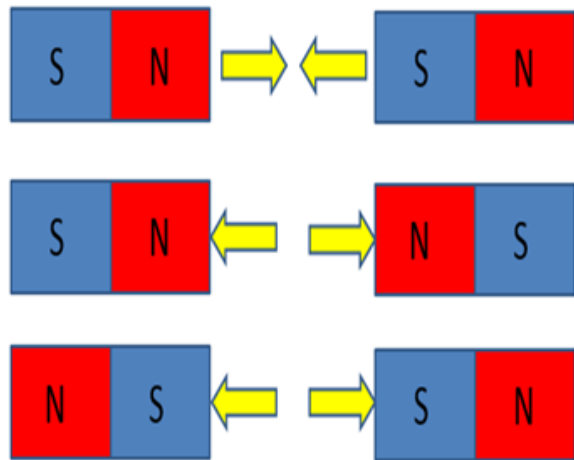# Textbook of
Applied Electrician
Class-IX

NAVTTC

National Vocational & Technical Training Commission (NAVTTC)

Textbook of

Applied Electrician

GRADE

IX

Ministry of Federal Education and Professional Training Islamabad

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PREFACE

This book has been written to cater the needs of Matric-Tech to teach & train the students for the subject of applied Electrician. Matric-Tech is a new initiative of NAVTTC and Applied Electrician trade is introduced for the first time at SSC level. It is highly suitable for present day needs. It covers both the Electrical & Electronic aspects of the field. Key effort has been made to make the book interesting and useful. All the chapters presented cover the basic details understandable to the students of Matric Tech. All chapters include assessments in the form of MCQs, Short Questions & Long Questions. Any suggestions for the betterment of this book will be highly appreciated. I am especially thankful to NAVTTC & review team for their kind guidance and cooperation.

Executive Director
National Vocational & Technical Training Commission
(NAVTTC)

Table of Contents

Chapter 01   Fundamentals of Electricity

Students Learning Outcomes

After completion of this chapter you will be able to:

- ➢ understand matter and its states.
- ➢ define atom, ions and their structure.
- ➢ define current, voltage and resistance
- ➢ describe electrical units (current, voltage, resistance)
- ➢ recognize and draw electrical symbols
- ➢ define conductor, insulator & semi-conductor
- ➢ use measuring instruments
- ➢ define ohm's law
- ➢ describe application of Ohm's Law for measuring Current, Voltage and Resistance

1.2   1.1 Matter and its States

Matter is anything that occupies space and has mass. All physical objects are composed of matter. All matter is made up of small indivisible and indestructible particles called atoms, which are in turn made up of protons, neutrons and electrons. Atoms come together to form molecules, which are the building blocks for all types of matter. Both atoms and molecules are held together by a form of potential energy called chemical energy.

Figure 1.1: States of matter

There are four natural states of matter:

     i.   Solid

    ii.   Liquid

   iii. Gas

   iv. Plasma.

i.   Solids

In a solid, particles are packed tightly together so they don't move much. The electrons of each atom are constantly in motion, so the atoms have a small vibration, but they are fixed in their position. Because of this, particles in a solid have very low kinetic energy.

Solids have a definite shape, as well as mass and volume, and do not conform to the shape of the container in which they are placed. Solids also have a high density, meaning that the particles are tightly packed together. The examples of solids include ice, wood, iron etc.

ii.   Liquids

In a liquid, the particles are more loosely packed than in a solid and are able to flow around each other, giving the liquid an indefinite shape. Therefore, the liquid will conform to the shape of its container.

Much like solids, liquids (most of which have a lower density than solids) are incredibly difficult to compress. The examples of liquids include water, mercury, blood etc.

iii. Gases

In a gas, the particles have a great deal of space between them and have high kinetic energy. A gas has no definite shape or volume. If unconfined, the particles of a gas will spread out indefinitely; if confined, the gas will expand to fill its container. When a gas is put under pressure by reducing the volume of the container, the space between particles is reduced and the gas is compressed. The examples of gases include air, oxygen, carbon dioxide etc.

iv. Plasma

According to the Jefferson Laboratory, Plasma is not a common state of matter here on Earth, but it may be the most common state of matter in the universe. Stars are essentially superheated balls of plasma.

Plasma consists of highly charged particles with extremely high kinetic energy. The noble gases (helium, neon, argon, krypton, xenon and radon) are often used to make glowing signs by using electricity to ionize them to the plasma state.

Do you know?

Lightning is as an example of plasma present at Earth's surface: Typically, lightning discharges 30 kilo amperes at up to 100 megavolts. Plasma temperatures can approach 30000 K and electron

Figure 1.2: Lightning

1.2 Atom, Ions and Atomic Structure

All the matters are composed of small particles which are called as **atoms**. Atom cannot exist freely as a single particle and combines with other atoms and forms molecules. A substance which has same nature of molecules is called as an element. At present, almost 118 elements have been discovered. **Atoms** are neutral; they contain the same number of protons as electrons.

By definition, an **ion** is an electrically charged particle produced by either removing electrons from a neutral **atom** to give a positive **ion** or adding electrons to a neutral **atom** to give a negative **ion**.

Atomic Structure

According to the modern electron theory, atom is composed of the three fundamental particles, which are invisible to bare eyes. These are the neutron, the proton
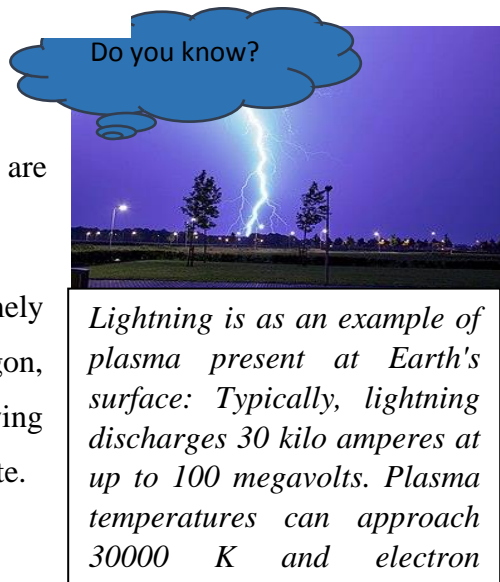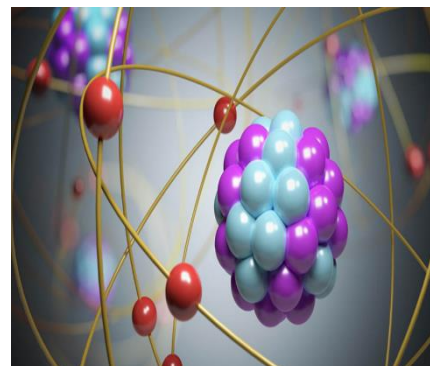
Figure 1.3: Atom structure

and the electron. The proton is defined as positively charged particle while the electron is defined as negatively charged particle. The neutron is uncharged i.e. neutral in nature possessing no charge. The mass of neutron and proton is same while the electron is very light, almost 1/1840th the mass of the neutron and proton.

An atom consists of following parts:

(i) External Part.

(ii) Internal Part.

i. External Part

External part consists of electrons. Electrons are negatively charged particles and the value of this charge is 1.602×10^{-19} coulombs and has mass 9.11 x 10^{-28} grams or 9.11 x 10–31 Kg. It radius is 1.9 x 10–15 meter. Electrons are the lightest part of an atom.

ii. Internal Part

Internal part of the atom is called as **Nucleus** and it consists of two particles i.e. protons and neutrons. Proton is positively charged particle

Figure 1.4: Electron shell

and the amount of this charge is same as the charge of an electron i.e. 1.6 x 10^{-19} coulombs the mass of proton is 1836 times heavier than that of the mass of the electron.

The neutrons have no charge and its mass is equal to the mass of the proton. So the total mass of an atom is due to the mass of the protons and neutrons.

Electron revolves around the nucleus in fixed paths which are called as **orbits**.

The number of protons and electrons in an atom is same. Since the electrons are negatively charged and protons are positively charged, a force of attraction exists among these charges. This force keeps the electron continuously revolving around the nucleus in an atom.

K, L and M Shells

Electrons revolve around the nucleus in the orbits. These orbits are called shells. These shells are represented by K, L and M etc.

The shell which is closest to the nucleus is called as K shell; next shells are L, M and so on. Every shell has a fixed number of electrons and is determined by the rule as described below.

No. of electron in n shell no. $= 2n^2$

Where n = No. of shell.

No. of electrons in K shell is $= 2 (1)^2 = 2$

No. of electrons in L shell is $= 2 (2)^2 = 8$

No. of electrons in M shell is $= 2 (3)^2 = 18$

and so on.

Every atom follows the formula $2n^2$ to fell the orbit. However last orbit can be considered as filled if it has at least 8 electrons.

Energy Levels

Electrons revolve around the nucleus in fixed orbits. These electrons have a fixed energy in the orbit which is called as is Energy Level. The energy level of K orbit is lowest. However, being nearest to the nucleus it is bound with strong force. As we move away from the nucleus energy level is increased but the force of the nucleus on the electrons is decreased.
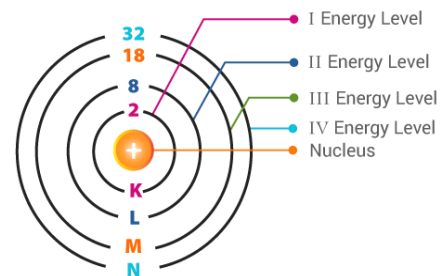
Figure 1.5: Energy levels

Valence Electrons

Electrons in outer most shell are called as **Valence Electrons** and this shell is called as the **Valence Shell**. Valence electrons lightly bound to the nucleus compared with those electrons which are closer to the nucleus. The reason is that the force of attraction between the positively charged nucleus and negatively charged electrons decreases with the increase in
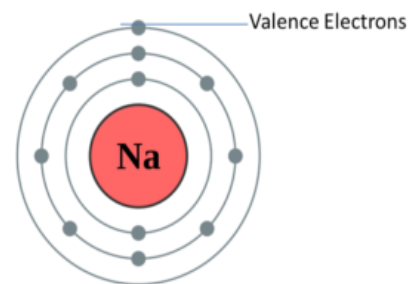
Figure 1.6: ValenceElectrons

distance from the nucleus.

Electrons which have highest energy levels exists the outermost shell of an atom, and are relatively loosely bound to the atom.

1.3   1.3 Define Current, Voltage and Resistance

Voltage is a potential difference which maintains the flow of charge through a conductor. It is represented by V and its unit is **Volt.**

Voltage is measured by specifying a certain reference value. This reference value is normally 0 V.

Current

Current is the flow rate of electric charge through a conducting medium with respect to time. Electric current is expressed mathematically (e.g. in formulas) using the symbol "I" or "i". The unit for current is ampere or amp. It is represented by A.

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

Where **Q** is charge in coulomb and **t**is time in second.

The flow of current depends on the conductive medium. For example:

- In the conductors, the flow of current is due to electrons.
- In semiconductors, the flow of current is due to electrons or holes.
- In an electrolyte, the flow of current is due to ions and

When an electrical potential difference is applied between two points in a conductive medium, an electric current starts flowing from higher potential to lower potential. The higher the voltage or potential difference, the more the current to flow between two points.

AC & DC

Based on the flow of charge, the electric current is classified into two types, i.e., alternating current (AC) and direct current (DC).

Alternating Current

The flow of electric charge in a periodically reverse direction is known as alternating current (AC). AC is also referred to as "AC Current". Although this is technically saying the same thing twice "Alternating Current".

An alternating current changes its direction at a periodic interval.

The alternating current starts from zero, rises to maximum, decreases to zero, and then reverses and reaches a maximum in the opposite direction, then again returns to the original value and repeats this cycle infinitely.

The type of alternating current waveform may be sinusoidal, triangular, square, or saw tooth, etc. The particularly waveform don't matter—so long as it as a repeating waveform. In most electrical circuits, the typical waveform of alternating current is a sine wave. A typical sine waveform that you might see as an alternating current is shown in the image below.
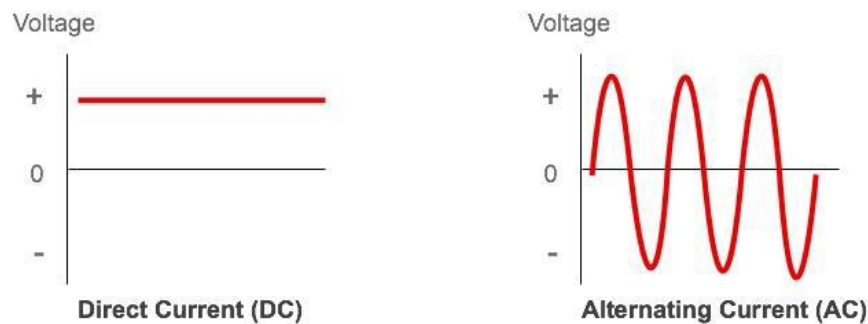
Figure 1.7: DC and AC

Direct Current

The flow of electric charge in only one direction is known as direct current (DC). Although this is technically saying the same thing twice "Direct Current".

As DC flows only in one direction; hence it is also referred to as unidirectional current. A waveform of a direct current is shown in the above figure. DC can be generated by batteries, solarcells, fuel cells, thermocouples, commutator type electrical generators, etc. An alternating current can be converted to direct current by using a rectifier.

DC electric power is generally used in low-voltage applications. Most electronic circuits need a DC power supply.

Resistance

Resistance is a property of a material which opposes the flow of current through it. It is represented by R and measured in ohm (Ω).

The value of the resistance is different for different materials. It depends on the nature and atomic structure of

Figure .8: Resistors

the material. Wood, glass, mica, plastic have very large resistance. Materials having low value of resistance are called as conductors. Copper has very low value of resistance and is considered as very good conductor. The symbol of resistance is:

Applications of Resistors

Resistors are used in many applications to limit the current and voltage in the circuits. Resistor shows the similar behavior at dc and ac supplies. Some of the many applications of resistors are enlisted as follows:

Figure 1.9: Resistor Symbols

- In order to control or divide the voltage.
- To control the current in the circuit.
- In electronics circuits for wave shaping and many other applications.
- In ampere meters and voltmeters.
- In domestic application in electric iron, bulbs, heaters etc.
- To control the temperatures.
- In the protection of electric circuits and systems.

Resistor Color Coding

Resistor color coding is used to find the resistance value by using the different color bands found on the body of the resistor. Since the size of the resistor is very small so it is not possible to write the value of the resistance on the body of the resistor. In color coding 4 or 5 bands of various colors are printed on the body of the resistor. The value of the resistance is read by using the table and following technique:

- First band represent the first significant digits of the value of the resistor.
- Second band represents the second significant digit of the value of the resistor.
- 3rd band specifies the no. of zero to be assigned to 1st two significant digits found in steps 1 & 2.

- Fourth band represents the possibility of tolerance. If its color is silver it represents 10% tolerance, if the color is gold it represents 5% tolerance and if there is no band it means 20% tolerance.

	1st digit	2nd digit	3rd digit	multiply	tolerance	TCR (ppm/K)
Black	0	0	0	1	1% (F)	100
Brown	1	1	1	10	2% (G)	50
Red	2	2	2	100		15
Orange	3	3	3	1K		25
Yellow	4	4	4	10K		
Green	5	5	5	100K	0.5% (D)	
Blue	6	6	6	1M	0.25% (C)	10
Violet	7	7	7	10M	0.1% (B)	5
Gray	8	8	8	100M	0.05% (A)	
White	9	9	9	1G		
Gold				0.1	5% (J)	
Silver				0.01	10% (K)	
None					20% (M)	
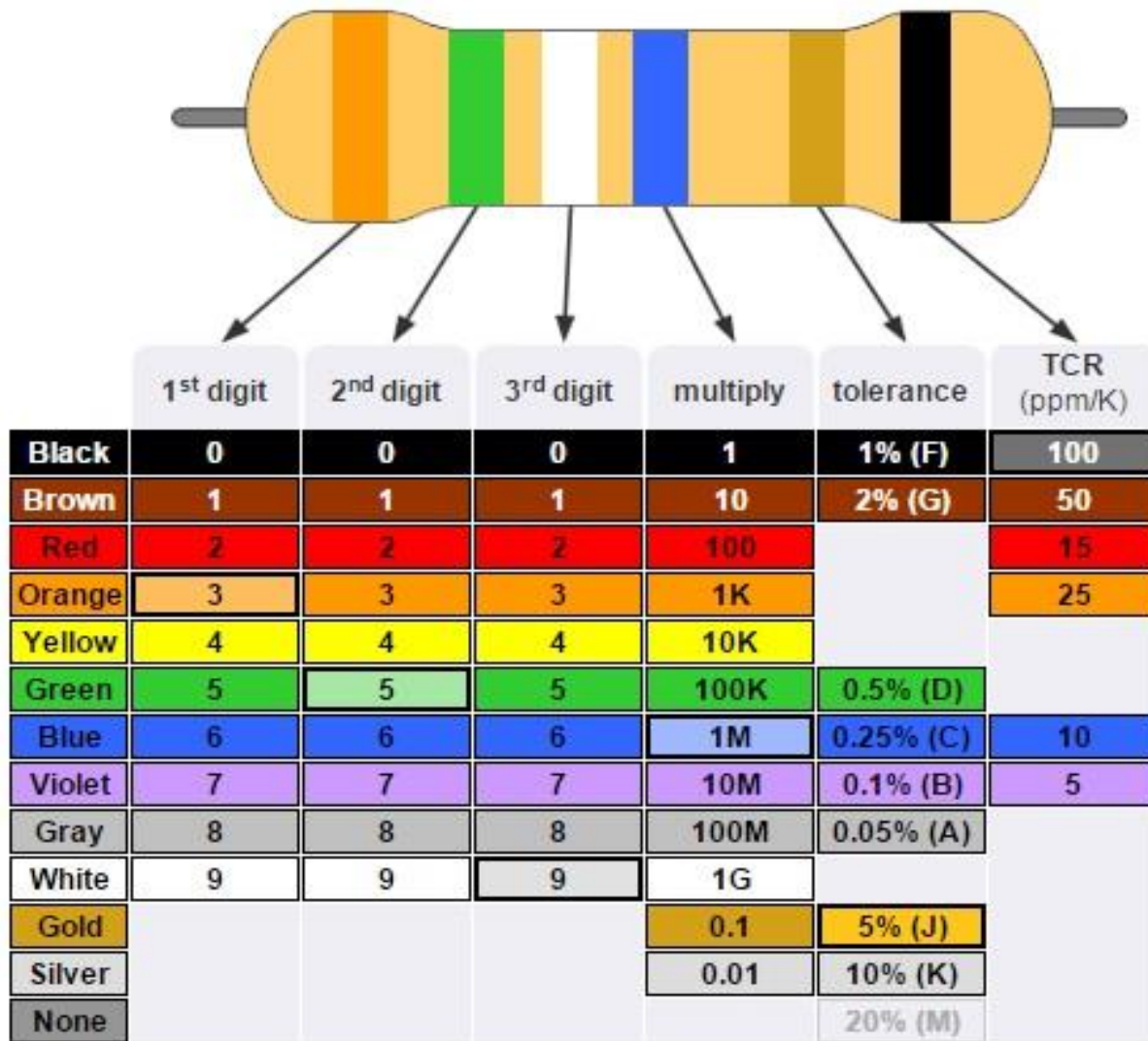
Figure 1.10: Resistor Color Coding Symbols

1.4   1.4 Electrical Units (Current, Voltage, Resistance)

Unit of Voltage (Volt)

The SI unit of electric Voltage is volt.

Voltage between two points will be 1 volt if one Joule of energy is required to move one Coulomb of charge between these points.

Mathematically we can say:

$$1 \text{ Volt} = 1 \text{ Joule/ } 1 \text{ Coulomb}$$

or

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

$$W = VQ$$

Where W represents work done in joules

Unit of Current (Ampere)

The SI unit of electric current is Ampere. It is denoted by "A".

