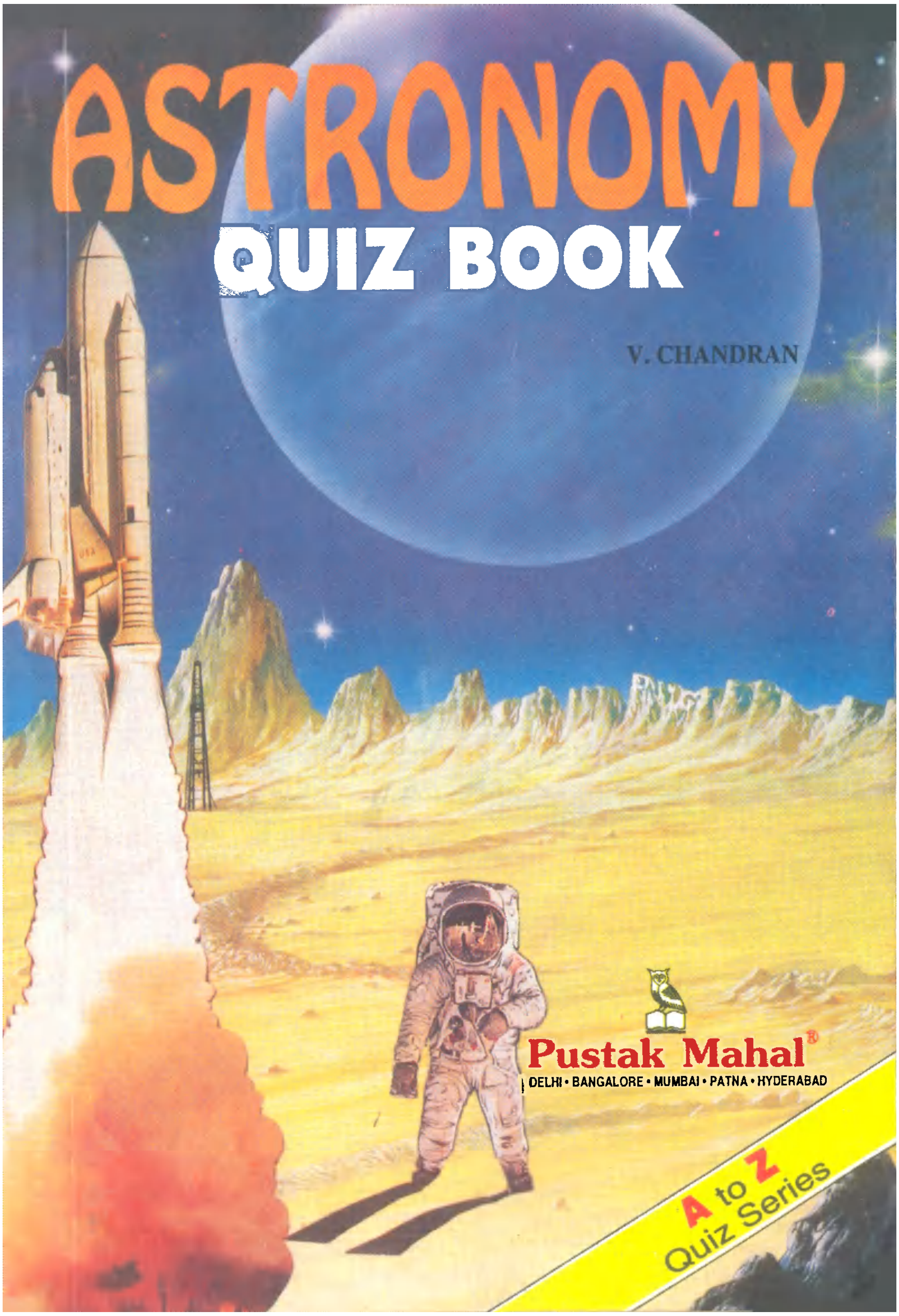
ASTRONOMY
QUIZ BOOK
V. CHANDRAN
Pustak Mahal®
DELHI • BANGALORE • MUMBAI • PATNA • HYDERABAD
A to Z
Quiz Series

ASTRONOMY
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AUTHOR'S NOTE

The First Edition of the **Astronomy Quiz Book** came out in 1992. It was the first time that such a book had been brought especially for the Indian reader in an affordable and easy-to-understand volume containing profuse illustrations.

The book has been well-received by the students and the general public. Many readers have found the book useful not only for educating themselves about the basics of astronomy but also for scoring better results in competitive examinations. Some suggestions have also been received for improving the format and presentation. In the meantime there have been many new developments in astronomical discoveries, which need to be included in the book.

It is in view of the above that the Astronomy Quiz Book is now being brought out in a totally new format and presentation with a good deal of additional information.

It is hoped that Edition will also be as well-received by the readers as the previous editions.

V.CHANDRAN

Nehru Centre

(Registered under the Societies Registration Act 1960)

24th January, 1992

FOREWORD

Plato has said, "Astronomy compels the soul to look upwards". Astronomy is the oldest of sciences and is also a delightful subject, both amusing as well as philosophical.

The ASTRONOMY QUIZ BOOK writtenby Mr. V. Chandran (Published by Pusthak Mahal, Delhi) is a welcome venture in popularising Astronomy among students and the general public. Mr. Chandran has lucidly brought out various aspects of the subject in a very interesting question and answer format covering nearly a thousand items with profuse illustrations. The book can be easily understood even by high school students.

I strongly recommend the book, both for students and the general public, for obtaining glimpses of astronomical insights.

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CONTENTS

1. THE UNIVERSE (PART 1)

Q. What is the Universe?

A. The Universe consists of everything one can cognise through one's senses and through observations using instruments.
The Sun and the Moon are components of the Universe one can easily observe but some objects too faint or too far away can only be observed through instruments like telescopes.

Q. What are the main components of the Universe in general terms?

A. The Universe consists of a vast emptiness called space with unknown boundaries, containing matter and energy in various forms.

Q. In what forms does matter exist in the Universe?

A. Matter exists in the form of stars, planets, comets, satellites, meteors, asteroids, galaxies etc.

Q. In what forms does energy exist in the Universe?

A. Energy exists in the form of heat, light, X-rays, microwaves, gamma rays, radio waves etc. What the eyes detect is only a minute range of wavelengths and frequencies (visible light) from a vastly broader spectrum of electromagnetic radiation. The heat and light from the Sun is a part of the energy we can easily feel through our senses. Other forms of energy can be detected only through instruments.

Q. Does the Universe remain steady and unchanging?

A. No. The Universe is constantly changing with the passage of time.

Q. What is a star?

A. A star is a massive heavenly body which emits enormous quantities of energy and appears to be glowing.

Q. Which star is nearest to the Earth?

A. The Sun.

Q. Which heavenly body is nearest to the Earth?
A. The Moon.

Q. What do we mean by the Solar System?
A. The solar system refers to the Sun and the various heavenly objects that move around the Sun.

Q. Name the heavenly bodies that move around the Sun?
A. Planets, satellites, asteroids, comets etc.

Q. What is a planet?
A. A planet is a major heavenly body. For example, the Earth is a planet and so are Venus and Mars.

Q. What is a natural satellite?
A. A natural satellite is a smaller natural heavenly body that moves around a planet. For example, the Earth has one natural satellite (the Moon), Mars has two and Venus has none. Natural satellites that orbit planets are also called the moons of their planets.

Q. What is the difference between natural and artificial satellites?
A. Nowadays man-made objects can be launched into space from the Earth. Today, the satellites circling the Earth in space include the Moon as well as such man-made objects. Satellites such as the Moon are called natural satellites and man-made ones are called artificial satellites.

Q. What are asteroids?
A. Asteroids are tiny heavenly bodies that move around the Sun. Most of them occur in the region between Mars and Jupiter. They are thought to be fragments left over from the formation of the solar system.

Q. What is a trajectory?
A. Trajectory is a general term for the path of any object moving in a force field such as a gravitational field that exerts a force on the object. Hence, the term trajectory can be applied to the path of a space probe moving in a gravitational field.

Q. What is an orbit?

A. When a small heavenly body moves around a larger one, the smaller body is said to orbit the larger one and the path followed by the smaller body is called its orbit around the larger body. For example, the Earth orbits the Sun.

Q. What are comets?

A. Comets are small heavenly bodies which orbit the Sun but regularly come close to the Sun. They are partially vapourised by the Sun's heat and glow brightly for a short time when near the Sun. A comet consists of a central nucleus a few kilometers across and can be described as a dirty snow-ball because it consists mostly of ice mixed with dust.

Q. What are meteorides?

A. Meteorides are tiny particles of matter floating in space.

Q. What are meteors?

A. Sometimes meteorides fall on Earth but burn due to the heat of friction when falling through the Earth's atmosphere. They are then known as meteors or shooting stars. Meteors are visible in the night sky as shortlived bright streaks.

Q. What are meteorites?

A. Meteors usually completely burn up before reaching the Earth's surface. In some cases, where the meteor is large, the burning is incomplete and a residual piece called a meteorite falls on the Earth.

Q. What are galaxies?

A. Galaxies are clusters of stars. The Sun and the Solar System are part of a star cluster called the Milky Way galaxy visible as a cloudy white area in the night sky and commonly called *"Akash Ganga"* in India.

Q. What is Gravity?

A. "Gravity" or "Gravitational Force" or "Gravitation" refers to the natural force of attraction existing between objects in space.

For example, we fall down when we jump up, because our bodies are attracted by the Earth's gravity. The Moon orbits the Earth because the Earth's gravity holds it in place in its orbit. The Earth, the planets and the other objects in the Solar System orbit the Sun due to the gravitational force exerted on them by the Sun. It plays a vital role in the behaviour of the Universe. (Refer Fig. No. 1.1).

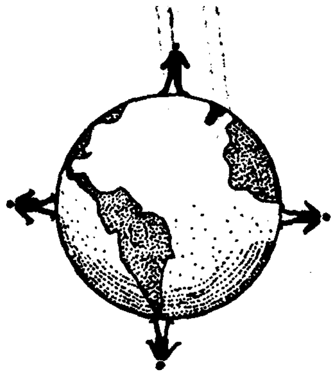


Fig. 1.1 The force of gravity acts equally on every part of the Earth's surface.

Q. Can an orbit be of any shape?

A. The shape of an orbit is normally in the form of one of the curves called "conic sections", obtained by cutting a cone in different ways. The four types of conic sections are: circle, ellipse, parabola and hyperbola (Refer Fig. No. 1.2).

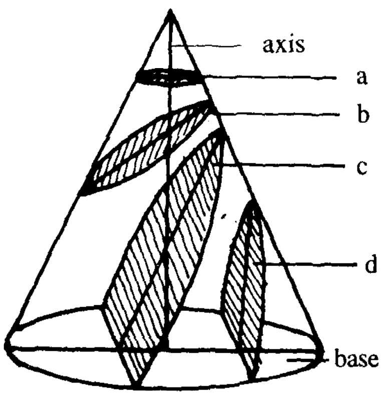


Fig. 1.2 The cone shown here has a circular base and the axis of the cone is perpendicular to the base.

a — a plane parallel to the base, cuts the cone in a circle.

b — a plane making an angle with the base less than that made by the side of the cone, cuts the cone in an ellipse.

c — a plane parallel to the side of the cone, cuts the cone in a parabola.

d — a plane making an angle with the base greater than that made by the side of the cone, cuts the cone in a hyperbola.

Q. What is the implication of the conic orbits?

A. In circular orbit, the distance of the orbiting object from the body around which it orbits is constant (equal to the radius of the circle). For example, artificial satellites can be placed in circular orbits around the Earth.

If the orbit is elliptical the distance of the orbiting object from the body around which it orbits, varies between a maximum and a minimum. For example, the Earth moves in an elliptical orbit around the Sun.

Parabolic orbits are similar to ellipses, but with a much higher degree of eccentricity with the result that the orbiting object moves farther away taking appreciable time to orbit. For example, some comets move in parabolic orbits around the Sun.

Hyperbolic orbits are open-ended in the sense that the orbiting object leaves the system forever. For example, a spacecraft which leaves the Earth and does not want to orbit around the Earth has to follow a hyperbolic trajectory. (Refer Fig. No. 1.3).

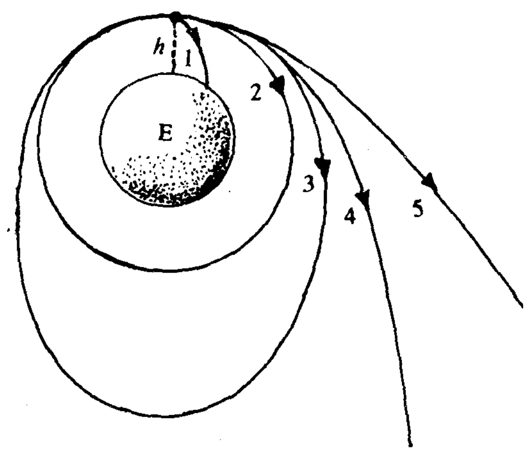


Fig. 1.3 If we imagine launching space vehicles from a given height, h, above the Earth (and in a direction parallel to the Earth's surface), there are five possibilities:

1. If the velocity is less than circular velocity, the craft will strike the Earth's surface.
2. If the velocity is precisely equal to the circular velocity, a circular orbit will result.
3. If the velocity is greater than circular velocity but less than escape velocity, the craft will follow an elliptical orbit.
4. If the velocity is precisely equal to escape velocity, a parabolic trajectory will result.
5. A velocity in excess of escape velocity results in a hyperbolic trajectory.

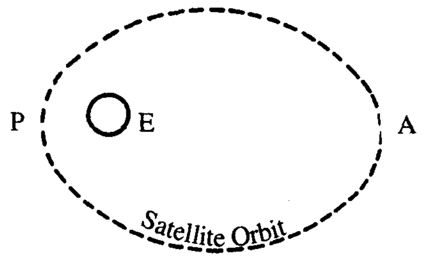
Q. Are actual orbits true conic sections in the mathematical sense?

A. No. The paths of bodies orbiting through the Solar System are affected by the gravitational forces of many heavenly bodies.

Q. What is meant by "Apogee" and " Perigee"?

A. Apogee (Aphelion with reference to solar orbits) is the point in the elliptical orbit at which the orbiting body is at its farthest distance from the body around which it orbits.

Perigee (Perhelion with reference to solar orbits) refers to that point where the orbiting body is closest to the body around which it orbits. For example, in the case of an artificial satellite moving in an elliptical orbit around the Earth, its distance from the Earth would fluctuate during each orbit from a maximum at apogee to a minimum at perigee. (Refer Fig. No. 1.4).



A : Apogee
P : Parigee
E : Earth

Fig. 1.4 Satellite Orbit.

Q. What is a nebula?

A. A nebula (Plural : nebulae or nebulas) is a vast cloud of gas and dust floating in space. Nebulae are usually detected in the night sky as bright or dark patches against the background of stars.

Q. What are the main differences between astronomy and astrology?

A. In astrology (dating back to ancient times), only heavenly phenomena and movements visible to the naked eye are considered. Hence, the planets beyond Saturn that can only be seen with telescopes do not figure in astrology. Astrology also places great importance on the visual pattern (constellations) of the heavenly objects in the night sky, whereas they are of least significance to astronomers. The heavenly objects recognised by astrologers also include objects like "Rahu" and "Ketu" considered non-existent by astronomers. The movements of the heavenly objects are believed by astrologers to influence the lives of people on Earth in a specific manner, whereas according to astronomers such a contention has no scientific basis and any astrological correlations are considered purely coincidental.

Q. What are the principles of Conservation of Matter and Energy?

A. The Principle of Conservation of Matter and Energy states that Matter and Energy can neither be created nor destroyed. However, they can be converted from one form to another.

Q. What are the three Laws of Motion (applicable to all bodies in the Universe) propounded by Sir Isaac Newton?

A. Newton's Laws of Motion are:

1. A body at rest or moving in a straight line continues to do so unless disturbed by an external force.
2. The rate of change of momentum (product of mass and velocity) of a body is directly proportional to the force applied to it and is always in the direction of the applied force.
3. For every action force (force A) there is an equal and opposite reaction force (force R) (See Fig. No. 1.5).

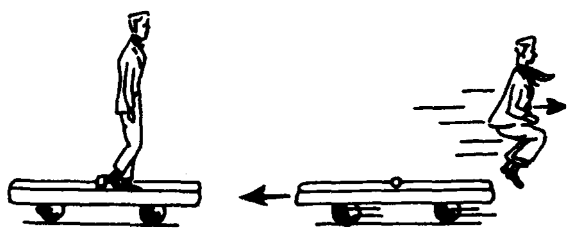
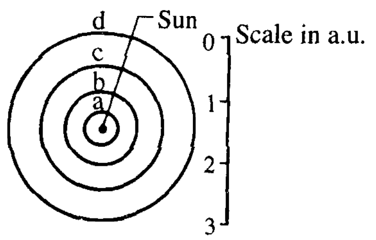


Fig. 1.5 The Principle of Reaction.

2. THE SOLAR SYSTEM (PART 1)

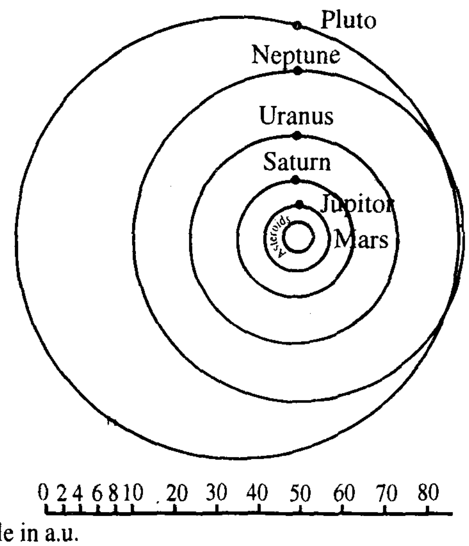
Q. What is meant by "Inner" and "Outer" Solar Systems?

A. The Inner Solar System refers to the region between the Sun and Mars where the planets are relatively close together. Beyond this is the Outer Solar System, where the planets are spaced relatively wider apart. (Refer Fig. No. 2.1).



a. Mercury, b. Venus, c. Earth, d. Mars

(A) INNER SOLAR SYSTEM (ORBITS)



(B) OUTER SOLAR SYSTEM (ORBITS)

a.u. = astronomical unit of distance

Fig. 2.1 Inner and Outer Solar Systems.

Q. What are the main constituents of the Solar System?

A. The Solar System consists of the Sun and all the heavenly bodies that orbit it, such as the planets, moons, asteroids, comets, etc. The term Solar System is also synonymously used to refer to the region of space occupied by the Sun and the other bodies of the Solar System.

Q. Name the planets and their symbols.

A. The nine planets orbiting the Sun are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto. Sometimes specific symbols are used to denote the planets. (Refer Fig. Nos. 2.2 and 2.3).

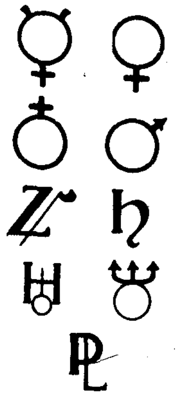


Fig. 2.2 Symbols used to designate the planets (reading from the top and left to right): Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto.

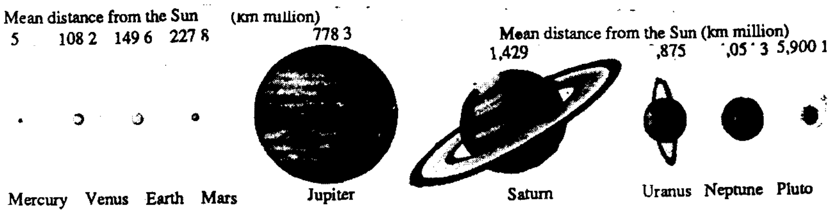


Fig. 2.3 Comparison of planetary sizes.

Q. Can a heavenly body be a temporary member of the Solar System?

A. Yes. For example, a comet following a hyperbolic trajectory can enter the Solar System, go around the Sun partially and leave the Solar System never to return.

Q. Are the names of the planets usually mentioned in ascending order of their distance from the Sun?

Yes, up to Uranus. However, Pluto has a highly eccentric orbit which partially overlaps the orbit of Neptune. Sometimes Pluto is the outermost planet and at other times Neptune is the outermost one. (Refer Fig. No. 2.1).

Q. Do all the planets orbit the Sun in the same direction?

A. Yes.

Q. Do all the planets rotate about their own axes while orbiting the Sun?

A. Yes.

Q. What is an Astronomical Unit?

A. An astronomical unit (usually abbreviated as "a.u.") is a unit of measurement for measuring distances in the Solar System. One a.u. is equal to 149,597,870 km which is the mean or average distance between the Earth and the Sun during the elliptical orbit of the Earth around the Sun.

Q. Do the planets orbit the Sun in the same plane?

A. Except Pluto, all the planets orbit the Sun nearly in the same plane. The plane of the orbit of Pluto is tilted by about 17° to the mean plane of orbit of the other planets.

Q. What is Bode's Law (Titus-Bode Law)?

A. Bode's Law, also known as Titus-Bode Law, relates to a unique empirical formula postulated by German astronomer J. Titus which apparently predicted the approximate distances of the then-known planets from the Sun in astronomical units.

The law correctly predicated the existence of Uranus and its distance from the Sun even before the planet Uranus was discovered. However, the law was rather off the mark in its predictions about Neptune and Pluto.

Astronomers feel that the accuracy of the Titus-Bode Law may be no more than a remarkable coincidence.

Planet	*Mean distance from Sun in a.u*	*Corresponding distance as per Bode's law*
Mercury	**0.39**	**0.40**
Venus	**0.72**	**0.70**
Earth	**1.00**	**1.00**
Mars	**1.52**	**1.60**
Asteroids (typical)	**2.80**	**2.80**
Jupiter	**5.20**	**5.20**
Saturn	**9.54**	**10.00**
Uranus	**19.20**	**19.60**
Neptune	**30.10**	**38.80**
Pluto	**39.50**	**77.20**

(The sequence may be expressed as, distance, in a.u. $r = 0.4 + 0.3 \times 2n$ where n is $-\infty$ for Mercury, 0 for Venus, 1 for Earth and so on.)

Q. What are "Inferior" and "Superior" Planetary orbits?

A. Mercury and Venus are said to have inferior orbits due to their greater nearness to the Sun than Earth. The other planets which are farther from the Sun than Earth are said to have superior orbits.

Q. What are transits of the inferior planets?

A. Sometimes, Mercury or Venus comes directly between the Earth and the Sun. They are, however, too small to cause an eclipse of the Sun but can be seen as black dots on the surface of the Sun when viewed through a dark glass. Such an event is called a transit.

Q. What are conjunctions of the inferior planets?

A. When Mercury or Venus is in line with the Sun and the Earth it is called a conjunction.
If the planet comes between the Sun and the Earth it is called an inferior conjunction. It is obvious that a transit coincides with an inferior conjunction.

On the other hand, if the Sun comes between a planet and the Earth it is called a superior conjunction. In a superior conjunction the planet is temporarily hidden by the Sun. (Refer Fig. No. 2.4).

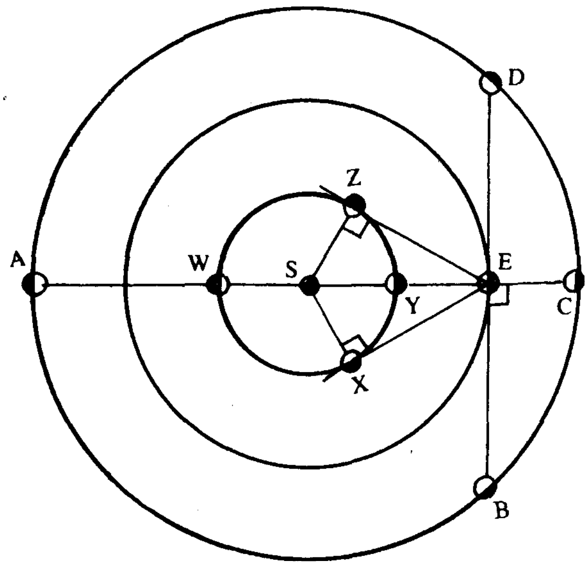


Fig. 2.4 Planetary conjunctions.

S represents the Sun and E the Earth. When the inner (or inferior) planet is at W, it is said to be at superior conjunction; position Y represents inferior conjunction; position X, greatest elongation east (i.e. the angle between the Sun and the planet, as seen from Earth, is a maximum, with the planet apparently on the east side of the Sun and visible in the evening sky); and position Z, greatest elongation west.
For the outer (or superior) planet, position A denotes that the planet is at superior conjunction; position C represents opposition; and positions B and D denote quadrature (at these positions the angle Sun-Earth-planet is a right angle and the apparent phase of the planet is most obvious).

Q. What are the "Morning Star" and the "Evening Star"?

A. Mercury and Venus, due to their inferior orbits, always appear close to the Sun and are difficult to see except in the twilight hours. Mercury and Venus are sometimes referred to as "Morning Star" and "Evening Star". However, they are really not stars but planets.

Q. Why did the ancients mistake the planets Mercury and Venus for stars?

A. Mercury and Venus appear bright during twilight hours when the stars are usually faint. Mercury is sometimes as bright as the brightest star Sirius. Venus appears brighter than Mercury (sometimes even ten times brighter).

Q. Are the "Navagrahas" (Nine heavenly bodies) of the astrologers the same as the nine planets known to astronomers?

A. No. The "Navagrahas" refer to the Sun, Moon, Mars, Mercury, Jupiter, Venus, Saturn, Rahu and Ketu. Rahu and Ketu are imaginary objects responsible respectively for solar and lunar eclipses.

Q. What is a satellite transit?

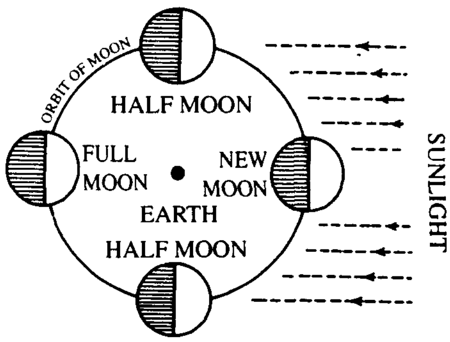
A. When a satellite of a planet comes between the Earth and the planet, the event is called a satellite transit. For example, if a satellite of Jupiter is in transit, it can be seen with a telescope as a dark dot on the brighter disc of the planet.

Q. What is a shadow transit?

A. As the Sun's light hits a satellite it produces a shadow. Sometimes, the shadow passes across the surface of the satellite's planet and is referred as a shadow transit.

Q. Why does the Moon brighten and darken in phases from full Moon to new Moon and vice versa?

A. In the case of the Earth and the Moon, the side facing the Sun is brightly lit, while the opposite side remains dark as it is facing away. The phases of the Moon occur due to the relative positions of the Moon as viewed from Earth. (Refer Fig. No. 2.5).



New and full moon position = Syzygy
Half moon position = Quadrature

Fig. 2.5 Syzygy and Quadrature of the Moon.

Q. Do the planets exhibit phases (like the Moon) when viewed from Earth?

A. Yes. The inferior planets do. (Refer Fig. No. 2.6).

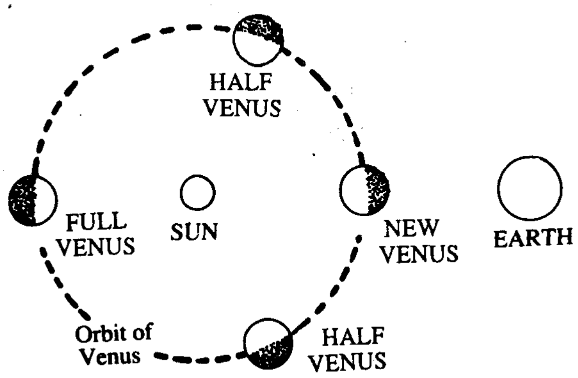


Fig. 2.6 Phases of Venus as seen from Earth.

Q. What are asteroids and where are they?

A. Asteroids are small bodies orbiting the Sun. Almost all of them (99.8%) move in orbits between those of Mars and Jupiter, in a zone known as the Asteroid Belt.

Q. How many asteroids exist and how many have been studied so far?

A. About 100,000 and 2,000 respectively.

Q. How were asteroids created?

A. Asteroids are supposed to represent space debris scattered by the perturbing effects of Jupiter's gravity.

Q. What is the estimated total mass of the asteroids?

A. The estimated total mass of all the asteroids is less than 0.1 per cent of the Earth's mass.

Q. What is the size range of the asteroids?

A. Asteroids generally range in diameter from less than a kilometre to about 800 km.

Q. What are Sun Grazers and Earth Grazers?

A. These is a small number of asteroids with highly elliptical orbits in relation to the Earth or the Sun, known as Earth Grazers and Sun Grazers, respectively.

Q. How close to the Sun can a Sun Grazer approach?

A. The notable example is the asteroid Icarus discovered in 1949 which is about 1.5 km in diameter and whose highly elliptical orbit takes it from an aphelion position beyond the orbit of Mars to a perhelion position within 28 million km of the Sun (less than half the mean distance of Mercury from the Sun).

Q. How close to the Earth do Earth Grazers approach?

A. Hermes, an asteroid less than 1 km in diameter, occasionally approaches the Earth within twice the Moon's distance from Earth. Another asteroid Eros can approach the Earth within 23 million km.

Q. What is Vulcan?

A. Vulcan was an imaginary planet never detected from Earth, but postulated by some astronomers to account for perturbations in the orbits of Mercury.

Q. What is the true reason for the per'urbations in 'he or' i' of Mercury?

A. Mercury not only orbits the Sun but the orbit itself rotates. (Refer Fig. No. 2.7).

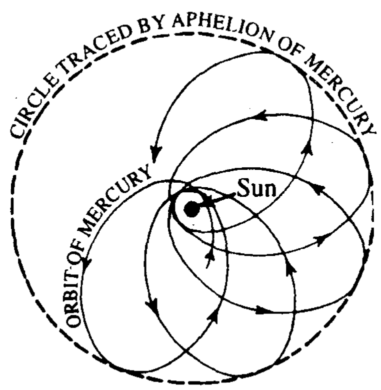


Fig. 2.7 The rotation of Mercury's elliptical orbit around the Sun (central dot), is shown as an ellipse that shifts with each orbit. The shift is greatly exaggerated in the diagram. (Actually the ellipse advances only 43 seconds of an arc per century.) Mercury's aphelion traces a circle (dotted line).

Q. Could the planets of the Solar System have formed differently?

A. It is a matter of accident that the planets exist as they do. It has been postulated that the planets could have been formed in a number of ways, all resulting in stable configurations (Refer Fig. No. 2.8).

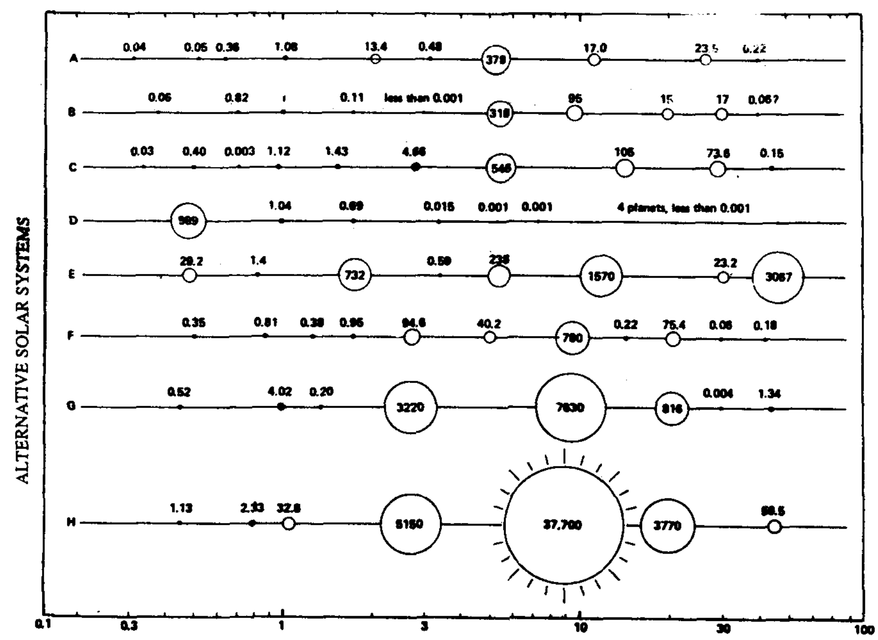


Fig. 2.8 Alternative Solar Systems.

Seven solar systems generated by computer program ACCRETE, and one real system our own (B). The distances of planets from their star are shown along the horizontal exis (I astronomical unit =150,000,000 km). The masses of the planets are shown in units of the Earth's mass. Systems A and C are very similar to our own, with terrestrial (Earth-like) planets close to the star, and large jovian (gaseous) planets farther away. System D has the opposite arrangement. Terrestrial and jovian planets are interspersed in E and F. Very massive jovian planets are produced in G. In H the fifth planet is so massive that it has become a star, and the configuration has become a double star system.

Note: Black dots represent terrestrial planets and white circles represent jovian planets.

Q. What are the "canals" of Mars?

A. In 1877 Italian astronomer G.V. Schiaparelli reported sighting a network of "Canali" ("Channels" in Latin) on Mars, but it was wrongly translated as "Canals" in English implying that the phenomenon is artificial. The canals of Mars are in fact only a natural phenomenon. (Refer Fig. No. 2.9).

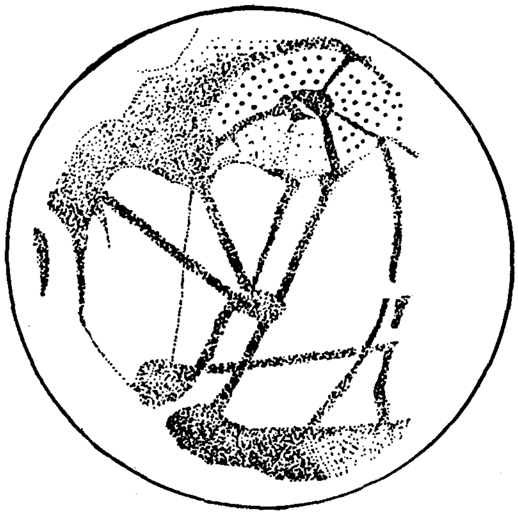


Fig. 2.9 One of Schiaparelli's drawings of Mars, showing "Canali".

Q. What are the "Rings" of Saturn?

A. Saturn possesses a large quantity of matter orbiting in the form of rings. They are classified into three major rings, A, B and C. Ring

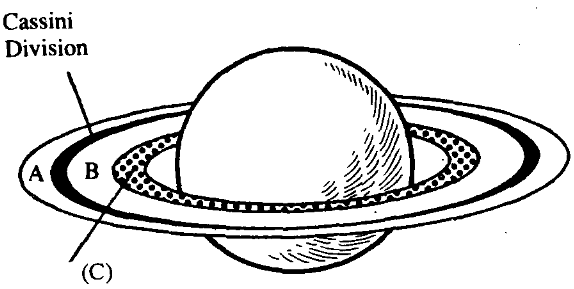


Fig. 2.10 The Rings of Saturn.

C is sometimes known by its nickname "Crepe Ring". There is a large gap between rings A and B called the Cassini Division. The rings are made up of small blocks of matter too small to be seen individually thereby creating an impression of a continuous sheet of material (Refer Fig. No. 2.10).

Q. Do any of the other planets, besides Saturn, have "rings'?

A. In 1977, Uranus was found to have thin rings around its equator.

Q. Among the objects of one of the voyages of the famous eighteenth century British explorer Captain Cook to the South Pacific, was an astronomical mission. Name it.

A. Observation of the transit of Venus.

Q. Is there any planet beyond Pluto?

A. Astronomers suspect the existence of a planet beyond Pluto (tentatively named Persephone but as yet undetected) roughly 5 times the Earth's size, 100 a.u. distant from the Sun and orbiting the Sun once in more than 1000 years.

3. THE EARTH (PART 1)

Q. Why is the study of the Earth significant for astronomers?

A. The Earth, the third planet from the Sun, is the only planet that can be easily studied. A study of the Earth (as a planet) helps astronomers to understand the other planets better.

Q. What is the shape of the Earth?

A. The Earth is not just a mere sphere but an oblate spheroid i.e., a sphere flattened slightly at the top and bottom (poles) and bulging at the central region. There is a little more flattening at the bottom than at the top. (Refer Fig. No. 3.1).

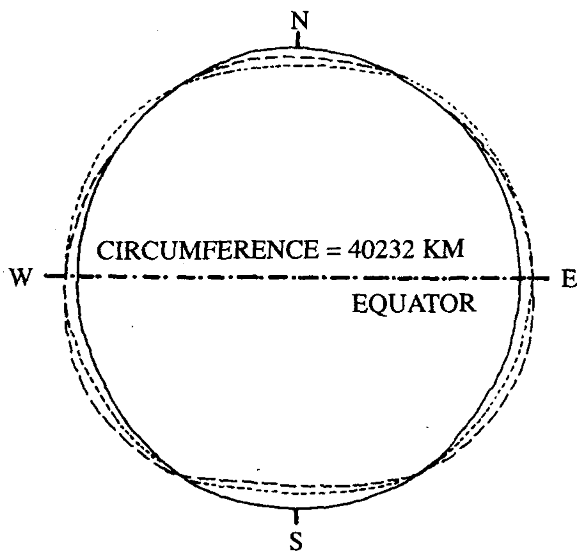


Fig. 3.1 The Earth's Shape.

The solid line represents perfect sphere; the dotted line indicates the traditional view of flattening of the poles and bulging at the equator; the dashed line depicts slightly pear-shaped Earth suggested by perturbations in the Vanguard I satellite orbit. Both dotted and dashed lines greatly exaggerate the actual tiny deviations from a perfect sphere (The exaggeration of the dashed lines is especially great).

Q. Why is the Earth an oblate spheroid rather than a sphere?

A. The Earth's spinning motion causes the central region to bulge leading to flattened top and bottom. (Refer Fig. No. 3.1).

Q. What is the speed of rotation of the Earth?

A. The Earth spins at 1500 km per hour at its central region.

Q. Is the rate of rotation of the Earth constant?

A. The Earth spins faster during September than during March in any year.

Q. What are poles?

A. All the bodies which rotate on their axes, such as the Earth, Sun, Moon, planets, etc. are said to have two poles, called North Pole and South Pole for convenience. They are the points at which the axis of rotation intersects the surface of the body. Hence, the Earth has a north pole and a south pole, and the line passing through the centre connecting the poles is the axis of rotation of the Earth. (Refer Fig. No. 3.2).

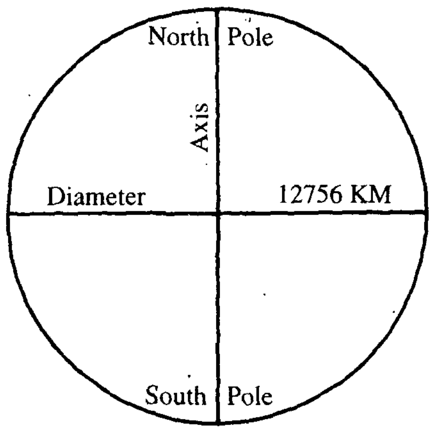


Fig. 3.2 The Geographic Poles and Axis of the Earth.

Q. How are the poles identified with respect to surface features on the Earth?

A. The poles are imaginary points and are never identified by any natural features on the Earth's surface.

Q. What is the Equator?

A. The equator is an imaginary line representing the Earth's circumference and situated midway between the north and south poles and thereby dividing the Earth equally into halves, called the northern and southern hemispheres.

Q. What is the difference between the geographic poles and the magnetic poles?

A. The Earth has a natural magnetic field and behaves as a magnet, influencing a mariner's navigational compass. The north and south poles (magnetic) are points on the Earth's magnetic axis. The Earth spins on its geographic axis and not on its magnetic axis.

Q. What is the difference between the geographic and magnetic equators?

A. The geographic Equator is an imaginary line circling the surface of the Earth midway between the geographic north and south poles. If the magnetic poles are considered instead of the geographic poles, the "magnetic equator" (corresponding to the magnetic poles) can be drawn.

Q. Does the geographic equator pass through India?

A. No.

Q. What are latitudes?

A. Latitudes are imaginary lines between the equator and the poles which run parallel to the equator and divide the surface of the Earth into parallel segments. Latitudes are also called "Parallels" or "Parallels of Latitude" eg. 20^{o}s latitude. (Refer Fig. No. 3.3).

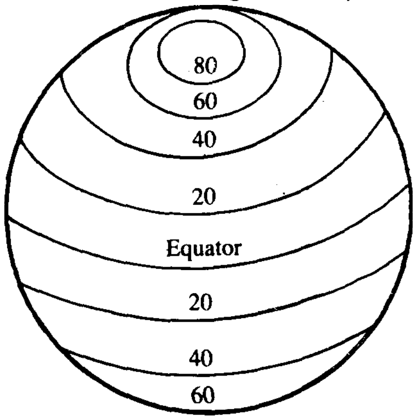


Fig. 3.3 Parallels of Latitude.

Q. What are longitudes?

A. Longitudes are imaginary lines through the geographic poles which run circumferentially and intersect the surface of the Earth dividing it into segments eg. 20°w longitude. (For example, if the Earth is imagined as an orange, the longitudes would divide it into its natural "slices"). Longitudes are also called "Meridians" or "Meridians of longitude". The 0° meridian is also called the "Greenwich" meridian since it passes through the town of Greenwich in England. (Refer Fig. No. 3.4).

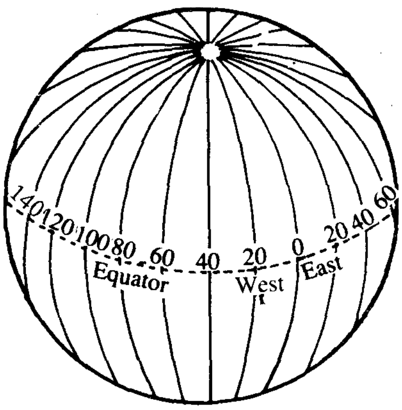


Fig. 3.4 Meridians of Longitude.

Q. Can all the spherical celestial bodies be imagined to have their own equator, poles, latitudes and longitudes?

A. Yes.

Q. What are the Tropics?

A. The latitude 23.5° north of the Earth's equator is called the Tropic of Cancer.

The Tropic of Capricorn is the latitude 23.5° south of the Earth's equator. These are the limits of the area of Earth's surface in which the Sun can be directly overhead. (Refer Fig. No. 3.5).

Q. What are the Arctic Circle and the Antarctic Circle?

A. The latitudes situated at 66.5 degrees north and south of the Earth's equator are called the Arctic circle and the Antarctic circle respectively. (Refer Fig. No. 3.5).

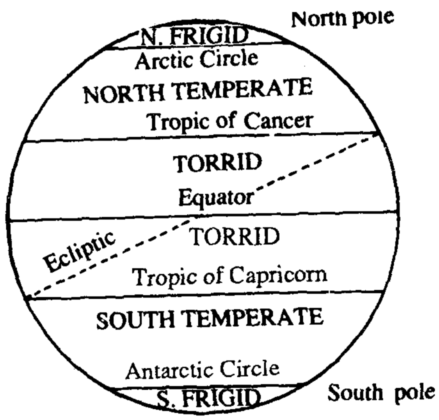


Fig. 3.5 Zones of the Earth.

Q. What are the regions or zones of the Earth?

A. The regions north of the Arctic Circle and south of the Antarctic Circle are called the polar regions or frigid zones.

The region between the Tropic of Cancer and the Tropic of Capricorn is called the torrid zone. The regions between the Tropic of Cancer and the Arctic Circle and between the Tropic of Capricorn and the Antarctic Circle are called the north and south temperate zones respectively. (Refer Fig. No. 3.5).

Q. What are the polar ice caps?

A. Extremely cold temperatures of the polar regions cause ice formation on land and sea, resulting in a permanent blanket of ice around the poles called the polar ice caps.

Q. What is the astronomical definition of 'Day'?

A. Almost every heavenly body (including the Sun, Earth and planets) spins around its 'axis of rotation', which is an imaginary line passing through the geographic poles, around which the body rotates. The time taken by the body to rotate once around its axis is astronomically defined as a 'Day'.

In the case of the Earth, the astronomical day also known as sidereal day is 23 hours 56 minutes and 4 seconds. The astronomical day does not differentiate between 'day' and 'night' and is independent of the position of the Sun in the sky.

Q. What is the time difference between a lunar and a solar year?

A. A solar year has 365 days. A lunar year has 354 days, and is based on twelve complete moonphase cycles or lunations.

Q. Are all calendars based on the solar year?

A. No. Some calendars (such as those of the Mohammedan era) are based on the lunar year.

Q. What is an astronomical year?

A. An astronomical year (also known as sidereal year) for a planet is the time taken by the planet to make a complete revolution around the Sun. In the case of the Earth, the sidereal year is equal to 365.2564 mean solar days or 365 days 6 hours 9 minutes and 9.5 seconds.

Q. What is a civil day?

A. A civil day is the day of 24 hours used routinely on Earth for setting clocks i.e., 24 hours divided into two portions—day time and night time—depending on whether the Sun shines in the sky or not. (Refer Fig. No. 3.6).

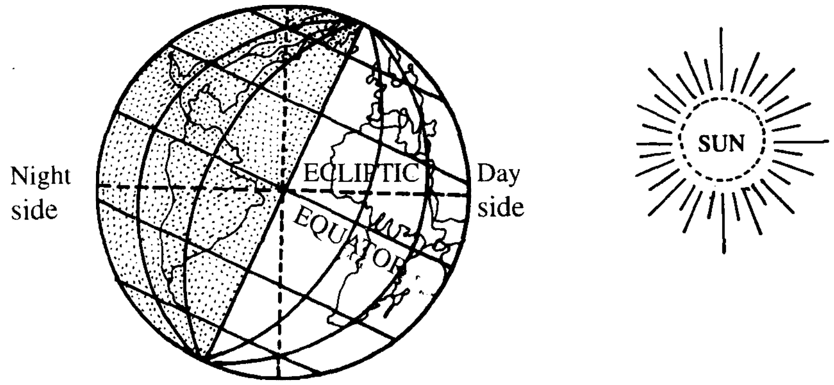


Fig. 3.6 Day and Night. (Note 23.5° Tilt of Earth's Axis)

Q. Does the difference between the civil and astronomical days have any significance in astronomical observations?

A. Since the civil day is 3 minutes and 56 seconds longer than the astronomical day, any star in the sky will rise 3 minutes and 56 seconds earlier every day compared to the previous day.

Q. What is the difference between mean local time and Indian Standard Time (IST)?

A. The actual time (mean local time) at any place varies depending on its longitude. However, for convenience one time (Indian Standard Time) has been adopted for the whole of India. Mean local time can be converted to IST as follows:

(Typical variation of IST from mean local time is depicted in minutes)

Port Blair	–41
Guwahati	–37
Patna	–11
Lucknow	+6
Delhi	+21
Srinagar	+31
Panaji	+35

Q. Does the change in the Earth-Sun distance during an year have any appreciable effect upon the seasons on Earth?

A. No.

Q. What causes the change in seasons on Earth?

A. In the northern hemisphere, the Earth's 23.5° tilt towards and away from the Sun during June and January causes summer and winter, respectively. It would be the converse in the southern hemisphere. (Refer Fig. No. 3.7).

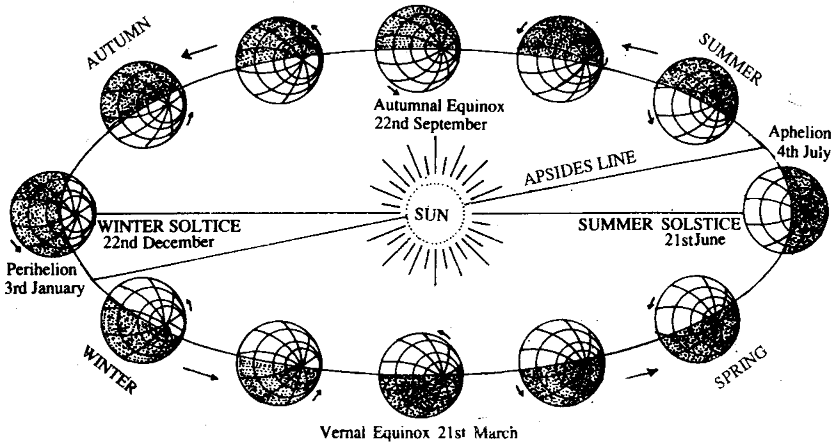


Fig. 3.7 The Seasons for Northern Hemisphere.

Q. Do the hemispheres have identical temperatures during summer and winter?

A. Theoretically, the Earth should have a slightly hotter climate in the southern hemisphere compared to the northern hemisphere. However, the larger mass of ocean in the southern hemisphere tends to even out most of this difference since the ocean heats up and cools down more slowly than land areas.

Q. What is the Apsides Line?

A. The Apsides Line is an imaginary line connecting two points on the Earth's orbit representing the dates of Aphelion and Perihelion. (Refer Fig. Nos. 3.8 and 1.4).

Q. What is the Ecliptic with reference to the Earth?

A. The Ecliptic is a circumferential line around the Earth and represents the intersection of the plane of the Earth's orbit around the Sun, with the Earth. (Refer Fig. Nos. 3.5 and 3.6).

Q. What are the Solstices?

A. During the year, the position of the Sun in the sky, as viewed from the Earth shifts from north to south and back again. In other words solistice occurs on either of the days on which the Sun is farthest north or south of the celestial equator each year. The points of solstice correspond to the northernmost and southernmost positions of the Sun in the sky. (Refer Fig. No. 3.7).

Q. What is the structure of the Earth?

A. Earth has a molten liquid core of iron, mickel and magnesium silicates. At the surface of the Earth is a solid layer called the crust. A semifluid zone called the mantle exists between the crust and core. About 70% of the Earth's surface includes north and south polar icecaps it is covered with water. (Refer Fig. No. 3.8).

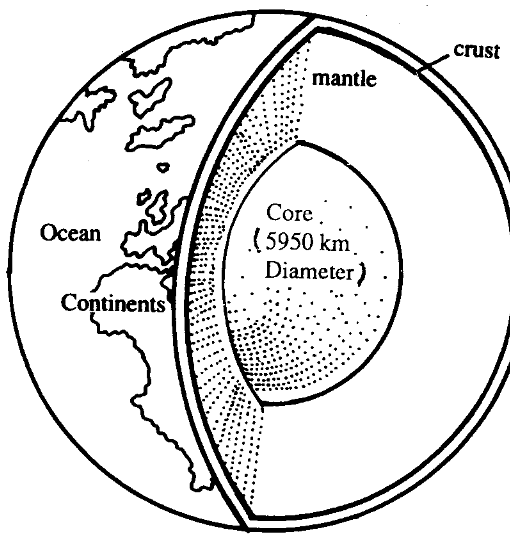


Fig. 3.8 Innerstructure of the Earth.

Q. What is the precession of the Earth's axis?

A. The Earth's axis does not remain steady but wobbles like that of a tilted spinning top. This wobbling is called the precession of the Earth's axis. (Refer Fig. No. 3.9).

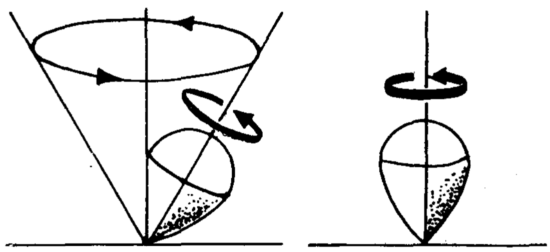


Fig. 3.9 Top Spinning Without Precession (Right), and Top Spinning With Precession (Left).

Q. How many meteors fall through the Earth's atmosphere every day?

A. About 1,000,000,000,000 (one trillion) meteors fall upon the Earth every day. Of these, about 5,00,000 are large enough to be seen by the naked eye. Most of these get burnt in the atmosphere completely before they hit the surface of the Earth.

Q. Approximately how many meteorites fall on the Earth?

A.
Small meteorites	— one every month.
50 tonne meteorites	— one every 30 years.
250 tonne meteorites	— one every 150 years.
50,000 tonne meteorites	— one every 100,00 years.

Q. Where does the material in meteors come from?

A. The material in meteors comes from the miscellaneous bits of matter (called space debris) floating in space.

Q. What causes meteor showers?

A. If the space debris (the origin of the meteors) has originated from a disintegrated comet, the debris tends to form a "Cloud" resulting in a greater frequency of meteors (a meteor shower) when the Earth passes through these "Clouds". Meteor showers for the year are given below:

Date of Meteor Shower	Meteor Stream	Location R.A.		Dec.
		h.	m	°
Jan. 1–4	Quadrantids	15	20	+ 52
Jan. 17	Cygnids	19	40	+53
Feb. 5–10	Aurigids	5	0	+41
Mar. 10–12	Bootids	14	32	+12
Apr. 19–23	Lyrids	18	4	+33
May 1–6	May Aquarids	22	16	–2
May 11–24	Herculids	16	28	+28
May 30	Pegasids			
June 2–17	Scorpiids	22	0	+28
June 27–30	Pons-Winnecke	16	48	– 23
	meteors	15	12	+58
July 14	Cygnids	20	56	+47
July 18–30	Capricornids	20	16	– 12
July 25 Aug. 4	Perseids	3	12	+43
July 26–31	Aquarids	22	36	– 11
Aug. 10–14	Perseods	3	8	+58
Aug. 10–20	Cygnids	19	20	+52
Aug. 21–23	Draconids	19	24	+60
Aug. 21–31	Draconids	17	28	+63
Sept. 7–15	Perseids	4	4	+36
Sept. 22	Aurigids	4	56	+42
Oct. 2	Quadrantids	15	20	+52
Oct. 9	Giacobinids	17	40	+55
Oct. 12–23	Arietids	2	48	+21
Oct. 18–23	Orionids	6	8	+15
Oct. 31 Nov. 6	Taurids	3	40	+15
Nov. 14–18	Leonids	10	0	+22
Nov. 26 Dec. 4	Andromedes	1	40	+45
Dec. 10–13	Geminids	7	32	+32

Q. Name the year when meteors rained profusely in recent times?

A. In 1966, there was a fantastic meteor shower with a maximum of two thousand meteors a minute. The peak activity was, however, visible only in the north Pacific region.

4. THE NIGHT SKY (PART 1)

Q. Why is the clear night sky important to astronomers?
A. It allows visibility of almost all celestial bodies unhindered by the Sun's glare.

Q. Name the brightest object in the sky after the Sun.
A. The Moon.

Q. How does the Moon shine?
A. The Moon does not generate light of its own but reflects the light emitted by the Sun. Its apparent large size causes it to appear brighter compared to other objects that are more brighter but farther away from the Earth.

Q. How do the planets shine?
A. The planets do not generate any light of their own but reflect light from the Sun, like the Moon does.

Q. What is the horizon?
A. The horizon is the limit of the observer's field of vision from any point on the Earth's surface. It is the maximum distance to which one can see accross the surface of a level of plain or the surface of the sea. In effect the horizon appears as a distant circular boundary surrounding the observer. The horizon recedes as one goes higher above the surface of the Earth i.e. the field of view increases. (Refer Fig. No. 4.1).

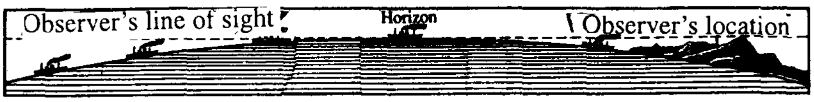


Fig. 4.1 Curve of the Earth.

Q. How do the stars shine?
A. The stars generate their own light like the Sun.

Q. How do meteors shine?

A. Meteors shine when they heat up and burn due to air friction while falling through the Earth's atmosphere.

Q. How do comets shine?

A. When a comet approaches the Sun, the heat from the Sun vapourises part of the material in the comet, causing it to glow.

Q. Why do stars twinkle?

A. Distortion of star light by Earth's atmosphere makes the stars apparently twinkle.

Q. Do stars twinkle uniformly in all parts of the night sky?

A. No. Stars twinkle more when they are near the horizon, since their light has to pass obliquely through a thicker layer of the Earth's atmosphere which has a greater distortion effect. (Refer Fig. No. 4.2).

Q. Do the planets also twinkle?

A. Mercury and Venus twinkle when observed near the horizon.

Q. Does nearness of a celestial body to the horizon have any effect other than increasing the twinkling?

A. Yes. The colour of the object turns pink, a reason why the Sun appears red during sunrise or sunset. Mercury also sometimes appears pink when seen near the horizon. (Refer Fig. No. 4.2).

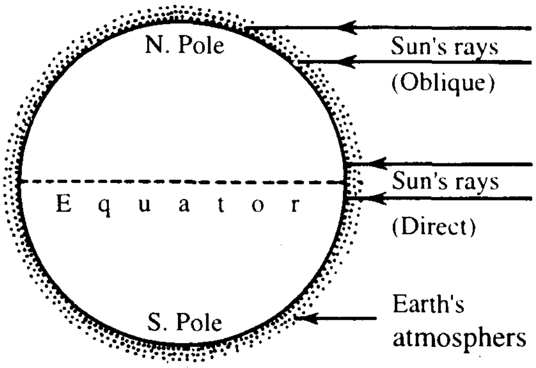


Fig. 4.2 In high latitudes, a cluster of solar rays is spread over a larger area and thus is less concentrated than a similar cluster of rays in lower latitudes. Similarly, it is evident that oblique rays pass through a greater thickness of atmosphere, consequently losing more of their lighting and heating power than direct rays.

Q. Why don't the Sun and Moon twinkle?

A. Though the Earth's atmosphere distorts the light in all cases, the twinkling phenomenon is noticeable only when the object appears very small in the sky. Even planets and large stars may appear to twinkle only when they are near the horizon. The Sun and the Moon are obviously too larger for the twinkling effect to be noticeable.

Q. What is meant by the apparent and true direction of the Sun?

A. The true direction of the Sun is always different from the apparent one due to refraction of Sun's radiation in the Earth's atmosphere. (Refer Fig. No. 4.3).

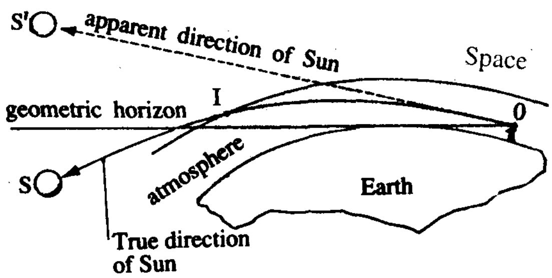


Fig. 4.3 Atmospheric Refraction.

The effect of atmospheric refraction on the apparent position of the rising or setting Sun as seen by the observer O is shown here, greatly exaggerated. A ray of light from the Sun, which is in fact below the observer's horizon, travelling in the direction SI enters the atmosphere at point I and is bent in such a way that it reaches O. To the observer it appears as if the ray of light is approaching along direction S'O. Thus, the Sun appears to be above the horizon. The maximum displacement in position due to this effect is about 35 minutes of arc.

Q. What is the Celestial Sphere?

A. It is an imaginary sphere with the Earth as its centre and having a very large radius. The position of bodies such as stars, planets and galaxies are specified by their coordinates on the celestial sphere. In ancient times, the astrologers considered the Earth to be surrounded by the Celestial Sphere and the stars were attached to it.

Q. Does the celestial sphere concept have any significance in modern astronomy?

A. It is used nowadays only for convenience. Since the Earth spins once on its axis every day, it is convenient to imagine the Earth as remaining stationary and the celestial sphere rotating once every day. When the Earth rotates from west to east, the celestial sphere appears to rotate from east to west and the stars appear to rise and set over the horizon.

Q. Can the entire celestial sphere be seen from any place on the surface of the Earth?

A. No. The Earth hides part of the celestial sphere below the horizon. (Refer Fig. No. 4.4).

Q. What is meant by Zenith and Nadir?

A. Zenith is the uppermost point on the celestial sphere seen vertically above an observer on the Earth's surface. The point on the celestial sphere diametrically opposite the Zenith is the Nadir. (Refer Fig. No. 4.4).

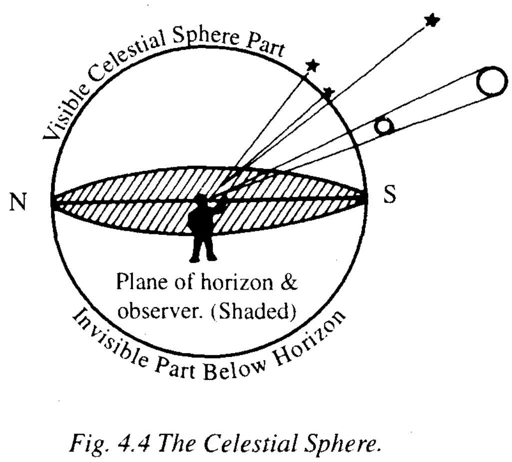


Fig. 4.4 The Celestial Sphere.

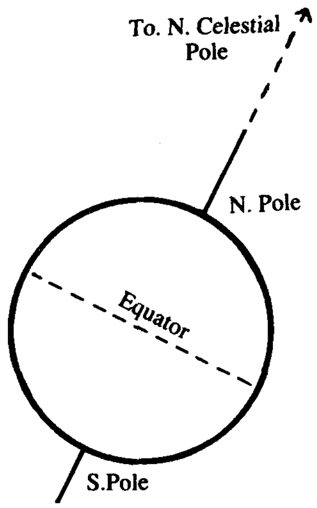


Fig. 4.5 The North Celestial Pole.

Q. What are the celestial poles, the celestial equator and celestial meridians?

A. The celestial sphere is assumed to possess poles, equator and meridians like the Earth. The point on the celestial sphere directly above the Earth's geographical north pole is assumed to be the north celestial pole. Similarly, the point on the celestial sphere directly above the Earth's geographical south pole is assumed to be the south celestial pole. (Refer Fig. Nos. 4.5, 4.7, and 4.9).

Q. What is the celestial equator?

A. The celestial equator is the imaginary line representing the circumference of the celestial sphere and situated midway between the celestial poles.

Q. What is the significance of the celestial poles?

A. When the Earth rotates on its axis, the celestial sphere also appears to rotate around its axis. A star situated at a celestial pole directly above any of the Earth's poles would appear not have any lateral movement while the Earth is rotating.

Q. Does the Pole Star have any practical significance?

A. The Pole Star (Polaris or "Dhruva") helps navigators locate the north direction in the absence of any landmark, even in deserts and oceans. This is also called the "North Star".

Q. What are the pointer stars or "The Pointers"?

A. The stars Alpha and Beta (Dubhe and Merak) in the constellation Ursa Major (also known as Great Bear, Big Dipper, Plough or "Saptarishi") are called "The Pointers" since a line drawn through these stars points towards the Pole Star. (Refer Fig. No. 4.6).

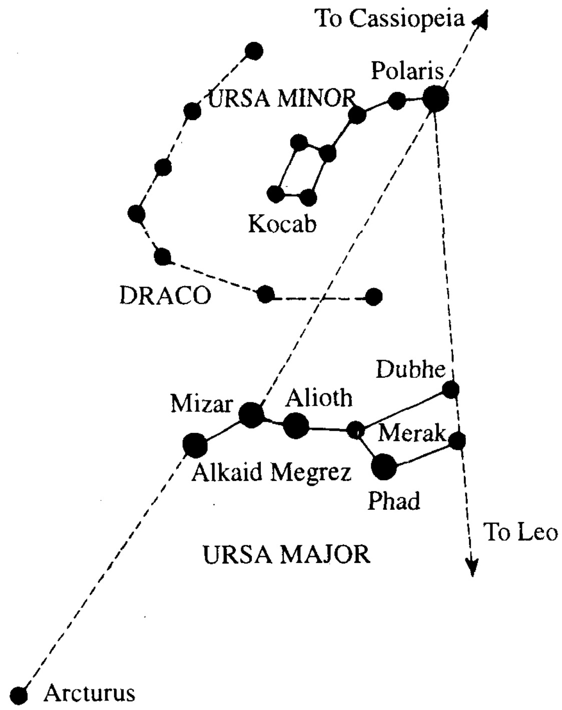


Fig. 4.6 The Pointers (Dubhe and Merak).

Q. Is there any star like Polaris at the South Celestial Pole?

A. No. However, a group of stars known as "Crux" ("Trishanku" or "Southern Cross") is situated almost at the South Celestial Pole and helps navigators in locating the south direction.

Q. What is the sidereal year?

A. Assuming the stars to be fixed in space on the Celestial Sphere, the time taken for the Sun's projection on the celectial sphere to make one complete revolution of the celestial sphere, is called the sidereal year. This aspect of the solar year is of great importance in astrological calculations.

Q. What is the ecliptic of the Earth's sphere?

A. The plane of Earth's equator is tilted by 23.5° with respect to the mean plane of the planets, hence the Equator is also tilted by 23.5°. The ecliptic of Earth's sphere refers to an imaginary, circumferential line around the Earth situated in the mean plane of the planets, or equivalent to the Equator tilted by 23.5°. (Refer Fig. Nos. 3.5 and 3.6).

Q. What is the ecliptic of the celestial sphere?

A. The ecliptic of the celestial sphere is the counterpart of the ecliptic of the Earth's sphere. Since the Earth's ecliptic is inclined to the Earth's Equator by 23.5°, the ecliptic of the celestial sphere is also inclined by 23.5°. Generally, when we say "the Ecliptic" we mean the ecliptic of the celestial sphere unless otherwise specified.
The ecliptic is therefore a circumferential line or great circle on the celestial sphere, tilted to the celestial equator at an angle of 23.5°. (Refer Fig. No. 4.7).

Q. What are the equinoxes?

A. The two times in each year when day and night are of equal duration are called eqinoxes. The ecliptic intersects the celestial equator at two points, called the points of summer or vernal equinox or "Vasanta Sampaat" (which occurs on 21st March) and the autumnal equinox or "Sharad Sampaat" (which occurs on 22nd September) respectively (Refer Fig. Nos. 4.7 and 3.7).

Q. What are the solstices?

A. The points midway between the equinoxes are called the points of summer solstice (which occurs on 21st June) and the winter solstice (which occurs on 22nd December). (Refer Fig. Nos. 4.7 and 3.7).

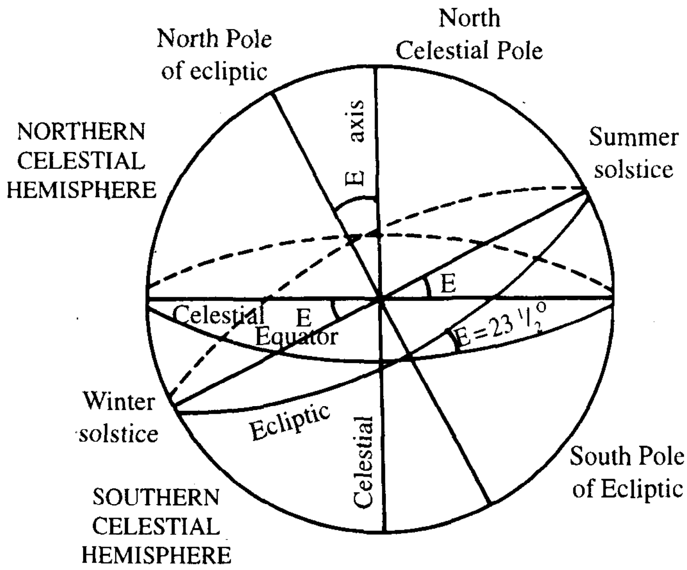


Fig. 4.7 Celestial Equator and the Ecliptic.

Q. What is the significance of the ecliptic, the equinoxes and the solstices?

A. These parameters have been closely related to the changes of seasons on Earth since ancient times.

Q. What are the North Pole of Ecliptic and the South Pole of Ecliptic?

A. Just as the ecliptic can be visualised as the celestial equator displaced on the celestial sphere by 23.5°, we can visualise the north and south celestial poles to be correspondingly displaced by 23.5° on the celestial sphere to form respectively the North Pole of Ecliptic and the South Pole of Ecliptic. (Refer Fig. No. 4.8).

Q. What are circumpolar stars?

A. Circumpolar stars (also called non-setting stars) are permanently visible above the horizon and neither rise nor set. The number and type of circumpolar stars will naturally depend on the location of the observer. At the Equator, the northern and southern celestial poles would appear on the horizon, and no stars would be circumpolar. For intermediate latitudes, some stars would be circumpolar, some would rise or set, and some would never be seen at all. (Refer Fig. No. 4.8).

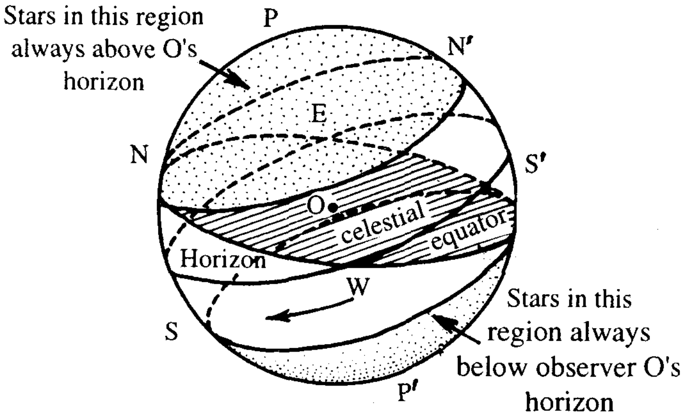


Fig. 4.8 Circumpolar Stars.

As the sphere rotates, stars in the region of the sphere bounded by the arc NPN' lie permanently above the observer's horizon and are called circumpolar stars. Stars in the region bounded by the arc SP'S' never rise above his horizon. Stars which are circumpolar for a particular observer depend upon his latitude.

Q. How do astronomers locate and refer to individual stars in the sky?

A. The coordinates that determine the position of a star on the celestial sphere are "Right Ascension" (R. A.) and "Declination"(D.). These are polar coordinates which specify the angles of reference of the star and determine the celestial longitude and latitude at which the star can be located. (Refer Fig. No. 4.9).

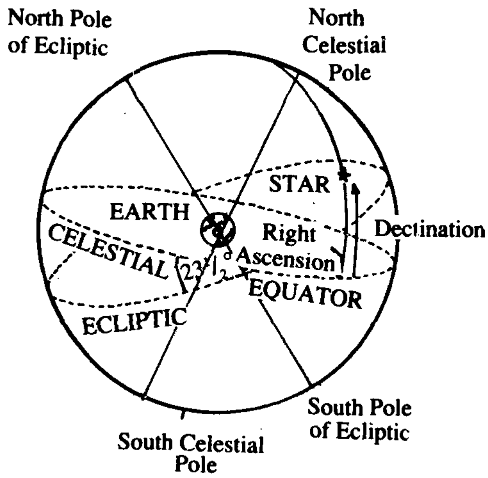


Fig. 4.9 Right Ascension and Declination reference of a star.

Q. What is Right Ascension?

A. The Right Ascension reference gives the celestial longitude of a body Zero Right Ascension reference is the point where the celestial equator and the ecliptic intersect. In other words, it is the vernal equinox or the point at which the Sun moves into the northern half of the celestial sphere. Considering that one circuit of the celestial sphere is equivalent to 360° in 24 hours, we can say that 15° of Right Ascension are equivalent to 1 hour of time. The meridians at intervals at 15° are therefore called Hour Circles for the same reason. The Right Ascension reference helps the observer to align himself in the correct direction on the horizontal plane. (Refer Fig. No. 4.9).

Q. What is Declination?

A. Once the observer has aligned himself in the correct direction on the horizontal plane through the Right Ascension reference, he can locate the star by aligning himself along the vertical plane. In other words, together with Right Ascension, Declination defines the position of a body in the sky. Declination is the extent to which the star is above the celestial equator. Declination can therefore vary from 0 to 90°. (Refer Fig. No. 4.9).

Q. What is correction for planetary parallax?

A. The coordinates (R. A. & D.) of astronomical bodies on the Celestial Sphere are theoretically with reference to the centre of the Earth. The observations of an observer located on the Earth's surface have necessarily to be corrected by the distance between the Earth's centre and the observer's location. This correction (the radius of the Earth) is called correction for planetary parallax.

5. THE MOON (PART 1)

Q. What is Selenology?
A. Selenology is the study of the Moon.

Q. What is the relative mass of Earth with respect to the Moon?
A. The Earth has 81 times the mass of the Moon.

Q. What is the gravity on the Moon's surface?
A. It is about one sixth of the gravity on the Earth's surface.

Q. What is the Earth Moon System?
A. The Earth Moon System represents the system comprising the Earth and the Moon held together by their mutual gravitational forces. The Earth has eighty-one times the mass of the Moon and is at a distance of 384,400 km.

Let us, for example, consider a 1 kg ball and an 81 kg ball connected by a bar. The bar can be balanced at a point nearer the 81 kg ball, so that the bar remains horizontal. The point at which the bar is balanced is called the "Centre of Mass" of the system representing the two balls and the bar.

In the case of the Earth Moon System, the two balls are replaced by the Earth and the Moon and the bar is replaced by the invisible force of gravity which holds them together. The Earth Moon System will remain in equilibrium at the centre of gravity or centre of mass of the system, which will obviously be nearer to the Earth than to the Moon. (Refer Fig. No. 5.1).

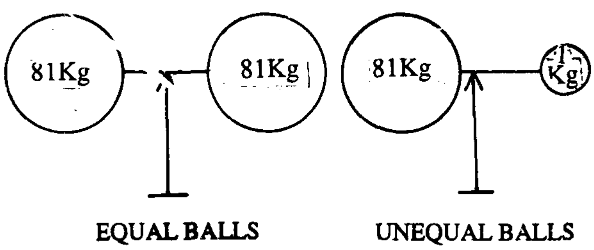


Fig. 5.1 Balancing Point of Two Balls.

Q. What is the barycentre of the Earth Moon System?

A. The barycentre of the Earth Moon system is the centre of mass of the Earth Moon System. (Refer Fig. No. 5.2).

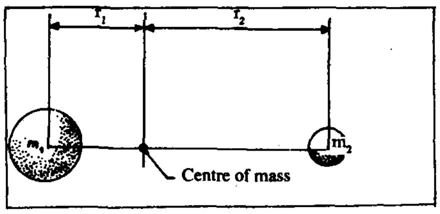


Fig. 5.2 Centre of Mass (Barycentre).

Q. What is the significance of the barycentre of the Earth Moon System?

A. Though we say the Moon goes around the Earth, it is not strictly correct. Both the Moon and the Earth are actually revolving around their common barycentre.

As such, the Moon and the Earth behave as independent planets while revolving in elliptical orbits around the Sun, but they simultaneously move relative to each other around their common barycentre. Therefore, the Earth Moon System can also be regarded as a double-planet system. Both the Earth and the Moon trace wobbly paths through space. (Refer Fig. No. 5.3).

Q. Where is the barycentre of the Earth Moon System located?

A. The Earth is so large compared to the Moon that the barycentre of the system is located about 1700 km below the Earth's surface. (Refer Fig. No. 5.3).

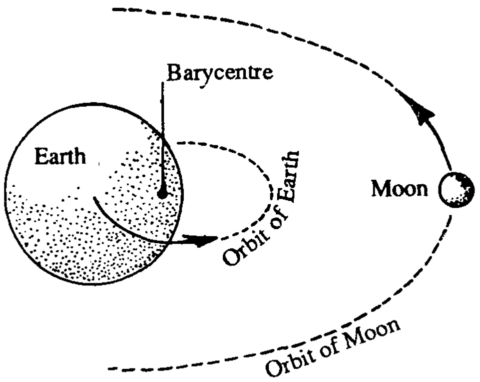


Fig. 5.3 Orbits of Earth and Moon around their common Barycentre.

Q. How was the Moon formed?

A. The Moon and the Earth are thought to have been formed at the same time and in the same manner, resulting from the coalescing of the same gas and dust orbiting around the Solar System.

Q. What is the age of the Moon?

A. A study of Moon rocks (brought to Earth by astronauts) indicates that the Moon and the Earth are of the same age (about 4,600 billion years old).

Q. What materials is the Moon made of?

A. The same elements found on the Earth are found on the Moon, though in different proportions. The Moon has no air or water.

Q. What is the density of the Moon?

A. The density of the Moon is about 60% of the Earth's density, since heavier elements like iron occur in lesser proportion on the Moon than on the Earth.

Q. What is the internal structure of the Moon?

A. The moon has a core, mantle and crust as in the case of the Earth (though the characteristics of these zones are different). The crust has however two distinct layers—the upper crust and the lower crust. Also between the lower crust and the mantle is another distinct but thin region called the astheno-sphere. (Refer Fig. No. 5.4).

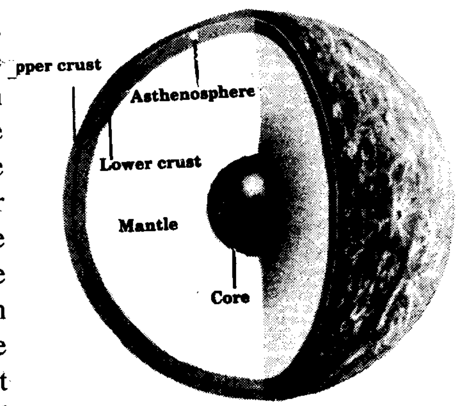


Fig. 5.4 The Interior of the Moon.

Q. Does the Moon have an atmosphere?

A. The Moon may once have had an atmosphere. But due to the low mass and consequently low gravity of the Moon, the atmosphere has slowly leaked out into space. At present, for all practical purposes, the Moon has no atmosphere.

Q. Why is there no atmosphere on the Moon?

A. Every star, planet or moon exerts a gravitational force on objects on its surface. An object has to achieve a critical velocity (escape ve-

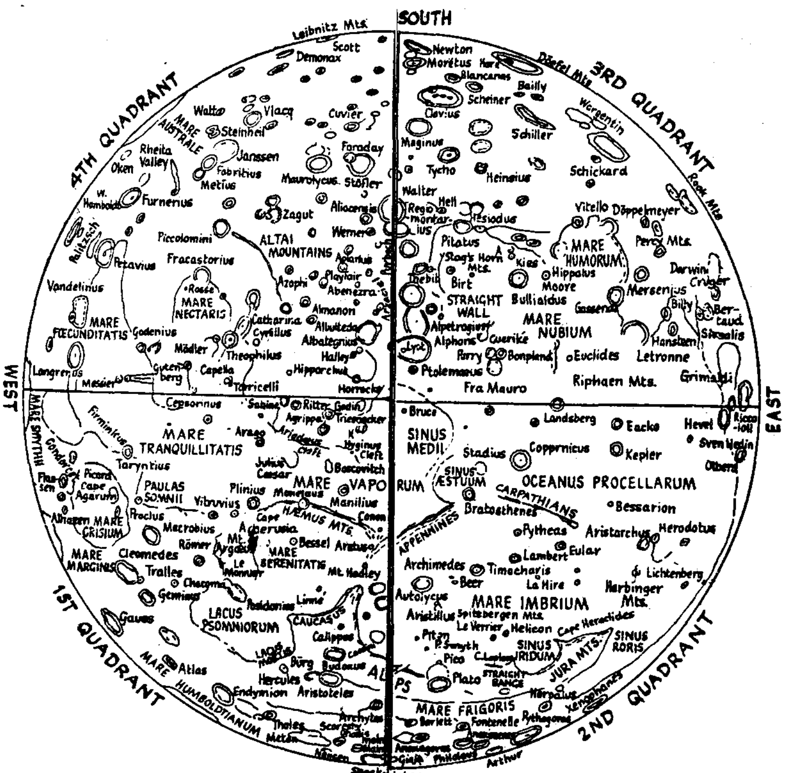


Fig. 5.5 Quaarants and Features on the Moon.

locity) to permanently leave the star, planet or moon. If the velocity of the object is less than the escape velocity it will fall back to the surface. The escape velocity is 60 kmps on Jupiter hence the gas molecules in its atmosphere hardly escape from it. On Earth, the escape velocity is 12 kmps, so here also gas molecules cannot easily escape. However, the escape velocity on the Moon is only 2.5 kmps which is insufficient to hold on to the gas molecules in its atmosphere. Hence, almost all the atmosphere on the Moon has leaked into space. Generally an escape velocity of at least 3.5 kmps is necessary to retain the atmosphere (e.g., Titan, the sixth satellite of Saturn, has an escape velocity of 3.5 kmps and does have a detectable atmosphere). Mars with an escape velocity of 5 kmps also has an appreciable atmosphere and even changing seasons. (Refer Fig. No. 1.3).

Q. How do we denote north and south on Moon maps?

A. On a Moon map, the north is usually at the bottom and the south at the top. This is the opposite of the north-south representation on an Earth map. (Refer Fig. No. 5.5).

Q. Why is the north-south direction on the Moon inverted as compared to that on Earth?

A. Generally astronomical maps are produced from images obtained through an astronomical telescope. Since these images are formed inverted, they can be used directly if the north-south direction is also inverted for convenience.

Q. Are all portions of the Moon visible from Earth.

A. No. Only one side of the Moon ("near side") is visible from the Earth at all times. The rear or "far side" of the Moon cannot be seen from Earth.

Q. Why is the far side of the Moon not visible from Earth?

A. Only one side of the Moon is visible from the Earth because the Moon rotates on its axis every 27.322 days, hence keeping the same face constantly towards Earth.

Q. How is it possible to know about the far side of the Moon?

A. Spacecraft launched from Earth have gone behind the Moon and transmitted images of the far side of the Moon. We know about the far side only from these images.

Q. When was the far side of the Moon first photographed?

A. In 1959, the Russian Moon probe Lunik first photographed the far side.

Q. What are the names of the four quadrants of the Moon?

A. The four quadrants (that divide the visible circle of the Moon into four equal sectors) are first or northwest, second or northeast, third or southeast and fourth or southwest quadrant. (Refer Fig. No. 5.5).

Q. What is libration in longitude?

A. The orbital speed of the Moon varies, while its speed of axial rotation is constant. Consequently, there is a slight swaying of the Moon which enables us to see a little beyond the eastern and western edges of the Moon. This is called libration in longitude.

Q. What is libration in latitude?

A. Since the Moon's orbit is tilted compared to the plane of the Earth's orbit, the Moon periodically shifts slightly in a north-south direction. This enables us to see a little beyond the Moon's poles. This is called libration in latitude.

Q. What is the effect of libration?

A. Libration enables us to see more of the Moon's surface. Instead of seeing only 50 percent of the Moon's surface, libration enables us to see 59 percent of the Moon's surface. However, the remaining 41 percent of the Moon's surface can be observed only from images transmitted from spacecraft orbiting the Moon.

Q. To what extent is libration represented in lunar maps?

A. Lunar maps are drawn based on mean libration.

Q. What is a New Moon?

A. During the period in the Moon's cycle when it appears totally dark, the Moon is called a New Moon (Refer Fig. No. 5.6).

Q. What are phases of the Moon?

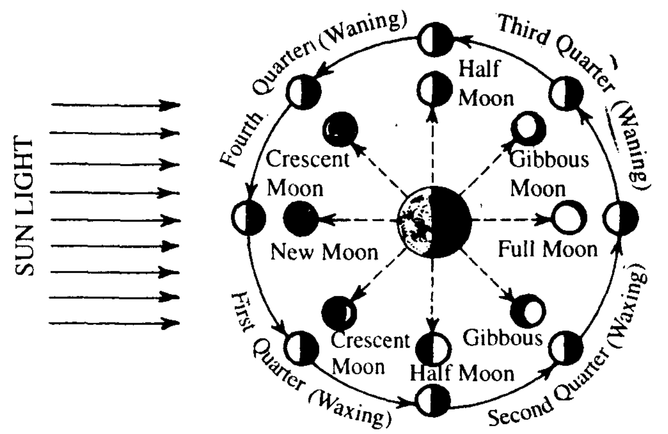
A. The Phases of the Moon refer to the appearance of the Moon when only a part of the Moon's circle appears to be bright. Hence, the Moon exhibits phases between New Moon and Full Moon. Such Moon phases can be described as Crescent Moon Half Moon etc. For example, at the half Moon phase, half the circle of the Moon appears to be bright.

Q. What is the change in brightness from Half Moon to Full Moon?

A. The Full Moon is nine times brighter than the Half Moon.

Q. What is waxing and waning of the Moon?

A. Waxing refers to the cyclic apparent enlarging of the bright portion of the Moon followed by waning which refers to the cyclic apparent decreasing of the bright portion of the Moon. (Refer Fig. No. 5.6).



5.6 The outer circle shows the Moon as illuminated by sunlight from the left. The inner circle shows the corresponding views of the Moon as viewed from the Earth (note the phases of the Moon).

Q. What is a crescent?

A. Crescent refers to the periods of appearance of a small bright portion of the Moon, called waning crescent and waxing crescent in the waning and waxing phases respectively. (Refer Fig. No. 5.6).

Q. When is the Moon said to be gibbous?

A. Gibbous refers to the periods of appearance of a small dark portion of the Moon, called waxing gibbous and waning gibbous in the waxing and waning phases respectively. (Refer Fig. No. 5.6).

Q. What are syzygy and quadrature?

A. The position of the Moon at Full Moon and New Moon is called syzygy, and that at half Moon is called quadrature. (Refer Fig. No. 2.6)

Q. What are the Quarters of the Moon?

A. The period between one New Moon and the next can be divided into four parts, each part being called a quarter. (Refer Fig. No. 5.6).

Q. What are the features of each quarter?

A. During the first quarter, the New Moon changes into a crescent and then into a semicircle. During the second quarter, the semicircle changes into the circle of the Full Moon. During the third and fourth quarters, this sequence is reversed. (Refer Fig. No. 5.6)

Q. What is the main difference between quarters of the Moon and phases of the Moon?

A. Quarter of the Moon refers to the position of the Moon with relation to its orbit. Hence at the end of the first quarter, the Moon has completed one fourth of its orbit around the Earth.
Phase of the Moon refers to the appearance of the Moon when only a part of the Moon's circle appears to be bright.
Hence half Moon occurs not at the end of the second quarter, but twice—once at the end of the first quarter and again at the end of the third quarter. (Refer Fig. No. 5.6).

Q. Why does the Moon rise later each night by an average of 50 minutes?

A. The period of the Moon's revolution around the Earth is not an exact multiple of the period of rotation of the Earth around its axis.

Q. How long do the Earth and the Moon take to complete one orbit around their barycentre?

A. 27-1/3 days. If the moon's position is observed in the sky with reference to any star (not planet), the Moon will return to the same position in the sky (with reference to that star) after a period of 27-1/3 days. (Refer Fig. No. 5.3).

Q. What do we mean by "Sidereal Period". "Synodic Month", and "Lunation" with reference to the Moon?

A. The period of 27-1/3 days for the Moon's orbit is known as the "Sidereal Period" or "Sidereal Month".
The period of 29-1/2 days for the Moon's phases is known as a "Synodic Month" or "Lunation".

Q. Why is there a difference between the sidereal period and the synodic month (Lunation)?

A. The answer lies in the changes in the relative positions of the Earth, Moon and Sun during the period of one orbit of the Moon. It must be remembered that while the Moon is orbiting the Earth, both are also orbiting the Sun. (Refer Fig. No. 5.7).

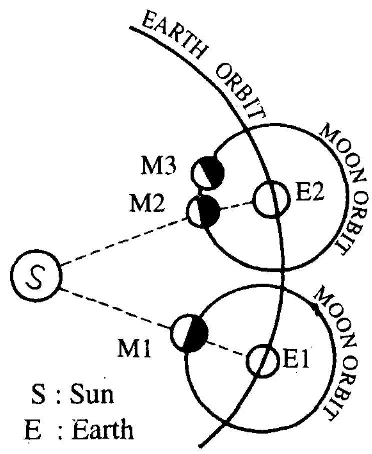


Fig. 5.7 The Lunation
E1 & E2 show movement of the Earth along its orbit. M1 & M2 show the moon in the same postion relative to the M1 & M3 show two successive new moons.

Q. What is the significance of the "Sidereal Period" of the Moon?

A. In one "Sidereal Period" the Moon completes one orbit of the Earth measured relative to the background stars which, for this purpose, are considered fixed in position.

6. THE PLANETS

Q. Can all the planets be seen from Earth with the naked eye?

A. Neptune and Pluto can be seen only with telescopes. The other planets, including a faint Uranus, can be seen with the naked eye. Astronomers in ancient times were hence unaware of the planets beyond Saturn since they did not have telescopes.

Q. When were the planets beyond Saturn first discovered?

A. In 1781, Sir William Herschel discovered the existence of the planet Uranus. It is twice as far out as the sixth planet Saturn.

Q. Which planet is farthest from the Earth?

A. The eccentric orbit of Pluto regularly brings it closer to the Sun than Neptune. Hence Neptune and Pluto will take turns to be the farthest planet from time to time. (Refer Fig. 2.1).

Q. Do all the planets have an atmosphere similar to that of the Earth?

A. Mercury and Pluto have no atmosphere. The other planets have atmospheres containing different gases. Earth's atmosphere, containing mainly nitrogen and oxygen, is unique. Venus has a carbon dioxide atmosphere. The atmosphere of Mars is mainly argon and carbon dioxide. Jupiter, Saturn, Uranus and Neptune have thin atmospheres containing hydrogen, helium and methane.

Q. Why are Mercury, Venus, Earth and Mars Called "Terrestrial" planets?

A. "Terrestrial" means Earth-like. All the terrestrial planets have large, solid, metallic cores surrounded by a rocky outer layer. All of them (with the exception of Mercury) have atmospheres.

Q. Why are Jupiter, Saturn, Uranus and Neptune called "Gas Giants"?

A. The gas giants or jovian planets do not have any significant solid cores and are almost entirely composed of gases or liquified gases. They are also enormous in size compared to the other planets.

Q. Do all planets have satellites?

A. Mercury and Venus have no satellites. Earth has one satellite (the Moon), Mars and Neptune have two satellites each. Uranus has five satellites. Jupiter and Saturn have a large number of satellites. Pluto has one satellite.

Q. Can a satellite be larger than a planet?

A. A satellite is much smaller than the planet around which it revolves. However, a large planet is capable of having a large satellite. Titan, one of the satellites of Satum, and Triton, a satellite of Neptune, are larger than the planets Mercury or Pluto.

Q. Does the period of spinning remain the same for all the planets?

A. The day of each planet is different. For example, the period of one day for Mercury is 59 Earth days; for Venus, it is 243 Earth days and for Mars, it is about 24-1/2 Earth hours. The large variations in the period of spinning is due to random collisions with comets and asteroids over very long periods.

Q. Why does the Sun rise in the east and set in the west on the Earth? Does the concept hold equally good for all the planets in the Solar System?

A. The Earth spins on its axis from west to east. Hence the sky (including the Sun and all the heavenly bodies in the sky) appear to move from east to west. In the case of the other planets, the Sun will rise in the east and set in the west, when viewed from the surface of that particular planet, only if that planet is spinning in the same direction as Earth, with respect to the Sun. In all the planets (excluding Venus, Uranus and Pluto) the Sun rises in the east and sets in the west. In the case of Venus, Uranus and Pluto, the Sun rises in the west and sets in the east, since the planets spin in the opposite direction.

Q. Is the size of a planet related to its rotation?

A. No. For example, Jupiter's day is only 9 hours 50 minutes eventhough it is by far the largest planet.

Q. Are all planets oblate spheroids?

A. All the planets exhibit oblate spheroidness to some degree, the extent of which increases with increasing speed of spinning and decreases with increasing density. Consequently, a gaseous planet with a rapid axial rotation like Saturn exhibits a very high degree of oblate spheroidness. For example, Jupiter whose day is less than 10 hours has its diameter over 140,000 km at the Equator and less than 133,000 km at the poles.

Q. What is the obvious snag in locating features on the gas giants Jupiter, Saturn, Uranus and Neptune?

A. Being gaseous planets, the rotation of the equatorial zone is faster than at the higher latitudes. Also there are no fixed reference points in the constantly shifting clouds of gas.

Q. How big is Jupiter, in general terms, as compared to the other planets of the Solar System?

A. If Jupiter was hollow, all the other planets of the Solar System could be accommodated within it. It is the largest in the Solar system. Its equatorial diameter is 142,800 km and it has a mass more than twice that all the other planets combined.

Q. Why was the astronomer Galileo persecuted by the Catholic Church?

A. Viewing Jupiter through his telescope, Galileo discovered it had four moons revolving around it. This went against the Church doctrine of that time that all heavenly bodies revolved around the Earth which was held to be the centre of the Universe.

Q. Which planet has a permanent large red spot on its surface which keeps changing and shifting?

A. Jupiter. The spot is believed to be an area of permanent turbulence.

Q. What are the Galilean Moons?

A. The four moons of Jupiter discovered by Galileo are called the Galilean moons.

Q. How powerful a telescope is required to observe the Galilean moons of Jupiter?

A. The Galilean moons of Jupiter can be seen with a good pair of modern binoculars.

Q. What is the problem in observing features on the surface of Venus?

A. Venus is permanently covered with a cloak of dense clouds of sulfuric acid droplets and carbon di-oxide. Hence no features on the surface are visible on visual observation. However, such features can be observed by instruments.

Q. Which planet is known as the 'Red planet'?

A. Mars. The colour is caused by large deposits of red iron oxide (limonite) on the surface of the planet.

Q. How hot is it on the surface of Mars?

A. The temperature on the surface of Mars can vary from 25°C during the day to minus 125°C at night.

Q. Name the English satirical writer who predicted the existence of the moons of Mars.

A. Jonathan Swift predicted the existence and the characteristics of the moons of Mars (no doubt by sheer coincidence) in his book Gullivers Travels (1735), 142 years before the moons were discovered.

Q. How far away are the moons Phobos and Deimos from Mars.

A. The moons are very close to Mars. Deimos is about 20,000 km away and Phobos is less than 6,000 km away.

Q. What is the synodic orbital period of a planetary moon?

A. The synodic orbital period of a planetary moon is the period from one new moon to the next. For the moons of Mars it is 7 hours 39 minutes for Phobos and 30 hours and 21 minutes for Deimos.

Q. What is unusual about the period of revolution of the two moons of Mars?

A. Phobos orbits once in 7 hours and 40 minutes and Deimos once in 30 hours. The inner moon Phobos orbits the planet faster than the spinning motion of the planet. The outer moon Deimos remains above a given landscape for nearly three days passing through all its phases twice.

Phobos not only rises in the west and sets in the east but it rises and sets twice each day. It is thought to be an asteroid captured by Mar's gravity.

Q. What is the apparent retrograde motion of a planet?

A. All the planets exhibit direct motion around the Sun. However, planets like Venus, Mercury or Mars can exhibit an occasional apparent retrograde motion when viewed in the sky from the earth, relative to the background of stars. This is due to the relative positions of the Earth and the planet as they orbit around the Sun. (Refer Fig. No. 6.1).

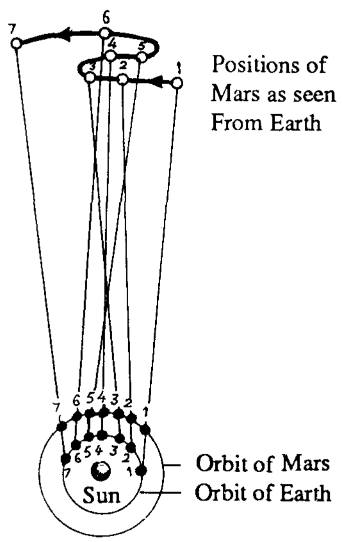


Fig. 6.1 Apparent direct and retrograde motion of Mars as viewed from the Earth.

Q. What are planetary perturbations?

A. Perturbations are the changes in the path of a planet or comet or asteroid around the Sun, due to the gravitational pulls of the other planets acting on it. The main culprits in this case are Jupiter and Saturn which have tremendous gravitational fields.

Q. What are Kepler's Laws of Planetary Motion?

A. Kepler's Laws of Planetary Motion state:

1) The orbit of a planet is an ellipse with the Sun as one focus of the ellipse. (Refer Fig. No. 6.2).
2) The planet moves in its orbit at such a velocity that its radius vector (the angle as seen from the Sun at any point on the orbit) sweeps out equal areas in an equal interval of time. (Refer Fig. No. 6.3).
3) The orbital period squared is proportional to the mean (average) distance from the Sun cubed.

These laws apply to all the planets including Uranus, Neptune and Pluto, planets discovered long after Kepler's death.

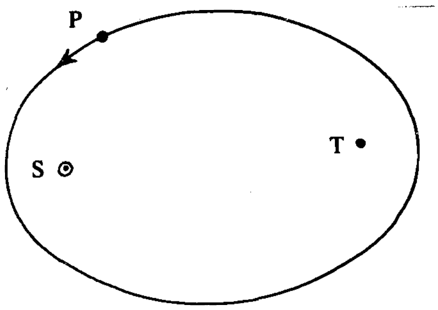


Fig. 6.2 Kepler's First Law: A planet (P) moves in an ellipse with the Sun (S) at one of the two foci. The empty focus is located at (T).

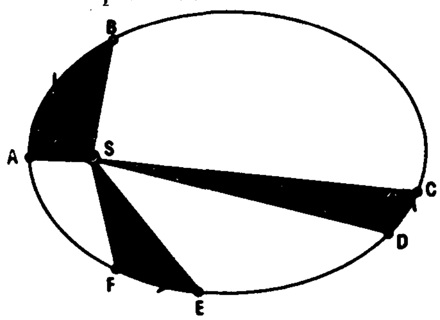


Fig. 6.3 Kepler's Second Law: A planet sweeps out equal areas in equal times. It takes as long to travel from B to A as from F to E as from D to C; and the shaded areas BSA, FSE and DSC are all equal.

Q. What is the empty focus?

A. An ellipse has not one focus but two foci, one at each end. Kepler's laws specify the Sun as one focus of the planet's elliptical orbit.

The other focus of the elliptical orbit is referred to as the empty focus. The distance between the empty focus and the aphelion point is equal to the distance between the Sun and the perihelion point. (Refer Fig. No. 6.2).

Q. Which planet has a large red spot?

A. Jupiter has a large red spot which keeps shifting and changing. The spot is believed to be an area of permanent turbulence.

Q. Do Kepler's laws equally apply to comets and asteroids also?

A. Yes. According to Kepler's law a comet spends most of its time moving very slowly and bursts into high speed (and high activity) only during its perihelion passage. (Refer Fig. No. 6.2).

Q. What is albedo?

A. Albedo refers to the proportion of incident light (or radiation)reflected back in all directions from the surface of a body. A perfect reflector has an albedo of 1, and a perfect non-reflector has an albedo of 0. The term usually applied to celestial objects within the solar system. A planet with clouds and atmosphere will have a higher albedo. The Moon has an albedo of 0.07 as it absorbs 93% of the sunlight falling on it and reflects the balance 7%. The albedo of atmosphereless Mercury is 0.06, while Earth and Venus (planets with cloudy atmospheres) have albedos of 0.39 and 0.76 respectively.

Q. What is the effect of albedo on the reflecting body?

A. The body heats up on absorbing the incident radiation. Hence a planet with a low albedo would warm up more, when sunlight falls on it.

Q. What are the objects with near zero albedos?

A. Some of the asteroids have an extremely low albedo with surfaces that reflect less than carbon paper.

Q. What is the origin of the names of the moons of Uranus (Miranda, Ariel, Umbrial, Titania and Oberon?

A. They are characters from Shakespeare's plays.

7. THE SUN (PART 1)

Q. What is the distance between the Earth and the Sun?

A. The distance between the Earth and the Sun varies from a maximum of 152×10^6 km at aphelion to a minimum of 147×10^6 km at perihelion. The average or mean distance is therefore about 149.6×10^6 km.

Q. If we could 'fly', in our imagination, how long would it take to reach the Sun?

A. At the speed of the Concorde, the fastest passenger plane (flying at about 2200 km per hour), it would take less than three hours to fly from New York to London, but to fly a distance equal to that between the Earth and the Sun (about 149,600,000 km), it would take nearly eight years.

Q. How long does it take the light from the Sun to reach the Earth?

A. Just under eight and half minutes.

Q. What percentage of the total mass of the Solar System is contributed by the mass of the Sun?

A. Over ninetynine per cent.

Q. Can the Sun ever be seen steadily with the naked eye?

A. Seeing the Sun steadily with the naked eye will cause permanent damage to the eye except during a total solar eclipse. It can, however, be viewed through special filters which make the Sun appear darker.

Q. At what speed is the Sun moving as it orbits the Milky Way galaxy?

A. About 275 km/sec.

Q. How long does the Sun take to complete one revolution around the centre of the Milky Way galaxy?

A. About 225 million years. This is also called the cosmic year or cosmological year.

Q. What was the stage of evolution of the Earth one cosmic year ago?

A. One cosmic year ago 'Coal Forests' still existed on the Earth, which were later transformed into coal deposits. Human beings had not yet appeared on the Earth.

Q. How large is the Sun compared to the Earth?

A. The Sun's mass is 333,000 times that of the Earth. However, average density of solar matter is only one fourth that of Earth. Hence more than a million Earths would fit inside the Sun. Also, 109 Earths would have to be placed side by side to equal the diameter of the Sun which is 1,392,000 km.

Q. What is the period of spinning of the Sun about its axis?

A. Since the Earth's surface is solid, all parts on its surface rotate in unison. However, since the Sun is appreciably gaseous, it rotates faster in its equatorial region (once in 27 days) than in its polar regions(once in 32 days).

Q. Is the Sun's axis tilted to the plane of the Earth's orbit?

A. Yes, by about 7°.

Q. Does the Sun have a magnetic field?

A. Yes.

Q. What is the temperature of the Sun?

A. The temperature of the Sun is about 6000°C near the surface and about 14 million degrees Celsius at the core.

Q. What is the Sun made up of?

A. Hydrogen, the most abundant element in the Universe, is also the main constituent of the Sun, with most of its mass concentrated towards its centre (90% within the inner half of its radius).

Q. Is the Sun a ball of fire?

A. In an ordinary fire (such as a kitchen fire), oxygen combines with various fuels, releasing heat and light. However, the fire in the Sun is not an ordinary fire but is similar to a continuous hydrogen bomb explosion, wherein a small quantity of matter is converted into an enormous quantity of energy in a conversion process that is ten million times more effective than ordinary combustion.

Q. What happens in a hydrogen bomb explosion?

A. In a hydrogen bomb explosion, hydrogen atoms are subjected to collision under tremendous pressure, resulting in their being merged or fused to form another element helium. In the process, also called a fusion reaction, large quantities of energy are released in the form of heat, light, X-rays, microwaves, gamma rays etc.

Q. How is the tremendous pressure created in the Sun for sustaining the fusion reaction continuously?

A. Hydrogen will convert to helium only under tremendous pressure. Such pressures can be sustained in laboratories on the Earth only for a brief instant during which a hydrogen bomb explosion takes place for a fraction of a second.

However, the Sun sustains this pressure continuously and so the explosion is continuous. Due to the enormous gravity of the Sun, the pressure inside the Sun is about 100 billion times the pressure of the Earth's atmosphere and is sufficient to sustain a continuous fusion reaction.

Q. Why is the diameter of the Sun relatively steady and why is its mass not scattered as in a normal explosion?

A. The large mass of the Sun creates tremendous gravity which forces all the mass towards the centre of the Sun. The centre of the Sun is subjected to tremendous heat and pressure, enough to sustain a continuous hydrogen bomb explosion. The explosion acts as an outward force throwing the mass away from the centre of the Sun while the gravity of the Sun acts as an inward force pushing back the mass towards the centre of the Sun. If the two forces are in equilibrium, the Sun would neither expand nor contract. This is what is actually happening. Hence, the Sun's size does not change appreciably.

Q. At what rate is the hydrogen being consumed in the nuclear reactions taking place in the Sun?

A. About six hundred million tons of hydrogen is consumed per second.

Q. What is the nature of radiation from the Sun?

A. Radiation from the Sun travels in waves of energy. There are different types of waves depending on wavelength, such as light, X-rays, gamma rays, radio waves etc.

Q. How much matter is converted to energy to produce the Sun's radiation?

A. About four million tons of hydrogen is consumed per second to produce the Sun's radiation which proliferates steadily in every direction.

Q. What proportion of the Sun's radiation reaches the Earth?

A. About one billionth of the Sun's radiation reaches the Earth and the rest streams off into space in all directions.

Q. Can all types of radiation from the Sun be detected on the Earth?

A. We can see light rays and feel heat rays. Ultra violet rays tan our skin.

Radio waves can be detected by instruments. But almost all the other rays from the Sun are absorbed by the Earth's atmosphere before they reach the Earth's surface and are detectable only by instruments placed on artificial satellites outside the Earth's atmosphere.

Q. What is the significance of the absorption of the Sun's rays by the Earth's atmosphere?

A. Some of the Sun's radiation is harmful to life on the Earth. Hence, the Earth's atmosphere acts as a protective shield by absorbing the harmful radiation of the Sun.

Q. What is the solar wind?

A. The solar wind is solar radiation in the form of a steady stream of electrically charged particles mostly protons and electrons which pours out of the Sun at the speed of upto 150,000 km/sec. The particles are however smaller than atoms.

Q. What happens when the solar wind hits the Earth?

A. The solar wind is deflected by the Earth's magnetic field and does not touch the Earth. The deflected solar wind streams behind the Earth similar to a cometary tail.

Q. Does the solar wind have any effect on the Earth?

A. Since the particles of the solar wind are electrically charged, they tend to move towards the Earth's magnetic poles, making the sky in the polar regions glow in vivid patterns called aurorae. (Aurora Borealis near the north magnetic pole and Aurora Australis near the south magnetic pole.)

Q. What is the solar limb?

A. The solar limb is the edge of the Sun's disc.

Q. What is the solar atmosphere?

A. The portion of the Sun lying in the region outside the limb is called the solar atmosphere.

Q. Is the solar atmosphere normally visible from the Earth?

A. No. The intense brightness of the Sun's disc prevents us from seeing anything else in the vicinity. The solar atmosphere can however be seen during a total solar eclipse when the Sun's disc is totally covered by the Moon.

8. THE STARS (PART 1)

Q. How many galaxies are there in the Universe?

A. It has been estimated that there are about a hundred billion galaxies in the Universe.

Q. How many stars are there in a galaxy?

A. On an average, there are about a hundred billion stars in each galaxy.

Q. How many stars are there in our galaxy, the Milky Way?

A. About four hundred billion stars.

Q. How many stars are bigger in magnitude than the Sun?

A. In the Milky Way galaxy alone, there are five billion stars larger in magnitude than the Sun.

Q. What is the shape of the Milky Way galaxy?

A. The Milky Way galaxy consists of a central core or nucleus with many stars, a disc with many stars distributed in a plane tilted at 62° to the celestial equator, and a halo with relatively few stars distributed in an outer region. The Sun is situated about three fifths of the way from the centre of the galaxy. (Refer Fig. No. 8.1).

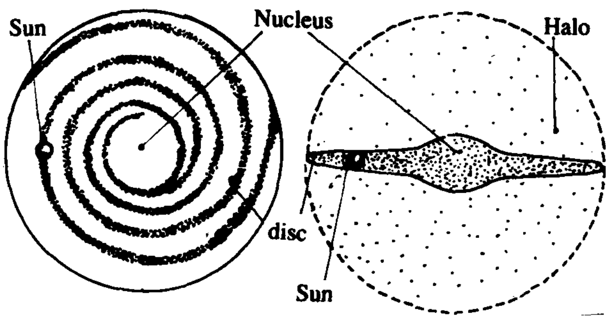


Fig. 8.1 The Milky Way Galaxy viewed from the top (left) and side (right).

Q. How are galaxies classified?

A. Galaxies are classified as elliptical, spiral and irregular depending on the nature of distribution of stars on the galactic disc.

The more common types have a regular structure. Elliptical galaxies are denoted by the letter E followed by a numeral having values from 0 to 7 depending on the degree of flattening of the ellipse. Spiral galaxies are denoted by Sa, Sb, Sc, SBa, SBb or SBc according to the pattern of the spiral arms. Barred spiral galaxies are denoted by SBa, SBb and SBc. SO denotes a class intermediate between elliptical and spiral. Irregular galaxies are denoted by Irr. (Refer Fig. No. 8.2).

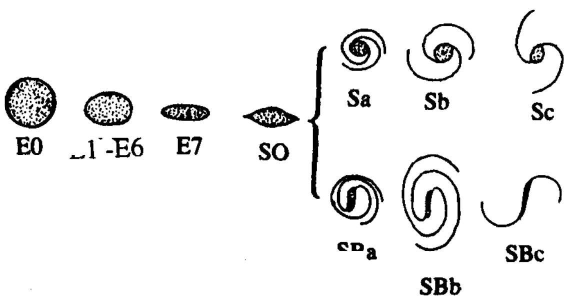


Fig. 8.2 Shape Classification of Galaxies.

Q. What are spiral, twin spiral, and multiple spiral patterns of galactic discs?

A. The spiral, twin spiral and multiple spiral patterns refer to the number of 'arms' of the spiral. (Refer Fig. Nos. 8.2, 8.3 and 8.4).

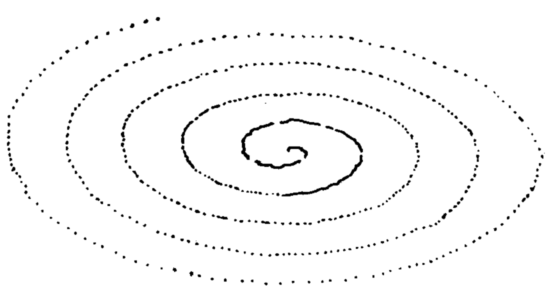


Fig. 8.3 Spiral.

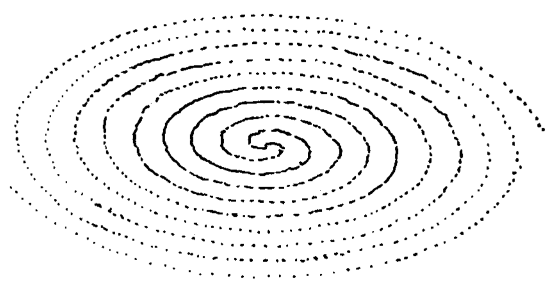


Fig. 8.4 Twin Spiral.

Q. How does a star form?

A. Over a period, particles of matter from space debris coalesce through gravitational forces to form a heavenly body which is rotating and has a spherical shape. As the matter continues to coalesce, the body becomes more dense and the pressure at its centre (due to gravitational forces) increases. If the mass of the body is sufficiently large, the high pressure at the centre causes the hydrogen fusion reaction to commence. The mass is then called a protostar. If the body is still larger the hydrogen fusion activity increases and makes the body glow brightly. The body is then called a star.

Q. Has the hydrogen fusion reaction started in Jupiter, the largest planet in the Solar System?

A. Some astronomers believe that the hydrogen fusion reaction occurs within Jupiter's core because Jupiter radiates more heat than can be accounted for by conventional explanations. However, Jupiter does not have enough mass to glow and needs to be over a hundred times larger than it is now to become a star. (Refer Fig. No. 2.9).

Q. How can protostars be detected?

A. As the interstellar cloud contracts to form a protostar, it heats up and radiates infra-red rays which can be detected by instruments.

Q. At what stage of the protostar does the hydrogen fusion reaction start?

A. The hydrogen fusion reaction starts when the temperature at the core of the star reaches about ten million degrees Celsius.

Q. What happens when a star starts glowing?

A. After a star start glowing, it reaches an equilibrium state when the outward explosive force of the hydrogen fusion reaction equals the inward force caused by the star's gravity. The star will then continue glowing at virtually a steady rate and remain at a steady size for a very long period.

Q. What is the main sequence?

A. The main sequence refers to the long period when the star shines steadily and brightly. Our Sun is now at the main sequence stage.

Q. What is stellar evolution?

A. Stellar evolution refers to the stages in the evolution of a star as follows:

1) The star begins as a cloud of interstellar material perhaps a light year in radius.
2) The cloud contracts and also heats up for a few million years.
3) A spherical star shape, called a protostar (about the size of the Earth's orbit), begins to emerge. The temperature is about 2000°C.
4) The protostar begins heating up and the fusion reaction begins. The star flares up in a short interval of time and starts glowing. At this stage, the luminosity of the star may increase to several hundred times the Sun's present luminosity.
5) The star cools down to a steady equilibrium stage. The main sequence stage is reached and continues for some ten billion years.
6) The star starts growing and the luminosity starts decreasing.
7) The star becomes a red giant and continues in that state for a few hundred million years.
8) The red giant starts shrinking. The luminosity increases.

9) The star becomes a white dwarf and continues to shine for a few billion years at the expense of its internal energy.

10) The star exhausts all its internal energy and ceases to glow. The star has now become a black dwarf and reached the final stage of stellar evolution. (Refer Fig. No. 8.6).

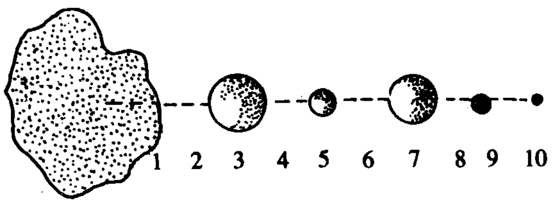


Fig. 8.5 Ten Stages of Stellar Evolution (2,4, 6 and 8 are not shown).

Q. What happens to the radius of the star as it passes through the ten stages of evolution?

A. The radius of the star continuously decreases through the various stages except at the red giant stage when it temporarily increases.

Q. What is a red giant?

A. In the transition of the star to the red giant stage, its inner part or core shrinks, while its outer part or envelope expands. A red giant is a star with a relatively low effective temperature (typically around 4000°C to 3000°C) and a large radius (about 100 times that of the Sun). The low temperature makes the star glow red and the larger size makes it a giant compared to its original size.

Q. What are the other characteristics of red giants?

A. Red giants are highly luminous and may have luminosities ranging from about 100 to even 10,000 times that of the Sun. They are very bright because they are so large although their surface temperature is lower than that of the Sun. The density of red giants is also extremely low ranging from 10^{-4} to 10^{-7} times the Sun's mean density. In other words, the mean density of a typical red giant is less than that of air at sea level.

Q. What are super giants?

A. Super giants are red giants having extremely large size and luminosity compared to a typical red giant. A typical red super giant would be about 100 times as luminous as a typical red giant.

Q. Are any red giants and super giants visible to the naked eye?

A. Aldebaran (in the constellation Taurus) is a red giant. Betelgeuse (in the constellation Orion) is a super giant. Both can be seen with the naked eye. There are many others also.

Q. How big is a super giant?

A. If the super giant Betelgeuse occupied the position of the Sun, all the planets up to and including Mars would be contained within it. Thirty million replicas of of Sun could fit inside the super giant Antares. (Refer Fig. No. 8.6).

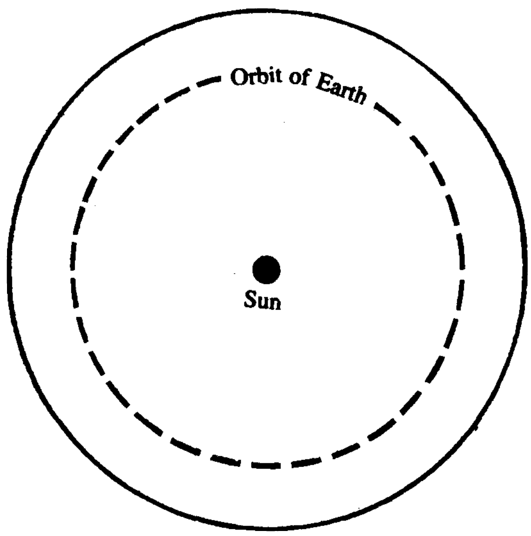


Fig. 8.6 Relative Size of Betelgeuse.

Q. Will the Sun become a red giant?

A. The Sun will become a red giant almost the size of Betelgeuse in about five to six billion years.

Q. Why does a star become a red giant?

A. As the hydrogen fusion in the star progresses, its mass moves towards the centre of the star due to the higher density of helium. As the concentration of the helium increases at the star's core, the pressure also increases.

At a certain stage, the pressure is sufficient to start the helium fusion reaction when helium fuses to form carbon and other heavier elements. Now, the outward force of the combined hydrogen and helium fusion reactions as well as the outward pressure (due to the increased heat in the star's core caused by the deposition of the heavier particles of helium) is greater than the inward force (due to the star's gravity). The star therefore starts expanding into a red giant and regains equilibrium at a larger size.

Q. How much energy is produced by the helium fusion reaction?

A. Almost 95% of the total energy that a star can generate through fusion reactions is generated through hydrogen fusion. The fusion of helium and heavier elements will account for just over 5% of the total energy that a star can generate.

Q. What happens when the hydrogen in the star is completely converted to helium?

A. As the hydrogen gets depleted the outward force of the fusion reaction starts diminishing and the inward force caused by the star's gravity gains the upper hand. Consequently, the star begins to shrink in size as well as increase in brightness. Its colour also changes from red to white.

Q. What is a white dwarf?

A. A red giant starts shrinking when its stock of hydrogen is nearing exhaustion. At a certain stage, the star becomes so dense that even its gravity cannot shrink it any more. White dwarfs consist of degenerate matter in which gravity has packed the protons and electrons together as tightly as is physically possible so that a spoonful of it, weighs several tonnes. At this stage, the star becomes stable again though it is much smaller in size than it was at the red giant stage. The star is now called a white dwarf.

Q. How does a white dwarf shine?

A. A white dwarf shines mainly by radiating away its stored internal energy, besides the fusion of any residual helium into other heavier elements. It slowly cools and darkens over millions of years.

Q. How long is the fusion reaction in a star likely to go on?

A. Once the hydrogen and the helium fusions stop due to the exhaustion of their supply, the fusion reactions may continue to produce heavier elements but energy generated by these reactions is rather negligible. The fusion reaction will continue (from helium to carbon to magnesium, to sulphur and finally to iron) until all the matter in the star is completely converted to the element iron. The star will then radiate energy only by depleting its stock of accumulated internal energy.

Q. Does the fusion reaction in a star always proceed to the iron stage?

A. Generally, the fusion reaction in all stars will proceed to the helium fusion stage. However, the extent to which it proceeds beyond this stage depends on the amount of pressure and temperatures developed at the core of the star. The larger the star the larger will be the number of fusion stages it will go through before the fusion reaction stops.

Q. How massive must a star be to completely convert into iron?

A. For a star to completely convert into iron, it must be at least 30 times as massive as the Sun.

Q. Why does the fusion reactions stop when all the matter is converted into iron?

A. The pressure created in the cores of ordinary stars is insufficient to continue the fusion reaction beyond the element iron.

Q. What is a black dwarf?

A. A white dwarf shines by radiating its internal energy. When the internal energy is completely exhausted the star ceases to shine and becomes a cold, dark body called a black dwarf.

Q. Which star other than Sun is the nearest to the Earth?

A. The star Proxima Centauri in the Constellation Centaurus ('Naraturanga') which is at a distance of nearly 40 trillion km (40×10^{12} km) from Earth. It is a faint red dwarf visible only with a telescope.

Q. What are ariables?

A. Variables or ariables stars are stars whose brightness increases and decreases periodically.

Q. What are Cephid Variables?

A. A Cephid Variable is a type of variable star (named after Delta Cephi, the first such star discovered). Cephid variables vary in magnitude over a period from one to sixty days. Also, the longer the period the more luminous the star.

Q. Why are Cephid Variables important to astronomers?

A. Since the period and luminosity of a Cephid Variable are closely related, one can obtain the absolute magnitude of the star by observing its period. Cephid variables are therefore used by astronomers as "Standard candles" for comparing with other stars.

Q. What are Cataclysmic Variables?

A. Two types of variable stars, called Novae and Supernovae, are classified as Cataclysmic Variables since their increase in brightness is accompanied by a spectacular flareup (in case of Novae) or explosion (in case of Supernovae).

Q. What are Quasars?

A. Quasar is the abbreviation for Quasi-stellar object (QSO). Quasars are star-like in appearance but have certain special characteristics that differentiate them from ordinary stars.

Q. When was the first Quasar discovered?

A. The first Quasar was discovered in 1963 by the Mount Wilson and Palomar Observatories in USA.

Q. How far away are Quasars?

A. Quasars exist at Cosmological distances, typically over fifteen billion light years away.

Q. What are the special characteristics of Quasars?

A. Quasars seem to be moving at speeds faster than of any known galaxy, and at more than 90% of the speed of light. The energy emitted by a Quasar is about a hundred times more than the energy emitted by an entire galaxy. However, the diameter of a Quasar is unbelievably compact (less than one light year in diameter). Quasars emit light which is extremely blue in colour and varying rapidly in brightness.

Q. What is the explanation for the special characteristics of Quasars?

A. As yet no one has given a satisfactory explanation and Quasars remain among the most enigmatic objects in the universe. They are thought to be at the centre of galaxies, their brilliance emanating from the stars and gas falling towards an immense black hole at their nucleus.

9. SATELLITES AND SPACE TRAVEL (PART 1)

Q. What are the vehicles used for space travel called?

A. Spacecraft or rockets.

Q. What is the difference between a jet plane and a rocket?

A. A jet plane carries only fuel onboard and no oxygen, since it absorbs oxygen from the air for burning its fuel. A rocket carries both fuel and oxygen onboard and is capable of travelling outside the atmosphere.

Q. How can rockets fly in space?

A. A rocket moves due to the reaction created by the gases escaping from its engines and not due to any aerodynamics. The exhaust gases ejected by a rocket engine cause the rocket to move in a direction opposite to that of the exhaust gases. (Refer Fig. Nos. 1.5 and 9.1).

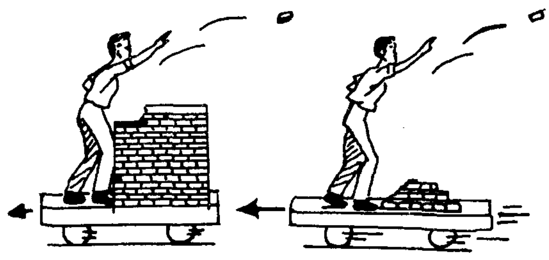


Fig. 9.1 The Rocket Principle.

Q. What are the different types of fuels (propellants) used in rockets?

A. Rockets use solid or liquid propellants. However, for sustained propulsion over very long periods in space, nuclear propulsion is preferable.

Q. What are the liquid fuels used in a rocket?

A. The commonly used liquid rocket fuels are liquid hydrogen, nitrogen tetroxide, kerosene etc. (used individually or blended). Rockets also carry liquid oxygen required for combustion of the fuel. Liquid fuel rockets are commonly used for launching rockets from Earth into space which calls for larger initial thrust. Liquid hydrogen and liquid oxygen are also called cryogenic fuels since they are stored at extremely low temperatures.

Q. How much fuel does a rocket need to carry on board?

A. The speed of the rocket will increase if its engine is kept running for a longer period. Hence, the amount of fuel (including o xygen) carried by the rocket will depend on the speed which it is required to achieve. For example, a rocket with an empty weight of 1 tonne will need to carry about 1.75 tonnes of fuel to reach the speed of its exhaust gases and about 19 tonnes of fuel to reach three times the speed of its exhaust gases. (Refer Fig. No. 9.2).

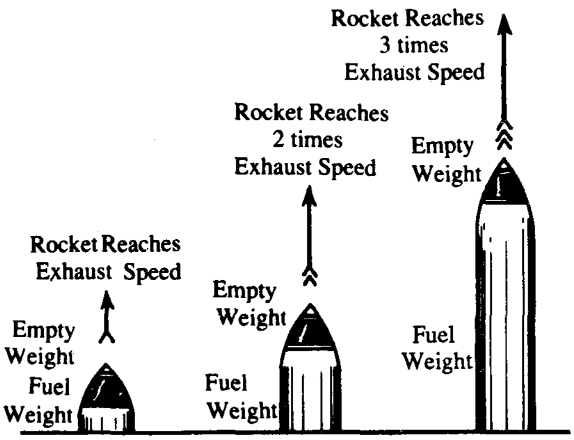


Fig. 9.2 The Effect of Fuel Weight (white portion) and empty weight (black portion) on Rocket Speeds.

Q. What is a multi-stage rocket?

A. In a multi-stage rocket specific sections or stages of the rocket are jettisoned or discarded in flight to lighten the load. The rocket is therefore specially constructed in detachable parts to enable such multi-stage operation. A multi-stage rocket (ballistic rocket) is more efficient than a single stage one and can reach much higher speeds. Depending on the number of stages, they may be designated as two-stage, three-stage, etc. (Refer Fig. No. 9.3).

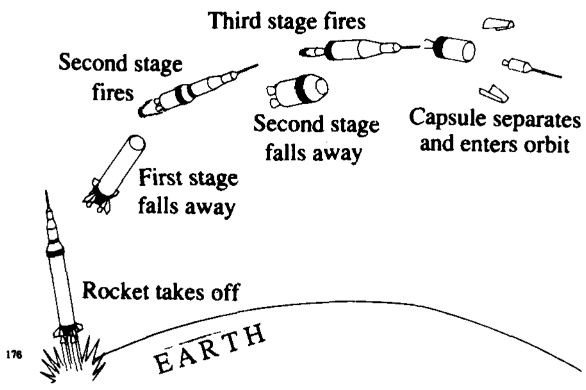


Fig. 9.3 Launch of Three-Stage Rocket.

Q. What is the countdown period?

A. The countdown period is the time taken from the time the order is given for launching the rocket to the time it actually gets launched. During the period, an elaborate prescribed procedure is followed for checking and putting into operation various mechanisms connected with the launching of the rocket and may even last for a week. The last twenty-four hours of countdown is referred to as the final phase of countdown. The last few seconds of the final countdown period are usually announced on the public address system as:

"... ... five, four, three, two, one, ZERO". Zero refers to the moment of launching.

Q. What is lift off?

A. Lift off refers to the point, a few seconds after lunching ('Zero' countdown), when the thrust from the rocket engines attains a level where it exceeds the total weight of the rocket. At this stage, the rocket literally begins to lift off the ground.

Q. What is re-entry?

A. The return of a spacecraft to Earth from space through the atmosphere is called re-entry.

Q. What is a spacecraft heat shield?

A. During re-entry, some parts of the space-craft may get heated up (like a meteor) or even melt due to air friction, if they are unprotected. Vulnerable parts of a space-craft are therefore protected by a heat shield made of special materials that can withstand the heat.

Q. What are splashdown and touchdown?

A. Splashdown is the moment a space vehicle or capsule lands in the ocean after completing its mission in space. If it comes down on land it is called touchdown.

Q. What is a space shuttle?

A. A space shuttle is a reusable spacecraft that can carry heavy payloads of upto 30 tonnes. It is launched like a rocket along with fuel and oxygen tanks. After launching, the tanks are jettisoned and splashdown to Earth. The space shuttle remains in space to complete its mission (such as launching a satellite etc.) and there after comes back to Earth and lands like an aircraft on a runway. (Refer Fig. No. 9.4).

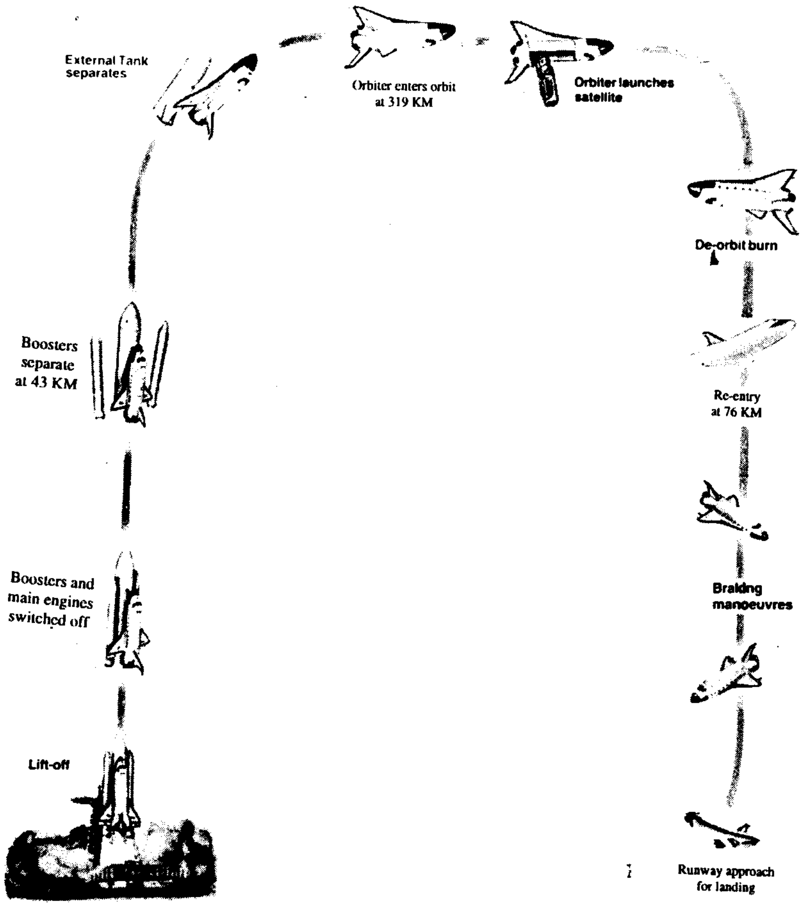


Fig. 9.4 Space Shuttle Launch and Recovery.

Q. What is a hyper plane?

A. A hyper plane takes off like a jet plane, with only fuel and without any oxygen of board. but once it is airborne, it draws oxygen from the atmosphere to fill its onboard oxygen tanks. Once the oxygen tanks are full, the hyper plane can travel into space like a rocket. A hyper plane is less expensive to launch than a rocket or space shuttle since it carries no oxygen during launching and is therefore lighter.

Q. Which organization in India is developing a hyper plane?

A. Bharat Dynamics Ltd., a defence undertaking in Hyderabad.

Q. What are artificial satellites?

A. Modern technology has enabled man to launch man-made artificial objects from the Earth and put them in orbit. Such objects are called artificial satellites.

Q. What are nodes with reference to the orbit of artificial satellites?

A. The inclination of an Earth orbit is measured by the angle formed by the orbital plane of the satellite with that of the Equatorial plane. Nodes are the points of inter-section between the orbit and the equatorial plane of the Earth. (Refer Fig. No. 9.5).

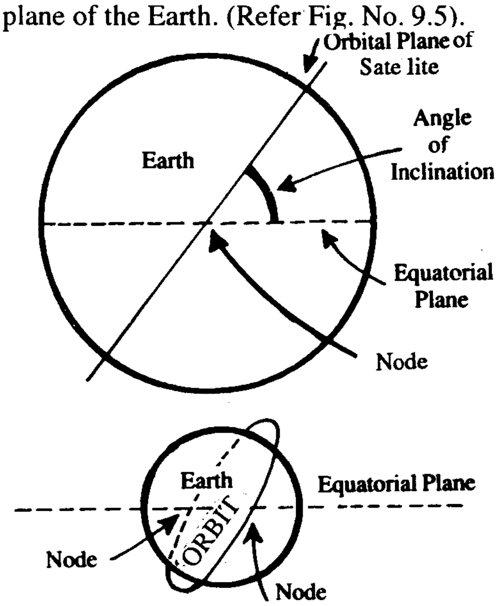


Fig. 9.5 Nodes of Artificial Satellites.

Q. What are the functions of an artificial satellite?

A. An artificial satellite is an outpost in space and can be used for communication, navigation, meteorology, remote sensing of Earth resources, astronomy, military applications etc.

Q. How is a satellite useful as an astronomical tool?

A. A satellite can be equipped with telescopes and instruments for carrying out astronomical observations. Observations from satellites are better than those made on the Earth since the distortions due to the Earth's atmosphere are eliminated.

Q. What are space probes?

A. Space probes are spacecraft sent on missions to study various bodies in the Solar System and even beyond.

Q. What are equatorial and polar orbits of satellites?

A. An orbit on or near the plane of the Equator is called an equatorial orbit. An orbit on or near the plane of the poles is called a polar orbit.

Q. What is retrograde orbit of a satellite?

A. In a direct orbit, the satellite goes eastwards as it crosses the Equator from the southern to be northern hemisphere. In a retrograde orbit the motion gets reversed. (Refer Fig. No. 9.6).

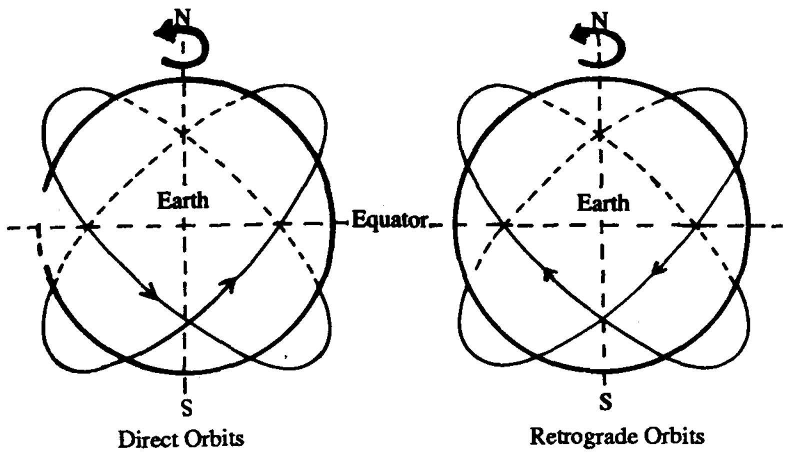


Fig. 9.6 Direct Orbit & Retrograde Orbit.

Q. What is regression of the nodes in the orbit of a satellite?

A. A satellite cannot go round the Earth at a fixed altitude close to Earth, as the Earth is not a perfect sphere. The orbit of a satellite is determined by the shape of the Earth which has an equatorial bulge. The Earth is also slightly pear-shaped. All these variations produce gravitational anomalies that affect the shape of the orbit. (Refer Fig. No. 3.1).

As a satellite crosses the equatorial region, the plane of its orbit will change or shift because of the Earth's equatorial bulge. This is known as regression of the nodes. (Nodes are the points of intersection between the orbit of a satellite and the equatorial plane of Earth). When a satellite passes from the southern to the northern hemisphere, in a west to east direction, the satellite will have a westward regression. If the satellite passes from east to west (retrograde orbit), from the southern to the northern hemisphere, it will have an eastward regression. The rate at which the regression takes place depends on the altitude of the orbit and its inclination to the Equator. No regression takes place in a true polar orbit or in a true equatorial orbit. (Refer Fig. No. 9.7).

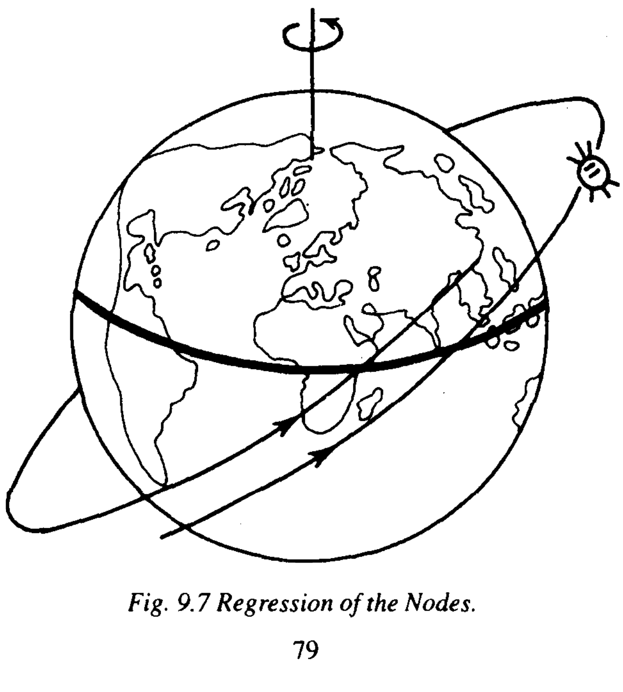


Fig. 9.7 Regression of the Nodes.

Q. What is a Sun-synchronous orbit?

A. In a Sun-synchronous orbit, the satellite appears over an area at the same Sun angle in successive orbits, which is ideal for remote sensing. The orbital plane is always at the same angle relative to the Sun-Earth line during all seasons. It also implies that the satellite will cross a given latitude at the same local time. The solar illumination angle desired for remote sensing or weather study can be fixed for the whole year in such orbits. Any number of Sun-synchronous orbits are possible if some conditions are met. One vital condition is that the satellite has to go in an east-to-west direction i.e., in a retrograde orbit. The angle of inclination of the orbital plane to the Equator will vary, depending on the altitude of the orbit. Earth's equatorial bulge will cause an eastward shift of the plane of the orbit. This eastward regression will nullify the shift of the orbital plane of a satellite caused by the Earth's movement relative to the Sun during the annual revolution.

Thus, the Sun-synchronous orbit becomes possible by a combination of natural forces and choice of orbits. Satellites at altitudes of 565 km, 893 km and 1261 km, having inclinations of 97.6°, 99° and 100.7° would complete 15, 14 and 13 revolutions per day respectively. It is obvious that but for the equatorial bulge of the Earth, there can be no Sun-synchronous orbits.

Q. What is a geo-synchronous orbit (also referred to simply as synchronous orbit)?

A. Geo-synchronous orbit is important for communications and weather study. This is a circular equatorial orbit at about 36,000 km above the Equator. A satellite in this orbit moving from west to east (as does the Earth) takes about the same time as the Earth takes to complete one rotation i.e. 24 hours. The satellite therefore appears as a fixed 'star' if its plane coincides with that of the Equator. This idea was first suggested by Arthur C. Clarke, a science writer, who propounded in 1945 the idea of covering the world with three satellites 120 degrees apart in a synchronous orbit, so that each can 'see' one-third of the globe. At this height (6.7 Earth radii), a satellite with nominal velocity of 3075 m/sec (11,000 kmh) will synchronize with the speed at which the Earth rotates about its axis viz 450 m/sec, and will appear stationary in the sky (geostationary).

Q. What is the relationship between the orbiting period of a satellite and its distance from Earth?

A. If an object such as a satellite moves at a velocity of about 8 km a second above the atmosphere (above 150 km) it starts orbiting around the Earth. When the centrifugal force (which depends on the speed of the satellite) is equal and opposite to the Earth's gravity there is a constant balance keeping the satellite in orbit. That implies that there is a definite speed for a satellite for a given altitude. At 7.91 km a second (28,800 kmh), the satellite will go into a circular orbit. If the velocity is increased, the orbit becomes elliptical. If an object is sent at an initial velocity of 8.04 km/sec it goes around the Earth at a height of 235 km. Only if an object attains a speed of 11.26 km/sec or 40,000 kmh, would it attain escape velocity to escape the pull of the Earth and cease to remain as its satellite.

The period of a satellite in Earth's orbit increases with the distance from the Earth. A satellite about 250 km from the Earth completes its orbit in 90 minutes, whereas the Moon at about 400,000 km takes almost a month to go round. At 1.6 million km from the Earth, the

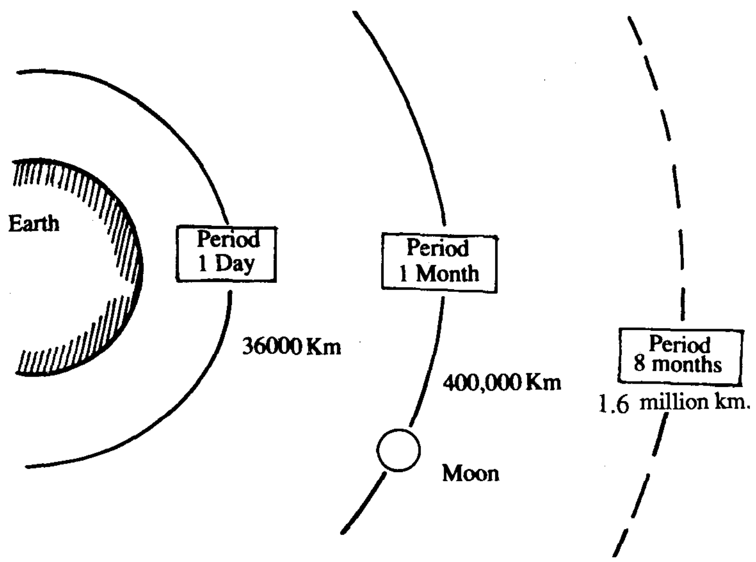


Fig. 9.8 Satellite Period-Distance Relationship.

orbital period becomes 8 months, and beyond this point, the Sun's gravitational field captures the satellite and Earth orbits are not practical. (See Fig. Nos. 1.3 and 9.8).

Q. What are transfer orbits?

A. Transfer orbit is the path pursued by a spacecraft in moving from one orbit to another, e.g., from the orbit of the Earth to the orbit of Mars. Generally speaking, such an orbit will be an ellipse which intersects the orbit of the target planet. If the spacecraft is to enter an orbit around the target planet, or effect a landing, then the engines must be fired to achieve the correct trajectory.

Q. What is the Hohmann transfer orbit?

A. The transfer orbit requiring the minimum expenditure of energy is an ellipse which just touches the orbits of the Earth as well as the target planet and is known as the Hohmann transfer orbit. (Refer Fig. No. 9.9).

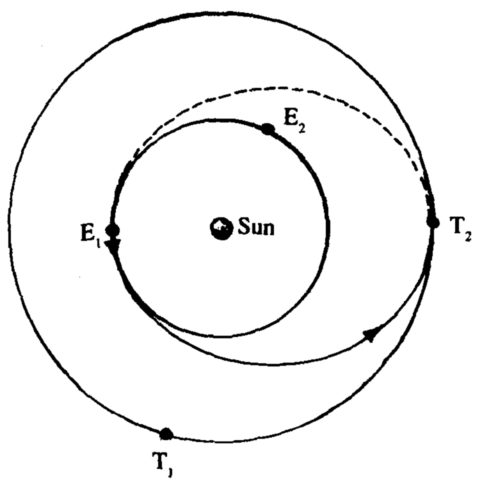


Fig. 9.9 Hohmann Transfer Orbit.

The Hohmann transfer orbit resembles an ellipse which just touches the orbits of Earth, E, and target planet T. A spacecraft launched when the Earth is at E_1 and the target planet at T_1 will reach the orbit of the target planet when it is at point T_2 and the Earth at point E_2.

Q. What are high velocity transfer orbits?

A. High velocity transfer orbits require much more energy than Hohmann transfer orbits but less time is required to reach the target planet. Such an orbit may be in the shape of a highly eccentric ellipse or a hyperbola.

Q. What are multiple transfer orbits?

A. The synchronous orbit is attained in stages and not in one step from the launch. Initially, the satellite is put in what is known as the transfer orbit where the perigee is at about 250 km, and the apogee about 35,800 km. The motor on board the satellite is then switched on to impart the incremental velocity required to circularize the orbit at 36,000 km. A 50-second burn of the motor will then increase the velocity by 1780 m/sec and take a satellite in a near synchronous orbit. Further corrections, if needed, are done by micro-thrusters on board the satellite.

Q. What is the optimum condition for a satellite launch?

A. A satellite is generally launched towards the east (so as to take advantage of the Earth's eastward rotation) possibly from a point on the Equator, if launching facilities are available there.

Q. What are the relative merits of three-axis body stabilisation over other types of stabilisations?

A. Three-axis body stabilisation is the method of satellite stabilisation preferred nowadays over older methods like spin stabilisation. In a three-axis body stabilised spacecraft, the entire structure is available for mounting antennas and other devices which need high pointing accuracy. Earth-viewing area is much larger than in a spinning satellite. Solar panels can be mounted with their axes in the north-south direction and can be rotated so as to keep them perpendicular to the Sun-satellite line. Moreover, as the spacecraft does not rotate at high rates, light weight panels initially folded and kept on board can be deployed in space. A given area of the solar panel will be three times more efficient in power generation compared with a spinning satellite. It would thus be possible to generate larger quantities of power needed by advanced communication satellites. (Refer Fig. No. 9.10).

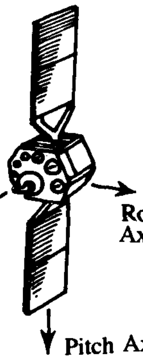


Fig. 9.10 A typical three-axis body stabilised satellite, which is not spun to achieve stability. The pitch axis is the north-south direction, while the yaw axis is perpendicular to it in the direction of the Earth. The roll axis is in the direction of the motion of the satellite.

Q. How does three-axis stabilisation work?

A. In three-axis stabilisation, the controlling mechanism is based on a momentum wheel, essentially a fly wheel actuated by an electric motor and rotated at a predetermined speed (usually 35,000 rpm). This system is known as zero momentum stabilisation where unwanted momentum accumulated by the wheel is reduced to zero. Correction is effected by accelerating or decelerating the momentum wheel on the basis of error signals provided by the satellite's Earth sensors which point towards the Earth and lock on to the Earth. The accuracy of alignment to the Earth is of a high order of 0.1 to 0.2 degree. This position is required to be maintained for 5 to 7 years, which nowadays is the operational lifetime of a satellite.

Q. What is drift control of a satellite?

A. In order to maintain a satellite's position, stability and accuracy in the synchronous orbit, its movement in the north-south as well as east-west directions should be constantly monitored within plus

or minus 0.1°. Maintenance of the satellite in its place, called station-keeping, requires more fuel (for onboard thrusters involved in corrections) for the north-south manoeuvres than for controlling the east-west drift. In order to minimize the use of fuel, specific time-slots are chosen to actuate the thrusters, when the orbital inclination is suitable for it. It is usual to rely upon electrothermal thrusters which have low thrust rates and would take about four hours to correct an orbit inclination of 0.2°. Due to ideal-period limitations, a manoeuvre may last a few days.
East-west station control has become important not only to ensure the accuracy of the satellite but also to reduce the minimum separating distance between two spacecraft in synchronous orbit to 0.2°, thereby efficiently using the orbit without mutual interference between satellites.

Q. What are the on-board systems used in a satellite for orbital corrections?

A. The propulsion sub-system of a three-axis satellite has several thrusters of varying capacity. The heaviest, for example, could give a thrust of 22 N (Newton) used for nutation or wobble control, while for pitch and yaw corrections or for east-west manoeuvres only small rockets (2.67 N) are used. Thrusters for roll control are less powerful (0.44 N). At the bottom of the scale are electrothermal thrusters which being very low in capacity (0.3 N) have to be used over a period. In order to maintain stability and arrest any drifts, the north-south station-keeping has to be constantly manoeuvred. It would increase the velocity of the satellite now and then and for this purpose adequate hydrazine fuel should be stored on-board.

Q. Why does a satellite constantly require orbital corrections?

A. A satellite is subjected to various forces of nature. The Sun and the Moon constantly exert pulls on it. Above 1600 km, solar radiation can cause pressure. The steady stream of charged particles from the Sun, known as solar wind, affects it. The Equator's bulge causes gravitational perturbations. The Sun and the Moon exert gravitational pulls that keep on varying. Another factor is the Earth's magnetic field which will reduce the spin rate of a satellite and affect its stability. Changes in the volume of on-board gas and liquid propellants can also tilt a satellite. Also the air molecules in the atmosphere of the Earth stretch far into space and when a satellite moves at 8 km a second, collisions with air molecules are frequent enough.

Q. What is orbital decay of a satellite?

A. So long as the Earth's gravity is unable to pull a satellite closer to the atmosphere, it can remains in orbit for years. However, its useful life depends on its stability in orbit and availability of on-board fuel for correction of any instability. If a satellite's perigee is about 100 km, its orbit begins to 'decay' and it begins its final plunge into the lower atmosphere. The orbit will decay if its period is about 87 minutes or less.

Q. Can artificial space satellites and other objects fall out of orbit?

A. Yes. It has been estimated that in the first 25 years of artificial satellites, over six thousand artificial objects have fallen out of space orbit. In fact, at any time, there are over 50,000 small and large objects in orbit. About 10 per week are slowed down to the point of re-entry. Most of them get burnt up in the heat of re-entry, while a very few such as Skylab have burnt out incompletely and fragments have hit the Earth.

Q. What is meant by inertial guidance system of a spacecraft?

A. It is a system comprising gyroscopes and accelerometers, that enables automatic plotting of the position of a moving spacecraft. This is because movement of the spacecraft and the distance travelled by it can be calculated if its acceleration and velocity are known. A specified star is usually taken as the reference point for this purpose. The inertial guidance system also takes corrective action when the errors in speed and position accumulate to unacceptable levels.

10. ASTRONOMICAL INSTRUMENTS (PART 1)

Q. Why are instruments necessary for astronomical observations?

A. With our senses we can feel only light and heat from the heavenly bodies and for that too, we need instruments to accurately measure them. Other forms of energy such as X-rays, microwaves, gamma rays, etc., present in the Universe cannot be detected without instruments.

Q. What instruments are used to detect the faint light from heavenly bodies?

A. Heavenly bodies faintly visible or invisible to the naked eye can be seen through telescopes. For observing very faint objects, telescopes of very high resolving power are used which can collect more light than the unaided eye.

Q. What are the different designs of telescopes?

A. Mirrors that use lenses are known as refractor telescopes and those using mirrors as reflector telescopes. Among the variations in design of reflector telescopes are Newtonian, Cassegrain, Herschelian, Gregorian, Conde and Schmidt designs. The refractor telescope has no major design variations.

Q. What are the main components of a telescope?

A. Telescopes are optical instruments which make distant objects appear closer. The size of the image depends on the magnifying power of the telescope. The two main components of a telescope are: the "Eyepiece" through which one looks and the "Objective" which receives the light from the distant object.

The objective in a refracting telescope is a lens and in a reflecting telescope it is a concave mirror. The eyepiece is always a lens. (Refer Fig. No. 10.1).

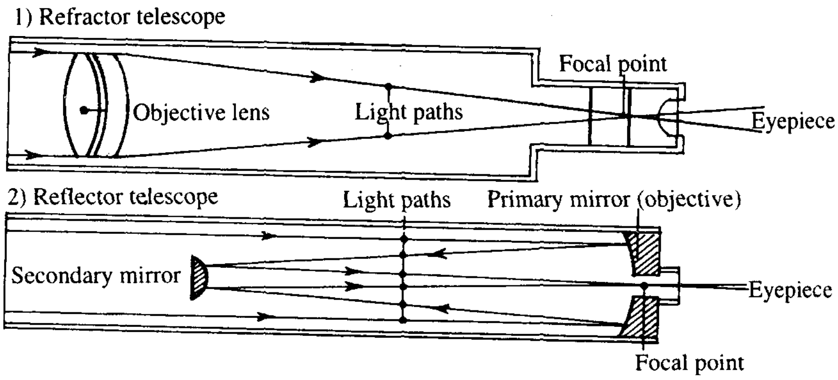


Fig. 10.1 Components of Refractor and Reflector Telescopes.

Q. How does a telescope magnify objects?

A. The objective of the telescope converges the light falling on it to a point called the focal point. The distance from the objective at which the light converges at the focal point is called the focal length. (Refer Fig. No. 10.1).

Q. How precisely are large lenses and mirrors of astronomical telescopes made?

A. Large lenses and mirrors for astronomical telescopes are made to precision levels of one ten thousandth of a millimetre and checked by a ruby laser that can detect microscopic flaws. For example a 4000 mm primary mirror is made from a single 25 tonne block of glass that is carefully polished for three years during which its weight reduces to 17 tonnes.

Q. How are photographic techniques used in astronomy?

A. By placing a photographic film at the position of the observer's eye, the telescopic image can be preserved on a photograph for a permanent record. Moreover very faint telescopic images can be intensified photographically by prolonged exposure using films very sensitive to light.

Q. How powerful a telescope is required to observe all the planets?

A. Probably, the most elusive planet for observation is Pluto for which at least a 60 cm focal length telescope is required. Also it must have a 30 cm aperture for visual observation or a 10 cm aperture for photographic observation.

Q. Why are larger aperture telescopes required for visual observation as compared to photographic observation?

A. A camera can record on smaller apertures by increasing the time of exposure or increasing the sensitivity of the film. This is not possible in the case of the human eye.

Q. What is a radio telescope?

A. A radio telescope receives and amplifies radio waves instead of light waves. Instead of lenses or concave mirrors a radio telescope uses parabolic reflectors. Radio telescopes are used to study radio waves emitted by the heavenly bodies. (Refer Fig. No. 10.2).

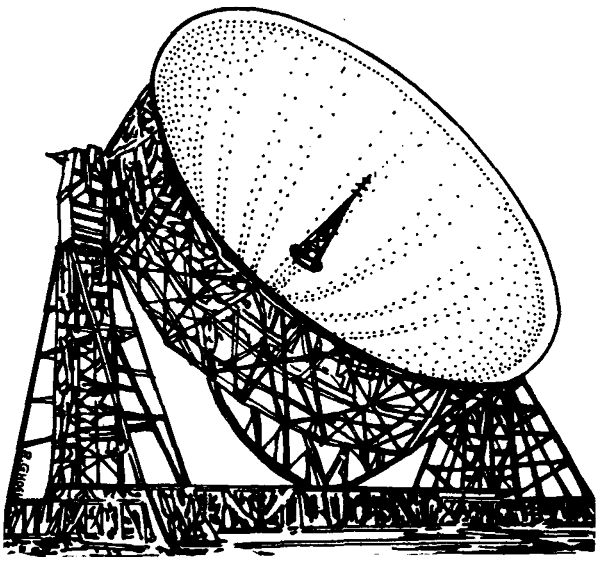


Fig. 10.2 The Jodrell Bank radio-telescope in Cheshire, England, was completed in 1957 and was used to track the orbit of the first Sputnik. Its reflecting bowl is about 76 metres in diameter and it can 'look' into the skies 1,000 times farther than optical telescopes.

Q. Name the five important observatories in India?

A. Kodaikanal, Hyderabad, Ooty, Nainital and Kavalur.

Q. How precise were ancient Indian astronomers?

A. According to the 4000 year old Rigveda, the solar year was 364.24675 days, the Sun was 108 Sun diameters from the Earth and the Moon was 108 Moon diameters from the Earth.

Q. What is a "Jantar Mantar"?

A. A Jantar Mantar is an ancient observatory used for observing the heavens before telescopes were invented. They are found in India, Arabia and north Africa. The Jantar Mantars in Jaipur and Delhi are well known. (Refer Fig. No. 10.3).

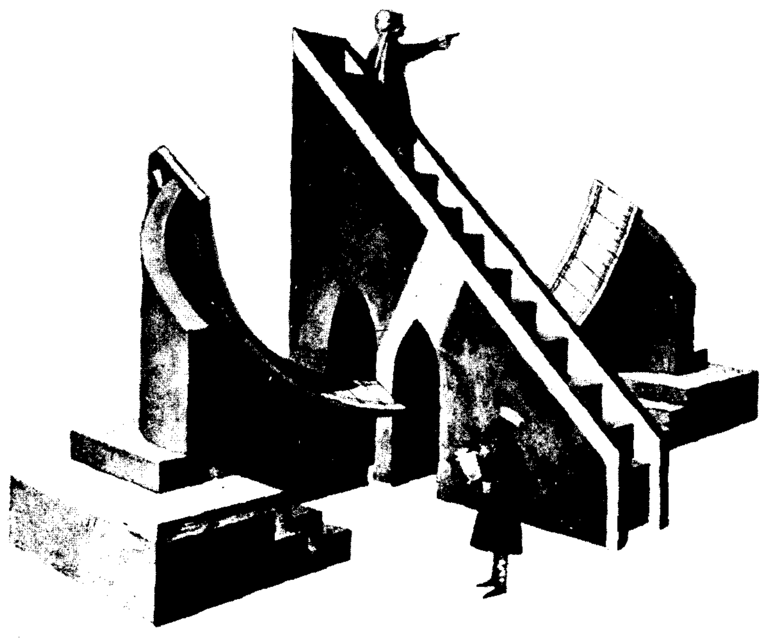


Fig. 10.3 The Jantar Mantar observatory at Jaipur built in the 18th Century.

Q. Is there a maximum physical limit to the size of a practical radio telescope?

A. It is possible to construct a radio telescope in sections, with each section located at a different place, the maximum limit of reparation being obviously the diameter of the Earth. The readings at the different locations are recorded independently, synchronised by atomic clocks (that are precise to 1 second in a million years), and integrated by processing the data in a computer.

Q. What units do astronomers use to measure distances in the Solar System?

A. Since distances are appreciably large, astronomers use a unit of distance called "astronomical unit" (a.u.). One a.u. is equal to 149,600,000 km which is the average distance between the Earth and the Sun. The Earth is at a distance of 1 a.u. from the Sun. Mercury and Venus are less than 1 a.u. from the Sun since they are nearer to the Sun than Earth. The other planets are more than one a.u. from the Sun since they are farther from the Sun than the Earth.

Q. How do astronomers measure large distances in space?

A. Distances in space are measured by the method of Trigonometrical Parallax based on the displacement in the apparent position of an

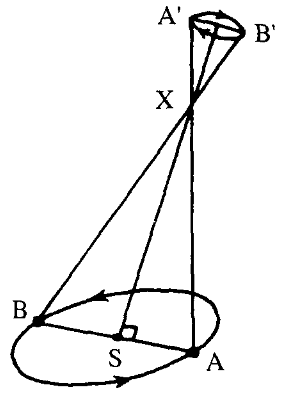


Fig. 10.4 A Parallax.

As the Earth moves round the Sun (S), the star (X) appears to trace out a small ellipse in the sky. The semi-major axis S A of this ellipse is equal (in angular measure) to the value of annual parallax.

object viewed from two different positions. In principle, two observations are possible for a star, separated by a time interval of six months during which the observer on Earth moves through a distance equal to half the orbit of the Earth around the Sun. Due to parallax, the star then appears to trace out a small ellipse while the Earth's orbit repeats another ellipse in space. Knowing the magnitude of the parallax (the Sun-star-Earth angle), the Sun-star-Earth triangle can be mathematically solved to arrive at the distance of the star. (Refer Fig. No. 10.4).

Q. What units do astronomers use to measure larger distances in space?

A. The common units, in addition to the astronomical unit (a.u.), are "Parsec" (parallax second) and "Light year".

Q. What is a parsec?

A. One parsec (pc) is that distance from Earth at which a star would have an annual parallax of one second of arc. 1 pc = 206265 a.u. = 3.09×10^{13} km (Refer Fig. No. 10.4).

Q. What is a light year?

A. A light year (l.y.) is the distance travelled by a ray of light in vacuum in a period of one year. (Refer Fig. No. 10.5).

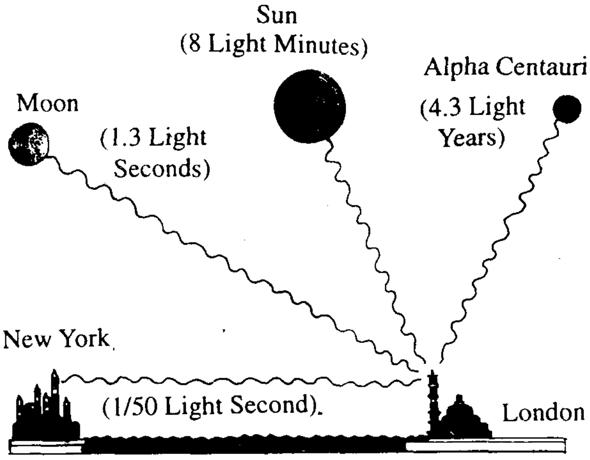


Fig. 10.5 The Concept of Light Year.

Light travels at a speed of 292,792 km per second. 1 l.y. = 63240 a.u. = 9.46×10^{12} km.

Q. How can we visualise the light year in simpler terms?

A. The nearest star Alpha Centauri is 4.3 light years away i.e., it would take 4.3 years to reach it travelling at the speed of light. From Earth the Sun is only 8 light minutes away and the Moon is just 1.3 light seconds away. New York is a mere 1/50 light second from London. (Refer Fig. No. 10.5).

Q. What is the relationship between parsecs and light years?

A. 1 pc = 3.26 l.y.

1 l.y. = 0.30675 pc.

Q. Are there any larger units for measuring distances in space?

A. Yes. Kilo parsecs and mega parsecs.

1 Kilo parsec (Kpc) = 1,000 parsecs

1 Mega parsec (Mpc) = 1,00,000 parsecs = 10^6 parsecs.

Q. Astronomical telescopes produce inverted images. Why are the images not corrected to look normal as in the case of terrestrial telescopes?

