ELECTRICAL DEVICES

CHAPTER 2

LEARNING OBJECTIVES

A student can understand the following in this Chapter

1. **Understand the basic working principles of electrical devices viz., cell, inductors, transformers, switches and fuses.**
2. **Understand the functions of microphone and loudspeaker.**

INTRODUCTION

In our day-today life, we are supposed to use many electrical appliances such as water pump, iron box, mixie, grinder, washing machine, UPS, TV etc. In order to understand the basic working principle of these appliances, it is better to know about some of the important electrical devices which are used in the appliances.

In this, we are going to read about

1. Cells
2. Inductors
3. Transformers
4. Switches and Fuses

2.1. CELLS

A device which converts chemical energy into electrical energy is called as a cell. A group of cells connected together is called battery.

In electric and electronic circuits, an electrical cell is denoted by the following symbol as shown in Figure 2.1.

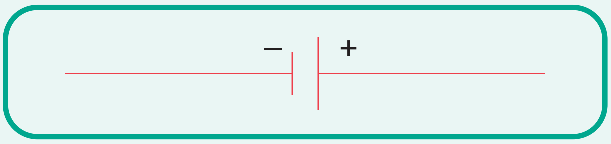

Figure 2.1 Symbol for Cell

When two dissimilar metals or electrodes are immersed in an electrolyte, there will be a potential difference produced between these metals or electrodes. In this, one electrode acts as positive terminal and another electrode acts as negative terminal.

2.1.1. Types of Cells

The cells are classified into two categories. They are,

1. Primary cells
2. Secondary cells

Primary Cells

Primary cells are widely used in clocks, watches, remote controls and calculators.

The cells that cannot be recharged are called as 'primary cells'. Some of the primary cells are Alkaline cell, Lithium cell, Zinc-Carbon cell and dry cell.

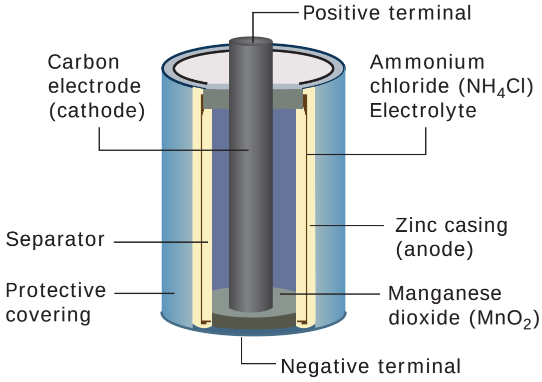

Figure 2.2 Structure of Primary Cell

Generally, primary cells (figure 2.2) are available in the voltage rating of 1.5 V, 3 V, 9 V and 12 V and the current rating of 0.2 A, 0.5 A, 1 A and 2 A. "AA" and "AAA" type of cells (1.5V) are used in clocks and remote controls. 1.5 V, 3 V button cells are used in watches and computers, respectively. 9 V cell is used in multimeter and cordless microphone.

Secondary Cells

The cells that can be recharged are called as 'secondary cells'. Some of the secondary cells are lead-acid cell, Lithium ion cell and Nickel Cadmium cell.

Lead-acid cell is widely used in two-wheel and four-wheel vehicles. Lithium ion cells are used in laptops and cell phones. Nickel cadmium cells are used in flash lights, emergency lights and toys.

2.2. INDUCTOR OR COIL

Inductor is the passive component used in electronic circuits. It stores energy in the form of magnetic field and delivers it as and when required. An inductor is usually a coil of copper wire wound around a core of ferromagnetic material. Figure 2.3 shows an inductor or coil.

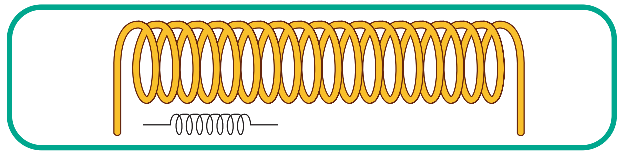

Figure 2.3 Inductors

2.2.1 Inductance

Whenever current passes through a coil, magnetic flux is generated around it. This magnetic flux opposes any change in current due to the induced EMF. The opposition to the change in current is known as inductance. The unit of inductance is Henry.

