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Energy Sources



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Introduction

A battery consists of two or more electric cells joined together. The cells convert chemical energy to electrical energy. The cells consist of positive and negative electrodes joined by an electrolyte. It is the chemical reaction between the electrodes and the electrolyte which generates DC electricity. In the case of secondary or rechargeable batteries, the chemical reaction can be reversed by reversing the current and the battery returned to a charged state



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Working Principle of Battery

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.

The cathode forms the negative terminal whereas anode forms the positive terminal of a battery. To understand the basic principle of battery properly, first, we should have some basic concept of electrolytes and electrons affinity. Actually, when two dissimilar metals are immersed in an electrolyte, there will be a potential difference produced between these metals.

It is found that, when some specific compounds are added to water, they get dissolved and produce negative and positive ions. This type of compound is called an electrolyte. The popular examples of electrolytes are almost all kinds of salts, acids, and bases etc. The energy released during accepting an electron by a neutral atom is known as electron affinity. As the atomic structure for different materials are different, the electron affinity of different materials will differ.



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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. Which metal (or metallic compound) will gain electrons and which will lose electrons, depend upon the electron affinity of these metals. 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 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.

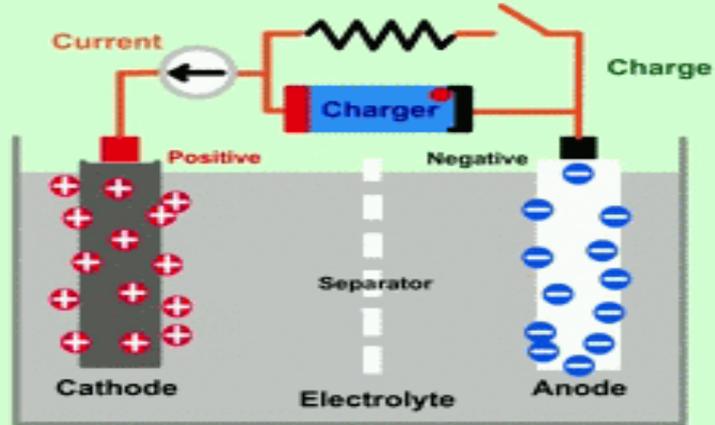
This difference in electron concentration causes an electrical potential difference developed between the metals. This electrical potential difference or emf can be utilized as a source voltage in any electronics or electrical circuit. This is a general and basic **principle of battery** and this is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



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Types of Batteries

Basically, batteries are divided into 2 types:

- Batteries that are non-rechargeable (primary batteries)
- Batteries that are rechargeable (secondary batteries)

Non-rechargeable Battery:

Basically, they are known as main batteries and they can only be used once. It is difficult to recharge these batteries and use them again. Let's see about the daily, everyday life of the main batteries we see.

Rechargeable Batteries

This are commonly referred to as secondary batteries that can be recharged and used again. While the cost is high, they can be recharged and reused and, when well used and safely charged, can have a large life cycle.

➤ **Lead-acid Batteries**

It consists of very inexpensive lead-acid that is often used in cars and trucks to fuel the lighting systems in it. In products where size / space and weight do not matter, these are more preferable. These come with a nominal voltage starting from 2V to 24V and are most widely used as batteries of 2V, 6V, 12V and 24V. It has a density of 7 Wh / Kg of energy.

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Advantages:

1. Inexpensive in price
2. Rechargeable quickly
3. Capability of high-power performance

Disadvantages:

1. Quite heavy, quite heavy.
2. Occupying a lot of space
3. The density of power is very low

Applications:

Used in vehicles, robots, heavy equipment, UPS (uninterrupted power supply), etc

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➤ **Ni-Cd Batteries:**

These batteries have a chemical composition of nickel and cadmium. While they are very rarely used, they are very inexpensive and, relative to NiMH batteries, their discharge rate is very low. These are available in AA, AAA, C and rectangular shapes in all regular sizes. In a range of 3 which gives 3.6V, the nominal voltage is 1.2V, always linked together. It has an output density of 60 Wh / Kg



Advantages:

1. Inexpensive in price
2. Quick to recharge
3. Available in all environments
4. Comes in all traditional sizes



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Disadvantages:

1. Higher density of electricity
2. Contains radioactive metal
3. To prevent the growth of crystals on the battery layer, it needs to be charged very regularly.

Applications:

Used in RC toys, cordless phones, solar lights, and mostly in applications where price is significant.

