SPACE SCIENCE & TECHNOLOGY

The Supplementary Physics Textbook for Class IX & X

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Centre for School Curriculum Development
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“Your parents, relatives, and friends would be very proud of what you have achieved. At your age, to have completed your studies is your personal accomplishment. Your knowledge and capabilities are a great asset for the nation. I congratulate you for your achievements.

Finally, your capabilities and predisposition towards hard work will invariably shape the future of Bhutan. You must work with integrity, you must keep learning, keep working hard, and you must have the audacity to dream big.”

- **His Majesty Jigme Khesar Namgyel Wangchuck**

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Advisors:

1. Karma Galay, Director General, Department of School Education, MoESD
2. Pem Tshering, Chief, School Curriculum Division, Department of School Education, MoESD

Research and Writing:

1. Phuntsho Norbu, Curriculum Developer, SCD, DSE, MoESD
2. Bhoj Raj Rai, Curriculum Specialist, SCD, DSE, MoESD
3. Karma Dorji, Curriculum Developer, SCD, DSE, MoESD
4. Wangchuk, Science Curriculum Developer, SCD, DSE, MoESD, Thimphu
5. Tobgay, CD, SCD, DSE, MoESD, Thimphu
6. Thinley Namgyel, Teacher, Loselling MSS, Thimthrom
7. Damcho Wangchuk, Teacher, Bajothang HSS, Wangdue
8. Yeshi Choden, Space Engineer, GovTech, Thimphu
9. Lhaten, Teacher, Chumey HSS, Bumthang
10. Sonam Tenzin, Teacher, Gaselo HSS, Wangdue
11. Kinga Choedrup, Teacher, Kuzukchen MSS, Thimphu
12. Sonam Wangchuk, Teacher, Jakar HSS, Bumthang
13. Dr. Pooja Lepcha, Space Engineer, GovTech, Thimphu
14. Chhophela, Teacher, Damphu CS, Tsirang
15. Tandin Wangmo, Teacher, Babesa HSS, Thimthrom
16. Sonam Choden, Teacher, Yangchen Gatshel HSS, Thimphu

Review and Writing:

1. Phuntsho Norbu, CD, SCD, DSE, MoESD, Thimphu
2. Bhoj Raj Rai, CS, SCD, DSE, MoESD, Thimphu
3. Karma Dorji, CD, SCD, DSE, MoESD, Thimphu
4. Thinley Namgyel, Teacher, Loselling MSS, Thimthrom
5. Damcho Wangchuk, Teacher, Bajothang HSS, Wangdue

6. Ugyen Dorji, Teacher, Babesa HSS, Thimthrom
7. Phuntsho, Teacher, Samtengang CS, Wangdue
8. Lhaten, Teacher, Chumey HSS, Bumthang
9. Dr. Pooja Lepcha, Space Engineer, GovTech, Thimph
10. Yeshi Choden, Space Engineer, GovTech, Thimphu
11. Dechen Peldon, Teacher, Drukgyel HSS, Paro
12. Shankar Lal Dahal, Principal, Bajothang HSS, Wangdue
13. Chimi Yuden, Teacher, Dekiling MSS, Sarpang
14. Nado, Teacher, Dashiding HSS, Punakha

FOREWORD

Bhutanese science education system has come a long way. Guided by the noble vision of His Majesty The King and the philosophical foundations of 21st century educational paradigms, Bhutanese science education system is making continuous progress. Bhutanese science education system has undergone many reforms such as refinement of, and changes to theories, ideas, and beliefs over time. Therefore, the current Bhutanese science curriculum is a product of years of initiatives undertaken over the past several decades.

As the world today is confronted with multitude of real-world issues, there is a grand call to upscale and enhance the relevancy of education in itself. As far as the Ministry of Education and Skills Development (MoESD) is concerned, Bhutanese education system cannot afford to sit back and wait for the optimal time and space to come. The MoESD is, therefore, in full pursuit to diversify and enhance the relevancy of the science curriculum. This is no exception with classes 9 to 12 physics curriculum.

Today, as evident in the curriculum, the MoESD as never before, endeavours to bring in space technology as the new elements of science. While it may not be new, perhaps, it is largely motivated, in part, by a general consensus around the notion to upscale learners' abilities in science and STEM particularly in the contexts of space technology. At the heart, such notion stems from the view that engaging in scientific practices not only helps learners to acquire a robust understanding of space technology but also develops their scientific temper and scientific habits of mind. In addition, the book, both by and of itself, aspires to capture students' sense of wonder; pique interest; spark curiosity; or motivate them to remain constantly engaged in activities related to space technology.

As the book is first of its kind, especially in Bhutanese science education, I am quite confident that it will inherently serve as a springboard to further the quality of teaching and learning. Overall, I believe that the book, as it aspires, would certainly serve as a strong foundation of science education in equipping learners with the abilities to think critically, analyse information, and solve complex problems - the skills needed to pursue opportunities both within and beyond the STEM fields.

Karma Galay
(Director General)

INTRODUCTION

Science education in Bhutan was largely started with a curriculum adapted from other established education systems. By 1986, however, the Royal Government of Bhutan (RGoB) started to implement a localised science curriculum. Since then, science education in Bhutan witnessed a series of evolution, including the refinement of, and changes to, theories, ideas, and beliefs over time. The present classes 9 to 12 physics curriculum is, thus, shaped by numerous initiatives undertaken in the past several decades.

To further the quality and the relevancy of the classes 9 to 12 physics curriculum, the erstwhile Royal Education Council (REC) initiated a major reform since 2009. The curriculum reform, for the most part, was informed partly or wholly by the noble vision of His Majesty the King; and the contemporary approaches of the 21st century educational paradigms. As never experienced before, the curriculum reform then felt the urgency to strengthen the aspects of space technology in classes 9 to 12 physics curriculum. Thus, the erstwhile REC in collaboration with the Department of Information, Telecom, and Technology (DITT) endeavored to raise the standards of space technology in classes 9 to 12 physics curriculum.

Today, the classes 9 to 12 physics curriculum presents a range of concepts and skills on space science and technology. These broadly include but are not limited to the universe, space, satellites, and rockets. Simply put, space technology is directly aimed to enhance learners' scientific abilities, scientific habits of mind, or spirits and practices of STEM in making informed decisions, evaluating policy ma ers, or weighing over scientific pieces of evidence. Beyond this, however, the inclusion of space technology is generally aimed to capture students' interest and sense of wonder, pique curiosity, or encourage learners to remain increasingly involved in space science.

Drawn especially from the curricular intentions of the classes 9 to 12 physics curriculum, this supplementary textbook on space science and technology for key stage 4 (classes IX & X) is mainly focused on Moon and its astronomical nature, the deep space exploration of the Moon, and scientific laws and principles that needs to be considered while carrying out space exploration.

To dig deeper into the above said aspects of the book, it contains a blend of concepts and activities that require learners as to how to deepen or sophisticate their understanding. More importantly perhaps, the book contains many, if not, most activities that require technology to be used as means. For each activity or the chapter, the book contains follow-up questions and chapter-end questions that relate either directly with the concepts or just demand the application of concepts in a contextual scenario.

