Course Guide

SED 312
EARTH AND UNIVERSE

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CONTENTS **PAGE**

Introduction

SED 312: Earth and Universe is a three-credit and one-semester undergraduate course. The course is made up of fifteen units spread across fifteen lectures weeks. It will provide you with a deeper knowledge of the earth and the universe. This course guide gives you an insight into the geologic study of the rock types on the earth, the atmosphere, the moon and solar system. The course guide tells you about the course materials and how you can work your way through these materials. It suggests some general guidelines for the amount of time required of you on each unit in order to achieve the course aims and objectives successfully.

What you will learn in this course

You will learn about geologic case scale and rocks, the atmosphere, the moon and the solar system. The aim of this course is to expand your knowledge about the stated phenomena and their importance and effect on human nature and existence. Specific focus is on rock types and formation, the atmosphere; its composition, structure, properties and effect of some natural occurrences as well as the study of the moon and solar system.

Course Objectives

At the end of studying the course material, you should be able to:

- Explain the division of geologic time scale and age
- Explain rock types and formation
- Describe the composition of the atmosphere and greenhouse gases
- Describe the phases of the moon, the concept of eclipse and the various types
- Explain the effects of space exploration and human development.

Working through this Course

To complete this course, you are expected to read and understand each unit, also use textbooks and other materials which may be provided for you by the National Open University of Nigeria (NOUN). This course is expected to last for a period of one semester after which there will be a final examination. Attempt with all seriousness Self-Assessment Exercises built into every unit in each module and at the end of the course, there is a final examination. You are supplied with the components of the course, what you have to do and how to allocate your time to each unit for timely and successful completion of the course. Devote adequate time to thoroughly study the course on your own but do not absent yourself from tutorial class sessions where you will meet and interact with facilitators and your colleagues.

Study Units

The course comprises of the following course units distributed in the two modules that make up the course.

References and Further Reading

Anyakoha, M. W. (2008). New school physics for senior secondary schools. Revised edition: AFP Africana First Publishers Limited.

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Presentation Schedule

Module 1 presents the subject matter content in six units. This module focuses on thermal, light, solar and nuclear energy.

Module 2 also presents the course in five units. It presents the subject matter content in five units focusing on entropy and radiation.

Your course materials have important dates for the early and timely completion and submission of your TMAs and attending tutorials. You are expected to submit all your assignments by the stipulated time and date and guard against falling behind in your work.

Course Marking Schedule	
Assignment	**Marks**
Assignments 1 – 4	Four assignments, best three marks of the four counts 10% each of the 30% course marks.
End of course examination	70% of overall course marks
Total	**100% of course materials.**

Assessment

There are eleven (11) assignments in this course, covering all the units studied.

Tutor-Marked Assignment

The Tutor-Marked Assignments (TMAs) at the end of each unit are designed to test your understanding and application of the concepts learned. Besides, you would be assessed electronically, as a continuous assessment during the period of studying the course. This would make up 30 % of the total score for the course. The other 70% would be determined by examination of the course at the end of the course.

The TMAs is a continuous component of your course which accounts for 30% of the total score. You will be given three (3) TMAs to answer. These must be answered before you are allowed to sit for the end of course examination. The TMAs would be given to you by your facilitator or online and returned after you have done the assignment. Assignment questions for the units in this course are contained in the assignment file. You will be able to complete your assignment from the information and material contained in your reading, references and study units. However, it is desirable that you are able to demonstrate that you have read and researched more into your references, which will give you a wider viewpoint of the subject.

Make sure that each assignment reaches your facilitator/submitted online, on or before the deadline given in the presentation schedule and assignment file. If for any reason you cannot complete your work on time, contact your facilitator before the assignment is due to discuss the possibility of an extension. Extension will not be granted after the due date unless there are exceptional circumstances.

Final Examination and Grading

The end of course examination for Energy and Matter II will be for about 3 hours and it has a value of 70% of the total course work. The examination will consist of questions, which will reflect the type of self-testing, practice exercise and Tutor-Marked Assignment problems you have previously encountered. All areas of the course will be assessed. You might find it useful to review your self-test, TMAs and comments on them before the examination. The end of course examination covers information from all parts of the course.

How to get the Most from the Course

In distance learning, the study units replace the lectures in the conventional systems. This is one of the great advantages of distance learning; you can read and work through specially designed study materials at your pace, and at a time and place that suit you best. Think of it as reading the lectures instead of listening to a lecturer. In the same way that a lecturer might set you some reading to do, the study units tell you when to read your set books or other material, and when to undertake computing practical work. Just as a lecturer might give you exercises in a face to face classroom situation, your study units also

provide exercises for you to do at appropriate points. Each of the study units follows a common format and the first item is an introduction to the subject matter of the unit, detailing how a particular unit is integrated with the other units and the course as a whole.
Next is a set of learning objectives which itemise what you should be able to do by the time you have completed the unit. You should use these objectives to guide your study. When you have finished the unit, you must go back and check whether you have achieved the objectives. If you make a habit of doing this you will significantly improve your chances of passing the course. Exercises are interspersed within the units and answers are given. Working through this exercise will help you to achieve the objectives of the unit and help you to prepare for the assignments and examinations.

The following is a practical strategy for working through the course: Read this course guide thoroughly.

1. Organise a study schedule. Refer to the 'Course Overview' for more details. Note the time you are expected to spend on each unit and how the assignments relate to the units. Important information, e.g. details of your tutorials, and the date of the first day of the semester, is available from the WebCT OLE. You need to gather together all this information in one place, such as your diary or a wall calendar. Whatever method you choose to use, you should decide on and write in your own dates for working on each unit.
2. Once you have created your own study schedule, do everything you can to stick to it. The major reason for students' failure is that they get behind with their course work. If you get into difficulties with your schedule, please let your tutor know before it is too late for help.
3. Turn to Unit I and read the introduction and the objectives for the unit.
4. Assemble the study materials. Information about what you need for a unit is given in the 'Overview' at the beginning of each unit. You will almost always need both the study unit you are working on and one of your set books on your desk at the same time.
5. Work through the unit. The content of the unit itself has been arranged to provide a sequence for you to follow. As you work through the unit you will be instructed to read sections from your set books or other articles. Use the unit to guide your reading.
6. Keep an eye on the WebCT OLE. Up-to-date course information will be continuously posted here.

7. Well before the relevant due dates (about 4 weeks before due dates), access the Assignment File on the WebCT OLE and download your next required assignment. Keep in mind that you will learn a lot by doing the assignments carefully. They have been designed to help you meet the objectives of the course and, therefore, will help you pass the examination. Submit all assignments not later than the due date.
8. Review the objectives for each study unit to confirm that you have achieved them. If you feel unsure about any of the objectives, review the study material or consult your tutor.
9. When you are confident that you have achieved a unit's objectives, you can then start on the next unit. Proceed unit by unit through the course and try to pace your study so that you keep yourself on schedule.
10. When you have submitted an assignment to the tutor for marking, do not wait for its return before starting on the next unit. Keep to your schedule. When the assignment is returned, pay particular attention to your tutor's comments, both on the Tutor-Marked Assignment firm and also written on the assignment. Consult your tutor as soon as possible if you have any questions or problems.
11. After completing the last unit, review the course and prepare yourself for the final examination. Check that you have achieved the unit objectives (listed at the beginning of each unit) and the course objectives (listed in this Course Guide).

Online Facilitation

There are 15 hours of tutorials provided in support of this course. You will be notified of the dates, times and location of the tutorials as well as the name and the phone number of your facilitator, as soon as you are allocated a tutorial group. Your facilitator will mark and comment on your assignments, keep a close watch on your progress and any difficulties you might face and provide assistance to you during the course. You are expected to mail your Tutor-Marked Assignment to your facilitator before the schedule date (at least two working days are required). They will be marked by your tutor and returned to you as soon as possible.
Do not delay to contact your facilitator by telephone or e-mail if you need assistance. The following might be circumstances in which you would find assistance necessary, hence you would have to contact your facilitator if you:

- do not understand any part of the study or the assigned readings
- have difficulty with self-tests

- have a question or problem with an assignment or with the grading of an assignment.

You should endeavour to attend the tutorials. This is the only chance to have face to face contact with your course facilitator and to ask question which are answered instantly. You can raise any problem encountered in the course of your study. To gain more benefit from course tutorials prepare a question list before attending them. You will learn a lot from participating actively in discussions.

MAIN CONTENT

PAGES

Module 1 The Geologic Case Scale and Rocks

Unit 1: Historical Geology: Terminology and Table of Geological Time

Unit Structure

1.1 Introduction

The geological history of the earth follows the major events in earth based on the geologic time scale, a system of chronological measurement based on the study of the planet's rock layers (Stratigraphy).

The earth formed about 4.54 billion years ago from the solar nebula-a disk-shaped mass of dust and gas left over from the formation of the sun which also created the rest of the "solar system".

The present pattern of 'ice ages' began about 40 million years ago and then intensified at the end of the "Pliocene". The polar regions have since undergone repeated cycles of glaciations and thaw, repeating every 40,000-100,000 years. The last 'glacial period' of the current 'ice age' ended about 10,000 years ago.

The geological time scale also showed how geologists came up with a time scale using units that are acceptable internationally. Though geologic units occurring at the same time but may differ since they occur at different locations. There are many examples where the same period was historically given different names in different locales. A key aspect of the work of the International Commission on Stratigraphy is to reconcile this conflicting terminology and define universal horizons (time division) that can be used around the world.

1.2 Intended Learning Outcomes

At the end of this unit, you will be able to:

- define some terminologies in geology
- identify the various periods and the major events that characterised them.
- mention events that led to the extinctions during some periods
- name some eras, supercontinents and how they come to be
- mention major events and the time they occur with certainty.

1.3 Historical Geology

Here you are going to learn about the historical geology by taken up historical events which are outlined by geologists using stratigraphy and paleontology to find out the sequence of events. These events are;

Precambrian

The Precambrian includes approximately 90% of the geologic time. It extends from 4.6 billion years ago to the beginning of the Cambrian period (about 541Ma). It includes three eons, the Hadean, Archean and Proterozoic.

Hadean Eon

During the Hadean time (4.6-4Ga), the solar system was forming, probably within a large cloud of gas and dust around the sun called an “accretion disc” from which earth formed 4,500 million years ago.

The Headean Eon is not formally recognized but it essentially marks the era before there was adequate record of significant solid rocks. The oldest Zircons dated from about 4,400 million years ago.

Earth was initially molten due to extreme “volcanism” and frequent collisions with other bodies. Eventually, the water layer of the planet cooled to form a solid “crust” when water began accumulating in the atmosphere. The ‘moon’ formed soon afterwards, possibly as the result of a ‘mars’ – sized object with about 10% of earth’s mass “impacting the planet” in a glancing blow. Some of this object’s mass merged with the earth’s significantly altering its internal composition, and a portion was ejected into space. Some of the materials survived to form an orbiting moon. It was suggested that the outgassing and “volcanic” activity produced the primordial atmosphere.

Condensing "water vapour" augmented by ice delivered from "comets" produced the "oceans".

It is believed that during the Hadean the "Late Heavy Bombardment" occurred (approximately 4,100 to 3800 million years ago) during which a large number of impact craters are believed to have formed on the "moon" and by inference on "earth", Mercury, Venus, and Mars as well.

Archean Eon

The earth of the early Archean (4,000-2500 million years ago) may have had a different tectonic style. The earth's crust during this time cooled enough, that rocks and continental plates began to form. Unlike the "proterozoic", Archaean rocks are often heavily metamorphized deepwater sediments, such as "graywackes", "mudstones", volcanic sediments and "banded iron formations". "Green stone belts" are typical Archean formations made up of alternating high and low metamorphic rocks.

Proterozoic Eon

The geologic record of proterozoic (2500 to 541 million years ago is more complete than that of the preceding Archean. Unlike the deepwater deposits of the Archean, the features of Proterozoic have many 'Strata' that were laid down in extensive shallow "epicontinental seas", many of its rocks are less "metamorphosed" than Archean-age. The first known glaciations occurred during Proterozoic, one occurred at the beginning of the eon, while there were four others during the Neoproterozoic, climaxing with the "snowball earth" of the Varangian glaciations.

Phanerozoic Eon

The Phanerozoic Eon is the current eon in the geologic timescale. It covers roughly 541 million years. During this period, continents drifted about, eventually collected into a single landmass known as "Pangea" and then split up into the current continent landmasses.

Figure 11: The Continents of the World

The Phanerozoic is divided into three eras which are; the “Paleozoic”, “Mesozoic” and the “Cenozoic”.

Palezoic Era

This Paleozoic spanned from 541-252 million years ago and is subdivided into six geologic periods which are from oldest to youngest.

- Cambrian
- Ordovician
- Silurian
- Devonian
- Carboniferous and
- Permian

Geologically, the Paleozoic starts after the breakup of a supercontinent called “Pannotia” and by the end of a global ice age. Through the early part of Paleozoic, the earth’s landmass was broken up into a substantial number of smaller continents. But by the end of the era, the continents gathered together into a supercontinent called “Pangaea” which included most of the earth’s land area.

Cambrian Period

This is a major division of the “geologic time scale” that begins about 541.0±1.0 Ma. Cambrian continents are thought to have resulted from the breakup of a Neoproterozoic supercontinent called Pannotia. The water then appear to have widespread and shallow. Continental drift rates may have been anomalously high. Laurenia, Baltica and Siberia remained independent continents following the breakup of the supercontinents of Pannotia. “Gondwana” started to drift towards the south pole.

Panthalassa covered most of the southern hemisphere, and minor oceans included the "Proto-Tethys Ocean, Lapetus ocean and Khantty Ocean.

Ordovician Period

Thus period started at a major extinction event called "Cambrianordovician extinction events" sometime about 485.4 ±1.9Ma. During the period, the southern continents were collected into a single continent called Gondwana. Gondwana started the period in the equatorial latitudes and as progressed, drifted towards the south pole. Early in the Ordovician, the continents Laurentia, Siberia and Balltica were still independent continents but "Baltica" began to move towards laurentia later in the period, causing the lapetus ocean to shrink between them. Avalonia also broke free from Gondwana and began to head north towards Laurentia. As a result of this, the "Rheic Ocean" was formed. Gondwana by now had moved close to the pole and was largely glaciated. Ordovician came to a close in a series of extinction events that comprise the second largest of the five major extinction events in "earth's history" in term of percentage of "geneva" that went extinct. The largest extinction event was the Permian Triassic extinction. The extinctions occurred approximately 447-443 million years ago and marked the boundary between the Ordovician and the following Silurian period.

Silurian Period

It is a major division of the geologic timescale that started about 443.4±0.8 Ma. During this period, Gondwana continue a slow southward drift to high southern latitudes. It is evidenced that the ice caps were less extensive than those of the late Ordovician glaciations. The melting of ice caps and glaciers contributed to a rise in "sea levels" which were evidence from the Siluvian forming "uncofmormity". Other cratons and continent fragments drifted together near the equator forming a secondary supercontinent known as "Euramerica". The vast Panthalassa ocean covered most of the northern hemisphere.

Devonian Period

This spanned from 419 to 359 Ma and the period was a time of great tectonic activity such as "Lauresia" and Gondwana drew closer together. The continent Euramarica was created earlier in the Devonian by the collision of Laurencia and Baltica, which rotated into the natural dry zone along "Tropic of Capricorn". In these near-deserts, the "Old Red Sandstone" sedimentary beds formed, made red by the oxidized iron (hermatite) characteristics of drought conditions. Near the equator, Pangaea began to consolidate from the plates containing North America and Europe, raising the northern "Appalachian Mountains" and forming the "Caledonian Mountains" in Great Britain and "Scandanavia". While the southern continents remained tied together in the supercontinent of Gondwana.

Carboniferous Period

Carboniferous extends from 358.9±0.40 to 298.9±0.15 Ma. There was a global drop in sea level at the end of the Devonian reversed early in the carboniferous. This created the widespread epicontinental seas and carbonate deposition of the "Missisippian" There was a drop in south polar temperatures, Southern Gondwana was glaciated throughout this period. The deep tropic at this period had lush "coal" swamps flourishing within 30 degrees of the northern most glaciers.

The carboniferous was a time of active mountain building as the supercontinent Pangea came together. The southern continents remained tied together in the supercontinent Gondwana, which collided with North America-Europe (Laurussia) along the present line of eastern North America. This resulted in the "Hercynian Orogeny" in Europe and the "Alleghenian Orogeny" in North America.

Figure 1.2: Pangaea Separation Ammation

Perimian Period

This period extended from about 298.9±0.15 to 252.17±0.06 Ma. During this, all the earth's major land masses, except parts of East Asia, were collected into a single supercontinent called Pangaea. This straddled the equator and extended towards the poles with a corresponding effect on ocean currents in the single great ocean Panthalassa, the universal sea, and the Paleo-Tethy's ocean, a large ocean that was between Asia and Gondwana. Large continent Land masses create climates with extreme variations of heat and cold (continental climate) and mosoon conditions with highly seasonal rainfall patterns "Deserts" seem to have been widespread on Pangaea.

There are many more era to look at because the geological scale is ever unfolding.

1.3.1 Table of Geological Time Scale (GTS)

The geological time scale shows some of the major units of geological time and definitive events of earth's history. The geologic time scale (GTS) is a system of "Chronological Measurement" that relates stratigraphy to time and is used by geologists, paleontologists and other earth scientists to describe the timing and relationships between events that have occurred throughout earth's history. The table spans presented have nomenclature, dates and standard of colour codes set forth by the International Commission on Stratigraphy.

As we have discovered in the first part of this unit, that evidence from radiometric dating shows that earth is about 454 billion years old. The geology or deep time of earth's past has been organized into various units according to events which took place in each period.

Self-Activity
Can you name two periods when there was glacier during the ice age?

Different spans of time on the GTS are usually delimited by changes in the composition of strata corresponding to them, indicating major geological or paleontological events such as "mass extinctions for example, the boundary between the Paleogene period is defined by the cretaceous-paleogenic extinction event which marked the demise of the non-avian "dinosaurs" and many other groups of life.

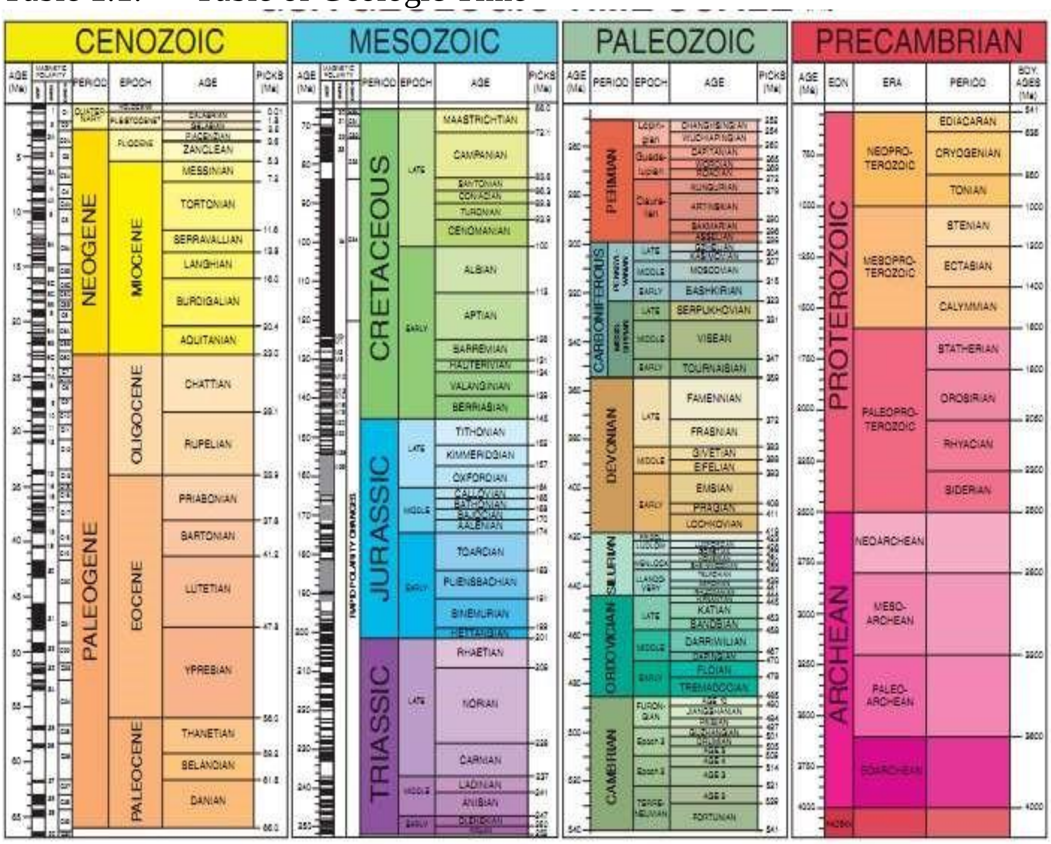
Terminology: Units in Geochronology and Stratigraphy

Segments of Rocks (Strata) in Chronostratigraphy	Time Spans in Geochronology	Notes to Geochronological units
Eonotherm	Eon	4 total, half a billion years or more
Eranothem	Era	14 total, several hundred million years
System	Period	
Series	Epoch	Tens of millions of years
Stage	Age	Millions of years
Chronozone	Chron	Subdivision of an age, not used by the ICS time scale

Table 1

The largest defined unit of time is the supereon, composed of eons. Eons are divided into “eras” which are in turn divided into “periods”, epochs and ages. The terms Eonathem, erathem system series and stages are used to refer to the layers of rock that correspond to these periods of geologic time in earth’s history.

