LESSON 4

# Batteries

HOT1D

## LEARNING OBJECTIVES

The main objective of a battery is to know the classifications of the various types of cells, also to know about the chemical reactions during charging and discharging, maintenance, and tips for care of battery.

## Table of Content

## 4.1 INTRODUCTION

Battery is a device that transforms chemical energy into electrical energy. Batteries consist of electro chemical cells that are electrically connected.

Every battery has two terminals. The positive one is called 'Anode' and negative one is called 'Cathode' as shown in and Fig 4.1.

Battery is a storage device used for the storage of chemical energy and for the transformation of chemical energy into electrical energy.

Battery consists of a group of two or more electric cells connected together electrically in series. Battery acts as a portable source of electrical energy.

Battery or cell is an electrochemical device consisting of two electrodes made up of different material and an electrolyte. The chemical reactions between the electrodes and the electrolyte produce voltage.

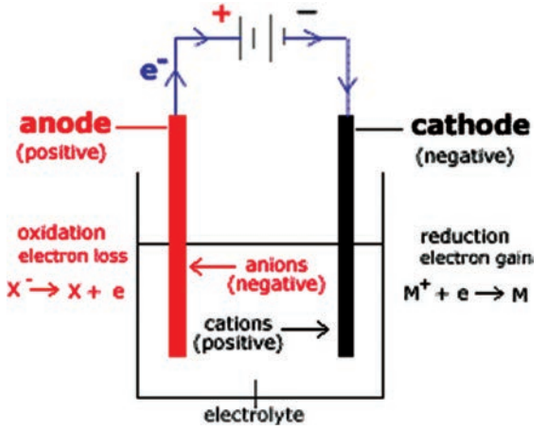


Fig 4.1 *Simple battery structure*

Cells are classified as 1. Dry and 2. Wet cells.

### 4.1.1 Dry cell

Dry cell is one that has a paste (or) gel electrolyte. It is semi sealed and can be used in any position. Nowadays the term 'Dry cell' refers to a cell that can be operated in any position without leakage.

### 4.1.2 Wet cell

Wet cells are cells that must be operated in an upright position. These cells have vents to allow the gases generated during charging or discharging to escape. The most common wet cell is the Lead-Acid cell.

### 4.1.3 Primary cells

Primary cells are those cells that are not rechargeable. That is, the chemical reaction that occurs during discharges is not easily reversed. When the chemicals used in the reactions are all converted, the cell is fully discharged. It must then be replaced by a new cell.

**Example:-**

Voltaic cell, Leclanche cell, Alkaline cell, Mercury cell, Lithium cell.

## 4.2 DRY CELL

The most common and the least expensive type of a dry cell battery in the Zinc-carbon type as shown in figure 4.2.

Fig 4.2 *Dry cell.*

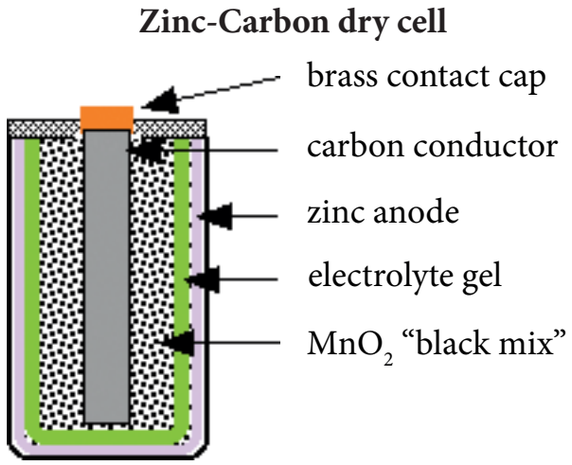


Fig 4.3 *Zinc-Carbon dry cell*

The Zinc-carbon consists of a zinc container which acts the negative electrode. In the center, a carbon rod is there which is electrode. The electrolyte in the form of a moist paste, made up of a solution containing ammonium chloride. As with all primary cells, one of the electrode becomes decomposed as part of chemical reaction. As a result, cells left in equipment for long periods of time can rupture, spilling the electrolyte and causing damage to the other parts.

Zinc-carbon cells are produced in common standard sizes. These include 1.5v AA, C, D cells.

(AA-pen type cell, C-minimum size, D-large/Economy size.)

### 4.2.1 Uses of primary cell

Primary cells are used in electronic products ranging from watches, smoke alarms, cardiac pacemaker torches, hearing aids, transister radios, etc.

### 4.2.2 Series cell connection

Cells are connected in series by connecting the positive terminal of one cell to the negative terminal of the next cell. (See the connection diagram in fig. 4.4)

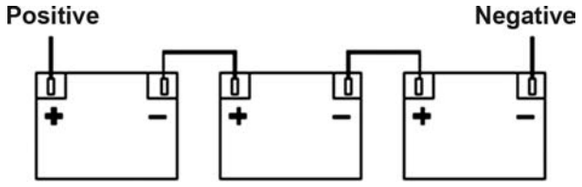


Fig 4.4 *Batteries in series connection*

Identical cells are connected in series to obtain a higher voltage is available as a single cell. With this connection of cells, the output voltage is equal to the sum of the voltages in the cells.However, the ampere hour rating remains equal to that of a single cell.

### 4.2.3 Parallel connection

Cells are connected in parallel by connecting all the positive terminals together and all the negative terminals together as shown in the fig 4.5.

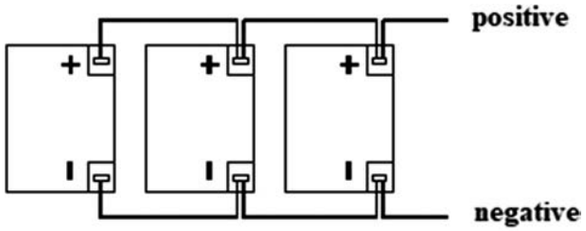


Fig 4.5 *Batteries in parallel connection*

Identical cells are connected in parallel to obtain a higher output current or ampere-hour rating. With this connection of cells, the output ampere-hour rating is equal to the sum of the ampere-hour rating of all the cells. However, the output voltage remains the same as that of a single cell.

When connecting groups of cells or batteries in parallel, each group must be in the same voltage level paralleling two batteries of unequal voltage levels set up a difference of potential energy between the two. As a result, the higher voltage battery will discharge its current into the other battery until both are at equal voltage value.

## 4.3 SECONDARY CELL

In a secondary cell, the charging and discharging processes are taking place according to Faraday's law of electrolysis.

A cell that can be recharged by sending electric current in the reverse direction to that of a discharge mode is known as a secondary cell. Secondary cells are Storage batteries since, after it is charged, it stores the energy until it is used or discharged.

### 4.3.1 Secondary cell classification

Secondary cells may be classified as

(i) Lead acid cell
(ii) Alkaline cell

Example: Nickel iron cell, Nickel cadmium cell

Secondary cell is a type of electrical battery, which can be charged, discharged into a load, and recharged many times, as opposed to a disposable or primary battery, which is supplied fully charged and discharged after use. It is composed of one or more electro chemical cells. The term 'accumulator' is used, as it accumulates and stores energy through a reversible electrochemical reaction. Rechargeable batteries are produced in many different shapes and sizes, ranging from button cells to mega watt systems connected to stabilize an electrical distribution network.

Several different combinations of electrode materials and electrolytes are used, including Lead-acid, Nickel-cadmium, Nickel-metal hydride, and Lithium ion.