It can be defined as: "If one coulomb of charge flows through a conductor in one second, the amount of current is one Ampere"

Unit of Resistance (Ohm)

The SI unit of resistance is "Ohm" and is represented by Ω (Ω is Greek alphabet "Omega").

It can be defined using Ohm's Law (to be discussed later):

$$V = IR \quad \text{or} \quad R = \frac{V}{I}$$

If a potential difference of 1 volt is applied to the ends of a conductor, and a current of 1 ampere flows through it, it is said that the value of the resistance is 1 ohm.

Prefixes Some of the prefixes and their abbreviations which are commonly used are tabulated as follows:

Prefixes

• Tera-	T	1,000,000,000,000	10^{12}
• giga-	G	1,000,000,000	10^{9}
• mega -	M	1,000,000	10^{6}
• kilo -	k	1,000	10^{3}
• deci-	d	0.1	10^{-1}
• centi-	c	0.01	10^{-2}
• milli-	m	0.001	10^{-3}
• micro-	μ	0.000001	10^{-6}
• nano-	n	0.000000001	10^{-9}
• pico-	p	0.000000000001	10^{-12}

Activity 1.1 Carryout Orientation Visit Of Electrical Lab/Workshop And Record The Observation
Components/Instruments Notepad, Stationary
Step 1: Arrange the Orientation Visit of Electrical Lab/Workshop Step 2: Guide the students regarding available tools and equipment in the lab Step 3: Record the observations

1.5   1.5 Electrical/Electronic Symbols

Electrical/Electronic Circuit diagrams are virtually represented by **Electrical Symbols**. There are some standard symbols to represent the components in a circuits. This article gives some of the frequently used symbols for drawing the circuits as follows:

Wires

Wire Represents a conductor that conducts electrical current. Also called a power line or electric line or wire	
Connected Wires (Represents the connection of two conductors. Dot shows the junction point)	
Unconnected Wires Represents two unconnected wires/conductors	

Sources

DC Supply This represents the DC power supply. It applies DC supply to the circuit	
AC Supply This represents AC supply in the circuit	

Single Cell Battery This provide Supply to the Circuit	
Multi Cell Battery Combination of multiple single cell batteries or a single large cell battery. The voltage is usually higher.	

Ground Symbols

Ground It is equivalent to theoretical 0V and is used as zero potential reference. It is the potential of perfectly conducting earth.	
Signal Ground It is a reference point from which the signal is measured. There may be several signal grounds in a circuit due to the voltage drops in a circuit.	
Chassis Ground It acts as a barrier between user and the circuit and prevents electric shock.	

Resistor Symbol

Fixed Resistor It is a device that opposes the flow of current in a circuit. These two symbols are used to represent fixed resistor.	
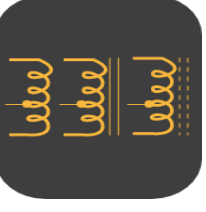
Variable Resistor (Rheostat) It is a two terminal variable resistor. They are generally used to control the current in the circuit. Generally used in tuning circuits and power control applications like heaters, ovens etc.	

Capacitor Symbols

Non Polarized Capacitor Capacitor stores the charge in the form of electrical energy. These two symbols are used for non-polarized capacitor. Non-polarized capacitors are big in size with small capacitance. They can be used in both AC and DC circuits.)	
Polarized Capacitor Polarized capacitors are small in size but have high capacitance. They are used in DC circuits. They can be used as filters, for bypassing or passing low frequency signals.	
Variable Capacitor (The capacitance of the variable capacitor can be adjusted by turning the knob. They are widely used to adjust the frequency that is for tuning.)	

Inductors

Inductors These are used as substitutes to ferrite core inductors. Ferrite core or Ferromagnetic inductors have high permeability and require air gap to reduce it. Iron powdered core inductors have this air gap integrated.	

Ferrite Core Inductors Core material, in this type of inductors is made of ferrite material. These are mostly used to suppress the interference of electromagnetic waves.	
Center Tapped Inductors These are used in coupling of signals	
Variable Inductors Movable ferrite magnetic core variable inductors are most common. The inductance is varied by sliding the core in or out of the coil.	

Diode

Diode A PN junction diode allows the current to flow only in forward bias condition. These diodes can be used in clipping and clamping circuits, as rectifiers in dc circuits etc.	
Zener Diode In forward bias condition, it acts as normal diode and allows current. It also allows current to flow in reverse bias condition when the voltage reaches a certain break-down point. Generally used in voltage regulator and over voltage protection circuits.	

LED Light emitting diode is similar to PN junction diode but they emit energy in the form of light instead of heat. These are mostly used in indication, lightening applications.	

Transistor Symbols

NPN It is made of combination of P-type semiconductor between two N-type semiconductors. It is switched ON when the base-emitter junction is forward biased. They are commonly used for amplifying and switching applications.	
PNP It is made of combination of N-type semiconductor between two P-type semiconductors. It is switched ON when the base-emitter junction is reverse biased. These are used for amplifying and switching applications.	
Phototransistor The photo transistor converts the light energy falling on it to its corresponding electrical energy. This can be used in light sensing applications. Base is left disconnected as light is used to enable the flow of current.	

Amplifiers

Basic Amplifier (An amplifier is a device that amplifies a relatively small input signal i.e. it increases the power of the signal. They are used in communication systems, audio devices etc.	

Operational Amplifier Operational Amplifier (Op Amp) is a voltage amplifier with very high gain. The input is differential. They are used in instrumentation devices, signal processing, control systems etc.	

Transformer

Transformer is the basic element that transfers energy in one circuit to the other circuit through electromagnetic induction. They are generally used in electric power applications to increase or decrease the voltage of AC current.	
Iron Core Transformer Uses a piece of magnetic material as core. Generally, Ferro magnetic metals like iron are used. The core has high permeability and is used to confine the magnetic field.	
Center Tapped Transformer (The center tapped transformer has its secondary winding divided into two parts with same number of turns in each part. This results in two individual output voltages across two line ends. Used in rectifier circuits.)	
Step Up Transformer (The no. of turns in secondary winding is more than that of primary winding. The output voltage is higher than input voltage. Significantly used in inverters.)	
Step Down Transformer (The no. of turns in secondary winding is less than that of primary winding. The output voltage is lesser than input voltage. It is widely used in low power applications.)	

Miscellaneous

Buzzer This is sound producing device. This produces buzz sound when the voltage is applied	
Light Bulb The symbol represents the light bulb. The bulb glows when required voltage is applied.	
Motor This converts the electric energy to mechanical energy.	
Fuse Symbol represents the fuse that protects the circuit from over current	

Activity 1.2 Draw electrical symbols
Components/Instruments Chart, Stationary
Step 1: Arrange the class Step 2: Assign them the task to draw electrical symbol

1.6   1.6 Conductor, Insulator & Semiconductors.

Conductor

A conductor is a type of material that allows the flow of charge. Conductors are mostly made up of metals. Such materials allow the current flow due to the presence of free electron which starts moving when voltage is appliede.g.Copper,Silver, Aluminum, Gold etc.

Semiconductor

Semiconductoris a material that has conductivity in-between conductors and insulators. It can block or allow the current flow providing total control over it. It modifies its properties like unidirectional current flow or amplification or energy conversion etc. The electrical conduction inside semiconductor is due to the movement of electrons & holese.g. Silicon and Germanium

Insulator

An insulator is a material that has very high electrical resistance & it does not allow the flow of current. There are no free electrons in insulator thus it cannot conduct electricitye.g.Glass, Rubber, Wood etc.

Characteristics of Conductors, Semiconductors & Insulators

Characteristics	Conductor	Semiconductor	Insulator
Definition	A conductor is a material that allows the flow of charge when applied with a voltage.	A semiconductor is a material whose conductivity lies between conductor & insulator	An insulator is a material that does not allow the flow of current.
Temperature Dependence	The resistance of a conductor increases with an increase in temperature.	The resistance of a semiconductor decrease with increases in temperature. Thus it acts as an insulator at absolute zero.	Insulator has very high resistance but it still decreases with temperature.
Conduction	The conduction in	The conduction in	There are no free

	conductors is due to the free electrons in metal bonding.	semiconductor is due to the movement of electron & holes.	electrons or holes thus, there is no conduction.
Valence Electron in Outer Shell	1 Valence electron in outer shell.	4 Valence electron in outer shell.	8 Valence electron in outer shell.
Examples	Gold, Copper, Silver, Aluminum etc.	Silicon, Germanium, Selenium, Antimony, Gallium Arsenide (known as semi insulator),Boron etc.	Rubber, Glass, Wood, Air, Mica, Plastic, Paper etc.
Applications	The metals like iron & copper etc. that can conduct electricity are made into wires and cable for carrying electric current.	Semiconductors are used every day electronic devices such as cellphone, computer, solar panel etc. as switches, energy converter, amplifiers, etc.	The insulators are used for protection against high voltages & prevention of electrical short between cables in circuits.

1.7   1.7   Measuring Instruments

Ohm Meter

An ohm meter is a device to measure resistance. Connecting leads ohm meter are connected with the resistance to measure and ohm meter displays the resistance.

Voltmeter

A voltmeter is used to measure voltages. Probes of voltmeter are connected with the terminals of the circuits across which voltages are to be measured. A voltmeter is always connected in parallel across a component whose voltages are to be measured.
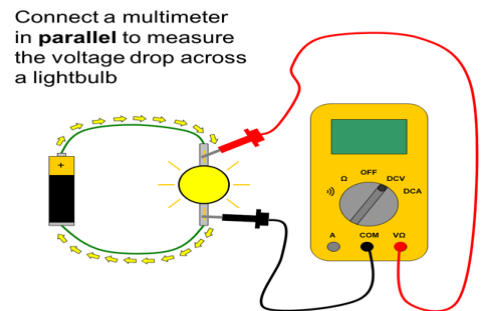
Figure 1.11: Voltmeter Connection

Ammeter

An Ammeter is used to measure current. Probes of Ammeter are connected with the terminals of the circuits across which current is to be measured. It should be noted that ammeter is always connected in series in the circuit whose current is to be measured.
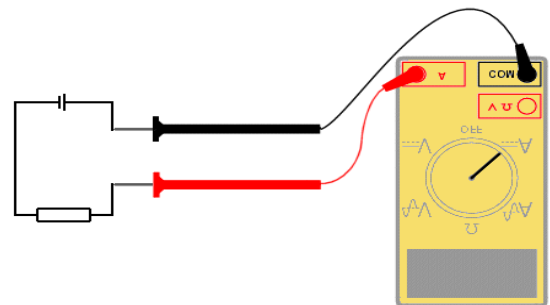
Figure 1.12: Ammeter Connection

Multimeter

A multimeter is an instrument used to measure different electrical quantities. It combines the testing capabilities of single-task meters-the voltmeter (for measuring volts), ammeter (amps) and ohmmeter (ohms).

Figure 1.13: Multimeter

Oscilloscope

An oscilloscope is a measuring instrument commonly used to display and analyze the waveform of electronic signals. It draws a graph of the instantaneous signal voltage as a function of time.

There are multiple controls on an oscilloscope. Scale of x-axis and y-axis can be adjusted. There is a separate control to adjust the time scale of x-axis. To scale the y-axis, there is a knob called

voltage/div. There are multiple channels on an oscilloscope. This means you can plot different signals simultaneously. To calibrate the oscilloscope, a probe is connected on an input of a channel and the other end is connected to the calibration terminal. The resulting waveform is then calibrated on the required scale.

Figure 1.14: Oscilloscope

1.8   1.8 Ohm's Law

Ohm's law states that the current through a conductor between two points is directly proportional to the voltage where resistance remains constant.

Mathematically:

I α V   when resistance is constant

I α$\frac{1}{R}$when voltage is constant
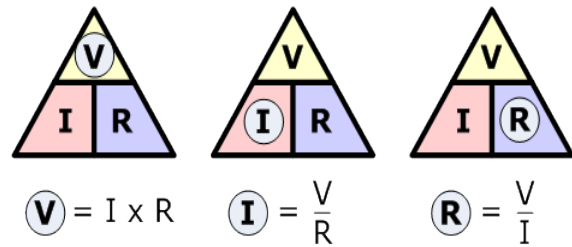
Figure 1.15: Ohm law relationship

(Consider the temperature of the circuit remains constant.)

Combine these two statements, this relation becomes

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

This mathematical form is known as the formula of Ohm's Law. We can use this triangle form to find any one value given remaining two values.

For a constant resistance, if the voltage in a circuit is increased more current will flow and if the voltage is decreased less current will flow. Also for a constant voltage if the resistance is decreased more current will flow.

Activity 1.3
Apply Ohm's law for measuring current, voltage and resistance
Components/Instruments
Resistor, Voltage source, Connecting wires, Breadboard and Multimeter

Step 1: Arrange the class in small groups

Step 2: Assign them the task to verify Ohm's law

Step 3: Collect the desired components and instruments

Step 4: Record the observations

Step 5: Draw the V-I characteristics graph

Key points

- Matter is anything that occupies space and has mass.

- All the matters are composed of small particles which are called as atoms

- An **ion** is an electrically charged particle produced by either removing electrons from a neutral **atom** to give a positive **ion** or adding electrons to a neutral **atom** to give a negative **ion**.

- Voltage is a potential difference which maintains the flow of charge through a conductor. It is represented by V and its unit is **Volt.**

- Current is the flow rate of electric charge through a conducting medium with respect to time. The unit for current is ampere or amp. It is represented by **A**.

- Resistance is a property of a material which opposes the flow of current through it. It is represented by R and measured in **ohm (Ω).**

- The electric current is classified into two types, i.e. **alternating current (AC)** and **direct current (DC).**

- Ohm's law shows the linear relationship between voltage and current.

Multiple Choice Questions

Select the most appropriate option (✓)

Q.1   The central part of atom is _____.

    a.   Electron

    b.   Proton

    c.   Neutron

    d.   Nucleus

Q.2   Proton has _____ charge.

    a.   Negative

    b.   Positive

    c.   Neutral

    d.   Zero

Q.3   The mass of electron is _____ the mass of proton.

    a.   Heavier than

    b.   Lighter than

    c.   Equal to

    d.   Twice of

Q.4   The shells around the nucleus are named as _____.

    a.   K, N, L...

    b.   K, L, M...

    c.   K, M, N...

    d.   K, L, N...

Q.5   The electron in incomplete outermost orbit is called _____ electron.

    a.   Free

    b.   Valence

    c.   Ion

    d.   Unique

Q.6   The closest shall to the nucleus is _____

    a.   K

    b.   L

    c.   M

   d. N

Q.7 The material between conductor and insulator is called _____

  a. Matter

  b. Composite

  c. Semiconductor

  d. Ceramics

Q.8 The _____ law states that potential difference is directly proportional to current.

  a. Coulomb's

  b. Ohm's

  c. Kirchhoff's voltage

  d. Lenz's

Q.9 According to Ohm's law

  a. $Q = CV$

  b. $V = IR$

  c. $R = \rho L / A$

  d. $B = \emptyset / A$

Q.10 Current flows through a circuit, having 20Ω resistance, the amount of applied voltage is 100v then the current is:

  a. 4A

  b. 5A

  c. 7A

  d. 12A

Give short answers of the following questions.

1. Define Atom
2. Enlist major parts of an atom
3. Define Conductor
4. Define Insulator
5. Define Semiconductor
6. Define energy level/shells

7. Define voltage and its unit

8. Define current with its unit

9. State Ohm's law

10. Differentiate between electron current and conventional current

Answer the following questions in detail

1. Describe the structure of atom in detail with help of a diagram

2. Differentiate between conductor, insulator and semiconductor with reference to the energy band

3. Explain Ohm's law with the help of a simple circuit

Practical Activities

1. Verify Ohm's law using different values of voltage and draw their V-I characteristic curve

2. Measure voltage, current and resistance using Multimeter and record observations

Instructions for the Teachers

1. Adopt Health and Safety measures in the lab

2. Use all the available ICT resources for better delivery of the content

3. Ensure proper functioning of lab equipment

Chapter 02   Cells and Batteries

Students Learning Outcomes

After completion of this chapter you will be able to:

- ➤ define cell and batteries.
- ➤ describe the importance of cell and batteries.
- ➤ explain the types of cell and batteries.
- ➤ explain the charging procedure of battery.
- ➤ use cell and battery as a series and parallel source.
- ➤ explain component/parts of cell and batteries.
- ➤ describe construction and working principle of battery.
- ➤ explain the procedure for maintaining a battery.
- ➤ describe the importance of electrolyte in the battery.
- ➤ explain the testing procedure of batteries.

➢ Explain the use of tools and equipment required for testing of batteries.

1.9   2.1 Types of DC Sources

There are two types of currents i.e. ac and dc. DC means direct current and it has only one direction of flow i.e. from the positive terminal to the negative terminal of the source or vice versa.

DC can be obtained from the following sources:

(i) Cells

A cell is a device which produces dc voltage by the chemical reaction.
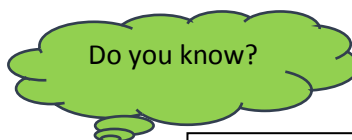
> **Do you know?**
>
> Battery is combination of cells

(ii) Batteries

When different cells are combined a battery is formed.

(iii) Generator

It produces dc by converting mechanical energy into electrical energy.

(iv) Power Supplies

Power supplies also provide dc. In power supplies ac is converted to dc through rectification.

Activity 2.1:
Enlist various types of cells and batteries
Components/Instruments
Notebook, Stationary

Make a list of cells and batteries on a chart using different colors and display it in classroom

---

1.10   2.2 Importance of Cells & Batteries

i.   Batteries are essential components of most electrical devices. They exist in our cars, laptops and other electronic appliances.

ii. A battery provides portability to a device / appliance.

2.3 Types of Cells & Batteries

Types of Cells

A cell is a device which produces direct current due to some internal chemical reactions. There are two basic types of cells.

   i. Primary Cell

  ii. Secondary Cell

i. Primary Cell

A primary cell is defined as a cell which cannot be recharged once it is discharged. The basic principle of cell is that when two dissimilar metals are called Electrodes are placed in an electrolyte; EMF is produced due to the chemical reaction. The EMF continues to remain available until the electrolyte is fully utilized and converted into some other shape. In a primary cell it is not possible to reverse the chemical action to bring the electrolyte to its original state. Examples of primary cells are Mercury Cell, Silver Oxide Cell etc.

ii. Secondary Cell

A secondary cell is one which can be charged once it is discharged. In the secondary cell the chemical reaction which takes place between the electrolyte and electrode during the discharging can be reversed by passing a current through the cell in the opposite direction. Examples of secondary cell are Nickel Cadmium Cell, Lead Acid Batteries etc.

Comparison of Primary and Secondary Cells

Primary Cells	Secondary Cells
It cannot be recharged.	It can be recharged.
It is light in weight.	It is heavy in weight.
Its life is short.	Its life is long.
Its output is small.	It has more output voltage.
It has large internal resistance.	It has small internal resistance.
Its price is low.	Its price is high.

Popular Primary Cells

Mercury Cell

Mercury Cell is a primary cell. It is used with a high current density with a uniform discharge characteristics are required. Its internal resistance is low and remains constant.

Mercury cell consists of a cathode which is made from compressed mercuric oxide mixed with a small percentage of graphite. The anode is made from a purified zinc powder. KOH is used as electrolyte. Mercury cell is made

Figure 2.1: Mercury Cell

in the shape of flat, round cylinder and small button shapes. It is shown in figure below.

These are used in radios, Electric watches, Instruments, Computers and measuring devices etc. It provides output in volts 1-2 volts.

Silver Oxide Cell

Silver oxide cell is a primary cell. It consists of depolarizing cathode and a powdered zinc anode. KOH or NaOH is used as Electrolyte. The depolarizing cathode consists of AgO2 and manganese dioxide MnO2.

