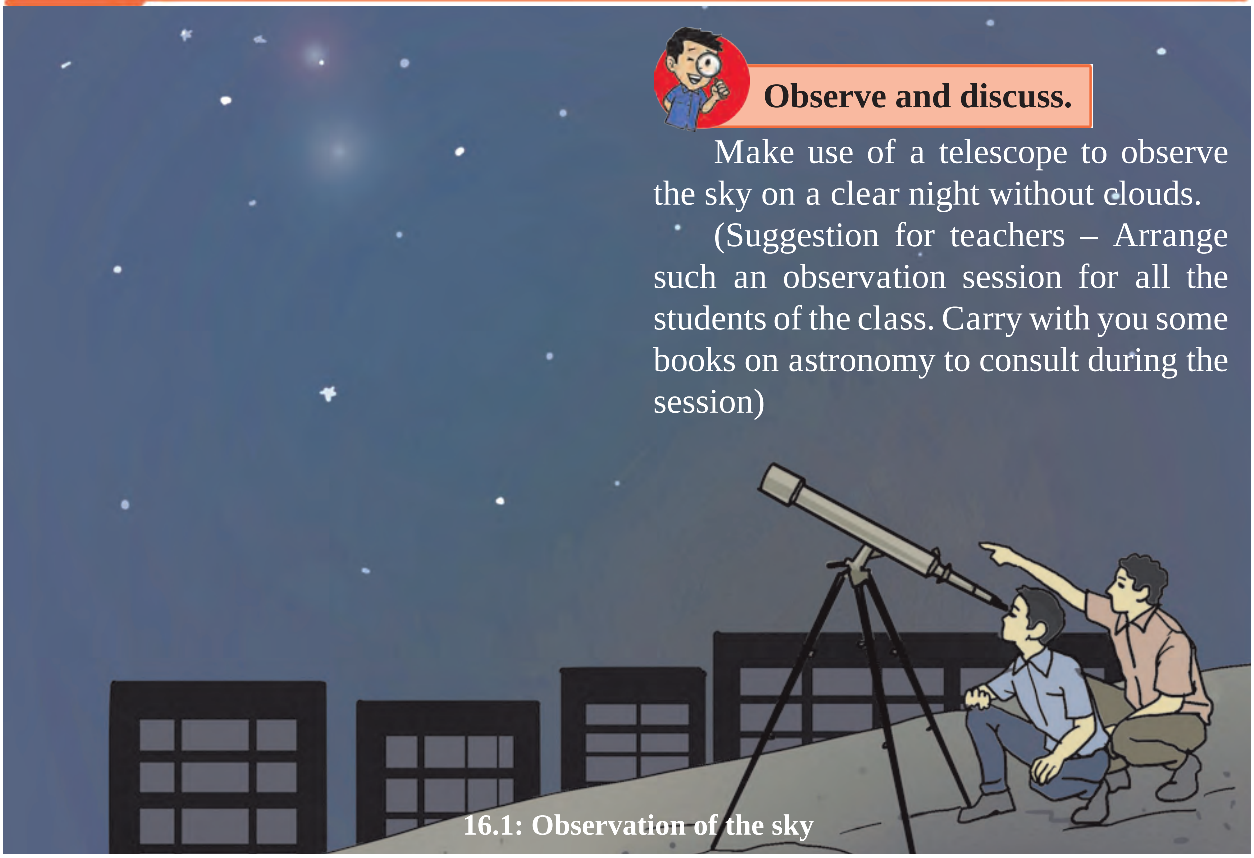
16. The Universe

Observe and discuss.

Make use of a telescope to observe the sky on a clear night without clouds.

(Suggestion for teachers – Arrange such an observation session for all the students of the class. Carry with you some books on astronomy to consult during the session)



16.1: Observation of the sky

If you observe the clear sky on a dark night, you will see a smoky white band full of stars spreading north-south in the sky. This is the Milky Way. It is also known as 'Mandakini'.

16.2 : The Milky Way

A group of innumerable stars and their planetary systems are together known as a 'galaxy'. The Milky Way is the galaxy in which our solar system is located. The Milky Way is a part of the 'Local Group' of galaxies. There are many such galaxies in the universe.

The Milky Way includes many stars smaller than our Sun as well as many others that are thousands of times bigger than the Sun. It also includes many other celestial bodies such as clusters of stars, nebulae, clouds of gases, clouds of dust, dead stars, newly born stars, etc. The galaxy that is closest to our Milky Way is called Andromeda.

16.3 : The Andromeda galaxy

The universe includes innumerable galaxies, the space between them and also energy.

Types of galaxies : Various types identified according to their shapes


Spiral


Elliptical


Barred spiral


Irregular

16.4 : Various galaxies

The scientist Edwin Hubble showed that there exist many galaxies beyond our Milky Way. In 1990, NASA, the American space agency launched the 'Hubble Telescope' in the orbit of the earth. The Hubble telescope has made it easier to look for stars, to take photographs and to obtain spectrums.


16.5 : Hubble Telescope

Stars

The thousands of twinkling stars that we observe in the clear night sky are part of our Milky Way. Some of the stars that we see are bright whereas others are faint. Stars radiating different colours such as blue, white, yellow and reddish can be seen in the sky. We also see stars with varying brightness (luminance). The birth place of stars are the huge nebulae, made of dust particles and gases. Generally, the surface temperature of stars ranges from 3500°C to 50000°C. The colour of stars changes according to their temperature.


16.6 : A nebula

Some types of stars

- **Sun-like stars :** These stars can be slightly smaller or bigger than the sun. But there is a lot of difference in their temperatures. Examples : stars like Sirius, Alpha Centauri.
- **Red Giants :** The temperature of these stars ranges between 3000°C and 4000°C. But their luminance can be 100 times that of the sun. Their diameter is 10 to 100 times that of the sun and they are red in colour.
- **Super Nova :** These are even brighter and larger than the red giant stars. Their temperature is between 3000°C to 4000°C but their diameter can be more than a hundred times greater than that of the Sun.
- **Binary or Twin Stars :** More than half of the stars in sky are binary stars. They consist of two stars that revolve around each other. At times, three or four stars that revolve around each other have also been located.
- **Variable Stars :** The luminance and shape of these stars is not stable. They are constantly contracting or expanding. When a star expands, it emits less energy and at such times its brightness decreases. As against this, when a star contracts, its surface temperature increases and the star emits greater energy and appears brighter. For example, Polaris (Pole Star).

Find out.

Visit the sites of the institutes ISRO (www.isro.gov) and NASA (www.nasa.gov) and collect information about the various celestial bodies in the solar system and universe, and discuss the same in the class.

Can you tell ?

1. Which celestial bodies form the solar system ?
2. What is the difference between stars and planets ?
3. How many planets are there in our solar system ?
4. What is to be found between Mars and Jupiter ?

The Mercury, Venus, Earth and Mars are the inner planets whereas the Jupiter, Saturn, Uranus and Neptune are outer planets. Outer planets have rings around them. The crust of all the inner planets is hard. The outer planets have gaseous outer cover.

The solar system

The solar system consists of the sun, the planets, asteroids, comets and meteors. The planets Mercury, Venus, Mars, Jupiter and Saturn can be easily seen.

The sun

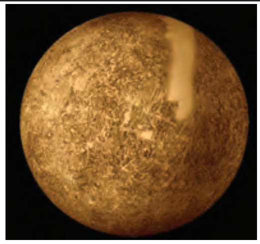
The sun which is at the centre of the solar system is a yellow coloured star. Its surface temperature is around 6000°C. The size of the sun is so huge that around 13 lakh planets of the size of the earth can be easily placed within it. Due to the gravitational force of the sun, the celestial bodies in the solar system revolve around it. The diameter of the sun is approximately 13,92,000 km. The sun rotates around its axis and while doing so, it revolves around the centre of the Milky Way taking the solar system along with it.

The sun

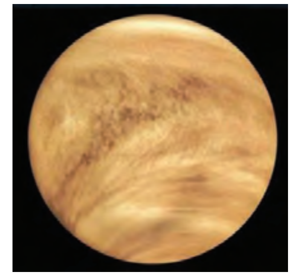
Planets of the solary system – facts and figures

Name of the planet	Number of known satellites	Inclination of the axis (in degrees)	Period of rotation*	Period of revolution*	Magnetism	Atmosphere	Rings
Mercury	0	0.01	58.65 days	88 days	No	No	None
Venus	0	177.2	243.00 days	225 days	No	Yes	None
Earth	1	23.5	24 hours	1 year (365 days)	Yes	Yes	None
Mars	2	25.2	24 hrs 37 mn	1.88 years	No	Yes	None
Jupiter	64	3.1	9 hrs 56 mn	11.87 years	Yes	Yes	Yes
Saturn	33	26.7	10 hrs 40 mn	29 years	Yes	Yes	Yes
Uranus	27	97.9	17 hrs 24 mn	84 years	Yes	Yes	Yes
Neptune	13	28.8	16 hrs 11 mn	164 years	Yes	Yes	Yes

Mercury : This planet is closest to the sun. It is visible in the morning and the evening if it is away from the sun. A number of depressions, which look like volcanic craters, but are actually caused by meteoric falls can be seen on the surface of Mercury. Mercury is the fastest moving planet.



Venus : It is the brightest planet in the solar system. It is seen in the sky in the east before the sunrise and in the west after the sunset. It rotates around itself from east to west. It is the hottest planet.



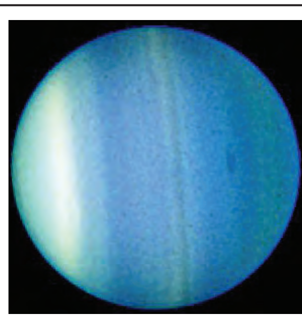
Earth : It is the third planet of the solar system. No other planet other than the earth has life on it. As the earth is a magnet, there is a magnetic field around the earth. It diverts the harmful rays from the sun towards the polar regions of the earth.

Mars : It is the fourth planet in the solar system. As the soil on Mars contains iron, its colour is reddish. Hence Mars is also called the Red Planet. The highest and longest mountain in the solar system 'Olympus Mons' is located on Mars.

Jupiter : This is the largest planet of the solar system. It is so huge that as many as 1397 planets of the size of the earth can get accommodated in it. Even though the planet is so huge, it revolves around itself with a great speed. As huge storms occur frequently on it, it is also called the 'Stormy Planet'.

Saturn : It is the sixth planet of the solar system and next only to Jupiter in size. It is considered to be a peculiar planet because of the rings around it. Though its mass is 95 times that of the earth, its density is very low. If it were dropped into a sea large enough to hold it; it would actually float in it!

Uranus : It is the seventh planet in the solar system. It cannot be seen without a telescope. Its axis is so greatly inclined that it appears as if it is rolling along on its orbit.



Neptune : It is the eighth planet in the solar system. A season on Neptune lasts for about 41 years. On this planet winds blow with extremely high speed.

*** The periods of rotation and revolution of the planets are expressed relative to those periods on the earth (Page 114).**

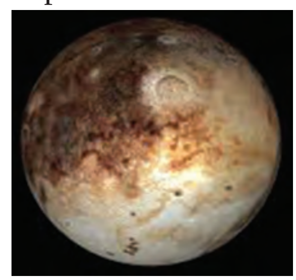
Satellite : The celestial bodies that revolve around a planet without independently revolving around the sun are called satellites. Like planets, satellites rotate around their respective axes. The Moon is the satellite of the earth. It does not have an atmosphere. Its periods of rotation and revolution are both of 27.3 days. Except for Mercury and Venus all other planets have satellites but in varying numbers.

Satellite

Asteroid : A great number of small sized bodies could not turn into planets when the solar system was formed, but continued to revolve around the sun. These bodies are known as asteroids. A belt of such celestial bodies has formed between the planets Mars and Jupiter.

Asteroid

Dwarf planet : A small sized celestial body that revolves independently around the sun is called a dwarf planet. A celestial body like Pluto can be classified as a dwarf planet. Pluto takes around 248 years to complete its revolution around the sun whereas it takes around 6.38 days for one rotation.



Dwarf planet

Use your brain power !

1. Why do we see only one side of the moon?
2. Which planet has a day longer than its year?

Find out.

Obtain information about the various asteroids and dwarf planets in the solar system and discuss it in the class.

Can you tell ? Have you ever seen in the evening or in the predawn hours a large celestial body with a long tail? What is it called?

A comet

A comet is a celestial body that revolves around the sun. Comets are formed out of ice and dust particles. They are part of the solar system. Since olden times, the appearance of a comet has been considered to be an inauspicious event. Comets appear like points when they are far away from the sun. But when they are close to the sun, they become easily visible to us because of the shorter distance and the heat of the sun.

Comets are made up of frozen matter and dust particles. When they are close to the sun, this frozen matter gets converted into gas due to the solar heat. These gases get thrown in a direction away from the sun. As a result, certain comets appear to have a long feathery tail. Due to their long elliptical orbits, their appearance in the sky is very rare. They reappear in the sky after very long periods of time.

Comets are classified in two main groups.

Long period comets : These comets take more than 200 years to complete one revolution around the sun.

Short period comets: These comets take less than 200 years to complete one revolution around the sun.

Do you know this?

