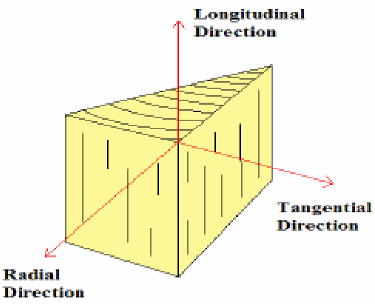
GLOSSARY

- **Anisotropy**

Anisotropy, in physics, is the quality of exhibiting properties with different values when measured along axes in different directions. *Encyclopedia Britannica, https://www.britannica.com/-science/ anisotropy*



https://www.researchgate.net/figure/Anisotropy-in-wood fig5 251494186

Figure GL.1 Anisotropy [Fair Use]
Anisotropy—at least one of the directions is different.

- **Biot-Savart Law (equation)**

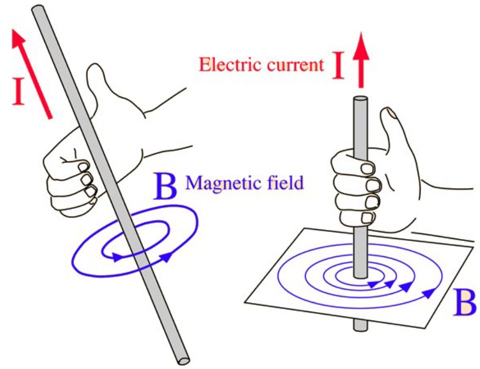
1. The **Biot-Savart Law** was named after Jean-Baptiste Biot and Felix Savart in 1820. They derived the mathematical expression for the magnetic flux density. The Biot-Savart Law is an equation that **explains the magnetic field created by a current-carrying wire**, allowing the calculation of its strength at various points.

   Just Science at *http://bit.ly/2FtM3WN*

2. A statement in electromagnetism: the magnetic intensity at any point due to a steady current in an infinitely long straight wire is directly proportional to the current and inversely proportional to the distance from point to wire.

   https://www.merriam-webster.com/dictionary/Biot-Savart%20law

3. The magnetic field lines around a long wire which carries an electric current from concentric circles around the wire. The direction of the magnetic field is perpendicular to the wire and is in the direction the fingers of your right hand would curl if you wrapped them around the wire with your thumb in the direction of the current.



http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/magcur.html#c1

Figure GL.2 Biot-Savart Law [Fair Use]
Figure represents a positive charge.

- **Bohr Model**

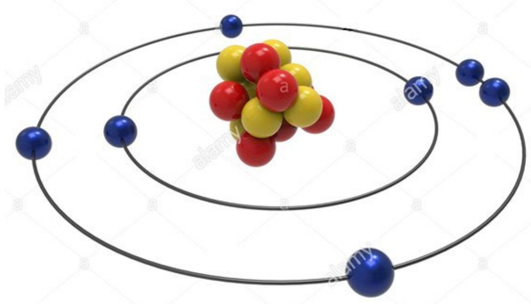
The **Bohr** model has an atom consisting of a small, positively charged nucleus orbited by negatively charged electrons. Below is a closer look at the Bohr model, which is sometimes called the Rutherford-Bohr model.

Niels Bohr proposed the Bohr model of the atom in 1915. Because the Bohr model is a modification of the earlier Rutherford model, some people call Bohr's model the Rutherford-Bohr model. The modern model of the atom is based on quantum mechanics. The Bohr model contains some errors, but it is important because it describes most of the accepted features of atomic theory without all of the high-level math of the modern version. Unlike earlier models, the Bohr model explains the Rydberg formula for the spectral emission lines of atomic hydrogen.

The Bohr model is a **planetary** in which the negatively charged electrons orbit a small, positively charged nucleus **similar to the planets orbiting the Sun** (except that the orbits are not planar). The gravitational force of the solar system is mathematically akin to the coulomb (electrical) force between the positively charged nucleus and the negatively charged electrons.

by Anne Marie Helmenstine, Ph.D., [ThoughtCo.]

https://www.thoughtco.com/bohr-model-of-the-atom-603815



http://bit.ly/2xvUFYv

Figure GL.3 Bohr Model [Fair Use]

- **Bremsstrahlung Radiation**

1. As in "braking radiation" or "deceleration radiation," bremsstrahlung radiation is produced by the deceleration of a charged particle when deflected by another charged particle, typically an electron by an atomic nucleus. The moving particle loses kinetic energy, which is converted into radiation (i.e., a photon), thus satisfying the law of conservation of energy. The term is also used to refer to the process of producing the radiation. Bremsstrahlung has a continuous spectrum, which becomes more intense and whose peak intensity shifts toward higher frequencies as the change of the energy of the decelerated particles increases.

2. Broadly speaking, bremsstrahlung or **braking radiation** is any radiation produced due to the deceleration (negative acceleration) of a charged particle, which includes synchrotron radiation (i.e., photon emission by a relativistic particle), cyclotron radiation (i.e., photon emission by a non-relativistic particle), and the emission of electrons and positrons during beta decay. However, the term is frequently used in the more narrow sense of radiation from electrons (from whatever source) slowing in matter.

   https://en.wikipedia.org/wiki/Bremsstrahlung

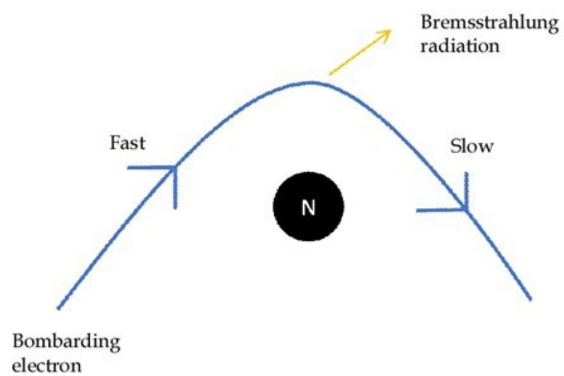
3. Bremsstrahlung, (German: "braking radiation"), electromagnetic radiation produced **by a sudden slowing down or deflection of charged particles (especially electrons) passing through matter in the vicinity of the strong electric fields of atomic nuclei**. Bremsstrahlung, for example, accounts for continuous X-ray spectra, i.e., that component of X-rays the energy of which covers a whole range from a maximum value downward through lower values. In generating Bremsstrahlung, some electrons beamed at a metal target in an X-ray tube are brought to rest by one head-on collision with a nucleus and thereby have all their energy of motion converted at once into radiation of maximum energy. Other electrons from the same incident beam come to rest after being deflected many times by the

positively charged nuclei. Each deflection gives rise to a pulse of electromagnetic energy, or photon, of less than maximum energy.

Bremsstrahlung is one of the processes by which cosmic rays dissipate some of their energy in the Earth's atmosphere. Solar X-rays have been attributed to bremsstrahlung generated by fast electrons passing through the matter in the part of the Sun's atmosphere called the chromosphere.

Internal bremsstrahlung arises in the radioactive disintegration process of beta decay, which consists of the production and emission of electrons (or positrons, positive electrons) by unstable atomic nuclei or the capture by nuclei of one of their own orbiting electrons. These electrons, deflected in the vicinity of their own associated nuclei, emit internal bremsstrahlung.

