CHAPTER 21

SPACE AND ENVIRONMENT

Student's learning outcomes (SLOs)

After studying this chapter, students will be able to:

- explain the nature of the Sun [as a star of medium size, it consists mostly of hydrogen and helium, and that it radiates most of its energy in the infrared, visible and ultraviolet regions of the electromagnetic spectrum].
- interpret and compare given planetary data [about orbital distance, orbital period, density, surface temperature and uniform gravitational field strength at the planet's surface].
- use ideas of convection to explain how cyclones are formed.
- explain how global warming contributes to extreme weather events [specifically in the case of hurricanes, heat waves, flooding, rainfall, wildfires, droughts, winter storms].
- explain what is meant by background radiation.
- state the sources that make a significant contribution to background radiation [including:
  (a) radon gas (in the air)
  (b) rocks and buildings
  (c) food and drink
  (d) cosmic rays].

Space and the environment are closely connected to each other. In order to understand and solve problems on the Earth, it is essential to explore the space. In the space, information regarding the environmental changes are collected by the satellites, orbiting around the Earth. This enables scientists to make efforts to protect the Earth using the data obtained from the satellites. New ideas have been created due to advancements in the space technology which help in obtaining renewable energy with better and efficient utilization of the materials. The study of space also enables us to understand the origin and evolution of the universe and to make the technological advancements. In this chapter, we will study the nature of the Sun, planetary data, formation of cyclones, phenomena of global warming, geothermal activity and background radiations.

21.1 Sun and Planetary Data

The Sun is the greatest source of light, heat and other forms of electromagnetic (E.M.) waves. The gravitational pull of the Sun keeps planets, including the Earth to orbit around it. The Sun is located at the centre of our solar system. The Sun contains 74 % of hydrogen and 24 % of helium along with few other elements. Nuclear fusion takes place at the core of the Sun (Fig. 21.1), in which hydrogen atoms are fused together to form helium, resulting in a tremendous increase in the temperature of the Sun (in millions of degree celsius). This releases a massive amount of energy which reaches the Earth in the form of light and heat. The energy released from the Sun travels through space in the form of various types of radiations such as infrared, heat, sunlight and ultraviolet radiations. These radiations have a considerable impact on the people living on the Earth and other form of lives. The energy obtained from the Sun plays an essential role in making weather patterns, changing the climate and supporting the ecosystems. For the study of planets, it is necessary to focus on different factors such as orbital distance, orbital period, density, surface temperature, gravitational field strength, etc. which makes each planet unique.

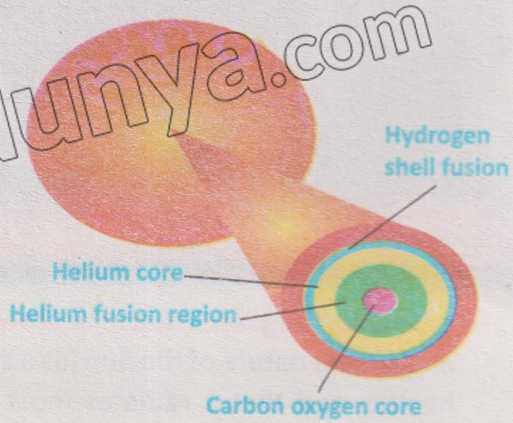


Fig. 21.1: Formation of the Sun

Tidbit

Even though it looks like a burning ball, the Sun does not burn like wood or coal. It fuses hydrogen into helium in its core, releasing immense energy through nuclear fusion, not combustion.

Orbital Distance

The solar system is shown in Fig. 21.2. Those planets that are closer to the Sun have smaller orbital distance and those located at a far away distance from the Sun have large orbital distances. Orbital distance plays a vital role in determining the amount of solar energy received by each planet.

