Voltage

In order for an electric current to flow through a circuit, there must be some sort of energy source that "pushes" the electrons around. This energy source can come in a variety of forms:

1. Chemical Energy

    - batteries use a chemical reaction to provide the energy
    - chemicals inside the battery produce a steady flow of electrons that will move through an external conductor

2. Thermoelectric

    - heat energy is converted into electricity through a process known as the thermoelectric effect
    - this occurs when two different metals are heated at one junction and cooled at another
    - a thermocouple is a device used for this purpose

3. Photoelectric

    - when light strikes certain materials, it can produce electricity
    - this is known as the photoelectric effect
    - the photoelectric effect is used in devices like solar panels

4. Piezoelectric

    - certain types of crystals produce electricity when they are pressed together (e.g. quartz)
    - this is called the piezoelectric effect
    - ultrasound machines produce ultrasonic waves by passing an electric current through a piezoelectric crystal

5. Electromagnetism

    - in 1831 Michael Faraday demonstrated that a magnet moved near a coil of wire would produce an electric current in the wire
    - this became the basis for the modern electric generator (e.g. hydro dams)

Devices that can provide the energy necessary to push electrons around a circuit are called voltage sources. Because a voltage source can provide energy to electrons, it is said to have **electric potential energy**. The metric unit of energy is the joule (J).

Inside a battery, electrons are moved from the positive terminal to the negative terminal by a chemical reaction. As they move, they **gain** electric potential energy.

The **potential difference**, or **voltage** (V), of the battery is defined as the amount of electric potential energy (E) gained per coulomb of charge.

$$voltage = \frac{energy\ gained}{charge} \qquad \text{or} \qquad V = \frac{E}{Q}$$

The metric unit for measuring the voltage is the volt (V). One volt is equivalent to one coulomb of charge gaining one joule of electric potential energy.

Outside of the battery, electrons are moved from the negative terminal to the positive terminal by electrostatic forces (they are repelled by the positive and attracted to the negative). As they move, they **lose** electric potential energy.

As an electron moves around a circuit, it will gain energy in the battery and then lose energy in the other parts of the circuit (wires, lights, etc.). By the time it completes one full lap, it will have lost all of the energy that it gained in the battery.

Where does this energy go?

It gets used up by the devices on the circuit. For example, a light bulb converts the electric potential energy into heat and light.

Example 1
A battery is able to supply $6\ J$ of energy to $2\ C$ of charge in a circuit. Calculate the voltage of the battery.

Example 2
How much energy must a $12\ V$ battery use to move $4\ C$ of charge around a circuit?

Voltage Worksheet

1. A battery does $24\ J$ of work on $4\ C$ of charge. What is the voltage of the battery?

2. Danielle recharges her dead $12\ V$ car battery by sending $28\ 000\ C$ of charge through the terminals. How much energy must Danielle store in the car battery to make it fully charged?

3. A $12\ V$ car battery supplies $1\ 000\ C$ of charge to the starter motor. How much energy is used to start the car?

4. What is the voltage of a refrigerator if $125\ C$ of charge transfers $16\ 000\ J$ of energy to the compressor motor?

5. A flash of lightning transfers $3\ 000\ 000\ 000\ J$ of energy between a cloud and the Earth. If the potential difference (voltage) between the Earth and the cloud is $48\ 000\ 000\ V$, what is the amount of charge transferred in the lightning bolt?

6. How much energy is gained by an electron whose charge is $1.6 \times 10^{-19}\ C$ as it moves through a $45\ 000\ V$ potential difference?