

# **PHYSICS**

**FOR**

**ASSOCIATE NURSING PROGRAM**

**SENIOR 6**

**TEACHER'S GUIDE**

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## FOREWORD

Dear teacher,

Rwanda Basic Education Board is honored to present Senior six Physics teacher's guide for Associate nursing program which serves as a guide to competence-based teaching and learning to ensure consistency and coherence in the learning of the physics' subject. The Rwandan educational philosophy is to ensure that learners achieve full potential at every level of education which will prepare them to be well integrated in society and exploit employment opportunities.

In line with efforts to improve the quality of education, the government of Rwanda emphasizes the importance of aligning teaching and learning materials with the syllabus to facilitate their learning process. Many factors influence what they learn, how well they learn and the competences they acquire. Those factors include the relevance of the specific content, the quality of teachers' pedagogical approaches, the assessment strategies and the instructional materials available. We paid special attention to the activities that facilitate the learning process in which learners can develop ideas and make new discoveries during concrete activities carried out individually or with peers. With the help of the teachers, learners will gain appropriate skills and be able to apply what they have learnt in real life situations. Hence, they will be able to develop certain values and attitudes allowing them to make a difference not only to their own life but also to the nation.

This is in contrast to traditional learning theories which view learning mainly as a process of acquiring knowledge from the more knowledgeable who is mostly the teacher. In competence-based curriculum, learning is considered as a process of active building and developing of knowledge and understanding, skills and values and attitude by the learner where concepts are mainly introduced by an activity, situation or scenario that helps the learner to construct knowledge, develop skills and acquire positive attitudes and values.

In addition, such active learning engages learners in doing things and thinking about the things they are doing and they are encouraged to bring their own real experiences and knowledge into the learning processes. In view of this, your role is to:

- Plan your lessons and prepare appropriate teaching materials.
- Organize group discussions for learners considering the importance of social constructivism suggesting that learning occurs more effectively when the learner works collaboratively with more knowledgeable and experienced people.
- Engage learners through active learning methods such as inquiry methods, group discussions, research, investigative activities and group or individual work activities.
- Provide supervised opportunities for learners to develop different competences by giving tasks which enhance critical thinking, problem solving, research, creativity and innovation, communication and cooperation.

- Support and facilitate the learning process by valuing learners' contributions in the class activities.
- Guide learners towards the harmonization of their findings.
- Encourage individual, peer and group evaluation of the work done in the classroom and use appropriate competence-based assessment approaches and methods.

To facilitate you in your teaching activities, the content of this teacher's guide is self-explanatory so that you can easily use it. It is divided in 3 parts:

- The part 1: Explains the structure of this book and gives you the methodological guidance;
- The part 2: Gives the sample lesson plans as reference for your lesson planning process;
- The part 3: Provides details the teaching guidance for each concept given in the student book.

Even though this teacher's guide contains the answers for all activities given in the learner's book, you are requested to work through each question and activity before judging learner's findings.

I wish to sincerely appreciate all people who contributed towards the edition of this teacher's guide, particularly REB staff who organized the whole process from its inception. Special gratitude goes to all experts in design and layout services, illustrations and image anti-plagiarism, lecturers and teachers who diligently worked to successful completion of this book. Any comment or contribution would be welcome for the improvement of this textbook for the next edition.

**Dr. Nelson MBARUSHIMANA**

**Director General of REB**



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**Joan MURUNGI,**

**Head of Department of Curriculum, Teaching and Learning Resources**

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## PART I. GENERAL INTRODUCTION

### 1.0. About the teacher's guide

This book is designed to accompany senior six Physics student's book and intends to help teachers in the implementation of competence-based curriculum specifically Physics syllabus.

It guides teachers when preparing lessons. Teachers are encouraged to be more creative during preparation of lessons based on the specific learning areas.

### 1.1. The structure of the guide

This section presents the overall structure, the unit and sub-heading structure to help teachers to understand the different sections of this guide and what they will find in each section.

#### Overall structure

The whole guide has three main parts as follows:

- **Part I: General Introduction.**

This part provides general guidance on how to develop the generic competences, how to integrate cross cutting issues, how to cater for learners with special educational needs, active learning methods and techniques of teaching Physics and guidance on assessment.

- **Part II: Sample lesson plan**

This part provides a sample lesson plan, developed and designed to help the teacher develop their own lesson plans.

- **Part III: Unit development**

This is the core part of the guide. Each unit is developed following the structure below. The guide ends with references.

## Structure of a unit

Each unit is made of the following sections:

- **Unit title:** from the syllabus
- **Key unit competence:** from the syllabus
- **Prerequisites (knowledge, skills, attitudes and values)**

This section indicates knowledge, skills and attitudes required for the success of the unit. The competence-based approach calls for connections between units within a subject and interconnections between different subjects. The teacher will find an indication of those prerequisites and guidance on how to establish connections.

- **Cross-cutting issues to be addressed**

This section suggests cross cutting issues that can be integrated depending on the unit content. It provides guidance on how to come up with the integration of the issue. Note that the issue indicated is a suggestion; teachers are free to take another cross-cutting issue taking into consideration the learning environment.

- **Guidance on the introductory activity :**

Each unit starts with an introductory activity in the learner's book. This section of the teacher's guide provides guidance on how to conduct an activity and the corresponding answers. Note that learners may not be able to find the right solution but they are invited to suggest possible solutions. Solutions are provided by learners gradually through discovery activities organized at the beginning of lessons or during the lesson.

- **List of lessons/sub-heading**

This section presents in a table suggestion on the list of lessons, lesson objectives copied or adapted from the syllabus and duration for each lesson. Each lesson /subheading is then developed.

### Note

- Time can vary depending on your timetable and Nature of your class.
- Depending on the size of your class, be flexible on the method to use. Do not stick on the suggested method in this book.

- **End of each unit**

At the end of each unit, teacher's guide provides the following sections:

- Summary of the unit which provides the key points of content developed in the student's book.
- Additional information which provides additional content compared to the student's book for the teacher to have a deeper understanding of the topic.
- End unit assessment which provides the answers to questions of end unit assessment in the textbook and suggests additional questions and related answers to assess the key unit competence.
- Additional activities: remedial, consolidation and extended activities). The purpose of these activities is to accommodate each learner (slow, average and gifted) based on end unit assessment results.

### **Structure of each sub heading**

Each lesson/sub-heading is made of the following sections:

#### **Lesson Sub heading title 1:**

- **Prerequisites/Revision/Introduction:**

This section gives a clear instruction to teacher on how to start the lesson

- **Teaching resources**

This section suggests the teaching aids or other resources needed in line with the activities to achieve the learning objectives. Teachers are encouraged to replace the suggested teaching aids by the available ones in their respective schools and based on learning environment.

- **Learning activities**

This section provides a short description of the methodology and any important aspect to consider. It provides also answers to learning activities with cross reference to text book:

- **Exercises/application activities**

This provides questions and answers for exercises/ application activities/

## 1.2. Methodological guidance

### 1.2.1 Developing competences

Teachers are responsible for knowledge transfer and fostering student’s learning achievement, and creating safe and supportive learning environment. It implies that a learner has to demonstrate what he/she is able to do using the knowledge, skills, values and attitude acquired in the learning process.

The competence-based curriculum employs an approach of teaching and learning based on discrete skills rather than dwelling on only knowledge or the cognitive domain of learning. It focuses on what learner can do rather than what learners know. Learners develop basic competences through specific subject unit competences with specific learning objectives broken down into knowledge, skills and attitudes. These competences are developed through learning activities performed by learners and evaluated based on set standards or criteria.

In addition to specific subject competences, learners develop generic competences which are transferable throughout a range of learning areas and situations in life. Below are examples of terms developing generic competences in Physics?

Generic competence	Examples of terms used in developing activities that develop generic competences
Critical thinking	<ul style="list-style-type: none"><li>• Research and discuss</li><li>• Compare and contrast exercises</li><li>• Observe, record, interpret</li><li>• Debate.....</li><li>• Make basic science equipment out of locally available materials</li></ul>
Research and Problem solving	<ul style="list-style-type: none"><li>• Use the internet</li><li>• Use a library</li><li>• Create a school library</li><li>• Collect data through observation and recording</li><li>• Identify a problem and design a methodology to collect the information needed to solve the problem</li></ul>

<b>Innovation and creativity</b>	<ul style="list-style-type: none"> <li>• Create an experiment to prove a concept</li> <li>• Invent new ways of doing traditional things</li> <li>• Develop a graph to illustrate information</li> <li>• Create a flow chart to show the main stages in a process</li> <li>• Design a data collection survey/questionnaire</li> <li>• Conduct experiments with objectives, methodology, observations, results, conclusions</li> <li>• Make hypotheses and identify ways to test them</li> <li>• Identify local problems and ways to resolve them</li> </ul>
<b>Cooperation, Personal and Interpersonal management and life skills</b>	<ul style="list-style-type: none"> <li>• Work individually</li> <li>• Work in Pairs</li> <li>• Small group work</li> <li>• Large Group Work</li> </ul>
<b>Communication</b>	<ul style="list-style-type: none"> <li>• Present Ideas - verbally, in writing, graphically, digitally</li> <li>• Set out pros and cons</li> <li>• Argue a Case – verbally, in writing, graphically (compare and contrast), digitally</li> <li>• Observe, Record, Interpret the results of a measurement accurately.</li> <li>• Select and use appropriate formats and presentations, such as tables, graphs and diagrams.</li> <li>• Organise and present a complete report in a clear and logical form using spelling, punctuation and grammar with an acceptable degree of accuracy.</li> <li>• Report accurately and concisely.</li> </ul>
<b>Lifelong learning</b>	<ul style="list-style-type: none"> <li>• Take initiative to update knowledge and skills with minimum external support.</li> <li>• Cope with the evolution of knowledge and technology advances for personal fulfilment</li> <li>• Seek out acquaintances more knowledgeable in areas that need personal improvement and development</li> <li>• Exploit all opportunities available to improve on knowledge and skills.</li> </ul>

### 1.2.2 Addressing cross cutting issues

The integration of cross cutting issues is an integral part of the teaching and learning process that are appropriately addressed within subjects. The eight cross cutting issues identified in the national curriculum framework are: genocide studies, environment and sustainability, gender, Comprehensive Sexuality Education (CSE), Peace and Values Education, Financial Education, standardization Culture and Inclusive Education.

Some of the cross cutting issues are specific to particular learning areas or subjects but the teacher is encouraged to address a cross cutting within the learning process where possible. In addition, learners should always be given an opportunity during the learning process to address these cross cutting issues both within and out of the classroom so as to progressively develop related attitudes and values.

Below are examples of statements that identify key points in setting examples addressing crosscutting issues in Physics:

<b>Cross-cutting issue</b>	<b>Examples of key points needed in setting examples that integrates cross-cutting issues</b>
Inclusive education	All activities and exercises in physics should be done in such way that they are diverse and cater ones background and abilities.
Gender	All students should have equal responsibilities while planning and performing activities. There is a tendency of girls being left to clean places where practical have been done. This should be avoided.
<b>Peace and Values Education</b>	Learners should be sensitised to know the relevance of working together in all activities. Learners should always respect one’s idea, supplementing someone’s findings, owning someone’s concern in all discussions.
<b>CSE</b>	Examples and statements used in class should provide information on healthy sexual lives. They should help learners in explaining and classifying feelings, values and attitudes and promote sustainable risk reducing behaviour
<b>Standardization culture</b>	Physics has a lot of practical in which different equipment are used. They should be aware of instruments that measure accurately.

<b>Environment and sustainability</b>	Though there are a lot of projects in physics, learners should know that their projects and innovations should rather protect environment than destroying it. Students will always want to discover but their discoveries should be environmental friendly.
<b>Financial Education</b>	Students have tendency of saying that all discoveries have to be done in expensive laboratories with expensive equipment. They should be aware that discoveries can be made with locally available materials.

### 1.2.3 Attention to special educational needs specific to each subject

When we think about inclusive education, often we just think about getting student *into school*, i.e. making sure they are physically present in school. However, we also need to ensure that students are *participating* in lessons and school life, and they are *achieving* academically and socially as a result of coming to school. So we need to think about presence, participation and achievement.

Some people may think that it is difficult to address the needs of a diverse range of students. However, by working as a team within your school, with support from families and local communities, and by making adaptation of teaching methods, teaching and learning materials, the teacher will be able to meet the needs of all students.

#### Teachers need to:

- Remember that students learn in different ways so they have to offer a variety of activities (e.g. role-play, music and singing, word games and quizzes, and outdoor activities);
- Always demonstrate the objective of the activity; show students what they expect them to do;
- Vary their pace of teaching to meet the needs of each student. Some students process information and learn more slowly than others.
- Use clear consistent language – explain the meaning (and demonstrate or show pictures) if you introduce new words or concepts.
- Make full use of facial expressions, gestures and body language.
- Pair a student who has a disability with a friend. Let them do things together and learn from each other. Make sure the friend is not over protective and does not do everything for the student. Both students will benefit from this strategy.
- Have a multi-sensory approach to your activities.

Below are strategies related to each main category of disabilities and how to deal with every situation that may arise in the classroom. However the list is not exhaustive because each student is unique with different needs that should be handled differently.

### **Strategies to help student with developmental disabilities:**

- Be patient! If you find that the student takes longer than others to learn or to do an activity, allow more time.
- Do activities together with the student.
- Gradually give the student less help.
- Let the student do the activity with other students and encourage them to help each other.
- Divide the activity into small achievable steps.
- Remember to praise and say ‘Well done’ when the student learns something new or makes a strong effort.

### **Strategies to help learners with physical disabilities or mobility difficulties:**

- Adapt activities so that students who use wheelchairs or other mobility aids, or other students, who have difficulty moving, can participate.
- Ask for adaptation of furniture – e.g. the height of a table may need to be changed to make it easier for a student to reach it or fit their legs or wheelchair under.
- Encourage peer support between students.
- Get advice from parents or a health professional about assistive devices

### **Strategies to help learners with hearing disabilities or communication difficulties**

- Always get the student’s attention before you begin to speak.
- Encourage the student to look at your face.
- Use gestures, body language and facial expressions.
- Use pictures and objects as much as possible.
- Ask the parents/caregivers to show you the signs they use at home for communication use the same signs yourself and encourage other students to also use them.
- Keep background noise to a minimum.

### **Strategies to help learners with visual disabilities**

- Help students to use their other senses (hearing, touch, smell and taste) to play and carry out activities that will promote their learning and development.
- Use simple, clear and consistent language.
- Use tactile objects to help explain a concept.
- If the student has some sight, ask them what they can see. Get information from parents/caregivers on how the student manages their remaining sight at home.
- Make sure the student has a group of friends who are helpful and who allow the student to be as independent as possible.
- Plan activities so that students work in pairs or groups whenever possible.
- In case of practical work where identifying parts, you can use a magnifying glass.

## **Adaptation of assessment strategies**

Each unit in the teacher's guide provides additional activities to help learners achieve the key unit competence. Results from assessment inform the teacher which learner needs remedial, consolidation or extension activities. These activities are designed to cater for the needs of all categories of learners; slow, average and gifted learners respectively.

Physics is a practical subject therefore all activities should be hands on.

All activities given to learners in physics should recognize all levels of learners in class.

### **1.2.4 Guidance on assessment**

Assessment is an integral part of teaching and learning process. The main purpose of assessment is for improvement. Assessment for learning/ Continuous/ formative assessment intends to improve learners' learning and teacher's teaching whereas assessment of learning/summative assessment intends to improve the entire school's performance and education system in general.

#### **Continuous/ formative assessment**

It is an ongoing process that arises out of interaction during teaching and learning process. It includes lesson evaluation and end of sub unit assessment. This formative assessment should play a big role in teaching and learning process. The teacher should encourage individual, peer and group evaluation of the work done in the classroom and uses appropriate competence-based assessment approaches and methods.

Formative assessment principles in physics is applied through administering several learning activities that are planned in each lesson to ensure that lesson's objectives are achieved before moving on. At the end of each unit, the end unit assessment is formative when it is done, it gives information on the progress of students and from there one decides what adjustments need to be done. Assessment standards are taken into consideration when setting these tasks.

#### **Summative assessment:**

The assessment done at the end of the term, end of year, is considered as summative. The teacher, school and parents are informed on the achievement of educational objective and think of improvement strategies. There is also end of level/ cycle assessment in form of national examinations.

In Physics, it is very important to include practical work while planning this summative assessment.

## 1.2.5 Students' learning styles and strategies to conduct teaching and learning process

There are different teaching styles and techniques that should be catered for. The selection of teaching method should be done with the greatest care and some of the factors to be considered are: the uniqueness of subjects; the type of lessons; the particular learning objectives to be achieved; the allocated time to achieve the objective; instructional available materials; the physical/sitting arrangement of the classroom, individual students' needs, abilities and learning styles.

There are mainly **four different learning styles** as explained below:

### a) Active and reflective learners

**Active learners** tend to retain and understand information best by doing something active with it discussing or applying it or explaining it to others. **Reflective learners** prefer to think about it quietly first.

### b) Sensing and intuitive learners

**Sensing learners** tend to like learning facts; **intuitive learners** often prefer discovering possibilities and relationships. Sensors often like solving problems by well-established methods and dislike complications and surprises; intuitive learners like innovation and dislike repetition.

### c) Visual and verbal learners

Visual learners remember best what they see—pictures, diagrams, flow charts, time lines, films, demonstrations, etc.; verbal learners get more out of words—written and spoken explanations.

### d) Sequential and global learners

**Sequential learners** tend to gain understanding in linear steps, with each step following logically from the previous one. **Global learners** tend to learn in large jumps, absorbing material almost randomly without seeing connections, and then suddenly “getting it.”

To cater for this, learners' textbook provides a lot of activities that include checking my progress, projects, quick checks and many others that helps these learners to find them learning and mastering physics.

## 1.2.6 Teaching methods and techniques that promote the active learning

The different student learning styles mentioned above can be catered for, if the teacher uses active learning whereby learners are really engaged in the learning process.

## What is Active learning?

Active learning is a pedagogical approach that engages students in doing things and thinking about the things they are doing. In active learning, learners are encouraged to bring their own experience and knowledge into the learning process.

### The role of the teacher in active learning

- The teacher engages learners through active learning methods such as inquiry methods, group discussions, research, investigative activities and group and individual work activities.
- He/she encourages individual, peer and group evaluation of the work done in the classroom and uses appropriate competence-based assessment approaches and methods.
- He provides supervised opportunities for learners to develop different competences by giving tasks which enhance critical thinking, problem solving, research, creativity and innovation, communication and cooperation.
- Teacher supports and facilitates the learning process by valuing learners' contributions in the class activities.

### The role of learners in active learning

Learners are key in the active learning process. They are not empty vessels to fill but people with ideas, capacity and skills to build on for effective learning. A learner engaged in active learning:

- Communicates and shares relevant information with other learners through presentations, discussions, group work and other learner-centred activities (role play, case studies, project work, research and investigation)
- Actively participates and takes responsibility for their own learning
- Develops knowledge and skills in active ways
- Carries out research/investigation by consulting print/online documents and resourceful people, and presents their findings
- Ensures the effective contribution of each group member in assigned tasks through clear explanation and arguments, critical thinking, responsibility and confidence in public speaking
- Draws conclusions based on the findings from the learning activities.

### Some active techniques that can be used in Physics

The teaching methods strongly emphasised in the competence Based Curriculum (CBC) are active methods. Below are some active techniques that apply in sciences:

- **Practical work/ experiments:**

Many of the activities suggested in the Physics curriculum as well as in the student's book are practical work or experiments.

Practical work is vital in learning chemistry; this method gives the learner the opportunity to implement a series of activities and leads to the development of both cognitive and hands-on skills. The experiments and questions given should target the development of the following skills in students: observation; recording and report writing; manipulation; measuring; planning & designing.

In case your school does not have enough laboratory materials, experiments can be done in groups but make sure every student participates. In case your school does not have materials, make arrangements with the neighbouring science school of excellence and take your students there for a number of experiments.

Care must be taken for both girls and boys to have equal responsibilities in preparation of practical work and even after the practical. In mixed schools, there is a tendency of girls being left to clean and prepare the apparatus.

- **Demonstration**

Literally demonstration means “show” the teacher shows something, such as a specimen, a model, or a skill (an experiment) while students watch. The method is preferred mainly under three conditions: Shortage of materials, use of sophisticated materials (very expensive materials) when safety is a major factor like dangerous experiments and it needs specific skills to be learnt first.

**Demonstration is done in three main stages:**

- **Preparation:** Checking materials to ensure they are available and at good state; try the experiment before; think of safety rule and give instructions to technician if you have any.
- **Performance:** Sitting or standing arrangement of students; introduction of the experiment: aims and objectives; setting up the apparatus; performing the experiment; write and record the data.
- **Discussion:** Observations and interpreting data; make generalisations and assignment: writing out the experiment report and further practice and research.

- **Project work**

Physics teachers are encouraged to sample and prepare project works and engage their students in as many as possible. A well produced project will demonstrate students' competence (basic and generic) of students and integration of cross cutting issues in a number of ways:

- It gives students an opportunity to link concepts, principles learnt in a classroom or laboratory to the outside world, thus aiding revision and anchoring of such concepts.
- Stimulates the interest of students in the subject
- It exposes students to a wider range of skills and instruments
- It trains students in the designing of a practical investigation or problem solving with suitable controls, sampling procedures and presentation
- It helps to improve student's communication skills
- When performed in groups, talents of all in groups are shared for the benefit of everybody in the group.
- It promotes interdisciplinary activities as it calls for use of different skills.

There are about three types of project work

- **Experimental:** work in a laboratory, carrying out an experiment to investigate a particular problem.
- **Observational:** Collecting data, analysing data and interpreting the data that already exists.
- **Survey:** use of techniques like questionnaires, provides information such as people's awareness.

- **Field trip**

One of the main aims of teaching chemistry in Rwanda is to apply its knowledge for development. To achieve this aim we need to show to students the relationship between classroom physics lessons and applied physics.

Field trip is one of the methods we can use to achieve this aim because it:

- **Makes learning more meaningful:** Experiences are fairly direct, making the learning more meaningful, realistic and memorable.
- **Motivates learners:** Experiences during the visits, use of more than one sense, thus offers stimulus variation, which is likely to motivate learners.
- **Orientation of career choice:** Can help students in their career choices

However, field trips are costly, disrupt lessons of other subjects if planned on a learning day, Take a lot of time to plan, Accidents may occur on the road to or from the trip and

some students can be difficult to control on a trip. Therefore the following guidelines should be observed:

- Write to the authority persons seeking for permission in your note include; date, time, purpose and number of students
- Start detailed plans
- Visit the area before the trip if possible to familiarise yourself with the place
- Write out the worksheet that will guide the learners on activities to observe, look for during the visit
- Work out the timetable for the trip
- Try to team up as science teachers and make it a science trip, arrange and go with at least one science teacher
- Finally leave the contact address to the school administration

When students come back from trip, the teacher should plan for follow-up. The follow-up should allow students to share experiences and relate them to the prior chemistry knowledge. This can be done in several ways;

**Either:** Students write a report individually or in groups and give to the teacher for marking. The teacher then arranges for discussion to explain possible misconceptions and fill gaps. **Or:** Students write reports in groups and display them on the class notice board for everyone to read.

**Note:** field trip can provide a worthwhile experience if planned well. Students like having a change from those classrooms and laboratories. Most students return from trip sounding refreshed, motivated and ready to absorb more chemistry concepts next day.

## **Main steps for a lesson in active learning approach**

All the principles and characteristics of the active learning process highlighted above are reflected in steps of a lesson as displayed below. Generally the lesson is divided into three main parts whereby each one is divided into smaller steps to make sure that learners are involved in the learning process. Below are those main part and their small steps:

### **1) Introduction**

Introduction is a part where the teacher makes connection between the current and previous lesson through appropriate technique. The teacher opens short discussions to encourage learners to think about the previous learning experience and connect it with the current instructional objective. The teacher reviews the prior knowledge, skills and attitudes which have a link with the new concepts to create good foundation and logical sequencings.

## 2) Development of the new lesson

The development of a lesson that introduces a new concept will go through the following small steps: discovery activities, presentation of learners' findings, exploitation, synthesis/summary and exercises/application activities, explained below:

- **Discovery activity**

### Step 1

- The teacher discusses convincingly with students to take responsibility of their learning
- He/she distributes the task/activity and gives instructions related to the tasks (working in groups, pairs, or individual to instigate collaborative learning, to discover knowledge to be learned)

### Step 2

- The teacher let the students work collaboratively on the task.
- During this period the teacher refrains to intervene directly on the knowledge
- He/she then monitors how the students are progressing towards the knowledge to be learned and boost those who are still behind (but without communicating to them the knowledge).

- **Presentation of learners' productions**

- In this episode, the teacher invites representatives of groups to presents the students' productions/findings.
- After three/four or an acceptable number of presentations, the teacher decides to engage the class into exploitation of the students' productions.

- **Exploitation of learner's productions**

- The teacher asks the students to evaluate the productions: which ones are correct, incomplete or false
- Then the teacher judges the logic of the students' products, corrects those which are false, completes those which are incomplete, and confirms those which correct.

- **Institutionalization (summary/conclusion/ and examples)**

- The teacher summarises the learned knowledge and gives examples which illustrate the learned content.

- **Exercises/Application activities**

- Exercises of applying processes and products/objects related to learned unit/sub-unit

- Exercises in real life contexts
- Teacher guides learners to make the connection of what they learnt to real life situations. At this level, the role of teacher is to monitor the fixation of process and product/object being learned.

### 3) Assessment

In this step the teacher asks some questions to assess achievement of instructional objective. During assessment activity, learners work individually on the task/activity. The teacher avoids intervening directly. In fact, results from this assessment inform the teacher on next steps for the whole class and individuals. In some cases the teacher can end with a homework assignment.

## PART II: SAMPLE LESSON PLANS

The teacher’s guide provides more than one lesson plan taking into consideration the type of lesson in the subject (Eg: one per main topic/theme) using the CBC format.

### 1. Competence – based Lesson Plan

School Name: .....

Teacher’s name: .....

Term	Date	Subject	Class	Unit No	Lesson No	Duration	Class size
First Term	20 /01/ 2018	Physics	S 6	1	1 of 10	80 min	45
Type of Special Educational Needs to be catered for in this lesson and number of learners in each category				Learners with visual difficulties.			

<b>Unit title</b>	<b>SOUND WAVES.</b>
<b>Key Unit Competence</b>	By the end of the unit the learner should be able to analyze the effects of Sound waves in elastic medium.
<b>Title of the lesson</b>	Sound production
<b>Instructional Objective</b>	With the help of provided apparatus, students perform an experiment to produce effective sound waves.
<b>(Plan for this Class (location: in / outside)</b>	Classroom

<b>Learning Materials (for all learners)</b>	open tubes/pipe, tuning fork, acoustic guitar, drum
<b>References</b>	<p>1. Breithaupt, J. (2000), Understanding Physics For Advanced Level (4, Ed.) Ellenborough House, Italy: Stanley Thorners;</p> <p>2. Abbot, A. F., &amp; Cockcroft, J. (1989). Physics. (5, Ed.) Heinemann: Educational Publishers.</p>

<b>Timing for each step</b>	<b>Description of teaching and learning activity</b>		Generic competences and Cross cutting issues to be addressed
1.Intro- duction  10min	<p><b>Teacher activities</b></p> <p>Motivate the learners by playing a guitar and asking what is heard and how it is produced?</p> <p>Form groups and guide the learners</p> <p>Moderate the presentations and articulate different ideas from learners</p> <p>Possible answers:</p> <p>Facilitate the learners to think about the topic of today</p> <p>presentations and articulate different ideas from learners</p> <p>Possible answers:</p> <p>Facilitate the learners to think about the topic of today</p>	<p><b>Learner activities</b></p> <ul style="list-style-type: none"> <li>Recall how mechanical waves are propagated in elastic medium</li> <li>They think what is heard and describe how it is produced.</li> <li>Discuss the question and take position</li> <li>In groups, they present their thoughts.</li> <li>Predictions:</li> <li>Most of us start our lives by producing sound waves! We spend much of our life surrounded by objects which produce sound waves. Most machines in use vibrate and produce sound so the only sure way to silence them would be to put them in vacuum there would be no surrounding medium for the vibrating surfaces of the machine to push against, hence no sound waves.</li> <li>Discover the objectives of the lesson</li> </ul>	<p>Communication, cooperation, critical thinking through responding to questions.</p>

<p>2.Development of the lesson</p> <p>60 min</p>	<p>Lead the process of examining learners' predictions</p> <p>Give the opportunity to the learner to suggest how to verify their predictions</p> <p>Give the learner the guitar in groups, discuss on how to handle it carefully and let them produce some notes on an acoustic guitar following given guidelines</p>	<ul style="list-style-type: none"> <li>• Suggest that they can play some notes on the string of acoustic guitar</li> <li>• Suggest some of the risks which may arise when they play a guitar and set the guidelines</li> <li>• Compare the results with different predictions</li> <li>• Present the results in plenary and write on the chalk board</li> </ul>	<p>Peace and value, inclusive education through co-operation in discussions.</p> <p>Through group discussions, each student develops critical thinking skills.</p> <p>Communication, numeracy, critical thinking, cooperation, creativity are developed through performing tasks.</p>
<p>Conclusion</p> <p>10 min</p>	<p>Summary</p> <p>correct, conclude and then generalize with the real life</p> <p>Assessment</p> <p>Verify using different methods the level of attainment of the learning outcomes</p>	<p>Correct their reports</p> <p>Apply the new concepts to answer questions and different tasks related to sound production:</p> <p>1) Explain how the sound is produced</p> <p>2) Suggest 2 other stringed instruments that can produce sound.</p> <p>Suggested answer</p> <p>The source of any sound is vibrating object. Almost any object can vibrate and hence be a source of sound. In musical instruments, the source is set into vibration by striking, plucking, bowing, or blowing. Standing waves are produced and the source vibrates at its natural resonant frequencies.</p>	<p>Critical thinking, analysis</p>

		The most widely used instruments that produce sound wave make use of vibrating strings, such as the violin, guitar, and piano or make use of vibrating columns of air, such as the flute, trumpet, and pipe organ. They are called wind instruments.	
Teacher self-evaluation			

## 1.1 Key Unit Competence

By the end of the unit, learners should be able to analyze the effects of sound waves in an elastic medium.

## 1.2 Prerequisite knowledge and skills

The success of this unit relies partly on the mastery of knowledge, skills acquired in Physics and other subjects in previous grades or unit as indicated below.

Propagation of mechanical waves (Unit 4, S.5)

Simple harmonic motion (unit 2, S.5)

## 1.3 Cross-Cutting Issues to be addressed

Inclusive education (promote education for all while teaching). Regardless of physical appearance and abilities learners should all be treated equally. This makes the learners to find out that they are all of great importance.

Peace and value Education (respect others view and thoughts during class discussions). Remember that someone's idea is very important. It may be correct or Not but what is important is to build on that Idea.

Gender (equal opportunity of boys and girls in the lesson participation). Care should be taken that both Sexes are given equal opportunities.

## 1.4 Guidance on the introductory activity

This activity aims at capturing students' attention and minds towards this concept

- Divide your students into groups (Grouping may depend on the nature of your class or number of learners you have).
- Tell the learners to open the introductory activity in the learner's book.
- Instruct learners to re-write the questions and answer them following the instructions from learner's book.
- While students are doing this activity, you move around and mark their work.
- When everyone is done and you are done, invite some member(s) or group(s) to discuss their findings to the whole class.
- Ask other members whether their answers correspond to the discussed points and if there is any point that is different from what have been raised to mention it. You can talk about those points (in a discussion together with other students)
- Together with students harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks
- Linking to the summary and what have discussed in class, emphasize on the difference between music and noise. You can take some minutes and explain them.
- Summarize your lesson by linking this concept to real life situations like in singing, designing musical instruments, designing musical halls etc

### Possible answers of the introductory activity.

1. Audible sounds are classified into two groups, namely musical sounds and noise. A musical sound is that in which the vibrations of the sounding body are periodic, follow each other regularly and rapidly, so as to produce a pleasing effect on the ear without any sudden change in loudness.

Noise is defined as unwanted disturbances superposed on a useful signal that tend to obscure its information content. Noise is not the same as signal distortion caused by a circuit. Noise may be electromagnetically or thermally generated, which can be decreased by lowering the operating temperature of the circuit.

When you sing or talk, you send out sound waves with all kinds of frequencies. These sound waves mix together. How they mix makes music or noise.

A chorus or choir sings in parts. The sounds of the parts mix well together. This kind of mixing is called harmony. Harmony makes the beautiful sounds of music.

Honking horns and the motors of cars, buses, and trucks send out sound waves that do not mix well together. That is why traffic on a busy street makes awful-sounding noise. Loud noise can cause loss of hearing; rock musicians can also suffer hearing loss.

## 1.5 list of lessons

S/No	Lesson Tittle	Learning Objectives (Adapted from syllabus)  By the end of the Lesson(s) Learners should be able to:	Suggested Number of Periods
1	Introductory activity and Characteristics and properties of sound waves	<ul style="list-style-type: none"> <li>Analyze relate sound and music</li> <li>Analyze different characteristics of sound waves and how they are applicable in real life</li> </ul>	5
2	Production of stationary sound waves	<ul style="list-style-type: none"> <li>Produce sound waves using locally available materials</li> </ul>	6
3	Characteristics of musical notes	<ul style="list-style-type: none"> <li>Explain characteristics of musical notes</li> </ul>	2
4	Applications of sound waves	<ul style="list-style-type: none"> <li>Explain doppler effect in sound waves</li> <li>Applications of doppler effect in communication.</li> </ul>	4
5	End Unit Assessment		4

## Lesson 1.1: characteristics of sound waves

### a) Prerequisites/Revision/Introduction:

Through guided discovery, assist learners to describe all the characteristics of sound waves. You can make a recap using Propagation of mechanical waves (Unit 4 S.5).

You can ask them questions like, why is not possible to hear someone that is far away from you? etc

### b) Teaching resources: Textbooks,

### c) Learning Activities:

#### Activity 1.1

This activity aims at capturing students' attention and minds towards this concept

- Divide your students into groups Tell the learners to open the activity 1.1 in the learner's book.
- Instruct learners to read the scenario in the activity 1.1 in the learners book and explain by writing in their notebooks all the underlined words
- While students are doing this activity, you move around and mark their work.
- When everyone is done and you are done, invite some member(s) or group(s) to discuss their findings to the whole class.
- Inquire from other students or groups whether their answers correspond to the ones discussed
- Together with students harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks
- Linking to the summary and what have been discussed in class, take a step and explain intensively transmission of sound in different media and reflection of sound at boundary.
- Link this lesson to real life like reflection of waves in string of a guitar when plucked.

#### Activity 1.2

- Remember the essence of this activity is to master and apply what they have already acquired from the previous activity 1.1
- Assign this activity as homework/exercise/ group work/ Assignment or any depending on what you want to achieve.

- Make sure you mark the activity when students are done with the work.
- Give them feedback and invite some members to discuss their findings to the whole class.
- Together with other students harmonize and make a summary and tell your students to write down key points in their notebooks.
- Linking to the summary and what have been discussed in class, take time and explain frequency range .ie. (20 Hz-20 kHz). You can use notes in student's book. You can explain why a dog is able to detect someone tiptoeing.
- Explain also comprehensively fundamental wave equation ( $V = \lambda f$ ), speed of sound in various media and their equations

## Expected answers

### Activity 1.1: Properties of sound waves

This activity is for about the review on waves and sound wave properties as seen in senior 5. For more information about sound waves properties we can see on additional information.

### Activity 1.2 Characteristics of sound

1. We may know wavelength and frequency
2. We may know power and area

#### d. Expected answer for 1.1.3 Checking my progress

1. B
2. D
3. D
4. (A) The speed of sound is not constant, but depends upon the temperature of the air. When it is hotter, the speed of sound is greater, so it takes less time for the echo to return.
5. B
6. We can only make a rough estimate because a spider's web is fairly complicated and many vibrate with a mixture of frequencies. We use SHM as an approximate model.

a) The frequency of SHM is given by:

$$f = \frac{1}{2\pi} \sqrt{\frac{k}{m}} \Leftrightarrow k = (2\pi f)^2 m = (30\pi)^2 (3.0 \times 10^{-4}) = 2.7 \text{ N/m}$$

b) The total mass is now  $0.10 \text{ g} + 0.30 \text{ g} = 0.4 \text{ g}$ . We could substitute

$m = 4.0 \times 10^{-4} \text{ kg}$  into

$$f = \frac{1}{2\pi} \sqrt{\frac{k}{m}} = 13 \text{ Hz}$$

## LESSON 1.2: Production of Sound waves

### a) Prerequisites/Revision/Introduction

Linking this lesson to the previous one, ask learners how sound can be produced.

b) **Teaching resources:** Textbooks, and guitar if you can access it.

### c) Learning Activities

#### Activity 1.3

This activity aims at making students how sound can be produced

- Put your students in groups.
- Instruct learners to read the questions and relate them to Fig 1.3
- Tell the students to attempt the questions in their notebooks.
- As students are doing this activity, you move around and mark their work.
- When everyone is done and you are done, invite some member(s) or group(s) to discuss their findings to the whole class.
- Inquire from other students or groups whether their answers correspond to the ones discussed
- Together with students harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks
- Using students work, explain harmonics in pipes,
- Link this lesson to real life like rhythm heard after drumming.

### Expected answers

#### Activity 1.3: Production of stationary sound waves

As student progress in this section he/she discover the answer

## b) Expected answer for quick check

1.1 An open end is a displacement antinode and a closed end is a displacement node. The placement of the displacement nodes and antinodes along the pipe is as sketched in Fig.1.1. The open ends are displacement antinodes

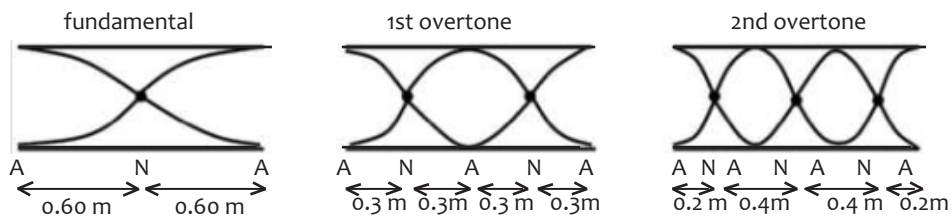


Fig.1. 1 Standing waves produced by open pipe at both ends

Location of the displacement nodes (N) measured from the left end:

- fundamental 0.60 m
- 1<sup>st</sup> overtone 0.30 m, 0.90 m
- 2<sup>nd</sup> overtone 0.20 m, 0.60 m, 1.00 m

Location of the pressure nodes (displacement antinodes measured from the left end:

- fundamental 0, 1.20 m
- 1<sup>st</sup> overtone 0, 0.60 m, 1.20 m
- 2<sup>nd</sup> overtone 0, 0.40 m, 0.80 m, 1.20 m

1.2 The open end is a displacement antinode and the closed end is a displacement node. The placement of the displacement nodes and antinodes along the pipe is sketched in Fig.1.2.

Location of the displacement nodes (N) measured from the closed end:

- fundamental 0
- 1<sup>st</sup> overtone 0, 0.80 m
- 2<sup>nd</sup> overtone 0, 0.48 m, 0.96 m

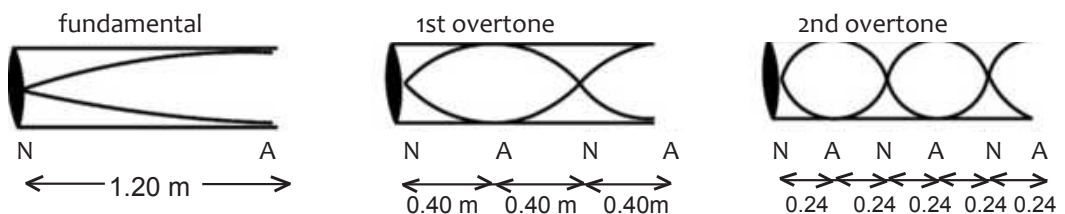


Fig.1. 2 Standing waves produced by pipe open at one end and closed at the other end

Location of the pressure nodes (displacement antinodes (A)) measured from the closed end:

- Fundamental 1.20 m
- 1st overtone 0.40 m, 1.20 m
- 2<sup>nd</sup> overtone 0.24 m, 0.72 m, 1.20 m.

1.3 a) Knowing that the frequencies of higher harmonics are integer multiples of the fundamental frequency  $f = 262 \text{ Hz}$ , we find that  $f_1 = 262 \text{ Hz}$

$$f_1 = 2f_1 = 2 \times 262 = 532 \text{ Hz} \text{ and } f_3 = 3f_1 = 3 \times 262 = 786 \text{ Hz}$$

b) Using Equation 54.44 for the two strings vibrating at their fundamental frequencies

$$f_{1A} = \frac{1}{2L} \sqrt{\frac{T_A}{\mu}} \text{ and } f_{1C} = \frac{1}{2L} \sqrt{\frac{T_C}{\mu}}$$

Setting up the ratio of these frequencies, we find that

$$\frac{T_A}{T_C} = \left(\frac{f_{1A}}{f_{1C}}\right)^2 = \left(\frac{440}{262}\right)^2 = 2.82$$

c) Using Equation 54.44 again, we set up the ratio of frequencies:

$$\frac{f_{1A}}{f_{1C}} = \frac{L_C}{L_A} \sqrt{\frac{T_A}{T_C}} \Leftrightarrow \frac{T_A}{T_C} = \left(\frac{f_{1A} L_A}{f_{1C} L_C}\right)^2 = 1.16$$

1.4. For beats to occur, the string must vibrate at a frequency different from  $400 \text{ Hz}$  by whatever the beat frequency is.

$$\text{The beat frequency is } f_b = \frac{20}{5} = 4 \text{ Hz}$$

This is the difference of the frequencies of the two waves. Because one wave is known to be  $400 \text{ Hz}$ , the other must be either  $404 \text{ Hz}$  or  $396 \text{ Hz}$ .

### Expected answers for 1.2.4 Check my progress

$$1. \text{ In a tube with two open ends } f = \frac{v}{L}; \lambda = \frac{v}{f} = 2L$$

$$\text{In a tube with one open end and one closed end } f_1 = \frac{v}{4L} \Rightarrow \lambda = \frac{v}{f} = 4L$$

The wavelength of the fundamental standing wave in a tube open at both ends is less than the wavelength of the fundamental standing wave in a tube with one open end and one closed end.

2. The bottle is a tube with one open end and one closed end. We need  $\lambda = 4L$ . The wavelength of middle C is 1.29 m. Therefore  $L = 32.25 \text{ cm}$

3. To get destructive interference the difference between the distances to the loudspeakers should be  $n\lambda/2$ ,  $n = 1, 3, 5, \dots$ . There will be destructive interference at

$\lambda/2$ , at  $3\lambda/2$  and at  $5\lambda/2$ .

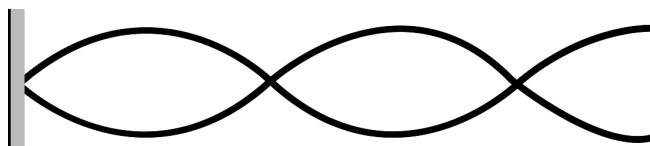
As the difference in distance is  $3.5 \text{ m} - 3.0 \text{ m} = 0.5 \text{ m}$ , then for destructive interference  $\lambda = 1.0$  and  $f_1 = \frac{v}{\lambda} = \frac{343}{1.0} = 343 \text{ Hz}$

The wavelength of the next frequency that also produces destructive interference is obtained doing

$$3\lambda/2 = 0.5 \text{ m} \text{ or } \lambda = 1/3 \text{ m} \text{ and then } f_2 = \frac{v}{\lambda} = \frac{343}{1/3} = 1029 \text{ Hz}$$

Similarly, doing  $5\lambda/2 = 0.5 \text{ m}$  or  $\lambda = 1/5 \text{ m}$  we get  $f_3 = 1715 \text{ Hz}$

4. To use a slinky to create a longitudinal wave, pull a few coils back and release. For a transverse wave, jostle the end coil side to side.
5. The speed of a wave on a “massless” string would be infinite!
6. First, you need to be able to draw the harmonics of one end fixed, one end open. The second harmonic looks like this:



Set up a number sentence:  $53.2 \text{ cm} = 3/4 \lambda$  therefore  $\lambda = 1.76 \text{ cm} = 0.176 \text{ m}$

The frequency  $f = \frac{v}{\lambda} = \frac{317}{0.176} = 1.80 \times 10^3 \text{ Hz}$

a) Set up a number sentence:  $45 \text{ cm} = \frac{5}{4} \lambda \Rightarrow \lambda = 36 \text{ cm}$

b) Set up a number sentence:  $2.67 \text{ m} = \frac{4}{4} \lambda \Rightarrow \lambda = 2.67 \text{ m}$

c) Set up a number sentence:  $68 \text{ cm} = \frac{2}{4} \lambda \Rightarrow \lambda = 136 \text{ cm}$

7. We know the total string length must be half of the fundamental wave length

$$L_1 = \frac{\lambda_1}{2} \Leftrightarrow \lambda_1 = 2L_1 = 2 \times 0.64 = 1.28 \text{ m}$$

The sound propagation velocity in this string is then  $v = \lambda_1 f_1 = 1.28 \times 330 = 420 \text{ m/s}$ .

When pressing the string, the string tension do not varies, and the propagation velocity  $v$  is also  $L_2 = \frac{\lambda_2}{2} = \frac{v}{2f_2} = \frac{422}{2 \times 350} = 0.603 \text{ m}$

The new string length  $L_2$  is obtained using .

The difference  $64 \text{ cm} - 60.3 \text{ cm} = 3.7 \text{ cm}$  is the distance from the first fret to the nut.

8. As the pulse moves down the string, the particles of the string itself move side to side. Since the medium—here, the string—moves perpendicular to the direction of wave propagation, the wave is transverse by definition.
9. The relation between string tension  $T$ , mass  $m$ , length  $L$  and string wave velocity

$$v \text{ is } v = \sqrt{\frac{T}{\mu}} \Leftrightarrow T = \frac{m}{L} v^2$$

In this case the string mass per unit length  $\mu = \frac{m}{L} = \frac{3.6 \times 10^{-3} \text{ kg}}{0.9 \text{ m}} = 4 \times 10^{-3} \text{ kg/m}$  .

Replacing  $T = 520 \text{ N}$  and  $\mu = 4 \times 10^{-3} \text{ kg/m}$  , we get  $v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{520}{4 \times 10^{-3}}} = 361 \text{ m/s}$  .

The wavelength associated to the fundamental frequency is:  $\lambda = 2L = 2 \times 0.6 = 1.2 \text{ m}$

The fundamental frequency is then  $f = \frac{v}{\lambda} = \frac{361}{1.2} = 301 \text{ Hz}$

The first and second overtones are respectively 602 Hz and 903 Hz.

### Lesson 1.3: Characteristics of musical notes

#### a) Prerequisites/Revision/Introduction

Connecting this lesson to the previous one, ask learners to explain different sounds we receive depending on their energy and how far a receiver is from the source

**b) Teaching resources:** Textbooks, whistle, drum and other musical instruments

#### c) Learning Activities

##### Activity 1.5

This activity major focuses on production of on characteristics of musical notes.

- Make groups (or you can vary the method depending on the type of your class)
- Instruct learners to READ INSTRUCTIONS CAREFULLY brainstorm the questions and then write them in their notebooks and then attempt the questions.

- Invite some group(s) to present their findings to the whole class and allow others to give their points in case they are different from what have been discussed.
- Together with learners make a summary (use student's work/findings)
- Linking to the summary you made with students, explain intensity and its equation, pitch and timbre.
- Tell students that this is important in production of music and designing different musical instruments

## Expected answers

### Activity 1.5: Characteristics of musical notes

Student answers this activity as they read.

### Activity 1.6: Noise or music (see introductory activity on page 11)

Noise is defined as unwanted disturbances superposed on a useful signal that tend to obscure its information content. Noise is not the same as signal distortion caused by a circuit. Noise may be electromagnetically or thermally generated, which can be decreased by lowering the operating temperature of the circuit.

## Expected answers for 1.3.4 Characteristics of sounds

1. (a) intensity (b) echoes (c) sound quality
2. A stationary wave is set up between the source and wall, due to the production of reflected wave. The wall is a displacement node, since the air in contact with it cannot move; and other nodes are at equal distances,  $d$ , from the wall. So if wavelength is  $\lambda$ , the first distance  $d$  of the minimum amplitude position or node from the wall is:

$$d = \frac{\lambda}{2} = \frac{v_0}{2f} = \frac{3.43}{2 \times 100} = 1.7 \text{ m}$$

So minimum amplitude of vibration is obtained  $A_{\min} = nd$

The antinodes are midway between the nodes. So maximum amplitude of vibration is obtained:

$$A_{\max} = \frac{nd}{2} \text{ from the wall.}$$

3. Sound intensity  $I = \frac{P}{A} = \frac{0.5 \times 10^{-4}}{5} = 10^{-5} \text{ W / m}^2$
4. Intensity level  $\beta = 10 \log \frac{I}{I_0} = 10 \log \frac{10^{-5}}{10^{-12}} = 3$
5. a. False, density b. False, pitch c. True,

## Lesson 1.4: Application of sound waves

### a) Prerequisites/Revision/Introduction:

Students are well conversant the meaning of sound and characteristics! Ask them where do we use sound in real life. You can relate this lesson to previous ones like by using examples of guitar and drums.

### b) Teaching resources: Textbooks, internet.

### c) Learning Activities:

- Decide on the method to use in this lesson (You can use group work, individual or whole class)
- Tell learners to open their books to activity 1.7
- Instruct them to read the instructions of the questions and attempt the questions in this activity
- Call some student(s) or group(s) to present their findings to the whole class. Under your guidance explain key terms like doppler effect and derive its equation.
- Together with students, come up with a summary and note down major points to the board and allow learners to write some important concepts in their notebooks.
- To concretize your lesson, together with learners do examples 1.9 to 1.12 in the learners book (This will help you to assess the mastery and acquisition of concepts by learners).

## Expected answers

### Activity 1.7: Doppler Effect

Student can answer correctly after complete this section about Doppler Effect and Student can enumerate the uses of sound as describe in Student book in her/his own word

#### d. Quick check 1.5:

$$\text{From } v = \lambda f \Rightarrow \lambda = \frac{v}{f} \Rightarrow \lambda = \frac{340 \text{ m/s}}{264 \text{ /s}} = 1.29 \text{ m}$$

## Expected answers for 1.4.4 Applications of sound

1. C
2. A
3. Echolocation, echocardiography, communication, exploration for oil and minerals, Radar use sound at airports to track aircraft, sonar,
4. The sonar or pulse-echo technique is used to locate underwater objects. A transmitter sends out a sound pulse through the water, and a detector receives its reflection, or echo, a short time later. This time interval is carefully measured, and from it the distance to the reflecting object can be determined since the speed of sound in water is known. The depth of the sea and the location of reefs, sunken ships, submarines, or schools of fish can be determined in this way.
5. a) The Doppler Effect is the frequency change of a sound perceived by the observer due to the movement of the sound source and/or the movement of the observer. If the source and the observer approach each other the perceived frequency increases and if they move away the perceived frequency decreases.

The new frequency  $f_r$  detected by the observer is given by the formula

$$f_r = f_s \frac{c \pm v_0}{c \mp v_s}$$

## 1.6 Summary of the Unit

We can distinguish three aspects of any sound. First, there must be a source for a sound; as with any mechanical wave, the source of a sound wave is a vibrating object. Second, the energy is transferred from the source in the form of longitudinal sound waves in air or other material. And third, the sound is detected, usually by an ear or by a microphone.

Sound waves whose frequencies are less than 20 Hz are called **infrasonic** waves and sound waves whose frequencies are higher than 20000 Hz are called **ultrasonic** waves.

The highness or lowness of a sound is called its **pitch**. The higher the frequency, the higher is the pitch.

The intensity of sound is proportion to the square of amplitude. The higher the intensity, the louder is the sound.

The frequency of the beats is equal to the difference in the frequencies of the two sound waves:

$$\text{beat frequency} = \text{frequency of loud sound heard} = f_1 - f_2$$

The sound waves of your voice go out until they hit a wall or other surface. Then they bounce back toward you and make an echo. Bats use echoes when they fly around on dark nights

An open pipe is one which is open at both ends. The distance between consecutive antinode is  $\frac{\lambda}{2}$  i.e.  $L = \frac{\lambda}{2}$  .

The longest standing wave in a tube of length L with two open ends has displacement antinodes (pressure nodes) at both ends. It is called **the fundamental**.

The longest standing wave in a tube of length L with one open end and one closed end has a displacement antinode at the open end and a displacement node at the closed end. This is the fundamental:

$$L = \frac{\lambda}{4} \Leftrightarrow f = \frac{v}{4L}$$

a single Doppler effect equation that covers all cases of both source and observer in motion:

$$f_r = f_o \frac{v \pm v_o}{v \mp v_s}$$

## 1.7 Additional information: Properties of sound waves

### 1.7.1 Reflection of sound waves at boundary

#### Reflection on a fixed end

First consider an elastic rope securely attached to a pole on a lab bench while the other end is held in the hand in order to introduce pulses into the rope as shown in Fig.1.3. Because the right end of the rope is attached to a pole the last particle of the rope will be unable to move when a disturbance reaches it. This end of the rope is referred to as a **fixed end**.



Fig.1. 3 An elastic rope securely tied to a pole used to study the behavior of waves at a fixed end

If a pulse is introduced at the left end of the rope, it will travel through the rope towards the right end of the medium. This pulse is called the incident pulse since it is incident towards the boundary which in this case is the pole. .

When the incident pulse reaches the boundary, two things are observed:

- A portion of the energy carried by the pulse is reflected and move back towards the left end of the rope. The disturbance that returns to the left after bouncing off the pole is known as the reflected pulse.
- A portion of the energy carried by the pulse is transmitted to the pole, causing the pole to vibrate.

When one observes the reflected pulse off the fixed end, there are several notable observations. First the reflected pulse is inverted. That is, if an upward displaced pulse is incident towards a fixed end boundary, it will reflect and return as a downward displaced pulse.

Similarly, if a downward displaced pulse is incident towards a fixed end boundary, it will reflect and return as an upward displaced pulse.

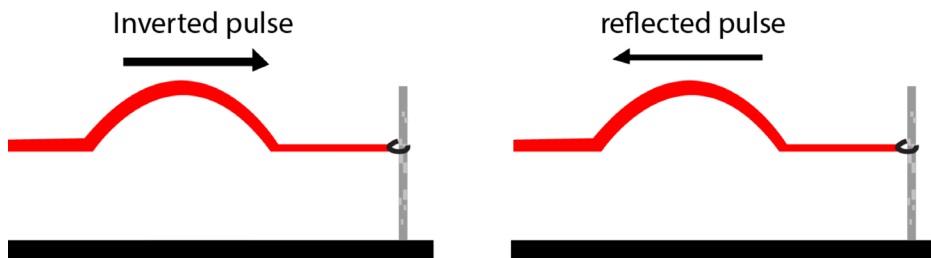


Fig.1. 4 Fixed end reflection

In general, **Reflection leaves wavelength, speed, amplitude and frequency unchanged**

## Reflection on Free End

Suppose a rope is attached to a ring that is loosely fit around the pole as in Fig.1.5. Because the right end of the rope is no longer secured to the pole, the last particle of the rope will be able to move when a disturbance reaches it. This end of the rope is referred to as a **free end**.



Fig.1. 5 An elastic rope that is not fastened to the pole used to study the behavior of a reflected wave at free end

An upward displaced pulse incident upon a free end returns as an upward displaced pulse after reflection and vice versa. Fig.1.5. shows that the inversion is not observed in free end reflection.

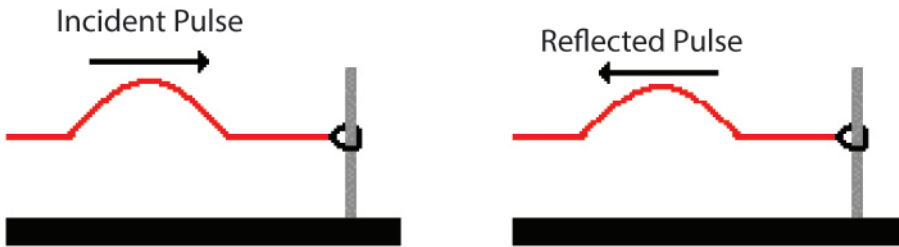


Fig.1.6 Reflection of waves on a free end

Depending on the distance between the two ends additional two phenomena are also observed. Those are **echo** and reverberation:

**Echo** occurs when a reflected sound wave reaches the ear 0.1 s after we hear the original sound. If the time that elaps between the arrivals of the two sound waves is more than 0.1 s, then the sensation of the first sound will have died out. An echo sounder or **fathometer** is a device using echos to estimate the depth of the sea.

In a small room the sound is also heard more than once, but the time differences are so small that the sound just seems to loom. This is known as reverberation.

### 1.7.2 Refraction and transmission of Sound Waves

Refraction of waves is the change in direction of waves as they pass from one medium to another. The bending of waves is accompanied by the change in speed and wavelength of the wave. So if there is any change in media, the wave speed changes. As an example the sound waves travel with less velocity in cool air than they do in the warmer air.

#### a)Transmission of a pulse across a boundary from less to more dense

Let's consider a thin rope attached to a thick rope, with each rope held at opposite ends by people as shown in Fig.1.6. And suppose that a pulse is introduced by the person holding the end of the thin rope. If this is the case, there will be an incident pulse traveling in the less dense medium (the thin rope) towards the boundary with a more dense medium (the thick rope).

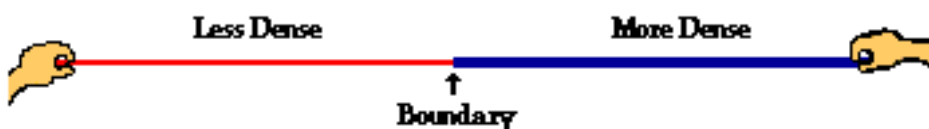


Fig.1.7 Transmission of a pulse across a boundary from less medium to denser medium

Upon reaching the boundary, the usual two behaviors will occur.

- A portion of the energy carried by the incident pulse is reflected and returns towards the left end of the thin rope. The disturbance that returns to the left after bouncing off the boundary is known as the reflected pulse.
- A portion of the energy carried by the incident pulse is transmitted into the thick rope. The disturbance that continues moving to the right is known as the transmitted pulse. The transmitted pulse is not inverted but reflected pulse is inverted as shown in Fig.1.8.

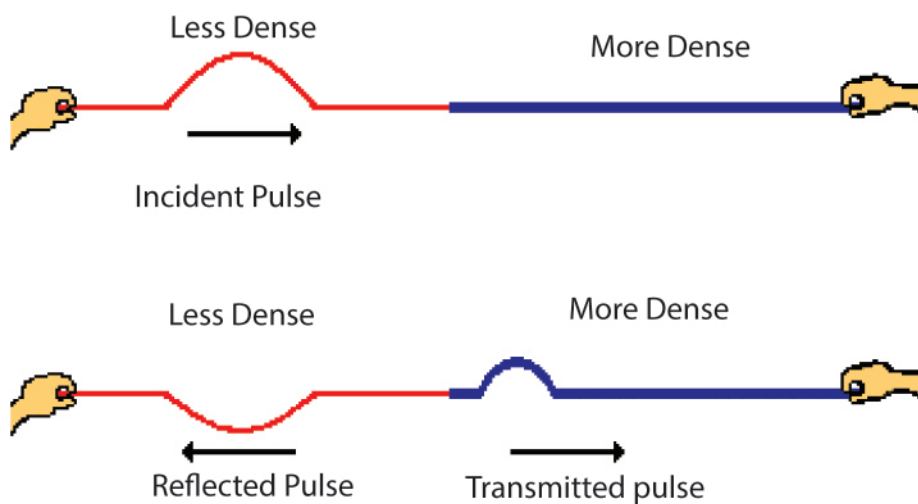


Fig.1. 8 A wave travelling from a less dense to a more dense medium will be reflected off the boundary and transmitted across the boundary into the new medium. The reflected pulse is inverted

### Example 1.1 Transmission of a pulse across a boundary from less to more dense

1. A pulse in a more dense medium is traveling towards the boundary with a less dense medium as shown in Fig.1.8 copy and complete

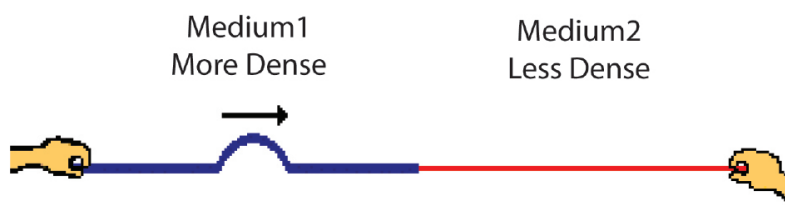


Fig.1. 9 Transmission of a pulse across a boundary from less to more dense

1. The reflected pulse in medium 1 \_\_\_\_\_ (will, will not) be inverted because \_\_\_\_\_.
2. The speed of the transmitted pulse will be \_\_\_\_\_ (greater than, less than, the same as) the speed of the incident pulse.
3. The speed of the reflected pulse will be \_\_\_\_\_ (greater than, less than, the same as) the speed of the incident pulse.

