Shock Value/Circuit Lab

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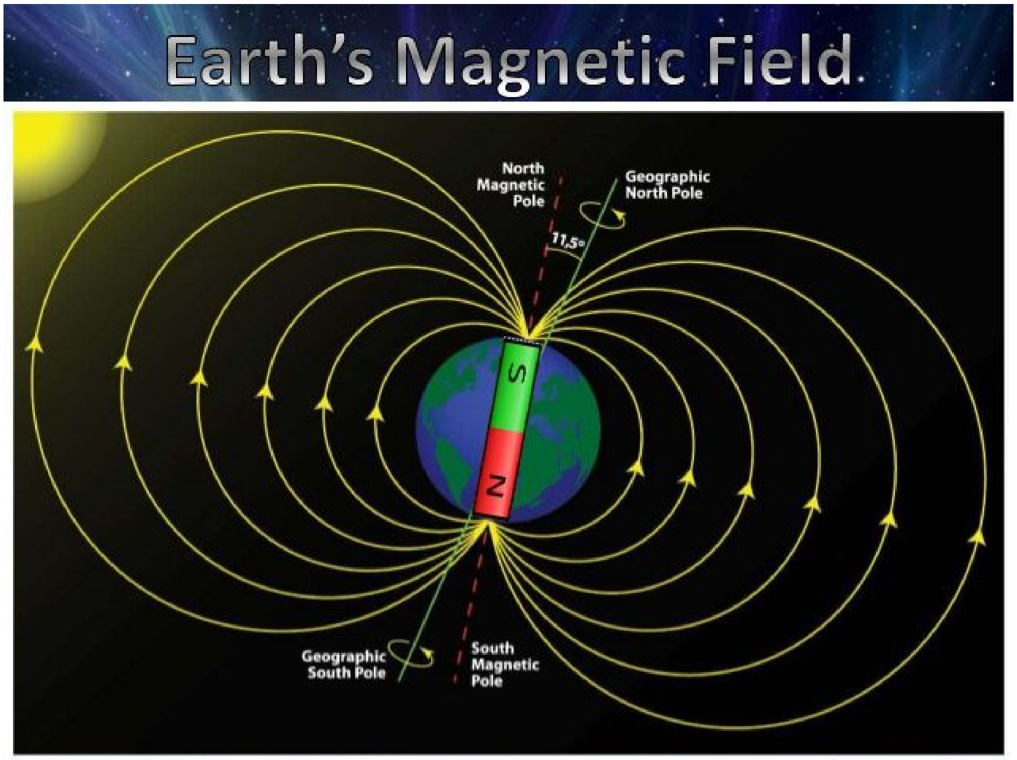
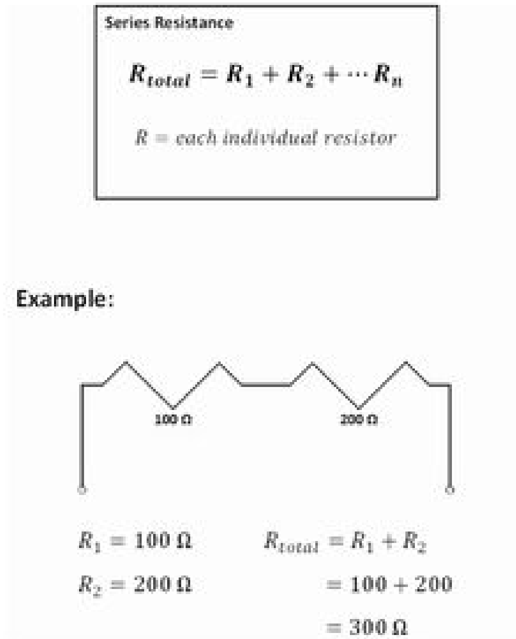
- Earth's magnetic field, also known as the geomagnetic field, is the magnetic field that extends from the Earth’s interior out into space, where it meets the solar wind, a stream of charged particles originating from the Sun.
- The magnetic field is caused by electric currents due to the motion of convection currents of molten iron in the Earth's outer core driven by heat escaping from the core, a natural process called a geodynamo.
- The North geomagnetic pole, located near Greenland in the northern hemisphere, is actually the south pole of the Earth's magnetic field, and the South geomagnetic pole is the north pole.
- More electrons=Negative charge More protons=Positive charge



Ohm's law	V=IR
Joule's law	P=IE P= Power in watts I= Current in amperes E= Voltage in volts
Voltage	The rate at which energy is extracted from a source that produces a flow of electricity in a circuit. (It comes from the battery)
Ohms	The resistance units Ω Are a unit of measurement of electrical resistance. Resistance is the opposition of the flow of something

Ohm’s Law	States that the current is strictly related to the voltage and has an opposite relation to the resistance. 2. V=I*R V/E = applied voltage in volts R = the resistance in ohms I = the current in amps 3. The law that states that resistance in a circuit is equal to voltage divided by current
Amps	The current units Measurement of the amount of electric current, the number of electrons that pass a given point at a given time
Volts	Units for Voltage
Power	(Physics), the rate of doing work. Joules per second
Watts	Units of Power
Insulator	Material that has a high resistance (wood, rubber, plastic, and glass).
Conductor	Material that has a low resistance (gold, silver, copper, and aluminum).

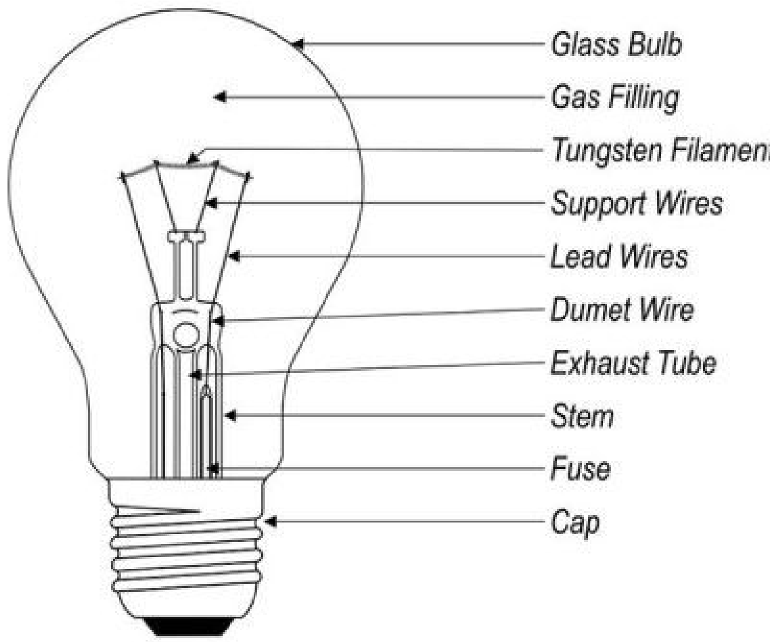
Circuit	A closed path through which a electric current flows or may flow.
Parallel Circuit	A closed circuit in which the current divides into two or more paths before recombining to complete the circuit. It has two or more paths for current to flow through
Resistance in parallel	1/Rt = 1/R1+ 1/R2+ 1/R3 Rt= Total resistance of the circuit (Ohms). $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ $\frac{1}{R_T} = \frac{1}{10} + \frac{1}{20} + \frac{1}{30} + \frac{1}{40}$ $\frac{1}{R_T} = 0.1 + 0.05 + 0.033 + 0.025$ $\therefore R_T = \frac{1}{0.2083} = 4.8\Omega$

Series Resistance	Circuit in which resistors are arranged in a chain, so the current has only one path to take 
Resistor (R)	Used to reduce current flow, (Ohms) Ω- (light bulb)
Current (I)	Which is the flow of electric charge across a surface at the rate of one, measured in Amperes (Amps) I

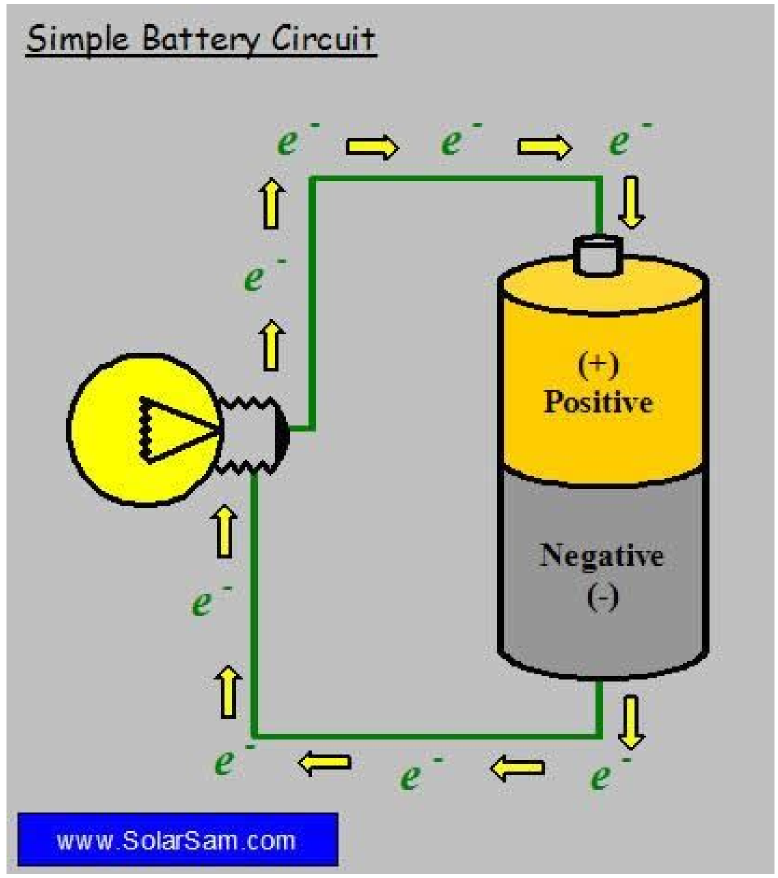
Electrical Current	The flow of charge through a material.
Voltmeter	The Voltmeter measures the voltage between two points in a circuit. To use a Voltmeter, place the meter 'parallel' to the circuit element. The Voltmeter has very high resistance, around 10MΩ, so it has minimal impact to the circuit when placed in parallel.
Ammeter	The Ammeter measures the current in a circuit. To use an Ammeter, place the meter in 'series' with the circuit. The Ammeter has very low resistance, so it has minimal impact to the circuit when placed in series.
Ohmmeter	The Ohmmeter measures the resistance of a circuit element. It can be placed either in series or parallel to the element. If an Ohmmeter is not provided, one can also place a Voltmeter parallel to the element and an Ammeter in series with the element and apply Ohm's Law to calculate the resistance.
Static Electricity	The buildup of charges on an object (do not flow).

Conversation of Charge (Law)	Electrons are only transferred from one location to another.
Kirchhoff's Current Law (KCL)	Kirchhoff's Current Law states that sum of currents entering a node is equal to the sum of currents leaving the node. Example: Here in this simple single junction example, the current I_T leaving the junction is the algebraic sum of the two currents, I_1 and I_2 entering the same junction. That is $I_T = I_1 + I_2$. Note that we could also write this correctly as the algebraic sum of: $I_T - (I_1 + I_2) = 0$. So if I_1 equals 4 amperes and I_2 is equal to 1 amperes, then the total current, I_T leaving the junction will be 4 + 1 = 5 amperes, and we can use this basic law for any number of junctions or nodes as the sum of the currents both entering and leaving will be the same.

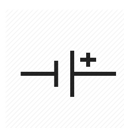
Kirchhoff's Voltage Law (KVL)	Kirchhoff's Voltage Law (KVL) states that for any closed loop in a circuit, the sum of voltages will be zero. Vs= Volt Battery Supply I= Amperes R1, R2, R3= Ohms $R_T = R_1 + R_2$ $I = \frac{V_S}{R_T} = \frac{V_S}{R_1 + R_2}$ $V_{R1} = IR_1 = V_S\left(\frac{R_1}{R_1 + R_2}\right)$ $V_{R2} = IR_2 = V_S\left(\frac{R_2}{R_1 + R_2}\right)$
Voltage Drop Across Each Resistor	$V_{R1} = I \times R_1 = (0.2) \times (10) = (2)$ volts $V_{R2} = I \times R_2 = (0.2) \times (20) = (4)$ volts $V_{R3} = I \times R_3 = (0.2) \times (30) = (6)$ volts

Parts of Light Bulb	

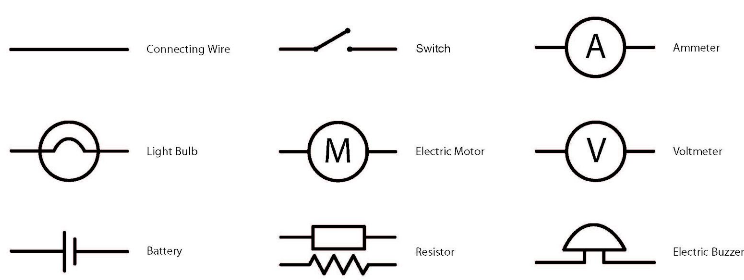
The Current of a Battery



Symbols



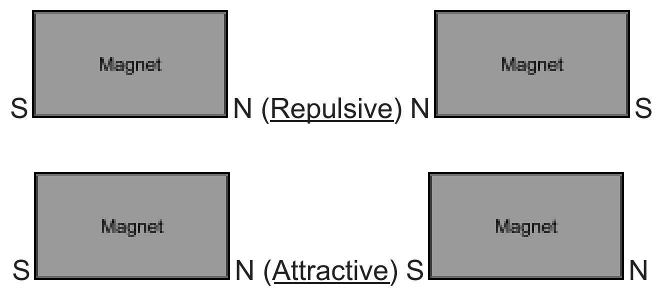
Negative (-) to positive (+)



Magnets

Magnetism- The attraction of a magnet for another object.

Materials that can be magnetized- Which are also the ones that are strongly attracted to a magnet, are called ferromagnetic (or ferrimagnetic). These include iron, nickel, cobalt, some alloys of rare-earth metals, and some naturally occurring minerals such as lodestone.



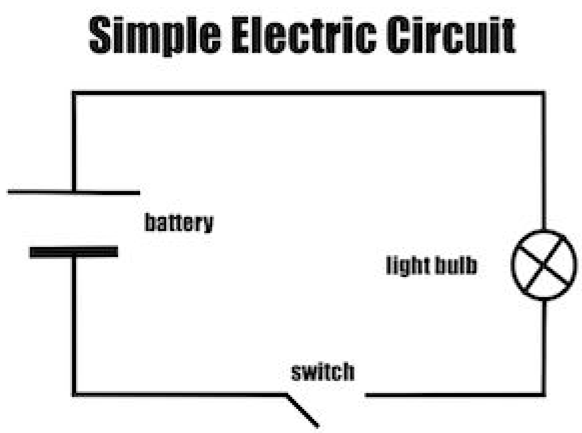
Magnetic Pole- Each magnet has two ends (N and S) where the magnetic effect is strongest.

3 Ways of Transferring Charge

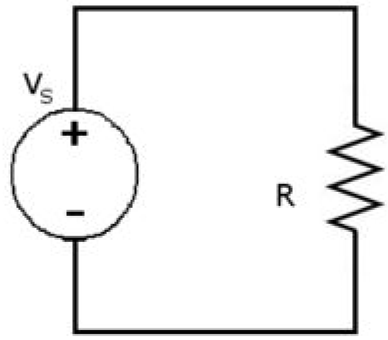
- Friction-The transfer of electrons from one object to another by rubbing.
- Conductor-The transfer of electrons from a charged object to another object by direct contact.
- Induction-The movement of electrons to one part of an object by the electric field of another object.

An **electrical network** is an interconnection of electrical components (e.g. batteries, resistors, inductors, capacitors, switches) or a model of such an interconnection, consisting of electrical elements (e.g. voltage sources, current sources, resistances, inductances, capacitances).

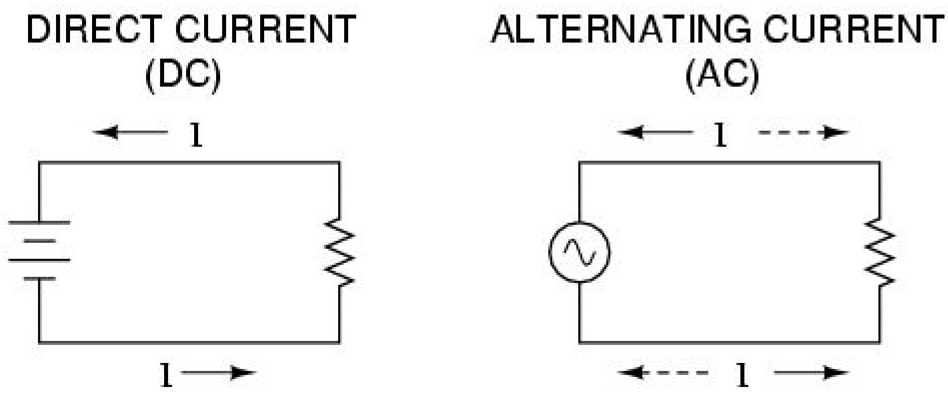
An **electrical circuit** is a network consisting of a closed loop, giving a return path for the current. Linear electrical networks, a special type consisting only of sources (voltage or current), linear lumped elements (resistors, capacitors, inductors), and linear given elements (transmission lines), have the property that signals are linearly super imposables. They are thus more easily evaluated, using powerful frequency domain methods such as Laplace transforms, to determine (Direct current) DC response, (Alternating current) AC response, and transient response.



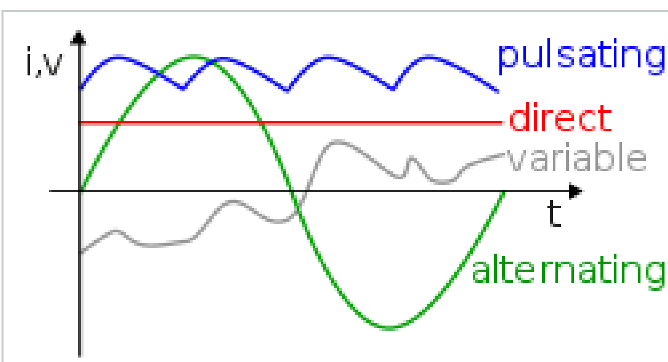
A **resistive circuit** is a circuit containing only resistors and ideal current and voltage sources. Analysis of resistive circuits is less complicated than analysis of circuits containing capacitors and inductors. If the sources are constant (DC) sources, the result is a DC circuit. For a random resistor network, the effective resistance and current distribution properties of the network can also be modeled in terms of graph measures and geometrical properties of network.



A network that contains active electronic components is known as an **electronic circuit**. Such networks are generally nonlinear and require more complex design and analysis tools.

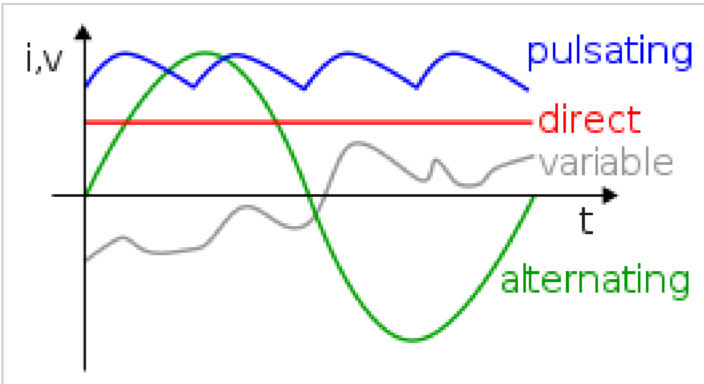


DC- **Direct current** (**DC**) is the unidirectional flow of electric charge. A battery is a good example of a DC power supply. Direct current may flow in a conductor such as a wire, but can also flow through semiconductors, insulators, or even through a vacuum as in electron or ion beams. The electric current flows in a constant direction, distinguishing it from alternating current (AC).



Direct Current (red line). The vertical axis shows current or voltage and the horizontal 't' axis measures time and shows the zero value.

AC- **Alternating current** (**AC**) is an electric current which casually reverses direction, in contrast to direct current (**DC**) which flows only in one direction. Alternating current is the form in which electric power is delivered to businesses and residences, and it is the form of electrical energy that consumers typically use when they plug kitchen appliances, televisions, fans and electric lamps into a wall socket.



Alternating current (green curve). The horizontal axis measures time; the vertical, current or voltage.

Solid State Component

A solid state component is part of a circuit in which a signal is controlled by a solid material, such as a semiconductor.

- Diodes- A solid-state component that has layers of the two types of semiconductors joined together. A diode allows current flow in one direction only.
- Transistors- Is formed when a layer of either type of semiconductor is squashed between two layers of the other type of semiconductor. A transistor carries out one of two functions: it either amplifies an electronic signal or switches current on and off.
- Integrated circuit- Is a circuit that has been made on a chip or, in other words, a tiny slice of semiconductor.

Electricity and Magnetism

Electricity and magnetism are presentations of a single masked electromagnetic force. Electromagnetism -is a branch of physical science that describes the interactions of electricity and magnetism, both as separate phenomena and as a singular electromagnetic force. A magnetic field is created -by a moving electric current or ,for example, a twisted wire with a electrical current flowing through it. The rules of electromagnetism also explain geomagnetic and electromagnetic phenomena by explaining how charged particles of atoms interact.

Before the development of technology, electromagnetism was perhaps most strongly experienced in the form of lightning, and electromagnetic radiation in the form of light. Ancient man kindled fires that he thought were kept alive in trees struck by lightning. Magnetism has long been employed for navigation in the compass. In fact, it is known that Earth's magnetic poles have exchanged positions in the past.

Some of the rules of *electrostatics*, the study of electric charges at rest, were first noted by the ancient Romans, who observed the way a brushed comb would attract particles. It is now known that electric charges occur in two different forms, positive charges and negative charges. Like charges repel each other, and differing types attract.

The force that attract positive charges to negative charges weakens with distance, but is intensively very strong—up to 40 times stronger than the pull of gravity at the surface of the earth. This fact can easily be demonstrated by a small magnet that can hold or suspend an object. The small magnet applies a force at least equal to the pull of gravity from the entire Earth.