Table 1.1: Table of Geologic Time



These tables summarize the major events and the characteristics of the periods of time, making up the geologic timescale. The timescale is based on international commission on stratigraphy.

Geologists often use the terms upper/late, lower/early and middle parts of periods and other units such as “Upper Jurassic” and “Middle Cambrian”. Upper, Middle and Lower are terms applied to the rocks themselves as in “Upper Jurassic Sandstone” while Late, Middle and Early refer to time as in “Early Jurassic Deposition” or “Fossils of Early Jurassic Age”.

Self -Assessment Exercise

i. The Paleozoic was divided into six periods, identify them.

1.4 Summary

In this unit, we discussed about geologic time scale and geological history. Here, you learnt about the geological method of dating using major events. The terminologies used by geologists in making geologic time were also learnt.

7.0 References/Further Reading/Web Resources

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1.6 Possible Answers to Self-Assessment Exercise(s)

i. The six Paleozoic periods are:
- Permian
- Carboniferous
- Devonian
- Silurian
- Ordovician
- Cambrain

Unit 2: Earth's Structure

Unit Structure

1.0 Introduction

The ability to describe the internal structure of the earth will enable you understand some of the features on the surface of the earth. Information gathered about the interior are based on what is gathered from the study of the earthquakes (seismology) and the materials ejected during volcanic eruptions (volcanology). Some information also are gotten from boring into the earth's crust during seismic scientific investigations. In this unit, you will study about these facts.

2.0 Intended Learning Outcomes

At the end of this unit, you will be able to:

- mention the different layers of the earth
- identify which part of the earth is rich in minerals
- separate the different layers and
- state the importance of the features of each layer

2.3 Internal Structure of the Earth

Scientific investigations have revealed that the earth is made up of several circular (concentric) layers. The three major ones include:

1. Barysphere (or Core)
2. Mesosphere (or Mantle or Substratum)
3. Lithosphere (Crust)

1. Barysphere (Core)
This is the core or interior of the earth. It has a diameter of about 7000km and it is the hottest part of the earth layers. The temperature at the centre of the core which is about 6371 km below the earth's surface is approximately 5500^{0}C and it is subjected to a very

extreme high pressure of about 3.8 x 10^6 kilograms per square centimeter. The earth's core is divided into two parts – a solid inner core and the liquid outer core. The solid inner core is a solidsphere of about 1220km in radius, and has a temperature of about 5500°C. The liquid outer core is 2260km thick; with temperature range of 4400°C – 6100°C, the radius of the liquid outer core is approximately 3400km. More so, the core composed of 80% Iron (Fe), as well as Nickel (Ni), Gold (Au), Platinum (Pt) and Uranium (U).

This zone is very rich in Iron (Fe) and Nickel (Ni) which gives this layer the name "NiFe). With the great temperature and pressure some of the rocks found here are semi-liquid (Molten) state though, some are still solid.

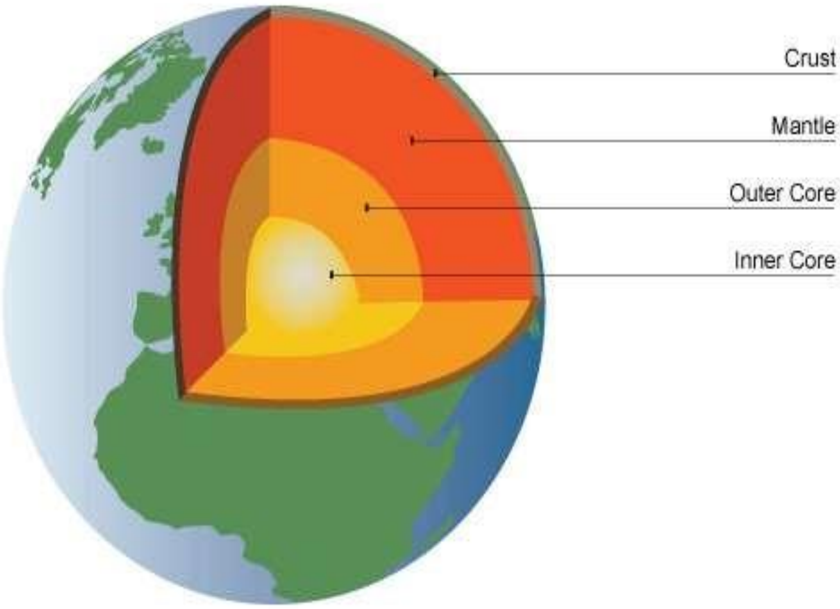

Figure 2.1a: Internal Structure of the Earth

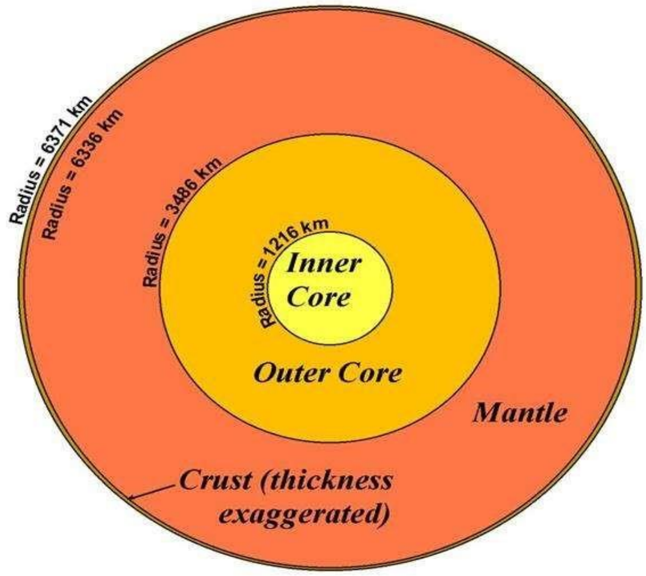

Figure 2.1b: Internal and Outer Zones the Earth

2. Mesosphere or Mantle

This zone is the thickest layer of the earth, extends for about 2900 km and surrounds the Barysphere as can be seen in Fig. 16a and 16b. The rock density increases from the upper part downwards but on the average it is 3.0 to 3.3. The upper part of the zone is solid rock but as the Barysphere is approached, some of the rocks become molten. The mesosphere is made up rocks rich in olivine (iron and magnesium). The Mantle is divided into the upper and lower mantle; divided by the transition zone. The lowest part of the mantle that is next to the core-mantle boundary is the D (D-double prime) layer. Movements in the upper mantle region is caused by heat variations from the core, causes the tectonic plate to shift. This shift can cause natural hazard like earthquakes and volcanic eruptions which in some cases, change the landscape and pose threats to the security of lives and properties.

The earth's mesosphere is made up of silicate rocks that are rich in Olive (Iron, Fe and Magnesium, Mg). The mantle is the most solid layer of the earth and it amasses 84% of the earth total volume.

3. Lithosphere or Crust

This is the thin, outermost layer of the earth. It accounts for less than 1% of the earth's total volume. The earth's crust is made of solid rocks and minerals. It has two sub layers – the SiAL and SiMA. The SiAL is the upper layer of the earth's crust with a light density of 2.7g/cm^3. This layer is made of rocks that are rich in Silica (Si) and Aluminum (Al) minerals. The **SiAL** is also referred to as continental crust. The **SiMA** is the lower layer, with a density of 3.0g/cm^3. This layer is composed of rocks that are rich in Silica(Si) and Magnesium (Mg) minerals. When it comes to the surface, the SiMa is also called Basalt. Another name for the SiMa is the Basalt/Oceanic crust

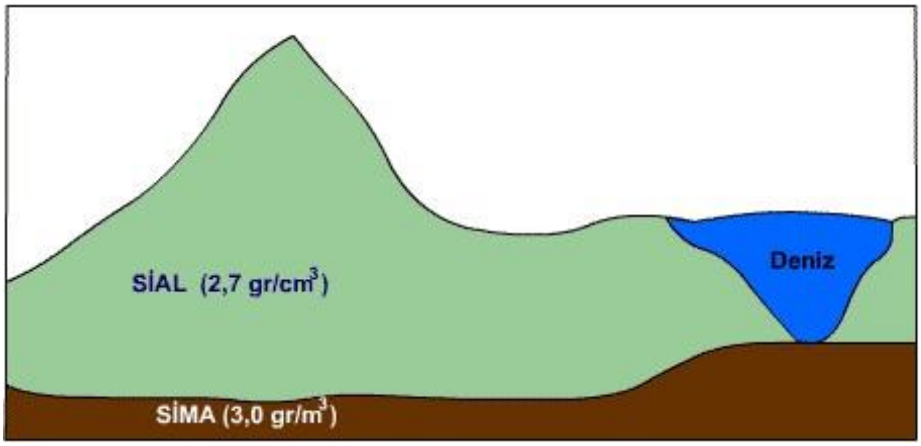

Figure 2.3: SiAl resting on SiMa

The main mineral constituents of SiAl are Silica and Aluminum from which it derived its name. The SiAl forms the continents and is discontinuous and separated by oceans while the SiMa is a concentric ring. Together, the SiAl and SiMa form the earth crust which varies in thickness from just about 6km beneath the oceans to as much as 48km in some highland areas of the continent.

A scientist by the name A. Mohorovicic in 1909 discovered a zone of discontinuity between the crust and the mantle which is named after him. It is called "Moho" zone of discontinuity. The zone exhibits a sudden increase in the speed of propagation of earthquake waves which shows a change in rock structure.

2.4 Outer Zones of the Earth

The outer structure of the earth is also concentric like the Internal Structure (Fig. 16b). It is made up of the three zones which are hydrosphere, biosphere and the atmosphere.

a. **The Hydrosphere:** The term hydrosphere is used to include all the natural water bodies of the earth's surface. It includes oceans, sea, rivers, lakes, ices sheets or glaciers and underground water in the lower part of the atmosphere. A planet's hydrosphere can be liquid, ice or vapour. Water vapour is not visible as clouds and fog.

b. About 97% of the water of this zone are accounted for by the oceans which also occupy about 70% of the earth's surface. Water locked up in ice sheets or glaciers amount to about 2% of the amount of water in the hydrosphere. In spite of the huge volume of water, the oceans are mainly useful for transportation for its salinity greatly renders it undrinkable and useless for agriculture. Water moves through the hydrosphere in a cycle called cycle. The water collects in the clouds, and then falls on the earth surface in the term of rain or snow. The water stores in the oceans, rivers and lakes. Then, after exposure to high solar temperature, it evaporates and the cycle starts over again

c. The Biosphere: This part of the earth is the one that supports life. This area therefore, includes the lower part of the atmosphere and the upper part of the lithosphere. It is a circular belt round the earth, hence the word "sphere". The Biosphere is very narrow on land where it rarely exceeds a few metres deep as the bulk of living organisms on land are usually confined to the surface or top soil. The sea also supports life to a great depth. Composition of the biosphere includes living organisms, both plants and animals. Some of these plants and animals are very small and can only be seen with the microscopes. Among such are organisms like bacteria and fungi which perform great functions of decomposing of dead plants and animals. Other large organisms include mammals, animals and trees, etc.

d. The Atmosphere: This is the envelope of gases surrounding the earth and this will be discussed in details in module 2.

Self-Assessment Exercise

i. Explain 'Moho" zone of discontinuity in your own words.
ii. Which part of the earth structure supports life and why?

2.5 Summary

In the unit, you discussed about the interior of the earth structure to be made up of Barysphere (Crust). Also that in the lithosphere the SiAl and the SiMa exist with different densities which caused the SiMa to be beneath while SiAl is above. The outer zones consist of hydrosphere, biosphere and the atmosphere. Hydrosphere consists of the water zone, while biosphere is the zone that support life and it spread from the lithosphere to the lower part of the atmosphere up to the upper part of the hydrosphere.

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2.7 Possible Answers to Self-Assessment Exercise(s)

i. Explain 'Moho" zone of discontinuity in your own words.

Moho discontinuity is a zone between the crust and mantle. It signifies a change in density of rock due to composition as P and S wave of earthquake moves through it.

ii. Which part of the earth structure supports life and why?

The biosphere is the structure of the earth that supports life which can be found at the interface of other spheres of the earth. This is due to the composition such as water, air (oxygen) and soil which are basics for plant and animal survival.

Unit 3: Rock Types and Formation

Unit Structure

3.1 Introduction

In previous units you have read about rocks, without full understanding of their importance, source and where they come from. In this unit, you will be discussing about rock formation and the various types. You will also learn about their importance.

As we learnt in the preceding unit, that rocks are substances that is or were natural part of the solid earth crust. Rocks come from great many varieties with various shapes, colour, sizes, texture, density and composition.

Most rocks are composed of variety of minerals which one can recognize the mineral as variations in the colour of the rocks. Dart mineral grains that occur in thin sheets are biolitemica that occur in stubby crystals are probably hornblende, the most common mineral in the amphibole family. Granite occur but not as common as these ones mentioned earlier.

3.2 Intended Learning Outcomes

The unit will discuss about rock formation, types and their importance.

At the end of the unit, you will be able to:

- name the various types of rocks from the formation
- identify the varieties of rock type
- recognise various types of rocks
  - list the type of minerals in a rock by their colour and composition.

3.3 Rock Formation and Types

Geologists have found it more useful to separate rocks into three groups based on how they are formed. The way rocks are formed is called their "origin". When solids are heated up enough, they melt, this is true even for rocks. If the melted material cools enough, it solidifies and the process of "**solidification**" is sometimes called "**crystallization**".

Based on the origin of rocks, the geologists group rocks into; igneous, sedimentary and metamorphic rocks. Let us examine each.

1. Igneous Rocks

These are formed from hot, molten (liquid) rock materials that originated from deep within the earth. Only igneous rocks have this origin. Hot, liquid rock is called "magma" and the earth surface magma is known as "lava". You learnt this in the last unit that earth temperature increases as you go deeper within the planet. In some parts of the earth, the temperature is hot enough to melt rock. When melted rock or molten rock rises to the earth's surface where it is cooler, the liquid rock material changes to solid rock.

Characteristics of Igneous Rocks

1. Igneous rocks do not occur in layers or starter but they exist as crystalline masses.
2. They may be broken by joints when they occurred during cooling and contraction.
3. They are usually very hard to break.

The chemical composition of the magma from which it is formed solidifies and rate of cooling determine the nature and character of the igneous rock. All lava contains silica. The more the silica, the more acidic the rock and the lower proportion of silica, the more basic igneous rock (Remember that you learnt about SiAl and SiMa in the last unit?).

Acidic igneous rocks are lighter in colour and in weight while the basic and ultra-basic igneous rocks are darker and heavier. In general, the rate of cooling affects the crystallization of igneous rocks. When the magma fails to reach the earth surface, the rate of cooling will be slower and will lead to formation of larger crystals. Examples of igneous rocks are granite, basalt, gabbro, diorite, perioditite, obsidian and olivine.

2. Sedimentary Rocks

Sedimentary rocks are formed through the gradual accumulation of "sediment" for example, sand on a beach or mud on a river bed. As the sediment is buried it is compacted as more and more materials is deposited on the top. They are derived from pre-existing rocks such as igneous rocks. They are referred to as "derived rocks" or "sedimentary rocks". The parent rocks were attached by the forces of weathering which could be by wind, water, frost, sun and were broken down. The rock materials were then carried away to some suitable locations, on the land, lake or sea. Most sedimentary rocks were however, formed on the floor of former sea.

Characteristics of Sedimentary Rocks

1. The deposition usually takes place in phases, so the rocks usually show distinct layers called "**strata**". Thus sedimentary rocks are stratified
2. They are usually fine-grained and non-crystalline.
3. They contain fossils (that is the remains of dead plants and animals). Therefore, they are said to be fossilized.
4. The connecting plane between two layers of sedimentary rocks is the Bedding plane
5. They richly contain the mineral Calcite.

There are three major types of sedimentary rocks, based on their formation:

a. Mechanically Formed Sedimentary Rocks

These are rocks formed by the breakdown or disintegration of preexisting rock during the process of mechanical weathering. Agents of erosion such as water, wind or glacier then transport the materials. These materials are later deposited in the sea or on land where they are pressed together to become solid as rock by water or the weight of overlying deposits. This process of solidification is called "compaction or cementation". Example: when larger pebbles are cemented this way to form a rock, it is called "conglomerate".

Sedimentary rocks built by up water may crack after the disappearing of the matter and the rocks are dried, this cause "joints" in the sedimentary rock.

In Nigeria, examples of mechanically formed sedimentary rocks are found in the Lake Chad basin, Sokoto basin, the Niger-Benue Trough, the Niger Delta and other coastal areas in Nigeria. These sedimentary rocks are formed by sand, silt, clay, mudstone, shale and gravel.

b. Chemically formed sedimentary rocks

These are rocks chemically precipitated from rocks before they solidified. Some sedimentary rocks are formed as a result of the precipitation of certain minerals from salt solutions. These are referred to as “evaporates”. An example of chemical precipitation into sedimentary rocks is the precipitation of calcium carbonate from calcium bicarbonate.

This is formed as water passes through limestone; it dissolves its mineral Unit Structure and carries them as solution. Over a period, this mineral carried in solution is used to build “stalactites” and stalagmites in limestone caves.

c. Organically Formed Sedimentary Rocks

Some sea animals do extract calcium carbonate from the sea to build their shells and skeletons. This calcium carbonate accumulates after their death to form rocks such as limestone, chalk and dolomite. Some sea animals like polyps (corals), sponges and planktons use silica to build their shells. When they die, their complex skeletons of silica which accumulate to form the nucleus of flint and other nodulus found in siliceous sedimentary rocks such as sandstone and some limestones.

Other buried coastal plants had been found along coastal land under clay and mud to form rock such as peat, lignite and coal after decay.

Another type is the bioclastic rocks which formed materials from or by living organisms. For example, a seam (layer) of coal, are remains of an ancient swamp environment where plants grew, died, accumulated layers upon layers which had been compressed and turned to stone. Like the green coloration of plants containing chlorophyll quickly breakdown when plants die.

The carbon content of the plant are especially common in coal are plants remains which gives coal its black colour. Coal is mined as a fuel and it can be used in making a variety of plastic and medicines.

3. Metamorphic Rocks

These are rocks which had once existed as igneous or sedimentary rocks but had subjected to varying degrees of pressure and heat within the earth's crust, making its structure and mineral content (mineralogy) altered.

The pressure may result from the rocks being buried at some depths. The processes involved will change the composition and fabric of the rock and their original nature such that it is often hard to distinguish or determine any of the characteristic features of the original parent rock. Example is limestone changed to marble.

During the recrystallization caused by metamorphism, valuable minerals are formed. Therefore, metamorphic regions are economically of great value. For example, the Canadian shield of North America is highly mineralized.

All rocks are subject to metamorphism and metamorphic rocks can metamorphose again.

3.4 Importance of Rocks

i. **Rocks and Soil Fertility:** Soil fertility is determined by the parent rock from which the soil is formed. Older rocks had been discovered to form poor soils while newer sedimentary rocks like alluvial deposits and recent volcanic rocks form fertile soils.

ii. Rocks and Underground Water: The type and nature of rocks determines the availability and the quality of underground water supply. The permeability of rock affects the circulation of ground water. Rock permeability is the capacity of the rock to allow water to pass through it. This varies from rock to rock. Limestone allows water pass through very easily and that makes it dry. Impervious rocks which are clay based do not allow water through it. Such rocks retain water at the surface to form a zone of saturation below which ground water cannot be found. This has an implication on the water table.

iii. Rocks and Occurrence of Minerals: All minerals are either derived or obtained from rocks. Among these are the world's major sources of fuel (Coal, Oil and Natural gas). Coal, which is one of the world's oldest forms of power provided the basis for Industrial revolution.

iv. Petroleum (referred to as black gold) is a major source of power. There are other non-fuel minerals from rocks.

v. Rocks and Construction: Some rocks provide good substances for the construction of buildings and roads. Examples of these are gravel and granite. Slate which is fine-grained metamorphic rocks like mudstone is used for roofing in the temperate regions.

vi. **Rocks and Industries:** Rocks form raw materials for the production of several goods in industries. The pottery industry is dependent on locally available clay. Kaolin and other raw materials are used for manufacturing household item such as china-wares (pots, cups, flower vases and the Nigerian clay in Niger State limestone and iron ore are used for the manufacturing of cement and steel respectively as in Obajanu and Itape in Kogi state of Nigeria.

vii. **Rocks and Tourism:** Rocks can provide distinctive types of scenery which is useful for tourism or recreation. Examples are Olumo Rock in Ogun State, Nigeria; the granite Tors of Dartmoor in Britain, the Rainbow Arch in the Glen Canyon, U.S.A. Volcanic rock features on the Jos Plateau (Nigeria) and other rock features in caves such as Stalactites and Stalagmites.

viii. **Rocks** provide foundations for all structures on the earth's surface. The type of rocks used often determines the type of structure build on it.

Self -Assessment Exercise

i. Give four economic importance of rocks
ii. Describe the characteristics and mode of formation of Igneous rocks
iii. Draw a well labeled diagram of the internal structure of the earth

3.5 Summary

In the unit, you learnt that there are three groups of rock formations which are igneous, sedimentary and metamorphic rocks. You discovered that only igneous rock originated from the earth's crust. Sedimentary rocks are formed by accumulations of weathered materials over time which could be mechanical, chemical or organically formed. Metamorphic rocks on the other hand, are rocks that had experienced several changes from the original materials due to heat or pressure or both. You also learnt about the importance of rocks based on their compositions.

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1.7 Possible Answers to Self-Assessment Exercise(s)

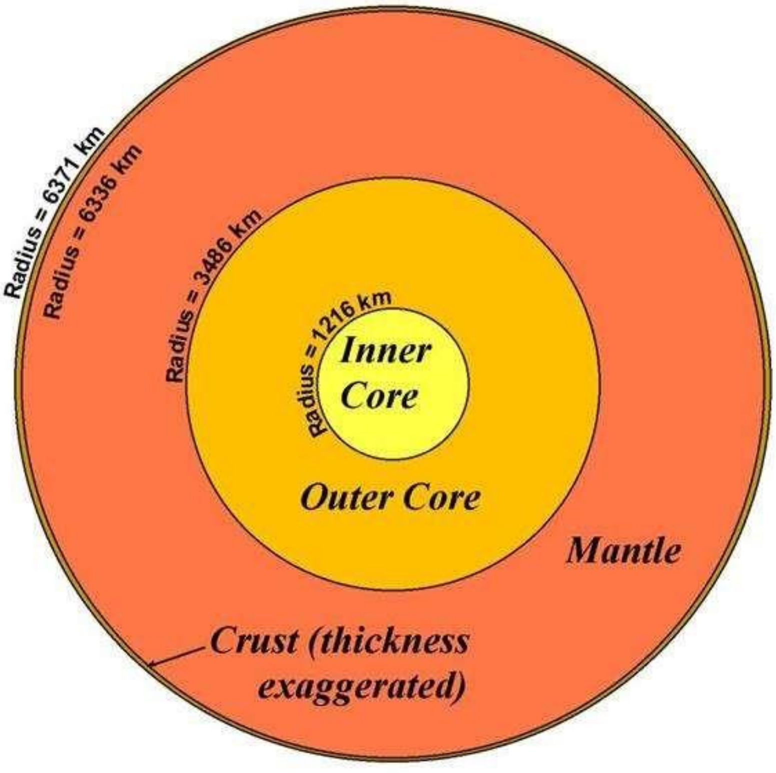
i. Give four economic importance of rocks

- Formation of soil
- Source of river
- Source of mineral resources
- Provision of Employment

ii. Describe the characteristics and mode of formation of Igneous rocks

- They are formed by the cooling and solidification of magma
- They do not contain fossil (dead plant and animal)
- They are crystalline in nature

iii. Draw a well labeled diagram of the internal structure of the earth



Internal structure of the earth

Unit 4: Tests for Common Rock Occurrence

Unit Structure

4.1 Introduction

Rocks are made of one or more minerals. These can be pure, solid or inorganic (nonliving) materials found in the earth's crust. Mineral can be made up of one or more elements. Elements are the most basic, naturally occurring substances on earth. They cannot be broken down but can undergo radioactive decay.

Minerals all have chemical compositions and physical properties that are unique to the specific mineral. Common rocks forming minerals are feldspars, quartz, calcite, mica and hornblende.

4.2 Intended Learning Outcomes

By the end of the unit, you will be able to carry out rock physical property test using hardness, colour, streak, luster, cleavage and chemical reactions.

4.3 Rocks Physical Properties Tests

All minerals have value, which varies. The rarer a mineral is the more valuable it is and this also goes with its usage. When a mineral is used for many of different things like copper, it becomes valuable. Some minerals are mined for their beautiful properties such as diamonds and other "gems" while some are so valuable that they are used for jewelry or decorations like "gold" and "platinum". Geologists use specific properties to identify rocks and minerals. They use the following tests to distinguish minerals and rocks. These include: Hardness, colour, streak, luster, cleavage, and chemical reaction.

Hardness
A scratch test developed by a German mineralogist Frediech "Mohs" in 1822 is used to determine mineral hardness. The scale measures hardest minerals (diamond). Common objects of known hardness can be used to determine mineral hardness. These common objects are; fingernail (2.5)

a coin (3), a piece of glass (6) and a knife blade or nail. If a fingernail can scratch the mineral, it has a hardness of less than 2.5, which is quite soft. But when a mineral can be scratched by glass, it has a hardness greater than 6 which is very hard.

Colour

Colour can sometimes be helpful when identifying minerals. However, some minerals have more than one colour, like quartz. Quartz can be blue, brown, pink, red, purple and almost any other colour or it can be colourless. So geologists had to develop a better way of using colour as an identifying property called “Streak”.

Streak

This is the name given to the coloured residue left by scratching a mineral across an abrasive surface such as a tile of unglazed porcelain. The streak may not always be the same colour seen in the specimen. A mineral with more than one colour will always leave a certain colour of streak. Hematite is a mineral that can be red, brown or black but will always leave a characteristics brown streak.

Luster

Geologists use luster for identifying mineral. It is a way in which the surfaces of a mineral reflect light. There are two main types which are (a) metallic and (b) nonmetallic. A metallic luster is shiny and looks like reflection from a metal object such as faucet while mineral that does not shine like metal has a non-metallic luster e.g. the wall has a non-metallic luster. There are many types of non-metallic luster. A glassy luster is bright and reflects light like a piece of glass. A greasy luster has an oily appearance while carthy luster is a very dull and looks like dirt. Waxy luster looks like the shininess of a crayon.

Cleavage

Cleavage is the tendency for minerals to break along flat planar surfaces. Cleavage is rated as good, fair and poor depending on the quality of the flat surface produced. Mica for example, is a mineral that has good cleavage. It breaks into very flat sheets. Minerals with poor cleavage will break along irregular surfaces. Quartz for example will break into pieces that have a seashell-like fracture plane. Garnet shatters with no distinguishable pattern, hence it has no cleavage at all.

Chemical Reaction

A weak acid is used to indicate if rocks or minerals contain calcium carbonate ($CaCO_3$). If the specimen fizzes (giving off CO_2) when it comes in contact with acid, it is considered carbonate rich but it does not fizz, then it does not contain calcium carbonate. Calcite and aragonite and two minerals that will always fizz.

Table 4.1: Some Common Minerals and their Properties

Mineral	Luster	Hardness	Streak	Specific Gravity
Graphite	Metallic	1	Black	2.1-2.3
Halite	Glassy	2.5	No colour	2.2
Calcite	Glassy	3	No colour	2.7
Magnetite	Dull	5.5-6.5	Black	5.2
Pyrite	Metallic	6.0-6.5	Gold	4.9-5.2
Feldspar	Glassy	6-6.5	Different colours	2.5-2.75
Quartz	Glassy	7	Different colours	2.6-2.7

Table 4.2: Mohs Hardness Scale

Mineral	Hardness
Talc	1
Gypsum	2
Calcite	3
Fluorite	4
Feldspar	5
Apatite	6
Quartz	7
Topaz	8
Corumdum	9
Diamond	10

Mohs Hardness Testing Procedure

1. Begin by locating a smooth unscratched surface
2. Hold specimen with one hand against a table top for support
3. Hold one of the standard hardness specimens in the other hand and place a point of that specimen against the selected flat surface of the unknown specimen
4. Firmly press the point of the standard specimens against the unknown specimen and drag the point of the standard specimen across the surface of the unknown specimen
5. Examine the surface of the unknown specimen with a finger. Brush away any mineral fragments or powder that was produced. Did the test produce a scratch? Be sure it is a scratch for the groove will be distinct on the mineral surface.
6. Repeat the test a second time to confirm your result.

Self -Assessment Exercise

i. Explain how to test hardness of a specimen using Mohs Hardness Testing.

4.4 Summary

The unit discussed about different tests used by geologists to identify rocks (minerals). It was learnt that some minerals react differently to chemical reaction which either give off CO_2 when they contain calcium carbonate called fizz or do not. The Mohs Test procedure for Hardness was also learnt and the tables showing examples of minerals and their hardness values on the Mohs hardness scale.

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4.6 Possible Answers to Self-Assessment Exercise(s)

i. Explain how to test hardness of a specimen using Mohs Hardness Testing.

Moh's scale is a relative hardness scale. Rather than carry samples of ten standard minerals, a geologist doing field work usually relies on common objects to test the hardness. Fingernails (<2.5), copper coin (between 3 and 4), knife or steel nail (slightly > 5) etc.

Unit 5: Nigerian Rock Types and Mineral Resources

Unit Structure

5.1 Introduction

Nigeria as a nation is richly endorsed with large land expanse and richly blessed with various types of mineral resources. Nigeria is an important producer of minerals and these are found in sedimentary rocks. Some of these minerals include coal, petroleum and limestone. Others are found within the basement of complex rocks and they are tin, columbite, gypsum, gold and others.

5.2 Intended Learning Outcomes

At the end of this unit, you will be able to:

- name the major minerals in Nigeria
- identify the locations where each mineral is found
- state the importance and usefulness of these minerals
- identify where mines are located

5.3 Mineral Deposits in Nigeria

Nigeria is an important producer of several minerals. These mineral deposits include:

Coal: The only coal mine is in West Africa and it is located in Enugu state where mining began in 1915. It is mined by the adit method where tunnels are driven into the hillsides to reach the coal layers called seems.

There are also coal deposits along the middle belt in Benue state. Nigeria resumed the export of coal in 1996.

Ignite: This is a form of coal but of poorer quality. It is found at the west of the coal deposit near Onitsha and Asaba but it is not being mined now.

Tin and Columbite: These two are minerals found together in alluvial deposits on the Jos Plateau. Mining is concentrated on the southern part of Jos around Bukuru and Barakin Ladi where the open cast method of mining is used. Tin and Columbite were the first minerals mined and exported from Nigeria. The extraction started about 1933.

Tin is used for coating containers for the canning industries. Columbite on the other hand is a rare ore. The metal obtained from it does not corrode and can resist high temperature. It is light in weight, which makes it useful in the steel industry where it is added with other metals in the manufacture of atomic reactors, gas turbines, jet engines for aircrafts and rockets.

90% of the world's columbite is mined in Nigeria and most of it together with tin is exported to the USA (see figure 18a).

Limestone: Limestone is found in several places in Nigeria giving rise to cement industries in the different places where they are found. Some of these areas are Ewekoro and Shagamu in Ogun State, Okpella in Edo State and Obajana near Lokoja in Kogi state (See Figure 18b).

Fig. 5.1: Map of Nigeria Showing Mineral Deposits

Gold: Gold deposits are located in Ilesha and in Sokoto along Zamfara river valley. The whole output is used within the country.

Iron Ore: There are many shallow deposits of medium to low grade ores all over the country. The largest deposit is that located at Agbala

Plateau near Lokoja, producing two billion tons of high quality iron ore and this is used for the Ajaokuta steel company.

Petroleum and Natural Gas: This is the most important mineral of Nigeria. It is found mainly in the Niger Delta areas (located mainly in Rivers, Akwa Ibom and Delta States) and in offshore locations. Petroleum accounts for about 90% of Nigeria's export earnings. Natural gas is produced along with petroleum and is now been liquidized as Liquefied Natural Gas Project (LNG) of Nigeria.

Petroleum is mined using “drilling method” pipes are drilled into the ground from surface structures called “derricks” and oil is forced out to the surface under pressure.

Self-Activity
Name some of the mineral deposits found in Nigeria.

5.4 Importance of Mining in Nigeria

There are several importance of mining in Nigeria and their economic benefits. These include:

a. Foreign exchange: Nigeria earns most of her foreign exchange from mineral export, especially petroleum totaling about 90%.
b. Empowerment: The various mining companies employ thousands of Nigerians both skilled and unskilled labour.
c. Technology Transfer: Nigerians employed in the mining sector have acquired technological knowledge from the foreign oil companies. This is what is being used in running the Nigerian owned Nigerian National Petroleum Corporation (NNPC).
d. Urban Development: Mining has led to the physical and economic growth of some major urban centres. Most major commercial and industrial centres in the country owe their growth and development to mining. Examples are Warri, Port Harcourt, Jos, Bukuru, Ilesha and even Lagos. The construction of the Federal Capital at Abuja has engulfed several billions of dollars gotten from the petroleum industry.
e. Infrastructural development: Mining has influenced road and rail construction throughout the county, e.g. the extension of railway lines to Enugu and Jos. Mining companies have constructed roads to facilitate easy access to, and exploitation of minerals.
f. Raw Materials: Minerals have served as raw materials for industries e.g. Limestone has given rise to several cement factories and oil has given rise to refineries in Port Harcourt, Warri and Kaduna. Petrochemical industries also benefit from the mining of minerals.

In the mining of minerals, there are several effects that sprang up in the country. Some of these include;

i. **Loss of Farmlands**: Mining has led to the destruction of farmlands or rendering of farmland useless land among the oil producing areas in the Niger Delta region.
ii. **Environmental Deterioration**: Mining has caused much environmental degradation among oil-producing communities on the Niger Delta area and on the Jos Plateau. For instance, the open cast method of mining tin has initiated much erosion especially on hill slopes.
iii. **Depletion of Reserves**: Minerals are non-renewable resources; they are depleted after a long period of exploration.
iv. **Shortage of spare Parts**: Many of the mining sites have equipment, which should be periodically renewed or replaced especially when they are getting old and rusty. There is therefore, constant breakdown, e.g. the poor management of oil refineries led to fuel shortage, making Nigeria to constantly import fuel from overseas.
v. **Inadequate Skilled Labour**: Mining engineers and other technical personnel needed by the oil industry are in short supply within the country. This leads to expatriate domination of the vital mining sector thereby draining the foreign reserves.
vi. **Poor Transportation**
vii. **Mining hazards**
viii. **Over dependence and others.**

Self -Assessment Exercise

1) Explain the locations where Tin and petroleum deposits are majorly located in Nigeria.
2) Identify some importance of mining to an area.
3) State four effects of mining in Nigeria.
4) List the locations of the deposits of the following minerals: Coal, Petroleum, Limestone.

5.5 Summary

In this unit, you learnt about the specific locations of mineral deposits and their mining processes. The commonly mined minerals like coal, tin and columbite, iron ore, lime stone and petroleum were discussed. The importance of mining to the Nigerian economy was also learnt. You also can now identify the mining locations of Nigeria and list the advantages and disadvantages of mining to an area.

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5.7 Possible Answers to Self-Assessment Exercise(s)

1. Explain the locations where Tin and petroleum deposits are majorly located in Nigeria.

   Tin are alluvial deposit of the Jos plateau of Plateau state. Petroleum are majorly located in Niger Delta basin of Nigeria. The areas include; Delta state, Akwa Ibom and Rivers.

2. Identify some importance of mining to an area.
   - Provision of employment
   - Infrastructural development
   - Generation of revenue

3. State four effects of mining in Nigeria.
   - Environmental pollution

- Overdependence
- Mining Hazard

4. List the locations of the deposits of the following minerals: Coal, Petroleum, Limestone.
   - Coal; Enugu State, Anambra State
   - Petroleum; Delta State, Akwa Ibom, Rivers
   - Limestone; Ogun State, Kogi State

Module 2 The Atmosphere

Unit 1: Importance of Atmosphere

Unit Structure

1.1 Introduction

The earth is the only known planet on which life exists. Other planets and moons in our solar system have atmospheres, but none of them could support life. They are either too dense or not dense enough; and none of them have much oxygen; the precious gas that the earth animals need every minute.

Other planets include Mars, Venus, etc. Atmosphere is only used for earth's atmosphere and it extends from a few meters below the earth surface or water surface to a height of about 60,000 km. however, about 90% of the atmosphere is within few kilometers from the ground level, as the gravity pulls most of the mass of the atmosphere towards the earth's center.

The atmosphere is very special in that it contains life-sustaining oxygen in large quantities (21% by volume). All the natural processes on earth are functioning harmoniously and these processes do not take place in isolation. The atmosphere is constantly exchanging energy and matter with other components of the earth which are the lithosphere, hydrosphere and the biosphere. Together with the oceans, the atmosphere shapes the earth's climate and weather patterns and makes some regions more habitable than others.

1.2 Intended Learning Outcomes

At the end of this unit, you will be able to:

- identify the components of the atmosphere
- define atmosphere
- state the extent of the height of atmosphere
- mention the importance of atmosphere

1.3 What is Atmosphere?

Atmosphere is a gaseous layer surrounding the earth. We can say that our earth is surrounded by a thin layer of gases, called atmosphere. This thin layer has its own influences various processes that take place on earth. It also contains a mixture of gases with some impurities.

The atmosphere is a critical system that helps to regulate earth's climate and distribute heat around the globe. The earth climate is not static but fluctuates. The atmosphere as a complex system experiences physical and chemical reactions, which occur constantly. Many atmospheric processes take place in a state of dynamic balance – for example, there is an average balance between the heat input to and output from the atmosphere. "This condition can be compared to a leaky bucket sitting under a faucet, when the tap is turned on and water flows into the bucket, the water level will rise towards a steady state where inflow from the tap equals outflow through the leaks. Once this condition is attained, the water level will remain steady even though water is constantly flowing in and out of the bucket". Similarly, earth's climate system maintains a dynamic balance between solar energy entering and radiant energy leaving the atmosphere.

1.3.1 What Height is the Atmosphere?

The atmosphere is only used for the earth's atmosphere. It extends from a few meters below the earth's surfaces or water's surface to a height of about 60,000 km. However, about 90% of the atmosphere is within few kilometers from the ground. Most of the atmosphere is near planetary surface as the gravity pulls them towards the earth's centre.

1.3.2 Is the Atmosphere Uniform throughout?

The atmosphere is the transparent layer through which life, sustaining solar radiation passes through before reaching the earth surface or into water. It is a wonder that solar radiation is described "as life-sustaining". This is because solar radiation is the only source of energy for photosynthesis on earth, which supports all other life.