The cathode is made depolarizing to avoid the hydrogen ions which are gathered at the silver plate during the chemical reaction. To avoid this gathering of hydrogen ions manganese dioxide is mixed with AgO2. It improves the life of the cell.

Figure 2.2: Secondary Cells

Silver oxide cells are made in the form of buttons or discs and provide few volts output 2-3 volts. Silver oxide cells are used in hearing and reference voltage sources, Electronic instruments and watches etc.

Nickel Cadmium Cell

Nickel Cadmium is a reversible cell or a secondary cell. The open circuit voltage provided by the cell is 1.25 to 1.5 volts. It is used for high current density applications and is highly reliable for long term applications. Nickel cadmium cell is available in both sealed and non-sealed designs but the sealed constructions are common. It is shown in figure

Nickel cadmium cell are used in portable power tools, alarm systems, and portable radio or television equipment.

The positive electrode is Ni and negative electrode is Cd. KOH is used as Electrolyte.

The chemical equation for NiCad cell can be written as follows.

Figure 2.3: Nickle Cadmium Cells

$$2Ni(oH)_3 + Cd \xrightleftharpoons[\text{Discharge}]{\text{Charge}} 2Ni(oH)_2 + Cd(oH)_2$$
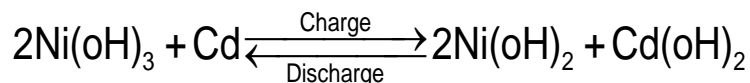
NiCad cell is a true storage cell with a reversible chemical reaction for recharging that can be cycled up to 1000 times. It should be noted that a new NiCad battery may need charging before use.

Do you know?

The capacity of battery is measure in AH

Lead Acid Battery

Lead Acid Cell is used when high values of load current are necessary. The electrolyte is dilute solution of sulphuric acid H_2SO_4. The lead acid cell is a secondary cell or storage cell which can be recharged. The charge and discharge cycle can be repeated many times to restore the output voltage as long as the cell is in good physical conditions. One cell has a nominal output of 2.1V but lead acid cells are often used in a series combination of three for a 6V battery and six far a 12-volt battery.

Figure 2.4:Lead acid Cell

In lead acid battery positive and negative electrodes consists of a group of plates welded to a connecting strap. The plates are dipped in the electrolyte consisting of 8 parts of water to 3 parts of concentrated Sulphuric acid.

This action reforms the positive plate and makes the electrolyte stronger by adding sulphuric acid. This chemical reaction for discharging and charging is shown below:

Do you know?

In a battery number of negative plates is always one more

$$Pb + Pbo_2 + 2H_2So_4 \xrightleftharpoons[\text{Discharge}]{\text{Charge}} 2PbSo_4 + 2H_2O$$

The state of the discharge of a lead acid is generally checked by measuring the specific gravity of the electrolyte. Specific gravity reading is taken with a battery hydrometer.

Solar Cell

A solar cell works on the principle called photo voltaic effect. A solar cell consists of two layers of different materials. One layer is photo sensitive that is when light energy falls on it, emits electrons. The other layer is capable of absorbing the electrons. The layer which emits electron i.e., losses the negative charge becomes positive and acts as a positive electrode. On the other hand, the layer which accepts electrons becomes negative and acts as negative electrode. In this way by these two electrodes a cell is formed which is called as Solar Cell.

Figure 2.5: Solar Cell

A silicon solar cell is made of P-type and N-type crystals or diode which is sealed and has a glass window on the top to collect the solar light. P-type surface, the top surface of the solar cell is made very thin so that it can easily reach the PN junction. When light energy falls on the surface of the cell then electrons gains the energy and leave their parent atoms and cross the junction. In this way one side of the junction becomes positive electrode and other side becomes negative electrode.

i.   Use cell and battery as a series and parallel source.

ii. Describe the components/parts of cell and battery

Activity 2.2 Perform series and parallel connection of cells/batteries **Components/Instruments** Connecting wires, cell/batteries, Bread Board
Step 1: Arrange the class in small groups
Step 2: Assign them the task to Perform series and parallel connection of cells
Step 3: Collect the desired components and instruments
Step 4: Record the observations

1.11   2.4 Working Principle of Batteries

A battery works on the oxidation and reduction reaction of an electrolyte with metals. When two dissimilar metallic substances, called electrode, are placed in a diluted electrolyte, oxidation and

reduction reaction take place in the electrodes respectively depending upon the electron affinity of the metal of the electrodes. As a result of the oxidation reaction, one electrode gets negatively charged called cathode and due to the reduction reaction, another electrode gets positively charged called anode.

If two different kinds of metals are immersed in the same electrolyte solution, one of them will gain electrons and the other will release electrons. The metal with low electron affinity will gain electrons from the negative ions of the electrolyte solution.

On the other hand, the metal with high electron affinity will release electrons and

(a) in case of charge
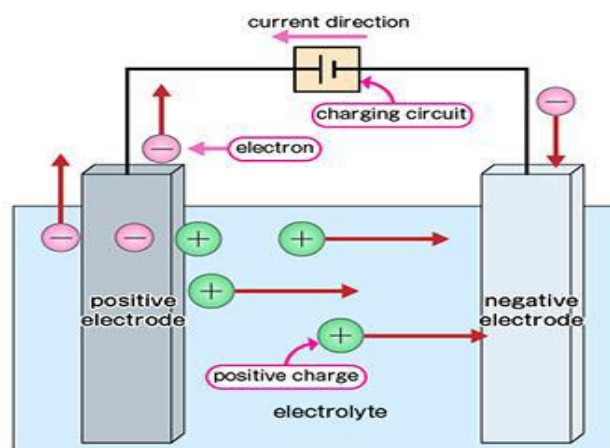
these electrons come out into the electrolyte solution and are added to the positive ions of the solution. In this way, one of these metals gains electrons and another one loses electrons. As a result, there will be a difference in electron concentration between these two metals.

This difference in electron concentration causes an electrical potential difference developed between the metals. This electrical potential difference or EMF can be utilized as a source of voltage in any electronics or electrical circuit. This is a general and basic principle of battery and this is how a battery works.

Activity 2.3
Perform charging of a battery

Step 1: Arrange the class in small groups

Step 2: Assign them the task to Perform series and parallel connection of cells

Step 3: Collect the desired components and instruments

Step 4: Record the observations

1.12   2.5 Charging Principle of Batteries

During charging of battery, external DC source is applied to the battery. The negative terminal of the DC source is connected to the negative plate or anode of the battery and positive terminal of the source is connected to the positive plate or cathode of the

battery. Now, due to external DC source, electrons will be injected in the anode. Reduction reaction takes place in the anode instead of cathode. Actually, in the case of discharge of battery, reduction reaction takes place at cathode. Due to this reduction reaction, the anode material will regain electrons and returns to its previous state when the battery was not discharged.

As the positive terminal of the DC source is connected to the cathode, the electrons of this electrode will be attracted by this positive terminal of DC source. As a result, oxidation reaction takes place at the cathode and cathode material regains its previous state (when it was not discharged). This is the overall basic of charging of battery.

1.13 2.6 Series & Parallel Combination of Cells

Series Combination of Cell

In a series connection, batteries of like voltage and amp-hour are connected to increase the output voltage. The positive terminal of the first battery is connected to the negative terminal of the second battery and so on, until the desired voltage is reached.
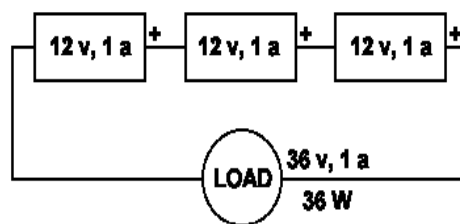
Figure 2.5: Cell in Series

Cells in parallel

In a parallel connection, batteries of like voltages and capacities are connected to increase the capacity of the overall assembly. The positive terminals of all batteries are connected together, or to a common conductor, and all negative terminals are connected in the same manner.
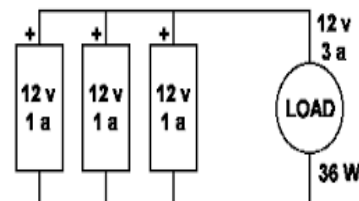
Figure 2.6: Cell in Parallel

Activity 2.4
Carryout maintenance of a battery
Required Tool & Equipment: Battery, Hydrometer, Distilled water, Toolbox

Step 1: Arrange the class in small groups

Step 2: Assign them the task to perform maintenance of a battery

Step 3: Collect the desired components and instruments

Step 4: Record the observations

1.14   2.7   Procedure for Maintaining Battery

Maintenance increases the life of battery. Follow the following procedures for proper maintenance of a battery.

   i.   Maintain electrolyte level of a battery

   ii.   Regularly clean the terminals of a battery

   iii. Battery should be charged slowly

   iv.   Allow the battery to cool down once it is fully charged

1.15   2.8 Importance of Electrolyte in Battery

The electrolyte is a chemical that allows an electrical charge to pass between the two terminals. The electrolyte puts the chemicals required for the reaction in contact with the anode and cathode, therefore converting stored energy into usable electrical energy.

1.16   2.9 Testing Procedure of Batteries

Visual Test

   i. Check the container, cover and terminals. If physical damage is present, replace the battery.

   ii.   Check the indicator (If the battery has the indicator). Always look right down when viewing the indicator and lightly tap the indicator on the battery to dislodge any air bubbles

Voltage Test

   i. If voltage is below 12.4V, recharge the battery immediately

Load Test

   i. Connect the battery tester to battery terminals.

   ii. Measure the temperature of the battery around.

iii. Apply the load for 15 seconds and read the voltage.

iv. If the voltages drop significantly, recharge the battery and test again.

v. If the battery fails the load test twice, replace it.

Gravity Test

The most accurate and direct way to test the state of charge of a battery cell is to determine the specific gravity of the battery electrolyte. The higher the specific gravity of the electrolyte the higher the state of charge.

1.17 2.10 Tools and Equipment Required for Testing of Batteries

The most accurate and direct way to test the state of charge of a battery cell is to determine the specific gravity of the battery electrolyte. The higher the specific gravity of the electrolyte the higher the state of charge. Hydrometer is used to perform gravity test.

Hydrometer

Hydrometer is an instrument used to perform gravity test. Hydrometers come in many sizes and shapes.

A hydrometer with a float is recommended, contained in a glass vessel with a rubber bulb to draw the acid into the tube. Stay away from floating-colored balls as the extra inaccuracy results in very subjective testing. The hydrometer should give you a numeric reading directly from the instrument. A good hydrometer is accurate to +/- 0.005 points so1.265 could read from 1.260-1.270. The instrument accuracy should be known.

Test

- It is recommended to disconnect the battery especially if on a high rate of charge/discharge.
- Remove vent cap. Carefully insert the hydrometer into the cell, not pushing down on the top of the plates.
- Carefully draw liquid into the hydrometer and avoid "bumping" the hydrometer. Be careful the float is not flooded (too much liquid) or sticking to the sides of the glass tube.
- Obtain a reading by looking directly at the float.
- Repeat steps 3-5 to reconfirm reading.
- Record the cell number and result.

Testing a Sealed Battery

To test a sealed battery or to troubleshoot a charging or electrical system, you will need a digital voltmeter with 0.5 percent (or better) accuracy. A digital voltmeter can be purchased at an electronics store. Analog (needle type) voltmeters are not accurate enough to measure the mili volt differences of a battery's state-of-charge or measure the output of the charging system. A battery load tester is optional.

Activity 2.5   Perform testing/maintenance of battery   **Components/Instruments**   cell/batteries, Hydrometer, Toolbox
Step 1: Arrange the class in small groups   Step 2: Assign them the task to Performtesting/maintenance of battery   Step 3: Collect the desired components and instruments   Step 4: Record the observations

Key points

- A cell is a device which produces DC voltage by the chemical reaction.

- A battery is formed by the combination of multiple cells

- A cell is a device which produces dc voltage by the chemical reaction

- Batteries are essential components of most electrical devices

- There are two types of cells i.e. Primary Cell and Secondary Cell

- A battery works on the oxidation and reduction reaction of an electrolyte

- During charging of battery, external DC source is applied to the battery

- When batteries are connected in series, output voltage is increased

- When batteries are connected in parallel, output current is increased

- Routine maintenance increases the life of a battery

- Hydrometer is used to check Specific gravity of a battery

Multiple Choice Questions

Select the most appropriate option (✓)

.1 DC sources are basically of _____ types.

   a. Two

   b. Four

   c. Six

   d. Eight

.2 Mercury cell is _____ cell.

   a. Primary

   b. Secondary

   c. Linear

   d. Constant

3. Which cell cannot be recharged?

   a. Primary

   b. Secondary

   c. Variable

   d. Constant

4. The combination of cells is called _____.

   a. Battery

   b. Adapter

   c. Voltage level

   d. Current level

5. Cells are connected in series to

   a. Increase power.

   b. Increase current.

   c. Increase voltage.

   d. Increase resistance.

6. In series connection, cell voltage will be

a. Increased.

b. Decreased.

c. Constant.

d. all of above

7. Basic types of Cell are

a. 2

b. 3

c. 4

d. 5

Give short answer of the following questions

1. Enlist types of DC sources.
2. Define series combination of cells.
3. Define parallel combination of cells.
4. Compare primary and secondary cells.
5. Define Battery
6. Enlist types of cell and battery
7. Enlist applications of cell and battery
8. Enlist steps to maintain Battery
9. Define solar cell.
10. Write down charging and discharging equation of Lead Acid battery

Answer the following question in detail

1. Describe the structure, working and uses of mercury cell

2. Describe the structure of nickel cadmium cell

3. Explain working of Nickel Cadmium Cell with the help of charging and discharging equation and its uses.

4. Describe the charging principle of a battery

5. Describe the procedure for maintaining a battery

Practical Activities

1. Perform series and parallel connection of cells.

2. Perform series and parallel connection of batteries.

3. Perform charging of a battery

4. Check   gravity of battery with the help of hydrometer

5. Perform testing of cell and battery by DC ammeter.

Instructions for the Teachers

1. The Teacher is required to adopt Health and Safety measures in the lab

2. The Teacher is required to use ICT resources for better delivery of the content

3. The Teacher is required to ensure proper functioning of lab equipment

4. The Teacher is required to ensure assessment during course of the activity and give input to the Trainee

Chapter 03   Magnetism & Electromagnetism
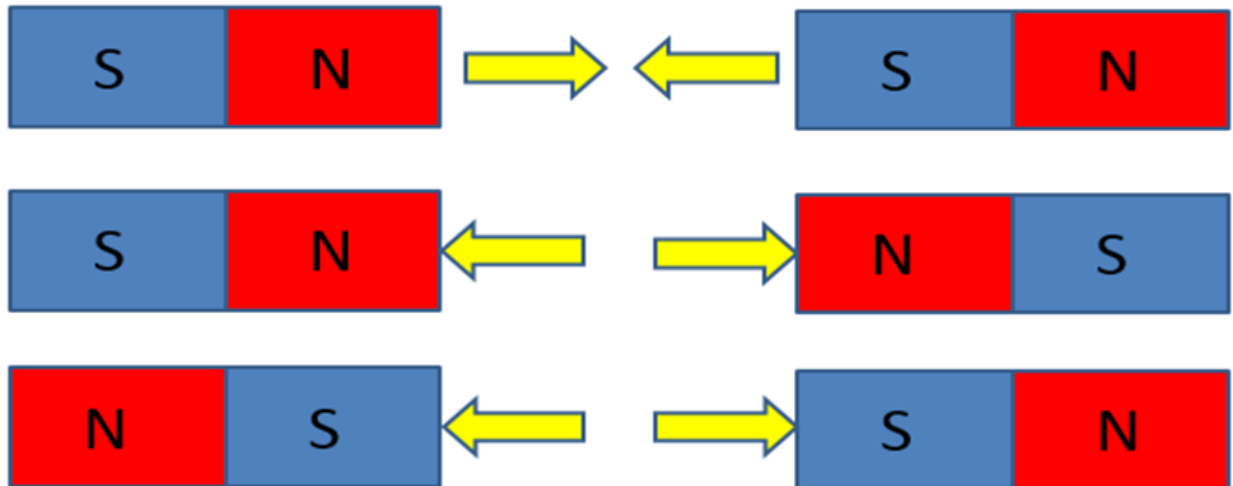
Students Learning Outcomes

After completion of this chapter you will be able to:

- ➢ define a magnet
- ➢ describe magnetic and nonmagnetic materials
- ➢ explain the properties of magnetic materials
- ➢ state the types of magnetism
- ➢ define electromagnetism
- ➢ describe the shapes of magnetic field by using magnet of different shapes and nature
- ➢ explain how electromagnetism is produced.
- ➢ explain faraday's laws of electromagnetic induction

1.18 3.1 Magnet and its Types

Magnet

Magnet is a piece of metal which can attract iron or materials made with iron. When a bar magnet is freely suspended it points in the direction of North and South. The side which points towards the north is called as North Pole and the side which points towards south is called as South Pole. Two similar poles repel each other and opposite poles attract each other.

Types of Magnet

There are two types of magnets.

     i.   Permanent Magnet

    ii.   Temporary Magnet

i. Permanent Magnet

Natural magnets are found in nature in the form of stones. For example, magnetite Fe_3O_4 has the magnetic properties. Our earth is also supposed to a very large magnet.

Figure 3.1: Types of magnets

ii. Temporary Magnet

These are made from hard magnetic materials such as cobalt steel magnetized by induction in the manufacturing process. A very strong field is needed for induction in these materials. When the magnetizing field is removed residual induction makes the material a permanent magnet. A common PM material is alnico, a commercial alloy of aluminum, nickel and iron with cobalt.

Commercial permanent magnets will last indefinitely if they are not subjected to high temperatures, to physical shock, or a strong demagnetizing field. A permanent magnet does not become exhausted with use, as its magnetic properties are determined by the structure of the internal atoms and molecules.

Magnetism

It is the property of a magnet to attract iron or things made with iron towards itself.

1.19 3.2 Electromagnets, Magnetic Field, Magnetic Lines of Force

Electromagnets

Electromagnets are temporary magnets. If a current is passed in a wire conductor, then a magnetic field is produced around the wire.

Consider a wire wrapped in the form of coil as shown in figure below, the current and its magnetic field become concentrated in a smaller space, resulting in a stronger field.
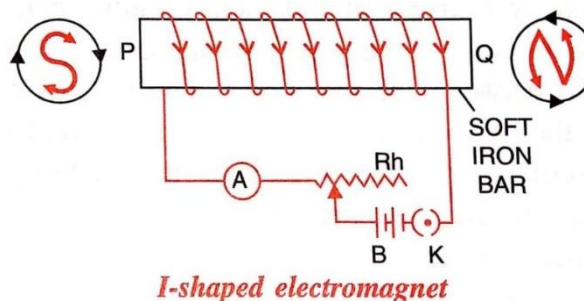
Fig.3.2: Arrangement for Electromagnet

The direction of the north and South Pole of an electromagnet is determined by right hand rule. Electromagnets are widely used in different application. Common applications of electromagnets are electric bell, relays, induction coils, transformers and measuring instruments.

Magnetic Field

The region or space around a magnet where the effects of magnetism on a test magnet or a compass needle can be detected is called a magnetic field.

Magnetic Lines of Force

The magnetic lines of forces are a path in a magnetic field along which a test magnet moves in a magnetic field

Flux (ϕ)
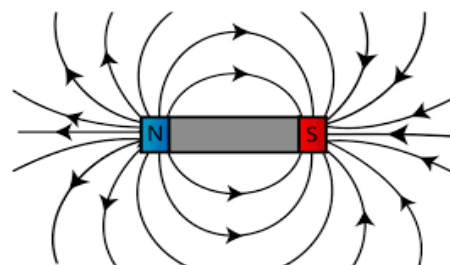
Fig.3.3: Magnetic lines of forces

Flux means magnetic flux. The total number of magnetic lines of force passing through a particular point is called as flux. It is denoted by φ.

