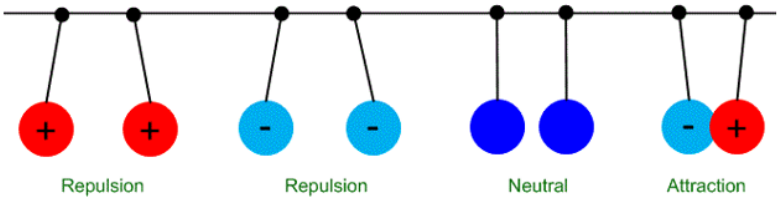
In order to understand electricity, we must understand electrical charge. If you think back to the chemistry unit on atom structure, you will remember that atoms are made up of a nucleus with positively-charged protons and neutral neutrons, and an electron cloud made up of fast moving, small, negatively-charged electrons. Protons and neutrons, then, have opposite charges. Thus, an atom with equal numbers of protons and electrons is described as being **electrically neutral**. On the other hand, if an atom has an unequal number of protons and electrons, then the atom is electrically charged (and called an "ion.") An atom that has more protons than electrons is said to be a **positively-charged** ion, while an atom with more electrons than protons is said to be a **negatively-charged** ion.

In fact, atoms are not the only thing that is capable of having an electrical charge. Molecules and even whole objects can be described as positively- or negatively-charged.

Charges on Objects		
Positively Charged	**Negatively Charged**	**Uncharged**
Possesses more protons than electrons	Possesses more electrons than protons	Equal numbers of protons and electrons

As you continue to study electricity in this lesson, it is useful to remember that opposite charges attract each other, and like charges repel each other. For example, positive and negative charges are attracted to each other (this is how negatively-charged electrons remain in an atom, because they are attracted to the positively-charged protons in the nucleus). Alternatively, negative and negative charges repel each other, just as positive and positive charges repel each other. Objects with no charge neither attract nor repel each other.



The Laws of Attraction and Repulsion

Electricity

Static electricity: Static electricity is an imbalance of electric charges within or on the surface of a material that remains static, or still, for some period of time. Static electricity can move, but not in a consistent manner. Thus, static electricity is not used to power electrical devices, because of this inconsistency. Some common examples of static electricity are when your hair stands up after pulling on a sweater, or when you get zapped by a doorknob in the winter.

Current electricity: Current electricity is electricity that flows through wires or other conductors and transmits energy in a consistent fashion. Current electricity is used to power electrical devices. We will learn more about current electricity later in this lesson.

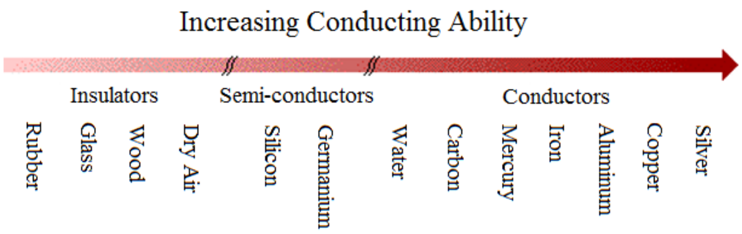
Conductors, Semiconductors, and Insulators

Many different types of materials can hold an electrical charge, but only some are capable of carrying current electricity.

Conductors: Conductors are materials that permit electrons to flow freely from particle to particle. Conductors are good at allowing electric current to move through them and even into another object, especially if the second object is made of a conducting material. Most solid conductors are made of metal. The inside of an electrical wire is made of copper, and is an example of a conductor. However, some saltwater solutions can also conduct electricity.

Insulators: In contrast to conductors, insulators are materials that do not allow the free flow of electrons from atom to atom and molecule to molecule. While insulators are not useful for transferring charge, their ability to prevent charge from moving to certain places makes them very useful. The reason that electrical wires do not pass their electrical charge onto humans is because they are coated with plastic or rubber, both examples of insulators.