2.2.2 EMF (Electro Magnetic Force)

Electro Magnetic Force is a force that acts between the charged particles and a combination of electrical and magnetic forces. It can be in attractive or repulsive. Fig 2.4 shows an EMF

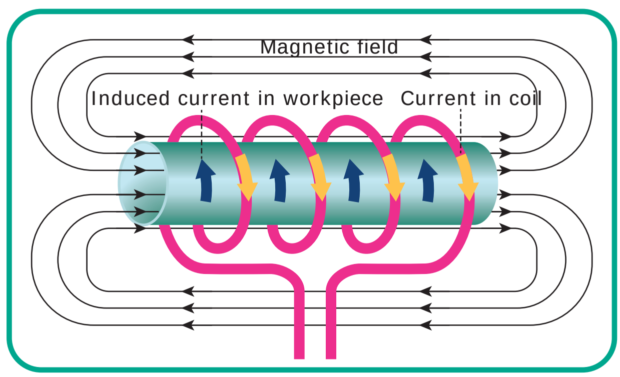

Figure 2.4 Electro Magnetic Force

2.2.3 Types of Inductor

Inductor can be divided in two categories.

1. Fixed inductors
2. Variable inductors

Fixed Inductor

The symbol of fixed inductor is shown in Figure 2.5 and can be further divided into three categories depending upon the type of core.

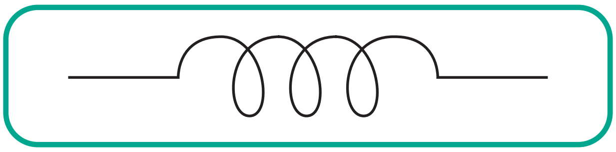

Figure 2.5 Fixed Inductor

They are,

1. Air Core Inductors
2. Iron Core Inductors
3. Ferrite Core Inductors

Variable inductors

In certain application such as tuned circuits, it is required to vary the inductance from minimum value to a maximum value. Ferrite core variable inductors are generally used for this purpose. The variable inductors are shown in Figure 2.6.

2.2.4 Relay

A relay is an electrically operated switch and is shown in Figure 2.7. The current flowing through the coil of a relay creates a magnetic field which attracts the lever and changes the switch contacts. Relay is used in applications to turn ON and OFF a circuit by a low power signal.

Uses: Relays are used in stabilizers, UPS (Uninterrupted power supply) and three phase change over switches.

2.2.5 Action of Coils in AC and DC Circuits

AC Circuits

Since the phase is alternatively changed in AC circuits, the back EMF continuously

