Energy

▶Energy is the ability to do work, and can be done only by the transfer of energy from one object or system to another. We define work in physics as the product of the magnitude of a force applied to an object and the distance through which the object moves.

▶Energy is never destroyed, nor is it created, but it can be transferred from one form to another. It is found in many forms: electrical, chemical, mechanical, thermal, nuclear, and sound.

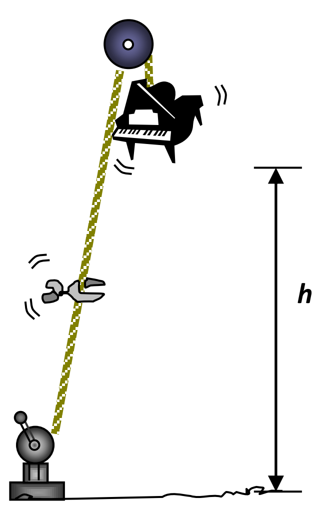
Types of Energy

Electrical energy is the energy used for running machines, television, computers, and all kinds of electrical devices.
Chemical energy is found in a battery or in the gasoline to run an engine.
The energy produced by friction is heat.
The energy generated by a string in motion is sound.
Mechanical energy is the ability to do work.

Potential and Kinetic Energy

There are two types of mechanical energy: kinetic and potential. Energy associated with motion is known as kinetic energy. Energy related to position is called potential energy.
To demonstrate, when an object is held above a surface, it has potential energy. If that object is then dropped, the potential energy is converted to kinetic energy.
A stretched spring, gasoline, gunpowder, and a stone placed on the top of a cliff, all have **potential energy (PE).**
A stone dropped from a cliff, a ball being thrown, and a car moving from one place to another all have **kinetic energy (KE)**

As any object is lifted from a surface, a vertical force is applied to that object. As this force acts through a height, energy is transferred to the object.



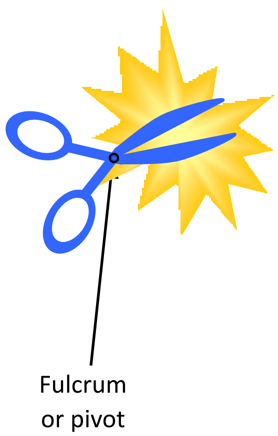
Simple Machines

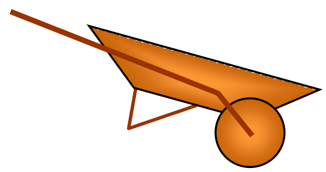
A simple machine is a device that requires only the force of a human to perform work. In a machine an applied force is increased, its direction is changed, or one form of motion or energy is changed into another form.

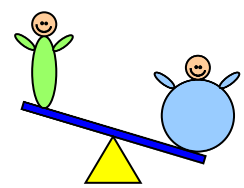
There are four types of simple machines: the lever, the pulley, the wheel and axle (including the gear), and the inclined plane (the wedge and the screw are special cases of the inclined plane).

The lever is a simple machine consisting of a rigid bar that is free to pivot on a fulcrum.

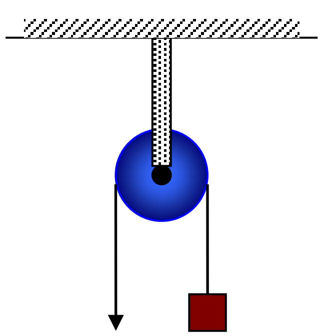
The human arm is actually a lever, and the muscles apply the force needed to lift weight or move objects. The oars of a boat, a wheelbarrow, a scissor or seesaw are examples of a lever.