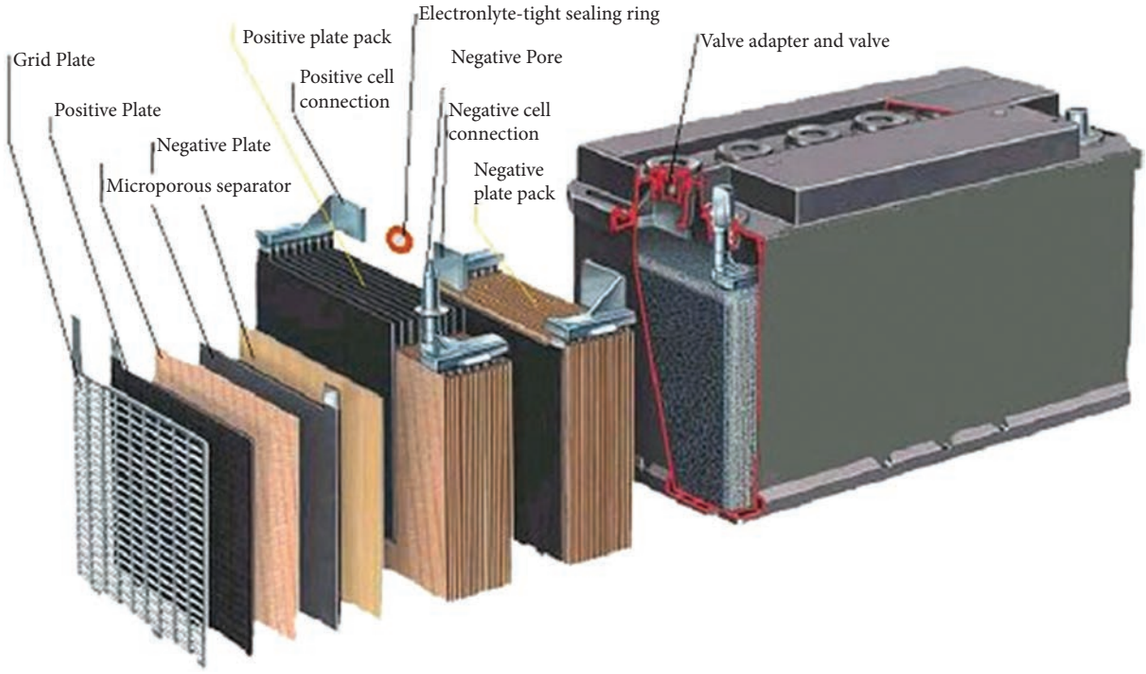


Fig 4.6 *Lead acid battery*

Initial cost of rechargeable batteries will be more than the disposable batteries, but have a much lower total cost of ownership.

Storage battery is a cell or a connected group of cells which converts chemical energy into electrical energy by reversible chemical reaction and may be recharged by passing a current through in the direction opposite to that of its discharge.

### 4.3.2 Lead acid battery

The battery which uses sponge lead and lead peroxide for the conversion of the chemical energy into electrical energy is called lead acid cell battery. This type of battery is most commonly used in the power stations and substations, because it has higher cell voltage and lower cost.

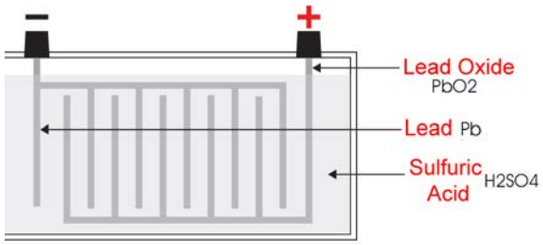


Fig 4.7 *Main parts of lead as acid battery*

**Construction**

First of all, we shall see the various parts of the lead acid cell battery with the help of fig 4.6. The container and the plates are the main parts of the lead acid cell battery.

**1. Container**

The container stores chemical energy which is converted into electrical energy with the help of plates. The container is made of glass, lead lined wood, ebonite, hard rubber of bituminous components, ceramic materials or moulded plastic and are seated at the top to avoid the discharge of electrolyte. At the bottom of the container, there are four ribs, on two of them rest on the positive plate and the others support the negative plate.

The prism serves as the support for the plates, and at the same time protects them from short-circuit. The material which the battery containers are made should be resistant to sulphuric acid.

**2. Plate**

The plates of the lead acid cell is of diverse designs and they all consist some form of a grid which is made up of lead and the active material. The grid is essential for conducting the electric current and for distributing the current equally on the active material. If the current is not uniformly distributed, then the active material will loosen and fall out.

