Rugved Task 5

1. Batteries

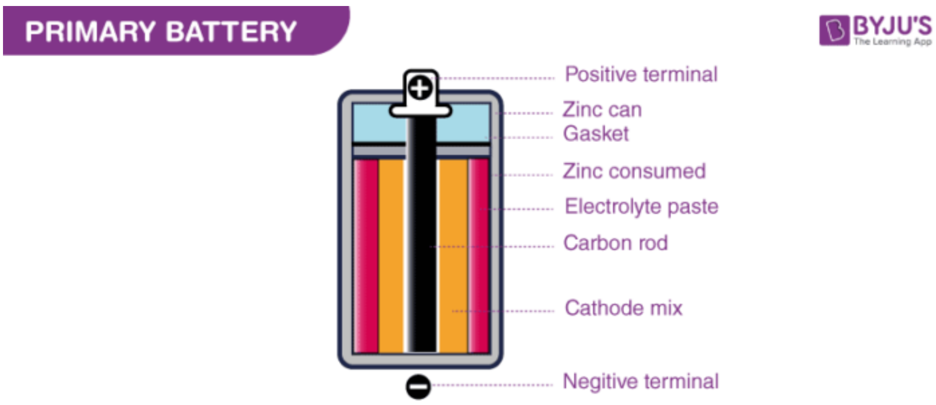
(i) Types of Batteries

There are two main types of batteries: -

- Primary Batteries
- Secondary Batteries

a) Primary Batteries

A Primary Battery is one of the simple and convenient sources of power for several portable electronic and electrical devices like lights, cameras, watches, toys, radios etc. As they cannot be recharged electrically, they are of “use it and when discharged, discard it” type.
Usually, primary batteries are inexpensive, light weight, small and very convenient to use with relatively no or less maintenance. Majority of the primary batteries that are used in domestic applications are single cell type and usually come in cylindrical configuration (although, it is very easy to produce them in different shapes and sizes).



Some of the common types of Primary Batteries: -

Battery Type	Characteristics	Applications
Zinc – Carbon	Common, low cost, variety of sizes	Radios, toys, instruments
Magnesium (Mg/MnO2)	High capacity, long shelf life	Military and aircraft Radios
Mercury (Zn/HgO)	Very high capacity, long shelf life	Medical (hearing aids, pacemakers), photography
Alkaline (Zn/Alkaline/MnO2)	Very popular, moderate cost, high performance	Most popular primary batteries
Silver/Zinc (Zn/Ag2O)	Highest capacity, costly, flat discharge	Hearing aids, photography, pagers
Lithium/Soluble Cathode	High energy density, good performance, wide temp range	Wide range of applications with capacity between 1 – 10,000 Ah
Lithium/Solid Cathode	High energy density, low temp performance, long shelf life	Replacement for button and cylindrical cells
Lithium/Solid Electrolyte	Low power, extremely long shelf life	Memory circuits, medical electronics

b) Secondary Batteries

A Secondary Battery is also called as Rechargeable Battery as they can be electrically recharged after discharge. The chemical status of the electrochemical cells can be “recharged” to their original status by passing a current through the cells in the opposite direction of their discharge.

Basically, secondary batteries can be used in two ways:

- In the first category of applications, the secondary batteries are essentially used as energy storage devices where they are electrically connected to a main energy source and charged by it and supplying energy when required. Examples of such applications are Hybrid Electric Vehicles (HEV), Uninterrupted Power Supplies (UPS), etc.
- The second category of applications of secondary batteries are those applications where the battery is used and discharged as a primary battery. Once it is completely discharged (or almost completely discharged), instead of discarding it, the battery is recharged with an appropriate charging mechanism. Examples of such applications are all the modern portable electronics like mobiles, laptops, electric vehicles, etc.

- Energy Density of secondary batterie are relatively lower than that of primary batteries but have other good characteristics like high power density, flat discharge curves, high discharge rate, low temperature performance.