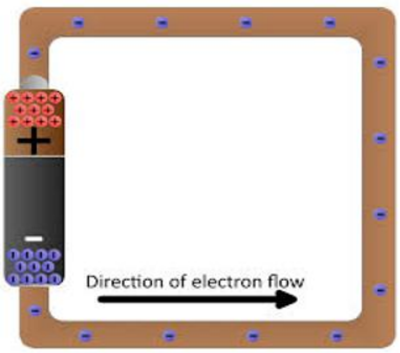
Semiconductors: The division of materials into the categories of conductors and insulators is a somewhat artificial division. It is more appropriate to think of materials as being placed somewhere along a continuum. Materials that are highly conductive (known as **superconductors**) would be placed at one end and the least conductive materials (best insulators) would be placed at the other end. Metals would be placed near the most conductive end and glass would be placed on the opposite end of the continuum. In the middle would be what are called **semiconductors**, substances whose electrical conductivity is between that of a conductor such as copper and that of an insulator such as glass. Semiconductors are the foundation of modern electronics, including transistors, solar cells, and light-emitting diodes (LEDs).



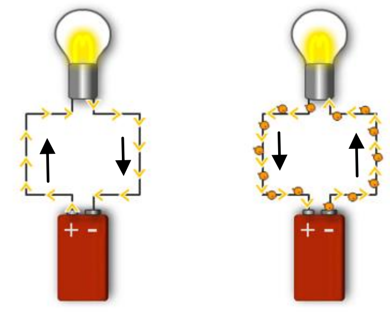
Conductivity of different materials

Electric current

An **electric current** is a flow of electric charge. In electric circuits this charge is often carried by moving electrons in a wire. Electric current is measured in units called **Amperes (A)**, which is the flow of electric charges through a surface at the rate of one coulomb per second.



In this diagram, a battery changes the chemical energy within it to electrical energy. Electrons are considered to flow out of the negative end of the battery, around the wire, and toward the positive end of the battery, to which the electrons are attracted. Though we know that electrical current involves the flow of electrons, this was not always known. When scientists first discovered electricity, they thought that positive charges flowed the opposite direction in an electrical circuit. While the end result is the same, we now have two different ways of talking about electrical current: by electron flow or conventional current. You find both of these methods used in textbooks and wiring diagrams. The two conventions for describing electrical current are pictured below:



Conventional current flow (+ to -)   Electron current flow (- to +)

Through inefficient energy transformations, electric currents convert much of their energy to unuseful heat. This is why energy lightbulbs such as fluorescents and LEDS are considered more efficient—they do not "lose" as much energy through transformation to heat. Electric currents can also create, or induce, magnetic fields. We will turn our attention to magnetic fields.

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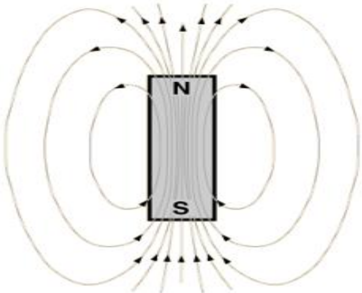
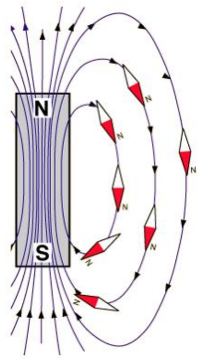
Magnetic Fields

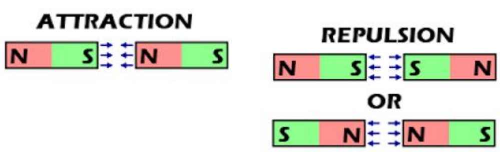
Magnetic fields are areas where an object exhibits or experiences a magnetic influence. In everyday life, magnetic fields are most often encountered as an invisible force created by permanent magnets which pull on materials such as ferromagnetic materials, such as iron, cobalt or nickel; and attract or repel other magnets. A magnet is an object made of ferromagnetic material that is capable of producing a magnetic field. If you bring a magnet close to a stack of paper clips (made up at least partially of iron), the paper clips will move toward the magnet, once they are within the magnetic field of the magnet.



Like electrical current, magnets and magnetic fields have a direction. A magnet has ends called magnetic poles. Magnetic poles are the places on a magnet where the magnetic field lines begin and end. Magnetic field lines are said to start at the North Pole and end at the South pole of a magnet. The magnetic field lines for a magnet are pictured in the left:



The piece of evidence we have for the direction of magnetic fields is the behavior of compasses when placed within the magnetic field of a magnet. Compasses are devices that point toward the north pole of the earth and assist in navigation. However, compasses do not selectively point to the earth's North Pole; they will point toward the north pole of any magnet. The diagram on right shows the behavior of compasses when placed within the magnetic field of a magnet:

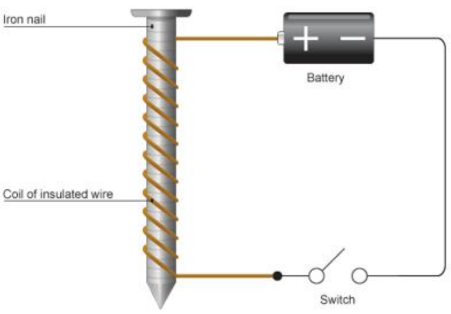


Notice that like in electricity, opposites attract in magnetism as well. The north end of the compass points toward the south end of the magnet, or away from the north end of the magnet.

Electromagnetism and Generators

It is most important to understand the interactions of electricity and magnetism. All electricity, with the exception of solar cells, is generated through the interaction of electricity and magnetism. Furthermore, motors, like the motors of cars, household appliances, etc., work because of those interactions. We will begin by looking at a simple interaction of electricity and magnetism.

When an electrical current flows through a wire, that current actually creates a magnetic field around the wire. This creation of a magnetic field from a flowing electrical current is called **electromagnetism.**



An electromagnet is a temporary magnetic field that is created from the flow of electrical current. The magnetic field that is generated is relatively weak, but it can be strengthened both by coiling the wire to concentrate the generated magnetic field, and by placing a ferromagnetic material within the coil of wire. The diagram shows a simple electromagnet:

An electromagnet is different from a regular magnet in more than just appearance. Since the magnetic field of an electromagnet is created from the flow of electrical current, the magnetic field disappears if the electrical current disappears. Thus, the magnetic field of an electromagnet is temporary.

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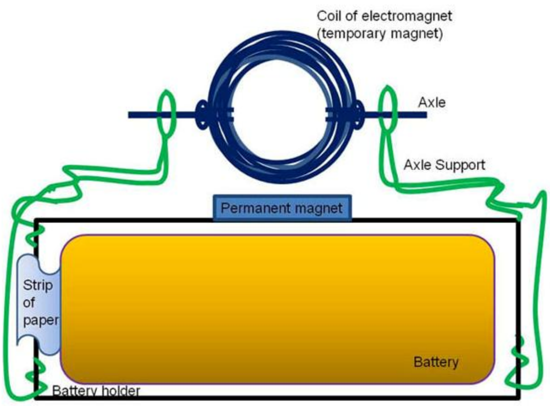
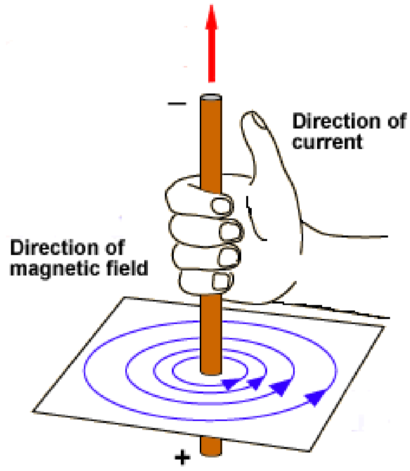
One way that electromagnets are used is in car junkyards. In junkyards, unworking cars need to be easily moved around. With an electromagnet, you can pick up a car (made largely of steel, a ferromagnetic material), move it to a new location, turn off the electromagnet, and drop the car in its new location. With a permanent magnet, this could not be done as the magnet would permanently hold on to the car and not be able to drop it in its new location!