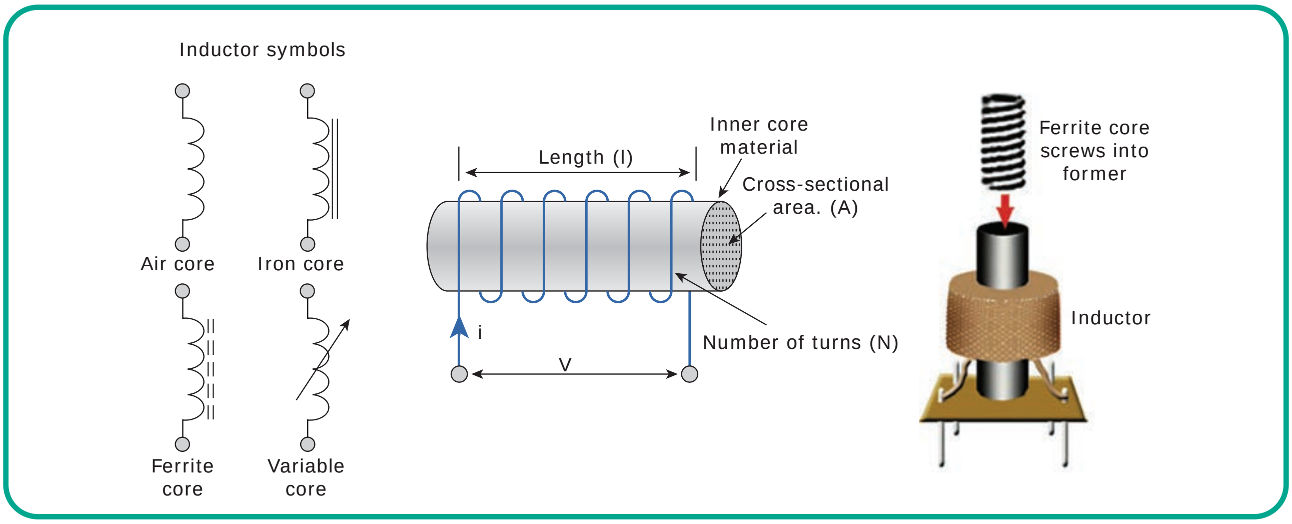

Figure 2.6 Variable Inductors

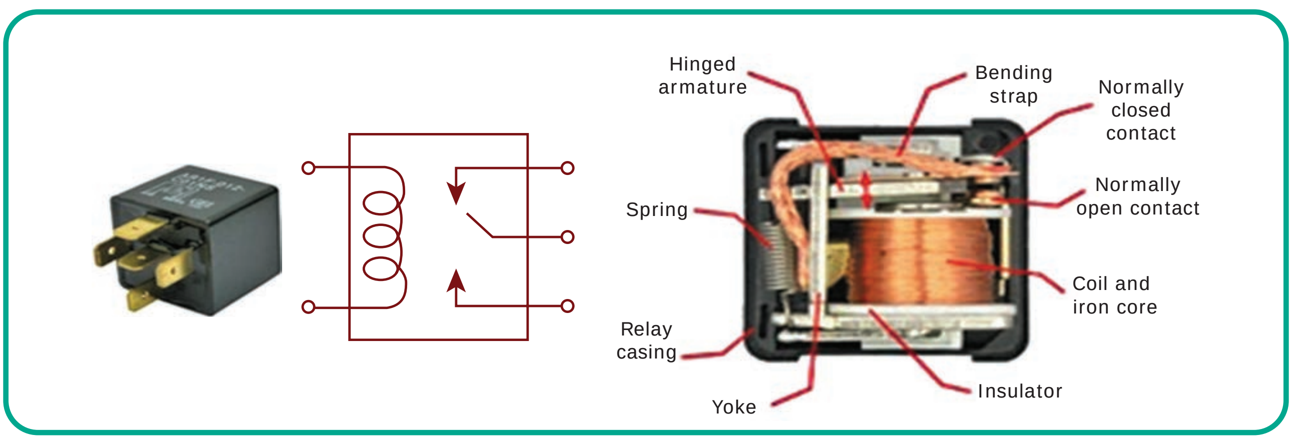

Figure 2.7 Relay

presents in the coil. This back EMF depends upon the frequency and the core of the coil. Hence, the coils in AC circuits have resistance carried by back EMF along with normal resistance. These two resistances combined together is known as inductive reactance.

Inductive Reactance $X_L = 2\pi f L$

where $\pi = 3.14$, f is the frequency of AC and L is the inductance. In AC circuits, the current flows in the coil lag 90° with reference to the voltage.

DC Circuits

When the switch is ON, the back EMF generated opposes the flow of current. The back EMF will get vanished when constant magnetic field is produced, i.e. the back EMF persists only to the fraction of switching on the circuit. When the circuit is switched ON, automatically the back EMF becomes zero. In DC circuits, coils would have only normal resistance. Hence, it may not be taken into consideration.

2.3. TRANSFORMERS

A device which has two or more coils wound on a core is termed as transformer. The electrical energy is transformed from one coil to other through mutual inductance in it.

The symbol of a Transformer is shown in Figure 2.18

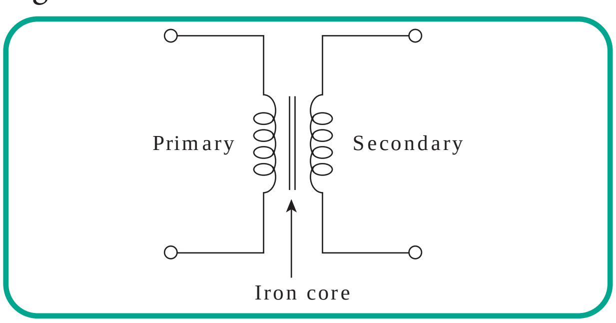

Figure 2.8 **Symbol of a Transformer**

History

In 1880s, the first commercially-used transformer was built by William Stanley, working under George Westinghouse that was wound to form a core of E-shaped plates in step-up and step-down variations.

2.3.1 Principle of Transformer Construction

Transformer is a static device which contains one primary and one or more secondary coils. The primary and secondary coil have high mutual induction The transformer works on the principle of Faradays Laws of electromagnetic induction and mutual induction. The electrical energy in primary coil produces a magnetic field (flux).This magnetic field strength induces an EMF in the secondary coil. Normally, this happen only in AC circuits. Figure 2.9 shows the parts of the transformer.

