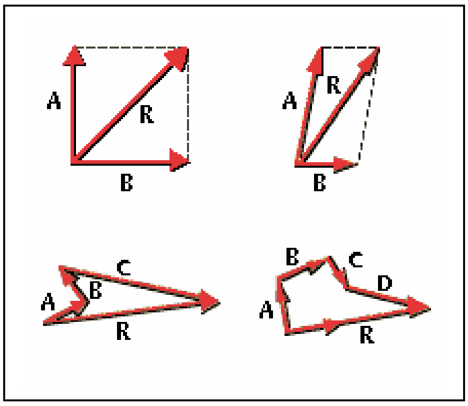
College entrance exam and science high school entrance test tips. Conquer UPCAT, ACET, USTET, DLSUCET, PSHS-NCE, and other entrance tests.

PHYSICS
BASIC LAWS AND CONCEPTS

PHYSICS

- major science, dealing with the fundamental constituents of the universe, the forces they exert on one another, and the results produced by these forces. Sometimes in modern physics a more sophisticated approach is taken that incorporates elements of the three areas listed above; it relates to the laws of symmetry and conservation, such as those pertaining to energy, momentum, charge, and parity.

VECTORS AND SCALARS



Vectors and Net Force
Often, an object will have many forces acting on it simultaneously. Calculating the effect of each of the forces separately can be extremely complex and difficult. However, forces are vectors, and as such, any number of forces can be combined into a single net force vector (R) from which the object's behavior can be determined.

Scalar – a measure with magnitude but no direction.
(e.g., distance, mass, speed)

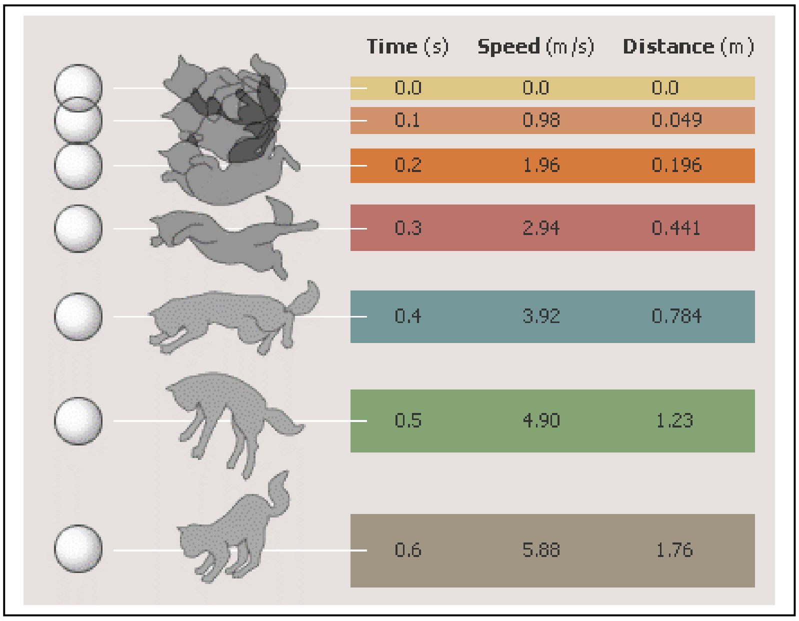
Vectors – a measure with both magnitude and direction.
(e.g., force, acceleration, velocity)

Mechanics

Mechanics, branch of physics concerning the motions of objects and their response to forces. Modern descriptions of such behavior begin with a careful definition of such quantities as displacement (distance moved), time, velocity, acceleration, mass, and force. Until about 400 years ago, however, motion was explained from a very different point of view. For example, following the ideas of Greek philosopher and scientist Aristotle, scientists reasoned that a cannonball falls down because its natural position is in the earth; the sun, the moon, and the stars travel in circles around the earth because it is the nature of heavenly objects to travel in perfect circles.

The Italian physicist and astronomer Galileo brought together the ideas of other great thinkers of his time and began to analyze motion in terms of distance traveled from some starting position and the time that it took. He showed that the speed of falling objects increases steadily during the time of their fall. This acceleration is the same for heavy objects as for light ones, provided air friction (air resistance) is discounted. The English mathematician and physicist Sir Isaac Newton improved this analysis by defining force and mass and relating these to acceleration. For objects traveling at speeds close to the speed of light, Newton's laws were superseded by Albert Einstein's theory of relativity. For atomic and subatomic particles, Newton's laws were superseded by quantum theory. For everyday phenomena, however, Newton's three laws of motion remain the cornerstone of dynamics, which is the study of what causes motion.

Kinetics



Time (s)	Speed (m/s)	Distance (m)
0.0	0.0	0.0
0.1	0.98	0.049
0.2	1.96	0.196
0.3	2.94	0.441
0.4	3.92	0.784
0.5	4.90	1.23
0.6	5.88	1.76

Falling objects accelerate in response to the force exerted on them by Earth's gravity. Different objects accelerate at the same rate, regardless of their mass. This illustration shows the speed at which a ball and a cat would be moving and the distance each would have fallen at intervals of a tenth of a second during a short fall.

Kinetics is the description of motion without regard to what causes the motion. Velocity (the time rate of change of position) is defined as the distance traveled divided by the time interval. Velocity may be measured in such units as kilometers per hour, miles per hour, or meters per second. Acceleration is defined as the time rate of change of velocity: the change of velocity divided by the time interval during the change. Acceleration may be measured in such units as meters per second per second or feet per second per second. Regarding the size or weight of the moving object, no mathematical problems are presented if the object is very small compared with the distances involved. If the object is large, it contains one point, called the center of mass, the motion of which can be described as characteristic of the whole object. If the object is rotating, it is frequently convenient to describe its rotation about an axis that goes through the center of mass.

To fully describe the motion of an object, the direction of the displacement must be given. Velocity, for example, has both magnitude (a scalar quantity measured, for example, in meters per second) and direction (measured, for example, in degrees of arc from a reference point). The magnitude of velocity is called speed.