When the earth is heated up, it emits energy in the form of infrared radiation during the nighttime which is subsequently absorbed by carbon dioxide, water and few other gases. This process, results in “greenhouse effect” and consequently the atmosphere is kept warm during the night, while it becomes so cool.

The earth is not heated by solar radiation uniformly due to its inclination, as such different weather patterns exist over the earth. In order to compensate these differences, air sets in motion resulting in winds and circulation of air. These wind currents are of global scale as well as of local scale. These are responsible for disastrous storms like cyclones, dust storms, tornadoes, etc.

These wind currents also influence water current in the oceans; which in turn affect the wind currents. Consequently, understanding the atmosphere and its functions and behavior is quite complex. Thus, understanding of the atmosphere is very essential and very important. These processes mentioned make the atmosphere dynamic and we need to know more about it.

Self-Assessment Exercise

1. Identify two reasons why we must know about our atmosphere.

1.4 Summary

We have learnt that the atmosphere is denser at the bottom than the upper part. We also learnt that the atmosphere is special because it contains life sustaining oxygen in large quantities (21% by volume). And that all natural processes on earth are functioning harmoniously.

1.5 References/Further Readings/Web Resources

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1.6 Possible Answers to Self-Assessment Exercise(s)

1. Identify two reasons why we must know about our atmosphere.
   - Human activities such as Agriculture and Sport
   - Climate change to mitigate the causes

Unit 2: Composition of the Atmosphere

Unit Structure

2.1 Introduction

In this unit we shall discuss about the composition of the atmosphere; the gases present, both in large and small amounts as well as the solids and the impurities.

2.1 Intended Learning Outcomes

By the end of this unit, you will be able to:

- identify the composition of the atmosphere
- separate into constant and variable gases present in the atmosphere
- explain the solid particles present in the atmosphere and their roles

2.3 Importance of Atmospheric Gases and other Constituents

The composition of atmosphere is gases, which are in large quantity, water vapour, and solid particles that are in small amount. The gases in the atmosphere are divided into two kinds depending on their concentration, which are (i) constant gases and (ii) variable gases.

Constant gases are those whose concentrations do not fluctuate over time but remain same. While the variable gases are present in different concentrations at different places and times. Nitrogen and oxygen are the two major constant gases that make up 99% of the air. Both are very important to the sustenance of life on earth. Nitrogen constitutes 78.0% while oxygen is 20.94% by volume thereby making the bulk of the atmosphere. The remaining 0.97% of the atmosphere is made up of nitrous oxide and inert gases such as argon, helium, krypton xenon, water vapour, carbon dioxide and ozone.

It is needless to stress the importance of oxygen to life, every living organism including humans need oxygen for respiration. Respiration is the process through which the chemical energy (food) is converted into usable form of energy by all living cells. Inert gases are used for commercial purposes such as in the neon lights.

2.3.1 Role of Carbon Dioxide in Atmosphere

All living organisms emit carbon dioxide as a product of respiration. Producer organisms (green plants and certain microorganisms) for the synthesis of food in turn use it. This process is called "photosynthesis". Photosynthesis is another example of natural processes that are interrelated and one inter-dependent. Plants utilize large amount of carbon dioxide and it constitutes only 0.04% of the dry air. Nevertheless, it plays a significant role in keeping the atmosphere at temperatures that permit life.

The concentration of carbon dioxide in the air has great effect on the temperature. Due to increasing human activities, there is increase in carbon dioxide concentration. Nowadays, human burns large amount of fossil fuel for various purposes that result in huge amount of carbon dioxide emission into the atmosphere. This ever increasing concentration has already resulted into "global warming" which in some places, melting of ice.

Water vapour on the other hand though, very small plays a crucial role. It is responsible for cloud formation in the atmosphere and precipitation. The concentration of water vapour varies over time at a given place and at different places. It is an important component of the atmosphere in determining the weather of a place at a given time. It is responsible for fog formation in the early morning hours in winter, rainfall and the fell of sultry near coastal regions during summer. Water vapour also absorbs outgoing radiation from earth as carbon dioxide does and it has a crucial role in greenhouse effect. Therefore, it is worthy to note that carbon dioxide and water along with Ozone (in troposphere), methane and nitrate oxide are called "Greenhouse gases".

2.3.2 Role of Other Constituents

As we learnt earlier, that the water present in the clouds can absorb and reflect incoming solar radiation. It can also determine the weather of a particular place at a given time. Water vapour also move along with the wind as it is in circulation, as such it is distributed to areas away from the sea. However, regions far away from the sea will have less moisture than places close to the sea.

Other variable gases present in the atmosphere include; hydrogen, helium, sulfur dioxide, methane, carbon dioxide and oxides of nitrogen. Some of them are air pollutants, emitted by human activities.

The atmosphere also contains solid particles in minute quantities. These could have originated from nature or by human activities or both. In minute quantities, they are beneficial as they initiate and partake in cloud formation. The solid particles absorb and scatter solar radiation. However, when their concentration is high, they reduce the visibility of the atmosphere and harmful to human health (for example during the harmattan season). They also affect other living organisms in many ways.

Table 2.1: Constituents of Atmosphere

Gas	Average Percentages (by volume or dry air)
Nitrogen (N)	78.09
Oxygen (O)	20.94
Argon (Ar)	0.9
Carbon Dioxide	0.03
(CO_2)	0.002
Neon (Ne)	0.0005
Helium (He)	0.0002
Methane (CH_4)	0.0001
Krypton (Kr)	0.00005
Hydrogen (H)	0.00005
Nitrous Oxide (N_2O)	

Self-Assessment Exercise

1. What are the two constituent of the atmosphere? Name them with their average proportions.
2. Discuss the contribution of water vapour and solid particles of the atmosphere in solar radiation control.

2.5 Summary

In this unit, you studied about the gases, solid particles and water vapour that are present in the atmosphere. The importance's of each were discussed and the effect of lack of each on the weather and the generality of the earth were mentioned. Also the constituents of atmosphere in percentage by volume in dry air were also learnt.

2.6 References/Further Readings/Web Resources

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2.7 Possible Answers to Self-Assessment Exercise(s)

1. What are the two constituent of the atmosphere? Name them with their average proportions.

   Nitrogen in its gaseous form in the atmosphere is not of much importance because it is non-poisonous. However, as it is converted into useful forms for life by microorganisms it becomes very important. **Nitrogen** is needed in the formation of **amino acids**, which are building blocks of proteins and in the formation of **nucleotides**, which are part of the genetic materials (DNA and RNA). Showing the best example of the natural processes, which are in perfect harmony with one another.

2. Discuss the contribution of water vapour and solid particles of the atmosphere in solar radiation control.

   Water vapour though very small plays a crucial role. It is responsible for cloud formation in the atmosphere and precipitation. The concentration of water vapour varies over time at a given place and at different places. It is an important component of the atmosphere in determining the weather of a place at a given time. It is responsible for fog formation in the early morning hours in winter, rainfall and the fell of sultry near coastal regions during summer. Water vapour also absorbs outgoing radiation from earth as carbon dioxide does and it has a crucial role in greenhouse effect. Therefore, carbon dioxide and water along with Ozone (in troposphere), methane and nitrate oxide are called “Greenhouse gases”.

The atmosphere also contains solid particles in minute quantities. These could have originated from nature or by human activities or both. In minute quantities, they are beneficial as they initiate and part take in cloud formation. The solid particles absorb and scatter solar radiation. But when their concentration is high, they reduce the visibility of the atmosphere and harmful to human health (for example during the harmattan season). They also affect other living organisms in many ways.

Unit 3: Structure of Atmosphere

Unit Structure

3.1 Introduction

The earth is surrounded by a thin layer of air called atmosphere. The atmosphere extends up to 60,000 km from the surface of the earth. Most of the mass of the atmosphere is found near the planetary surface which is near the earth surface from surface to about 80- 100 km. this is due to the earth's gravity which pulls the atmospheric constituents towards its center. This structure will be treated from two points of view

3.2 Intended Learning Outcomes

At the end of this unit, you will be able to:

- determine which layers are based on composition of constituents and those on temperature.
- explain the different layers of atmosphere
- mention the names of the different layers.

3.3 Layers of Atmosphere based on Composition of Constituents

The atmosphere where most of atmospheric processes take place according to the concentration of gases is divided into:

1. **Homosphere:** This is the lower region, extending from the surface of the earth to a height of 80-100 kilometers above the earth. Gases in this layer are more or less uniform in their chemical composition.
2. **Heterosphere:** This layer starts from the upper portion of the homosphere extending to a height of 60,000 km above the earth. Here, the chemical composition changes with height. The concentration of gases decrease as one goes up because of intermolecular distance increases with height hence, the decrease in the concentration.

3.4 Layers of Atmosphere based on Temperature Variation

The atmosphere can again be divided into four distinct layers using their temperature characteristics. These are:

1. **Troposphere:** This is the bottom layer of the atmosphere which contains 70% mass of the atmosphere. It extends to an average height of 12 km. However, the thickness varies with latitude: **i.** Over the poles it is only 8 km **ii.** Above the equator is about 16km

   A very important feature of this layer is that temperature decreases with height and the rate of decrease of temperature with altitude is called – “lapse rate”. The average lapse rate in troposphere is – 6.4^0C/km. Troposphere ends at “tropopause” which act as a lid over it where temperature stop decreasing with height.

2. **Stratosphere:** This lies just above the tropopause and extends to a height of 50 km from the earth’s surface. Ozonosphere is a very important layer found within this layer. Ozone present in ozonosphere prevents the harmful ultra-violet rays from reaching the earth, thereby protecting the life. Ozonosphere acts as a protective umbrella over the earth.

   Stratosphere is a calm layer consisting of relatively clean air. Cloud does not form in this layer because there is almost no water vapour present. In this layer, temperature increase with height which is opposite to that of troposphere. The increase of temperature with height prevents movement of vertical winds. Only horizontal winds are seen and they flow almost always parallel to the earth’s surface. The absence of vertical winds and horizontal winds parallel to the earth’s surface result in relatively calm atmosphere with no turbulence. This ensures smooth travel for flights (planes) and good visibility for pilots with the absence of clouds. It also enables jet air planes in this layer because of these features.

   It has also been observed that jet planes flying in the sky are partly responsible for the destruction of the ozone. Also above the stratosphere, the temperature neither decrease nor increase with height up to some level. This small layer is known as “stratopause”.

3. **Mesosphere:** This layer starts from the edge of stratosphere at about an approximate height of 52 km from the earth’s surface and extends to a height of 80 km from the ground. In this layer, the

temperature decreases with height just as in troposphere. The layer does not have any impact on life but gains importance as it plays crucial role in radio communication.

It is able to convert sunlight individual molecules to individual charged ion that is, ionization. Ionized particles are concentrated as a zone known as D-Layer. This D-Layer reflects radio waves sent from earth but blocks the communication between earth and astronauts.

During summer nights, spectacular displays of wispy clouds are seen over high latitudes. It is presumed that meteoric dust particles coated with ice crystals reflect the sunlight which results in wispy clouds.

Just above the mesosphere lies "mesopause" in which temperature neither decrease nor increase.

4. **Thermosphere:** This is the fourth layer and it is found approximately above 80km from earth's surface. It extends to the edge of space at about 60,000 km from earth's surface. In this layer, temperature keeps rising with increase in altitude which is likely reaching 900^0C at an altitude of 350 km. Nevertheless, this high temperature is not felt below. The air molecules are so far apart in this layer which makes only individual molecules are affected. In this layer there is ionization of molecules which results in individual charged ions. This process produces two ionized belts viz: E-and F- layers. These layers also reflect radio waves and have influence over radio communications. At the upper thermosphere, further concentration of ions are seen that comprise the "Van Allen radiation belts which is sometimes called "magnetosphere". It is thus refer to as the 'earth's magnetic field' which has influence over the movement of particles rather than earth's gravitational field. Thermosphere does not have upper boundary but gradually blends with space.

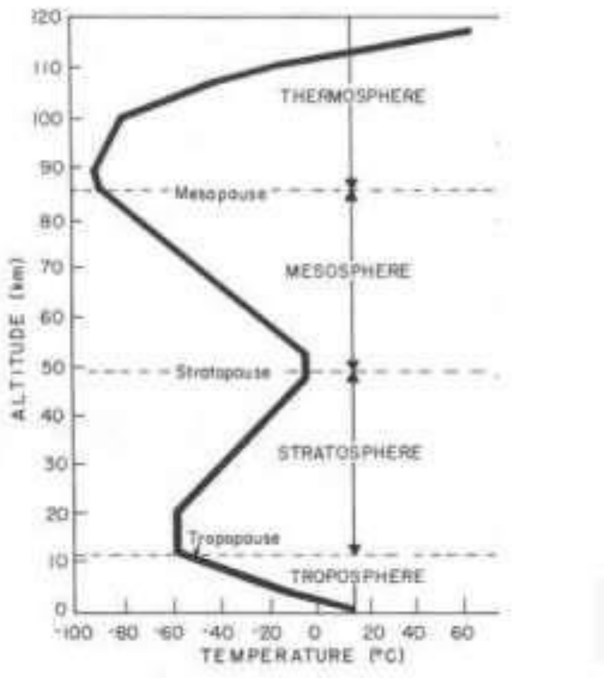

Figure 3.1: Vertical Temperature Variation of the Atmosphere and its Layers

Self-Assessment Exercise

i. Identify the significance of each layer by temperature
ii. Can you state the major constituents of the atmosphere?

3.5 Summary

In this unit, you have learnt the two types of structural division of the atmosphere either by composition of constituents into two by temperature which gives four layers. The characteristics of each layer were also identified.

3.6 References/Further Readings/Web Resources

lleslie, A.Y., Joshua, A.K., Andrew, J.S., Randall, G., Michael, E. S., Darrell, F.S., David, P. H., AlanStern, H., & Weaver, A.(2018). Structure and composition of Pluto's atmosphere from the New Horizons solar ultraviolet occultation. *Science Direct Journals* 300, 174-199 https://doi.org/10.1016/j.icarus.2017.09.006

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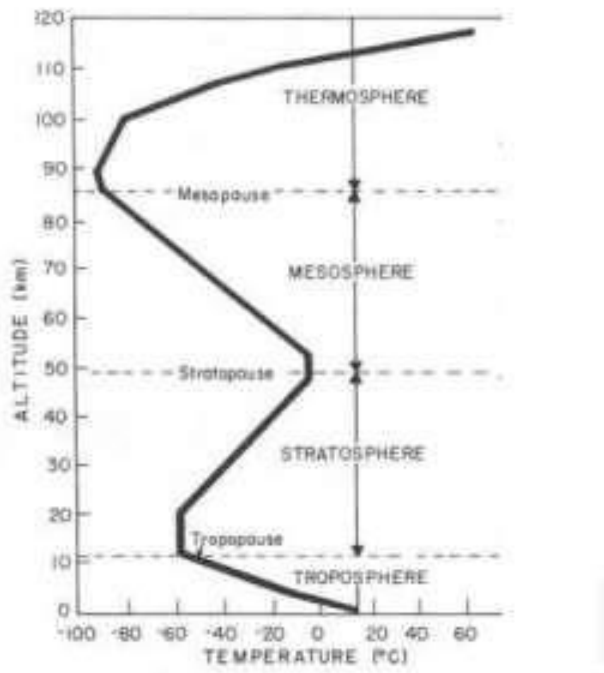
3.7 Possible Answers to Self-Assessment Exercise(s)

i. Identify the significance of each layer by temperatur



ii. Can you state the major constituents of the atmosphere?

1. Nitrogen
2. Oxygen
3. Argon
4. Carbon dioxide
5. Trace amount of neon, helium, methane, krypton and hydrogen, as well as water vapor.

Unit 4: Greenhouse Gases and Global Carbon Cycle

Unit Structure

1.0 Introduction

Earth's surface temperature has been remarkably constant over geologic time. The dramatic cooling that occurred during most recent ice age represented a change of only 3^0C in the global average. Seasonal changes in temperature, maybe large in one particular place but corresponds to very tiny changes in global mean temperature.

The earth exchanges energy with its environment primarily through transfers of electromagnetic radiation. At any time, the earth planet is simultaneously absorbing energy from the sun and radiating energy back into space at a rate that closely balances the energy input it receives from the sun.

The earth receives energy from the sun in form of solar radiation with varying wavelengths along the electromagnetic spectrum. The sun emits strongly in the visible light range but it also produces ultraviolet and infrared radiation. The earth radiates heat back to space mostly at much longer wave lengths than solar radiation (see fig. 2).

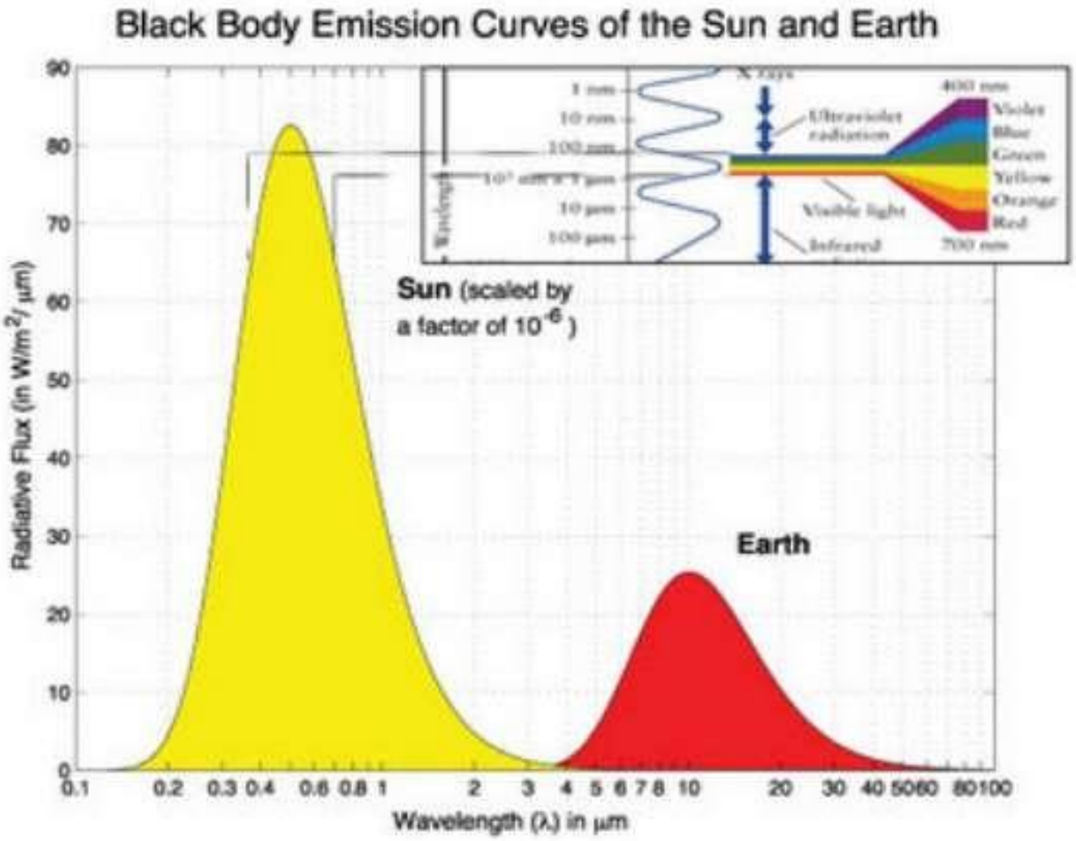


Figure 4.1: The Electromagnetic Spectrum

4.2 Intended Learning Outcomes

At the end of this unit, you will be able to:

- explain what happen to the solar radiation that the earth receives
- identify the various gases of greenhouse
- understand the effects of greenhouse gases
- explain the global carbon cycle

4.3 Radiative Balance and Natural Greenhouse Effect

When visible solar radiation reaches the earth, it may be absorbed by clouds, the atmosphere or the planet's surface. Once absorbed, it is transformed into heat energy which raises earth's surface temperature. However, not all solar radiation intercepted by the earth is absorbed. The fraction of incoming solar radiation that is reflected back to space constitutes earth's albedo (see fig 4.1).