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CLASS IX

Exploring the Moon

THE MOON

Exploring outer space starts with understanding our closest celestial neighbor, the Moon. While sending humans to the Moon presents significant challenges and risks, space agencies are exploring cheaper and safer alternatives, such as autonomous vehicles and robotic missions. Past missions have revealed many insights about the Moon. However, to unlock its full potential and explore beyond our solar system, a moon base is necessary.

Establishing a permanent presence on the Moon would enable us to conduct more extensive research, experiments, possibly harvest resources and, most importantly, allow spacecraft transfer trajectory from the Moon to the orbits of other celestial bodies. However, constructing a self-sustaining habitat on the Moon requires significant planning, resources, and international cooperation.

Despite the challenges, a moon base represents an essential step towards humanity's pursuit of interplanetary exploration. Figure 1 shows one of the images of the Moon captured by the Galileo spacecraft. The spacecraft surveyed the Moon on December 7, 1992, while on its way to explore the Jupiter system in 1995 to 1997.

Figure 1 The Moon

1. Advancement of the Moon Exploration

Objective

- Explore evidence related to advancement in the Moon exploration.

Advancement of the Moon exploration has received significant attention in recent years, owing to new technologies and growing interest in space exploration. The Moon's potential for scientific research and space tourism has sparked a renewed focus on exploring it.

After the successful launch of NASA's Artemis I, the program is now focused on Artemis II, which is actively dedicated to lunar exploration with the ultimate objective of landing the first woman and the next man on the Moon. This endeavor involves the development of cutting-edge technologies like the Space Launch System rocket and Orion spacecraft, as well as collaboration with commercial companies for the advancement of lunar lander technology.

Private space companies such as SpaceX and Blue Origin have emerged as major players in the Moon exploration. These companies have been working on new technologies and capabilities for space travel and exploration, including reusable rockets and lunar landers. Figure 1.1 shows the Starship rocket of SpaceX.

Figure 1.1 The Starship spacecraft is stacked atop the Super Heavy rocket booster at the SpaceX launch site in Texas, USA

Figure 1.2 Apollo 11 Commander Neil Armstrong working at an equipment storage area on the lunar module.

As we look into the future, understanding the history of the Moon exploration helps us appreciate the remarkable achievements of human ingenuity, bravery, and determination. It reminds us of the audacity of the Apollo missions and the significant milestones they accomplished, including the first human on the Moon as shown in Figure 1.2.

Understanding the challenges overcome in the past is an inspiration to push the boundaries of exploration and expand the knowledge of the universe.

Activity 1: A Wacky Journey Through Lunar History

Let us make a journey through lunar history to understand more about the expedition attempted by humankind to the Moon and observe the significant events in the advancement of the Moon exploration, from the first landing to the present day.

Use the QR code or link https://shorturl.at/bcd12 to explore and complete the worksheet provided in Table 1.1

Table 1.1 Worksheet of lunar exploration time line

Year	Name of the mission	Significant event
1959		First spacecraft to reach the vicinity of the Moon, and the first spacecraft to be placed in heliocentric orbit.
2022	Artemis 1	
	Apollo 11	
	Lunar Reconnaissance Orbiter (LRO) and Lunar Crater Observation and Sensing Satellite (LCROSS)	The combined observations showed grains of water ice in the ejected material. The LRO and LCROSS findings added to a growing body of evidence that water exists on the Moon in the form of ice within permanently shadowed regions.
2019		India's second mission to the Moon. It comprised an Orbiter, Lander and Rover to explore the unexplored South Pole of the Moon. A group of students from Bhutan were invited to witness the launch of the lunar craft.

Questions

1. Which lunar mission do you consider to be significant, and what is the reason behind your choice?
2. What is the purpose of NASA's Artemis mission, and what sets Artemis I apart from Artemis II in terms of objectives?
3. How has the advancement of the Moon exploration progressed since 2019 with regards to Moon missions, and the missions that have taken place up to the most recent ones?

Fun Fact

"Apollo 13", a 1995 American space docudrama film, offers valuable insights into the challenges and experiences encountered during the historic Apollo 13 missions.

2. Physical and Chemical Properties of the Moon and Its Environment

Objective

- Describe the composition, position, and size of the Moon relative to the Earth.

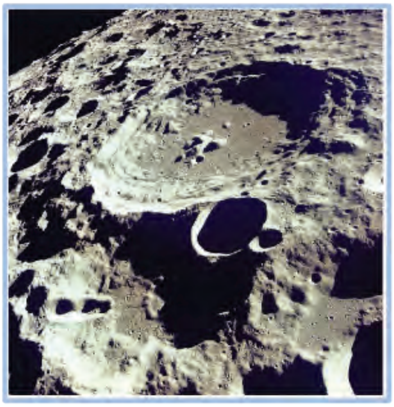


Figure 2.1 Heavily created lunar highlands. (credit: Apollo 11 Crew NASA).

Have you ever wondered what secrets lie beneath the dusty embrace of the lunar surface? Prior to the Luna, Surveyor, and Apollo soft landings on the Moon, many theories had been proposed regarding the lunar surface. One of the theories suggested that the craters were volcanic in origin and that the lunar surface was mostly lava and therefore very hard. Another popular theory suggested that the craters had been formed by meteorite impact.

The lunar surface is a captivating tapestry of highlands and lowlands that tell a story of the Moon's geological history. The highlands are heavily cratered, bearing the scars of all those billions of years of impacts by interplanetary debris as shown in Figure 2.1. Continuous meteoroid impact has converted the lunar surface materials into a well graded silty sand that has attained a "steady state" in thickness, particle size distribution, and other properties at most locations on the Moon as shown in Figure 2.2.

Figure 2.2 Three-inch square are of the lunar surface captured by the Apollo 35 stereo close-up camera during an Apollo 12 EVA

In contrast, the lowlands, referred to as the lunar maria, are vast plains of dark volcanic basalt. The maria are relatively flat compared to the highlands and contain fewer craters, indicating their younger age compared to the surrounding terrae.

A type of granite rich in aluminum and calcium minerals called anorthosite makes up the majority of the highlands. Basaltic lava flows, on the other hand, make up the lowlands.

Activity 2: An Expedition to Unveil the Lunar Surface

Get ready to dive deep into the captivating realms of the highlands and lowlands on the Moon's surface. Through hands-on exploration, we will unravel the secrets of these distinct lunar landscapes and the mysteries behind its diverse landforms.

What we need:

- Large tray (to represent the lunar surface)
- Modeling clay, paper pulp or playdough (in different colors)
- Stones or pebbles
- Fact sheets or reference materials about lunar highlands and lowlands
- Drawing materials (paper, pencils, colored pencils, etc.)

What to do:

1. Explore the Moon's surface and its unique features, with a focus on the highland and lowland regions and their importance for lunar exploration.
2. Create lunar landscapes using modeling clay or playdough, incorporating features representative of both highland and lowland regions.
3. Observe and explain the differences between highland and lowland regions in the model.