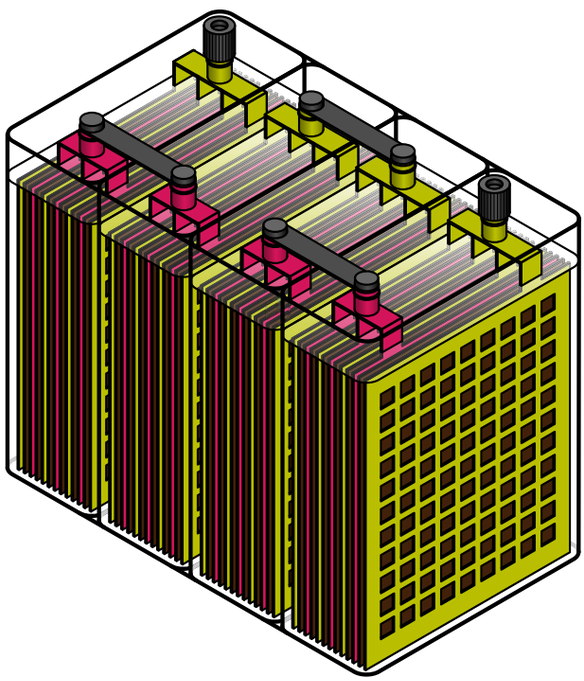

Fig 4.8 *Plate arrangements of lead-acid battery*

The grids are made up of an alloy of lead and antimony. The grid for the positive and negative plates are of the same design, (as shown in fig. 4.8) but the grids from the

negative plates are made lighter because they are not as essential for the uniform conduction of the current.

The number of negative plates in a cell is always more than one number of positive plates in a cell, so that end plates at both the sides of the group remain negative.

**3. Active material**

The material in a cell which takes active participation in a chemical reaction during charging or discharging is called the active material of the cell. The active element of the lead acid cells are

**a) Lead peroxide ($PbO_2$)**

It forms the positive active material. The $PbO_2$ is dark chocolate brown in colour.

**b) Sponge lead (Pb)**

It forms the negative active material. It is grey in colour.

**c) Dilute sulphuric acid ($H_2SO_4$)**

It is used as an electrolyte. It contains 31% of sulphuric acid.

**4.Separators**

The separators are thin sheets of non-conducting material made up of chemically treated leadwood, porous rubbers or mats of glass fibre and are placed between the positive and negative to insulate from each other. Separators are grooved vertically on one side and are smooth on the other side.

**5. Battery terminals**

A battery has two terminals:–

Positive and Negative

**a) Working principle**

In a lead acid cell, sulphuric acid is used as an electrolyte. In this $H_2So_4$, electrolyte is poured after pouring water in it. Then, sulphuric acid dissolves and the molecules of hydrogen and sulphate are formed. In this, hydrogen ions are positive and sulphate ions are negative.

Two electrodes of battery are dipped in an electrolyte and DC supply is given as an input. Hydrogen positive ions go towards negative plate of electrode. Sulphate negative ions go towards positive plate of the electrode. In this way lead acid battery functions.

The sign(+) indicates positive terminal and sign(–) indicates negative terminal

Positive terminal-17.5mm dia

Negative terminal-16mm dia

**b) Chemical reactions during discharging**

When the cell is discharging, current flow in the external circuit is from positive to negative. (See fig. 4.9) The flow of current through the electrolyte ($H_2SO_4$) splits into positive hydrogen ion ($H_{2-}^{+}$) and two negative sulphate ions ($SO_4^{-2}$).

Each sulphate ions move towards the cathode and on reaching there, give up two electrons to become radical $SO_4$, attack the metallic lead cathode and form lead sulphate, whitish in colour according to the chemical equation.

At Anode, $H_2$ combines with oxygen of $PbO_2$ and $H_2SO_4$ attacks lead to form $PbSO_4$.

At Anode:

$$PbO_2 + H_2 + H_2SO_4 \rightarrow PbSO_4 + 2H_2O$$

At cathode: $Pb + SO_4 \rightarrow PbSO_4$

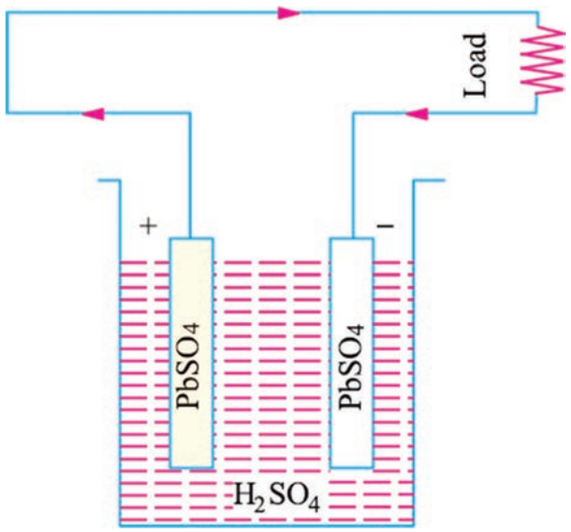


Fig 4.9 *Discharging process*

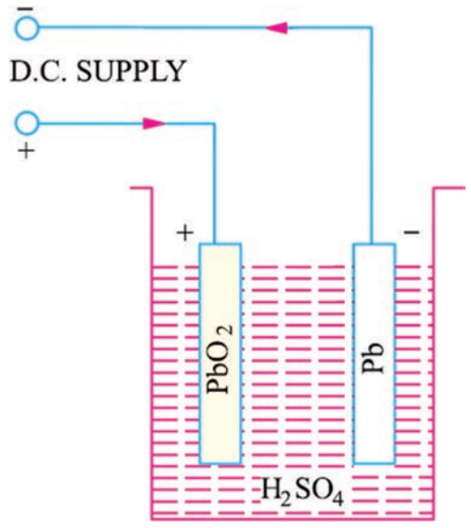


Fig 4.10 *Charging process*

**Physical changes while discharging**

1. Both the positive and negative plates are slowly converted into lead sulphate $PbSO_4$ (white in colour)
2. Water is formed during discharge. So the acid becomes more and more dilute. Specific gravity of sulphuric acid solution decreases.
3. Decrease in emf

**c) Chemical reaction during charging**

For recharging, the anode and cathode are connected to the positive and the negative terminal of the DC main supply. The hydrogen ions are positively charged move towards the cathode. (as in fig 4.10)

Sulphate ions move to the anode, and the following chemical reaction occurs.

At Anode: $PbSO_4 + H_2 \rightarrow Pb + H_2SO_4$

At Cathode:

$PbSO_4 + SO_4 + 2H_2O \rightarrow PbO_2 + 2H_2SO_4$

**Physical changes while charging**

1. Anode and cathode return back to their original colour (i.e positive plate dark brown and negative plate grey).
2. Specific gravity of an electrolyte is increased due to absorption of water.
3. Increase in emf values.

**d) Difference between primary and secondary cells**

| Primary cell | Secondary cell |
|---|---|
| 1. Primary cell cannot be recharged. | Secondary cell can be recharged. |
| 2. Chemical energy is converted into electrical energy. | In this, electrical energy is converted into chemical energy. |
| 3. Internal resistance is high. | Internal resistance is low. |
| 4. It is light in weight. | It is heavy in weight. |
| 5. It is less expensive. | More expensive. |
| 6. Short life. | Long life. |
| 7. Low efficiency. | High efficiency. |
| 8. Less maintenance. | High maintenance. |

## 4.4 LITHIUM ION BATTERY

A Lithium-ion battery is a type of rechargeable battery in which lithium ions move from the negative electrode to the positive electrode during discharge and lithium ions move from positive electrode to the negative electrode when charging.

The three primary functional components of a lithium ion battery are the positive electrode, negative electrode and electrolyte. The negative electrode is made from carbon. The positive electrode is a metal oxide and electrolyte is a lithium salt in an organic solvent.

Nominal cell voltage is 3.6/3.85 Volt


Fig 4.11 *Lithium ion battery*

Lithium ion battery is a primary cell type battery. (see fig 4.11) It is available in variety of sizes and configurations. Depending on the chemicals used with lithium, the cell voltage is between 2.5 to 3.6volt.

### 4.4.1 Advantages of lithium battery

The are many advantages of using lithium-ion battery.

**i) High energy density**

The main advantage of lithium ion battery is high energy density. In mobile phones, it needs to operate for a long time between charges while still charging more power, there is always a need to batteries, with a much higher energy density. It is a distinct advantage.

**ii) Self discharge**

One issue with battery is that they loose their charges overtime. The main advantage is that the rate of self-discharge is very low than the other batteries.

**iii) No requirement for priming**

In this, lithium ion battery does not need to be primed, but the other batteries require priming.

**iv) Low maintenance**

Lithium ion battery does not require any maintenance to ensure the performance.

### 4.4.2 Disadvantages

The disadvantages of lithium ion battery are as follows:

**i) Protection required**

Lithium ion cells require protection from being overcharged and discharged too much. In addition, they need to have the current maintained within safe limits. Accordingly, lithium ion battery disadvantage is that they require protection to ensure that is it kept within the safe operating limits.