The fact that unlike charges attract means that most of this force is normally neutralized and not seen in full strength. The negative charge is generally carried by the atom's electrons, while the positive lie with the protons inside the atomic nucleus. Other less known particles can also carry charge. When the electrons of a material are not tightly bound to the atom's nucleus, they can move from atom to atom and the substance, called a conductor, can conduct electricity. In the other hand, when the electron binding is strong, the material resists electron flow and is an insulator.

When electrons are weakly bound to the atomic nucleus, the result is a semiconductor, often used in the electronics industry. It was not initially known if the electric current carriers were positive or negative, and this initial ignorance gave rise to the idea that current flows from the positive terminal to the negative. In reality we now know that the electrons actually flow from the negative to the positive.

Electromagnetism is the theory of a fused expression of the electromagnetic force. This is seen in the movement of electric charge, that gives rise to magnetism (the electric current in a wire being found to deflect a compass needle), and it was Scottish physicist James Clerk Maxwell (1831–1879), who published a unifying theory of electricity and magnetism in 1865. The theory came from former specialized work by German mathematician Carl Friedrich Gauss (1777–1855), French physicist Charles Augustin de Coulomb (1736–1806), French scientist AndréMarie Ampère

(1775–1836), English physicist Michael Faraday (1791–1867), American scientist and statesman Benjamin Franklin (1706–1790), and German physicist and mathematician Georg Simon Ohm

(1789–1854). However, one factor that did not counter the experiments was added to the equations by Maxwell to ensure the conservation of charge. This was done on the theoretical grounds that charge should be a conserved quantity, and this addition led to the prediction of a wave phenomena with a certain anticipated velocity. Light, with the expected velocity, was found to be an example of this electro-magnetic radiation.

Light had formerly been thought of as consisting of particles (photons) by Newton, but the theory of light as particles was unable to explain the wave nature of light (diffraction and the like). In reality, light displays both wave *and* particle properties. The resolution to this unanswered idea lies in quantum theory , where light is neither particles nor wave, but both. It spreads as a wave without the need of a method and cooperates in the manner of a particle. This is the basic nature of quantum theory.

Classical electromagnetism, useful as it is, contains contradictions (acausality) that make it incomplete and drive one to consider its extension to the area of quantum physics, where electromagnetism, of all the fundamental forces of nature, it is perhaps the best understood.

There is much symmetry between electricity and magnetism. It is possible for electricity to give rise to magnetism, and symmetrically for magnetism to give rise to electricity (as in the exchanges within an electric transformer). It is an exchange of just this kind that constitutes electromagnetic waves. These waves, although they don't need a medium of being widely spread, are slowed when traveling through a transparent substance.

Electromagnetic waves differ from each other only in maximum length of vibration, frequency, and location (polarization). Laser beams are particular in being very logical, that is, the radiation is of one frequency, and the waves coordinated in motion and direction. This permits a highly concentrated beam that is used not only for its cutting abilities, but also in electronic data storage, such as in CD-ROMs.

The differing frequency forms are given a variety of names, from radio waves at very low frequencies through light itself, to the high frequency x rays and gamma rays.

The unification of electricity and magnetism allows a deeper understanding of physical science, and much effort has been put into further fusing the four forces of nature (e.g., the electromagnetic, weak, strong, and gravitational forces. The weak force has now been fused with electromagnetism, called the electroweak force. There are research programs attempting to collect data that may lead to a combination of the strong force with the electroweak force in a grand fused theory, but the adding of gravity remains an open problem.

Maxwell's theory is in fact in contradiction with Newtonian mechanics, and in trying to find the resolution to this conflict, Einstein was lead to his theory of special relativity. Maxwell's equations withstood the conflict, but it was Newtonian mechanics that were corrected by relativistic mechanics. These corrections are most necessary at velocities, close to the speed of light.

Magnetism is a counterexample to the frequent claims that relativistic effects are not noticeable for low velocities. The moving charges that compose an electric current in a wire might typically only be traveling at several feet per second (walking speed), and the resulting Lorentz contraction of special relativity is indeed minute. However, the electrostatic forces at balance in the wire are of such great magnitude, that this small contraction of the moving (negative) charges exposes a remainder force of real world magnitude, namely the magnetic force. It is in exactly this way that the magnetic force derives from the electric. Special relativity is indeed hidden in Maxwell's equations, which were known before special relativity was understood or separately formulated by Einstein.

Electricity at high voltages can carry energy across extended distances with little loss. Magnetism derived from that electricity can then power vast motors. But electromagnetism can also be employed in a more delicate fashion as a means of communication, either with wires (as in the telephone), or without them (as in radio communication). It also drives motors and provides current for electronic and computing devices.

Electromagnetism

Electromagnetism

Electromagnetism is the force involving the interaction of electricity and magnetism. It is the science of electrical charge, and its rules control the way charged particles of atoms work together. Electromagnetism is one of the four fundamental forces of the universe (gravity and the "strong" and "weak" forces that hold an atomic nucleus together are the other three). Because its effects can be observed so easily, electromagnetism is the best understood of these four forces.

Some of the rules of electrostatics, or the study of electric charges at rest, were first noted by the ancient Romans, who observed the way a brushed comb would attract particles. Until the nineteenth century, however, electricity and magnetism were thought to be totally different and separate forces. In 1820, a direct connection between the two forces was confirmed for the first time when Danish physicist Hans Christian Oersted (1777–1851) announced his discovery that an electric current, if passed through a wire placed near a compass needle, would make the needle move. This suggested that electricity somehow creates a magnetic force or field, since a compass needle moves by magnetism.

Shortly afterward, French physicist André Marie Ampère (1775–1836) conducted experiments in which he discovered that two parallel wires each carrying a current attract each other if the currents flow in the same direction, but repel each other if they flow in opposite directions. He concluded that magnetism is the result of electricity in motion.

A decade after Oersted's experiments, English physicist Michael Faraday (1791–1867) observed that an electric current flowing in a wire created what he called "lines of force" to expand outward, inducing or causing an electric flow in a crossed wire. Since it was known from Oersted's work that an electric current always produces a magnetic field around itself, Faraday concluded from his experiments just the opposite: that a wire moving through a magnetic field will induce an electric current in the wire.

Finally, between 1864 and 1873, Scottish physicist James Clerk Maxwell (1831–1879) devised a set of mathematical equations that unified electrical and magnetic phenomena into what became known as the electromagnetic theory. He and his fellows now understood that an electric current creates a magnetic field around it. If the motion of that current changes, then the magnetic field varies, which in turn produces an electric field.

Words to Know

Electromagnetic radiation: Radiation (a form of energy) that has properties of both an electric and magnetic wave and that travels through a vacuum with the speed of light.

Electromagnetic spectrum: The complete range of electromagnetic radiation, including radio waves (at the longest-wavelength end), microwaves, infrared radiation, visible light, ultraviolet radiation , X rays, and gamma rays (at the shortest-wavelength end).

Frequency: The rate at which vibrations take place (number of times per second the motion is repeated), given in cycles per second or in hertz (Hz). Also, the number of waves that pass a given point in a given period of time.

Maxwell also discovered that the swinging or fluctuation of an electric current would produce a magnetic field that expanded outward at a constant speed. By applying the ratio of the units of magnetic phenomena to the units of electrical phenomena, he found it possible to calculate the speed of that expansion. The calculation came out to approximately 186,300 miles (300,000 kilometers) per second, nearly the speed of light. From this, Maxwell theorized that light itself was a form of electromagnetic radiation that traveled in waves. Since electric charges could be made to swing at many velocities (speeds), there should be a corresponding number of electromagnetic radiations. Therefore, visible light would be just a small part of the electromagnetic spectrum, or the complete array of electromagnetic radiation.