Its unit is Weber. It is equal to 10^8 magnetic lines of force.

Properties of Magnetic Lines of Force

i.   The magnetic lines of force start from North Pole and end at South Pole.

ii.   The no. of lines of force at a point represents the strength of the field. Larger no. of lines shows a strong and smaller lines corresponds a weak field.

iii. No two magnetic lines of force intersect each other.

iv.   The magnetic lines of force are invisible.

v.   If magnetic lines of force try to contract each other, then they start from north pole and ends at south pole i.e. they show different poles.

vi.   Magnetic lines of force try to expand; they represent similar poles.

Activity 3.1 Identify magnetic and non-magnetic material with the help of magnet
Required Tool & Equipment: Magnet, Iron, Copper, Wood, Plastic, Glass
Step 1: Arrange the class in small groups Step 2: Assign them the task to identify magnetic and non-magnetic material with the help of magnet Step 3: Collect the desired components and instruments Step 4: Record the observations

1.20   3.3 Types and Properties of Magnetic Materials

Types of Magnetic Materials

Materials can be classified as magnetic and non-magnetic. Iron, Nickel and Cobalt are magnetic materials and are easily magnetized. Non-magnetic materials cannot be magnetized. Examples are air, glass, wood, paper, plastic and rubber etc.

Magnetic materials can be further divided into three types:

Fig.3.4: Types of magnetic materials

    i.   Diamagnetic material

   ii.   Paramagnetic materials

  iii.   Ferromagnetic materials

Diamagnetic Materials

These include bismuth, antimony, copper, zinc, and mercury, gold and silver. Their permeability is less than 1. They become weekly magnetized in the direction opposite to the magnetizing field.

The basics of all the magnetic effects are the magnetic field associated with electric charges in motion. The atoms of each substance consist of electrons which revolve around the nucleus and
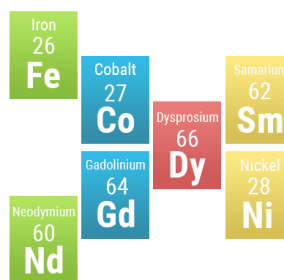
at the same time rotating and spinning about its own axis. These rotations and spin both give rise to magnetic field.

Since the atom consists of many electrons, so every electron will have its own magnetic field. The directions of the magnetic fields produced by these electrons are random. These fields may cancel each other or these fields can build up each other.

If the magnetic fields produced by the atoms cancel each other effect it is called as Diamagnetic Material.

Paramagnetic Materials

These materials include aluminum, platinum, manganese and chromium. Their permeability is slightly more than 1. In paramagnetic materials the magnetic fields produced due to orbital motion of electrons and spin of electrons support each other. They become weekly magnetized in the same direction as the magnetizing field.

Ferromagnetic Materials

Ferromagnetic materials include iron, steel, nickel, cobalt, and commercial alloys such as alnico and Perm alloy. These materials become strongly magnetized in the same direction as the magnetizing field with high values of permeability from 50 to 5000. In ferromagnetic materials the orbital motion and spin motion produces magnetic field and this field is greatly strengthened by other atoms.

Properties of Magnetic Materials

Different properties of magnetic materials are as follows:

i. Two similar poles of a magnet repel each other and different poles attract each other.

ii. When a magnet is freely suspended in air it points in the direction of north and south. The side which is pointing in the direction of north is called as North Pole and the side which point in the direction of South is called as South Pole.

iii. When a magnet is broken in to pieces, at the center the separate pieces become independently.

Activity 3.2
Identify the poles and magnetic field of different types of Magnets
Required Tool & Equipment: Magnets (Bar, U-shaped, Circular), Iron, Magnetic Compass needle
Step 1: Arrange the class in small groups Step 2: Assign them the task to identify the poles and magnetic field of different types of Magnets Step 3: Collect the desired components and instruments Step 4: Record the observations

1.21

1.22 3.4 Magnetism, Electromagnetism, Electromagnetic Induction

Magnetic Induction

The electrical effect of one body on another without any physical contact between them is called **Induction**. For example, a permanent magnet can induce an un-magnetized iron bar to become a magnet without the two touching.

It is due to the fact that the magnetic lines of force gathered by the permanent magnet make the internal molecular magnets in the iron bar line up in the same direction, compared with the random directions in the unmagnified iron. The magnetized iron bar then has the magnetic poles at the ends as a result of the magnetic induction.

Since opposite poles attract so the iron bar will be attracted towards the magnet. A magnet attracts any magnetic material towards itself due to Induction.

Electromagnetism

When a current pass through a conductor, a magnetic field is established around the conductor. This magnetic field is surrounded along its full length. It can be verified by a simple experiment as shown below.

Consider a current carrying conductor wire and around this
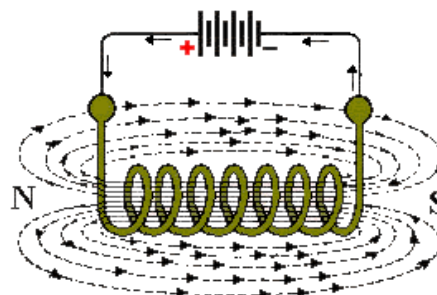
Fig.3.5: Arrangement for electromagnetism

wire, iron fillings are aligned in concentric rings as shown in the above figure. Since the magnetic field is invisible,

however its effects can be seen easily. This effect of producing magnetic field by the current passing through the conductor is called as Electromagnetism.

Activity 3.3
Check the magnetic field around a current carrying conductor
Required Tool & Equipment: Conductor, Voltage source, Compass needle/Iron fillings
Step 1: Arrange the class in small groups
Step 2: Assign them the task to check the magnetic field around a current carrying conductor
Step 3: Collect the desired components and instruments
Step 4: Record the observations

1.23

1.24   3.5 Electromagnetic Induction

Electromagnetic induction is a technique in which current or EMF is induced in a conductor when it is moved in a magnetic field.

Suppose a conductor is moved in a magnetic field as shown in figure below. If the conductor is at rest, there is no deflection in the galvanometer. Now if we move the loop conductor in one direction say from right to left at a constant speed in the magnetic field, the

Fig.3.6: Electromagnetic Induction

galvanometer indicates a deflection. Now if we reverse the direction of the movement of the conductor, then the direction of movement of the needle coil is opposite to the first case. This phenomenon of production of current or **EMF** is known as Electromagnetic Induction.
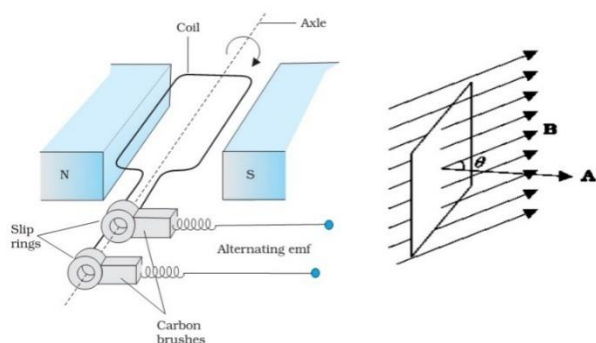
Activity 3.4
Verify Faraday's laws of electromagnetic induction
Required Tool & Equipment:
Magnet, Current carrying conductor, Galvanometer, Multimeter
Step 1: Arrange the class in small groups
Step 2: Assign them the task to verify Faraday's law of electromagnetic induction
Step 3: Collect the desired components and instruments
Step 4: Record the observations

1.25   3.6   Magnetic Effect of Electric Current

When current passes through a conductor a magnetic field is established around it. Consider a copper wire carrying a current I and is passed through a card board as shown in the figure below. Now we place a compass needle near the current carrying conductor. We move in the deflection of the needle and found circular paths along the current carrying conductor.
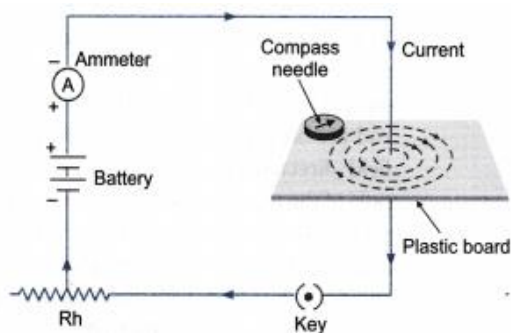
Fig.3.7: Magnetic Field around a Current Carrying Conductor

This shows that a magnetic field exists around the current carrying conductor. This field retains as long as the current continues to flow in the wire. The direction of the magnetic field can be determined by the right hand rule. This rule states that if the right hand thumb points in the direction of current and figures are allowed to curl the wire, the finger ends or tips will point in the direction of the lines of force.

3.7   Shapes of Magnetic Fields

The magnetic field produced by different shapes of magnets are as below:

1.   **Bar Magnet**
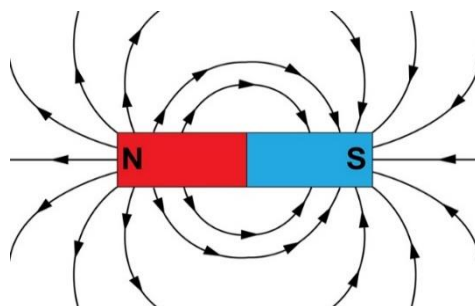
2. **U-Shaped Magnet**

Fig.3.8: Bar Magnet
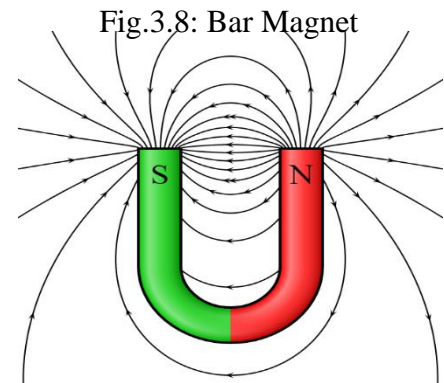
Fig.3.9: U- Shape Magnet

3. **Circular Magnet**
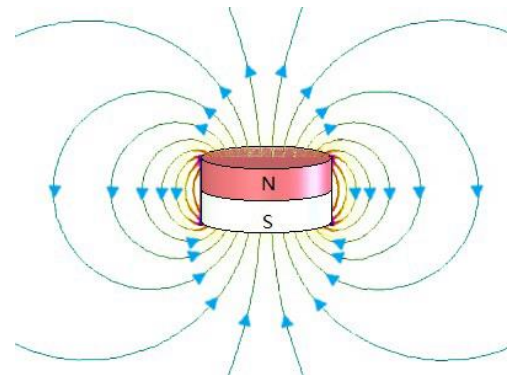
Fig.3.10: Circular Magnet

1.26 3.8 Faraday's Law of Electro-Magnetic Induction

Faraday's law states that a current will be induced in a conductor which is exposed to a changing magnetic field. The changing magnetic field induces voltage in the conductor. This value is electromotive force. The magnitude of the emf can also be found by using Faraday's Laws. There are two laws:

Fig.3.11: Faraday's Laws of ElectromagneticInduction

Faraday's First Law

When a charging magnetic field is linked to a conductor then an EMF is induced in the conductor. This EMF lasts only for the duration, the changing magnetic field continues.

Faraday's Second Law

The magnitude of the induced EMF is directly proportional to the rate of change of the flux.

$$EMF \propto -\frac{\Delta \emptyset}{\Delta t}$$

$$EMF = -N\frac{\Delta \emptyset}{\Delta t}$$

$$EMF = -N\frac{d\emptyset}{dt}$$

Where, N is the No. of turns of coil in case of electromagnet. Negative sign shows that direction of the induced EMF is opposite to the applied voltage which produces the magnetic field.

Key points

- Magnet is a piece of metal which can attract iron or materials made with iron.

- There are two types of magnets i.e. Permanent Magnet& Temporary Magnet

- Electromagnets are temporary magnets. If a current is passed in a wire conductor, then a magnetic field is produced around the wire.

- The region or space around a magnet where the effects of magnetism on a test magnet or a compass needle can be detected is called a magnetic field.

- Flux means magnetic flux. The total number of magnetic lines of force passing through a particular point is called as flux. It is denoted by φ.

- Materials can be classified as magnetic and non-magnetic. Iron, Nickel and Cobalt are magnetic materials and are easily magnetized. Non-magnetic materials cannot be magnetized. Examples are air, glass, wood, paper, plastic and rubber etc.

- The electrical effect of one body on another without any physical contact between them is called Induction.

- Electromagnetic induction is a technique in which current or EMF is induced in a conductor when it is moved in a magnetic field.

Multiple Choice Questions

Select the most appropriate option (✓)

1. Magnetic field is always mapped out in the form of magnetic _____
   a. Strength
   b. Lines of force
   c. Area
   d. Width

2. Magnetic lines of force always travel from _____.
   a. North to North
   b. South to North
   c. South to North
   d. North to South

3. Magnetic flux is denoted by _____.
   a. φ
   b. θ
   c. $\in$
   d. ω

4. Increased number of lines means _____ magnetic field.
   a. Wider
   b. Stronger
   c. Greater
   d. Bigger

5. The magnet made up of soft iron is called _____ magnet.
   a. Soft
   b. Temporary
   c. Permanent
   d. Electromagnet

6. Like poles of magnet _____ each other.
   a. Attract
   b. Repel
   c. May attract

    d.   May repel

7. Opposite poles of magnet _____ each other.

    a.   Attract

    b.   Repel

    c.   May attract

    d.   May repel

8. The magnetic effect of a body on another without physical contact is called magnetic _____.

    a.   Reluctance

    b.   Permeability

    c.   Induction

    d.   Conduction

Writer Short answer of the following

1. Define magnet.
2. Define magnetic lines of force.
3. Define flux.
4. List the types of magnetic material.
5. Enlist types of magnets.
6. Write three properties of magnetic materials.
7. What is electromagnetic induction?
8. Define an electromagnet.
9. State Faraday's laws of electromagnetic induction.
10. Define magnetic field.

Answer the following question in detail

1. Describe magnetic materials in detail.

2. What is electromagnetism? Discuss in detail.

3. Describe the magnetic field produced around a current carrying conductor.

4. Explain laws of electromagnetic induction.

5. Describe the properties of magnetic materials.

Practical Activities

1. Identify Magnetic and nonmagnetic material with the help of magnet

2. Identify the poles and magnetic field of different types of magnets.

3. Demonstrate the   magnetic effect of electric current.

4. Apply Faraday's laws of electromagnetic induction.

Instructions for the Teachers

2. Adopt Health and Safety measures in the lab

3. Use ICT resources for better delivery of the content

4. Ensure proper functioning of lab equipment

5. Ensure assessment during course of the activity and give input to the Trainee

Chapter 04   Electrical Power and Energy

Students Learning Outcomes
After completion of this chapter you will be able to:

- ➢ explain the construction of series circuit for calculation of current, voltage and resistance.
- ➢ explain the construction of parallel circuit for calculation of current, voltage and resistance
- ➢ explain the construction of combinational circuit for calculation of current, voltage and resistance
- ➢ define electrical power
- ➢ understand the unit and symbol of electrical power
- ➢ explain the circuit for electrical power
- ➢ explain electrical power.
- ➢ define various types of energies.
- ➢ define electrical energy.
- ➢ understand the unit and symbol of electrical energy.
- ➢ understand the formula for calculation of electrical energy.
- ➢ explain the tariff.
- ➢ calculate the Energy consumed and determine its cost.

5.2   4.1 Series & Parallel Circuits

4.1.1 Series Combination of Resistances

When two or more resistances are connected end to end across a voltage source such that there is only one path for the current to flow through the circuit then this combination is called a Series circuit. Three resistances R1, R2, and R3 are connected end to end across a power supply V as shown in Fig 4.1below. Same amount of the current I is flowing through the circuit.
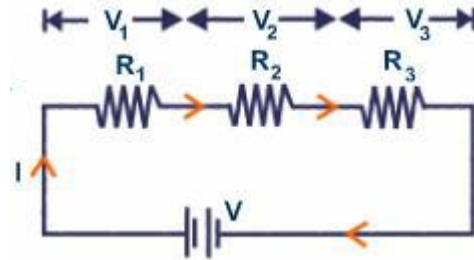
Figure 4.1: The Series Circuit

Calculation of Current, Voltage & Resistance for Series Combination

   i.   In series circuit current flowing through each resistor is the same as total current

$I_1 = I_2 = I_3 = I$

  ii.   Voltage drop across each resistor is different and is according to the value of resistor. The sum of voltage drops across all resistor is equal to the supply voltage.

V $= V_1 + V_2 + V_3$

      $= IR_1 + IR_3 + IR_3$

 iii.   The total or equivalent resistance of the circuit is equal to the sum of all individual resistance connected in series.

  R_{equ} $= R_1 + R_2 + R_3$

It can be very easily verified. According to Ohm's Law:

$$V = I x R$$

For above circuit: $V = V_1 + V_2 + V_3$

IR_{equ} $= IR_t = IR_1 + IR_2 + IR_3$

IR_{equ} $= I (R_1 + R_2 + R_3)$

R_{equ} $= R_1 + R_2 + R_3$

So value of the total resistance is increased if there is an increase in the individual resistances.

  iv.   In series circuit if any of the resistor becomes faulty whole circuit will be turned off.

Example 4.1:

Three resistances of 10Ω, 20Ω, and 30Ω are connected in series across a 30 V power supply as shown in Fig.4.2
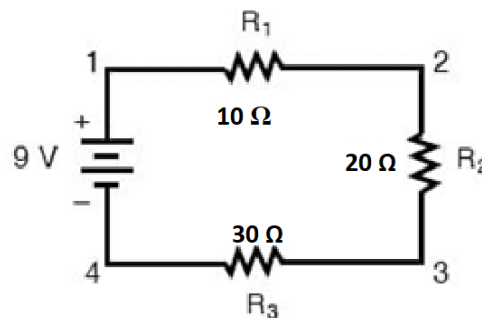
Figure 4.2: Series Circuit

Calculate:

    a.   Equivalent Resistance

    b.   Current in the Circuit

    c.   Voltage drop across each resistance

Solution:

(i) We know that in series circuit

$R_t = R1 + R2 + R3$

Putting the values

$R_t = 10+20+30 = 60\ \Omega$

(ii) Current in series circuit is same in all resistors as well as total current. So

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

$$I = \frac{30}{60} = 0.5 \text{Amp}$$

    (i) To find voltage drop across each resistor use Ohm's law

$V1 = IxR1$

$V2 = IxR2$

$V3 = IxR3$

$V1 = (0.5)\ (10) = 5$ Volts

$V2 = (0.5)\ (20) = 10$ Volts

$V3 = (0.5)\ (30) = 15$ Volts

Total Voltage = 5+10+15= 30Volts

Activity 4.1
Construct combinational circuit and measure current using given voltage and resistance values
Required Tool & Equipment: Voltage source, Resistor, Connecting wires, Breadboard, Multimeter
Step 1: Arrange the class in small groups
Step 2: Assign them the task toconstruct combinational circuit and measure current using given voltage and resistance values
Step 3: Collect the required components and equipment
Step 4: Measure the current
Step 5: Record the observations

Voltage Division Rule

Voltage division rule is used for the measurement of voltage drops for a series combination of resistances. Consider a series circuit consisting of two series resistances R_1 and R_2 as shown in Fig. 4.3

According to voltage Division Rule

$$V_{R1} = \frac{R1}{R1+R2} \times V$$

$$V_{R2} = \frac{R2}{R1+R2} \times V$$

Figure 4.3: Voltage Division rule

So according to the voltage division rule, the voltage drops across any resistance in a series is equal to the ratio of that resistance to the total resistance, multiplied by the applied voltage.

Generalizing:

$$V_{R} = \frac{R}{Rt} \times V$$

Example 4.2:

Two resistances of 20Ω and 30Ω are connected in series across a 24V source in Fig4.4 below. Using voltage division rule find the voltage drop across each resistance.