Encyclopedia Britannica *https://www.britannica.com/science/bremsstrahlung*



https://www.radiologycafe.com/radiology-trainees/frcr-physics-notes/production-of-x-rays

Figure GL.4 Bremsstrahlung Radiation [Fair Use]

- *Bombarding electron approaches the nucleus.*
- *Electron is diverted by the electric field of the nucleus.*
- *The energy loss from this diversion is released as a photon (bremsstrahlung radiation).*

- **De Broglie Wave Equation**

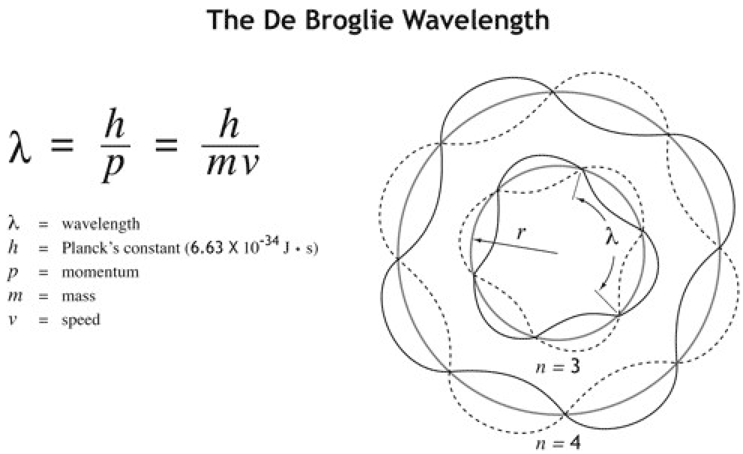
1. An equation in physics: the de Broglie wavelength of a moving particle is equal to the Planck constant divided by the momentum of the particle.

   Merriam Webster Dictionary http://bit.ly/2ZEe6dA

2. In layman's terms, the de Broglie equation says that every moving particle—microscopic or macroscopic—**is associated with a wavelength**. For microscopic objects, wave nature is observable. For larger objects, the wavelength is even smaller still, quickly becoming so small as to become unnoticeable.

   Quora.com http://bit.ly/2J2QmJp

De Broglie wavelength is a wavelength, which is manifested in all the particles in quantum mechanics, according to wave-particle duality, and it determines the probability density of finding the object at a given point of the configuration space.



https://www.quora.com/What-is-de-Broglie-wavelength

Figure GL.5 De Broglie Wave [Fair Use]

De Broglie's extension of the concept of particle-wave duality from photons, to include all forms of matter, allowed the interpretation of electrons in the Bohr model as standing electron waves. De Broglie's work marked the start of the development of wave mechanics.

- **Dipole**

1. A **dipole** is a pair of equal and opposite electric charges or magnetic poles of opposite sign separated especially by a small distance.

   Merriam-Webster Dictionary https://www.merriam-webster.com/dictionary/dipole

2. In electromagnetism, there are two kinds of **dipoles**:

   An electric dipole deals with the separation of the positive and negative charges found in any electromagnetic system. A simple example of this system is a pair of electric charges of equal magnitude but opposite sign separated by some typically small distance. (A permanent electric dipole is called an electret.)

   https://en.wikipedia.org/wiki/Dipole

Electric Dipole

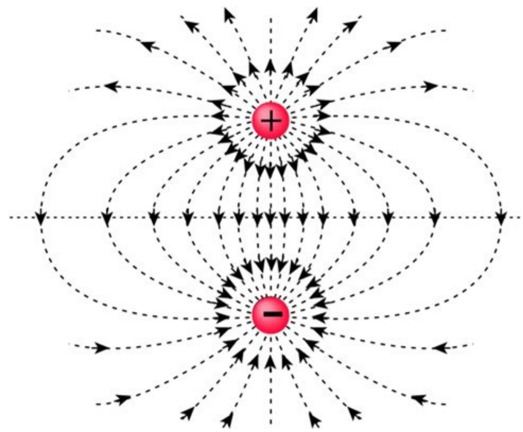


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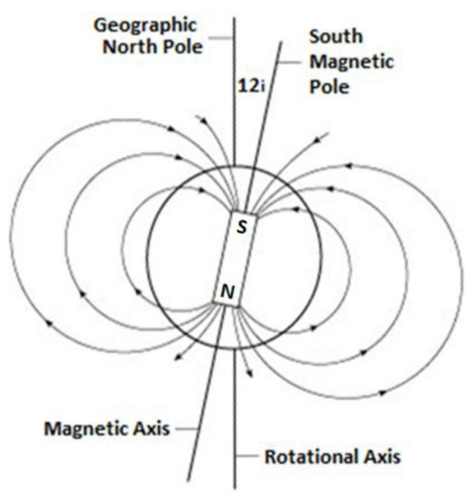
Figure GL.6 Dipole [Fair Use]

Magnetic Dipole

A magnetic dipole is the closed circulation of an electric current system. A simple example is a single loop of wire with constant current through it. A bar magnet is an example of a magnet with a permanent magnetic dipole moment.



https://ase.tufts.edu/cosmos/view_picture.asp?id=326 Wikipedia

Figure GL.7 Earth's Magnetic Dipole [Fair Use]

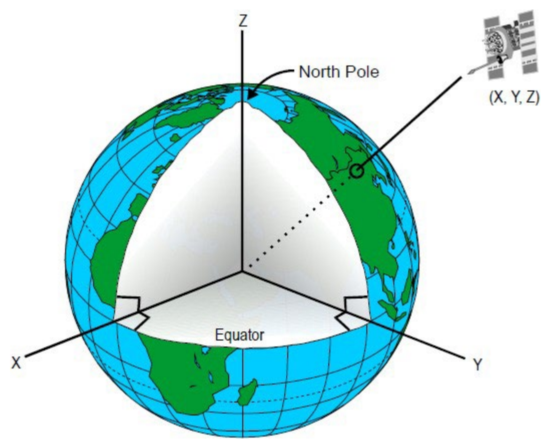
- ***E* = *mc*²**

$E = mc^2$ is defined as a scientific equation that shows that energy equals mass times the speed of light squared, which shows the relationship between mass and energy. [Dictionary.com]

- **Earth-Centered Frame**

The Geocentric-Equatorial Coordinate System, a.k.a. the Earth-Centered Inertial frame, has its origin right at the center of the earth; however, it is not fixed to the earth. Although this frame has its origin at the center of the earth, it does not rotate with the earth.

https://adcsforbeginners.wordpress.com/tag/earth-centred-inertial-frame/



Wikipedia

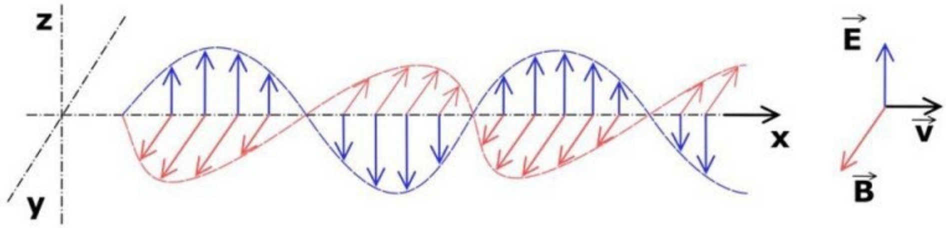
Figure GL.8 Earth-Centered Frame [Fair Use]

Earth-centered inertial (ECI) coordinate frames have their origins at the center of mass of the Earth. ECF frames are called inertial in contrast to the Earth-centered, Earth-fixed (ECEF) frames, which rotate in inertial space in order to remain fixed with respect to the surface of the Earth.

- **Electromagnetic radiation (EMR)**

Electromagnetic radiation (EM radiation or EMR), in physics, indicates waves (or their quanta, photons) of the electromagnetic field, traveling through space carrying electromagnetic radiant energy. It includes radio waves, microwaves, infrared, light, ultraviolet, X-ray, and gamma ray radiation.