Indeed, modern scientists know that radio and television waves, microwaves, infrared rays, ultraviolet light, visible light, gamma rays, and X rays are all electromagnetic waves that travel through space independent of matter. And they all travel at roughly the same speed—the speed of light—different from each other only in the frequency at which their electric and magnetic fields oscillate.

Many common events depend upon the broad span of the electromagnetic spectrum. The ability to communicate across long distances despite intervening obstacles, such as the walls of buildings, is possible using the radio and television frequencies. X rays can see into the human body without opening it. These things, which would once have been labeled magic or out of the world, are now ordinary ways we use the electromagnetic spectrum.

The unification of electricity and magnetism has led to a deeper understanding of physical science, and much effort has been put into further fusing the four forces of nature. Scientists have demonstrated that the weak force and electromagnetism are part of the same fundamental force, which they call the electroweak force. There are proposals to include the strong force in a grand unified theory, which attempts to show how the four forces can be thought of as a manifestation of a single basic force that broke apart when the universe cooled after the big bang (theory that explains the beginning of the universe as a tremendous explosion from a single point that occurred 12 to 15 billion years ago). The inclusion of gravity in the fused theory, however, remains an open problem for scientists.

Electromagnetism Branch of physics dealing with the laws and phenomena that involve the interaction or interdependence of electricity and magnetism. The region in which the effect of an electromagnetic system can be detected is known as an *electromagnetic field*. When a magnetic field changes, an electric field can always be detected. When an electric field varies, a magnetic field can always be detected. Either type of energy field can be regarded as an electromagnetic field. A particle with an electric charge is in a magnetic field if it experiences a force only while moving; it is in an electric field if the force is experienced when still.

Curie temperature (T_C), or Curie point- Is the temperature above which certain materials lose their permanent magnetic properties, to be replaced by induced magnetism.

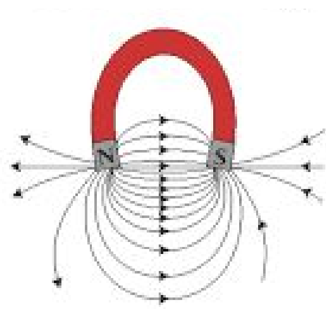
Ferromagnetic metals- are strongly attracted by a magnetic force. (Cobalt 1388k, Iron/steel 1043k, Nickel 627k, Gadolinium 292k, Dysprosium 88k, and etc)

Paramagnetic- are weakly attracted by a magnetic force. (Tungsten, Uranium, Lithium, Caesium, Platinum, Magnesium, Aluminium, and etc)

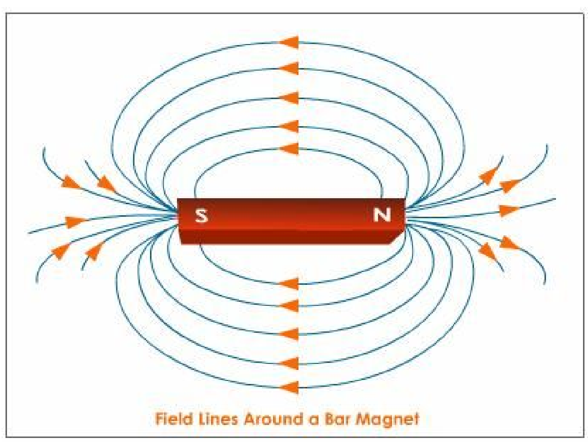
Diamagnetic metals- repel the magnet, though the force is typically very weak. (Carbon graphite, Gold, Silver, Lead, Bismuth, and etc)

Magnetism was first discovered- In a natural rock called magnetite, or lodestone. Its strange property of attracting iron objects was known nearly 3,000 years ago. Later, Chinese explorers discovered that a piece of lodestone, if able to move freely, would always point north. This led to the development of the compass.