Several special types of motion are easily described. First, velocity may be constant. In the simplest case, the velocity might be zero; position would not change during the time interval. With constant velocity, the average velocity is equal to the velocity at any particular time. If time, *t,* is measured with a clock starting at $t = 0$, then the distance, *d,* traveled at constant velocity, *v,* is equal to the product of velocity and time.

$$d = vt$$

In the second special type of motion, acceleration is constant. Because the velocity is changing, instantaneous velocity, or the velocity at a given instant, must be defined. For constant acceleration, *a,* starting with zero velocity ($v = 0$) at $t = 0$, the instantaneous velocity at time, *t,* is

$$v = at$$

The distance traveled during this time is

$$d = \tfrac{1}{2}at^2$$

An important feature revealed in this equation is the dependence of distance on the square of the time (t^2, or "*t* squared," is the short way of notating $t \times t$). A heavy object falling freely (uninfluenced by air friction) near the surface of the earth undergoes constant acceleration. In this case the acceleration is 9.8 m/sec/sec (32 ft/sec/sec). At the end of the first second, a ball would have fallen 4.9 m (16 ft) and would have a speed of 9.8 m/sec (32 ft/sec). At the end of the second second, the ball would have fallen 19.6 m (64 ft) and would have a speed of 19.6 m/sec (64 ft/sec).

Circular motion is another simple type of motion. If an object has constant speed but an acceleration always at right angles to its velocity, it will travel in a circle. The required acceleration is directed toward the center of the circle and is called centripetal acceleration (*see* Centripetal Force). For an object traveling at speed, *v,* in a circle of radius, *r,* the centripetal acceleration is

$$a = \frac{v^2}{r}$$

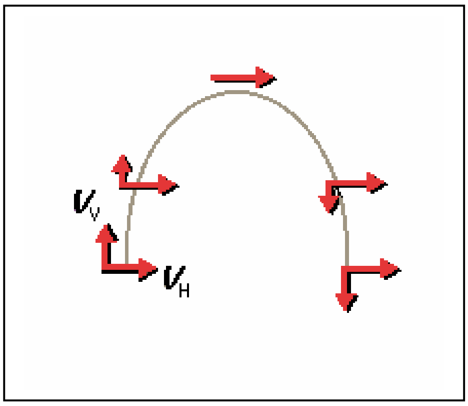
Another simple type of motion that is frequently observed occurs when a ball is thrown at an angle into the air. Because of gravitation, the ball undergoes a constant downward acceleration that first slows its original upward speed and then increases its downward speed as it falls back to earth. Meanwhile the horizontal component of the original velocity remains constant (ignoring air resistance), making the ball travel at a constant speed in the horizontal direction until it hits the earth. The vertical and horizontal components of the motion are independent, and they can be analyzed separately. The resulting path of the ball is in the shape of a parabola.

DYNAMICS

To understand why and how objects accelerate, force and mass must be defined. At the intuitive level, a force is just a push or a pull. It can be measured in terms of either of two effects. A force can either distort something, such as a spring, or accelerate an object. The first effect can be used in the calibration of a spring scale, which can in turn be used to measure the amplitude of a force: the greater the force, *F,* the greater the stretch, *x.* For many springs, over a limited range, the stretch is proportional to the force

$$F = kx$$

where *k* is a constant that depends on the nature of the spring material and its dimensions.



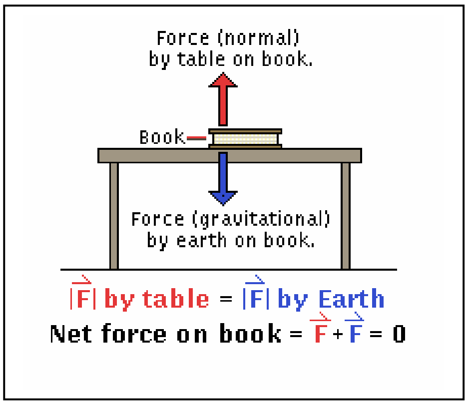
Components of Velocity
Neglecting air resistance, a ball thrown into the air at an angle will travel in a parabolic path. The velocity of the ball (**V**) has independent vertical (V) and horizontal (H) components; the horizontal component stays the same the entire time the ball is in the air, while the vertical component, the only component affected by gravity, changes continuously while the ball is aloft.

TORQUE

For equilibrium, all the horizontal components of the force must cancel one another, and all the vertical components must cancel one another as well. This condition is necessary for equilibrium, but not sufficient. For example, if a person stands a book up on a table and pushes on the book equally hard with one hand in one direction and with the other hand in the other direction, the book will remain motionless if the person's hands are opposite each other. (The net result is that the book is being squeezed). If, however, one hand is near the top of the book and the other hand near the bottom, a torque is produced, and the book will fall on its side. For equilibrium to exist it is also necessary that the sum of the torques about any axis be zero.

A torque is the product of a force and the perpendicular distance to a turning axis. When a force is applied to a heavy door to open it, the force is exerted perpendicularly to the door and at the greatest distance from the hinges. Thus, a maximum torque is created. If the door were shoved with the same force at a point halfway between handle and hinge, the torque would be only half of its previous magnitude. If the force were applied parallel to the door (that is, edge on), the torque would be zero. For an object to be in equilibrium, the clockwise torques about any axis must be canceled by the counterclockwise torques about that axis. Therefore, one could prove that if the torques cancel for any particular axis, they cancel for all axes.

NEWTON'S THREE LAWS OF MOTION



Acceleration and Newton's Laws

Newton's second law states that the net force on an object is proportional to the acceleration that object undergoes. If there is no net force, then according to Newton's first law, there can be no acceleration. A book on a table experiences a downward force due to gravity, and an upward force due to the table pushing on the book (called the normal force). The two forces cancel each other out exactly; there is no net force, so the book does not accelerate off the table.

Newton's first law of motion states that if the vector sum of the forces acting on an object is zero, then the object will remain at rest or remain moving at constant velocity. If the force exerted on an object is zero, the object does not necessarily have zero velocity. Without any forces acting on it, including friction, an object in motion will continue to travel at constant velocity.