A. All Telescopes first produce an inverted image. In a terrestrial telescope, an erecting prism is used to make the image look normal. However, such a prism causes a slight loss of brightness undesirable in observing the faint light from the stars. Hence, astronomical telescopes tolerate inverted images.

Q. How do astronomers observe the Sun without damage to their eyes?

A. Instead of observing the Sun directly through dark glasses, astronomers view the image of the Sun projected on a screen by a telescope.

Q. What is the magnification of a telescope?

A. $\text{Magnification of the Telescope} = \dfrac{\text{Focal length of the objective}}{\text{Focal length of the eyepiece}}$

For example, with an objective of focal length 1 metre (1000 mm) and an eye piece of focal length 10 mm a telescope will give a magnification of :

$$\frac{1000}{10} = 100$$

Since the focal length of the eyepiece does not vary much in actual practice, the focal length of the objective is of paramount importance in determining the magnification of the telescope. (Refer Fig. No. 10.1).

Q. What is the altazimuth type of telescope mount?

A. Any instrument with a magnification beyond 7 must have some form of mounting for precision. For small telescopes and more powerful types of binoculars, the altazimuth mount is commonly used, permitting vertical (altitude) and horizontal (azimuth) movements simultaneously. The altazimuth mount is fine for low-power wide-field work, but it becomes increasingly difficult to keep objects inside the narrow field of view of a large telescope, and both axes of the mount require constant adjustment. (Refer Fig. No. 10.6).

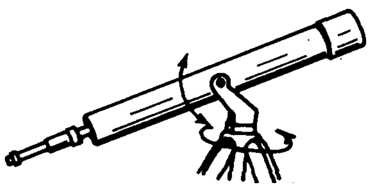


Fig. 10.6 An altazimuth-mounted telescope moves in both horizontal and vertical planes. But because objects in the sky appear to move in a curved line, both axes have to be continually adjusted.

Q. What is the equatorial type of telescope mount?

A. To overcome the problems of the altazimuth mount, astronomers generally prefer the equatorial types of telescope mount, which permits an object to be followed by the adjustment of one axis only. It has two axes—polar and declination (δ)—placed at right angles to each other. The polar axis is permanently fixed, parallel to the Earth's axis and pointing to the celestial pole. Once the mount is set up, both axes are used to bring an object into the field of view. The declination axis is then clamped in position and the object is followed by slowly turning the telescope tube around the polar axis (Refer Fig. Nos. 10.7 and 10.8).

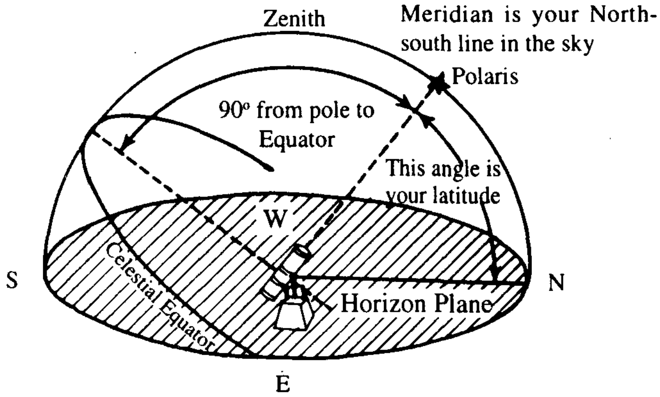


Fig. 10.7 Equatorial Telescope Alignment.

Q. What are drive systems for modern astronomical telescopes?

A. Instead of turning mounts manually, they can be driven automatically. And although normally electrically driven, more sophisticated computer drives are now available.

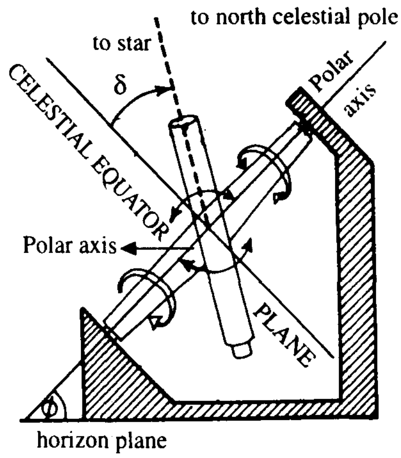


Fig. 10.8 Equatorial Mounting.

The equatorial mounting may take a wide variety of forms, but consists essentially of a polar axis aligned parallel with the axis of the Earth (the polar axis points towards the celestial poles) and a declination axis aligned at right angles to it. The telescope is attached to the declination axis and rotation about this axis allows the telescope to be pointed at a star at any desired declination, δ Rotation about the polar axis allows the telescope to be directed towards the appropriate hour angle or right ascension. Because the polar axis is parallel to the Earth's axis, if the telescope is pointed at a particular object and the polar axis driven so that it rotates at the same rate as the Earth, the object will remain in the field of view. (The angle ϕ is equal to the latitude of the telescope on the Earth).

Q. What is spectrograph (spectroscope)?

A. A spectrograph allows astronomers to record the spectrum or analysis of the light from a heavenly body, by splitting the light into its constituent wavelengths or colours. A study of the images obtained through a spectrograph enables astronomers to understand various properties of the heavenly body. (Refer Fig. No. 10.9).

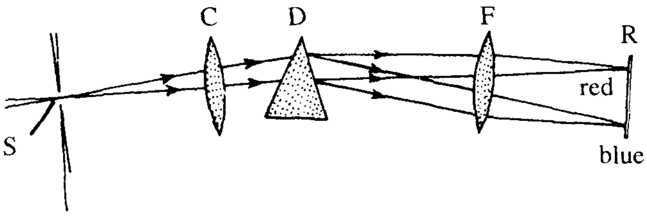


Fig. 10.9 Spectrograph.

In essence a spectrograph consists of the principal elements shown. At the focal plane of a telescope is the narrow slit, S. Light from, say, a star passes through the slit to a collimator, C, and then to a dispersing element, D, which may be a prism or a diffraction grating. This spreads out the light according to its wavelength. Finally, the focusing system, F, produces an image of the spectrum on the recording element, R, which may be a photographic plate, image tube etc.

Q. What is the apparent magnitude of a star?

A. Apparent magnitude is the apparent brightness of a star as seen from Earth. Star magnitudes are denoted by numbers 1 to 6 where 1 refers to the brightest stars and 6 to the faintest star visible to the unaided eye. The scale is logarithmic. Hence magnitude 2 stars are 2.512 times fainter than magnitude 1 stars. Magnitude 3 stars are 6.310 times fainter than magnitude 1 stars.

Celestial objects brighter than magnitude one may have zero or negative magnitude. Celestial objects fainter than magnitude six may have higher values of magnitude. The lower the apparent magnitude, the brighter is the star.

Q. What are the apparent magnitudes of the Sun, Moon and the planets?

A. A few examples of the apparent magnitudes are given below:

S. No.	Object	Apparent magnitude	Apparent brightness *
1.	Sun	–26.7	1.2×10^{11}
2.	Full Moon	–12.7	3.0×10^{5}
3.	Venus	–4.4	1.4×10^{2}
4.	Sirius (Brightest star)	–1.4	9.1
5.	Faintest stars visible to the naked eye	+6.0	1.0×10^{-2}
6.	Faintest detectable object	+23.0	1.6×10^{-9}

* Compared to magnitude 1.

It can be seen from the above that the faintest detectable object in the Universe is 10^{20} times (or one hundred million trillion times) fainter than the Sun.

Q. What is the absolute magnitude of a star?

A. The absolute magnitude of a star is a hypothetical concept and is the apparent magnitude the star would have if it were located at a standard distance of 10 parsecs from the Earth.

The absolute magnitudes of stars provide a measure of their relative luminosities, by comparing the apparent brightness which stars would have if they all lay at the same distance. If the Sun was at a distance of 10 parsecs, it would be a faint star of absolute magnitude +4.8.

Q. What are "Red Shift" and "Blue Shift" with reference to a star's spectrum (caused by 'Doppler Effect')?

A. A shift of pattern towards the red end of the spectrum ("Red Shift") indicates that the star is moving away from us. A "Blue Shift" indicates a movement towards us.

Q. What is colour temperature?

A. As a star's temperature rises, its predominant colour changes from infra red through ultraviolet.

Q. How are spectral patterns of the stars classified to indicate the temperature of the stars?

A. Spectral patterns of stars are classified in descending order of star temperatures as O, B, A, F, G, K, M, R, N and S (O stars are blue and M stars are red).

11. THE UNIVERSE (PART 2)

Q. How large is the Universe?

A. The Universe apparently stretches out to an infinite distance. There is however a limit as to how far we can observe the distant objects with our naked eyes or even with instruments.

Q. How did the Universe originate?

A. It is believed by most astronomers that all the matter and energy was once concentrated at one point and there was then a cataclysmic explosion in which matter and energy were scattered in all directions. The matter later coalesced into galaxies and other celestial objects to form the Universe as existing now.

Q. What is the Big Bang?

A. The cataclysmic explosion at the time of the birth of the Universe has been nicknamed as the "Big Bang". The analogy is to a bomb which bursts with a bang and scatters fragments at random.

Q. What is the "Cosmic Egg"?

A. The concentration of matter and energy prior to the Big Bang has been nicknamed as the 'Cosmic Egg' — an analogy with an egg which gives birth to life.

Q. What is cosmology?

A. Cosmology refers to the study of the Universe as a whole, its origin, evolution and future development.

Q. Is there any observational evidence in support of the Big Bang theory of the origin of the Universe?

A. According to the Big Bang theory, there must be some very weak background microwave radiation across the Universe as a result of the Big Bang. In 1965, the manifestation of such microwave radiation approaching us from all directions (cosmic rays) was discovered thereby providing observational evidence in support of the Big Bang theory.

Q. Is the Universe now expanding, shrinking or steady in volume?

A. Astronomical observations have inferred that the matter scattered by the Big Bang continues to fly off in all directions confirming the continuing expansion of the Universe.

Q. Will the Universe continue to expand?

A. If the mean density of the Universe is less than a certain critical value, the rate of expansion should tend to remain steady and the Universe would expand forever.

If the density is greater than the critical value, the expansion will eventually slow down and cease, followed by a contraction phase. According to the Oscillating Universe Theory, the Universe expands and contracts in a cyclic manner repeatedly. Refer Fig. No.11.1.

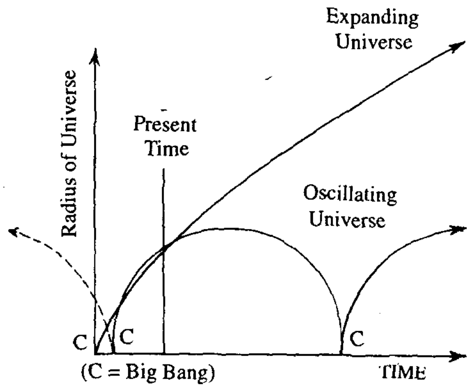


Fig. 11.1 Expanding and Oscillating Universes.

Q. Is the volume of matter so far detected in the Universe likely to exceed the critical value required to substantiate the Oscillating Universe Theory?

A. The volume of matter detected so far is below the critical value. However, there are various types of matter in the Universe about which we have incomplete knowledge e.g., inter-galactic matter and "invisible" matter (Black Holes).

Q. What is meant by inter-galactic matter?

A. Inter-galactic matter refers to the rarefied matter (mainly invisible gas) that exists in the space between the galaxies. Its existence has not been proved by direct observation but indirectly by inferences.

Q. What are the basic constituents of the "matter" in the Universe?

A. Matter refers to material objects. The smallest unit of matter that can exist independently as a chemical element is the atom. Groups of atoms combined together are known as molecules. The atom itself consists of a core called the "nucleus" (containing particles called protons and neutrons) surrounded by an outer shell containing particles called electrons.

Q. What portion of the universe is influenced by gravitational force?

A. Gravitational force (or gravitation or gravity) is a form of force of attraction in the Universe. Every particle of matter exerts a gravitational pull on every other particle in the Universe.

Q. Is gravitational force variable?

A. In 1687, the famous British scientist Issac Newton proved that bodies having more mass exert greater gravitational pulls and as one moves farther from the centre of a massive body, the effect of such pull decreases. For example, a person standing on the surface of the Moon would weigh less than what he weighed on Earth since the gravity on the Moon's surface is less than that on the Earth's surface. Also if he goes away from the Earth in a rocket, his weight will go on decreasing as the distance between him and the Earth goes on increasing.

Q. What is the relationship between gravity, mass, weight and density?

A. Mass is the amount of matter that an object contains. All objects have mass. When gravity acts on a body, the body appears to have weight. As gravity increases, weight of the body also increases but the mass of the body remains unchanged. A stone weighing 1 kg and a pillow weighing 1 kg, both have the same mass and therefore the same weight, but the stone has less volume than the pillow, because the material in the stone is more densely packed compared to the similar mass in the pillow. Hence, the stone has a greater density than the pillow.

Q. How many stars are there in a galaxy?

A. Galaxies generally contain between 10^6 and 10^{12} stars. Our own Milky Way Galaxy, also known as the Home Galaxy, is one of the large galaxies and contains 10^{11} stars (one hundred thousand million stars).

Q. What is the galactic plane?

A. Galactic plane is the plane of the Milky Way Galaxy, and follows a line running more or less through the centre of the galaxy and inclined to the celestial equator by an angle of 62°. (Refer Fig. No. 8.1).

Q. Which is the nearest galaxy to our own Milky Way Galaxy?

A. The Andromeda galaxy (technically called the M31 galaxy) is situated at a distance of 2.2×10^6 light years from us. Under good sky conditions, it can even be seen with the naked eye in the constellation Andromeda ("Devayani").

Q. To what cluster of galaxies does the Milky Way Galaxy belong?

A. It belongs to the Local Group of Galaxies which contains about 20 galaxies including the Milky Way Galaxy, the Andromeda galaxy and the two Magallenic clouds.

Q. How many galaxies are there in a cluster of galaxies?

A. Galaxies tend to form clusters containing up to a few thousand galaxies. The Local Groups of Galaxies is a relatively small cluster of galaxies.

Q. Are galactic clusters visible to the naked eye?

A. Yes. The Pleiades and the Hyades are examples of galactic clusters visible to the naked eye.

Q. How did galactic clusters originate?

A. Galactic clusters are thought to have originated from the fragmentation of large gas clouds into smaller gas clouds which in turn have formed stars. All galaxies in a galactic cluster may therefore be assumed to be of the same age. Most galactic clusters are relatively young, perhaps a few tens or hundreds of millions of years old.

Q. To what super cluster of galaxies does the Local Group of Galaxies belong?

A. The Local Group of Galaxies belongs to the Virgo Super Cluster of Galaxies containing thousands of galaxies.

Q. What is the nature of the path traced by the Earth across the Universe?

A. The path of the Earth across the Universe is in an elaborate series of loops and whirling spirals. A person on the Earth's surface would move in a path governed by:

1) Rotation of the Earth about its axis at 460 metres/sec at Equator.
2) Earth's rotation about the barycentre of the Earth-Moon System.
3) Earth's rotation about the Sun at 30 km/sec.
4) The sun's rotation about the Milky Way Galaxy at 220 km/ sec.
5) The Milky Way Galaxy's rotation about the Local Group of Galaxies (LGOG) towards the constellation Hercules.
6) The rotation of the LGOG about the Virgo Super Cluster of Galaxies (VSCG) towards the constellation Southern Cross.
7) The rotation of VSCG about the Universe.

Of the above, only items 1 to 4 are clearly known. Items 5 and 6 are still speculative while item 7 is still unknown.

Q. What are open star clusters?

A. They are clusters of stars. In galaxies, the stars are densely packed together, whereas in open star clusters the stars are not densely packed together but only loosely associated.

Q. What are globular star clusters?

A. They are a spherically shaped cluster of stars. Typically, it contains about ten thousand to ten million stars apparently concentrated towards the centre.

Q. Are globular star clusters visible to the naked eye?

A. Only two clusters are visible to the naked eye, though more than 120 can be observed with instruments.

Q. What is a "Nebula"?

A. A Nebula (Plural: Nebulae or Nebulas) is a cloud of gas and dust floating in space. It is visible either as a luminous region or a dark patch against the back ground of stars.

Q. What is a Planetary Nebula?

A. A planetary nebula (it has nothing to do with planets) is a spherical or ellipsoidal shell of gas around a white dwarf, and is formed when a red giant leaves behind an outer shell of matter while contracting.

Q. What are the Magellanic clouds?

A. In 1519, Ferdinand Magellan the navigator observed two small star clouds in the heavens, similar to the Milky Way, visible to the naked eye. These have been named after him, and are visible only from the southern hemisphere. These clouds have since been identified as satellite galaxies of our own system.

A. What are radio galaxies?

A. They are galaxies emitting a significantly large amount of radiation at radio wave frequencies though not necessarily emitting a large amount of visible light. A strong radio galaxy may be emitting radio power of up to a hundred times that of an ordinary galaxy like the Milky Way.

Q. What are Seyfert galaxies?

A. They are peculiar galaxies having very bright compact nuclei within which gas appears to be moving at high speed as if due to some violent activity. One per cent of all galaxies are Seyfert galaxies, named after Carl Seyfert who first investigated them in 1943.

Q. What is galactic evolution?

A. There appears to be some evidence of a possible evolutionary progression among the types of galaxies such as normal galaxies, radio galaxies, Seyfert galaxies and even some other bodies such as quasars. However, galactic evolution has not been conclusively proved and is still undergoing investigation.

Q. What happens when two galaxies collide?

A. In spite of the colossal mass of stars and space debris contained in galaxies, the mass is very highly dispersed. Though several colliding galaxies have been studied, there does not seem to be any evidence of catastrophic impact.

However, due to the tidal forces, the total masses of both galaxies are redistributed between them, though the two nuclei are comparatively less affected.

Q. What is the Messier List?

A. The Messier List or Messier Catalogue represents the first attempt (in 1784) to publish a catalogue of heavenly bodies difficult to identify, and contains particulars of 109 such objects including remote nebulae and galaxies. The list was prepared to forewarn astronomers who were constantly mistaking these for comets and stars.

Q. What is the Messier Number?

A. The Messier Number is the identification code (M followed by a number) of a heavenly body in the Messier Catalogue. An example is the Andromeda galaxy designated as M31.

Q. Since we are already inside the Milky Way Galaxy, why don't we see the stars of the Milky Way all over the sky in-stead of only in one region?

A. The Milky Way in the sky is actually the dense concentration of stars in the direction of the galactic centre. In other directions there are relatively few stars. (Refer Fig. No. 8.1).

Q. What is a white sky image?

A. The white sky image, often used by astronomers for convenience, refers to 'negative' photographs of the sky where the stars show up as black dots against a white background.

12. THE SOLAR SYSTEM (PART 2)

Q. Can comets be seen in daylight?

A. To be seen in daylight a body has to be sufficiently bright. Generally comets can be seen only at night (as in the case of the stars). However, there have been cases of bright comets, visible in the daytime also. For example, comet Ikeya-Seki was visible in daylight when it appeared in 1965. Another case is that of the so-called 'Daylight Comet' seen in 1910.

Q. What is meant by the period of a comet?

A. The time taken by a comet to make one revolution around the Sun is called the year of the comet or the period of the comet. For example, the year of Halley's Comet is 76 Earth Years. (Refer Fig. No. 12.1).

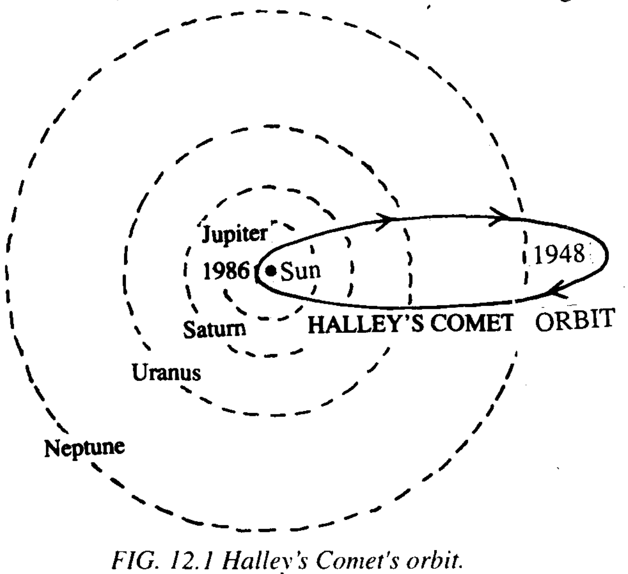


FIG. 12.1 Halley's Comet's orbit.

Q. What kind of material does a comet contain?

A. A comet contains frozen gases and dust in the form of a giant "ice ball" less than a hundred kilometres in diameter. In astronomical terms, they are extremely tiny bodies.

Q. Can a comet fail to return?

A. Sometimes, a comet may be deflected by the gravity of Jupiter so that the shape of the comet's orbit is changed from an elliptical trajectory to a hyperbolic one resulting in the comet being ejected from the Solar System into deep space never to return.

Q. What is unusual about the shape of the orbit of the comets as compared to those of planets?

A. Comets move in elliptical orbits as in the case of planets. But while orbits of planets are nearly circular, in the case of comets the ellipses

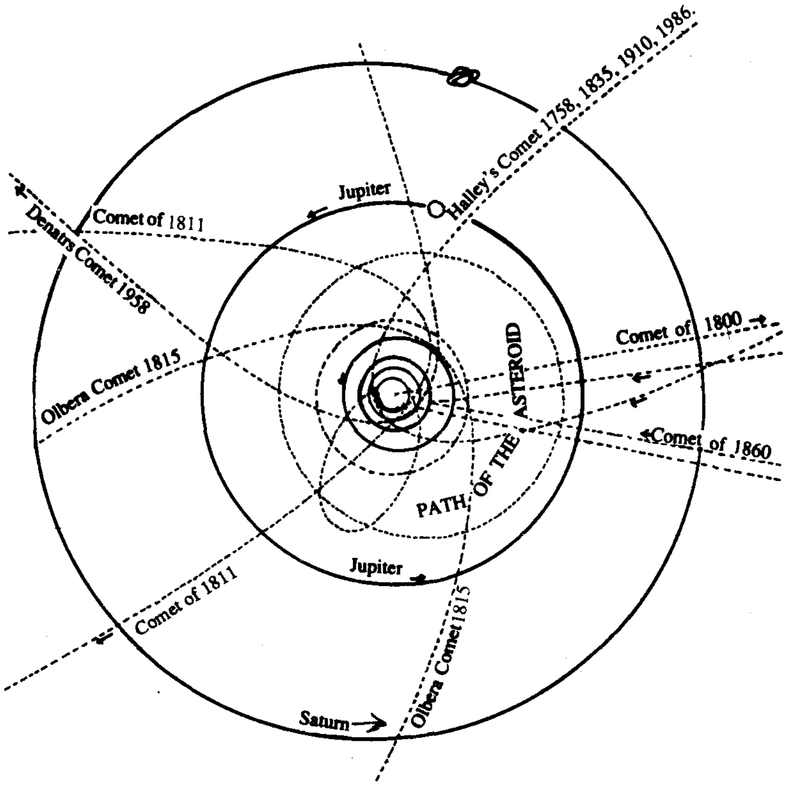


Fig. 12.2 Cometary Orbits.

are highly elongated. In some extreme cases, a comet's orbit may be very nearly parabolic. It is because of this reason that at aphelion a comet may be extremely far away from the Sun, often about 100,000 times farther away from the Sun as the Earth is. Again, for the same reason, the period of some comets is very long, sometimes thousands or even millions of Earth years. Comet Kohoutec which appeared in 1974 will reappear after ten million years! (Refer Fig. No. 12.2).

Q. Can a comet cease to exist?

A. When a comet nears the Sun, a part of its material gets vaporised. After many orbits a comet may lose its mass completely and cease to exist.

Q. Do all comets have very long periods?

A. Comets are usually divided into two categories—short period comets and long period comets. Short period ones have periods of up to two centuries. Their orbits usually do not extend far beyond the orbit of Jupiter. Long period comets have orbits usually extending far beyond the orbit of Jupiter. (Refer Fig. No. 12.2).

Q. Is the period of a comet constant?

A. A comet is sometimes deflected by the gravity of the gas giants like Jupiter (and to a lesser extent) Saturn, Uranus and Neptune, leading to alteration of the period of the comet.

Q. What is a comet family?

A. A group of comets, with each member having a similar aphelion distance, all under the gravitational influence of a large planet, is called a comet family. An example is the Jupiter family of comets. Saturn, Uranus and Neptune also have smaller comet families.

Q. Can a long period comet get converted into a short period one?

A. Sometimes after successive deflections by Jupiter over many orbits, the orbit of a comet may get distorted so highly as to leave its original orbit and join the Jupiter family of comets, thereby converting it into a short period comet.

Q. What happens to the material in a comet when the comet comes close to the Sun?

A. For a short duration, when the comet comes very close to the Sun, the Sun's heat vapourises some of the comet's material to form a vapour cloud around the comet. The cloud is only a temporary 'atmosphere' that recondenses on the comet when it moves away from the Sun.

Q. What is the composition of a comet and its vapour cloud?

A. When it is near the Sun, the comet consists of a solid portion called the nucleus surrounded by three layers. The first layer is called the coma. The second and third layers consist of dust particles and gas respectively. (Refer Fig. No. 12.3).

Q. What is meant by the tail of a comet?

A. When the solar wind strikes the vapour cloud of a comet, it deflects and scatters the dust and gases, and part of the vapour cloud, with the result that the comet appears to have a "Tail". The size of the tail depends on the density of the dust and gas present in the cloud. The tail is more prominent when the comet is very near the Sun. (Refer Fig. No. 12.3).

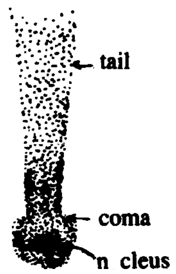


Fig. 12.3 Cometary Structure.

Q. Is the comet's tail always situated behind the comet?

A. The tail is caused by the solar wind which blows from the Sun. Hence, the tail always points away from the Sun and has no relation to the direction of motion of the comet. The tail can therefore be at the rear, in front, or at the side of the comet. (Refer Fig. No. 12.4).

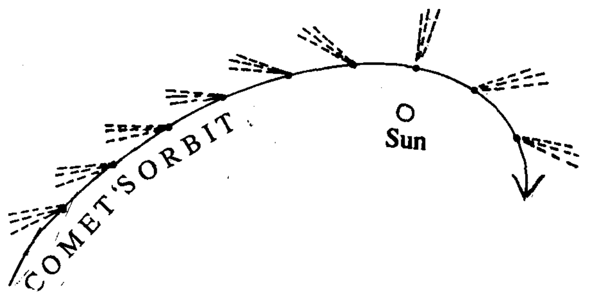


Fig. 12.4 Tail of a Comet.
(Note changes in position of the tail.)

Q. How long is the tail of a comet?

A. Cometary tails can be short or long. However, some comets have been observed to have extremely long tails with the length even exceeding the distance from the Earth to the Sun.

Q. Are there different colours of cometary tails?

A. Some cometary tails contain very few dust particles and give out a faint blue light. Some other cometary tails contain a large number of dust particles which reflect the Sun's light, making the tail appear yellow.

Q. Do cometary tails maintain a constant shape?

A. Cometary tails do not maintain a constant shape. Some of such shape changes can be spectacular. Tails may remain straight or curved, or lengthen, or may even detach and disappear. Tails can exhibit bright spots which appear like "knots" along the tail. Some comets may even have multiple tails.

Q. How dense are the gases in a comet's tail?

A. It is usually in the order of less than 1000 gas molecules per cubic centimetre (compared to about 30×10^{18} gas molecules per cubic centimetre in the Earth's atmosphere). It is, more or less, close to a perfect vacuum. The tail is consequently almost completely transparent and stars can even be seen through it.

Q. What would happen if the Earth were to pass through the tail of a comet?

A. In 1910, Halley's Comet was due to approach the Sun and it was thought that the Earth would pass through the tail of the comet. There was a worldwide scare that poisonous gases in the tail of the comet would annihilate all species on Earth. Conan Doyle, the creator of "Sherlock Holmes", even wrote a story on this theme called "The Poison Belt". But the density of gases in the comet's tail is extraordinarily low and is incapable of exerting any noticeable effect on any living creature. Over the millions of years of its existence, the Earth must have passed through the tails of many such comets without any apparent ill effects.

Q. Is a comet always visible from the Earth?

A. A comet normally emits no light of its own and can be seen only when it reflects light from the Sun (as in the case of the Moon). Since the comets are extremely tiny, they are not visible (even with instruments) when they are far from the Sun. A comet, however, develops a vapour cloud for a short period when it is near the Sun, which enables it to reflect more of the Sun's light and become more visible. The gases in the vapour cloud also emit light when the ultraviolet light from the Sun falls on them (as in the case of fluorescent lights). Consequently most of the comets are visible from Earth only during a portion of their total period of orbit. However, some short period comets like Encke (period 3.3 years) are always visible through telescopes.

Q. What is the shape of the solid portion of a comet?

A. The solid portion of a comet is of irregular shape, since its gravitation is too weak to make the material assume a spherical shape as in the case of the planets.

Q. What comets are known as Sun grazers?

A. Sun grazers are comets that almost touch the Sun during their orbit. Some come perhaps as close as 27,000 km from the visible surface of the Sun. An example is comet Ikeya-Seki which grazed the Sun in 1965.

Q. What are cometary gas jets?

A. Sometimes, some internal portions of a comet's nucleus may vapourise due to the heat from the Sun. The gas then escapes through cracks on the surface of the nucleus in the form of gas jets (similar to volcanoes).

Q. What is a cometary corona?

A. The cometary vapour cloud is surrounded by a glowing halo or corona due to the breakdown of the water molecules by the Sun's radiation. The halo is very faint and cannot be seen from Earth but only from space.

Q. Does a comet spin on its axis?

A. The spinning motion of a comet upon its axis appears to be at random and the axis may keep on shifting. The gas jets also act like thrusters and produce changes in the rotation of the nucleus. From past observations, it has been noted that the period of spinning of comet Encke has not appreciably changed during the past 140 years. But, some other comets show marked changes.

Q. How are comets named?

A. Comets are usually named after the person or persons who discovered them. For example, comet Ikeya-Seki is named after Kaoru Ikeya and Tsutomu Seki of Japan who discovered it.

Q. Are there any known comets not named after their discoverers?

A. Yes. For example Halley's Comet is named after Edmond Halley who did not discover the comet but accurately predicted the period of its orbit as 76 years.
Another one is Twefik's comet discovered in Egypt in 1882 and named after the king of Egypt.

Q. Which ancient civilization studied comets closely?

A. Chinese astronomers have kept detailed records of comets for 1,300 years.

Q. Why was the appearance of a comet conceived to be a bad omen in ancient times?

A. Ancient people thought that comets caused calamities on Earth. Even in recent times people have been scared that gases from a comet's tail would poison life on Earth.

Q. Is it possible to see details of comets with the naked eye?

A. Comets can sometimes be seen with the naked eye. One can even identify their tail and the head (the portion containing the nucleus and coma). Once in a few thousand years, comets have appeared when even the luminous gas jets have been visible to the naked eye. The 'swastika' symbol is believed to be a representation of a comet with multiple gas jets and has been considered an auspicious symbol in many countries from the period of yore. Also the "Menorah" (ceremonial candleholder) used in Jewish ceremonies is believed to be a representation of a comet with multiple tails.

Q. How does a comet group come into being?

A. When a comet comes very close to the Sun the nucleus is subjected to various forces due to gravity, heat, pressures within and the force of its gas jets. Sometimes, these may cause the nucleus to crack up into fragments. If such fragments continue in orbit close together, they are called a comet group. In 1846, the comet Biela was observed to split into two fragments which moved together with each part showing all the characteristics of a comet including head and tail.

Q. Can collision of a planet with a large comet or asteroid occur?

A. Large comets or asteroids are rare phenomena now and hence the possibility is remote. However, such large bodies were abundant in the early history of the Solar System and there is evidence that major catastrophic collisions did occur. Craters and basins hundreds or even thousands of kilometres in diameter have been observed on the Moon, Mars and the large satellites of Jupiter. A large comet or asteroid colliding with a small planet or moon can even completely shatter it. Mimas, one of the moons of Saturn, seems to have barely escaped being completely shattered by such a collision but only half of the original moon exists and the other half has been shattered.

Q. Name a recent planet-comet collision.

A. In July 1994, the comet Shoemaker-Levy-9 collided with Jupiter. The comet split into fragments before impact, and was closely monitored from Earth and from space probes.

Q. Is there any possibility of a comet colliding with a planet like the Earth?

A. There is a possibility that small comets, or small fragments of large comets, may fail on a planet provided the bodies are close and the gravitational pull is appreciable enough. In such cases, it is likely to burn up in the atmosphere sometimes even resulting in a powerful explosion before the comet hits the Earth.

Q. Has a comet fragment actually hit the Earth in Modern times?

A. An unprecedented explosion occurred on 30th June 1908 in the largely uninhabited Tunguska valley in Siberia and was heard up to 14,000 km away. At the explosion site neither was there any crater nor signs of impact but the trees around over an area of 3000 sq. km were flattened. Obviously, it must have had the force of a 2 megaton atom bomb. But no atom bombs existed at that time. Could it have been an exploding comet fragment?

Q. What would happen if a comet collides with the Moon?

A. Since the Moon has no atmosphere, the comet wouldn't burn up but would directly hit the surface of the Moon. At the point of impact, a crater would be formed. Such craters can be seen on the Moon even with the naked eye (they look like smallpox scars). Even in planets like Earth with an atmosphere, impact craters of comets do occur if the comet did not explode or completely burn out before reaching the surface of the Earth. Such an impact crater has been found at Lonar near Pune in Maharashtra.

Q. Are all craters the result of cometary impacts on Earth?

A. Craters can be caused by impact of comets or asteroids. About a third of the craters on Earth are caused by long period comets and the rest by asteroids. In the case of those observed on the moons of Jupiter, half are caused by asteroids, a quarter by long period comets and the remainder by short period comets.

Q. Is there a possibility of a large comet colliding with the Earth?

A. There is some evidence that large comets of about ten kilometres in diameter have hit the Earth in the past creating craters of more than 100 km in diameter. Three such craters have been identified on Earth, and there may be some more on the seabeds. If a large comet hits the Earth it would annihilate most species on Earth. There is evidence of periodic large-scale destruction of plant and animal life on Earth through such collisions.

Q. Which are the comets or asteroids most likely to collide with the Earth?

A. Some asteroids called Earth grazers regularly pass close to Earth. Asteriod Hermes has passed within 77,000 km from Earth (only twice the distance of the Moon from Earth). Other smaller objects may also graze or collide with the Earth. However, with advances in technology, scientists might know well in advance of any comet or asteriod likely to collide with Earth and deflect or destroy them using rockets and nuclear bombs.

Q. What is the Oort Cloud?

A. Cometary periods range from a few years to even ten million years (as in the case of the comet Kohoutec). It is beleived that most of the long period comets emanate from a region extending beyond the orbit of Pluto to a distance of some 100,000 a.u. which contains the bulk of the comets in the Solar System.

According to the currently accepted theory, there are at least a trillion long period comets in this region referred to as the Oort cloud. Comets in the Oort cloud cannot be detected from Earth. The only comets visible from Earth are those that have highly eccentric orbits which brings them near the Sun.

Q. What causes a comet to swerve from the Oort cloud towards the Sun?

A. According to the currently accepted theory, passing stars and interstellar clouds quite often disturb the equilibrium of the Oort cloud making some comets change their circular orbits and come near the Sun.

It remains a perpetual phenomenon with old comets dying out and new ones displaced from the Oort cloud appearing.

Q. Name the space-probe that made a rendezvous with two comets.

A. Space probe Giotto was launched from Earth in 1985 on a fifteen-year mission. In 1986 it flew within 600 km of the nucleus of Halleys comet, and in 1992 within 200 km of Grig-Skjellerup comet. It flew past Earth in 1990.

13. THE EARTH (PART 2)

Q. What causes a solar eclipse?

A. A solar eclipse occurs when the Moon comes between the Earth and the Sun, blocking the view of the Sun. (Refer Fig. No. 13.2).

Q. What are partial and total solar eclipses?

A. When the Moon partially covers the Sun it is a partial solar eclipse. A total solar eclipse occurs when the Sun is completely covered by the Moon. (Refer Fig. No. 13.1).

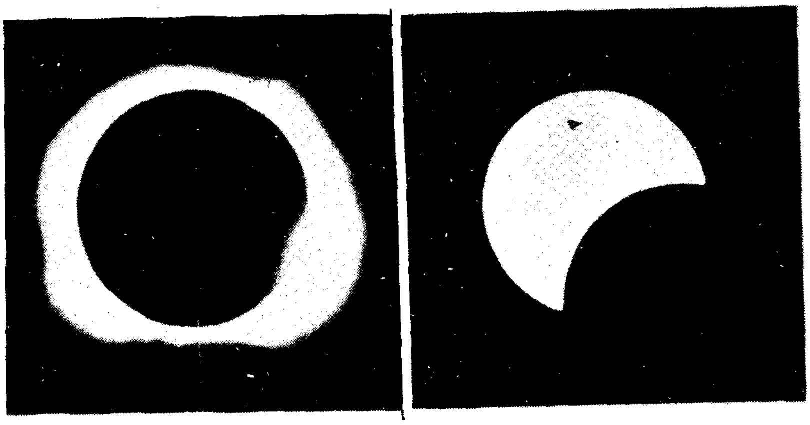


Fig. 13.1 Partial (right) and Total (left) Solar Eclipses.

Q. What is an annular solar eclipse?

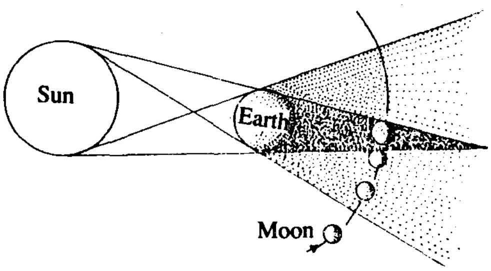
A. Sometimes, the disc of the Moon appears smaller than that of the Sun in which case it is an annular eclipse, where the rim of the Sun's disc remains visible around the dark disc of the Moon.

Q. How does an annular eclipse occur?

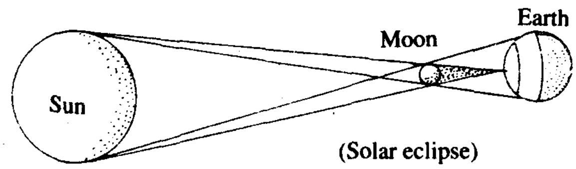
A. The Sun and the Moon generally have the same apparent size in the sky. During a total solar eclipse, the Moon just covers the Sun completely. However, if there is an eclipse while the Moon is at apogee, then the apparent size of the Moon becomes slightly smaller, resulting in an annular solar eclipse.

Q. Can a solar eclipse be seen from all places on Earth?

A. No. The eclipse is actually a shadow transit where the Moon's shadow crosses the surface of the Earth. Hence, only observers on Earth along the line of transit can see it. (Refer Fig. Nos. 13.2 and 13.3).



(Lunar eclipse)



(Solar eclipse)

Fig. 13.2 Umbra and Penumbra in Lunar and Solar Eclipses.

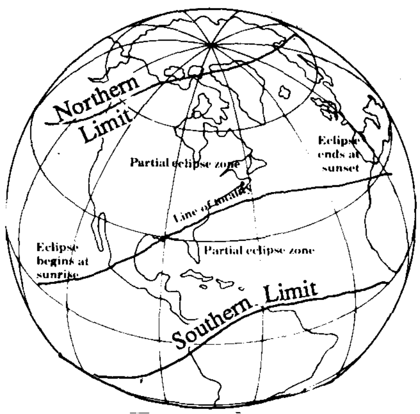


Fig. 13.3 Total and Partial Eclipse Zones.

The long, narrow zone of the Moon's inner shadow (line of totality) has an average width of about 160 km on the Earth's surface. A partial eclipse is visible from a much greater outer zone (northern & southern limits shown).

Q. How do partial and total eclipses occur?

A. A shadow of the Earth or the Moon consists of two regions—a dark central region called "umbra" and a less dark outer region around it called a "penumbra". The eclipse is total, if the observer is in the umbra region and partial if he is in the penumbra region. (Refer Fig. Nos. 13.2 and 13.6).