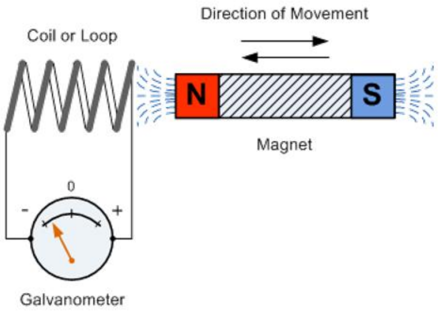


Another device that takes advantage of the fact that electrical currents create magnetic fields is a motor. If an electrical current creates a magnetic field, and that magnetic field is placed in the opposite direction to an existing magnet, motion can be generated as a result. Remember that like charges on a magnet repel each other. If you place two magnets close to each other, with their north ends facing each other, they will generate motion and push away from each other. In a motor, you can purposefully place the north end of an electromagnet, and the north end of a permanent magnet in proximity to each other to create motion. When the electrical current is turned on, the electromagnet is created, and the North end of the electromagnet pushes against the North end of the permanent magnet. When the electrical current is turned off, the motion ceases, because the electromagnet is no longer active. The diagram shows a simple electrical motor made from a battery, some wire, and a permanent magnet:



In order to determine where the north end of an electromagnet is, you could go through a trial and error process, and check it with a compass. However, when building a complex motor, you would want to anticipate ahead of time where the north end of the electromagnet would be. The direction of the magnetic field generated by an electrical current can be determined by using the "right hand rule" as shown in the diagram:

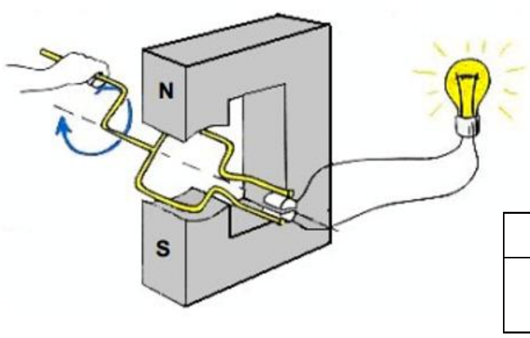
This rule says that if you point your thumb in the direction of conventional electrical current flow (positive to negative), your fingers will curl in the direction of the magnetic field. The tip of your fingers will point north.



Not only do flowing electrical currents produce magnetic fields, but moving magnetic fields can create electrical currents. The following diagram shows a set-up in which a magnet moved into and out of a coil of wire will generate an electric current in that loop of wire. A galvanometer is a device that measures electricity:

The creation of an electrical current from moving magnetic fields is called electromagnetic induction.

Electromagnetic induction is also responsible for how power plants generate electricity. Consider a hydroelectric power plant, or a hydropower plant or dam, for a moment. In a hydropower plant, the force of falling water spins a mechanism that has a coil of wire on it. That coil of wire is made to spin next to a magnet. This movement, though involving a wire moving next to a stationary magnet, is equivalent to a magnet moving next to a stationary wire. As a result, electricity begins to flow in the electrical wire. A device that takes mechanical energy and converts that to magnetic energy and then to electrical energy is called a generator. The following diagram shows a very simplified generator:



Notice that motors and generators are the exact opposite. Motors use electrical energy to create magnetic energy, which creates motion. Generators take motion to create magnetic energy to create electrical energy.

Motors	Generators
electrical energy→magnetic energy→motion energy	motion energy→magnetic energy→electrical energy

Basics of Electrostatics:

- Electrical charges are either negative (electrons) or positive (protons)
- The unit of charge, q , is called the coloumb.
- When there are equal numbers of positive and negative charges there is no electrical force as there is no net charge. This is the case for a neutral atom.
- Electrical force is created when electrons are transferred from one material to another (e.g. rubbing a wool cloth with a plastic comb).
- Electrical charge is conserved; charge is neither created nor destroyed

Properties of Electricity:

CURRENT: denoted by *I* and measured in amperes. Current flows from negative material to positive material and is essentially the number of electrons per second that are carried through a conductor.

$$I = \frac{Q}{T}$$

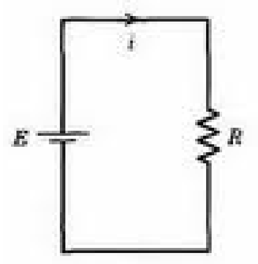
VOLTAGE: Potential difference between a negatively charged object and a positively charged one (like two terminals on a battery). Potential difference is measured in units of Volts (V)which represents the work done per unit charge to move electrons between the positive and negative terminals. If a potential difference exists, then energy can be extracted.

RESISTANCE: Property of material that helps prevent the flow of electrons in it. Metals are good conductors due to low resistance. Wood is a poor conductor due to high resistance. Resistance, R , is measured in ohms and depends upon both the type of material and its size. Long wires have more resistance than short wires; thin wires have more resistance than thick wires. R is also temperature dependent.

OHM's LAW: The electric current flowing through any circuit or conductor is directly proportional to the voltage applied across the conductor or circuit. This is known as **Ohm's law**. Mathematically, we can write ohm's law as;

$$I = \frac{V}{R}$$

Where, R is proportionality constant and is known as resistance of the circuit or the conductor.



Electric Circuit is the closed path in which electric current flows from the high potential to the low potential point. The electric circuit is formed when the electric current finds a path with low resistance.

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Electric energy is defined as the total energy stored in for of electrical form. It is also defined as total energy consumed in electrical form. Its unit is joules and is denoted by E.

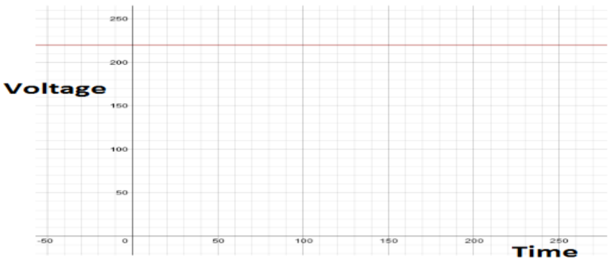
$$E = VIT = PT$$

Electric power is de fined as the rate of flow of electrical energy. Its unit is watt.

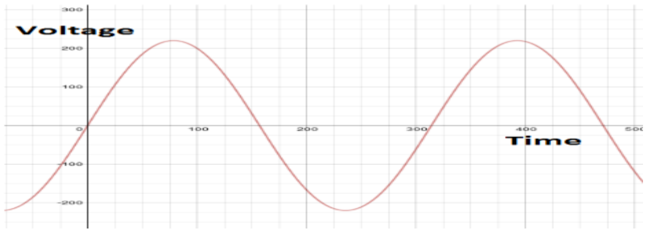
$$P = \frac{E}{T} = \frac{VIT}{T} = VI$$

AC/DC

Electrical current can transfer energy from an energy source to a device in two ways. We are used to a cell providing current in one direction only. We call this direct current or DC.



Direct Current is the movement of electrons in a wire in a constant direction. If we connect a DC power supply to an oscilloscope, we will see a constant line like this:



However, it is possible to transfer energy using a current that changes direction all the time. By moving electrons one way, then back, then repeating, energy can be transferred. We call this alternating current or AC.
Alternating Current is the movement of electrons in a wire backwards then forwards repeatedly. In Bangladesh this change repeats 50 times per second (or 50 Hz). In the USA, the frequency is 60 Hz. AC is remarkably useful because it allows us to change electricity very easily using transformers which cannot work with DC.

Circuit: A circuit is a closed path where current can flow.

Fuse: Fuse is a protective element used in electrical circuit. If excessive current flows through the fuse melts and current flowing through the circuit becomes zero. So a fuse has to be of low melting temperature.

Earthing: Earthing or Earth is used in ac circuit as a protective element to help dissipate accidental current on the casing of device to the earth.

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