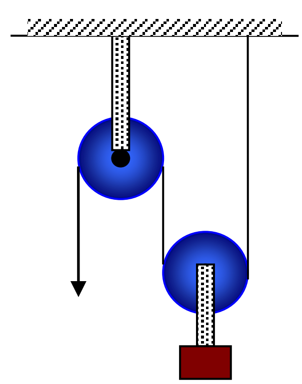




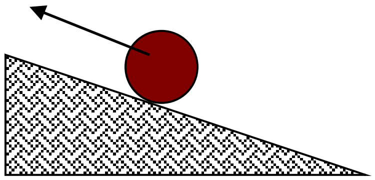


The pulley is a simple machine consisting of a wheel that rotates around a stationary axle. The outer rim of the pulley is grooved to accommodate a rope or chain. Pulleys are used for lifting by attaching one end of the rope to the object, threading the rope through the pulley (or system of pulleys), and pulling on the other end of the rope. A common example of a pulley can be found at the top of a flagpole. Pulleys reduce the effort to lift an object by increasing the distance over which the effort is applied.



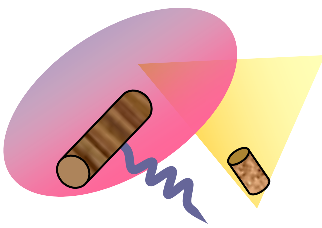


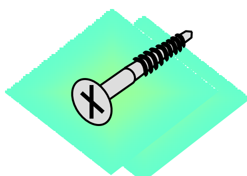
The inclined plane is a simple machine, consisting of a sloping surface, which has some angle above or below the horizontal used to raise objects that are too heavy to lift vertically. Gangway, chutes, and ramps are all examples of the inclined plane.



Switchbacks on mountain roads are inclined planes that reduce the effort of an automobile engine but increase the distance a car must travel to ascend the mountain. The inclined plane has been modified in many ways.

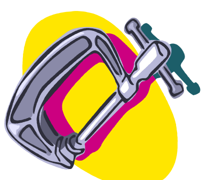
The screw and wedge are applications of the principle of the inclined plane but do not require that the load be moved vertically for their successful operation

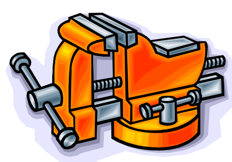




screw

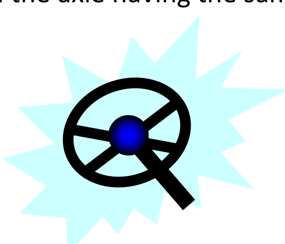
wedge

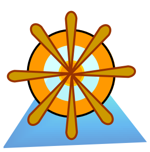




The screw consists essentially of a solid cylinder, usually of metal, around which an inclined plane winds spirally, either clockwise or counterclockwise. It is used to fasten one object to another, to lift a heavy object, or to move an object by a precise amount.

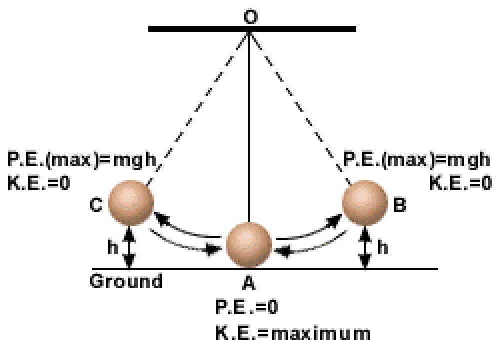
The wheel-and-axle is a wheel attached rigidly upon an axle or drum of smaller diameter, the wheel and the axle having the same axis so that both can turn together.





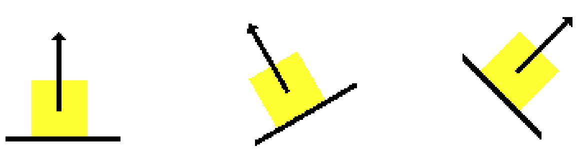
Pendulum

A pendulum is a weight suspended from a **pivot** so that it can swing freely. The full swing motion is called the **period**. The period is dependent on the length of the string only. The motion of a pendulum is a classic example of mechanical energy conservation. A pendulum consists of a mass (known as a ***bob***) attached by a string to a pivot point. As the pendulum moves it sweeps out a circular arc, moving back and forth in a periodic fashion. Disregarding air resistance, there are only two forces acting upon the pendulum bob, gravity and tension from the string. As the bob starts at some height, all the energy is potential. When released and the bob starts to swing, the energy will transition from potential to kinetic. At the low point of the swing, all the energy is kinetic since the pendulum has no height. As the bob starts to swing upwards again, the cycle repeats and the bob will have all potential energy at the height of the swing. The height of the swing from side to side is called the extreme.