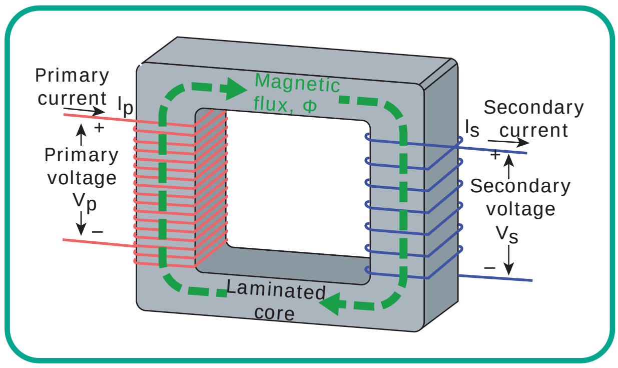

Figure 2.9 **Transformer**

The AC current flowing through the primary induces an alternating magnetic field. This magnetic field creates an EMF in the secondary. If we are giving DC in the primary, it won't induce any EMF, hence the phase does not get changed. Therefore, the transformer can be used only in AC Circuits.

2.3.2 Turns Ratio

The strength of current induced in the secondary depends upon the number of turns in the secondary coil. That is, the

Table 2.1 Classifications of Transformer		
Turns ratio	Core	Use
Step-up Transformer	Air Core	Power Transformer
Step-down Transformer	Iron Core	R.F Transformer
Isolating Transformer	Ferrite Core	I.F Transformer
Step-down Transformer	Iron Core	Audio Transformer

induced EMF is directly proportional to the turns in the coil. The voltage ratio between the primary and secondary is equal to the ratio between the number of turns in the primary and secondary.

$$\frac{E_P}{E_S} = \frac{N_P}{N_S}$$

$E_p \rightarrow$ primary coil voltage

$E_s \rightarrow$ Secondary coil voltage

$N_p \rightarrow$ Number of turns in primary coil

$N_s \rightarrow$ Number of turns in secondary coil

2.3.3 Types of Transformer

Based on the turns ratio, type of the core and the type of application, the transformers are classified as shown in Table 2.1.

Step-up Transformer

In this type, the number of turns in secondary coil must be more than the turns in the primary coil. These types of transformers are used in power generating plants, where the electricity is carried over a long distance and also in Television. The step up transformer is shown in Figure 2.10 and its turns ratio is given in Table 2.2.

Table 2.2 Turns ratio of step-up transformer		
	Primary	**Secondary**
Turns ratio	*1*	*2*
Voltage ratio	*1*	*2*

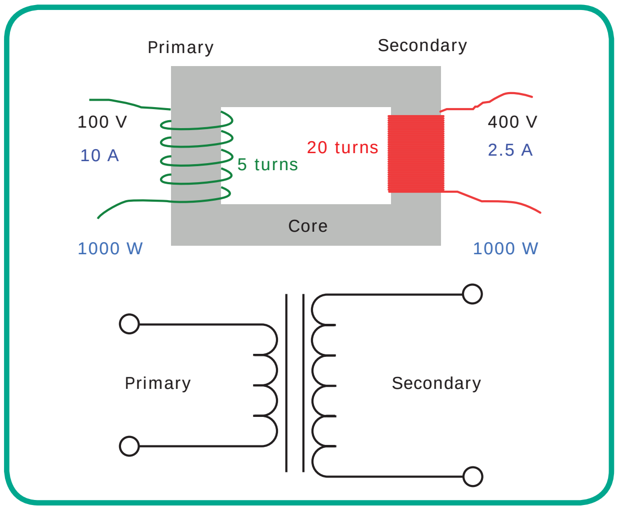

Figure 2.10 Step-up Transformer

Step-down Transformer

In this type, the number of turns in the secondary coil must be less than the number of turns in the primary coil. This type of transformer is used in Radio and TV receivers, eliminators and other video equipment. Figure 2.11 shows a step-down transformer. Table 2.3 summarizes the turns ratio of step-down transformer.