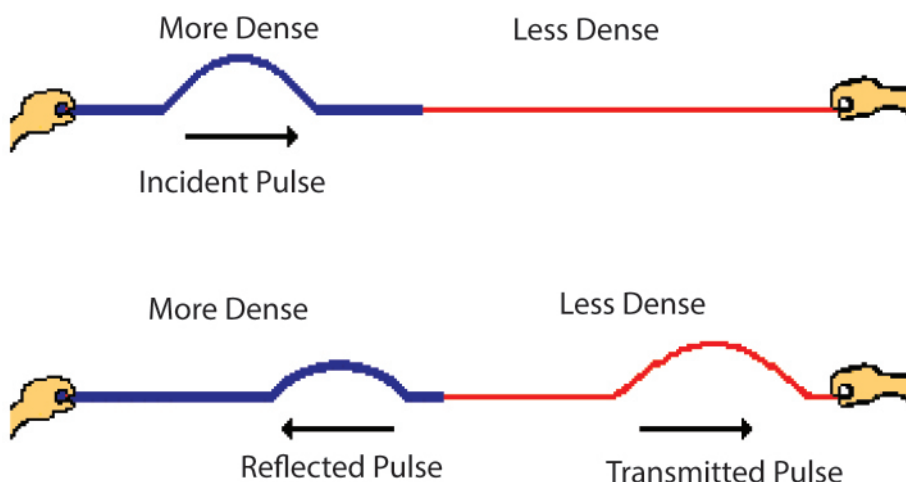
4. The wavelength of the transmitted pulse will be \_\_\_\_\_ (greater than, less than, the same as) the wavelength of the incident pulse.
5. The frequency of the transmitted pulse will be \_\_\_\_\_ (greater than, less than, the same as) the frequency of the incident pulse.

### Answer

1. will not...
2. Faster
3. the same as
4. greater than
5. the same as

### b)Transmission of a pulse across a boundary from more to less dense

Let's consider a thick rope attached to a thin rope, with the incident pulse originating in the thick rope as in Fig.1.9. If this is the case, there will be an incident pulse traveling in the more dense medium (thick rope) towards the boundary with a less dense medium (thin rope).



*Fig.1. 10 A wave travelling from a more dense to a less dense medium will be reflected off the boundary and transmitted across the boundary into new medium. There is no inversion*

Once again there will be partial reflection and partial transmission at the boundary. The reflected pulse in this situation will not be inverted. Similarly, the transmitted pulse is not inverted (as is always the case). Since the incident pulse is in a heavier medium, when it reaches the boundary, the first particle of the less dense medium does not have sufficient mass to overpower the last particle of the more dense medium.

## b) Snell's law and waves

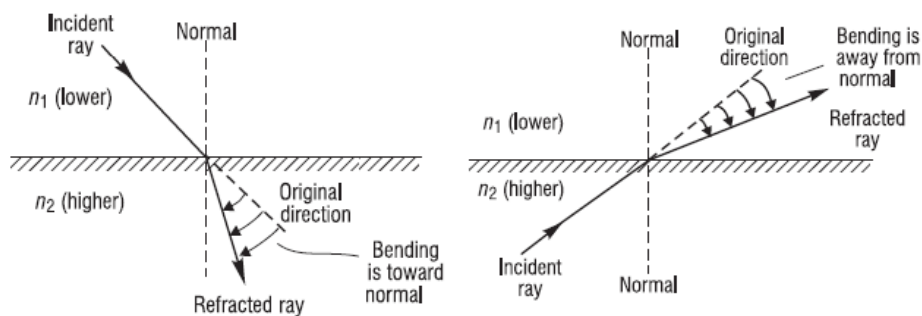


Fig.1. 11 Refraction of light at the interface between two media of different refractive indices, with  $n_2 > n_1$

When a wave travels from denser medium to less dense medium in such a way that it meets the boundary between the two depths straight on, no change in direction occurs. On the other hand, if a wave meets the boundary at an angle, the direction of travel does change. This phenomenon is called refraction

Since the velocity is lower in the second medium ( $v_2 < v_1$ ), the angle of refraction  $\theta_2$  is less than the angle of incidence  $\theta_1$ ; that is, the ray in the higher-index medium is closer to the normal.

Snell's law (also known as Snell–Descartes law and the law of refraction) is a formula used to describe the relationship between the angles of incidence and refraction, when referring to light or other waves passing through a boundary between two different isotropic media, such as water, glass, or air.

Snell's law states that the ratio of the sines of the angles of incidence and refraction is equivalent to the ratio of phase velocities in the two media, or equivalent to the reciprocal of the ratio of the indices of refraction:

$$\frac{\sin \theta_1}{\sin \theta_2} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} \quad (1.01)$$

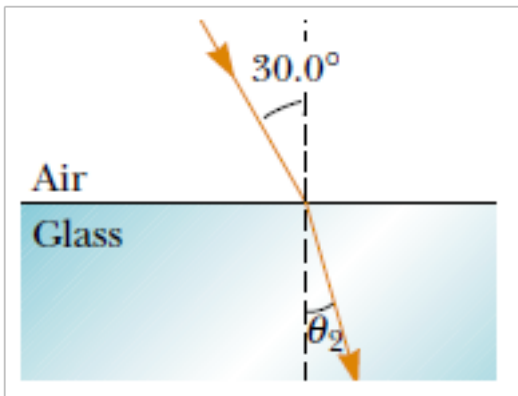
with each  $\theta$  as the angle measured from the normal of the boundary,  $v$  as the velocity of light in the respective medium (SI units are meters per second, or m/s),  $\lambda$  as the wavelength of light in the respective medium

Comparisons between the characteristics of the transmitted pulse and the reflected pulse lead to the following observations.

- The transmitted pulse (in the less dense medium) is traveling faster than the reflected pulse (in the more dense medium).
- The transmitted pulse (in the less dense medium) has a larger wavelength than the reflected pulse (in the more dense medium).
- The speed and the wavelength of the reflected pulse are the same as the speed and the wavelength of the incident pulse.

## Example 1.2: Determine the angle of refraction

1. Incident on a smooth, flat slab of crown glass ( $n = 1.52$ ) at an angle of  $30.0^\circ$  to the normal, as sketched in Figure at right. Find the angle of refraction.



### Answer

We rearrange Snell's law of refraction to obtain

$$\sin \theta_2 = \frac{n_1}{n_2} \sin \theta_1 \Leftrightarrow \sin \theta_2 = \frac{\sin 30.0}{1.52} = 0.329 \Leftrightarrow \theta_2 = 19.2^\circ$$

Because this is less than the incident angle of  $30^\circ$ , the refracted ray is bent toward the normal, as expected. Its change in direction is called the angle of deviation and is given by

$$\sigma = \theta_1 - \theta_2 = 30.0 - 19.2 = 10.8^\circ$$

### 1.7.3 Checking my progress

1. How is a wave changed by reflection?
2. What causes refraction when a wave enters a medium at an angle
3. What is the amplitude of the wave that results when two identical waves interfere constructively?
4. A pulse in a less dense medium is traveling towards the boundary with a more dense medium as shown in Fig.1.10 copy and complete.

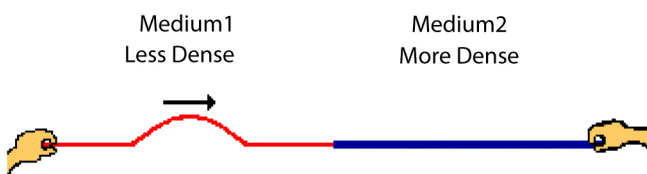


Fig.1.12 Transmission from less dense medium to dense medium

1. The reflected pulse in medium 1 \_\_\_\_\_ (will, will not) be inverted.
2. The speed of the transmitted pulse will be \_\_\_\_\_ (greater than, less than, the same as) the speed of the incident pulse.
3. The speed of the reflected pulse will be \_\_\_\_\_ (greater than, less than, the same as) the speed of the incident pulse.
4. The wavelength of the transmitted pulse will be \_\_\_\_\_ (greater than, less than, the same as) the wavelength of the incident pulse.
5. The frequency of the transmitted pulse will be \_\_\_\_\_ (greater than, less than, the same as) the frequency of the incident pulse.

### Suggested answer

1. In general, Reflection leaves wavelength, speed, amplitude and frequency unchanged but the wave can be flipped upside down.
2. When a wave enters a medium at an angle, refraction occurs because one side of the wave moves more slowly than the other side
3. The amplitude of resulted two combined waves add together to produce a wave with a double amplitude
4. 1. will... 2. less than 3. the same as 4. less than 5. the same as

## 1.8 End Unit Assessment

1. B
2. A
3. B)A node is a point along a standing wave where the wave has minimum or zero amplitude
4. D)Sound waves are longitudinal waves, so (a) is incorrect. The sound waves can be characterized either by the longitudinal displacement of the air molecules or by the pressure differences that cause the displacements.
5. E)In a string or open tube the lowest vibration mode is equal to half of a wavelength. In a tube closed at one end the lowest vibration mode is equal to a quarter of a wavelength. Therefore, none of the listed objects have a lowest vibration mode equal to a wavelength.
6. (C) The frequency is the number of wave crests that pass a certain point per unit time. If this value were to change as it entered the water, then wave crests would build up or be depleted over time. This would make the interface an energy source or sink, which it is not. The speed of sound in water is greater than in air, so the speed of the wave changes. Since the frequency cannot change, the increase in speed results in an increase in wavelength.

7. No. Waves with other waveforms are also trains of disturbance that add together when waves from different sources move through the same medium at the same time.
8. The energy has not disappeared, but is still carried by the wave pulses. Each particle of the string still has kinetic energy. This is similar to the motion of a simple pendulum. The pendulum does not stop at its equilibrium position during oscillation—likewise the particles of the string do not stop at the equilibrium position of the string when these two waves superimpose.
9. No. A wave is not a solid object, but a chain of disturbance. As described by the principle of superposition, the waves move through each other.
10. They can, wherever the two waves are nearly enough in phase that their displacements will add to create a total displacement greater than the amplitude of either of the two original waves. When two one-dimensional sinusoidal waves of the same amplitude interfere, this condition is satisfied whenever the absolute value of the phase difference between the two waves is less than  $120^\circ$ .
11. No. The total energy of the pair of waves remains the same. Energy missing from zones of destructive interference appears in zones of constructive interference.
12. The air in the shower stall can vibrate in standing wave patterns to intensify those frequencies in your voice which correspond to its free vibrations. The hard walls of the bathroom reflect sound very well to make your voice more intense at all frequencies, giving the room a longer reverberation time. The reverberant sound may help you to stay on key.
13. Beats. The propellers are rotating at slightly different frequencies.
14. What is needed is a tuning fork—or other pure-tone generator—of the desired frequency. Strike the tuning fork and pluck the corresponding string on the piano at the same time. If they are precisely in tune, you will hear a single pitch with no amplitude modulation. If the two pitches are a bit off, you will hear beats. As they vibrate, retune the piano string until the beat frequency goes to zero.
15. A. frequency

## **B. an open tube (open at both ends)**

### **C. Closed tube (closed at one end)**

### **D. The Doppler effect, higher, lower.**

16. Use the Doppler formula, and remember that the bat is a moving source. If the velocity of the insect is  $v_s = 5.00 \text{ m/s}$ ,  $f_s = 40.0 \times 10^3 \text{ Hz}$ ,  $f_r = 40.0 \times 10^3 \text{ kHz}$  and  $v = 340 \text{ m/s}$ . The bat move toward the insect which is moving away the bat:
- $$f_r' = f_s \frac{v - v_0}{v - v_s}$$

The insect reflect the sound received:  $f_r = f_r' \frac{v + v_s}{v + v_0}$

We get  $f_r = f_s \left( \frac{v - v_0}{v - v_s} \right) \left( \frac{v + v_s}{v + v_0} \right) \Leftrightarrow v_0 = 3.31 \text{ m/s}$

Therefore the bat is gaining on its prey at 1.69 m/s

17. Use moving source  $f_r = f_s \frac{v}{v + v_s} \Leftrightarrow 225 = 216 \frac{343}{343 - v_s} \Leftrightarrow v_s = 13.7 \text{ m/s}$

Since the frequency is higher (225 vs 216) you know that the velocity is toward, so you set it up with a - sign in the denominator, but it really doesn't matter if you guess this wrong - you'll just get a minus sign in your answer and then ignore it.

18. Use  $f_r = f_s \frac{v + v_o}{v} = 518 \frac{343 + 12.5}{343} = 537 \text{ Hz}$  moving observer

Since you are moving toward, you want a higher frequency, so you would use a + in the numerator.

19. Use  $f_r = f_s \frac{v + v_o}{v} \Leftrightarrow 557 = 518 \frac{343 + v_o}{343} \Leftrightarrow v_o = 25.8 \text{ m/s}$  moving observer

Since the frequency is higher, you must be moving toward - so you would set it up with a + in the numerator - but it really doesn't matter if you guess this wrong - you'll just get a minus sign in your answer and then ignore it.

## 20. Regulations are needed to reduce noise pollution from large ships

Whales use their songs in ways that affect their survival-eating, mating, and avoiding predators. Studies often focus on the effects of noise from a single ship, but in routes taken by ocean freighters, noise from many ships combines to produce a higher volume. Ocean freighters often travel near whale migration routes, so even noise that affects whales at a distance of 20 km may have an impact on whale survival. If regulations are delayed until research can prove that noise pollution affects whales, it may be too late to help the whales. Many kinds of whales are on the endangered species list, so it is important to err on the side of safety.

## Regulations are not needed to reduce noise pollution from large ships

Whale songs can be lengthy and are often repeated, so the effect of noise from ships is limited because ships quickly move out of an area. One study showed that whales changed the rhythm and tempo of their songs in response to noise from large ships, but there was no evidence that the communication was less effective. Also, it is expensive to modify ship propellers to reduce low-frequency noise. If less-developed countries cannot afford to modify ships, regulations will not be effective in reducing ocean noise levels.

## 1.9 Additional activities

### (Remedial activities, Consolidation activities, extended activities)

1. Choose the best answer: A guitar player shortens the length of a guitar's vibrating string by pressing the string straight down onto a fret. The guitar then

emits a higher-pitched note, because the string's tension has been dramatically increased. The string can vibrate with a much larger amplitude. The string vibrates at a higher frequency.

2. Choose the best answer: An organ pipe with a fundamental frequency  $f$  is open at both ends. If one end is closed off, the fundamental frequency will

a) **Drop by half.**

b) **Not change.**

c) **Double.**

3. To keep animals away from their cars, some people mount short, thin pipes on the fenders. The pipes give out a high pitched wail when the cars are moving. How do they create the sound?
4. When the base of a vibrating tuning fork is placed against a chalkboard, the sound that it emits becomes louder. This is because the vibrations of the tuning fork are transmitted to the chalkboard. Because it has a larger area than the tuning fork, the vibrating chalkboard sets more air into vibration. Thus, the chalkboard is a better radiator of sound than the tuning fork. How does this affect the length of time during which the fork vibrates? Does this agree with the principle of conservation of energy?
5. If you stretch a rubber hose and pluck it, you can observe a pulse traveling up and down the hose. What happens to the speed of the pulse if you stretch the hose more tightly? What happens to the speed if you fill the hose with water?
6. If you wet your finger and lightly run it around the rim of a fine wineglass, a high-frequency sound is heard. Why? How could you produce various musical notes with a set of wineglasses, each of which contains a different amount of water?
7. You have a standard tuning fork whose frequency is 262 Hz and a second tuning fork with an unknown frequency. When you tap both of them on the heel of one of your sneakers, you hear beats with a frequency of 4 per second. Thoughtfully chewing your gum, you wonder whether the unknown frequency is 258 Hz or 266 Hz. How can you decide?
8. Consider a wave traveling on a taut rope. What is the difference, if any, between the speed of the wave and the speed of a small segment of the rope?
9. When all the strings on a guitar are stretched to the same tension, will the speed of a wave along the most massive bass string be faster, slower, or the same as the speed of a wave on the lighter strings?
10. If a long rope is hung from a ceiling and waves are sent up the rope from its lower end, they do not ascend with constant speed. Explain.
11. If one end of a heavy rope is attached to one end of a light rope, the speed of a wave will change as the wave goes from the heavy rope to the light one. Will it increase or decrease? What happens to the frequency? To the wavelength?
12. Children sometimes play with a homemade telephone by attaching a string to the bottoms of two paper cups. When the string is stretched and a child speaks

into one cup, the sound can be heard at the other cup. Explain clearly how the sound wave travels from one cup to the other.



13. Dolphins use sound waves to locate food. Experiments have shown that a dolphin can detect a 7.5 cm target 110 m away, even in murky water. For a bit of “dinner” at that distance, how much time passes between the moment the dolphin emits a sound pulse and the moment the dolphin hears its reflection and thereby detects the distant target?
14. By what factor would you have to multiply the tension in a stretched string in order to double the wave speed?
15. A guitar string has a length of 64.5 cm, and a fundamental frequency of 110 Hz.  
Draw the first three harmonics of vibration on the string below, and calculate the wavelength and frequency for each.  
What is the velocity of the waves on this string?  
If this string is fingered 51.5 from one end (it is shortened by that amount). What is the frequency of the fundamental now?
16. An organ pipe has two successive harmonics with frequencies 1372 and 1764 Hz.  
(a) Is this an open or a stopped pipe? Explain. (b) What two harmonics are these?  
(c) What is the length of the pipe?
17. The Human Voice. The human vocal tract is a pipe that extends about 17 cm from the lips to the vocal folds (also called “vocal cords”) near the middle of your throat. The vocal folds behave rather like the reed of a clarinet, and the vocal tract acts like a stopped pipe. Estimate the first three standing-wave frequencies of the vocal tract. Use (The answers are only an estimate, since the position of lips and tongue affects the motion of air in the vocal tract.)
18. You hear the sound of a hammer striking concrete 1.21 seconds sooner in the concrete than through the air. If the speed of sound through the air is 339 m/s, and the hammer is 724 m away, what is the speed of sound in the concrete?

### Suggested answers

1. C
2. C
3. Air blowing fast by a rim of the pipe creates a “shshshsh” sound called edge

tone noise, a mixture of all frequencies, as the air turbulently switches between flowing on one side of the edge and the other. The air column inside the pipe finds one or more of its resonance frequencies in the noise. The air column starts vibrating with large amplitude in a standing wave vibration mode. It radiates sound into the surrounding air (and also locks the flapping airstream at the edge to its own frequency, making the noise disappear after just a few cycles).

4. Instead of just radiating sound very softly into the surrounding air, the tuning fork makes the chalkboard vibrate. With its large area this stiff sounding board radiates sound into the air with higher power. So it drains away the fork's energy of vibration faster and the fork stops vibrating sooner. This process exemplifies conservation of energy, as the energy of vibration of the fork is transferred through the blackboard into energy of vibration of the air.
5. Higher tension makes wave speed higher. Greater linear density makes the wave move more slowly.
6. The difference between static and kinetic friction makes your finger alternately slip and stick as it slides over the glass. Your finger produces a noisy vibration, a mixture of different frequencies, like new sneakers on a gymnasium floor. The glass finds one of its resonance frequencies in the noise. The thin stiff wall of the cup starts vibrating with large amplitude in a standing wave vibration mode. A typical possibility is shown in Figure 18.17. It radiates sound into the surrounding air, and also can lock your squeaking finger to its own frequency, making the noise disappear after just a few cycles. Get a lot of different thin-walled glasses of fine crystal and try them out. Each will generally produce a different note. You can tune them by adding wine.
7. Stick a bit of chewing gum to one tine of the second fork. If the beat frequency is then faster than 4 beats per second, the second has a lower frequency than the standard fork. If the beats have slowed down, the second fork has a higher frequency than the standard. Remove the gum, clean the fork, add or subtract 4 Hz according to what you found, and your answer will be the frequency of the second fork.
8. The section of rope moves up and down in SHM. Its speed is always changing. The wave continues on with constant speed in one direction, setting further sections of the rope into up-and-down motion.
9. Slower. Wave speed is inversely proportional to the square root of linear density.
10. Each element of the rope must support the weight of the rope below it. The tension increases with height. (It increases linearly, if the rope does not stretch.) Then the wave speed  $v = \sqrt{\frac{T}{\mu}}$  increases with height.
11. As the wave passes from the massive string to the less massive string, the wave speed will increase according to  $v = \sqrt{\frac{T}{\mu}}$ . The frequency will remain unchanged. Since  $v = f\lambda$ , the wavelength must increase.
12. The child speaking into a cup creates sound waves which cause the bottom of the cup to vibrate. Since the string is tightly attached to the bottom of the cup, the

vibrations of the cup are transmitted to longitudinal waves in the string. These longitudinal waves travel down the string, and cause the bottom of the receiver cup to vibrate. This relatively large vibrating surface moves the adjacent air, and generates sound waves from the bottom of the cup, traveling up into the cup.

These waves are incident on the receiver's ear, and they hear the sound from the speaker.



Fig.1.1 These children are talking over a cup-and-string “telephone.”