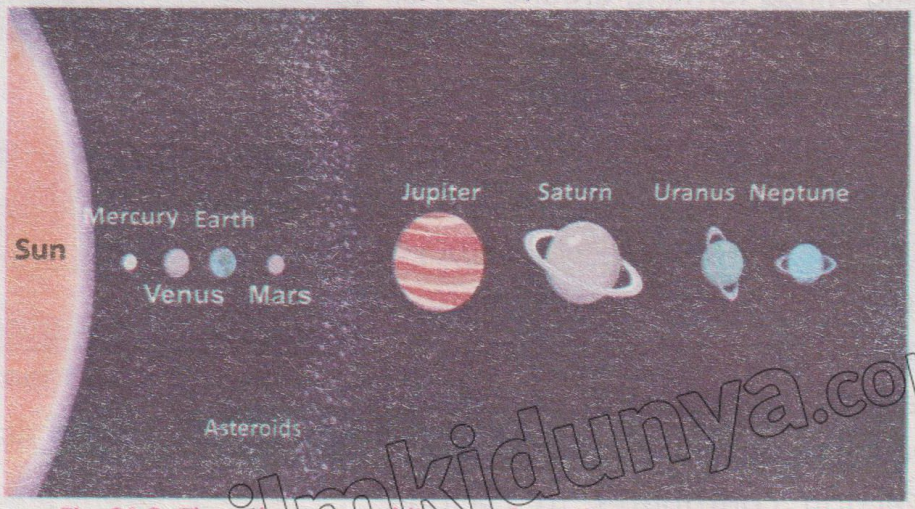


Fig. 21.2: The solar system (distance from the Sun is not to scale)

Orbital Period: This is the time a planet takes to complete one orbit around the Sun. Planets closer to the Sun have shorter orbital periods.

Density: Density reflects a planet's composition. Rocky planets like Earth and Mars have higher densities due to their solid, metallic cores, while gas giants like Jupiter and Saturn have lower densities because they are composed mostly of hydrogen and helium.

Surface Temperature: This depends on factors like distance from the Sun, atmospheric composition, and greenhouse effects. For example, Venus has an extremely high surface temperature due to its thick, heat-trapping atmosphere, while Mars is much colder due to its thin atmosphere and greater distance from the Sun.

Gravitational Field Strength: For a planet, the gravitational field strength at its surface depends on its mass, and is nearly uniform across its surface. The strength of the gravitational field decreases as the distance from the planet increases. Smaller

Do You Know?

Planets have different orbital periods. While Earth takes 365.25 days to orbit the Sun, Mercury takes just 88 days, and Neptune takes 165 Earth years!

Tidbit

Even after 4.5 billion years, the Earth's core remains molten, partly due to radioactive decay and the heat leftover from planetary formation.

planets (like Mars) have weaker gravitational force, while larger planets (such as Jupiter) have stronger gravitational relative to the Earth.

Formation of Cyclones

Cyclones refer to heavy storms containing fast and spinning winds forming around low air pressure area (Fig. 21.3). The phenomenon of convection is responsible to develop these cyclones. The convection takes place due to rise of the warm air (being lighter) as compared to the (heavier) cool air that moves down. Due to rise in the warm air, more air rushes in to take its place, which creates the spinning effect. The cyclone grows stronger and bigger due to the movement of air (Fig. 21.4). The convection contributes to cyclone formation in the following ways:

Fig. 21.3: Cyclone

1. Warm Ocean Waters: Formation of cyclones occurs (over warm oceans) where temperature of the sea surface is very high (27 °C or 300 K). The air above the warm water is heated, becomes less dense and rises rapidly. This movement of the warm air in the upward direction creates an area of low pressure at the surface.

2. Rising Air and Condensation: The rising warm air moves to low air pressure areas, causing the air to expand. The clouds are formed due to the moisture in the air and as a result, heat is released into the surrounding air. Due to this heat, the air becomes even warmer and it rises even faster. As this process continues, the warm air further rises, forms more clouds and increases the release

Fig. 21.4: Formation of cyclone

of more heat in the surroundings. This cycle keeps going, making the cyclone stronger and helping it grow bigger.

3. Formation of a Low-pressure Centre: As the warm air keeps rising, it leaves behind empty space near the surface, like a small vacuum. To fill this space, warmer, moist air from the surrounding areas rushes in. Because the Earth is spinning, this moving air does not go in a straight line. Instead, it starts to spin around the low-pressure area. This effect is called the Coriolis effect. In the northern hemisphere, the air spins anticlockwise, while in the southern hemisphere, it spins clockwise. This spinning motion helps shape the cyclone and keeps it growing stronger.

Tidbit

Earth-observing satellites can detect heat patterns, water vapour, and storm movement, helping scientists predict cyclones and track climate change with astonishing precision.

4. Development of a Cyclonic System: As more warm air keeps getting pulled into the storm, the rising and spinning of the air becomes even stronger. The cyclone keeps growing as long as it has warm, moist air from the ocean. In the middle of the cyclone, a special area called the eye forms, where the air moves downward, making it calm and clear. However, just outside this calm centre is the eye wall, which is the most dangerous part of the cyclone. Here, the winds are extremely strong, and heavy rain falls, making this the most powerful part of the storm.

5. Energy Dissipation: Cyclones start to weaken when they move over land or colder water because they can no longer get warm, moist air, which acts like fuel for the storm. Over the ocean, this warm air keeps the cyclone strong by helping the air rise and spin. But when the cyclone moves away from the warm ocean, the air stops rising as much, and the spinning slows down. Without this energy, the storm loses its strength, the winds become weaker, and the cyclone slowly fades away.

21.2. Global Warming and Geothermal Activity

Global warming is a long-term increase in the average surface temperature of the Earth due to burning of fossil fuels, release of gases like methane, carbon dioxide, nitrous oxide, cutting down forests, and using certain industrial and farming methods. The gases trap the heat coming from the Sun and causes an increase in

the temperature. The global warming has a great impact on the weather, sea level and disruptions to ecosystems. Similar to global warming, the inner heat of the Earth (Geothermal Activity) causes volcanic eruptions, geysers, hot springs, and the movement of tectonic plates. Geothermal energy is considered as renewable resource of energy due to its sustainability as long as the Earth's internal heat remains active. Global warming has been illustrated in Fig. 21.5.

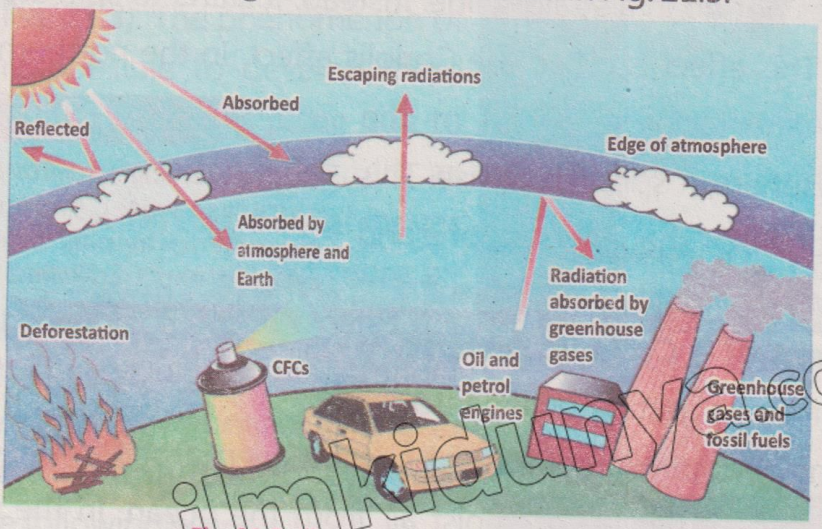


Fig. 21.5: Illustration of global warming

Hurricanes

Due to rise in the temperature, more heat is absorbed by the ocean which fuels hurricanes, making them stronger and more destructive. Intensity of hurricanes is increased by the warmer ocean waters, with higher wind speeds and heavier rainfall, causing greater damage (Fig. 21.6). Furthermore, ice begins to melt and seawater expands due to rise in the temperatures. This results in higher sea levels. Consequently, stronger storm surges and more frequent flooding in coastal areas take place, increasing the damage to homes and communities.

Fig. 21.6: Hurricane

Heat Waves

The rise in the global temperatures produces heat waves. The heat is trapped by the gases in the atmosphere, leading to extended periods of extreme heat. Buildings and roads absorb heat and retain it. Cities are particularly affected, as buildings and roads absorb and retain heat, causing those areas to be much hotter compared to the others (Fig. 21.7).

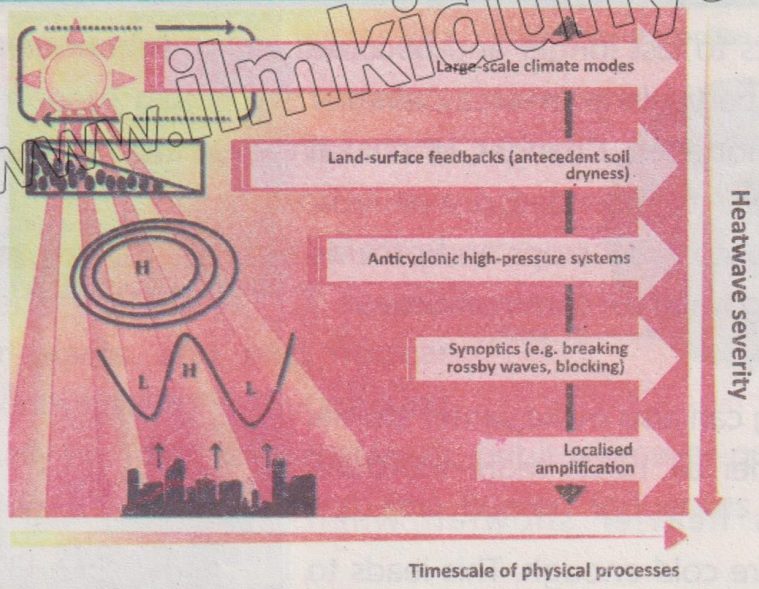


Fig. 21.7: Heatwave schematic illustrating the various physical processes

Flooding

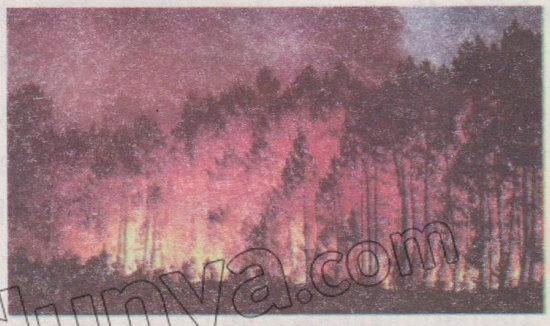
Heavier rainfall comes to a warmer atmosphere because it can hold more moisture, resulting in intense flooding in those areas. As global warming changes weather patterns, storms become stronger, increasing the risk of both inland and coastal floods. In addition sea levels to rise due to melting glaciers and ice sheets, resulting in more flood in the coastal regions.

For Your Information

Thanks to water's high specific heat capacity, oceans absorb and release heat slowly, helping to regulate global climate and reduce the intensity of heatwaves until global warming messes with the balance.

Wildfires

Wildfires often result from high temperatures and long period of dryness. With reduced moisture in the air and soil, forests and grasslands become more susceptible to ignition. The wildfire season is also lasting longer due to earlier snowmelt and extended dry periods. As a result, wildfires are becoming more common, more severe, and more damaging, threatening ecosystems and communities alike.



California wildfire fury

Droughts

Due to increase in the temperature, more water evaporates from the land, drying out the soil. This reduces the water available for plants, animals, and people which

causes droughts to last longer and become more intense, particularly in areas already facing water shortages. Changes in rainfall patterns also lead to extended dry periods, making it harder to grow crops and provide enough drinking water for communities.

Tidbit

As temperatures rise, more water evaporates from land and water bodies. This leads to longer droughts, drying out the soil and stressing water supplies for agriculture, wildlife, and cities.

Winter Storms

Global warming can also make winter storms stronger. Warmer air holds more moisture, which means heavier snowfall when temperatures are cold enough. This leads to extreme winter storms, including heavy snow, ice storms, and longer periods of freezing weather in unexpected places.

Florida winter storm chaos

Tidbit

Global warming heats up the oceans, and warm ocean water acts like fuel for hurricanes. The hotter the water, the more energy the storm gets leading to stronger winds, heavier rainfall, and longer-lasting storms.