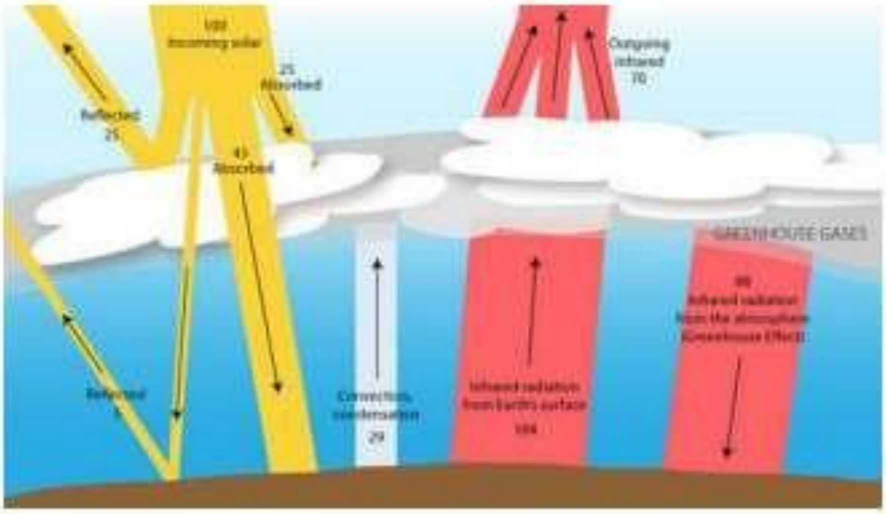


Figure 4.2 Earth – Atmosphere Energy Balance

Some outgoing infrared energy emitted from the earth is trapped in the atmosphere and prevented from escaping to space, through a natural process called the “Greenhouse Effect”. The most abundant gases in the atmosphere – nitrogen, oxygen and argon neither absorb nor emit terrestrial or solar radiation. But cloud, water vapour and some relatively rare greenhouse gases (GHGs) such as carbon dioxide, methane and nitrous oxide in the atmosphere can absorb long wave radiation. Molecules that can absorb radiation of a particular wavelength can also emit same radiation, so GHGs in the atmosphere therefore, will radiate energy both to space and back towards earth. This back-radiation warms up the planet’s surface.

From Figure 3, 100 units of solar radiation are intercepted by the earth every second. On the average, 30 units are reflected, 5 by the surface and 25 by clouds. Energy balance is achieved by earth’s emission of 70 units of infrared (terrestrial) radiation to space. The earth’s surface is warmed directly by only 45 units of solar energy, twice as much energy from thermal radiation (88 units)) from greenhouse gases and clouds in the atmosphere. Energy is removed from the surface by radiation of infrared energy back to the atmosphere and space (88 units) and by other processes such as evaporation of water and direct heat transfer (29 units).

***** Note that the amount of heat received by the surface is actually much more (3times) than the amount the surface receives in solar radiation due to the natural greenhouse effect. The result is that the surface temperature on the average is around 15^0C (60^0F) as compared to temperatures colder than 18^0C (0^0F) if there were no greenhouse effect.

4.4 Major Greenhouse Gases (GHGs)

As mentioned earlier, there are many greenhouse gases which include:

- Water vapour (the most important)
- Ozone
- Carbon dioxide - Methane and
  - Nitrous Oxide which are naturally present in the atmosphere.

Other GHGs are synthetic chemicals that are emitted only as a result of human activity. Anthropogenic (human) activities are significantly increasing atmospheric concentrations of many GHGs. Let us look at each of these GHGs closely and their sources.

- **Carbon Dioxide (CO_2):** The most significant GHG directly affected by anthropogenic activity is the product of the oxidation of carbon in organic matter, either through combustion of carbonbased fuels or the decay of biomass. Natural CO_2 sources include volcanic eruption, respiration of organic matter in natural ecosystem, natural fires, and exchange of dissolved CO_2 with the ocean. The main anthropogenic sources are: a. Fossil fuel combustion. Deforestation and land use changes (such as converting agricultural land or forest to urban development) which releases stored organic matter and reduce the ability of natural ecosystem to store carbon.
- **Methane (CH_4):** Is produced by anaerobic decay of organic materials in landfills, wetlands, and rice fields, enteric fermentation in the digestive tract of ruminant animals such as cattle, goat and sheep, manure management, waste water treatment, fossil fuel combustion and leaks from natural gas transportation and distribution system and abandoned coal mines.
- **Nitrous Oxide (N_2O):** Is produced by fertilizer use, animal waste management, fossil fuel combustion and industrial activities.
- **Hydrofluorocarbons (HFCs) and Perfluorocarbons (PFCs):** Are synthetic chemicals that are used in a variety of industrial production processes such as semi-conductor manufacturing. PFCs are also produced as a by-product of aluminium smelting. Both groups of chemicals are finding increasing use as substitutes for ozone-depletion chlorofluorocarbons (CFCs) which are being phased out. HFCs and PFCs are replacing CFCs in applications such as refrigeration and foam blowing for insulation.

When there is an increase in the atmospheric greenhouse gases concentrations, earth temporarily traps infrared radiation more efficiently, so the natural radiative balance is disturbed until there is a rise in its surface temperature to restore equilibrium between the incoming and outgoing radiation.

The effect of greenhouse gases takes decades to be realized in the higher surface temperatures because the oceans have a huge capacity to store heat. Figure 4.3 shows the relative effects of contribution from man-made emission of various GHGs to climate change (see fig 4.3).

Figure 4.3: Importance of Human-Produced Greenhouse Gases

4.5 Climate and Weather

Climate and weather are closely connected but it is very important to distinguish between them. Climate refers to long term weather trends and the range of variations that can be detected over years in a particular region. Specific weather trends like annual rainfall may vary from one year to another for example Nigeria have a hot dry climate in April and May but its weather patterns include heavy rain storm.

Weather is the condition of the atmosphere at a particular place and at a particular time but climate can be seen as the average condition of the weather experienced in a particular place. This average is arrived at after taking the weather records for about thirty years.

The major elements of climate and weather are rainfall, temperature, wind, humidity, atmospheric pressure and sunshine. Climate and weather affect people's way of life in various ways. It determines their feeding, clothing and housing.

Climate varies from one place to place because various factors affect it. Some of these factors are:

1. **Latitude:** Temperature decrease from the equator to the Polar regions. In the tropical region, the sun's ray strike the surface of the earth at an angle close to 90^0 so that the heating is direct and concentrated. But in the temperate and polar regions, the sun's rays strike obliquely therefore, the energy of the sun is dispersed and its heating power reduced (see fig 4.4).

Fig. 4.4: World Globe

The sun's rays pass through a greater thickness of atmosphere in temperate and polar regions because of the slanting position, much of the ray energy is dissipated.

The equatorial regions have a more constant or equable climate because the sun is always near. There is much greater seasonal variation at the temperate regions and the poles where the sun is near at one season and far away at another.

2. **Altitude:** Generally, the higher we go, the cooler it becomes. Therefore, the top of plateau and mountains is usually cooler than the plains. As we had learnt, temperature decreases as we ascent. For every 1000 km there is a decrease in the temperature about 6.5^{0}C. This decrease in temperature with increasing elevation is called “lapse rate” or “environmental lapse rate” and high altitude locations usually receive much rain called “Relief or Orographic rain”.

3. **Ocean Currents:** Generally, warm ocean currents raise the temperature of adjacent coastlands and cause much rainfall while cold currents lower temperatures causing dryness on the coastland. This dryness often created desert as the western coast of most deserts is bathed by cold currents.

4. **Slope or Aspect:** Sun facing slopes are usually warmer than sheltered slopes. In the northern hemisphere, for example, southfacing slopes are usually warmer than the north-facing slopes which are sheltered from direct influence of the sun. this also happen to slopes of mountains facing the direction of the prevailing winds also receives more rain than the leeward side.

5. **Distance from the Sea:** Climates of places close to the sea usually differs from those places further inland. Coastal areas have more equable climate, more rainfall and a longer rainy season than further inland. In Nigeria, as one moves from Lagos or Calabar to Maiduguri or Sokoto places far inland often experience deserts or semi-desert conditions.

6. **Cloud Cover:** Clouds serve as a filter in the daytime thereby helping to dissipate the Sun’s heating power with the effect that day time temperatures are moderate clouds have cooling effect during the day and in the night serves as blanket which traps long wave radiation from the earth’s surface which prevent the earth from getting too cold when the sun goes down. In the desert where there is no cloud, daytime is usually very hot and the night very cold

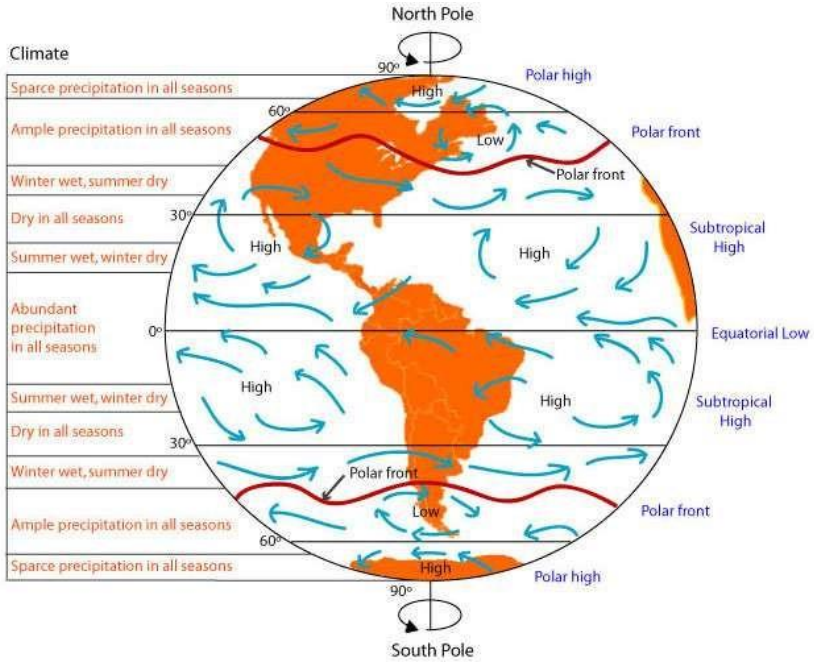


Figure 4.5: Global Circulation and Climate

4.6 Global Carbon Cycle

One of the key issues in current atmospheric science research is that of understanding how GHG emissions affect natural cycling of carbon between the atmosphere, oceans and land. The rate at which land and ocean stake up carbon will determine the fraction of man-made CO_2 emissions remain in the atmosphere which alters the earth's radiative balance.

The carbon cycle can be viewed as a set of reservoirs each of which holds a form of carbon (e.g. calcium carbonate in rocks or CO_2 and methane in the atmosphere) with carbon moving various natural rates of transfer between reservoirs. The total amount of carbon in the system is fixed by very long term geophysical processes such as weathering of rocks. Human actions that affect carbon cycle include; fossil fuel, combustion and deforestation, change the rate at which carbon moves between important reservoirs. Burning fossil fuels speeds up the 'weathering' of buried hydrocarbons and deforestation accelerates the natural pace at which forests die and decompose, thereby releasing carbon back to the atmosphere.

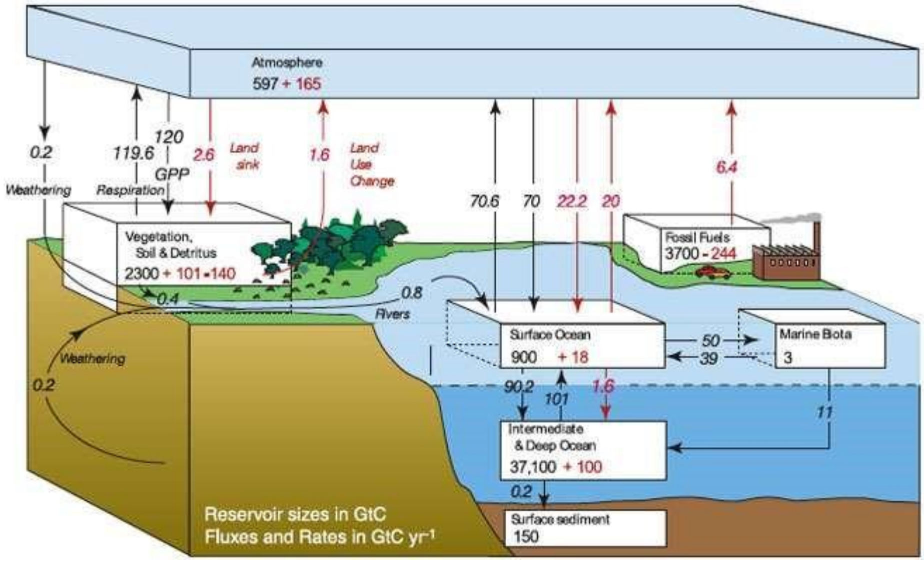


Figure 4.6: Global Carbon Cycle

Two processes remove CO_2 from the atmosphere: photosynthesis by land plants and marine organisms and dissolution in the oceans.

Photosynthesis:
6CO2+6H2OLight energy−−−−→C6H12O6+6O2

Respiration:
C6H12O6+6O2→6CO2+6H2O + energy

* CH_2O denotes the average composition of organic matter.

CO_2 taken up during photosynthesis is converted into organic plant material whereas CO_2 dissolved in the ocean is transferred to a new carbon reservoir but remains in inorganic form. Organic carbon in plant tissues can remain sequestered for thousands or millions of years if buried in soils or ocean sediments but it returns to the atmosphere quickly from materials such as leaf litter. Similarly, CO_2 dissolved in the oceans will stay a long time if sequestered in deep waters, but will escape more readily back into the atmosphere if ocean mixing brings it to the surface.

Oceans and land ecosystems thus serve as both sources and sinks for carbon. Until of recent these processes were in rough equilibrium but the balance is being disrupted today as human activities add more carbon to the atmosphere and a large fraction of that anthropogenic carbon is transferred to the oceans.

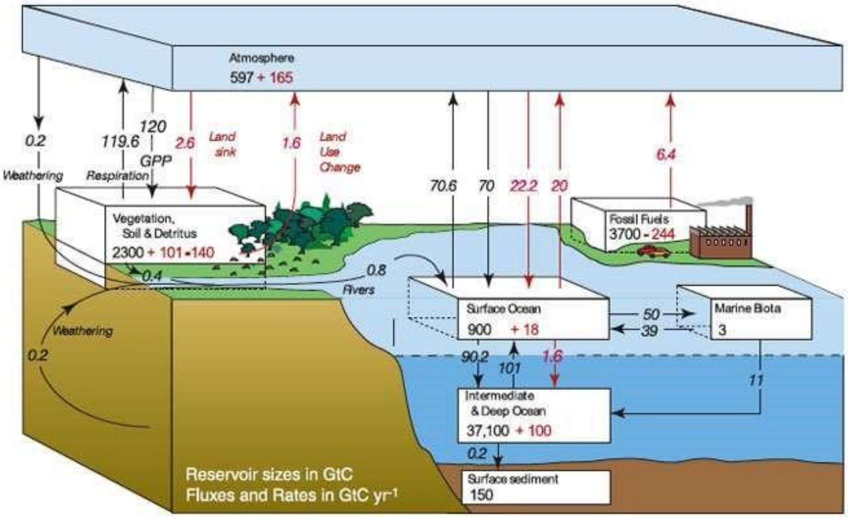


Figure 4.7: Global Carbon Cycle

Therefore, it is very important to understand the chemical and biological processes through which the oceans take up CO_2.

Atmospheric CO_2 dissolves into surface waters, where it reacts with liquid water to form carbonic acid, carbonate and bicarbonate. This process makes the oceans an important buffer against global climate change, but there are limits to how much CO_2 the oceans can absorb. Seawater is slightly basic, with a pH value of 8.2. Adding CO_2 acidifies the water. Dissolved CO_2 gas reacts with carbonate (CO_2^{2-}) ions in the water, increasing concentration of H^+ and other hydrogen ions, which drives pH values lower. Over the long-term, reducing the concentration of carbonate ions (CO_3^{2-}) slows the rate at which oceans take up CO_2. However, this process can alter the ocean chemistry.

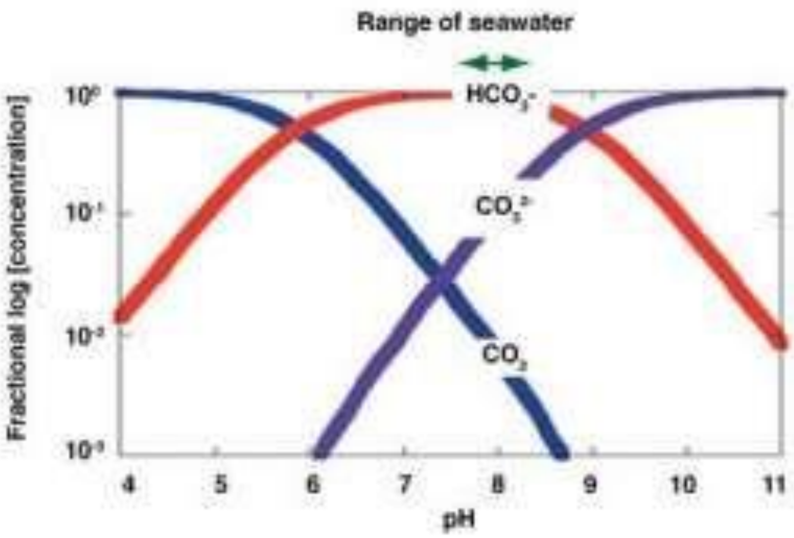


Figure 4.8: Relative Proportions of Inorganic Forms of CO_2 Dissolved in Seawater

Self-Assessment Exercise

i. Can forests solve the problem of rising CO_2 levels?
ii. What are the factors that affect climate and weather.

4.7 Summary

In this unity you learnt about how the sun's radiation gets to the earth surfaces and how some absorbed while some emitted back to the atmosphere and space. You also learnt about the climate and weather and how these two determine the type of clothing, houses etc of a place. The greenhouse gases and their effects on the weather and climate were discussed lastly. How the activities of man affect the global carbon cycle was discussed.

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4.9 Possible Answers to Self-Assessment Exercise(s)

i. Can forests solve the problem of rising CO_2 levels?
ii. What are the factors that affect climate and weather.
1. Latitude

2. Altitude
3. Ocean Currents
4. Slope or Aspect
5. Distance from the Sea
6. Cloud Cover

Unit 5: Elemental Properties of Atmosphere

Unit Structure

5.1 Introduction

In the preceding units you had learnt about the importance of atmosphere, its temperature, layers and the importance of the greenhouse gases and their effects. Here in this unit, the chemical properties of the atmosphere and various chemical reactions taking place in it will be discussed.

5.2 Intended Learning Outcomes

You had learnt that the atmosphere is not static but dynamic gaseous medium in which many physical and chemical processes take place continuously.

At the end of this unit, you will be able to:

- learn about chemical properties of the atmosphere
- explain reactions taking place in the atmosphere
- learn depletion of ozone layer by some chemical reactions.

5.3 Chemical and Photochemical Reactions

In the atmosphere, several chemical and physical processes are taking place. Some of them occur naturally while others occur due to man activities. The atmosphere is a gaseous medium and is very large.

Fist let us learn about what is happening in the Ozonosphere. There are reactions here which help in the maintenance of the concentration of ozone at this altitude.

Secondly, you will learn about the reactions that occur in troposphere and the chemical reactions taking place in troposphere and the stratosphere.

5.3.1 Photochemical Reactions in Ozone Layer

The existence of ozone layer was discovered by two French Physicists, Charles Fabry and Henri Bulsson in 1913. It is located at the lower part of the stratosphere approximately between altitude 15 and 35 km. The concentration of ozone at its maximum is 10 ppm at an altitude of 25 – 30 km. but the concentration ranges from 2 to 8 ppm between altitude 15 and 40 km.

The concentration of ozone is naturally maintained at these levels mentioned above the “ozone oxygen” cycle. Sidney Chapman a British Physicists studied the photochemical mechanisms of Ozone-Oxygen cycle in 1930. When ultra-violet radiation strikes the oxygen molecule, O_2, it splits the molecule into two individual. Oxygen atoms (O and O).

