Types of Batteries, their important characteristics and Applications

- Batteries are complex electrochemical devices, composed of distinct cells, that generate electrical energy from the chemical energy of their cell components
- A battery cell consists primarily of a:
  - Metallic anode (negative electrode),
  - A metallic oxide cathode (positive electrode), and
  - An electrolyte material that facilitates the chemical reaction between the two electrodes.
- Electric currents are generated as the anode corrodes in the electrolyte and initiates an ionic exchange reaction with the cathode
- Batteries are used in motor and marine vehicles, electronics, watches, cameras, calculators, hearing aids, cordless telephones, power tools and countless other portable household devices.

Types of Batteries

Batteries are classified and distinguished according to their chemical components.

- Batteries are referred to as wet or dry cells.
- In wet cell batteries, the electrolyte is a liquid.
- In dry cell batteries, the electrolyte is contained in a paste, gel or other solid matrix within the battery.

But under all of these are two major battery types;

1. Primary Batteries
2. Secondary Batteries

1. Primary Batteries

- Primary batteries contain cells in which the **chemical reactions** are **irreversible**, and they therefore cannot be **recharged**.
- Primary batteries exist in different forms **ranging from coin cells to AA batteries**. They are commonly used in standalone applications where charging is impractical or impossible.

- Primary batteries always have high **specific energy** and the systems in which they are used are always designed to consume low amount of power to enable the battery last as long as possible.
- Some other **examples of devices using primary batteries include**;
  a. Pace makers,
  b. Animal trackers,
  c. Wrist watches,
  d. remote controls; and
  e. children toy to mention a few.

Figure: Primary Batteries

- The most popular type of primary batteries are **alkaline batteries**.
- They have a high specific energy and are environmentally friendly, cost-effective and do not leak even when fully discharged.
- They can be stored for several years, and have a good safety record.
- The only disadvantage to alkaline batteries is the low load current, which limits its use to devices with low current requirements like remote controls, flashlights and portable entertainment devices.

2. Secondary Batteries

- Secondary batteries are batteries with electrochemical cells whose chemical reactions can be reversed by applying a certain voltage to the battery in the reversed direction.
- Also referred to as **rechargeable batteries**, secondary cells unlike primary cells can be recharged after the energy on the battery has been used up.

- Secondary batteries are further classified on the basis of their charge capacity. Such as **small capacity** and **heavy duty batteries**.
- **Small capacity secondary batteries** are used to power portable electronic devices like **mobile phones**, and other gadgets and appliances.
- While **heavy-duty batteries** are used in powering diverse **electric vehicles** and other high drain applications like **load levelling** in electricity generation. T
- They are also used as standalone power sources alongside **Inverters to supply electricity**.
- Although the **initial cost** of acquiring **rechargeable** batteries is always higher than that of **primary batteries** but they are the most **cost-effective** over the **long-term**.
- Secondary batteries can be further classified into several other types based on their chemistry**.**
- This is very important because the chemistry determines some of the attributes of the battery including its specific energy, cycle life, shelf life, and price to mention a few.

There are basically four major chemistries for rechargeable batteries;

1. Lithium-ion(Li-ion)
2. Nickel Cadmium(Ni-Cd)
3. Nickel-Metal Hydride(Ni-MH)
4. Lead-Acid

1. Nickel-Cadmium Batteries

The nickel–cadmium battery (NiCd battery or NiCad battery) is a type of rechargeable battery which is developed using nickel oxide hydroxide and metallic cadmium as electrodes.

Some of the properties of Nickel-Cadmium batteries are listed below.

- Specific Energy: 40-60W-h/kg
- Energy Density: 50-150 W-h/L
- Specific Power: 150W/kg
- Charge/discharge efficiency: 70-90%
- Self-discharge rate: 10%/month
- Cycle durability/life: 2000cycles

Figure: Nickel – Cadmium battery

2. Nickel-Metal Hydride Batteries

- Nickel metal hydride (Ni-MH) is another type of chemical configuration used for rechargeable batteries.
- The chemical reaction at the positive electrode of batteries is similar to that of the nickel–cadmium cell (NiCd), with both battery type using the same nickel oxide hydroxide (NiOOH).
- However, the negative electrodes in Nickel-Metal Hydride use a hydrogen-absorbing alloy instead of cadmium which is used in NiCd batteries.