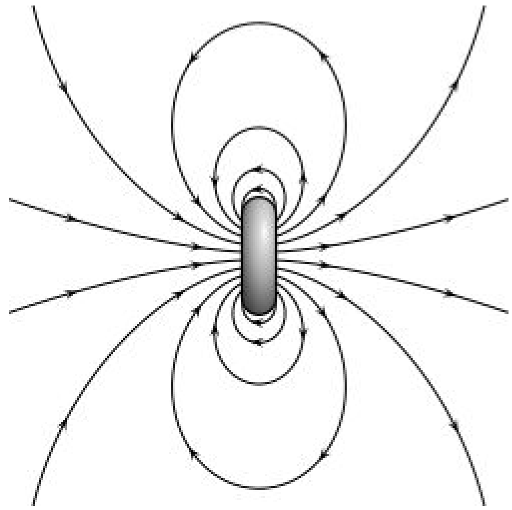
Shapes of Magnets



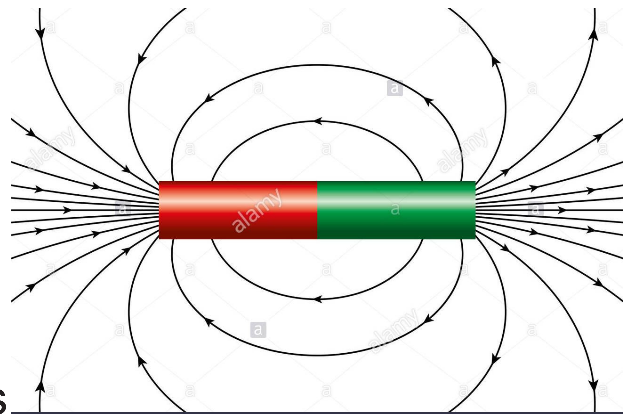
Horseshoe Magnets



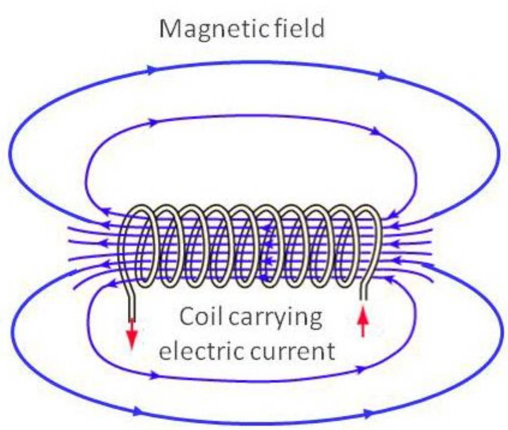
Bar Magnets



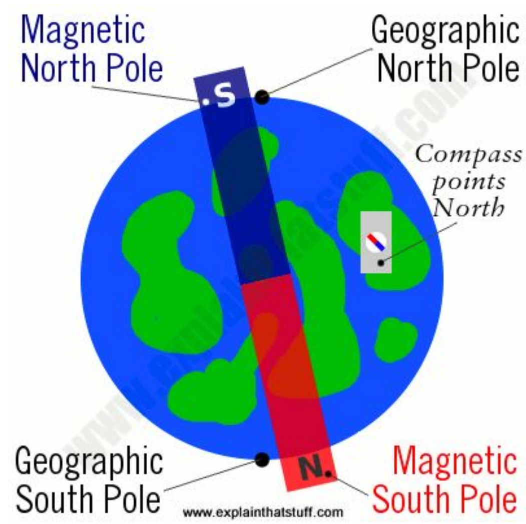
Ring Magnets



Cylindrical Magnets

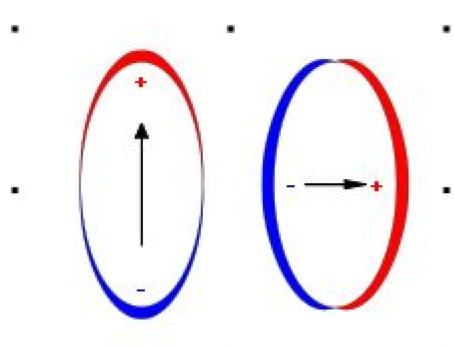


Solenoid

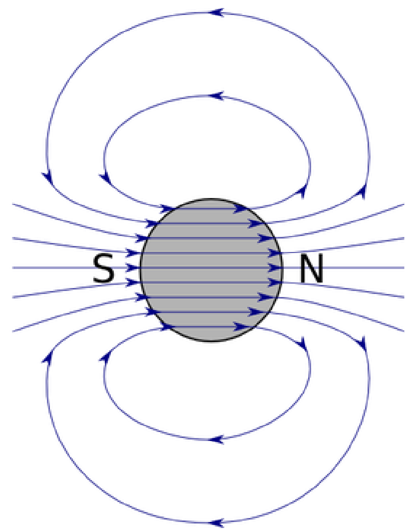


Magnetic Compass

The Earth is a magnet that can interact with other magnets in this way, so the north end of a compass magnet is drawn to align with the Earth's magnetic field. Because the Earth's magnetic North Pole attracts the "north" ends of other magnets, it is technically the "South Pole" of our planet's magnetic field. While a compass is a great tool for navigation, it doesn't always point exactly north. This is because the Earth's magnetic North Pole is not the same as "true north," or the Earth's geographic North Pole. The magnetic North Pole lies about 1,000 miles south of true north, in Canada.

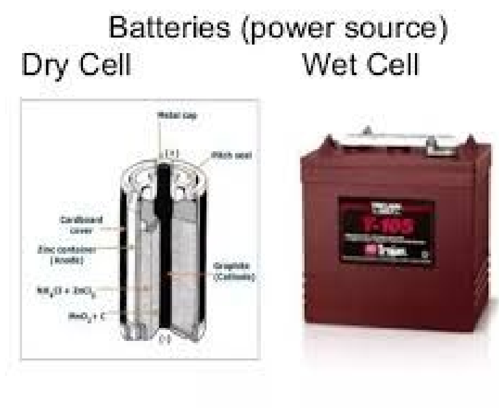


Ellipsoidal Magnet



Circular Magnet

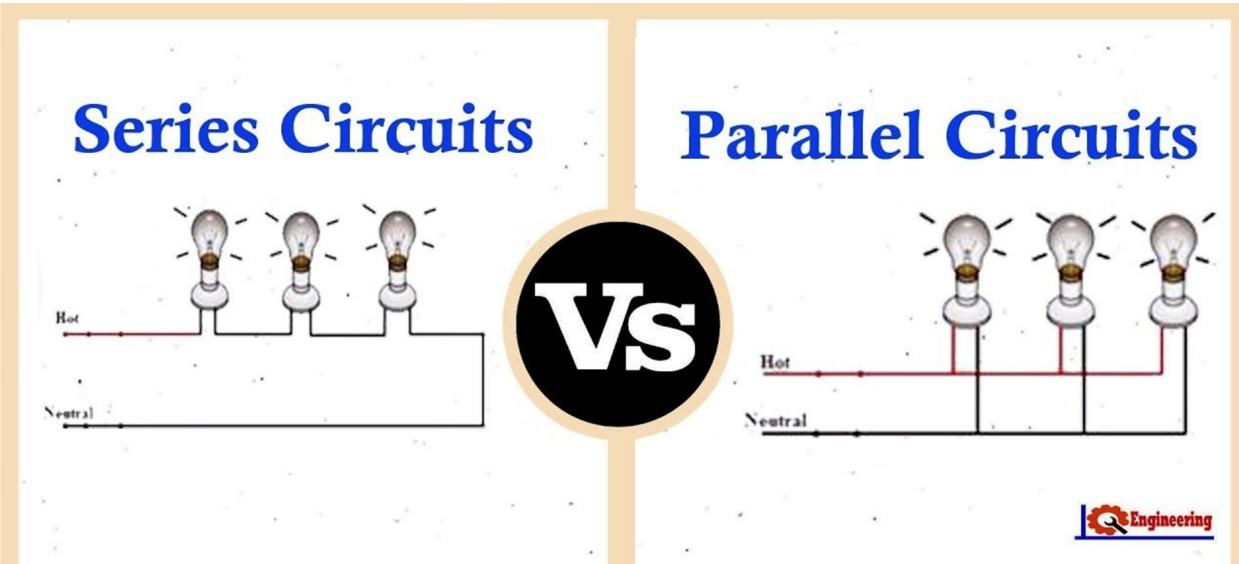
Dry cell Vs Wet Cell



Wet-cell battery- Is the original type of rechargeable battery. It is commonly found in aviation, electric utilities (cars), energy storage and cellphone towers. The battery contains a liquid electrolyte such as sulfuric acid, a dangerous corrosive liquid.

Dry-cell battery- Does not contain liquid. Smaller dry-cell batteries, such as alkaline or lithium ion, are typically used in portable electronics, such as toys, phones and laptops.

Parallel Vs Series



Components connected in Series are connected along a single path, so the same current flows through all of the components. $I_{total} = I_1 = I_2 = . . . I_n$ Total resistance in a series circuit is equal to the sum of the individual resistances, making it *greater* than any of the individual resistances. $R_{total} = R_1 + R_2 + . . . R_n$ Total voltage in a series circuit is equal to the sum of the individual voltage drops. $E_{total} = E_1 + E_2 + . . . E_n$ They are also sometimes called current-coupled or daisy chain-coupled.

Components connected in Parallel are connected along multiple paths, so the same voltage is applied to each component (share the same voltage). It is related with Kirchhoff’s current law. $E_{total} = E_1 = E_2 = . . . E_n$ Total resistance in a parallel circuit is *less* than any of the individual resistances. $R_{total} = (R_1 + R_2 + . . . R_n)$ R=Ohms Total current in a parallel circuit is equal to the sum of the individual branch currents. $I_{total} = I_1 + I_2 + . . . I_n$