Inclined Plane

In physics, a tilted surface is called an inclined plane. Objects are known to accelerate down inclined planes because of an unbalanced force. To understand this type of motion, it is important to analyze the forces acting upon an object on an inclined plane. The rate at which the object slides down the surface is dependent upon how *tilted* the surface is; the greater the *tilt* of the surface, the faster the rate at which the object will slide down it. There are always at least two forces acting upon any object that is positioned on an inclined plane - the force of gravity and the normal force. <u>The force of gravity (also known as weight)</u> acts in a downward direction; yet the <u>normal force acts in a direction perpendicular to the surface</u> (in fact, *normal* means "perpendicular"). As an object moves down an inclined plane, some energy is lost due to friction.

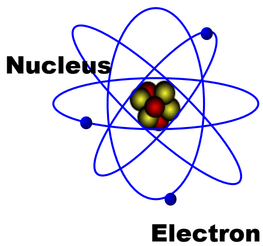


Normal forces are always directed perpendicular to the surface.

Electricity

▫Electricity is one of the basic forms of energy. Thales of Miletus (600 BC) in ancient Greece knew about electricity and found that rubbing fur on various substances, such as amber (*elektron*: amber), would cause an attraction in light objects, such as hair. Furthermore, if the amber was rubbed long enough, a spark could be produced.

▫All matter is formed by atoms, and atoms are formed of smaller particles: the proton, the neutron, and the electron. Electrons spin around the center, or nucleus, of the atoms. The nucleus is made up of neutrons and protons.



Electrons have a negative charge, protons a positive charge. Neutrons have neither a positive nor a negative charge; they are neutral.

Electrons and protons hold the opposite, but same amount of, electric charge.

If an atom has **more protons** than electrons, it is said to be **positively charged**. If it has **more electrons** than protons, it is said to be **negatively charged**.

If an atom contains **as many protons as electrons**, the charges will cancel each other, and the atom is said to be **uncharged**, or **electrically neutral**.
According to the law of charges, unlike charges attract each other and like charges repel each other. Electric charges can be stationary, as in static electricity, or they can be moving, as in an electric current. The flow of electrons through a conductor is called current. If two objects are connected by a material that lets charge flow easily, such as a copper wire, then electric current flows from one object to the other through the wire.

Conductors are materials that allow an electric current to flow through them easily. Most metals are good conductors.

Current that flows in one direction only, such as the current in a battery-powered flashlight, is called direct current (DC). Current that flows back and forth, reversing direction again and again, is called alternating current (AC).

There are three basic systems of units used to measure electrical quantities; the most common is the one in which the ampere is the unit of current, the volt is the unit of electromotive force, and the ohm is the unit of resistance.

- The **ampere (A)** is used to measure the rate of current flow, the number of electrons flowing past a given point in a conductor per second.
- The **volt** (V) is a unit used to measure the force (*electromotive force (emf) or potential difference*) that pushes electrons through the conductor.
- The **ohm (Ω)** measures the amount of resistance to the flow of electrons.

The law that relates current, voltage, and resistances is the **Ohm's Law** and is represented by the following formula:

V = I• R

where:

- **V** is the difference in volts between two locations (called the potential difference),
- **I** is the amount of current in amperes that is flowing between these two points, and
- **R** is the resistance in ohms of the conductor between the two locations of interest.

It can also be written as $I = \frac{V}{R}$ or $R = \frac{V}{I}$

Example 1: What is the resistance of a metallic conductor that allows a current of 5 A to flow through it when is connected to a source that provides a potential difference of 220 V?

Solution:

From Ohm's Law we know V = I • R

Since we need to know the resistance, we can use $R = \frac{V}{I}$

From the problem V = 220 V and I = 5A , so $R = \frac{V}{I} = \frac{220V}{5A} = 44\Omega$

Example 2: What is the voltage needed to produce a current flow of 3 A through a resistance of 40 ohms?

Solution

From Ohm's Law V = I • R , and I = 3A R = 40 Ω

so V = 3 A • 40 Ω = 120 V

To drive an electric current through a circuit, resistance energy is required. This energy is supplied by the source of the current, such as a battery or an electric generator.
P**ower** is the rate at which the energy is supplied to a device, and it is often measured in units called **watts.**

We can define **Power** as the work per unit of time.

Power = Work / Time or $P = \frac{W}{T}$.

Now, the definition of **Electric Power** is Voltage times Current.

P = V• I

Using Ohm's Law we can write V = I• R

and replacing in the first equation P = I• R• I = $I^2 \bullet R$

where P = power, V = voltage, I = current in amperes and R resistance in ohms.

Electric power is also measured in watts, but we normally see electric power measured in kilowatts, since we use so much of it.

1000 watts = 1 kilowatt

There are several different devices that can provide the voltage necessary to generate an electric current. The two most common sources are generators and electrolytic cells.

Generators use mechanical energy, such as water pouring through a dam or the motion of a turbine driven by steam, and electrolytic cells use chemical energy to produce electricity. An electric battery consists of a cell or group of cells connected together.

Alternating current (AC) has several characteristics that make it more efficient than direct current (DC) as a source of electric power. One of these characteristics is that the voltage of the current can be changed to almost any value using a simple electromagnetic device called a **transformer**.

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Coil

AC

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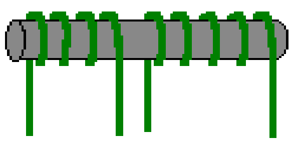
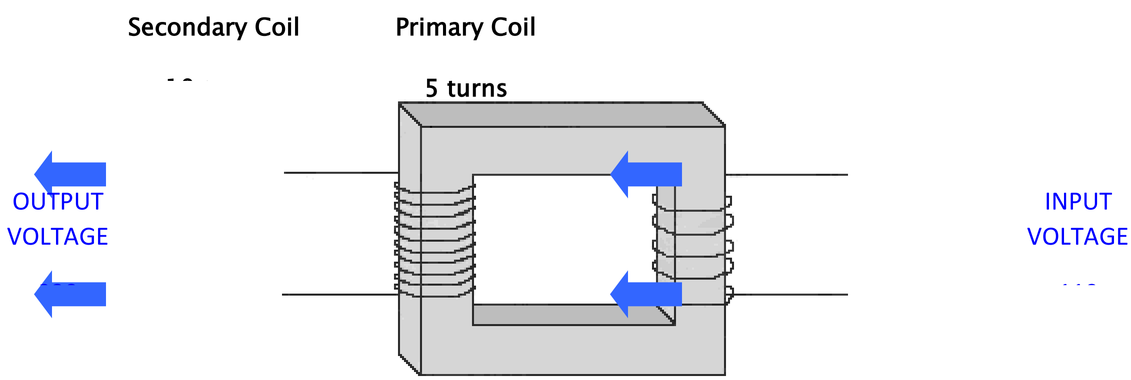


A transformer can be a long piece of iron with wire wrapped around it near one end and wire at the other end to create current wrapped around it (with AC current going through it).

A more common configuration is a square or donut shaped iron core with the wire wrapping on both sides.



If the number of turns of wire on the primary coil is greater than the numbers of turns of wire on the secondary coil, the voltage decreases. In the same way, when the number of turns of wire in the primary coil is less than in the secondary coil, the voltage increases.

Optics

Light is radiant energy that can be detected by the human eye.

There are many theories about the nature of the light:

- In the Particle theory (1670), Newton thought that light was made up of streams of particles (corpuscles). This theory held until the nineteenth century. When diffraction and interference were observed, the theory failed.

- In the Wave theory, by Huygens (1680), light is a type of wave. This explained reflection and refraction of the light.

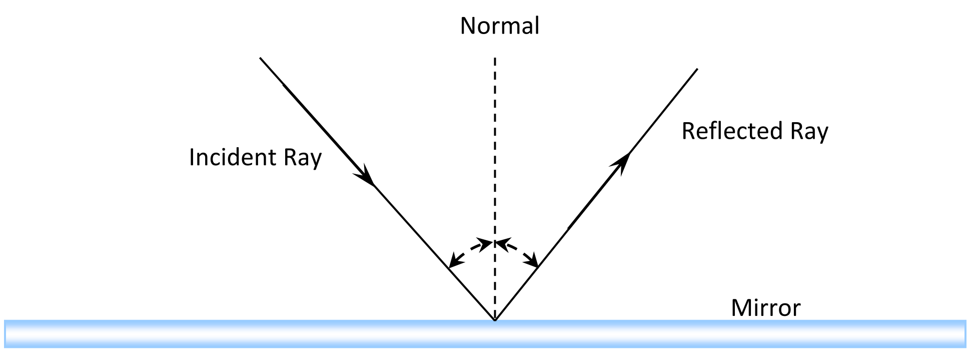
- In 1860, with the Maxwell's equations, experiments confirmed the Electromagnetic theory that visible light is a small portion of the electromagnetic spectrum. This theory, however, did not give a complete explanation of the nature of light.

- In 1905, the photoelectric effect was discovered. Einstein received a Nobel Prize for his work in electromagnetic radiation.
  The particle theory of light explains the photoelectric effect while the wave theory does not. The electromagnetic wave theory fails to fully explain the nature of these electrons' emissions.

- Planck & Einstein developed the idea that light was energy radiated at the speed of the light in the form of wave packets of energy (photons) like particles (quantum theory).
-
- The present point of view is that light seems to have one double nature. The phenomena of the propagation of light and the interaction of light and matter. This is related to the theory that indicates that all waves behave, at some time, like particles; and particles, at some time, behave like waves.

The Law of Reflection

The law of reflection states that the angle at which a ray of light strikes the reflecting surface is exactly equals to the angle the reflected ray makes with the same surface.

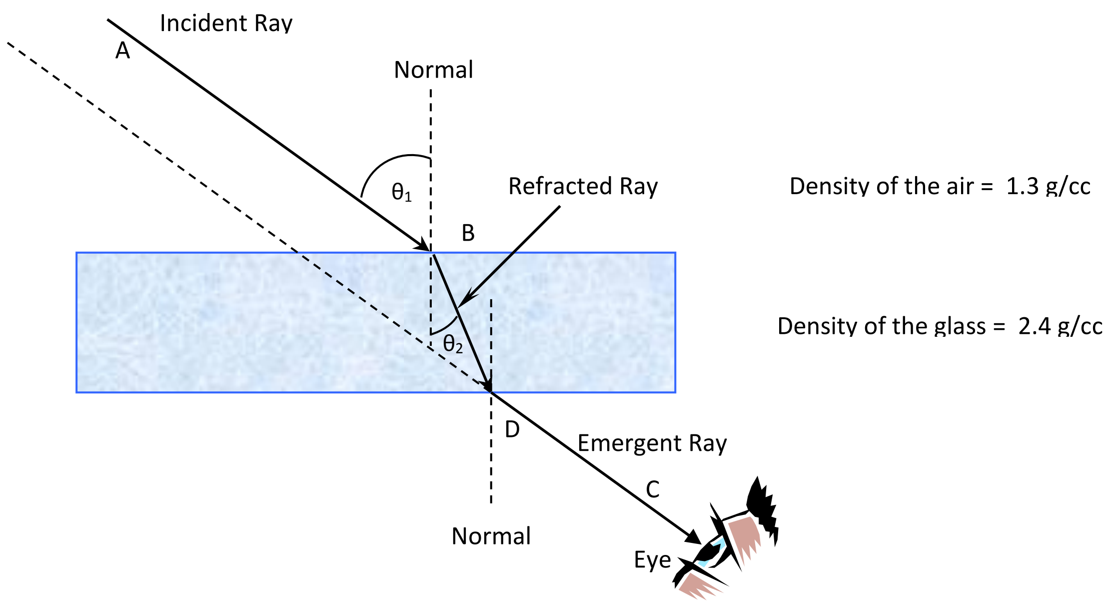


The Law of Refraction

The law of refraction states that when a beam of light enters obliquely from an optically less dense medium, it is bent toward the normal at the point of incidence.