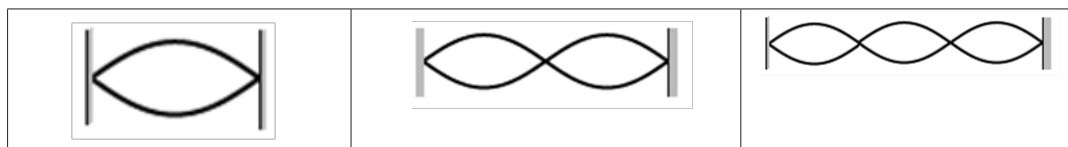
13. The total distance covered by the sound wave as it travels from dolphin to target and back is  $\Delta S = 2 \times 110 \text{ m} = 220 \text{ m}$

From equation  $v = \frac{\Delta S}{\Delta t}$ , we have, for  $25^\circ\text{C}$  water  $\Delta t = \frac{\Delta S}{v_x} = \frac{220}{1533} = 0.14 \text{ s}$

14. From  $v = \frac{\Delta}{\Delta t}$ , we must increase the tension by a factor of 4.

15. a-c. A guitar string has a length of 64.5 cm, and a fundamental frequency of 110 Hz.

- a. The first three harmonics of vibration on the string, and calculate the wavelength and frequency for each.



<p>This is the fundamental - we know its frequency is 110 Hz, and that the string is 0.645 m long.</p> <p>Set up a number sentence:  <math>L = \frac{2}{4} \lambda \Leftrightarrow \lambda = 1.29 \text{ m}</math></p>	<p>Set up a number sentence:  <math>0.625 \text{ m} = \frac{4}{4} \lambda, \lambda = 0.625 \text{ m}</math></p> <p>For this type of standing wave, the second harmonic frequency is twice the fundamental  <math>f = 220 \text{ Hz}</math></p>	<p>Set up a number sentence:  <math>0.625 \text{ m} = \frac{6}{4} \lambda, \lambda = 0.430 \text{ m}</math></p> <p>For this type of standing wave, the third harmonic frequency is thrice the fundamental,  <math>f = 330 \text{ Hz}</math></p>
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b. Use  $f = 110 \times 1.29 = 141.9 = 142 \text{ m/s}$

c. The new length of the string is  $0.645 \text{ m} - 0.215 \text{ m} = 0.430 \text{ m}$

For the fundamental, set up a number sentence:  $0.430 \text{ m} = \frac{2}{4} \lambda$ , then  $\lambda = 0.860 \text{ m}$

The new frequency:  $f = \frac{v}{\lambda} = \frac{141.9}{0.860} = 165 \text{ Hz}$

16. The frequency of any harmonic is an integer multiple of the fundamental. For a stopped pipe only odd harmonics are present. For an open pipe, all harmonics are present. See which pattern of harmonics fits to the observed values in order to determine which type of pipe it is. Then solve for the fundamental frequency and relate that to the length of the pipe.

For an open pipe the successive harmonics are  $f_n = n f_o$  where  $n = 1, 2, 3,$

For a stopped pipe the successive harmonics are  $f_n = n f_o$  where  $n = 1, 3, 5, \dots$

If the pipe is open and these harmonics are successive, then  $f_n = n f_o = 1372 \text{ Hz}$  and  $f_{n+1} = (n+1) f_o = 1764 \text{ Hz}$

Subtract the first equation from the second:  $(n+1) f_o - n f_o = 1364 - 1372$

This gives  $f_o = 392 \text{ Hz}$ . Then  $n = \frac{1372}{392} = 3.5$ . But  $n$  must be an integer, so the pipe can't be open.

If the pipe is stopped and these harmonics are successive, then

$f_n = n f_o = 1372 \text{ Hz}$  and  $f_{n+2} = (n+2) f_o = 1764 \text{ Hz}$  (in this case successive harmonics differ in  $n$  by 2).

Subtracting one equation from the other gives  $2 f_o = 392 \text{ Hz}$  and  $f_o = 196 \text{ Hz}$ .

Then  $n = \frac{1372}{196} = 7$  so  $7 f_o = 1372 \text{ Hz}$  and  $9 f_o = 1764$ .

The solution gives integer  $n$  as it should; the pipe is stopped.

(b) From part (a) these are the 7th and 9th harmonics.

(c) From part (a)  $f_0 = 196 \text{ Hz}$  .

For a stopped pipe  $f_0 = \frac{v}{4L} \Leftrightarrow L = \frac{v}{4f_1} = \frac{344}{4 \times 196} = 0.439 \text{ m}$

Therefore ,the length of the pipe is 0.439 m

It is essential to know that these are successive harmonics and to realize that 1372 Hz is not the fundamental. There are other lower frequency standing waves; these are just two successive ones.

17. For a stopped pipe, the standing wave frequencies are given by Eq.  $f_1 = \frac{v}{4L}$  .  
The first three standing wave frequencies correspond to  $n = 1, 3$  and  $5$ .

$$f_1 = \frac{344}{4 \times 0.17} = 506 \text{ Hz} \quad f_3 = 3f_1 = 1517 \text{ Hz} \quad f_5 = 5f_1 = 2529 \text{ Hz}$$

18. In general these are solved by setting the difference in transmission times equal to the “sooner” time. In this case it looks like this:  $1.21 = \frac{724}{339} - \frac{724}{v}$   
where  $\frac{724}{339} =$  time for sound to go through the air ( $v = \frac{s}{t}$  so  $t = \frac{s}{v}$ )  
and  $\frac{724}{v} =$  time to travel through concrete, where  $v =$  the speed of sound in concrete.

### 2.1 Key Unit Competence

Evaluate applications of Physics in Agriculture.

### 2.2 Prerequisite knowledge and skills

Learner will use the knowledge acquired in senior four and five to interpret and analyze clearly concepts related to application of physics in agriculture.

**NB:** Care must be taken not to discuss completely this Unit Using Only Geography Knowledge. Explain all the concepts relating them to Physics.

### 2.3 Cross-Cutting Issues to be addressed

Environment and sustainability: discussing the need of sustainable future in Rwanda, ensuring that the application of physics in agriculture is achievable while using available resources responsibly.

- Peace and value: assigning work peacefully
- Inclusive education: all learners are included.
- Gender: recognize male and female in performing tasks.

### 2.4 Guidance on the introductory activity

- This activity introduces students to know when and why people apply physics in agriculture and environment in the limitation of hazards to agricultural objects (soils, plants, agricultural products and foods) and environment based on suitable programs of transformation and modernization of agriculture in our country.
- Brainstorm with your students if there any application of prior knowledge of physics learnt before applied on the image?
- Your discussion should include role of machines in agriculture in rapid development of the country towards suitable programs of transformation and modernization of agriculture, and stages of growing plants that benefit use of technology.

- Continue the discussion with a brief brainstorming in other physics aspects involved in agricultural processes and the environment to create critical thinking in students about agrophysics.
- Comment on students ideas written on the chalkboard, explaining the tips of the unit based on students’ ideas.
- They should get an overall appreciation of application of physics in agriculture. Students will use this understanding later as they begin to appreciate the scope and importance of applying physics in agriculture.

## 2.5 List of lessons

S/ No	Lesson Title	Learning Objectives(Adapted from syllabus)  By the end of the Lesson(s) Learners should be able to:	Suggested Number of Periods
1	Atmosphere and its constituents.	Explaining how the atmosphere protects life on the earth due to long-term changes in the climate.  Explaining clearly the role of atmospheric knowledge in evaluating and improving agricultural activities.  Classifying the layers of the atmosphere.	4
2	Heat and Mass transfer.	Explain clearly concepts on water vapour in the atmosphere, Variation of atmospheric pressure, air density and water vapour with altitude.	4
3	Physical properties of soil (soil texture and structure).	Explain clearly the concepts on Physical properties of soil.	3
4	Mechanical weathering	Explain clearly and evaluate the cause and effects of mechanical weathering in environment.	4
5	End unit assessment		2

## **Lesson 2.1: Atmosphere and its constituents**

### **a) Prerequisites/Revision/Introduction:**

Through guided discovery, assist learners to discover the effect of

### **b) Teaching resources: Internet and textbooks, .**

### **c) Learning Activities:**

This lesson focuses on making students understand apply the concept of

### **Guidance in activity 2.1**

- This activity introduces students to know the atmosphere and its composition.
- Divide your class into groups, and let students follow the working procedures to obtain the results.
- Let the learner(s) perform the activity using their prior knowledge about atmosphere and its composition and write the ideas in the note book.
- Have sample group present their work to the class.
- Check student's responses to review the students' plans and ideas to continue the discussion with a brief brainstorming of the concepts using student's work and book.
- Comment on students' responses written in their notebooks, and give them the summary of expected feedback based on their findings.

### **Expected feedback**

- a) Atmosphere of Earth is the layer of gases commonly known as air that surrounds the earth and is retained by Earth's gravity. The atmosphere is composed of a mix of several gases in differing amounts. The permanent gases whose percentages do not change from day to day are nitrogen, oxygen and argon. Gases like carbon dioxide, nitrous oxides, methane, and ozone are trace gases that account for about a tenth of one percent of the atmosphere.
- b) I have to care the atmosphere because the composition of the atmosphere among other things, determines its ability to transmit sunlight and trap infrared light, leading to potentially long-term changes in climate.
- c) The atmospheric knowledge can be helpful in evaluating and improving the quality of soils and agricultural products as well as the technological processes in different agricultural activities.

### **Guidance in activity 2.2**

- This activity support students to learn about the height of Earth's atmosphere as compared to the size of the planet overall and the relative thickness of each of the four main layers of the atmosphere.

• **Time Required:**

- About 15 minutes to set up model
- About 30 minutes for activity

## **Student Learning Objectives**

- Students will be able to explain how relatively thin the atmosphere is, compared to the size of Earth.
- Students will understand the relative extent (thickness) of the four major atmospheric layers.

## **Activity Format**

Hands-on activity and demonstration

Materials for class demonstration are given in learner's book.

## **Directional procedures**

### **Case 1**

- a) Let the learner(s) use a model to explore how far the Earth's atmosphere extends above the surface of the Earth and learn about the thickness of the different layers of the atmosphere. Ask students "How far do you think the atmosphere extends above us?" Learner(s) try to respond to the question.
- b) Let one group member demonstrate and tie a dry eraser marker or a piece of chalk to one end of the string as shown on figure 3.2 in learner's book. Standing next to the board, place his/her foot on the free end of the string and draw an arc on the board with a radius of about 1.2 m. His/her foot represents the center of the Earth. The arc represents the surface of the Earth.
- c) Ask students to suggest how far the Earth's atmosphere would extend above the surface in his/her drawing. Evaluate suggestions given by learner(s) on the board above the chalk/marker line.
- d) Brainstorm with the students trying to harmonize their feedback relating scientific investigation that over 90% of the Earth's atmosphere is within about 12 km of the Earth's surface and the distance from the center of the Earth to its surface equals about 6440000km. The scale of the chalkboard drawing is about 11,610 km. So, on this scale, 11.265 km is a little less than 1/8th of 2.54 cm (about as thick as the chalk line), and 90% of the Earth's atmosphere lies within the thickness of the chalk line used to draw the surface of the Earth.

### **Case 2**

- a) Let learners build a model of the structure of the atmospheric layers to understand the thickness of each of the four layers of the atmosphere (troposphere, stratosphere, mesosphere, and thermosphere).

b) Let learners use a 1000 mL (1 liter) graduated cylinder and represent the layers by using the following amounts of fish gravel or colored sand found in the photo and table given in learner's book. Students can choose what color they want for each atmospheric layer. Keep in mind that these are relative proportions and not exact points of departure for the different layers. In this scale model, each milliliter of volume represents one kilometer of atmosphere layer thickness (for example, the troposphere is 10 km thick and is represented by 10 ml of sand or gravel in the graduated cylinder).

### **Expected answers of activity 2.2**

1. Depends on what colors students choose
2. We live in the troposphere.
3. 30 km which is  $45 \text{ km} - 10 \text{ km}$
4.  $830 \text{ km} = 915 \text{ km} - [10 \text{ km} + 40 \text{ km} + 35 \text{ km}]$
5. Troposphere
6. Troposphere
7. Thermosphere
8. Thermosphere
9. Stratosphere

### **Guidance in activity 2.3**

- Introduce the activity and let the learner(s) perform the activity reviewing the layers of the atmosphere to interpret the graph in their corresponding groups.
- Learners brainstorm on their results and write the work in their notebook.
- Check students's work and let one group present the work.
- Comment on students' responses written in their notebooks and the presentation, and give them the expected feedback summarizing their work.

### **Expected feedback:**

a)

i) Movement of the artificial bodies.

ii) Positioning of space crafts

It is very important because it contains the gas that protects everything living on the earth surface from harmful ultraviolet rays from the sun. This means without the layer of ozone in the atmosphere, it would be very difficult for anything to survive on the surface.

b) It is because of the presence of the ozone layer.

c)

- i. A rocket moves in the corresponding layer because it navigates alone.
- ii. Aeroplanes decide to move in the corresponding layer because of the passengers that want to be protected from harmful ultraviolet rays from the sun.

### **Answer for 2.2.3 checking my progress**

1. It is because the atmosphere is too small compared to the size of the earth.
2. I would expect the atmosphere which is half way of my planet.
3. Solar energy increases the temperature of the atmosphere
4. They interact through evaporation and precipitation processes.
5. Troposphere and stratosphere because of the presence of ozone.

## **Lesson 2.2: Heat and mass transfer**

### **a) Prerequisites/Revision/Introduction:**

This lesson requires knowledge and skills from:

In brief, ask learners how heat from a certain source is transmitted in vacuum or air?  
You can use concepts from;

**b) Teaching resources:** Internet and textbooks, burning frame from a Bunsen burner, or any stove, old iron sheet

### **c) Learning Activities:**

#### **Guidance in activity 2.4**

- This activity introduces students to know the modes of heat transfer in the atmosphere.
- Let the learner(s) brainstorm with their prior knowledge about modes of transfer in atmosphere and write the ideas in the note book.
- Have sample group present their work to the class.
- Check student's responses to review the students' ideas to continue the discussion with a brief brainstorming of the concepts using student's work and book.

- Comment on students' responses written in their notebooks, and give them the expected feedback.

### **Expected feedback:**

- a) Earth's atmosphere involves radiation, conduction, and convection, all occurring simultaneously. A basic theory of meteorology is that the Sun warms the ground and the ground warms the air. This activity focuses on radiation, the process by which the Sun warms the ground. Energy from the Sun is the driving force behind weather and climate.
- b) Modes of heat transfer affect agricultural activities simultaneously each with its role based on the explanation above.

### **Guidance in activity 2.5**

- This activity introduces students to know water vapor.
- Let the learner(s) brainstorm with their prior knowledge about water vapor in the atmosphere and its composition and write the ideas in the note book.
- Have sample group present their work to the class.
- Check student's responses to review the students' plans and ideas to continue the discussion with a brief brainstorming of the concepts using student's work and book.
- Comment on students' responses written in their notebooks, and give them the expected feedback.

### **Expected feedback:**

- a) It condenses into clouds that reflect and adsorb solar radiation, thus directly affecting the energy balance which is very important in growing stages of the plant. It transports latent heat in the atmosphere
- b) Yes, it plays a role in water cycle (hydrological cycle) describes the continuous movement of water on, above and below the surface of the Earth.

### **Guidance in activity 2.6**

- This activity introduces students to know the atmospheric pressure and its variation.
- Let the learner(s) brainstorm with their prior knowledge about atmospheric pressure and its impact in agriculture and write the ideas in the note book.
- Have sample group present their work to the class.
- Check student's responses to review students' ideas to continue the discussion with a brief brainstorming of the concepts using student's work and book.

- Comment on students' responses written in their notebooks, and give them the expected feedback.

### **Expected feedback:**

Atmospheric pressure refers to the force per unit area exerted against a surface by the weight of air above that surface. The effects of weather on crop production depends on atmospheric pressure variation.

### **Guidance in activity 2.7**

- This activity introduces students to know air density and its effect in the earth's atmosphere.
- Let the learner(s) brainstorm with their prior knowledge and write the ideas in the note book.
- Check student's responses and continue the discussion with a brief brainstorming of the concepts using student's work and book.
- Comment on students' responses written in their notebooks, and give them the expected feedback.

### **Expected feedback:**

The density of air (air density) is the mass per unit volume of Earth's atmosphere and it have an important effect upon engine performance and the take off characteristics of air-craft.

### **Guidance in quick check1**

- Let the learner(s) brainstorm with their prior knowledge about radiation and try to respond by writing the answer in the notebook.
- Check students's answer and comment on students' responses written in the notebooks, and give them the expected feedback.

### **Expected feedback:**

Each one is a source of radiation to some degree.

### **Answer for 3.2.4 checking my progress**

1. It is because the density of air decreases with increase in height so the pressure also decreases with increase in height.
2. a. As the altitude reduces ,the pressure increases.  
b. It is around 200 Pa

## Lesson 2.3: Physical properties of soil

### a) Prerequisites/Revision/Introduction:

This lesson uses knowledge from black body radiation from S.5 unit 1

Building on the previous lesson, ask learners to relate

### b) Teaching resources: Internet and textbooks

### c) Learning Activities:

#### Guidance in activity 2.8

- Students investigate how different surfaces of the Earth reflect and absorb heat and apply this knowledge to real-world situations.

#### • Time Required

- Teacher introduction: 10 minutes
- Student activity: 40 minutes
- Discussion/assessment: 20 minutes

#### • Student Learning Objectives

- Students will understand that the physical characteristics of the Earth's surface affect the way that surface absorbs and releases heat from the Sun.
- Lesson Format

Hands-on activity or demonstration, data analysis, and class discussion

- Materials for a class demonstration or for each team of students are available in learner's book.
- Preparation
- Print the Heating and Cooling Data Tables for recording.
- This activity can be done as a class demonstration or in groups of 3-4 students. If you are doing it as a demonstration, you'll need one set of materials and graph paper and data tables for each student. If the activity will be done by small groups, each group will need supplies.
- Check the light bulbs to ensure they generate heat. Use incandescent light bulbs instead of LED bulbs.

## Directions

1. Introduce the activity by brainstorming on the types of soil found of the Earth's surface.
  - Let students think about what they already know about how the color and type of material affects how hot it gets in the sunshine. For example, ask students, "When it is a hot day, what color shirt would you wear to keep cool and why?" and "During the summer, what would it feel like to walk on gravel with no shoes?"
  - Learners explore how different types of surfaces found at the Earth's surface (such as sand, soil, and water) heat up when the Sun's energy reaches them, and how they cool down when out of the sunshine.
  - Students notice that this experiment uses materials to model sunshine and Earth materials. Show students the materials and explain how each relates to the Earth system. (The lamp represents the Sun in this model. The sand represents beaches, sand dunes, and rocks. The potting soil represents large areas of soil outdoors. And the water represents lakes, rivers, and the ocean.)
2. If small groups are doing this activity on their own, distribute supplies to students.
3. Do not turn on the lamp yet.
4. Let learners follow instructions and place a thermometer into each pie pan.
5. Provide students with data tables and explain how the tables relate to the experimental design.
6. Students record the temperature right before they turn on the lamp and record the result.
7. Students record the temperature following all instructions.
8. Students graph the temperature data using graph paper and colored pencils and prepare for the presentation.
9. Schedule the presentation for sample and let them compare their graphs as they discuss findings and try to use the skills gained to answer questions given.
10. Help learners to comprehend their responses and give them the summarized feedback.

## Summary of the feedback

1. Dark soil (dark-colored surfaces absorb most of the radiation instead of reflect)
2. Dark soil (the surface that absorbs the most heat, also emits the most heat)

3. a) The land heats up more than the ocean throughout the day. The darker-colored surface, the land, absorbs more of the Sun's radiation compared to the highly reflective surface of the ocean.
- b) The ocean will cool more slowly at night because surfaces that reflect most the radiation will also emit less radiation (analogous to Question 2)
4. City A will likely have the highest average air temperature because it has the darkest land surface. Darker land surfaces absorb higher amount of radiation and this absorption leads to an increase in the temperature.
5. City C (large man-made desert lake). A good reflector (desert lake) is a poor absorber (and a poor emitter) of radiation.
6. Refer back to the Earth's Energy Budget. The sunlight that makes it to the ground warms the Earth's surface through absorption. The rest is reflected away by bright white clouds or ice or gets absorbed by the atmosphere.

### Guidance in activity 2. 9

- Introduce the activity and let the learner(s) brainstorm with their prior knowledge about soil texture and write their ideas in the note book.
- Check student's responses to review the students' ideas and continue the discussion with a brief brainstorming of the concepts in student's work.
- Comment on students' responses written in their notebooks, and give them the expected feedback.

### Expected feedback:

- a) **Elements in soil proportions are sand, silt and clay**
- b) **Soil Texture refers to the relative proportions of particles of various sizes such as sand, silt and clay in the soil.**

### Guidance in activity 2.10

- This activity introduces students to know the atmosphere and its composition.
- Decide on the method to use and have students use the materials you have provided following the working procedures to obtain the results.
- Let the learner(s) brainstorm with their prior knowledge about atmosphere and its composition and write the ideas in the note book.
- Have sample group present their work to the class.
- Check student's responses to review the students' plans and ideas to continue the discussion with a brief brainstorming of the concepts using student's work and book.