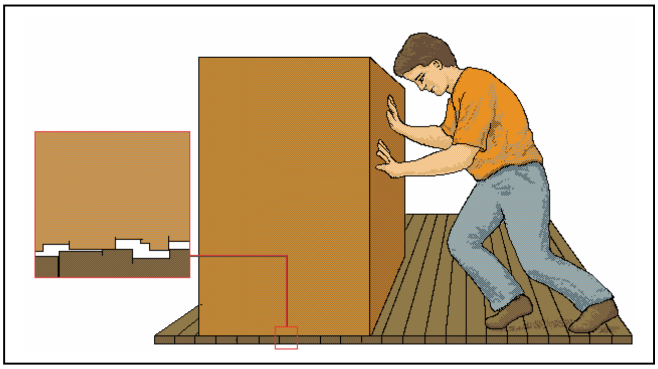
The Second Law

Newton's second law relates net force and acceleration. A net force on an object will accelerate it—that is, change its velocity. The acceleration will be proportional to the magnitude of the force and in the same direction as the force. The proportionality constant is the mass, *m,* of the object.

$$F = ma$$

In the International System of Units (also known as SI, after the initials of Système International), acceleration, *a,* is measured in meters per second per second. Mass is measured in kilograms; force, *F,* in newtons. A newton is defined as the force necessary to impart to a mass of 1 kg an acceleration of 1 m/sec/sec; this is equivalent to about 0.2248 lb.

A massive object will require a greater force for a given acceleration than a small, light object. What is remarkable is that mass, which is a measure of the inertia of an object (*inertia* is its reluctance to change velocity), is also a measure of the gravitational attraction that the object exerts on other objects. It is surprising and profound that the inertial property and the gravitational property are determined by the same thing. The implication of this phenomenon is that it is impossible to distinguish at a point whether the point is in a gravitational field or in an accelerated frame of reference. Einstein made this one of the cornerstones of his general theory of relativity, which is the currently accepted theory of gravitation.



Friction
Microscopic bumps on surfaces cause friction. When two surfaces contact each other, tiny bumps on each of the surfaces tend to run into each other, preventing the surfaces from moving past each other smoothly. An effective lubricant forms a layer between two surfaces that prevents the bumps on the surfaces from contacting each other; as a result the surfaces move past each other easily.

Friction acts like a force applied in the direction opposite to an object's velocity. For dry sliding friction, where no lubrication is present, the friction force is almost independent of velocity. Also, the friction force does not depend on the apparent area of contact between an object and the surface upon which it slides. The actual contact area—that is, the area where the microscopic bumps on the object and sliding surface are actually touching each other—is relatively small. As the object moves across the sliding surface, the tiny bumps on the object and sliding surface collide, and force is required to move the bumps past each other. The actual contact area depends on the perpendicular force between the object and sliding surface. Frequently this force is just the weight of the sliding object. If the object is pushed at an angle to the horizontal, however, the downward vertical component of the force will, in effect, add to the weight of the object. The friction force is proportional to the total perpendicular force.

Where friction is present, Newton's second law is expanded to

$$F_{effective} - F_{friction} = ma$$

The left side of the equation is simply the net effective force. (Acceleration will be constant in the direction of the effective force). When an object moves through a liquid, however, the magnitude of the friction depends on the velocity. For most human-size objects moving in water or air (at subsonic speeds), the resulting friction is proportional to the square of the speed. Newton's second law then becomes

$$F_{effective} - kv^2 = ma$$

The proportionality constant, *k,* is characteristic of the two materials that are sliding past each other, and depends on the area of contact between the two surfaces and the degree of streamlining of the moving object.

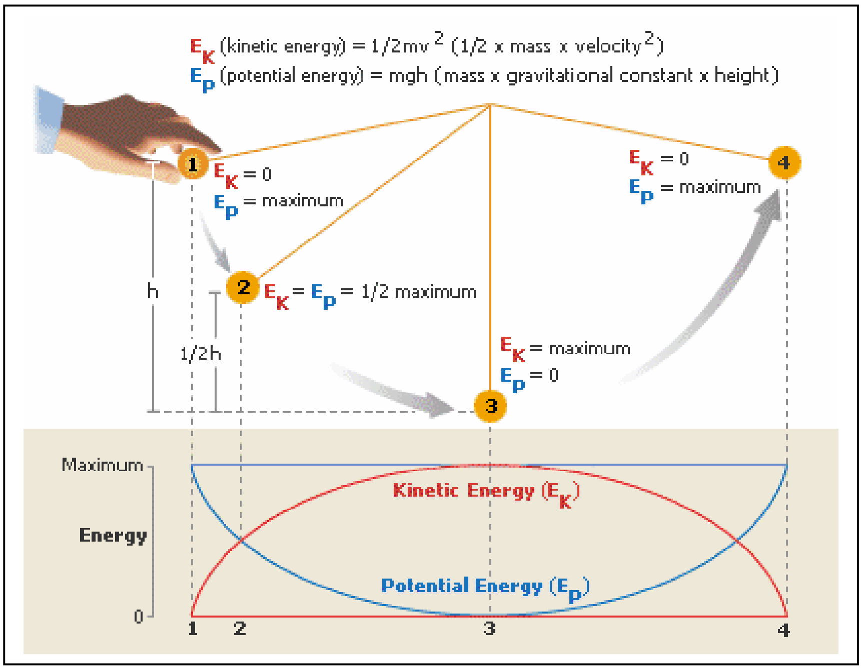
The Third Law

Newton's third law of motion states that an object experiences a force because it is interacting with some other object. The force that object 1 exerts on object 2 must be of the same magnitude but in the opposite direction as the force that object 2 exerts on object 1. If, for example, a large adult gently shoves away a child on a skating rink, in addition to the force the adult imparts on the child, the child imparts an equal but oppositely directed force on the adult. Because the mass of the adult is larger, however, the acceleration of the adult will be smaller.

Newton's third law also requires the conservation of momentum, or the product of mass and velocity. For an isolated system, with no external forces acting on it, the momentum must remain constant. In the example of the adult and child on the skating rink, their initial velocities are zero, and thus the initial momentum of the system is zero. During the interaction, internal forces are at work between adult and child, but net external forces equal zero. Therefore, the momentum of the system must remain zero. After the adult pushes the child away, the product of the large mass and small velocity of the adult must equal the product of the small mass and large velocity of the child. The momenta are equal in magnitude but opposite in direction, thus adding to zero.

Another conserved quantity of great importance is angular (rotational) momentum. The angular momentum of a rotating object depends on its speed of rotation, its mass, and the distance of the mass from the axis. When a skater standing on a friction-free point spins faster and faster, angular momentum is conserved despite the increasing speed. At the start of the spin, the skater's arms are outstretched. Part of the mass is therefore at a large radius. As the skater's arms are lowered, thus decreasing their distance from the axis of rotation, the rotational speed must increase in order to maintain constant angular momentum.

ENERGY



Energy of a Pendulum
A moving pendulum changes potential energy into kinetic energy and back again. When the bob (weight on the end of string) is first released, it has potential energy due to its height, but no kinetic energy since it is not yet moving. As the bob accelerates downward, potential energy is traded for kinetic. At the bottom of its swing, the bob has no potential energy since it cannot fall any further. The bob is moving quickly at this point since all of its former potential energy has been transformed into kinetic energy.

The quantity called energy ties together all branches of physics. In the field of mechanics, energy must be provided to do work; work is defined as the product of force and the distance an object moves in the direction of the force. When a force is exerted on an object but the force does not cause the object to move, no work is done. Energy and work are both measured in the same units—ergs, joules, or foot-pounds, for example.

If work is done lifting an object to a greater height, energy has been stored in the form of gravitational potential energy. Many other forms of energy exist: electric and magnetic potential energy; kinetic energy; energy stored in stretched springs, compressed gases, or molecular bonds; thermal energy; and mass itself. In all transformations from one kind of energy to another, the total energy is conserved. For instance, if work is done on a rubber ball to raise it, its gravitational potential energy is increased. If the ball is then dropped, the gravitational potential energy is transformed to kinetic energy. When the ball hits the ground, it becomes distorted and thereby creates friction between the molecules of the ball material. This friction is transformed into heat, or thermal energy.

Electricity

Electricity, one of the basic forms of energy. Electricity is associated with electric charge, a property of certain elementary particles such as electrons and protons, two of the basic particles that make up the atoms of all ordinary matter. Electric charges can be stationary, as in static electricity, or moving, as in an electric current.

Projectile, in military terminology, a missile discharged from small arms or from artillery weapons or a self-propelled weapon such as a rocket or a torpedo, or guided missiles. The terms projectile, shell, and missile are loosely interchangeable, but in modern military usage projectile is preferable as a more precise term. In physics and ballistics, a projectile is any body projected through space.

ELECTRIC CHARGE

Electricity consists of charges carried by electrons, protons, and other particles. Electric charge comes in two forms: positive and negative. Electrons and protons both carry exactly the same amount of electric charge, but the positive charge of the proton is exactly opposite the negative charge of the electron. If an object has more protons than electrons, it is said to be positively charged; if it has more electrons than protons, it is said to be negatively charged. If an object contains as many protons as electrons, the charges will cancel each other and the object is said to be uncharged, or electrically neutral.

Electricity occurs in two forms: static electricity and electric current. Static electricity consists of electric charges that stay in one place. An electric current is a flow of electric charges between objects or locations.

Static electricity can be produced by rubbing together two objects made of different materials. Electrons move from the surface of one object to the surface of the other if the second material holds onto its electrons more strongly than the first does. The object that gains electrons becomes negatively charged, since it now has more electrons than protons. The object that gives up electrons becomes positively charged. For example, if a nylon comb is run through clean, dry hair, some of the electrons on the hair are transferred to the comb. The comb becomes negatively charged and the hair becomes positively charged. The following materials are named in decreasing order of their ability to hold electrons: rubber, silk, glass, flannel, and fur (or hair). If any two of these materials are rubbed together, the material earlier in the list becomes negative, and the material later in the list becomes positive. The materials should be clean and dry.

Coulomb's Law

Objects with opposite charges attract each other, and objects with similar charges repel each other. Coulomb's law, formulated by French physicist Charles Augustin de Coulomb during the late 18th century, quantifies the strength of the attraction or repulsion. This law states that the force between two charged objects is directly proportional to the product of their charges and inversely proportional to the square of the distance between them. The greater the charges on the objects, the larger the force between them; the greater the distance between the objects, the lesser the force between them. The unit of electric charge, also named after Coulomb, is equal to the combined charges of 6.24×10^{18} protons (or electrons).

Electric current - is a movement of charge. When two objects with different charges touch and redistribute their charges, an electric current flows from one object to the other until the charge is distributed according to the capacitances of the objects. If two objects are connected by a material that lets charge flow easily, such as a copper wire, then an electric current flows from one object to the other through the wire. Electric current can be demonstrated by connecting a small light bulb to an electric battery by two copper wires. When the connections are properly made, current flows through the wires and the bulb, causing the bulb to glow. Electric current is measured in units called amperes (amp). If 1 coulomb of charge flows past each point of a wire every second, the wire is carrying a current of 1 amp.

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

Insulators Substances that do not allow electric current to flow through them are. Rubber, glass, and air are common insulators. Electricians wear rubber gloves so that electric current will not pass from electrical equipment to their bodies.

Voltage, or Potential Difference

When the two terminals of a battery are connected by a conductor, an electric current flows through the conductor. One terminal continuously sends electrons into the conductor, while the other continuously receives electrons from it. The current flow is caused by the voltage, or potential difference, between the terminals. The more willing the terminals are to give up and receive electrons, the higher the voltage. Voltage is measured in units called volts. Another name for a voltage produced by a source of electric current is electromotive force.

Resistance

A conductor allows an electric current to flow through it, but it does not permit the current to flow with perfect freedom. Collisions between the electrons and the atoms of the conductor interfere with the flow of electrons. This phenomenon is known as resistance. Resistance is measured in units called ohms. The symbol for ohms is the Greek letter omega, Ω.

Ohm's Law

The relationship between current, voltage, and resistance is given by Ohm's law. This law states that the amount of current passing through a conductor is directly proportional to the voltage across the conductor and inversely proportional to the resistance of the conductor. Ohm's law can be expressed as an equation, $V = IR$, where V is the difference in volts between two locations (called the potential difference), I is the amount of current in amperes that is flowing between these two points, and R is the resistance in ohms of the conductor between the two locations of interest. $V = IR$ can also be written $R = V/I$ and $I = V/R$. If any two of the quantities are known, the third can be calculated. For example, if a potential difference of 110 volts sends a 10-amp current through a conductor, then the resistance of the conductor is $R = V/I = 110/10 = 11$ ohms. If $V = 110$ and $R = 11$, then $I = V/R = 110/11 = 10$ amp.

ELECTRIC CIRCUITS

An electric circuit is an arrangement of electric current sources and conducting paths through which a current can continuously flow. There are two basic ways in which the parts of a circuit are arranged. One arrangement is called a series circuit, and the other is called a parallel circuit.