There are 4 types of Secondary Batteries: -

- Lead-Acid Batteries
- Nickel-Cadmium Batteries
- Lead-Metal Hydride Batteries
- Lithium-Ion Batteries

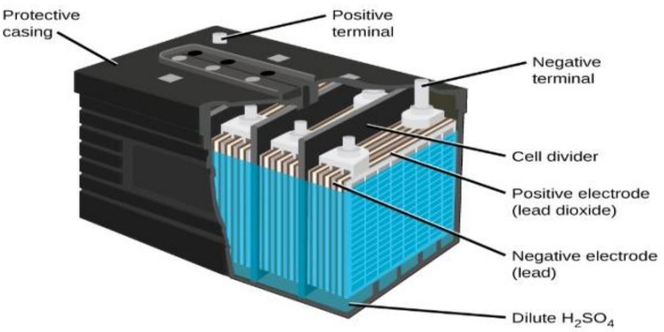
I. Lead-Acetate Batteries

The lead-acid batteries are by far the most popular and most used rechargeable batteries. They have been a successful product for more than a century. Lead-acid batteries are available in several different configurations like small sealed cells with capacity of 1 Ah to large cells with capacity of 12,000 Ah.

Electrical efficiency of lead-acid batteries is between 75 to 80%. This efficiency value them suitable for energy storage (Uninterrupted Power Supplies – UPS) and electric vehicles.

One of the major applications od lead-acid batteries are in the automotive industry as they are primarily used as SLI Batteries (Starting, Lighting and Ignition).

Other applications of lead-acid batteries include energy storage, emergency power, electric vehicles (even hybrid vehicles), communication systems, emergency lighting systems, etc.



II. Nickel-Cadmium Batteries

The Nickel – Cadmium Batteries or simply Ni-Cd Batteries are one of the oldest battery types available today along with the lead-acid batteries. They have a very long life and are very reliable and sturdy.

One of the main advantages of Ni-Cd Batteries is that they can be subjected to high discharge rates and they can be operated over a wide range of temperatures. Also, the shelf life of Ni-Cd batteries is very long. The cost of these batteries is higher that lead-acid batteries on per Watt-hour basic but it is less that other type of alkaline batteries.

As mentioned earlier, the Ni-Cd batteries use Nickel Oxyhydroxide (NiOOH) as Cathode and Cadmium metal (Cd) as anode. Typical consumer grade batteries come with an on-line voltage of 1.2V. In industrial applications, Ni-Cd are just second to lead-acid batteries due to their low temperature performances, flat discharge voltage, long life, low maintenance and excellent reliability.

Unfortunately, there is one major characteristic of Ni-Cd batteries called the “memory effect”, which is their only disadvantage. When Ni-Cd cells are discharged partially and then recharged, they lose their capacity progressively i.e., cycle-by-cycle. “Conditioning” is the process where the lost capacity of the batteries can be restored.

III. Nickel-Metal Hydride Batteries

These are relatively new type of batteries are an extended version of Nickel – Hydrogen Electrode Batteries, which were exclusively used in aerospace applications (satellites). The positive electrode is the Nickel Oxyhydroxide (NiOOH) while the negative electrode of the cell is a metal alloy, where hydrogen is stored reversibly.

During charge, the metal alloy absorbs the hydrogen to form metal hydride and while discharge, the metal hydride loses hydrogen.

One main advantage of Nickel-metal hydride batteries over Ni-Cd batterie its higher specific energy and energy density. Sealed Nickel-metal hydride batteries are available commercially as small cylindrical cells and are used in portable electronics.

IV. Lithium-Ion Batteries

The emergence of lithium-ion batteries in the last couple of decades has been quite phenomenal. More than 50% of the consumer market has adopted the use of lithium-ion batteries. Particularly, laptops, mobile phones, cameras, etc. are the largest applications of lithium-ion batteries.

Lithium-ion batteries have significantly high energy density, high specific energy and longer cycle life. Other main advantages of lithium-ion batteries are slow self-discharge rate and wide range of operating temperatures.

(ii) Application

Batteries are electrochemical devices, which contain one or more electrochemical cells and can be charged with an electric current. Batteries can be discharged whenever required.