Q. Why are total solar eclipses a rare phenomenon?

A. The area of the Earth's surface covered by the umbra in a solar eclipse is very small. Consequently, a total solar eclipse on any given point on Earth happens only very rarely.

Q. What is the zone of totality in a solar eclipse?

A. The narrow strip of the Earth's surface over which the Moon's shadow sweeps during a total solar eclipse is called the zone of totality or line of totality. The eclipse will be total only if the observer is located in the zone of totality (the umbra region). (Refer Fig. No. 13.3).

Q. What is the maximum possible width of the zone of totality?

A. Since the Moon's shadow just touches the Earth, the zone of totality is very narrow, having a maximum width of not more than 270 km approximately.

Q. What is the Diamond Ring effect?

A. Just before the Moon covers the Sun completely or just after the Moon uncovers the Sun during a total solar eclipse, a tiny portion of the Sun's bright disc becomes visible on the Moon's dark disc, giving an impression of a ring (signified by the corona) with a brilliant diamond on it (signified by the tiny portion of the Sun's disc exposed.) (Refer Fig. No. 13.4).

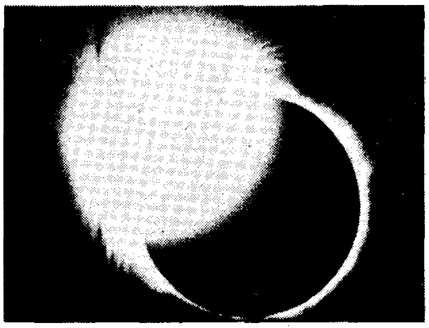


Fig. 13.4 Diamond Ring Effect.

Q. How long can a solar eclipse last?

A. Not more than seven minutes and fifty eight seconds.

Q. At what speed does the Moon's shadow sweep across the Earth during a total solar eclipse?

A. About 2250 km per hour.

Q. Can an observer in a supersonic aircraft follow the Moon's shadow during a total solar eclipse so that it can be observed for a longer period?

A. It is possible to follow the Moon's shadow in a supersonic aircraft during a total solar eclipse, thereby extending the observation period to about 40 minutes.

Q. What is a node?

A. The Moon's orbit is inclined at an angle of about 5° relative to the Earth. The monthly path of the Moon is therefore tilted relative to the ecliptic. If the path of the Moon and the ecliptic are imagined to be two hoops hinged along a diameter and slightly displaced at an angle to each other, then the hinges will represent the points of intersection known as nodes. (Refer Fig. No. 13.5).

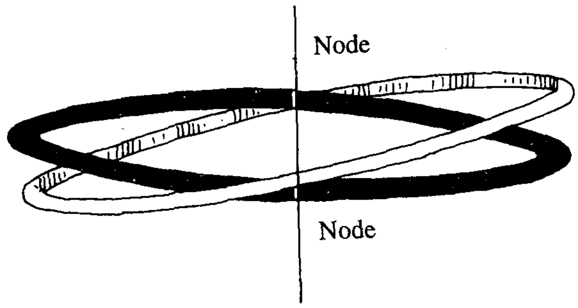


Fig. 13.5 Two Inclined Hoops hinged at the nodes.

Q. Why are solar eclipses comparatively rare?

A. Unless there is a new Moon near the node, solar eclipses cannot occur. A solar eclipse occurs during a new Moon if the Sun, Moon and Earth are in line. It is, therefore, a rare phenomenon. (Refer Fig. No. 13.6).

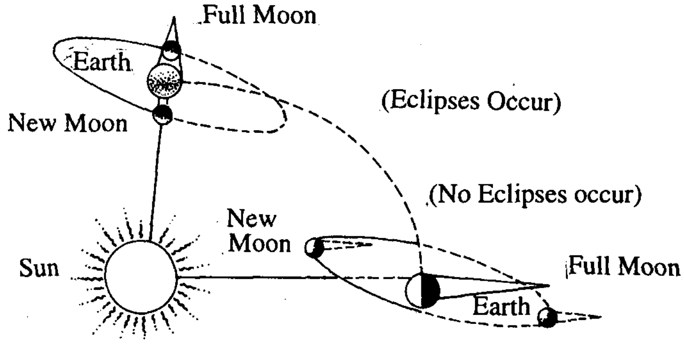


Fig. 13.6 Eclipses and Nodes.

Eclipses of the Sun or Moon occur only when New Moon or Full Moon occurs at or near one of the nodes of the Moon's orbit. On the right at New Moon, the Moon's shadow passes above the Earth, while at Full Moon, the Moon passes below the Earth's shadow and hence no eclipse occur.

Q. How does a lunar eclipse occur?

A. A lunar eclipse occurs when the Moon enters the shadow of the Earth and when the Earth comes between the Sun and the Moon. (Refer Fig. Nos. 13.2 and 13.6).

Q. What is the relation between the phase of the Moon and a lunar eclipse?

A. When the Earth comes between the Sun and the Moon during a Full Moon, a lunar eclipse occurs if all the three bodies are in a line.

Q. What is Saros Period?

A. It is a cycle of 18 years and 11.3 days during which the Sun, Earth and Moon return to almost the same relative positions.

The ancient astronomers used the Saros Period as a rough empirical formula for predicting the cycle of eclipses.

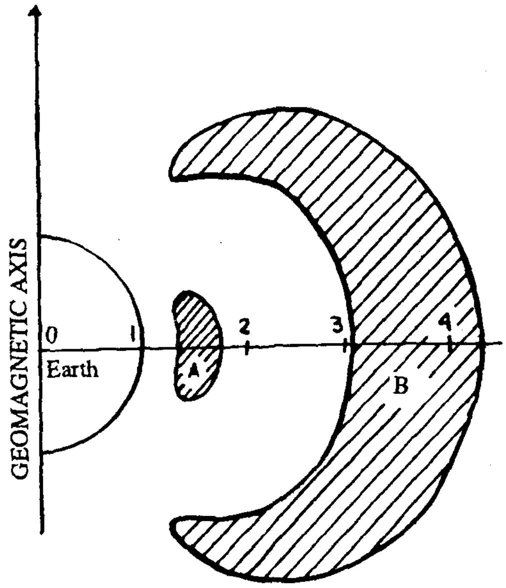


Fig. 13.7 Van Allen Belts.
A: Inner Van Allen belt
B: Outer Van Allen belt
(The scale is in Earth radii)

Q. Why does the Earth have a magnetic field?

A. The spinning motion of the molten metallic core of the Earth generates a magnetic field (magnetosphere).

Q. Does the solar radiation have any effect on the Earth's magnetic field?

A. The Earth's magnetic field absorbs some of the Sun's radiation. The trapped radiation hovers around the Earth in the form of two distinct bands or belts called the inner and the outer Van Allen Belts. (Refer Fig. No. 13.7).

Q. What is the magnetopause?

A. The boundary of the magnetosphere is called the magnetopause, beyond which lies the shock front (rather like the bow wave of a ship) where the solar wind meets the Earth's magnetic field.

Q. What is the exosphere?

A. It refers to the outermost boundary of the Earth's atmosphere, where it blends into the emptiness of space. By convention, it is nominally taken to be at an altitude of 1000 km above the mean sea level.
The density of the atmosphere at the exosphere is one thousand trillionth (10^{15}) that at the mean sea level.

Q. What is geodesy?

A. Geodesy refers to the study of the shape and the gravitational field of the Earth based upon data collected from artificial satellites.

Q. What is meant by the geoidal shape of the Earth?

A. The geoidal shape of the Earth is the one established from data obtained from geodesy. The Earth is an oblate sphereoid or a geoid (equivalent to a figure obtained by rotating an ellipse about its minor axis) with mean polar radius of 6356.779 km and equatorial radius of 6378.164 km. The Equator itself is basically elliptical and differs from the circular shape by a maximum of about 100 metres. (Refer Fig. No. 3.1).

Q. What is equation of time?

A. Equation of time (E) is the difference between apparent solar time (AT) and mean time (MT).
E = AT–MT
Mean time refers to the time shown by a clock and apparent solar time refers to that shown by the movement of the shadow cast by the Sun on a Sundial (a primitive kind of solar clock).
The difference E between MT and AT arises due to the elliptical nature of the Earth's orbit resulting in non-uniform motion of the Earth relative to the Sun. The basis for MT is the mean Sun that moves along the celestial equator, whereas the basis for AT is the real Sun that moves along the ecliptic. A positive E means that AT is ahead of MT while a negative E means that AT is lagging behind MT.

Q. What is the pattern of variation of the mean time (MT) from apparent solar time (AT)?

A. MT and AT can differ by up to 16.3 minutes. The variation in the length of the apparent solar day (due to the apparent motion of the Sun, relative to the back-ground stars, being more rapid near perihelion than near to aphelion) depends on the daily change of right ascension of the Sun. This change in right ascension is equal to the projection of the Sun's elliptic motion onto the celestial equator and it is maximum near the solstices and minimum near the equinoxes. (Refer Fig. Nos. 4.7 and 13.8).

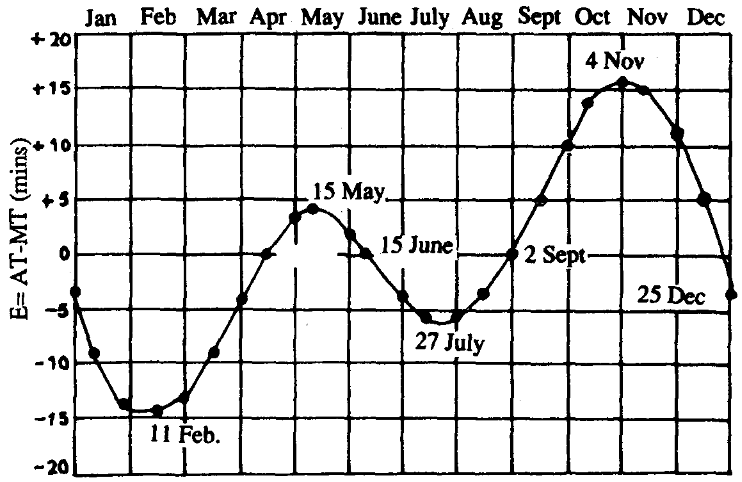


Fig. 13.8 Equation of Time.

Q. What is the tropical year?

A. The tropical year refers to the cycle in which the seasons repeat themselves. The length of the tropical year is 365.2422 mean solar days.

For comparison, the sidereal year (during which the Sun completes one revolution of the celestial sphere) is 365.2564 mean solar days and the calendar year is taken as 365 days and corrected by one extra day in every four years to avoid fractional days. Hence the calendar year is virtually the same as the topical year for practical purposes.

14. THE NIGHT SKY (PART 2)

Q. What are constellations?

A. Constellations are arbitrary groupings of stars. In some cases they constitute a recognisable pattern.

Q. How did the stars come to be grouped into constellations?

A. In ancient times, astrologers and astronomers grouped the stars into constellations and divided the celestial sphere into various regions according to the predominent constellation in each region.

Q. What relationships do the constellations have with one another?

A. A constellation appears as such only when observed from Earth. Actually, each star in the constellation is of different size and at a different distance from the Earth.

Q. How many constellations are there?

A. There has been some confusion in defining the constellations among the astrologers and astronomers over the years but by international convention; eighty eight major constellations have now been recognised.

Q. How appropriate are the names of the constellations?

A. In some cases (eg. Scorpio) the name is somewhat appropriate, whereas in others there appears to be no appropriateness.

Q. How are the individual stars in a constellation formally designated?

A. In modern sky charts, Greek alphabets are used to designate the stars in a constellation. For example, the constellation Centaurus has four stars designated Alpha Centauri, Beta Centauri, Gamma Centauri and Omega Centauri. (Refer Fig. No. 14.1).

α	alpha	o	omicron
β	beta	π	pi
γ	gamma	ρ	rho
δ	delta	σ	sigma
ε	epsilon	τ	tau
ζ	zeta	υ	upsilon
η	eta	ϕ	phi
θ	theta	χ	chi
ι	iota	ψ	psi
κ	kappa	ω	omega
λ	lambda		
μ	mu		
ν	nu		
ξ	xi		

Fig. 14.1 Greek letters.

Q. What are the Zodiacal constellations?

A. The Zodiacal constellations refer to twelve specified constellations.

Q. What are the Zodiacal signs or the signs of the Zodiac?

A. The Zodiacal signs are the symbols that are used to represent the zodiacal constellations.

Q. What are the twelve Zodiacal constellations traditionally considered important by astrologers from ancient times?

A. The twelve Zodiacal constellations are:

1. Aries (Mesha) or Ram.
2. Taurus (Vrishabha) or Bull.
3. Gemini (Mithuna) or Twins.
4. Cancer (Karka) or Crab.
5. Leo (Simha) or Lion.

6. Virgo (Kanya) or sea Goddess.
7. Libra (Tula) or Weighing Scales.
8. Scorpio (Vrischika) or Scorpion.
9. Sagittarius (Dhanu) or Archer.
10. Capricorn (Makara) or Mythical Creature.
11. Aquarius (Kumbha) or Water Carrier.
12. Pisces (Meena) or Fish.

Q. What is the Zodiac?

A. The Zodiac is an imaginary belt of the heavens along which the Sun, Moon and the planets appear to move, sequentially through twelve equal areas called signs of the Zodiac. (Refer Fig. No. 14.2).

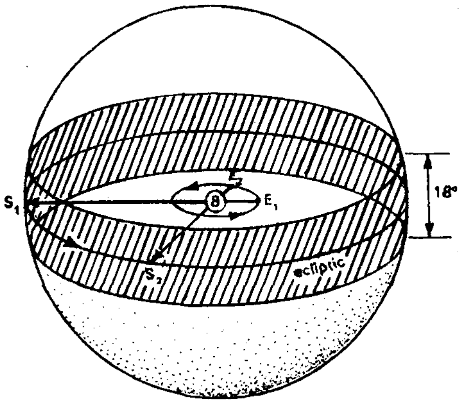


Fig. 14.2 Ecliptic and Zodiac.

As the Earth, E moves round the Sun, from E_1 to E_2, so, projected against the celestial sphere, the Sun, S, appears to move from S_1 to S_2. In the course of a year the sun appears to race out a complete circle, the ecliptic. The Zodiac is the band round the celestial sphere extending 9 on either side of the ecliptic, within which the planets are normally to be found. The constellations which lie within this band are the zodiacal constellations. For the purposes of astrology, the Zodiac is divided into twelve equal areas, represented by the signs of the zodiac.

Q. What is the significance of the Zodiacal constellations?

A. If the zodiac is divided into twelve zones of 30°, each zone will contain one Zodiacal constellation. As the Earth moves around the Sun, the projection of the Sun on the celestial sphere appears to trace out a complete circle (the ecliptic), passing turn through these twelve zones.

Q. Why are the Zodiacal constellations called by that name?

A. All the twelve Zodiacal constellations except one (Libra), are named after living creatures. Hence they are called the Zodiacal constellations since the word Zodiac means "circle of animals" in Greek and the Zodiacal constellations are distributed in the sky in a circular manner.

Q. Name some of the important non–Zodiacal constellations.

A.
1. Aquila (Garuda) constellation which includes the star Altair (Shravan).
2. Argo Navis (Nowka) constellation which includes the star Canopus Alpha Carinae (Agastya).
3. Auriga (Sarathy) constellation which includes the stars Mekalinan Beta (Agni) and Epsilon Aurigae (variable star).
4. Bootes (Bhootap) constellation which includes the stars Arcturus Alpha (Swati).
5. Canis Major (Bhrihad Lubdhaka) constellation which includes the star Sirius Alpha (Vyadha) (the brightest star).
6. Canis Minor (Laghu Lubdhaka) constellation ("Smaller dog of Orion") which includes the star Procyon Alpha (Prashwa).
7. Cassiopea (Sharmishta) constellation.
8. Centaurus (Naraturanga) constellation which includes the stars Alpha Centauri (Mitra) or Proxima Centauri (the closest star to us) and Omega Centauri (the finest globular cluster of stars).
9. Cepheus constellation (Vrishaparva).
10. Cetus (Timingal) constellation which includes the stars Tau Ceti and Mira Omicron Ceti (an unstable red giant).

Q. What are junction stars?

A. Astrologers in India consider the following twenty seven stars (called *nakshatras*) as junction stars. (Astronomers have no such classification.)

1.	*ASHVINI*	:	*SHERATAN (BETA ARIETIS)*
2.	*BHARANI*	:	*35-ARIETIS*
3.	*KRITTIKA*	:	*ALCYONE (PLEIADES)*
4.	*ROHINI*	:	*ALDEBARAN (ALPHA TAURI)*
5.	*MRIGASHEERSHA*	:	*HEKA (LAMBDA ORIONIS)*
6.	*ARDRA*	:	*ALHENA (GAMMA GEMINORUM)*
7.	*PUNARVASU*	:	*CASTOR AND POLLUX (ALPHA AND BETA GEMINORUM)*
8.	*PUSHYA*	:	*DELTA CANCRI*
9.	*ASHLESHA*	:	*EPSILON HYDRA*
10.	*MAGHA*	:	*REGULUS (ALPHA LEONIS)*
11.	*POORVA PHALGUNI*	:	*ZOSMA (DELTA LEONIS)*
12.	*UTTARA PHALGUNI*	:	*DENEBOLA (BETA LEONIS)*
13.	*HASTA*	:	*DELTA CORVI*
14.	*CHITRA*	:	*SPICA (ALPHA VIRGINIS)*
15.	*SWATI*	:	*ARCTURUS (ALPHA BOOTIS)*
16.	*VISHAKHA*	:	*ZUBEN ELGENUBI (ALPHA LIBRAE)*
17.	*ANURADHA*	:	*DSCHUBBA (DELTA SCORPII)*
18.	*JEYSHTHA*	:	*ANTARES (ALPHA SCORPII)*
19.	*MOOLA*	:	*SHAULA (LAMBDA SCORPII)*
20.	*POORVASHADHA*	:	*DELTA SAGITTARII*
21.	*UTTARASHADHA*	:	*SIGMA SAGITTARII*
22.	*SHRAVAN*	:	*ALTAIR (ALPHA AQUILAE)*

23.	*DHANISHTHA*	:	*ROTANEV (BETA DELPHINI)*
24.	*SHATATARAKA*	:	*LAMBDA AQUARII*
25.	*POORVA BHADRAPADA*	:	*MARKAB (ALPHA PEGASI)*
26.	*UTTARA BHADRAPADA*	:	*ALGENIB (GAMMA PEGASI)*
27.	*REVATI*	:	*ZETA PISCIUM*

Q. What are optical doubles?

A. Optical doubles are two stars that seem close together because they happen to lie in almost exactly the same direction as seen from earth. Optical doubles are not binaries and the stars are not linked in any way.

Q. What is meant by the precession of the Earth?

A. The Earth actually spins about a wobbling axis and the movement of the wobbling axis is known as precession of Earth. (Refer Fig. No. 3.9).

Q. What is the precession or precessional translation of the Poles?

A. The Earth's axis turns very slowly during the precession of the Earth's axis, and describes a full circle once in 25,800 years. The circular movement of the Earth's poles due to this precession is called the precessional translation (shift) of the Earth's poles. (Refer Fig. Nos. 14.3 and 3.9).

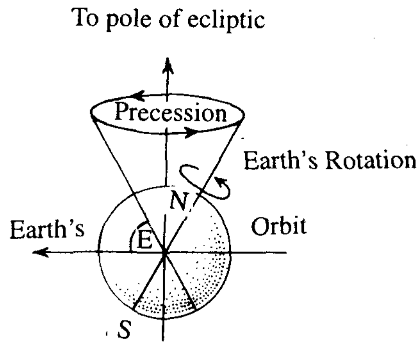


Fig. 14.3 Precession.

The axis of the Earth is tilted by an angle E. The effect, primarily of the attractions of Sun and Moon, is to cause the axis of the Earth to precess in a similar way, over a period of 25800 years. This precession causes the celestial pole to trace out a circle round the pole of the ecliptic.

Q. What is the effect of the precession of the celestial poles on the Zodiac?

A. Precessional translation of the poles results in a shift of not only the celestial poles but also the celestial equator relative to the ecliptic. Hence when the pole shifts, the vernal equinox also shifts along the ecliptic, completing a full cycle every 25,800 years. When the ancient astrologers defined the Zodiac during the second century B.C., the vernal equinox occurred while the Sun was in the constellation Aries. They were, however, unaware of the precessional translation of the celestial poles and made no corrections for it in their calculations. Subsequently the point of vernal equinox has moved from Aries to Pisces due to precessional effect. Naturally, all the other zodiacal signs are also one constellation behind relative to their original position. However, astrologers regard 21 March, the day of vernal equinox to lie in Aries even today. It is also called by them as the 'First Point of Aries' since it is the point of vernal equinox or the beginning of the year for them when they consider the Sun to enter the sign of Aries.

Q. What is the best possible time for viewing the planets in the night sky?

A. Mercury and Venus are best viewed in the hours just before sunrise and just after sunset. The other planets appear with full intensity when situated due south.

Q. What is the absolute and apparent visible brightness of a celestial body?

A. The Sun is visually brighter than the Moon and the Moon is visually brighter than the stars when viewed in the sky. However, the brightness is only the apparent brightness since some of the stars have actually greater absolute brightness than the Sun and seem less bright only because they are very much further away than the Sun.

If it were possible to keep all the celestial bodies at the same distance from Earth and view them, then we would get to know their real or absolute brightness relative to one another.

Absolute brightness can be ascertained only through calculations unlike apparent value from visual observations.

Q. What is the effect of the precession of the Earth on the celestial sphere?

A. The precession of the Earth causes an apparent precession of the celestial sphere resulting in the movement or processional translation of the celestial poles. That is to say, the celestial poles move around the constellations in a circular fashion or the north celestial pole tends to move away from Polaris. Hence Polaris is not the permanent pole star. (Refer Fig. No. 14.4).

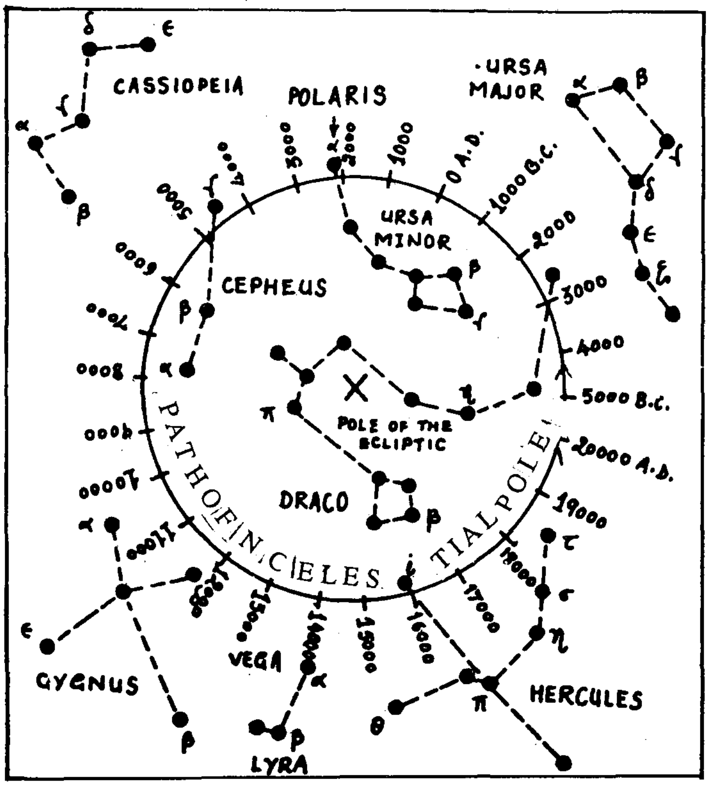


Fig. 14.4 Postion of North Celestial Pole.

The Earth's axis wobbles like a spinning top in such a way that the Celestial Poles describe a circle in the heavens in a period of nearly 26,000 years. The star which happens to lie very close to the celestial pole is known as the 'Pole Star'. At present 'Polaris' is the Pole Star. The figure indicates the past and future pole stars from 5000 BC to 20,000 AD.

Q. Do the constellations undergo a change in shape?

A. Yes. Over a very long period, due to the movements of the stars in different directions, the constellations slowly change shape. (Refer Fig. No. 14.5).

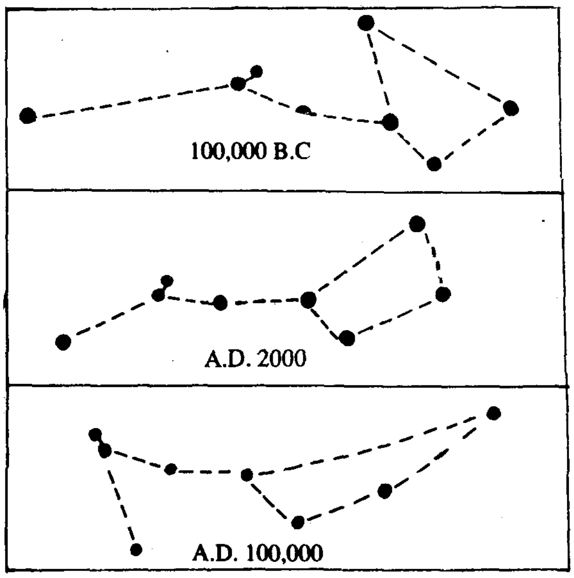


Fig. 14.5 Changes in the Constellation of the Great Bear in 200,000 years.

Q. What are the north polar region and the south polar region, with reference to constellations?

A. The northern hemisphere of the celestial sphere is called the north polar region. The converse is true for the south polar region. (Refer Fig. Nos. 14.6 and 14.7).

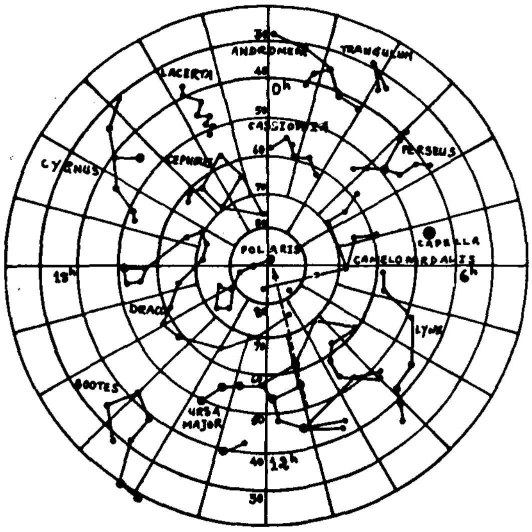


Fig. 14.6 Stars of the North Polar Region.

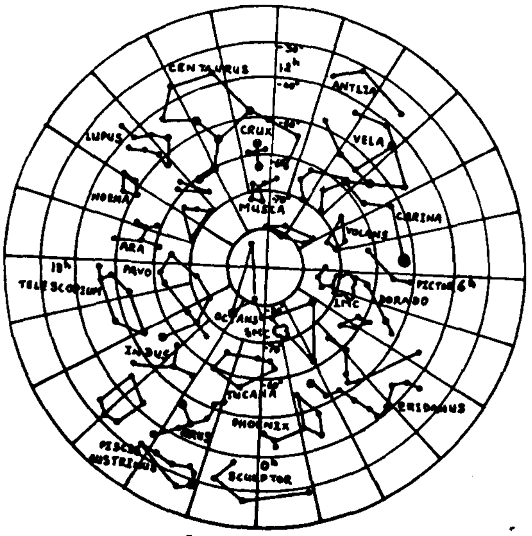
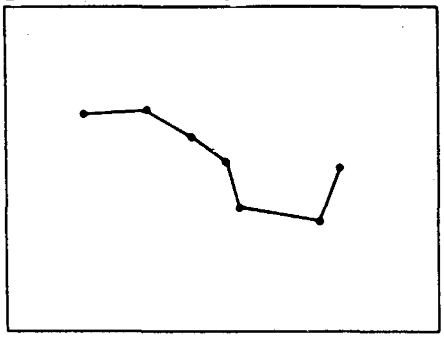


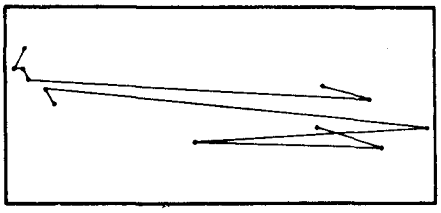
Fig. 14.7 Stars of the South Polar Region.

Q. Does a constellation appear the same irrespective of the point of observation?

A. No. If the observer is situated in space very far from the earth, the appearance of a constellation would change depending on the point of observation. A constellation, therefore, is not a real star grouping and has no true astronomical significance. (Refer Fig. No. 14.8).



Big Dipper as seen from the Earth



Big Dipper as seen from the side

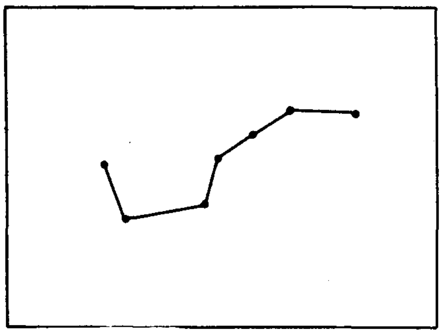


Fig. 14.8 The Big Dipper, as seen from the earth (top), from the side (middle) and from the back (bottom). The last two views would be seen if we were able to travel to the proper vantage points, about 150 light years away.

Q. In which constellation is the centre of the Milky Way located?
A. Sagittarius (also known as *Dhanu* or Archer).

Q. In which constellation is Alpha Centauri (Mitra), the star system closest to the Sun, located?
A. Centaurus (Naraturanga).

Q. *Which constellation honours Julius Ceasar?*
A. The stars of the constellation Libra (Tula) were originally part of the constellation Scorpio (Scorpion) and represented the claws of the scorpion. The Romans redesignated it as a separate constellation, Libra, representing scales of justice in honour of Julius Ceasar who introduced the Julian Calendar and was reputed for his justice.

15. THE MOON (PART 2)

Q. What is the shape of the Moon's orbit?

A. The orbit of the Moon around the Earth is elliptical and the distance between the Earth and the Moon varies from apogee to perigee. At perigee, the Moon is about 360,000 km from Earth and at apogee, it is about 400,000 km away, giving a mean or average distance of about 380,000 km.

Q. How long does it take for moonlight to reach the Earth?

A. Light from the Sun after being reflected off the Moon, takes about 1.3 seconds to reach the Earth.

Q. What does the Earth look like from the Moon?

A. The Earth would look like a shining disc, as the Sun's light would be reflected from it. However, a clear picture of the Earth's features would not be visible all the time due to the obscuring clouds above the Earth's surface.

Q. What is Earthshine?

A. Earthshine refers to the sunlight falling upon the Moon after being reflected from Earth. It is often strong enough to make the night side of the Moon faintly luminous. The Earth's disc would also wax and wane from new Earth to full Earth regularly as seen from the Moon, and the degree of Earthshine would be dependent on the phase of the Earth as seen from the Moon. For example, Earthshine would be maximum when a full earth is visible from the Moon.

Q. What are lunar haloes?

A. Lunar haloes are beautiful luminous rings around the lunar disc. They are due to the ice crystals present in "cirrostratus clouds" (a type of cloud formation) in the Earth's upper atmosphere which diffuse the moonlight resulting in the lunar haloes.

Q. What is a watery Moon?

A. Sometimes, the Moon looks watery or liquid, due to the ice crystals in cirrostratus clouds, if such clouds are denser and lower (below 6 km altitude).

Q. What are Mock Moons?

A. Mock Moons (also known as paraselenae) are brilliant images of the Moon formed at some distance from the actual disc of the Moon. Mock Moons are very rare and are mirages caused by the ice crystals in the higher atmosphere under certain special conditions.

Q. What are lunar rainbows?

A. Just as sunlight produces solar rainbows, moonlight produces lunar rainbows. Both are similar. Since moonlight is fainter in intensity, lunar rainbows are less brightly coloured and rarer than solar rainbows.

Q. What is the Moon illusion?

A. To an observer on the Earth's surface, the Moon looks larger in size, when it is on the horizon than when directly overhead. This is an illusion caused by the behaviour of the human eye. In fact, the Moon overhead is actually almost 2% larger in size as compared to the Moon on the horizon.

Q. Can the colour of the Moon change?

A. The Moon is usually silvery white. However, the nature of the dust in the Earth's atmosphere can distort the light and make the Moon appear brown, red, blue or even green. Some events like blue Moon are very rare (Hence the colloquial expression "Once in a Blue Moon").

Q. What is the tidal effect?

A. The Earth and the Sun both exert a pull on the Moon. However, the Moon's power over the tides is more than twice that of the Sun, since the Moon is much closer to the Earth than the Sun and force of gravity is inversely proportional to the square of distance.

Q. Does the tidal effect apply to solid bodies like the Moon?

A. If the Moon were composed of liquid or gas, it would tend to bulge out in the direction of such pull. This is called the tidal effect.

However, since the Moon is solid, the tidal effect does not result in any noticeable distortion of its shape, but nevertheless the imbalance of forces created by the tidal effect does distort the Moon's shape slightly.

Q. Does the tidal effect apply to the Earth also?

A. Yes. The Earth is pulled by the Moon and the Sun. However, since there is a large body of water on the Earth (the oceans), the Earth actually distorts and changes shape, resulting in the water levels of the oceans periodically rising and receding. These are known as ocean tides.

Q. Just as tidal effects occur on Earth in the oceans, do they occur in the atmosphere also?

A. Yes. The tidal effect applies to the atmosphere also since the atmosphere is really a gaseous ocean.

Q. Does the tidal effect act on the molten liquid core of the Earth?

A. The Earth is solid only over a thin portion of its surface. Most of the inner portion of the Earth is hot liquid material, which is also affected by the tidal forces in the same way as the oceans of water on the surface.

The tidal effect on the liquid core of the Earth influences geological activity such as earthquakes, volcanic eruptions and the gradual drifting apart of the continents.

Q. What is the frequency of the ocean tides on Earth?

A. One high tide occurs approximately every 12.5 hours followed by a low tide. (Refer Fig. No. 15.1).

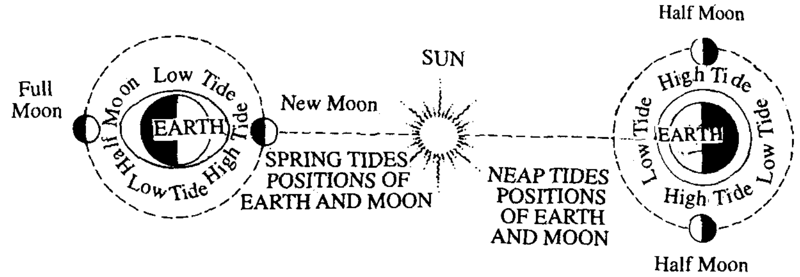


Fig. 15.1 Ocean Tides.

Q. Why does high tide occur twice each day instead of once?

A. One high tide is caused by the bulge produced in the ocean as the Moon pulls the ocean towards it.
Another high tide is created in the ocean due to the slight shift in the solid portions of the Earth (other than the oceans) towards the Moon, caused by the pull of the Moon. Strictly speaking, this type of tide is not due to the sea 'rising' but the land 'sinking'. The second type of high tide occurs on the side of the Earth facing away from the Moon. (The ocean on the side opposite to the Moon is comparatively further away from the Moon and is hence subjected to a weaker attraction than the land).

Q. Why does the tide appears to move from east to west?

A. On account of the Earth's spinning motion from west to east, the tide appears to move from east to west.

Q. What are spring tides?

A. Spring tides are the maximum tides. They occur when the Sun is in line with the Moon, resulting in a maximum combined tidal effect. (Refer Fig. No. 15.1).

Q. What are neap tides?

A. Neap tides are the minimum tides. They occur when the Moon, Earth and Sun form right angles, resulting in a minimum combined tidal effect. (Refer Fig. No. 15.1).

Q. Are spring tides and neap tides related to the seasons such as spring, summer, etc.?

A. No.

Q. Does the tidal effect apply to human beings on Earth?

A. Yes. Your weight on Earth will very slightly decrease when the Moon is directly overhead.

Q. What is the main result of the tidal effect on the Earth-Moon System?

A. The mutual tidal effects between the Earth and the Moon result in the slowing down of the spinning motion of the Earth and the Moon, as the tides act as a brake on the spinning heavenly bodies. Millions of years ago, both the Earth and the Moon were spinning much faster than they do now. In fact, the Moon has completely ceased to rotate relative to the Earth and the other side of the Moon (the 'far side') is permanently hidden from observers on Earth.

Q. What is the rate at which the Earth's rotation is slowing down?

A. About one second in 50,000 years.

Q. Does the Moon move with constant velocity at all times?

A. No. The velocity of the Moon is appreciably greater near perigee than near apogee. The Moon speeds up and slows down regularly during each orbit.

Q. What is secular acceleration?

A. Besides the regular speeding up and slowing down of the Moon during each orbit, there is also a gradual slowing down of the average speed of the Moon over a very long period. This is due to a combination of the tidal effects and also because of the slight orbital changes caused by the pulls of the planets Venus and Mars. The effect is very small and is noticeable only over a period of hundreds of years.

Q. How can secular acceleration be studied?

A. Modern astronomers study secular acceleration by going through the records of total solar eclipses left by ancient astronomers. This is because a total solar eclipse can only happen at New Moon, and hence such ancient records are a reliable guide to the behaviour of the Moon in the past.

Q. Does the slowing down of the Earth's spinning rate, due to tidal forces, have any other effect on the Earth Moon System?

A. Yes. The distance between the Earth and the Moon is slowly increasing. The Moon is moving away from the Earth at a rate of about 3 centimeters per year.

Q. Will the Moon continue to move away from the Earth indefinitely?

A. At some stage in the future, the Earth would slow down its rotation relative to the Moon to such an extent that it would present only one face to the Moon, just as the Moon now presents only one face to the Earth. When such an event occurs, all tidal effects would cease except for tidal effects caused by the Sun. When it is at a distance of about 545,000 km compared to the present distance of about 382,000 km the Moon will stop moving away from the Earth and will instead start moving towards the Earth.

Q. In the far future, when the Moon starts moving towards the Earth, to what extent would it move closer to the Earth?

A. As the Moon approaches very close to the Earth, the Earth's gravity would stretch and distort the Moon. Finally, at a critical distance from Earth (approximately 2.4 times the radius of the Earth, called the Roche Limit) the distorting forces developed in the Moon would be sufficient to shatter the Moon into millions of pieces which would orbit the Earth in the form of a ring. The ring around the planet Saturn is believed to have been formed in this manner.

16. THE SUN (PART 2)

Q. Is the material in the Sun uniformly homogeneous?

A. No. The Sun contains a central core where the nuclear reactions take place. The core is surrounded by a radiative zone through which the energy radiates outwards from the core. The next layer is the convective zone which is in constant turmoil and heat transfer takes place by convection. The final layer is the photosphere which is the outer shell of the Sun (which we see which radiates light, heat and other forms of energy into space. (Refer Fig. No. 16.1).

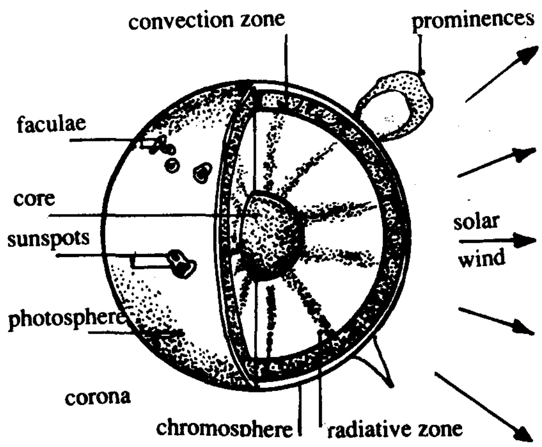


Fig. 16.1 The Internal Structure of the Sun.

The cross-section consists of the core, radiative zone and convective zone. The visible surface is the photosphere on which are seen the dark sunspots and the bright faculae. Above this lies the chromosphere, and then the hot rarefied corona. The stream of subatomic particles moving out through the corona into space is the solar wind.

Q. What are the disturbances that occur on the surface of the Sun due to the nuclear reactions within?

A. The nuclear reactions within the Sun cause tremendous upheavals inside the Sun, resulting in disturbances on the surface of the Sun. These disturbances usually take the form of granulation, spicules and prominences.