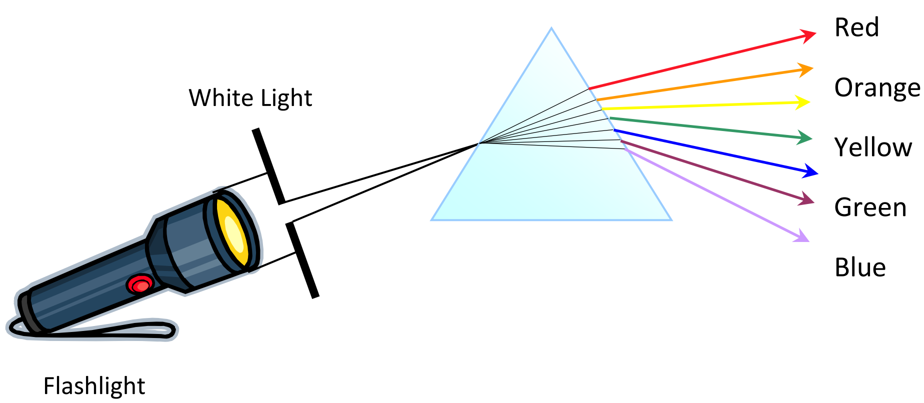
The angle of incidence θ_1, between the normal and the incidence ray ($\overrightarrow{AB}$) is larger than the angle of refraction, θ_2 ,between the normal and the refracted ray($\overrightarrow{BD}$).

The normal is an imaginary line that goes perpendicular to the surface. As the beam leaves the denser medium, it is bent away from the normal.



Dispersion of the light

Another aspect of light that is quite common is the breaking up of white light into its constituent colors. For example, if a beam of white light enters a glass prism, as shown in the figure below, what emerges from the other side is a spread out beam of many colored light.



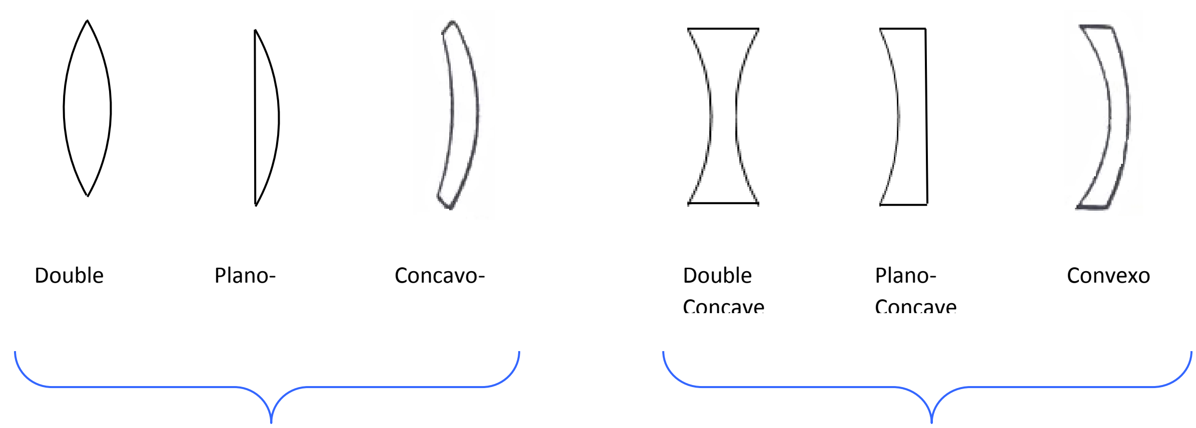
The explanation for this phenomenon is simple: the white light consists of literally all the colors in the rainbow. The various colors are refracted through different angles by the glass, and are ``dispersed'', or spread out. From the figure, we see that violet light gets bent more by the glass than red light. The triangular shape of the prism is designed to maximize this effect.