**ii) Ageing**

Another disadvantage of this battery is ageing. The battery is dependent upon the number of charge and discharge cycles that the battery has undergone. Lithium ion battery should be kept in a cool storage area, that will increase the life of battery.

**iii) Transportation**

Lithium ion battery applications are restricted on their transportation, especially by air. These batteries require care and protection while on transportation.

**iv) Cost**

The cost of lithium ion battery is high compared with other types of batteries.

## 4.5 SEVEN FEATURES ABOUT THE DISPARITY BETWEEN LEAD ACID AND LITHIUM ION BATTERIES

**1. Weight**

Lithium ion batteries are one third the weight of lead acid batteries

**2. Efficiency**

Lithium-ion batteries are of nearly 100% efficiency both charge and discharge, allowing the same ampere hours both in and out. But lead acid cell battery is 85% efficiency.

**3. Discharge**

Lithium-ion batteries are discharged 100%, but lead acid batteries discharge less than 80%.

**4. Life cycle**

Life cycle of the lithium-ion battery is 400–1200 cycles, whereas lead acid battery life cycle is 400 to 500 cycles

**5. Voltage**

Lithium-ion batteries maintain their voltage throughout the entire discharge cycle. This allows greater and longer lasting efficiency of electrical components. Lead acid cell battery voltage drops consistently throughout the discharge cycle.

**6. Cost**

Despite the higher upfront cost of lithium ion batteries, the true cost of ownership is less than lead acid battery when considering the life span and performance.

**7. Environmental impact**

Lithium ion batteries are updated technology and are safer for the environment.

**Applications**

Lithium-ion batteries are one of the most popular types of rechargeable battery for portable electronics with a high energy density, tiny memory effect and low self-discharge. Also used in electric vehicle and aerospace application.

## 4.6 UPS BATTERY

Fig 4.12 *UPS Battery*

An uninterruptible power supply is called UPS. It is a device that permits supply to keep on running for a short period of time, when the primary power is off.

UPS contains a battery that "kicks in" when the device senses a loss of power from the primary source (as in fig. 4.12).

If you are using computer, when the UPS notifies you of the power loss, you have time to save and data you are working on and exit, before the secondary power source runs out. When all power runs out, any

