7.4.1: Current

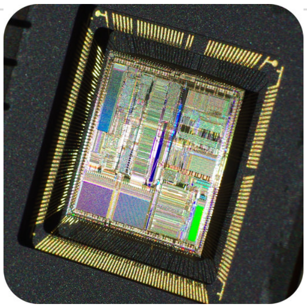

Figure 16.2.1

You've probably heard of vacuum tubes and large transistors, which were once common in electronics like televisions. These individual devices were mounted on large printed circuit boards. Then, in 1959, two researchers working independently developed the first integrated circuits. These circuits could combine several transistors and resistors into one circuit on one small chip of silicon. These chips, like the one pictured above, are used today in virtually every electrical device.

Electric Current and Circuits

Electric Current

Remember that it often requires work to force electrons into a specific location. If we have two conducting spheres and we have forced excess electrons onto one of the spheres by doing work on the electrons, then that sphere, and those electrons, will have a higher potential energy than those on the uncharged sphere. If the two spheres are touched together, electrons will flow from the sphere with excess electrons to the sphere with no excess electrons. That is, electrons will flow from the high potential energy position to the lower potential energy position. The flow will continue until the electrons on the two spheres have the same potential energy. A flow of charged particles such as this is called an **electric current.**

It is possible for an electric current to be either a flow of positively charged particles or negatively charged particles. In gases, both positive and negative ions can flow. The difficulty of freeing protons, however, makes it extremely rare to have an electric current of positive particles in solid conductors. Virtually all electric currents consist of the movement of electrons.

Common Misconceptions

It is easy to assume that current is the flow of positive charges. In fact, when the conventions of positive and negative charge were invented two centuries ago, it was assumed that positive charge flowed through a wire. In reality, however, we know now that the flow of positive charge is actually a flow of negative charge in the opposite direction. That is, when an electron moves from position A to position B, it is the same as a positive hole moving from B to A.

Today, even though we know it is not correct, we still use the historical convention of positive current flow when discussing the direction of a current. **Conventional current**, the current we commonly use and discuss, is the direction positive current would flow. When we want to speak of the direction of electron flow, we will specifically state that we are referring to electron flow.

Electric current flows from positions of higher potential energy to positions of lower potential energy. Electrons acquire higher potential energy from an electron pump that does work on the electrons, moving them from positions of lower *PE* to positions of higher *PE*. Electrons in galvanic cells (several cells together comprise a battery) have higher potential energy at one terminal of the battery that at the other. This difference in potential is related to chemical energy. When the two terminals of the battery are connected to each other via a conducting wire, the electric current will travel from the terminal with higher potential energy to that with lower potential energy. This setup is the most simple of **electric circuits**.

It can be helpful to think about an electric circuit like water flowing through a system. Use the Electric Analogies simulation below to help you visualize what is going on in an electric circuit. The pump and water tower represent the battery and the water wheel represents a resistor. You can adjust the slider to put these “resistors” in series and in parallel. Have fun exploring:

Electric Circuits

An electric circuit is any closed loop that goes from one battery terminal to the other and allows current to flow through it. A relatively simple circuit is shown in the image below. The charges move from the higher potential energy terminal on the battery, through the light bulb, through the switch, and back to the lower potential energy terminal on the battery.

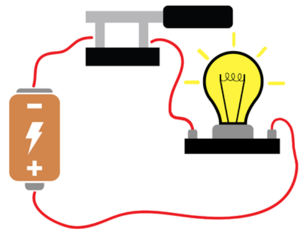

Figure 16.2.2

Other resistors include motors, which convert energy into kinetic energy, and heaters, which convert it into thermal energy. A circuit consists of a battery, or a charge pump, which increases the potential energy of the charges, and one or more devices that decrease the potential energy. As the potential energy is reduced, it is converted into some other form of energy. In the image above, the device that decreases the charges' potential energy is the light bulb; the excess energy is converted into light energy. Any device that reduces the potential energy of the charge flowing through it is said to have **resistance** because it resists the flow of charge.

The charges in the circuit can neither be created nor destroyed, nor can they pile up in one spot. The charged particles moving through the circuit move the same everywhere in the circuit. If one coulomb of charge leaves the charge pump, then one coulomb of charge moves through the light, and one coulomb of charge moves through the switch. The net change of energy through the circuit is zero. That is, the increase in potential energy through the charge pump is exactly equal to the potential drop through the light. If the generator (charge pump) does 120 J of work on each coulomb of charge that it transfers, then the light uses 120 J of energy as the charge passes through the light.

The electric current is measured in coulombs per second. A flow of one coulomb per second is called one **ampere,** A, of current.

$$1.00 \text{ Ampere}=1.00 \text{ coulomb}/1.00 \text{ second}$$

The energy carried by an electric current depends on the charge transferred and the potential difference across which it moves, $E=qV$. The voltage or potential difference is expressed in Joules/coulomb and multiplying this by the charge in coulombs yields energy in Joules.

Electrical power is a measure of the rate at which energy is transferred, and is expressed in watts, or Joules/second. Power can also be obtained by multiplying the voltage by the current:

$$\text{Power, } P=VI=(\text{Joules/coulomb})(\text{coulomb/second})=\text{Joules/second}=\text{watts.}$$

Examples

Example 16.2.1

What is the power delivered to a light bulb when the circuit has a voltage drop of 120 V and produces a current of 3.0 ampere?

Solution

$$P=VI=(120 \text{ J/C})(3.0 \text{ C/s})=360 \text{ J/s}=360 \text{ watts}$$

✓ Example 16.2.2

A 6.00 V battery delivers a 0.400 A current to an electric motor that is connected across the battery terminals.

1. What power is consumed by the motor?
2. How much electric energy is delivered in 500. seconds?

Solution

1. $P=VI=(6.00 \text{ V})(0.400 \text{ A})=2.4$ watts
2. Joules=(J/s)(s)=(2.4 J/s)(500. s)=1200 Joules

Launch the Flashlight simulation below to see how electricity flows in a simple circuit. Be sure to observe the Power vs Current graph to develop a deeper understanding of the relationship between these two variables. Can you adjust the sliders to maximize the current running through the circuit? Try it out:

Summary

- Electric current is the flow of electrons from the high potential energy position to the lower potential energy position.
- Current flow is the direction a positive current would be traveling, or the opposite direction that electrons actually flow.
- A closed loop containing current flow is called an electric circuit.
- Electric current is measured in coulombs per second, or amperes.
- Electric power is measured in joules per second, or watts.
- The energy carried by an electric current depends on the charge transferred and the potential difference across which it moves, E=qV.
- Power, P=VI=(Joules/coulomb)(coulomb/second)=Joules/second=watts.

Review

1. The current through a light bulb connected across the terminals of a 120 V outlet is 0.50 A. At what rate does the bulb convert electric energy to light?
2. A 12.0 V battery causes a current of 2.0 A to flow through a lamp. What is the power used by the lamp?
3. What current flows through a 100. W light bulb connected to a 120. V outlet?
4. The current through a motor is 210 A. If a battery keeps a 12.0 V potential difference across the motor, what electric energy is delivered to the motor in 10.0 s?

Explore More

Use this resource to answer the questions that follow.

1. What type of current is described in this video (electron or conventional)?
2. What drives the current through the circuit?
3. What inhibits the flow of current in the circuit?

Additional Resources

Study Guide: Electrical Systems Study Guide

Real World Application: Stunning Technology

Videos: