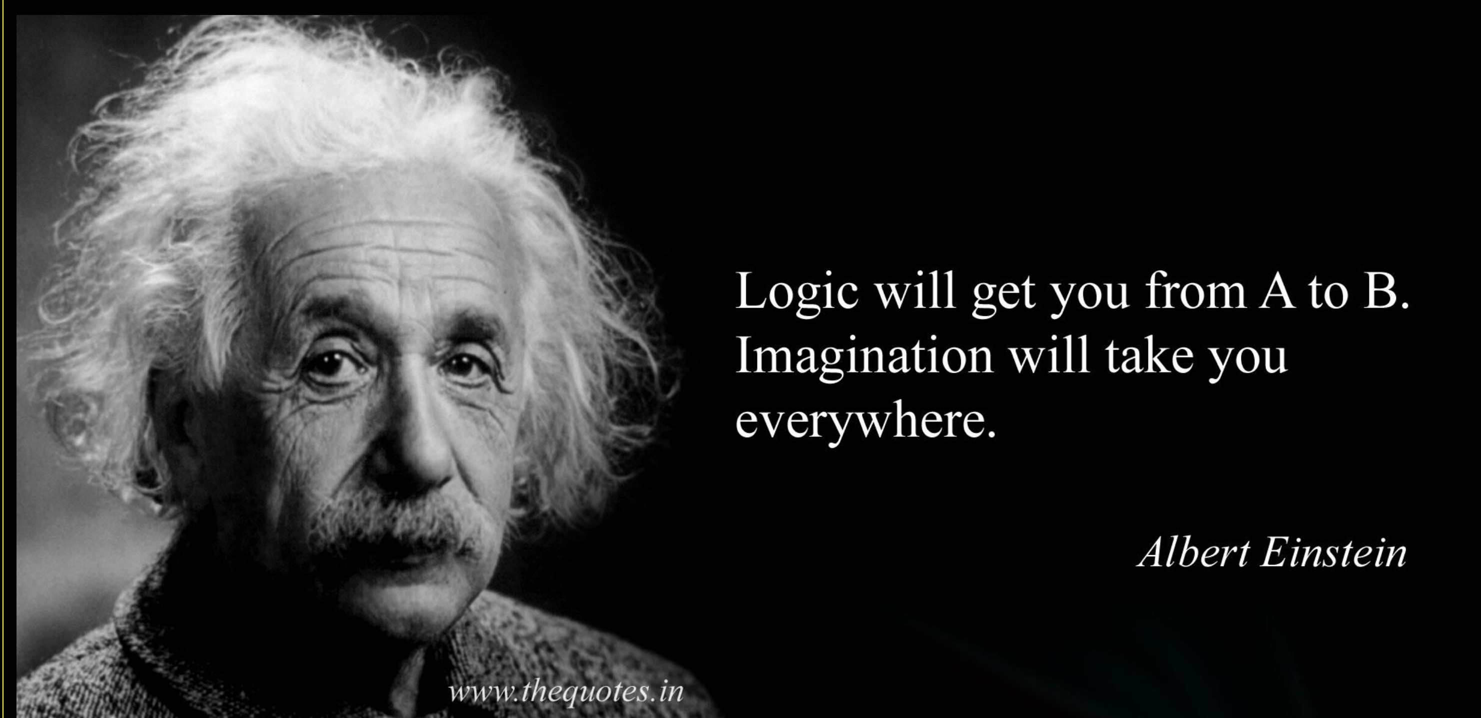
PEBBLES

(A Magazine by Department of Physics, Narasinha Dutt College)



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INTRODUCTION

The three-year course in physics is presented from the point of view that, the readers, are going to be a physicist. This is not necessarily the case of course, but that is what every professor in every subject assumes! If you are going to be a physicist, you will have a lot to study: two hundred years of the most rapidly developing field of knowledge that there is. So much knowledge, in fact, that you might think that you cannot learn all of it in three years, and truly you cannot; you will have to go to university too! Surprisingly enough, in spite of the tremendous amount of work that has been done for all this time it is possible to condense the enormous mass of results to a large extent—that is, to find *laws* which summarize all our knowledge. Even so, the laws are so hard to grasp that it is unfair to readers to start exploring this tremendous subject without some kind of map or outline of the relationship of one part of the subject of science to another. Following these preliminary remarks, the books therefore outline the relation of physics to the rest of the sciences, the relations of the sciences to each other, and the meaning of science, to help us develop a "feel" for the subject. You might ask why teachers cannot teach physics by just giving the basic laws on page one and then showing how they work in all possible circumstances, as we do in Euclidean geometry, where we state the axioms and then make all sorts of deductions.(So, not satisfied to learn physics in three years, you want to learn it in three minutes?) We cannot do it in this way for two reasons. First, we do not yet *know* all the basic laws: there is an expanding frontier of ignorance. Second, the correct statement of the laws of physics involves some very unfamiliar ideas which require advanced mathematics for their description. Therefore, one needs a considerable amount of preparatory training even to learn what the *words* mean. No, it is not possible to do it that way. We can only do it piece by piece. Each piece, or part, of the whole of nature is always merely an *approximation to* the complete truth, or the complete truth so far as we know it. In fact, everything we know is only some kind of approximation, because *we know that we do not know all the laws* as yet. Therefore, things must be learned only to be unlearned again or, more likely, to be corrected. The principle of science, the definition, almost, is the following: *The test of all knowledge is experiment.* Experiment is the *sole judge* of scientific "truth." But what is the source of knowledge? Where do the laws that are to be tested come from? Experiment, itself, helps to produce these laws, in the sense that it gives us hints. But also needed is *imagination* to create from these hints the great generalizations—to guess at the wonderful, simple, but very strange patterns beneath them all, and then to experiment to check again whether we have made the right guess. This imagining process is so difficult that there is a division of labor in physics: there are *theoretical* physicists who imagine, deduce, and guess at new laws, but do not experiment; and then there are *experimental* physicists who experiment, imagine, deduce, and guess. We said that the laws of nature are approximate: that we first find the "wrong" ones, and then we find the "right" ones. Now, how can an experiment be "wrong" ?First, in a trivial way: if something is wrong with the apparatus that you did not notice. But these things are easily fixed, and checked back and forth. So without snatching at such minor things, how *can* the results of an experiment be wrong? Only by being inaccurate. For example, the mass of an object never seems to change; a spinning top has the same weight as a still one. So a "law" was invented: mass is constant, independent of speed. That "law" is now found to be incorrect. Mass is found to increase with velocity, but appreciable increases require velocities near that of light. A *true* law is: if an object moves with a speed of less than one hundred miles a second the mass is constant to within one part in a million. In some such approximate form this is a correct law. So in practice one might think that the new law makes no significant difference. Well, yes and no. For ordinary speeds we can certainly forget it and use the simple constant mass law as a good approximation. But for high speeds we are wrong, and the higher the speed, the more wrong we are.
Finally, and most interesting, *philosophically we are completely wrong* with the approximate law. Our entire picture of the world has to be altered even though the mass changes only by a little

bit. This is a very peculiar thing about the philosophy, or the ideas, behind the laws. Even a very small effect sometimes requires profound changes in our ideas.Now, what should we teach first? Should we teach the *correct* but unfamiliar law with its strange and difficult conceptual ideas, for example the theory of relativity, four-dimensional space-time, and so on? Or should we first teach the simple "constant-mass" law, which is only approximate, but does not involve such difficult ideas? The first is more exciting, more wonderful, and more fun, but the second is easier to get at first, and is a first step to a real understanding of the second idea. This point arises again and again in teaching physics. At different times we shall have to resolve it in different ways, but at each stage it is worth learning what is now known, how accurate it is, how it fits into everything else, and how it may be changed when we learn more. Let us now proceed with our outline, or general map, of our understanding of science today (in particular, physics, but also of other sciences on the periphery), so that when we later concentrate on some particular point we will have some idea of the background, why that particular point is interesting, and how it fits into the big structure. So, what *is* our over-all picture of the world?

Now I will give physical explanations beyond some events which to most of people seems to be unnatural, but actually it's not......let's start....

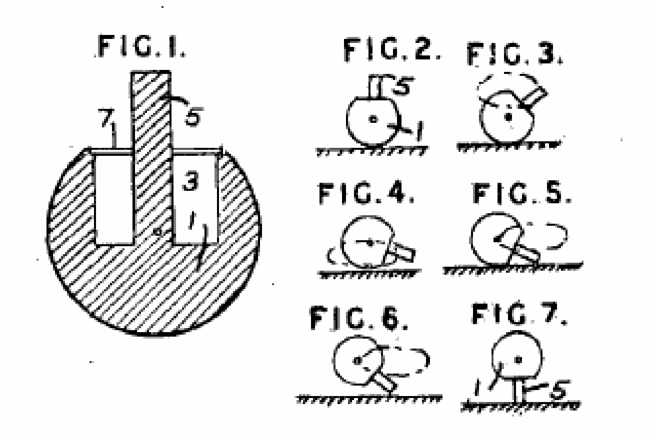
Motion of a Boomerang

Boomerangs are the famous wooden weapons used by Australian aborginals. These are made out of thin discs of wood, usually given a shape of the letter V with the bottom part rounded. Boomerangs are thrown into air with a rotation in the plane of the disc. It is slightly convex on one side and more decidedly convex on the other. It is held at one end and thrown over the shoulder by a right handed thrower with the nearly flat side vertically up and more convex side turned down. The missile is set into rotational motion about a normal to the mean plane and it finally returns to the thrower tracing a closed loop in the air. A professional thrower can make the boomerang complete a no. of loops before it is caught at the position as it was thrown.

The cross section of the boomerang's arms an aerofoil section, much like an aeroplane wing and therefore it generates a lift force when it moves through the air. At the same time the boomerang spins rapidly in the vertical plane as it flies forward.

As the boomerang spins, the relative velocity of the air over each arm is larger when it advances into the air stream and smaller when it retreats during the other half of it's cycle. The lift force on the arm depends on this velocity and so is larger during one half cycle. This results in net torque acting on the spinning boomerang. The boomerang responds to this torque like gyroscope, by precessing. This change in orientation is what makes the flight path curve. For demonstration watch www.youtube.com/watch?v=jPj53n33F7Q .

Motion of a Tippe Top



This delightful toy top has the fascinating property that, given sufficient spin about its axis of symmetry in the statically stable orientation, it will turn itself upside down and then behave like a sleeping top. No matter what the orientation of the top was w.r.t the initial vertical spin, it will end up standing on its leg. People like Sir William Thomson and Neils Bohr were interested in this problem, but the first correct explanation came to light in the early 1950's by C.M. Braams and W.A. Pliskin.

Tippe Top has the shape of a part of a sphere with a small stem added to it. When this top is spun on its head such that the centre of mass lies below the centre of the spherical part, it gradually proceeds to flip over and finally it rotates on its stem. If we compare the initial and the final positions of the top, we notice that

1. The C.M. rises indicating an increase in the P.E. at the final position.

2. The sense of rotation of the top w.r.t. an axis (Z axis of the figure) fixed in the body of the top changes in the process of flipping, so as to keep the direction of angular momentum unchanged.

The former point implies that there must be corresponding decrease in the K.E., i.e. a decrease in vertical component of the angular momentum. The decrease must be caused by an external vertical torque which can be nothing other than the torque due to the force of sliding friction. For demo watch www.youtube.com/watch?v=ItuAtgvkIkM .

Manoeuvre of the motion of a motorcycle

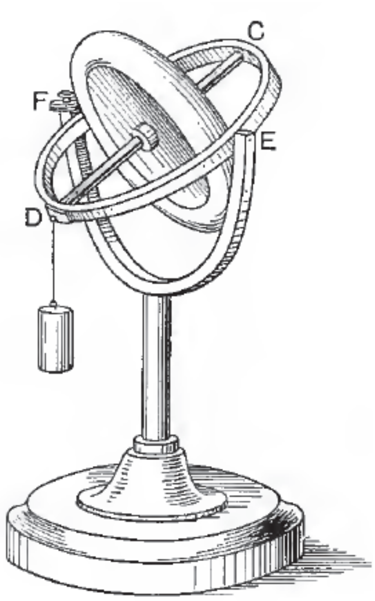
The wheels of a motorcycle at high speed may be regarded as too fast rotating flywheels with their axes of rotation pointing horizontally to the left of the rider.Let us now determine out the sequence of operations that the rider has to follow in order to take a left turn.From experience, we know that it involves two steps of actions.1st, the handle bars are twisted clockwise, i.e. to the right in order to make the vehicle incline to the left, the vehicle automatically begins to take the left turn.The rider allows it to continue till the entire curve is negotiated, just bu keeping the handle bars in the normal positions.2^{nd} , when the left turn is over, the vehicle is to be returned to it's upright posture or which a leftward twist on the handle bars(the wrong way!) is applied.

The initial twist to the right produces a vertically downward couple acting on the flywheel.Since the initial angular momentum was to the left(horizontal) of the rider, the tip of **L** moves a bit vertically downward.This makes the vehicle leans towards the left.As the vehicle leans towards the left, the gravitational couple begins to act on the system.The direction of the gravitational couple is in the backward(horizontal) direction of the instantaneous motion.Hence the tip of **L** must change in that direction.So that the plane of the motorcycle wheel keeps on turning to the left.This is how the left turn is accomplished by the vehicle.Once the negotiation of the curve is over, the vehicle has to be made upright for which the tip of the **L** vector is to be pushed upward.This can be effected simply by exerting a leftward twist on the handle bars.

PHYSICS beyond the MYSTERIOUS behavior of Gyrostatics

What is Gyroscope and Gyrostat ?

A gyroscope is generally regarded as a toy, the behavior of which is mysterious and unnatural. It consists of a flywheel, generally in the form of a disk with a massive rim, mounted in an open frame, which may be supported in various ways, for example as shown in the adjoining diagram. But the flywheel may be enclosed in a case which completely conceals it, as when, in the music-hall entertainment, a cheese-shaped body is set up on edge and successfully resists the efforts of a strong man to turn it down flat. The concealment of the rapidly rotating flywheel in this case gives an additional element of mystery.When the flywheel is thus concealed we have what Lord Kelvin called a gyrostat, because, in virtue of the rotation of the flywheel, the arrangement stands with any of the edges of the case resting on a hard smooth table.The arrangements of the apparatus shown in the diagram below allow some remarkable facts to be verified. In diagram of the figure the flywheel is shown with its axis CD held by a ring, which can turn about bearings E, F at right angles to CD. These bearings are at the extremities of a vertical fork carried by an upright stem, which we shall suppose is free to turn in a vertical socket carried by a massive base-piece resting on the table. The bearings E, F are so arranged that the ring and flywheel can be readily removed from the fork and securely replaced when desired.For the present we suppose that there is no weight applied at D, and that the axis EF passes through the centre of gravity of the wheel and frame, which coincides with the centre of the wheel.

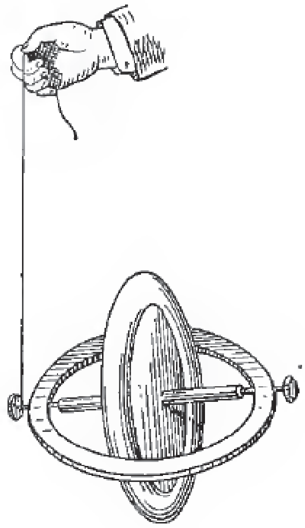


Effect of couple applied by weight hang on one side.

Let the weight be hung on at D, as shown in the diagram. If the flywheel were not turning on its axis the effect would be simply to turn the ring and wheel about EF, and the weight would descend until it came into contact with the supporting stem. But with the wheel rotating rapidly the result is widely different. A very slight downward motion of the point D can be detected as the immediate effect, but as soon as the least such deflection has taken place the whole system begins to turn round, so that the point D moves sideways, or, with reference to the diagram at right angles to the paper. This motion goes on, and presently, as far as the eye can detect, a steady motion of the stem, fork, ring and flywheel (all as if they composed a rigid body) about the vertical has been set up. The point D of the axis does not appear to descend further, and the axis CD remains at a constant inclination to the horizontal while its azimuth changes, that is the vertical plane containing CD turns steadily round the vertical. If there were no friction between the moving parts, what would be seen Would be that the axis CD alternately rose and fell through a small range, so that on the average the apparatus turned steadily round as just described.

Experiment of gyrostat supported by cord attached at point in line of axis.

As shown in diagram, let the ring and flywheel be removed from the fork and hung by a string attached to a knob projecting from the ring. The wheel is steadied until the axis of rotation is horizontal and the arrangement is left to itself. It is supposed that the wheel is rotating rapidly about its axis. Again a downward deflection, so slight as to be hardly observable, takes place, and a sideways motion is set up, so that the axis of spin of the flywheel turns round in a horizontal plane. Strictly speaking, the gyroscope does not turn about the string as a vertical axis, for the string is not exactly vertical. If the point at which it is gripped by the hand remains fixed, the string is inclined so that its lower end is a little displaced from the vertical towards the supported gyroscope, for upon the gyroscope moving as a whole round the vertical through the point of support—the upper end of the string—the string must exert an inward component of pull. But this displacement is slight, and we may say, with a considerable approach to accuracy, that the axle of the flywheel turns steadily round in a horizontal plane while the string remains vertical.In reality the string describes a narrow cone about a vertical axis. For demonstration watch www.youtube.com/watch?v=ty9QSiVC2g0 .

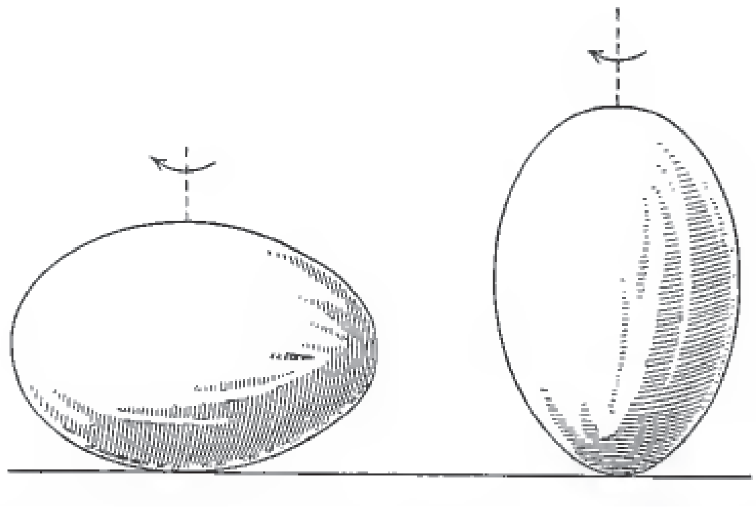


Behavior of gyroscope dynamical but apparently unnatural

The ordinary undynamical observer who knows a little of the facts, but practically nothing of the reasons, of the behavior of ordinary non-rotating bodies, immediately asks the question, " Why does the gyroscope not fall down ? " The question is a natural one, for the behavior of the gyroscope appears to him to be most unnatural. He does not pause to consider that if it did fall down the planes of rotation of the matter of a massive wheel would have to be quickly changed, and that such a change may possibly be difficult or impossible to effect by a direct overturning action applied to the wheel. His attitude is just that of the ordinary music-hall spectator of the unoverturnable " cheese."The idea that suggests itself to those who, without any dynamical knowledge, try to think out causes, is the erroneous one that gravity is neutralised in some way by the rotation. On this supposed neutralisation of gravity has been based a proposal (perhaps several proposals) for the construction of a flying machine. Such observers fail to note the significant fact that the gyroscope, when its axis remains horizontal in this apparently paradoxical manner, is turning round in azimuth and that if this turning is checked by a resistance applied to the turning axle, the wheel at once begins to descend in the "natural way".But here another puzzling result is obtained. If, instead of trying to impede the motion of the axle in azimuth (the precessional motion, as it is called), the observer tries to assist it, the outer end of the axle rises, that is to say the centre of gravity of the gyroscope is raised. For demonstration watch www.youtube.com/watch?v=cquvA_IpEsA .

Egg-shaped solid body stable with long axis vertical when spinning, "Liquid gyrostats".

The question of the behavior of a spheroidal shell filled with a liquid and made to spin is an interesting one. We take a spheroidal piece of wood, a nearly egg-shaped piece, as shown in the diagram, and laying it with its long axis horizontal, apply two horizontal forces in opposite directions at its ends with the fingers so as to make it spin rapidly, say in the direction of the circular arrow on the left. The wood does not continue to spin with the long axis horizontal, but raises its centre of gravity until the long axis is vertical, as shown on the right, and spins in stable equilibrium in this position, like an ordinary top.If now the same experiment be tried with a metal shell filled with a liquid, or with a fresh egg, it will not succeed. The arrangement will spin in a feeble way, but it will not behave as an ordinary top and stand up on end.The rotational motion set up is not stable, and dies away fairly quickly.But the shell can be stopped by placing the finger on the egg for a moment.When the finger is removed the shell moves on again, being dragged round by the still rotating liquid. But if the egg is boiled hard it will behave like the wooden spheroid. This is one way of solving the problem of Columbus—to make an egg stand on end !

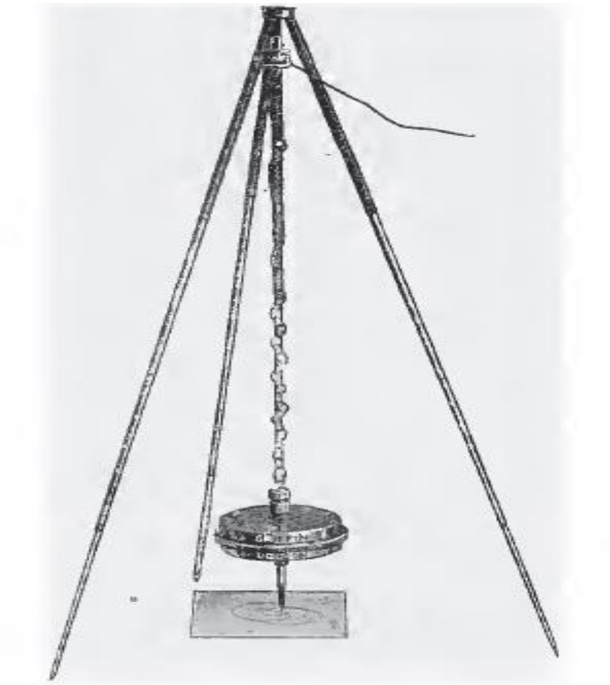


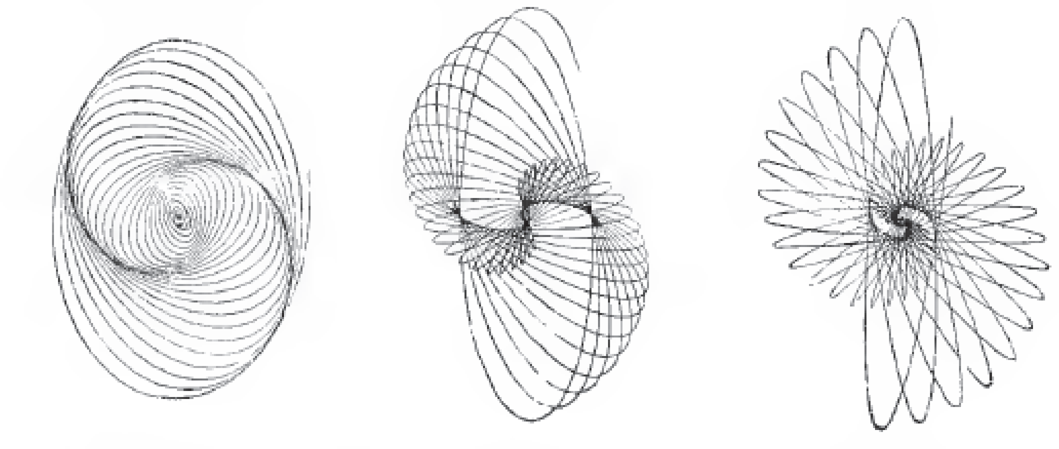
Stability Of rotational motion of spheroidal shell

Stability of the rotation of the liquid contents of a spheroidal shell depends on the form of the shell. If the spheroid is oblate, that is if the axis of figure is, like the axis of the earth, the shortest diameter, the rotation is stable, and will endure so that the shell filled with liquid may be used as the flywheel of a gyrostat. If however the shell is prolate, that is if the axis of figure is the long axis, as in the case of the piece of wood, the motion is unstable, unless indeed the shell be sufficiently prolate. We may place the gyrostat, with prolate liquid spheroid as wheel, on the spinner and get up a great speed ; as soon however as the gyrostat is removed from the machine it is found that the spin has disappeared.For prolate and oblate spheroids the deviation from sphericity is 5 percent, in each case, but in opposite directions. The oblate one admits of stable motion of the liquid, the other does not.Oblateness however is not absolutely essential for steady rotational motion of a liquid round the axis of figure in a spheroidal case turning with the liquid. It was shown by Sir George Greenhill in 1880 that steady motion is possible in a prolate spheroid, if it be sufficiently prolate.The axial diameter, in fact, must either be shorter than the equatorial diameter, or be more than three times as long. As Sir George Greenhill points out, a modern elongated projectile if filled with a liquid would not rotate steadily about its axis of figure, and therefore would not have a definite trajectory as a rifle bullet has; it would (unless abnormally long) turn broadside on to the direction of motion.The possibility of spinning an oblate ellipsoidal mass of liquid was discovered mathematically by Colin MacLaurin, Professor of Mathematics at Edinburgh in the first half of the eighteenth century. He showed that, provided the angular speed was kept under a certain limit depending on the density of the fluid, there were two revolution ellipsoids of different eccentricities, which were figures of equilibrium for a mass of liquid spinning about the axis of figure, with its surface free. With one or other of the eccentricities proper for the speed, the case may be supposed removed without affecting the equilibrium. Of course it is understood that there is no terrestrial gravity to produce disturbance : the spinning ellipsoid of liquid, without enclosing case, could not be realised except in a laboratory at the centre of the earth, and perhaps for various reasons not even there.

Gyrostatic Pendulum

Now we consider a pendulum consisting of a rigid suspension rod, and a bob rigidly attached to it, which contains a gyrostat with axis of rotation directed along the suspension rod as shown in the figure. Without rotation, the two freedoms of this system are stable and if the bob be made to describe a circle about the vertical through the point of support, the period of revolution is the same for both directions of the circular motion. When the gyrostat is spun the behaviour is very different.Circular motion may take place in either direction, but the periods are different, that of the circular motion in the same direction as the rotation being the smaller.The ratio of the periods depends on the arrangement.A combination of the two circular motions in different periods and in opposite directions gives a star figure, which in the diagram the pen attached below the bob is shown describing. The peculiar appearance of the graphs here pictured is due to a very rapid falling off of amplitude, and therefore shortening of the rays, due to friction.

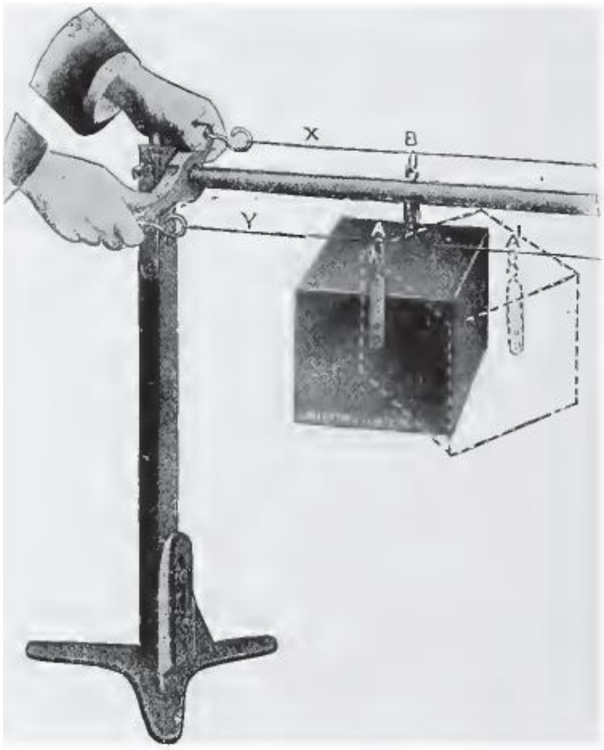




Gyrostatic bicycle rider.

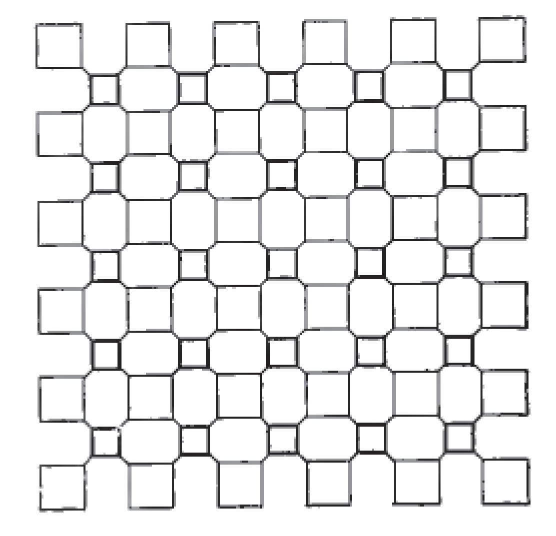
The rider of a bicycle is here replaced by a gyrostat. The apparatus may be so contrived that, the balancing is entirely due to gyrostatic action, or so that it is effected as a human rider does it. In the former case the bicycle is stable both when at rest and when in motion, in the latter it is stable when driven in the forward direction. We give here the second case, in which an old type of bicycle is used.The gyrostat is spun in the direction of rotation of the wheels in the forward motion of the cycle. Then tilting of the machine to the left, say, and the consequent alteration of direction of the axis of spin of the fly-wheel, causes, as can easily be seen, precession of the gyrostat, which turns the wheel to the left. Gyrostatic bicycle rider.For the tilting gives a rate of production of angular momentum about a downward axis, and there being initially no couple about that axis, the gyrostat and wheel begin to turn round in azimuth in the direction to neutralise the angular momentum produced.The forward motion of the rider and machine then gives the upright making action in the usual way.When perfectly balanced the bicycle has a straight path.When a weight is hung on one side the path becomes curved.

Walking Gyrostat



Another entirely novel experiment is shown in the figure. A box is suspended by two arms of equal length from two horizontally stretched wires. The wires are carried by a frame mounted on two trunnions mounted on wooden uprights as shown in the diagram, which however display only one end of the arrangement of wires and supports.The wires are conveniently made about 12 or 14 feet long, and strung upon them are two rings, to which the arms attached to the box are hooked. Fitted within the box is a gyrostat with its axis horizontal and in the plane of the arms.For the experiment the gyrostat is taken out and spun rapidly, and replaced in the box. When the frame is oscillated to and fro on the trunnions, the box proceeds hand over hand along the wires, as if it were endowed with life.It will be seen that the tilting of the frame to and fro throws the weight of the gyrostat and box alternately on each of the arms. The illustration shows the weight of the box thrown on the arm B ; since Y is lower than X. The resulting precessional motion of the gyrostat (which is supposed to be spinning counter-clockwise as viewed by the reader) causes the arm A to move forward to A'. At this instant the wire frame is tilted so that the weight is thrown on the arm A', when the arm B swings forward, and so on. At the start of the motion the spin is great and the precession small, and the box has a slow and stately motion. As the spin falls off the precession, and consequently the rate of walking, increases; until finally the box literally runs along the wires.
When the box has walked from one end of the frame to the other it must be brought back to the starting end to repeat the experiment.The direction of walking depends on the direction of the spin ; if it is desired to cause the box to walk in the reverse direction it must be reversed on the wires.

Gyrostatic structure of a rigid solid



We come now to an interesting application of these ideas. Lord Kelvin endeavoured to frame something like a kinetic theory of elasticity, that is he conceived the idea that, for example, the rigidity of bodies, their elasticity of shape, depends on motions of the parts of the bodies, hidden from our ordinary senses as the flywheel of a gyrostat is hidden from our sight and touch by the case. Consider this diagram of a web. It represents two sets of squares, one shown by full the other by fine lines; the former are supposed to be rigid squares, the latter flexible. Unlike ordinary fabrics, which are almost unstretchable except in a direction at 45° to the warp and woof, this web is equally stretchable in all directions. If the web is strained slightly by a small change of each flexible square into a rhombus, or into a not rectangular parallelogram, the areas are to the first order of small quantities unaltered.Now imagine that a gyrostat is mounted in each of the rigid squares so that the axis of the trunnions and the axis of rotation are in the plane of the square shown in the figure. If the angular speeds of the flywheels are sufficiently great, it is impossible to turn the squares in azimuth at any given small angular speed, for the gyrostat would very strongly resist the change of direction of its axis. Thus any strain involving turnings of the small squares is resisted, and we have azimuthal rigidity conferred on the web by the gyrostats. Here is however no resistance to non-rotational displacement of the squares as wholes.To get a model in three dimensions Lord Kelvin imagined an analogous structure made up of cubes, each composed of a rigid framework to play the part of the squares, and connected by flexible cords joining adjacent corners of the cubes. In each cube he supposed mounted three gyrostats with their trunnions at right angles to the three pairs of sides. This arrangement would, like the web of squares, resist rotation, but now about any axis whatever ; and there would be no resistance to mere translation of the cubes as wholes. Thus the body so constituted would be undistinguishable from an ordinary elastic solid as regards translatory motion, but would resist turning.

The Gyro-Compass

The invention of a gyrostatic compass came as a surprise to most people, and yet the fact that a gyrostat could act in this way had been known for two generations. So long ago as 1852, the French philosopher, Foucault, demonstrated that any gyrostat, free to be turned in two directions only, will tend to set itself with its axis of rotation parallel to the axis of the earth, by reason of the relative rotations of the two bodies. He pointed out that this law would hold good for a gyrostat (with two degrees of freedom) at any place on the earth's surface other than the two poles.

The average man probably knows little more of a gyrostat than can be observed by handling one of those simple gyrostatic tops, such as are sold as toys at exhibitions. Even if one sets such a gyrostat spinning, and holds it with the axle, say, in a vertical position, one may feel that the gyrostat resists any attempt to move the axle away from its vertical position. Better still for our present purpose if the spinning gyrostat is held with its axle in a horizontal position, whereupon the same resistance is apparent if we seek to alter the direction of the axle.

A gyrostat may be given three degrees of freedom. For instance, we might suspend the toy gyrostat by a piece of string attached to its equator ring. If care is taken to balance the gyrostat in this position, with its axle horizontal, it is quite apparent that it remains in a definite position and that it resists any change in the direction of its axle. In whatever direction we place its plane of rotation, it will remain in that position in space while the earth turns round beneath it. This was the first law which Foucault laid down concerning gyrostats. He pointed out that a gyrostat, if free to turn in all three directions, would serve in the same manner as his pendulum to demonstrate the rotation of the earth; the gyrostat would take up a fixed position in space, and we should see the earth turn round beneath it.

Dr Anschutz, of Germany, began experiments in 1900 with a gyrostat having three degrees of freedom. Of course, if such a gyrostat, say on board ship, were placed with its axle pointing north and south, it would remain in that position, no matter how much the ship turned about, but it would possess no directive force. If the motor driving it had to be stopped for any reason, the direction would be lost. If while it was spinning any one happened by contact to alter its direction, it would remain pointing in some false direction.

Anschutz had no intention of using such an arrangement in place of the magnetic compass, but merely to get fixed lines in space, for obtaining bearings or maintaining a course already definitely known. However, he found it practically impossible to construct a gyrostat having its centre of gravity and centre of suspension absolutely coincident.

In 1906 Anschutz turned his attention to a gyrostat having only two degrees of freedom. At first he combined this gyrostat with his earlier one having three degrees of freedom, and he found that it directed the combined system into the meridian line. He then experimented with a single gyrostat having two degrees of freedom only, which, according to Foucault's law, should set itself with its axis of rotation parallel to the axis of the earth.

A toy or an experimental gyrostat does not exhibit any directive phenomenon. The existence of the directive force can be observed only when the speed of rotation is high, and when all precautions have been taken to eliminate friction. Although this is so, it is easy to demonstrate with an experimental gyrostat that if the spinning body has only two degrees of freedom the position of its axle and the direction of its rotation will be affected when the gyrostat as a whole is revolved.

Picture an experimental gyrostat suspended in gymbals so carefully that it has three degrees of freedom, so that it will take up a definite position in space. An experimenter may take this in his hand and turn round without affecting the gyrostat, but let him clamp the vertical spindle carrying the supporting frame, and the conditions are changed; the gyrostat has only two degrees of freedom. If the experimenter now revolves himself and carries the gyrostat with him, it will immediately set its axle parallel to the axis of rotation of the experimenter, which, of course, is vertical. We have supposed that the experimenter happened to revolve himself in the same direction as that in which the fly-wheel of the gyrostat was rotating. If he should revolve himself in the opposite direction, the gyrostat would immediately turn a somersault, and thus place its fly-wheel with its direction of rotation corresponding with the direction of revolution imposed upon it as a whole. It is quite obvious that a gyrostat with only two degrees of freedom behaves in a different manner to a gyrostat having three degrees of freedom.

The gyro-compass, as already indicated, is a gyrostat with only two degrees of freedom, so that it seeks to bring its axle parallel to the earth's axis, with its direction of spin the same as that of the earth. But the gyro-compass is floating in a bowl of mercury, and the axle of its fly-wheel will remain horizontal. It is clear that under these conditions the gyro-compass could not have its axle parallel to the earth's axis unless the apparatus happened to be at the equator. Although the gyrostat would tend to do so when carried north or south, it could not, as its axle would be pulled into a horizontal position by gravity. Those accustomed to experiment with gyrostats know what this means; the applied forces tend to set the axis of the gyrostat parallel to the earth's axis, causing the gyrostat to 'precess' or wheel round in a direction at right angles to the direction in which the applied forces tend to turn it.

This phenomenon of 'precession' is beautifully demonstrated by the well-known Wheatstone compound gyrostat, in which we may apply a weight to one end of the horizontal axle. Instead of tilting the axle, as would be the case if the fly-wheel were at rest, the applied force causes the gyrostat to wheel round, and it will continue this 'precession' so long as the force is applied. We have a demonstration of 'precession' in the school-boy's spinning top, and we know that the earth precesses, principally because of the attractive pull of the sun and moon on the oblate portion at the equator. We know that it is because of this precession that the north pole of the earth has not pointed always to the Pole Star, but that the earth's axis of revolution describes a curve, which is very nearly circular, about the pole of the ecliptic.

Even when one holds a toy gyrostat in one's hand, say with the axle horizontal, when one seeks to depress one end of the axle, there is not only a feeling of resistance, but a distinct twisting motion of the gyrostat. This we recognise as the wheeling round of the gyrostat at right angles to the applied force, or in a single word—its 'precession.'

It is this precessional motion which turns the gyro-compass into the desired position. The applied forces, due to gravity, keeping the axis of the gyrostat horizontal, cause the gyro-compass to wheel round until it gets into the position with its axle parallel with the meridian, in which position the gyrostat may be carried round by the earth without resistance. Should the axle swing beyond the meridian on the other side, the pull of gravity will be on the end of the axle opposite to that which we have been considering, and the precession will be in the opposite direction, bringing the axle of the gyro-compass back to the meridian.

One difficulty, in giving the gyro-compass only two degrees of freedom, was that such a gyrostat would be affected by other forces which might be brought to bear on it, as, for instance, by the movements of the ship. Such forces would set the gyrostat swinging, and render its indications unreliable. It became evident that if a gyro-compass were to be of practical value it would require to possess a very large gyroscopic resistance, strongly opposing any attempt to tilt its axle to an angle. Also that it would be necessary to have the friction of the suspension system as small as possible. But when these objects have been attained there remains a serious difficulty. If for any reason the gyrostat should be deflected a long way out of the meridian line, its swinging motion to and fro will last a very long time. This would render the gyroscope useless as a compass, unless it were possible to damp out this swinging motion. The first idea of overcoming this difficulty was to use a second gyrostat to damp out the oscillations, but it was soon found that a reliable damping could be obtained by a much simpler arrangement, which will be described when we consider the construction of the practical compass.

It need hardly be pointed out that although Foucault set forth the laws describing the actions of the gyrostat, it would have been quite impossible for him to produce a gyro-compass, as he had no means of supplying the necessary continuous motion to the fly-wheel, the rotary speed of which must be very high. Besides, in his day, there was no necessity for such a compass, as the simple magnetic compass would serve all practical requirements. Indeed, until recently it was found quite satisfactory to apply proper compensation to the magnetic compass to balance the attractive force of the iron in the ship. But with the increase in size of warships, and the great masses of moving steel in use in modern guns and their shields, this magnetic compensation became a very serious problem. Then, again, the submarine with its great number of electric motors, producing magnetic fields of their own, and thus affecting the compass, created a demand for a non-magnetic compass.

Prevention of Ships Rolling

Another gyrostatic invention of general interest has been made in connection with the rolling of ships. Of the three motions, heaving, pitching, and rolling, it is the last-mentioned which is feared most by those who dislike sea passages. Most of us do not worry about the heaving of a ship as it rises and falls bodily keeping its deck in a horizontal position; the greater the displacement the lower is the frequency. But the motion which is caused by pitching is not so pleasant, one may be moved up and down through a distance of thirty feet in a few seconds, but we can escape this motion almost entirely by getting amidships. There is no doubt that it is the rolling of a ship which brings about the discomforts of sea-sickness most easily. The vertical motion of the sides may be avoided by getting to the centre of the deck, but the angular movement cannot be evaded, a° it affects equally all parts of the ship.

Several inventors have suggested anti-rolling devices, but by far the most ingenious of these is the gyrostatic invention patented by Dr Otto Schlick, of Hamburg, an eminent marine engineer, who gave successful demonstrations of his apparatus both in his own and in this country.

It was the gyrostatic action of paddle wheels in a steamer which led Dr Schlick to study this subject. He had observed that when a steamer is heeled over by a wave, the course of the steamer is altered slightly, and conversely that when the course of a steamer is altered suddenly the steamer heels over. With an ordinary paddle steamer these phenomena are not very apparent, for the speed of rotation of the paddles is comparatively slow.

In order to study the subject, Dr Schlick used a model with two solid discs to represent the paddles. To increase the gyrostatic action, these were driven at a high speed, and the model ship was pivoted to permit of its turning freely upon a vertical axis. When this model was heeled over to starboard by the addition of a weight on that side, the how of the model turned to starboard. When the weight was transferred to the port side, the vessel turned to port. The same holds good in the case of an actual steamer on the water, but the amount of turning is very slight. The action is not what one would expect, for when a vessel is heeled over to starboard, the paddle on that side will get a bigger grip of the water, and one would expect the vessel to turn to port, but not so.

It was when studying these phenomena that Dr Schlick was led to the invention of his anti-rolling apparatus. In this case the gyrostat is not placed with its fly-wheel in a vertical position, as are the paddles of a steamer; the gyrostat revolves in a horizontal plane, with its axle vertical. It may be remarked that a gyrostat, if placed with its fly-wheel in a vertical plane, and its axis of rotation transverse to the ship, could be used in an anti-rolling device, but not so conveniently.

In Dr Schlick's invention the gyrostat is mounted in a frame which has trunnions or bearings at the sides, and is so placed that its pendulum motion will be fore and aft. Any attempt to tilt the vertical axle of the gyrostat from side to side will cause the gyrostat to swing at right angles to that, which will be lengthwise in the ship.

In connection with the gyro-compass, we have considered how the gyrostat's resistance is at right angles to the applied force. But the enforced pendulum motion of the gyrostat, swinging fore and aft, will not prevent the rolling of the vessel; it is necessary to oppose this force. This Dr Schlick has done by applying brakes to the swinging movement of the gyrostat frame.

These brakes damp the pendulum motion and thus absorb the energy of the waves which tend to tilt the ship. The brakes may be either hydraulic or friction, but they must be automatic in their action.

Dr Schlick made an experiment with a German torpedo boat measuring 117 feet long by 12 feet 6 inches broad, and displacing 65 tons on a draft of 3 feet 6 inches. The meta-centric height was 1.3 feet, and the natural period of rolling was about 2.1) ?> seconds from side to side. Such a vessel would prove a very bad roller, as its natural period would be very similar to the period of the waves; the test, therefore, would be a severe one.

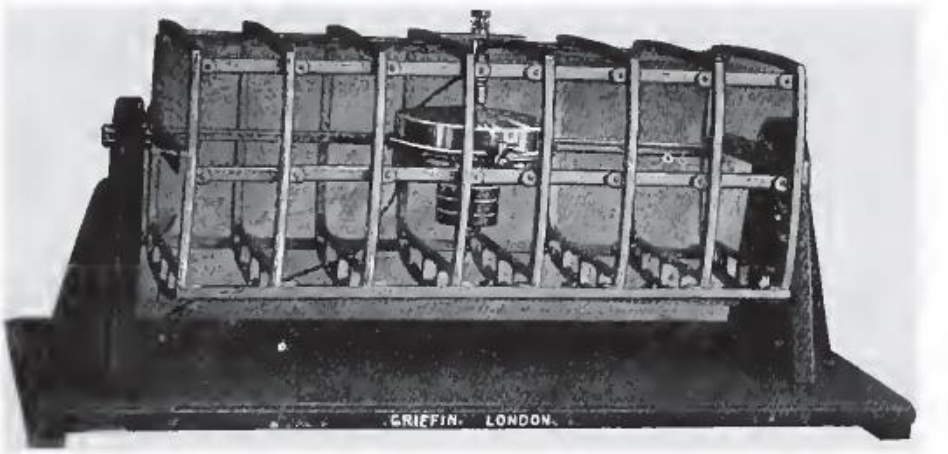
The gyrostat wheel was driven by steam, turbine blades being fixed on its circumference. The frame enclosing the gyrostat formed a steam-tight cast-iron casing, receiving and exhausting the steam through the trunnions on which the frame oscillated. The diameter of the steel fly-wheel of the gyrostat was 39 inches, and its speed of revolution was about 1600 revolutions per minute.

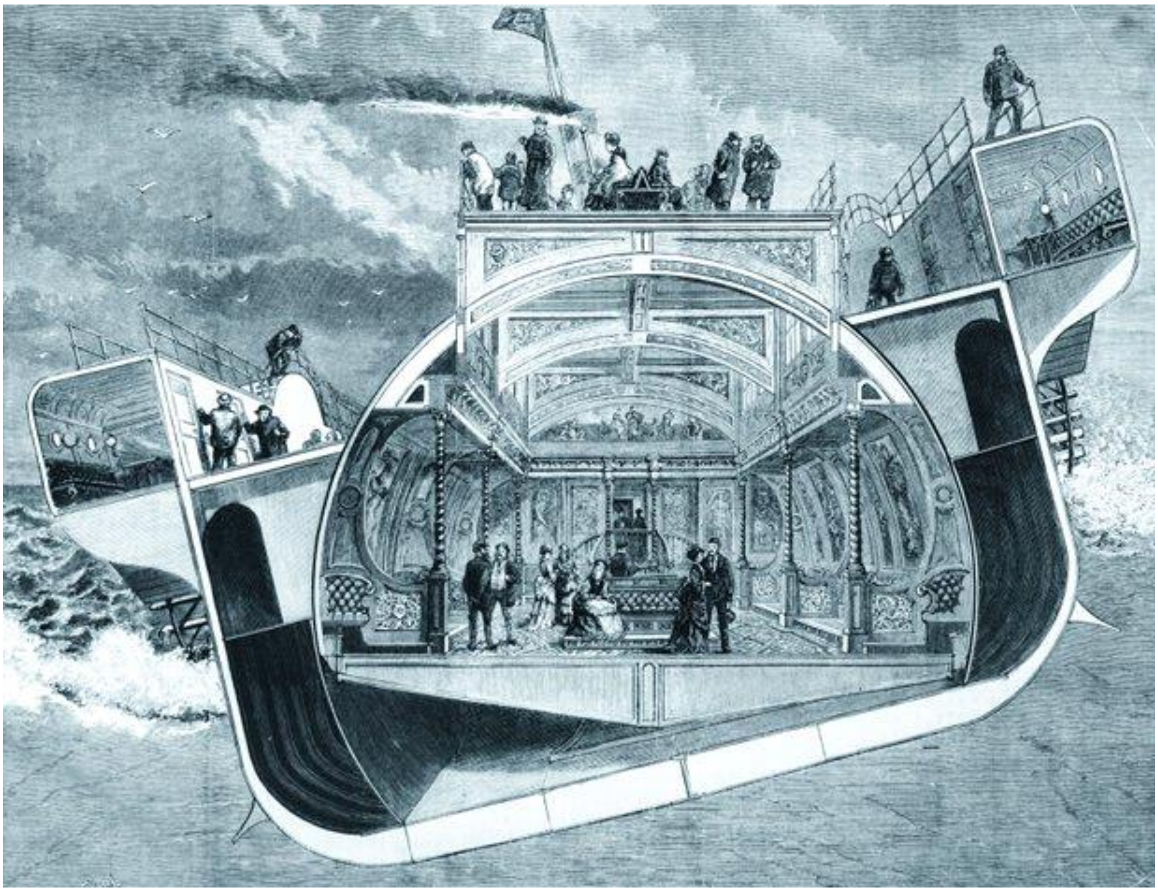
The hydraulic brake for controlling the oscillatory movement of the frame consists of a cylinder, with a piston forcing the fluid through a valve, the opening of which can be regulated from deck. The whole apparatus could be thrown in or out of action by means of a friction hand-brake, by which the gyrostat frame may be held in a fixed position or released as may be required.

All the trials at sea were most successful. The little vessel could be taken out into a rough sea, with the apparatus clamped out of action, so that the natural rolling might be witnessed, but as soon as a certain wheel on dock was turned, the rolling stopped almost immediately. So long as the gyrostat was left free to act, the vessel would defy the rolling motion of the waves.

When experiments were made in the Highlands of Scotland, on one of the steamers running between Oban and Tire, where rolling is an almost constant complaint, the demonstration was entirely successful. On a sea which caused the ship to roll through an area of 32 degrees (while the gyrostat was in check), it was found possible to reduce the roll to four degrees whenever the apparatus was released. A rolling motion through only four degrees is quite inappreciable on any vessel.

When Dr. Schlick propounded his theory in 1904, there was considerable discussion as to whether the steadying up of the ship would not be too great a strain on her. Some naval authorities declared that if a ship were stopped from rolling in a beam sea, the next wave would come on board. One speaker went so far as to declare that 'the rolling was provided by Nature to save the ship.' The reply to these statements was that no greater strain would be put upon the ship than was the case when a ship rolled through an angle of twenty-five degrees. Further, that the tendency to swamp the decks would be reduced instead of increased. This reply was endorsed by the great naval authority, Sir William White, I.C.B. It will be understood that a vessel equipped with the gyro-apparatus does not offer resistance such as a rock would do; the vessel is free to rise and fall in the water.





Potato Clock

A potato clock runs by converting chemical energy into electrical energy, which is then used to power a clock. The potatoes, in combination with zinc and copper strips (which act as electrodes), act as a battery. Most people aren't aware that this is possible, which is what makes it so interesting.

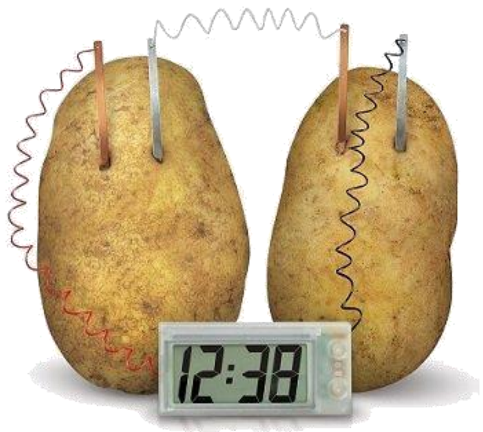
The energy comes from the chemical change in the zinc when it dissolves inside the mild phosphoric acid content of the potato. The energy does not come from the potato itself. What happens is that the zinc is oxidized inside the potato, exchanging some of its electrons with the potato acid in order to reach a lower energy state, and the energy released provides the electrical power.

Let's imagine first that we have one potato and the zinc and copper strips are inserted into this potato, with a wire connecting the two strips. This potato battery works as follows:

1) The zinc atoms in contact with the potato dissolve in the presence of the acid. This causes some electrons to separate from the zinc atoms. As a result of this, positively charged zinc ions, and negatively charged electrons, are produced.

2) The electrons produced in the above reaction travel out through the zinc, through the wire, and into the copper strip also inserted in the potato. They do this because they are attracted to the positive hydrogen ions in the potato, located on the copper side (these hydrogen ions are there due to the acid content of the potato). Since the electrons cannot pass through the potato itself, they pass through the wire joining the zinc and copper strips. These electrons then combine with these positive hydrogen ions (on the copper side) and produce hydrogen gas, which then bubbles away.

Note that the above chemical reaction happens spontaneously. It is self-driven. The electrons are forced to travel an external path, and if this external path is connected to an electrical device, such as a clock, it powers the device. Two potatoes can be connected together in order to double the voltage, the same way you join two batteries together to double the voltage. This voltage is sufficient to power the potato clock. For demo watch www.youtube.com/watch?v=00pGUJEZuyk .



Plasma Ball

A plasma ball is a sealed glass globe containing an inert gas inside. The gas most commonly used is neon, sometimes combined with other inert gases such as argon, xenon, and krypton. The gas inside the globe is typically at a pressure close to atmospheric pressure. This gas is highly energized, using electricity, which causes it to become a plasma state. This plasma appears to us as a colorful display of filaments moving around inside the glass globe. The light emitted by the highly energized gas depends on the type of gas used. The type of filaments created, whether more lightning-like, or fuzzy streamer-like, also depend on the type of gas used.

When atoms of a gas are highly energized, they heat up to a very high temperature. This causes the electrons to break free from the parent atoms of the gas. The parent atoms then become positively charged ions as a result (since they are missing electrons, which are negatively charged). This combination of highly energized (positively charged) ions and (negatively charged) electrons is like a "soup" which we call plasma.

Inside the plasma ball there is an electrode in the shape of a ball. The reason the gas inside the globe is chosen to be inert is to prevent it from reacting with the electrode surface during operation. During operation, the electrode is negatively charged with a high voltage of 2-5 kilovolts. This voltage is made to oscillate at a high frequency of about 35 kilohertz, which in turn generates oscillating current. The high voltage causes the gas to break down and conduct electricity, and the high frequency enables the current (flow of electrons) to pass through the glass and into the surrounding air by a process called "capacitive coupling". The electrons, which carry a negative charge, are attracted to the earth, which has a neutral charge. If you touch the globe with your hand, you are creating an easier pathway for the electrons to travel, which is why the filaments move to the location of your hand, as this provides an easier path for the electrons to reach the earth (by passing through your body).

In addition, the plasma ball creates an electromagnetic field, due to the oscillating electrons. To test this out, bring a fluorescent light tube near the plasma ball, without touching it. The electromagnetic field causes the electrons inside the light tube to oscillate as well. These moving electrons constitute an electric current, which causes the tube to light up the way it normally would inside a light fixture. You can also cause the tube to light up by touching the plasma ball with it. In this case, the electrons flow through the tube, through you, and into ground. The flow of electrons through the tube causes it to light up. For demonstration watch www.youtube.com/watch?v=IDiyldCkdD0 .

Chaos Tower

The chaos tower is a fascinating display of motion. Balls travel from the top of the tower to the bottom in a complicated way. You can design your own twists and turns and other obstacles for the balls to go through. The end result is a beautiful display of seemingly chaotic motion, much like the kind you would imagine exists in an eccentric inventor's workshop.
Test and improve your visualization skills and basic understanding of physics. By placing turns, inclines, baskets, and other components in the right places you can create a very interesting path for the balls to travel on the way down. If you encounter a problem and the ball gets stuck somewhere, or falls off, you just tweak the design until the problem is fixed. The number of designs you can come up with is practically infinite.

It can be tricky to assemble, so it may be necessary for an adult to assist in putting it together. But the end result is a fun toy illustrating how much fun science can be.
This next video shows two chaos towers put together. The creator of this got especially creative. For demo www.youtube.com/watch?v=G6JdXG6cmso .

Drinking Bird

The drinking bird (also called a dippy bird or dunking bird) tilts up and down in response to the temperature difference between the top part and bottom part of the bird. The top and bottom parts of the bird consist of two glass bulbs. These two glass bulbs are joined with a glass tube. The top bulb is decorated to look like a bird's head. The head and beak is covered with felt-like material, and the remaining body is constructed as shown.

The empty space inside the glass bulbs and glass tube has the air removed, and is filled with a special liquid (which is usually colored), typically dichloromethane. Inside the enclosed space, the liquid partially turns into a vapor and in doing so reaches an equilibrium pressure. This equilibrium pressure is interrupted during the operation of the drinking bird, as described below.

The drinking bird operates in a cycle. This cycle begins when the beak and head of the bird are wetted with water. The water evaporates and cools the top (head) bulb, by a process known as evaporative cooling. This causes the gas pressure inside the top bulb to decrease. The resulting pressure in the top bulb is lower than in the bottom bulb. This causes the liquid to rise up through the glass tube from the bottom bulb into the top bulb. This causes the bird to become top heavy, and the bird dips forward as a result. As the bird dips down far enough, some vapor bubbles travel through the glass tube from the bottom bulb and into the head bulb (due to the higher pressure in the bottom bulb). These vapor bubbles displace some of the liquid in the head bulb (and push it back down), which makes the head lighter and results in the bird becoming bottom heavy. This causes the bird to tilt back into the upright position. As the water on the bird's head continues to evaporate, the bird will once more dip forward, and the process continues.

One can place a glass of water into which the bird's head dips, which keeps the beak and head constantly wet, and the process going. In doing this, we truly have a drinking bird. For demo watch www.youtube.com/watch?v=o9v9Dn4ildo .

Fly Stick

Atoms form the basis of electric charge creation. Atoms are the building blocks of matter, and they are extremely tiny. There are many billions of atoms in even the smallest substance, such as a grain of sand.

Atoms have an equal amount of protons and electrons. Each electron has a negative charge and each proton has a positive charge. These two charges are equal, which means that each atom has zero net charge. As a result, it is electrically neutral.

Like charges repel, which means that electrons repel other electrons and protons repel other protons. In addition, unlike charges attract which means that electrons and protons are attracted to each other.

When a substance has a negative charge it has an excess number of electrons. That is, the number of electrons in the substance is greater than the number of protons. When a substance has a positive charge it has an excess number of protons. That is, the number of protons in the substance is greater than the number of electrons.

In general, electrons are much more free to move around inside a substance than protons, and it is the flow of electrons to or from a substance which allows the substance to become either negatively charged or positively charged.

A way to give a substance either a negative charge or positive charge is by rubbing another type of material on it. This causes the two materials to exchange electrons, and one of the materials gains electrons and the other material loses electrons. This phenomenon is due to the triboelectric effect. It results in one of the materials gaining a negative charge and the other material gaining a positive charge. For example, in winter you sometimes receive a shock when touching a doorknob. This is due to you gaining a positive or negative charge while walking on the floor. When you touch the doorknob you lose that charge.

The fly stick uses the triboelectric effect to create a negative or positive charge on the wand end of the stick. This effect is created by a small battery powered Van de Graaff generator contained inside the stick. The generator has a belt powered by a motor, and this belt runs over two rollers. To understand the basics of how it works, consider first what happens with the belt and roller located at the bottommost position of the fly stick (closest to the handle). Due to the difference in material type between belt and roller, electrons are removed from one of them (either the belt or the roller) which causes it to gain a positive charge as a result. The other material (either the roller or the belt) then gains a negative charge as a result (since it gains electrons). The belt then, being either positively charged or negatively charged, travels to the wand end of the stick where it contacts the second roller (which is made of a suitably chosen material different from the first roller), and due to the triboelectric effect the belt then gains a negative or positive charge (opposite to before).
This causes the wand end at this location to either lose or gain electrons, and as a result the wand becomes either positively or negatively charged. This happens through a rather elaborate set of steps (not described here). Lastly, the belt then travels back down to the first roller and the process continues, thereby sustaining the level of charge on the wand. In summary, the charge of the wand (positive or negative) becomes the same as the charge of the belt just after it contacts the first roller at the bottommost position of the fly stick.

With the wand charged it can then be used to levitate the mylar strips.

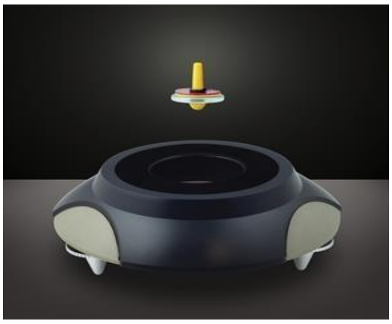
When the wand touches the mylar strips they gain the same charge as the wand. For example, if the wand is negatively charged it will transfer excess electrons to the mylar strips and they too will become negatively charged. If the wand is positively charged it will "pull" electrons from the mylar strips and they too will become positively charged. The like charges contained inside the mylar strips repel each other which causes the mylar itself to expand as a result. And at the same time the like charge on the wand and mylar strips cause them to repel each other hence producing the levitation effect.
You can do a neat trick where you make the mylar strips jump back and forth between your hand and the fly stick. When the mylar touches your hand it loses its charge to your body and the ground you're standing on (which can be thought of as a charge "sink"). The mylar then becomes electrically neutral. At this point the mylar becomes attracted to the charged fly stick. This happens because the like charges on the fly stick and mylar repel each other and as a result the like charges inside the mylar physically move away from the fly stick. At the same time the unlike charges on the fly stick and mylar attract each other which causes the unlike charges inside the mylar to physically move towards the fly stick. The net effect becomes one of attraction since the closer unlike charges have a stronger attraction force than the repulsive force created by the (further away) like charges. Hence the net force is one of attraction and the mylar moves towards the fly stick as a result. When the mylar

touches the fly stick it once again gains the same charge as the fly stick and repels away from it until it touches your hand, and the cycle repeats.

It should be mentioned that the type of charge developed on the fly stick, either positive or negative, is something I do not know since it depends on the manufacturing specifics of the fly stick. But it can be fun trying to come up with a way to figure it out! For demo watch www.youtube.com/watch?v=pRcpTffhLw4 .

Levitron

The Levitron is commonly referred to as an anti-gravity device. Although this is not actually the case it is still an amazing toy. The operating principle of the Levitron is based upon what is known as spin stabilized magnetic levitation. The spinning top of a Levitron is a disk which is made up of strong permanent magnet material, in addition to plastic and brass. In the base of the Levitron there is a strong neodymium magnet. The top spins above this base. The magnets of the top and the base are oriented so that they repel each other when the top is in its upright spinning position.
When the top spins inside the magnetic field of the base magnet, a gyroscopic effect creates stability, and as a result the top spins in a stationary position, as shown in the video. The gyroscopic effect is related to the angular momentum of the spinning top. As the top spins in the presence of the strong magnetic field (from the base magnet), stability is created due to a gyroscopic effect. This effect prevents the spinning top from turning over, and what happens instead is that the top spins and precesses about the vertical axis.
Eventually, after enough time passes, the spinning top slows down enough, due to air friction, such that it turns over and stops levitating. In other words, it falls. For demo watch www.youtube.com/watch?v=VylZJrep1MM .



Rattleback

The rattleback (also known as the Celtic stone, or wobble stone) is a fascinating object. You spin it in one direction, it slows down, wobbles, and then starts spinning in the opposite direction!

The counter-intuitive behaviour of the rattleback is difficult to explain in a physics sense. I gave it a stab once, and what I came up with is that the rocking motion of the rattleback creates a dynamic imbalance that causes it to spin the other way. It's a chain of dynamic events, and understanding the rattleback means understanding the chain of events that cause it to first slow down, and then spin in the other direction. Spinning it in one direction results in it just spinning normally. But spinning it in the other direction causes a secondary rocking motion to be set up which causes the rattleback to slow down, stop, and then spin the other way. This is all due to the non-symmetric shape of the rattleback, which creates uneven mass distribution. For demo watch www.youtube.com/watch?v=LmEf7aIhpF8 .

Dynamo Torch

The dynamo torch is a mechanically powered flashlight. It is considered a green technology since it requires no batteries. It is powered by cranking a handle. The cranking motion turns a dynamo, which is an electric generator. This produces electricity, which turns on the light. The faster you turn the crank, the brighter the light becomes. This is because you are producing more energy, which makes the light brighter.

This toy demonstrates that energy can be converted from one form into another. You are converting the mechanical energy, provided by turning the crank, into electrical energy which is used to power the light. Electrical generating stations do this as well. They turn large turbines using mechanical energy, which is usually provided by falling water (hydro power) or hot steam pressure. And these turbines then turn generators which produce electricity for use in our homes and businesses.

A dynamo torch, even though it's a toy, works the same as mechanically powered flashlights which are often kept as emergency lights in case of power outages or other emergencies. In case of such an emergency, you want to be able to have a handy light source which is always ready for use. This is particularly useful for vacation homes, cabins, and other remote locations.

As you put the dynamo torch together, have a close look at the mechanism connecting the crank to the dynamo. You will notice that the dynamo (generator) looks like a small electric hobby motor. It is in fact a motor, but one which is operating in reverse. Generators are basically electric motors going in reverse. For an electric motor to run you must supply electrical power, which makes the shaft of the motor turn. To use it as a generator you turn the motor shaft to generate electricity. For demo www.youtube.com/watch?v=v5m2KDz0dkg .

Hoberman Sphere

The Hoberman sphere is a structure resembling a geodesic dome, and which can fold down to a fraction of its normal size. The scissor-like action of its joints enables it to do this. It's impressive to watch. Some museums have this sphere on display, using a motorized control system to continuously change the size of the sphere from fully closed to fully open.

If you get your hands on one, have a look how it works. Look at how the joints bend relative to each other when the sphere opens and closes. If you look at it closely you can see a pattern in how its structured. It's a beautiful toy both aesthetically and how it's put together. The geometry of the pieces have to work smoothly together and not interfere with each other, otherwise the sphere will bind up somewhere and it won't be able to open and close properly.

Does the sphere feel heavier when it's open or closed? Obviously, the weight is the same, but sometimes the shape of an object can affect the perception of weight.

You can play many different games and create many interesting effects with the Hoberman sphere. This is explained with the manual that comes with the sphere.

One really neat trick you can do with the sphere is shown in the video. The guy in the video spins the sphere while in its open position, while holding it between his hands. He then pushes the sphere into its closed position, and the sphere spins faster as a result. This is the same effect that's created when a figure skater pulls his arms in during a spin. It causes him to spin faster. In scientific terms, this effect is caused by conservation of momentum, which is a subject covered in physics classes.

To purchase a Hoberman sphere, click on the image link below. You will be taken to the Amazon website, where you can make your purchase. For demo watch www.youtube.com/watch?v=S9SVP-dRx0w

Salt Water Fuel Cell Car

A salt water fuel cell car works using salt water. You just put a drop of salt water in one of the compartments and it will run.

The salt water provides the electrolyte used in a chemical reaction inside a fuel cell. This chemical reaction creates electricity, similar to how a battery creates electricity. This electricity runs a small motor which powers the car.

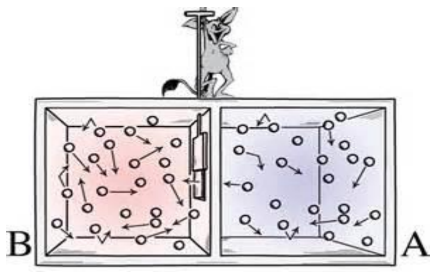
After a few minutes of use, the salt water gets used up and you need to add new salt water to keep the car going. After a few hours of use the magnesium plate used in the fuel cell also gets used up and you have to replace it.

This toy demonstrates that something as simple as salt water can be used to power a vehicle. It should be mentioned that the salt water itself does not provide the power for the car. It is an "ingredient" necessary to keep the car running and it is what needs to be replenished most often to keep the car running. It is the magnesium plate, which gets used up, which provides the energy source for the car, by way of its chemical reaction with the salt water, and air.

It's called a fuel cell car because it uses a simple fuel cell to operate. A fuel cell is a device that converts the chemical energy from a fuel into electricity by way of a chemical reaction with oxygen or another oxidizing agent. Fuel cells are different from batteries in that they require a constant source of fuel and oxygen/air to sustain the chemical reaction. However, fuel cells can continue to produce electricity as long as these inputs are supplied. For demo watch www.youtube.com/watch?v=Yr_AJXigeek .

Tanmay Dhara (2nd year)

MAXWELL DEMON



According to 2nd law of thermodynamics, in a closed system entropy can never decrease. As Entropy is a measure of disorder of the system, disorder can't decrease. After the 2nd law was stated, many renowned scientists have tried to evade it, mostly James Clerk Maxwell with his notorious demon. He suggested a super human-being which stands at the partition of two volumes of same gas kept at the same temperature & pressure. This creature, known as Maxwell's demon, has the ability to discriminate between the individual molecules. It allows the faster molecules to move from one part to another & slower molecules to enter the other. As speed is related with temperature, the two parts will be at different temperature and the entropy of the whole system decreases though no work has been done. Is it not against the 2nd law of thermodynamics ?

Several physicists like Szilard, Brillouin, Landauer, Bennett etc. showed that there is something missing in the previous approach. According to them, there is a connection between thermodynamic entropy and information-content. To let the molecules enter correctly from one part to another this demon must know some information about that molecule i.e. it has to measure the state of the molecule. There are two options, either storing or deleting the information. As deleting is a thermodynamically irreversible process, so deleting must cause an increase in entropy. But can it store this information indefinitely? Though the demon is very intelligent one, it has finite capability to store information and as soon as the storage is full, it must start to delete the previously stored information. So entropy of the system the increases as stated by 2nd law of thermodynamics. Hence we can conclude that this demon doesn't violate 2nd law.

Saikat Mondal

EXPERIMENTS THAT CONFIRM EINSTIEN TO BE CORRECT

ADVANCE OF THE PERIHELION OF MERCURY:

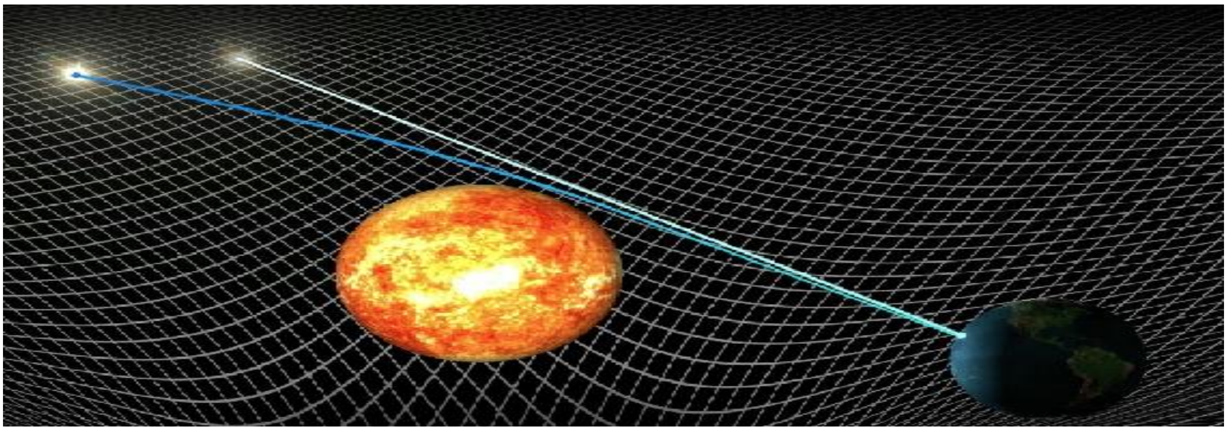
According to Einstein the space near a heavy mass is curved so that anybody which enters this space travels in a curved path. The curvature of the space increases and the closer the body approaches the heavy mass. The orbits of the planets around the sun are explained in the basis. For relatively distant planets whose orbits are nearly circular, the Einstein's law of Gravitational theory reduces to Newtonian inverse square law. But for mercury which is very close to the sun the orbit is very eccentric, so that Einstein's law departs sufficiently from Newton's law here in the experimental test.

In the case of Mercury it had long been known that's its perihelion process at the rate of 574 sec of arc per century. Using perturbation theory we can solve that the perihelion of Mercury at the rate of 532 sec of arc per century, only, so that 42 sec difference left over.

But Einstein using his theory of Gravitation solves the riddle, disposed of Vulcan as imaginary and successfully accounted for the difference by showing that the orbit of a planet is a Keplar orbit only to the first approximation. From the difference of 3α which exists between his differential equation of the planet round the sun and that proposed by Newton, he determined the precession of the perihelion, which is given by

$$\epsilon = 6\pi M^2 / h^2$$

This equation solves the problems of 43 sec using the known values of "M" and "h". This is a remarkable success of Einstein's Gravitational Theory of Relativity.



BENDING OF A RAY OF LIGHT DUE TO A GRAVITATIONAL FIELD :

We have seen that in the Special Theory of Relativity any type of energy is equals to a mass for a body which is in a uniform velocity relative to the velocity of light. This mass is equals to the inertial mass of a body which is also equals to its "Gravitational mass". Now a quantum light having energy $h\nu$ and should therefore both have an inertial and "Gravitational mass" $h\nu/c^2$. Since mass distorts space-time continuum which is equivalent to the production of a variable refractive index in the space in the neighborhood of the mass, a ray of light passes close to the sun should be deflected slightly towards the sun.

Considering therefore the light from a star passing close to the sun, Einstein predicts a small deviation, is given by

$$\Delta = 4GM/ac^2$$

Using the known values in that equation Einstein shows that it works out with a value1.74 sec. This Einstein's effect measured during the total eclipses of the sun at the year 1919 and 1922.This completely verified the Theoretical prediction.

REF : "RELATIVITY" BY EINSTEIN.

:BASIC IDEAS OF GRAND UNIFICATION THEORY:

Introduction:

As a student of physics, you may think that how many types of forces is exists in the universe? Does there exist any 'Unique force' by which one can explain all the forces he encounters? Actually there exists 4 numbers of basic forces which are presently known in the physics world.

I list of them,

- **Strong**
- **Electromagnetic**
- **Weak**
- **Gravitational**

The above list may surprise you. Because you must think where is our well known frictional force? Where is cohesive or adhesive force? What's about the force when kick your football? The answer is that all these forces we encounter in our daily life is electromagnetic.

The '**Strong forces**', are responsible for binding protons and neutron together inside the atomic nucleus and acts over extremely short range.

The '**Weak forces'**, which account certain kinds of radioactive decay, also of short range.

For '**Gravitational forces**', a mass attracts another by their force and in this case there is no range of limit.

The unification of physical theories:

The list of fundamental interaction has changed over the years. In the beginning, the '**Electricity**' and '**Magnetism**' existed in physics as two entirely separated subjects in 1820. **Oersted**'s experiment showed us that <u>magnetism is the relativistic effect of electricity</u>. By the time **Maxwell** and **Lorentz** put the finishing touches of the previous and opened a new window of the subject, **'Electrodynamics'**. **Albert Einstein**, one of the pioneers of the unification theory, dreamed of a further unification which would combine gravity and electrodynamics. His '**unified field theory'** could not get the proper success. Through in 1960, **Glashow**, **Salon** and **Weinberg** succeed to join the week and electromagnetic forces. At each step in this hierarchy, the mathematical difficulties mount and the gap between inspired conjecture experimental tests widens; nevertheless, it is clear that the unification of forces initialed by electrodynamics has become a major theme in the progress of physics. One of the goals of physics is a single theoretical picture that unites all the ways in which the particle of matter interacts with each other. Much progress has been made but the physicists are still searching for that single '**Unique force'**.

TABLE

The four fundamental interactions. The graviton hasn't been experimentally detected yet.

Interaction	Particle affected	Range	Relative strength	Particles exchanged	Roll in the universe
Strong	Quarks, Hadrons	10^{-15}	1	Gluons Mesons	Hold QUARKS together to form Nucleons Hold nucleons to form nuclei
Electro-Magnetic	Changed particles	Infinity	10^{-2}	Photons	Determine structure of atoms , molecules, solid, liquid; is important factor in astronomical universe.
Weak	Quarks and Lepton	10^{-18}	10^{-5}	Intermediate Bosons	Mediates transformation of quarks and leptons, helps to determination the composition of atomic nuclei
Gravitational	All	infinity	10^{-39}	Gravitons [not detected yet]	Assembles matter into planets, stars and Galaxies.

Sayan Maity
3rd year.

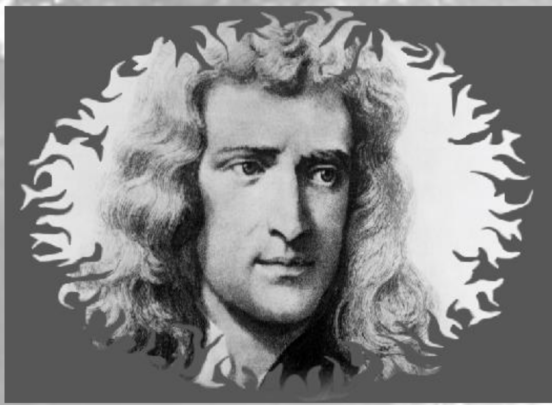
GRAVITATION

Newton to Einstein

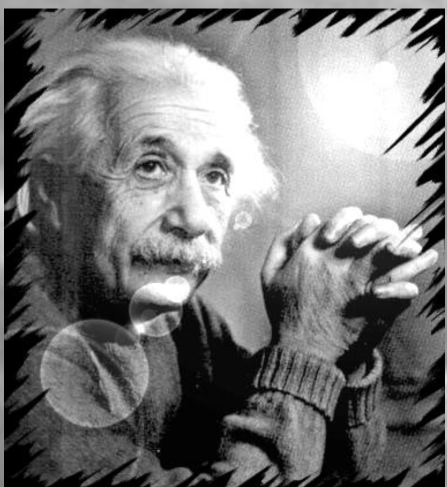
Submitted by:-

Soham Sau
Diganta Konar
Swapnadeep Mondal
Souvik Sana

Newton proposed the first theory of gravity on the basis of Kepler's laws, Galileo's works, etc. His model of gravitational field, space and time was static. Although, he suggested that space is non-absolute, but time is. After Newton, many new concepts arose and new theories were proposed. One of them was of Maxwell's Electromagnetic (E.M.) wave, and visible light was a part of them. Maxwell said that E.M. waves propagate at a certain velocity. Now, as Newton's theory told that nothing was at absolute "rest", it was supposed that light would move relative to something, named it "ether". Ether was considered to be everywhere, even in "empty" space. It was considered to be the medium through which light travelled. In particular, as the earth was moving through the ether on its orbit round the sun, we would measure different speeds of light in different directions .In 1887, Albert Michelson and Edward Morley compared the speed of light in the direction of the earth's motion with that at right angles to the earth's motion. To their great surprise, they found they were exactly the same! This discarded the need for a medium called "ether" and after that light was considered to propagate without the help of any medium, unlike sound waves.



•ENTRY OF THE HERO……THE ''CLERK"



Between 1887 and 1905, several attempts were made to explain the results of the Michelson - Morley experiment. However, in 1905, a hitherto unknown clerk in the Swiss patent office, Albert Einstein, discarded the idea of "ether" and was willing to abandon the idea of absolute time.

•THE SPECIAL THEORY OF RELATIVITY

He postulated the concept that the speed of light (or any E.M. wave) is same for all observers, may be in any frame, and that the laws of Physics is same in any non-accelerating frame of reference. But, as speed can't vary and as speed is distance travelled with respect to time, time has to vary (has to slow down, to compensate the speed). Therefore, a moving clock ticks more slowly than a clock at rest. This came to be known as the Special Theory of Relativity. For visualizing this, consider, two similar clocks. One is at rest and another is at rest on the earth an another in a spacecraft that moves with a speed v relative to the ground. In each clock, a pulse of light is reflected back and forth between two mirrors L0 apart. Whenever the light strikes the lower mirror, we count manually. An observer watches both clocks: what does he find? Here, the time interval between the ticks is the proper time t0 and the time needed for the light pulse to travel between the mirrors at the speed of light c is t0/2.Hence, t0 = 2L0/c (Eq.1) . The time interval between the ticks is t. Because the clock is moving, the light pulse as seen from the ground follows a zigzag path.

On this way, the pulse travels a horizontal distance of v(t/2) and a total distance of c(t/2). Since L0 is the vertical distance between the mirrors,

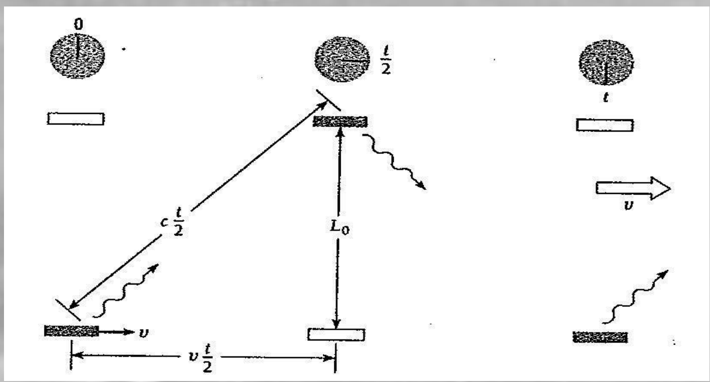
$$\left(\frac{ct}{2}\right)^2 = L_0^2 + \left(\frac{vt}{2}\right)^2$$

$$\frac{t^2}{4}(c^2 - v^2) = L_0^2$$

$$t^2 = \frac{4L_0^2}{c^2 - v^2} = \frac{(2L_0)^2}{c^2(1 - v^2/c^2)}$$

$$t = \frac{2L_0/c}{\sqrt{1 - v^2/c^2}}$$

But t0 is the time interval between the ticks on the clocks on the ground, as in Eq. 1, and so,



This figure shows a light-pulse clock in a spacecraft seen by an observer on the ground. The mirrors are parallel to the direction of the spacecraft. The dial represents a conventional clock on the ground. So,

Time dilation:
$$t = \frac{t_0}{\sqrt{1 - v^2/c^2}}$$

And, here,

t_0 = time interval on clock at rest relative to an observer = proper time
t = time interval on clock in motion relative to an observer
v = speed of relative motion
c = speed of light

Because the denominator in Eq. 2 cannot exceed 1 for a moving object, t is always greater than t0.Einstein also gave us the equation E= MC^2 . Which is known as the mass-energy equivalence. This is arguably the most powerful and simple equation ever, unhiding so much, with the so less!!! This equation tells that you could never reach the speed of light as it would require an infinite amount of energy. Now, from this theory the dynamicity of the universe clearly visible, unlike Newton's laws. Thanks to the "clerk"! Relativity has completely changed the idea of space and time. Previously, man thought they were separate but now, Einstein completely changed the idea to the fact that they are fused together.

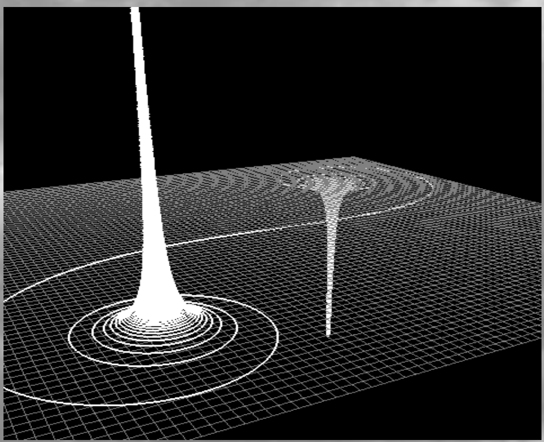
Fused to be named as ‘’space-time”.

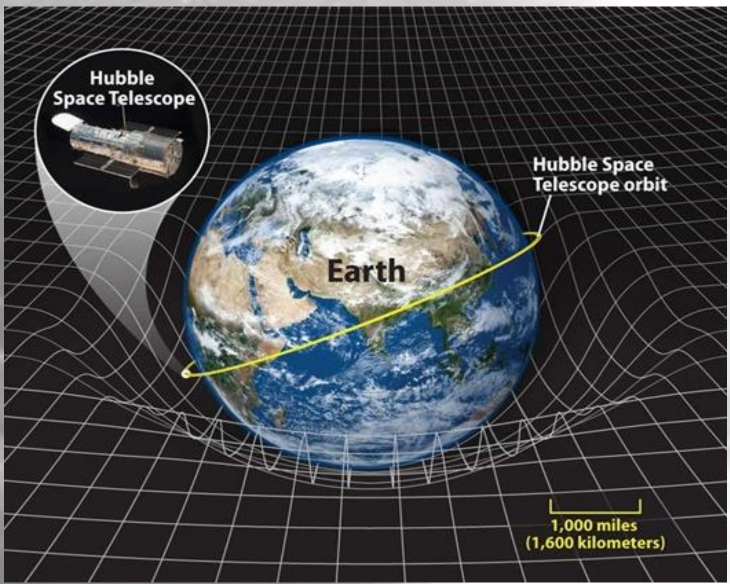
•THE GENERAL THEORY OF RELATIVITY

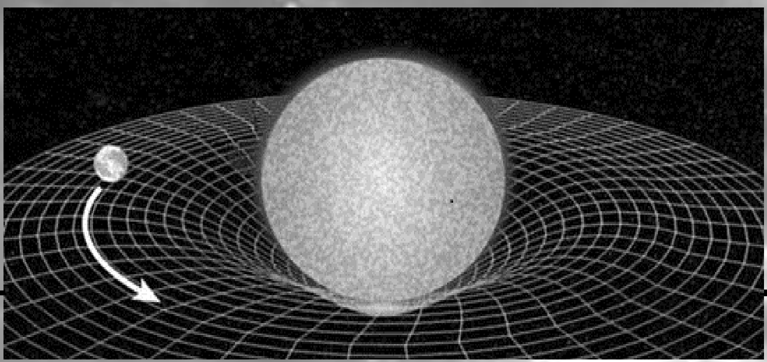
Einstein knew something was missing. As Newton’s said that gravity was a force and it would act instantaneously; which violated Einstein’s thought and result that one cannot exceed the speed of light. In 1907, Einstein had an epiphany that put gravity in the picture and he worked on this for nearly eight years and finally in the year 1915, he trapped, rather conquered gravity by his masterpiece, which came to be known as the General Theory of Relativity.

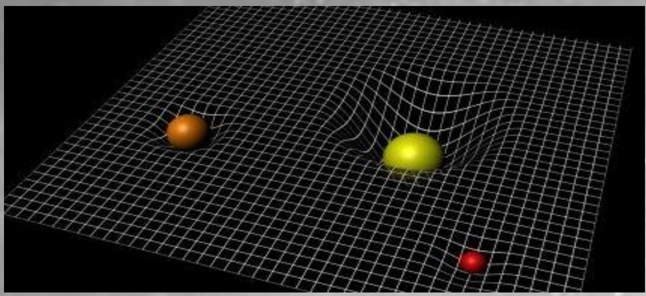
According to Einstein, gravity was not a force, rather nothing exists as the so called “Gravitational Force” at all. He realized that the effect of gravity was just like the effect of acceleration. He proposed that the thing called gravity was not at all the property of matter but the property of space- time. The mathematical details are complex (hence ignored), but thankfully, we have a metaphor for this. Imagine a big ball kept on a stretched bed sheet. The sagging is most pronounced near the area closest to the ball. This is the “warping” of space-time “fabric” which was earlier identified as force.

Now, if we leave a small ball just around the warp with a little velocity tangentially to the warp, the small ball will move around through the warp, revolving around the big ball. This is just what happening in the solar system and other gravitational force fields. We just replace sun with the big ball and the planet(s) with the small ball(s). Eventually, we can see that the big ball comes as much nearer to the big ball as much as it revolves. This is just what going on in our solar system.

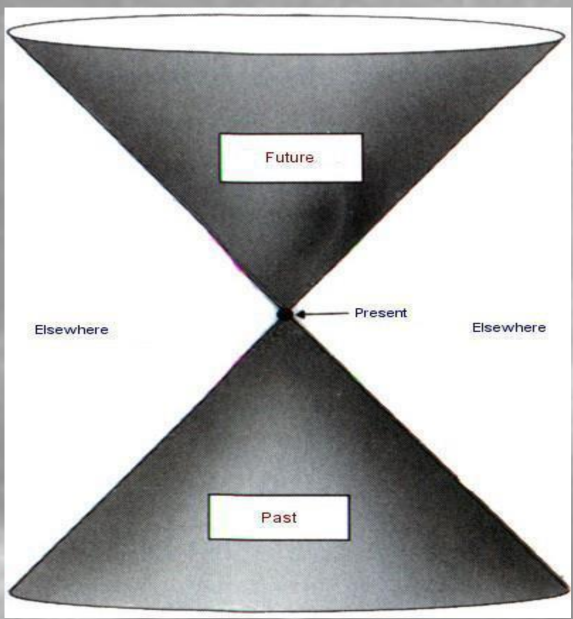


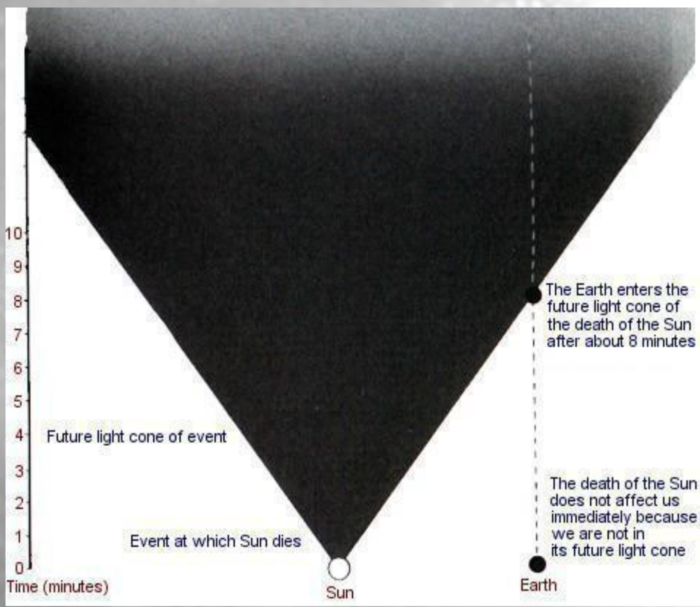






Relativity also put a limit on our thinking. Earlier, to predict or to interpret the past and future of any event we had to think and calculate by taking the whole picture, but as we know that any process’ speed can’t exceed the speed of light, our thinking and calculation is limited. This is well visualized by the future-past light cone diagrams.





In the picture, the parts (rather seems two, it is a single part) doesn’t affect the event (at present).

As said earlier, gravity was thought to be instantaneous but after Einstein put the limit to speed of anything, many concepts changed that if sun suddenly vanished or vaporized then the planets will be affected just after it enters the sun’s future light cone (figure below). For earth, the time is nearly eight minutes.

This theory was experimentally tested for Mercury by the British Astronomer, Sir Arthur Eddington in the year 1919. And also, recently the so called “Gravitational Waves” were detected by a group of scientists in 2015 in an observatory abbreviated as L.I.G.O. (Gravitational waves are the name given to the propagating space-time curvature, quite similar to the E.M. waves, which are predicted to be produced from the acceleration of massive objects).

•So, What is Gravity? What it means?

Gravity is just the dancing of the mass on the curved arena known as space-time and which is curved by another mass.(Mass is also just form of energy, much condensed and stable)And yes, the General theory of Relativity suggests that the path is already decided by the mass on which another mass has to dance (move, rather!), just like a train's path is fixed on the lines. The theory of General Relativity is truly a beautiful one. It displays one of the finest beauties in nature in the macroscopic level. And as we know, beauty symbolizes truth.

Once Einstein remarked that,
"I would have to feel sorry for God, because the theory is correct."

This is one of the pillars of Theoretical Physics along with Quantum Mechanics and the quest for unification continues as many theories, Quantum Field Theory, String Theory, etc. have come up for the purpose.

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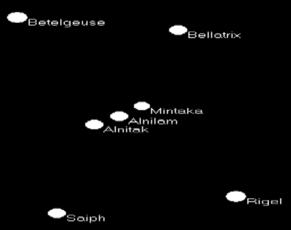
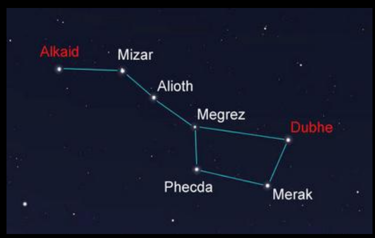
Keep eyes on night sky

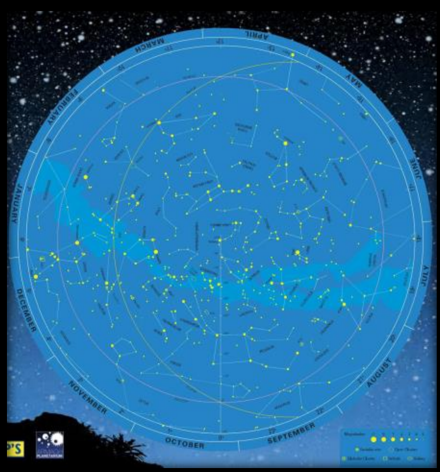
A clear night sky is a thing of beauty and wonder. Thousands of scattered stars twinkle in the darkness. What are the stars? Over the past century or so astronomers have by observation and calculation established the true nature of these gleaming specks. Now we know that stars are basically enormous balls of very hot gas, mainly hydrogen, with some helium and small amounts of a few other things. Inside the star huge quantities of energy are generated by a nuclear process called fusion. Planets, in contrast are balls of rock, metal and gas with no internal nuclear energy source. Earth is a planet, while the sun is a star. Stars come in different brightness's, sizes and colours. Look out at the sky tonight and you will see how stars vary in brightness. Some are bright because they are relatively close to us, while others are bright because they are thousands of times brighter than our own nearby Sun. Find the easily-spotted constellation of Orion the hunter. There you will see the red star Betelgeuse in his shoulder, the bluish white Rigel in his foot. To bring order to star catalogues, astronomers classify stars into what are called spectral types. This means stars are listed and placed in an order based on the temperature and brightness of their surfaces and the characteristics of the spectrum of light they shine out.

In order of brightest to dimmest star, the sequence runs OBAFGKM.
Here is the classification sequence with a rough guide to how common each type is.

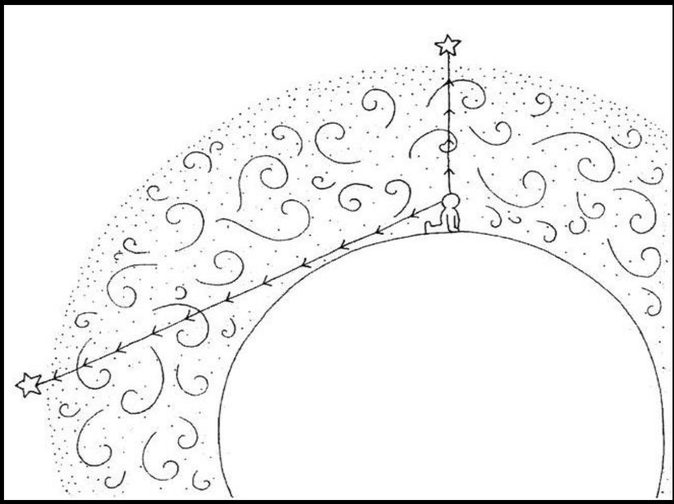
- O- blue-white, brightest and hottest (30 000°C or more). About 1 star in every thirty thousand is type O.
- B- white, very bright stars. About 1 star in every thousand is type B.
- A- bluish white stars. About 1 star in a hundred is type A.
- F- yellowish white stars. About 1 star in thirty is type F.
- G- yellow stars (about 5500°C). About 1 star in fifteen is type G, eg the Sun.
- K- orange stars, not as bright as the Sun. About 1 star in eight is type K.
- M- red stars (about 3500°C). About four out of five stars are type M.

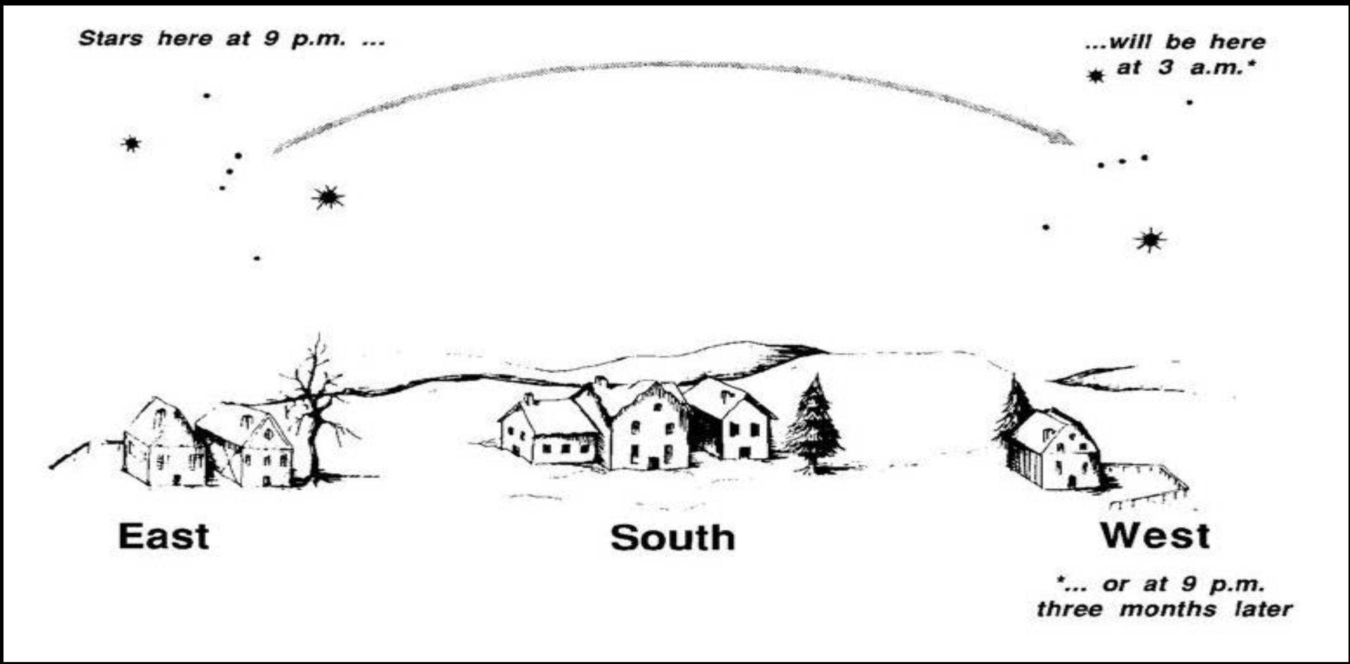




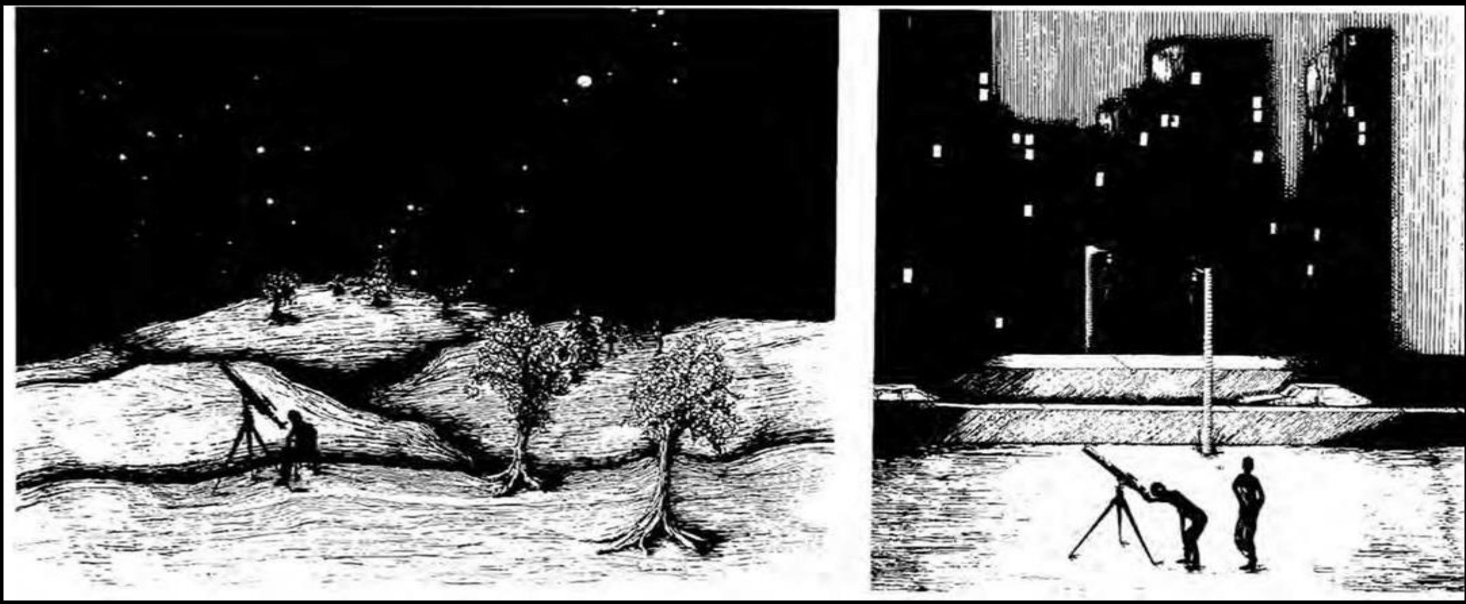


When you look directly overhead, you don't have to look through as much dirty, turbulent air as you do when you look at something low on the horizon. Try to avoid looking at things low on the horizon.
Stars to the south never do rise very high; there's nothing you can do about that. But stars along the other horizons will appear higher in the sky during different seasons, or at different times of the night.

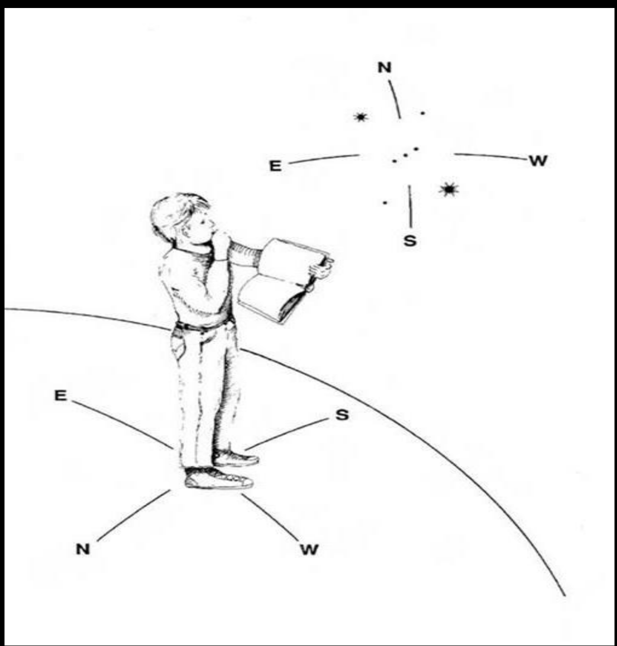




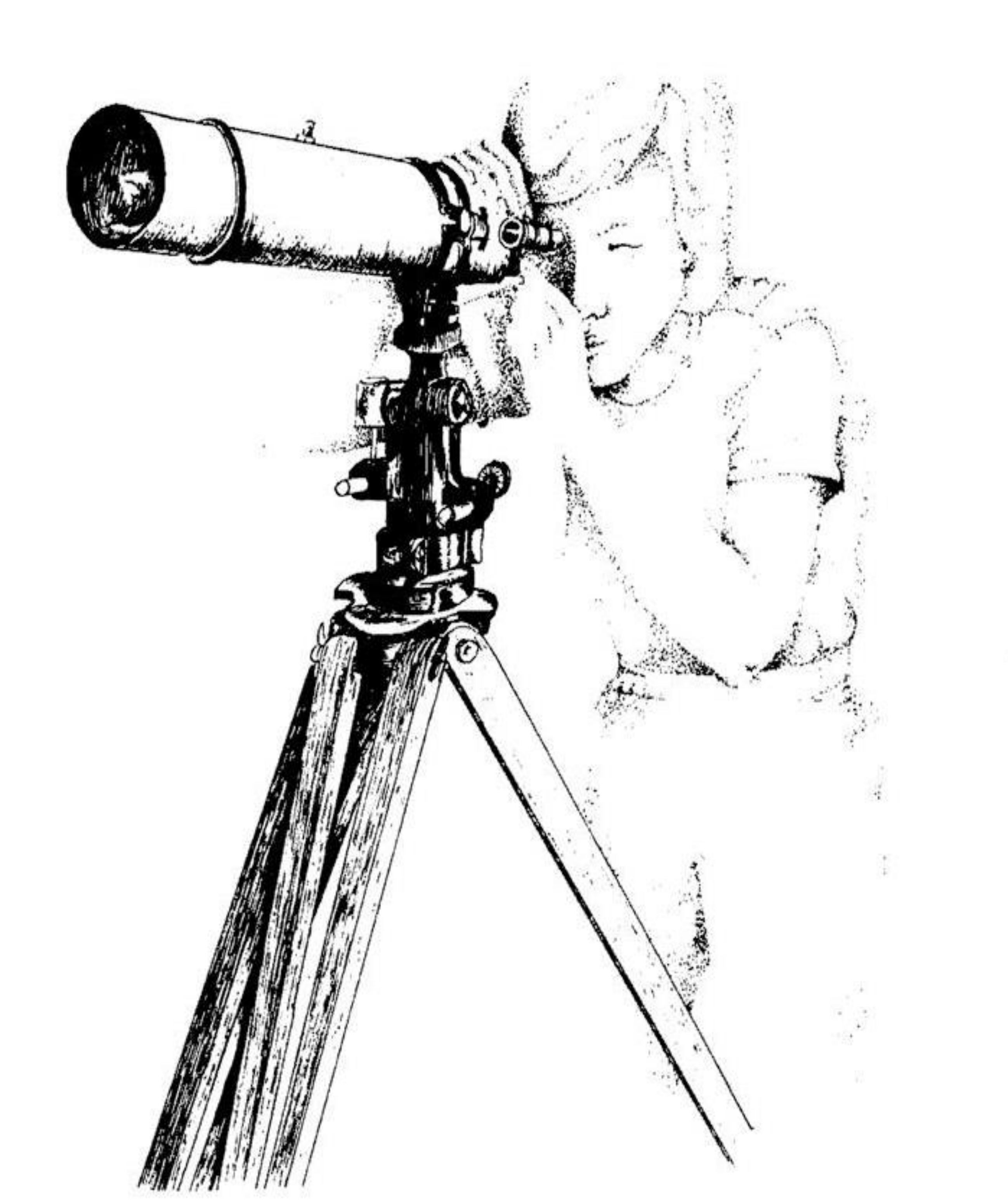
The stars and deep sky objects stay in fixed positions relative to one another. But which of those stars will be visible during the evening changes with the seasons; objects that are easy to see in March will be long
gone by September. Thus we refer to these objects as "seasonal." Some objects are visible in more than one season. When we talk about "winter skies" we're referring to what you'd see in the winter at around 9:00 p.m.
local standard time. If you are up at 3 in the morning the sky will look quite different. The general rule of thumb is to advance one season
for every six hours, so spring stars will be visible on winter mornings, summer stars on spring mornings, and so forth.



The ideal observing conditions are to be alone on a mountain top, hundreds of miles from city lights, on a cool, crisp, moonless night. Be sure to bring your telescope along when you go camping! You shouldn’t wait for perfect conditions,
however. Most of the objects we describe in this book can be seen even from a city. The roof of an apartment building can make a fine place for an informal observatory.



Standing on the Earth, looking out towards the globe of the sky, the directions east and west appear to be reversed compared with what we’re used to on ordinary maps.



When You Go Out to Observe

The Moon

You don't need a book to tell you to look at the Moon with your telescope. It is certainly the easiest thing in the night time sky to find, and it is probably the richest to explore. But it can be even more rewarding to observe the Moon, if you have a few ideas of what to look for

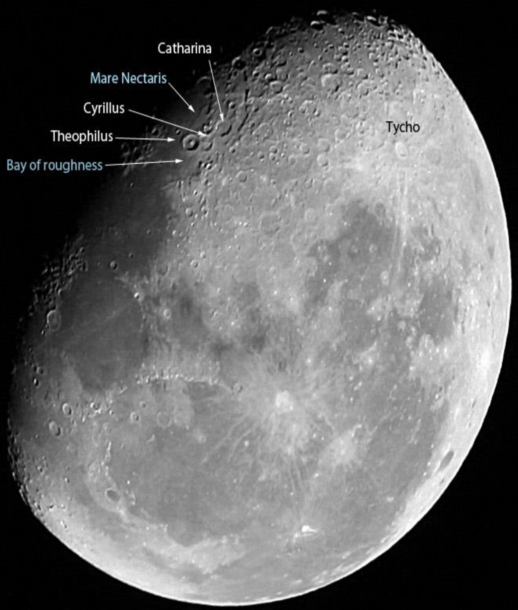
Earth's Moon

The Crescent Moon

(1–5 Days after New Moon)

The Half Moon
(6–8 Days after New Moon)

The Gibbous Moon
(9–11 Days after New Moon)



The Full Moon
(12–16 Days
after New Moon)

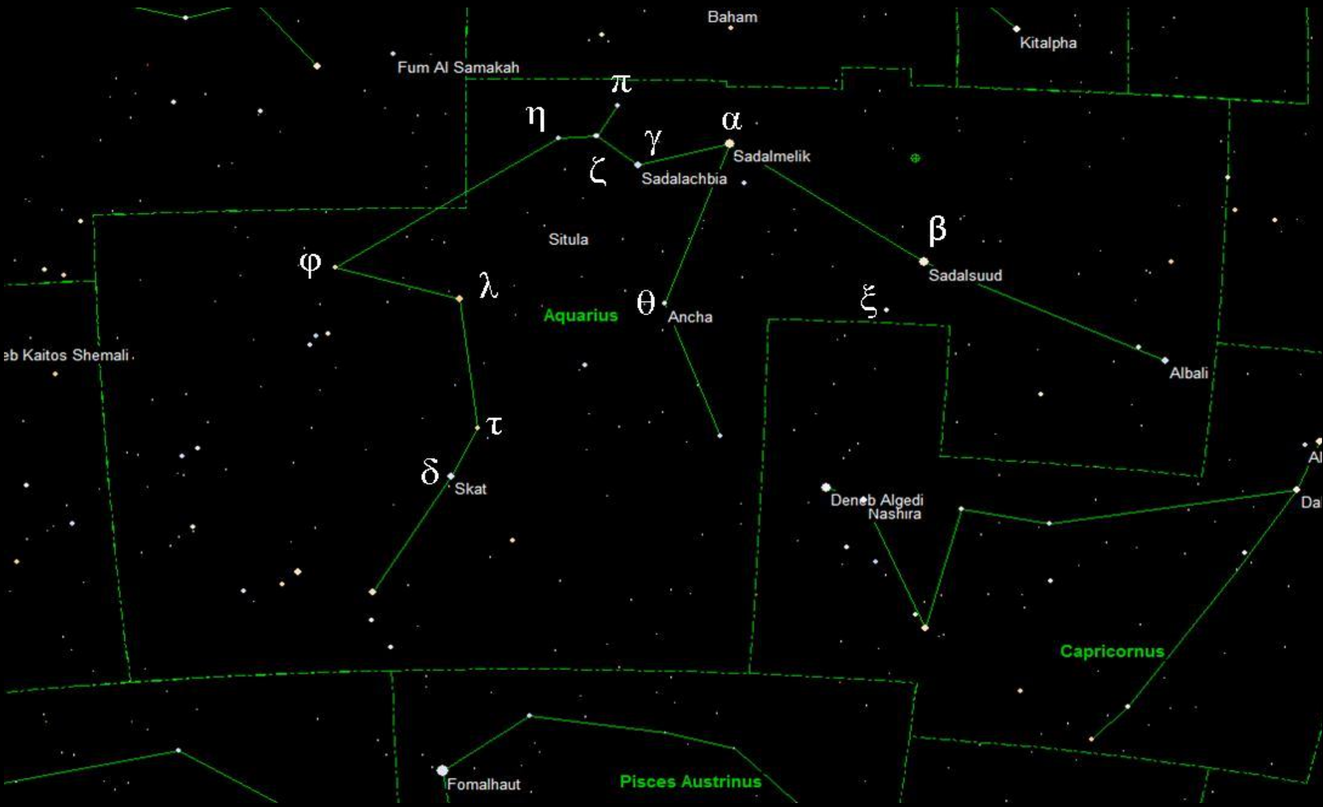
Lunar Eclipses

Lunar Eclipses Worldwide, 2004–2020

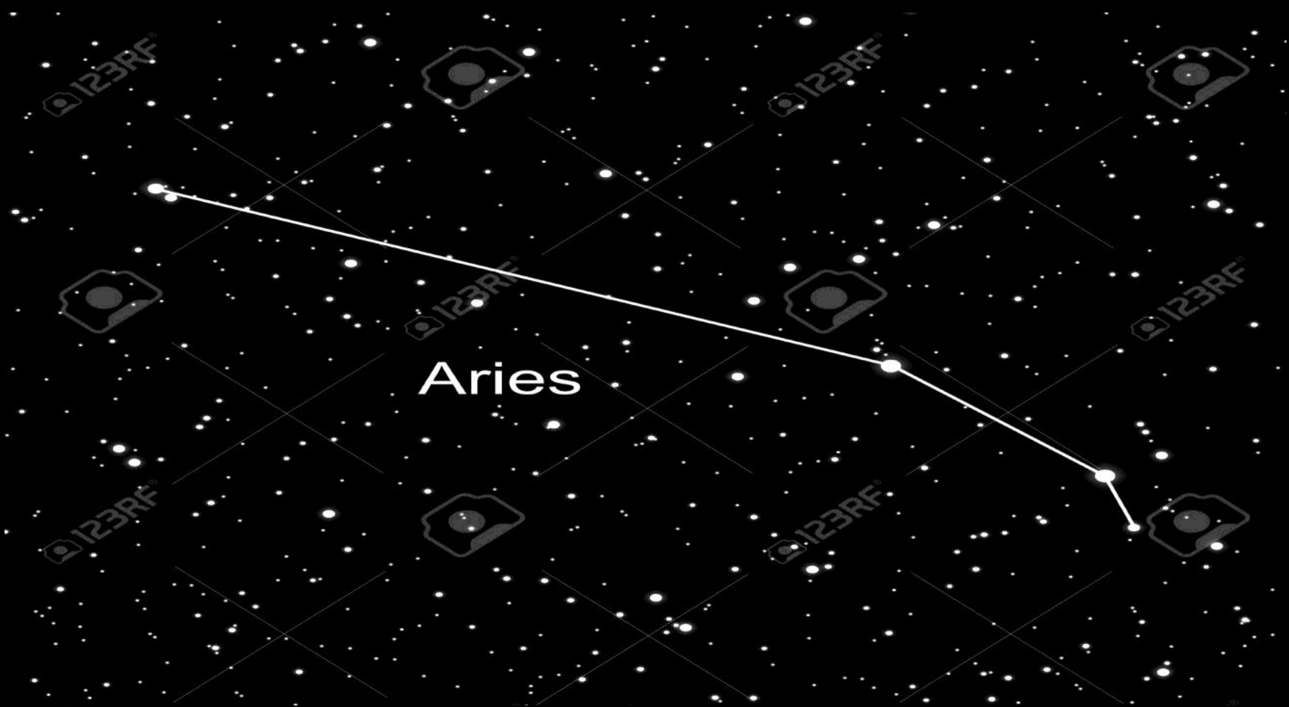
Local date	Type	Best Visible From:
May 4–5, 2004	total	Africa, E. Europe, W. Asia
October 27–28, 2004	total	Americas, W. Afr., W. Eur.
April 23–24*, 2005	89% penumbral	Pacific, W. North America
October 16–17*, 2005	7% umbral	E. Asia, Pacific
March 14–15, 2006	100% penumbral	Africa, Europe, W. Asia
September 7–8, 2006	19% umbral	E. Africa, Asia
March 3–4, 2007	total	Africa, Europe, W. Asia
August 27–28*, 2007	deep total	Pacific
February 20–21, 2008	total	Americas, W. Afr., W. Eur.
August 16–17, 2008	81% umbral	Africa, E. Europe, W. Asia
February 9–10**, 2009	92% penumbral	E. Asia, Pacific
December 31–January 1, 2009/10	8% umbral	Europe, Africa, Asia
June 25–26*, 2010	54% umbral	Pacific
December 20–21*, 2010	total	E. Pacific, N. America
June 15–16, 2011	deep total	E. Africa, Central Asia
December 10–11**, 2011	total	E. Asia, W. Pacific
June 3–4*, 2012	38% umbral	Pacific
November 28–29**, 2012	95% penumbral	Asia, W. Pacific
April 25–26, 2013	21% umbral	Africa, E. Eur., Central Asia
Ocober 18–19, 2013	80% penumbral	Africa, Europe, W. Asia
April 14–15*, 2014	total	E. Pacific, W. Americas
October 7–8*, 2014	total	Pacific, W. North America
April 3–4*, 2015	total	Pacific
September 27–28, 2015	total	E. Americas, W. Afr. & Eur.
March 22–23*, 2016	80% penumbral	Pacific
September 16–17, 2016	93% penumbral	E. Africa, E. Europe, Asia
February 10–11, 2017	100% penumbral	E. Americas, Europe, Africa
August 7–8, 2017	25% umbral	Central Asia, Indian Ocean
January 30–31*, 2018	total	E. Asia, W. Pacific
July 27–28, 2018	deep total	E. Africa, Central Asia
January 20–21, 2019	total	Americas, W. Europe
July 16–17, 2019	66% umbral	Africa, E. Europe, W. Asia
January 10–11, 2020	92% penumbral	Africa, Europe, Asia

evening, while the eclipse will occur closer to sunrise for those in the last continent listed.

<u>Constellation</u>



Aquarius



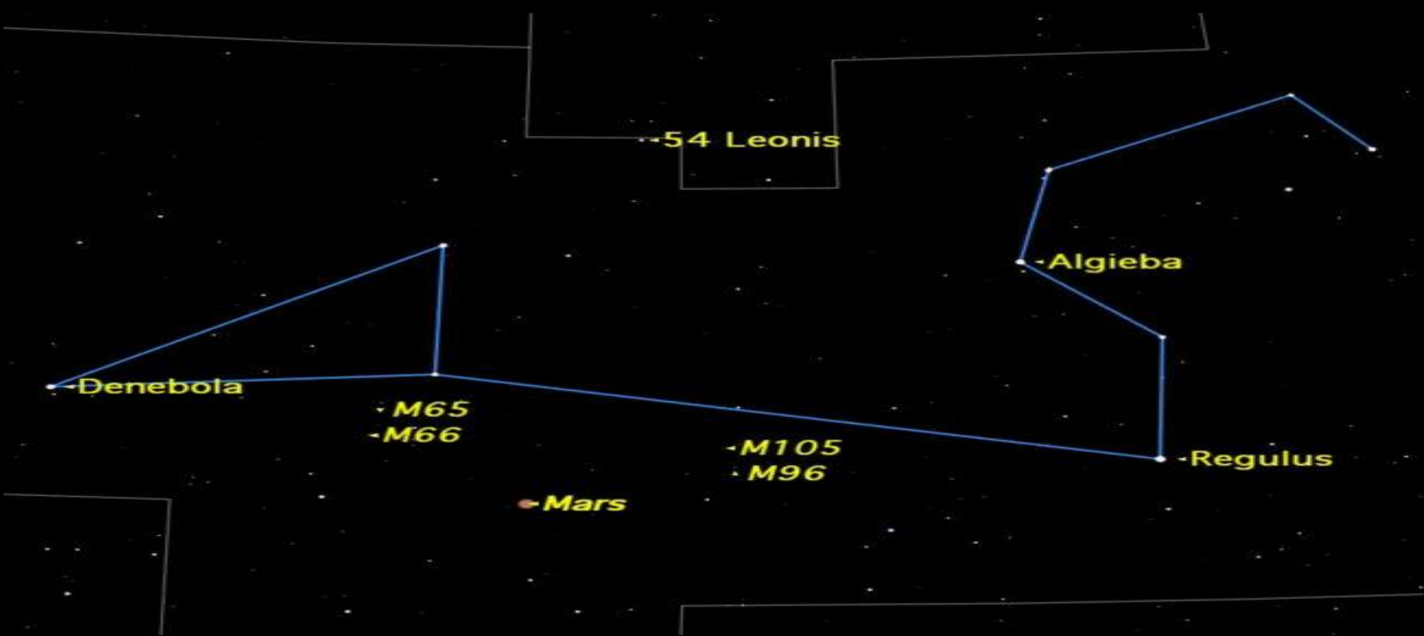
Aries

Cancer

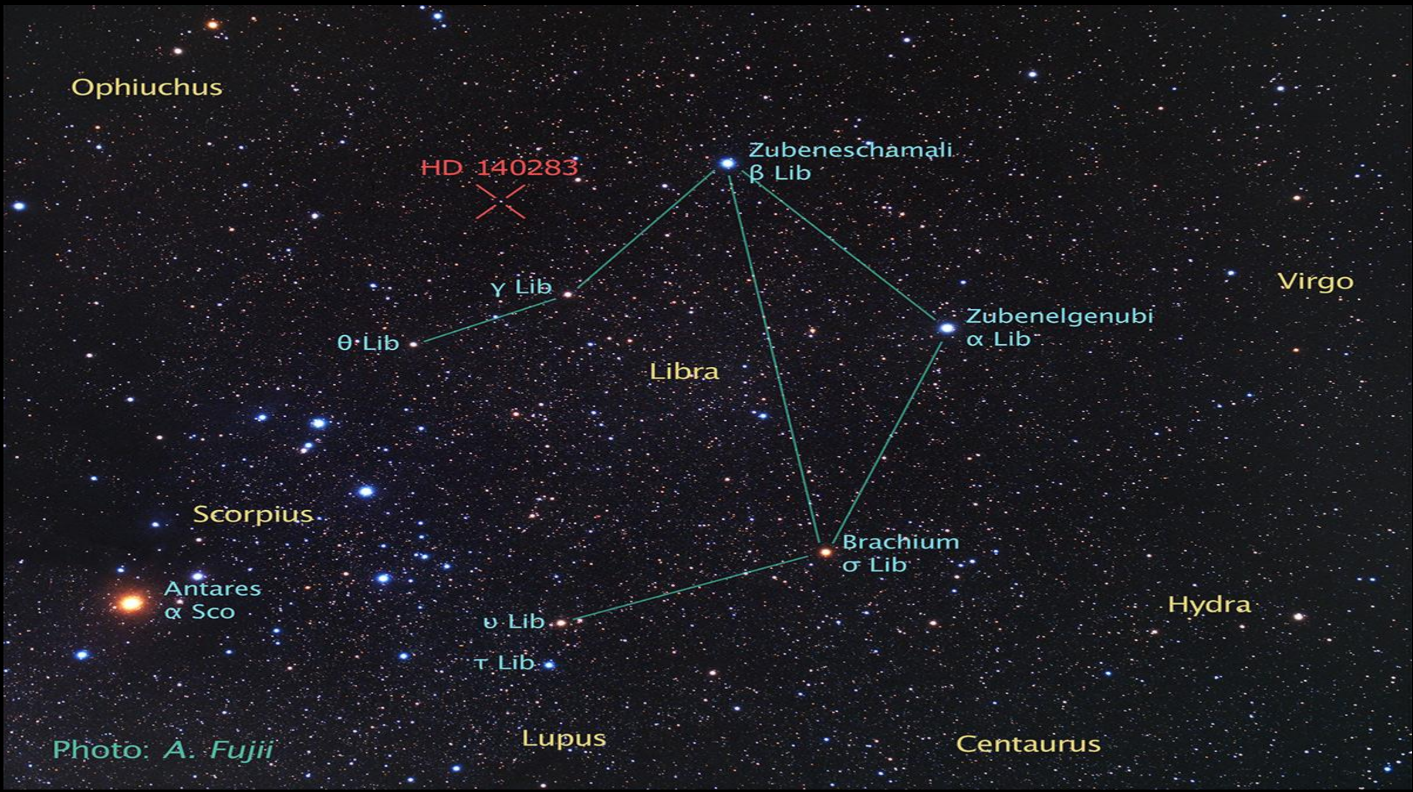
Capricornus


Lynx
Castor
Gemini
Auriga
M 36
M 37
Pollux
Tau
M 35
Orion
Canis Minor
Monoceros
Betelgeuse
Procyon
NGC 2238

Gemini


54 Leonis
Algieba
Denebola
M65
M66
M105
M96
Regulus
Mars

Leo



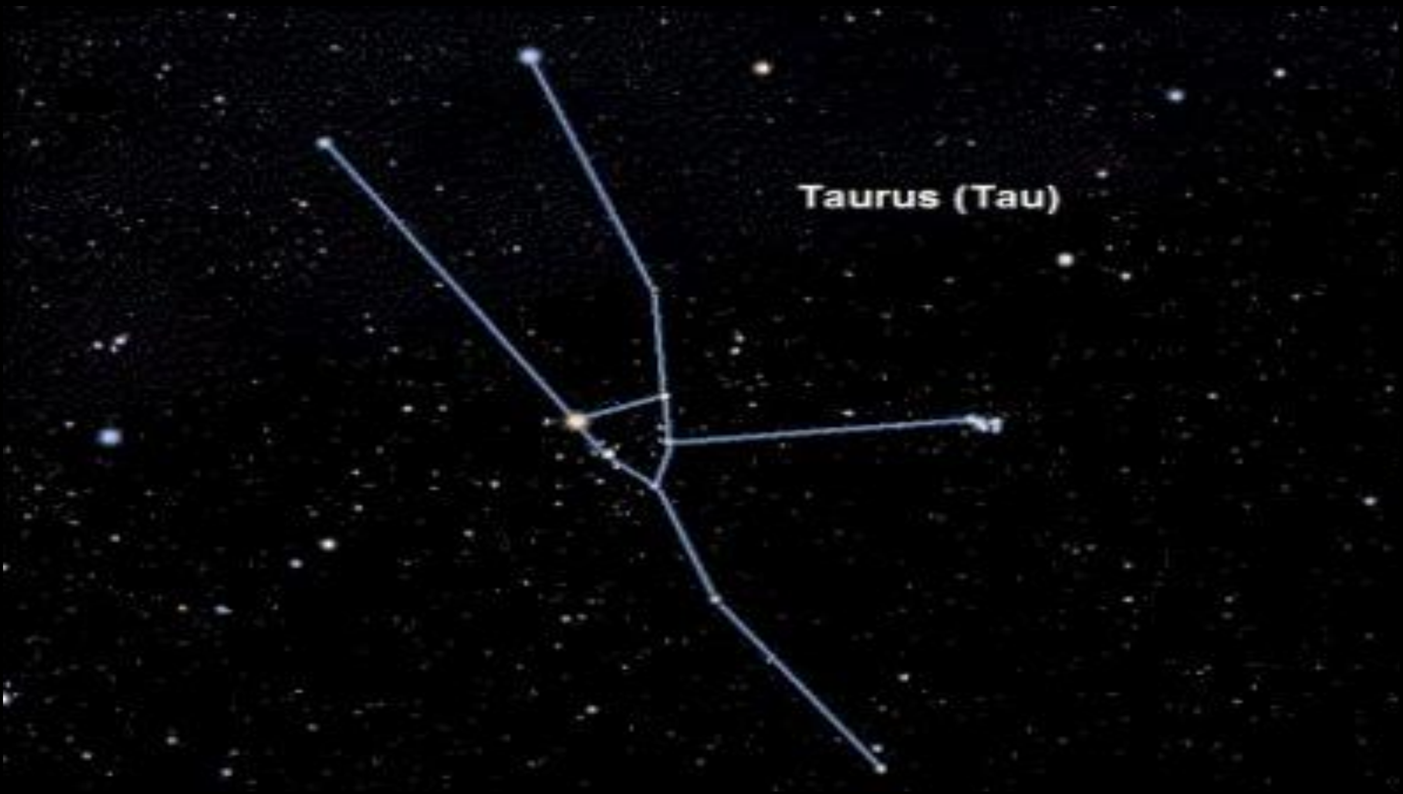
Libra

Ophiuchus

Piscis Austrinus

Sagittarius

Scorpius



Tarus

Virgo

These Constellations are used in astrology.

Table of timings of constellations visible from earth.

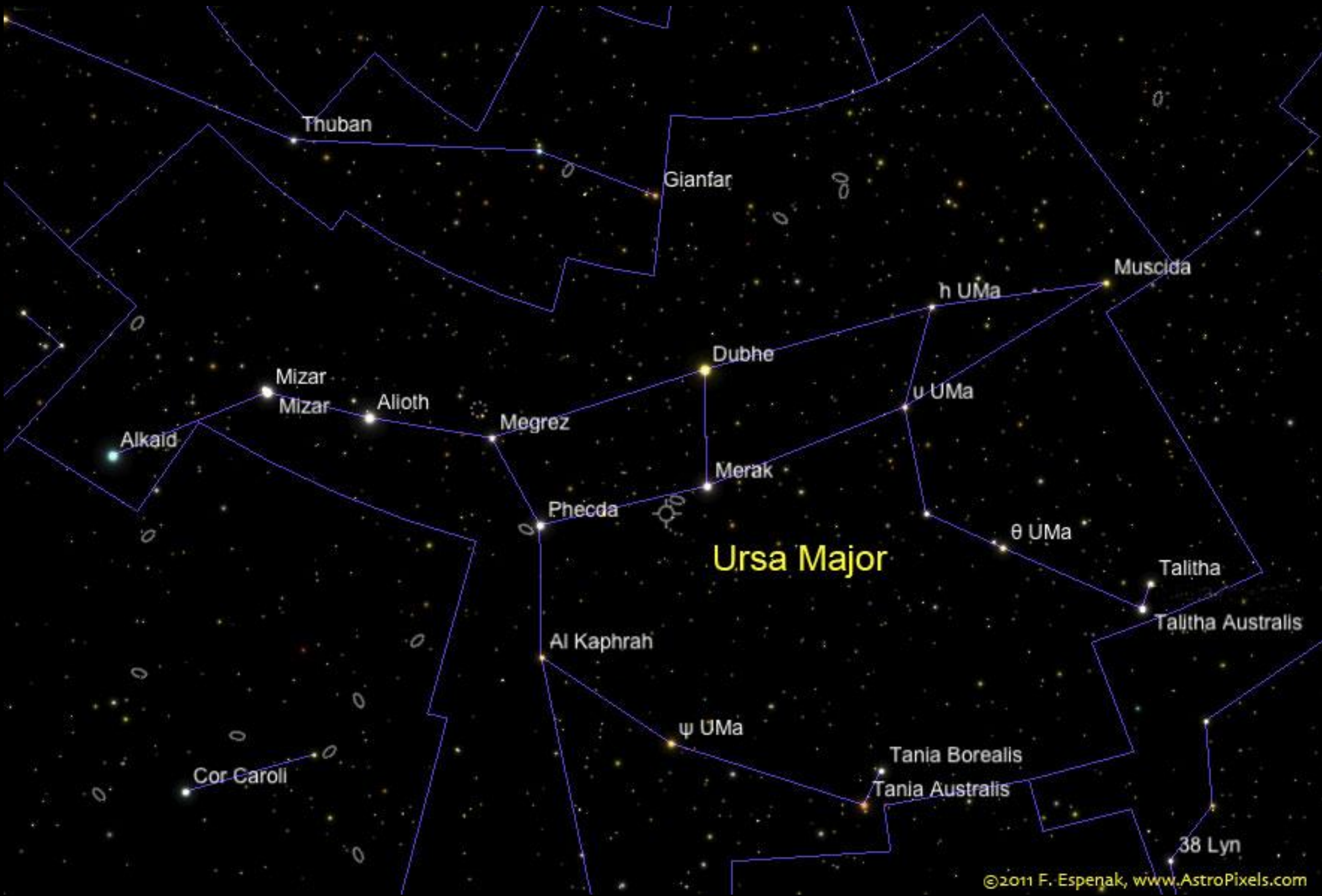
Constellation			
Name	**IAU boundaries**[45]	**Solar stay**[45]	**Brightest star**
Aries	19 April – 13 May	25 days	Hamal
Taurus	14 May – 19 June	37 days	Aldebaran
Gemini	20 June – 20 July	31 days	Pollux
Cancer	21 July – 9 August	20 days	Al Tarf
Leo	10 August – 15 September	37 days	Regulus
Virgo	16 September – 30 October	45 days	Spica
Libra	31 October – 22 November	23 days	Zubeneschamali
Scorpius	23 November – 29 November	7 days	Antares
Ophiuchus	30 November – 17 December	18 days	Rasalhague
Sagittarius	18 December – 18 January	32 days	Kaus Australis
Capricornus	19 January – 15 February	28 days	Deneb Algedi
Aquarius	16 February – 11 March	24 days	Sadalsuud
Pisces	12 March – 18 April	38 days	Eta Piscium

There are 88 recognized constellations. In astronomical works, the Latin names of the constellations are used. The letter N or S following the Latin name indicates whether the constellation is located to the north or south of the Zodiac. The letter Z indicates that the constellation is within the Zodiac.

Latin name	*Letter*	*English version*
Andromeda	*N*	*Andromeda*
Antlia	*S*	*Airpump*
Apus	*S*	*Bird of Paradise*
Aquarius	*Z*	*Water Bearer*
Aquila	*N*	*Eagle*
Ara	*S*	*Altar*
Aries	*Z*	*Ram*
Auriga	*N*	*Charioteer*
Boötes	*N*	*Herdsmen*
Caelum	*S*	*Sculptor's Tool*
Camelopardalis	*N*	*Giraffe*
Cancer	*Z*	*Crab*
Canes Venatici	*N*	*Hunting Dogs*
Canis Major	*S*	*Great Dog*
Canis Minor	*S*	*Little Dog*
Capricornus	*Z*	*Goat (or SeaGoat)*
Carina	*S*	*Keel (of Argo)*[1]
Cassiopeia	*N*	*Cassiopeia*
Centaurus	*S*	*Centaur*
Cepheus	*N*	*Cepheus*
Cetus	*S*	*Whale*
Chameleon	*S*	*Chameleon*
Circinus	*S*	*Compasses*
Columba	*S*	*Dove*
Coma Berenices	*N*	*Berenice's Hair*
Corona Australis	*S*	*Southern Crown*
Corona Borealis	*N*	*Northern Crown*
Corvus	*S*	*Crow (Raven)*
Crater	*S*	*Cup*
Crux	*S*	*Southern Cross*
Cygnus	*N*	*Swan*
Delphinus	*N*	*Dolphin*
Dorado	*S*	*Swordfish (Goldfish)*
Draco	*N*	*Dragon*
Equuleus	*N*	*Filly*
Eridanus	*S*	*Eridanus (river)*
Fornax	*S*	*Furnace*
Gemini	*Z*	*Twins*
Grus	*S*	*Crane*
Hercules	*N*	*Hercules*
Horologium	*S*	*Clock*
Hydra	*N*	*Sea Serpent*
Hydrus	*S*	*Water Snake*
Indus	*S*	*Indian*
Lacerta	*N*	*Lizard*
Leo	*Z*	*Lion*
Leo Minor	*N*	*Little Lion*
Lepus	*S*	*Hare*
Libra	*Z*	*Scales*
Lupus	*S*	*Wolf*
Lynx	*N*	*Lynx*
Lyra	*N*	*Lyre (Harp)*
Mensa	*S*	*Table (mountain)*
Microscopium	*S*	*Microscope*
Monoceros	*S*	*Unicorn*
Musca	*S*	*Southern Fly*
Norma	*S*	*Rule (straightedge)*
Octans	*S*	*Octant*
Ophiuchus	*N*	*Serpent-Bearer*
Orion	*S*	*Orion*
Pavo	*S*	*Peacock*
Pegasus	*N*	*Pegasus*
Perseus	*N*	*Perseus*
Phoenix	*S*	*Phoenix*
Pictor	*S*	*Painter (or his Easel)*
Pisces	*Z*	*Fishes*
Piscis Austrinus	*S*	*Southern Fish*
Puppis	*S*	*Poop (of Argo)*[1]
Pyxis	*S*	*Mariner's Compass*
Reticulum	*S*	*Net*
Sagitta	*N*	*Arrow*
Sagittarius	*Z*	*Archer*
Scorpius	*Z*	*Scorpion*
Sculptor	*S*	*Sculptor*
Scutum	*N*	*Shield*
Serpens	*N*	*Serpent*
Sextans	*S*	*Sextant*
Taurus	*Z*	*Bull*
Telescopium	*S*	*Telescope*
Triangulum	*N*	*Triangle*
Triangulum Australe	*S*	*Southern Triangle*
Tucana	*S*	*Toucan*
Ursa Major	*N*	*Big Dipper*[2]
Ursa Minor	*N*	*Little Dipper*[3]
Vela	*S*	*Sail (of Argo)*[1]
Virgo	*Z*	*Virgin*
Volans	*S*	*Flying Fish*
Vulpecula	*N*	*Fox*

Some important constellation.

Orion


Thuban
Gianfar
Muscida
h UMa
Dubhe
Mizar
Mizar
Alioth
Megrez
υ UMa
Alkaid
Merak
Phecda
θ UMa
Ursa Major
Talitha
Talitha Australis
Al Kaphrah
ψ UMa
Tania Borealis
Tania Australis
Cor Caroli
38 Lyn
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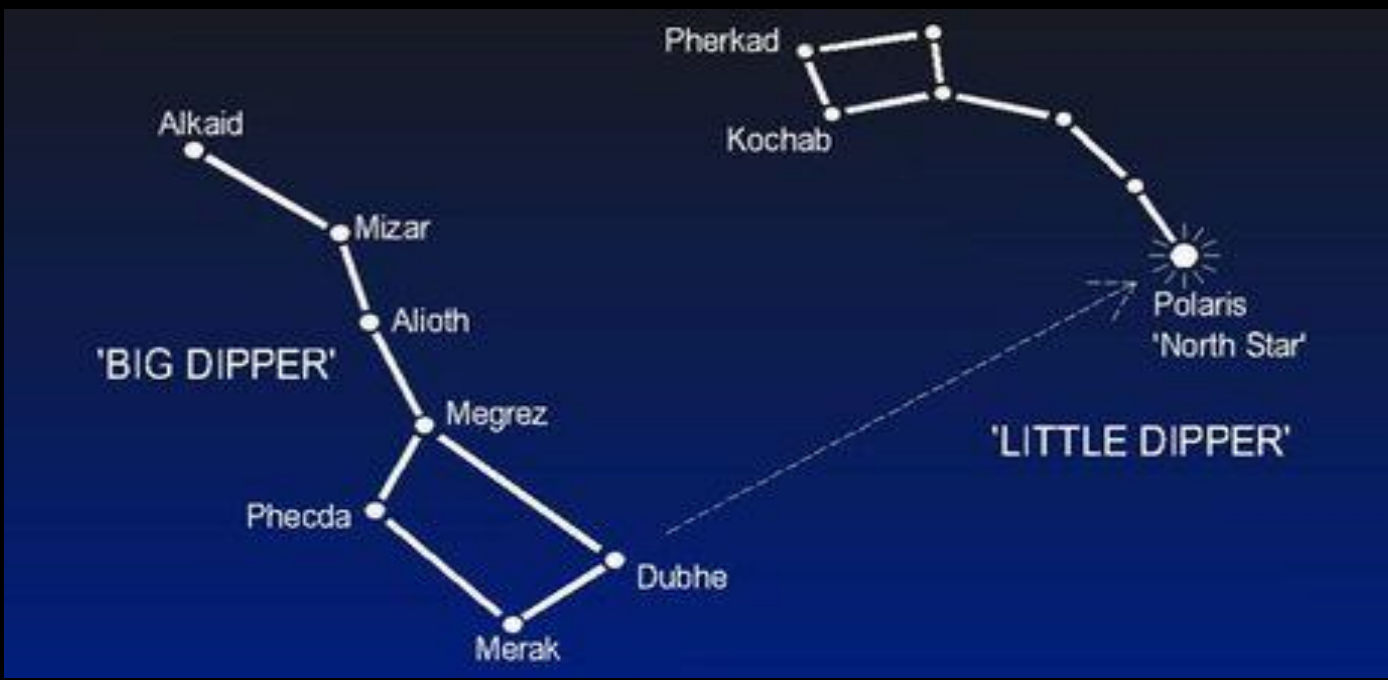
Usra Major


Polaris
(Alpha)
Yildun
(Delta)
Alifa al Farkadain
(Zeta)
Anwaw al
Farkadain
(Eta)
Kochab
(Beta)
Pherkad
(Gamma)
Ursa Minor


Pherkad
Kochab
Alkaid
Mizar
Alioth
'BIG DIPPER'
Megrez
Phecda
Dubhe
Merak
Polaris
'North Star'
'LITTLE DIPPER'

Usra Minor

Summer Triangle

Approximate Positions of the Planets, 2004–2019

Season	Venus	Mars	Jupiter	Saturn
Winter 2004	setting	southwest	rising	high southeast
Spring 2004	**setting**	low west	high south	west
Summer 2004	M	M	setting	•
Autumn 2004	M	•	•	M
Winter 2005	M	M	M	southeast
Spring 2005	•	M	southeast	west
Summer 2005	•	M	low southwest	•
Autumn 2005	**setting**	**east**	•	M
Winter 2006	**M**	high southwest	M	east
Spring 2006	M	west	southeast	southwest
Summer 2006	M	M	southwest	•
Autumn 2006	•	•	•	M
Winter 2007	•	M	M	east
Spring 2007	low west	M	M	high southwest
Summer 2007	setting	M	south	•
Autumn 2007	M	rising	setting	M
Winter 2008	M	high south	•	rising
Spring 2008	M	west	M	high south
Summer 2008	•	setting	low southeast	setting
Autumn 2008	•	•	low southwest	•
Winter 2009	**setting**	•	•	rising
Spring 2009	**M**	M	M	south
Summer 2009	M	M	rising	setting
Autumn 2009	M	M	southwest	•
Winter 2010	•	**east**	•	rising
Spring 2010	setting	high west	M	high south
Summer 2010	setting	setting	rising	setting
Autumn 2010	**M**	•	high south	•
Winter 2011	M	•	low west	rising
Spring 2011	M	M	•	south
Summer 2011	•	M	M	setting
Autumn 2011	setting	M	east	•
Winter 2012	setting	**east**	west	M
Spring 2012	**setting**	high west	•	south
Summer 2012	M	setting	M	setting
Autumn 2012	M	setting	east	•
Winter 2013	•	setting	high southwest	M
Spring 2013	•	•	setting	southeast
Summer 2013	**setting**	M	M	southwest
Autumn 2013	setting	M	low east	•
Winter 2014	**M**	M	high southeast	M
Spring 2014	M	south	west	southeast
Summer 2014	M	low west	•	southwest
Autumn 2014	•	setting	M	•
Winter 2015	setting	setting	east	M
Spring 2015	setting	•	west	rising
Summer 2015	•	•	•	southwest
Autumn 2015	M	M	M	•
Winter 2016	M	M	rising	M
Spring 2016	•	**low east**	high south	rising
Summer 2016	•	west	setting	southwest
Autumn 2016	setting	west	•	•
Winter 2017	setting	setting	M	•
Spring 2017	M	setting	southeast	M
Summer 2017	M	•	setting	south
Autumn 2017	M	M	•	setting
Winter 2018	•	M	M	•
Spring 2018	setting	M	low southeast	M
Summer 2018	setting	M	low southwest	south
Autumn 2018	•	M	•	setting
Winter 2019	M	•	M	M
Spring 2019	M	M	M	M
Summer 2019	•	**east**	low south	south
Autumn 2019	setting	southwest	setting	setting

When to See Mercury in the Evening Sky, 2004–2019

Look within about a week of the date shown …

29 March 2004	22 January 2008	5 March 2012	**18 April 2016**
27 July 2004	**14 May 2008**	1 July 2012	16 August 2016
21 November 2004	11 September 2008	26 October 2012	11 December 2016
12 March 2005	4 January 2009	16 February 2013	**1 April 2017**
9 July 2005	**26 April 2009**	12 June 2013	30 July 2017
3 November 2005	24 August 2009	9 October 2013	24 November 2017
	18 December 2009		
24 February 2006	**8 April 2010**	31 January 2014	15 March 2018
20 June 2006	7 August 2010	**25 May 2014**	12 July 2018
17 October 2006	1 December 2010	21 September 2014	6 November 2018
7 February 2007	23 March 2011	14 January 2015	27 February 2019
2 June 2007	20 July 2011	**7 May 2015**	23 June 2019
29 September 2007	14 November 2011	4 September 2015	20 October 2019
		29 December 2015	

How to Use the Tables

*To see whether **Venus**, **Mars**, **Jupiter**, or **Saturn** will be visible during the evening, use the table on the left. Find the season and the year when you will be observing. The rough position of the planet in question, during the evening hours of that season, is listed in the table.*

If the entry in the table says "M" the planet will not be visible during the evening for most of this season, but instead can be found during the early morning hours, to the east or southeast. If a black dot ("•") is listed, then the planet is too close to the Sun to be easily seen at any time during the night. The planets, and the sky, change slowly during the seasons, so this table serves only as a rough guide. For example, during the last month of a season where a planet is marked as visible to the west, it may actually already be too close to the Sun to be seen.

The seasons when Venus is a large crescent, and Mars is closest to us, are indicated in boldface.

*Though **Mars** can be visible for several seasons at a time, it is at its best within a month or two of "opposition", when it is in the direction opposite the Sun and relatively close to Earth. The months of opposition are given in the table to the right, along with how big and bright Mars will appear.*

***Mercury** moves too quickly for a table like the one on the left to be useful. Instead, consult the table above. Within a week of the dates given above, Mercury will be visible as a moderately bright star low on the western horizon, just before sunset. About six weeks after these dates, it is visible in the east just before sunrise. The dates in boldface (late spring) offer the best viewing for observers in the northern hemisphere, with Mercury sitting nearly 20° above the horizon at sunset.*

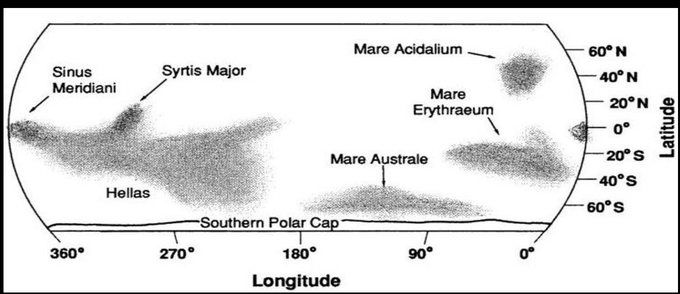
Oppositions of Mars, 2003–2020

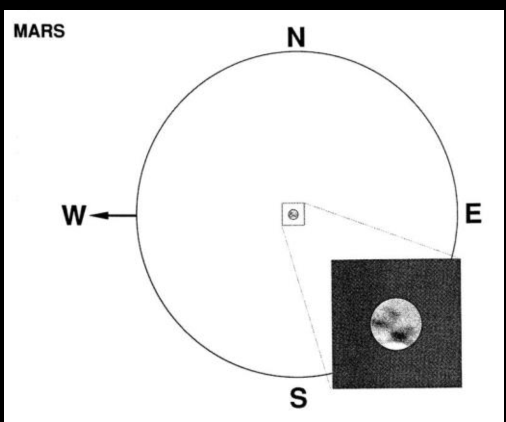
Date	Size (arc seconds)	Magnitude
August 2003	25	–2.4
November 2005	20	–1.8
December 2007	16	–1.1
January 2010	14	–0.8
March 2012	14	–0.8
April 2014	15	–1.0
May 2016	18	–1.5
July 2018	24	–2.3
October 2020	23	–2.2

Venus and Mercury

Venus is the brightest planet. Depending on where it is in its orbit, its magnitude ranges from about –3 to as bright as –4.4. It is an absolutely dazzling spot of light, yellow in colour; when it's up, it is the brightest dot in the sky. By contrast, Mercury is several magnitudes fainter, and far more elusive. Venus and Mercury orbit between the Earth and Sun, and so from our vantage point they always appears to be in the same general direction as the Sun. That means that whenever either is visible in the evenings, it will be near the western horizon, following the setting Sun. Mercury sets soon after sunset, and you generally won't be able to observe Venus easily for more than about two hours past sunset.

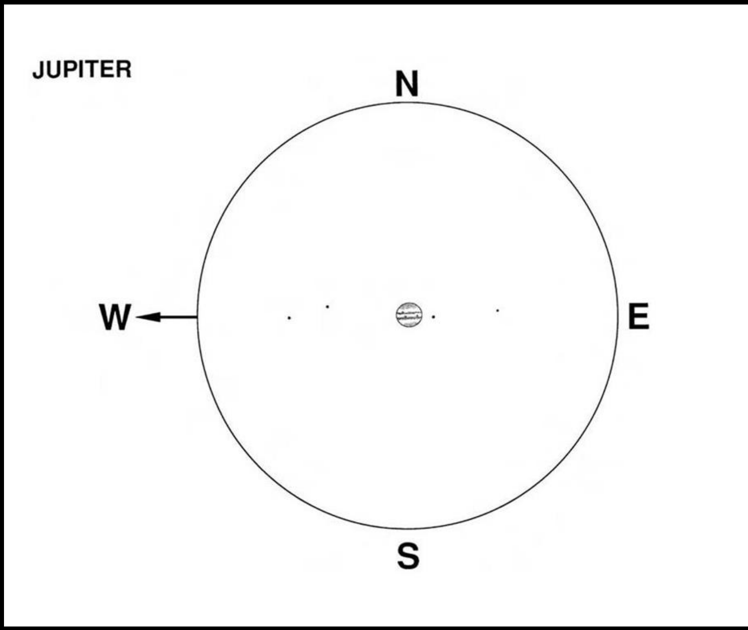
Mars



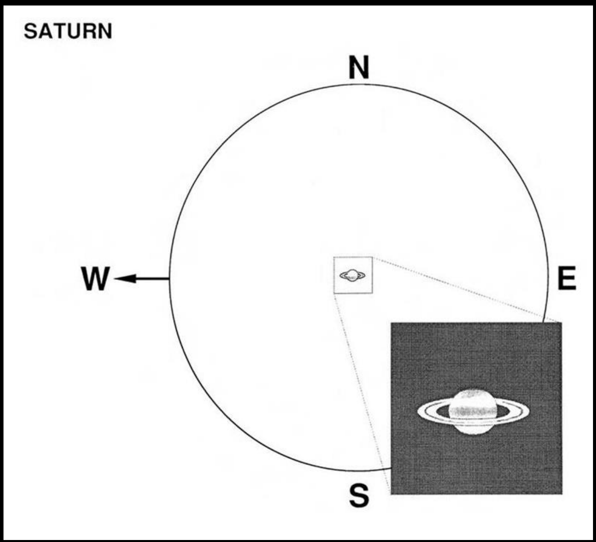


During oppositions, Mars comes close enough for considerable detail to be seen on its surface, even with a small telescope. The sketch map to the right is based on observations made with a 2.4" refractor during the very favourable 1971 opposition. This is a map of the entire surface of Mars, so only half is visible at any given time.
To find out the longitude of the part of Mars facing the Earth when you plan to stargaze, consult an astronomical almanac

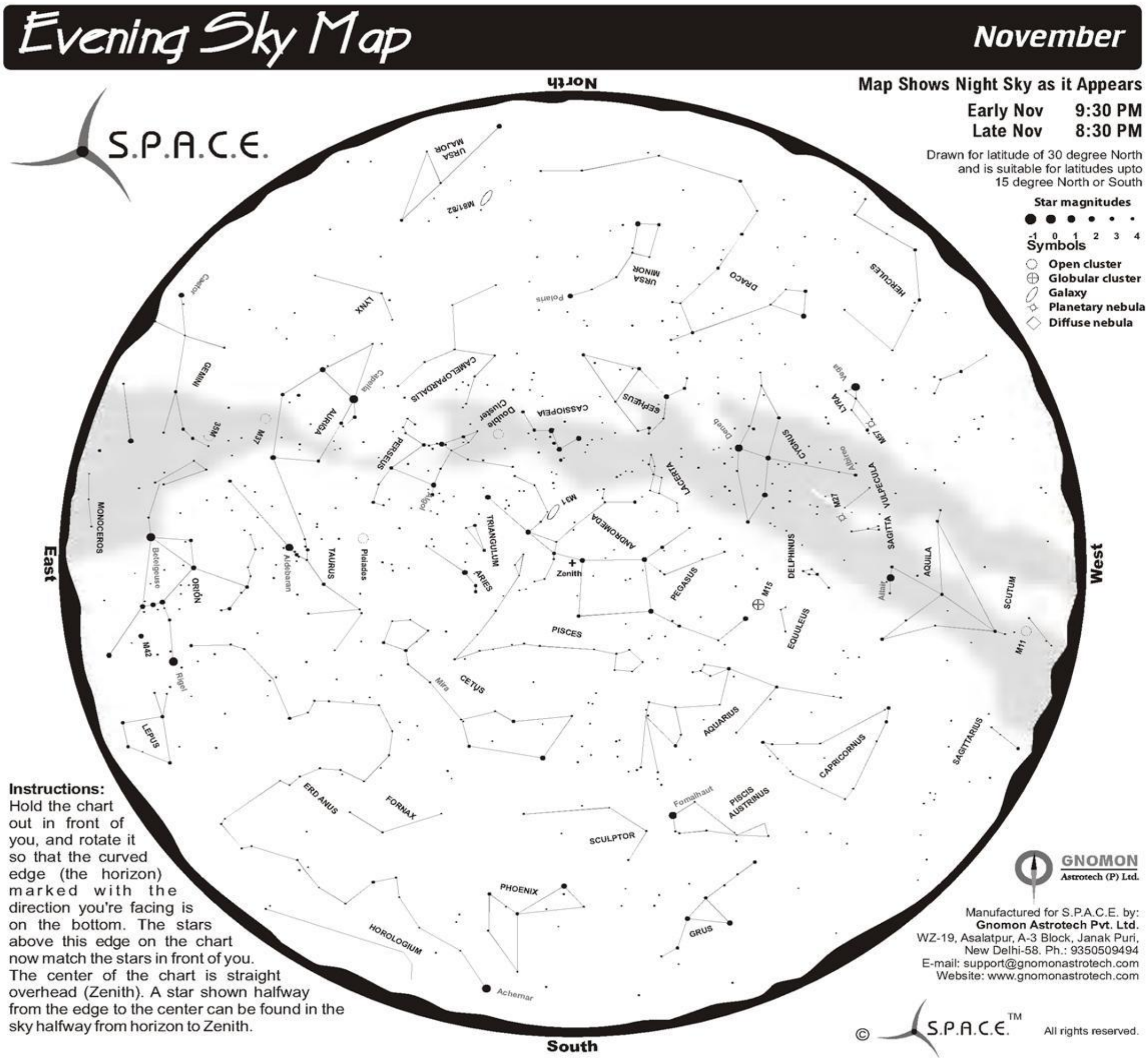
Jupiter



Saturn



Observer's note: Watch for the changing of the rings. They were at their widest in 2003, with the ring shadows and narrow Cassini division at their best visibility. From 2008 to 2011 the rings are at their shallowest angle to us; that's the best time to look for Saturn's smaller moons. The rings will be nearly edge-on, and thus disappear from our sight, in December, 2008; September, 2009; and June, 2010. Then in late 2017 they return to their widest, most visible aspect again.



Evening Sky Map
November
North
Map Shows Night Sky as it Appears
Early Nov 9:30 PM
Late Nov 8:30 PM
Drawn for latitude of 30 degree North and is suitable for latitudes upto 15 degree North or South
Star magnitudes
-1 0 1 2 3 4
Symbols
Open cluster
Globular cluster
Galaxy
Planetary nebula
Diffuse nebula
S.P.A.C.E.
URSA MAJOR
URSA MINOR
Polaris
DRACO
HERCULES
LYNX
CAMELOPARDALIS
CASSIOPEIA
CEPHEUS
LYRA
Vega
CYGNUS
Deneb
GEMINI
Castor
AURIGA
Capella
PERSEUS
Double Cluster
LACERTA
VULPECULA
SAGITTA
MONOCEROS
TAURUS
Aldebaran
Pleiades
TRIANGULUM
ANDROMEDA
M31
Zenith
PEGASUS
DELPHINUS
AQUILA
Altair
SCUTUM
M11
East
West
Betelgeuse
ORION
M42
Rigel
ARIES
PISCES
M15
EQUULEUS
CETUS
Mira
LEPUS
AQUARIUS
CAPRICORNUS
SAGITTARIUS
ERIDANUS
FORNAX
SCULPTOR
PISCIS AUSTRINUS
Fomalhaut
PHOENIX
HOROLOGIUM
GRUS
Achernar
South
Instructions:
Hold the chart out in front of you, and rotate it so that the curved edge (the horizon) marked with the direction you're facing is on the bottom. The stars above this edge on the chart now match the stars in front of you. The center of the chart is straight overhead (Zenith). A star shown halfway from the edge to the center can be found in the sky halfway from horizon to Zenith.
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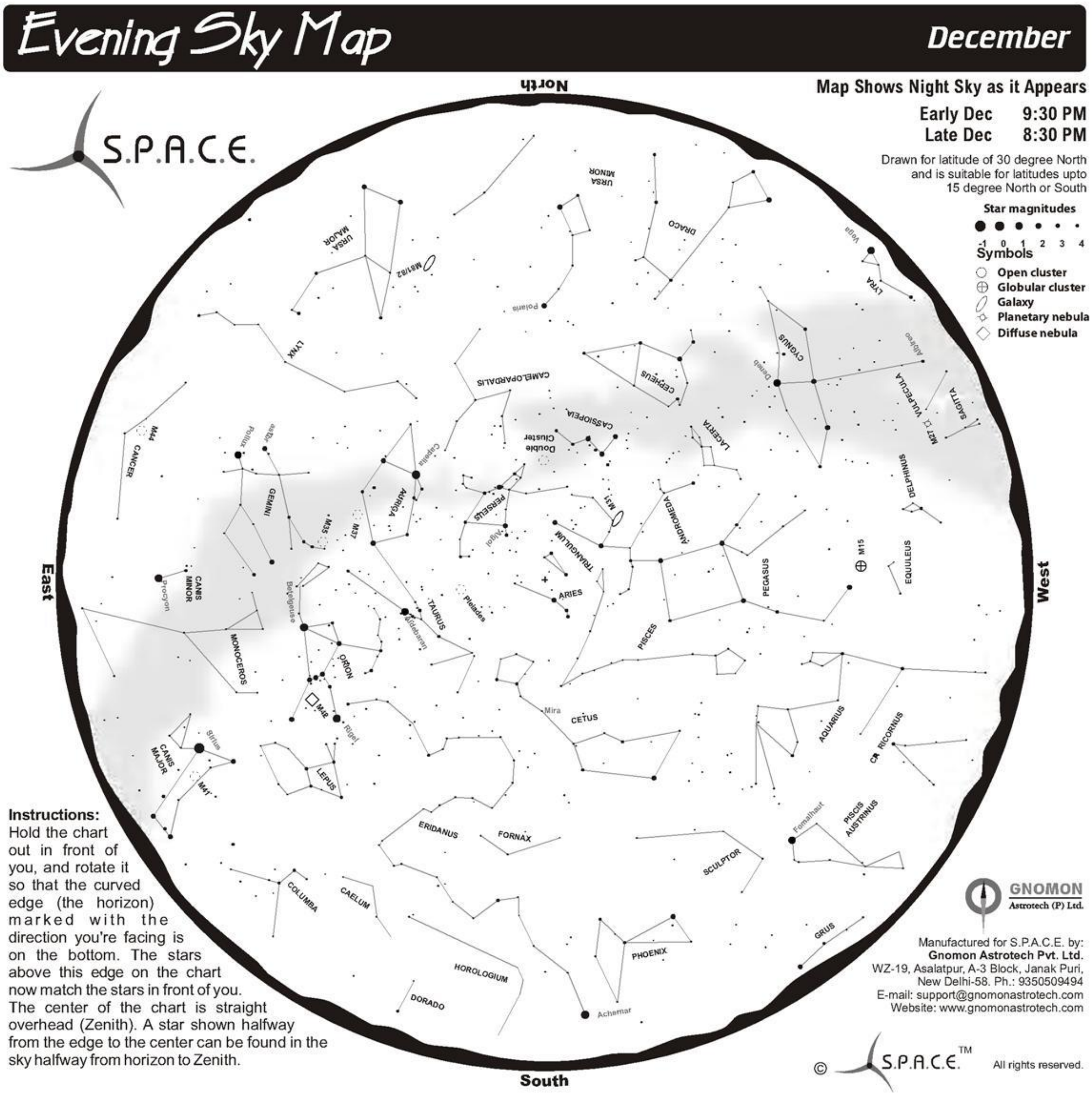

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By Trinesh Sana (2nd year)

The universe is a pretty amazing place from the unimaginably large, right down to the incredibly small. Let's take a look at some this awe-inspiring matter now.

A Human body, or any object on the Earth, is never at rest. Even when you are asleep in bed, you are moving pretty fast. Our 'Milky Way' Galaxy is rotating at 225 kilometers per second and hurling through the cosmos at an estimated 305 kilometers per second. Add those figures together we are racing through space at around 530 kilometers per second. So in a one minute time you are traveled almost 20,000 kilometers, or more than 12,000 miles but your friends always complain that you never goes anywhere.

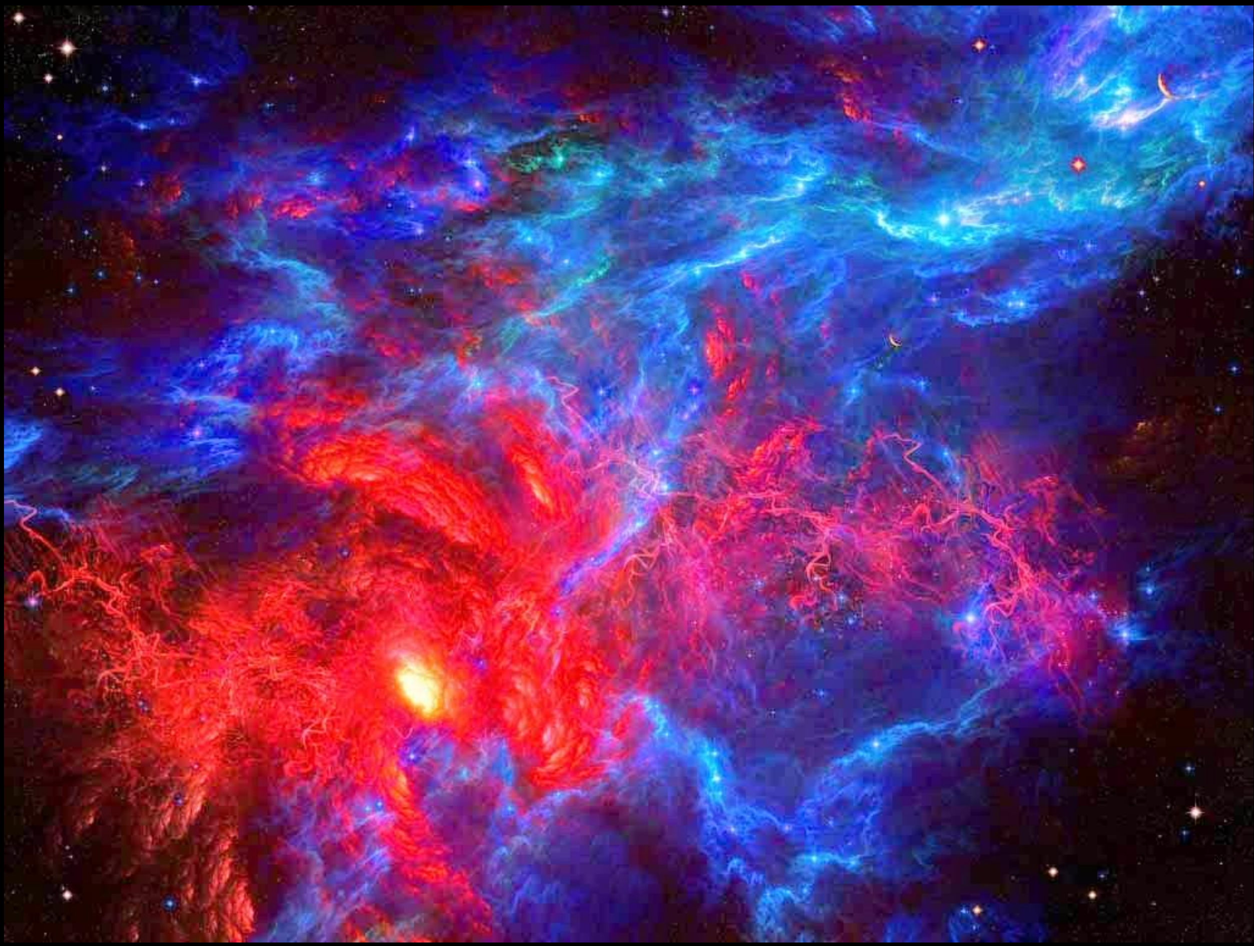
Is there any idea about the number of stars in the universe? The number of star in the universe is at least 10 Billion Trillion. That is a very big number. When you really think about it, 10 billion trillion stars makes the cult of the sun worship seem a little obsolete, although our star, the Sun, is very important to us. Without it, life on earth would not be possible.

Let's put 10 billion trillion stars into perspective, shall we? For those of you who know a bit of math that would be 10 to the power of 22 stars. There are probably more stars in existence than grains of sand on all of the world's beaches. If only 1% of those stars had Earth-like planets, the universe would literally be teeming with life.

Let's know how the universe created. The earliest scientific models of universe were developed by Greek and Indian philosophers and were geocentric, placing the Earth at the center of the universe. Over the centuries, more precise astronomical observation led Nicolas Copernicus to develop the heliocentric model with the Sun at the center of the solar system. In developing the law of gravitation, Sir Isaac Newton built upon Copernicus's work as observations by Kepler's laws of planetary motion. Further observational improvements led to the realization that our Solar system is located in the Milky Way galaxy and is one of many solar systems and galaxies.

It is assumed that galaxies are distributed uniformly and the same in all directions, meaning that the universe has neither an edge nor a center. Discoveries in the early 20th century have suggested that the Universe had a beginning and that it is expanding at an increasing rate. The majority of mass in the Universe appears to exist in an unknown form called 'Dark Matter'.

The 'BIG BANG THEORY', the prevailing model describing the development of the Universe, states that space and time were created in the Big Bang and were given a fixed amount of energy and matter that becomes less dense as space expands.

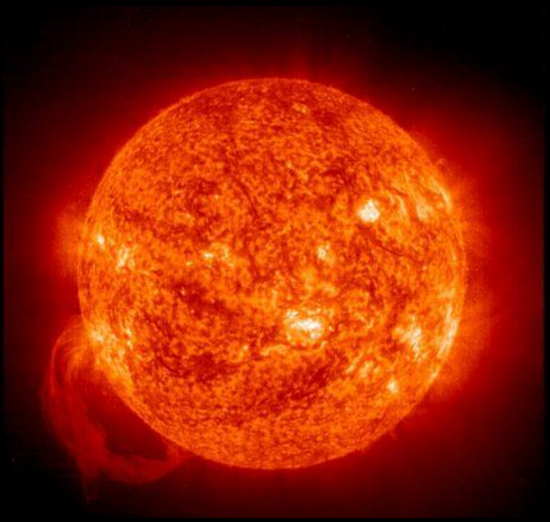


After the initial expansion, the Universe cooled, allowing subatomic particles to form and then simple atoms. Giant molecules later merged through gravity to form stars.

Assuming that the Standard model of the BIG BANG THEORY is correct, the age of the Universe is measured to be 13.8 Billion years approximately.

Since Sun is most important star to us, let's know something about the Sun.

The Sun is the star at the center of the solar system. It is a nearly perfect sphere of hot Plasma. It is by far the most important source of energy for life on the Earth. Its diameter is about 109 times of Eartg and its mass is about 330,000 times of the earth, accounting for about 99.86% of the total mass of the solar system. About three quaters of the Sun's mass consists of hydrogen, the rest is mostly helium, with smaller quantities of heavier elements includeing oxygen,carbon,neon and iron.



The Sun is roughly middled-aged. It formed approximately 4.6 billion years ago from the gravitational collapse of matter within a region of a large molecular cloud. Most of the matter gathered in the center. The central mass becomes so hot and dense that it eventually initiated nuclear fusion at its core. It is thought that almost all stars form by this process.

The sun has not changed dramatically for more than 4 billion years and will remain fairly stable for more than another 5 billion years. After hydrogen fusion in its core stopped, the sun will undergo severe changes and becomes a red giant. It is calculated that the Sun will become sufficient large to engulf the current orbits of Mercury, Venus and possibly Earth.

Picture: Artist's depiction of the life cycle of a Sun-like star, starting as a main-sequence star at lower left then expanding through the sub-giant and giant phases until its outer envelope is expelled to form a planetary nebula at upper right.

So what happens after death of a Star???

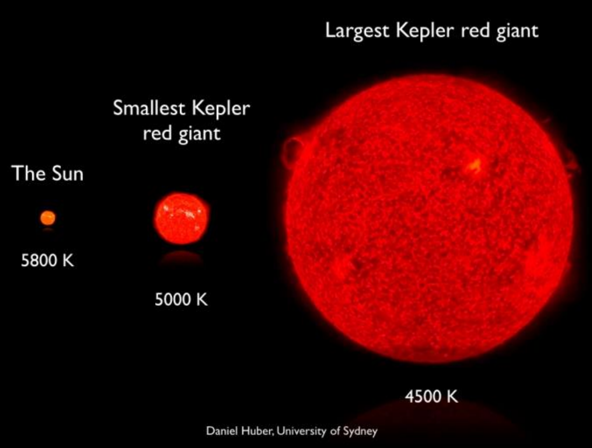
You may easily replies that the star converts into red giant...but the answer is not too easy. To know exact what happens after the death of a star, we must know the 'Stellar Evolution'.

Stellar evolution is the process by which a star the process by which a star changes over the course of time. Depending on the mass of the star, its lifetime can range from a few million years for the most massive to trillion of years for the least massive, which is considerably longer than the age of the universe.

All stars are born from collapsing clouds of gas and dust, often called nebulae or molecular clouds. Over the course of millions of years, these 'protostar' settle down into a state of equilibrium, becoming what is known as a 'main-sequence' star.

Mass (solar masses)	Time (years)	Spectral type
60	3 million	O3
30	11 million	O7
10	32 million	B4
3	370 million	A5
1.5	3 billion	F5
1	10 billion	G2 (Sun)
0.1	1000s billions	M7

'Nuclear fusion' power a star for most of life. Initially the energy is generated by the fusion of hydrogen atoms at the core of the 'main-sequence' star. Later as the preponderance of atoms at the core becomes helium, star like the sun begin to fuse hydrogen along a spherical shell surrounding the core. This process cause the star to gradually grow in size, passing through the 'sub-giant'



stage until it reaches the 'red-giant' phase. Star with at least half the mass of the Sun can also begin to generate energy through the fusion of helium at their core, whereas more massive stars can fuse heavier elements along a series of concentric shells. Once a star like Sun exhausted its nuclear fuel, its core collapses into a dense white dwarf and the outer layer are expelled as a planetary nebula. Stars with around ten or more times the mass of the Sun can explode in a supernova as their inert iron cores collapse into an extremely dense 'neutron star' or 'black hole'.

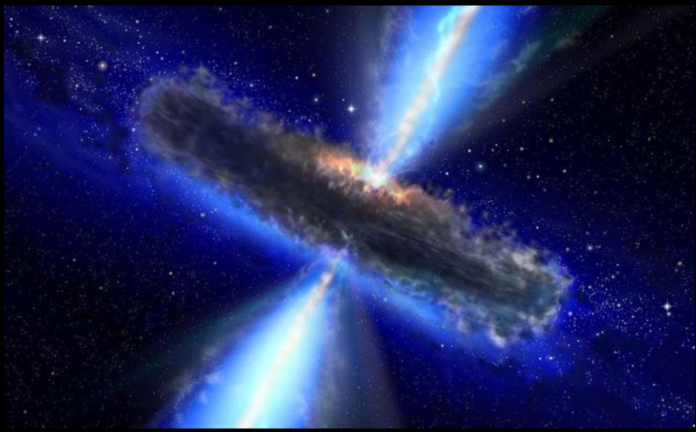
Although the universe is not old enough for any of the smallest 'red dwarfs' to have reached the end of the lives, stellar models suggest they will slowly become brighter and hotter before running out of hydrogen fuel becoming low-mass white dwarf.

Black Hole, White Hole and Worm Whole

A black hole is a region of space-time exhibiting such strong gravitational effects that nothing- not even particles and electromagnetic radiation such as light- can escape from inside it. The theory of general relativity predicts that a sufficiently compact mass can deform space-time to form a black hole.

The boundary of the region from which no escape is possible is called 'event horizon'. In many ways a black hole acts like an ideal black body as it reflects no light. The event horizon emit Hawking radiation, with the same spectrum as a black body of a temperature inversely proportional to its mass.

Black holes of stellar mass are expected to form when very massive star collapse at the end of their life cycle. After a black hole has formed, it can continue to grow by absorbing mass from its surroundings. By absorbing other star and merging with other black holes, super-massive black holes of millions of solar masses may form. there is general consensus that super-massive black holes exist in the centers of most galaxies.



End of a black hole:

As long as it has material 'feed' on, a black hole will continue to grow. The process accreting material release enormous amount of energy, which can be blow away some of the surrounding matter, so a black hole may in this sense regulate its own growth. As for the ultimate fate of black holes, some scientist have speculated that in the far distant future after all the stars have burned out, elementary particles have decayed into neutrinos and gamma rays, black holes will eventually evaporate by the Hawking process. The time for this process is huge, being about a 100 trillion octillion yotta-years or 1 followed by 65 zeroes, for a 10 solar mass black hole, and a quintillion times longer than that for a 10 million solar mass black hole.

So what happens when the black hole dies??? Is it end of the universe or beginning of new one...!?

If a black hole resembles a one-way portal to oblivion would there be any way to enter that portal from other end and travel in the opposite direction? Theoretically this thought should make perfect sense- since General Relativity and Newtonian physics are time-symmetric concepts. And this opposing gateway is a theoretical concept, known as a White Hole. White Hole may be concerned the time reversed equivalent of a black hole.

A White hole is a hypothetical region of space-time which cannot be entered from the outside although matter and the light can escape from it. In this sense it is the reverse of a black hole, which can only be entered from the outside and from which matter and light cannot escape. White holes appear in the theory of the eternal black holes. In addition to a black hole region in the future, such of the Einstein field equation has a white hole region in its past.

However the region does not exist for black holes that have formed through gravitational collapse, not are there any known physical processes through which a white holes could be formed.

No white hole has been observed also, the 2nd laws of thermodynamics say that the net entropy in the universe can either increase or remain constant. This rule is violated by white holes, as they tends to decrease entropy.

But some scientist still believes that white holes exist.

The Creation of White Holes:

Most black holes are formed when stars collapse in a supernova explosion. However it has been suggested that black holes and their lives by transforming into white holes - which explosively pour out the information that had been swallowed by the black holes. This model is developed by the Carlo Rovelli and Hal Haggard from Aix-Marseille University .

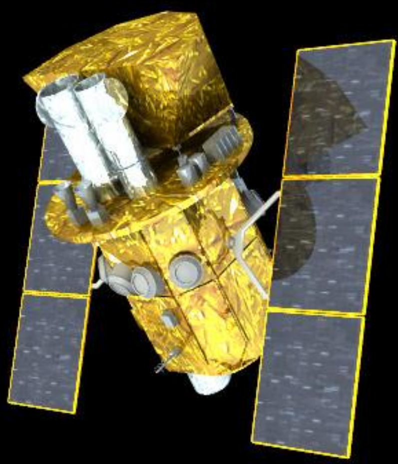
As a black hole is formed, it is shielded by event horizon, however at one point, the star that is collapsing under its own gravity will reach a point beyond which it cannot shrink any further. At this moment, it experience an outward pressure called quantum bounce - which transform a black hole into a white hole. As concluded by the calculations of the team, the transformation should be instantaneous. However, it would seem like black holes exist for billions of years due to their intense gravitational pull, which makes time appear to go slower to an observer.

White Holes and the BIG BANG:

Most of us have a rough idea about the Big Bang Theory, approximately 13.8 Billion year ago, the matter in the universe was compressed into a single, infinitesimally small point. This point then enlarged in a heated explosion, and is still expanding today. There is a great amount of evidence to buttress this theory, which includes the observation that all the galaxy are moving away from us.

Now, the question about the proof of the existence of white holes...right?

The answer of that question was not found before June 14, 2006. White holes ceased to become complete theory after an unforgettable discovery on June 14, 2006. On this day an extraordinarily powerful gamma-ray burst was sighted by the Swift Satellite (of NASA), this phenomenon was called GRB 060614. However, this gamma-ray burst did not fit into the normal category or are commonly linked with supernovae.

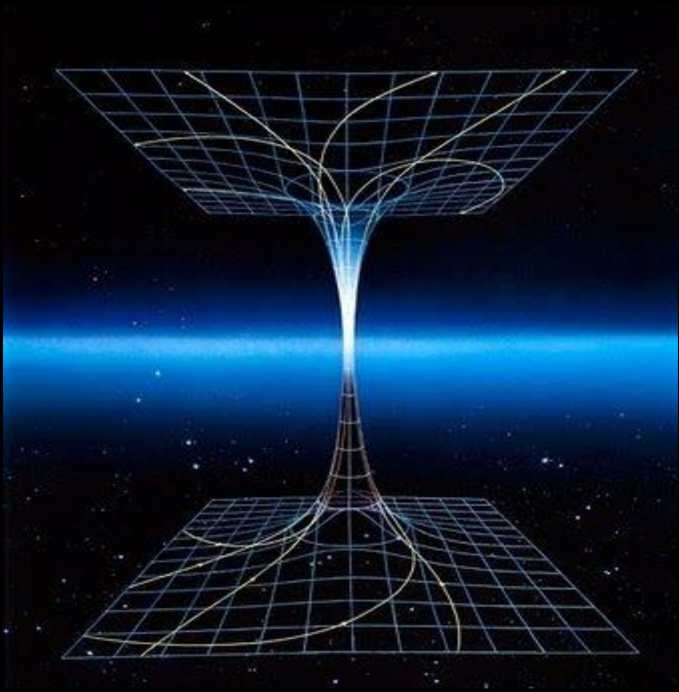


Moreover, whereas typical gamma-ray burst last for only a few seconds, the one detected in June 2006 had lasted for a remarkable 102 seconds, and trillions of times more powerful than our own star! And since this sudden massive burst did not originate from a supernova, astronomers and astrophysicists could only conclude that it had emerged from white hole.

The features of the 2006 gamma-ray burst perfectly matched with the little knowledge humans have about white holes, i.e. the spewing out of a huge amount of matter in a few minutes, before disappearing into oblivion. Certainly the occurrence of this astonishing phenomenon does not confirm the existence of a white hole, but it does lead to some interesting speculation.

Black Holes, White Holes and Worm Holes:

Amazingly enough, it has been speculated that there is a white hole at the other end of a black hole: so the matter and information that have been swallowed by the black hole are ejected by the white hole into an alternative universe. Ludwig Flamm, an Austrian physicist, also suggested that these two region in space-time could be connected by a space-time conduit, and that the black hole 'entrance' and white hole 'exit' could be located in two entirely different universes. This speculations were so intriguing that Einstein and Nathan Rosen further built upon these ideas, finally reaching at a solution in 1935 known as the Einstein-Rosen bridge.

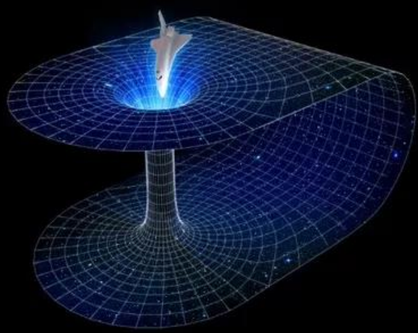


A worm hole may be defined as a hypothetical area of warped space-time with enough energy to create tunnels through the fabric of space-time.

The possibilities of Time Travel:

Could the existence and concept of the white holes lead to advance in the field of time travel?

It has been speculated that in some special cases a worm hole (or Einstein-Rosen bridge), rather than connecting two points in space, could connect two points in time. Hence a body failing into black hole could travel through a worm hole, be ejected by the white hole, and land up in another region of space-time. However there are several flaws with this idea namely worm hole is so unstable that it would immediately collapse upon itself and that anybody entering a black hole would be ripped apart by the tremendous gravitational forces.



Pabitra Kumar Hazra

Introduction

In little more than a generation, the launching of a satellite has gone from stopping the nation's business to guaranteeing that it runs like clockwork. Today, satellites, like clocks, telephones, and computers, are commonplace tools of technology. They help us navigate, communicate, monitor the environment, and forecast weather. Appropriately, the word satellite means an "attendant.

In 1957, the launching of the Russian satellite Sputnik changed the course of our nation. The United States immediately launched massive efforts to compete in a breakneck Race to the Moon. In the space of a decade, our nation of armchair explorers sat glued to their television sets while Alan Shepard went up and back in a Mercury capsule in 1961, as John Glenn circled the globe 3 times in 1962, and as Neil Armstrong set foot on the moon in 1969.
That sense of discovery has muted over time as we became accustomed to the miracles of space travel. The launching of a Space Shuttle mission may not even come up in a class discussion of current events, yet satellites bring those same students the ability to watch the Olympics, the weather, and news of other events from around the world that are considered "newsworthy."

What is a satellite?

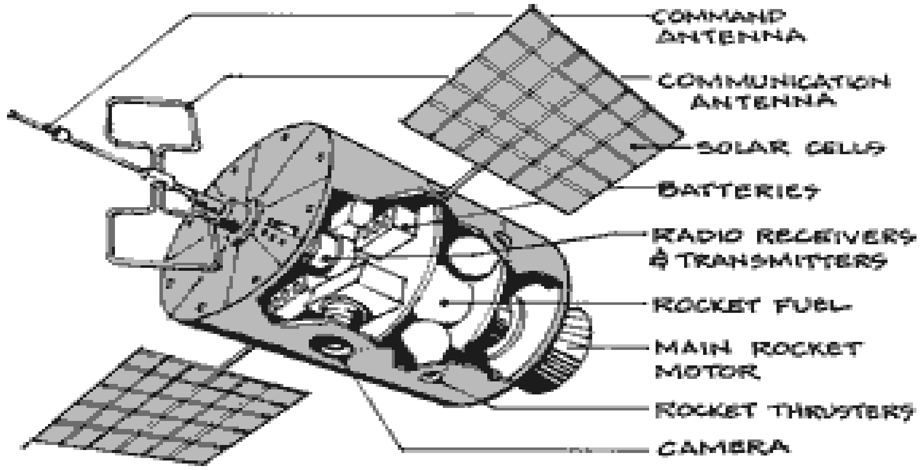
A satellite is an object that goes around, or orbits, a larger object, such as a planet. While there are natural satellites, like the moon, hundreds of man-made satellites also orbit the Earth.

What are the components of a human-made satellite?

- communication capabilities with Earth
- a power source
- a control system to accomplish its mission

Communications antennae, radio receivers and transmitters enable the satellite to communicate with one or more ground stations, called command centers. Messages sent to the satellite from a ground station are "uplinked"; messages transmitted from the satellite to Earth are "downlinked."
Many satellites are powered by rechargeable batteries, taking advantage of the ultimate battery charger, the sun. Silvery solar panels are prominent features on many satellites. Other satellites have fuel cells that convert chemical energy to electrical energy, while a few rely on nuclear energy. Small thrusters provide attitude, altitude, and propulsion control to modify and stabilize the satellite's position in space.
Specialized systems accomplish the tasks assigned to the satellite. These often include sensors capable of imaging a range of wavelengths. Telecommunications satellites require no optics, while environmental satellites do. Environmental satellites transmit images as numbers to a computer on Earth, which translates this digital data into images.
Some of the data can be enhanced to look like photographs. Bright colors (false colors) are often added to enhance the contrast, make details stand out, or allow us to see what was recorded in the wavelengths beyond our visual range. The false colors do not necessarily correspond to the

colors we expect to see. For example, a field of wheat might look pink; clear water may appear black.

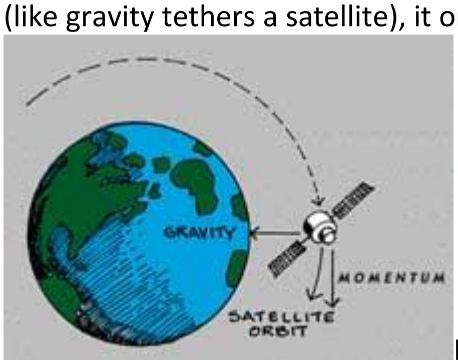


How are satellites launched?

The trick to launching a satellite is getting it high enough to do its job without losing the capsule to outer space. It's a delicate balance of push and pull, accomplished by the inertia of the moving object and the Earth's gravity. If you launch a satellite at 17,000 mph, the forward momentum will balance gravity, and it will circle the Earth. On the other hand, if the satellite is launched faster than 23,500 mph, it will leave the gravitational pull of the Earth.

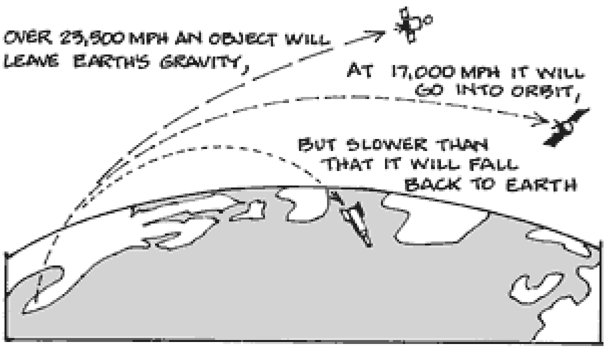
Why does a satellite stay in orbit?

Due to the balance of two effects:
(1) velocity, or the speed at which it would travel in a straight line,
(2) the gravitational pull between the Earth and the satellite.
To illustrate this principle, attach a small weight or a ball to a string, and swing it around in a circle. If the string were to break, the ball would fly off in a straight line. But because it is tethered (like gravity tethers a satellite), it orbits your hand.

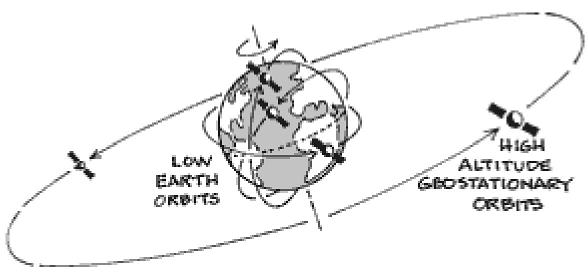


Imagine that you could climb an imaginary mountain whose summit pokes above the Earth's atmosphere (it would be about ten times higher than Mt. Everest). If you threw a baseball from the mountain top, it would fall to the ground in a curving path. Two motions act upon it: travelling in a straight line and falling toward Earth. The faster you throw the ball, the farther it will go before it hits the ground. If you could throw the ball at a speed of 17,000 mph, the ball wouldn't reach the ground. It would circle the Earth in a curved path; it would be in orbit. (It would be traveling at 5 miles per second and take about 10 minutes to cross the United States.) This is the speed needed to put satellites into orbit, which is why the Space Shuttle and other satellites require such powerful boosters.

Orbits



Human-made satellites circle the Earth in two special ways: polar orbits and geostationary orbits. A satellite in a polar orbit travels over the North and South Poles. A polar orbit may be several hundred miles to several thousand miles above Earth. A satellite in a relatively low orbit circles the Earth approximately 14 times each day, while higher-orbiting satellites orbit less frequently. Because the Earth is turning more slowly than the satellite, the satellite gets a slightly different view on every revolution. Over the course of a few days, a satellite in a polar orbit will cover almost all of the planet.



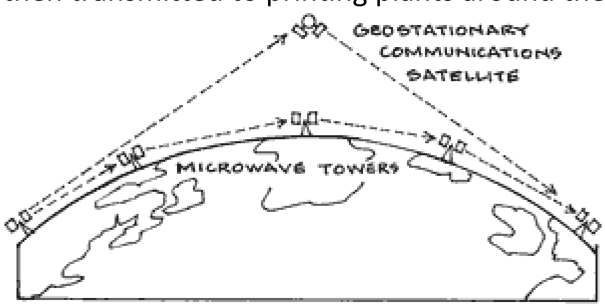
A satellite in a high-altitude, geostationary orbit circles the Earth once every 24 hours, the same amount of time it takes for the Earth to spin on its axis. The satellite turns eastward (like our Earth) along the Equator. It stays above the same point on Earth all the time. To maintain the same rotational period as the Earth, a satellite in geostationary orbit must be 22,237 miles above the Earth. At this distance, the satellite can view half of the Earth's surface. (Its viewing area is called its "footprint.") Because the high-altitude satellite appears to remain fixed in one position (it's really orbiting at the same rate as the Earth turns), it requires no tracking to receive its downlink signal. That is why when we turn our home satellite dish to receive the TV signal from a particular geostationary satellite, we don't have to keep jumping up to adjust its position.
One of the advantages of geostationary satellites is that imagery is obtained and displayed constantly, compared to imagery transmitted more sporadically by low Earth-orbiting platforms. Most satellites serve one or more functions:

- Communications
- Navigation

- Weather Forecasting
- Environmental Monitoring
- Manned Platforms

Communications Satellites:

Communications satellites have a quiet, yet profound, effect on our daily lives. They link remote areas of the Earth with telephone and television. Modern financial business is conducted at high speed via satellite. Newspapers such as USA Today and The Wall Street Journal are typeset and then transmitted to printing plants around the country via satellite.



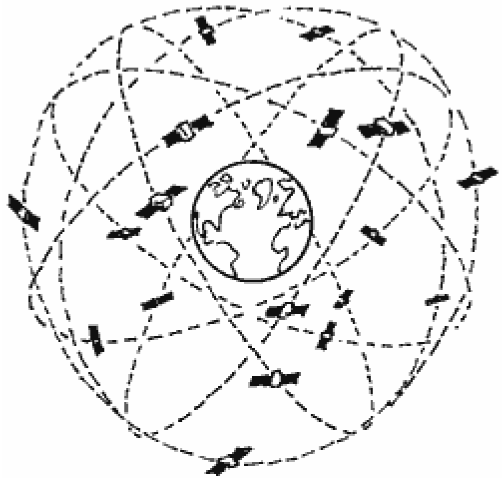
Radio signals near the microwave frequency range are best suited to carry large volumes of communications traffic, because they are not deflected by the Earth's atmosphere as lower frequencies are. Basically, they travel in a straight line, known as "line-of-sight communication." If someone in San Francisco tried to beam a microwave signal directly to Hawaii, it would never get there; it would disappear into space or dissipate into the ocean. Over short distances, we erect microwave towers every 25 miles or so to act as "repeaters" to repeat and boost the signal. Think of a geostationary communications satellite as a repeater in the sky.

Navigation Satellites

here am I? Where do I want to go? How can I get there? These are questions we've all asked at one time or another. Satellites for navigation were developed in the late 1950s as a direct result of surface ships and submarines needing to know exactly where they were at any given time. In the middle of the ocean out of sight of land, one can't determine an accurate position by looking out the window.

The idea of using satellites for navigation began with the launch of Sputnik 1 on October 4, 1957. Monitoring that satellite, scientists at Johns Hopkins University's Applied Physics Laboratory noticed that when the transmitted radio frequency was plotted on a graph, a curve characteristic of the Doppler shift appeared. By studying this apparent change of radio frequency as the satellite passed overhead, they were able to show that the Doppler shift, when properly used, described the orbit of the satellite.

Most navigation systems use time and distance to calculate location. Early on, scientists recognized the principle that, given velocity and the time required for a radio signal to be transmitted between two points, the distance between the two points can be computed. To do this calculation, a precise, synchronized departure time and measured arrival time of the radio signal must be obtained. By synchronizing the signal transmission time between two precise clocks, one in a satellite and one at a ground-based receiver, the transit time could be measured and then multiplied by the speed of light to obtain the distance between the two positions.



This three-dimensional satellite navigational system (NAVSTAR) enables a traveler to obtain his or her position anywhere on or above the planet. Data transmitted from the satellite provides the user with time, precise orbital position of the satellite, and the position of other satellites in the system. Currently, there is a full constellation of 24 orbiting satellites devoted to navigation. Using a commercial Global Positioning System (GPS) locator, the user can calculate distance by measuring the time it takes for the satellite's radio transmissions, traveling at the speed of light, to reach the receiver. Once distance from four satellites is known, position in three dimensions (latitude, longitude, and altitude) can be calculated by triangulation, and velocity in three dimensions can be computed from the Doppler shift in the received signal. The new GPS receivers do all of the work; a traveler simply turns on the unit, makes certain that it's locked onto at least four satellites, and the precise position of the GPS unit is displayed automatically. One innovative application of GPS technology is to determine Earth's ground movement after an earthquake. Referencing a network of these sensitive receivers can lead to a remarkably accurate assessment of plate movement.

There are two available radio signals that GPS receivers can use: the Standard Positioning Service (SPS) for civilians, and the Precise Positioning Service (PPS) for military and other authorized personnel. The most significant cause of errors in positioning is the deliberate effort by the

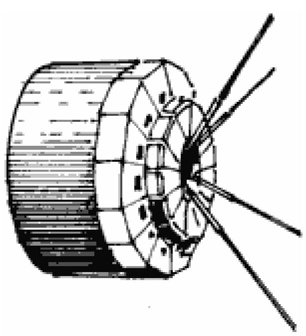
Department of Defense to decrease the accuracy of user systems for national security reasons. Selective Availability (SA) refers to the purposeful degradation of the information broadcast by the satellites. SA affects the accuracy of the SPS, but not PPS. With SA, a GPS system will be accurate 95% of the time to within 328 feet (100 meters) horizontally and 512 feet (156 meters) vertically.

For those who require positions with higher accuracy, Differential Global Positioning Systems (DGPS) add a new element to GPS. DGPS places a GPS stationary receiver at a known location on or near the Earth's surface. This reference station receives satellite signals and adjusts for transmission delays and Selective Availability, using its own known latitude, longitude, and altitude. The stationary receiver sends out a correction message for any suitably-equipped local receiver. A DGPS-compatible receiver adjusts its position calculations using the correction message. DGPS reference stations are constructed, operated, and maintained by the United States Coast Guard.

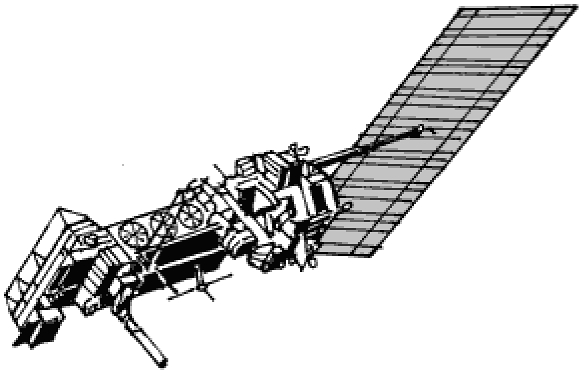
Weather Satellites

Weather satellites have been our eyes in the sky for more than 30 years, since the April, 1960 launch of Tiros I. Today, satellite images showing the advance of weather fronts are regular elements of the evening news. This meteorological information is also available to anyone with a personal computer. A network of American, European, Japanese, and Russian satellites orbits the Earth in various configurations to provide "real-time" monitoring of our environment. Many of these satellites transmit signals directly to ground stations in schools, including the Frank H. Harrison Middle School in Yarmouth, Maine, and Wiscasset Primary School in Wiscasset, Maine. Highly-trained technicians, like Georgie Thompson's second-grade students, operate the controls of such a station. They are able to predict when the satellites will be overhead, when they can expect to receive an image, and they can loop together several images of cloud conditions and movements from different passes of the satellites to make reliable weather predictions. Any school can establish such a ground station at a surprisingly low cost.

Polar Orbiting Satellites



TIROS polar orbiting satellites (NOAA-class), launched and operated by the United States, are the principal sources of environmental data for the 80% of the globe that is not covered by conventional monitoring equipment. These satellites measure temperature and humidity in the Earth's atmosphere, record surface ground and surface sea water temperatures, and monitor cloud cover and water/ice boundaries. They have the capability to receive, measure, process, and retransmit data from balloons, buoys, and remote automatic stations distributed around the globe. These satellites also carry Search and Rescue (SAR) transponders, which help locate downed airplanes or ships in distress. Polar orbiting satellites send back pictures to Earth via Automatic Picture Transmission (APT) or High Resolution Picture Transmission (HRPT) formats.



NOAA (National Oceanic and Atmospheric Administration) class satellites and Russian Meteor class satellites orbit very close to the poles on each revolution of the Earth. At an altitude of 860 km. (600 miles), the sensors scan the Earth's entire surface over a 24-hour period. The sensors are sensitive to visible light and infrared (IR) radiation. As each NOAA polar-orbiting satellite orbits the Earth, it sends back a constant stream of data.

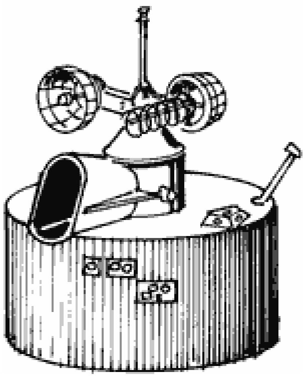
Instruments on board the satellite scan the Earth's surface from side to side (perpendicular to the ground track), with each scan covering an area about 2 km. high and 3,000 km. wide. Typically, the lower resolution APT imagery is transmitted at 2 lines/second, or 120 lines/minute. In a pass lasting 12 minutes, this translates into an image approximately 5,800 km. long and 3,000 km. wide. As an example, the entire east coast of the United States would be visible in one image, from southern Florida north up to Hudson Bay, and from the Atlantic Ocean to west of the Great Lakes.

During the day, this data stream consists of one visible and one infrared image. At night, both channels are infrared. Imagery in both the visible and infrared formats is transmitted simultaneously. Students are familiar with the visible image because it is similar to one from a conventional camera. Understanding what the infrared imagery represents is sometimes harder to grasp. Various land and water bodies absorb heat differentially, so they reflect different levels of heat energy. The Gulf Stream offers an excellent example: on an infrared image, the warmer temperatures of the Gulf Stream are clearly delineated as the darker portions of the image, while the cooler temperatures of the surrounding Atlantic are lighter in color. With readily-available computer software, students can use a mouse to place a cursor anywhere on the image and accurately measure the surface water temperature to within 2 degrees Fahrenheit.

Currently, four NOAA-class satellites, which transmit both APT and HRPT imagery, are available for classroom use. NOAA 14 passes over Maine in the middle of the day. NOAA 12 is considered the primary early morning and early evening satellite. In addition to the United States' NOAA satellites, Russian Meteor class satellites transmit weather satellite imagery in the APT format as well. As a result, these satellites are also a valuable resource for your classroom.

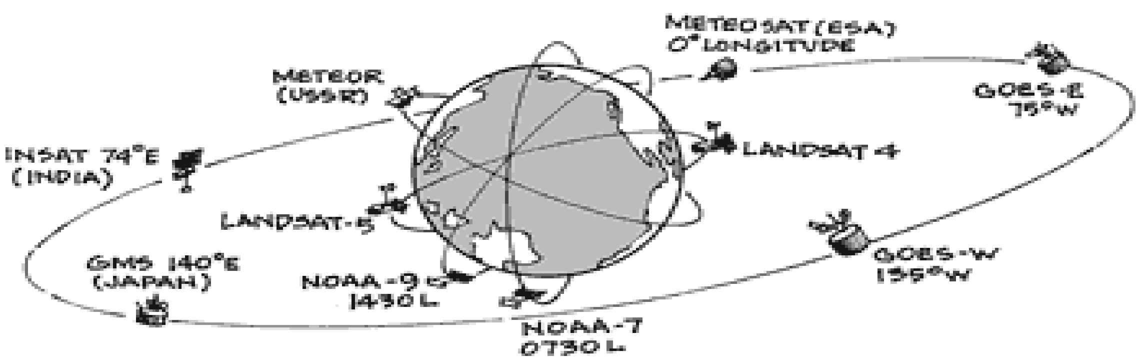
Geostationary (GOES) Satellites

In late 1966, ATS-1 was launched into a geostationary orbit over the equator south of Hawaii. For the first time, meteorologists could monitor the weather continuously during daylight. It provided images of nearly one-third of the Earth's surface every 23 minutes with 4 km. resolution.



In May of 1974, the first of a new series of GOES satellites was launched. Both visible and infrared images were acquired simultaneously by the Visible and Infrared Spin Scan Radiometer (VISSR) on board the spacecraft. The visible channel offers ground resolution of 0.8 km. for sections of the full Earth view and 6.2 km. resolution in the infrared spectra. The greatest advantage to having both visible and infrared capability is that weather systems can be monitored both day and night (at 30-minute intervals). Thus, destructive hurricanes can be tracked around the clock. Most satellite images seen on our local evening news and the Weather Channel are produced by GOES satellites. Usually, the infrared images are "loop animated" to show the progression and movement of storms.

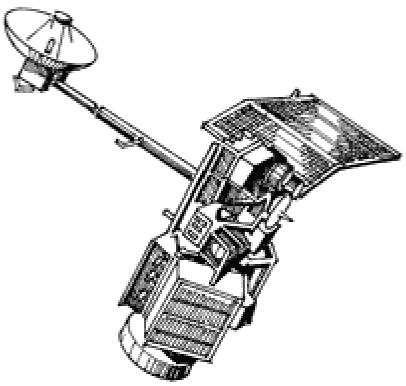
While the United States maintains and operates its GOES satellites, the European community is served by its European Space Agency (ESA) Meteosat satellite, and Japan with its GMS satellite. This network provides complete global coverage of all but the extreme north and south polar regions.



GOES satellites make day and night observations of weather in the coverage area and transmit real-time VISSR data, monitor cataclysmic weather events such as hurricanes, relay meteorological observation data from surface collection points, and perform facsimile transmission of processed graphic and imaged weather data. This rebroadcast function is known as WEFAX, which stands for Weather Facsimile.

The primary function of our GOES satellites to the education community is to provide imagery of varying resolution and time frames. VISSR is the most stunning example, although it requires a much more sophisticated ground station to receive and process the signal. From Hawaii to Maine, land features can be examined to 0.8 km. resolution. The snow-capped Rocky Mountains stand out nicely, as do larger lakes and reservoirs.
WEFAX, on the other hand, is easily received with relatively simple equipment. Much of the imagery transmitted via WEFAX is considered low resolution, usually 4 km. Along with satellite imagery, weather charts and other information are also transmitted regularly.

Mission to Planet Earth



Four Landsat satellites (launched in 1972, 1975, 1978, and 1982) were specifically designed to learn about how different parts of the planet interact. Three are still sending back data. The newest generation of environmental satellites is part of a National Aeronautics and Space Administration (NASA) initiative that aims its space instruments at the Earth instead of the stars. This program, Mission to Planet Earth, may well take precedence over space exploration for the next few years. Its Earth Observing System (EOS) will include 17 new satellites to be launched over the next 15 years. "The idea grew out of a critical mass of scientists coming together to understand how the Earth as a system is changing," explains Robert Price, director of the Mission to Planet Earth office for NASA. "If humankind is changing the face of the Earth, it's time we started answering some of the scientific questions relating to that." EOS focuses on the remote sensing of climate change indicators such as the ozone layer in the upper atmosphere, cloud cover, and sea-ice at the poles. In addition, it follows the climatological effects of localized phenomena like volcanic eruptions and El Niño, a periodic change in wind patterns and current movements that results in decreased fisheries along the southern Pacific coast. The information provided by EOS satellites will determine the course of environmental management in the future.

Topex/Poseidon

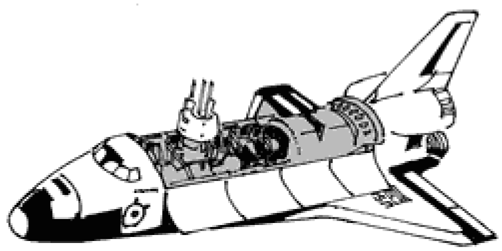
The Topex/Poseidon project is a joint venture between NASA and the French Space Agency designed to study the dynamics of the ocean as part of Mission to Planet Earth. The satellites orbit 830 miles above the Earth and measure the height of sea level to within 5 inches. Using these measurements, scientists examine ocean circulation patterns and interactions between the ocean and the atmosphere in an effort to predict climate changes on a global level.

Topex/Poseidon imagery helped scientists predict the 1994-1995 El Nino and its effects in the Northern Hemisphere.

SeaWIFS

The SeaWIFS satellite will provide important data on ocean productivity. SeaWIFS stands for the Sea-viewing Wide Field of View Sensor, designed to measure the amount of phytoplankton in the ocean and the seasonal changes in distribution. This satellite will also examine the fate of sediments washed from the land into the ocean and the mixing of nutrients at the edge of eddies and boundary currents. Measuring phytoplankton blooms from space has an obvious advantage over trying to cover the vast tracts of the ocean from a boat. The SeaWIFS satellite replaces an earlier sensor called the Coastal Zone Color Scanner (CZCS) that failed in the late 1980s.

Space Shuttle



The Space Transportation System (STS) followed the Apollo Project to the Moon and Skylab which orbited the Earth from 1973 to 1979. With the flight of the shuttle Columbia on April 12, 1981, America entered a new era in manned space flight. The reusable shuttle enables regularly-scheduled transportation for people and cargo between Earth and low Earth orbit, providing dramatic imagery of bold satellite rescue and repair missions. Less dramatic, but more personal, offshoots of this aerospace research include computer software in cars and airplanes and a host of medical technologies including CAT scans, portable x-ray machines, and laser surgery.

The current schedule of space shuttle missions provides an excellent opportunity for students and teachers to monitor flight activity on a real-time basis. Shuttle launch manifests offer approximate dates and durations of upcoming missions. A great deal of space-related information, including current shuttle manifests, is available at NASA's SpaceLink WWW page.

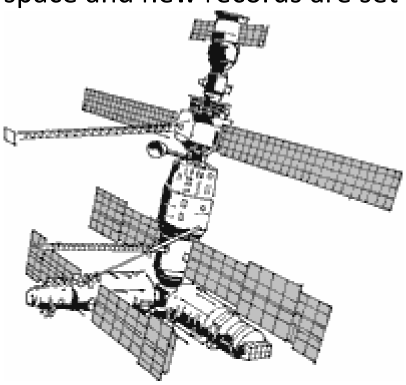
Schools with Amateur Radio ("ham") equipment or short-wave listening equipment can also monitor the audio portion of most shuttle missions. Station WA3NAN, located at the Goddard Space Flight Center in Greenbelt, Maryland, re-transmits live air-to-ground shuttle communications on amateur frequencies. The best times to monitor transmissions are during the launch and landing sequence and satellite deployment or repair missions

SIR-C/X-SAR

In recent missions the Space Shuttle has carried a new type of radar called Space Bourne Imaging Radar - C/X - band Synthetic Aperture Radar (SIR-C/X-SAR). After launching, the cargo doors on the shuttle open to deploy this radar, which is designed to look at vegetation, soil moisture levels, ocean dynamics, volcanic activity, and erosion. The projects that have evolved using this data include studies of deforestation in the Amazon, desertification of the Sahara, and soil moisture retention in the Midwest.

Mir Space Station

In February of 1986, the then-Soviet Union launched a space platform called Mir (Russian for "peace") Space Station as a replacement for the aging SALYUT 7 space station. The Russians hold the world record for long-duration flight. In 1987, two cosmonauts spent more than 300 days in space and new records are set every year.



It is especially exciting to view the Mir Space station or to monitor its progress by radio because it is one of the few satellites manned almost continuously. Students may feel a connection with the people in the capsule when they can observe it speeding overhead. Mir was launched in a fairly high inclination orbit (51.6 degrees), so the orbit is directly over the most populated portions of the Earth. Using a simple pinwheel device, students can determine when and where to look for this and other space objects. One of the largest and brightest objects currently orbiting the Earth, this platform provides for spectacular viewing several times during a 5-6 week period. Mir traverses the sky with an apparent magnitude of 0 or +1. In comparison, the brightest stars or planets are usually of a magnitude of -1, and the faintest stars visible with the naked eye are in the range of +6, +7.

In preparation for the proposed International Space Station, seven dockings between the Space Shuttle and the Mir Space Station are planned between now and 1997. In June of 1995, the Shuttle Atlantis successfully docked with Mir and began the journey to the ultimate completion of the International Space Station by the year 2002.

Tracking "Space Junk"

Tracking Earth-orbiting satellites visually makes for a great outdoor homework assignment. Literally thousands of objects orbiting our planet are listed in the latest Satellite Situation Report compiled by NORAD (North American Air Defense), and distributed by NASA. Any satellite larger than a softball is tracked by NORAD, and the data is disseminated by NASA. Many of these are debris from payloads and rocket bodies, called "space junk." On any clear evening, you have an excellent chance to see a satellite about 1 to 1 1/2 hours after sunset. Most will be observed in north-south or south-north orbit. In the space of an hour or more, a dozen satellites can be spotted. Brightness of the objects will vary depending on orbital altitude, size, and spin rate.

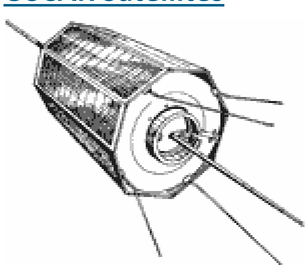
Although part of the Earth is in the sun's shadow at night, the satellite is still in sunlight, and the reflected sunlight illuminates it for Earth-bound observers.

How does one know when and where to look for specific satellites, such as the Soviet Mir Space Station, and, on occasion, even the US Space Shuttle? Amateurs have been tracking satellites for more than two decades. Before the microcomputer became a household item, ham radio operators plotted orbits on maps to determine when the satellites could be seen overhead. This method is still in use and is a good primer for those interested in tracking orbiting satellites.

In 1969, interested hams formed the Amateur Radio Satellite Corporation (AMSAT) to continue to enhance amateur satellite communication. Through the years, AMSAT has been a leader in research and development for amateur satellite technology. With the advent of microcomputers, tracking programs were written to automatically track specific satellites of interest, thus leaving the operator with more time to communicate.

How does the computer operator know which satellite is which? The user must input information for each satellite. These numerical data sets are called Keplerian Elements, named after Johannes Kepler. These elements, unique to each satellite, are orbital parameters which define individual orbits. They are available from a variety of sources on the Internet. Many of the newer tracking programs, including InstaTrack (PC) and OrbiTrak (Mac), provide users with quick means of updating elements. Complete files can be downloaded in a matter of minutes, and the computer software updates elements for as many as 200 satellites in seconds. Compare this with the arduous task of updating each satellite via computer keyboard, which takes several minutes per satellite. Either way, information is available for all satellites of interest to educators, including weather satellites, amateur satellites, and objects of high visibility such as the Mir space station. It is important to secure the latest Keplerian element sets available when tracking the Russian Mir Space Station or the Space Shuttle.

OSCAR Satellites



The satellite UOSAT-11 is one of dozens of amateur satellites orbiting the earth. Sputnik, the world's first artificial Earth-orbiting satellite, transmitted a beacon on 20.005 MHz. which was monitored by thousands of hams and Short Wave Listeners (SWL). Since 1957, many OSCAR (Orbiting Satellites Carrying Amateur Radio) satellites have been constructed by ordinary people interested in satellite communications. Oscar 1, launched in December of 1961, weighed 10 pounds and transmitted a 15 milliwatt beacon for about 3 weeks. Oscar 13, launched in the summer of 1988, provides reliable, near-global communications. Interestingly enough, the OSCAR series of satellites are actually ballast for larger primary NASA payloads. It is simpler and cheaper to ballast a rocket with dead weight than to reduce the thrust. As a result, it is possible to add secondary payloads of homemade satellites to multimillion-dollar NASA missions at minimal costs.

There are currently nineteen OSCAR satellites orbiting our planet with various communications capabilities and functions. Most are used by ordinary amateur radio operators for educational, scientific, and purely recreational purposes. Anyone interested in knowing more about the OSCAR series of satellites is encouraged to contact the Amateur Radio Satellite Corporation (AMSAT).

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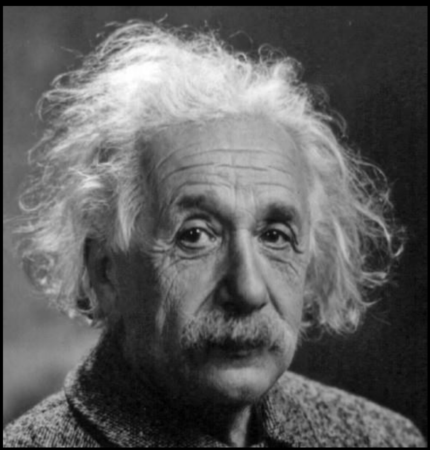
I do not know what I may appear to the world; but to myself I seem to have been only like a boy playing on the seashore, and diverting myself in now and then finding a smoother PEBBLE or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me.

-Issac Newton

My goal is simple. It is a complete understanding of the universe, why it is as it is and why it exists at all.

-Stephen Hawking



Not everything that can be counted counts, and not everything that counts can be counted.

-Albert Einstein

The sun, with all those planets revolving around it and dependent on it, can still ripen a bunch of grapes as if it had nothing else in the universe to do.

-Galileo Galilei