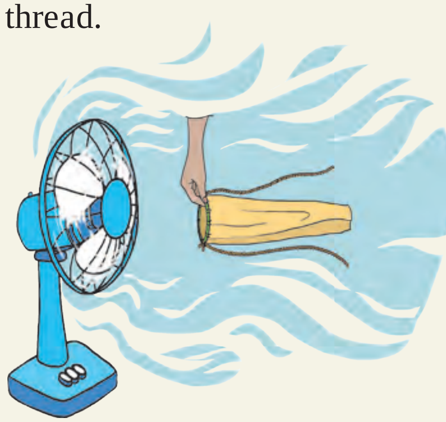
Halley's comet appeared in the year 1910 and reappeared in 1986. Its central part or nucleus was found to be 16 km long and 7.5 km wide. Halley's comet takes 76 years to complete its revolution around the sun.

Halley's comet

A bit of fun !

Material required – a table fan, a bangle, a piece of light cloth, twinned string and thread.

As shown in the picture, sew the cloth around the bangle. Take a string as long as the length of the cloth and tie it to the bangle. Now hold the bangle in front of the fan and put on the fan.



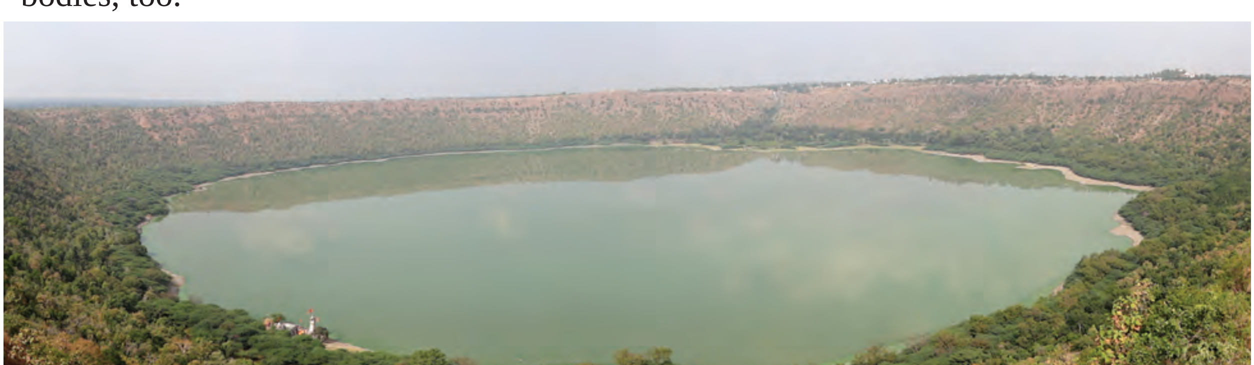
In the past ...

Fred Whipple, an American astronomer, proposed that comets consist of an icy cluster of various constituents. That is why, comets came to be called 'dirty snowballs'. By 1950, Whipple had discovered six comets.

5Y5NZA

A meteor

At times, we see a falling star. This event is called a meteor fall. Mostly these meteors are rocky pieces originating from the asteroid belt. Smaller rocky pieces get completely burnt due to friction with air after they enter the earth's atmosphere. Sometimes the meteors do not burn completely and fall to the surface of the earth. These are called meteorites. It is believed that the Lonar lake in Maharashtra has been formed by the impact of such a meteorite. Meteors or meteorite falls occur on other celestial bodies, too.



Always remember...

Science tries to explain different events occurring in the universe. We should study phenomena like meteor falls, eclipses, etc. rather then attach any blind faith or superstition with them.

What we have learnt–

- There are innumerable galaxies in the universe. Our solar system, various star clusters are part of the Milky Way.
- Various types of stars like the sun can be seen in the Milky Way.
- Different planets in the solar system have peculiar characteristics. Some planets have satellites whereas others do not have any.
- Comets have a characteristic structure but their appearance keeps on changing.

Exercise

1. Name these -

(a) Birth place of stars
(b) Biggest planet in the solar system
(c) The galaxy which is our neighbour.
(d) Brightest planet in the solar system
(e) Planet with largest number of satellites
(f) Planets without a single satellite
(g) Planet with a rotation different from other planets.
(h) A celestial body that carries a tail along.

2. Fill in the blanks.

(a) The group of galaxies of which our Milky Way is a part is called ....
(b) Comets are made of ....
(c) The planet .... appears as if it is rolling along its orbit.
(d) .... is a stormy planet.
(e) The Pole Star is the best example of a .... type of star.

3. Say if the statements given below are right or wrong. Rewrite the statements after correcting them.

(a) Venus is the planet closest to the sun.
(b) Mercury is called a stormy planet.
(c) Jupiter is the biggest planet.

4. Answer the following.

(a) What is a special characteristic of the planet Mars?
(b) What are the types of galaxies?
(c) Which celestial bodies does a galaxy include?
(d) Name the different types of stars.
(e) What are the types of comets and on what basis are they classified?
(f) What is the difference between meteors and meteorites?
(g) What are the characteristics of the planet Neptune?

5. Match the following.

Group A	Group B
(1) Galaxy	(a) From east to west
(2) Comet	(b) 33 satellites
(3) Sun-like star	(c) Spiral
(4) Saturn	(d) Sirius
(5) Venus	(e) Halley

Activity :

- Using the material you can find in your house, prepare a model of the solar system.
- Collect information about different aspects of each planet such as its distance from the sun, its diameter, its volume, etc. and present it in a science exhibition.

20. In the World of Stars

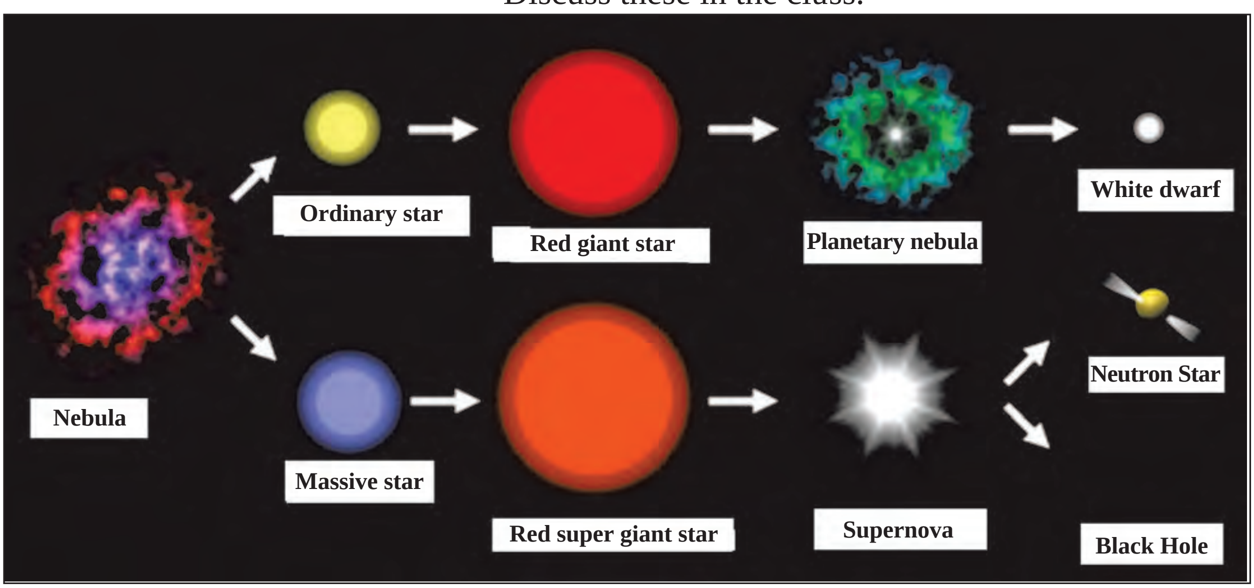
Let's recall.

1. What is a galaxy? What are the various components of a galaxy?
2. What are the different types of stars?

We have already learnt about galaxies and stars as well as the solar system and its different components. Stars are born out of nebulae. Nebulae are clouds made up mainly of hydrogen gas and dust particles. The particles in these clouds are attracted towards one another due to the force of gravity. As a result, the cloud contracts and becomes dense and spherical in shape. At the same time, the pressure of the gas at the core of the cloud increases causing the temperature to rise tremendously and energy generation processes start there. Such a spherical cloud of hydrogen is called a 'star'. Later, processes such as contraction, expansion, rise in temperature, etc. bring about changes in the nature of the star. These changes occur over a very long period of time and constitute the lifecycle of stars. The different forms of the stars at various stages during this lifecycle are identified as different types of stars.

Observe and discuss.

The following figure shows different stages in the lifecycle of stars after their birth from a nebula. Discuss these in the class.



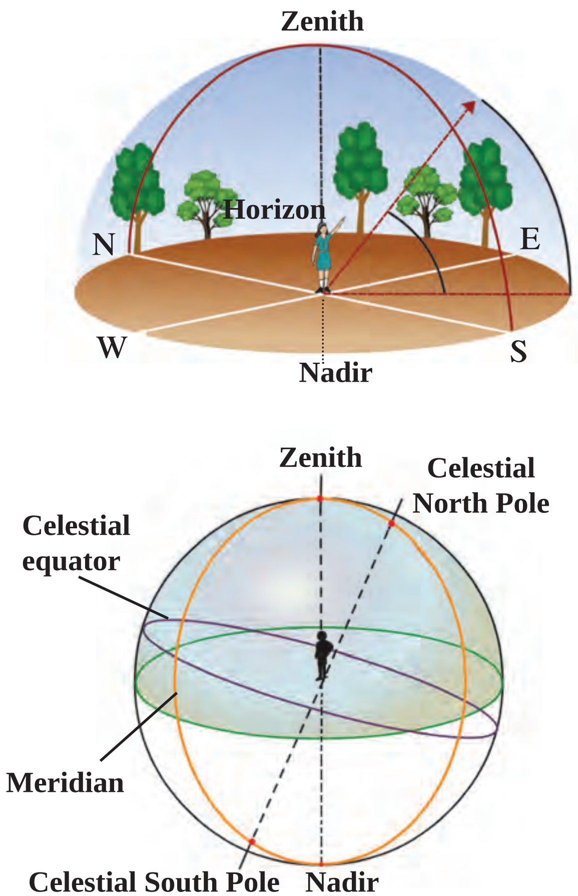
20.1 Lifecycle of stars

Our solar system is a tiny part of a galaxy called the Milky Way, which is many, many times larger than the solar system. There are lakhs of stars in the Milky Way, some of them being many times bigger than our Sun. Some of them have their own planetary systems. Stars in the Milky Way show a great diversity in colour, brightness, as well as size. Some stars, which appear to be close to one another making a particular figure are together known as a constellation. We shall learn more about constellations in this chapter. But, before that, let us learn a few basic concepts related to sky watching.

My friend, the internet! www.avkashvedh.com, www. space.com

Sky watching

Stand still in an open space and look into the distance. What do you notice about the ground and the sky? Now, still looking into the distance, turn around yourself and observe the ground and the sky as you do so.



20.2 Virtual sphere

Far away, the sky seems to be touching the ground. The line at which they meet is called the **horizon**. While turning around oneself, the horizon will be seen to form a circle and on looking up, the sky will appear to be a sphere based on this circle. The stars and planets moving in the sky appear to be moving on this sphere. This virtual sphere is called the **celestial sphere**. The circular horizon divides this sphere into two halves.

1. **Zenith :** While standing on the ground, the point on the celestial sphere exactly above our head is called the zenith.

2. **Nadir :** While standing on the ground, the point on the celestial sphere exactly below our feet is called the nadir.

3. **Celestial poles :** If we extend the axis of rotation of the earth in the north and south directions it will penetrate the celestial sphere at points called the celestial North Pole and the celestial South Pole, respectively.

4. **Meridian :** In astronomy, the great circle which passes through both the celestial poles and the observer's zenith and nadir is called a **meridian**.

5. **Celestial equator :** If we uniformly expand earth's equator in all directions indefinitely, it will penetrate the celestial sphere along a circle. This circle is known as the **celestial equator**. It is in the same plane as the earth's equator.

6. **Ecliptic :** The earth moves around the sun, but, seen from the earth, the sun appears to move along a circle on the celestial sphere. This circle describing the apparent motion of the sun around the earth is called the **ecliptic.**

Sky and space

Sky : Standing in an open space, if we look at the sky on a cloudless night, we see numerous stars against a dark background. The portion of earth's atmosphere and the portion beyond that which can be seen in the form of a roof by our eyes while standing on the earth is called the sky.

Space : The continuous, empty space between the spheres (planets, stars, etc.) in the sky is called space. It may contain gas and dust particles. Numerous star clusters have formed in space.

The sun, the moon and the stars are seen to rise in the east and set in the west because the earth rotates from the west to the east. If we observe carefully, we will also notice that stars rise and set 4 minutes earlier every day. That is, if a star rises at 8 pm tonight, it will rise at 7:56 pm tomorrow. Against the background of stars, the sun and the moon appear to move from the west to the east, the sun moving through one degree every day and the moon through 12 to 13 degrees. This happens due to the motion of the earth around the sun and that of the soon around the earth.

Constellations

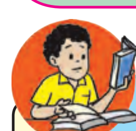
A group of stars occupying a small portion of the celestial sphere is called a **constellation**. Some of these stars appear to form certain figures of animals, humans or objects. These figures have been named after certain events or beliefs of the times when the constellations were identified. In this way, western observers have divided the celestial sphere into 88 constellations. Similarly, ancient western astronomers put forward the idea of 12 zodiac signs, whereas Indian astronomers suggested the 27 *nakshatras*.

Zodiac sign : The ecliptic has been imagined to be divided into 12 equal parts. Thus each part subtends 30 degrees at the centre of the celestial sphere. Each of these parts is called a *raashi* or zodiac sign. They are named Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricorn, Aquarius and Pisces.

Nakshatra : The moon completes one revolution around the earth in approximately 27.3 days. The portion traversed by the moon in one day is called a *nakshatra*. So if we divide 360 degrees into 27 equal parts, each part is about 13 degrees and 20 minutes. A *nakshatra* is known from the brightest star that it contains. This brightest star is called the *yogatara*. Which *nakshatra* we can see during a sky watch depends upon the position of the earth along its orbit.

Always remember –

1. The place for sky watching should be away from the city and, as far as possible, it should be a new moon night.
2. Binoculars or telescopes should be used for sky watching.
3. Identifying the Pole Star in the north makes the sky watch easier. Hence, the Pole Star should be used as a reference point for sky watch.
4. As the stars in the west set early, sky watching should begin with stars in the west.
5. As in geographical maps, the east and west are shown to the right and left respectively in a sky map.
6. On a sky map, the north and south are towards the bottom and top of the map respectively. This is because the sky map is to be held overhead. Hold the sky map in such way that the direction we face is at the bottom side.



Find out.

Using a Marathi calendar, collect information about the 27 *nakshatras* and divide them into the following three categories:

Monsoon *nakshatras*	
Winter *nakshatras*	
Summer *nakshatras*	

Use your brain power !

One zodiac sign = ….. *nakshatras*.

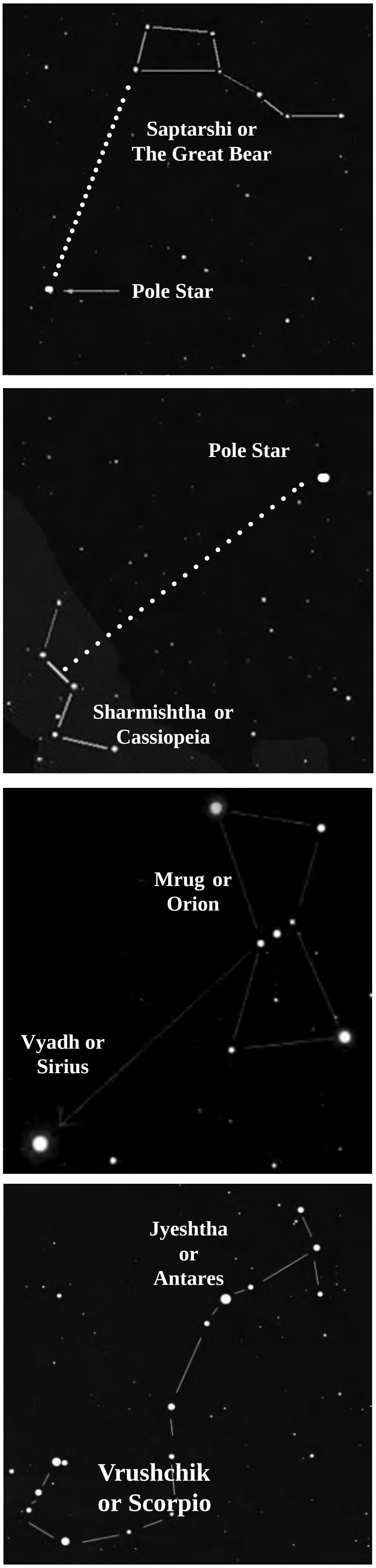
Getting to know some constellations

1. During summer nights one can see a particular arrangement of seven stars. We call them Saptarshi. In the month of February, this constellation rises around 8 pm in the north-east. It is on the meridian in the month of April and in the month of October, it sets around 8 pm. As the name suggests, Saptarshi is a group of seven bright stars. It is in the shape of a quadrangle with a tail made up of three stars. It thus resembles a kite and can be easily recognized. If we extend one side of the quadrangle, it reaches the Pole Star or Polaris as shown in figure 20.3. Different countries have different names for this constellation. In English it is called the Great Bear.

2. The constellations of Saptarshi and Sharmishtha or Cassiopeia are useful in locating the Pole Star. Sharmishtha is made up of five bright stars which are distributed along the figure of the letter M. The perpendicular bisector of the line joining the third and fourth stars in Sharmishta goes towards the Pole Star. (See figure.) The Pole Star has Saptarshi on one side and Sharmishtha on the other. As Sharmishtha sets, Saptarshi rises. Thus, we can always use either one or the other as a reference point on any given night.

3. Mrug *nakshatra* or Orion has very bright stars. On winter nights, they can be easily identified. It has seven-eight stars of which four are at the corners of a quadrangle. The line passing through the three middle stars of the constellation, when extended, meets a very bright star. This is Vyadh or Sirius. During the month of December, Mruga *nakshatra* rises at 8 pm on the eastern horizon. It is on the meridian during February and in June, it sets around 8 pm.

4. Vrushchik or Scorpio is a constellation with 10 to 12 stars. Jyeshtha or Antares is the brightest among them. This constellation is below the equator, in the sky of the southern hemisphere. In the third week of April, it can be seen in the eastern sky a few hours after sunset.



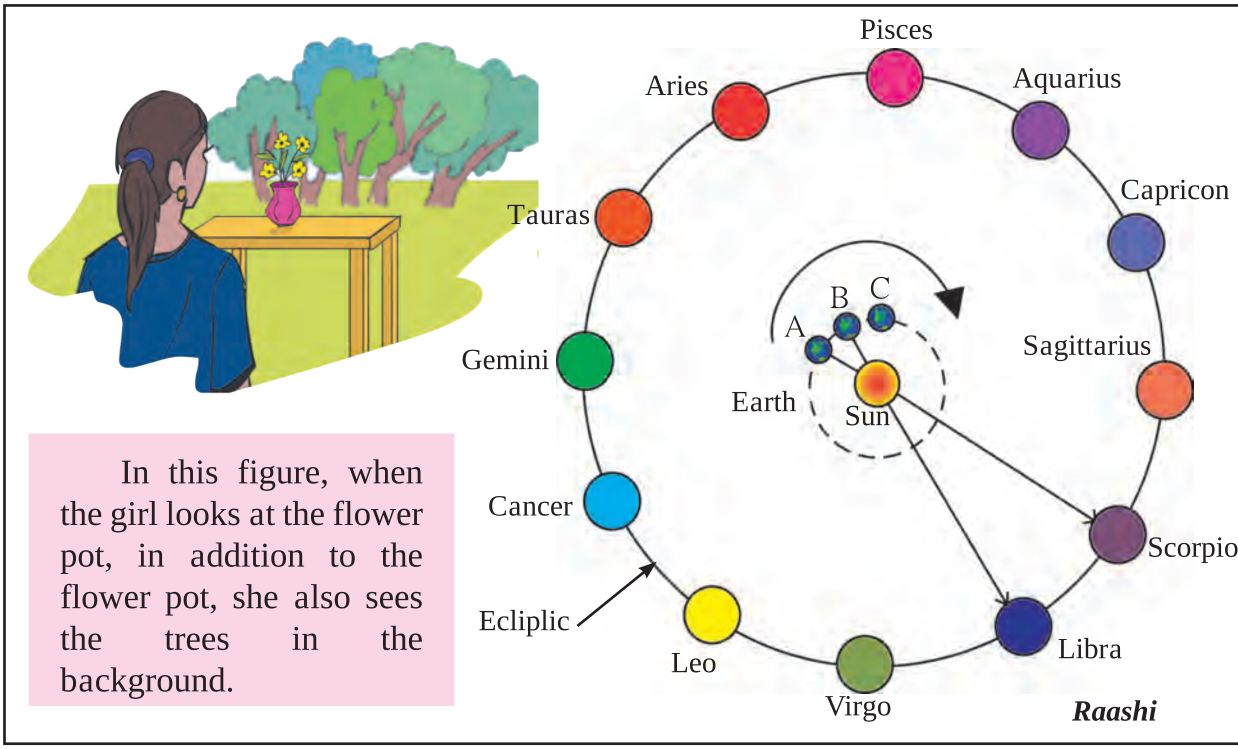
20.3 Some constellations

1. Why is the Pole Star important for sky watch?
2. What is the relation between the Pole Star and the constellations Saptarshi and Sharmishtha ?

Try this.

With the help of your friends, draw a big circle on the ground as shown in figure 20.4. Ask twelve of your friends to stand at equal distances along the circle, each holding a placard with the name of one zodiac sign in proper order.

Make one friend stand as the sun at the centre of the circle. Now, move along a smaller circle around the sun, as if you are the earth, facing the sun all the time. What do you notice as you move along this circular orbit? Ask your friends to take turns to do the same. Discuss what everybody sees.



In this figure, when the girl looks at the flower pot, in addition to the flower pot, she also sees the trees in the background.

20.4 Diagram of the experiment

The observer looking at the sun sees not only the sun but also a constellation behind the sun. The constellation cannot be seen in bright sunlight, but it is indeed present behind the sun. As the earth changes its position, a different constellation or zodiac sign or *raashi* appears behind the sun. This is what we express when we say that the sun enters a particular zodiac sign or *raashi*. For example, on Makar Sankranti we say that the sun enters Makar *raashi* (Capricorn zodiac sign).

When the earth is at A, for an observer on the earth, the sun appears to be in the Scorpio zodiac sign. When the earth moves from A to B, the observer will say that the sun has entered Libra. In reality, the sun does not move, but we perceive it as moving due to the motion of the earth around it. This motion of the sun is called its **apparent motion** and its path is called the **apparent path**. The rising of the sun in the east and its setting in the west is also an apparent motion. You might have heard some elders saying that a particular *nakshatra* is in the rising and now prevails. It means that, at that time, if you look at the sun from the earth, that particular *nakshatra* is behind the sun and gives you an idea about the position of the earth revolving around the sun.

National Institutions

IUCAA (Inter University Centre for Astronomy and Astrophysics) in Pune carries out fundamental research in astronomy.

In India, planetariums named after Pandit Jawaharlal Nehru have been established at New Delhi, Bangaluru, Allahabad, Mumbai and at New English School in Pune. They present a virtual projection of various stars and constellations as if it were a sky watch. Do visit these places during a school tour or whenever possible.

Layout of a planetarium

Website : www.taralaya.org

Always remember –

Science has proved that the constituents of the solar system e.g. planets, satellites and comets as also distant stars and constellations do not have any influence on human life. Man stepped on the moon in the twentieth century. He will conquer Mars in the twenty-first century. Hence, in this age of science, holding on to beliefs which have been proved to be wrong through numerous scientific tests, is an unnecessary waste of one's time, energy and money. It is necessary to consider all these issues with a scientific frame of mind.

Books, my friends !

'*Aakashashi Jadale Naate*', '*Chhand Aakashadarshanachaa*', '*Vedh Nakshatrancha*', and '*Taarakanchya Vishvat*' are a few books which you may read to get more information on constellations and sky watching.

Exercise

1. **Write the proper words in the blanks.**
   (meridian, horizon, twelve, nine, apparent, celestial, ecliptic)
   (a) When seen from a great distance, the sky seems to be touching the ground along a circle. This circle is called the ....
   (b) The .... is used while defining the zodiac signs.
   (c) Classified according to seasons, one season will have .... *nakshatras*.
   (d) The rising of the sun in the east and its setting in the west is the .... motion of the sun.

2. **A star rises at 8 pm tonight. At what time will it rise after a month? Why?**

3. **What is meant by 'The sun enters a *nakshatra*'? It is said that in the rainy season the sun enters the Mrug *nakshatra*. What does it mean?**

4. **Answer the following questions.**
   (a) What is a constellation?
   (b) What points should be considered before a sky watch?
   (c) Is it wrong to say that the planets, stars and *nakshatras* affect human life? Why?

5. **Write a paragraph on the birth and lifecycle of stars using figure 20.1**

Project : Visit a planetarium, collect information and present it in your school on Science day.

♦ ♦ ♦

19. Life Cycle of Stars

Can you recall?

1. What is a galaxy?
2. What are the different constituents of our solar system?
3. What are the major differences between a star and a planet?
4. What is a satellite?
5. Which is the star nearest to us?

We have learnt about the structure of the universe in earlier standards. Our solar system is situated in a galaxy. A galaxy is a collection of billions of stars, their planetary systems and interstellar clouds which are present in the empty spaces between stars. The universe is made up of innumerable such galaxies. Galaxies differ in structure and shape. We can divide them into three types : spiral, elliptical and irregular galaxies. Our galaxy is a spiral galaxy and is called the Milky Way and Mandakini. A spiral galaxy is show in figure 19.1

19.1 The figure shows a spiral galaxy. Our solar system is situated in a similar galaxy.

How did we obtain all this information about the universe?