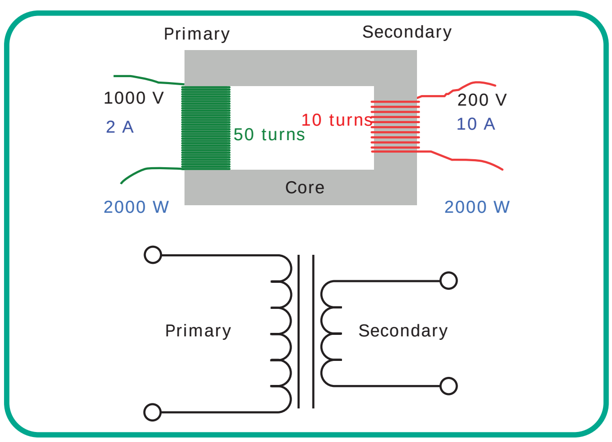

Figure 2.11 Step-down Transformer

Table 2.3 Turns ratio of step-down transformer		
	Primary	Secondary
Turns ratio	2	1
Voltage ratio	2	1

Isolating Transformer

This type of transformer has 1:1 ratio of winding. These types of transformer are used mainly in fault finding places. This transformer is used to avoid materials to have direct contact with main supply. Figure 2.12 shows an isolation transformer.

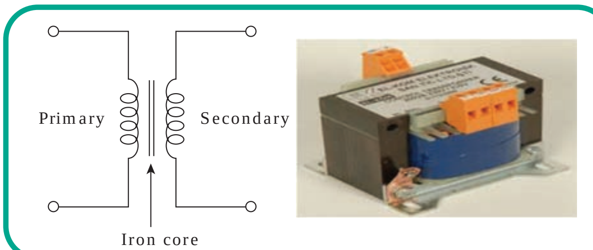

Figure 2.12 Isolating Transformer

Table 2.4 Turns ratio of Isolating transformer		
	Primary	Secondary
Turns ratio	1	1
Voltage ratio	1	1

2.3.4 Transformer Losses

Even in best transformers, unavoidable losses are occurred. These losses may be reduced using quality materials and cannot be totally nullified. The losses are of three types.

1. **Copper Loss:** The loss appeared because of the resistivity of copper string in the coil.
2. **Hysteresis Loss:** When AC changes its phase, the magnetic phase also gets changed. This causes some loss in the strength of the current. This is known as Hysteresis loss.
3. **Eddy Current Loss:** When current flows in an iron, it will get heated. This heat creates some loss. This loss is said to be Eddy current loss. To minimize this loss, the core should be laminated.

2.4. MICROPHONES AND LOUD SPEAKERS

In this Section, we are going to study about microphones and loud speakers. They may also be called as transducers, because they are converting one form of energy into another form.

2.4.1 Microphone

A device, which converts sound waves into electrical waves, is called as microphone. There are few types based on the construction.

Types of microphone

1. Carbon microphone
2. Ribbon microphone
3. Dynamic microphone
4. Condenser microphone

Let us see some of the important microphones.

Dynamic Microphone

The dynamic microphone can also be called as moving coil microphone, which is shown in Figure 2.13. It is working under the principle of electromagnetic induction. This works on the basis of the following principle which states that "in a magnetic field, a conductor is placed in such a way that it cuts the magnetic field and then inducing an electrical field in it".

In dynamic microphone, between the two-strong magnetic ends a coil spring is placed. A diaphragm is attached along with this coil spring. The diaphragm is firmly attached to the body of the microphone. The coil spring laminated so it won't have any contact with other parts. This total setup is fixed in a case.

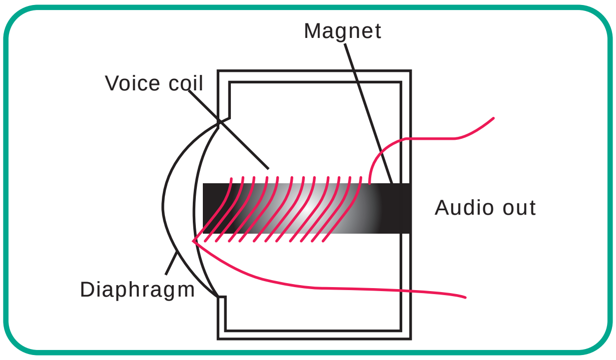

Figure 2.13 Dynamic Microphone

When sound waves strike the diaphragm, the coil attached to it will vibrate front and back. Due to this, the coil cuts the magnetic field and creating electrical signal. The strength of this electrical signal and frequency decides the true deflection of vibration occurred in the diaphragm. This electrical signal is the output of the microphone. The dynamic microphone will give equal frequency response for the sound waves in the range of 50 Hz to 10000 Hz. It is made up of low impedance material.

Condenser Microphone

When the distance between the electrodes of a capacitor gets changed the capacitance also varies. The condenser microphone is working under this principle. A condenser microphone is shown in Figure 2.14. The construction of this microphone is also similar to the construction of a capacitor. In this, one plate is kept static and another plate can vibrate on receiving the sound wave.