Characteristically, electromagnetic radiation consists of electromagnetic waves, which are synchronized oscillations of electric and magnetic fields that multiply at the speed of light through a vacuum. Creating a transverse wave, the oscillations of the two fields are perpendicular to each other and perpendicular to the direction of energy and wave propagation. The electromagnetic spectrum could be portrayed by either its frequency of oscillation or its wavelength. In order of increasing frequency and decreasing wavelength, the electromagnetic spectrum includes radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays, and gamma rays.



https://mystreetmychoice.com/slides/img/hero/emr-propagation-960.jpg

Figure GL.9 Electromagnetic Radiation (EMR)
E is the electric field; B is the magnetic field; and V is direction of the electromagnetic wave

- **Gauss**

Gauss, unit of magnetic induction in the centimeter-gram-second system of physical units. One Gauss corresponds to the magnetic flux density that will induce an electromotive force of one abvolt (10^{-8} volt) in each linear centimeter of a wire moving laterally at one centimeter per second at right angles to a magnetic flux. One Gauss corresponds to 10^{-4} Tesla (T), the International System Unit. The Gauss is equal to 1 Maxwell per square centimeter, or 10^4 Weber per square meter. Magnets are rated in Gauss. The Gauss was named for the German scientist Carl Friedrich Gauss.
Encyclopedia Britannica

- **Geodesic Motion/Curved Space**

If we envision an astronaut in his accelerating spaceship cabin and visualize him pointing a laser horizontally across the cabin, the upward motion of the spacecraft would result in the path of the laser appearing to curve very minimally downwards as it travels across the cabin. Now, it is posited that light always takes the shortest path between two points, which we usually think of as a straight line. However, a straight line is only the shortest distance between two points on a flat surface.

Alternatively on a curved surface, the shortest distance between two points is actually a curve, technically known as a geodesic, which we can picture when we think, for example, of a plane flying the shortest route between London and New York which, as travelers will know, follows a "great circle" path over Newfoundland rather than what appears to be a more direct straight line on a flat map.

The only conceivable explanation of the curving laser beam, then, is that the space inside the cabin is in some way curved. If we combine this concept with Einstein's principle of equivalence, then it would appear that light in the presence of gravity follows a curved trajectory, or, put in another way, gravity bends the path of light. In fact, it turns out that gravity is nothing more than curved space, or, in other words, the warpage of four-dimensional space-time.

A simple analogy might help us to understand this notoriously hard-to-visualize concept. If a group of ants spend their entire lives on the essentially two-dimensional surface of a trampoline, and a heavy weight like a bowling ball is placed in the middle of the trampoline, the ants will find their paths mysteriously bent towards the bowl-like depression in the trampoline. The ants might explain it by saying that the weight is exerting a force of attraction on them, but, from the elevated point of view of the third dimension, it is clear that the ants are merely following the curve of the trampoline and that no actual force is acting on them.

An even better visual analogy might be if a marble is rolled along the trampoline surface. It might roll straight past the bowling ball, or it might be deflected a little (or a lot) as it follows the dip but then "escapes" (similar to the idea of using gravity to deflect or brake or slingshot a spaceship around a planet's orbit). Or, if the marble comes too close, then it might be drawn inexorably into the depression of the bowling ball, rolling in ever-decreasing circles until it joins the ball in its hollow. The path of the Earth as it travels though space is constantly bent towards the Sun in this way, so much so that the planet traces out a nearly circular orbit.

From the God-like perspective of the fourth dimension, however, it can be seen that there is no actual force being exerted on the Earth, merely that the Sun has created a valley-like depression in four-dimensional space, and the Earth is just following the shortest path along a geodesic through the curved space-time (just as the ants were in three-dimensional space).

The Earth, then, is actually in free fall around the Sun and so we do not feel the Sun's gravity on Earth, just as astronauts on the International Space Station in free fall around the Earth do not feel the Earth's gravity. Thus, although free fall is usually defined as motion with no acceleration other than that provided by gravity, what it is really is just a body travelling along the straightest possible path through space-time. We only "feel" gravity on the Earth when our natural motion of free fall towards the center of the Earth is thwarted by the ground, an inertial force similar to centrifugal force.

This may at first seem counter-intuitive. We are used to the Newtonian idea that, when we throw a ball straight up in the air, for example, a graph of its height versus time traces out a parabola curve. Under relativity, however, we must recognize that a massive body like the Earth actually curves the coordinate system itself, so that rather than following a curved path in a flat (Cartesian) coordinate system, the ball actually follows a minimum-distance path, or geodesic, in a curved coordinate system, returning to the thrower's hand at a later time because the geodesic leads it there.

The Physics of the Universe

https://www.physicsoftheuniverse.com/topics_relativity_curved.html

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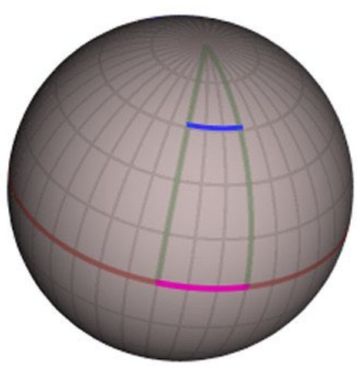


http://en.wikipedia.org/wiki/Introduction_to_general_relativity)

Figure GL.10 Geodesic Motion/Curved Space [Fair Use]

A geodesic is the shortest path between two points in curved space.

- **Gluon**

1. A gluon is an unobserved massless particle with spin 1 that is believed to transmit the strong force between quarks, binding them together into baryons and mesons. [Dictionary.com]

2. Gluon, the so-called messenger particle of the strong nuclear force, which binds subatomic particles known as quarks within the protons and neutrons of stable matter as well as within heavier, short-lived particles created at high energies. Quarks interact by emitting and absorbing gluons, just as electrically charged particles interact through the emission and absorption of photons.
Encyclopedia Britannica https://www.britannica.com/science/gluon

- **Gravitational Mass**

1. (Physics) The mass of a body as measured by its gravitational attraction for other bodies.
https://www.thefreedictionary.com/gravitational+mass

2. The property of a body that causes it to have weight in a gravitational field.
https://www.thefreedictionary.com/gravitational+mass

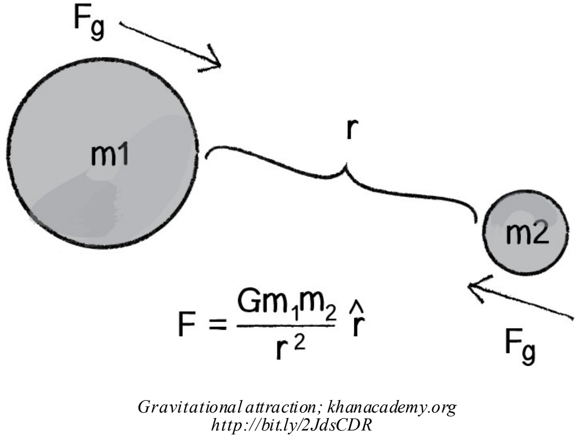
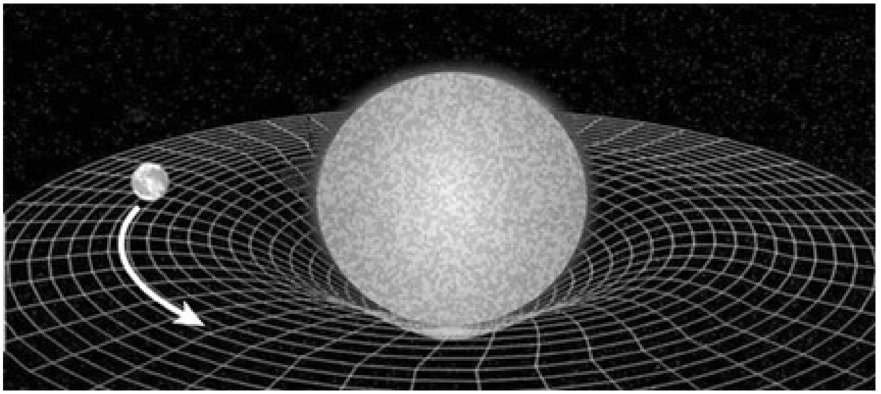


Figure GL.11 Gravitational Mass [Fair Use]

- **GRT (General Relativity Theory)**

Albert Einstein's general theory of relativity is one of the greatest triumphs of 20th-century physics. Published in 1916, it explains that what we recognize as the force of gravity, in fact, arises from the curvature of space and time. Einstein posited that objects such as the Sun and the Earth change this geometry. In the presence of matter and energy space-time can evolve, stretch and warp, forming ridges, mountains and valleys that cause bodies moving through it to zigzag and curve. So, although Earth appears to be pulled towards the Sun by gravity, there is no such force. It is merely the geometry of space-time around the Sun telling Earth how to move.

New Scientist https://www.newscientist.com/round-up/instant-expert-general-relativity/



http://www.uh.edu/ jclarage/astr3131/lectures/4/einstein/Einstein_stanford_Page7.html

Figure GL.12 GRT [Fair Use]

- **Homopolar Generator**

A homopolar generator is a direct current (DC) electrical generator comprising an electrically conductive disc or cylinder rotating in a plane perpendicular to a uniform static magnetic field. Also, the homopolar generator is unique in that no other rotary electric machine can produce DC without using rectifiers or commutators.

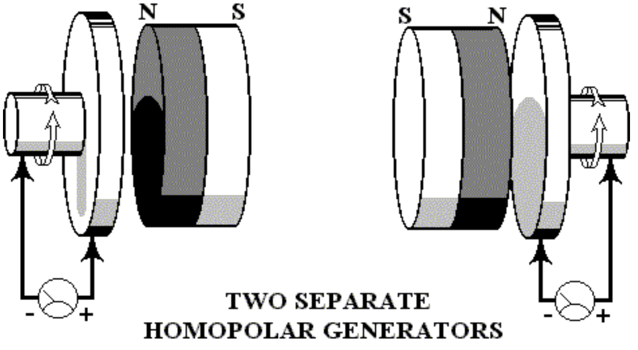


Figure GL.13 Two Separate Homopoloar Generators, Wikipedia [Fair Use]

- **Inertial Mass**

The second law of motion states that if an unbalanced force acts on a body, that body will experience acceleration (or deceleration), that is, a change of speed. One can say that a body at rest is considered to have zero speed (a constant speed). So, any force that causes a body to move is an unbalanced force. Also, any force, such as friction or gravity, that causes a body to slow down or speed up, is an unbalanced force. This law can be shown by the following formula:

$F = ma$

F is the unbalanced force.

m is the object's mass.

a is the acceleration that the force causes.

Inertial mass is the mass of a body that represents it's resistance to acceleration. This is the mass that appears in Newton's second law of motion.

If the units of force are in newtons, then the units of mass are kilograms and the units of acceleration are m/s^2. If the units of force are in pounds (English), then the units of mass are in slugs, and the units of acceleration are ft/s^2.

Motion of an object that is not accelerated (moving at a constant speed and in a straight line) can be found using the formula

$d = v \times t$

d is the distance traveled.

v is the rate of motion (velocity).

t is the time.

[National Aeronautics and Space Administration, contributed by Carol Hodanbosi]

- **Isotropy**

Isotropy means equal physical properties along all axes. [Dictionary.com]

- **Kinetic Energy**

1. Kinetic energy is the energy of motion, observable as the movement of an object, particle, or set of particles. Any object in motion is using kinetic energy: a person walking, a thrown baseball, a crumb falling from a table, and a charged particle in an electric field are all examples of kinetic energy at work. Objects that are not in motion possess potential energy (the other main type of energy), which is converted to kinetic energy when some force, such as gravity, acts upon the object to set it in motion. Elastic potential energy, for example, is stored in a stretched rubber band; when the rubber band is released, the stored energy is converted to kinetic energy. [WhatIs.com]

2. Kinetic energy is energy of motion. The SI unit for energy is the joule = newton x meter in accordance with the basic definition of energy as the capacity for doing work. The kinetic energy of an object is the energy it possesses because of its motion. The kinetic energy of a point mass m is given by

$$\textbf{Kenetic Energy} = \frac{1}{2} mv^2$$

3. Kinetic energy is an expression of the fact that a moving object can do work on anything it hits; it quantifies the amount of work the object could do as a result of its motion. The total mechanical energy of an object is the sum of its kinetic energy and potential energy. The total energy of an isolated system is subject to the conservation of energy principle.

   For an object of finite size, this kinetic energy is called the translational kinetic energy of the mass to distinguish it from any rotational kinetic energy it might possess–the total kinetic energy of a mass can be expressed as the sum of the translational kinetic energy of its center of mass plus the kinetic energy of rotation about its center of mass.

   http://hyperphysics.phy-astr.gsu.edu/hbase/ke.html

- **Law of Conservation of Energy**

By Anne Marie Helmenstine, Ph.D. (Updated May 06, 2019)

The law of conservation of energy is a physical law that states energy cannot be created or destroyed but may be changed from one form to another. Another way of stating this law of chemistry is to say the total energy of an isolated system remains constant or is conserved within a given frame of reference.

In classical mechanics, conservation of mass and conservation of energy are considered to be two separate laws. However, in special relativity, matter may be converted into energy and vice versa, according to the famous equation $E = mc^2$. Thus, it's more appropriate to say mass-energy is conserved. [ThoughtCo.com]

Conservation of energy

Principle of physics according to which the energy of interacting bodies or particles in a closed system remains constant. The first kind of energy to be recognized was kinetic energy, or energy of motion. In certain particle collisions, called elastic, the sum of the kinetic energy of the particles before collision is equal to the sum of the kinetic energy of the particles after collision. The notion of energy was progressively widened to include other forms. The kinetic energy lost by a body slowing down as it travels upward against the force of gravity was regarded as being converted into potential energy, or stored energy, which in turn is converted back into kinetic energy as the body speeds up during its return to Earth. For example, when a pendulum swings upward, kinetic energy is converted to potential energy. When the pendulum stops briefly at the top of its swing, the kinetic energy is zero, and all the energy of the system is in potential energy. When the pendulum swings back down, the potential energy is converted back into kinetic energy. At all times, the sum of potential and kinetic energy is constant. Friction, however, slows down the most carefully constructed mechanisms, thereby dissipating their energy gradually. During the 1840s, it was conclusively shown that the notion of energy could be extended to include the heat that friction generates. The truly conserved quantity is the sum of kinetic, potential, and thermal energy. For example, when a block slides down a slope, potential energy is converted into kinetic energy. When friction slows the block to a stop, the kinetic energy is converted into thermal energy. Energy is not created or destroyed but merely changes forms, going from potential to kinetic to thermal energy. This version of the conservation-of-energy principle, expressed in its most general form, is the first law of thermodynamics. The conception of energy continued to expand to include energy of an electric current, energy stored in an electric or a magnetic field, and energy in fuels and other chemicals. For example, a car moves when the chemical energy in its gasoline is converted into kinetic energy of motion.

Encyclopedia Britannica https://www.britannica.com/science/conservation-of-energy

- **Lexicology**

A branch of linguistics concerned with the signification and application of words.

[*Miriam Webster Dictionary*]

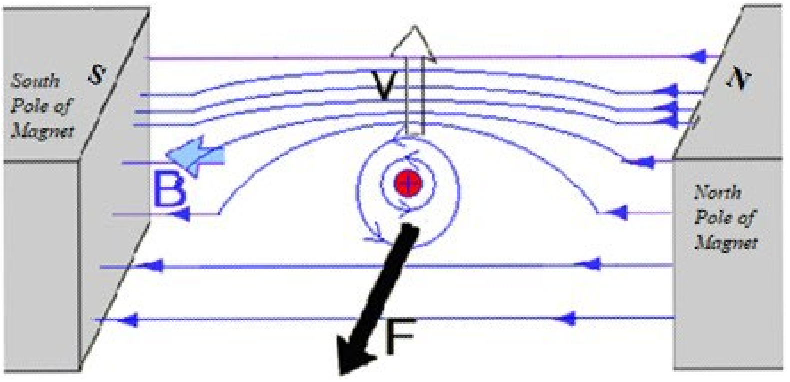
- **Lorentz Force**

Lorentz force, the force exerted on a charged particle q moving with velocity v through an electric field E and magnetic field B. The entire electromagnetic force F on the charged particle is called the Lorentz force (after the Dutch physicist Hendrik A. Lorentz) and is given by

$F = qE + qv \times B$.