- Ni-MH batteries



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Because of their lower environmental effects, the Nickel-Metal Hydride batteries are even safer than Ni-Cad batteries. Its nominal voltage, higher than Ni-Cad batteries, is 1.25 V. It has less nominal voltage than alkaline batteries and, owing to its affordability and less environmental effects, is a reasonable substitute. For Ni-MH batteries, the power density is 100 Wh / Kg.

Advantages:

1. Accessible in all sizes that are normal.
2. Elevated density of electricity.
3. Recharge quickly.
4. A strong substitute to alkaline, which is rechargeable and has about any resemblance.

Disadvantages:

1. Self-discharge is exceptionally high.
2. It's cheaper than Ni-Cad batteries.

Applications:

Used in both alkaline and Ni-Cad battery-like applications.

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➤ **Li-Po batteries**

This are often referred to as rechargeable Lithium Ion polymer batteries because they use electrolyte polymer gel / polymers of high conductivity instead of liquid electrolyte. Under the Li-ion technology, these arrive. This are a little expensive. But, as opposed to Li-ion batteries, the battery is very well shielded. It has a density of 185 Wh / Kg of energy.



Advantages:

1. These, similar to Li-ion batteries, are extremely protective.
2. Extremely light in weight
3. Thin as opposed to Li-ion batteries in structure.
4. Compared to Ni-Cad and Ni-MH batteries, power density and nominal voltages are comparatively very high.

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Disadvantages:

1. Costly.
2. If wrongly linked, it could blow.
3. It should not be twisted or exposed to elevated temperatures that can cause an explosion.

Applications:

It can be found in all handheld gadgets such as helicopters, robots, RC toys, etc. that need to be recharged.

➤ **Li-ion batteries**

They are composed of lithium metal and are the newest in rechargeable technologies. Since they are small in nature, they can be used in most lightweight applications that need requirements for high strength. These are the best available rechargeable batteries. These have a nominal voltage of 3.7V (we have 3.6V and 7.2V most commonly) and have varying power capacity levels (from mAh 100s to mAh 1000s). The C-rate also varies from 1C to 10C and the Li-ion battery power capacity is 126 Wh / Kg

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Advantages:

1. The weight was really light.
2. Elevated C-rating.
3. The energy density is incredibly high.
4. The cell voltage is elevated.

Disadvantages:

1. They're a little pricey.
2. If the terminals are short circuited the battery could burst.
3. A circuit for battery protection is required.

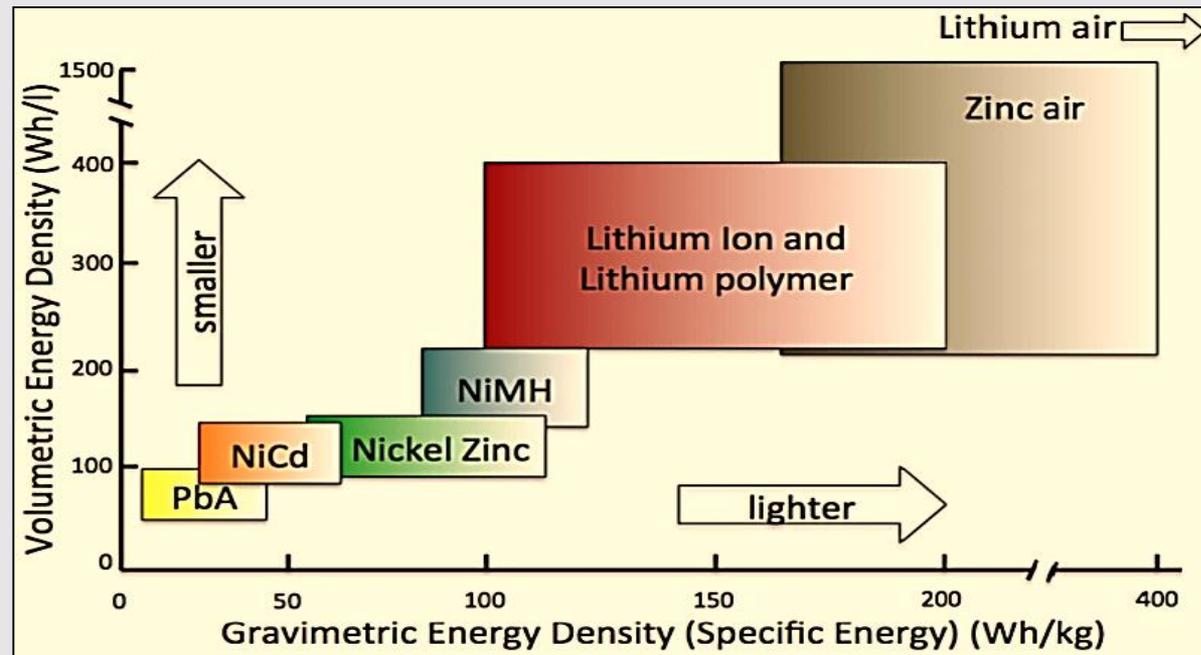


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Why we Use LI-ion battery?

