi = \left(\frac{R}{Z}\right)$	Remarks

Precautions:

1. Make the connections properly.
2. Note the readings of wattmeter, voltmeter and ammeter properly.
3. Avoid loose connections and don't touch wire with wet hand.

Conclusion:

……………………………………………………………………………………

……………………………………………………………………………………

………………………………………………………………………………….

Viva-voce

1. What do you mean by power factor?
2. Write the formula to calculate power factor for RL circuit.

3. What will be the response of ac in inductive circuit? (Phase difference)
4. Define impedance of the RL circuit.
5. Write the relation for inductive reactance.

EXPERIMENT NO. 20

Titlle: Measurement of voltage and current in R-L, R-C and R-L-C series circuit.

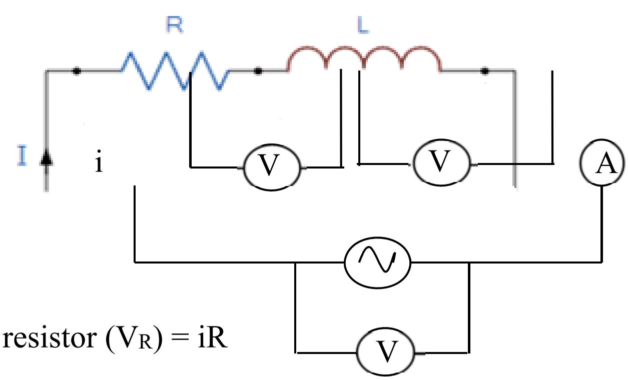
Objective: To measure voltage and current in R-L, R-C and R-L-C series circuit.

Apparatus Required:

1. AC voltage source
2. Resistive Load
3. Capacitive Load
4. Inductive Load
5. Connecting wires

Theory:

R-L Circuit:



Voltage drop across resistor (V_R) = iR

Voltage drop across inductor (V_L) = iX_L

When an ac signal is passed through a circuit containing resistor and inductor connected in series, it is found that the voltage is equal to the vector sum of voltage drop across resistor and inductor.

$$i.e. V = \vec{V_R} + \vec{V_L}$$

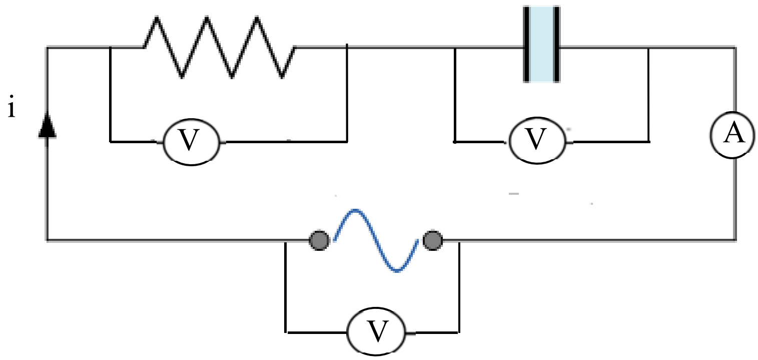
$$\therefore V = \sqrt{(V_R)^2 + (V_L)^2}$$

And,

Impedance of circuit (Z) = $\sqrt{(R^2 + X_L{}^2)}$

Current through the circuit (i) = $\dfrac{V}{Z}$

R-C Circuit:



Voltage drop across resistor (V_R) = iR

Voltage drop across capacitor (V_c) = iX_c

When an ac signal is passed through a circuit containing resistor and inductor connected in series, it is found that the voltage is equal to the vector sum of voltage drop across resistor and inductor.

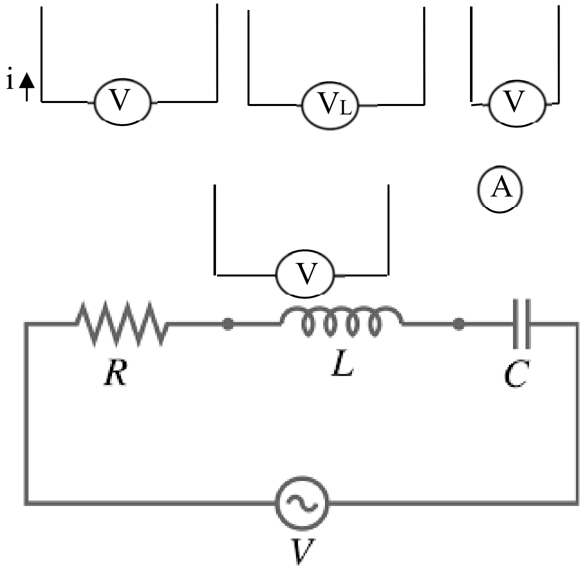
$$i.e. V = \overrightarrow{V_R} + \overrightarrow{V_C}$$