- Comment on students' responses written in their notebooks, and give them the expected feedback.

### Expected feedback:

- a) Soil Structure refers to the aggregation of primary soil particles (sand, silt and clay) into compound particles or cluster of primary particles which are b.separated by the adjoining aggregates by surfaces of weakness. The nature of the pore spaces of a soil control to a large extent the behaviour of the soil water and the soil atmosphere, and influence soil temperature
  - i. Elements in soil particles are sand, silt and clay
  - ii. Soil structure refers to the arrangement of soil particles (sand, silt and clay) and pores in the soil and to the ability of the particles to form aggregates whereas pores are spaces in the soil
  - iii. The pores between the aggregates are usually large (macropores), and their large size allows good aeration, rapid infiltration of water, easy plant root penetration, and good water drainage, as well as providing good conditions for soil micro-organisms to thrive. The smaller pores within the aggregates or between soil particles (micropores) hold water against gravity (capillary action) but not necessarily so tightly that plant cannot extract the water.

### Guidance in quick check2

Rainfall and temperature can affect the rate in which rocks weather.

The process is weathering.

### Answer for 2.2.5 checking my progress

1. **Soil texture** and soil structure. They greatly affect crop production, land use and management.
2. (i) Well structured soil refers to one with stable aggregates and many pores. Poor structured soil refers to one with unstable aggregates and few pore space.
  - (ii) a) Sample 1 is 6% and sample 2 is 2%.
    - b).Sample A ( in sample 1)
    - c).Sample A ( in soil sample 2)

## **Lesson 2.4: Mechanical weathering**

### **a) Prerequisites/Revision/Introduction:**

Through guided discovery, ask learners to state to state changes in the atmospheric conditions they normally experience in their daily life (in their communities)

You can use concepts from: Environmental phenomena and related physics concepts. (S.3 unit 15)

### **b) Teaching resources: Internet and textbooks**

### **c) Learning activities:**

#### **Guidance in activity 2.11**

- Let the learner(s) brainstorm with their prior knowledge on effects of temperature on mechanical weathering and write the ideas in the note book.
- Have sample group present their work to the class.
- Check student's responses to review the students' ideas to continue the discussion with a brief brainstorming of the concepts using student's work and book.
- Comment on students' responses written in their notebooks, and give them the expected feedback.

#### **Expected feedback:**

Temperature affects the rate and type of weathering. At high elevations, cold nighttime temperatures during much of the year can produce relentless freeze-thaw cycles. This process explains the presence of broken boulders and stony fragments that litter mountaintops. And, the minerals in volcanic rock that formed at the highest temperatures and pressures are the most vulnerable to chemical weathering at Earth's surface.

#### **Activity 2.13: Importance of abrasion in real life situations**

With the help of knowledge gained in the concepts above, explain how abrasion is formed and suggest its importance in real life situations?

#### **Guidance in activity 2.12**

- This activity introduces students to know the atmosphere and its composition.
- Decide on the method to use and have students use the materials you have provided following the working procedures to obtain the results.
- Let the learner(s) brainstorm with their prior knowledge about atmosphere and its composition and write the ideas in the note book.

- Have sample group present their work to the class.
- Check student's responses to review the students' plans and ideas to continue the discussion with a brief brainstorming of the concepts using student's work and book.
- Comment on students' responses written in their notebooks, and give them the expected feedback.

### **Expected feedback:**

By gravity that makes the rock to tumbles down a mountainside or cliff and moving water that makes the water collide and bump against one another.

They are used in construction of structures.

### **Guidance in activity 2.13**

- This activity introduces students to know the causes of mechanical weathering.
- Decide on the method to use and have students use the materials you have provided following the working procedures to obtain the results.
- Let the learner(s) brainstorm about the observation and write the ideas in the note book.
- Have sample group present their work to the class.
- Check student's responses to review the students' plans and ideas to continue the discussion with a brief brainstorming of the concepts using student's work and book.
- Comment on students' responses written in their notebooks, and give them the expected feedback. Expected feedback:
- Rocks breaks into smaller pieces due to applied force.
- Chemical effects
- Ice wedging, pressure release, plant root growth, and abrasion can all cause mechanical weathering. Mechanical weathering results from changes in temperature and pressure surrounding rocks. The expansion or contraction of air and pressure creates fractures in rock surfaces, ultimately making rocks break into smaller pieces.

### **Guidance in activity 2.14**

- This activity introduces students to know the factors affecting the rate of weathering.
- Let the learner(s) brainstorm on the observation and write the ideas in the note book.

- Check student's responses to review the students' ideas to continue the discussion with a brief brainstorming of the concepts using student's work and book.
- Comment on students' responses written in their notebooks, and give them the expected feedback.

### **Guidance in activity 2.15**

- This activity introduces students to know the effects of thermal expansion and contraction affect minerals.
- Let the learner(s) brainstorm on the observation and write the ideas in the note book.
- Check student's responses to review the students' ideas to continue the discussion with a brief brainstorming of the concepts using student's work and book.
- Comment on students' responses written in their notebooks, and give them the expected feedback.

### **Guidance in activity 2.16**

- This activity introduces students to know the atmosphere and its composition.
- Think of a method to use in this lesson and have students use the materials you have provided
- following the working procedures to obtain the results.
- Let the learner(s) brainstorm with their prior knowledge about atmosphere and its composition
- and write the ideas in the note book.
- Have sample group present their work to the class.
- Check student's responses to review the students' plans and ideas to continue the discussion with
- a brief brainstorming of the concepts using student's work and book.
- Comment on students' responses written in their notebooks, and give them the expected
- feedback. Expected feedback:
  - i. Soil erosion refers to washing away of the soil.
  - ii. Wind and water erosion.
  - iii. Formed soil supports in variety of agricultural activities

## Answer for 2.2.6 checking my progress

1. a) Mechanical weathering and soil erosion

b) i. depends on student's response.

ii. Mechanical weathering refers to breaking of rocks into small pieces due to a variety of factors.

Soil erosion refers to the process of taking away soil from the banks of the river by water flowing.

c). Mechanical weathering is caused by high temperature exposed on the rocks and other various factors.

Soil erosion is caused by water flowing.

d) Yes it is possible

Soil formation mostly needed in agriculture (positive impact)

Soil destruction due to poor soil eroded which induces negative impact on agriculture..

## 2.6 Unit Summary

- The physical and chemical structure of the atmosphere, the way that the gases interact with solar
- energy, and the physical and chemical interactions between the atmosphere, land, and oceans all
- combine to make the atmosphere an integral part of the global biosphere.
- The earth's atmosphere is a very thin layer wrapped around a very large planet.
- Two gases make up the bulk of the earth's atmosphere: nitrogen ( $N_2$ ), which comprises 78% of
- the atmosphere, and oxygen ( $O_2$ ), which accounts for 21%. Various trace gases make up the
- remainder.
- Based on temperature, the atmosphere is divided into four layers: the troposphere, stratosphere,
- mesosphere, and thermosphere.
- Energy is transferred between the earth's surface and the atmosphere via conduction, convection, and radiation.

- Human activities contribute slightly to water vapor concentrations through farming, manufacturing, power generation, and transportation. However, these emissions are so dwarfed in comparison to emissions from natural sources we can do nothing about, that even the most costly efforts to limit human emissions would have a very small, perhaps undetectable, effect on global climate.
- Mechanical weathering breaks down existing rocks and minerals without changing them chemically.
- Ice wedging, abrasion, and some actions of living organisms and humans are some of the agents of mechanical weathering.
- Mechanical weathering refers to physical processes that break down the structure of rocks. It differs from chemical weathering, by which rocks are broken down by reactions among chemicals inside and outside the rock. You can observe mechanical weathering's effects nearly anywhere: In addition to producing some of the most impressive rock formations on Earth, mechanical weathering is responsible for the cracked and smoothed rocks you see in your daily life.
- Significance of Mechanical Weathering Rocks that are weathered mechanically eventually form very smaller particles called sediments, which are the basic structural ingredient of all types of soil. Sometimes, sediments are washed away from where they originally formed due to various natural forces - a process called erosion. The removed sediments are then transported to other areas, where they can become compacted into new rocks (sedimentary rocks). Thus, mechanical rock weathering is an important part of the formation of both soils and new rocks, and an important part of the entire rock cycle.
- More important than acute effects of extreme temperature stress are the chronic effects of continuously warmer temperatures on crop growth and development. Chronic effects of high temperature include effects on grain growth discussed above. Record crop yields clearly reflect the importance of season-long effects on crop yields: crops generally yield the most where temperatures are cool during growth of the harvested component.
- Crop growth simulations show that rice yields decrease 9% for each 1°C increase in seasonal average temperature. This chronic effect of high temperature differs significantly from the acute effect of short-term temperature events, because seasonal temperature effects are mostly a result of effects on crop development.
- Agro physics is a science that studies physical processes and properties affecting plant production. The fundamentals of agro physical investigations are mass (water, air, nutrients) and energy (light, heat) transport in the soil–plant–atmosphere and soil–plant–machine–agricultural products–foods continuums.

## 2.7 Additional Information:

Mechanical weathering refers to physical processes that break down the structure of rocks. It differs from chemical weathering, by which rocks are broken down by reactions among chemicals inside and outside the rock. You can observe mechanical

weathering's effects nearly anywhere: In addition to producing some of the most impressive rock formations on Earth, mechanical weathering is responsible for the cracked and smoothed rocks you see in your daily life.

### **Frost and Salt Wedging**

One of the most common forms of mechanical weathering is frost wedging. This occurs when water gets into the small holes and gaps in rocks. If the water in the gap freezes, it expands, splitting the existing gaps into wider cracks. When the water thaws, the wider gaps allow even more water to enter the rock and freeze. Frost wedging can repeat over months or years, turning microscopic gaps in the rock into large cracks.

Salt wedging is also caused by water intruding into rocks. When water containing salt evaporates from within a gap in a rock, the salt is left behind. Over time, salt builds up, creating pressure that will split the gaps in the rock.

### **Unloading and Exfoliation**

Many rocks form deep beneath the surface of the Earth under conditions of intense pressure; hundreds of tons of rock or ice often press down on them. If the rocks above these rocks erode, or the ice above them melts, the release of this weight causes the rock to expand upward and crack at its top. The release of weight is known as unloading. When a rock expands and cracks this way, the top of the rock may split into sheets that slide off the exposed rock. This process is called exfoliation.

### **Water and Wind Abrasion**

Abrasion occurs when the surface of rocks is exposed to water or wind. These elements can carry tiny particles of sediment or rock that then collide against the rock's surface. When these particles rub against the rock's surface, they break off tiny pieces of the rock. Over time, abrasion can wear down and smooth extremely large sections of rock.

## **2.8 End unit assessment answers**

### **Part I: Multiple choices questions**

1. E. Troposphere
2. C. I and II are correct but III is wrong
3. E. The branch of natural sciences dealing with the application of physics in agriculture and environment.
4. E. All statements (A), (B), and (C)
5. B. Radiative balance and the hydrological cycle

## Part II: Structured Questions

a) Write the missing word or words on the space before each number. For items 1-9

1. **Moisture** speeds up chemical weathering.
2. Weathering happens **very slowly** in hot and wet (humid) climates.
3. Weathering occurs very slowly in **hot** and wet climates.
4. Without **temperature** changes, ice wedging cannot occur
5. In very **cold** and **dry** areas, there is little weathering.
6. Most weathering occurs on **exposed surfaces** of rocks and minerals
7. The **more** surface area a rock has, the quicker it will weather.
8. Some minerals resist weathering. **Quartz** is a mineral that weathers slowly.
9. Rocks made up of minerals such as feldspar, **calcite**, and iron, weather more quickly.

b) If the statement is true, write true. If it is false, change the underlined word or words to make the statement true.

1. Water vapor is very important in predicting weather. **True**
2. Gravity is a reason why atmosphere is more dense close to the earth's surface. **False**
3. Agrophysics plays an important role in the limitation of hazards to agricultural objects and environment. **True**
4. Energy is transferred between the earth surface and atmosphere in a variety of ways. **False**
5. As the temperature increases in the atmosphere, **the maximum radiation** occurs at short wavelengths. **False**

c) Analytical questions

1. i) Gravity is a reason why atmosphere is denser close to the earth's surface.  
ii) The rocks contract slightly when the temperatures cool down.
2. It means that Marry will have a scientific journal with a purpose of studying how sensor and communication machines work in agrophysics to track changes about physical conditions in agricultural and natural environments.

Terms	Impact of temperature and water vapor in agricultural activities.
Temperature	Temperature affects on plant growth and development.
	Increase in temperature can increase crop yields in some places.
Water vapor	It condenses into clouds that reflect and adsorb solar radiation, thus directly affecting the energy balance which is very important in growing stages of the plant.
	It transports latent heat in the atmosphere.
	It plays a role in water cycle (hydrological cycle) describes the continuous movement of water on, above and below the surface of the Earth.

3.

Term	An example of economic activities taking place in the corresponding layer if available
1.Troposphere	Various agricultural activities.
2.Stratosphere	Strategic positioning of space crafts.
3. Mesosphere	Strategic layer that allows for movements of rockets.
4. Thermosphere	Many satellites actually orbit Earth within the thermosphere.

5. Climate change can disrupt food availability, reduce access to food, and affect food quality.

6. They are used to till the ground, plant seed and perform other tasks.

Application of machineries in the day to day farm activities increases marginal output in food production and poverty eradication.

All stages benefit the use of technology (variation occurs depending on kind of plant).

7. Rock fragments separate and tumble down and makes the surface bulge upward.

8. Weathering is the breaking of rocks into smaller pieces whereas soil erosion is washing away of soil.
9. time the rock breaks into smaller pieces its surface area or part exposed to weathering is increased.
10. Mechanical weathering is minimized by effective practicability and implementation of human activities.
11. Soil is formed due to disintegration of rocks into small pieces.

### **Part III: Essay Questions**

The outcome depends on students' trial and research and the guidance of the respective teacher giving the students good approach of making and reporting scientific research.

# UNIT 3: Fossil and Non-fossil Fuel and Power Production

# 3

## Know this

Fossil fuel power plants burn carbon fuels such as coal, oil or gas to generate steam that drives large turbines to produce electricity. These plants can generate electricity reliably over long periods of time. However, on burning, carbon fuels produce large amounts of carbon dioxide, which causes climate change. This unit explains the types of these fossil fuels and explains non-fossil fuels and how they are used in power production and in making atomic bombs. We should understand the need for this content and special attention is needed on how to avoid the negative results that may erupt when using these fuels.

## 3.1 Key unit competence

By the end the learner should be able to evaluate fossil and non fossil fuels for power production

## 3.2 Unit description

This lesson seems to be theoretical but is more comprehensive when real life examples are used. Fuels are used everywhere in our everyday activities. The teacher should allow learners to closely interact and grasp the necessary information that will help them understand the content. This unit discusses;

### 3.2.1 Introduction

### 3.2.2 Fossil fuels and Non fossil fuels

Fossil fuels

Non fossil fuels

### 3.2.3 Storage and transportation of different types of fossil fuels

- Coal
- Transporting Natural Gas and crude oil

- 3.2.4 Advantages and disadvantages of fossil fuels
- 3.2.5 Energy production using fossil fuels
- 3.2.6 Nuclear fuel and nuclear fission
- 3.2.7 Controlled fission (power production)
- 3.2.8 Uncontrolled fission (nuclear weapons)
- 3.2.9 Impacts of nuclear weapons
- 3.2.10 Energy transformations in a nuclear power station.
- 3.2.11 Problems associated with generation nuclear power
- 3.2.12 Environmental problems due to use of fossil fuels
- 3.2.14 Safety issues and risks associated with nuclear power.
  - Nuclear Meltdown
  - Nuclear (Radioactive) Wastes

### Summary of Knowledge, Skills, Attitudes and Values

As you teach this unit, you should ensure that learners acquire the following skills, values and attitudes;

Knowledge	Skills	Attitudes and value
Outline historical and geographical reasons for use of fossil fuels	Distinguish between fossil fuel and non fossil fuel	Appreciate that industrialization requires larger deposits of fossil fuels
Explain energy density of fossil fuels and power station demand	Distinguish between controlled fission and uncontrolled fission	Be aware of moral and ethical issues associated with nuclear weapons
Discuss advantages and disadvantages associated with the transportation and storage of fossil fuels	Evaluate advantages and disadvantages associated with the transportation and storage of fossil fuels	Appreciate the need to think scientifically in producing nuclear power
State efficiency of power station fuelled by fossil fuels	Estimate the rate of fuel consumption in power stations	Recognize the value of adapting to scientific method of storing fossil fuels
Explain environmental problems associated with recovery of fossil fuels after use in power stations	Apply knowledge attained to identify safety issues and risks of nuclear power	
Outline safety issues and risks of nuclear power		

## Learning objectives

By the end of this lesson, learners should be able to:

- explain the concept of fossil and non-fossil fuels and their use in power production properly.
- explain the differences between fossil and non-fossil fuels properly.
- discuss the use of nuclear fuel and nuclear fission in energy production and their associated dangers properly.
- explain the environmental problems of fossil fuels and suggest their solution clearly.

## Scope and Sequence

This unit will be delivered in 18 lessons each of 40 minutes.

Unit 6: Fossil and non fossil fuel and power production			
Lesson 1	Lesson 2	Lesson 3	Lesson 4
<b>This lesson should cover:</b>  Introduction	<b>This lesson should cover:</b>  Fossil fuels and Non fossil fuels	<b>This lesson should cover:</b>  Storage and transportation of different types of fossil fuels	<b>This lesson should cover:</b>  Storage of coal
Lesson 5	Lesson 6	Lesson 7	Lesson 8
<b>This lesson should cover:</b>  Transportation of coal	<b>This lesson should cover:</b>  Transporting Natural Gas and crude oil	<b>This lesson should cover:</b>  Assessment 1	<b>This lesson should cover:</b>  Advantages and disadvantages of fossil fuels
Lesson 9	Lesson 10	Lesson 11	Lesson 12
<b>This lesson should cover:</b>  Energy production using fossil fuels	<b>This lesson should cover:</b>  Nuclear fuel and nuclear fission reaction	<b>This lesson should cover:</b>  Controlled fission and uncontrolled fission reactions	<b>This lesson should cover:</b>  Assessment 2

Lesson 13	Lesson 14	Lesson 15	Lesson 16
<b>This lesson should cover:</b> Impacts of nuclear weapons	<b>This lesson should cover:</b> Energy transformations in a nuclear power station	<b>This lesson should cover:</b> Problems associated with the production of nuclear power	<b>This lesson should cover:</b> Environmental problems of fossil fuels
Lesson 17	Lesson 18		
<b>This lesson should cover:</b> Safety issues and risks associated with nuclear power	<b>This lesson should cover:</b> Assessment 3		

## Lesson development

Lesson 1	Title: Introduction
Learning objectives	By the end of this lesson, using real life examples, learners should be able to explain the concept of fossil and non-fossil fuels and their use in power production properly.
Key words	Fossil fuel , non-renewable energy
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education
Competence developed	Critical thinking, Lifelong learning, Communication, Co-operation, interpersonal management and life skills
Attention to special educational need children	Intellectual challenges, developmental challenges, speech and communication difficulties, gifted and talented, emotional difficulties, behavioral difficulties, learners with health challenges
Lesson 2	Title: Fossil fuels and Non fossil fuels
Learning objectives	By the end of this lesson, using real life examples, learners should be able to explain the differences between fossil and no-fossil fuels properly.

Key words	Coal, Oil and natural gas
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life, Literacy, science and technology, citizenship and national identity
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties, gifted and talented learners, emotional difficulties, behavioural difficulties, learners with health challenges
<b>Lesson 3</b>	<b>Title: Storage and transportation of different types of fossil fuels</b>
Learning objectives	By the end of this lesson, using real life examples, learners should be able to explain the storage and transportation of fossil fuels.
Key words	Types of coal, Means of transporting coal storage
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life, literacy, science and technology, Citizenship and national identity
Attention to special educational need children	Special attention is given to learners with intellectual challenges and developmental challenges
<b>Lesson 4</b>	<b>Title: Storage of coal</b>
Learning objectives	By the end of this lesson, using real life examples, learners should be able to explain the means of storing coal properly.
Key words	Dead storage, Living storage, Means of coal storage, Coal transfer
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education

Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life, Literacy, science and technology, Citizenship and national identity
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties, gifted and talented learners, emotional difficulties, behavioural difficulties, learners with health challenges
<b>Lesson 5</b>	<b>Title: Transportation and storage of coal</b>
Learning objectives	By the end of this lesson, using real life examples learners should be able to explain how coal is transported.
Key words	Dead storage, Living storage, Storage in coal heaps, Underwater storage, Coal transfer
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life, Literacy, science and technology, Citizenship and national identity
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties, gifted and talented learners, emotional difficulties, behavioural difficulties, learners with health challenges
<b>Lesson 6</b>	<b>Title: Transporting Natural Gas and crude oil</b>
Learning objectives	By the end of this lesson, using real life examples learners should be able to explain the means of transporting natural gases and crude oil.
Key words	Gathering pipelines, Transportation pipelines, Distribution pipelines

Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education
Competence developed	Critical thinking, communication, co-operation, interpersonal management and life, literacy, science and technology, citizenship and national identity
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties, gifted and talented learners, emotional difficulties, behavioural difficulties, learners with health challenges
<b>Lesson 7</b>	<b>Title: Assessment 1</b>
Learning objectives	By the end of this assessment using knowledge and skills gained from lesson 1 to lesson 6, learners should be able to relate the content with the real life experiences.
Key words	Fossil fuel , non-renewable energy  Coal, Oil and natural gas Types of coal, Means of transporting coal, Dead storage, Living storage, Means of coal storage, Storage in coal heaps, Underwater storage, Gathering pipelines, Transportation pipelines, Distribution pipelines
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, problem solving
Attention to special educational need children	Special attention is given to learners with visual difficulties
<b>Lesson 8</b>	<b>Title: Advantages and disadvantages of fossil fuels</b>
Learning objectives	By the end of this lesson, using real life examples learners should be able to explain the advantages and disadvantages of fossil fuels properly.
Key words	Advantages and disadvantages of fossil fuels
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education

Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life, literacy, science and technology, citizenship and national identity
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties, gifted and talented learners, emotional difficulties, behavioural difficulties, learners with health challenges
<b>Lesson 9</b>	<b>Title: Energy production using fossil fuels</b>
Learning objectives	By the end of this lesson, using real life examples learners should be able to explain energy production using fossil fuels properly.
Key words	fossil-fuel power station, production of electricity, steam cycle, cooling towers
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life, Literacy, science and technology, Citizenship and national identity
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties, gifted and talented learners, emotional difficulties, behavioural difficulties, learners with health challenges
<b>Lesson 10</b>	<b>Title: Nuclear fuel and nuclear fission</b>
Learning objectives	By the end of this lesson, using the knowledge of chemical reactions, learners should be able to explain nuclear fuel and nuclear fission.
Key words	Plutonium 239, uranium 235, fission chain reactions, exothermic reaction
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education

Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life, literacy, science and technology, citizenship and national identity
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties, gifted and talented learners, emotional difficulties, behavioural difficulties, learners with health challenges
<b>Lesson 11</b>	<b>Title: Controlled fission and uncontrolled fission reactions</b>
Learning objectives	By the end of this lesson, learners should be able to explain Controlled fission and Uncontrolled fission properly.
Key words	Moderation, uncontrolled fission chain reaction, Controlled fission reaction
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life, Literacy, science and technology, Citizenship and national identity
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties, gifted and talented learners, emotional difficulties, behavioural difficulties, learners with health challenges
<b>Lesson 12</b>	<b>Title: Assessment 2</b>
Learning objectives	By the end of this assessment, using knowledge and skills gained from lesson 7 to lesson 11, learners should be able to relate the content with the real life experiences.

Key words	Advantages and disadvantages of fossil fuels, fossil-fuel power station, production of electricity, steam cycle, cooling towers  Plutonium 239, uranium 235, fission chain reactions, exothermic reaction, Moderation, uncontrolled fission chain reaction, Controlled fission reaction
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education
Competence developed	Critical thinking and problem solving
Attention to special educational need children	Special attention is given to learners with Visual Difficulties
<b>Lesson 13</b>	<b>Title: Impacts of nuclear weapons</b>
Learning objectives	By the end of this lesson, using real life examples learners should be able to explain the impacts of nuclear weapons on environment and the lives of the people properly.
Key words	nuclear explosion
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life, Literacy, science and technology, Citizenship and national identity
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties, gifted and talented learners, emotional difficulties, behavioural difficulties, learners with health challenges
<b>Lesson 14</b>	<b>Title: Energy transformations in a nuclear power station</b>

Learning objectives	By the end of this lesson, using block diagrams and energy flow, learners should be able to explain the working mechanism of nuclear power stations properly.
Key words	Nuclear Steam Supply System, Nuclear power plant
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life, Literacy, science and technology, Citizenship and national identity
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties, gifted and talented learners, emotional difficulties, behavioural difficulties, learners with health challenges
<b>Lesson 15</b>	<b>Title: Problems associated with the production of nuclear power</b>
Learning objectives	By the end of this lesson, using real life examples, learners should be able to explain the problems associated with the production of nuclear power clearly.
Key words	nuclear power
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life, Literacy, science and technology, Citizenship and national identity
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties, gifted and talented learners, emotional difficulties, behavioural difficulties, learners with health challenges

<b>Lesson 16</b>	<b>Title: Environmental problems of fossil fuels</b>
Learning objectives	By the end of this lesson, using real life examples, learners should be able to explain the environmental problems of fossil fuels and suggest their solution clearly.
Key words	Population Explosion, Global Warming , Greenhouse Effect , Ozone Layer , Acid Rain , Air Pollution , Water Pollution, Introduced Species, Biological Control, Biological Magnification , Soil Salinity
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life, Literacy, science and technology, Citizenship and national identity
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties, gifted and talented learners, emotional difficulties, behavioural difficulties, learners with health challenges
<b>Lesson 17</b>	<b>Title: Safety issues and risks associated with nuclear power</b>
Learning objectives	By the end of this lesson, using real life examples, learners should be able to explain the safety issues and risks associated with nuclear power clearly.
Key words	Nuclear Meltdown, loss of pressure control, loss of coolant, power excursion, Radioactive Wastes
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life, Literacy, science and technology, Citizenship and national identity

Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties, gifted and talented learners, emotional difficulties, behavioural difficulties, learners with health challenges
<b>Lesson 18</b>	<b>Title: Assessment 3</b>
Learning objectives	By the end of this assessment, using knowledge and skills gained from lesson 1 to lesson 16, learners should be able to relate the content with the real life experiences.
Key words	Fossil fuels, Types of Fossil Fuels, Non fossil fuels, Storage and transportation of different types of fossil fuels, Types of coal storage, Means of coal storage, Transporting Natural Gas and crude oil, nuclear fission
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education
Competence developed	Critical thinking and problem solving
Attention to special educational need children	Special attention is given to learners with Visual Difficulties

## Main contents and concepts to emphasise

Fossil fuels are hydrocarbons, primarily coal, fuel oil or natural gas, formed from the remains of dead plants and animals.

### Types of Fossil Fuels

- Coal
- Natural Gas
- Oil (Petroleum)

### Types of coal storage

- Dead storage
- Living storage

## Means of coal storage

- Storage in coal heaps
- Underwater storage

## Energy production using fossil fuels

A fossil-fuel power station is a power station which burns fossil fuel such as coal, natural gas or petroleum to produce electricity.

Nuclear fuel and nuclear fission

Nuclear fuel is any material that can be consumed to derive nuclear energy.

### Controlled fission (power production)

A fission reaction which leads to a new fission reaction, which further leads to more reactions, and so on is called controlled fission. The amount of heat required is controlled by raising and lowering the rods in the reactor.

### Uncontrolled fission (nuclear weapons)

A fission reaction whereby the reaction is allowed to proceed without any moderation (by removal of neutrons) is called an uncontrolled fission reaction. An uncontrolled fission reaction is used in nuclear bombs.

## Problems associated with the production of nuclear power

- problem of radioactive waste
- High risks
- targets for terrorist attacks
- nuclear weapons
- Uranium is a scarce
- illusion to build new nuclear power plants

## Environmental problems of fossil fuels

- **Climate Change / Global Warming and Greenhouse Effect**

The earth's atmosphere allows a lot of sunlight to reach the earth's surface, but reflects much less part of that light back into space.

The result is a gradual increase in earth's temperature or Global Warming.

- **Hole' in the Ozone Layer**

Ozone acts to block of the sun's ultraviolet radiation which causes skin cancer and contributes to fluctuations in global climatic conditions that affect the environment.

- **Acid Rain**

When gases such as sulphur dioxide and nitrogen oxides react with water in the atmosphere they form sulphuric acid and nitric acid. This results in rain which can destroy vegetation.

- **Air Pollution**

Air pollution is the release of excessive amounts of harmful gases as well as particles into the atmosphere.

Other environmental problems of fossil fuels include

- Biological Control
- Biological Magnification
- Introduced Species
- Soil Salinity
- Population Explosion

## 4.1 Key Unit Competence

Analyse atomic nuclei and radioactivity decay

## 4.2 Prerequisite knowledge and skills

The success of this unit relies partly on the mastery of knowledge and skills acquired in Physics (Unit 9, S5 Advanced Level) and other subjects in previous grades or units such as Chemistry of Ordinary Levels (Unit 5, S1) and Chemistry S4 Advanced Level (Unit 1, S4 Chemistry).

## 4.3 Cross-Cutting Issues to be addressed

**Inclusive education** (The teacher must promote education for all while teaching). Regardless of the physical appearance and abilities, learners should be treated equally. This makes all learners to be involved in teaching and learning process. They find out that they are all of great importance.

**Peace and value Education** (This is the respect of others views and thoughts during class discussions). Remember that someone's idea is very important. It may be correct or not but what is important is to build on that idea.

**Gender education** (equal opportunity of boys and girls in the lesson participation). Care should be taken that both sexes are given equal opportunities.

**Standardization culture** (Be aware of radiations so that they do not harm our health). The teacher put emphases on the care that should be taken on harmful radioactive substances and how to handle them efficiently. This should be done through the whole lesson of radioactivity

**Environment sustainability:** During delivering different lessons within this unit, let learners be familiar with the negative impact of radiations and chemicals on the environment. They will acquire knowledge, skills, attitude and values which will enable them to deal with the environmental change issues.

## 4.4 Guidance on the introductory activity

This activity aims at capturing students' attention and minds towards this concept. The activity should not take more than ten minutes.

- Divide your students into groups (Grouping may depend on the nature of your class or number of learners you have). Always take care of learners with any kind of disability while making groups.
- Tell the learners to open the introductory activity in the learner's book. Give them clear information about the activity.
- While learners are doing this activity, you move around, guide or answer to the questions of slow learners. You may mark the working of those who have finished.
- When everyone has finished the activity, invite some member(s) or group(s) to present their findings to the whole class. Guide the discussion
- Ask other members whether their answers correspond to the discussed points and if there is any point that is different from what have been raised to mention it.
- Note some misconceptions and misunderstanding so that they will be corrected and harmonised in the lesson. Together with students, harmonize the points and make a summary on the board. Give to the learners the opportunity to write the main points in their notebooks.
- Harmonize the lesson by linking what have been discussed and the summary of the lesson.
- Summarize your lesson by linking this concept to real life situations.

## Possible answers of the introductory activity

1. It is a sign indicating that the area contains radioactive materials. The symbol is a symbol of radiation precautions
2. They come from radioactive substances (radionuclides elements)
3. Yes. There are alpha ,beta and gamma radiations
4. The sources of radiations are radioisotope materials, cosmic radiations and unstable radionuclides. In short some radiations come from human made materials and other sources are natural materials.
5. They cause different diseases on human body: Both beta particles and gamma rays can pass easily through the skin and can easily destroy or even kill cells, causing illness.

They can cause mutations in a cell's Deoxyribonucleic Acid (DNA), which means that it cannot reproduce properly, which may lead to diseases such as cancer.

Alpha particles cannot pass through the skin. However, they are extremely dangerous when they get inside your body. This can happen if you inhale radioactive material.

6. Discuss and explain the dangers of using radiations in real life.

Radiations have sufficient energy to cause chemical changes in cells and damage them. Some cells may die or become abnormal, either temporarily or permanently. By damaging the genetic material (DNA) contained in the body's cells, radiation can cause cancer.

A very large amount of radiation exposure can cause sickness or even death within hours or days. Pregnant women and children are sensitive to radiation exposure. The cells in children and fetuses divide rapidly, providing more opportunity for radiation to disrupt the process and cause cell damage.

7. They should be held with forceps and never touched with hands as ways of minimising their impact.

No eating, drinking or smoking where radioactive materials are in use

Wash your hands thoroughly after exposure to any radioactive materials

Any cuts in the body should be covered before using radioactive sources

Arrange the source during experiments such that the radiation window points away from your body

## 4.5 List of lessons

S/No	Lesson title	Learning Objectives	Periods
1	Introductory activity and Atomic nuclei-nuclide	<ul style="list-style-type: none"><li>Define atomic mass and atomic number</li><li>Identify the constituents of a nucleus</li><li>Explain Einstein's mass-energy relation</li><li>Determine the stability of a nuclei</li></ul>	2

2	Mass Defect and Biding Energy	<ul style="list-style-type: none"> <li>Define the terms mass defect and biding energy</li> <li>Calculate the binding energy of some elements</li> <li>Plot a graph of binding energy against nucleon and explain its features.</li> <li>Use Einstein equation in problem solving</li> </ul>	4
3	Radioactivity and nuclei stability	<ul style="list-style-type: none"> <li>Describe properties of different radiations.</li> <li>Define Nuclei fusion and fission</li> <li>Describe creation of artificial isotopes.</li> <li>Calculate the decay rate of unstable isotopes.</li> <li>Classify radioactive detectors</li> <li>Describe creation of artificial isotopes.</li> <li>Calculate the decay rate of unstable isotopes.</li> </ul>	6
4	Application of radioactivity	<ul style="list-style-type: none"> <li>Identify the application of radioactivity in life.</li> <li>Appreciate that the nucleus of an atom and quantum system has discrete energy levels</li> </ul>	3
5	Hazards and safety precautions of when handling radiations	<ul style="list-style-type: none"> <li>Appreciate the safety precautions to be taken when handling radioactive materials.</li> <li>Appreciate that the nucleus of an atom and quantum system has discrete energy levels</li> </ul>	1
6	Evaluation		2

## Lesson 1: Atomic nuclei-nuclide

### a) Introduction:

Through guided discovery, assist learners to describe an atom. You can make a recap using Units of chemistry mentioned above on Prerequisite Knowledge (4.2). You can use probing questions techniques to remind the learners the structure of an atom.

### b) Teaching resources:

Textbooks and Periodic tables.

### c) Learning Activities

#### Activity 4.1: Investigating the stable and unstable nucleus

This activity aims to capture students' attention and minds them towards the concept of atomic nuclei and nuclide. Therefore, the following guidelines should help the teacher to monitor the lesson efficiently.

- Divide your students into groups, accordingly. Tell the learners to open and read the activity 4.1 in the learner's book.
- Instruct learners to observe fig.4.1 and read the questions and answer them by writing in their notebooks. Give them the time to reflect on their prior knowledge (thinking time).
- While students are doing this activity, you move around and mark the work of those who have finished.
- When everyone is done, invite some member(s) or group(s) to present their findings to the whole class. Make sure that you are developing generic competences in your learners: cooperation, critical thinking, etc.
- Inquire from other students or groups whether their answers correspond to the ones discussed
- Together with students harmonize the points discussed and make a summary on the board. Linking to the summary and what have been discussed in class, this will be the opportunity for the teacher to correct misconceptions met during presentation.
- Allow learners to write the main points in their notebooks. Make summative assessment to make sure that learning objectives have been achieved.
- Link this lesson to real life. You should talk about cross-cutting issues to be addressed in this lesson like peace education.

#### Possible answers

1. The number  $A$  stands for the mass number (or number of nucleons) while  $Z$  stand for the atomic number (number of protons in the nucleus) of the nucleus.

- The mass number  $A$  is the number of nucleons (neutrons plus protons) which is equal to the sum of number of nucleons in the nucleus.
- An atom is stable when the number of protons equals the number of electrons, it is unstable when it get more or less electrons.

Some atom of the same element can contain different numbers of neutrons. Atoms of the same element which have different numbers of neutrons are called isotopes. Isotopes of an element have the same proton number but different nucleon numbers i.e. they have the same number of protons but different numbers of neutrons.

#### d) Checking my progress

- a) nuclides b)  ${}_{17}^{35}\text{Cl}$
- a) proton b) neutron or proton c) neutron
- Protons = 56 and electrons = 56 X is Barium(Ba)
- B
- Using the formula (5.01)  $N=A-Z$ , we get  
a) 14 b) 16 c) 155 d) 114
- The atom of strontium 90 has a symbol of  ${}_{38}^{90}\text{Sr}$ .

Then the number of neutrons = mass number – atomic number ( $90-38=52$ neutrons)

- Q = lithium; R = magnesium; S = argon; T = oxygen; X = potassium

## Lesson 2: Mass Defect and Biding Energy

### a) Introduction

In this lesson, you are going to guide learners to discover words in the Puzzle. Initially, verify the prerequisite knowledge of your learner in English. These include the meaning of a word and different parts of simple sentence. You can use probing questions techniques to remind the learners the structure of a sentence.

### b) Teaching resources textbooks.

### c) Learning Activities

#### Activity 4.1 Select words in the puzzle

The activity aims to capture students' attention and develop critical thinking and collaboration on learners. The activity is divided into three sub activities: the first is to discover sentences and use them in their own sentences. The second is to fill in the missing words in the sentences, and the third one is to discuss and explain

expression found in the sentences given in the book. These sub activities should be done individually, depending on the size of your class and the textbooks you have. To achieve this, the teacher should monitor efficiently the lesson when he/she follows the following guidelines.

- Through guided questions, ask learners to brainstorm about the formulation of a good sentence.
- Then ask learners to open their books on page 9. Invite them to observe and read the questions about the puzzle. Give them clear instructions so that they do not write in the book.
- Ask them to read the puzzle (Horizontally, Vertically or obliquely) in order to find different words hidden in the puzzle. They write the list of words in their notebooks, and then they close text books.
- Ask each learner to make at least one sentence (in Physics domain) using discovered word and present it to the whole class. You eventually help learners to reformulate sentence that are not correct or clear. The activity should take seven minutes.
- After the harmonization of the activity, ask learner to reopen their books and copy the sentences below the puzzle. Invite them to fill in the missing words using those that have been discovered in the Puzzle.
- You should move around to mark the on-going work of the learners.
- When all learners are done, ask learners to write the solution on the chalkboard and ask them to discuss about their findings, and correct misconceptions if any. The activity should have seven minutes.
- Ask learners to form groups (depending on the size of the class) and tell them to carry out activity in the corner. They circulate to discuss and explain the physical meaning of given expressions in the corner.
- When they finish, let them to present their findings to the whole class. Engage learners in discussion aimed to correct wrong answers and harmonise the lesson putting an emphasis on key terms or expressions and related formula. From the learner's presentations, write the summary on the board including missing ideas. Give to learners the opportunity to write the summary on their notebooks.
- Summarize the lesson by indicating cross cutting issues met in the lesson and their role in real daily life.

### **Expected answers**

1. Discovered words: electronvolt, kilogram, mass, energy, stability, Einstein, nucleus and force
2. The teacher corrects a formulated sentence according to Physics logic and the universal formulation of a correct sentence in English.

3. Complete the following answers:
  - a. An **electronvolt** is the SI unit of energy.
  - b. On the atomic scale, the **kilogram** is not the SI unit of mass.
  - c. The mass of nucleons is greater than the mass of a nucleus.
  - d. The atom releases **energy** when its nucleus is formed from its constituent particles
  - e. The binding energy per nucleon gives an indication of the **stability** of the nucleus.
  - f. The surprising suggestion that energy and mass are equivalent was made by **Einstein** in 1905.
  - g. The mass of a **nucleus** is less than the combined mass of its protons and neutrons
  - h. Protons and electrons are held together in the nucleus of an atom by an attractive **Force**.
4. **Mass defect:** it is the difference between the mass of an atom and the sum of the masses of its individual components in the free state.

**Binding energy:** is the energy released when a nucleus is formed from its constituent particles.

**Electronvolt:** is the energy transferred to a free electron when it is accelerated through a potential difference of one volt. The symbol is eV.

**Stable nuclides:** these are nuclides that are not radioactive and so (unlike radionuclides) do not spontaneously undergo radioactive decay. They are also called stable isotopes.

#### d) Check my progress

1. a) The mass defect of a nucleus is the sum of the individual masses of the separated nucleons minus the mass of the intact nucleus.
- b) Some mass is converted into energy as the nucleus is formed. Hence the nucleus has less mass than the particles it was made from. This is the mass defect or in another way; as the particles come together to form the nucleus, they lose energy. This energy is 'lost' as radiation and manifests itself as a loss in mass.
- c) The binding energy of a nucleus is the energy required to separate it into its constituent protons and neutrons.

2. According to  $E = mc^2$ , the increase in mass of the water is  $m = \frac{E}{c^2}$

3. a) total mass  $m_t = (2 \times 1.0087) + (2 \times 1.0078) = 4.033 u$

b) the mass defect =  $(4.0330 - 4.0026) = 0.0304 u$

Since  $1u$  is equivalent to 931 MeV, it follows that the binding energy of helium is 28.3 MeV.