If we look at the sky at night we see only planets and stars, then how did we get information about the other components of the universe? The answer to the question is telescopes. Several telescopes are placed on the surface of the earth, while some others are kept aboard manmade satellites which are orbiting the earth in fixed orbits. As these telescopes are situated above the earth's atmosphere they can observe astronomical objects more effectively. Astronomers study the observations made by all these telescopes to obtain detailed information about the universe. We are going to learn about all this in higher standards. Here, let us learn about the properties of stars and their life cycle.

Do you know?

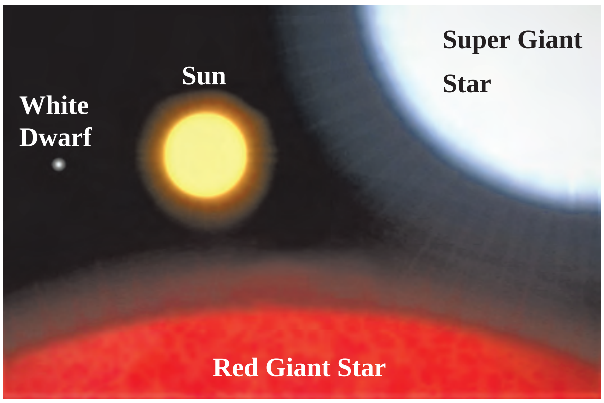
Our galaxy has about 10^{11} stars. Its shape is like a disc with a bulge in the centre and its diameter is about 10^{18} km. The solar system is situated at a distance of 2×10^{17} km from its centre. The galaxy is rotating around an axis passing through its centre and perpendicular to the disc. Its period of rotation is about 2×10^{8} yrs.

Properties of stars : At night, we can see about 4000 stars with our naked eyes. Sun is an ordinary star among them. The reason to call Sun an ordinary star is that even though it appears to be larger than all others stars in the sky because of its being nearest to us, there are bilions of stars which have higher or lower mass size and temperature than those of the Sun. Stars are gigantic spheres of hot gas. Some properties of the Sun are given in the table below. Hydrogen makes up for 72% of the mass of the Sun while helium is 26%. The rest 2% is made up of elements heavier than helium.

Properties of the Sun :

Mass	2×10^{30} kg
Radius	695700 km
Surface temperature	5800 K
Temperature at the centre	1.5×10^{7} K
Age	4.5×10^{9} yr

The mass of the Sun is about 3.3 lakh times that of the earth and its radius is 100 times that of the earth. Other stars have masses between $\frac{1}{10}$ ($\frac{M_{Sun}}{10}$) that of the Sun and 100 times that of the Sun (100 M_{Sun}) and their radii can between $\frac{1}{10}$ to 1000 times the radius of the Sun. (Fig. 19.2)



19.2 A comparison of sizes of different stars

Do you know?

The masses of other stars are measured with respect to the mass of the Sun. This means that the mass of the Sun, written as M_{Sun} is used as the unit of mass.

The age of the Sun and other stars, which is the time elapsed after their formation, can be between a few million years to a few billion years. If the properties of the Sun had changed in its life time, it would have caused changes in the properties of the earth and in the life on the earth. Detailed studies of the properties of the earth have led scientists to conclude that the properties of the Sun have remained unchanged over its lifetime i.e. the past 4.5 billion years. According to the studies made by astromomers, these properties will slowly change in further after 4.5 billion years.

Birth of stars

Huge clouds of gas and dust are present in the empty spaces between stars in a galaxy. These are called interstellar clouds. Figure 19.3 shows a picture of such clouds taken by the Hubble space telescope. Scientists use the unit of light year for measuring large distances. **A light year is the distance travelled by light in one year.** As the speed of light is 3,00,000 km/s, the light year is equal to 9.5 x 10^{12} km. The sizes of interstellar clouds are about a few light years, i.e. light takes a few years to go from one end of a cloud to the other. From this you can imagine the huge size of the cloud.

19.3 A picture of interstellar clouds taken by the Hubble space telecope

Due to some disturbance, these clouds start contracting. Because of the contraction, their density starts increasing and their temperature also starts to increase and a dense sphere of hot gas is formed from the cloud. Once the temperature and density at the centre of the sphere increase sufficiently, nuclear energy (energy generated through fusion of atomic nuclei) generation starts there. Because of this energy generation, the gas sphere becomes self luminous and a star is formed or we can say that a star is born. In the Sun, this energy is generated by the fusion of hydrogen nuclei to form helium nuclei. This means that the hydrogen at the centre of the star acts as a fuel and energy is generated by the burning of this fuel.

Do you know?

Light takes about 1 s to reach us from the moon while it takes 8 minutes to reach us from the Sun. It takes 4.2 years to reach us from the star alpha Centauri which is the star closest to the Sun.

Do you know?

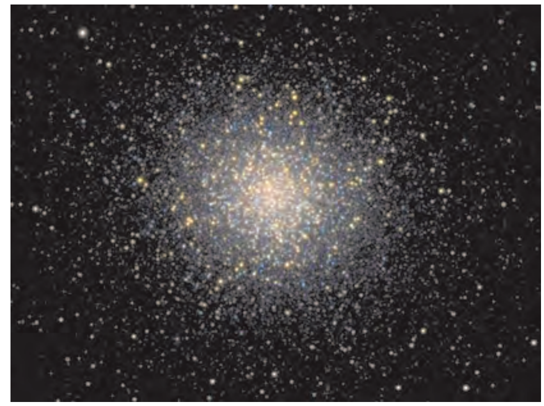
When a gas sphere contracts, its temperature increaes. This happens because of transformation of its gravitational potential energy into heat energy.

More than one star can be produced by the contraction of a huge interstellar cloud. Figure 19.4 shows a cluster of thousands of stars. Most of these stars have formed from a single gigantic interstellar cloud.

Can you recall?

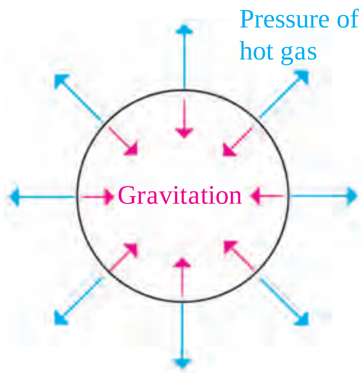
What is meant by balanced and unbalanced forces?

Stability of stars : If we burn an incense stick in one corner of a room, the fragrance spreads all over the room instantaneously. Similarly, when we remove the lid of a vessel containing boiling water, the steam spreads in the surrounding region. This means that hot gas spreads everywhere. Then, why doesn't the hot gas in the stars disperse in space? And why have the properties of the Sun remained unchanged over the last 4.5 billion years?



19.4 : A large cluster of stars. Most of these stars have formed from a single interstellar cloud.

The answer to these questions is the gravitational force. The gravitational force between the gas particles of the star keeps these particles together. If the gravitational force which is constantly trying to bring the gas particles close together and the pressure of the hot gas which is constantly trying do disperse the gas are balanced, then the star remains stable. The gravitatinal force is acting inwards, towards the centre of the star while the gas pressure is acting outwards, i.e. away from the centre of the star (see figure 19.5).



Think about it.

You must have played tug of war. In this, two ends of a rope are pulled on two sides by two groups. When the forces applied by both sides are equal, they balance each other and the centre of the rope remains static. When the force on one side of the rope is larger than that on the other side, the centre of the rope moves towards that side. Something similar happens in the case of a star. When the gravitational force and gas pressure are balanced, the star is stable. But when one of them is more than the other, the star either contracts or expands.

Do you know?

1. If there was no gas pressure in the Sun, it will collapse to a point in 1-2 hours.
2. Gas pressure depends on the density and temperature of the gas. Higher the temperature and density, higher is the pressure.

Evolution of stars

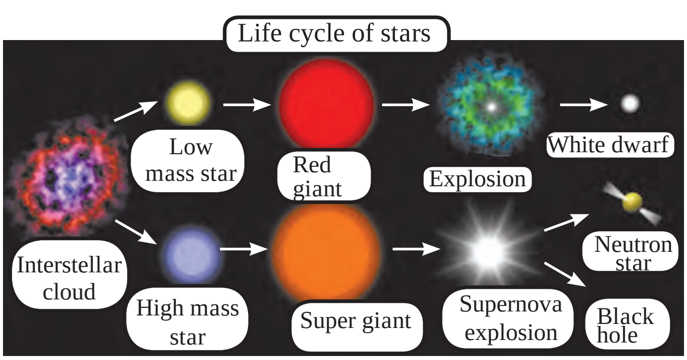
Evolution of a star means change in its properties with time resulting in its passing through different stages. We have seen that the properties of the Sun have not changed in the past 4.5 billion years. Stars evolve very slowly for most of their life time. As stars are continuously emitting energy, their energy is constantly decreasing.

For their stability to remain intact i.e. for maintaining a balance between the gas pressrue and the gravitational force, it is necessary that the temperature remains constant. For the temperature to remain constant, energy must be generated inside the star. This generation of energy occurs because of burning of fuel at the centre of the star. The reason for the evolution of stars is the burning of and therefore, the decrease in the amount of fuel in their centre. When the fuel in the centre finishes, the energy generation stops. As a result, the temperature of the star starts decreasing. Due to the decrease in temperature, the gas pressure decreses and the balance between gas pressure and gravitatinal forece cannot be maintained. As the gravtational force is now higher than the gas pressure, the star starts contracting. This causes another fuel to start burning e.g. when hydrogen at the centre is finished, helium starts undergoing fusion and energy generation starts again. How many fuels will be used depends on the mass of the star.

Higher the mass of the star higher is the number of fuels used. During this a lot of changes occur in the star. As a number of processes occur inside the star, it sometimes contracts and expands at other times and the star goes through different stages. When all possible fuels are exhausted, the energy generation finally stops and the temperature of the star starts decreasing. The balance between gravitational force and gas pressure cannot be maintained. Let us now see how the evolution of the stars ends and what the end stages of stars are.

End stages of stars : The higher the mass of the star faster is its rate of evolution. The different stages during the evolution of the star which is the path of evolution of the star, also depends on its mass. How does the evolution finally stop?

We have seen that when the energy generation stops, the temperature decreases causing the gas pressure to decrease. The star contracts and its density increases. When the density becomes very high, some new types of pressures are generated which do not depend on the temperature of the gas. In such case, the gas pressure remains constant even after the energy generation stops completely and the temperature of the gas goes on decreasing. The stability of the star can remain intact for ever and this can be considered as the end stage of a star.



There are three ways of evolution of stars depending on their initial mass. Thus, we can divide stars in three groups. The path of evolution and end stage for all stars in the same group is the same. Lets us learn more about it.

19.6 Evalution of stars based on their mass and their end stages

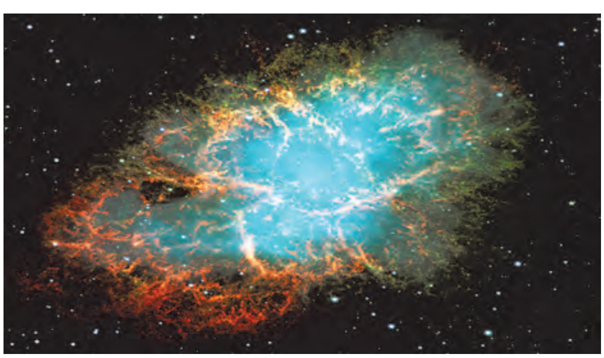
1. End stages of stars having initial mass less than 8 time the mass of the Sun ($M_{star} < 8 M_{Sun}$) : Stars in this group undergo huge expansion and their radius increases by a factor of 100 to 200. In this stage they are called red giant stars. This name is given because of the large size and because of the fact that the stars look reddish due to their lower temperature. The size of a red giant star in comparison to other types of stars is shown in figure 19.2. At the end of its evolution, these stars explode and their outer gas envelope is thrown out. The inner part contracts and its size becomes similar to the size of the earth. As the mass of the star is much higher than that of the earth and the size is similar to that of the earth, the density in the star becomes very high. In this state, the pressure due to the electrons in the star becomes independent of temperature and is able to balance the gravitatinal force for ever. In this state, the star looks white and due to its small size it is called a white dwarf. After this its temperature keeps decreasing but its size and mass remain unchanged for ever and so white dwarf is the end stage of stars in this mass range.

19.7 : The outer gaseous envelop which is thrown out during the formation of a white dwarf which is at the centre.

Do you know?

When the sun will become a red giant, its diameter will increase so much that it will swallow Mercury and Venus. It is possible that the earth will also be absorbed by the Sun. It will take 4-5 billion years for the Sun to reach this state.

2. End stages of stars having mass between 8 and 25 time the mass of the Sun ($8\ M_{Sun} < M_{Star} < 25\ M_{Sun}$) : These stars also go through the red giant stage and later through the supergiant stage during which their size may increase 1000 times. The huge explosion, called the supernova explosion, which occurs at last is very powerful and so much energy is given off that we can see the star during the day also.



The central portion which is left behind after the explosion, contracts and its size becomes as small as about 10 km. In this state, the stars are completely made up of neutrons and are called neutron stars. The pressure of these neutrons is independent of temperature and is capable of balancing the gravitatinal force for ever. Neutron star is the end stage of these stars.

