PhyzGuide: Batteries and Current

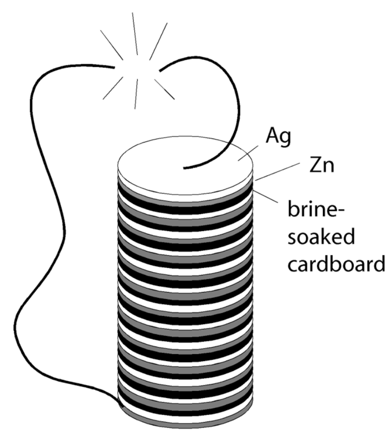
SCIENCE GETS THE BOOT FROM ITALY

When Galileo was sentenced to house arrest for his “crimes” against the Roman Catholic Church, the Scientific Revolution fled Italy for the more hospitable regions of France and England. In England, Isaac Newton advanced the understanding and mathematical description of the dynamics of motion, gravity, and geometric optics. In British America, Benjamin Franklin advanced the understanding of static electricity, and in France, Charles Coulomb applied newtonian mathematical rigor to the description of electrostatic forces.

LUIGI AND ALESSANDRO: SCIENCE RETURNS TO ITALY

A century and a half after Galileo’s death, something of scientific importance was to develop in Italy. During the 1780’s, biologist Luigi Galvani performed experiments at the University of Bologna involving electric charges and frogs. It had been found that a charge applied to the spinal cord of a frog could generate muscular spasms throughout its body. Charges could make frog legs jump even if the legs were no longer attached to a frog. While cutting a frog leg, Galvani’s steel scalpel touched a brass hook that was holding the leg in place. The leg twitched. Further experiments confirmed this effect, and Galvani was convinced that he was seeing the effects of what he called *animal electricity*, the life force within the muscles of the frog.

At the University of Pavia, Galvani’s colleague Alessandro Volta was able to reproduce the results, but was skeptical of Galvani’s explanation. Volta, a former high school physics teacher, found that it was the presence of two *dissimilar metals*, not the frog leg, that was critical. In 1800, after extensive experimentation, he developed the *voltaic pile*. The original voltaic pile consisted of a pile of zinc and silver discs and between alternate discs, a piece of cardboard that had been soaked in saltwater. A wire connecting the bottom zinc disc to the top silver disc could produce repeated sparks. No frogs were injured in the production of a voltaic pile.



The Voltaic Pile

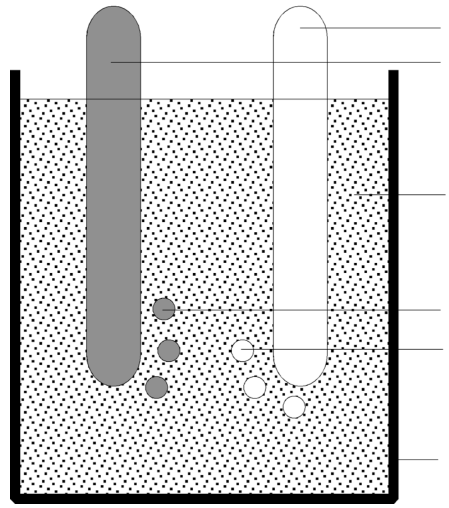
Before the voltaic pile was developed, sparks had to be generated by friction. This involved work. When the charge was released, another spark could be generated only by more frictional work. The voltaic pile provided a continuous source of charge flow. Volta’s pile is widely regarded as the first battery*.

The terms *galvanic*, *galvanize*, and *galvanometer* (among others) honor Luigi Galvani. The unit of electric potential, the *volt*, was named in honor of Alessandro Volta. Electric potential itself is commonly referred to as *voltage*.

*An item found in an archeological excavation beneath the city of Baghdad consisted of a ceramic vessel enclosing a copper cup which—in turn—enclosed a smaller silver cup. This reveals that a battery may have existed in ancient Persia. Unfortunately, we do not know why it was constructed or what it was used for. We do know these details in the case of the voltaic pile.

HOW BATTERIES WORK

The diagram to the right is a simplified depiction of an old form "dry cell." The container holds the electrolyte, a nasty concoction of corrosive agents absorbed in a powder to form a paste. Two posts are immersed in the electrolyte. One is zinc, the other a composite of carbon and manganese dioxide.



The corrosive electrolyte attacks the zinc, drawing off positive zinc ions in the chemical reaction. Each zinc ion that enters the electrolytic solution leaves two electrons on the zinc post. A chemical reaction at the carbon post draws negative ions into solution, leaving a positive charge on the carbon post.

Reactions at both posts quickly stop. The negatively charged zinc post pulls back any positive ions that try to enter the electrolyte; the positive carbon post pulls back any negative ions that try to enter the electrolyte. This is why a battery in storage can last for long periods of time.

However, if a conducting path is placed between the negative zinc terminal and the positive carbon terminal, electrons will flow from the zinc to the carbon, and the chemical reactions will resume. The conductive path typically involves an electrical device of some sort (light bulb, radio, etc.). The battery can provide energy as long as the reaction continues. Eventually, the reactants are used up and the battery dies.

Connecting the terminals of a battery by a direct conducting path like a wire or a coin is wasteful and dangerous. This is referred to as creating a short circuit. It is wasteful because this allows the materials in the battery to react quickly, causing the battery to die quickly. It is dangerous because the chemical reactions are somewhat exothermic and—when happening as rapidly as they do in a short circuit—release considerable heat. The heat can cause burns, and can destroy the seals that hold the corrosive electrolyte in the battery's container. Leaking "battery acid" can destroy electrical components and tissue (skin, etc.).

One number listed on all batteries is the electric potential it provides between its terminals. This number is determined by the chemical reaction occurring within it and the number of cells it is made of. For example, AAA, AA, C, and D cells have different sizes, yet all provide 1.5 V of potential. (If they all provide the same potential, what's the difference between them, other than their sizes?) This is because they all use the same chemical reactants. A 9-V battery uses the same reactants as well, but consists of six cells (each cell provides 1.5 V). The "button batteries" used in watches, cameras, and other small electric devices use different reactants (mercury oxide or silver oxide and zinc). These reactions produce a potential of 1.34 V across their terminals.

CURRENT

The rate of flow of electric charge is called **current**. The symbol for current is I. Thus $I = Q/t$. Since charge is measured in coulombs (C) and time is measured in seconds (s), current has units of coulombs per second (C/s). The abbreviation for coulombs per second is the ampere (A), named after André Marie Ampère.

When Ben Franklin arbitrarily chose positive and negative charges, he also determined the direction of current. Current naturally flows from regions of positive charge to regions of negative charge. (From too much fluid to not enough fluid in Franklin's model.) This convention is followed to this day. Today, however, we know that only negative charges (electrons) move in a current-carrying wire. The directions of current and electron flow are, therefore, opposite. *C'est la Morte!*