Questions

1. How is crater different from maria?
2. Why are highlands and lowlands crucial for lunar exploration?
3. How do lunar highlands and lowlands impact the visual appearance of the Moon?

2.1 How big is the Moon?

The Moon, Earth's brightest celestial object during the night, is relatively smaller compared to our home planet. According to NASA, it has a diameter that is less than one-third the width of the Earth.

Fun Fact

During the Apollo missions of the 1960s and 1970s, astronauts embarked on a round trip to the Moon that lasted three days each way, with their spacecraft attaining velocities of almost 40,000 km/h.

Activity 3: Mapping the Moon

Create detailed diagrams of the Moon and the Earth using different materials like clay, paper pulp or digital apps (Tinkercad, fusion 360, minecraft) focusing on their size, shape and position. Label accurate representations of their position, shape and size in space relative to oneanother.

Individually use a Venn diagram to compare and contrast the shape, size, and position of the Moon relative to the Earth after you have completed the above task.

Step into the 3D simulator to get the precise positioning of the Moon in relation to the Sun and the Earth on the specific day of your model creation.
https://shorturl.at/zGNU1

Questions

1. Compare the size of the Moon with the Earth.
2. How does the Moon's position in its orbit affect its visibility from the Earth?
3. Does the Moon's apparent size imply that it is the largest celestial object in space? Justify.

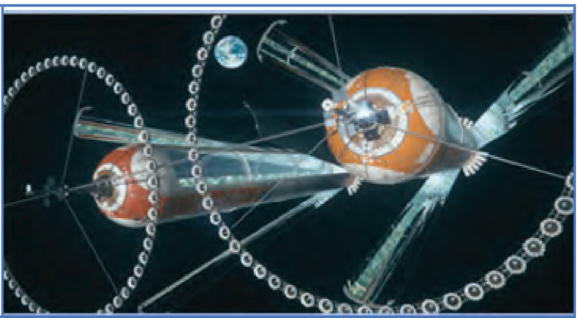
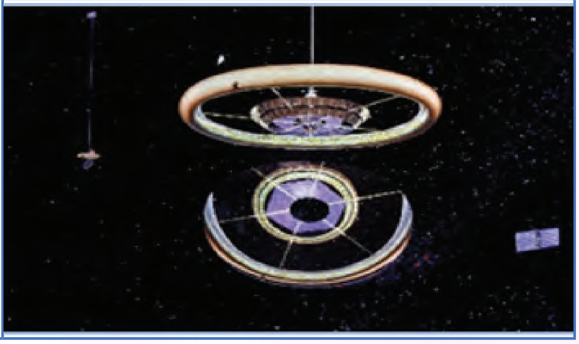
3. Impact of the Moon's Environment on Human Health and Survival on the Moon

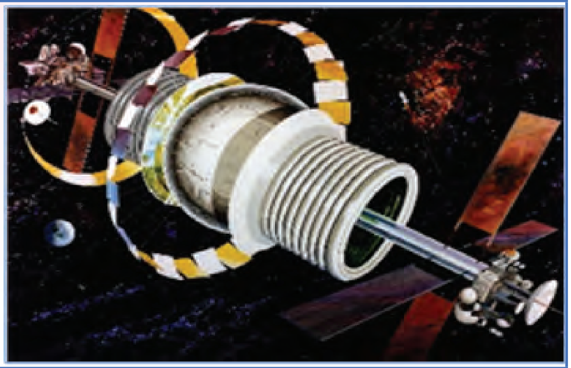
Objectives

- Explore the requirements for human survival on the Moon.
- Design physical or virtual prototype of any one of the items necessary for human survival on the Moon.

Human settlement on the Moon is an ambitious and exciting prospect that has captivated the imaginations of scientists, engineers, and space enthusiasts alike. Establishing a permanent human presence on the Moon would require overcoming numerous challenges, such as developing sustainable habitats, ensuring a steady supply of essential resources, and addressing the long-term effects of lunar conditions on human health. For example, protection from lunar dust: exposure to lunar dust has the potential to cause significant health effects, including respiratory, cardiopulmonary, ocular, or dermal harm, which could impact the performance of the crew during these missions.

Figure 3.1 illustrates the technological advancements bringing us closer to realizing the dream of a sustainable and thriving human settlement on the Moon, despite the challenges.

O'Neill Cylinder	
Standford Torus	

Bemal Sphere	

Activity 4: Journey to Lunar Survival

Embark on an exciting mission to design a settlement base on the Moon. Your challenge is to create a habitat that provides essential conditions for human survival and ensures the well-being of future lunar residents.

Explore more about the habitable conditions essential for human survival on the Moon using the link https://shorturl.at/mwGJX or QR code and carry out the following activity.

What we need:

- Tables, charts
- Pencil, sticky notes, paper

What to do:

- Set up a moonbase (in group).
- Identify and analyze the challenges that humans face in surviving on the Moon.
- Brainstorm potential solutions to the challenges.
- Create a prototype of a potential habitat structure for the Moon using the available resources.
- Display your design for feedback and comments.

Questions

1. Is life possible on the Moon? Why?
2. Which part of the design process did you find challenging? Why?
3. What are some of the possible solutions for creating a habitable environment on the Moon?

Activity 5: Test Your Lunar Survival Skills

Read the scenario given below and rank the survival items.

The Scenario

"You are a member of a space crew scheduled to rendezvous with a mother ship on the lighted surface of the Moon. However, due to mechanical difficulties, your own ship was forced to land at a spot 200 miles from the rendezvous point.

15 items are listed as being intact and undamaged after landing. Your task is to rank them in terms of their importance for your crew, to allow them to reach the rendezvous point. Place the number 1 by the most important item, the number 2 by the second most important, and so on through to number 15 for the least important."

What we need:

- Pen/pencil

What to do:

- Rank the items individually first using Table 3.1.
- Everyone gets together in a group(s) and ranks the items together.
- Read or display the answers and explanations to the group and have them score themselves. Their score will be a calculation of (1) For each time, find the difference in their ranking and the actual ranking (the positives and negatives don't matter) and (2) Sum those.
- The lower the total the better The Score!
- Compare your rankings with rankings from NASA experts using a link or QR code

https://www.csuchico.edu/anthmuseum/_assets/documents/nasa-exercise-survival-on-the-moon.pdf

Use the rating scale given below to check your survival rate after completing table 3.1.

0 - 25	Excellent! You and your crew demonstrate great survival skills!
26 - 32	Good. Above average results. You made it!
33 - 45	Average. It was a struggle, but you made it in the end!
46 - 55	Fair. You are still alive, but barely.
56 - 70	Poor. Unfortunately, not everyone made it back.
71+	Very Poor. It's a grim reality. Your team will spend eternity on the moon.