Lenses

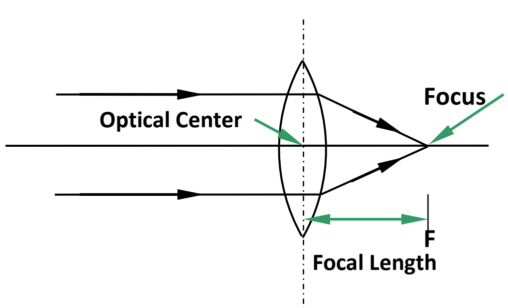
A lens is a piece of transparent material, usually glass, enclosed by two curved surfaces.

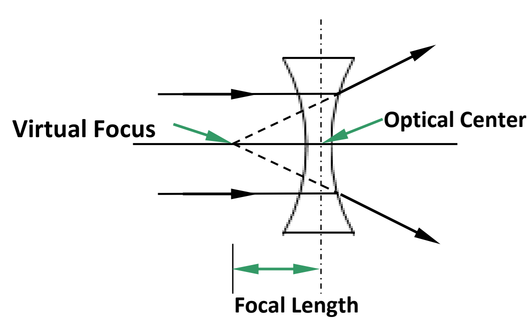
When parallel rays of light pass through a lens, they are refracted.

- ☆ If they are bending toward the center, they converge and the lenses are called Converging Lenses or Convex Lens. These lenses are thicker in the middle than on the edges.
- ☆ If they are bending toward the edges, they diverge and the lenses are called Diverging Lenses or Concave Lenses. These lenses are thicker on the edges than in the center.



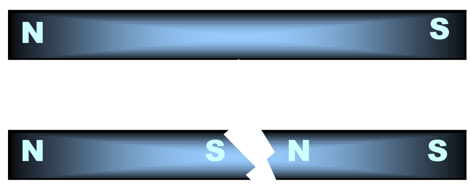
Converging Lenses ***Diverging Lenses***





Magnetism

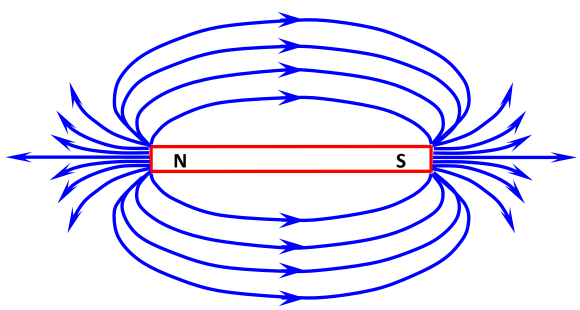
◦The ancient Greeks discovered that certain rare stones, called lodestones, could attract small pieces of iron. When these lodstones are freely suspended by a piece of string, they always point in the same direction. They were used as magnets. The name magnet comes from Magnesia, a district in Thessaly, Greece where one legend claims magnets to have first been discovered.
◦The magnetic north pole corresponds to the south geographic pole, and the magnetic south pole corresponds to the geographic north pole. The magnetic poles are not aligned with the earth's rotational axis.   Also, the poles move and occasionally reverse for a couple of hundred thousand years or so.
◦When two or more magnets are brought together, they exert forces on each other:like poles repel; unlike poles attract.
◦Some substances, such as iron, become magnetized when placed near a magnet. Different substances offer varying degrees of susceptibility to this type of magnetization.
◦Breaking a magnet into pieces does not isolate the poles from each other. Instead, all the pieces become magnets, each with its own two poles. Objects that are magnets always have both poles; single poles do not exist.