Figure 4.4

Solution:

$R_1 = 20\Omega$ $\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ $R_2 = 30\ \Omega$ $\qquad$ $V = \qquad 24V$

$$V_{R1} = \frac{R1}{R1+R2} \times V \qquad = \frac{20}{20+30} \times 24 \quad =9.6 \text{ Volts}$$

$$V_{R2} = \frac{R2}{R1+R2} \times V \qquad = \frac{30}{20+30} \times 24 \quad =14.4 \text{ Volts}$$

4.1.2 Parallel Combination of Resistances

In parallel combination of resistances, two or more resistances are connected in such a way their one ends at one side are joined together, other ends are joined together and across these ends a powersupply is connected. It is shown in Fig4.5:
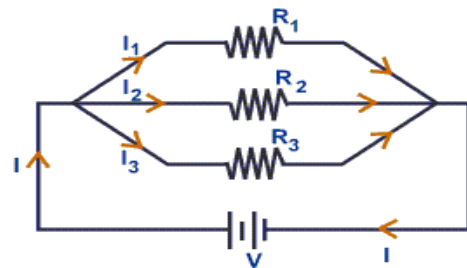
Figure 4.5

Calculation of Current, Voltage & Resistance for Parallel Combination

i. The applied voltage across all resistances connected in parallel is the same.

$V_T = V_1 = V_2 = V_3$

Where V_1, V_2, V_3 are voltage drop across respective resistor

ii. There are two or more than two paths to flow the current compared with series combination, current in each resistor is called branch current. The sum of branch currents is equal to the total current of the circuit.

$I_T = I_1 + I_2 + I_3$ $\qquad$ Where I_1, I_2, I_3 are branch currents respectively

iii. The equivalent resistance of the circuit is less than the resistance of any individual component/resistance in the circuit.

Refer to the circuit shown in Fig.4.5 above.

$I = I_1 + I_2 + I_3$

By Ohm's law $I = \dfrac{V}{R}$

$\dfrac{V}{R_{equ}} = \dfrac{V}{R1} + \dfrac{V}{R2} + \dfrac{V}{R3}$

$\dfrac{1}{R_{equ}} = \dfrac{1}{R1} + \dfrac{1}{R2} + \dfrac{1}{R3}$

This expression shows that the reciprocal of the equivalent resistance of the circuit is equal to the sum of the reciprocals of the individual resistances connected in the parallel combination.

If two resistances are connected in parallel, the total resistance can be found as:

$$R_{equ} = \dfrac{R_1 R_2}{R_1 + R_2}$$

If more than two resistances are connected in parallel with same value, the total resistance can be found as:

$$R_{equ} = \dfrac{Value\ of\ one\ Resistance}{Number\ of\ Resistances}$$

Example 4.3

A parallel circuit of two resistances R_1 and R_2 is shown in Fig 4.6 below:
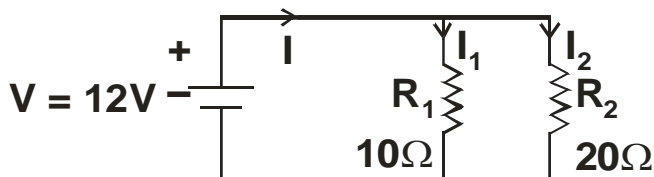
Fig.4.6

Find:

    a. Total Resistance

    b. Current in Each Resistance

    c. Total Current

Solution:

    a.   R1 = 10Ω,   R2 = 20Ω,   V= 12Volts

$R_{equ} = \dfrac{R_1 R_2}{R_1 + R_2}$

$= \dfrac{10 \times 20}{10 + 20}$

R_{equ} = 6.66 Ω

    b. I_1 = Current in $I_1 = \dfrac{V}{R1}$

$$= \frac{12}{10}$$

$$= 1.2 \text{ Amp}$$

I_2= Current in $I_2 \quad = \frac{V}{R2}$

$$= \frac{12}{20}$$

$$= 0.6 \text{ Amp}$$

c.   Total Current $= I = I_1 + I_2 = 1.2 + 0.6 = 1.8 \text{ Amp}$

Current Division Rule

Current division rule is applicable to find the current, for the resistances connected in parallel. Consider two resistors R1 and R2 connected in parallel to R_1 and R_2.

According to Current division rule

$$I_1 = \frac{R2}{R1+R2} \times I_T$$

$$I_2 = \frac{R1}{R1+R2} \times I_T$$

So current division rule states that

"Current in a resistance connected in parallel is equal to the other resistance divided by the total resistance multiplied by the total current."

Current Divider

Figure 4.7: Current Divider Circuit

Example 4.4

Two resistances 5Ω and 10Ω are connected in parallel across a 24 Volt DC supply as shown in Fig4.8 below. Using current division rule find the amount of current flowing through each resistance.
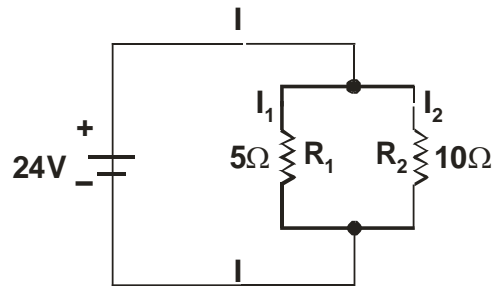
Fig 4.8

Solution:

        $V \quad = 24 \text{ volts}$

$R_1 \quad = 5\Omega$

$R_2 = 10\Omega$

Using Current Division Rule

$I_T = ?$

$\dfrac{I}{Requ} = \dfrac{1}{R1} + \dfrac{1}{R2}$

$\dfrac{1}{Requ} = \dfrac{1}{5} + \dfrac{1}{10} = \dfrac{2+1}{10} = \dfrac{3}{10}$

$R_{equ} = \dfrac{10}{3}$ $\qquad\qquad$ =3.333 Ω

$I_T = \dfrac{V}{Requ} = \dfrac{24}{3.333}$ $\qquad$ = 7.2 Amp

$I_1 = \dfrac{R2}{R1+R2} \times I_T$

$\quad = \dfrac{10}{5+10} \times 7.2$ $\qquad$ = 4.8 Amp.

$I_2 = \dfrac{R1}{R1+R2} \times I_T$

$\quad = \dfrac{5}{5+10} \times 7.2$ $\qquad$ = 2.4 Amp.

4.1.3 Series Parallel Combination of Resistances

In series parallel combination of the resistors both serial and parallel connections of resistances are connected together to form a network. A combination of series and parallel resistances is shown in Fig 4.9 below. Five resistances R_1, R_2, R_3, R_4, & R_5 are connected to a power supply V in series parallel combination.
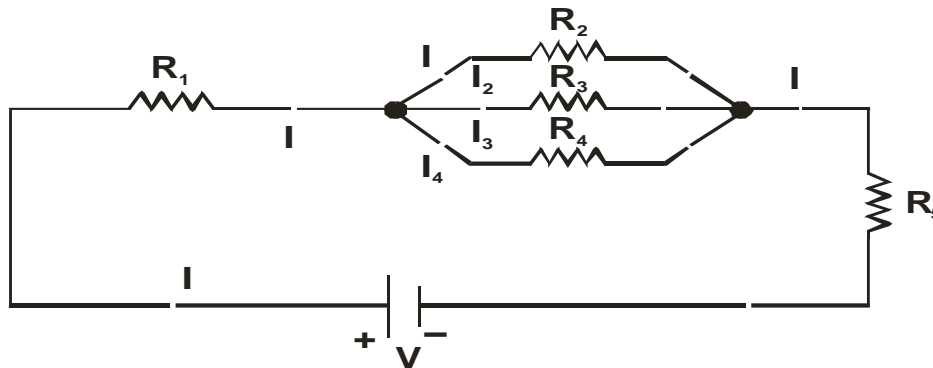
Fig.4.9: Circuit for Series Parallel Combination

Compare Series and Parallel Circuit of Resistors

Series Combination	Parallel Combination
Current is same through all the elements of the series circuit i.e.	Branch Current flows different in all parallel resistors according to the value of each resistor
$I = I_1 = I_2 = I_3$	$I = I_1 + I_2 + I_3 + ...$
The sum of the voltage drops is equal to the applied voltage.	The voltage is same across all the voltage connected in parallel
$V = V_1 + V_2 + V_3 + ...$	$V = V_1 = V_2 = V_3$
The total resistance is equal to the sum of all the resistance connected in series. So	The reciprocal of total resistance is equal to the sum of the reciprocals of all the resistances connected in parallel. $\frac{1}{R_{equ}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$
$R_{equ} = R_1 + R_2 + R_3 + ...$	
The Total resistance of the circuit is greater than any individual resistance of the circuit.	The total resistance of the circuit is less than any of the resistance connected in parallel.

Problems on Series Parallel Combination of Resistors

If we want to connect various resistors together in "BOTH" parallel and series combinations within the same circuit to produce more complex resistive networks, how do we calculate the combined or total circuit resistance, currents and voltages for these resistive combinations.

Resistor circuits that combine series and parallel resistors networks together are generally known as **Resistor Combination** or mixed resistor circuits. The method of calculating the circuit's equivalent resistance is the same

Figure 4.10: Series parallel combination

as that for any individual series or parallel circuit and hopefully we now know that resistors in

series carry exactly the same current and that resistors in parallel have exactly the same voltage across them.

For example, in the following circuit calculate the total current (I_T) taken from the 12v supply.

Two resistors, R_2 and R_3 are actually both connected together in a "SERIES". The resultant resistance for this combination would therefore be:

$R_2 + R_3 = 8\Omega + 4\Omega = 12\Omega$

So we can replace both resistor R_2 and R_3 above with a single resistor of resistance value 12Ω

So our circuit now has a single resistor R_A in "PARALLEL" with the resistor R_4.
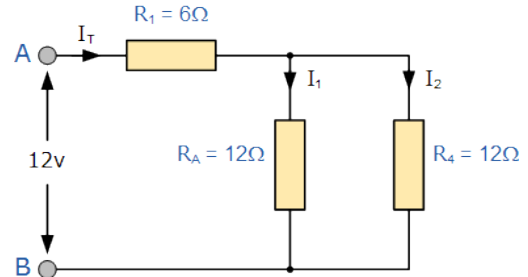
$$R(parallel) = \frac{RA \times R4}{RA + R4}$$

$$= \frac{12 \times 12}{12 + 12}$$

$$= 6 \text{ ohm}$$

The resultant resistive circuit now looks something like this:

We can see that the two remaining resistances, R_1 and $R_{(comb)}$ are connected together in a "SERIES" combination and again they can be added together (resistors in series) so that the total circuit resistance between points A and B is therefore given as in Fig 4.13:

$R_{(ab)} = R_{comb} + R_1 = 6\Omega + 6\Omega = 12\Omega$

Total Current $I = \frac{V}{R} = \frac{12}{12} = 1 \, Amp$
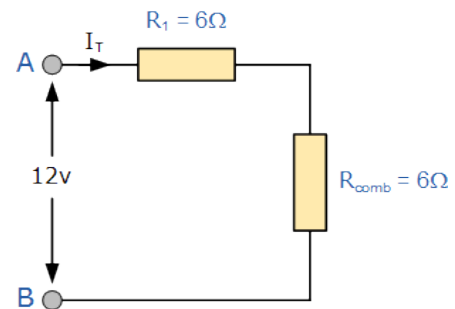
Figure 4.11: Resultant Circuit

Example 4.5

Find the equivalent resistance in the following circuits below:
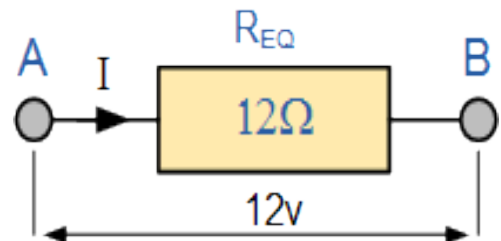
Figure 4.13

Part: a

(a)
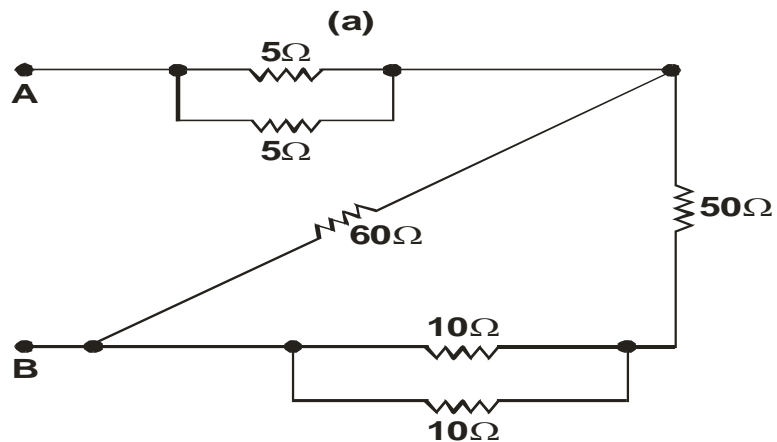
Fig.4.14 (a)

Solution:

The equivalent resistance of 5Ω and 5Ω parallel combination is evaluated and the equivalent resistance of parallel combination of 10Ω and 10Ω is evaluated.

$$R_{equ1} = \frac{5 \times 5}{5+5} = \frac{25}{10} = 2.5$$

$$R_{equ2} = \frac{10 \times 10}{10+10} = \frac{100}{20} = 5$$

⇓
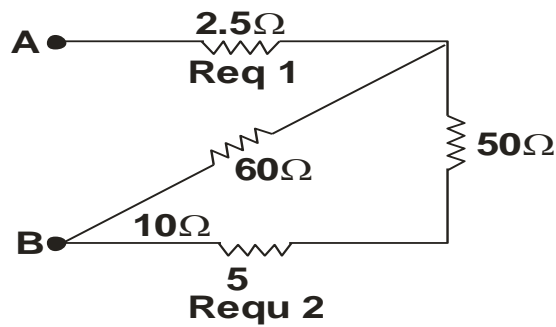
Now 50 Ω and 5 Ω are in series so their equivalent is 55Ω,

$$R_{equ3} = 5 + 50 = 55\Omega$$
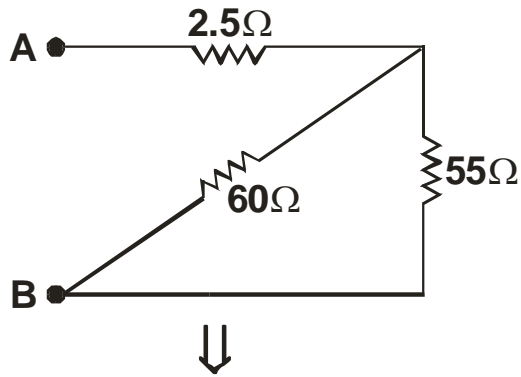
Now 60 Ω and 55 Ω are in Parallel so their equivalent is,
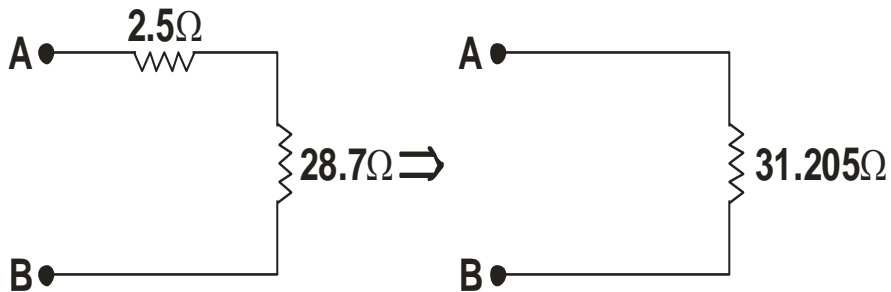
So the equivalent resistance is 31.205Ω

Part: b
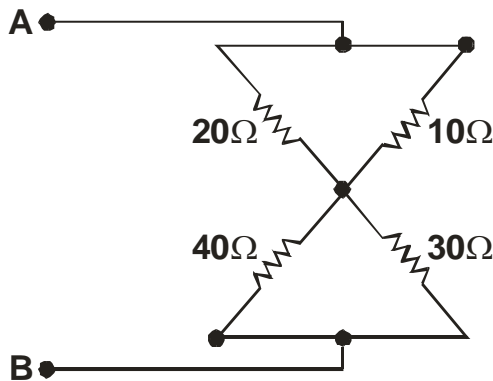
Fig.4.14 (b)

Solution:

In the figure 10Ω and 20Ω are in Parallel and 30 Ω and 40 Ω are in parallel.

$$\frac{20\times10}{20+10} = \frac{200}{30} = 6.67\Omega$$

$$\frac{30\times40}{30+40} = \frac{1200}{70} = 17.14\Omega$$
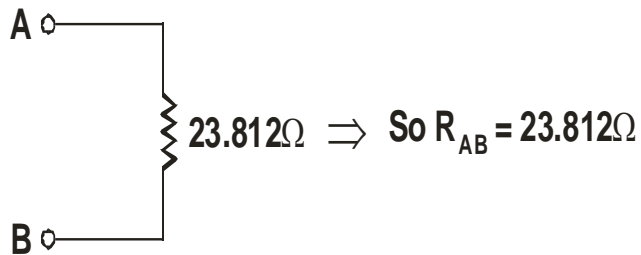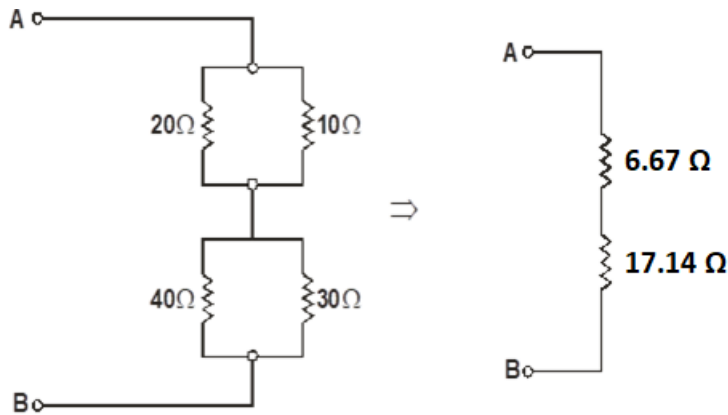
5.3   Electrical Power

Electric Power

The rate of doing work is called as Power. In other words, we can say the rate at which energy is used is called as Power. Electric Power is the rate (per unit time) at which electrical energy is transferred by an electric circuit. It is represented by P (Symbol of Electric Power).

Mathematically,

$$\text{Power} = \frac{\text{Energy}}{\text{Time}}$$

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

$$= \frac{V \times Q}{t}$$

$$= \frac{V \times I \times t}{t} \quad (\text{As } Q = I \times t)$$

$$P = V I$$

Other formulae of electric power is:

$$P = I^2 R$$

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

Summarizing;

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

Units of Electric Power

The SI unit of power is the watt. It is defined as if one Joule of work is done in one second then the power consumed is one Joule/Second.

This SI unit of power represents a small amount of power and therefore it is inconvenient to use it where a large amount of power is involved. So, for commercial purposes a bigger unit of electric power called kilowatt is used.

1 kilowatt   =   1000 watt

or   1 KW   =   1000 W

Circuit for Electric Power

A simple circuit is considered for calculating the power as shown in figure Fig 4.15:
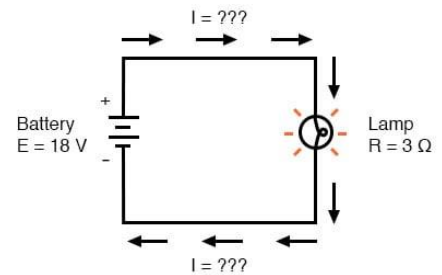
Figure 4.15

Power Calculation

Using Ohm's Law, we have:

Activity 4.2
Calculate the power dissipation for given load
Required Tool & Equipment: Voltage source, Resistor, Connecting wires, Breadboard, Multimeter
Step 1: Arrange the class in small groups
Step 2: Assign them the task tocalculate the power dissipation for given load
Step 3: Collect the required components and equipment
Step 4: Measure the current
Step 5: Record the observations

$$I = \frac{E}{R} = \frac{18 \text{ V}}{3 \text{ }\Omega} = 6 \text{ A}$$

The power is given by:

$$P = 1E = (6\ A)(18\ V) = 108\ W$$

5.4   Electrical Energy

"The Capability of doing work of a body is called as Energy."