21.3 Radiation Exposure

Radiation exposure happens when someone comes into contact with radiation, which is a type of energy (Fig. 21.8). This energy can come from natural sources like the Sun and the ground or from man-made sources like X-ray machines and nuclear power plants. A small amount of radiation is usually safe, but too much exposure can harm our bodies by damaging cells. That is why we use safety measures, like protective wear and limited exposure, to stay safe while using radiation for useful purposes.

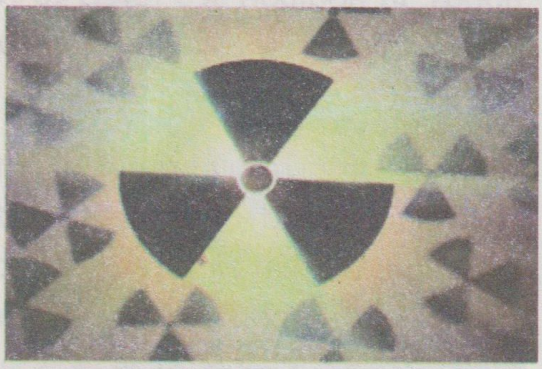


Fig. 21.8: Radiation exposure warning

Background Radiation

The radiation that exists around us all the time is known as background radiation.

It is the constant, low-level ionizing radiation present in the environment from both

natural and human-made sources. It includes cosmic rays from space, radioactive materials in the Earth's crust (like uranium and radon), and even tiny amounts of radiation in our food and bodies. Human activities, such as medical procedures (X-rays, CT scans), nuclear power plants, and past nuclear testing, also contribute to it. Background radiation is usually harmless at normal levels, but it is an ever-present part of our world, reminding us of the natural and human influences that shape our environment (Fig. 21.9).

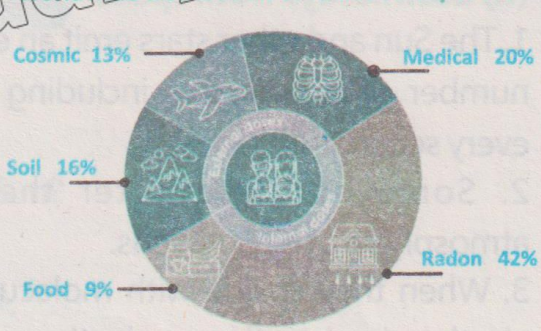


Fig. 21.9: Sources of radiation

Sources of Radiation

(a) Radon gas (in the air)

1. Radon gas is an alpha emitter.
2. Radon gas is particularly dangerous if it is inhaled into the lungs in large quantities.
3. The gas is tasteless, colourless and odourless, but it is not generally a health issue unless levels are significantly high.

Tidbit

Radon gas from the ground can seep into homes especially basements and contribute to natural background radiation. It is invisible, odourless, and radioactive.

(b) Rocks and buildings

1. Natural radioactivity can be found in building materials, including decorative rocks, stones and bricks.
2. Heavy radioactive elements, such as uranium and thorium, occur naturally in rocks in the ground.
3. Uranium decays into radon gas.

(c) Food and Drink

1. Food and water contain small amounts of naturally occurring radioactive isotopes, such as potassium-40 and carbon-14.
2. These isotopes are absorbed by plants and animals and enter the human body through consumption.
3. The contribution from food and drink is generally small but consistent.

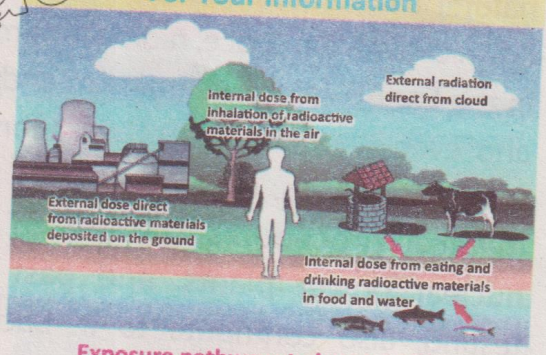
Do You Know?

Some cosmic rays that hit the Earth have travelled for millions of years from distant galaxies before colliding with atoms in our atmosphere to produce background radiation.

(d) Cosmic rays from space

1. The Sun and other stars emit an enormous number of cosmic rays including protons every second.
2. Some of these enter the Earth's atmosphere at high speeds.
3. When they collide with molecules in the air, they lead to the production of gamma radiation.