◦Heating a magnet weakens its magnetism; however, cooling does not ordinarily strengthen it.

◦Magnets create magnetic fields that can influence other magnets or other magnetic materials without physically contacting them. The magnetic field around a magnet can be mapped by spreading small iron filings. The iron filings will line up along the magnetic field lines of the magnet.

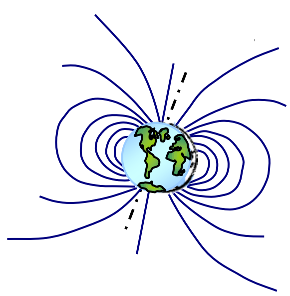
(See experiment in http://micro.magnet.fsu.edu/electromag/java/magneticlines/)



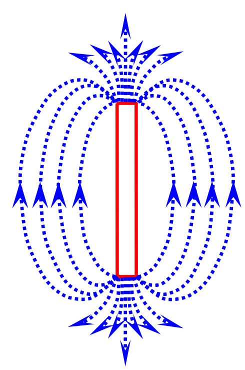
◦There are three main types of magnets: permanent magnets, temporary magnets, and electromagnets.

- Permanent magnets are those we are most familiar with, such as the magnets hanging onto our refrigerator doors. They are permanent because once they are magnetized, they keep a level of magnetism.
- Temporary magnets are those which act like permanent magnets when they are within a strong magnetic field but lose their magnetism when the magnetic field disappears. Examples would be paperclips and nails and other soft iron items.
- An electromagnet is a coil of wire, usually with an iron core, which acts like a permanent magnet when current is flowing in the wire. The strength and polarity of the magnetic field created by the electromagnet are adjustable by changing the magnitude of the current flowing through the wire and by changing the direction of the current flow.

Magnetic Field Sources



Earth



Bar Magnet

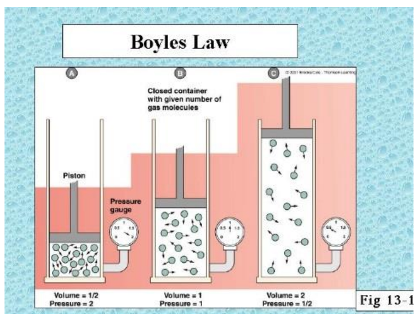
GAS LAWS

Gases respond more obviously to temperature and pressure than do the other three basic types of matter (liquids, solids and plasma). For gases, temperature and pressure are closely related to volume, and this allows us to predict their behavior under certain conditions.

Boyle's law notes that when temperature is constant, an inverse relationship exists between the volume and pressure of a gas. An inverse relationship exists when there are two variables, where one of the two increases in direct proportion to the decrease in the other. In Boyle’s Law, the greater the pressure, the less the volume and vice versa.

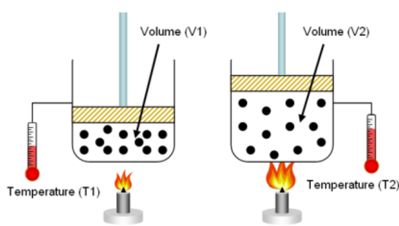
When pressure goes up, volume goes down. When volume goes up, pressure goes down.

$$V = \frac{1}{P} \qquad P_1 V_1 = P_2 V_2$$



Charles determined that the ratio of temperature to volume is a direct relationship. **Charles's law** states that at a constant pressure, the temperature and volume may vary. As the gas heats up, its volume increases, and as it cools, its volume decreases. The kinetic energy of gas molecules is increased as the temperature is increased.

This law states that the volume of a given amount of gas held at constant pressure is directly proportional to the Kelvin temperature. As the temperature goes up, the volume also goes up, and vice-versa. $\uparrow V \rightarrow \uparrow T \qquad \uparrow T \rightarrow \uparrow V$



Using the Kelvin scale of absolute temperature, **Gay-Lussac** found that at lower temperatures, the pressure of a gas is lower, while at higher temperatures its pressure is higher. Thus, the ratio of pressure to temperature is directly proportional.