19.8 A recent picture of the supernova explosion which was first seen in 1054 A.D.

Do you know?

1. As the size of the white dwarfs is similar to that of the earth, their density is very large. One spoonful material of the white dwarf will weight a few tons. As neutron stars are much smaller than the white dwarfs, their density is even higher and one spoonful material of these stars will weigh as much as the weight of all living beings on the earth.
2. A star in our galaxy exploded about 7500 years back. As the star is about 6500 light years away from us, the light emitted in the explosion took 6500 years to reach us. It was first seen on the earth by the Chinese in the year 1054. It was so bright that it could be seen during the day also for 2 years. After 1000 years of the explosion, the gases emitted during the explosion are seen to be expanding with velocities higher than 1000 km/s.

3. End stages of stars having mass larger than 25 times the mass of the Sun ($M_{star} > 25\ M_{Sun}$)

These stars evolve like the stars in the second group but after the supernova explosion, no pressure is capable of balancing their huge gravitational force and they continue contracting for ever. As their size becomes smaller, their density and their gravitational force increase tremendously. All nearby objects get attracted towards these stars and nothing can come out of them, not even light. Also, any light falling on these stars does not get reflected and gets absorbed inside the star. Thus, we cannot see the star at all but can probably see a minute black hole at its place. This end stage of the star is therefore, called a black hole.

Thus, we have seen that, depending on mass, there are three paths of evolution and three end stages of stars. These are shown in the following table.

Initial mass of the star	End stage of the star
$< 8\ M_{Sun}$	White dwarf
Between 8 to 25 M_{Sun}	Neutron star
$> 25\ M_{Sun}$	Black hole

Exercises

1. Search and you will find.

a. Our galaxy is called.........

b. For measuring large distances........ is used as a unit.

c. The speed of light is .... km/s.

d. There are about .... stars in our galaxy.

e. The end stage of the Sun will be......

f. Stars are born out of ..... clouds.

g. Milky way is a .... galaxy.

h. Stars are spheres of .... gas.

i. The masses of other stars are measured relative to the mass of the............

j. Light takes .... to reach us from the Sun while it takes........... to reach us from the moon.

k. The larger the mass of a star the faster is its.......

l. The number of fuels used in the life of a star depends on its............

2. Who is telling lies?

a. Light year is used to measure time.

b. End stage of a star depends on its initial mass.

c. A star ends its life as a neutron star when the pressure of its electrons balances its gravity.

d. Only light can emit from the blank hole.

e. The Sun will pass through the supergiant stage during its evolution.

f. The Sun will end its life as a white dwarf.

3. Answer the following question.

a. How do stars form?

b. Why do stars evolve?

c. What are the three end stages of stars?

d. Why was the name black hole given?

e. Which types of stars end their life as a neutron star?

4. A. If you are the Sun, write about your properties in your own words.
B. Describe white dwarfs.

Project :

1. Use your imagination and make models of the Milky Way and the solar system.
2. Write the effects : If the Sun disappears ....

JY7FKQ

Figures courtesy : ESO and Nasa

18. Observing Space : Telescopes

- Forms of light
- Telescopes and types of telescopes
- Telescopes in space
- Indian Space Research Orgnaisation (ISRO)

Can you recall?

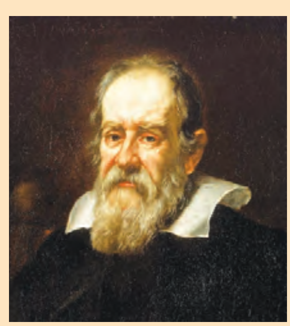
1. What is the difference between the sky and space?
2. What is meant by space observation? Why is it important?

From early days, man has been curious about the sun as well as the moon and stars seen in the night sky. Using his boundless imagination, he tried to understand the sky as observed by the naked eyes. He noticed that the position of the stars changed with time and had something to do with the occurrence of seasons. As the knowledge of the cycle of seasons was necessary for agriculture, sky watching began to prove useful to him. The position of the constellations was also useful to sea goers for navigation. Man began to make determined efforts to find answers to questions which arose out of his sky watching. But he did not have any equipment to get a closer view of the stars and planets in the sky.

Today, 400 years after Galileo's use of the telescope, tremendous progress has been made in telescope technology and in space science and technology on the whole. This great leap in technology has helped to construct for us an astounding picture of our universe. Space science and technology are not only important for research purposes, but also to help provide us with many of the comforts and facilities we enjoy in our everday life. A telescope is used to observe space, but will one telescope be sufficient for us to observe space completely? Why do we need different telescopes for the purpose? Are telescopes installed even in space? In this chapter, we are going to study the science behind many such questions.

An introduction to scientists

In 1608, spectacle maker and researcher, Hans Lippershey discovered that seeing through two lenses kept one behind the other, seems to brings objects closer to us. He thus made the first telescope. Galileo made a telescope in 1609 and used it for space observations. He realized that there are many more stars than what could be seen with naked eyes. Using his telescope, he also discovered the moons of Jupiter, the black spots on the sun, etc.



Galileo Galilei

Different forms of light

Light is an electromagnetic wave. Every wave has a characteristic wavelength. Our eyes can see only that light which has wavelengths between 400 nm to 800 nm. Such light is called visible radiation. However, there are electromagnetic waves of wavelengths other than the visible ones most of which we cannot 'see' as our eyes are not sensitive to them.

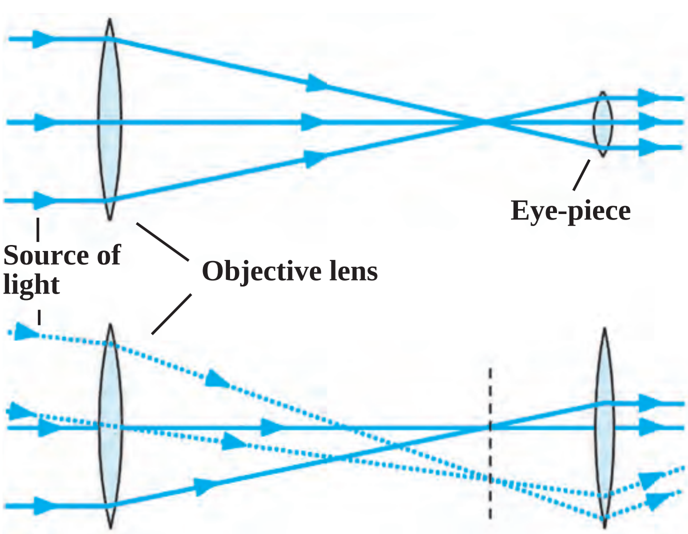
Study the following table.

1 nm (nanometer) = 10^{-9} m and 1 pm (picometer) = 10^{-12} m

Type of radiation	Wavelength
Radio waves	Longer than about 20 cm
Micro waves	0.3 mm – 20 cm
Infrared waves	800 nm – 0.3 mm
Visible light rays	400 nm – 800 nm
Ultraviolet rays	300 pm – 400 nm
X-rays	3 pm – 300 pm
Gamma rays	Shorter than 3pm

Of all the above types, our eyes are only capable of seeing the visible radiation. Thus, we use the visible radiation telescopes i.e. optical telescopes, made from regular lenses or mirrors to see the visible radiation coming from the space. However many heavenly bodies emit radiations other than the visible light. Thus we need different types of telescopes like the X-ray, gamma-ray and radio telescopes to receive such radiation and to study their sources.

Telescopes



18.1 A refracting telescope

Optical telescopes

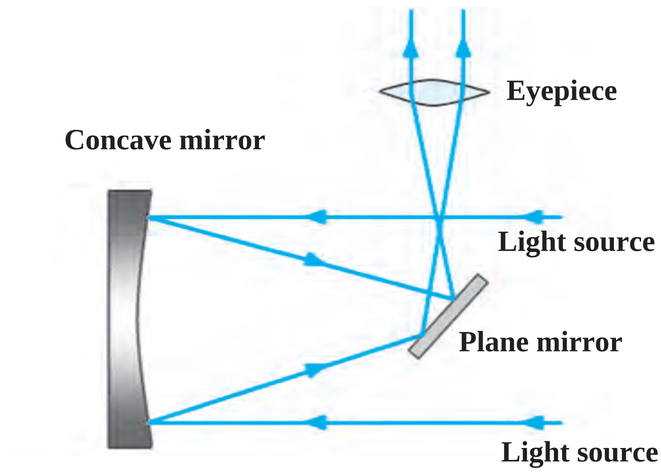
Most optical telescopes are made with two or more lenses as shown in figure 18.1. To collect the maximum amount of light coming from a heavenly object, the objective lens should be made as large as possible. Using the light collected by the objective a smaller lens, called the eyepiece, produces a large image of the source. Light rays change their direction as they enter a lens from the atmosphere and again when they enter the atmosphere after passing through the lens. This is called refraction. Hence such telescopes are called **refracting telescopes**. We shall study image formation by lenses in the next standard.

Even though such a telescope is useful for space observations, it presents certain difficulties.

1. As we saw above, if we wish to obtain a bright image of a source by collecting the maximum possible light from it, the objective lens must be made as large as possible. However, it is very difficult to make very large lenses. Also, large lenses are very heavy and tend to get distorted.
2. As the objective and eyepiece are placed at the opposite ends of the telescope, the length of the telescope also increases with increase in the size of the lenses and the telescope becomes difficult to manage.
3. The images formed by lenses have erorrs of colours. This is called chromatic aberration.

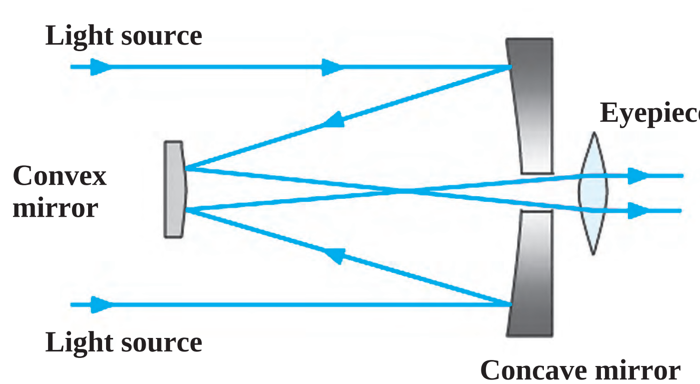
To overcome these difficulties, telescopes are made using concave mirrors. As light rays get reflected by mirrors in these telescopes, they are called **reflecting telescopes**. In order to get a bright image of a source, large mirrors are necessary (so that they can collect a large amount of light from the source), but it is easier to make large mirrors as compared to making large lenses. Also, big mirrors can be made by combining several smaller pieces. The weight of a large mirror too is less than that of a lense of the same size. The images formed by mirrors do not have errors of colour. Only by using these large telescopes, can we see far away stars and galaxies, which we could never have seen using our naked eyes.

The reflecting telescopes are mainly of two types: Newtonian and Cassegrain. As shown in figure 18.2 light rays coming from space are reflected by the concave mirror. Before these reflected rays converge at the focus, they are deflected again by a small plane mirror. As a result, they get focused at a point lying on the perpendicular to the axis of the telescope's cylinder. They pass through the eyepiece and we get a magnified image of the source.



18.2 The Newtonian telescope

The construction of a Cassegrain type of telescope is shown in figure 18.3. The Cassegrain telescope also uses a concave mirror. However, here light rays, after reflection from the concave mirror, are reflected back towards it by a small convex mirror. They pass through a hole at the centre of the concave mirror and then through the eyepiece situated at the back of the mirror. The eyepiece gives us a magnified image of the source.



18.3 The Cassegrain telescope

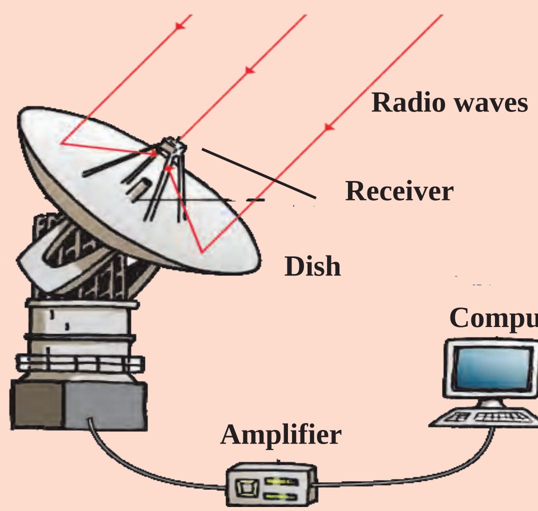
In India, we have several telescopes with concave mirrors of 2 m diameter that have been in use for many years. The biggest optical telescope in India, having a mirror of 3.6 m diameter is situated in the Aryabhatt Research Institute of Experimental Sciences, Nainital. This is the largest optical telescope in Asia.

Radio telescope

Many heavenly objects emit radio waves in addition to visible radiation. We cannot see this radiation with our eyes. Hence, a special type of telescope is used to receive these rays. It is called a radio telescope. It is made from one or more dishes of a particular parabolic shape. As in optical telescope the incident radio waves are reflected by these dishes and converge at the focus. A radio receiver is placed at the focal point. The information gathered by this receiver is passed on to a computer which analyses it and constructs an image of the source.