The vibrating plate will act as diaphragm. When the sound signal strikes the microphone, the vibrating plate starts slight movement (vibration) in front and back. Due to this, the gap between the two plates gets changed and in turn there is a change in capacitance occurs. The change in capacitance depends upon the sound waves. Hence, the electrical signal produced also gets changed and is taken as output. The condenser microphone is a high impedance microphone.

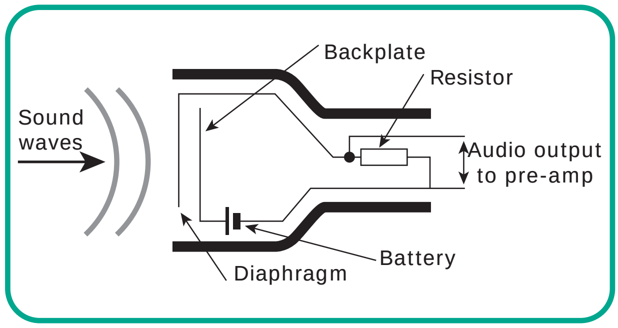

Figure 2.14 Condenser Microphone

2.4.2 Loud Speaker

A material which converts electrical energy into mechanical energy and converting such energy into sound energy is known as loud speaker. Simply to say, the part that converts amplified audio frequency signals back to the original sound is the speaker.

Dynamic Loudspeaker

Figure 2.15 shows a cross sectional view of a Dynamic Loudspeaker.

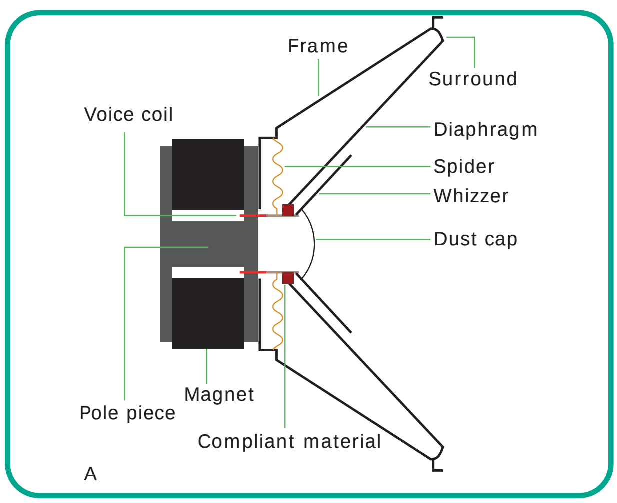

Figure 2.15 Dynamic Loudspeaker

Voice coil is placed in between the strong magnetic ends in order to fill the air gap. Spider is placed on the voice coil.

Spider helps the voice coil to fill the air gap. Paper cone is used to connect the voice coil with the frame of the speaker and so as vibration will be proper.

When the amplified audio signal is given to the voice coil, it will create variable magnetic field. The force develops in between the static and dynamic magnetic field move the voice coil front and back. Due to this the paper cone gets vibrated.

2.5. FUSES

A fuse is made up of a piece of metal that melts when over-heated. It should be connected in series with the load. Fuse is made up of 37% of lead and 67% of iron. Most common sizes having maximum working voltages are 32 V, 125 V, 600 V to 25000 V. Electronic fuses having a current rating of 0.1 A, 0.5 A, 1 A, 2 A, 3 A, 5 A, 10 A, 100 A and 500 A.

2.5.1 Types of fuses

Fuses can be divided into two main categories, according to the type of input supply voltage. They are,

1. AC fuses
2. DC fuses

There is a little difference between AC and DC fuses in size.

2.5.2 Other Types of Fuses

1. Cartridge Fuse
2. Blade Type Fuse
3. Surface Mount Device (SMD) Fuse
4. Axial Type Fuse
5. Thermal Type Fuse
6. HRC Type Fuse
7. Resettable Type Fuse

Cartridge Fuse

Cartridge fuses are used to protect electrical appliances such as motors, air conditioners, refrigerators, pumps etc., where high voltage rating and current rating are required. Cartridge fuse is shown in Figure 2.16

Figure 2.16 Cartridge Fuse

Surface Mount Device (SMD) fuse

This type of fuses directly soldered in the printed circuit board. These fuses are available in low-voltage and low-current ratings. It is the latest method of fuse and also no need to pierce on the PCB. The SMD fuse is shown in Figure 2.17.