Series Circuits

If various objects are arranged to form a single conducting path between the terminals of a source of electric current, the objects are said to be connected in series. The electron current first passes from the negative terminal of the source into the first object, then flows through the other objects one after another, and finally returns to the positive terminal of the source. The current is the same throughout the circuit. In the example of the light bulb, the wires, bulb, switch, and fuse are connected in series.

Parallel Circuits

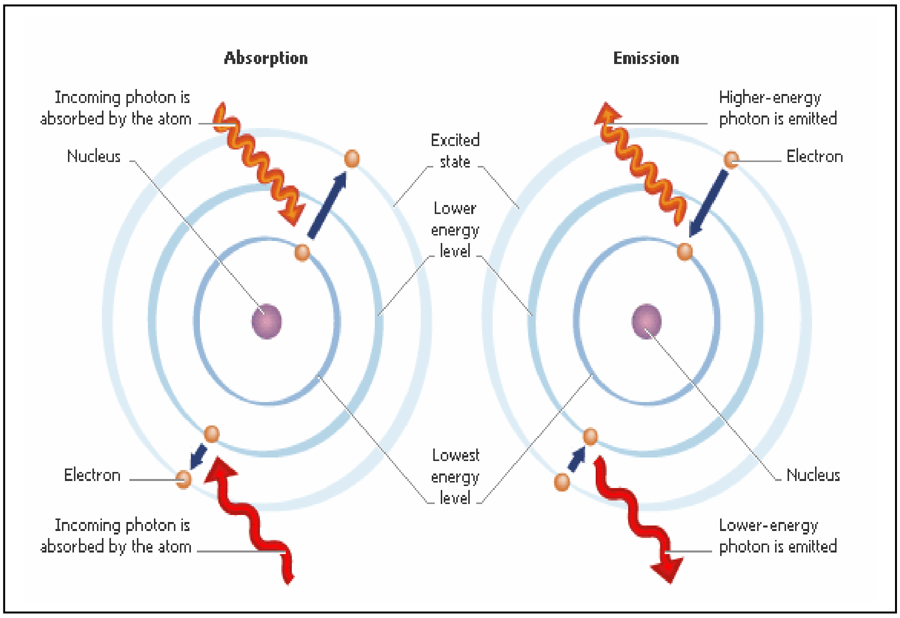
If various objects are connected to form separate paths between the terminals of a source of electric current, they are said to be connected in parallel. Each separate path is called a branch of the circuit. Current from the source splits up and enters the various branches. After flowing through the separate branches, the current merges again before reentering the current source.

MAGNETISM

Magnetism, an aspect of electromagnetism, one of the fundamental forces of nature. Magnetic forces are produced by the motion of charged particles such as electrons, indicating the close relationship between electricity and magnetism. The unifying frame for these two forces is called electromagnetic theory (see Electromagnetic Radiation). The most familiar evidence of magnetism is the attractive or repulsive force observed to act between magnetic materials such as iron. More subtle effects of magnetism, however, are found in all matter. In recent times these effects have provided important clues to the atomic structure of matter.

LIGHT

Light, form of energy visible to the human eye that is radiated by moving charged particles. Light from the Sun provides the energy needed for plant growth. Plants convert the energy in sunlight into storable chemical form through a process called photosynthesis.



Light Absorption and Emission
When a photon, or packet of light energy, is absorbed by an atom, the atom gains the energy of the photon, and one of the atom's electrons may jump to a higher energy level. The atom is then said to be excited. When an electron of an excited atom falls to a lower energy level, the atom may emit the electron's excess energy in the form of a photon. The energy levels, or orbitals, of the atoms shown here have been greatly simplified to illustrate these absorption and emission processes. For a more accurate depiction of electron orbitals, see the Atom article.

WAVELENGTH, FREQUENCY, AND AMPLITUDE

The wavelength of a monochromatic wave is the distance between two consecutive wave peaks. Wavelengths of visible light can be measured in meters or in nanometers (nm), which are one-billionth of a meter (or about 0.4 ten-millionths of an inch). Frequency corresponds to the number of wavelengths that pass by a certain point in space in a given amount of time. This value is usually measured in cycles per second, or hertz (Hz). All electromagnetic waves travel at the same speed, so in one second, more short waves will pass by a point in space than will long waves. This means that shorter waves have a higher frequency than longer waves. The relationship between wavelength, speed, and frequency is expressed by the equation: wave speed equals wavelength times frequency, or

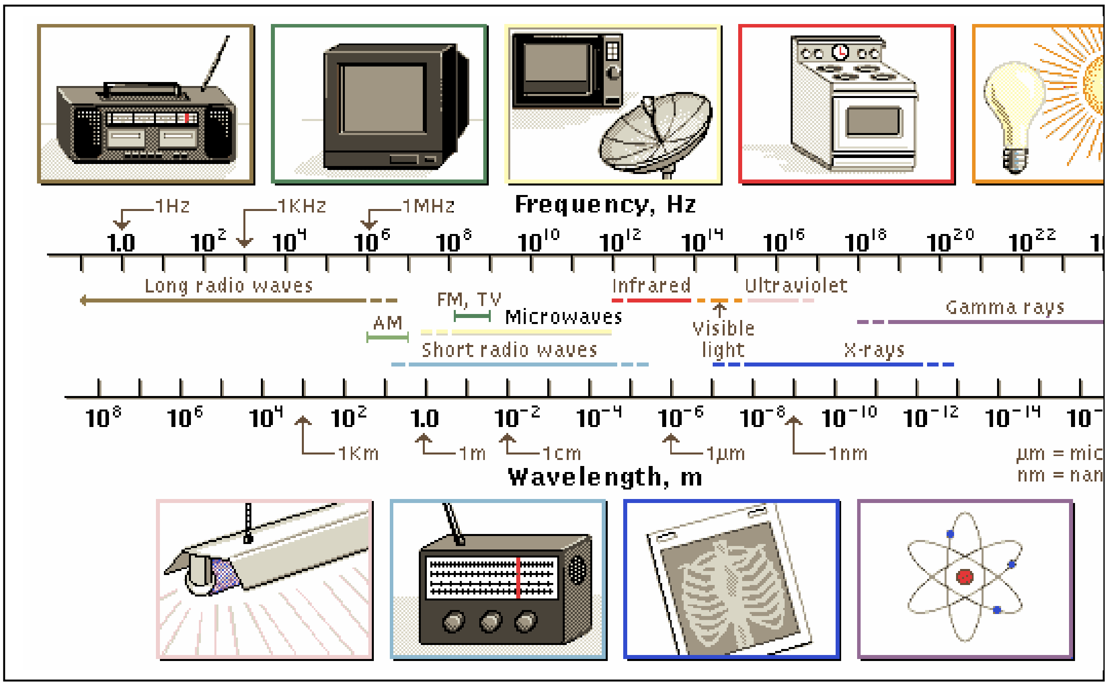
c = lf

Where c is the speed of a light wave in m/sec (3x108 m/sec in a vacuum), l is the wavelength in meters, and f is the wave's frequency in Hz.