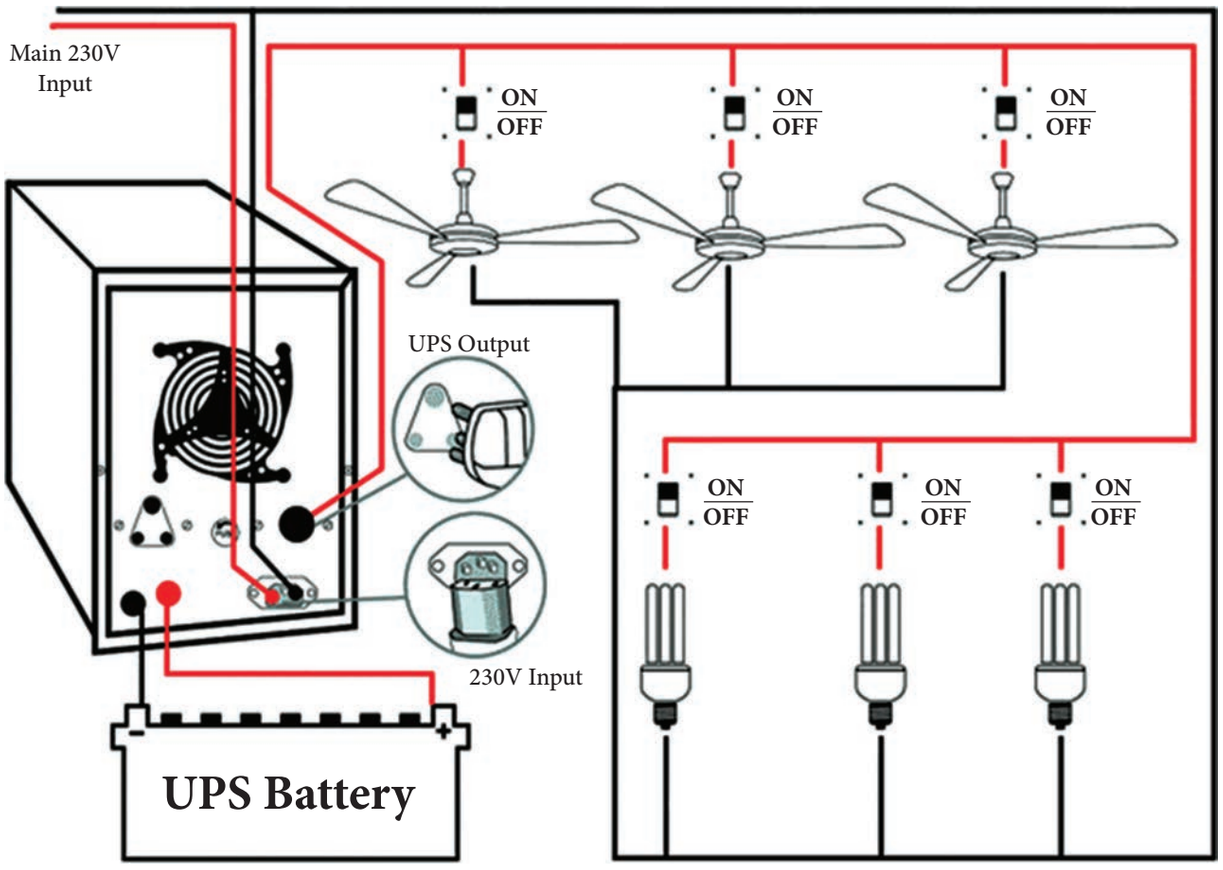


Fig 4.13 *Components of UPS System*

data in computers Random Access Memory (RAM) is erased when power surges occur, a UPS intercepts the surge, so that it doesn't damage the computer.

**How does UPS work?**

In a continuous UPS, the computer is always running short of battery power and the battery is continuously being recharged. The battery charger continuously produces DC power, which the inverter continuously turns back into 120 volt AC power. If the power fails, the battery provides power to the inverter.

**Components of UPS (Ref. fig. 4.13)**

1. The Static Bypass
2. The Rectifier
3. The Battery
4. The Inverter

**Types of UPS**

| Range | | Types |
|---|---|---|
| 0.5 to 3 KVA | - | Line interactive |
| 0.5 to 5 KVA | - | Stand by online hybrid |
| 3.0 to 15 KVA | - | Stand by ferro double |
| 5.0 to 5000KVA | - | Conversion online |

## 4.7 MAINTENANCE OF BATTERIES

1. Battery should be cleaned properly
2. Cable connection of the battery should be clean and tightened, Many battery problems are caused by dirty and loose connection.
3. The fluid level of the battery will always be higher at a full charge.

4. Distilled water alone is the best for filling because other types of water are loaded with chemicals and minerals that are harmful to the battery. Don't over fill the battery especially in warm weather.
5. Use silicon seals in the cable leads. Coat the cable washer end with grease or petroleum jelly (vaseline).

## 4.8 DO'S AND DONT'S OF STORAGE BATTERY

**Do's**

1. Store batteries in a clean, ventilated and dry area.
2. Store batteries in a fully charged state.
3. Ensure the correct polarity connection when recharging.
4. Follow proper recharging schedules to prevent overcharging.
5. Keep the battery away from spark, heat and sources of fire.
6. Use proper size of cables along with correct plugs.
7. Charge the batteries immediately after it is discharged.
8. Terminal bolts are to be tightened with spring washers and apply torque. The tightness is to be checked.

**Don'ts**

1. Do not add any acid or distilled water in battery, during supply.
2. Do not tamper the vent plug.
3. Do not over tight or make loose the terminal bolts which may cause terminal breakage or fire due to loose contact.
4. Do not keep any metal object to rest on battery. It may cause short circuit.
5. Do not keep the battery in direct sunlight, dust or moist area.
6. Do not allow discharged battery for more than 12 hours in idle condition.

**Precautions**

1. Always handle a battery and its parts by wearing hand gloves, as the acid is corrosive.
2. Always pour the acid into water and not the water into the acid. Heat is produced when the acid is mixed with water.
3. Since the electrolyte is highly corrosive, the storage of electrolyte is used only glass or lead lined container If the batteries are handled with the above precautionary measures, the life of the battery will be prolonged. Follow the correct procedures and be safe while handling the battery.

