Current, Resistance, Batteries

Electron Motion inside a Conductor due to an Applied Electric Field

We are now starting a new part of the course, in which we look at circuits. Let us start with a look at a microscopic model of how electrons move in a wire. Simulation (conductors_sim.html)

Wires that are made of a conductor have conduction electrons that move about randomly, much like gas molecules in an ideal gas.

When a battery is connected to the wire, we get a non-zero field inside the conductor (this is a dynamic equilibrium situation) that imposes a small drift velocity on top of the random motion.

Electric current

Electric current, I, is the rate at which charge flows.

$$I = \frac{\Delta Q}{\Delta t}$$

Note that positive charge flowing in one direction is equivalent to an equal amount of negative charge flowing in the opposite direction.

In most cases electrons, which are negative, do the flowing, but current is defined to be in the direction of positive charge flow.

In the previous simulation, the electric field set up by the battery causes a net flow of charge.

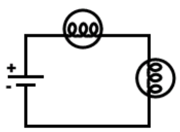
Doubling the current

Consider a sequence of positive charges $+q$ flowing to the right with a speed v (see figure on the lower right). Which of the following corresponds to a doubling of the current?

1. Twice as many charges going right at v
2. Same number of charges going right at $2v$
3. Add $-q$ charges going right at v
4. Add $-q$ charges going left at v
5. Both 1 and 2
6. 1, 2 and 3
7. 1, 2 and 4
8. 1 and 3
9. 1 and 4

Least current

In the electrical circuit shown, at what point is the current the least?



1. Nowhere - the current is the same everywhere
2. The current is least near the positive terminal of the battery
3. The current is least between the lightbulbs
4. The current is least after the second lightbulb
5. The current is least near the negative terminal of the battery

An analogy with fluids

In a fluid system

- water flows because a pump maintains a pressure difference
- the current (how quickly the fluid flows) depends on both the pressure difference and on the overall resistance to flow in the set of pipes
- energy can be extracted from the fluid to do work (e.g., turning a water wheel)

Simulation

An analogy with fluids

In an electrical system

- charge flows because a battery maintains a potential difference
- the current (how quickly the charge flows) depends on both the potential difference and on the overall resistance to flow in the circuit
- energy can be extracted from the charges to do work (e.g., lighting a bulb)

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How a battery works

A battery is an electron manufacturing factory.

A chemical reaction frees up electrons at the negative electrode. These flow through the external circuit to the positive electrode, where another chemical reaction recycles the electrons.

The electrodes are used up in this process and waste products are produced. This is why batteries run out. In a rechargable battery, the chemical reactions are run in reverse to repair the electrodes. That can only be done so many times.

Fuel cells are like batteries where raw materials are continually added, and waste products are constantly removed.

The voltage across a battery tells us how much the battery can drive a current through an external circuit. We call the voltage across a battery its electromotive force (emf).

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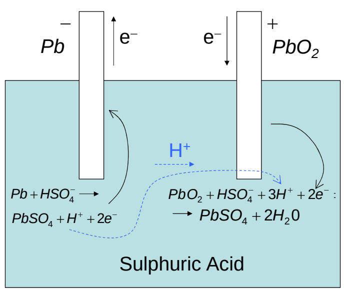
A lead-acid battery

A lead acid battery consists of two electrodes, one made from lead and the other from lead dioxide, immersed in a solution of sulfuric acid.



The flow of current is completed by the flow of electrons outside the battery and the flow of the H^+ ions inside the battery.

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