Specific energy and energy density the maximum stored energy per unit weight or volume (respectively) is determined by specific energy and energy density. Higher specific energy holds more energy for a given weight. The higher specific energy cells with a given storage size are lighter for a given volume, the higher energy density holds more energy. Higher energy density cells are smaller for a given storage space, In contrast to historical chemistries, lithium ions have larger energy density and specific energy.





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	Flooded Lead Acid	VRLA AGM	Lithium-Ion (NMC)
Initial Cost per Capacity (\$/kWh)	131	221	530
Cost per Life Cycle (\$/kWh)	\$0.17	\$0.71	\$0.19
Specific Energy (Wh/kg)	30	40	150
Regular Maintenance	Yes	No	No
Number of Cycles to 80% SOH	200 – 1000	200 – 650	1000 – 4000
Typical State of Charge Window	50%	50%	80%
High Temperature Sensitivity	Degrades above 25°C	Degrades above 25°C	Degrades above 45°C
Available Power Constant Current	0.2C	0.3C	1C
Fast Charging Time (hrs)	8 – 16	4 – 8	2 – 4

	Lead Acid Batteries	Lithium-ion Batteries (LiFePO4)
Power Density	40 watts per kilogram	125 watts per kilogram
Cycle Life	200 @ 100% DoD	2800 @ 100%DoD
Usable Energy	50%	80%
Temperature sensitivity	Degrades significantly above 76° F (25° C)	Degrades above 95° F (45° C)
Voltage Per Cell	2 V	3.2 V
Maintenance Requirements	Regular maintenance, every 3 months	Basic annual maintenance



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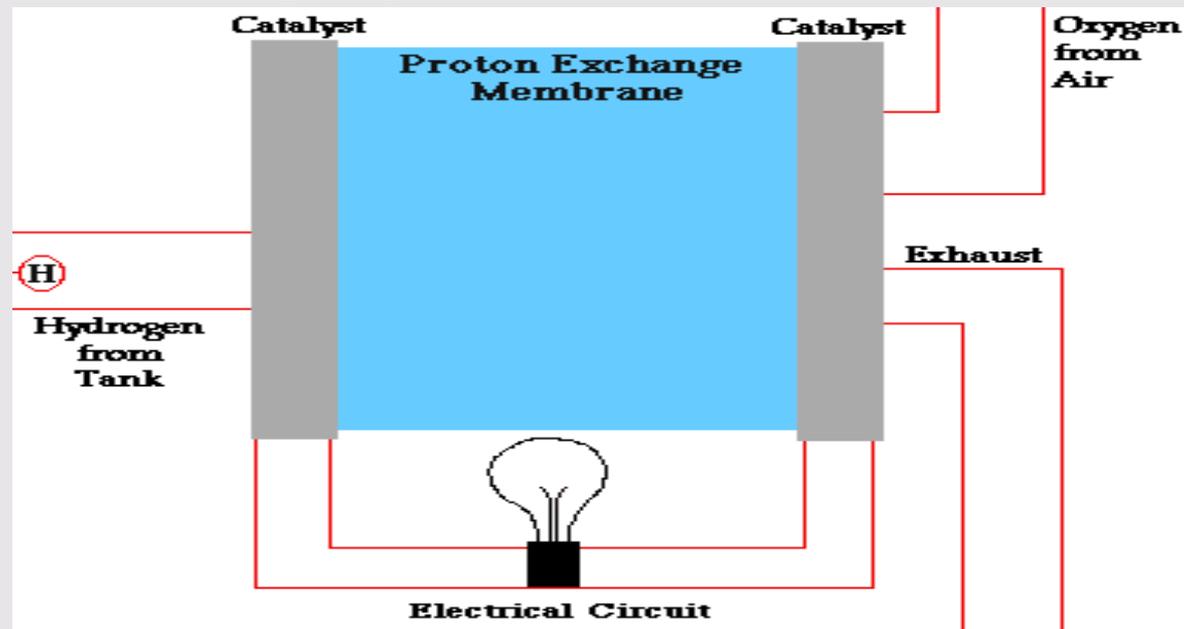
Fuel Cells

A fuel cell is a device that generates electricity by a chemical reaction. Every fuel cell has two electrodes called, respectively, the anode and cathode. The reactions that produce electricity take place at the electrodes.