Table 3.1 Ranking Worksheet

Items	Individual rank	Group rank	NASA's Rank	Individual score	Group score
Box of matches					
Food concentrate					
Nylon rope					
Parachute silk					
Two pistols					
One case of dehydrated milk					
Stellar map (celestial map)					
Two tanks of oxygen.					
Self-inflating life raft					
Magnetic compass					
20 liters of water					
Signal flares					
First aid kits containing needles					
Portable heating unit					
Score					

Questions

1. After checking your survival rate, do you think you can survive on the Moon?
2. Which item did you choose as the most important for survival? Why?
3. Which item reigns supreme as the ultimate key to survival?

Fun Fact

The lunar south polar region refers to the southernmost area of the Moon's surface. Surprisingly, the lunar polar regions and the far side have remained unexplored.

4. Astronomical Instruments

Objective

- Explain the components and basic operation of different types of telescopes and design a prototype of a telescope.

What makes astronomy a significant field of study?

Astronomy allows us to explore and understand the vastness of the universe, expanding our knowledge of celestial objects such as stars, galaxies, and planets. It offers us a glimpse into the cosmic wonders that surround us.

What instrument or tool would you utilize to observe a celestial body? Telescopes are designed to collect and magnify light, enabling us to observe distant stars, planets, galaxies, and other astronomical wonders as shown in Figure 5.1 .

Figure 4.1 Telescope

Telescopes come in various types, each with its own unique design and purpose:

a. Refractor Telescope

Refractor telescope employs a lens system to gather and focus light as shown in Figure 4.2.

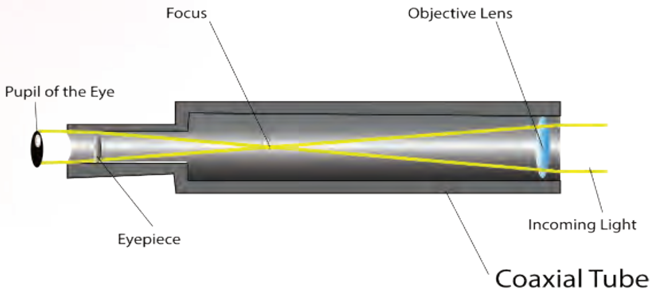


Figure 4.2 Refracting Telescope

b. Reflector Telescope

Reflector telescope uses a curved mirror as the primary light-gathering element as shown in Figure 4.3.

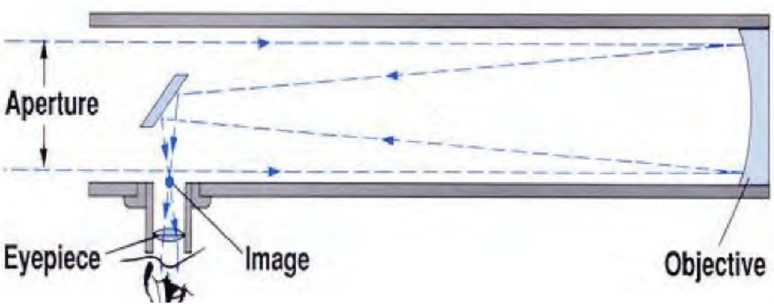


Figure 4.3 Reflecting Telescope

c. Catadioptric Telescope

Catadioptric telescope combines elements of both refractor and reflector designs as shown in Figure 4.4.

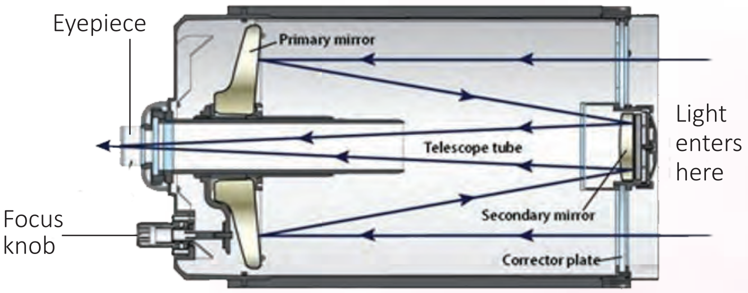


Figure 4.4 Catadioptric Telescope

d. James Webb Telescope

The James Webb Space Telescope (JWST) is the largest and most powerful space science telescope ever built as shown in Figure 4.5.

It can observe all of the cosmos, from planets to stars to nebulae to galaxies and beyond – helping scientists uncover secrets of the distant universe as well as exoplanets closer to home. Webb can explore our own solar system's residents with exquisite new detail and search for faint signals from the first galaxies ever made.

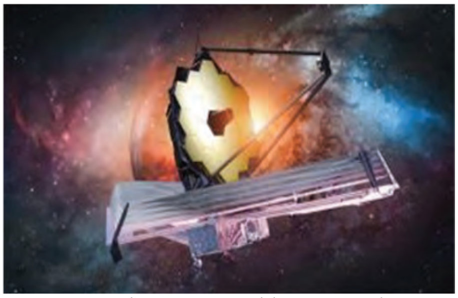


Figure 4.5 The James Webb Space Telescopre (Image credit: dima_zel via Getty Images)

Activity 6: Building Your Own Telescope

Let's apply our knowledge by engaging in the exciting task of designing a telescope.

What we need:

- Two lenses with different focal lengths
- Paper towel roll
- 1 piece of paper or cardstock
- Tape

What to do:

- Read the guide on parts of the telescope using a link https://shorturl.at/DWZ06.
- Roll up the sheet of paper or cardstock the long way to form a tube that is about the diameter of the lens with the shortest focal length. This will be the eyepiece.
- Tape the edges of the eyepiece lens to one end of the tube as neatly as possible.
- Tape the second lens neatly to the end of the paper towel tube.

- Insert the empty end of the paper tube into the cardboard tube. Now your telescope is ready to be used!
- Look through the eyepiece and point the other end of your telescope at a distant object. DO NOT look directly at the Sun.
- Slide the two tubes in and out until the object comes into focus. You will see the image upside down and magnified.

Questions

1. Why are different types of telescopes used to study the universe?
2. Which telescope have you designed in the above activity? Why?
3. How is a reflecting telescope different from a refracting telescope for observing distant celestial objects?

CHECK YOUR UNDERSTANDING

1. Read the question carefully and choose the correct option.

i. During what series of space missions did Armstrong and Aldrin land on the Moon?

A. Mercury
B. Gemini
C. Apollo
D. Skylab

ii. What was the name of the Apollo 11 lunar lander?

A. Eagle
B. Enterprise
C. Bounty
D. Beag

iii. The reason why the maria are considered younger than the highlands is because

A. they exhibit a higher number of craters compared to the highlands.
B. they were formed through lava flows that occurred subsequent to the initial formation of the highlands.
C. highlands are characterized by their taller and brighter features, indicating their formation prior to the maria.
D. they are formed by relatively more recent volcanic activity on the Earth's

surface.

iv. The best evidence that the distance between the Moon and the Earth varies is provided by the apparent change in the Moon's

A. phase.
B. altitude.
C. shape.
D. diameter.

v. Which one of the following statements about telescopes is true?