The first term is contributed by the electric field. The second term is the magnetic force and has a direction perpendicular to both the velocity and the magnetic field.

https://www.britannica.com/science/Lorentz-force



http://bit.ly/2S0fg0l

Figure GL.14 Lorentz Force [Fair Use]

B is the direction of the magnetic field; v is the direction of the + charged particle; and F is the direction of the resultant Lorentz force.

- **Meson**

Meson, any member of a family of subatomic particles composed of a quark and an anti-quark. Mesons are sensitive to the strong force, the fundamental interaction that binds the components of the nucleus by governing the behavior of their constituent quarks. Predicted theoretically in 1935 by the Japanese physicist Yukawa Hideki, the existence of mesons was confirmed in 1947 by a team led by the English physicist Cecil Frank Powell with the discovery of the pi-meson (pion) in cosmic-ray particle interactions. More than 200 mesons have been produced and characterized in the intervening years, most in high-energy particle-accelerator experiments. All mesons are unstable, with lifetimes ranging from 10^{-8} seconds to less than 10^{-22} seconds. They also vary widely in mass, from 140 mega-electron volts (MeV; 10^6 eV) to nearly 10 giga-electron volts (GeV; 10^9 eV). Mesons serve as a useful tool for studying the properties and interactions of quarks. [*Encyclopedia Britannia*]

- **MMX**

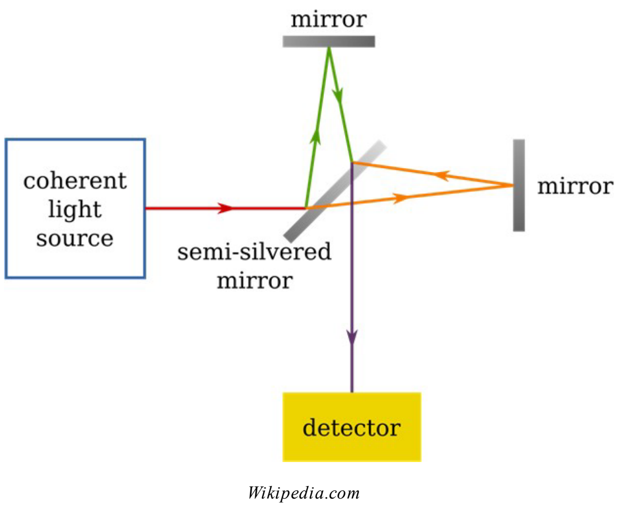


Figure GL.15 MMX [Fair Use]

Michelson-Morley experiment, an attempt to detect the velocity of the Earth with respect to the hypothetical luminiferous ether, a medium in space proposed to carry light waves. First performed in Germany in 1880–81 by the physicist A.A. Michelson, the test was later refined in 1887 by Michelson and Edward W. Morley in the United States.

The procedure depended on a Michelson interferometer, a sensitive optical device that compares the optical path lengths for light moving in two mutually perpendicular directions. It was reasoned that, if the speed of light were constant with respect to the proposed ether through which the Earth was moving, that motion could be detected by comparing the speed of light in the direction of the Earth's motion and the speed of light at right angles to the Earth's motion. No difference was found. This null result seriously discredited the ether theories and ultimately led to the proposal by Albert Einstein in 1905 that the speed of light is a universal constant. [*Encyclopedia Britannia*]

- **NANRMS**

Non-Attracting/Non-Repulsion Magnetic Shield

Given the fact that this type of shield is constructed from an equal number of opposite-oriented magnetic poles, there is no overall effect exerted on a single externally placed permanent magnet (PM). In essence, this is a **non-attracting/non-repulsion magnetic shield** (NANRMS). For future reference, this form of shield will be labeled as (NANRMS).

A magnetic shield that neither attracts nor repels a solitary externally placed PM. On the other hand, it must be capable of reducing/diverting a magnetic field; such that it decreases the Lorentz forces of two repelling PMs, when placed on opposite sides of the plane of the shield. [Warfield]

- **Neodymium**

Neodymium is a chemical element and a rare-earth element with the symbol Nd and atomic number 60 that belongs to the lanthanide series. It is a hard, slightly malleable silvery metal, that tarnishes quickly in air and moisture. When oxidized, neodymium reacts to produce pink, purple/blue, and yellow compounds in the +2, +3, and +4 oxidation state.

The element was discovered in 1885 by Austrian chemist Carl Auer von Welsbach and is now mined primarily in China. Neodymium is present in significant quantities in the ore minerals monazite and bastn asite. Neodymium is not found naturally in metallic form or unmixed with other lanthanides, and it is usually refined for general use. Although neodymium is classed as a rare-earth element, it is fairly common, no rarer than cobalt, nickel, or copper, and is widely distributed in the Earth's crust.

Neodymium is also used with various other substrate crystals, such as yttrium aluminium garnet in the Nd:YAG laser. This laser usually emits infrared at a wavelength of about 1,064 nanometers. The Nd:YAG laser is one of the most commonly used solid-state lasers.

Another important use of neodymium is as a component in the alloys used to make high-strength neodymium magnets—powerful permanent magnets. [Source: *Wikipedia*]

- **Newton's Third Law**

1. Formally stated, **Newton's third law** is "For every action, there is an equal and opposite reaction." The statement means that in every interaction, there is a pair of forces acting on the two interacting objects. The size of the forces on the first object equals the size of the force on the second object. [ThePhsyicsClassroom.com *http://bit.ly/2XcKCH1*]

2. Examples of Newton's 3rd Law. When you jump off a small rowing boat into water, you will push yourself forward towards the water. The same force you used to push forward will make the boat move backwards. When air rushes out of a balloon, the opposite reaction is that the balloon flies up. [*http://bit.ly/30fXXeE*]

- **Occam's Razor**

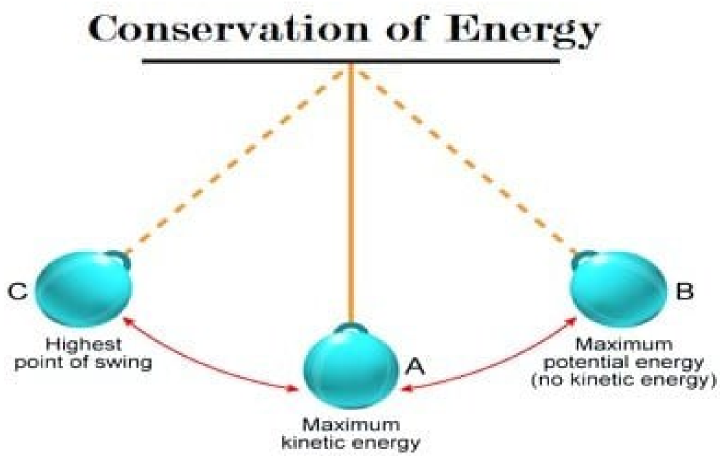
Occam's razor, also spelled Ockham's razor, stated by the scholastic philosopher William of Ockham (1285-1347/49) that principle gives precedence to simplicity. Or in other words of two competing theories, the simpler explanation of an entity is to be preferred. [*Encyclopedia Britannica, Britannica.com*]

- **Over Unity**

An over unity device should produce more energy than it receives as input. The term was coined to avoid patent rules that prevent seemingly impossible technologies (such as perpetual motion machines) being patented.