For Your Information



Exposure pathways to humans from environmental release of radioactive materials

4. High exposure to radiation in a short time can cause radiation sickness, with symptoms like nausea, vomiting, fatigue, and organ damage.
5. Long-term exposure to low levels of radiation increases the risk of cancer, especially in organs like the lungs, thyroid, and bones.
6. Radiation can damage DNA, leading to genetic mutations that may affect future generations.
7. Radioactive materials can contaminate air, water, soil, and food, spreading radiation to the environment.
8. Inhaling radioactive dust or drinking contaminated water can cause internal exposure, where radioactive particles stay in the body and keep emitting radiation.
9. Accidents, such as leaks, spills, or explosions, can occur if radioactive materials are not stored or handled safely.
10. Nuclear power plant accidents or improper waste management can lead to large-scale disasters, harming communities and ecosystems.
11. Radioactive materials can be misused in nuclear bombs, which spread radiation using conventional explosives, causing panic and long-term contamination.

Brain Teaser

Which type of radiation comes from space and can affect airline pilots, but never passes through walls?

EXERCISE

A. Multiple Choice Questions

Tick (✓) the correct answer.

21.1 What process generates energy in the Sun?
(a) Nuclear fission
(b) Nuclear fusion
(c) Radioactive decay
(d) Chemical reactions

21.2 The factor which primarily determines a planet's surface temperature:
(a) its density
(b) its orbital distance from the Sun
(c) its gravitational field strength
(d) the number of moons it has

21.3 What is the primary reason cyclones form over warm ocean waters?
(a) The presence of strong winds
(b) The high atmospheric pressure
(c) The rising of warm, moist air creating low pressure
(d) The gravitational pull of the moon

21.4 Which of the following gas contributes the most to global warming?
(a) Oxygen
(b) Carbon dioxide
(c) Nitrogen
(d) Argon

21.5 How does the Coriolis effect influence cyclones?
(a) It causes cyclones to spin in opposite directions in different hemispheres
(b) It strengthens cyclones over land
(c) It prevents warm air from rising
(d) It stops the formation of low-pressure areas

21.6 A major cause of rising sea levels is:
(a) increased volcanic activity
(b) the Earth moving closer to the Sun
(c) melting glaciers and ice sheets
(d) decreased solar radiation

21.7 A significant source of background radiation is:
(a) oxygen in the air
(b) cosmic rays from space
(c) sound waves in the atmosphere
(d) light from the Sun

B. Short Answer Questions

21.1 What are the two main elements that make up the Sun?
21.2 What factors are used to compare planets in terms of their characteristics?
21.3 Explain how global warming increases the intensity of hurricanes.
21.4 What is background radiation, and what are its natural sources?
21.5 Name three safety measures used to handle radioactive materials safely.
21.6 Why do cyclones weaken when they move over land?
21.7 How does the Coriolis Effect influence the movement of cyclones?
21.8 What is the primary cause of rising sea levels due to global warming?

C. Constructed Response Questions

21.1 Why do gas giants like Jupiter, despite their larger size, have lower densities than rocky planets such as Earth and Mars? What does this tell us about their internal structure?
21.2 If two planets receive the same amount of sunlight but have different atmospheric compositions, why might their surface temperatures still differ significantly?
21.3 How does the coriolis effect play a role in creating the spiraling motion of cyclones, and what might happen to cyclone formation if the Earth stopped rotating?
21.4 Compare the ways radiation, conduction, and convection each contribute to geothermal activity. Why is convection considered the primary driver of tectonic plate motion?
21.5 Explain why background radiation is always present in our environment and how cosmic and terrestrial sources balance each other despite fluctuations in human activity.

D. Comprehensive Questions

21.1 Describe the process of nuclear fusion in the Sun and explain how it generates energy.
21.2 How does a planet's orbital distance affect its surface temperature and the amount of solar energy it receives?
21.3 Explain the role of convection in the formation and strengthening of cyclones.
21.4 What are the major sources of background radiation, and how does human activities contribute to it?
21.5 Explain how radiation exposure can be harmful and describe three key safety measures used to minimize its risks.