Figure: Ni-MH Battery

Some of the properties of batteries based on the Nickel-metal hydride chemistry;

- Specific Energy: 60-120h/kg
- Energy Density: 140-300 Wh/L
- Specific Power: 250-1000 W/kg
- Charge/discharge efficiency: 66% - 92%
- Self-discharge rate: 1.3-2.9%/month at 20oC
- Cycle Durability/life: 180 -2000

3. Lithium-ion Batteries

- Lithium ion batteries are one of the most popular types of rechargeable batteries.
- They are found in different portable appliances including mobile phones, smart devices and several other battery appliances used at home.
- They also find applications in aerospace and military applications due to their lightweight nature.

Figure: Lithium-Ion Battery

Some of the attributes of lithium ion batteries are listed below;

- Specific Energy: 100: 265W-h/kg
- Energy Density: 250: 693 W-h/L
- Specific Power: 250: 340 W/kg
- Charge/discharge percentage: 80-90%
- Cycle Durability: 400: 1200 cycles
- Nominal cell voltage: NMC 3.6/3.85V

4. Lead-Acid Batteries

- Lead acid batteries are a low-cost reliable power workhorse used in heavy duty applications.
- Lead-acid storage batteries are used in automobiles, motorcycles, boats and several industrial applications.
- They are primarily used to provide starting, lighting and ignition for automotive products.
- These are wet cell batteries consisting of lead electrodes in a liquid sulfuric acid electrolyte.
- The average battery weighs ~16 kg, one-half of which is composed of lead anode and lead dioxide cathode

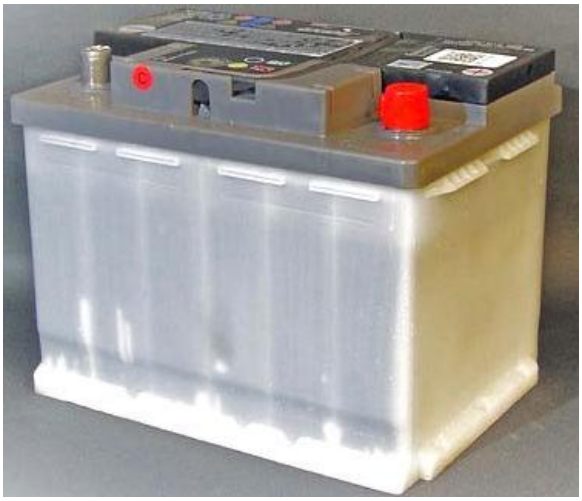

Figure: Lead – Acid Battery

- In addition to lead, each battery contains;
  - ~ 4 L of sulfuric acid,
  - ~ 1.5 kg of polypropylene plastic casing,
  - ~ 1.5 kg of polyvinyl chloride rubber separators, and
  - ~ 1.5 kg of various chemical sulfates and oxides to which the lead is bound.
- The typical useful lifetime of lead-acid storage batteries is 3 to 4 years.

Criterion to select a battery for appropriate application:

Factors to consider when selecting the right type of battery for an appropriate application are listed below:

1. **Energy Density:** The energy density is the total amount of energy that can be stored per unit mass or volume. This determines how long your device stays on before it needs a recharge.

2. Power Density: Maximum rate of energy discharge per unit mass or volume. Low power: laptop, i-pod. High power: power tools.

3. Safety: It is important to consider the temperature at which the device you are building will work. At high temperatures, certain battery components will breakdown and can undergo exothermic reactions. High temperatures generally reduces the performance of most batteries.

4. Life cycle durability: The stability of energy density and power density of a battery with repeated cycling (charging and discharging) is needed for the long battery life required by most applications.

5. Cost: Cost is an important part of any engineering decisions you will be making. It is important that the cost of your battery choice is commensurate with its performance and will not increase the overall cost of the project abnormally.