The Electric Energy consumed by an electrical appliance is given by the product of its power and the time for which it is used i.e.

Electrical Energy = Power x Time

Or, E =   P X t

Unit of Electrical Energy

The SI unit of Electrical Energy is Joule.

If a charge Q is moved in a potential difference V volt then energy or work done (W) can be found by using the following relation.

Work Done   = Volts x Change

W = V x Q

"When a charge of one coulomb is moved in a potential difference of one volt then the amount of the work done on the charge is the energy spent and will be 1 Joule".

1 Joule $= 1\ Volts \times 1\ Coulomb$

Types of Energies

There are different forms/types of energy which are inter convertible. These are Chemical Energy, Electrical Energy, Mechanical Energy, Chemical Energy, Thermal Energy,
Nuclear Energy etc.
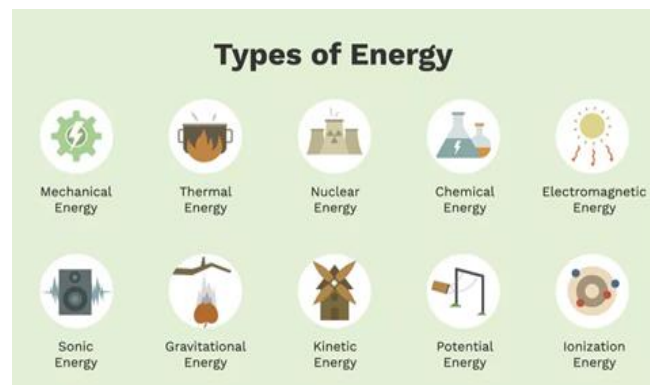
Figure 4.16: Types of Energy

Energy Tariff

The Energy Tariff or Electrical Tariff is the amount of money frame by the supplier for the supply of electrical energy to various types of consumers. In other words, the tariff

is the methods of charging a consumer for consuming electric power. The tariff covers the total cost of producing and supplying electric energy plus a reasonable cost.

Energy Consumed and its Costing

The unit of electrical energy is defined as being **watts per second or joules** and it can become a very large value when used to actually calculate the energy consumed by a component.

For example, if a 100 watt light bulb is left-"ON" for 24 hours, the energy consumed will be 8,640,000 Joules (100W x 86,400 seconds), so prefixes such as **kilojoules** (kJ = 10^3J) or **mega joules** (MJ = 10^6J) are used instead and in this simple example, the energy consumed will be 8.64MJ (mega-joules).

But dealing with joules, kilojoules or mega joules to express electrical energy, the math involved can end up with some big numbers and lots of zero's, so it is much easier to express electrical energy consumed in **Kilowatt-hours.**

If the electrical power consumed (or generated) is measured in watts or kilowatts (thousands of watts) and the time is measure in hours not seconds, then the unit of electrical energy will be the **Kilowatt-Hours**, (KWh). Then our 100-watt light bulb above will consume 2,400 watt hours or 2.4kWhr, which is much easier to understand the 8,640,000 joules.

1 **KWh** is the amount of electricity used by a device rated at 1000 watts in one hour and is commonly called a "**Unit of Electricity**". This is what is measured by the utility meter and is what we as consumers purchase from our electricity suppliers when we receive our bills.

Kilowatt-hours are the standard units of energy used by the electricity meter in our homes to calculate the amount of electrical energy we use and therefore how much we pay. So if you switch ON an electric fire with a heating element rated at 1000 watts and left it on for 1 hour you will have consumed 1 kWh of electricity.

So, consuming 1000 watts for one hour uses the same amount of power as 2000 watts (twice as much) for half an hour (half the time). Then for a 100-watt light bulb to use 1 kWhr or one unit of electrical energy it would need to be switched on for a total of 10 hours (10 x 100 = 1000 = 1kWhr).

Example 4.6

A consumer consumes 1000 watts load per hour daily for one month. Calculate The Total Energy bill of the consumer if per unit rate is Rs.9. Take 1 month = 30 Days

Solution:

Energy Consumed (Watts) = 1000 x 24 x 30 = 720000 watts/hour

Activity 4.3
Connect energy meter with the load and read the value of energy
Required Tool & Equipment: Voltage source, Resistor, Connecting wires, Breadboard, Energy meter etc.
Step 1: Arrange the class in small groups   Step 2: Assign them the task toconnect energy meter with the load and read the value of energy   Step 3: Collect the required components and equipment   Step 4: Measure the current   Step 5: Record the observations

Activity 4.4
Calculate the cost of energy consumed for the given load
Required Tool & Equipment: Calculator, Stationary
Step 1: Arrange the class in small groups   Step 2: Assign them the task tocalculate the cost of energy consumed for the given load   Step 3: Collect the required components and equipment   Step 4: Measure the current   Step 5: Record the observations

So Total Energy Consumed Units (KWh) = 720000/1000= 720KWh

Since Cost of per unit is Rs.9

So total Cost or bill= 720 x 9 = Rs. 6480.

Ohms Law Pie Chart & Matrix Table

To help us understand the relationship between the various values a little further, we can take all of the Ohm's Law equations from above for finding Voltage, Current, Resistance and of course Power and condense them into a simple **Ohms Law Pie Chart** for use in AC and DC circuits and calculations as shown.
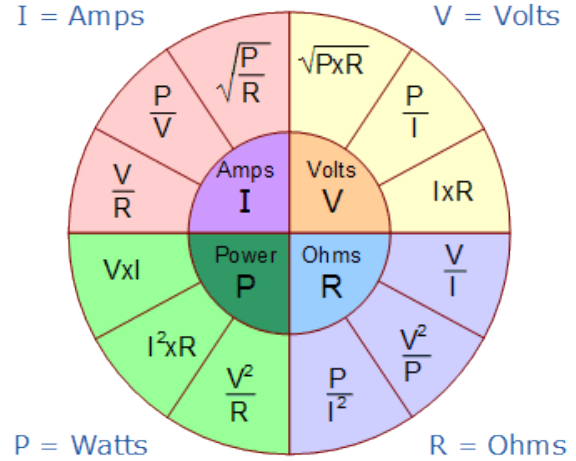
Figure 4.17: Ohm law Pie Chart

As well as using the Ohm's Law Pie Chart shown above, we can also put the individual Ohm's Law equations into a simple matrix table as shown for easy reference when calculating an unknown value.

Ohms Law Matrix Table

Ohms Law Formulas				
Known Values	Resistance (R)	Current (I)	Voltage (V)	Power (P)
Current & Resistance	---	---	$V = I{\times}R$	$P = I^2{\times}R$
Voltage & Current	$R = \dfrac{V}{I}$	---	---	$P = V{\times}I$
Power & Current	$R = \dfrac{P}{I^2}$	---	$V = \dfrac{P}{I}$	---
Voltage & Resistance	---	$I = \dfrac{V}{R}$	---	$P = \dfrac{V^2}{R}$
Power & Resistance	---	$I = \sqrt{\dfrac{P}{R}}$	$V = \sqrt{P{\times}R}$	---
Voltage & Power	$R = \dfrac{V^2}{P}$	$I = \dfrac{P}{V}$	---	---

Key points

- When two or more resistances are connected end to end across a voltage source such that there is only one path for the current to flow through the circuit then this combination is called a Series circuit.

- Voltage division rule is used for the measurement of voltage drops for a series combination of resistances

- Two or more resistances are connected in such a way their one ends at one side are joined together other ends are joined together and across these ends a power supply is connected

- Current division rule is applicable to find the current, for the resistances connected in parallel

- The rate of doing work is called as Power. The SI unit of power is the watt

- The Capability of doing work of a body is called as Energy

- There are different forms/types of energy which are inter convertible

- The unit of electrical energy is defined as being watts per second or joules

- If the electrical power consumed (or generated) is measured in watts or kilowatts (thousands of watts) and the time is measure in hours not seconds, then the unit of electrical energy will be the Kilowatt-Hours, (KWh)

Multiple Choice Questions

Select the most appropriate option (✓)

1. In series circuit of resistances, the current _____ in each resistor.
   a. Increases
   b. Decreases
   c. Reverses
   d. Remains Constant

2. Voltage remains _____ in parallel combination of resistors.
   a. Increasing
   b. Decreasing
   c. Constant
   d. Changing

3. The SI unit of energy is
   a. Watt
   b. Ampere
   c. Joule
   d. Volt

4. Electrical unit of power is
   a. Watt
   b. Ampere
   c. Volt
   d. Ohm

5. In DC circuit VI is used to find
   a. Current
   b. Voltage
   c. Flux
   d. Power

6. Two resistors of 4 Ohm are connected in parallel. What will be equivalent resistance

a. 2

b. 4

c. 6

d. 8

7. 1-watt x 1 second is ----------------

a. 1 volt

b. 1 farad

c. 1 joule

d. 1 ampere

8. A potential difference of 20 V is applied a resistor of 10 Ohm. The power will be

   a. 20 watts

   b. 40 watts

   c. 60 watts

   d. 80 watts

9. 1 HP is equal to --------------

   a. 746 Watts

   b. 742Watts

   c. 346 Watts

   d. 342 Watts

10. The ability of a body to do work is called _____.

   a. Power

   b. Force

   c. Work

   d. Energy

Give short answer of the following questions

1. Write any two characteristics of series combination of resistors.

2. What is the equivalent resistance of 4 & 8 Ohms connected in series?

3. What is the equivalent resistance of two 20 Ohms resistance connected in parallel?

4. Write the SI units of energy and power.

5. Define watt.

6. Define power.

7. Write any two formulae for power.

8. A potential difference of 24 volts is applied across a resistor of 6 Ω. Calculate the current and the power dissipated.

9. Give formula for total resistance of three resistances R1, R2, R3 connected in parallel.

10. Enlist various forms of energy.

Answer the following question in detail

1. Describe the characteristics of series combination of resistors.

2. Enlist any four characteristics of parallel combination of resistors.

3. Compare series and parallel combination of resistors.

4. Compare Energy & Power of Electrical Circuits.

5. Find the equivalent resistance of following circuit.
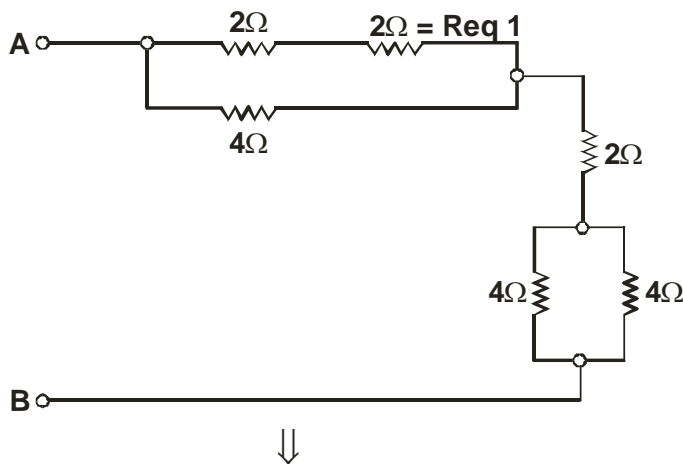
Ans: 6 Ω

Practical Activities

1. Verify (Ohm's Law) using series and parallel combination of circuits.
2. Three resistances of 1kΩ, 2kΩ and 3kΩ are connected in series to a power supply of 12V supply. Find:
    *   Total Resistance
    *   Current Flowing in the Circuit
    *   Voltage Drop Across Each Resistance
3. Three resistances of 10 kΩ, 20 Ωk and 30kΩ are connected in series across a 24 V supply. Find:
*   Total Resistance
*   Current across each Resistance
*   Voltage drop across each Resistance

Instructions for the Teachers

1. Adopt Health and Safety measures in the lab
2. Use ICT resources for better delivery of the content
3. Ensure proper functioning of lab equipment
4. Ensure assessment during course of the activity and give input to the Trainee

Practical Activities

1. Verify (Ohm's Law) using series and parallel combination of circuits.
2. Three resistances of 1kΩ, 2kΩ and 3kΩ are connected in series to a power supply of 12V supply. Find:

Chapter 05   Capacitor and Inductor

- ➤ explain capacitance.
- ➤ describe capacitor and its types.
- ➤ understand the connection procedure of capacitors in series and parallel.
- ➤ explain inductance.
- ➤ describe inductor and its types
- ➤ understand the behavior of capacitors and inductors connected with AC &DC

5.5   5.1 Capacitor & Inductor

5.1.1 Capacitor & Capacitance

Capacitor is a device which is used to store electric charge. A simple capacitor consists of two parallel metal plates separated by an insulator which is called as dielectric. One plate is positively charged and other plate is negatively charged. The insulating material can be paper, mica, ceramic, plastic or glass etc.
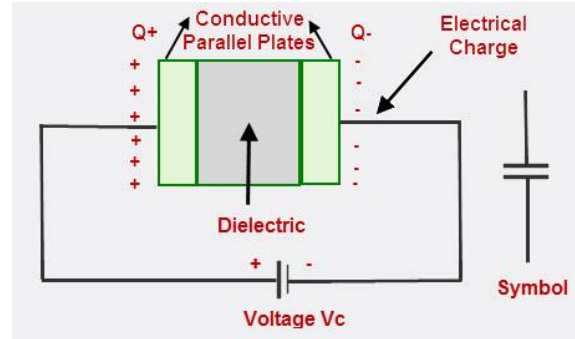
Figure 5.1: Capacitor

The plate which is connected to the positive terminal of the battery acquires positive charge and the plate which is connected to negative plate acquires negative charge. It should be noted that no current flows between the plates because of the dielectric present. Also the charges remain stored on the plates even if voltage source is removed. If we short the two terminals charge will be discharged.

Capacitance

In a parallel plate capacitor if has been observed that:

$$Q \propto V$$
$$Q = \text{Constant} \times V$$
$$Q = CV$$

Where C is a constant and is called as the capacitance of the capacitor. The total capacity of strong the charge of a capacitor is called its capacity.

Since $C = \dfrac{Q}{V}$

So we can also define capacitance as the ratio of charge to the voltage applied. If a capacitor stores 1 coulomb of charge when the potential difference applied to its plates is 1 volt, then its capacitance will be 1 Farad.

Activity 5.1
Connect the capacitor in series and calculate total capacitance
Required Tool & Equipment:
Step 1: Arrange the class in small groups
Step 2: Assign them the task toconnect the capacitor in series and calculate total capacitance
Step 3: Collect the required components and equipment
Step 4: Measure the voltage and calculate the capacitance
Step 5: Record the observations

Activity 5.2
Connect the capacitor in parallel and calculate total capacitance
Required Tool & Equipment:
Step 1: Arrange the class in small groups
Step 2: Assign them the task toconnect the capacitor in parallel and calculate total capacitance
Step 3: Collect the required components and equipment
Step 4: Measure the voltage and calculate the total capacitance
Step 5: Record the observations

Example 5.1

A capacitor stores 40μC when 20V are applied across its plates. What is its capacitance?

Solution:

$$Q = 40\mu C = 40 \times 10^{-6}\ \text{Coulomb}$$

$$V = 20\ \text{Volts}$$

$$Q = C\ V$$

$$C = \frac{Q}{V} = \frac{40\mu C}{20} = 20\mu F$$

Important Terms &Definitions

Dielectric

The insulating material placed between the two charges or the two plates of a capacitor is called as Dielectric. By inserting the dielectric between the charges, the capacity of storing the charges is increased by the redistribution of charges in the Dielectric. It is called as polarization of the dielectric.

Suppose a parallel plate capacitor and a dielectric is placed between the plates of the capacitor. The surface of the dielectric adjacent to the positive plate acquires negative charge. The surface of the dielectric which is adjacent to the negative plate acquires positive charge. This redistribution of the charges inside the molecules of the dielectric is called as Polarization
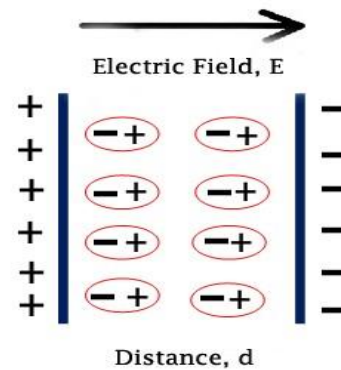
Figure 5.2: Polarization

Dielectric Strength

Dielectric strength is the maximum amount of the voltage applied to dielectric which it can withstand without breaking down. Voltage up to less than this value is safe to use for the dielectric. Voltages more than this value applied to dielectric will cause damage to the dielectric. Dielectric strength is measured in volts/mil (1 mil=0.001 inch). Typical values of dielectric strength for various materials are tabulated below:

Sr. No.	Material	Dielectric Constant
1	Air	75
2	Oil	380
3	Bakelite	400
4	Glass	3000
5	Mica	5000

Dielectric Constant

The ability of dielectric to establish an electric field is called as its Dielectric Constant or permittivity. It is denoted by ε. In case air is a dielectric then it is denoted by ε_0. The value of ε_0 is 8.85×10^{-12} F/m (Farad/meter). If some other material than air is used as dielectric than dielectric constant is termed as Relative Permittivity and is denoted by ε_r. ε_0 and ε_r are related by the relation:

$\varepsilon = \varepsilon_0 \times \varepsilon_r$

Typical values of relative permittivity of some materials are listed below:

Sr. No.	Material	Dielectric Constant (ε_r)
1	Air	1
2	Oil	2.5
3	Bakelite	5.0
4	Glass	4.5
5	Mica	2.0

Break Down Voltage

The maximum value of the voltage at which a dielectric breaks down is called as break down voltage. If we apply voltage equal or greater than breakdown the dielectric will be damaged and capacitor will be damaged. In properly designed circuit and circuit implementation proper voltage should be taken into account.

5.6   5.2 Types of Capacitor

There are two major types of capacitors

  i.   Fixed Capacitors
  ii.   Variable Capacitors

Fixed Capacitors

Fixed capacitors are defined as the capacitors whose capacitance values cannot be changed.