- **Pendulum motion**

A simple pendulum consists of a relatively massive object hung by a string from a fixed support. It typically hangs vertically in its equilibrium position. The massive object is affectionately referred to as the pendulum bob. When the bob is displaced from equilibrium and then released, it begins its back-and-forth vibration about its fixed equilibrium position. The motion is regular and repeating, an example of periodic motion. [ThePhysicsClassroom.com]



QSstudy.net
https://www.assignmentpoint.com/science/physics/pendulum.html

Figure GL.16 Pendulum Motion [Fair Use]

- **Permalloy**

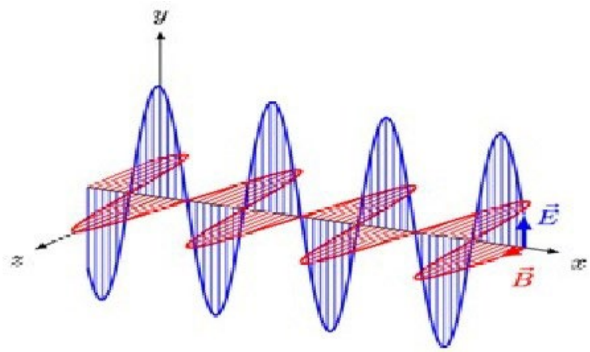
Permalloy 80 is a highly magnetic nickel-iron-molybdenum alloy, with roughly 80% nickel and 15% iron and 5% molybdenum content. It's useful as a magnetic core material in electrical and electronic equipment. Commercial permalloy alloys typically have relative permeability of around 100,000, compared to several thousand for ordinary steel. It provides maximum magnetic permeability and minimal core losses at low field strengths. This vacuum-melted product also offers the advantages of small size and weight in magnetic core and shielding materials for the applications shown below. Other magnetic properties are near zero magnetostriction and significant anisotropic magnetoresistance.
[*https://www.espimetals.com/index.php/technical-data/175-permalloy-80*]

Photon

A **photon** is a particle of light defined as a discrete bundle (or quantum) of electromagnetic (or light) energy. Photons are always in motion and, in a vacuum (a completely empty space), have a constant speed of light to all observers. Photons travel at the vacuum speed of light (more commonly just called the speed of light) of $c = 2.998x10^8 m/s$.

Basic Properties of Photons
According to the photon theory of light, photons:
1. Behave like a particle and a wave, simultaneously.

2. Move at a constant velocity, $c = 2.998x10^8 m/s$ (i.e., "the speed of light"), in empty space.
3. Have zero mass and rest energy.
4. Carry energy and momentum, which are also related to the frequency (nu) and wavelength (lamdba) of the electromagnetic wave, as expressed by the equation $E = h\nu$ and $p = h/\lambda$.
5. Can be destroyed/created when radiation is absorbed/emitted.
6. Can have particle-like interactions (i.e., collisions) with electrons and other particles, such as in the Compton effect in which particles of light collide with atoms, causing the release of electrons. [ThoughtCo.com]



Wikimedia Commons

Figure GL.17 Photon [Fair Use]

Image shows alternating right-angled magnetic (B) and electric (E) fields. This in association with its given length, frequency, and amplitude, is the photon.

- **PM - Permanent Magnet**

Permanent magnets are materials where the magnetic field is generated by the internal structure of the material itself. Inside atoms and crystals, you have both electrons and the nucleus of the atom. Both the nucleus and the electrons themselves act like little magnets, like little spinning chunks of electric charge, and they have magnetic fields inherent in the particles themselves. There's also a magnetic field that's generated by the orbits of the electrons as they move about the nucleus. So the magnetic fields of permanent magnets are the sums of the nuclear spins, the electron spins, and the orbits of the electrons themselves. In many materials, the magnetic fields are pointing in all sorts of random directions and cancel each other out and there's no permanent magnetism. But in certain materials, called ferromagnets, all the spins and the orbits of the electrons will line up, causing the materials to become magnetic. This would be your normal iron, cobalt, nickel. Permanent magnets are limited by the structure of the material. And the strongest magnetic field of a permanent magnet is about 8,000 gauss. The strongest magnets at the national Magnet Lab are 450,000 gauss, which would be almost 50 times stronger than that.

[*https://nationalmaglab.org/about/maglab-dictionary/permanent-magnet*]

- **Quantum Mechanics (QM)**

Quantum mechanics is a theory of matter that is based on the concept of the possession of wave properties by elementary particles, that affords a mathematical interpretation of the structure and interactions of matter on the basis of these properties, and that incorporates within it quantum theory and the uncertainty principle. Also called wave mechanics.
[*Merriam Webster Dictionary*]

- **Quark**

1. A **quark** is any member of a group of elementary subatomic particles that interact by means of the strong force and are believed to be among the fundamental constituents of matter. Quarks associate with one another via the strong force to make up protons and neutrons, in much the same way that the latter particles combine in various proportions to make up atomic nuclei. There are six types, or flavors, of quarks that differ from one another in their mass and charge characteristics. These six quark flavors can be grouped in three pairs: up and down, charm and strange, and top and bottom. Quarks appear to be true elementary particles; that is, they have no apparent structure and cannot be resolved into something smaller. In addition, however, quarks always seem to occur in combination with other quarks or with antiquarks, their antiparticles, to form all hadrons—the so-called strongly interacting particles that encompass both baryons and mesons. [*Encyclopedia Britannica*, Britannica.com]
2. Quarks and electrons are the tiniest particles. There are three quarks in every proton and three in every neutron, and protons and neutrons are constituents of an atom. One cannot see a quark, even with an electron microscope, but we know they must exist since that's the only way to explain what happens when scientists do certain experiments.

[Quatr.us from Professor Carr.*https://quatr.us/physics/quarks-nuclear-physics-science.htm*]

- **Railgun**

A railgun is basically a large electric circuit, made up of three parts: a power source, a pair of parallel rails and a moving armature. Let's look at each of these parts in more detail.

The power supply is simply a source of electric current. Typically, the current used in medium-to large-caliber railguns is in the millions of amps.

The armature bridges the gap between the rails. It can be a solid piece of conductive metal or a conductive sabot—a carrier that houses a dart or other projectile. Some railguns use a plasma armature. In this set-up, a thin metal foil is placed on the back of a non-conducting projectile. When power flows through this foil, it vaporizes and becomes plasma, which carries the current.

Here's how the pieces work together:

An electric current runs from the positive terminal of the power supply, up the positive rail, across the armature, and down the negative rail back to the power supply.

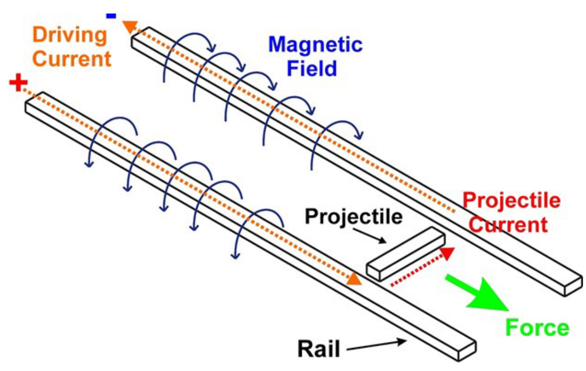
Current flowing in any wire creates a magnetic field around it–a region where a magnetic force is felt. This force has both a magnitude and a direction. In a railgun, the two rails act like wires, with a magnetic field circulating around each rail. The force lines of the magnetic field run in a counterclockwise circle around the positive rail and in a clockwise circle around the negative rail. The net magnetic field between the rails is directed vertically.