Every fuel cell also has an electrolyte, which carries electrically charged particles from one electrode to the other, and a catalyst, which speeds the reactions at the electrodes.

Hydrogen is the basic fuel, but fuel cells also require oxygen. One great appeal of fuel cells is that they generate electricity with very little pollution—much of the hydrogen and oxygen used in generating electricity ultimately combine to form a harmless byproduct, namely water.

One detail of terminology: a single fuel cell generates a tiny amount of direct current (DC) electricity. In practice, many fuel cells are usually assembled into a stack. Cell or stack, the principles are the same





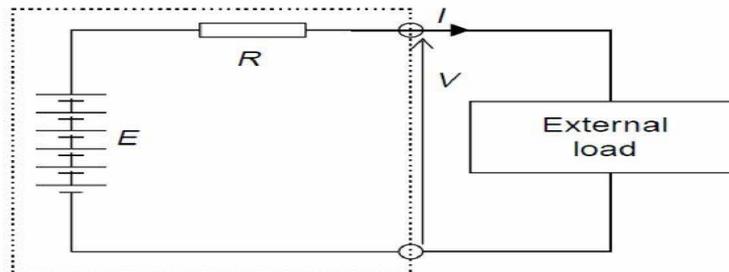
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Battery Parameters

Cell and battery voltages: All electric cells have nominal voltages which gives the approximate voltage when the cell is delivering electrical power. The cells can be connected in series to give the overall voltage required. The 'internal resistance' and the equivalent circuit of a battery is shown in Figure 1. The battery is represented as having a fixed voltage E , but the voltage at the terminals is a different voltage V , because of the voltage across the internal resistance R . Assuming that a current I is flowing out of the battery, as in Fig. 1, then by basic circuit theory we can say that: $V = E - IR$

BATTERY PARAMETER CELL AND BATTERY VOLTAGES



$$V = E - IR$$

E - open circuit
Voltage is constant
But varies with
State of Charge &
Temperature

R - low

Simple equivalent circuit model of a battery - composed of six cells



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- **Charge (or Ahr) capacity** :The electric charge that a battery can supply is clearly a most crucial parameter. The SI unit for this is the Coulomb, the charge when one Amp flows for one second. The capacity of a battery might be, say, 10Amphours. This means it can provide 1Amp for 10 hours.
- **Energy stored** :The energy stored in a battery depends on its voltage, and the charge stored. The SI unit is the Joule, but this is an inconveniently small unit, and so we use the Whr instead. Energy in Whr = $V * Ahr$
- **Specific energy** :Specific energy is the amount of electrical energy stored for every kilogram of battery mass. It has units of $Wh.kg^{-1}$.
- **Energy density** :Energy density is the amount of electrical energy stored per cubic metre of battery volume. It normally has units of $Wh.m^{-3}$
- **Specific power** :Specific power is the amount of power obtained per kilogram of battery. It is a highly variable and rather anomalous quantity, since the power given out by the battery depends far more upon the load connected to it than the battery itself.
- **Ahr (or charge) efficiency**: In an ideal world a battery would return the entire charge put into it, in which case the amp hour efficiency is 100%. However, no battery does; its charging efficiency is less than 100%. The precise value will vary with different types of battery, temperature and rate of charge. It will also vary with the state of charge.

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- **Energy efficiency** :This is another very important parameter and it is defined as the ratio of electrical energy supplied by a battery to the amount of electrical energy required to return it to the state before discharge.
- **Self-discharge rates** :Most batteries discharge when left unused, and this is known as self-discharge. This is important as it means some batteries cannot be left for long periods without recharging. The rate varies with battery type, and with other factors such as temperature; higher temperatures greatly increase self-discharge.
- **Battery temperature, heating and cooling needs**: Although most batteries run at ambient temperature, some run at higher temperatures and need heating to start with and then cooling when in use. In others, battery performance drops off at low temperatures, which is undesirable, but this problem could be overcome by heating the battery. When choosing a battery the designer needs to be aware of battery temperature, heating and cooling needs, and has to take these into consideration during the vehicle design process.
- **Battery life and number of deep cycles** :Most rechargeable batteries will only undergo a few hundred deep cycles to 20% of the battery charge. However, the exact number depends on the battery type, and also on the details of the battery design, and on how the battery is used. This is a very important figure in a battery specification, as it reflects in the lifetime of the battery, which in turn reflects in electric vehicle running costs.