A. Refracting telescopes use lenses to focus light.
B. Reflecting telescopes use a mirror to magnify images.
C. Catadioptric telescopes are only used to observe radio waves.
D. Telescopes are only used to observe objects within our solar system.

2. State whether the following statements are 'True' or 'False'.

Statement	True/False
Footprints and tyre tracks that have been left behind by astronauts on the moon will stay there forever.	
Buzz Aldrin was the first man to step onto the Moon's surface.	
Neil Armstrong and Buzz Aldrin a empted to play golf on the Moon.	
The Moon is expanding.	
The Moon is completely silent.	

3. Answer the following questions.

i. What would happen if there was no Moon? How does the Moon affect Earth?
ii. How does the Moon's composition differ from the Earth? And how do these differences help us to understand the formation of the lunar surface?
iii. Distinguish the highland and lowland regions on the Moon's surface and mention why it is essential to study.
iv. How can we create a sense of psychological well-being and social connectivity for individuals living in isolation on the Moon?
v. What makes a catadioptric telescope different from both refracting and reflecting telescopes?

CLASS X

Understanding Space Exploration

SPACE EXPLORATION

Space exploration relies on the law of universal gravitation, formulated by Newton, to understand and predict the movements of celestial bodies. Newton's law states that the force between two bodies depends on their masses and the distance between them. Gravity is a force that affects everything and keeps us on the ground. Gravitational force also shapes the formation and evolution of the universe. This knowledge allows scientists to calculate launch trajectories, use gravitational assists, and explore phenomena like black holes.

The dream of space exploration was realized in 1969 when humans first landed on the Moon. Since then, missions have been sent to explore other celestial bodies. The search for extraterrestrial life and habitable planets serves as a driving force behind advancements in space exploration, leading to new discoveries and an expanded understanding of the cosmos.

Figure 1 Space exploration

1. Universal Law of Gravitation

Objective

- Explain the law of universal gravitation using the formula.

The moon orbits around the Earth due to the gravitational force of a raction between them as shown in Figure 1.1. Which mass will a ract the other mass with greater force?

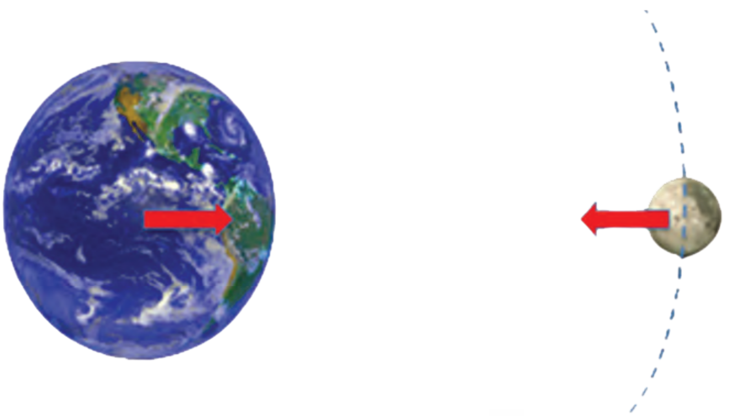
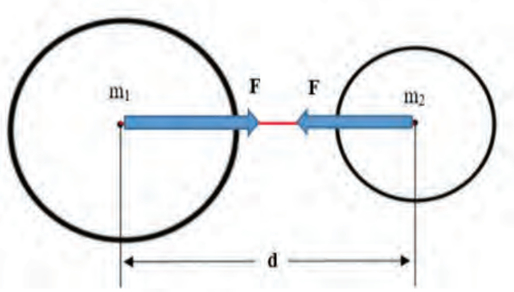


Figure 1.1 Gravitational force between two bodies

The Universal law of gravitation states that “every particle in the universe a racts every other particle in the universe with the force that is proportional to the product of their masses and inversely proportional to the square of the distance between the particles". The force acts along the line joining the centers of the objects.

The formula of gravitational force is shown in Figure 1.2. Here, G is the Universal gravitational constant = 6.673×10^{-11} Nm^2kg^{-2}, F is the force of gravity, m_1 and m_2 are the masses of the two objects, and d is the distance between the centers of the objects.



$$F \propto \frac{m_1 m_2}{d^2}$$

$$F = G\frac{m_1 m_2}{d^2}$$

Figure 1.2 Formula of gravitional force

Activity 1: Investigating relationship between gravitational force and mass

The gravitational force between two bodies depends on the mass of the bodies.

Use the cases given in Figure 1.3 to calculate the gravitational force and complete Table 1.1.

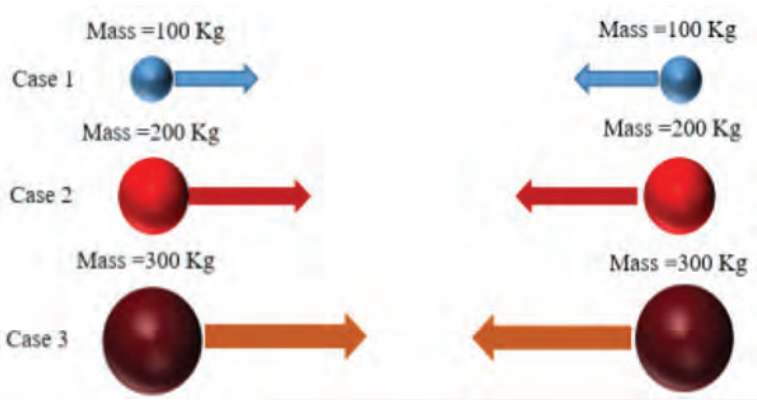


Figure 1.3 The gravitional force between two objects of varied mases

Table 1.1 Different cases related to force and mass

	Mass (m_1) (kg)	Mass (m_2) (kg)	Product of masses (m_1 x m_2) (kg^2)	Distance (d) (m)	Gravitational Force (Fg) (N) $Fg = G\frac{m_1 m_2}{d}$
Case 1				4	
Case 2				4	
Case 3				4	

Questions

1. What can you conclude about the force of gravity between two bodies if we:
    a. double the masses of both the objects?
    b. half the masses of both the objects?

2. What conclusion can you draw from the activity?

Activity 2: Investigating relationship between gravitational force and distance

The gravitational force between two bodies depends on the distance between them. Complete Table 1.2 for each case using the given Figure 1.4.

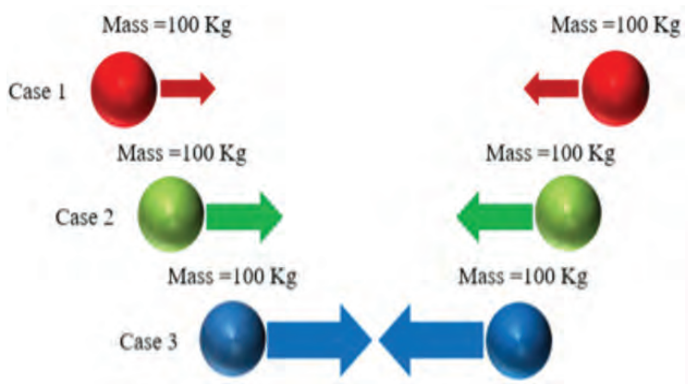


Figure 1.4 The gravitional force between two objects t different distances

Table 1.2 Different cases related to force and distance.

