10. Space Missions

- Space Missions
- Classification of artificial satellites
- Satellite launch vehicles
- Artificial satellites
- Orbits of artificial satellites
- 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 ?

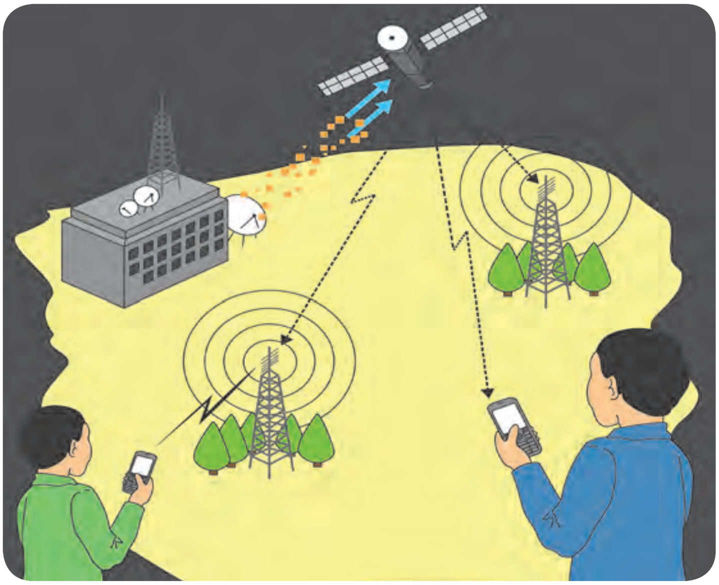
The first person to go into the space in a spacecraft was Yuri Gagarin of the then USSR. He orbited the earth in 1961. The first person to step on the Moon (1969) was Neil Armstrong of USA. Rakesh Sharma of India orbited the earth in 1984 in a Russian spacecraft. Kalpana Chawla and Sunita Williams of 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:

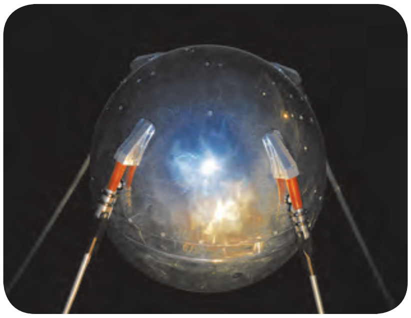
The world has become a global village due to space missions. Today, we can contact a person in any part of the world within a second. We can gather information about worldwide events sitting at home. You all know the importance of internet. Due to internet, every information is available at our fingertips.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

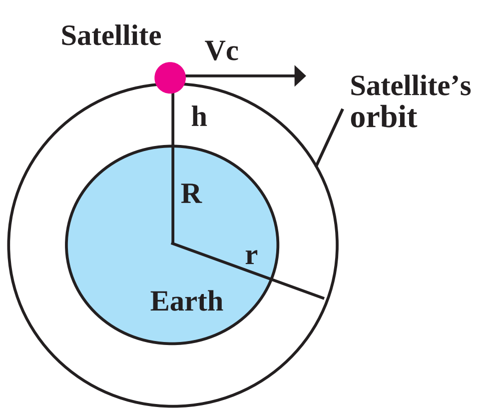
Watch and share with others
1.https://youtu.be/cuqYLHaLB5M
2. https://youtu.be/y37iHU0jK4s

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.

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

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

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

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)

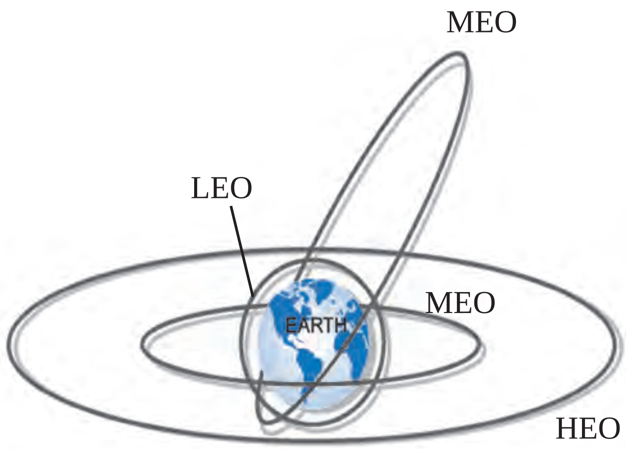
If the height of the satellite orbit above the earth's surface is in between 2000 km and 35780 km, the orbits are called medium earth orbits. The geostationary satellites orbit above the equator. These are, therefore, not useful in the study of polar regions. For this purpose, elliptical medium earth 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) = 6.4×10^6 m ,
h = height of the satellite above the earth's surface 35780 km.
v = ?
R + h = 6400 + 35780 = 42180×10^3 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:

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

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

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

$$= 86003.38 \text{ sec}$$

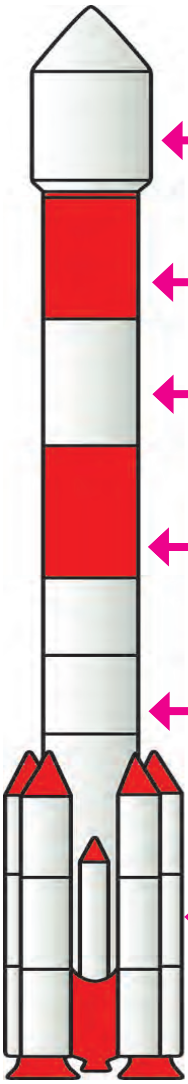
= 23.89 hrs. = 23 hrs 54 M.

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

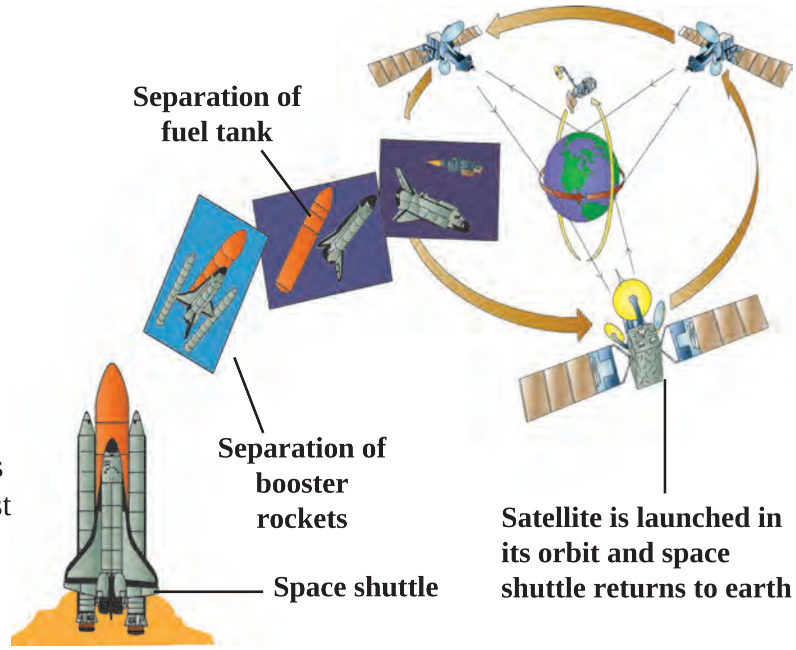
Satellite Launch Vehicles

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.

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