The amplitude of an electromagnetic wave is the height of the wave, measured from a point midway between a peak and a trough to the peak of the wave. This height corresponds to the maximum strength of the electric and magnetic fields and to the number of photons in the light.

Electromagnetic Spectrum

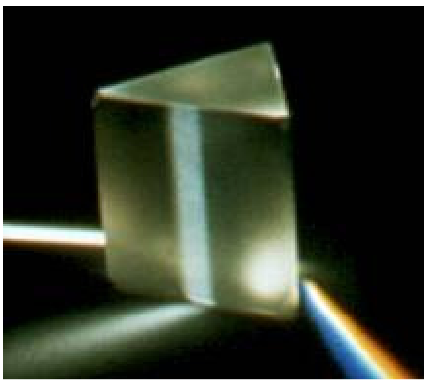
The electromagnetic spectrum includes radio waves, microwaves, infrared light, visible light, ultraviolet light, x rays, and gamma rays. Visible light, which makes up only a tiny fraction of the electromagnetic spectrum, is the only electromagnetic radiation that humans can perceive with their eyes.



BEHAVIOR OF LIGHT

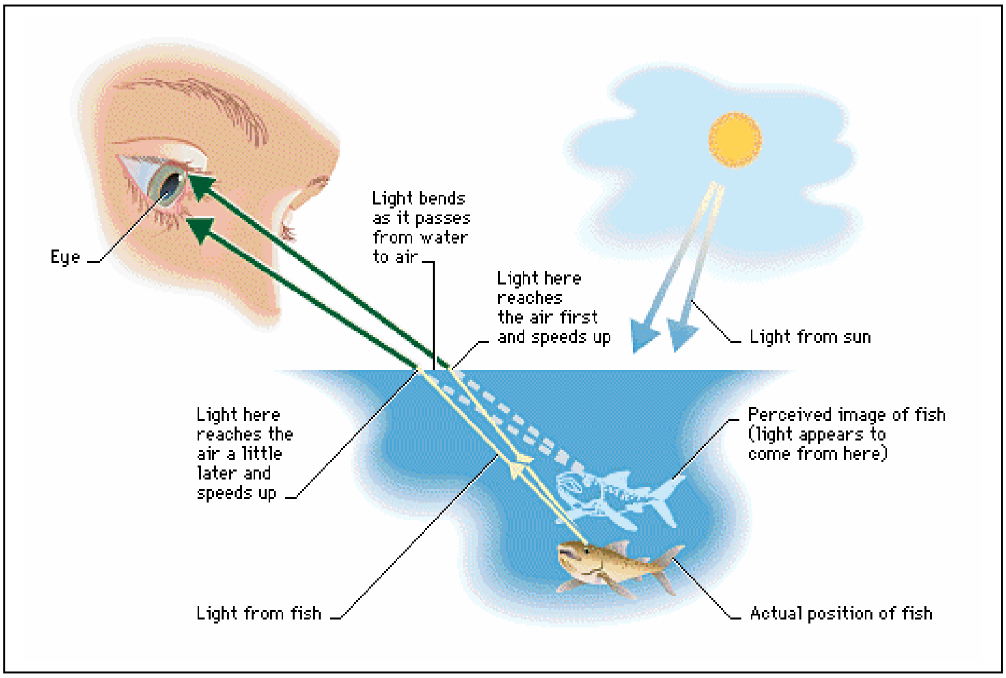
Light behavior can be divided into two categories: how light interacts with matter and how light travels, or propagates through space or through transparent materials. The propagation of light has much in common with the propagation of other kinds of waves, including sound waves and water waves.

Interaction with Material



Separation of White Light into Colored Light
Light from many sources, such as the sun, appears white. When white light passes through a prism, however, it separates into a spectrum of different colors. The prism bends, or refracts, light of different colors at different angles. Red light bends the least and violet light bends the most.

When light strikes a material, it interacts with the atoms in the material, and the corresponding effects depend on the frequency of the light and the atomic structure of the material. In transparent materials, the electrons in the material oscillate, or vibrate, while the light is present. This oscillation momentarily takes energy away from the light and then puts it back again. The result is to slow down the light wave without leaving energy behind.



Refraction of Light
Refraction is the bending of a light ray as it passes from one substance to another. The light ray bends at an angle that depends on the difference between the speed of light in one substance and the next. Sunlight reflecting off a fish in water, for instance, changes to a higher speed and bends when it enters air. The light appears to originate from a place in the water above the fish's actual position.

Refraction

Refraction is the bending of light when it passes from one kind of material into another. Because light travels at a different speed in different materials, it must change speeds at the boundary between two materials.

Reflection

Reflection also occurs when light hits the boundary between two materials. Some of the light hitting the boundary will be reflected into the first material. If light strikes the boundary at an angle, the light is reflected at the same angle, similar to the way balls bounce when they hit the floor.

Scattering

Scattering occurs when the atoms of a transparent material are not smoothly distributed over distances greater than the length of a light wave, but are bunched up into lumps of molecules or particles. The sky is bright because molecules and particles in the air scatter sunlight.