Like a charged wire in an electric field, the projectile experiences a force known as the Lorentz force (after the Dutch physicist Hendrik A. Lorentz). The Lorentz force is directed perpendicularly to the magnetic field and to the direction of the current flowing across the armature. You can see how this works in the diagram below (Figure GL.18).

Notice that the Lorentz force is parallel to the rails, acting away from the power supply. The magnitude of the force is determined by the equation F = (i)(L)(B), where F is the net force, i is the current, L is the length of the rails, and B is the magnetic field. The force can be boosted by increasing either the length of the rails or the amount of current.

Because long rails pose design challenges, most railguns use strong currents—on the order of a million amps—to generate tremendous force. The projectile, under the influence of the Lorentz force, accelerates to the end of the rails opposite the power supply and exits through an aperture. The circuit is broken, which ends the flow of current.

How Stuff Works *https://science.howstuffworks.com/rail-gun1.htm*

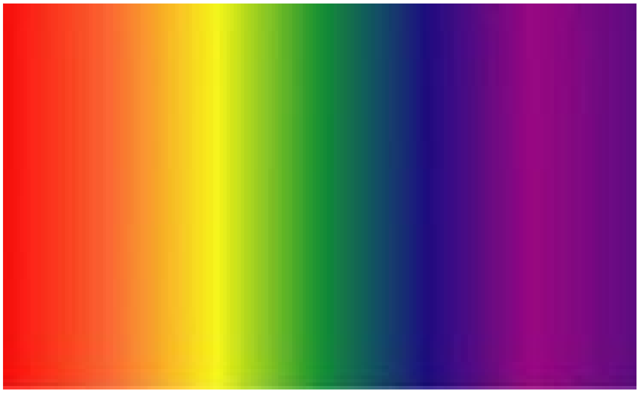


https://www.doityourselfgadgets.com/2013/10/homemade-railgun.html

Figure GL.18 Railgun [Fair Use]

- **Redshift / Blueshift**

What Are Redshift and Blueshift? By Elizabeth Howell, Space.com Contributor, May 2, 2014
Share Tools



Credit: NASA

Figure GL.19 Redshift/Blueshift [Fair Use]
The visible light spectrum

Redshift and blueshift explain how light changes as objects in space (such as stars or galaxies) move closer or farther away from us. The conception is key to charting the universe's expansion.

Visible light is a spectrum of colors, which is apparent to anyone who has observed a rainbow. When an object moves away from us, the light is shifted to the red end of the spectrum, as its wavelengths get longer. If an object moves closer, the light moves to the blue end of the spectrum, as its wavelengths get shorter.

To think of this more clearly, imagine yourself listening to a police siren as the car rushes by you on the road. Everyone has heard the increased pitch of an approaching police siren and the sharp decrease in pitch as the siren passes by and recedes. The effect arises because the sound waves arrive at the listener's ear closer together as the source approaches, and further apart as it recedes.

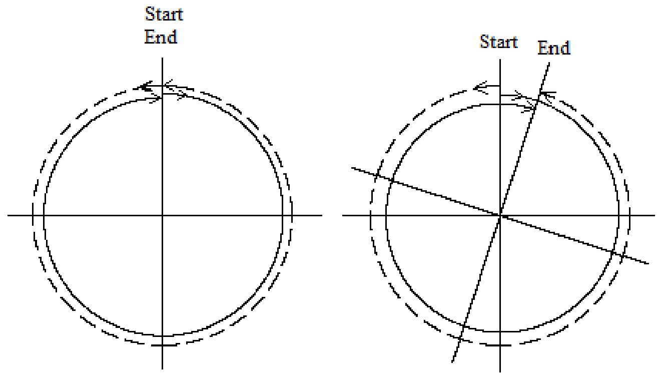
American astronomer Edwin Hubble was the first to describe the redshift phenomenon and tie it to an expanding universe. His observations, revealed in 1929, showed that nearly all galaxies he observed are moving away. This phenomenon was observed as a redshift of a galaxy's spectrum. "This redshift appeared to be larger for faint, presumably further, galaxies. Hence, the farther a galaxy, the faster it is receding from Earth. The galaxies are moving away from Earth because the fabric of space itself is expanding. While galaxies themselves are on the move——the Andromeda Galaxy and the Milky Way, for example, are on a collision course——there is an overall phenomenon of redshift occurring, as the universe expands. The terms redshift and blueshift apply to any part of the electromagnetic spectrum, including radio waves, infrared, ultraviolet, X-rays, and gamma rays."

Three types of redshift

At least three types of redshift arise in the universe—from the universe's expansion, from the movement of galaxies relative to each other and from "gravitational redshift," which transpires when light is shifted due to the massive amount of matter inside of a galaxy. [Space.com]

- **Sagnac Effect**

If two pulses of light are sent in opposite directions around a stationary circular loop of radius R, they will travel the same inertial distance at the same speed, so they will arrive at the end point simultaneously. This is illustrated in the left-hand figure below.



sensors:gyroscope [SensorWiki.org]; Canadian journal of physics

Figure GL.20 Sagnac Effect [Fair Use]

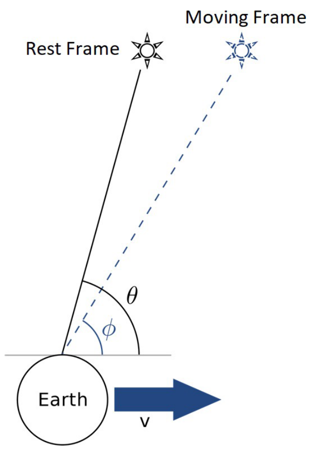
The figure on the right indicates what transpires if the loop itself is rotating during this procedure. Obviously, the pulse traveling in the same direction as the rotation of the loop must travel a slightly greater distance than the pulse traveling in the opposing direction, due to the angular displacement of the loop during the transit. As a result, if the pulses are emitted simultaneously from the ”start” position, the counter-rotating pulse will arrive at the ”end” point slightly earlier than the co-rotating pulse. [Mathpages.com]

- **Stellar Aberration**

Stellar aberration is an apparent shift in the observed position of a star compared with the position stated in the catalogue, due both to the finite nature of the speed of light and to the motion of the observer relative to the stars. Stellar aberration is divided into annual aberration and diurnal aberration.

The aberration of light (also referred to as astronomical aberration, stellar aberration, or velocity aberration) is an astronomical phenomenon, which produces an apparent motion of celestial objects about their true positions, dependent on the velocity of the observer. Aberration causes objects to appear to be displaced towards the direction of motion of the observer compared to when the observer is stationary. The change in angle is typically very small–of the order of v/c where (c) is the speed of light and v the velocity of the observer. In the case of ”stellar” or ”annual” aberration, the apparent position of a star to an observer on Earth varies periodically over the course of a year as the Earth’s velocity changes as it revolves around the Sun, by a maximum angle of approximately 20 arc-seconds in right ascension or declination.

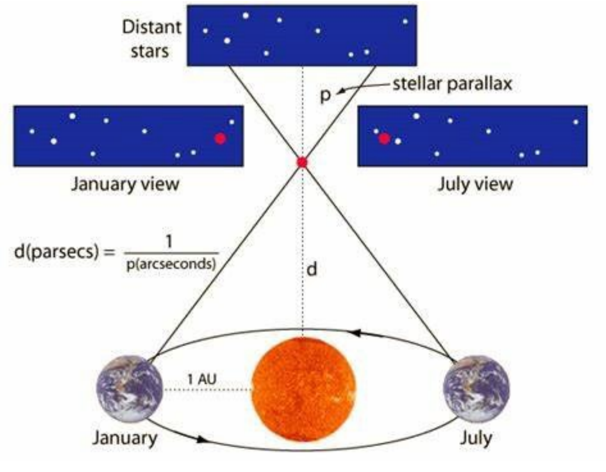
The term *aberration* has historically been used to refer to a number of related phenomena concerning the propagation of light in moving bodies. Don’t confuse aberration with *parallax*. The latter is a change in the apparent position of a relatively nearby object, as measured by a moving observer, relative to more distant objects that define a reference frame. The amount of parallax depends on the *distance* of the object from the observer, whereas aberration does not.