	Mass (m_1) (kg)	Mass (m_2) (kg)	Product of masses (m_1 x m_2) (kg^2)	Distance (d) (m)	Gravitational Force (Fg) (N) $Fg= G \frac{m_1 m_2}{d}$
Case 1				4	
Case 2				3	
Case 3				2	

Question

1. What can you conclude about the force of gravity between two bodies if we:
    a. double the distance?
    b. half the distance between the two bodies?
2. What can you conclude from the activity?
3. Verify the relationship amongst gravitational force, mass and the based on the data in Table 1.1 and Table 1.2 using the link https://tinyurl.com/2p87ch37 OR using OR code.

Fun Fact

Newton's curiosity about the apple's descent ultimately sparked his groundbreaking exploration into the nature of gravity and the formulation of the universal law of gravitation.

2. Evolution of Universe, Star, Solar System and Planet

Objective

- Communicate scientific and technical information about the evolution of the universe, solar system, planets, and stars.

2.1 Evolution of the Universe

Did you ever look up at the night sky and wonder how the universe came into existence?

There are several theories about the formation of the universe. However, according to the standard model of cosmology, the most widely accepted one is the Big Bang theory. The theory states that the universe began around 13.8 billion years ago as a single point of infinite density and temperature, also known as a singularity. This point contained all the ma er and energy that would eventually form the entire universe. After the Big Bang, the universe began to rapidly expand and cool down as shown in Figure 2.1.

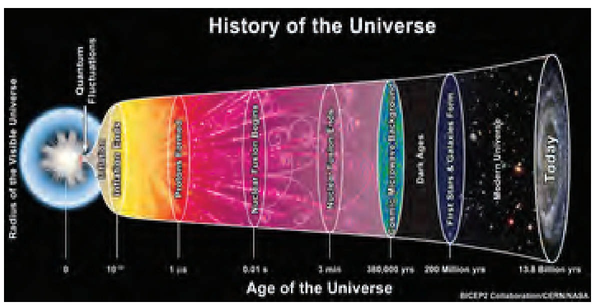


Figure 2.1 Timeline of the Universe

The part of the universe of which we have knowledge of is called the observable universe. It is evident from studies and observations that the expansion and cooling of the universe continues. When a celestial body moves away from us, the light emitted from it is shifted to the red end of the spectrum or redshifted as shown in Figure 2.2. When a celestial body moves closer to us, the light is shifted to the blue end of the spectrum or blueshifted.

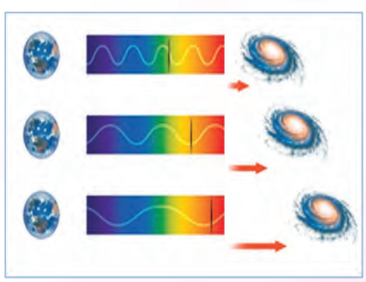


Figure 2.2 Reddhit

The light emitted by the galaxies is redshifted showing that the universe is continuously expanding.

Cosmic Microwave Background (CMB) is a type of electromagnetic radiation that fills the entire universe and is thought to be the residual heat left over from the Big Bang. The characteristics of the CMB such as its uniform temperature and radiation in all directions provide important clues about age and composition of the early universe.

Accounts of creation and the end of the universe have always been complex and controversial. Cosmologists have postulated potential endings to the universe as follows:

1. **The Big Freeze:** Continuous expansion leads to a cold and black universe as all sources of energy cool and fade, making life and processes impossible.
2. **The Big Crunch:** Overwhelming gravity causes the universe to collapse, resulting in a hot and dense state similar to the early cosmos.
3. **The Big Rip**: Accelerating expansion tears apart galaxies, stars, and even particles, eventually destroying the fabric of space itself.
4. **Vacuum Decay or Big Slurp:** If the universe transitions to a lower energy state, a destructive bubble of vacuum could form and rapidly expand, annihilating everything in its path.
5. **Big Bounce:** The universe undergoes cycles of expansion and contraction, with each contraction leading to a "bounce" and a new phase of expansion.

Activity 3: Expansion of the Universe

What we need:

- Paper
- marker
- ruler

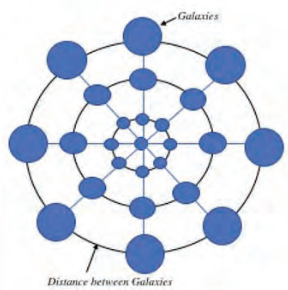


Figure 2.3 Expansion and cooling of Universe

What to do?

1. Mark a dot in the center of the paper representing the singularity that existed before the Big Bang and lines radiating out from the center in all directions.
2. Draw circles with varying radii from the fixed center as shown in Figure 2.3.
3. Mark with dots at the intersection of lines and circles to represent galaxies.

4. Measure the distance between two dots of the same circle on adjacent lines.

Questions

1. What happens to the distance between the dots on different lines as the radius of the circle increases?
2. As the dots move further from the center what does it indicate?

Activity 4: Representing Expansion of the Universe

What we need:

- balloon
- marker pen

What to do?

1. Mark dots on the balloon as shown in Figure 2.4.
2. Inflate the balloon slightly and measure the distance between the dots.
3. Inflate furthermore and measure the distance again

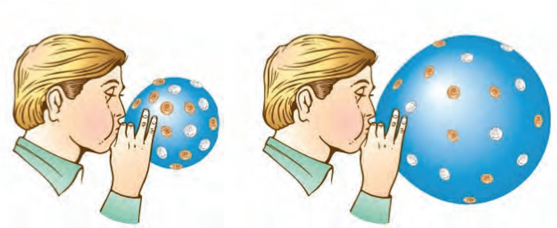


Figure 2.4 Expansion of Universe

Questions

1. What happens to the distance between the dots as you inflate the balloons as shown in Figure 2.4?
2. Construct an explanation related to expansion of the universe based on your observation?

2.2 Birth and Death of Star

Similar to the life cycle of living organisms, the birth, evolution, and eventual decline of a star occur. The formation of a star is an intricate and captivating process that unfolds through multiple stages, each playing a vital role in shaping its ultimate destiny.
Starting from immense clouds of gas and dust, the journey towards the emergence of a new star is a remarkable event in the cosmos. Figure 2.5 depicts the path from the initial stages to the birth of a celestial entity that will shine brightly in the night sky.