The Speed of Light

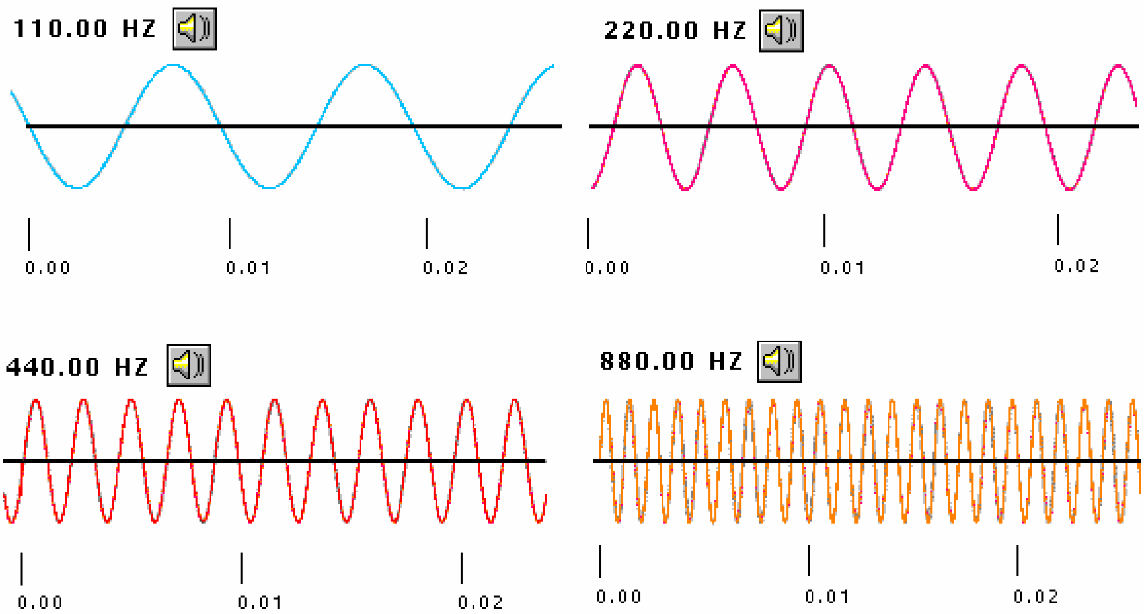
Scientists have defined the speed of light in a vacuum to be exactly 299,792,458 meters per second (about 186,000 miles per second).

SOUND

Sound, physical phenomenon that stimulates the sense of hearing. In humans, hearing takes place whenever vibrations of frequencies from 15 hertz to about 20,000 hertz reach the inner ear. The hertz (Hz) is a unit of frequency equaling one vibration or cycle per second. Such vibrations reach the inner ear when they are transmitted through air. The speed of sound varies, but at sea level it travels through cool, dry air at about 1,190 km/h (740 mph). The term sound is sometimes restricted to such airborne vibrational waves. Modern physicists, however, usually extend the term to include similar vibrations in other gaseous, liquid, or solid media. Physicists also include vibrations of any frequency in any media, not just those that would be audible to humans. Sounds of frequencies above the range of normal human hearing, higher than about 20,000 Hz, are called ultrasonic.

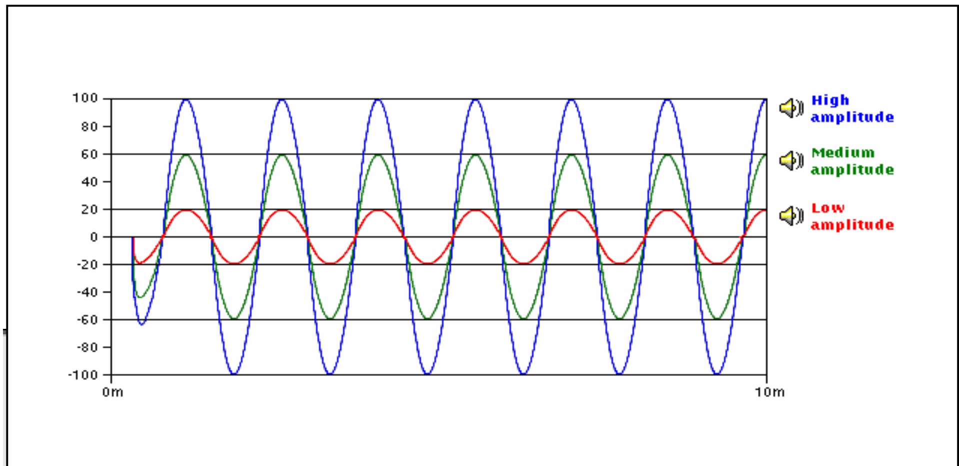
PHYSICAL CHARACTERISTICS

Frequency



Frequency
We perceive frequency as "higher" or "lower" sounds. The frequency of a sound is the number of cycles, or oscillations, a sound wave completes in a given time. Frequency is measured in hertz, or cycles per second. In these examples, the frequency of each higher wave is double that of the one below, producing the same note at different frequencies, from 110.00 Hz to 880.00 Hz. Waves propagate at both higher and lower frequencies, but humans are unable to hear them outside of a relatively narrow range.