Q. What is granulation?

A. Granulation refers to the wavy appearance of the Sun due to the fact that the surface of the Sun is in a state of constant agitation.

Q. What are supergranules?

A. Supergranules are bubbles of gas rising very slowly from the interior of the Sun and breaking through the surface. A supergranule may even take a million years to rise from the centre of the Sun to the surface.

However, once it breaks through the surface, it dissipates in less than half a day. A supergranule is about 30,000 km wide. It is still tiny compared to the size of the Sun.

Q. What are spicules?

A. Spicules are the eruptions occurring on the Sun's surface due to the regular upwelling of supergranules. Spicules are analogous to the eruptions on the surface of water boiling in a vessel. Spicules rise up to about 10,000 km above the Sun's surface.

Q. What are prominences?

A. Prominences are gigantic geysers of gas which surge out of the Sun. Prominences may fall back into the Sun (sometimes in graceful loops) or they may be thrown out of the Sun and get dissipated. Prominences are analogous to the flames in a fire and can rise more than 1,00,000 km above the Sun's surface. (Refer Fig. No. 16.1).

Q. What are flares?

A. While prominences are analogous to ordinary flames, flares are analogous to sudden bursts of flame such as would happen if an ordinary fire were to pass over a stock of petrol. Flares are therefore similar to prominences, only more spectacular. Flares are so violent that they are usually ejected out of the Sun. A flare is seen as a short-lived (typically lasting a few minutes) burst of light. However, it gives out a variety of radiations from X-rays to radio waves, which may sometimes cause disturbances even on Earth.

Q. What kind of disturbances can be caused on Earth by solar flares?

A. The radiation from solar flares may cause curtain-like auroral displays in the sky and interference in radio communication, by causing disturbances in the Earth's atmosphere and magnetic field disruptions.

Q. What are solar filaments?

A. Smaller solar prominences in the form of streamers and loops occurring in front of the Solar disc appear as dark lines (since they are colder than the surrounding area) and are known as filaments.

Q. What is the corona?

A. The corona refers to the outermost regions of the Sun's atmosphere. The corona can be seen from Earth only during a total solar eclipse, or by using an occulter—a disc used on the telescope to block the view of the sun's disc (photosphere). (Refer Fig. Nos. 16.1 and 13.2).

Q. What are sunspots?

A. Sunspots are comparatively dark areas on the Sun which appear in the form of spots on the Sun's disc. (Refer Fig. Nos. 16.1 and 16.2).

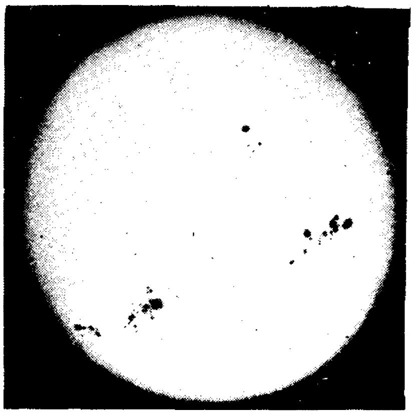


Fig. 16.2 Sunspots.

Q. What is the energy released in a solar flare?
A. A force equal to about ten million hydrogen bombs.

Q. What causes sunspots?
A. Internal disturbances in the Sun's magnetic field manifest themselves as sunspots on the Sun's surface.

Q. What is the temperature of a sunspot?
A. About 4,000°C, which is cooler than the rest of the surface of the Sun. Hence, the sunspot appears as a dark patch, though it is really very bright.

Q. How large are sunspots?
A. Some sunspots may even be five times larger than the Earth.

Q. How powerful is the magnetic field at a sunspot?
A. The magnetic field at a sunspot is several thousand times stronger than Earth's average magnetic field.

Q. How can we measure the tilt of the Sun's axis and the speed of rotation of the Sun?
A. By observing the movement of sunspots on the surface of the Sun, we can get an idea of the axial tilt and rotational speed of the Sun.

Q. Are sunspots permanent?
A. No. Sunspots appear and disappear and also undergo change in size.

Q. How long do sunspots last?
A. Small sunspots survive only for a few hours, while larger ones may persist for a few months.

Q. What are sunspots groupings?
A. While migrating, it can be observed that certain sunspots move together and these are called sunspot groupings. Single spots are known but mostly they form in groups or pairs. Pairs of sunspots are quite common and even larger groupings can be seen.

Q. What are active areas of the Sun?

A. Active areas of the Sun are the areas of large sunspot groupings and movements.

Q. What is the sunspot cycle or solar cycle?

A. The sunspot activity on the Sun increases and decreases periodically over a number of years. This is called the sunspot cycle or solar cycle. (Refer Fig. No. 16.3).

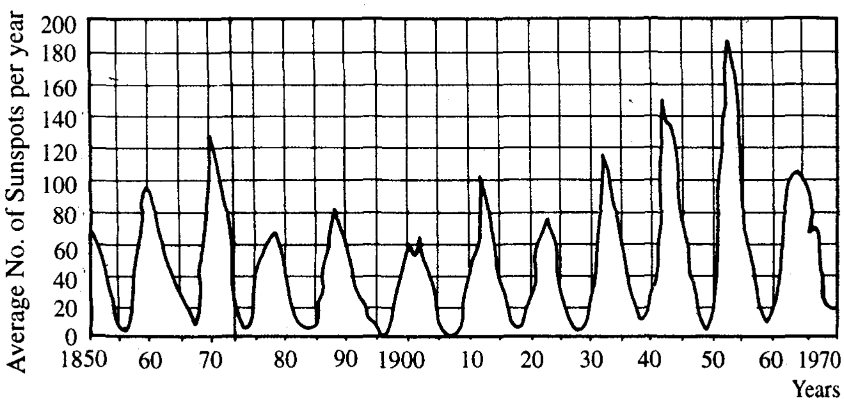


Fig. 16.3 The Solar Cycle.

Q. What is migration of sunspots?

A. Sunspots do not generally remain in one place, but keep moving towards the solar equator. This is called migration of sunspots.

Q. What is the period of the sunspot cycle?

A. The period of the sunspot cycle is approximately 11 years.

Q. What is the pattern of recurrence of the sunspot cycle?

A. The pattern of the years of maximum sunspot activity can be taken as 1979, 1990, 2001, 2012, etc. as a rough eleven year cycle.

Q. What are the apparent and true solar cycles?

A. The apparent solar cycle is observed to be about 11 years.

However, studies of the magnetic fields of pairs of sunspots show that magnetic polarity also reverses every 11 years. The true period of solar activity is therefore 22 years or twice the apparent period.

Q. What is the significance of sunspots?

A. Sunspots are an indicator of the internal turmoil in the Sun. Hence, appreciable increase in sunspots indicates that there is a larger level of turmoil within the Sun.

Q. When is the Sun said to be quiet?

A. The Sun is said to be quiet when very few sunspots erupt. For example, the Sun was relatively quiet from 1645 to 1715 and few sunspots could be seen during this period.

Q. Does the sunspot cycle affect the Earth?

A. Over the sunspot cycle, or solar cycle, there is a slight change in the level of radiation emanating from the Sun as light, heat, etc. Hence, temperatures on Earth are slightly more when the Sun is more active. This may cause melting of the polar ice caps and change in climate on Earth.

Q. Does the sunspot cycle have any influence on human beings?

A. There seems to be an unexplained correlation between sunspot peaks and violence upon Earth. It has been witnessed over many 11-year sunspot cycles that incidents of violence, murders, immolations, shootouts and accidents seem to be increasing with the number of sunspots.

Q. What is an ice age?

A. The unusually cold climate on Earth which accompanies a period when the Sun is quiet, is called an ice age.

Q. Have there been any ice ages in recent times?

A. Ice ages occur cyclically over a long period of thousands of years. However, there was a mini ice age from 1400 to 1850 when the Earth's climate became unusually cold.

Q. How long will the Sun continue to shine in a stable fashion as at present?

A. About five to eight billion years more.

Q. What will happen to the Sun after five to eight billion years?

A. The Sun will cease to be stable and will expand into a giant star categorised as "Red Giant".

Q. Will the Sun cease to shine?

a. The Sun, currently yellow, will appear red in the red giant stage, then white in the white dwarf stage and finally black in the black dwarf stage. When it becomes a black dwarf, the Sun will cease to shine.

Q. At what stage in the life of the Sun, will the Earth become uninhabitable?

A. When the Sun starts becoming a red giant, the Earth will become so hot that everything will start melting. Obviously, life on Earth will cease to exist.

Q. Is mankind doomed to extinction when the Earth becomes uninhabitable?

A. Hopefully by the time Earth becomes uninhabitable, mankind would have sufficiently progressed technologically to leave the Solar System in spaceships and colonise other parts of the galaxy.

Q. Can ice crystals in the clouds cause mock Suns and solar haloes similar to mock Moons and lunar haloes?

A. Yes. Mock Suns are also known as parhelia.

Q. What is a Sun pillar?

A. A Sun pillar is an optical illusion of a vertically stretched image of the Sun, formed in a manner similar to mock Suns.

17. THE STARS (PART 2)

Q. Do all stars evolve into red giants, then into white dwarfs and ultimately into black dwarfs?

A. The conventional ten stages of evolution are applicable only to stars that have a mass of up to a certain critical limit.

Q. What is the *Chandrasekhar Limit*?

A. the limit of mass beyond which a star will not become a red giant is called the *Chandrasekhar Limit* after the Nobel Prize winning India-born U.S. astrophy-sicist who first propounded this theory. The *Chandrasekher Limit* can very between 1.2 to 1.4 times the mass of the Sun, depending on certain conditions.

Q. What happens to a star that has a mass exceeding the *Chandrasekhar Limit*?

A. When a star with a mass exceeding the *Chandrasekhar Limit* exhausts its supply of hydrogen, the inward force due to its gravitation is so tremendous that it undergoes an immediate inward collapse followed by a sudden heating of the core, resulting in a cataclysmic explosion that blows the star apart and hurls the fragments far out into space. A star that undergoes such an explosion and disintegration is called a supernova. (plural: supernovae). (Refer Fig. No. 17.1).

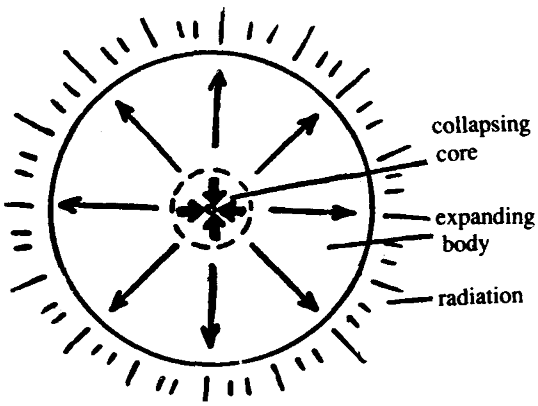


Fig. 17.1 The Collapse of the Central Regions in a Supernova.

Q. What is the difference between the fusion reactions up to the element iron and beyond?

A. Up to the element iron, the fusion reaction is exothermic and there is a net energy output which makes the star shine. Beyond this, the fusion reaction is endothermic and there is a net energy input at the expense of the internal energy of the star.

Q. How are the heavier elements beyond iron produced in a star?

A. The heavier elements beyond iron are produced only in certain kinds of stars called supernovae where the very high energy inputs required to sustain the necessary endothermic fusion reactions are available.

Q. What are the second generation stars?

A. First generation stars were the originally formed ones after the Big Bang. Stars formed from matter remaining after the disintegration of first generation stars are classified as second generation stars.

Q. What are the characteristics of second generation stars?

A. A first generation star will only contain the elements up to iron. When the star disintegrates after becoming a supernova, the debris will contain the heavier elements. The debris may again coalesce to form another star which would be called a second generation star.

Q. Is the Sun a second generation star?

A. The matter in the Sun and planets contains elements heavier than iron and hence the sun can be said to be a second generation star. The matter in the Solar System (including the matter in our bodies) was once part of a supernova.

Q. How cataclysmic is a supernova explosion?

A. When a star becomes a supernova, its luminosity may increase by one hundred million times. A supernova can even become bright enough to be seen in daylight. The explosion is very sudden and occurs in a matter of days and gradually loses its brightness within a few months.

Q. What causes the sudden collapse of a star when it becomes a supernova?

A. When the star starts to collapse, its temperature starts increasing and it starts radiating more energy. However, beyond a critical temperature (around six billion degrees Celsius) most of the radiation is in the form of neutrino particles that have no measurable mass or electric charge and hence offer no outward resistance to the inward gravitational force which can thereafter proceed unchecked.

Q. How frequently do supernovae occur?

A. The average frequency of a supernova in a galaxy like the Milky Way, is about three super-novae per century. Three spectacular supernovae, recorded in our galaxy, occurred in 1054, 1573 and 1604.

Q. After a supernova fades, is there any evidence of its existence other than a neutron star?

A. The turbulent expanding cloud of matter thrown out by a supernova can sometimes be detected from Earth after the supernova has faded.

Q. What is a neutron star?

A. After a supernova explosion, the collapsed core of the star is called a neutron star. The matter in a neutron star is so severely compressed that the entire star would have a diameter of about 10 km. The density of a neutron star is incredibly large (beyond a thousand trillion tonnes per cubic metre) and consists of only neutrons since protons and electrons also fuse to form neutrons.

Q. What is the ultimate fate of a neutron star?

A. A neutron star radiates away its internal energy as no fusion takes place. As the internal energy of the neutron star depletes, it cools and ends up as a black neutron star similar to a black dwarf, but more dense.

Q. What is the maximum limit for the mass of a neutron star?

A. The maximum possible mass of neutron star is 3.2 times the mass of the Sun.

Q. How does a star evolve whose final mass exceeds the maximum limit of mass for a neutron star?

A. When the final mass of a star exceeds the limit of mass for a neutron star, it becomes a Black Hole instead of a neutron star.

Q. What is a Black Hole?

A. A Black Hole is the extremely massive remnant of a dying star. A Black Hole is so massive that its gravity prevents anything from escaping. Not even light can escape from a Black Hole. In other words, the escape velocity of a Black Hole is greater than that of light.

Q. How did the Black Hole get its name?

A. A Black Hole allows no light to radiate and appears dark. Also anything falling into it, cannot get out ever.

Q. What is the alternative name for a Black Hole?

A. A Black Hole is actually a star which has collapsed beyond the neutron star stage. It is therefore also called a collapsed star or "Collapsar" for brevity. If the entire Earth collapses to form a neutron star it would have a diameter of 200 metres. If it further collapses to form a Black hole, it would be just the size of a golf ball.

Q. What is the boundary of a Black Hole?

A. Using Einstein's General Theory of Relativity, it is possible to calculate, for a known amount of matter in the Black Hole, the distance at which the escape velocity is equal to the speed of light. This radius (called the Schwarzchild radius) is the boundary of the Black Hole. Any object going closer to it than the Schwarzchild radius must fall into the Black Hole. Hence the boundary of a Black Hole is not actually the boundary of a solid body but the boundary of the region of space from which nothing can escape. The larger the mass of the Black Hole, the greater will be its Schwarzchild radius.

Q. What is the event horizon?

A. Since no light can escape from a Black Hole beyond the Schwarzchild radius, the Schwarzchild radius represents the limit up to which we can observe the events happening inside a Black Hole. Any event occurring within the Schwarzchild radius cannot be seen by an observer situated outside the Black Hole. Hence the boundary of the Black Hole denoted by the Schwarzchild radius is also called the event horizon of the Black Hole.

Q. Can a Black Hole expand?

A. The Schwarzchild radius of a Black Hole depends on the total mass in the Black Hole. If matter in the vicinity of a Black Hole falls into it, the mass of the Black Hole will increase and it will expand.

Q. Can a Black Hole shrink?

A. A Black Hole maintains its enormous gravity at the expense of its internal energy. Hence a Black Hole standing by itself in space (without any other matter nearby) will slowly start shrinking and eventually disappear out of existence when its mass is consumed entirely.

Q. What is a mini Black Hole?

A. A mini Black Hole is one that has shrunk to a small size. The matter in it continues to be intensely dense as in a normal Black Hole.

Q. What would happen if a mini Black Hole hits the Earth?

A. A mini Black Hole hitting the Earth would instantaneously punch a hole through the Earth and continue on its journey through space. The hole punched in the Earth by the mini Black Hole would close up immediately and any affected areas on the surface would be limited to the points of entry and exit of the mini black Hole. However, the mini Black Hole would pick up some matter from the Earth and grow larger, as it passes through the Earth.

Q. What would happen if a slowly moving mini Black Hole enters a very large body?

A. There is a possibility that a slowly moving mini Black Hole may further slow down and even get trapped while passing thorough a very large body. In such a case, the mini Black Hole will continue to consume matter from its host body and grow, completely consuming the host body eventually.

Q. Do Black Holes rotate on their axis like other heavenly bodies?

A. Yes.

Q. What is the Stationary Limit for a Black Hole?

A. The Schwarzchild radius applies to rotating as well as non-rotating Black Holes. However, rotating Black Holes bulge at the equator just like other rotating bodies and this creates a centrifugal effect with the emergence of another boundary outside the Schwarzchild radius called the Stationary Limit. In a non-rotating Black Hole, the Stationary Limit coincides with the Schwarzchild radius.

Q. What is the significance of the Stationary Limit?

A. An object approaching a Black Hole is in no danger of falling into the Black Hole if it stays outside the Stationary Limit. If the object approaches the Black Hole within the Schwarzchild radius, it is certain to fall into the Black Hole. However, an object approaching within the Stationary Limit but remaining outside the Schwarzchild radius would be s emitrapped, meaning that it may be able to escape but only by moving in the direction of rotation of the Black Hole and using the Black Hole's rotational energy to hurl the object (like a stone in a slingshot) outside the Stationary Limit (Refer Fig. No. 17.2).

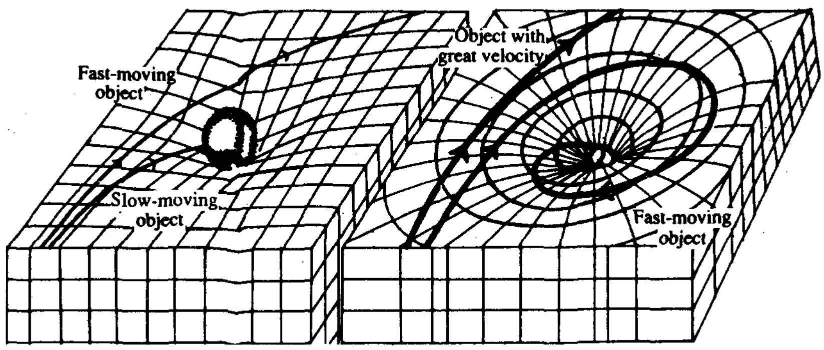


Fig. 17.2 Gravity Field of a Star (Left) and Gravity Field of a Black Hole (Right).

Every star exerts a gravitational pull. It can be thought of as making a 'dent' in the surrounding space grid. This means (as at left) that any body that goes near will fall towards it. The sort of dent a star makes will depend on how massive it is. The heavier the star, the steeper and more widespread the dent. White dwarfs and neutron stars are massive and make broad, steep dents. Black holes exert such a gravitational pull that not even light can escape from them. Their dents are the steepest of all (as at right). In them, space 'folds over' so that material falling into them is never seen again. Bodies near the dents of such stars must be moving very fast if they are not to fall on to the star.

Q. What is the maximum possible size of a Black Hole?

A. There is really no maximum limit to the size of a Black Hole as it can grow bigger and bigger by sucking in more mass from its surroundings.

Q. What is a galactic Black Hole?

A. A very compact and energetic microwave source exists at the centre of the Milky Way Galaxy. There is a theory that this is caused by a giant Black Hole or galactic Black Hole having a mass of 100 million stars. There is also another theory that there are such galactic Black Holes at the centre of every galaxy. For example, the Galaxy NGC-6240 which is 300 million light years away from earth is suspected to contain a Black Hole 100 billion times as massive as the Sun.

Q. How does a Black Hole get the enormous energy to sustain itself.

A. All matter falling into a Black Hole will have about 30% of its mass converted into radiation immediately. This is far more than in any fusion reaction. The remaining matter is further converted into energy to sustain the intense gravitation field of the Black Hole. All the matter entering a Black Hole would end up as energy in the above two stages.

Q. To what extent will matter in a Black Hole collapse?

A. Matter in a Black Hole will continue to collapse indefinitely until, in principle, it is compressed into appoint of infinite density known as a singularity (or Schwarzchild singularity).

Q. What is a gravitational lens?

A. Light rays passing near a Black Hole would be bent towards the Black Hole due to the tremendous gravity exerted by the Black Hole in the same way as a lens makes light rays converge. The Black Hole therefore behaves as a gravitational lens deflecting the light rays.

Q. What is a binary star system?

A. In a binary star system, there are two stars, both orbiting their common barycentre.

The stars in a binary star system are separated by about 10 to 20 a.u. (Refer Fig. No. 2.10).

Q. What is a tristar system?

A. A tristar system is a system in which two companion stars (sharing a common orbit) orbit a central star.

Q. What are Lagrangian orbits?

A. A tristar system appears to be clearly an unstable system at first glance, since minor gravity disturbances (perturbations) in the system will cause one of the two orbiting stars to advance on the other leading to collision and ultimate merger of the two orbiting stars.

However, there are two points in such an orbit where there is comparative stability and safety from any such catastrophic collisions. These points are called the Lagrangian points. Located 60° ahead or behind the other orbiting body, the Lagrangian points form a perfect equilateral triangle with the central star. The stars located at Lagrangian points in such an orbital configuration would then be said to be in a Lagrangian orbit. A Lagrangian orbit can apply to planets also e.g. the Lagrangian points of Jupiter containing the 'Trojan' asteroids.

Q. Do tristar systems actually exist?

A. No tristar systems have been detected so far. However, if such tristar systems do exist, then the orbit would have to be large in relation to the diameters of the stars to avoid serious tidal effects and ensure stability of the system.

Q. Do binary stars actually exist?

A. It is estimated that fifty percent of all stars in the Universe are contained in binary systems.

Q. Why is the study of binary star systems of importance to astronomers?

A. Applying Kepler's laws (linking stellar masses with time and distance) to binary systems, the stellar masses of the component stars can be directly calculated. This is of utmost importance to astronomers.

Q. What causes a star to become a nova?

A. Most, if not all, novae (not to be confused with supernovae) are members of binary systems in which one member is a body like a white dwarf on Black Hole whose intense gravitation draws out a stream of matter from the other body. From time to time such matter is transferred from the second star to the first star which undergoes an unpredictable violent explosion called a nova, often periodically every few decades.

Q. *Can a nova be visible to the eye?*

A. Yes. for example a nova visible to the naked eye occurred in August 1975 in the constellation Cygnus. Typically, a nova's brightness increases by a factor of 10,000 to 100,000 in a few days or even in a few hours, and returns to its original brightness, more or less, over or period of many years.

Q. How can Black Holes be detected?

A. Since nothing can radiate out of a Black Hole, it is invisible and cannot be directly observed. It can only be observed when the influence of its tremendous gravity is detected on some other visible object near it. For example, in a binary system if one star is an invisible Black Hole, it will certainly influence its visible companion star.

Q. What is 'Nemesis'?

A. There is an unproven theory that the Sun may be part of a binary star system containing a distant dark companion named 'Nemesis'.

Q. How is a Black Hole likely to influence its companion in a binary system?

A. If one star in a binary system is a Black Hole, its visible companion will be seen to be following an orbit around an invisible object. Moreover due to the tremendous gravity of the Black Hole a steady stream of matter from the visible star will be flowing to the Black Hole, and this matter will emit X-rays when falling into the Black Hole. Hence an X-ray source containing a massive invisible object is likely to be the location of a Black Hole.

Q. Have any Black Holes been detected?

A. The best example of a likely Black Hole is Cygnus X-1 which is an X-ray source containing an invisible object too massive to be a white dwarf or neutron star.

Q. When was the first double (binary) Quasar discovered?

A. The first double Quasar (named 0957+56) was discovered in 1980.

Q. What is a Pulsar?

A. Pulsar is an abbreviation for Pulsating Radio Star, first discovered in 1967. Pulsars are radio sources which emit brief pulses of signals at very regular short intervals of typically one second or less.

Q. Can neutron stars be detected from Earth?

A. It is thought that Pulsars are neutron stars which have an extraordinarily high speed of rotation caused by the sudden decrease in size following the supernova explosion. In theory a neutron star can rotate in periods as short as a millisecond. Pulsars can be detected from Earth.

Q. How rapidly are pulses from a pulsar transmitted?

A. The Pulsar in the Crab Nebula (one of the fastest) transmits pulses at intervals of 0.033 seconds and each pulse has a duration of just 0.002 seconds.

Q. Do Pulsars transit only radio pulses?

A. Some Pulsars transmit pulses at non-radio wavelengths also. For example, the Pulsar in the Crab Nebula transmits pulses in the X-ray and optical wavelengths also.

Q. What is the explanation of the behaviour of a Pulsar?

A. A Pulsar is thought to be a type of rapidly rotating neutron star having an intense magnetic field. The radiation is trapped by the magnetic field and leaks out in narrow beams at the two magnetic poles. As the star rotates the beam sweeps round like the beam of a light house and each time the beam points in the direction of Earth, a pulse signal is received.

Q. Is the period of a Pulsar constant?

A. The period of a Pulsar can suddenly increase and decrease due to turbulences in the neutron star which cause the rotation to change, to conserve the angular momentum.

The loss of energy of a Pulsar by radiation also causes it to slow down over a period. Hence a slowly pulsing Pulsar is likely to be an old Pulsar which has slowed down while a rapidly pulsing Pulsar is likely to be a young Pulsar that has not yet slowed down.

Q. How do astronomers keep track of the orbits of the individual stars in a binary star system?

A. While observing binary star systems one star (called the primary) is considered stationary and the orbit of the other companion star around it is plotted. From this information the actual paths of both stars can be computed.

Q. What is the Time Dilation Effect?

A. According to Einstein's special relativity theory, time slows down for a moving object as measured by an observer considered to be stationary. The theory predicts for example that if one member of a pair of identical twins travels at near light speed to a distant star and back, he will return to find that his clock has been running slow and that his homebound brother has aged more than he has. This "time dilation" effect has been confirmed by experiment: Atomic clocks taken on long rides in space have been found to lag a few billionths of a second behind clocks that remained on Earth.

Q. What are visual binaries?

A. In visual binaries the two component stars are clearly visible.

Q. What are astrometric binaries?

A. In astrometric binaries one of the stars is a dark companion (such as a black dwarf or a Black Hole) which emits little or no radiation. The existence of the dark companion star can therefore be deduced only from an observation of the minute perturbations in the motion of the visible star caused by the gravitational field of its dark companion.

Q. What are contact binaries?

A. In contact binaries, the gravity of one star is so great that it is actually sucking out material from the other star in the form of a stream of matter continuously transferring from one star to the other.

Q. What are X-ray binaries?

A. An X-ray binary system is a contact binary system containing a collapsed star (a white dwarf, neutron star or, possibly, a Black Hole) and a normal star. As the normal star expands (in the giant phase of evolution) material flows from it towards the collapsed star, giving rise to a kind of gravitational whirlpool in the form of an extremely thin hot disc) orbiting round the collapsed star. This disc is a source of X-rays.

Q. What are eclipsing binaries?

A. In eclipsing binaries each of the stars periodically passes in front of the other eclipsing it, resulting in the combined brightness of the two stars diminishing periodically.

Q. What is a worm hole?

A. The theories of Black Holes and wormholes are derived from Einstein's Theory of General Relativity. Einstein's Theory of Gravity states that gravity exists because massive objects curve the space around them and things fall simply because they are following the shortest path through curved space. Wormholes and blackholes have long been recognised as possible solutions to Einstein's equations. Both are severe space warps, or intense gravitational fields. But there are two important differences between them. A blackhole has a 'bottom'— a 'singularity' at which its gravitational field becomes infinitely strong.

A wormhole in contrast does not have a bottom, but has two "mouths" connected by a "throat". The mouths may be very far apart in space even though the throat is short. Thus a worm hole might in principle serve as a kind of cosmic shortcut, like the one a worm takes when it burrows through an apple rather than crawling the long way around the surface. An object sucked into one mouth of a wormhole and down the throat might emerge from the second mouth only a few moments later, but possibly halfway across the universe. However there is no completely satisfactory theory that explains how worm holes are formed and maintained in nature. No wormholes have so far been detected.

Q. What is the relationship between the size of a star and its life span?

A. The more massive the star, the shorter is its life span. Stars having much more mass than the Sun burn their fuel prodigally in a flaming youth and hurry to an early death. For example, a star ten times as massive as the sun radiates a thousand times as much power, but survives for only a hundred million years. To sustain its greater weight, its nuclear furnace must burn hotter. The rate of nuclear fusion is very sensitive to temperature; at 20 million degrees the nuclear fuel is consumed 30,000 times faster than at million degrees.

Q. What are spectroscopic binaries?

A. In spectroscopic binary systems the two component stars are usually too close together to be discerned separately, but they can be identified by spectroscopic analysis of light from the binary system.

18. ARTIFICIAL SATELLITES AND SPACE TRAVEL (PART 2)

Q. When did the space age begin?

A. The space age began on 4 October 1957 when the world's first artificial satellite Sputnik-1 was launched.

Q. Name the first living creature to be sent into space.

A. On 3 November 1957 the Russian dog Laika was sent into space on the Sputnik-2 spacecraft (Refer Fig. No. 18.1).

Fig. 18.1 The Russian dog Laika became the first creature to travel in space.

Q. Who was the first man to enter space?

A. On 12 April 1961, Yuri Gagarin of Russia became the first man to enter space, on the Vostok -I spacecraft. (Refer Fig. No. 18.2).

Fig. 18.2 Russian Cosmonaut Yuri Gagarian (1934–68) became the first man in space.

Q. Who was the first Indian to enter space?

A. Squadron Leader Rakesh Sharma was the first Indian who went into space. He went into space with two Russian cosmonauts on the Russian spacecraft Soyuz T-11 on 3 April 1984.

Q. Name the spacecraft which first photographed the far side of the Moon.

A. The Russian spacecraft Lunik-3 (also known as Luna-3) first photographed it on 6 October 1959.

Q. Who was the first woman to enter space?

A. Valentina Tereshkova of Russia became the first woman to enter space on 16 June 1963 on the Vostok VI spacecraft. (Refer Fig. No. 18.3).

Fig. 18.3 Russian Cosmonaut Valentina Tereshkova (b. 1937). She became the first woman in space.

Q. Name the American spacecraft that went around the Moon in 1966–67.

A. Five Orbiter spacecrafts were successfully sent around the Moon in 1966–67. They transmitted photographs of the Moon taken from heights of only a few tens of kilometres, including photographs of the far side.

Q. Name the first manned spacecraft to go round the Moon.

A. Apollo 8 with three crew members became the first manned spacecraft which went round the Moon, in December 1968.

Q. Name the space probe whose findings drastically revised our views of the planet Mars.

A. The space probe Mariner-3 which went into orbit around Mars photographed Mars in 1971–72 and sent back amazing pictures, including pictures showing a cratered moon-like surface, great volcanoes and even dust storms. It was also established that the atmosphere of Mars was unexpectedly thin and was made up of carbon dioxide rather than oxygen. It also became clear that the polar ice caps on Mars were probably made up of solidified carbon dioxide and not ice.

Q. Name the first man-made object to reach another world.

A. Luna-2 became the first man-made object which reached another world, when it crashed on the Moon on 14 September 1959.

Q. Has any spacecraft left the Solar System?

A. On 2 March 1972, the spacecraft Pioneer-10 was launched with a mission to leave the Solar System and travel for at least two million years. It will never come back.

Q. What is meant by docking of spacecraft?

A. Docking means linking of spacecraft in space. The spacecraft have to be specially designed for docking, with access doors, tiny rockets for steering and alignment, and clamps to keep the spacecraft locked together after the docking.

Q. What is a space station?

A. A space station is a special kind of large satellite much bigger than a space capsule that is placed in orbit around the Earth. A space station is usually designed to accommodate a number of astronauts for a comparatively longer period.

Q. Can artificial gravity be provided in a spacecraft or a space station?

A. Artificial gravity is created by the centrifugal force produced by rotating the spacecraft. Hence, there is really no 'up' and 'down', but only 'inwards' and 'outwards' from the axis of rotation. Also the gravity is not uniform and increases as one moves away from the axis of rotation.

Q. What is a space colony?

A. A space colony is a very large space station similar to an island in space, where a very large number of persons can live and work. So far, no space colonies have been placed in orbit.

Q. What is the difference between an astronaut and a cosmonaut?

A. Both words are from Greek, astronauts meaning "Sailors among the stars" and cosmonauts meaning "Sailors of the universe". Americans call their space explorers astronauts, and the Russians call their's cosmonauts.

Q. What is a space walk?

A. When astronauts go outside their spacecraft briefly in protective suits they are said to be taking a spacewalk. Actually they do not walk but drift beside the spacecraft. (Refer Fig. No. 18.4).

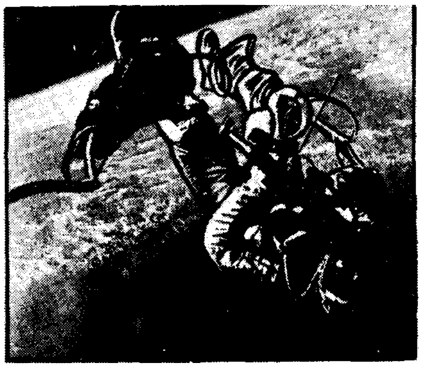


Fig. 18.4 Edward White, the first American astronaut to walk in space, remained outside the Gemini-4 space capsule for twenty minutes.

Q. What is an umbilical cord?

A. It is a safety cord which keeps the astronaut tethered to the spacecraft during a spacewalk. Without the umbilical cord, the spacewalking astronaut would drift away into space. It is called the umbilical cord as it is analogous to the umbilical cord that connects the unborn baby to its mother. (Refer Fig. No. 18.4).

Q. Who was the first man to walk in space?

A. In March 1965, the Russian cosmonaut Alexei Leonov left his spacecraft and performed the first spacewalk.

Q. Why does an astronaut seem weightless, while orbiting the Earth in space?

A. Actually, an astronaut orbiting the Earth in space is still firmly in the Earth's gravitational field and seems weightless only because, he is moving in free fall i.e. in the same direction and at the same speed as the spacecraft (Refer Fig. No. 18.5).

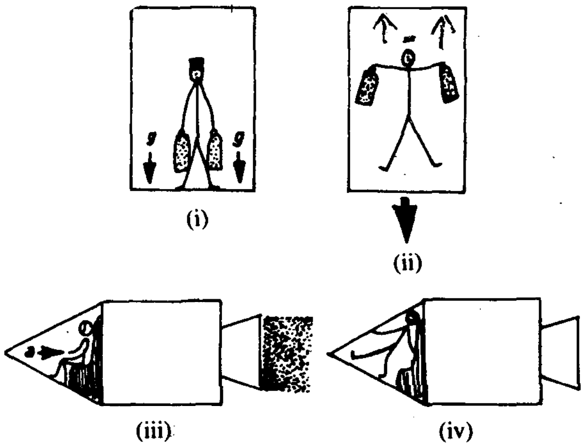


Fig. 18.5 Free Fall.

(i) Stationary Elevator.

(ii) Falling Elevator.

(iii) Spacecraft with engine on.

(iv) Spacecraft with engine off.

g: Force of gravity.

a: Force of engine.

Q. What are the main physical problems the astronauts face while remaining in space?

A. The lack of gravity in space tends to make the muscles weaker and the bones more porous, as comparatively less strength has to be used in space. This creates some problems on long space journeys and also when the astronauts return to Earth. Providing artificial gravity on spacecraft can solve this problem to a certain extent.

Q. What are the dangers to astronauts in outer space?

A. In outer space, there is neither gravitational pull nor air. There are also extremes of temperature and hazardous radiation. There is also the possibility of the spacecraft being hit by meteoroids.

Q. How do astronauts in space suits communicate with each other in outer space?

A. Each space suit is provided with a two-way radio for communication.

Q. What kind of food do astronauts eat in space?

A. The food is frozen and dried to retain its freshness and to conserve space. Some types of food are stored in concentrated form. Liquids and even solids are consumed from squeeze bottles to avoid any spilling of crumbs or droplets. Since there is no gravity, any food crumbs or liquid bubbles will float around inside the spacecraft, causing inconvenience.

Q. How are astronauts protecte n outer space?

A. Inside a space station, astronauts are relatively safe. However, when they venture outside they have to wear protective space suits, specially designed to ensure survival and safety in outer space. (Refer Fig. No. 18.6).

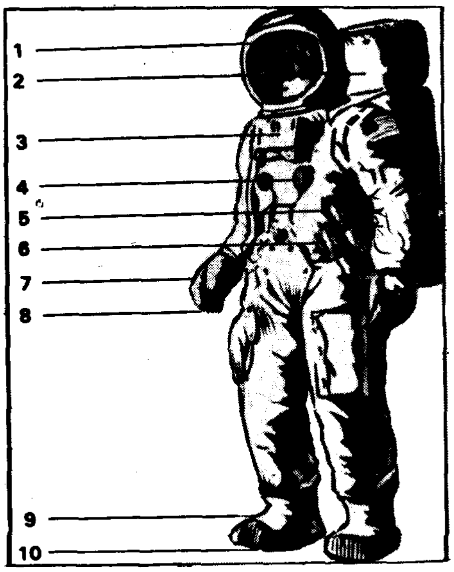


Fig. 18.6 Space Suit of Apollo Astronaut.

1. Lunar visor which protects the wearer from meteoroids and lunar glare. 2. Portable life support system. 3. C...t..l b x f . main support system. 4. Water inlet for cooling suit. 5. Oxygen inlet. 6. Outlet for carbon dioxide and contaminated oxygen. 7. Insulated gloves. 8. Fingertips of gloves made from silicon rubber. 9. Overshoes. 10. Soles made from silicon rubber with ribbed bottoms.

Q. How do astronauts get rid of body wastes in space?

A. Liquid waste is pumped into space where it vapourises. Solid waste is kept in bags filled with germicide and the bags are disposed of when the spacecraft returns to Earth.

Q. What is a space capsule?

^. A space c-‐-ul- i- a small container launched into space. The Mercury capsules were bell-shaped, little bigger than telephone boxes and not at all comfortable for the astronaut. The Vostok capsules were somewhat bigger. The American Gemini capsules carried two astronauts, but was still cramped for two people.. It was made up of three separate sections. Only the crew section came back to Earth (Refer Fig. No. 18.7).

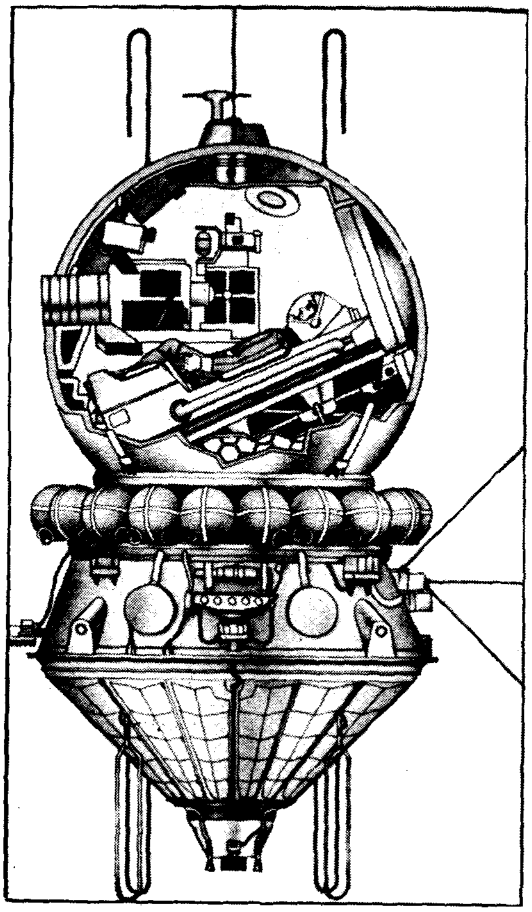


Fig. 18.7 The first Russian cosmonauts were launched into space in this kind of craft, called Vostok. They parachuted back to Earth, and came down on land.