A large radio telescope called the Giant Meterwave Radio Telescope (GMRT) has been erected at Narayangaon near Pune. It uses radio waves having wavelengths of about a metre, coming from planets and stars to study those heavenly bodies. This telescope is actually a collection of 30 dishes, each having a diameter of 45 m. It is called a giant telescope as the arrangement of the 30 dishes over an area which measures up to 25 km across, is made in such a way that it works as a single dish having a diameter of 25 km. This means that the GMRT gives the same data that we would have got from a telescope having a single dish of 25 km diameter! GMRT has been made by Indian scientists and engineers at minimum cost. It is a world standard research facility. Scientists study the solar system, solar winds, pulsars, supernova, interstellar hydrogen clouds, etc. with the help of the GMRT. Scientists from all over the world come to India to make use of this facility.

A



B

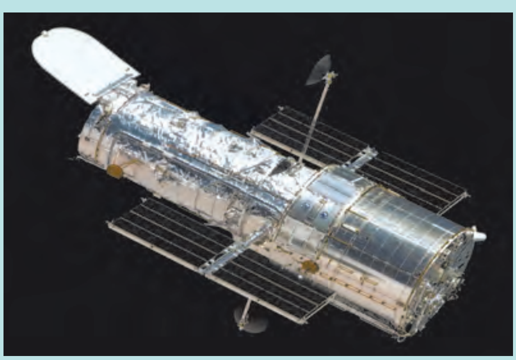
18.4 **A. Radio telescope (photograph) B. The structure of a radio telescope**

Telescopes in space

Visible light and the radio waves emitted by heavenly bodies in space can pass through the earth's atmosphere and reach the earth's surface. So, optical and radio telescopes can be erected on the surface of the earth. However, these earth-based telescopes present some problems in making good quality observations.

The visible light coming from a heavenly body has to pass through the earth's atmosphere to reach the earth's surface. During this journey, some of the light is absorbed by the atmosphere and the intensity of the light reaching the earth's surface decreases. A second problem is caused by the changes in atmospheric pressure and temperature. These changes cause turbulence in the atmosphere which in turn cause of the light rays to change their path slightly and thereby shake the position of the image. Also, because of Sunlight, we cannot use optical telescopes during the day. During the night too city lights and cloudy weather can cause difficulties in observing the heavenly bodies. To reduce these problems, optical telescopes are situated on top of mountains, at in uninhabitated places. However, if we want to get rid of all the above problems completely, we should place the telescope above the earth's atmosphere, in space itself. These problems do not exist in the space and thus the image obtained by space telescopes would be bright and very clear and will ramain at one place. Scientists have turned this idea into reality.

In 1990, the National Aeronautics and Space Administration launched into space an optical telescope called the **Hubble telescope**. It has a mirror of diameter 94 inches and is orbiting the earth at a height of 589 km from it. This telescope is still working and has helped to make important discoveries.



In 1999, the National Aeronautics and Space Administration launched an X-ray telescope named **Chandra**, in space, to study X-rays coming from heavenly objects. Special mirrors which can reflect X-rays were used in this telescope. Chandra has given us very useful information about stars and galaxies. The telescope is named after the famous Indian scientist Subramanian Chandrashekhar.

Indian Space Research Organization (ISRO) Bengaluru

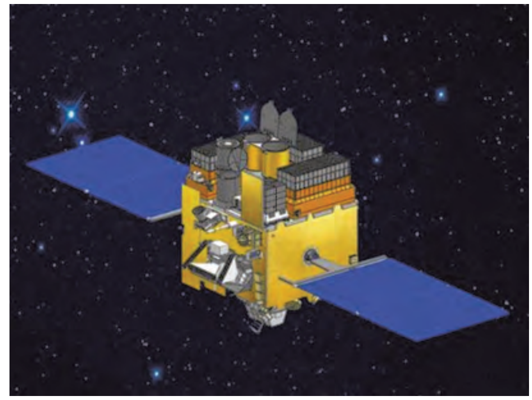
This institute was established in 1969 with the aim of developing technology for making and launching of artificial satellites. Till date, ISRO has successfully launched a large number of satellites. ISRO's programme is foremost among the successful programs undertaken by independent India. India's progress in space science has played a big role in national and social development.

The INSAT and GSAT series of satellites support our telecommunication network, television broadcasting and meteorological services. It is because of them that telephone, television and internet services are available everywhere in the country. The EDUSAT satellite in this series is used exclusively for education. The IRS satellite series is used for the monitoring and management of natural resources as well as disaster management.

Website : www.isro.gov.in

Astrosat

In 2015, Indian Space Research Organization (ISRO) launched an artificial satellite called Astrosat, in space. This satellite has ultraviolet and X-ray telescopes and detectors. Most of the parts used in this satelite are made in India. It is a unique system having different kinds of telescopes on a single satellite. Indian scientists are studying various aspects of the Universe using the data obtained with these telescopes.



Find out

Collect more information about telescopes that work in space apart from the Hubble and Chandra telescopes.

78Z55H

Exercises

1. **Fill in the blanks with the proper words.**
   a. The wavelength of visible light is between …….. and ………
   b. GMRT is used for ……. waves.
   c. A certain X-ray telescope is named after scientist ………..
   d. The first scientist to use a telescope for space observationwas ....
   e. The biggest optical telescope in India is situated at ………

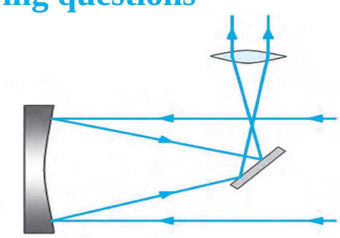
2. **Form pairs**

'A' Groups	'B' Groups
(i) X-rays	(a) GMRT
(ii) Optical Telescope	(b) ISRO
(iii) Indian radio telescope	(c) Hubble
(iv) Launching artificial satellites	(d) Chandra

3. **What are the difficulties in using ground based optical telescopes? How are they overcome?**

4. **Which type of telescopes can be made using a concave mirror, convex mirror, plane mirror and a lens? Draw diagrams of these telescopes.**

5. **Study the figure and answer the following questions**



   a. What type of telescope is shown in the figure?
   b. Label the main parts of the telescope.
   c. Which type of mirror does the telescope use?
   d. What other type of telescope uses a curved mirror?
   e. Explain the working of the above telescope.

6. **Answer the following questions.**
   a. Explain the construction of Galileo's telescope.
   b. Explain the construction of a radio telescope.
   c. Why are optical telescopes located in uninhabited places on mountains?
   d. Why can an X-ray telescope not be based on the earth?

Project : Collect information about various observatories in India and present it in the class.

◈◈◈

10. Space Missions

- Space Missions
- Artificial satellites
- Classification of artificial satellites
- Orbits of artificial satellites
- Satellite launch vehicles
- Space missions away from the Earth

Can you recall

1. What is the difference between space and sky?
2. What are different objects in the Solar system?
3. What is meant by a satellite?
4. How many natural satellites does the earth have?

Man has always been curious about unknown places and he has always been eager to expand the horizons of his knowledge by exploring the unknown world. He must have had deep curiosity about the space and the many twinkling stars in the dark sky. He must have had dreams to fly to the space and must have been working for that.

Space missions

Substantial developments in technology, specially space technology, in the later half of twentieth century resulted in the development of space crafts making space voyage possible. Since then, more than a thousand artificial satellites have been placed into orbits around the earth. Additionally, space missions have been undertaken for close observation of various objects in our solar system. We will learn about all this in this chapter.

We can classify the space missions into two categories. In one type of missions, the objective is to put artificial satellites in orbits around the earth for research and various other useful applications. The objective of second type of missions is to send the spacecrafts to outer space for close observations and understanding of the objects in solar system, or even outside the solar system.

Do you know ?

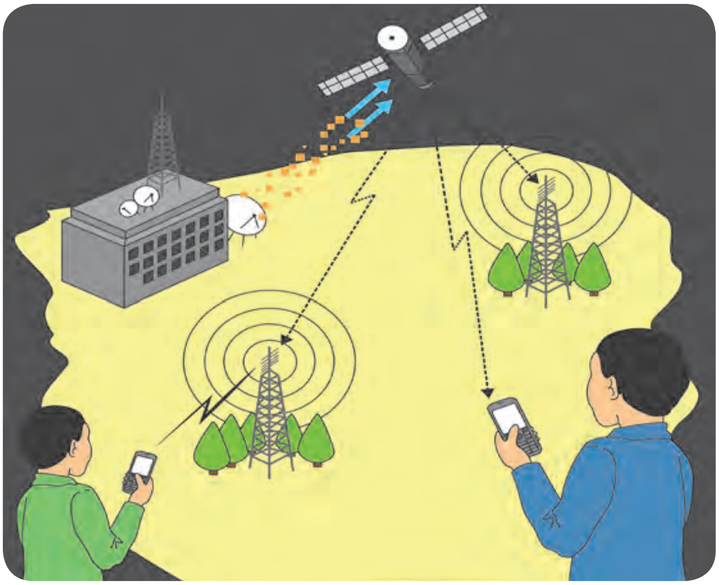
The first person to go into the space in a spacecraft was Yuri Gagarin of the then USSR. He orbited the earth in 1961. The first person to step on the Moon (1969) was Neil Armstrong of USA. Rakesh Sharma of India orbited the earth in 1984 in a Russian spacecraft. Kalpana Chawla and Sunita Williams of Indian origin also participated in space explorations through missions organized by NASA (National Aeronautics and Space Administration) of USA.

Can you recall?

Which types of telescopes are orbiting around the earth? Why it is necessary to put them in space?

Can you tell?

Where does the signal in your cell phone come from? Where from does it come to mobile towers? Where does the signal to your TV set come from? You may have seen photographs showing the position of monsoon clouds over the country, in the newspaper. How are these images obtained?



10.1 Communication by artificial satellite

Need and importance of space missions:

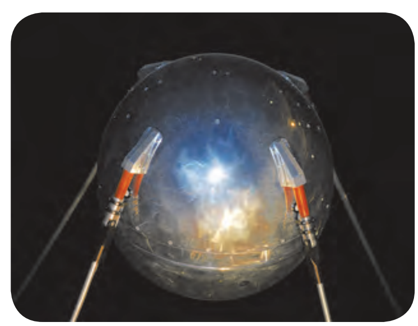
The world has become a global village due to space missions. Today, we can contact a person in any part of the world within a second. We can gather information about worldwide events sitting at home. You all know the importance of internet. Due to internet, every information is available at our fingertips. It has become possible to get advance alert about natural calamities and take proper precautions.

During war, it is possible to get information about the actions of the enemy through aerial surveillance using satellites. It is also possible to explore the fossil reserves and minerals in the earth. Thus, there are unlimited applications of space missions. Today, space technology is an inevitable part for development of a nation.

Artificial satellite

A natural satellite is an astronomical object orbiting the earth or any other planet. The moon is the only natural satellite of the earth. Some other planets in the solar system have more than one natural satellites. Similarly if a manmade object revolves around the earth or any other planet in a fixed orbit it is called an artificial satellite (fig 10.1).

The first artificial satellite '*Sputnik*' was sent to space by Soviet Union in 1957(see figure 10.2). Today, more than thousand satellites are orbiting the earth. The satellites work on solar energy. So, solar photovoltaic panels are attached on both sides of these satellites like wings. Instruments are installed in the satellites to receive and transmit signals from and to the earth.



10.2 *Sputnik*

The satellites have various other types of instruments, depending on their functions. One such satellite is shown in figure 10.1. Signals transmitted from the earth to the satellite and from the satellite to a mobile tower and mobile phone are also shown. These satellites are sent into the space to perform various functions. Depending on their functions, satellites are classified into following categories:

Use of ICT

Prepare a power point presentation showing India's contribution in space research and present it in the class.

INSAT: Indian National Satellite
GSAT: Geosynchronous Satellite
IRNSS: Indian Regional Navigation Satellite System
IRS : Indian Remote Sensing Satellite
GSLV: Geosynchronous Satellite Launch Vehicle
PSLV: Polar Satellite Launch Vehicle

Type of satellite	Function of the satellite	The names of Indian satellite series and their launch vehicles
Weather satellite	Study and prediction of weather.	INSAT and GSAT. Launcher: GSLV.
Communication satellite	Establish communication between different location in the world through use of specific waves.	INSATand GSAT. Launcher: GSLV.
Broadcast satellite	Telecasting of television programs.	INSAT and GSAT. Launcher: GSLV.
Navigational satellite	Fix the location of any place on the earth's surface in terms of its very precise latitude and longitude.	IRNSS. Launcher : PSLV.
Military Satellite	Collect information for security aspects.	
Earth Observation Satellite	Study of forests, deserts, oceans, polar ice on the earth's surface, exploration and management of natural resources, observation and guidance in case of natural calamities like flood and earthquake.	IRS. Launcher : PSLV.