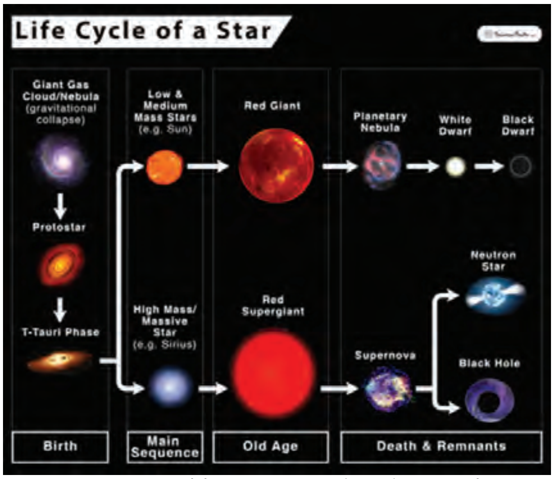


Figure 2.5 Stages of formation and evalution of stars

Dying Stars: Formation of Black Holes

It is a great amount of ma er packed into a very small area - a star ten times more massive than the Sun squeezed into a sphere. When a massive star dies in a supernova explosion, it leaves behind a small, dense remnant core as shown in Figure 2.6. This results in a gravitational field so strong that nothing, not even light, can escape.

Gradually it will draw all other ma er nearby in a process known as accretion which leads to collapsing under the influence of gravity. For example, if a normal star passes close to a black hole, it can tear the star apart as it pulls it toward itself.

Figure 2.6 Image of black hole

Activity 5: Identifying the Stages of a Star

Study the life of a star in Figure 2.7 and assign sequential numbers to the images reflecting the progression from the initial stages to the eventual conclusion of a star's life span in Table 1.3. Briefly describe what stage in the life span of a star is represented in each image and answer the following questions.

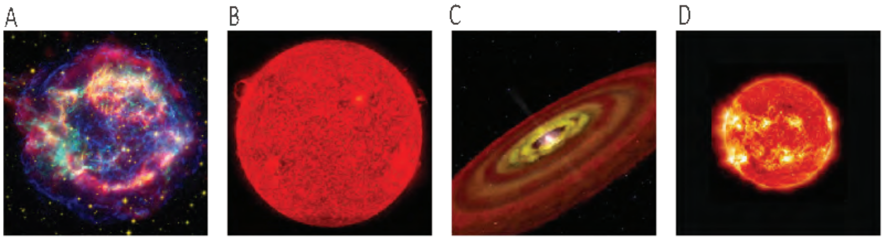


Figure 2.7 Life of Star

Table 1.3 Worksheet

Sl no.	Stage	Descriptions
1		
2		
3		
4		

Questions

1. What are the distinctions between the protostar and T-Tauri stages of star formation?
2. Gravity plays a pivotal role in the overall process of star formation. How does gravity exert its influence on the formation of a protostar?
3. What is a supernova and how does it impact the universe on a broader scale?

Fun Fact

1. There are approximately 200-400 billion stars in our Milky Way Galaxy alone.

2. The light from stars takes millions of years to reach Earth, therefore when you look at the stars, you are literally looking back in time.

3. There is a maximum of 2,500 stars visible to the naked eye at any time in the night sky.

2.3 Solar System

If given the opportunity to explore the Solar System for human se lement other than the Earth, which destination would you prioritize and why?

The Solar System is located in an outer spiral arm of the Milky Way galaxy. The Solar System contains planets, numerous dwarf planets, asteroids, comets, and moons. Dwarf planets such as Pluto are bodies that are smaller than planets but larger than asteroids. Comets are icy bodies that also orbit the Sun, but have long tails that can be visible from the Earth when they get close enough to the Sun. Moons, also known as natural satellites, orbit around planets and dwarf planets as shown in Figure 2.8.

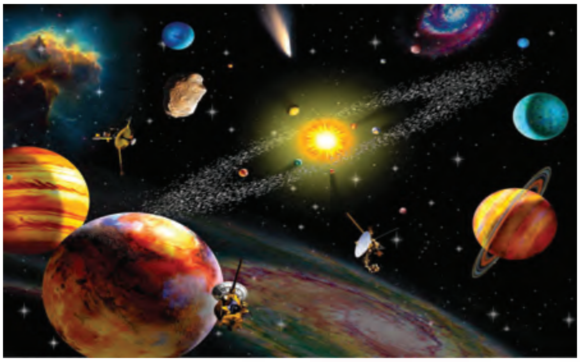
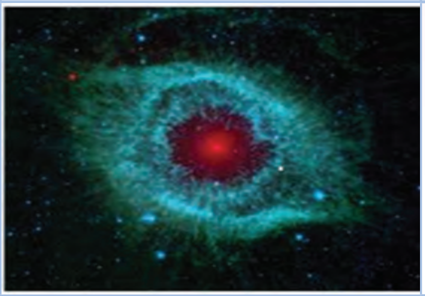


Figure 2.8 Image of Solar System

The Solar System is a vast and mysterious place waiting to be explored. The study of the formation of the Solar System offers insight into the origin of our planet and the possibility of life beyond Earth. Knowledge on the formation of other planetary systems in our galaxy and beyond helps scientists understand how planets evolve, form, and the conditions that are required for life. Table 6 illustrates the Nebula Theory, the most widely accepted model for formation and evolution of the Solar System.

Table 1.4 Formation of Solar System

Illustration	Descriptions
	The Solar System began from a nebula, which was a swirling concentration of cold interstellar gas and dust.
	As a result of a supernova event, a disturbance occurred in a nebula, causing it to collapse. The conservation of angular momentum led to the spinning of the collapsing cloud of gas and dust. This spinning motion caused the cloud to fla en into a disc shape. Within this disc, the pressure and temperature increased to a level where nuclear fusion was ignited, giving birth to the Sun at its center.
	The gas and dust in the disc condensed into tiny particles that gradually stuck together and became larger objects, eventually forming protoplanets.
	The protoplanets continued to grow by a racting additional gas and dust through a process called accretion. As they accumulated more material, they gradually transformed into the planets.

There are four major hypotheses regarding the formation of moons

1. **Giant impact hypothesis:** When a planet collides with another large object, such as a protoplanet, the material from both objects is ejected into space. This material can then begin to orbit the planet and eventually form a moon.
2. **Fission hypothesis:** The moon is formed when it breaks away from the planet.

3. **Capture hypothesis:** Moon formed elsewhere in the solar system and was captured by the planet's gravity.

4. **Co-formation hypothesis:** Planet and moon formed in the protoplanetary disk at the same time.

Fun Fact

The Moon orbits Earth every 27.3 days, but the lunar phase cycle (from new Moon to new Moon) is 29.5 days.

Activity 6: Demonstrating the process of the nebula theory through an interactive role-play.

What we need:

- Name tags or labels representing different celestial bodies (Gas Cloud, Protostar, Young Star, Planet, Supernova Remnant)

What to do?

1. Choose a role by selecting a name tag or label representing a specific celestial body involved in the process.
2. Formation of a Gas Cloud: The participant assigns the role of the Gas Cloud to stand in the center of the play area spreading arms wide and gently swirling around representing a large, diffuse cloud of gas and dust.
3. Collapse and Formation of a Protostar: The participant assigned the role of the Protostar moves closer to the Gas Cloud bringing arms together, simulating the collapse of the Gas Cloud due to gravity. Form a small, dense core in the center to represent the protostar forming within the collapsing Gas Cloud.
4. Birth of a Young Star: Raise arms and slowly rotate, representing the protostar undergoing nuclear fusion and becoming a young star.
5. Formation of Planets: The participant assigned the role of the Planet joins the scene and orbits around the Young Star, symbolizing the formation of a protoplanetary disk.
6. The small particles within the disk start to collide, combine, and form planetesimals, eventually leading to the birth of planets.