Q. What was the rocket used for the Apollo lunar missions?

A. The Apollo lunar missions used the Saturn V rocket. The Saturn V was the largest rocket ever successfully flown. With the Apollo spacecraft attached, it stood 111 metres high and lifted off the launch pad with a thrust of more than 3 million kilograms. It was a three-stage rocket and the third stage provided the power to speed the spacecraft on its three-day journey to the Moon. (Refer Fig. No. 18.8).

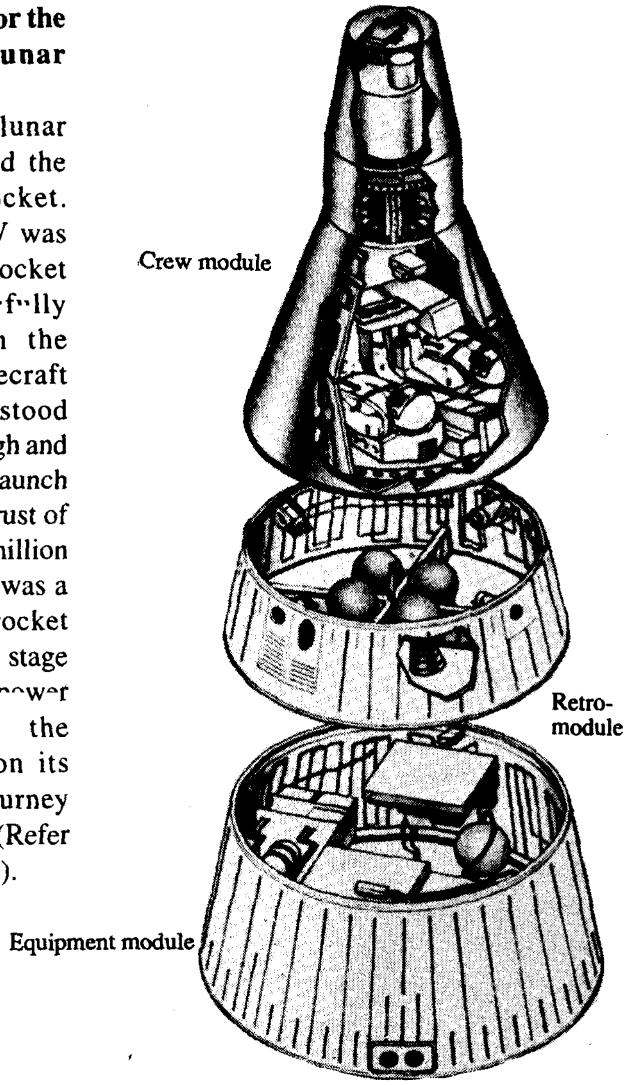


Fig. 18.8 Gemini Capsule.

Q. What are the main sections of the Saturn V rocket?

A. In the three-stage rocket, the upper part contains the third stage with the Apollo command, service and lunar modules, the launch escape system and steering jet.

The second stage lies just below the much smaller third stage and has five steering jets.

The first stage is the largest and has five jets through which its fuel of kerosene and liquid oxygen can fire. (Refer Fig. No. 18.8).

Q. What was the type of spacecraft lifted into space by the Saturn V rocket for the Apollo lunar missions?

A. The Apollo missions to the Moon were achieved with a cleverly designed spacecraft made up of three main modules. One housed the crew, the next one contained equipment and the third was the Moon landing craft. The Moon-landing craft itself was designed in two parts. The astronauts left the Moon in the upper part of this module. (Refer Fig. No. 18.9).

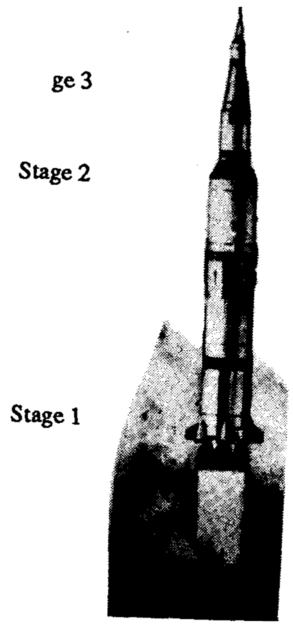


Fig. 18.9 Saturn V Rocket.

Q. When did man first land on the Moon?

A. On 20 July 1969, the lunarmodule "Eagle" (launched from the spacecraft Apollo 11) landed on the Moon, carrying two astronauts. (Refer Fig. Nos. 18.9 and 18.10).

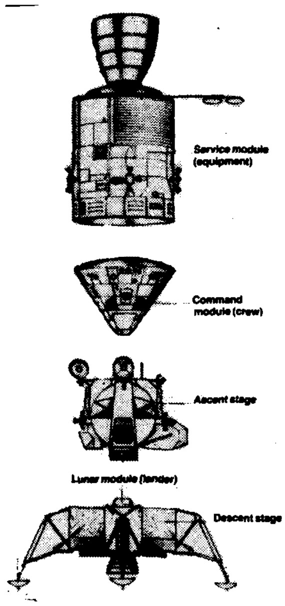


Fig. 18.10 Apollo Spacecraft.

Q. What was the first message from the Moon?

A. Immediately after Eagle landed, the astronauts sent the message "The Eagle has landed".

Q. How many persons have walked on the Moon as part of the Apollo missions?

A. Twelve persons (all American astronauts) have walked on the Moon as part of the Apollo missions. They are:

Apollo 11 — Neil Armstrong, Edwin Aldrin.
Apollo 12 — Charles Conrad, Alan Bean.
Apollo 14 — Alan Shepard, Thomas Mitchell.
Apollo 15 — David Scott, James Irwin.

Apollo 16 — Charles Duke, John Young.
Apollo 17 — Eugene Cernan, Harrison Schmitt.
(Refer Fig. No. 19.4).

Q. Who were the first persons to walk on the Moon?

A. The Apollo 11 astronauts Neil Armstrong and Edwin "Buzz' Aldrin who landed on the Moon aboard Eagle were the first and second persons respectively to walk on the Moon. (Refer Fig. No. 18.11).

Fig. 18.11 In the photograph taken by Neil Armstrong after he had reached the Moon's surface, Edwin Aldrin is seen as he steps out of the module.

Q. What is a solar-sail spacecraft?

A. A solar-sail spacecraft employs a large sail just like a sailing ship. However, the wind that strikes the sail and provides thrust to the spacecraft is not the normal wind but the solar wind. Hence, the spacecraft exploits the tiny force generated by the solar radiation, when it is reflected off a surface.

That solar radiation reflected by a surface exerts pressure is well known, but the pressure is too weak to be of any practical use on Earth. In space, where Earth's gravity is negligible, solar sails can be used to propel a spacecraft.

A spacecraft designed by a group of universities and companies in Europe has a solar sail 100 metres long and 100 metres wide made of aluminum coated mylar as thick as a human hair.

When solar radiation is reflected from the sail, it will generate a thrust of 0.08 Newton (one Newton is the force that will accelerate one kg of mass by one metre).

Computer simulation studies have shown that this craft would complete the lunar fly-by mission in about 700 days by always keeping the reflecting surface of the sail pointed towards the Sun.

This European spacecraft will also have a payload of 80-kg of scientific instrumentation.

Q. Arthur C. Clarke, who predicted the use of synchronous satellites also predicted the use of solar-sail spacecraft. Name his science fiction story.

A. "The Wind from the Sun".

Q. What is the ESA space sail contest?

A. The European Space Agency (ESA) has announced the first race in space open only to solar-sail spacecraft.

The winner of the "Space Sail Cup" will be the first craft that makes a loop around the Moon, flies into deep space and gets as close as 10,000 km to the planet Mars.

Launching of the spacecraft will be done free of cost by Ariane rocket. After reaching the high Earth orbit, the spacecraft must exclusively exploit the weak thrust of the solar radiation to escape the Earth's gravity and, after a lunar fly-by, reach an interplanetary orbit around the Sun heading towards Mars.

The solar-sail spacecraft is nominally expected to make the lunar fly-by in two years and arrive near Mars in less than three and half years.

19. THE MOON (PART 3)

Q. What are the main parts of a lunar map?

A. Basically two maps of the Moon are used, one representing the near side and another representing the far side of the Moon.

Q. How many features on the surface of the Moon have been recorded?

A. Over 100,000 features on the surface of the Moon have been recorded but many are not of importance and only the large ones are visible to the naked eye.

Q. What are the different types of features visible on the Moon's surface?

A. Some of the important features on the Moon's surface are seas, mountains, valleys, peaks, domes, faults, ridges, craters, walled plains, small craters, ruined craters, twin craters, craterlets, plateaus, clefts, crater chains, rays, etc.

Q. What is the lunar limb?

A. The lunar limb is the Moon's apparent edge as seen from the Earth. (Refer Fig. No. 19.1).

Q. Does the limb remain in the same position on the Moon's disc?

A. Yes. The limb remains in more or less the same position on the Moon's disc except for very minor shifts due to perturbations.

Q. What is the terminator?

A. The terminator is the boundary between the day and night sides of the Moon.

Q. Does the terminator remain stationary?

A. No. The terminator sweeps right across the Moon's disc, once when the Moon is waxing (called morning terminator) and again when the Moon is waning (called evening terminator). (Ref. Fig. No. 19.1).

Q. Why is the terminator important for studying features on the Moon's surface?

A. The terminator does not appear as a smooth line, due to the unevenness of the Moon's surface. At the morning terminator line when the Sun has just started rising, the peaks of the mountains which catch the first rays of the sun are brightly lit while the valleys are still in shadow. A study of the lights and shadows at the terminator therefore can provide a valuable insight into the topography of the lunar terrain. (Refer Fig. No. 19.1).

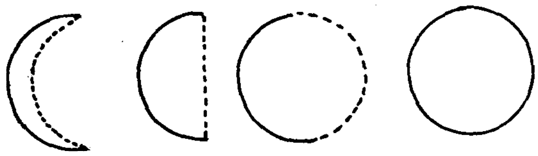


Fig. 19.1 The Terminator.

(The dotted line is the terminator. The thick line is the limb.)

Q. What are the lunar seas?

A. The lunar seas refer to the vast dark plains on the Moon. There is no water on the Moon and the name "Seas" is therefore a misnomer.

Q. Is there any significant difference between the near side of the Moon and the far side?

A. Yes. The far side of the Moon does not have any "Seas" like in the near side.

Q. Why is the last quarter of the Moon less brilliant than the first quarter?

A. In the last quarter the eastern portion of the Moon is shining. Since no bright seas cover most of this portion, the last quarter is less bright than the first quarter.

Q. How are the lunar seas named?

A. Sea in Latin is "Mare" (pronounced "Mahri") and its plural is Maria (pronounced "Mah-ri-ah"). Lunar seas are denoted by the word Mare followed by the Latin name for each sea.

Q. What are the important lunar seas?

A. The important lunar seas are:

Mare Crisium	Sea of Crises.
Mare Fecunditatis	Sea of Fecundity.
Mare Nectairs	Sea of Nectar.
Mare Tranquillitatis	Sea of Tranquillity.
Mare Serentitatis	Sea of Serenity.
Mare Frigoris	Sea of Cold.
Mare Imbrium	Sea of Showers.
Mare Vaporum	Sea of Vapors.
Mare Nubium	Sea of Clouds.
Mare Humorum	Sea of Humors.

Q. How high are the mountains on the Moon?

A. Lunar mountains are mainly found in the southern part of the Moon. The highest lunar mountains are higher than the mountains on Earth.

Q. How is the height of a lunar mountain measured?

A. The height of the lunar mountains can be estimated by studying the type of lighting and the shadows cast by the mountains at the terminator and mathematically analysing them.

Q. How deep are lunar craters?

A. Lunar craters can be several kilometres deep. The crater Newton near the south pole is so deep that it could almost accommodate Mount Everest, the highest mountain on Earth.

Q. What is the Linne Crater mystery?

A. There is recorded evidence of a crater named Linne estimated to be about 10 km across and about 300 m deep. The last record of Linne was in 1843. However, an observation in 1866 revealed that there was virtually no evidence of Linne. Between 1843 and 1866, Linne had apparently just vanished. No satisfactory explanation is available.

Q. What are lunar craters actually?

A. Lunar craters are circular in shape with raised walls and sunken floors. They are not the conventional type of craters and are more in the nature of walled depressions. (Ref. Fig. Nos. 19.2 and 19.3).

Fig. 19.2 Cross-section of Lunar crater Theteurs.

Fig. 19.3 Lunar Crater Grassendi (showing sharp shadows).

Q. How large are lunar craters?

A. Lunar craters vary vastly in size from tiny craters to huge walled plains hundreds of kilometres wide. (Ref. Fig. No. 19.3).

Q. Where did the first mooncraft "Eagle" land?

A. "Eagle" landed on Mare Tranquillitatis (the sea of tranquillity) at a spot appropriately named "Tranquillity Base" (Refer Fig. No. 19.4).

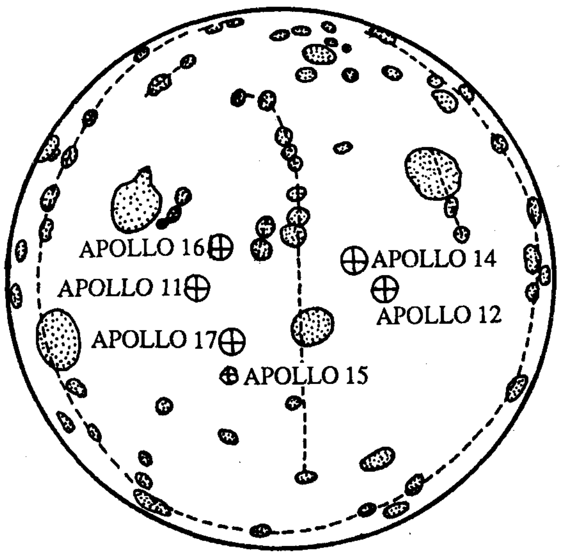


Fig. 19.4 Lunar Map, showing only well-defined craters of diameter 100 km and over (South at top) as well as Apollo landing sites.

Q. What are craterlets?

A. Craterlets are tiny craters ranging in diameter from a few metres to about twenty kilometres. The Moon has plenty of such craterlets.

Q. How were the lunar craters formed?

A. It is believed the lunar craters were formed partly by volcanic action (when part of the inside of the Moon was still liquid many millions of years ago), and partly due to meteor impacts later.

Q. What are twin craters?

A. Twin craters are those that occur close together, sometimes s eparated and sometimes joined together. In some cases, one crater crosses the boundary of another crater causing damage to it. Since large craters have been formed earlier, it is usually the small ones formed later which intrude and do the damage.

Q. What are ruined lunar craters?

A. Ruined craters are ones that have been formed in the early stages of the Moon's history but have been devastated subsequently by later volcanic erruptions and crustal disturbances. The outlines of some of the heavily ruined craters are barely recognizable.

Q. What are lunar clefts?

A. A lunar cleft has the appearance of a river bed on Earth. This is a mere coincidence since there is no water on the Moon and appearances can be deceptive. One of the impressive clefts, the great Heroclotus Valley cleft, is 500 m deep and winds impressively like a river gorge across the plain.

Q. What are crater chains?

A. Sometimes craterlets occur in a linear series which gives the impression that it is a cleft. The Huygens cleft, for example, is not a genuine cleft but actually a crater chain. (Refer Fig. No. 19.5).

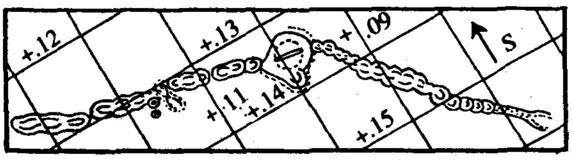


Fig. 19.5 The Huygens Cleft (a crater-chain).

Q. What are lunar rays?

A. Lunar rays appear as lines, more or less straight, drawn on the surface of the Moon. They are also called bright rays since they usually appear as brilliant white streaks. The rays however become invisible when close to the terminator.

Also, the rays are not continuous and when observed closely are seen to possess a definite structure. How they came to be formed has however still not been satisfactorily explained.

Q. What is a lunar plateau?

A. A lunar plateau is a crater in which the volcanic lava that filled the crater during its formation has not drained out or subsided but has solidified. The best known example is the Wargentin plateau where the true floor is hidden, and the top of the plateau is really the surface of the solidified lava lake which in some areas even reaches to the top of the surrounding crater wall.

Q. What is known as the "Monarch of the Moon"?

A. The Crater Copernicus has been nicknamed "Monarch of the Moon" due to its impressive features. The crater is about 90 km in diameter and is surrounded by mountain walls about 6,000 m high. The inner mountain walls around Copernicus are also not uniformly sloping but terraced, as if the original lava lake in its centre had receded in discrete stages.

Q. What are lunar domes?

A. Lunar domes are small convex swellings on the Moon.

Q. How did lunar domes originate?

A. Lunar domes are possibly large solidified bubbles of lava.

Q. What are lunar faults and ridges?

A. Lunar faults and ridges are similar to those on Earth. One fault called strangely the Straight Wall is some 200 km long and about 300 m high. Lunar ridges run for hundreds of kilometres and may even form complex branch ridges.

Q. What are the lunar walled plains?

A. Walled plains are lunar craters which are so vast that they resemble plains surrounded by circular walls of mountains. One of the walled plains, Clavius, is large enough to contain the whole of Switzerland within it. (Refer Fig. No. 19.2).

20. FOLKLORE OF ASTRONOMY

Q. Which planet is named after the Greek god of the underworld (Hades)?

A. Pluto. Also, the moon of Pluto, Charon, is named after the Greek god who ferries the dead souls to the underworld.

Q. Which planet is named after the Roman god of water?

A. Neptune.

Q. How are the satellites of Neptune named?

A. One satellite of Neptune, Triton, is named after the son of Neptune (Poseidon) who calmed stormy seas. The other satellite of Neptune is named Nereid after the group of fifty sea nymphs who attended on Neptune.

Q. Name the planet that takes its name after the Greek god of the sky.

A. Uranus.

Q. The offspring of the Greek goddess of Earth, Gaia, and the Greek god of the sky, Uranus, were the male Titans and the female Titanesses. Name the heavenly bodies named after them.

A. Saturn's satellites seven and eight (counting outward from the planet) are named after the Titans Hyperion and Iapetus respectively. Satellites three, four, five and nine are named after Titanesses Thetys, Dione, Rhea And Phoebe respectively. The sixth satellite of Saturn is named Titan after the group of these gods.

Q. How is the Titan Hyperion associated with the Sun and the Moon?

A. Hyperion's son Helios was considered the Sun god. Hyperion's daughter Selene was considered the Moon goddess. The names are still sometimes used when referring to the Sun and Moon.

Q. Which element was discovered in the Sun through spectral analysis of sunlight in India in 1868, even before it was discovered on Earth?

A. Helium, which means "Element of the Sun".

Q. Which element is named after the Moon?

A. Selenium, named after the Moon (Selene).

Q. Name the element named after the Earth.

A. Tellurium, named after Tellus (also known as Terra) the Roman name of the Earth goddess.

Q. After which heavenly bodies are some of the days of the week named?

A. Sun (Sunday), Moon (Monday), Mars or the equivalent name Tieu or Tyr in Norse mythology (Tuesday), Jupiter or the equivalent name Woden or Odin in Norse mythology (Wednesday) and Saturn (Saturday).

Q. In astrology, with which heavenly body is each day of the week associated?

A. Sun (Sunday), Moon (Monday), Mars (Tuesday), Mercury (Wednesday), Jupiter (Thursday), Venus (Friday) and Saturn (Saturday).

Q. Among astrologers, with which metals are the heavenly bodies associated?

A. Gold (Sun), Silver (Moon), Copper (Venus), Iron (Mars), Lead (Saturn), Mercury (Mercury) and Tin (Jupiter). The astrological symbols for these metals are also the same as the symbols for the corresponding planets. (Refer Fig. No. 2.2).

Q. After whom is the planet Mercury named?

A. Mercury (Hermes) the Roman god of speed and commerce.

Q. After whom is the planet Venus named?

A. Venus (Aphrodite) the Roman goddess of beauty.

Q. After whom are the Martian satellites Phobos and Deimos named?

A. Mars is named after the god of war. Phobos ("Fear" in Greek) and Deimos ("Terror" in Greek) are his sons who accompany him to war.

Q. Which planets have inspired the commonly prevalent symbols for sex?

A. The symbol of Mars (a circle with an inclined arrow on the side) is used widely as a male symbol. The symbol of Venus (a circle with a cross below it) is used widely as a female symbol. (Refer Fig. No. 2.2).

Q. What do the symbols of Mars and Venus really represent?

A. The Symbol of Mars is supposed to represent war (a shield and spear). The symbol of Venus is supposed to represent beauty (a hand mirror). (Refer Fig. No. 2.2).

Q. How did Jupiter get its name?

A. Jupiter is named after the Roman god of the sky Jupiter (also known as Jove). The satellites of Jupiter are referred to as jovian satellites.

Q. How are the satellites of Jupiter named?

A. Each satellite of Jupiter is named after a character closely connected with Jupiter (also known as Zeus or Jove) in mythology.
The Four jovian satellites discovered by Galileo are named after either the sweethearts of Jupiter (namely Io, Callisto and Europa) or his servant (namely Ganymede).
The fifth satellite is named after Amaltheia, the goat that nursed the infant Jove.
The other seven satellites of Jupiter are very small, quite distant from Jupiter and insignificant.

Q. How are Shakespeare's dramatic characters connected with the planet Uranus?

A. The moons of Uranus (Miranda, Ariel, Umbrial, Titania and oberon) are all named after characters in the plays of Shakespeare.

Q. What is the meaning of the word "Constellation"?
A. It is a Latin world meaning "with stars".

Q. In what way has the mythical goat Amaltheia been honoured among the constellations?
A. The constellation Capricornus (meaning "Horned goat" in Latin) has been named after the mythical goat Amaltheia.

Q. How has Amaltheia been honoured on Earth?
A. The Tropic of Capricorn has been named after Amaltheia. (Refer Fig. No. 3.5).

Q. How has Callisto, the sweetheart of Zeus, been honoured among the constellations?
A. Callisto (who once assumed the shape of a bear) has inspired the name of the constellation Ursa Major ("Great Bear" in Latin). Ursa Minor ("Little Bear" in Latin) is named after Arcas the son of Callisto. (Refer Fig. No. 4.6).

Q. Which star is known as the guardian of the constellations Ursa Major and Ursa Minor?
A. The bright star Arcturus (meaning "To guard the bears" in Greek) situated near these two constellations. (Refer Fig. No. 4.6).

Q. Which constellation honours the legend of Europa?
A. Taurus (Latin for "Bull") honours the legend of Europa being carried away by Zeus disguised as a bull.

Q. Which constellation is named after the legend of Ganymede?
A. According to legend, Zeus in the form of an eagle, carried away Ganymede. This legend is honoured by the constellation Aquila (Garuda) which is Latin For "Eagle".

Q. How did the stars "Cephid Variables" get their names?
A. Cephid variables are found in the constellation Cepheus (Wrishaparva) named after a mythical king of Egypt.

Q. What are the other constellations associated with the legend of Cepheus?

A. Cassiopeia (Sharmishta) and Andromeda (Devyani) are named after the wife and daughter respectively of Cepheus.

Q. What are the stars representing the seven rishis in the constellation Saptarishi (Ursa Major)?

A. Kratu (Alpha), Pulaha (Beta) Pulastya (Gamma), Atri (Delta), Angira (Epsilon), Marichi (Eta) and Vasishta (Zeta). In Vasishta (Zeta) its tiny companion star is named after Arundhati, the wife of Vasishta. (Refer Fig. No. 4.6).

Q. What have the names Aldebaran, Algol and Alwaid have in common?

A. They are all names given to the stars by Arab astronomers and retained in modern times. For example the stars of the Saptarishi constellation are even today known by their Arabic names Dubhe (Kratu), Merak (Pulaha), Phekda (Pulastya), Megrez (Atri), Benetnash (Marichi) and Mizar (Vasishta). (Refer Fig. No. 4.6).

Q. Why are there so many similarities among the Roman, Greek, Arab and Hindu names of the stars and constellations?

A. Astronomy and astrology, in the form of codified observations, originated in the ancient Babylonian civilization. It later spread to other cultures such as Arab, Hindu, Greek and Roman where the names were reinterpreted to suit the local cultures. Hence Aquila/Garuda, Leo/Singha, Hydra/Vasuki and other similarities in names.

21. HISTORY OF ASTRONOMY

Q. What was the contribution of Pierre Laplace, the French Astronomer and Mathematician, to the science of astronomy?

A. Pierre Laplace is famous for his application of applied mathematics to practical astronomy. He published his work Mecanique Celeste in the years 1799–1825. It was an attempt to explain the mechanical problems presented by the Solar System. (Refer Fig. No. 21.1).

Fig. 21.1 Pierre Laplace (1749–1827).

Q. Name the astronomer who is acclaimed as the father of modern practical astronomy.

A. John Flamsteed, first Astronomer–Royal of England. In 1676, when Greenwich Observatory was built, he began observations which really began modern practical astronomy. The first reliable catalogue of fixed stars was compiled by him, and he wrote the great book *Historia Coelestis Britannica,* published in 1725. His work supplied the background for some of Newton's theories. (Refer Fig. No. 21.2).

Fig. 21.2 John Flamsteed (1646–1719).

Q. Which astronomer conclusively proved that the Sun was the centre of the Solar System?

A. Nicolas Copernicus, the Polish astronomer, studied optics, mathematics, perspective and canon law. Appointed canon in 1497, he studied medicine and worked as a medical attendant until 1512. He completed his book De Revolutionibus *Orbium Coelestium,* he proved that the Sun was at the centre of the Solar System, in 1530. His heliocentric theories was bitterly opposed. (Refer Fig. No. 21.3).

Fig. 21.3 Nicolas Copernicus (1473–1543).

Q. What was the name of the astronomer who discovered the laws governing the movement of the heavenly bodies?

A. Johann Kepler, German astronomer and professor of mathematics, who later studied astronomy and worked with Tycho Brahe. He first published his views on the universe in 1596. His analysis of Tycho's observations of the planets led him to discover "Keplers' Laws".

With these fundamental laws, Kepler gained immortal fame. But he could not adequately explain why the planets behaved in this way. (Refer Fig. No. 21.4).

Fig. 21.4 Johann Kepler (1571–1630).

Q. What discoveries is Jean Foucault, French Physicist and astronomer, noted for?

A. Jean Foucault is noted mainly for his proof that light travels more slowly in water than in air, and his measurement of the speed of light. In 1851, he proved that the Earth rotates by using a freely suspended pendulum and studying the way it swings from side to side. He also invented the gyroscope and some optical instruments. (Refer Fig. No. 21.5).

Fig. 21.5 Jean Foucault (1819–68).

Q. Name the Danish astronomer who detected serious mistakes in the astronomical tables of his time and revised them.

A. Tycho Brahe, originally studied law, but was more interested in astronomy. In 1563, he discovered serious mistakes in the astronomical tables then in use. He did much important work on the movement of the stars and the Moon. (Refer Fig. No. 21.6).

Fig. 21.6 Tycho Brahe (1546–1601).

Q. What were the other contributions of Fredrick Herschel to astronomy, besides his discovery of the planet Uranus?

A. Frederick Herschel, the German-British astronomer, was born in Hanover. At first, he was a musician, then took up astronomy and made a reflecting telescope in 1774. He discovered the planet Uranus, which he called 'Georgium Sidus' and in 1782, he was appointed astronomer to King George III. He also discovered 2 satellites of Saturn, the rotation of Saturn's rings and the motions of binary stars. (Refer Fig. No. 21.7).

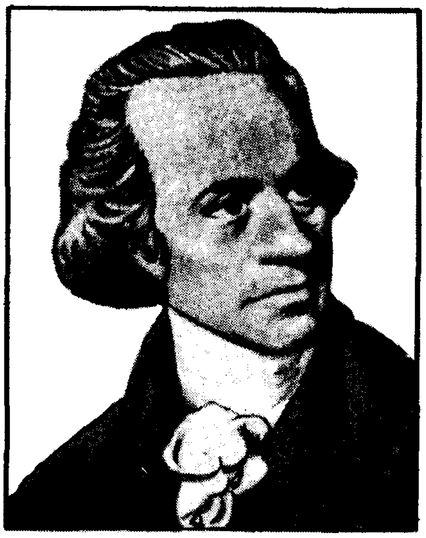


Fig. 21.7 Frederick (William) Herschel (1738–1822).

Q. Who was Aryabhata, after whom India's first satellite was named?

A. Aryabhata (476–550 A.D.) was an astronomer and mathematician at the court of king Chandragupta Vikramaditya.

Q. Who was Bhaskara, after whom India's second satellite was named?

A. Bhaskara (1114–1185 A.D.) was a famous Indian mathematician.

Q. What was the contribution of the Indian astronomer and mathematician Aryabhata?

A. Aryabhata worked out a highly precise value for the Earth's circumference. He also discovered the causes of solar and lunar eclipses and pointed on that the Sun is stationary and the Earth rotates.

Q. Which Indian scientist predicted the hydrogen line in the solar spectrum, X-ray emission from the Sun and molecules existing in interstellar space?

A. Meghnad Saha (1893–1956).

Q. How did Albert Einstein revolutionise the theories of astronomy and physics?

A. Einstein posed simple questions that could have been asked centuries earlier. For example: "What do we mean when we say two events are simultaneous?" or "What happens when two objects approach each other at the speed of light?"

Paradoxes seemed to emerge everywhere if you could travel at the speed of light. By providing explanations for such paradoxes, Einstein unravelled the riddles of the Universe. He is noted chiefly for his General and Special Theories of 'Relativity' that hold that motion, time, distance, acceleration and gravitation are not absolute, but relative to moving frames of reference. (Refer Fig. No. 21.8).

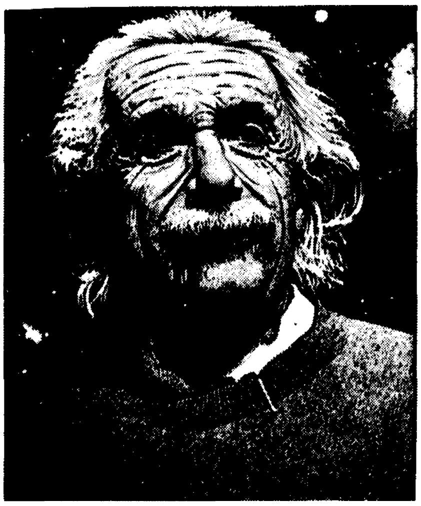


Fig. 21.8 Albert Einstein (1879–1955).

22. ARTIFICIAL SATELLITES AND SPACE TRAVEL (PART 3)

Q. Name India's first satellite.

A. India's first satellite was Aryabhata launched on 19 March, 1975 from the Baikanur cosmodrome in Kazakstan, U.S.S.R.

Q. What was the mission of Aryabhata?

A. The primary mission of Aryabhata was the development of Indian expertise in satellite technology and control of a satellite in orbit. However, some experiments in communication, remote sensing and weather monitoring were also included.

Q. What was India's second satellite?

A. India's second satellite was Bhaskara-I launched on 7 June 1979 from the USSR. The satellite was designed and built at the Satellite Centre, Bangalore and its primary mission was to collect information on India's land, water, forest and ocean resources.

Q. Name India's first operational multipurpose domestic satellite.

A. Insat-IA was launched on 10 April 1982 from USA with a mission to enhance communicational, meteorological, TV relay and radio broadcasting facilities.

Q. Which was the first Indian satellite launched by space shuttle?

A. Insat-IB was launched on 30 August 1983 by space shuttle from Nevada Base, USA.

Q. How are the Indian satellites controlled from Earth?

A. At the time of the launching of Insat-1, a network of ground-based communication facilities was developed all over India. (Refer Fig. No. 22.1).

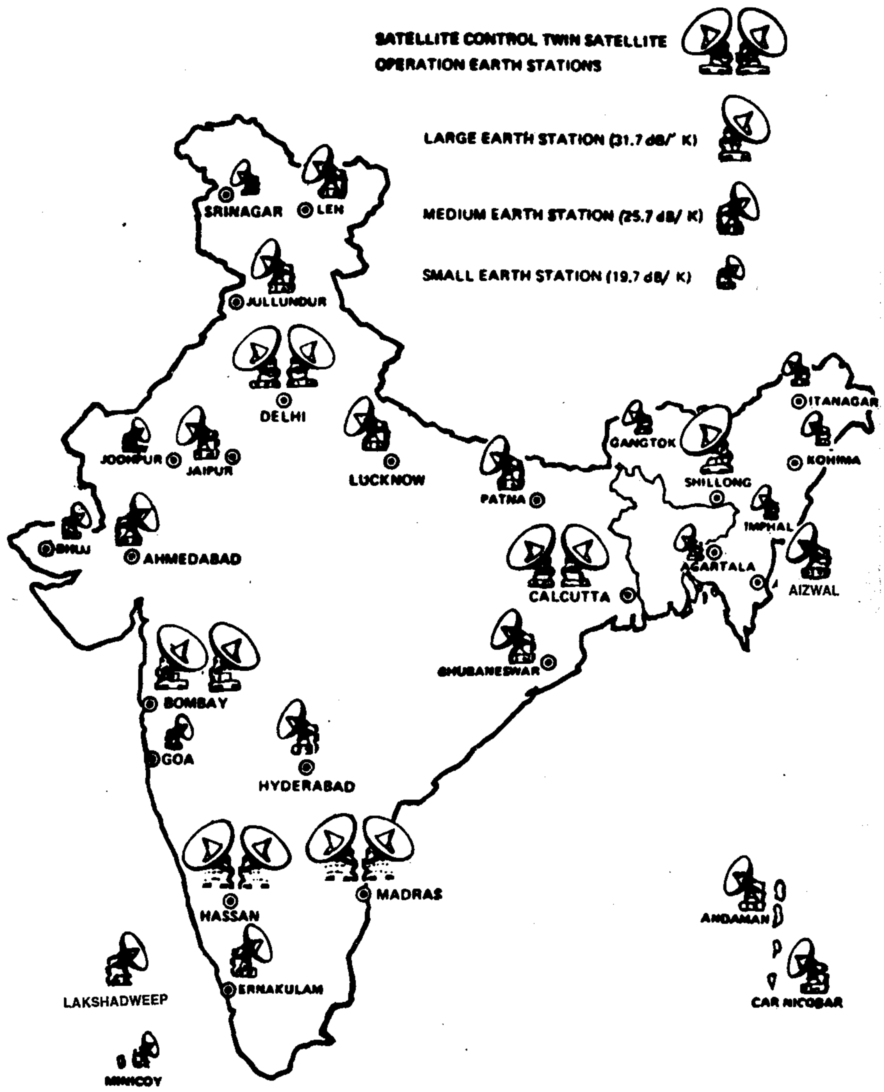


Fig. 22.1 Insat-1 Ground Facilities (Telecommunications) in India.

Q. Name the first Indian satellite launching vehicle (SLV).

A. SL V-3 was the first satellite launching vehicle developed in India. It was fabricated at the Vikram Sarabhai Space Centre, Thiruvananthapuram, Kerala. It was later replaced by the augmented version ASLV.

Q. Which was the satellite first launched by SLV-3?

A. Rohini-I launched on 10 August 1979 from Sriharikota (Andhra Pradesh) went into orbit but could not accomplish its mission due to some snags. A "stretched" version was launched successfully on 20 May, 1992.

Q. Name the Indian satellite used exclusively for remote sensing?

A. Indian Remote-sensing Satellite (IRS). The first satellite IRS-1A went into a Sun-synchronous polar orbit on 19 March 1988 enabling it to concentrate on specific areas and register optical as well as radiation images.

Q. What is the PSLV?

A. The successor to the ASLV, the Polar Satellite Launch Vehicle (PSLV), designed to put up a 1200 kg satellite in sun-synchronous polar orbit, was launched on 29 September 1997 from Sriharikota.

Q. The Indian space Research organization (ISRO) today encompasses various Indian space centers. Name them.

A. They are (i) Vikaram Sarabhai Space Centre (VSSC), Thiruvanthapuram, (ii) S H A R Centre (Sriherikota), (iii) ISRO Satellite Centre, (ISSC) Bangalore, (iv) Auxliary Propulsion system Unit (APSO) Banglarore, (v) Space Application Centre (SAC) Ahmedabad, (vi) Development and Educational Communication Unit (DECU) Ahmedabad, (vii) ISRO Telemetry, Traeking & Command Network. (ISTRAC) with its Head Quarters at Bangalore.

Q. Name the spacecraft that provided detailed map of Venus.

A. The American spacecraft Pioneer Venus and Magellan carried out a detailed radar survey of Venus.

Q. Name the Apollo mission that returned without landing on the Moon.

A. Apollo 13 returned without landing on the Moon following an explosion on board during the outward Journey.

Q. At what speed is space travel possible today?

A. Since today's rockets never achieve more than a small fraction of the speed of light, space travel requires about three days to the moon, two years to Jupiter, and 15 years to Pluto. To reach the nearest star, Alpha Centauri, at a distance of 4.3 light-years, would take nearly 100,000 years!

Q. What are the practical difficulties in two-way radio communication between Earth and space travellers?

A. Two way communication requires almost instantaneous transmission for practical conversations to take place. Since radio waves travel at the speed of light, the time lag between transmission and receipt of signal in each direction would be about 0.02 second to a satellite in near orbit, 1.3 seconds to the Moon, 4 minutes to Mars (minimum), 5 hours to Pluto (minimum) and 4.3 years to the nearest star Alpha Centauri. Hence beyond Mars, no practical two way radio conversations from Earth are possible.

Q. How can satellites be deployed for producing artificial daylight?

A. The Sun is always shining somewhere on earth if not always where people need or want it. But what if someone put a big reflector high in space to peer over the curvature of earth, capture some of the Sun's rays and shine them down on the dark side?

On 4 February 1993 the Russian spacecraft Progress attached to the Mir space station successfully deployed a giant space mirror 20 M in diameter called 'Banner' in a six minute experiment that cast a 10 km wide beam from France to Belarus.

This could be the first step in creating a revolutionary stellar spotlight out of several such banners.

Q. Can artificial daylight be used on a mass scale?

A. Russian theorists have eagerly proposed solar reflector systems that could constantly illuminate areas the size of several cities every night. The most ambitious proposal foresees a constellation of 100 reflectors, each 1,300 feet in diameter with a surface area of 30 acres. But there my be environmental costs for disturbing the natural day-night cycle if on plants, animals, climate etc.

Q. What are the latest special features of the Mars exploration programme of the U.S.A.?

A. In 1992, the U.S.A. started a series of launches of space probes designed to explore Mars, and culminate in the first decade of the twenty first century. Theoretically, it is possible to launch a space probe to Mars once every 2.6 months with great fuel economy, due to the favourable alignment of Earth and Mars. An unmaned craft named as "The pathfinder" already landed on the surface of Mars in 1972, roamed about for a year and returned to Earth with rock samples. A space probe takes about 11 months to make the 725 million kilometre journey from Earth to Mars. Under the Mars Exploration Programme the Global Surveyor is preparing to begin a year long orbit to the red planet. It will draw detailed maps of the surface to help future mission to seek out the likeliest hiding place for life.

Q. What are the special features of the Euro-U.S. joint space probe Cassini to explore the planet Saturn?

A. The Cassini space probe is designed to leave Earth and travel 3,540 million kilometres via Mars and Jupiter, reach Saturn in 2004, explore the Saturn system for 4 years or more, and finally land a craft on the surface of Titan the largest moon of Saturn.

Q. Name the space probe that was used to study the Sun.

A. The space probe Ulysses was launched in 1990 by a U.S. shuttle under the joint project by NASA and European space Agency and arrived near the Sun in 1994 in a three and half years journey via Jupiter covering a distance of 150 million kilometres. It went into a polar orbit around the Sun and transmitted a large amount of useful data back to Earth.

Q. Name the powerful optical telescope placed in Earth orbit.

A. The Hubble Space Telescope was launched into Earth orbit by the space shuttle "Discovery" in 1990, and is designed to transmit useful data about the universe better than Earth based telescopes.

In January 1994, a historic repair of its main mirror was carried out after 30 hours of space walks by five astronauts sent on a space shuttle at a cost of $ 360 million. NASA announced that it had repaired the fault. It now performs 10 times better than any ground based instruments.

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