Types of satellites

Internet is my friend

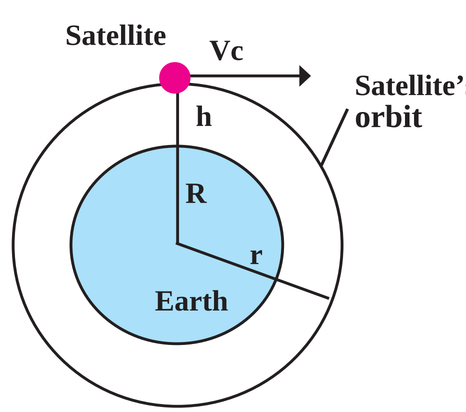
Watch and share with others
1.https://youtu.be/cuqYLHaLB5M
2. https://youtu.be/y37iHU0jK4s

Orbits of Artificial Satellites

All artificial satellites do not revolve in similar orbits around the earth. The functions of the satellite decide the height of the satellite's orbit from the earth's surface, the nature of the orbit (circular/elliptical) and whether the orbit shall be parallel to equator or making some angle with it. To put the satellite in its proper orbit at specific height above the earth's surface, the satellite is taken to that height using a satellite launcher. Then the satellite is given a specific velocity known as the critical velocity (v_c) in a tangential direction to the orbit (fig 10.3). The satellite then starts revolving around the earth. The formula for the velocity v_c can be derived as below.

If a satellite of mass 'm' is revolving around the earth in an orbit of height 'h' with speed 'v_c', then as seen in the chapter on 'Gravitation', a centripetal force $\frac{mv_c^2}{r}$ will act on it.

Here, 'r' is the orbital radius of the satellite from the centre of the earth.



10.3 Orbit of an artificial satellite

This centripetal force is provided by the gravity of the earth.

Therefore, centripetal force=gravitational force between the Earth and the satellite.

$$\frac{mv_c^2}{R+h} = \frac{GMm}{(R+h)^2}$$

$$v_c^2 = \frac{GM}{R+h}$$

$$v_c = \sqrt{\frac{GM}{R+h}} \qquad \text{.......... (1)}$$

G = Gravitational constant = 6.67×10^{-11} N m^2/kg^2
M = Mass of the earth = 6×10^{24} kg
R = Radius of the earth = 6.4×10^6 m = 6400 km
h = Height of the satellite above earth surface
R + h = Radius of the orbit of satellite.

It can be seen that the critical velocity does not depend on the mass of the satellite. As the height of the satellite's orbit from the earth's surface increases, the critical velocity decreases. Depending on the height of the satellite's orbit above the earth's surface, the satellite orbits are classified as below:

High Earth Orbits : (Height from the earth's surface > 35780 km)

If the height of the satellite's orbit above the earth's surface is greater than or equal to 35780 km, the orbit is called High earth Orbit. As we will see in the next solved example, a satellite revolving in an orbit 35780 km above the earth's surface, will take around 24 hours to complete one revolution. We know, that the earth also takes almost 24 hrs for one revolution. If the satellite is revolving in an orbit parallel to the equator, the time of revolution for the earth around itself and that for the satellite to revolve around the earth being the same, the satellite will appear to be stationary with respect to the earth. For a passenger in one vehicle, another vehicle, moving parallel to him with equal velocity, appears to be stationary. This is what happens here also. These satellites are, therefore, called geosynchronous satellites. Since, these satellites are stationary with reference to the earth, they can observe a specific portion of the earth, continuously. Therefore, they are used in applications like meteorology and for carrying signals for telephone, television, radio etc.

Medium Earth Orbit (height above the earth's surface 2000 km to 35780 km)

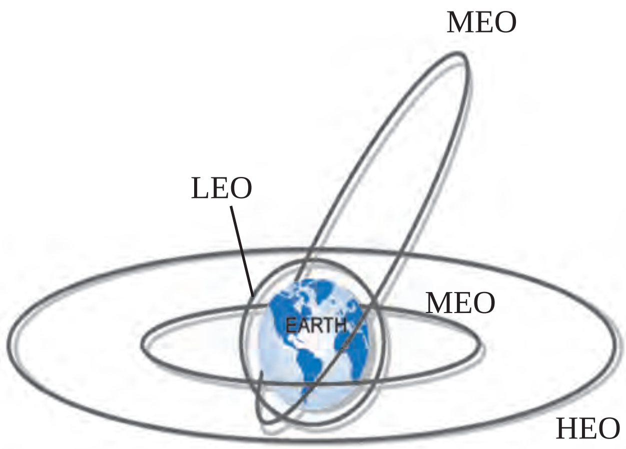
If the height of the satellite orbit above the earth's surface is in between 2000 km and 35780 km, the orbits are called medium earth orbits. The geostationary satellites orbit above the equator. These are, therefore, not useful in the study of polar regions. For this purpose, elliptical medium earth orbits passing over the polar region are used. These orbits are called polar orbits. In these orbits, the satellites complete one revolution in 2 to 24 hours.

Some of these satellites revolve in circular orbits at a height of around 20,200 km above the earth's surface. Global positioning satellites revolve in such orbits.

Low Earth Orbits (height above the earth's surface: 180 km to 2000 km)

If the height of the satellite orbit above the earth's surface is in between 180 km and 2000 km, the orbits are called Low earth Orbits. The satellites used for scientific experiments and atmospheric studies revolve in low earth orbits. Depending on the height of their orbits, they complete one revolution in around 90 minutes. International Space Station and Hubble telescope also revolve in Low earth Orbits.

Figure 10.4 shows various orbits of satellites.



10.4 Orbits of satellites

Do you know ?

A group of students from COEP (College of Engineering, Pune) made a small satellite and sent it to the space through ISRO in 2016. The name of the satellite is 'Swayam' and it weighs around 1 kg. It is orbiting the earth at a height of 515 km. The main objective of the satellite was to provide point to point messaging services using a special method.

Solved Example

Example 1. Suppose the orbit of a satellite is exactly 35780 km above the earth's surface. Determine the tangential velocity of the satellite.

Given : $G = 6.67 \times 10^{-11}$ N m^2/kg^2 ,
$M = 6\times10^{24}$ kg (for earth)
$R = 6400$ km (for earth) $= 6.4 \times 10^6$ m ,
h = height of the satellite above the earth's surface 35780 km.
v = ?
$R + h = 6400 + 35780 = 42180 \times 10^3$ m

$$v = \sqrt{\frac{GM}{R+h}}$$

$$= \sqrt{\frac{(6.67 \text{ x } 10^{-11}) \text{ x } (6 \text{ x } 10^{24})}{42180 \times 10^3 \text{ m}}}$$

$$= \sqrt{\frac{40.02 \text{ x } 10^{13}}{42180 \text{ x } 10^3}}$$

$$= \sqrt{\frac{40.02}{42180} \times 10^{10}}$$

$$= \sqrt{0.0009487909 \times 10^{10}}$$

$$= \sqrt{9487909}$$

v = 3080.245 m/s = 3.08 km/s

Example 2. In the previous example, how much time the satellite will take to complete one revolution around the earth?

Given: Height of the satellite above the earth's surface= 35780 km.

Velocity of the satellite=3.08 km/sec

Solution: Suppose, the satellite takes T seconds to complete one revolution around the earth. The distance travelled during this one revolution is equal to the circumference of the circular orbit. If r is the radius of the orbit, the satellite will travel a distance $2\pi r$ during one revolution. Thus, the time required for one complete revolution can be obtained as follows:

$$v = \frac{\text{distance}}{\text{time}} = \frac{\text{circumference}}{\text{time}} = \frac{2\pi r}{T}$$

$$T = \frac{2\pi r}{v} = \frac{2\pi (R+h)}{v}$$

$$= \frac{2 \times 3.14 \times (6400 + 35780)}{3.08}$$

$$= 86003.38 \text{ sec}$$

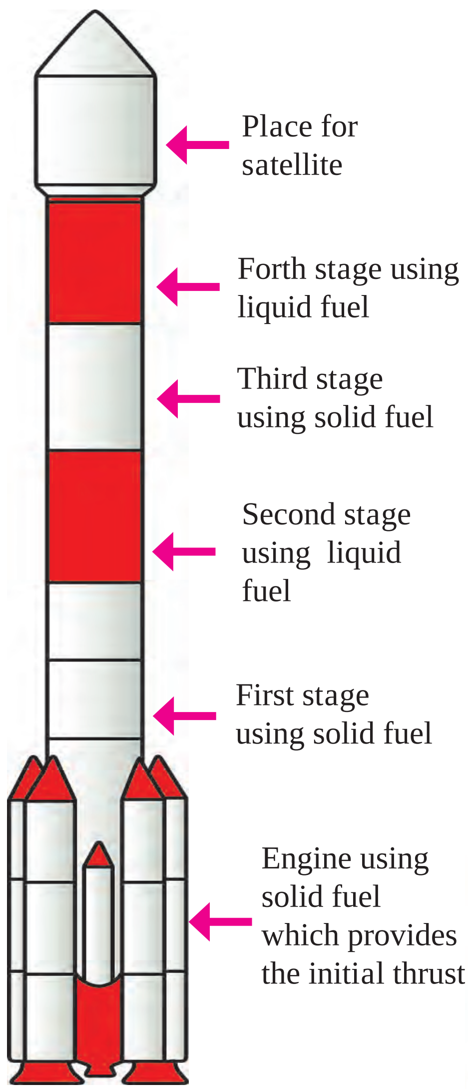
= 23.89 hrs. = 23 hrs 54 M.

(Here, since the velocity is taken in the unit of km/s, the radius is also taken in unit of km)

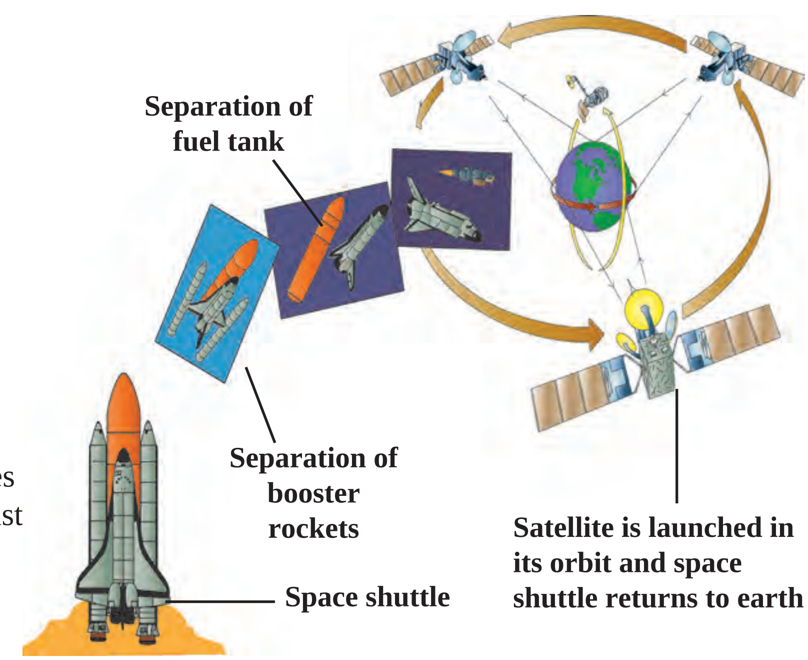
Satellite Launch Vehicles

Satellite launch vehicles are used, to place the satellites in their specific orbits. The functioning of the satellite launch vehicle is based on the Newton's third law of motion. The launch vehicle uses specific type of fuel. The gas produced due to combustion of the fuel expands due to its high temperature and is expelled forcefully through the nozzles at rear side of the launch vehicle. As a reaction of this, a thrust acts on the vehicle, which drives the vehicle high in to the space.

The structure of the launch vehicle is decided by the weight of the satellite and the type of satellite orbit. The fuel of the vehicle also depends on these factors. The fuel forms a major portion of the total weight of the launch vehicle. Thus, the vehicle has to carry a large weight of the fuel with it. To overcome this problem, launch vehicles with more than one stage are used. Due to this, the weight of the vehicle can be reduced step by step, after its launching. For example, consider a launch vehicle having two stages. For launching the vehicle, the fuel and engine in the first stage are used. This imparts a specific velocity to the vehicle and takes it to a certain height. Once the fuel in this first stage is exhausted, the empty fuel tank and the engine are detached from the main body of the vehicle and fall either into a sea or on an unpopulated land. As the fuel in the first stage is exhausted, the fuel in the second stage is ignited. However, the vehicle now contains only one (i.e. the second) stage. The weight now being reduced, the vehicle can move with higher speed. Almost all vehicles are made of either two or more stages. As an example, the structure of a Polar Satellite Launch Vehicle (PSLV) developed by ISRO of India is shown in fig 10.5a.



10.5 a. Structure of PSLV made by ISRO



10.5 b. Space shuttle

The launch vehicles are costly, because they can be used only once. USA has, therefore, developed space shuttle (fig 10.5b) which returns to the earth except for the fuel tank and can be reused in multiple launches.

Always Remember

The 'rocket', a type of fire-cracker used in Diwali, is also a sort of launcher. In this rocket, the fuel is ignited using a fuse and the rocket is projected into the sky just like a satellite launcher. Similarly, if a balloon is blown and released with its end open, the air in the balloon is forcefully ejected and the balloon is pushed in opposite direction. This can be explained using the Newton's third law of motion.

Space missions away from earth

As we have seen above, artificial satellites are being used for making our life more and more enriched. However, in the previous standard, we have learnt about how the telescopes aboard artificial satellites are used to gather information about various objects in the universe. Similarly some space missions are used to gain further knowledge about the universe. In these missions, spacecrafts are sent to the nearby objects in the solar system to observe them more closely. New information has been obtained from such missions and it is helping us to understand the creation and evolution of our solar system.