The atomic oxygen thus produced will combine with un-split oxygen molecule (O_2) to produce ozone molecule (O_3). In this reaction a third body, M plays a crucial role in absorbing the excess energy liberated. This type of Ozone formed will be split by striking ultra-violet radiation at the wavelength around 308 nm into a molecule of O_2 and an atom of oxygen.

By this ozone-oxygen cycle, the concentration of ozone is maintained. The actual concentration of ozone is determined by the rate of its formation and its destruction.

But due to photochemical dissociation by ultra-violet radiation, other forms of oxygen are also present in the atmosphere. These are O^-, O and O_2 – ionic form and excited form.

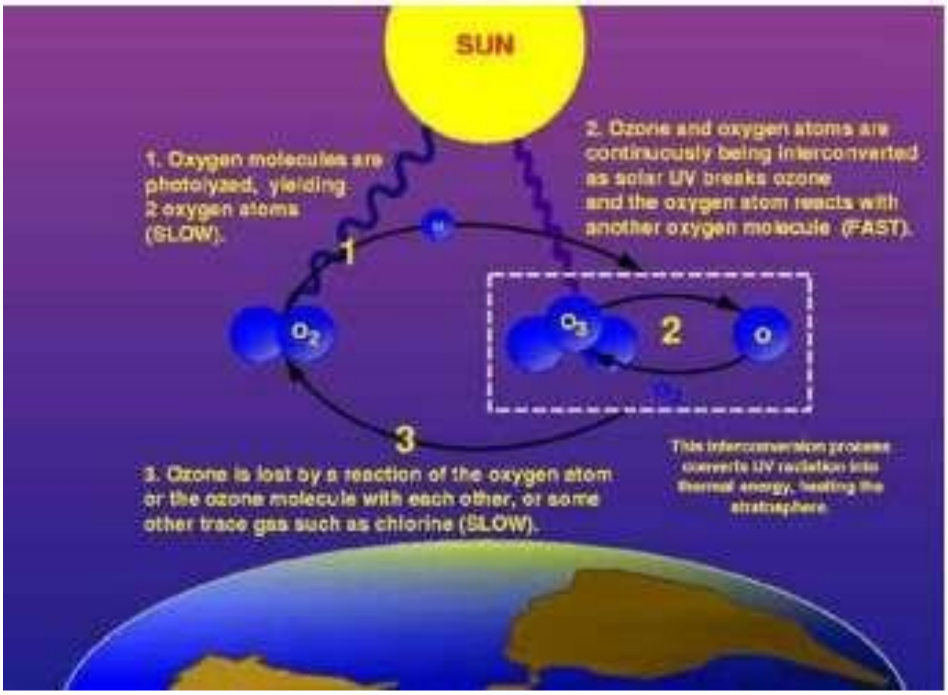

Figure 5.1: Importance of Atmosphere

The amount of zone present in the stratosphere can be measured by simple "spectrophotometer" from the ground. Ozone in the column is measured in "Dobson Units" named in honour of G.M.B. Dobson.

5.4 Ozone Layer Depletion

Due to human activities, the ozone layer is becoming thin. The thinning of the ozone layer is called "ozone depletion". At the zones where thinning is too severe, they are referred to as "ozone holes". The ozone hole can be defined as the area having less than 220 Dobson units (DU) of ozone in the overhead cololumn (that is between the ground andspace). Ozone hole, observed over Antarctic region is shown in figure 12.

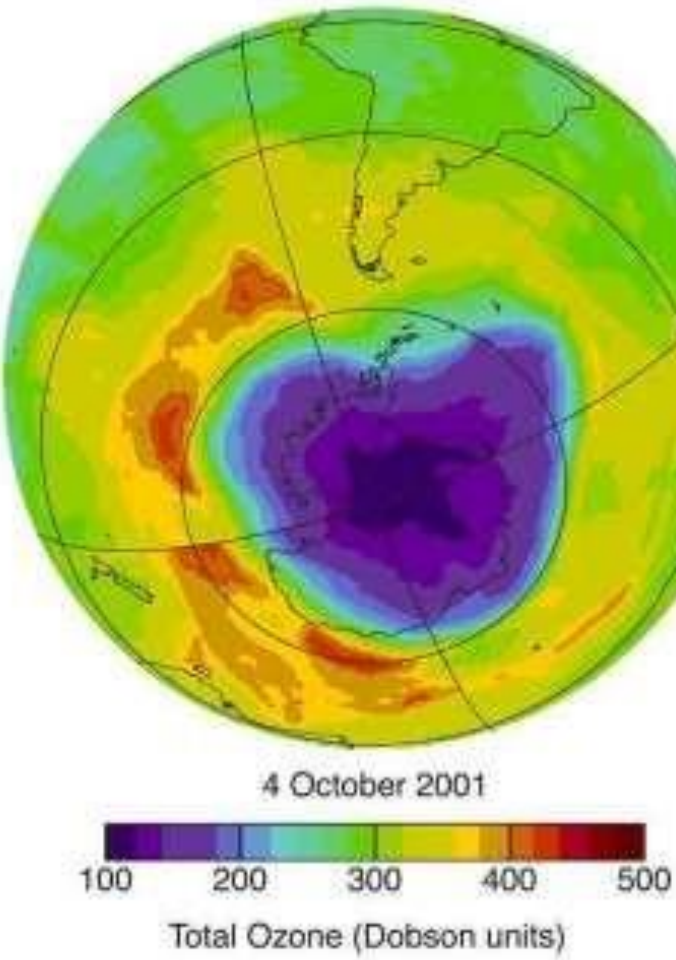

Figure 5.2: Importance of Atmosphere

The mechanism of ozone depletion is not well understood but the emission of chloro-fluorocarbons (CFCs) used for refrigerators, air conditioners, propellants, etc and oxides of nitrogen by air crafts flying near stratosphere are responsible for this. Ozone layer is depleted by free radical catalysts – nitric oxide (NO), hydroxyl (OH), atomic chlorine (Cl) and atomic bromine (Br). Halogens have the ability to catalyze ozone breakdown. A catalyst is a compound which can alter the rate of a reaction without permanently being altered by that reaction and so can react over and over again. Chlorine atom or any other halogen atom released from CFC or BFC by striking ultra-violet radiation is no available for catalyzing ozone breakdown. Although, these species occur naturally, but large amounts are released by human activities through the use of CFCs and bromofluorocarbons.

5.4.1 Ozone Depletion by CFCs

CFCs and BFCs are stable compounds in the atmosphere and had live long there. As the live longer they are able to rise to the stratosphere, Cl and Br radicals initiate and catalyze the breaking down of ozone molecules. One single molecule is capable of breaking down over 100,000 ozone molecules. Ozone concentration is decreasing at the rate of 4% per decade over northern hemisphere. CFCs have long life time between 50-100 years. As they remain for such a long duration, they deplete ozone layer continuously. And as more and more CFCs are released, the depletion rate keep increasing.

Ozone depletion by chlorine atom can be seen in figure 13.

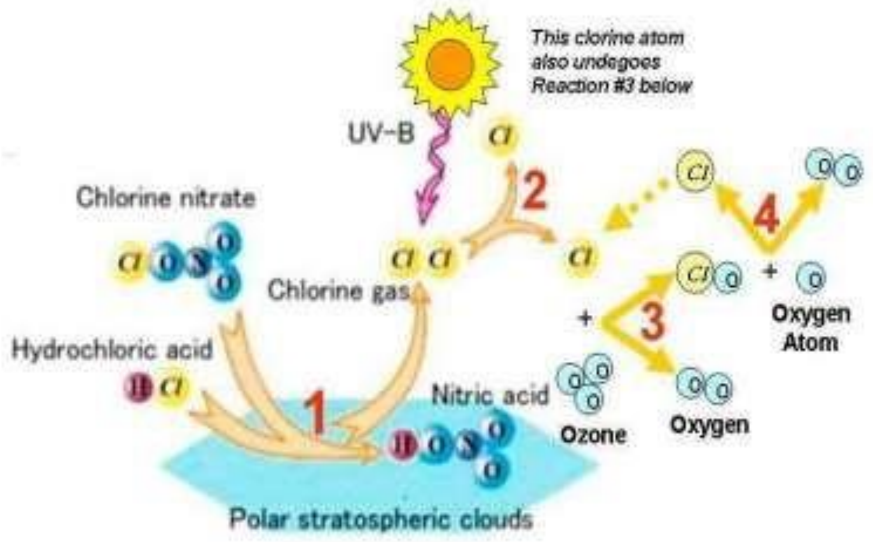

Figure 5.3: Importance of Atmosphere

Countries all over the world after realizing the seriousness of the problem caused by CFCs and BFCs came forward to ban completely the use of CFCs. The ban came to force on January 23rd 1978 in Sweden and other countries joined by 1985 and an international treaty came to be and the Montreal Protocol for complete phase-out of CFCs by 1996. And due to this ban, by 2003, the depletion of ozone layer had slowed down due to the ban on CFCs HCFC was developed to replace CFC for the same purpose. HCFCs are short-lived in the atmosphere to reach the stratosphere and have effect on the ozone layer.

5.4.2 Ozone Layer Depletion by Nitric Oxide

Nitric oxide also has great effect on the ozone layer as explained below: When a nitric oxide (NO) molecule combines with Ozone (O_3), it is oxidized to nitrogen dioxide (NO_2). This NO_2 then combine with another molecule O_3 to become NO_3 and O_2. Both NO_2 andNO_3 may combine to form N_2O_5. When atomic oxygen is available, it readily combines with NO_2 to yield NO_3. From here, you can see that all O_3 is completely utilized for the reactions and thereby depleted.

International community after realizing the seriousness has agreed to with draw the operation of jet planes that emit NO in stratosphere.

Self -Assessment Exercise

i. Write the sequence of photochemical reactions taking place in the stratosphere.
ii. At what wavelength regions of ultra-violet radiation absorption by O_3 and O_2?

5.5 Summary

In this unit, the different elemental properties of the atmosphere, the chemical and photochemical reactions were learnt. The effects of these reactions on the ozone layer located in the stratosphere were mentioned. Different natural and human induced releases of some gases which are responsible for the depletion of the ozone layer were illustrated.

You are now aware that there are natural protections available in the stratosphere. It protects human life and that of other living organisms from harmful ultra-violet radiation. You are now also aware that man by his activities cause great harm to the atmosphere.

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5.7 Possible Answers to Self-Assessment Exercise(s)

i. Write the sequence of photochemical reactions taking place in the stratosphere.

- When ultra-violet radiation strikes the oxygen molecule, O_2, it splits the molecule into two individual. Oxygen atoms (O and O).

- The atomic oxygen thus produced will combine with un-split oxygen molecule (O_2) to produce ozone molecule (O_3). In this reaction a third body, M plays a crucial role in absorbing the excess energy liberated.
- This type of Ozone formed will be split by striking ultra-violet radiation at the wavelength around 308 nm into a molecule of O_2 and an atom of oxygen.
- By this ozone-oxygen cycle, the concentration of ozone is maintained. The actual concentration of ozone is determined by the rate of its formation and its destruction.

ii. At what wavelength regions of ultra-violet radiation absorption by O_3 and O_2?

This type of Ozone formed will be split by striking ultra-violet radiation at the wavelength around 308 nm into a molecule of O_2 and an atom of oxygen.

Module 3 Moon and the Earth

Unit 1: Moon and the Earth

Unit Structure

1.1 Introduction

Here you will learn about the moon, its structure, composition and its importance to the Earth. The Atmosphere of the moon will also be discussed.

1.2 Intended Learning Outcomes

At the end of this unit, you will be able to:

- explain the moon and its compositions
- identify the content of the moon atmosphere and
- mention the internal structure of the moon.

1.3 The Earth's Moon

The moon is an astronomical body that orbits the Earth as its only permanent satellite which is occasionally distinguished as Luna. It is the fifth-largest satellite in the solar system and the largest among planetary satellite relative to the size of the planet that it orbits.

Our moon has different names during ancient times when many thought of it as goddess. Some of the given names were; Diana, Lunea, Cynthia, and Selene. It has been both worshipped and feared. It has many interpretations such as being an object representing romance, being a factor in transforming people to warewolves and could even cause people to become ‘lunatics’, derived from the Latin word ‘Luna’.

Though a satellite of earth, the moon with a diameter of about 2,159 mile (3,475 km) is bigger than Pluto. The moon is a little more than a quarter ¼ (27%) of the earth or it can be said that the moon ratio to the earth is 1:4. This means the moon has a greater effect on the planet and probably is what makes life possible on earth.

1.3.1 How did the Moon form?

Several theories abound on how the moon was created, but evidence recently shows that it was formed when a huge collision tore a part of the earth away. The leading explanation for how the earth moon was formed was that a great impact knocked off the raw ingredients for the moon off the primitive molten earth into orbit. Scientists also have suggested the impactor was about 10%, the earth and the moon are so similar in composition which made researchers to conclude that the impact must have occurred about 95million years ago. After the formation of the solar system.

The giant-impact hypothesis, sometimes called the Big splash, or the Theia impact suggest that the moon formed out of the debris left over from a collision between Earth and an astronomical body size of Mars, approximately 4.5 billion years ago, in the Hadean eon; about 20 to 100 million years after the solar system.

The giant-impact hypothesis is currently the favored scientific hypothesis for the formation of the moon. Supporting evidence includes;

- Earth’s spin and the moon’s orbit have similar orientation
- The moon has a relatively small iron core
- The moon has a lower density than the Earth.

Another theory however suggests that two young moons could have collided to form a single large one while a recent theory believes that they must have stolen the moon from Venus.

1.4 Internal Structure and Surface Composition of the Moon

The moon has a small core about 1 – 2% of the moon’s mass with a width of roughly 420 miles (680 km). It consists mostly of iron but contain large amount of sulphur and other elements. Its rocky mantle is approximately 825 miles (1,330 km) thick and has dense rocks very rich in iron and magnesium Magmas in the mantle made their way to the moon surface in the past, erupting volcanically more than a billion years (3-4 billion years).

The curst on top is on the average some 42 miles (70 km) deep while the outer part of the crust is broken and jumbled due to all the great impact it received, shattered zone that gives way to some inert materials below a depth of about 6 miles (9.6 km).

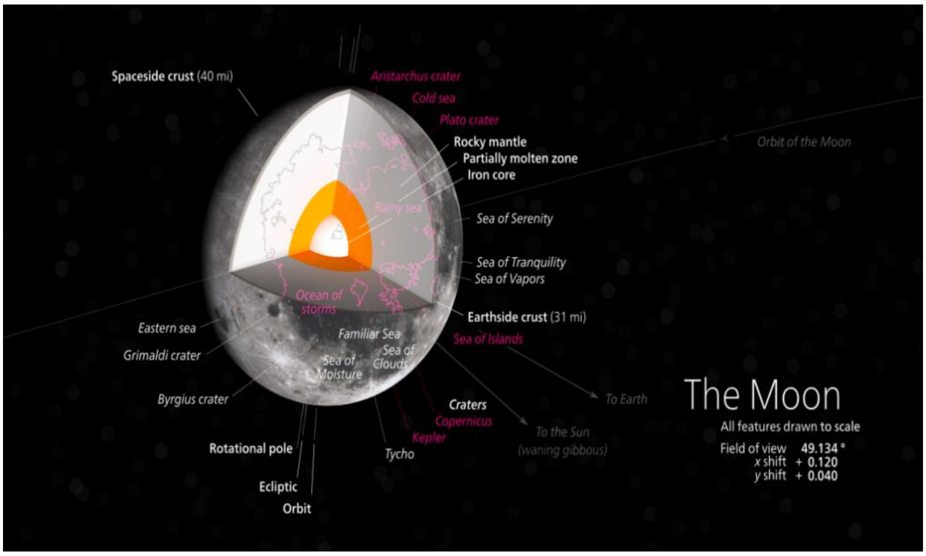

Figure 1.1: Surface Composition

The moon is very rocky pockmarked with craters formed by asteroid impacts millions of years ago. In the moon, there is no weather, the craters have not eroded. The average composition of the lunar by weight is roughly:

Oxygen	-	43%
Silicon	-	20%
Magnesium	-	19%
Iron	-	10%
Calcium	-	3%
Aluminum	-	3%
Chromium	-	0.42%
Titanium	-	0.18%
Manganese	-	0.12%

It had been found by orbiters that there are traces of water on the lunar surface which they concluded to have originated from deep underground. They also located hundreds of pits that could have housed explorers who must have stayed long term.

1.5 Atmosphere of the Moon

The moon has a very thin atmosphere which makes it possible that a foot print can sit undisturbed for centuries. As a result of the thin atmosphere, heat is not meld near the surface, making the temperature to vary widely. Daytime temperature on the sunny side of the moon can reach 273^0f (134^0c) on the dark side, it gets as cold as -243^0F (-153^0c).

There is no air pressure in the surface and the temperature range from 280^0F (-173^0c) at night to +260^0F (+127^0c) in daytime at the equator.

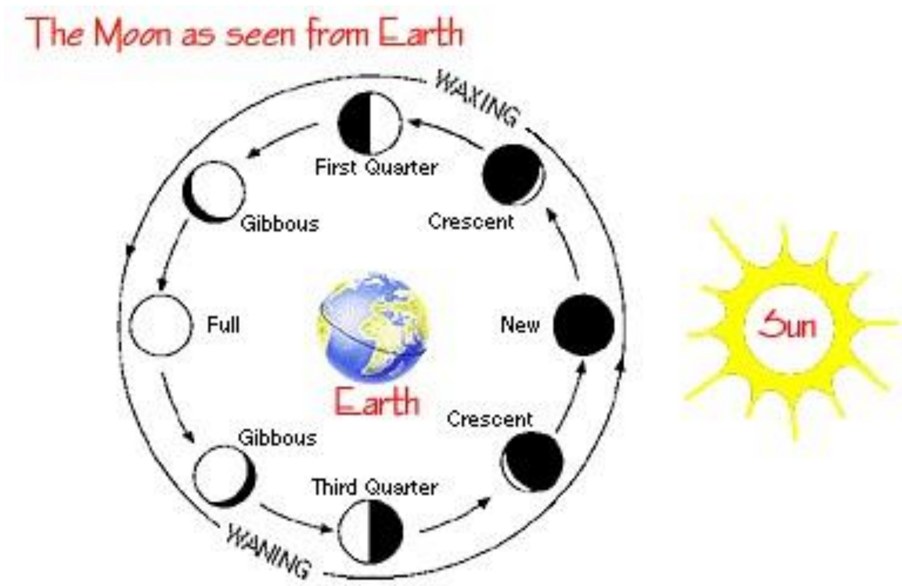

Figure 1.2: Earth's Moon

The Mass of the Moon is about 7.3477 x 10^{22}g/c and the surface gravity is 1.622m/s^2. The moon is synchronous rotation with the earth, always showing the same face with its near side marked by dark volcanic Maria that fill between the bright ancient crustal highlands and the prominent "impact craters"

Self -Assessment Exercise

1. Compare the earth and moon compositions and explain the reason why there is similarity between them.
2. Explain briefly how the moon was formed.

1.6 Summary

In the unit, you discussed about the various theories about the formation of the moon some billion years ago. You learnt about the compositions of the moon, the surface conditions which includes the temperature range during the day and the night. You also learnt that there is no air pressure on the moon surface.

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1.8 Possible Answers to Self-Assessment Exercise(s)

1. Compare the earth and moon compositions and explain the reason why there is similarity between them.

   Both the moon and earth are similar in composition this is evident in their composition such as Aluminum, Silicon, Magnesium, Iron which are the dominant element present in the earth crust. This is due to the formation of the moon as a result of the collision which broke off part of the earth and lead to its formation.