There are two types of fixed Capacitors.

  i.   Electrostatic Capacitors
  ii.   Electrolytic Capacitors

```
                              Capacitor
                                  |
                 +----------------+----------------+
                 |                                 |
               Fixed                           Variable
                 |                                 |
        +--------+--------+            +-----------+--------+--------+
        |                 |            |                    |        |
  Electrostatic    Electrolytic   Tunning      Trimmer/Padders   Varactors
        |                 |
        |          +------+------+
        |          |             |
        |       Tantalum     Aluminium
        |
  +-----+------+--------+--------+
  |     |      |        |
Paper  Oil  Ceramic   Mica
```
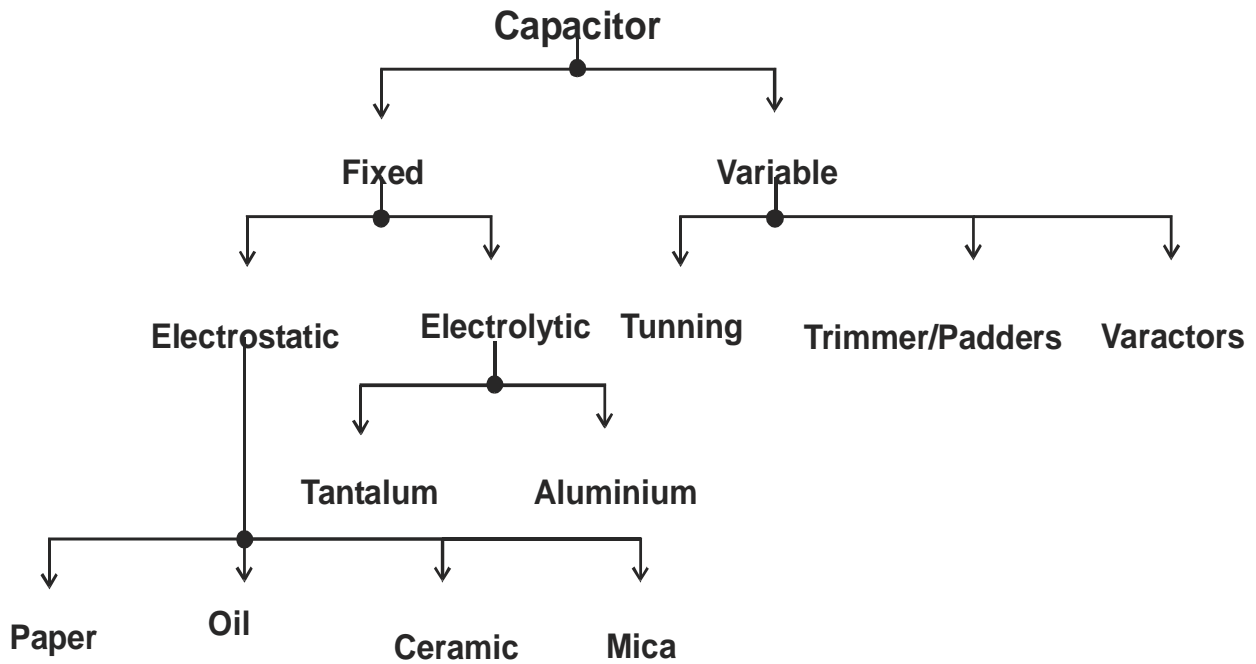
Electrostatic Capacitor

Electrostatic capacitors are made of two thin metal plates between which papers, mica, ceramic, oil etc. is used as dielectric. Such capacitors have no issue of polarity i.e., can be connected in the circuit in either direction. There are different types of electrostatic capacitors.

Paper Capacitor

In paper capacitor two thin aluminum plates are separated by dielectric which is paper or oil dipped paper. Aluminum plates are called as metal foils. These are made for the ranges of 0.001mF with voltage up to 2000V. These are made in the form of cylinders and used for high frequency application.
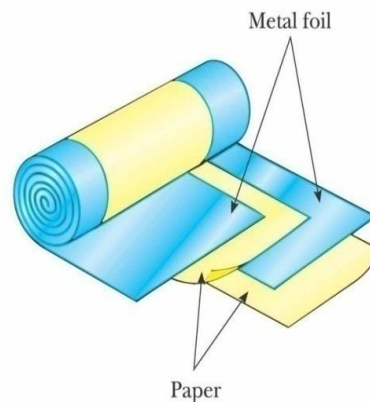
Figure 5.3: Paper capacitor

Mica Capacitors

Mica capacitors are made as stacked foil and silver-mica. These are available for the capacitance values ranging from 1pF to 0.1mF and voltage ratings up to 2500V.

Stacked Mica capacitors are made by combining two thin sheets of tin or copper separated by mica and repeating this arrangement for greater values of

Figure 5.3   Mica capacitor

capacitance. The final assembly is closed in an insulating material such as plastic or Bakelite. It is shown in figure 5.4

Silver mica type is same as stacked mica type, except in the silver mica capacitor, the silver film is deposited directly on the dielectric mica compared with tin or copper. These capacitors are available in capacitance values ranging from 5pF to 10mF for 500V.

Oil Capacitor

In the oil capacitor or oil filled capacitors, the dielectric used is oil filled or impregnated paper. These capacitors are used to acquire very large values of capacitances and in are used for industrial applications like filtering, arc suppression, power factor correction, start of ac motor, voltage regulation, voltage multiplications etc.

Figure 5.4: Oil capacitor

Ceramic Capacitors

In ceramic capacitors ceramic is used as dielectric material and thin film of silver is deposited on both sides of electric. These capacitors are made in the shape of disc end tabular form as shown in figure.

Ceramic capacitors have large dielectric constant $\varepsilon_r=1200$. In very small size, a very large value of the capacitance can be achieved for the ceramic capacitors. Ceramic capacitors are economical and have a large
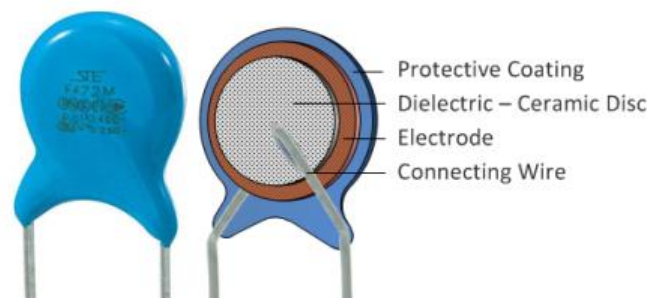
Figure 5.5: Ceramic capacitor

capacitance in small package and can have very good high frequency response and frequently used for electronics applications.

Electrolytic Capacitors

Electrolytic capacitors are polarized type of capacitors. In these capacitors are plate is positive and the other plate is negative. In electrolytic capacitors we used some form of the electrolyte as dielectric. These capacitors are designed to achieve high value of capacitance i.e. up to 200,000 mF.

Figure 5.6: Tantalum Capacitors & Aluminum Capacitors

     i.   Tantalum Capacitors

    ii.   Aluminum Capacitors

These capacitors consist of two foils of aluminum or tantalum separated by a paper which is dipped with electrolyte. Frequently ammonium borate is used as electrolyte. During the manufacturing an electrochemical reaction is induced which cause an oxide layer to be produced on the inner surface of the positive plate. This oxide acts as dielectric.

Variable Capacitors

Variable capacitors are whose values can be charged over a fixed range. In these capacitors different components can move to vary the effective area due to which capacitance varies. Dielectric materials can be air, mica or ceramic etc.

i. Tuning Capacitor (or Air Capacitor/Ganged Capacitor)

The variable capacitors using air as dielectric are called tuning or ganged or air capacitor. These capacitors consist of two sets of metal plates and air is used as dielectric. It is shown in figure below.

Fig.5.7: Tuning Capacitor

In tuning capacitors, one set of plate in fixed and is called as stator while the plate is moving and is called as Rotor. Stator and rotor are separated by a very small air gap. The moving plate is rotated with the help of a knob connected to it. As the plate moves, the effective area between the plates varies, which results in the variation of the capacitance. If the two plates completely overlap, the capacitance will be maximum. When many such plates are grouped together it is called as Ganged Capacitor. These capacitors are used in tuned oscillators.

ii. Trimmer

A trimmer is a variable capacitor in which the two metal plates are separated by air or mica or ceramic slab as the dielectric. The spacing between the two plates can be charged by means of an adjustable screw attached to it. By moving the screw inward or outward with the help of a screw driver, the capacitance can be varied. Trimmers can be made from 10pF to 500pF values.

Figure 5.8: Trimmer capacitor

iii. Varactors

Varactor is a type of variable capacitor in which the capacitance is changed by changing the voltage applied to the terminals of the capacitor. Varactor is also called as voltage variable capacitor diode (VVC). Its range is in pF and is used for automatic frequency control device. The length of the dielectric changes by

Figure 5.9   Varactors

the variation of voltage and resulting in the change of capacitance. It is shown in figure 5.09
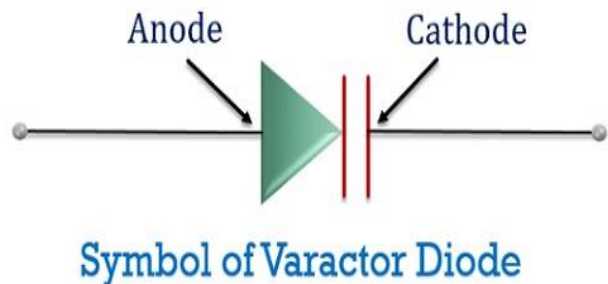
Uses of Capacitors

Capacitors are used to block the dc voltage and to allow pass the ac signal. If a dc is applied to a capacitor it gets charged at this value. Capacitors are used in variety of applications. Some of these are as follows.

    i.   Coupling

    ii.   Filtering of ac signal

    iii.   Power Factor improvement

    iv.   In resonant circuits for tuning frequencies

    v.   In voltage multiplier circuits

    vi.   In communication systems like wireless, Radar, Transmitters and modulation etc.

    vii.   Electronics Circuits.

    viii.   Radio, T.V sets, Computers.

5.7   5.3 Capacitors in Series & Parallel

Capacitors in Series

Suppose three capacitors C_1, C_2 and C_3 are connected in series to a power supply V as shown in figure below:

Fig.5.10 Capacitors in Series

In this case there will be only one path for the current to flow through the capacitors and so the charges on the capacitors C1, C2 and C3 will be the

Figure 5.10: Capacitor in series

same. However, in this case the voltage across each capacitor will be different and say it is V1, V2 and V3.

So $Q = C_1V_1$, $Q = C_2V_2$, $Q = C_3V_3$ and $Q = C_{equ}V$

According to Kirchhoff's voltage law:

    $V = V_1 + V_2 + V_3$

$$\frac{Q}{C_{equ}} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$\frac{1}{C_{equ}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

So the reciprocal of the equivalent capacitance of the series combination is equal to the sum of the reciprocals of the individual capacitances connected in series.

Capacitors in Parallel

Consider three capacitors C_1, C_2 and C_3 connected in parallel across a voltage source V as shown in figure5.11 below

It is evident from the figure that one plate of each capacitor is connected to positive terminal of the battery and other
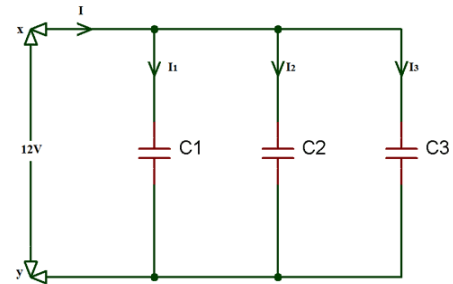
Figure 5.11: Capacitor in Parallel

plates are connected to negative terminal of the battery.

So the potential difference across the plates of the capacitor is V. Since capacitors are connected in parallel so the charges on the capacitors will be different. Let Q_1, Q_2 and Q_3 be the charges on the capacitors C_1, C_2 and C_3 respectively then.

Total charge$=Q =Q_1 + Q_2 + Q_3$

Since Q=CV

$Q_1 =C_1$

$Q_2 = C_2V$

$Q_3 = C_3V$

Since $Q = C_{equ}$ V

Therefore $Q = Q_1 + Q_2 + Q_3$

C_{equ} V $=C_1V + C_2V + C_3V$

$V \times C_{equ}=V\times (C_1 + C_2 + C_3)$

$C_{equ}= C_1 + C_2 + C_3$

When the capacitors are connected in parallel, the total capacitance is equal to the sum of the capacitances of individual capacitors.

Series Parallel Combination of Capacitors

If we connect some of the capacitors in series and some in parallel, then it is called as series parallel combination. We apply the results of series and parallel circuits to simplify the circuit.

Example 5.2

Three capacitors of 5µF, 10µF and 15µF are connected in series to a supply of 30 volts. Find equivalent capacitance and voltage drop across each capacitor.

Solution:

C_1 =5µF

C_2 =10µF

C_3 =15µF

V =30 volts
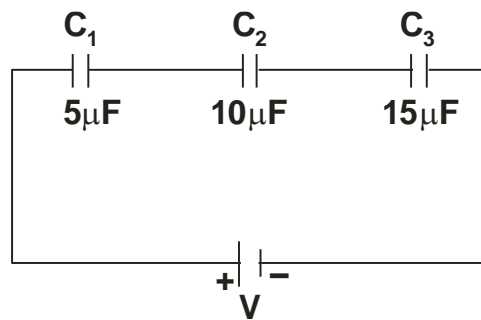
Fig.5.12

$$\frac{1}{Ceqe} = \frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3}$$

C_{equ} =$\frac{30}{11}$ =2.73 µF

Q=CV $\qquad$ = 2.73 × 30 = 81.90 µ Coulomb

$Q_1 = Q_2 = Q_3 = Q$ $\qquad$ = 81.90 µ Coulomb

V_1=$\frac{Q}{C1}$ $\qquad$ = 81.90 µ $Coulomb/5µF$

$\qquad$ =16.38 Volts

V_2=$\frac{Q}{C2}$ $\qquad$ = 81.90 µ $Coulomb/10µF$

$\qquad$ =8.19 Volts

V_2=$\frac{Q}{C3}$ $\qquad$ = 81.90 µ $Coulomb/30µF$

=5.46 Volts

Example 5.3

Three capacitors 10 µF, 20 µF and 30 µF are connected in parallel to a supply of 20 Volts. Find the total capacitance.

Solution:

$C_1=10µF$, $C_2=20µF$, $C_3=30µF$
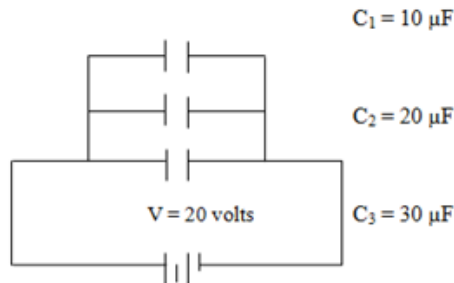
Fig.5.13

$C_{equ}=$?

C_{equ} $=C_1 + C_2 + C_3 = 10 + 20 + 30 = 60$ µF

5.8   5.4 Inductor & Inductance

An **inductor**, also called a coil, choke, or reactor, is a passive two-terminal electrical component that stores energy in a magnetic field when electric current flows through it.

When current flows through an inductor produces a magnetic flux that is proportional to the current. But unlike a Capacitor which oppose a change of voltage across their plates, an inductor opposes the rate of change of current flowing through it due to the buildup of self-induced energy within its magnetic field. This is the property of inductor.
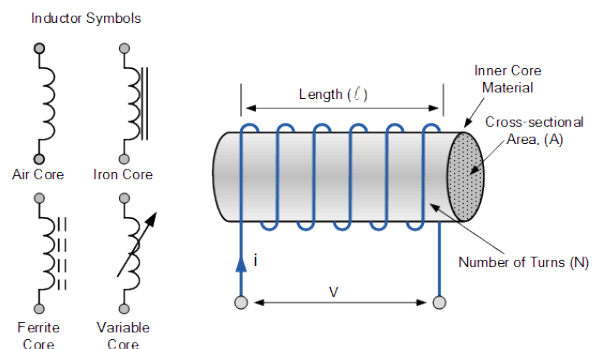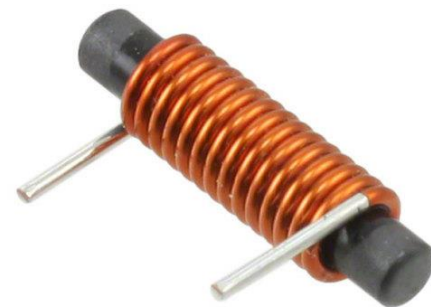
Figure 5.15: Basic Inductor

Inductance

An inductor is characterized by **its inductance**, which is the ratio of the voltage to the rate of change of current.

Its symbol is L and unit is Henry.

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

$$L = \frac{V}{di/dt}$$

5.9   5.5   Types of Inductor

Inductors are available in different shapes and has different uses. Their sizes vary depending upon the material used to manufacture them. The main classification is done as fixed and variable inductors. The Core of the Inductor is its heart. There are many types of Inductors according to the core material used. Let us have a look at a few of them

i.   Air-core Inductor

The commonly seen inductor, with a simple winding is this air-Core Inductor. This has nothing but **air as the core** material. The non-magnetic materials like plastic and ceramic are also used as core materials and they also come under this air-core Inductors. The following image shows various air-core inductors.

Figure 5.16: Air core Inductor

These Inductors offer a minimum signal loss at the applications having a very high magnetic field strength. Also, there exists no core losses as there is no solid core material.

ii.   Iron-Core Inductor

These Inductors have Ferromagnetic materials, such as ferrite or iron, as the core material. The usage
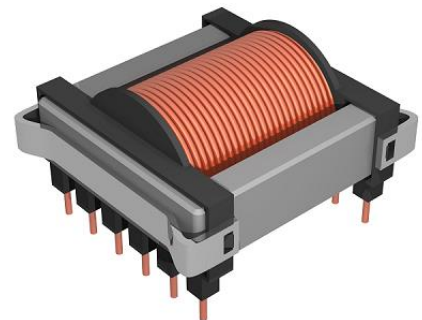
Figure 5.17: Iron core Inductor

of such core materials helps in the increase of inductance, due to their high magnetic permeability. The following image shows how an Iron-core Inductor looks like:

The inductors that have ferromagnetic core materials just like these, suffer from core losses and energy losses at high frequencies. These Inductors are used in the manufacture of few types of transformers.

iii.   Toroidal Inductors

These Inductors have a magnetic material as the core substance to which the wire is wound. These are in circular ring shape, just as shown in the following Fig 5.18.

Figure 5.18: Toroidal Inductor

The main advantage of this type of inductors is that, due to the circular shape, symmetry is achieved in the whole shape of the inductor, due to which there are minimum losses in the magnetic flux. These inductors are mostly used in AC circuit applications.

RF Inductors

RFinductors arethe radio frequency inductors, which are used at high resonant frequencies. These can be multilayered coil inductor or a thin film coated ceramic inductor or some wire wound ceramic inductor. The following figure represents few RF inductors. These inductors are characterized by low current rating and high electrical resistance. But as the high frequencies are used here, the wire resistance increases.
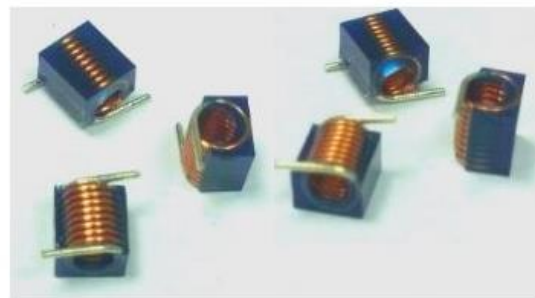
Image showing RF inductors

Figure 5.19

5.10   5.6 Behavior of Inductors when connected with AC & DC

There is a very important difference between the property of inductor and capacitor that Inductor block AC but pass DC whereas the capacitor block DC but pass AC. Now, the question is why and how they block or pass AC and DC? It is explained as follows:
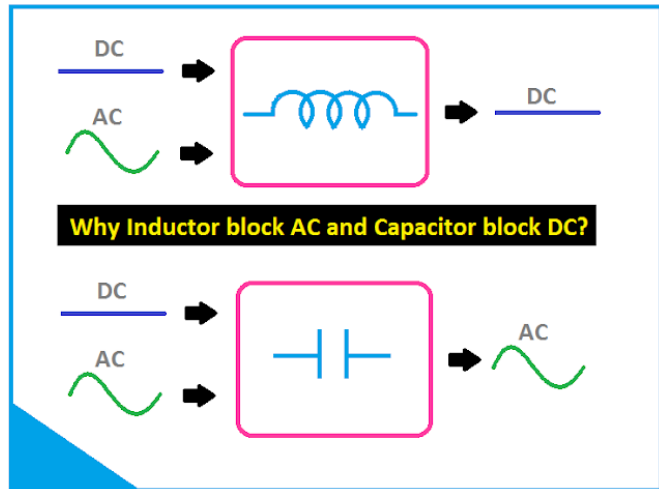
Why Inductor Block AC?