Figure 2.17 SMD Fuse

Thermal Type Fuse

The thermal type fuse is used to protect electrical appliances from the damages caused due to over-heating. Thermal fuses are used in coffee makers, refrigerators etc., in the form of thermostats. Figure 2.18 shows the thermal fuse.

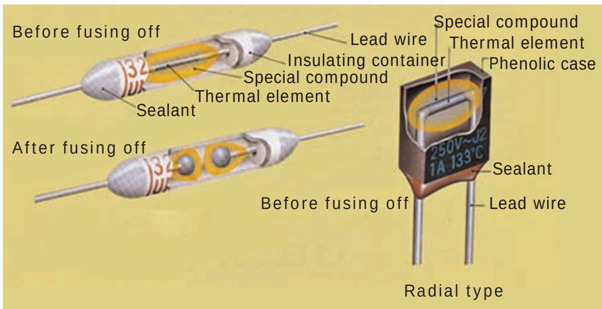

Figure 2.18 Thermal Fuse

2.6 CIRCUIT BREAKER

A circuit breaker is an automobile operated electrical switch designed to protect an electrical circuit from damage caused due to excess current, typically resulting from an over-load or short-circuit. Its basic function is to stop current flow after short-circuit or over-load is detected. There are different types of circuit breakers and are summarized below:

2.6.1 MCB (Miniature Circuit Breaker)

Presently, we use MCB in low-voltage electrical network instead of fuse. MCB is an electromechanical device which protects an electrical circuit from over-current. An MCB is better alternative to fuse, since it does not require replacement once an over-load is detected. Unlike fuse, an MCB can easily reset and thus offers improved operational safety.

Working principle

MCBs are either electromagnetic or a bi-metallic strip. In either case, when turned ON, the breaker allows electrical current to pass from a bottom to an upper terminal across the solenoid or strip. When the current reaches un-safe levels, the magnetic force of the solenoid becomes so strong, that a metal lever within the switch mechanism is thrown and the current gets cut-off. Alternatively, the metal strip bends throwing the switch and disconnecting the connection. To reset the flow of electricity after the problem is resolved, the switch can simply be tuned back to ON, thus reconnecting the circuit. Figure 2.19 shows a layout of MCB.

Figure 2.19 Layout of Miniature Circuit Breaker

2.6.2 ELCB (Earth Leak Circuit Breakers)

An ELCB is a safety device, used in electrical installations with high earth impedance to prevent even minor shock. It detects even small stray voltages on any electrical equipment enclosures and terminates the supply to them. An ELCB is a specialized type of a latching relay that has a provision for incoming mains power connected through its switching contacts. So, the ELCB disconnects the power when earth leakage is detected.

The difference between MCB and Fuse is summarized in Table 2.5.

The ELCB detects fault currents from live to earth (ground) within the installation and protect the circuit. If sufficient voltage appears across the ELCB's sense coil, it will switch off the power and remain off until

Table 2.5: Difference between Fuse and MCB	
Fuse	**MCB**
Fuse is usually made up of a fuse wire. It is an alloy which has a no melting point	MCB has a tripping circuit
Fuse works on the electrical and thermal properties of the conducting materials.	MCB works on the electromagnetism and switching principle
Fuses can be used only once	MCB can be used a number of times
Fuse cannot be used as an ON/OFF switch	MCB can be used as an ON/OFF switch
Operating time of Fuse is Very less (0.002 sec)	Operating time is comparatively more than that of fuse (0.02-0.05 sec)
Cost of fuse is low	Cost of MCB is high

manually reset. A voltage sensing ELCB does not sense fault currents from live to any other earthed body. A typical ELCB is shown in Figure 2.20.

Figure 2.20 Earth Leak Circuit Breakers

2.6.3 RCCB (Residual Current Circuit Breakers)

A RCCB is one of the essential safety devices when it comes to protection of electrical circuits. It is a current detection device which always detects the fault occurring in the current network and immediately disconnects the circuit.

It is also known as RCD (Residual Current Device) or RCB (Residual Current Breaker)

Classification of RCCB

1. Two pole RCCB (used in single phase supply connection)
2. Four pole RCCB (used in three phase supply connection)

The RCCB Shown in Figure 2.21

Figure 2.21 RCCB

2.7 SWITCHES

These are designed depends upon the contact points (pole) and number of connections (ways).

A device which is used to connect supply from one point to another point (load) is called a switch.