7. Supernova Remnant: The participant assigned the role of the Supernova Remnant enters the scene, representing the remnants of a massive star that has exploded. Move around the play area, showcasing the dispersal of heavy elements and shockwaves caused by the supernova explosion.
8. Facilitate a discussion among the participants, encouraging them to reflect on the process they just enacted.

Questions

1. What role did each celestial body play in the nebula theory?
2. How did the gas cloud collapse and give birth to a protostar?
3. Who took the role of the young star and what is the responsibility of the actor?
4. How did planets form within the protoplanetary disk?
5. What happened to the massive star that resulted in the supernova remnant?

Fun Fact

The Sun contains 99.86% of the total mass of the entire solar system. It is so massive that it exerts a gravitational pull that keeps all the planets, moons, and other celestial bodies in orbit around it.

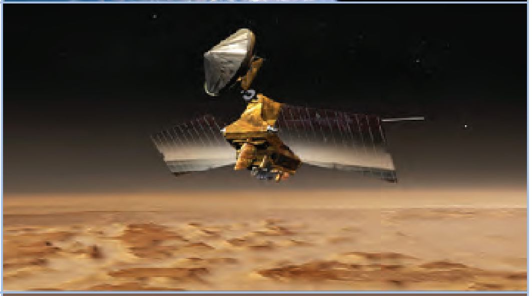
3. Space Explorer

Objectives

- Describe various types of space exploration and spacecraft used to enhance understanding of space exploration.
- Design a prototype of spacecrafts to explore the universe.

Space exploration is sending people or machines into space to visit other planets and objects. Different space missions include different types of explorations such as flyby, orbiter, rover, and human space explorations as discussed in Table 1.5.

Table 1.5 Types of Space Exploration

Types of space exploration	**Illustration/picture**
Flyby is a type of spacecraft that passes by a celestial object but isn't held in its orbit.	
Orbiter is a type of spacecraft that enters and stays in orbit around a planet.	
Rover is an electrically powered spacecraft that can roam around the celestial object.	

Human space missions are the programs that send people into space or other celestial objects.

Activity 7: Analyzing the advantages and disadvantages of different types of space exploration

Go through the link https://youtu.be/1dD1sK5i-7I or QR Code provided and complete Table 1.6.

Space mission

Table 1.6 Advantages and disadvantages of types of space exploration

Types of space exploration	Advantage	Disadvantage
Flyby		
Orbiter		
Rover		
Human space mission		

Activity 8: Designing Spacecraft

What we need:

- paper
- drawing materials (colour pen, pencil)
- craft supplies (cardboard, scissors, glue)
- 3D designing tool (Fusion 360, TinkerCAD)

What to do?

1. Identify a specific mission for your spacecraft.
2. Use paper and drawing materials to create a conceptual design or opt for a more hands-on approach using craft supplies to build a physical model, OR use Fusion 360 or TinkerCAD to design a spacecraft.
3. Present and explain your spacecraft to the class, discussing the mission, design choices, and any interesting features or innovations.

4. Purpose of Space Exploration

Objective

- Explore the possibility of human survival beyond the Earth.

4.1 Possibilities of life beyond the Earth

The question of whether life exists beyond the Earth has captivated scientists, philosophers and the general public. Mars being our closest planetary neighbor, has long been a subject of fascination and speculation regarding the possibility of extraterrestrial life. Recent scientific discoveries such as evidence of liquid water and organic molecules, have intensified our excitement and curiosity about the potential for hosting life on Mars.

Activity 9: Exploring the possibility of life beyond the Earth

Retrieve the details regarding the essential elements required for sustaining life in alternate locations from the link https://bit.ly/3pyF092 and answer the following questions.

1. What are the fundamental requirements for supporting life beyond the Earth?
2. Do you think there are possibilities of life on Mars? Justify.
3. Why do we need to explore the possibilities of life on other planets?
4. Why are extremophiles important for understanding the possibility of life beyond the Earth?

Fun Fact

Perseverance Rover has reached an ancient delta in Jezero Crater, a prime location on Mars for exploring possible evidence of past life. This delta is believed to have formed when a river carried sediments into a lake billions of years ago.

4.2 Spinoff Technology

Technologies and innovations that are usually developed for specific needs may have multiple applications. This is known as spinoff technology. Over the years, space agencies have made many technological advancements some of which have had practical applications beyond space exploration.

Some of the space spinoff technologies are Global Positioning System (GPS), Magnetic resonance Imaging (MRI) body scanning, water purification system, scratch-resistant lense, memory foam, cordless tool, fire-resistant material and freeze-dried food.

CHECK YOUR UNDERSTANDING

1. Read the question carefully and choose the correct option.

i. What happens to the gravitational force between two objects when the distance between them is tripled?

   A. It increases by a factor of 3.
   B. It decreases by a factor of 3.
   C. It increases by a factor of 9.
   D. It decreases by a factor of 9.

ii. Which of the following is the most fundamental factor for the existence of life?

   A. Organic molecules.
   B. Heat and pressure.
   C. Liquid water.
   D. Atmosphere.

iii. In the death of a large mass star gravitational collapse is so complete that no energy or ma er can escape. This is called a

   A. Black Hole.
   B. Supernova.
   C. Neutron Star.
   D. Black Dwarf.

iv. What is the current stage of our Sun in its life cycle?

   A. Nebula.
   B. Protostar.
   C. Red Giant.
   D. Main sequence.

v. Which force is responsible for the proper alignment and revolution of planets around the sun, as well as the revolution of moons around their respective planets?

   A. Gravitational force.
   B. Electrostatic force.
   C. Magnetic force.
   D. Nuclear force.

2. Read the following statement andstate True/False.

Statement	True/False
The gravitational force is inversely proportional to the product of masses.	
The commencement of star formation takes place within every nebula.	
The presence of organic molecules on Mars does not indicate that life once existed.	
The central region of the collapsing solar nebula eventually formed the Sun.	
Flyby mission would be most suitable to bring soil samples from Mars.	

3. Answer the following questions.

i. Identify four phenomena explained by the universal law of gravitation.

ii. If the gravitational force of a raction between a 500 kg bag of potatoes and a 200 kg bag of cabbage is measured to be 8.3x10-7 N, and the gravitational constant is G = 6.673 × 10-11 Nm2kg-2, what is the distance of separation between the bags?

iii. To what extent do you consider gravitational collapse as a crucial phenomenon in driving the formation of a star? Provide a rationale to support your perspective.

iv. If two stars with different masses but identical compositions are formed simultaneously, what can be inferred about their subsequent evolution?

v. Describe the prevailing scientific theory on the formation of the solar system?