The answer to this question can be given in many ways. Let's find the answer from the below equation. We know that inductor has inductive reactance property by which it opposes the flow of current through it. The equation of inductive reactance is,

You can see in the above equation, frequency is there. So when we apply AC supply to the inductor, it will oppose the flow of current because as the AC has some frequency, there will be inductive reactance occur.

if,
X_L = Inductive Reactance
f = frequency
L = inductance

$$X_L = 2\pi f L$$

ㅠ,
f = 60Hz
L = 2 henry

$$XL = 2\pi \times 60 \times 2$$
$$= 753 \text{ ohm}$$

The opposition by the inductor due to the inductive reactance property is proportional to the supply frequency that means if supply frequency increases the opposition also be increased. For this reason, an inductor can totally block the very high-frequency AC.

Why Inductor Pass DC?

Now if we apply DC supply to an inductor, the inductive reactance will be zero because the frequency of DC is zero.

$$X_L = 2\pi \times 0 \times L$$
$$= 0$$

So, as the inductive reactance is zero it will not oppose the flow of current. So the inductor passes the DC current, of course, it will offer very small resistance to the flow of current which depends upon the internal resistance of the inductor material.

Why Capacitor Block DC?

Here also we will find the answer from the equation of the capacitor that is capacitive reactance. Capacitive Reactance is the property of the capacitor by virtue of which it opposes the flow of current. The equation of capacitive reactance is,

if,
X_C = Capacitive Reactance
f= frequency
C = capacitance

$$X_C = \frac{1}{2\pi fC}$$

So, according to the above equation if we apply DC supply to the capacitor the capacitive reactance will be indeterminate (we can say very high) because the frequency of DC is zero.

$$X_C = \frac{1}{2\pi \times 0 \times C}$$

$$= \frac{1}{0} = \text{undefined}$$

So as the capacitive reactance is very high, the current cannot flow through the capacitor.

Why Capacitor pass AC?

Now if we apply AC supply to the capacitor, it will pass because AC has a frequency.

$$\text{if,}$$
$$f = 60Hz$$
$$C = 2 \text{ Farrad}$$

$$X_C = \frac{1}{2\pi \times 60 \times 2}$$

$$= \frac{1}{753}$$

$$= 1.32 \times 10^{-3} \text{ ohm}$$

The blocking property of the capacitor is inversely proportional to the frequency that means if supply frequency increases, the capacitive reactance decreased so the capacitor will pass more current

Activity 5.3
Check the behavior of capacitor for AC & DC
Required Tool & Equipment:
Step 1: Arrange the class in small groups
Step 2: Assign them the task tocheck the behavior of capacitor for AC & DC
Step 3: Collect the required components and equipment
Step 4: Measure the current
Step 5: Record the observations

Activity 5.4
Check the behavior of Inductor for AC & DC
Required Tool & Equipment:
Step 1: Arrange the class in small groups
Step 2: Assign them the task tocheck the behavior of inductor for AC & DC
Step 3: Collect the required components and equipment
Step 4: Measure the current
Step 5: Record the observations

Key points

- Capacitor is a device which is used to store electric charge
- $Q = CV$, where C is a constant and is called as the capacitance of the capacitor
- The insulating material placed between the two charges or the two plates of a capacitor is called as Dielectric
- Dielectric strength is the maximum amount of the voltage applied to dielectric which it can withstand without breaking down
- There are two major types of capacitors i.e. Fixed Capacitors & Variable Capacitors
- If we connect some of the capacitors in series and some in parallel, then it is called as series parallel combination
- An inductor, also called a coil, choke, or reactor, is a passive two-terminal electrical component that stores energy in a magnetic field when electric current flows through it.
- An inductor is characterized by its inductance, which is the ratio of the voltage to the rate of change of current.

Multiple Choice Questions

Select the most appropriate option (✓)

1. A simple parallel plate capacitor consists of _____ plates.

   a. Two

   b. Three

   c. Four

   d. Six

2. Electrolytic capacitors are also called _____ capacitors.

   a. Metal

   b. Ceramic

   c. Composite

   d. Polarized

3. Variable capacitors are frequently used in _____ circuits.

   a. Timing

   b. Radioactive

   c. Tuning

   d. Transformer

4. Capacitor uses a _____ material as separator.

   a. Inductor

   b. Capacitance

   c. Dielectric

   d. Charge

5. Which of the Capacitor is preferably used at higher frequency?

   a. Electrolytic

   b. Ceramic

   c. Polarized

   d. Constant

6. With the increase in distance between capacitor plates, capacitance is ___.

   a. Decreased

   b. Increased

   c. Constant

d.   Variable

7.   When the voltage across a capacitor is increased, the stored charge

a.   Increases

b.   Decreases

c.   Remain constant

d.   None of above

8.   Which of the following capacitors can have the highest capacitance value?

a.   Mica

b.   Paper

c.   Electrolytic

d.   All equal

9.   Which of the following is not a dielectric?

a.   Paper

b.   Mica

c.   Air

d.   Alloy

10.   Three capacitors of the same value 4F are connected in parallel. What will be the total capacitance?

a.   4

b.   8

c.   12

d.   16

Give short answer to the following questions

1. Define Capacitor.
2. Define Capacitance.
3. What is an Inductor?
4. What is dielectric?
5. Compare the behavior of Inductor & Capacitor.
6. Enlist types of electrostatic capacitors.
7. Define fixed capacitor.
8. Define variable capacitor.

9. Write the formula for the total capacitance of three capacitors C1, C2 &C3 connected in series.
10. Name few popular inductors.

Answer the following question in detail

1.   Explain any two types of capacitors.
2.   Compare series and parallel combination of capacitors.
3.   Describe the behavior of Capacitors on AC &DC
4.   Describe the behavior of Inductors on AC &DC
5.   Describe air core and magnetic core inductors in detail.
6.   Three capacitors of 3F, 4F& 5F are connected to a 24V, DC Supply in parallel. Find the charge and Voltage across each capacitor.

Practical Activities

1. Find the equivalent capacitance of following combinations.
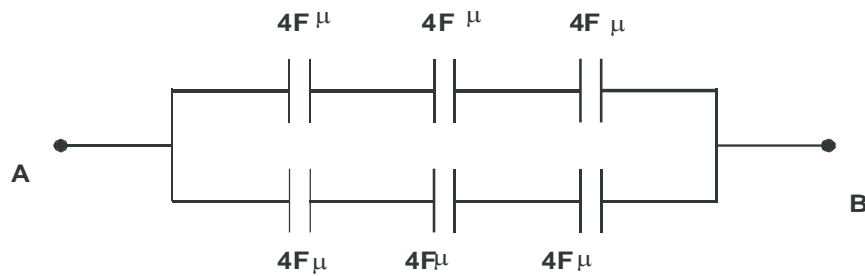
Fig.5.14

Instructions for the Teachers

1. Adopt Health and Safety measures in the lab

2. Use ICT resources for better delivery of the content

3. Ensure proper functioning of lab equipment

4. Ensure assessment during course of the activity and give input to the Train

Chapter 06   Digital Communication and Social Media

Students Learning Outcomes

After completion of this chapter you will be able to:

- ➤ create, access and manage email account.
- ➤ learn how to write and respond official email.
- ➤ understand the role social media in marketing and business development.
- ➤ analyze merits and de-merits of social media

5.11   6.1 Email

Electronic mail (email or e-mail) is a method of exchanging messages ("mail") between people using electronic devices. It is the fastest way for exchange of written communication. Email entered limited use in the 1960s, but users could only send to users of the same computer. Email operates across computer networks, primarily through Internet. Email servers accept, forward, deliver, and store messages.

Create, Access and Manage Email Account Creating Email Account

The following are the prerequisite for creation of new email account and use:

1.User Name

In order to plan a new email address for personal or work correspondence, make sure to register a user name that reflects this intention. Your nickname might be fine for family or friends, but your first and last name or the name of your business is probably better when you set up an email account for professional purposes.

2.Domain Name

For running a business, you might pick consultant.com, engineer.com or one of our many professional domain names. What's your hobby? Maybe artlover.com or bikerider.com is right for you. With more than 200 domains, mail.com is sure to have one that suits you. Together, your user name and email domain form a unique email ID that sets you apart from the crowd.

3. Password

A password is a string of characters used to verify the identity of a user during the authentication process. A strong password is essential to protect the data in your system. Remember that the length of a password determines its strength, so your password should have at least eight characters and contain both upper- and lowercase letters as well as numbers and symbols.

Activity 6.1
Creating Email account using Gmail
Required Tool & Equipment:
PC, Internet
Step 1: Visit Google account creation page, accounts.google.com
Step 2: Click on Create account.
Step 3: The sign-up form will appear. Enter your first and last name.
Step 4: Choose a Username for your account. (Here you can also use an existing email address)
Step 5: After choosing a username, enter a password. Type the password again to confirm. (As per Google's instruction always use 8 or more characters with a mix of letters, numbers & symbols)
Step 6: At last tap on Next. (Right corner of the screen)
Step 7: On the next page enter your phone number to verify your account. (It is a two-step verification process for security)
Step 8: On the given mobile number you will receive a text message from Google with a verification code. Enter the verification code and tap on Verify.
Step 9: On the next page enter your date of birth (DOB) in the specified fields.
Step 10: Choose a Gender.
Step 11: Tap on Next.
Step 12: Read, Google's Terms of Service and Privacy Policy will appear on the screen and click on I agree.

Access and manage Email Account

Access email account means to log in to your already created account for the purpose of sending and receiving massages or data. There are different aspects to manage your email account. In our email page, there are various folders like inbox, sent, draft, draft, important, spam, junk, scheduled etc. used for different purposes. The user is required to know about these folders for storing and easy retrieval of important data. You can compose new messages to be sent, forward the received messages, reply to messages, delete the messages and move the messages from on folder to another.
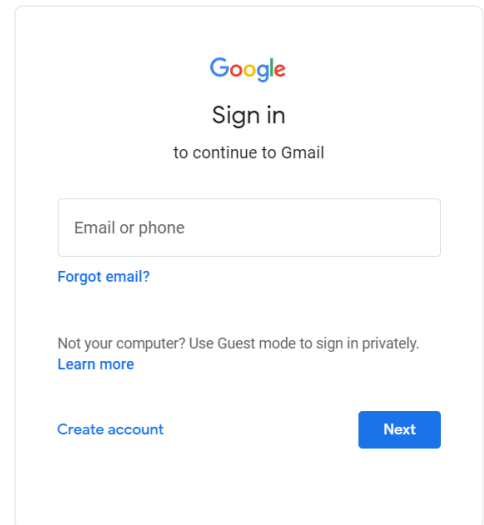
Activity 6.2
Write an official email to school principal on subject of any importance
Required Tool & Equipment: PC, Internet
Step 1: Log in your Gmail account   Step 2: Click on Compose option   Step 3: Write the recipient email address (School Principal)   Step 4: Write the Subject (Purpose of the email)   Step 5: Write main body of the email.   Step 6: Write your particulars (Name, Class, Roll Number etc.)   Step 7: Click the 'Send' button   Step 8: Log out from your Gmail account

5.12   6.2 Introduction to Social Media Platforms

Social media is a computer-based technology that facilitates the sharing of ideas, thoughts, and information through the building of virtual networks and communities. The largest social media networks include Facebook, Instagram, Twitter, YouTube. Social media typically features user-generated content and personalized profiles.

Social media has changed the way that we all interact with each other online. It has given us the ability to discover what is happening in the world in real-time, to connect with each other and stay in touch with long-distance friends, and in order to have access to endless amounts of information at your fingertips. In many senses, social media has helped many individuals find common ground with others online, making the world seem more approachable. Few social media networks are explained here:

Facebook

Facebook is a social networking site that makes it easy for user to connect and share with family and friends online. Facebook was created in 2004 by Mark Zuckerberg. By 2006, anyone over the age of 13 with a valid email address could join Facebook. Today, Facebook is the world's largest social network, with more than 1 billion users worldwide.

Instagram

Instagram is a free, online photo-sharing application and social network platform that was acquired by Facebook in 2012. Instagram allows users to edit and upload photos and short videos through a mobile app. Users can add a caption to each of their posts and use hashtags and location-based geotags to index these posts and make them searchable by other users within the app. As with other social networking platforms, Instagram users can like, comment on and

bookmark others' posts, as well as send private messages to their friends via the Instagram Direct feature. Instagram is not only a tool for individuals, but also for businesses.

Twitter

Twitter is a 'micro blogging' system that allows you to send and receive short posts called tweets. Tweets can be up to 140 characters long and can include links to relevant websites and resources. Twitter users follow other users. If you follow someone you can see their tweets in your twitter 'timeline'. Twitter is a social media site, and its primary purpose is to connect people and allow people to share their thoughts with a big audience. You can get the latest news based on importance quickly.

YouTube

YouTube is a video sharing service where users can watch, like, share, and comment and upload their own videos. The video service can be accessed on PCs, laptops, tablets and via mobile phones. The service was started as an independent website in 2005 and was acquired by Google in 2006. YouTube videos are posted by people from all over the world, from all types of backgrounds.

5.13   6.3 Role of Social Media in marketing and Business Development

Role of Social Media in Marketing

Social media aids in providing relevant statistics of their target customer behavior. Their likes and dislikes, demographics, etc. which otherwise have to be collected by spending a huge amount of money on marketing research companies. The role of social media is of extreme importance in digital marketing due to its widespread presence. It is very unlikely for a business to grow without the help of social media. The key aspects of social media are mentioned below which makes it pivotal in digital marketing.

i.   Reach of social media in marketing

ii.   Average time spent by the audience on social media

iii. The need for social media

iv.   The Trust Factor

Role of Social Media in Business

Social media can help you engage with your customers and find out what people are saying about your business. You can also use social media for advertising, promotional giveaways and mobile applications. Social media can help your business to:

- Attract customers, get customer feedback and build customer loyalty
- Increase your market reach, including international markets
- Do market research and reduce marketing costs
- Increase revenue by building customer networks and advertising
- Develop your brand
- Exchange ideas to improve the way you do business
- Recruit skilled staff for example through job networking sites like LinkedIn
- Increase traffic to your website and improve its search engine ranking
- Keep an eye on your competitors.

Merits and Demerits of Social Media

Merits:

- You reach large audiences
- You have a direct connection with your audience
- You provide better customer service
- You gain valuable insight about your customers
- You see how your audience perceives your business
- You can create organic content
- You have access to paid advertising services
- You build your brand
- You drive traffic to your website
- You can evaluate your performance
- You can join social media networks for free
- You can create viral content
- You can uncover valuable insights

Demerits:

- You can receive negative feedback

- You open up the potential for embarrassment

- You must spend a lot of time on your campaigns

- You have to wait to see results

Activity 6.3
Create a social media page for marketing purpose (Business Page)
Required Tool & Equipment: PC, Internet
Step 1: Go to the Facebook website and log in to your account.   Step 2: From the homepage, click Pages in the sidebar menu on the left.   Step 3: Click the Create New Page button in the menu on the left.   Step 4: On the left side of the next screen, enter a Page name, select a Category, and write a Description. The right side of the page shows you a preview of your page as you add information to it.   5 Scroll down and click Create Page.   Step 5: Click "Create Page" at the bottom-left.   Step 6: Next you can add images. Click Add Profile Picture or Add Cover Photo to upload photos from your device. Hit Save at the bottom.   Step 7: A pop-up may appear asking if you want to connect your page to WhatsApp. If you want to, enter your phone number and click Send Code. If you don't want to, click the "X" icon in the top-right corner of the pop-up.   Step 8: Your new Facebook page is now created, and you can continue customizing it to your liking.

Key Points

- Electronic mail (email or e-mail) is a method of exchanging messages ("mail") between people using electronic devices

- Social media is a collective term for websites and applications that focus on communication, community-based input, interaction, content-sharing and collaboration

Multiple Choice Questions

Select the most appropriate option (✓)

1. Which option is selected to access an email?

a. Create

b. Compose

c. Log in

d. Log out

2. The length of password contains _____ characters.

a. 2

b. 4

c. 6

d. 8

3. The strong password consists of:

a. Letter and numbers

b. Numbers and symbols

c. Letters and symbols

d. Letters, symbols and numbers

4. Which of the following is a correct format of Email address?

a. name@website@info

b. name@website.info

c. www.nameofebsite.com

d. name.website.com

5. A Website's front page /main page is called

a. Browser Page

b. Search Page

c. Home Page

d. Bookmark

6. Which one of the following is not a search engine?

a. Bing

b. Google

c. Yahoo

d. Windows

7. Internet explorer falls under:

a. Operating System

b. Compiler

c. Browser

d. IP address

8. Social networks are organized primarily around _____.

a. brands

b. people

c. discussions

d. interests

9. Which social network is considered the most popular for social media marketing?

a. Twitter

b. Facebook

c. Linkdin

d. Whats App

Write short answer of the following questions

1. What is Digital Communication?
2. Enlist types of digital communication
3. Define Social Media
4. Enlist any three merits of social media
5. Enlist any three Demerits of social media

Answer the following question in detail

1. Write down steps for creating an email account in detail
2. Discuss the role of social media in marketing and business
3. Compare advantages and disadvantages of social media on education sector

Practical Activities

1. Write an email to PTA regarding misuse of Social Media

Instructions for the Teachers

1. The Teacher is required to use ICT resources for better delivery of the content

Glossary

Words/Terms	Meanings/Descriptions
Chapter 1: Fundamentals of Electricity	
Density	The density of a substance is its mass per unit volume. The symbol is ρ
Voltage	It is the 'push' that causes charges to move in a wire or other electrical conductor
Resistance	It is the measure of the opposition to current flow in an electrical circuit
Chapter 2: Cells and Batteries	
Electrode	An electrical conductor used to make contact with a nonmetallic part of a circuit
Anode	The anode is the negative terminal
Cathode	The anode is the positive terminal
Chapter 3: Magnetism & Electromagnetism	
Magnet	A magnet is a material or object that produces a magnetic field
Flux	The total number of magnetic lines of force passing through a particular point
Magnetic Induction	The production of an electromotive force across an electrical conductor in a changing magnetic field
Chapter 4: Electrical Power and Energy	
Energy	The Capability of doing work of a body
Joule	When a charge of one coulomb is moved in a potential difference of one volt then the amount of the work done on the charge is the energy spent and will be 1 Joule
Power	The rate of doing work is called as Power.
Chapter 5: Capacitor and Inductor	
Dielectric	The insulating material placed between the two charges or the two plates of a capacitor is called as Dielectric
Capacitor	A capacitor is a device that stores electrical energy in an electric field
Inductor	An inductor stores energy in a magnetic field
Chapter 6: Digital Communication and Social Media	
E-mail	E-mail stands for Electronic Mail
Media	The main means of mass communication

About The Author

The Author of the Book, Engr. **Shahbaz Hussain** is a renowned TVET Expert having almost 26 years of experience in the sector. He has got his education from GCU and UET, Lahore. Apart from Pakistan, he has received his training from UK in the field of Curriculum Development. He has vast experience of teaching, TVET administration as Principal, District Manager, Director in the P-TEVTA and NAVTTC. He is the author of almost a dozens of Books for the TVET-DAE students. His famous publications/textbooks include:

i. Electric Circuits / Electrical Essential & Networks (ELTR-114)
ii. Electrical Essential & Networks (MTR-132)
iii. Electronic Devices & Circuits (ELTR-123)
iv. Microprocessor Architecture (ELTR-314)
v. Principles of Electrical Engineering (ET-115)
vi. Propagation of Electromagnetic Waves (ELTR-212)
vii. Electrical Machines/Motors and Generators (ELTR-243)
viii. Electronics-1 (CIT-134)
ix. Digital Logic Design (ET-282)

قومی ترانہ

پاک سَر زمین شاد باد!   کشورِ حسین شاد باد!

تو نِشانِ عزمِ عالی شان   ارضِ پاکستان

مرکزِ یقین شاد باد!

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قوم ، مُلک ، سلطنت   پائندہ تابندہ باد!

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سایۂ خُدائے ذُوالجلال!