Uses of Magnets in Our Daily Life

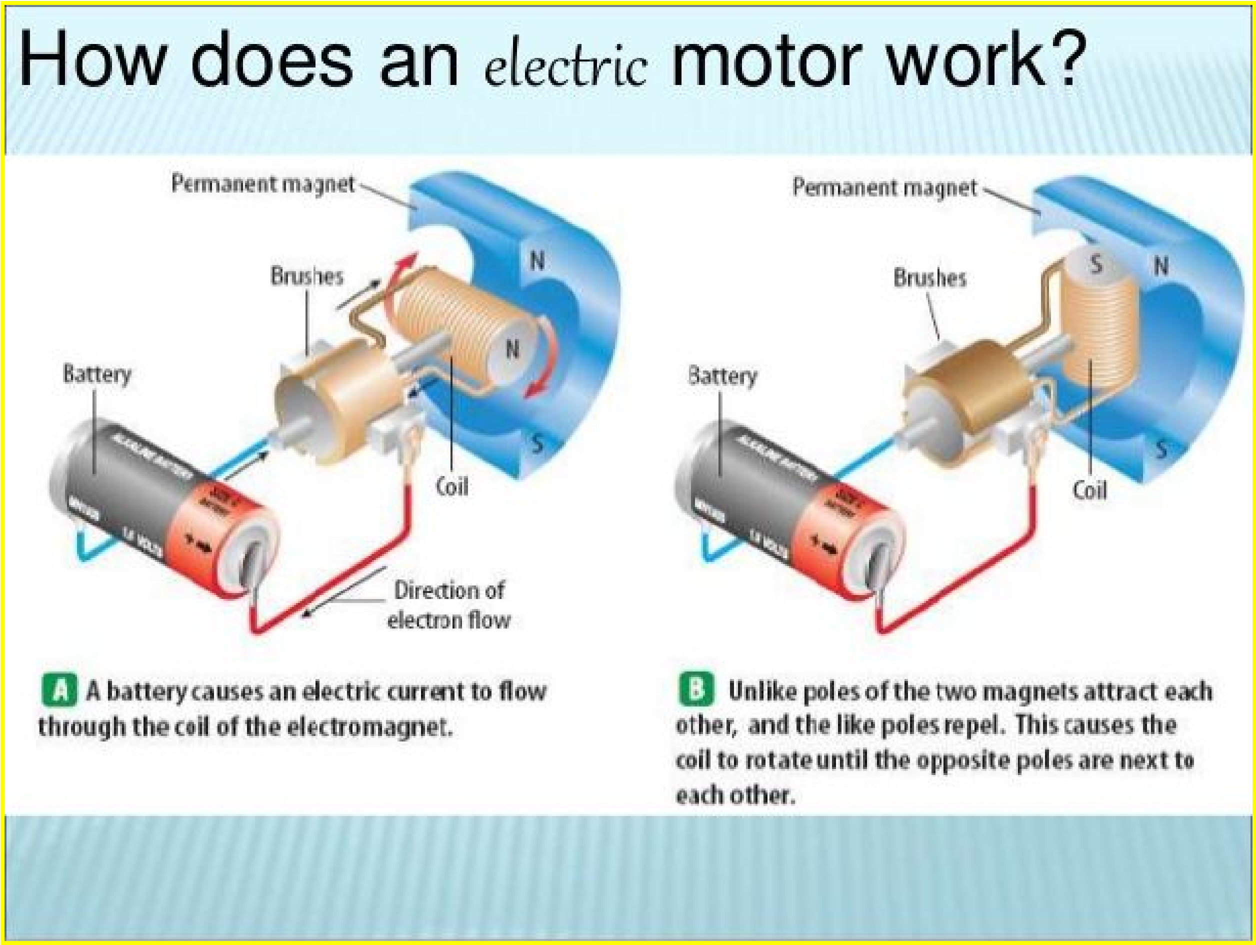
You come into contact with magnets many times in the course of your daily life. They play an important role in a wide range of devices including simple toys, computers, credit cards, MRI machines and business equipment. Magnets range in size from barely-visible objects to industrial monsters weighing tons. Though some are plainly visible, others are often tucked inside the inner workings of devices and other household, medical and commercial items, doing their job silently and unseen.

Computers and Electronics

Many computers use magnets to store data on hard drives. Magnets alter the direction of a magnetic material on a hard disk in segments that then represent computer data. Later, computers read the direction of each segment of magnetic material to "read" the data. The small speakers found in computers, televisions and radios also use magnets; inside the speaker, a wire coil and magnet converts electronic signals into sound vibrations.

Electric Power and Other Industries

Magnets offer many benefits to the industrial world. Magnets in electric generators turn mechanical energy into electricity, while some motors use magnets to convert electricity back into mechanical work. An electromagnetic coil is attracted to a permanent magnet within the magnetic motor assembly, and this attraction is what causes the motor to rotate. *(They pass alternating current through opposing pairs of magnets to create a rotating magnetic field, which creates a magnetic field in the motor's rotor, causing it to spin around).* When the source of electrical power is removed, the wire loses its magnetic qualities and the motor stops.



In recycling, electrically-powered magnets in cranes grab and move large pieces of metal, some weighing thousands of pounds. Mines use magnetic sorting machines to separate useful metallic ores from crushed rock. In food processing, magnets remove small metal bits from grains and other food. Farmers use magnets to catch pieces of metal that cows eat out in the field. The cow swallows the magnet with its food; as it moves through the animal’s digestive system it traps metal fragments.

Health and Medicine

Magnets are found in some commonly used medical equipment such as a Magnetic Resonance Imaging machines. MRIs use powerful magnetic fields to generate a radar-like radio signal from inside the body, using the signal to create a clear, detailed picture of bones, organs and other tissue. An MRI magnet is very strong – thousands of times more powerful than common kitchen magnets. Another medical use for magnets is for treating cancer. A doctor injects a magnetically-sensitive fluid into the cancer area and uses a powerful magnet to generate heat in the body. The heat kills the cancer cells without harming healthy organs.

In the Home

Though it may not be obvious, most homes contain many magnets. Refrigerator magnets hold papers, bottle openers and other small items to the metal refrigerator door. A pocket compass uses a magnetic needle to show which way is north. The dark magnetic strip on the backside of a credit card stores data in much the same way as a computer’s hard drive does. Vacuum cleaners, blenders and washing machines all have electric motors that work by magnetic principles. You’ll find magnets in phones, doorbells, shower curtain weights and children's toys.

Active* device** is any type of circuit component with the ability to electrically control electron flow. In order for a circuit to be properly called *electronic*, it must contain at least one active device. Components incapable of controlling current by means of another electrical signal are called ***passive* devices**. Resistors, capacitors, inductors, transformers, and even diodes are all considered passive devices. Active devices include, but are not limited to, vacuum tubes, transistors, silicon-controlled rectifiers (SCRs), and TRIACs. All active devices control the flow of electrons through them. Some active devices allow a voltage to control this current while other active devices allow another current to do the job. Devices using a static voltage as the controlling signal are called ***voltage-controlled* devices**. Devices working on the principle of one current controlling another current are known as ***current-controlled* devices**. For the record, vacuum tubes are voltage-controlled devices while transistors are made as either voltage-controlled or current controlled types. The first type of transistor successfully demonstrated was a current-controlled device. The practical benefit of active devices is their ***amplifying* ability**. Whether the device in question be voltage-controlled or current-controlled, the amount of power required of the controlling signal is typically far less than the amount of power available in the controlled current. In other words, an active device doesn't just allow electricity to control electricity; it allows a *small* amount of electricity to control a *large* amount of electricity. Because of this disparity between *controlling* and *controlled* powers, active devices may be employed to govern a large amount of power (controlled) by the use of a small amount of power (controlling). This behavior is known as ***amplification. It is a fundamental rule of physics that energy can neither be created nor destroyed. Stated formally, this rule is known as the **Law of Conservation of Energy**, and no exceptions to it have been discovered to date. If this Law is true -- and an overwhelming mass of experimental data suggests that it is -- then it is impossible to build a device capable of taking a small amount of energy and magically transforming it into a large amount of energy. All machines, electric and electronic circuits included, have an upper efficiency limit of 100 percent.

For example, if an amplifier takes in an AC voltage signal measuring 2 volts RMS and outputs an AC voltage of 30 volts RMS, it has an AC voltage gain of 30 divided by 2, or 15:

$$A_V = \frac{V_{output}}{V_{input}}$$

$$A_V = \frac{30\ V}{2\ V}$$

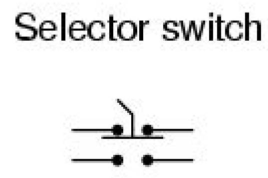
$$A_V = 15$$

Switches

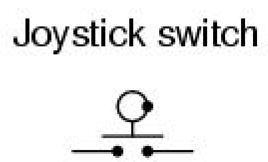
Any switch designed to be operated by a person is generally called a ***hand switch***, and they are manufactured in several varieties:

Toggle switches are operate by a lever angled in one of two or more positions. The common light switch used in household wiring is an example of a toggle switch. Most toggle switches will come to rest in any of their lever positions, while others have an internal spring mechanism returning the lever to a certain *normal* position, allowing for what is called "momentary" operation.