For such missions, the spacecrafts must escape the earth's gravitational force to travel into the outer space. To achieve this, the initial velocity of the moving object must be greater than the escape velocity of the earth as we have learnt in the Chapter on Gravity. Escape velocity on a planet can be obtained using following formula:

$$v_{esc} = \sqrt{\frac{2GM}{R}}$$

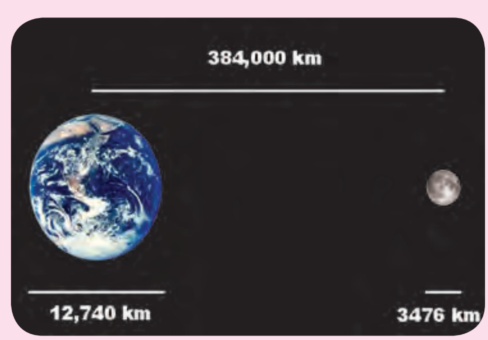
G = Gravitational constant = 6.67×10^{-11} N m^2/kg^2
M = mass of the planet = 6×10^{24} kg (for earth)
R = Radius of the planet = 6.4×10^6 m (for earth)

$$v_{esc} = \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 6 \times 10^{24}}{6.4 \times 10^6}} = 11.18 \times 10^3 \text{ m/s} = 11.18 \text{ km/s}$$

Thus, if a spacecraft is to escape the earth's gravitational force to travel to the outer space, it must have minimum velocity of 11.2 km/s.

Do you know ?

The astronomical object closest to us is the moon. Light takes 1s to reach from moon to the earth. It means that if we travel with the speed of light, it will take 1s to reach the moon. However, since a spacecraft travels at much smaller speed, it takes longer time to reach the moon. The shortest time taken by a spacecraft to reach the moon, so far, is 8 hours and 36 minutes.



Moon missions

Since the moon is the closest astronomical object to us, the first space missions to objects in the solar system were the missions to the moon. Such missions have so far been executed by USA, Soviet Union, European countries, China, Japan and India. The space crafts in the Luna series sent by Soviet Union reached near the moon. Luna 2, launched in 1959 was first such craft. After that, till 1975, 15 space crafts made chemical analysis of the moon and also measured its gravity, density and radiations. Last four crafts even landed on the moon and brought the samples of stones on the moon for analysis in the laboratories. All these missions were unmanned.

America also executed moon missions from 1962 to 1972. The specialty of these missions was that some of these were manned missions. In July, 1969, Neil Armstrong became the first human to step on the moon. In 2008, Indian Space Research Organization (ISRO) successfully launched Chandrayaan- 1 and placed it an into an orbit around the moon. It sent useful information to earth for about a year. The most important discovery made during the mission was the presence of water on the moon surface. India was the first country to discover this.

Mars missions

Next to the moon, the astronomical object nearest to the earth is the Mars. Many nations sent space crafts to the Mars. Mars mission is difficult and almost half the missions were unsuccessful. However, ISRO's performance in this mission is remarkable and we all must be proud of it. The spacecraft '*Mangalyaan*' made by ISRO using minimum expenses was launched in November, 2013 and was placed into orbit around the Mars in September, 2014. It obtained very useful information about the surface of the Mars and the atmosphere around it.

Rakesh Sharma

Rakesh Sharma was the first Indian to travel to space. He went into space along with two Russian astronauts under the joint Indo - USSR space programme. He stayed in space for 8 days.

Kalpana Chawla

Kalpana Chawla obtained her Engineering in Aeronautics degree from Punjab and in 1988 obtained her doctorate from University of Colorado. She was in space for 336 hrs during research mission. While returning to earth from space, on 1st February, 2003, the Columbia space craft exploded and Kalpana perished.

Sunita Williams

Sunita Williams travelled to the international space station in space shuttle Discovery in 2006. She worked for 29 hrs outside the space station. She created a record by staying for 192 days in space.

Missions to other planets

Many missions have been executed to study other planets also. In some of these missions the space crafts orbited the planets, some landed on the planets and some just passed near the planet and observed them. Additionally, spacecrafts have been sent to observe asteroids and comets and they have successfully collected some dust and stones from the asteroids and brought them back on the earth. We are getting very useful information from all these missions clarifying our concepts about the origin and evolution of the solar system.

India and space technology

India also has made remarkable progress in the science and technology of launch vehicles. Various types of launch vehicles have been developed to put satellites having weight up to 2500 kg, into all types of orbits. PSLV and GSLV are two important launchers. The scientific and technological feats achieved by India in this field have a significant contribution to the national and social development. INSAT and GSAT satellite series is actively working in the field of telecommunication, television broadcasting and meteorological services. Availability of television, telephone and internet services all over the nation has been possible due to these satellites only. EDUSAT satellite in this series is used specially in the field of education. IRS satellite series is working for monitoring and management of natural resources and disaster management. To exactly locate position of any place on the earth's surface in terms of its precise latitude and longitude, the IRNSS satellite series has been established.

Read about:

Satellite Launch Centers:
1. Thumba, Thiruvanathapuram
2. Sriharikota
3. Chandipur, Odisha

Space Research Organizations:
1. Vikram Sarabhai Space Center, Thiruvanathapuram
2. Satish Dhavan Space Research Center, Sriharikota
3. Space Application Center, Ahmedabad

Introduction to scientists

Vikram Sarabhai is considered as the father of Indian space program. His efforts led to foundation of Physical Research Laboratory (PRL) at Ahmedabad. In 1962, Indian government constituted 'Indian National Committee for Space Research' under his Chairmanship and first satellite launch center was established at Thumba in 1963. The launching of India's first satellite 'Aryabhatta' into the space, was the result of his efforts. He played an important role in the establishment of Indian Space Research Organization (ISRO).

Space Debris and its management

In addition to the artificial satellite, some other objects are also revolving around the earth. It includes, non-functional satellites, parts of the launcher detached during launching and debris generated due to collision of satellite with other satellite or any other object in the space. According to one estimation made in 2016, there are about 2 crore pieces of length more than 1 cm, revolving around the earth! All this is nothing but the debris in space.

This debris can be harmful to the artificial satellites. It can collide with these satellites or space crafts and damage them. This debris is increasing day by day. Soon, it will be difficult to launch new spacecrafts. It is, therefore, very essential to manage the debris. Some studies and experiments are being done with this in view. Hope that soon we will have a solution for this problem and the future satellites and spacecrafts will not be in danger any more.

Books are my friends: For more information read the reference books in your library.

1. Space and science - Dr. J V Narlikar.
2. Story of ISRO - Dr. V. R. Gowarikar.

Exercise

1. **Fill in the blanks and explain the statements with reasoning:**

   a. If the height of the orbit of a satellite from the earth surface is increased, the tangential velocity of the satellite will …

   b. The initial velocity (during launching) of the Managalyaan, must be greater than …………..of the earth.

2. **State with reasons whether the following sentences are true or false**

   a. If a spacecraft has to be sent away from the influence of earth's gravitational field, its velocity must be less than the escape velocity.

   b. The escape velocity on the moon is less than that on the earth.

   d. A satellite needs a specific velocity to revolve in a specific orbit.

   e. If the height of the orbit of a satellite increases, its velocity must also increase.

3. **Answer the following questions:**

   a. What is meant by an artificial satellite? How are the satellites classified based on their functions?

   b. What is meant by the orbit of a satellite? On what basis and how are the orbits of artificial satellites classified?

   c. Why are geostationary satellites not useful for studies of polar regions?

   d. What is meant by satellite launch vehicles? Explain a satellite launch vehicle developed by ISRO with the help of a schematic diagram.

   e. Why it is beneficial to use satellite launch vehicles made of more than one stage?

4. **Complete the following table.**

IRNSS		
	Weather study & predict	
		Earth's observation

5. **Solve the following problems.**

   a. If mass of a planet is eight times the mass of the earth and its radius is twice the radius of the earth, what will be the escape velocity for that planet?

   Ans : 22.4 km/s

   b. How much time a satellite in an orbit at height 35780 km above earth's surface would take, if the mass of the earth would have been four times its original mass?

   Ans : ~ 12 hrs

   c. If the height of a satellite completing one revolution around the earth in T seconds is h_1 meter, then what would be the height of a satellite taking $2\sqrt{2}\,T$ seconds for one revolution?

   Ans : $R + 2h_1$

Project :

1. Collect information about the space missions undertaken by Sunita Williams.
2. Assume that you are interviewing Sunita Williams. Prepare a questionnaire and also the answers.

I2JX89

amphibian – उभयचर
annual – वार्षिक
appendicular skeleton – उपांग सांगाडा
aquatic – जलचर
asteroids – लघुग्रह
autotrophic – स्वयंपोषी
axial skeleton – अक्षीय सांगाडा
balanced diet – संतुलित आहार
ball and socket joint – उखळीचा सांधा
bar magnet – पट्‌टी चुंबक
biennial – द्‌विवार्षिक
blood vessel – रक्तवाहिनी
boiling – उत्कलन
boiling point – उत्कलनांक
brittleness – ठिसूळपणा
cartilage – कूर्चा
cellular structure – पेशीमय रचना
chemical energy – रासायनिक ऊर्जा
circular motion – वर्तुळाकार गती
comet – धूमकेतू
complex machine – गुंतागुंतीचे यंत्र
compound leaf – संयुक्त पान
condensation – संघनन
conventional resource of energy – पारंपरिक ऊर्जा साधन
deficiency diseases – अभावजन्य आजार
density – घनता
dermis – त्वचा
disaster – आपत्ती
displacement – विस्थापन
ductility – तन्यता
elasticity – स्थितिस्थापकता
electric energy – विद्‌युत ऊर्जा
electrical conductivity – विद्‌युतवाहकता
electrostatic force – स्थितिक विद्‌युत बल
epidermis – बाह्यत्वचा
excretion – उत्सर्जन
fat, fatty subtance – स्निग्ध पदार्थ
fibrous – तंतुमय
first aid – प्रथमोपचार
fluidity – प्रवाहिता
food adulteration – अन्नभेसळ
force – बल
freezing point – गोठणांक (गोठणबिंदू)
frictional force – घर्षण बल
fulcrum – टेकू
funnel – नसराळे
galaxy – दीर्घिका
gravitational force – गुरुत्वाकर्षण बल
groundwater – भूजल
hardness – कठीणपणा
heterotrophic – परपोषी
hinge joint – बिजागरीचा सांधा
horseshoe magnet – नालाकृती चुंबक
humus – कुथित मृदा
immovable joint – अचल सांधा
inclined plane – उतरण
inert gas – निष्क्रिय वायू
insectivorous – कीटकभक्षी
invertebrate – अपृष्ठवंशीय
joint – सांधा
kinetic energy – गतिज ऊर्जा
lever – तरफ
lifespan – आयुर्मान
linear motion – रेषीय गती
load – भार
lustre – चकाकी
magnetic field – चुंबकीय क्षेत्र
magnetic force – चुंबकीय बल
magnetic substance – चुंबकीय पदार्थ
magnetism – चुंबकत्व
malleability – वर्धनीयता

malnutrition – कुपोषण
mechanical energy – यांत्रिक ऊर्जा
melting – विलयन
melting point – विलयबिंदू
meteor – उल्का
meteorite – अशनी
Milky Way, the – आकाशगंगा
minerals – खनिजे
motion – गती
movable joint – चल सांधा
multicellular – बहुपेशीय
natural substance – नैसर्गिक पदार्थ
nebula – तेजोमेघ
non-conventional energy resource– अपारंपरिक ऊर्जा साधन
nutrients – पोषकतत्त्वे
oscillatory motion – आंदोलित गती
oviparous – अंडज
perennial – बहुवार्षिक
periodic motion – नियतकालिक गती
Pole Star – ध्रुव तारा
potential energy – स्थितिज ऊर्जा
prism – लोलक
propagation of sound – ध्वनिप्रसारण
proteins – प्रथिने
pulley – कप्पी
random motion – यादृच्छिक गती
reflection of light – प्रकाशाचे परावर्तन
reproduction – पुनरुत्पादन/प्रजनन
satellite – उपग्रह
sensory organ – ज्ञानेंद्रिय
shadow formation – छायानिर्मिती
simple machine – साधे यंत्र
Sirius – व्याध तारा
skeletal system – अस्थिसंस्था
skull – कवटी
solubility – विद्राव्यता
states of substances – पदार्थांच्या अवस्था
sterile – निर्जंतुक
sternum – उरोस्थि
sublimation – संप्लवन
sunstroke – उष्माघात
taproot – सोटमूळ
terrestrial – भूचर
thermal conductivity – उष्णतावाहकता
transparency – पारदर्शकता
unicellular – एकपेशीय
uniform motion – एकसमान गती
universal solvent – वैश्विक विद्रावक
vacuum – निर्वात
variable star – रूपविकारी तारा
vertebral column – पाठीचा कणा
vertebrate – पृष्ठवंशीय
vibration – कंपन
viviparous – जरायुज
vocal cord – ध्वनितंतू
volume – आकारमान
weathering – अपक्षय
wedge – पाचर
worm – कृमी