2. Explain briefly how the moon was formed.

   Several theories abound on how the moon was created, but evidence recently shows that it was formed when a huge collision tore a part of the earth away. The leading explanation for how the earth moon was formed was that a great impact knocked off the raw ingredients for the moon off the primitive molten earth into orbit. Scientists also have suggested the impact was about 10%; the earth and the moon are so similar in composition which made researchers to conclude that the impact must have occurred about 95million years ago

Unit 2: Phases of the Moon, Eclipse and Types

Unit Structure

2.1 Introduction

The moon is a cold, rocky body of about 2,160 miles (3,476 km) in diameter. It has no light of its own but shines by sunlight reflection from its surface. The moon orbits earth about once every 29½ days. As it rotates the earth, the changing position of the moon with respect to the sun causes the moon which is the earth's natural satellite to cycle through a series of phases.

NEW MOON →NEW CRESCENT → 1ST QUARTER → WAXING GIBBOUS →WANING GIBBOUS → LAST QUARTER → OLD CRESCENT → NEW MOON

The phase known as new moon cannot actually be seen because the side of the moon then points away from earth (see Fig. 20)

Figure 2.1: Earth – Moon- Sun

Sunlight is shown coming from the right. The earth is in the centre of the diagram (Fig. 20). The moon is shown in various stages during its revolution around the earth. The moon phase name is shown along the image. The larger moon images show what one see at that point in the cycle.

2.2 Intended Learning Outcomes

At the end of this unit, you will be able to:

- identify and explain the different phases of the moon
- describe the relationships between the sunlight, moon and the earth
- explain what happens at the different phases of the moon.

2.3 Understanding the Moon Phases

In this section, you will be made to understand the various cycles the moon undergoes. It is in the following order; New moon, and full moon, first quarter and third quarter while you now fix the phase between. From Fig 20, the appearances of the moon in the cycle can be explained thus?

New Moon: This occurs when the moon is positioned between the earth and sun. the three are in approximate alignment showing that the entire moon is at the back side, which cannot be seen. It means the moon is between the sun and the earth.

Full Moon: At the full moon, the earth, moon and the sun are in approximate alignment just as at the new moon but the moon is on the opposite side of the earth, so that the sunlit part of the moon is facing the earth. The earth is now between the sun and the moon. The entire illuminated portion of the moon is facing the earth while the shadowed part is hidden.

The First Quarter and Third Quarter: Moon at these two portions is halved often referred to as "half-moon". This happens when the moon is at a 90^0angle with respect to the earth and sun. So the illuminated half of the moon is seen while the 90^0 shadowed is unseen. In the **First Quarter**, you see the right half while in the **Third Quarter** you see the left half of the moon.

Waxing Crescent: After the new moon, the sunlit portion still increasing but it is now more than half, it is then "**Waxing Gibbous".** While after the full moon (maximum illumination), the light continually decreases. So the waning "gibbous phase" occurs next.

Following the third quarter, is the waning crescent which wanes until light is completely gone – a new moon.

Figure 2.2: Phases of the Moon

2.4 The Moon's Orbit

Commonly, you would have observed the moon going through a complete moon phases cycle in about a month. But it is not exactly one month. The "synodic period" or "lunation" is exactly 29.5305882 days. This is the time required for the moon to rotate round the earth. But when the observation is made from the sun (view point of the stars), the time required is 27.3217 days. This figure is called the "sidereal period" or "orbital period". Why there is a difference between the synodic period and sidereal period can be explained that because the earth has moved approximately one month along its year-long orbit around the sun, thereby altering the angle of view with respect to the moon, thereby altering the phase. The earth's orbital direction is such that it lengthens the period for earth bound observations.

At special times during the year the earth, moon and sun do in fact "line up" when the moon blocks the sun or part of it, it is called "solar eclipse" and this only happens during new moon phase. When the earth casts a shadow on the moon, it is called a "lunar eclipse", and can only happen during full moon phase. Roughly 4-7 eclipses happen in any given year, but most of them minor or "partial" eclipses. Major lunar or solar eclipses are relatively uncommon.

2.5 Eclipse Types

An eclipse of the sun (solar eclipse) can only occur during the new moon phase when the moon passes between the earth and sun. When the moon's shadow falls upon earth's surface, it is seen that some portion of the sun disk covered or "eclipsed" by the moon. Since the new moon occurs 29½ days, one will expect this to occur frequently, but this is not the case because the moon's orbit around the earth is tilted 5 degrees to earth's orbit around the sun as a result, the moon's shadow usually misses earth as it passes above or below the earth at new moon. At least twice in a year, the geometry lines up just right so that some parts of the moon's shadow fall on earth's surface and an eclipse of the sun is seen from that region.

The moon's shadow has two parts which are;

(1) Penumbra:
  i. The moon's faint outer shadow
  ii. partial solar eclipses are visible from within the penumbral shadow

(2) Umbra:
  i. The moon's dark inner shadow
  ii. Total solar eclipses are visible from within the umbral shadow

When the moon's penumbral shadow strike earth, a partial eclipse of the sun is seen from that region. Partial eclipses are dangerous to look at because the un-eclipsed part of the sun is still very bright.

2.5.1 Types of Lunar Eclipse

If the moon is at one of its 'nodes' at new moon, a solar eclipse can occur. There are different kinds of solar eclipses:

- Partial
- Total
- Annular and
- Annular-total

Total Solar Eclipse: if the sun and moon are aligned and the moon's angular diameter is greater than that of the sun, what we have is a total solar eclipse
Annular Solar Eclipse: this occurs when the sun and moon are aligned but the moon is too far away from the earth to completely cover the sun disk
Partial Solar Eclipse: It occurs when the moon is quite at one of its nodes

Some solar eclipses are such that they are annular at the start and end of the track and total in the middle. The radius of the earth is just big enough to make a total eclipse in the middle.

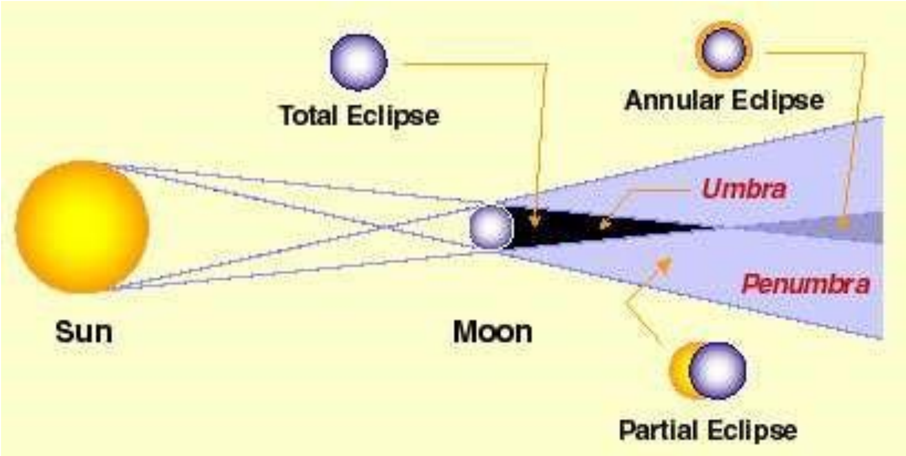


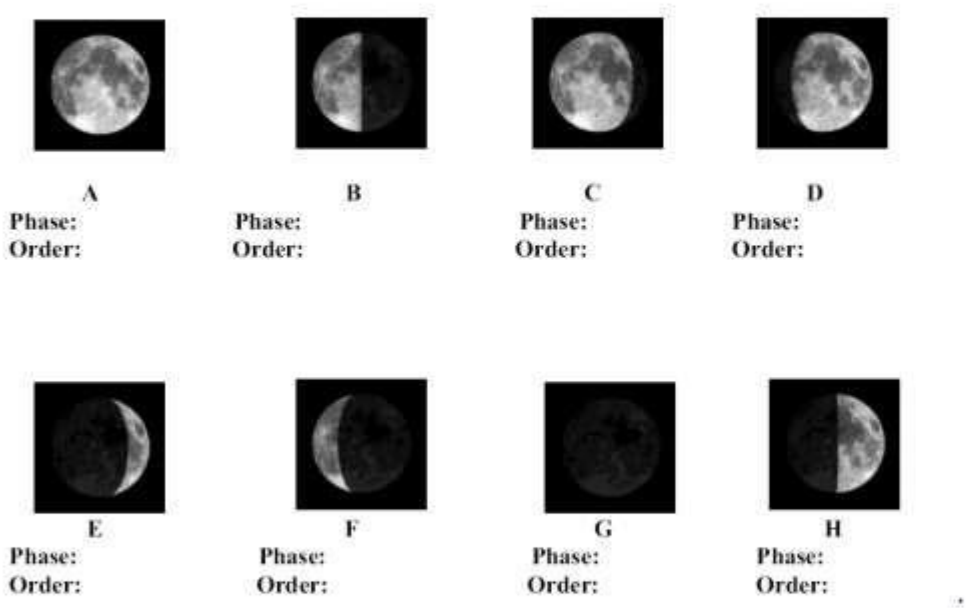
Figure 2.3: Types of Eclipse

A big difference between total solar eclipse and total lunar eclipses, is that you usually have to travel to be situated in the path of totality of solar eclipse.

The maximum duration of a total solar eclipse is a little over 7 minutes some last a couple of seconds.

Self-Assessment Exercise

1. What is the difference between a solar eclipse and a lunar eclipse?
2. For each of the diagrams below, identify the exact phase of each and then order the phases in sequence beginning with the new moon as #1.



2.6 Summary

In the unit you learnt about the different phases of the moon and that it moves round the earth in approximately 29,503,5882 days. You were also informed that the earth revolves round the sun on its orbit once a year.

You were also informed about the different phases of the moon as it completes its cycle round the earth. The different phases are new moon, waning crescent, 3rd quarter, waning gibbous, full moon, waxing gibbous and first quarter, waxing crescent and the new moon … and the cycle continues.

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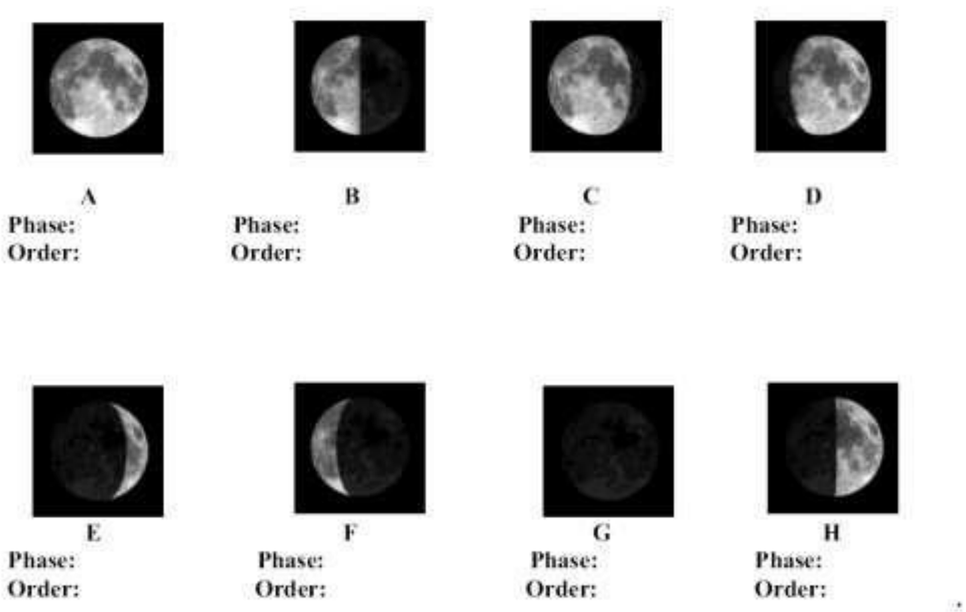
2.8 Possible Answers to Self-Assessment Exercise(s)

1. What is the difference between a solar eclipse and a lunar eclipse?

   A lunar eclipse is an eclipse of the moon rather than the sun, it happens when the moon passes through earth's shadow. This only happens when the moon is in the full moon phase.

2. For each of the diagrams below, identify the exact phase of each and then order the phases in sequence beginning with the new moon as #1.



Phases:

i. New Moon
ii. Waxing Crescent

iii. 1st Quarter
iv. Gibbous Waxing
v. Full Moon
vi. Gibbous Waning
vii. Last Quarter
viii. Waning Crescent

Unit 3: The Solar System

Unit Structure

3.1 Introduction

In this unit, you will learn about the solar system the sun and its planetary system.

3.2 Intended Learning Outcomes

This unit will explain the organization of the sun and the planetary system and describe their relative movement, coupled with the effect they have on one another and on the planet Earth.

3.3 The Solar System

The sun and the planets of the solar system

Age	4568 billion years
Location	Local interstellar colocal Bubble Orion – Cygnus Arm of the Milky way
System mass	1,0014 Slar masse
Nearest Star	Proxima centauri (4/y) Alpha centauri system (4.37/y)
Nearest known planetary system	Alpha centauri system (4.37/y)
Planetary System	
Semi-major axis of outer planet "Neptune"	30.10 AU (4.503 billionkm)
Distance to "kuper clift"	50 AU
Populations	
Stars planets	1 (sun)
Planets	8(Mercury, Venus, Earth, Mars, Jupiter, Saturn, Neptune

Known dwarf-planet s	Possibly several hundred five currently recognized by AU “ceres” in Pluto “Haume, Makamake, Eris
Known natural satellites	439 173 planetary 266 minor planetary
Known minor satellites	670,452 (as of 7/1/2015)
Known comets	3,319 (as of 7/1/2015)
Identified rounded satellites	19
Orbit About Galactic Center	
Invariable to galactic plane inclination	60.19^0 (ecliptic)
Distance to Galactic center	27,000±1,000/y
Orbital speed	220 km/s
Orbital period	225-250 myr
Spectral typ	G2v
Distance to heliopause	= 120 AU
Frost line	= 5AU
Hill sphere radius	= 1-2/yr

The mass of the solar system mostly lies on a disc - shaped flat plane called the **plane of the ecliptic**. Surrounding this is a gaseous, magnetic bubble. The **Sun** (our star) makes up most of the volume of the solar system’s mass (99.86%) and on its measurable energy. It is also the gravity anchor. The gas planets account for over 99% of the remaining mass of our solar system.

The solar system comprises the “sun” and the objects that orbit it, where they orbit it directly or by orbiting other objects that orbit the sun directly, the largest eight are the planets that form the “planetary system”.

The majority of the planets, moons and asteroids follow the same basic gravitational rules that govern our solar system; they even travel in the same direction around the Sun. If you looked down toward the north pole of the sun, these objects would be moving counter clockwise.
The orbiting objects that dominate the Solar System can be classified into three groups:

Planets: Earth, Jupiter, Neptune (all planets) and so on.
Planetoids: Ceres, Pluto (all planetoids) and so on.
Small Solar System Celestial Bodies: Halley's Comet, (all comets), the Moon, (all moons) and so on.

The composition of these objects fall into three general areas: They contain one, some or all, of either types of rock, gas or ice. The rock can range from sandy (**silicates**), to minerals such as salts and metals such as iron or gold. Gases range from hydrogen, oxygen (a gaseous metal), ammonia and methane to molecules such as water vapor and other molecular compositions. Ice can be composed of not only water, but also carbon dioxide, methane, and even more exotic frozen gases. They can be large blocks or floating crystals.

Throughout the Solar System's space there are flows of particles are coming from the Sun. They move quickly at speeds up to nearly 1,000,000 miles per hour, carried by what is called **solar winds**. This creates an atmosphere to the Solar System known as the **heliosphere**. If there is atmosphere, there should be weather! The Sun has magnetic storms and solar flares that result in solar winds of charged particles and of energy. If there is an atmosphere, does it protect and shield as ours does? The answer is yes. Our heliosphere shields out dangerous cosmic rays that emanate from outside our solar system.

While the rest are significantly smaller objects such as dwarf planets and (small solar system bodies (SSSBS) such as comets and asteroids.

The solar system formed 4.6 billion years ago from gravitational collapse of a giant "molecular cloud". The vast majority of the system's 'mass' is in the sun, with the remaining contained in "Jupiter". The four smaller inner planets' "Mercury", "Venus", "earth" and "Mars" are also called the "terrestrial planet" are primarily composed of rocks and metal. The four outer planets, the "giant planers" are substantially more massive than the terrestrials. The two largest, the "gas" giants "Jupiter" and "Saturn" are composed mainly of hydrogen and helium the two outer most planets, the "ice giants" "Uranus and Neptune" are composed largely of substances with relatively high melting points compared with hydrogen and Helium called "ices" such as water, ammonia, and methane. All planets have almost circular orbits that lie within a nearly flat disc called "ecliptic plane".

The solar system also contains regions populated by "smaller objects". The "asteroid belt" which lies between Mars and Jupiter, mostly contains objects composed of rocks and metal like the terrestrial planets. Beyond Neptune's orbit lies the "Kuper belt" and scattered disc" linked populations of "trans-Nepotonia objects" composed mostly of ices, within these populations and several dozen to more than ten thousand objects that may be large enough to have been rounded by their own gravity. Such objects are referred to as "dwarf planets". Identified dwarf planets include the asteroid "Ceres" and the trans-Neptunian objects "Pluto" and "Eris". In addition to these two regions, various other small body populations, including "comets", centaurs" and "interplanetary dust" freely travel between regions. Six of the planets at least three of the dwarf planets and many of the smaller bodies are orbited by "Natural satellites" usually called "moons after the earth's moon. Each of the outer planets is enriched by "planetary rings" of dust and other small objects.

Our solar system is located in the Orion arm of the Milky way Galaxy. There are most likely billions of other solar systems in our galaxy. And there are billions of galaxies in the universe.

NASA's twin voyager 1 and 2 space craft are the first space craft to explore the outer reaction of our system.

Self- Assessment Exercise

1. Name two of the outer planets beyond the orbit of mars.

3.5 Summary

In this unit, you learnt detail about the solar system which consists of many other planetary systems, dwarf planets, and a couple of moons.

Also, you learnt about the NASA's twin voyager 1 and 2 spacecraft that were the first to explore the outer reaches of the solar system.

7.0 References/Further Reading/Web Resources

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3.6 Possible Answers to Self-Assessment Exercise(s)

1. Name two of the outer planets beyond the orbit of mars.

   - Jupiter
   - Neptune

Unit 4: Space Science

Unit Structure

4.1 Introduction
4.2 Intended Learning Outcomes
4.3 Space Science Astronomy
4.4 Branches of Space Science
4.5 Summary
4.6 References/Further Readings/Web Resources
4.7 Possible Answers to Self-Assessment Exercise(s)

4.1 Introduction

Space science is the study of anything and everything in outer space which had been called "Astronomy" but recently had been regarded as a branch of space science which has grown with more knowledge to include other related fields such as;

- Space travel
- Space exploration (space medicine)
- Space archaeology and
- Space research.

4.2 Intended Learning Outcomes

At the end of this unit, you will be able to:

- define space science
- mention the various branches of space science
- explain the various ideas in space science.
- state the trends of science after the first space exploration.

4.3 Space Science: Astronomy

Astronomy is the study of virtually everything beyond earth; it includes studying planets, solar systems, stars, galaxies, comets, asteroids, nebulae, moon and the universe itself.

Astrology' on the other hand is a form of historical predictions based on the starts and the period of the year. Horoscopes are based on astrology but astronomy is grounded in science and hoes mathematics and science to study and predict the actions of the universe.

A good astronomer needs to be understood from the historical scientific discovery point of view. Over thousands of years, man have developed and proved many ideas about space providing fact that the:

i. Earth revolves around the sun which ancient societies understood this movement of earth long before it was accepted. Now orbiting telescopes to photograph black holes (Hubble, Chandra). There are still volumes of unanswered questions though there is hope on future exploration into space to provide answers to these questions. Physical cosmology proposes a timeline to the origin of space.