Pushbutton switches are two-position devices operated by a button that is pressed and released. Most pushbutton switches have an internal spring mechanism returning the button to its "out," or "unpressed," position, for momentary operation. Some pushbutton switches will latch alternately on or off with every push of the button. Other pushbutton switches will stay in their "in," or "pressed," position until the button is pulled back out. This last type of pushbutton switches usually have a mushroom-shaped button for easy push-pull action.



Selector switches are operated by a rotary knob or lever of some sort to select one of two or more positions. Like the toggle switch, selector switches can either rest in any of their positions or contain spring-return mechanisms for momentary operation.



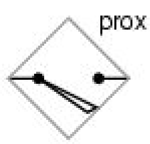
A joystick switch is operated by a lever free to move in more than one axis of motion. One or more of several switch contact mechanisms are actuated depending on which way the lever is pushed, and sometimes by how *far* it is pushed. The circle-and-dot notation on the switch symbol represents the direction of joystick lever motion required to actuate the contact. Joystick hand switches are commonly used for crane and robot control.

Some switches are specifically designed to be operated by the motion of a machine rather than by the hand of a human operator. These motion-operated switches are commonly called ***limit switches***, because they are often used to limit the motion of a machine by turning off the operating power to a component if it moves too far. As with hand switches, limit switches come in several varieties:

Lever actuator limit switch

These limit switches closely resemble rugged toggle or selector hand switches placed with a lever pushed by the machine part. Often, the levers are added with a small roller bearing, preventing the lever from being worn off by repeated contact with the machine part.

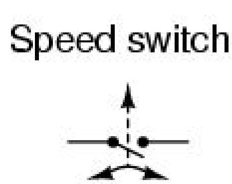
Proximity switch



Proximity switches sense the approach of a metallic machine part either by a magnetic or high-frequency electromagnetic field. Simple proximity switches use a permanent magnet to operate a sealed switch mechanism whenever the machine part gets close (typically 1 inch or less). More complex proximity switches work like a metal detector, energizing a coil of wire with a high-frequency current, and electronically monitoring the magnitude of that current. If a metallic part (not necessarily magnetic) gets close enough to the coil, the current will increase, and trip the monitoring circuit. The symbol shown here for the proximity switch is of the electronic variety, as indicated by the diamond-shaped box surrounding the switch. A non-electronic proximity switch would use the same symbol as the lever-actuated limit switch.

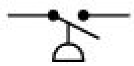
Another form of proximity switch is the **optical switch,** comprised of a light source and photocell. Machine position is detected by either the interruption or reflection of a light beam. Optical switches are also useful in safety applications, where beams of light can be used to detect personnel entry into a dangerous area.

In many industrial processes, it is necessary to monitor various physical quantities with switches. Such switches can be used to sound alarms, indicating that a process variable has exceeded normal parameters, or they can be used to shut down processes or equipment if those variables have reached dangerous or destructive levels. There are many different types of **process switches**:



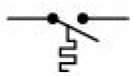
These switches sense the rotary speed of a shaft either by a centrifugal weight mechanism mounted on the shaft, or by some kind of non-contact detection of shaft motion such as optical or magnetic.

Pressure switch



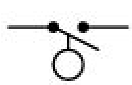
Gas or liquid pressure can be used to actuate a switch mechanism if that pressure is applied to a piston, diaphragm, or bellows, which converts pressure to mechanical force.

Temperature switch



An inexpensive temperature-sensing mechanism is the "bimetallic strip:" a thin strip of two metals, joined back-to-back, each metal having a different rate of thermal expansion. When the strip heats or cools, differing rates of thermal expansion between the two metals causes it to bend. The bending of the strip can then be used to actuate a switch contact mechanism. *Other temperature switches* use a brass bulb filled with either a liquid or gas, with a tiny tube connecting the bulb to a pressure-sensing switch. As the bulb is heated, the gas or liquid expands, generating a pressure increase which then actuates the switch mechanism.

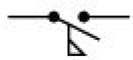
Liquid level switch



A floating object can be used to operate a switch mechanism when the liquid level in an tank rises past a certain point. If the liquid is electrically conductive, the liquid itself can be used as a conductor to bridge between two metal probes inserted into the tank at the required depth. The conductivity technique is usually implemented with a special design of relay triggered by a small amount of current through the conductive liquid. In most cases it is impractical and dangerous to switch the full load current of the circuit through a liquid.

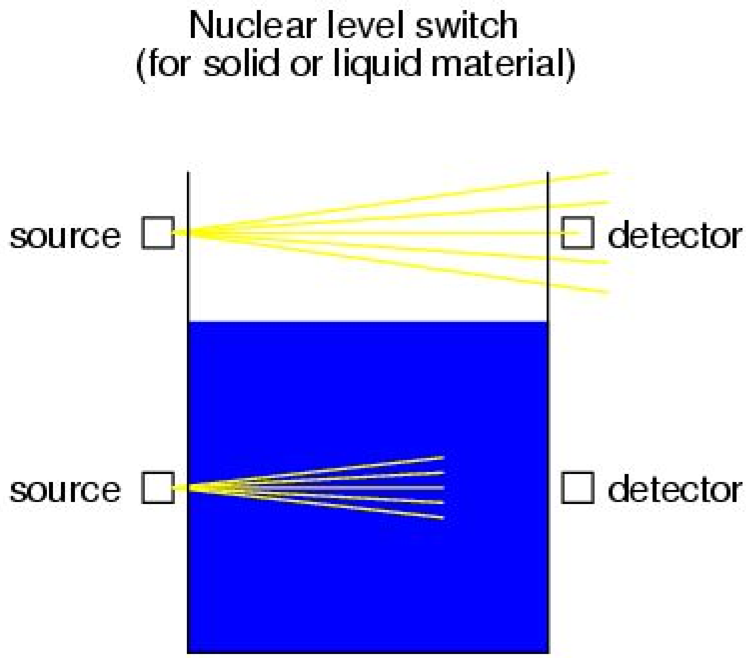
Level switches can also be designed to detect the level of solid materials such as wood chips, grain, coal, or animal feed in a storage silo, bin, or hopper. A common design for this application is a *small paddle wheel*, inserted into the bin at the desired height, which is slowly turned by a small electric motor. When the solid material fills the bin to that height, the material prevents the paddle wheel from turning. The torque response of the small motor than trips the switch mechanism. Another design uses a *"tuning fork"* shaped metal prong, inserted into the bin from the outside at the desired height. The fork is vibrated at its resonant frequency by an electronic circuit and magnet/electromagnet coil assembly. When the bin fills to that height, the solid material dampens the vibration of the fork, the change in vibration amplitude and/or frequency detected by the electronic circuit.

Liquid flow switch



Inserted into a pipe, a flow switch will detect any gas or liquid flow rate in excess of a certain threshold, usually with a small paddle or vane which is pushed by the flow. Other flow switches are constructed as differential pressure switches, measuring the pressure drop across a restriction built into the pipe.

Another type of level switch, suitable for liquid or solid material detection, is the **nuclear switch.** Made of a radioactive source material and a radiation detector, the two are mounted across the diameter of a storage vessel for either solid or liquid material. Any height of material beyond the level of the source/detector arrangement will reduce the strength of radiation reaching the detector. This decrease in radiation at the detector can be used to trigger a relay mechanism to provide a switch contact for measurement, alarm point, or even control of the vessel level.



Both source and detector are outside of the vessel, with no intrusion at all except the radiation flux itself. The radioactive sources used are fairly weak and pose no immediate health threat to operations or maintenance personnel.