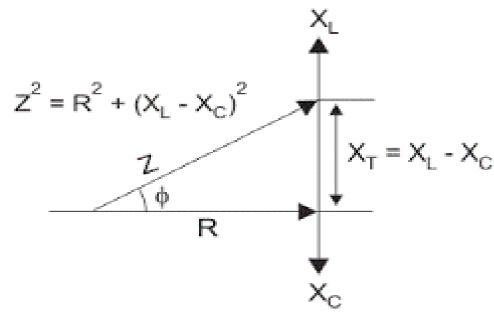
$$\therefore V = \sqrt{(V_R)^2 + (V_C)^2}$$

And, Impedance of circuit (Z) = $\sqrt{(R^2 + X_C{}^2)}$

Current through the circuit (i) = $\dfrac{V}{Z}$

R-L-C Circuit





Voltage drop across resistor (V_R) = iR

Voltage drop across capacitor (V_c) = iX_c

Voltage drop across inductor (V_L) = iX_L

Since the voltage drop across inductor and capacitor are acting in opposite direction, so the resultant voltage drop is V_L-V_C (assuming V_L>V_C). And the applied voltage $(\overrightarrow{AC})$ is equal to the vector sum of $(\overrightarrow{AB})$ and $(\overrightarrow{BC})$.

$$i.e. \overrightarrow{AC} = \overrightarrow{AB} + \overrightarrow{BC}$$

$$\text{Now, } AC = \sqrt{AB^2 + BC^2}$$

$$or, V = \sqrt{V_R^2 + (V_L - V_C)^2}$$

And Impedance of RLC circuit (Z) = $\sqrt{R^2 + X^2}$, where, X = $(X_L - X_C)$ = net reactance

Current through the circuit (i) = $\dfrac{V}{Z}$

And if ($V_C > V_L$)

$$or, V = \sqrt{{V_R}^2 + (V_C - V_L)^2}$$

And Impedance of RLC circuit (Z) = $\sqrt{R^2 + X^2}$, where, X = $(X_C - X_L)$ = net reactance

Current through the circuit (i) = $\dfrac{V}{Z}$

Procedure:

R-L Circuit:

1. Connect the circuit as shown in the figure.
2. Measure the voltages across resistor and inductor.
3. Compare it with supply voltage.
4. Observe the ammeter reading and compare it with theoretical value.
5. Repeat the process varying the supply.

R-C Circuit:

1. Connect the circuit as shown in the figure.
2. Measure the voltages across resistor and capacitor.
3. Compare it with supply voltage.
4. Observe the ammeter reading and compare it with theoretical value.
5. Repeat the process varying the supply.

R-C Circuit:

1. Connect the circuit as shown in the figure.
2. Measure the voltages across resistor, inductor and capacitor.
3. Compare it with supply voltage.
4. Observe the ammeter reading and compare it with theoretical value.
5. Repeat the process varying the supply.

Observation:

R-L Circuit:

S.N.	Supply voltage(V)	Voltage across resistor(V_R)	Voltage across inductor(V_L)	Calculated $V_{cal} = \sqrt{(V_R)^2 + (V_L)^2}$	Remarks

Current:

S.N.	Ammeter reading (i)	Supply voltage(V)	Impedance, $Z = \sqrt{(R^2 + X_L{}^2)}$	Calculated current $i_{cal} = \frac{V}{Z}$	Remarks

R-C Circuit:

S.N.	Supply voltage(V)	Voltage across resistor(VR)	Voltage across capacitor(VC)	Calculated $V_{cal} = \sqrt{(V_R)^2 + (V_C)^2}$	Remarks

Current:

S.N.	Ammeter reading (i)	Supply voltage(V)	Impedance, Z $= \sqrt{(R^2 + X_C{}^2)}$	Calculated current $i_{cal} = \frac{V}{Z}$	Remarks

R-L-C Circuit(If $V_L > V_C$):

S.N.	Supply voltage(V)	Voltage across resistor(VR)	Voltage across inductor(VL)	Voltage across capacitor(VC)	Calculated $V_{cal} = \sqrt{(V_R)^2 + (V_L - V_C)^2}$	Remarks

Current:

S.N.	Ammeter reading (i)	Supply voltage(V)	Impedance, Z $= \sqrt{(R^2 + (X_L - X_C)^2}$	Calculated current $i_{cal} = \frac{V}{Z}$	Remarks

Precautions:

1. Make the connections properly.
2. Note the readings of voltmeters and ammeters properly.
3. Remove insulations from the connecting wire so as the current will flow properly.
4. Avoid loose connections and don't touch wire with wet hand.

