How Batteries Work

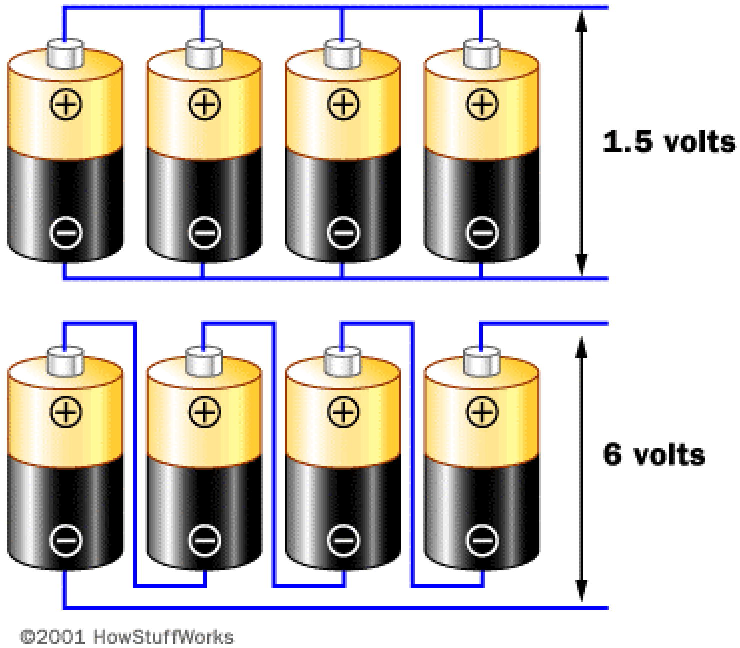
In any battery, the same sort of electrochemical reaction occurs so that electrons move from one pole to the other. The actual metals and electrolytes used control the **voltage** of the battery -- each different reaction has a characteristic voltage. For example, here's what happens in one cell of a car's **lead-acid battery**:

- The cell has one plate made of lead and another plate made of lead dioxide, with a strong sulfuric acid electrolyte in which the plates are immersed.
- Lead combines with SO_4 to create $PbSO_4$ plus one electron.
- Lead dioxide, hydrogen ions and SO_4 ions, plus electrons from the lead plate, create $PbSO_4$ and water on the lead dioxide plate.
- As the battery discharges, both plates build up $PbSO_4$ (lead sulfate), and water builds up in the acid. The characteristic voltage is about 2 volts per cell, so by combining six cells you get a 12-volt battery.

A lead-acid battery has a nice feature -- the reaction is completely **reversible**. If you apply current to the battery at the right voltage, lead and lead dioxide form again on the plates so you can reuse the battery over and over. In a zinc-carbon battery, there is no easy way to reverse the reaction because there is no easy way to get hydrogen gas back into the electrolyte.
Modern batteries use a variety of chemicals to power their reactions. Typical battery chemistries include:

- **Zinc-carbon battery** - Also known as a **standard carbon** battery, zinc-carbon chemistry is used in all inexpensive AA, C and D dry-cell batteries. The electrodes are zinc and carbon, with an acidic paste between them that serves as the electrolyte.
- **Alkaline battery** - Used in common Duracell and Energizer batteries, the electrodes are zinc and manganese-oxide, with an alkaline electrolyte.
- **Lithium photo battery** - Lithium, lithium-iodide and lead-iodide are used in cameras because of their ability to supply power surges.
- **Lead-acid battery** - Used in automobiles, the electrodes are made of lead and lead-oxide with a strong acidic electrolyte (rechargeable).
- **Nickel-cadmium battery** - The electrodes are nickel-hydroxide and cadmium, with potassium-hydroxide as the electrolyte (rechargeable).
- **Nickel-metal hydride battery** - This battery is rapidly replacing nickel-cadmium because it does not suffer from the memory effect that nickel-cadmiums do (rechargeable).
- **Lithium-ion battery** - With a very good power-to-weight ratio, this is often found in high-end laptop computers and cell phones (rechargeable).
- **Zinc-air battery** - This battery is lightweight and rechargeable.
- **Zinc-mercury oxide battery** - This is often used in hearing aids.
- **Silver-zinc battery** - This is used in aeronautical applications because the power-to-weight ratio is good.
- **Metal-chloride battery** - This is used in electric vehicles.

In almost any device that uses batteries, you do not use just one cell at a time. You normally group them together serially to form higher voltages, or in parallel to form higher currents. In a **serial arrangement**, the voltages add up. In a **parallel arrangement**, the currents add up. The following diagram shows these two arrangements:



The upper arrangement is called a *parallel* arrangement. If you assume that each cell produces 1.5 volts, then four batteries in parallel will also produce 1.5 volts, but the current supplied will be four times that of a single cell. The lower arrangement is called a *serial* arrangement. The four voltages add together to produce 6 volts.

Normally, when you buy a pack of batteries, the package will tell you the voltage and current rating for the battery. For example, my digital camera uses four nickel-cadmium batteries that are rated at 1.25 volts and 500 milliamp-hours for each cell. The milliamp-hour rating means, theoretically, that the cell can produce 500 milliamps for one hour. You can slice and dice the milliamp-hour rating in lots of different ways. A 500 milliamp-hour battery could produce 5 milliamps for 100 hours, or 10 milliamps for 50 hours, or 25 milliamps for 20 hours, or (theoretically) 500 milliamps for 1 hour, or even 1,000 milliamps for 30 minutes.

However, batteries are not quite that linear. For one thing, all batteries have a **maximum current** they can produce -- a 500 milliamp-hour battery cannot produce 30,000 milliamps for 1 second, because there is no way for the battery's chemical reactions to happen that quickly. And at higher current levels, batteries can produce a lot of heat, which wastes some of their power. Also, many battery chemistries have longer or shorter than expected lives at very low current levels. But milliamp-hour ratings are somewhat linear over a normal range of use. Using the amp-hour rating, you can roughly estimate how long the battery will last under a given load.

If you arrange four of these 1.25-volt, 500 milliamp-hour batteries in a serial arrangement, you get 5 volts (1.25 x 4) at 500 milliamp-hours. If you arrange them in parallel, you get 1.25 volts at 2,000 (500 x 4) milliamp-hours.

Manufacturers caution against disassembling batteries, to avoid personal injury.
However, a partially disassembled 9-volt battery would look like this.

Have you ever looked inside a normal 9-volt battery?
It contains six, very small batteries producing 1.5 volts each in a **serial arrangement**! 1.5v x 6 = 9v