## 4.9 NINE TIPS FOR PROPER BATTERY CARE

1. Size your battery correctly.
2. Periodically check the voltage of your batteries.
3. Don't try to charge alkaline batteries.
4. Prevent alkaline batteries from leaking.
5. Take care with parallel connections.
6. Give VRLA (Valve-Regulated Lead-Acid) battering breathing space.
7. Don't leave lead acid batteries in a discharged state.
8. Take off golden ornaments when connecting a battery.
9. Protect from cold temperatures and snowy climates.

## Activities

1. Test the supply voltage from lemon?
2. Test the voltage produced in carrot?
3. How to produce electricity from orange?

## GLOSSARY

| | | |
|---|---|---|
| Battery | — | மின்கலம் |
| Dry cell | — | உலர் மின்கலம் |
| Wet cell | — | பசை மின்கலம் |
| Separator | — | பிரிப்பான் |
| Charging | — | மின்னேற்றம் |
| Discharging | — | மின்னிறக்கம் |
| UPS-Battery (Un-interrupted Power Supply) | — | தடையில்லா மின்சாரம் தரும் சாதனம் |

## Q A

## PART A

Mark 1

8WSZM

**Choose the correct answer:**

1. Battery is a storage of _____
   a) heat energy
   b) electrical energy
   c) chemical energy
   d) solar energy
2. In battery, chemical energy is trans-formed into _____ energy.
   a) electrical energy
   b) light energy
   c) sound energy
   d) heat energy.
3. Primary cells are _____
   a) not rechargeable
   b) chargeable
   c) partly chargeable
   d) not available
4. In dry cell, carbon rod is _____ electrode
   a) positive electrode
   b) negative electrode
   c) phase
   d) neutral

5. Charging and discharging process in secondary cell fulfills in which law?
   a) Ohm's law
   b) Faraday's laws of electrolysis
   c) Lenz's laws
   d) current law
6. Lead acid battery is commonly used in _____
   a) railway station
   b) radio station
   c) TV station
   d) power station and substation
7. Separators in a battery is of _____ material
   a) conductive
   b) non –conductive
   c) partly conductive
   d) heavy conductive
8. The voltage range of lithium-ion battery is _____
   a) 2 to 2.5V
   b) 2.5 to 3.6V
   c) 3.6 to 5V
   d) 5 to 6.6V
9. Advantage of using lithium ion battery is _____
   a) high energy density
   b) low energy density
   c) medium energy density
   d) poor energy density
10. The battery used in electric vehicles and Aerospace applications is_____
   a) lead acid cell battery
   b) lithium-Ion battery
   c) UPS battery
   d) charger battery

## Q A

## PART B

**Mark 3**

### Answer the questions in briefly

1. What is called a battery?
2. State the different types of battery.
3. Write about the primary cell.
4. State the uses of a primary cell.
5. What is called a secondary cell?
6. What is called a Lead acid cell battery?
7. What is a the use of separators?
8. What is called a Lithium-ion battery?
9. Write a short note on UPS Battery.
10. Write down the types and range of UPS.
11. What are the precautions to be followed in a battery?

## Q A PART C

**Mark 5**

**Answer the questions not exceeding one page**

1. State the differences between primary and secondary cell.
2. State the advantages of lithium-ion battery.
3. Write seven features about the disparity between a Lead acid and a lithium ion battery.
4. State the Do's and Don'ts of a storage battery.
5. What are the maintenance produces to be observed in a battery?

## Q A PART D

**Mark 10**

**Answer the questions not exceeding two page**

1. Explain dry cell with a neat sketch.
2. Explain the construction working principle of lead acid battery.
3. Explain the chemical reactions and physical changes during discharging in lead-acid battery.
4. Explain the chemical reactions and physical changes during charging in lead-acid battery.
5. Explain in detail about Lithium ion battery with diagram.
6. Draw and explain about an UPS battery with a circuit diagram.

## Reference book

1. A text book of Electrical Technology' Volume I and Volume III by B.L. Theraja and A.K. Theraja, S. Chand & Company Ltd.

## Internet resource

www.sciencebuddies.org