Conclusion:

…………………………………………………………………………………………
…………………………………………………………………………………………
……………………………………………………………………………………….

Viva-voce

1. Define impedance of the circuit.
2. Define capacitive reactance. Write its relation.
3. Define inductive reactance. Write its relation.
4. In which type of circuit, do we have leading power factor?
5. In which type of circuit do we have lagging power factor?

EXPERIMENT NO. 21

Title: Familiarization of different types of connection of three phase system.

Objective: To be familiar with star and delta connection.

Apparatus Required:

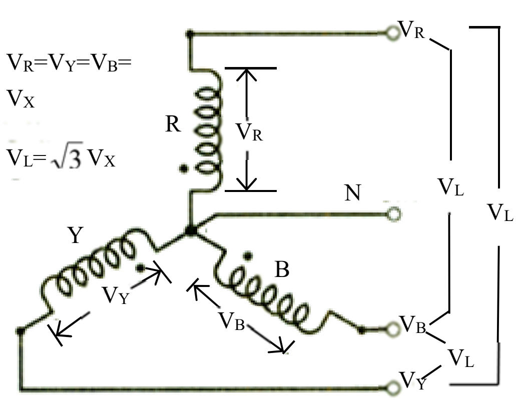
1. Three phase supply
2. Connecting wires

Theory:

Star Connection:

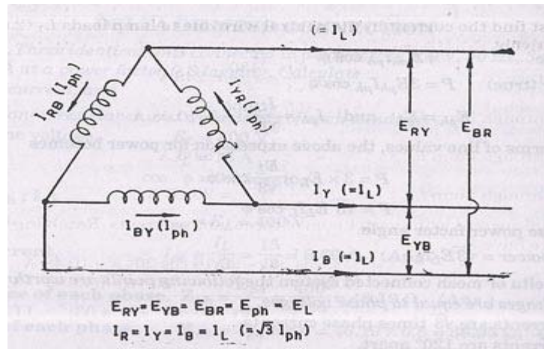
All of the three phases in three phase system have two ends i.e start and end. In this type of connection, one end of each of the three phases is connected to a common point known as neutral point. While connecting the ends, it should be noted that either start of all the three phases or end of all three phases is connected. It should not be connected at random. And the remaining three ends of the phases give R, Y and B. These three line conductors run from the star connection are commonly called lines.

Generally, three wires are brought to the circuit giving a three phase three wire star connected system. However, sometimes a fourth wire can also be taken from the neutral point giving a three phase four wire star connected system.



Delta Connection:

In delta connection, the three windings or phase lines are connected to each other forming a triangle. i.e the three windings are connected to each other in such a way that the starting end of one winding is connected to finishing end of another winding forming a closed mesh. In delta connection, there is absence of neutral point. So it is generally a three wired system.



Procedure:

1. Connect the three phase supply to the above mentioned connection.
2. Show the structure and different parameters of the connections.

Observation:

Findings about the star and delta connection.

Precautions:

1. Make the connections properly.
2. Remove insulations from the connecting wire so as the current will flow properly.
3. Avoid loose connections and don't touch wire with wet hand.

Conclusion:

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………………………

Viva Voce

1. In how many ways the three phases can be connected?
2. What do you mean by delta connection of three phase system?
3. What do you mean by star connection of three phase system?
4. Write the applications of star connection.
5. Write the applications of delta connection.
6. Compare delta connected & star connected three phase system.
7. Why the star connected three phase system can also be referred as four wired three phase system?

EXPERIMENT NO. 22

Title: Measurement of parameters of three phase system in different connection.

Objective: To measure the line and phase current and voltages by connecting a load in star and delta connection.

Apparatus Required:

1. Three phase supply
2. Connecting wires
3. Voltmeters
4. Ammeters

Theory:

Star Connection:

- The current flowing through each of the phases is called phase current (I_{ph}) and the current flowing through each of the line conductor is known as line current (I_L).(i.e I_R, I_Y and I_B)
- Similarly, the voltage across each phase or winding is called phase voltage(V_{ph}) or it can also be defined as the voltage between the line and neutral (i.e. V_{NR}, V_{NY}, V_{NB})
- Likewise, the voltage across the two line conductors or two windings is known as line voltage (V_L) or can be said as line to line voltage. (i.e V_{RY}, V_{YB}, V_{BR})
- In a wye or star connected three phase system, it is found that the line voltage is $\sqrt{3}$ times greater than the phase voltage.

  i.e Line voltage = $\sqrt{3}$ X Phase voltage

$\therefore V_{RY} = \sqrt{3} \times V_{ph}, V_{YB} = \sqrt{3} \times V_{ph}, V_{BR} = \sqrt{3} \times V_{ph}$