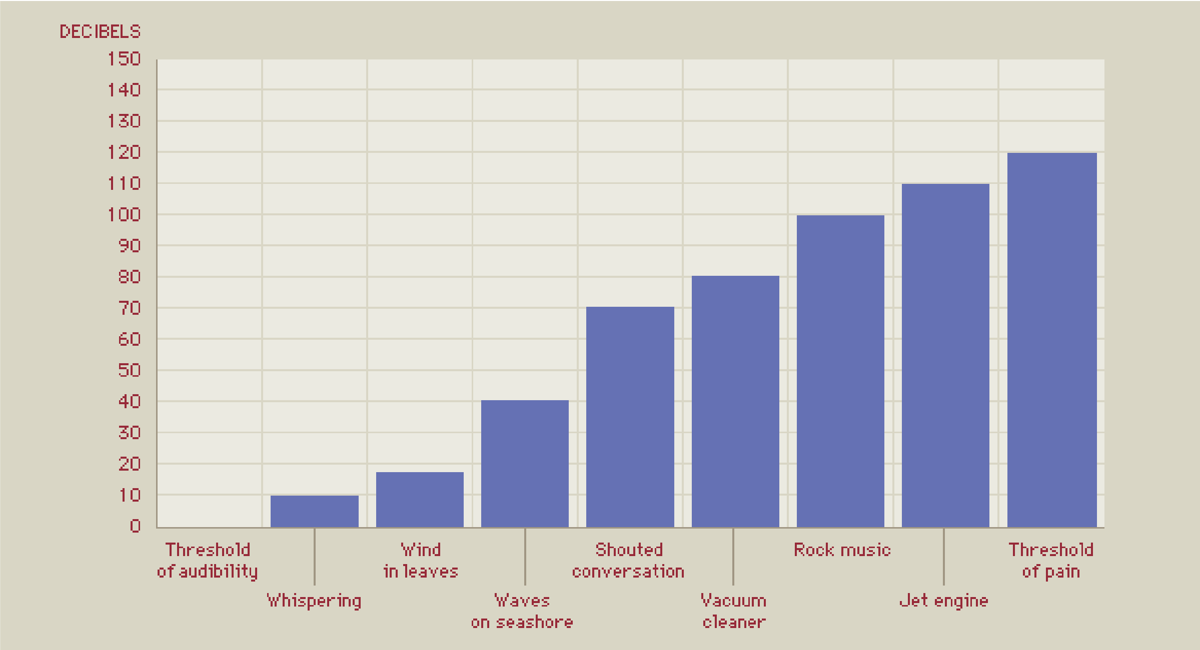
Amplitude



Amplitude and Volume
Amplitude is the characteristic of sound waves that we perceive as

volume. The maximum distance a wave travels from the normal, or zero, position is the amplitude; this distance corresponds to the degree of motion in the air molecules of a wave. As the degree of motion in the molecules is increased, they strike the ear drum with progressively greater force. This causes the ear to perceive a louder sound. A comparison of samples at low, medium, and high amplitudes demonstrates the change in sound caused by altering amplitude. These three waves have the same frequency, and so should sound the same except for a perceptible volume difference.

Intensity



Sound Intensities
Sound intensities are measured in decibels (dB). For example, the intensity at the threshold of hearing is 0 dB, the intensity of whispering is typically about 10 dB, and the intensity of rustling leaves reaches almost 20 dB. Sound intensities are arranged on a logarithmic scale, which means that an increase of 10 dB corresponds to an increase in intensity by a factor of 10. Thus, rustling leaves are about 10 times louder than whispering.

Quality

Quality is the characteristic of sound that allows the ear to distinguish between tones created by different instruments, even when the sound waves are identical in amplitude and frequency. Overtones are additional components in the wave that vibrate in simple multiples of the base frequency, causing the differences in quality, or timbre. The ear perceives distinctly different qualities in the same note when it is produced by a tuning fork, a violin, and a piano.

Speed of Sound

The speed of sound in dry, sea level air at a temperature of 0°C (32°F) is 332 m/sec (1,088 ft/sec). The speed of sound in air varies under different conditions. If the temperature is increased, for example, the speed of sound increases; thus, at 20°C (68°F), the speed of sound is 344 m/sec (1,129 ft/sec). The speed of sound is different in other gases of greater or lesser density than air. The molecules of some gases, such as carbon dioxide, are heavier and move less readily than molecules of air. Sound progresses through such gases more slowly.

Decibel Scale

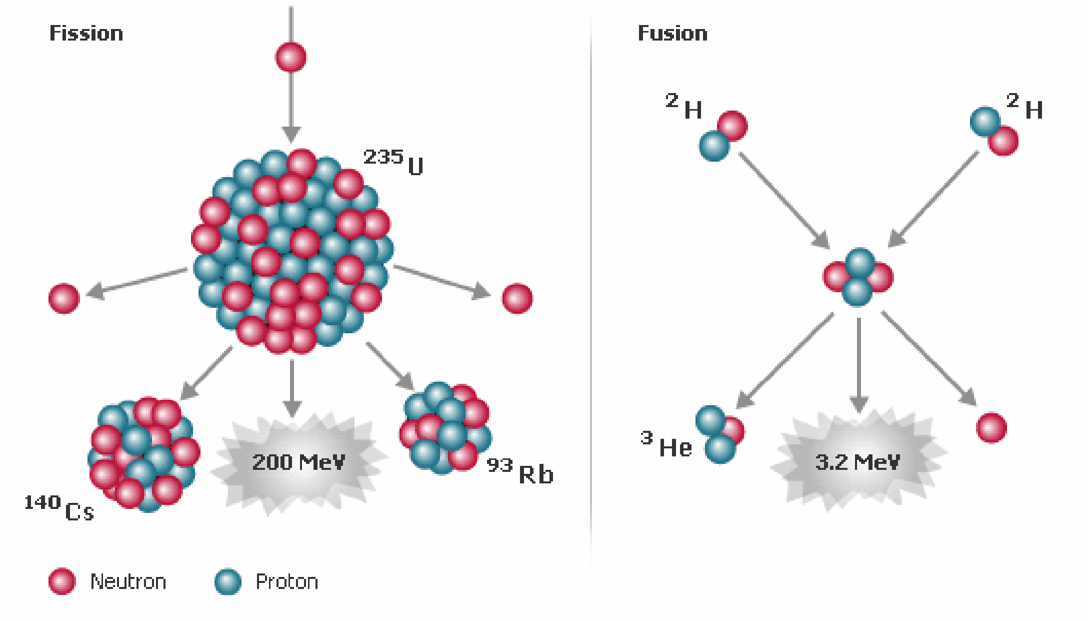
The decibel scale is used primarily to compare sound intensities although it can be used to compare voltages.

Decibels	Typical sound
0	threshold of hearing
10	rustle of leaves in gentle breeze
10	quiet whisper
20	average whisper
20-50	quiet conversation
40-45	hotel; theater (between performances)
50-65	loud conversation
65-70	traffic on busy street
65-90	Train
75-80	factory (light/medium work)
90	heavy traffic
90-100	Thunder
110-140	jet aircraft at takeoff
130	threshold of pain
140-190	space rocket at takeoff

NUCLEAR PHYSICS

Nuclear Fusion

The release of nuclear energy can occur at the low end of the binding energy curve (see accompanying chart) through the fusion of two light nuclei into a heavier one. The energy radiated by stars, including the Sun, arises from such fusion reactions deep in their interiors. At the enormous pressure and at temperatures above 15 million ° C (27 million ° F) existing there, hydrogen nuclei combine according to equation (1) and give rise to most of the energy released by the Sun.



Fission and Fusion
Nuclear energy can be released in two different ways: fission, the splitting of a large nucleus, and fusion, the combining of two small nuclei. In both cases energy—measured in millions of electron volts (MeV)—is released because the products are more stable (have a higher binding energy) than the reactants. Fusion reactions are difficult to maintain because the nuclei repel each other, but fusion creates much less radioactive waste than does fission.