- Batteries are devices composed of multiple electrochemical cells connected to external inputs and outputs.
- It is widely used to power small electric devices, including mobile phones, remotes, and flashlights.
- Historically, the term ‘battery’ has been used to refer to a combination of two or more electrochemical cells.
- However, the modern battery definition only applies to accommodate devices featuring a single cell.

2. Battery Parameters

a. Storage Capacity:

It determines for number of hours for which the battery can be discharged at a constant current to a defined cutoff voltage. It is represented by the Coulomb SI unit (Amperes per second) but since this unit is usually very small, the Ampere-hour (Ah) unit is used instead (1 Ah represents 3600 C).

The value of this capacity depends on the ambient temperature, the age of the battery, and the discharge rate. The higher the discharge rate, the lower the capacity, although it affects each battery technology differently. Additional to the Ampere-hour unit, the storage capacity can also be defined in Watt-hours (Wh=V x Ah), where 1 Wh represents 3600 J.

b. Energy Density:

The energy density is the amount of energy that can be stored, per cubic meter of battery volume, expressed in Watt-hour per cubic meter (Wh/m3). This is a very important parameter to select a specific battery technology for transportation applications, where space availability is critical.

c. Specific Power:

This parameter is defined as the power capacity per kilogram of battery, in W/kg . Some battery technologies offer high energy density but low specific power, which means that even though they can store a large amount of energy, they can only supply a small amount of power instantly. In transportation terms, this would mean that a vehicle could run for a long distance, at low speed. On the contrary, batteries with high specific power usually have low energy density, because high discharge currents usually reduce the available energy rapidly (e.g., high acceleration)

d. Cell Voltage:

The cell voltage is determined by the equilibrium thermodynamic reactions that take place inside the cell; however, this value is often difficult to measure and therefore, the open circuit voltage (OCV) measured between the anode and cathode terminals is used instead. For some battery technologies (e.g., lead-acid), the OCV can be used as a basic estimate of the state of charge (SoC). Another measure often used is the closed-circuit voltage (CCV), which depends on the load current, state of charge, and cell's usage history. Finally, battery manufacturers provide the nominal voltage value, from the cell's characterization and therefore, cannot be experimentally verified

e. Charge and Discharge Current:

During the discharging process in a battery, electrons flow from the anode to the cathode through the load, to provide with the required current and the circuit is completed in the electrolyte. During the charging process, an external source supplies with the charging current and the oxidation takes place at the positive electrode while the reduction takes place at the negative electrode. For practical purposes, the term C-rate is used to express the charge or discharge current relative to the rated capacity. For example, a discharge rate of 1 C means that the battery will be fully discharged in 1 h.

f. State of Charge:

The state of charge (SoC) defines the amount of stored energy relative to the total energy storage capacity of the battery. Depending on the battery technology, different methods are used to estimate this value.

g. Depth of Discharge:

Often referred to as DoD (in %), this parameter expresses the battery capacity that has been discharged relative to the maximum capacity. Each battery technology supports different maximum recommended levels of DoD to minimize its impact on the overall cycle life.

h. Cycle Life:

The cycle life determines the number of charge/discharge cycles that the battery can experience before it reaches a predetermined energy capacity or other performance criteria. The current rate at which the battery is charged/discharged as well as environmental conditions (e.g., temperature and humidity) and the DoD can affect this number, since it is originally calculated by the manufacturer based on specific charge and discharge conditions.

i. Self-discharge:

This parameter defines the reduction in energy capacity of the battery under no-load conditions (e.g., open circuit), as a result of internal short-circuits and chemical reactions. This parameter can be affected by environmental conditions such as temperature and humidity, as well as the DoD and the battery's charge/discharge history. Additionally, this parameter is particularly important for long-term shelf storage of batteries.

j. Round-Trip Efficiency:

Due to internal losses and material degradation, not all the energy supplied to the battery during charging can be recovered during discharge. The amount of energy that can be taken from the battery during the discharging process over the energy supplied determines the round-trip efficiency. This efficiency is sensitive to the charging and discharging currents. At higher currents, thermal losses increase and therefore the efficiency is reduced