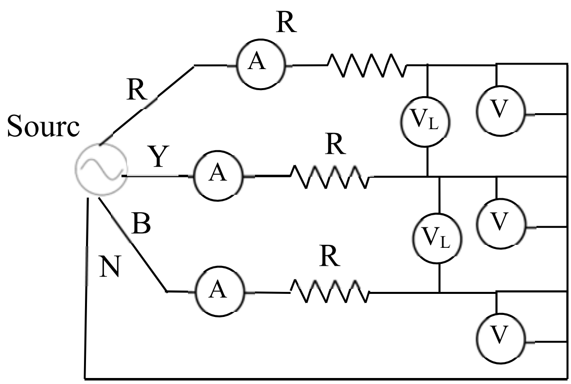


Fig: Load connection

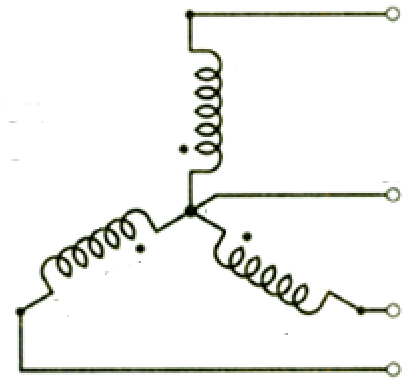


fig: Star connection

As, the line conductor is connected in series with the phase winding, it is clear that the same current flows through the phase winding and the line conductor

Line current = phase current (i.e IL = Iph)

Delta Connection:

The three line conductors R, Y and B run from the three junctions called line conductors. The current flowing through each of the phases or windings is known as phase current (I_{ph}) and the current flowing through each of the line conductor is called line current (I_L).

In a delta connected three phase system, there is no presence of neutral point. So the line voltage is measured between any two windings and the phase voltage will have the same value as that of the line voltage.

i.e Line voltage = Phase voltage

$\therefore E_{line} = E_{phase}$

And in delta connected three phase system, it is found that the current flowing through each windings or phases is $\sqrt{3}$ times greater than the current through each load resistor.

$$\therefore I_{line} = \sqrt{3} I_{phase}$$

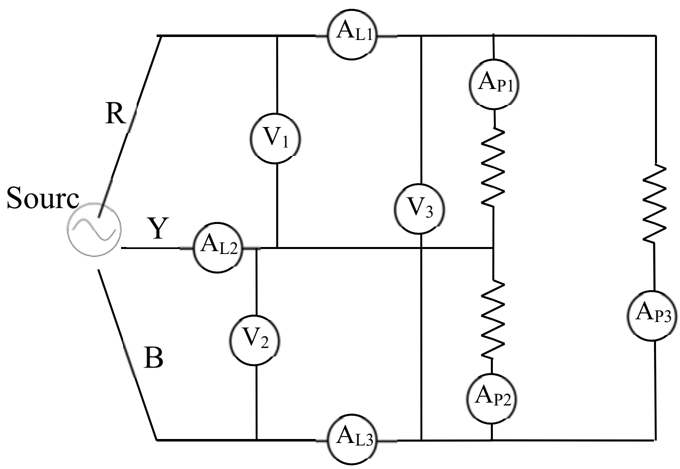


Fig: Load connection

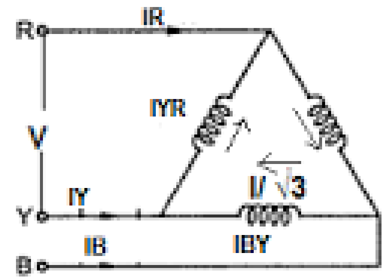


Fig: Delta connection

Procedure:

1. Connect the three phase supply to the above mentioned connection.
2. Observe the different parameters of the connections.
3. Measure the parameters for each connection and relate them.

Observation:

Find the line current, phase current, line voltage and phase voltage for each type of connection and find the relation between them.

Precautions:

1. Make the connections properly.
2. Note the readings of voltmeters and ammeters properly.
3. Remove insulations from the connecting wire so as the current will flow properly.
4. Avoid loose connections and don't touch wire with wet hand.

Conclusion:

…………………………………………………………………………………………

…………………………………………………………………………………………

……………………………………………………………………………………

Viva-voce

1. Define line voltage.
2. Define phase voltage.
3. Define line current.
4. Define phase current.
5. Write the relation between line current and phase current in three phase wye (star) connected three phase system.
6. Write the relation between line current and phase current in three phase delta connected three phase system.
7. Write the relation between line voltage and phase voltage in three phase wye (star) connected three phase system.
8. Write the relation between line current and phase current in three phase delta connected three phase system.