Wikipedia
future-sciences.com

Figure GL.21 Stellar Aberration [Fair Use]
The apparent position of a star viewed from the Earth depends on the Earth's velocity. The effect is typically much smaller than illustrated.

- **Stellar Parallax**



hyperphysics.phy-astr.gsu.edu hyperphysics

Figure GL.22 Stellar Parallax [Fair Use]

When viewed from the position of the sun (large central red mottled ball], the distant object (smaller red oval) appears to be in the center of the rectangle of stars. Alternatively when viewed from Earth, its position changes with respect to those same stars (rectangle), moreover, January different from July (using trigonometry).

What Is Parallax

By Jim Lucas, Space.com Contributor, August 29, 2015

Share Tools

Astronomers use a technique called parallax to precisely measure the distance to stars in the sky. Using the technique, which requires observing targets from opposite sides of Earth's orbit around the Sun, astronomers have pinpointed the distance to the famed "Seven Sisters" star cluster, the Pleiades. See photo below. [*Space.com*]

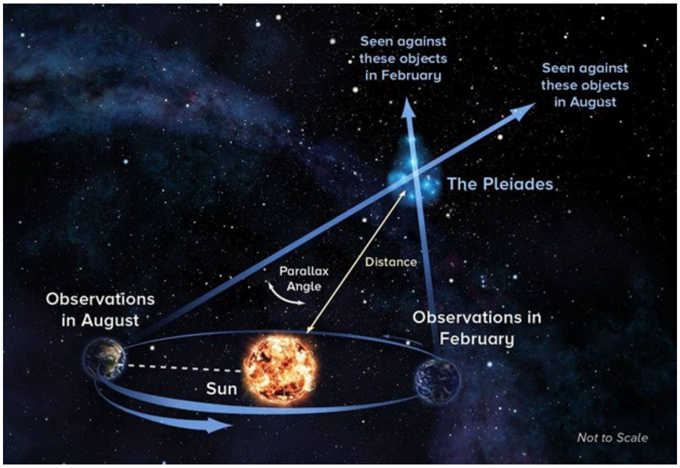


Figure GL.23 Stellar Parallax [Fair Use]

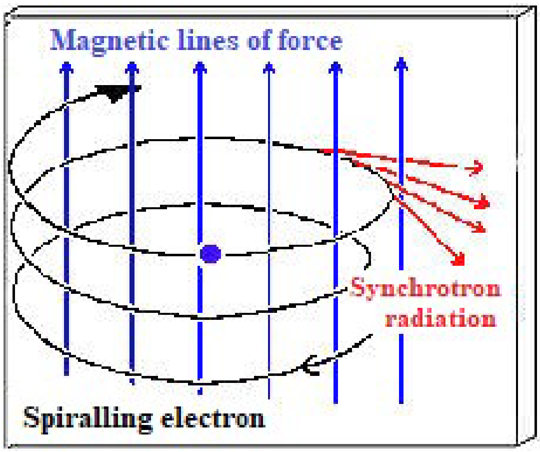
- **Substance**

A substance is matter which has a specific composition and specific properties. Every pure element is a substance. Every pure compound is a substance. [*Chemicool Dictionary* chemicool.com]

- **Synchrotron Radiation**

Synchrotron radiation is emitted by charged particles, usually electrons, moving at relativistic speeds in magnetic fields. In a magnetic field, a charged particle is forced to circle around the field line in a helical path. An accelerating charged particle emits electromagnetic radiation that is radiated along the direction in which the particle is moving. A large population of relativistic particles moving in a magnetic field will radiate over a wide range of frequencies and has a high degree of polarization.

[*http://universe-review.ca/R05-02-synchrotron.htm*]



http://universe-review.ca/R05-02-synchrotron.htm

Figure GL.24 Synchrotron Radiation [Fair Use]

- **VMF (Velocity Magnetic Field)**

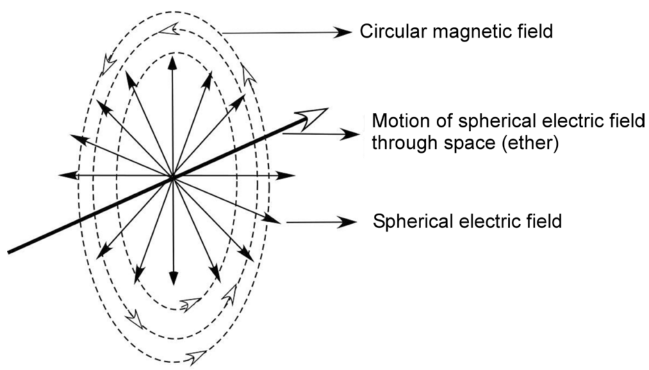


Figure GL.25 VMF (Velocity Magnetic Field) [Fair Use]

Electrons possess two forms of magnetic fields. The first is related to the electron's intrinsic spin within the ether (up down). This is a function of EMR spinning upon itself, therefore, transforming into an electron (electric field). The second is a function of the electron's velocity, with regard to the ether of PFSRT (Chapter 1). For future reference, these two categories of magnetic fields will be defined as, first, the spin electromagnet field (SMF) and second, the velocity magnetic field (VMF).

- **Wavefront**

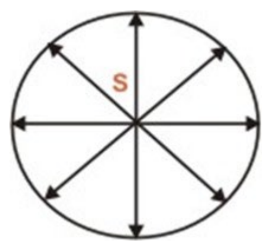
1. Wavefront is defined as the locus of all the particles of a medium vibrating in the same phase at a given instant. The phase difference between any two points situated on the same wavefront is zero; the shape of a wavefront depends upon the shape of the source of disturbance. [assignmenthelp.net http://bit.ly/2NfvrZ5]

2. A wavefront is a surface or line in the path of wave motion on which the disturbances at every point have the same phase.

Depending upon the source of light, wavefronts can be of three types, spherical wavefront, cylindrical wavefront, or plane wavefront.

Spherical Wavefront

If a point source in an isotropic medium is sending out waves in three dimensions, the wavefronts are spheres centered on the source as shown in Figure GL.26 below. Such wavefront is called a spherical wavefront.

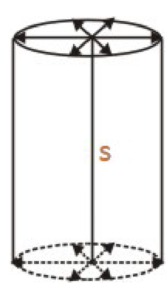


http:www.physicshandbook.com/topic/topicw/wavefronthtm

Figure GL.26 Spherical Wavefront [Fair Use]

Cylindrical Wavefront

When the source of light is linear, all the points equidistant from the linear source lie on the surface of a cylinder as shown in figure. Such a wavefront is called a cylindrical wavefront.

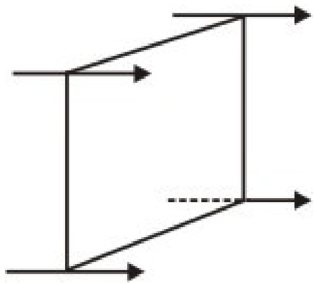


http:www.physicshandbook.com/topic/topicw/wavefronthtm

Figure GL.27 Cylindrical Wavefront [Fair Use]

Plane Wavefront

At a large distance from a source of any kind, the wavefront will appear plane as shown in figure. Such a wavefront is called plane wavefront.



http:www.physicshandbook.com/topic/topicw/wavefront.htm

Figure GL.28 Plane Wavefront [Fair Use]

Here is an example of a wavefront An explosion located at a central point in the atmosphere resulting in a pressure wave radiating from its origin. The leading edge of the pressure wave is the wavefront.