4.4 Branches of Space Science

The various branches of Space Science are explained below

1. **Astronomy**: Astronomy has various branches based on the following outlines

- Field of astronomy defined by **approach**

i. **Observational Astronomy:** Are observatories on the ground as well as space observations which take measurement of celestial entities and phenomena.
ii. **Astrometry**: Studies the position and movements of celestial objects.
iii. **Amateur Astronomy**: Involves observation of celestial objects in the sky using unaided eye, binoculars, or telescopes.
iv. **Theoretical Astronomy**: Involves the mathematical modelling of celestial entities and phenomena

- Fields of astronomy defined by **scope**

i. **Astrophysics**: This is the study of the physics of the universe; of extraterrestrial objects and interstitial spaces.
ii. **Space plasma physics**: This is the study of plasmas as they occur naturally in the Earth's upper atmosphere (aeronomy) and within the solar system.
iii. **Astrodynamics:** Otherwise known as orbital mechanics is the application of ballistics and celestial mechanics to the practical problems concerning the motion of rockets and other spacecraft
iv. **Stellar Astronomy:** Involves the study of stars
v. **Solar Astronomy:** This involves the study of our sun
vi. **Galactic Astronomy:** Galactic astronomy is the study of our milky way galaxy

vii. **Planetary science:** This is the study of planets, especially those other than Earth

viii. **Planetary Geology:** Alternatively known as **astrogeology or exogeology** is a planetary discipline concerned with the geology of the celestial bodies such as planets and their moons, asteroids, comets, and meteorites.

ix. **Extragalactic Astronomy:** This is the study of the larger universe beyond the Milky Way.

x. **Physical Cosmology**: Physical cosmology involves the study of the universe as a whole.

2. **Aerospace engineering:** Is the primary field of engineering concerned with the development of aircraft and spacecraft. It has two major and overlapping branches, which are:

    i. **Aeronautical engineering:** Is the science or art involved with the study, design and manufacturing of air flight capable machines, and the techniques of operating aircraft and rockets within the atmosphere.

    ii. **Astronautical Engineering:** Is the theory and practice of travel beyond Earth's.

Self -Assessment Exercise

1. Enumerate and briefly explain the branches of space science as discussed above.

4.5 Summary

In the unit, more were discussed on the various branches of space science. It focused more on "Astronomy and the branches of space science like, Space travel, exploration of space science, archaeology and space research. Despite that, there are still thousands of unanswered questions about space science which could be embedded in future space exploration.

4.6 References/Further Readings/Web Resources

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4.7 Possible Answers to Self-Assessment Exercise(s)

Enumerate and briefly explain the branches of space science as discussed above.

The various branches of Space Science are explained below

1. **Astronomy**: Astronomy has various branches based on the following outlines
   - Field of astronomy defined by **approach**

   i. **Observational Astronomy:** Are observatories on the ground as well as space observations which take measurement of celestial entities and phenomena.
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   iv. **Theoretical Astronomy**: Involves the mathematical modelling of celestial entities and phenomena

   - Fields of astronomy defined by **scope**

   i. **Astrophysics**: This is the study of the physics of the universe; of extraterrestrial objects and interstitial spaces.
   ii. **Space plasma physics**: This is the study of plasmas as they occur naturally in the Earth's upper atmosphere (aeronomy) and within the solar system.
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   iv. **Stellar Astronomy:** Involves the study of stars
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   vii. **Planetary science:** This is the study of planets, especially those other than Earth
   viii. **Planetary Geology:** Alternatively known as **astrogeology or exogeology** is a planetary discipline concerned with the

geology of the celestial bodies such as planets and their moons, asteroids, comets, and meteorites.

ix. **Extragalactic Astronomy:** This is the study of the larger universe beyond the milky way.

x. **Physical Cosmology**: Physical cosmology involves the study of the universe as a whole.

2. **Aerospace engineering:** Is the primary field of engineering concerned with the development of aircraft and spacecraft. It has two major and overlapping branches, which are:

   i. **Aeronautical engineering:** Is the science or art involved with the study, design and manufacturing of air flight capable machines, and the techniques of operating aircraft and rockets within the atmosphere.

   ii. **Astronautical Engineering:** Is the theory and practice of travel beyond Earth's.

Unit 5: Space Exploration and Human Development

Unit Structure

5.1 Introduction

For more than fifty years, human have explored space, and this has produced a continuing flow of societal benefits. By its very nature, space exploration expands the envelope of human knowledge and presence throughout the solar system and this process has been accelerated by a combination of human and robotic activities.

The first satellites, designed to study the space environment and test initial capabilities in Earth orbit, contributed critical knowledge and capabilities for developing satellite telecommunications, global positioning, and advances in weather forecasting. Space exploration initiated the economic development of space that today, year after year, delivers high returns for invested funds in space. The challenges of space exploration have sparked new scientific and technological knowledge of inherent value to humankind, leading to better understanding of our Universe and the solar system in which we live. Knowledge, coupled with ingenuity, provides people around the globe with solutions as well as useful products and services. Knowledge acquired from space exploration has also introduced new perspectives on our individual and collective place in the Universe.

Space exploration is the ongoing discovery and exploration of celestial structures in outer space by means of continuously evolving and growing space technology. Mainly astronomers carry out the study of space with telescopes, and both unmanned robotic probes and human space flight conduct the physical exploration of space.

The observation of objects in space were carried out by astronomers, predates reliable recorded history was developed. Until in the 20th century that relative efficient rockets that allowed physical space exploration come to be.

Common rationales for exploring space include advancing scientific research, uniting different nations, ensuring the future survival of humanity and developing military and strategic advantages against other countries.

5.2 Intended Learning Outcomes

At the end of this unit, you will be able to:

- itemize the rationales for space exploration by super power nations of the world.
- state the various targets for exploration.
- identify human development that are associated with space exploration and
- explain the future plans by explorers for space exploration

5.3 History of Exploration in the 20th Century

Space exploration has often been used as a proxy competition for geopolitical rivalries such as the cold war. The early era of space exploration was driven by a “space race” between the Soviet Union and the United States, the launch of the first man-made object to orbit the earth, the “USSR’s SPUTNIK 1” on 4th October 1957, and the moon landing by the American Apollo 11 craft on 20th July 1969 are often taken as landmarks for this initial period. The Soviet space program achieved many of the first milestones including; the first living being in orbit in 1957, the first human space flight (Yuri Gagarin aboard” Vostoki”) in 1961, the first spacewalk (by Ajeksei Leonov) on 18th March 1965, the first automatic landing on another celestial body in 1966 and the launching of the first space station (Skalyut 1) in 1971.

i. After 20 years of these first explorations, focus shifted from oneoff flights to renewable hardware, such as the space shuttle programme from competitions to cooperation as with the International Space Station (ISS).
ii. In the 2000s, the People’s Republic of China initiated a successful manned spaceflight program while the European Union, Japan and India have also planned future manned space missions. China, Russia, and India have advocated manned missions to the moon during the 21st century, while European Union has advocated manned missions to both the moon and Mars during the same period.
iii. With the substantial completion of the ISS, following STS – 133 flight in March 2011, plans for space exploration by USA remain in flux. Constellation, a Bush Administration Program for a

return to the moon by 2020 was judged inadequately funded and unrealistic by an expert review panel in 2009. The Obama Administration proposed a revision of constellation in 2010 to focus on the development of the capability for crewed missions beyond Low Earth Orbit (LEO), envisioning extending the operation of ISS beyond 2020 transferring the development of launch vehicles for human crews from NASA to the private sector, and developing technology to enable missions to go beyond LEO, such as Earth/Moon L1, the moon. Earth/Sun L.2, near-earth asteroids and phobos or mars orbit.

The first steps of putting a man-made object into space were taken by German scientists during World War II, while testing the V-2 rocket. This became the first man-made object in space on 3rd October 1942 with the launching of the A-4. After the war, the U.S used German scientists and their captured rockets in programs for both military and civilian research.

First Flights: The first successful orbital launch was the Soviet Unmanned Sputnik 1 (satellite 1) mission in 1957. The satellite weighted about 83kg (1831b) and was believed to have orbited earth at a height of about 250 km (160 miles). It had two radio transmitters (20 and 40 MHz), which 'beeps' that could heard by radios around the globe. The analysis of the radio signals was used to gather information about the electron density of the ionosphere, while temperature and pressure data were encoded in the duration of the radio beeps. Sputnik 1 was launched by an R-7 rocket. This success led to an escalation of the American space programme which unsuccessfully attempted to launch a Vanguard satellite in 1958 the US successfully orbited Explorer 1 on a Juno rocket. In the meantime, the soviet clog Laika became the first animal in orbit on November 1957.

First Human Flight: The first successful human spaceflight was Vostok 1 (East 1), carrying 27-year old Russian Cosmonault Yuri Gagarin on the 12 April 1961. The space craft completed one orbit around the globe, lasting about 1 hour 48 minutes. This was a demonstration of the advanced soviet space program which opened an entirely new era in space exploration (human spaceflight).

The U.S. first launched a person into space within a month of Vostok 1 with Alan Shepard's suborbital flight in Mercury-Redstone 3. Orbital flight was achieved by the U.S. when John Glenn's Mercury-Atlas 6 orbited the Earth on 20th February 1963. China first launched a person into space 42 years after the launch of Vostok 1 on 15 October 2003 with the flight of Yang Liwei aboard the Shenzhou 5 (Spaceboats) Space craft.

First Planetary Explorations: The first artificial object to reach another celestial body was Luna in 1959 and the first automatic landing on another celestial body was preferred by Luna 9 in 1966. Lunalo became the first artificial satellite of the moon. The first manned landing on another celestial body was performed by Apollo II in its lunar landing on 20th July 1969. First interplanetary flyby was 1962 Mariner 2 flyby of Venus (closes approach 34,773 km). Flybys for the other planets were first achieved in 1965 for Mars by Mariner 4, 1973 for Jupiter by Pioneer 10, 1974 for Mercury by mariner 10, 1979 for Saturn by Pioneer II, for Uranus by Voyager 2 and 1989 Neptune by Voyage 2.

Figure 5.1: Sputnik 1

Figure 5.2: Apollo CSM in Lunar orbit

5.4 Targets of Exploration

a. Sun: The sun will probably not be physically explored in the nearest future because of the sun generate most space weather, which can affect power generation and transmission systems on earth and interfere with and may even damage satellites and probes.

b. Mercury: Mercury remains the least explored of the inner planets. As of May 2013, the Mariner 10 and MESSENGER missions have been only missions that have made close observations of mercury. MESSENGER entered orbit around mercury in March 2011, to further investigate the observations made by Mariner 10 in 1975.

A third mission to Mercury is scheduled to arrive in 2020. Bepicolombo is to include two problems and this is a joint mission by Japan and the European Space Agency. MESSENGER and Bepi Colombo are intended to gather complementary data to help scientists understand many of the mysteries discovered by Mariner 10's flybys.

c. Venus: Venus was the first target of interplanetary flyby and lander missions, despite it's one of the most hostile surface environments in the solar system, has had more Landers sent to it. Nearly all the Soviet Union, American Mariner 2 space craft, starting in 1975, with the Soviet orbiter Vinera 9, some the successful orbiter missions have been sent to Venus. Later missions also had been able to map the surface of Venus using radar to pierce the obscuring atmosphere.

d. Earth: Several space explorations had been used as tool to understand the earth as a celestial object. Difficult data for the earth had been obtained from such exploration which would have been near impossible from the ground. For example, the existence of Van Allen belts was unknown until their discovery by US's first artificial satellite, Explorer I. These belts contain radiation trapped by the earth's magnetic fields, which currently renders construction of habitable space stations above (1000 km in practical). This discovery led to the dispatch of more satellites to explore the earth from a space based perspectives. For examples, the hole in the ozone layer was found by an artificial satellite that was exploring the earth atmosphere.

e. **Earth is Moon:** This was the first celestial body to be the object of space exploration. In addition to all that had been discussed earlier, the Soviet Unmanned missions culminated in

f. the Lunokhod program in the early 70's which included the first unmanned rovers and also successfully returned lunar soil samples to the earth for study.

g. **Mars:** The exploration here has been important part of space exploration programs of the Soviet Union (Later Russia), the Unite States, Europe and Japan Dozens of Robotic Space Craft, including orbiters, landers and rovers have been launched towards Mars since 1960s. these missions were aimed at gathering data about current conditions and answering question about the history of Mars and for a better appreciation of the red planet. And also yield further insight into the past, and possible future of Earth. There was high rate of failure to Mars explorations because of the great financial loses. But India had become the first country to achieve success of the maiden attempt. India's mars orbiter mission (MOM) is one of the least expensive interplanetary missions ever undertaken with an approximate total cost of £450 crore (USD 73 million).

Read more about the exploration of other targets in Jupiter, Saturn, Uranus, Neptune and other objects in the Solar System.

5.5 Human Development and Future of Space Exploration

Human's interest in the heavens has been universal and enduring. Humans are driven to explore the unknown, discover new worlds, push the boundaries of their scientific and technical limits. The intangible desire to explore and challenge the boundaries had provided benefits to the society for centuries.

Human space exploration helps to address fundamental questions about the place in the universe and the history of the Solar System. Through addressing the challenges related to human space exploration, they expand technology, create new industries and help to foster a peaceful connection with other nations.

Curiosity and exploration are vital to the human spirit and accepting the challenge of going deeper into space will invite the people of the world today and the generations of tomorrow to join on the exciting journey.

With the international collaboration developed through ISS program and the experience of constructing a building in space, the next step will be the establishment of an international lunar base. Because there is an idea for a manned asteroid mission and the next target after the ISS will be the moon leaving human space exploration in low earth orbit.

The Flexible Path

This is the beginning of new era in space exploration in which NASA has been challenged to develop systems and capabilities required to explore beyond low-earth orbit including destinations near-earth asteroids and Mars. In seeking for answers to questions, human have always asked. Combining both human and robotic exploration methods, technology and senses to increase the ability to observe, adapt, and to uncover new knowledge. This quest keeps pushing human to make further advances in space exploration.

Why the International Space Station (ISS)?

The first step in embarking on a long and challenging journey involves laying a solid ground for a successful voyage. The ISS serves as a national laboratory for human health, biological and materials research, as technology test-bed and as a stepping stone for going further into solar system. It will improve and ensure astronauts are safe, healthy and productive while exploring and will continue to expand the knowledge about how materials and biological systems behave outside of the influence of gravity.

Why Asteroids?

Asteroids are believed to have formed early in the solar system's history about 4.5 billion years ago when a cloud of gas and dust called the solar nebula collapsed and formed the sun and the planets. By visiting these near earth objects, to study the materials that came from the solar nebula, one can look for answers to some of human kind's most compelling questions such as; how did the solar system form and where did the earth's water and other organic materials come from?

Space exploration of the asteroids is expected to unlock clues about the solar system and to learn more about past earth impacts and finding a way to reduce future impacts.

Why Mars?

Mars has always been a source of inspiration for explorers and scientists. Robotic missions have found evidence of water in Mars, though, no life exists beyond the earth.

A mission to the nearest planetary neighbour could provide the best opportunity to demonstrate that humans can live for extended, even permanent beyond earth orbit. The technology and space system required to transport and sustain explorers will drive innovation and encourage creative ways to address challenges. The challenge of travelling to Mars and learning how to live there will encourage nations around the world to work together to achieve such an ambitious undertaking. The ISS has shown that opportunities for collaboration will highlight the common interests and provide a global sense of community.

Future Space Exploration

In the 2000s, several plans for space exploration were announced by both government entities and the private sector. China also announced plans to have a 60-ion multi-module space station by 2020.

The NASA Authorization Act of 2010 provided a re-prioritized list of objectives for the space programs, as well as funding for the first priorities. It proposes to move forward with the development of the Space Launch System (SLS) which will be designed to carry the Orion Multi-purpose Crew vehicle as well as important cargo, equipment, and science experiments to earth's orbit and destination beyond. The SLS rocked will incorporate technological investments from space shuttle program and constellation program in order to take advantage of proven hardware and reduce development and operational costs. The first developmental flight is targeted for the end of 2017.

5.6 Prospective Benefits from Space Exploration

There are great opportunities and benefits to be derived from space explorations. The wide spread consultation with technology and commercial experts across non-space sectors revealed a number of

areas where there are synergies in the technology challenges faced by space exploration and non-space sectors. Four areas were identified. These are:

- **Renewable Energy (Global Challenge: Climate Change):** Carbon (i.e. renewable) energy sources to meet international agreements and to limit climate change in the longer term. Space exploration requires capabilities for efficient, reliable and compact energy generation and storage on-board spacecraft and on the planetary surface. These energy sources are by the very nature of space exploration not based on fossil fuels and therefore, fall into the renewable energy category. While not all terrestrial opportunities for renewable energy generation have parallels in space (e.g. wind, wave, tidal), there are a number of synergies such as fuel cells, batteries, photovoltaics' and nuclear power.

- **Healthcare for an Ageing Population (Global Challenge: Healthcare):** The cost of healthcare provision in Europe and elsewhere are increasing year by year due to a large extent to meeting the needs of an ageing population. Improved understanding of the conditions of ageing (Osteoporosis, cardiovascular problems, etc.) along with the ministration of medical technologies and their integration with communications technologies will enable better and "smarter" diagnosis and treatment that can be delivered at the point-of-care that is, at home or local clinic. These developments have the potential to reduce the cost of healthcare provision improving the quality of healthcare provision, improve the quality of healthcare services and ensure ongoing quality of life for everyone.

  The provision of equipment and services to manage crew health on long distance space-flights has similar requirements. Point-of-care delivery of healthcare by small (or even embedded) intelligent and autonomous system is essential as inter-planetary travel times scales will be of the order of years rather than months and unplanned and premature return to earth is not an option. Space fight even short duration creates physiological effects that are akin to accelerated ageing (reduced bone density, cardio-vascular de-conditioning etc.). Therefore, improved understanding of cardiovascular and muscular skeletal systems and development of counter measures e.g. nutrition and exercise regimes is essential to ensure crew remains healthy throughout long duration missions.

- **Secure Access to High Quality Water Resources (Global Challenge: Water Supply):** Water supplies on earth are likely to come under increasing pressure in future as a result of population growth and climate change. The availability of high quality water resources to meet human needs requires more efficient use of existing water resources. This can only be achieved through increased re-cycling and re-use of waste water. Furthermore, widespread provision of high quality water will help to avoid consequences of lack of access to water, such as displaced populations and conflict.

  Similarly, space missions have access to limited water supplies to support all human needs (drinking, cleaning, food production). Launch costs and weight restrictions limit the amount of water and other consumables that can be supplied at the start of a long mission and therefore, all supplies must be efficiently managed with re-cycling re-use factor approaching 100%.

- **Secure Access to Oil and Gas Resources (Global Challenge: Energy Supply):** Despite the moves towards a low carbon economy, humans will continue to rely on oil and gas as a significant energy source. For many years to come. Existing reserves are rapidly being depleted and the remaining unexploited oil and gas fields and difficult to access locations and as such under the polar ice cap and in deep and ultra-deep water. the oil and gas sector therefore, requires technologies to increase the automation and autonomy of oil and gas exploration to access and explore these reserves, reduce costs of production and ensure safe and secure operations.

Space exploration also has significant requirements for robotics, automation and safe operations – to only for robotic precursor missions to the moon and/or Mars but also for human missions. More specifically, projected space exploration activities include autonomous robotic sub-surface exploration of planetary surfaces (i.e. drilling, sample collection, preparation and analysis for scientific purposes and for the discovery and development of materials to support human activities.

All these four support opportunities are tentative because both space and non-space stakeholders are aware of the synergies in the technology required. However, both group of experts have identified as area of mutual interest and therefore they currently present the most fruitful opportunities for the future.

Self -Assessment Exercise

i. Explain the contribution of Soviet Union to space exploration in the early days.
ii. Identify two benefits of space exploration to global challenges.

5.7 Summary

In this unit, you have learnt about human development and future space explorations. The various plans by nations and private sectors for greater and more result-oriented space explorations had been planned up to 2050. You also learnt about the possible benefits that can be derived from technological solutions to global challenges.

5.8 References/Further Readings/Web Resources

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5.9 Possible Answers to Self-Assessment Exercise(s)

i. Explain the contribution of Soviet Union to space exploration in the early days.

The Soviet space program achieved many of the first milestones, including the first living being in orbit in 1957, the first human space flight (Yuri Gagarin aboard" Vostoki") in 1961, the first spacewalk (by Ajeksei Leonov) on 18th March 1965, the first automatic landing on another celestial body in 1966 and the launching of the first space station (Skalyut 1) in 1971.

ii. Identify two benefits of space exploration to global challenges.

- Healthcare for an Ageing Population (Global Challenge: Healthcare)
- Secure Access to High Quality Water Resources (Global Challenge: Water Supply)