There are few type of switches based on requirements.

1. Single Pole Single Way
2. Single Pole Two Way
3. Single Pole Multi Way
4. Double Pole Single Way
5. Double Pole Two Way
6. Double Pole Multi Way
7. Multi Pole Multi Way

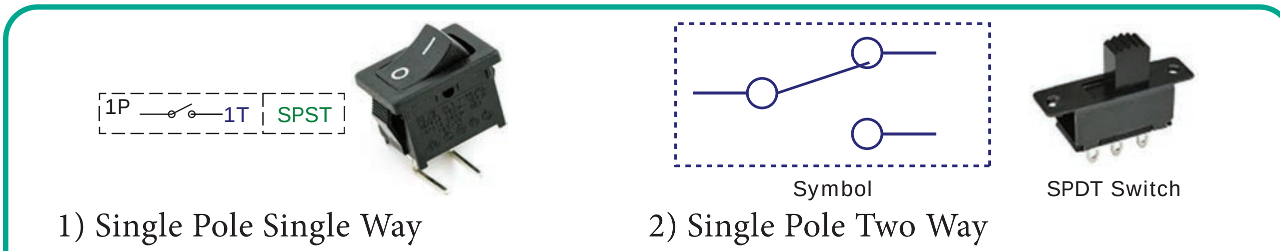

Figure 2.22 Types of Switches

LEARNING OUTCOMES

After studying this Chapter, a student can understand the following

1. **Remembering the concept of primary cells and secondary cells.**
2. **Acquiring depth knowledge about working principles of cells, inductors and transformers.**
3. **Designing and testing of the circuit breakers.**

GLOSSARY

S. No	Terms	Explanation
1	Auto transformer	Transformer that uses a common winding for both primary and secondary windings
2	Electromotive Force	Measured in volts, a force that exists between positive and negative charges
3	Inductors	A device for introducing inductance into a circuit
4	Transducer	Device that converts energy from one form to another

QUESTIONS

I Choose the best answer 1 Mark

1. A device which converts chemical energy into electrical energy?
   a) Capacitor b) Cell
   c) Resistor d) Transformer

2. Voltaic pile was invented by……………..
   a) Graham Bell b) Michael Faraday
   c) Alessandra Volta d) Marconi

3. The unit of an inductor is ………………
   a) Ohms b) Farad
   c) Hertz d) Henry

4. Which of the following is a transducer?
   a) Resistor b) Condenser
   c) Transformer d) Microphone

5. Electrical signal can be converted into audio signal by …………
   a) Microphone b) Speaker
   c) Condenser d) Cell

6. Audio signal can be converted into electrical signal by ……………..
   a) Transformer b) Microphone
   c) Speaker d) None of these

7. The formula for inductive reactance is _____
   a) $X_L=2\Pi fL$ b) $X_L = \frac{1}{2\pi L}$
   c) $X_L = 2\Pi\sqrt{f}L$ d) $X_L = \frac{1}{2\pi LC}$

8. Which speaker works efficiently in the low frequency audio range?
   a) Tweeter b) Woofer
   c) Squawker d) Horn type speaker

9. The ratio of winding in isolating transformer is __________
   a) 1:2 b) 1:1 c) 2:1 d) 2:2

10. Which among these is the least expensive protection for over-current in low-voltage system
    a) Rewirable fuse b) Isolator
    c) Circuit Breaker d) Air Breaker switch

II Answer in few sentences 3 Marks

1. What is meant by a cell?
2. What is meant by secondary cell? Give examples.
3. Define Electromagnetic force.
4. What is 'Q factor' of inductor?
5. What is a transformer?
6. What is meant by transducers?
7. What is the function of microphone?
8. Write down the function of loudspeaker?
9. What is switch?
10. What is the function of circuit breaker?

III Explain the following questions 5 Marks

1. How the inductors are classified? Explain.
2. Explain the working of coils in AC and DC circuits?
3. How speakers are classified as per the frequencies handled by them?
4. Explain two-way and three-way speaker system and wattage rating of speakers?
5. Explain about the losses occurred in a transformer.

IV Briefly explains the following questions 10 Marks

1. Explain the series and parallel connection of cells with necessary diagram.
2. Explain the working of a transformer and turns ratio with neat diagram.
3. Explain the working of a dynamic microphone.

Answers

1) **b**	2) **c**	3) **d**	4) **d**	5) **b**
6) **b**	7) **a**	8) **b**	9) **b**	10) **a**