4. (a) Binding energy

$$(Z \times m_H + N \times m_n) - m_o = (8 \times 1.007825 + 8 \times 1.008665) - 15.994915 = 0.13700 u = 127.62 \text{ MeV}$$

(b) Binding energy per nucleon  $E_b = \frac{127.62}{16} = 7.98 \text{ MeV / nucleon}$

## Lesson 3: Radioactivity and nuclear stability

### a) Introduction

In this lesson, you are going to guide learners to open and to observe the figure 5.3 on learner's book. Learners should have prerequisite knowledge in geography they learnt in ordinary level about the observation of image, picture, figure or maps. If you do not have sufficient text books for all your learners or groups, you should use photocopies of the picture. You may reformulate the questions using probing question techniques to facilitate the understanding of your learners.

**b) Teaching resources:** Textbooks or photocopies of the picture, pencils, graph papers, erase and rulers.

### c) Learning Activities

#### Activity 4.3 Investigating radioactivity

This activity aims to capture students' attention and develop critical thinking, collaboration and long-life learning solutions on learners. You may engage learners in an organized discussion or debate. Make sure that everyone is participating actively. To achieve this, follow the guidelines below:

- Organize your class in groups depending on the nature of your class of time of the lesson. Give them clear instructions. tell them to open their books or provided materials. through guided questions, ask learners to brainstorm about the image in their respective groups
- Then ask learners to open their books on page 14. Invite them to observe and read the questions about the image. Give them clear instructions so that they do not write in the books.
- Ask them to observe the figure and brainstorm on it. If no questions from the learners, let them answer to the task freely. Allow them time to finish. However, you may check if all learners are engaged in working.
- After a period of time assigned to this activity, ask each group to present their

findings. Notes the differences, misconceptions and or misunderstanding met by learners. This will help you to harmonize all presentation accurately.

- Develop your summary based on key concepts and findings of learners. Allow them to answer some questions that should consolidate further understanding of the concepts.
- Give them the time to write the summary. Conclude your lesson by developing cross cutting issues that have been aroused in the lesson such as Environment sustainability, peace education and financial education. Relates them to real-life situation. Then end your lesson by giving the assignment or quiz to your learners.

## Expected answers

1. IMAGE A: Town of Nagasaki, with Buildings, roads, bridges, and the town is bombarded with an atomic bomb. It is exploding, and emits fire, radiations of different wavelengths which destroy the entire city and all living things.

IMAGE B: On this image, all living things have been destroyed. Even water are contaminated. There is no life at all.

2. The atomic bomb was very harmful to human being because it killed more than 70.000 people died in 9 seconds, and the city of Hiroshima was levelled.
3. Beside shock, blast, and heat a nuclear bomb generates high intensity flux of radiation in form of  $\gamma$ -rays, x-rays, and neutrons as well as large abundances of short and long-lived radioactive nuclei which contaminate the entire area of the explosion and is distributed by atmospheric winds worldwide.
4. They are called radionuclides materials or unstable radionuclides.

These unstable materials have a tendency to break up for stability. They are said to undergo disintegration or decaying process. The result of this process is that energy is released in the form of heat and radiation emitted from the nucleus. They then emit alpha, beta and gamma decays.

5. Radioactive materials used above are probably be plutonium, Uranium Hydrogen...
6. To generate heavy energy by using radioactive materials, fission and fusion are used in nuclear power plants.

Fission is a splitting up of a radionuclide into two or more parts, emitting alpha, beta and gamma radiations. The energy is found to be the difference between the original materials and its constituents produces energy given by

Fusion is a process of combining two or more distinct entities into a new massive nuclei with the concomitant release of energy.

#### **Activity 4.4: Investigating the mass decay of matter.**

This activity aims at encouraging learners to be familiar with the drawing of graphs and their interpretation. The learners already have these prerequisites in the previous topics (Unit 1 S3, Graphs of linear motion). You may make a recap on graph of linear motion to be aware of learner's ability to carry out the new activity. Then after that, follow the following instructions to achieve your goals.

- Distribute the materials such as pencils, eraser and rulers.
- Ask learners to open their books on activity 5.4 and read the questions attentively in their groups.
- Ask them to plot a graph of particles emitted per minute against time. Move around to see what they are doing.
- When they finishes, ask each group to hang up their work so that everybody can give his comments and remarks in order to agree on the model graph to use in the next steps.
- Instruct them to continue on the next step. You may guide slow learners in order to encourage them.
- Finalise the lesson by bridging the findings of learners and the new concepts. Summarise the lesson by showing learners all the working. Let them write the summary and give them assignment of consolidation of the activity.
- Emphasize on cross-cutting issues to be addressed. These include financial education and environment sustainability among others you may find.

#### **Activity 4.5 Functioning of a radiation detector**

The purpose of the activity is to encourage students to discover and to carry out research (in library and on internet) and make a report. One part of this activity should be done in class, the other (question number 4) as homework, and harmonized during the next lesson. The learner should have skills on electric circuits studied in S4, Unit 5 and S5, Unit 5. Those who did not study electricity in advanced level have probably studied electricity in Ordinary Level. This activity should be done in the Smart classroom or library.

- Introduce your lesson by discussion about the detection of radiations that are invisible rays. Let the learners brainstorm about this issues.
- Give instructions about the new activity
- Ask learners to open their books on page 24 and observe the figure of a smoke detector.
- When they finish, recommend them to present their results to the whole class. This is the opportunity for the teacher to note similarities, misconceptions and errors of the learners as they present. They will be harmonised in the next step.

- The teacher helps learners to harmonise and summarise the content. Let them write the summary on their notebooks.
- After they are done, allow learners to read questions number 4. This is a question for research, using library or Smart classroom. Give them at least 20 minutes to finalise the work, which will be presented as a report.
- You should allow the learners to present their working one group after another, and then conclude the lesson by writing the summary.

## Expected answers

1. A: radioactive detector, B: Battery, C: alarm circuit, D: alarm.
2. A smoke detector is a life-saving device that uses radioactive substances and is used in houses. They detect smokes in the house and give an alert that something like smoke is in the house (or the house gets fire) so that intervention is needed in urgency.
3. The functioning of a smoke detector.

A tiny quantity of radioactive americium dioxide emits alpha particles, which ionize air molecules and consequently, permit a small current to flow between the plates.

When Smoke particles arise, they absorb the radiation and cause the current to drop significantly, thus activating an alarm circuit.

4. Other radiation detectors include, Ionization Chamber, Proportional Counter, Geiger-Müller Counter, Semi-conductor detector, Neutron Detector, Scintillation Counter, and Cerenkov Counter, Photographic Emulsion, Expansion Cloud Chamber, Diffusion Cloud Chamber, Bubble Chamber, Spark Chamber

## Checking my progress

1. D. Beta particle (definition)
2. B. Atoms spontaneously break apart to produce energy. Beta decay, alpha decay and positron emission are all forms of radioactive decay. Energy is released because for the nucleus to become stable the excess energy must be released
3. B. The ratio for small stable atoms is 1:1, and the ratio for large stable atom is greater than 1:1. As atomic weight goes up, the ratio of neutrons to protons for stable atoms increases up to as much as 1.8:1 ratio.
4. A. Polonium-214 the alpha decay removes 4 from the mass number and 2 from the atomic number. The net result is a decrease of 4 in the mass number and no change in the atomic number

5. (a) Charge: alpha (+2), beta (-1) and gamma (no charge)

(b) Range in air: alpha (about 5cm); beta (about 500 cm) Gamma (no limit)

Alpha particles are stopped by a thin paper; beta particles pass through paper and cardboard and but are stopped a 2 mm thick aluminium sheet. Gamma radiations penetrate all materials but are only stopped by thick lead (4 cm) thickness or concrete blocks.

6.

a) (i) radioactive decay is the disintegration of unstable nuclei in an attempt to achieve stability

(ii) The half-life of a radioactive substance is the time taken for half of the unstable nuclei to decay.

$$\text{b)(i)} \quad 32 \text{ g} \xrightarrow{T_1/2} 16 \text{ g} \xrightarrow{T_1/2} 8 \text{ g} \xrightarrow{T_1/2} 4 \text{ g} \xrightarrow{T_1/2} 2 \text{ g}$$

$$4T_{1/2} = 96 \text{ days} \Leftrightarrow T_{1/2} = \frac{96}{4} = 24 \text{ days}$$

$$\text{(ii)} \quad 2 \text{ g} \xrightarrow{T_1/2} 1 \text{ g} \xrightarrow{T_1/2} \frac{1}{2} \text{ g} \xrightarrow{T_1/2} \frac{1}{4} \text{ g} \xrightarrow{T_1/2} \frac{1}{8} \text{ g}$$

$\frac{1}{8}$  g would remain after a further 96 days.

## Lesson 4: Application of Radioactivity

### a) Introduction

This lesson is divided into two parts. Part one refers to application of radionuclides in industry, in tracers studies, in nuclear power stations and nuclear fusion. Part two refers to applications in Medicine, agricultural sector and in food preservation and radiocarbon dating. The objective of this activity is to initialize learners to the discoveries of Physical facts by research activities. Through this lesson, problems solving and lifelong learning generic competences will be developed.

Using internet and library, learners will understand advantages of radioactive nuclides in real life. Therefore encourage them to think critically on advantages or uses of radioactive materials. Do not interrupt them when they brainstorm on this activity. Organise your class and tasks for better time management.

### b) Teaching resources: Textbooks, Internet and library

### c) Learning Activities

#### Activity 4.6 Use of nuclear energy to generate electricity

The following guidelines are set to facilitate teacher in teaching and learning process in activity above:

- Introduce your lesson by giving instructive guidelines of pair groups.
- Ask them to open books activity 4.6 in learn book and observe figure 4.6.
- Let them read in pair and answer to questions. After a while, tell them to exchange their works with other pairs. Give them a time to read and analyse other's views. This is a pair share exercises.
- Ask them to finalise the work and invite 3 or 4 pairs to present their final answers, looking whether there are differences or similarities. Take notes of them.
- Harmonize the activity by adding additional information about what the learners have not mentioned.
- After that, distribute learners in groups depending on the size of the class. Instruct them about the new activity of research. Tell them what to do and where to find information.
- When they finish (during about 25 minutes), the learners will present their new findings. The teacher supervises presentations. Engage learners in learning from other's views.
- Summarise your lesson by correcting misconceptions and bridge the lesson with cross-cutting issues found in the lesson, e.g. financial education, peace and values education, sustainable environment, etc.

### Expected answers

1. People are disagreeing because they think about the security of their live and environment in general. It is difficult to control radiations from nuclear power station. In addition, one country may pretend to use nuclear power plant to generate electricity while it is producing nuclear weapons.
2. Main parts are Reactor, steam generator, Turbine, Cooling towers and Generator
3. Nuclear energy- Heat energy- Mechanical energy- Electrical energy.
- 4.

Advantages of using nuclear energy as a source of electricity	Disadvantages of nuclear energy as a source of electricity
very large release of electricity	High cost to implement
Low cost electricity	Lack of skilled people
	Lack or insufficient equipment
	Lack of natural resources
	Difficult to monitor and to control

5. Other application of radioactivity: It is used in carbon dating, in medicine, in agriculture, tracer studies, food preservation and in industry

### Activity 4.7

- In groups, ask learners to open books activity 4.7 and observe clearly the figure 5... Tell them to observe it and read attentively the questions. Remind them to use their notebooks while giving the answers
- You may move to mark answers of learners. When the time assigned to the exercise is finished, invite them to present their findings.
- Harmonise the lesson by putting additional information in order to consolidate the understanding. They write the summary
- Present another work of research. Ask them to use internet or library in order to investigate how radionuclides radiations are used in food preservation, in radiocarbon dating and in agriculture.
- Each group should have one task in order to save time. Guide each group, and assist those who may encounter difficulties in research. This research should have 25minutes
- When they finish, invite each group to present their findings. Monitor the group presentation so that you will add other missing elements that your learners did not mention.
- Harmonise the lesson by engaging learners to discover cross-cutting issues they found in the lesson. Give them a time to take notes and to pose pertinent questions they may have. You should prepare another assignment of search on internet to consolidate their skills.

### Expected answers

- 1) A man
- 2) In Hospital (Radiography department)
- 3) The image represent a human skeleton
- 4) He is suffering from thorax bones
- 5) Rectilinear propagation of light.
- 6) Reflection of light. Because the image shows thoracic bones.
- 7) It is gamma radiation

## Checking my progress

1. **Medicine:** Sterilization, Treatment of cancer, Diagnosis - Tracers and imaging  
**Food and Agriculture:** Fertilizers, Increasing genetic variability, Food irradiation and preservation and Control of fly pest
2. a) Telephones, TVs sets and computers, food we eat like banana, culinary utensils...  
b) They come from materials used to manufacture them. Some contains magnesium  
c) Cosmetics are sterilized with radiation to remove allergens (fig.4.1.5(a))  
Non-stick pans are treated with radiation to fix the non-stick coating to the pan (fig.4.1.5(b))  
Computer disks (e.g. Floppy disk) remember data better when they are treated with radioactive materials (fig.4.1(c)).

## Lesson 5. Dangers of radionuclides substances

### a) Introduction:

Through guided discovery, assist learners to describe the fig.5.14. You can make a recap using Prerequisite Knowledge of the previous lessons on advantages of radionuclides described above. You can use probing questions techniques to remind the learners the advantages of radionuclides. Apart from the picture, invite learners to continue research using different resources to further information about the dangers of radiations safety precautions when handling materials with radiations.

### a) Teaching resources: Textbooks, Library and internet.

### b) Learning Activities

#### Activity 4.8: Investigating the safety in a place with radiations

This activity aims at investigating risk management of radiations on human body. Engage learners in learning accurately in order to acquire skills and behaviours o radiations so that they preserve their life in class and outside the class.

- Start the lesson by asking learners to open their books. Let them observe the fig. 4.8
- Let learners discuss in their groups and find answers. Initiate learners to think on the impact of radiations to the human body and measures to be taken.
- Move around to see whether all learners are working. Mark answers of the learners.

- Ask one group to present its responses to the whole class.
- Ask other groups to mention the supplements answers which are not raised.
- Complete the learner's ideas that are incomplete and confirms correct answers.
- Harmonize learner's ideas.
- Connect the impact of radiations on human body to real life and focus on cross-cutting issues to be addressed. These include: financial education, standardisation culture, etc.

## Possible answers

1. Leukaemia and other immune system diseases, redness of muscles, stomach diseases when swallowed, sterility, DNA damage, Cancer of thyroid, cataracts of the eye.

2. Use of radiation level badges. Check the radiation level regularly. Store and transport radioactive materials in thick lead-walled containers. Use of remote control equipments behind thick glasses or lead walls to handle safely radioactive materials. They should be held with forceps and never touched with hands. No eating, drinking or smoking where radioactive materials are in use. Wash your hands thoroughly after exposure of to any radioactive materials. Any cuts in the body should be covered before using radioactive sources. Arrange the source during experiments such that the radiation window points away from your body

## 4.6 Summary of the Unit

### Nucleus and nuclide

A nucleus is composed of two types of particles: protons and neutrons. In representing nuclei, it is convenient to use the symbol  ${}^A_Z X$  to show how many protons and neutrons are present in the nucleus.  $X$  represents the chemical symbol of the element.

- The atomic number or the number of protons  $Z$  in the nucleus (sometimes called the charge number).
- The neutron number or the number of neutrons in the nucleus  $N$ .
- The mass number or the number of nucleons in the nucleus,  $A = Z + N$ .

Each type of atom that contains a unique combination of protons and neutrons is called **nuclide**

Depending on the combinations of protons and neutrons in the nucleus, nuclides can be classified in the following 3 categories: **Isotopes, Isobars and Isotones.**

## Mass defect and binding energy

The mass of a nucleus is less than the combined mass of its protons and neutrons (nucleons). The missing mass is called the mass defect. This observed mass defect represents a certain amount of energy in the nucleus known as the binding energy  $E_b$  calculated using the Einstein formula as:

$$E_b = \Delta mc^2$$

The binding energy is the energy released when a nucleus is formed from its constituent particles or the energy required to break up (to split) the nucleus into protons and neutrons.

Instead of looking at the total binding energy of a nucleus, it is often more useful to consider the binding energy per nucleon. This is the total binding energy divided by the total number of nucleons.

$$\frac{E_b}{A} = \frac{\Delta mc^2}{A}$$

## Radioactivity

Radioactivity is one of the dynamic properties of nuclei, in this process the system makes a transition from a high energy state to a low energy state by emitting  $\alpha$  and  $\beta$ -particles or  $\gamma$ -rays.

## Characteristics of radioactive substances

Radioactive substances (nuclides) present one or more of the following features

- The atoms of radioactive elements are continually decaying into simpler atoms as a result of emitting radiation
- The radiations from radioactive elements produce bright flashes of light when they strike certain compounds. The compounds fluoresce. For example, rays from radium cause zinc sulphide to give off light in the dark. For this reason, a mixture of radium and zinc sulphide is used to make luminous paints.
- They cause ionization of air molecules. The radiations from radioactive substances knock out electrons from molecules of air. This leaves the gas molecules with a positive charge.
- Radiations from radioactive substances can penetrate the heavy black wrapping around a photographic film. When the film is developed, it appears black where the radiations struck the film.
- Radiations from radioactive substances can destroy the germinating power of plants seeds, kill bacteria or burn or kill animals and plants. Radiations can also kill cancers.

## **Nuclear fission and nuclear fusion**

### **a) Nuclear fission**

Heavy unstable nuclides can be broken up to produce energy in a process called nuclear fission. When uranium decays naturally, alpha and beta particles are emitted. However, when uranium-235 is bombarded by neutrons it forms uranium-236. Uranium-236 is unstable and breaks down, splitting into two large particles and emitting three neutrons.

### **Advantages**

The energy can be released in a controlled manner in nuclear power station and used in driving steam turbines and produce electric power.

### **Disadvantages**

When produced in uncontrolled manner it will result in the fabrication of atomic bomb that may release a large amount of heat energy and damaging radiations. The emitted radiations have both short term and long term effect on the living things.

### **b) Nuclear fusion**

When lighter nuclides merge together in a process called fusion, energy is produced and mass is lost. For example, two heavy mass of hydrogen may fuse together to form helium and a neutron.

### **Applications**

Radioactive isotopes are widely applied in industries, in medicine, in agriculture, in carbon dating, in security, in tracer studies, in nuclear fission and fusion.

### **Dangers of radioactivity**

- Both beta particles and gamma rays can pass easily in the skin and can easily destroy or even kill cells, causing illness.
- They can cause mutations in a cell's DNA, which means that it cannot reproduce properly, which may lead to diseases such as cancer.
- Alpha particles cannot pass through the skin. However, they are extremely dangerous when they get inside your body. This can happen if you inhale radioactive material.

Safety precautions when Handling Radiations

The precautions taken by workers who deal with radioactive materials are:

- Wearing protective suits

- Wearing radiation level badges
- Checking the radiation level regularly
- Using thick lead-walled containers for transporting radioactive materials
- Using remote control equipment from behind thick glass or lead walls to handle radioactive materials.
- They should be held with forceps and never touched with hands.
- No eating, drinking or smoking where radioactive materials are in use
- Wash your hands thoroughly after exposure of to any radioactive materials
- Any cuts in the body should be covered before using radioactive sources
- Arrange the source during experiments such that the radiation window points away from your body

#### 4.7 Additional information for teacher:

##### Radioactivity at home

Everything we meet in our daily life may contain radioactive substances. Some of them are natural others are man-made. This is a simple fact of life. On the Earth, radiations are all around us, every day in our homes. Here are some items that contain radiation in far greater amounts than the iodine-131 found in the milk samples.

Products in your home that contain radioactivity, but are not hazardous to anyone's health, include smoke detectors, some foods, fertilizers and others.

Examples include:

- Bananas contain potassium, a metal that decays, releasing infinitesimal amounts of radiation.
- **Watches** - Some old watches and clocks, even gyroscopes, have dials painted in radium to make them glow in the dark. Radium emits Alpha and Gamma rays. More recently, Tritium, a radioactive isotope of Hydrogen, has been used to paint the dials, but it is too weak to penetrate the watch lens.
- **Smoke detectors** - Contain an alpha and beta ray producing radioactive isotope of the element Americium that senses smoke. This is sealed, though, and may not give you any reading.
- **TVs.** The X-rays emitting from TV and computer screens have much lower levels of radiation than medical images.
- **Brazil nuts**, which contain radium that the trees absorb from the ground. Many other plants have naturally occurring radiation from metals in the soil.

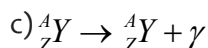
- **The house** itself. Radon, a naturally occurring radioactive gas, can become trapped inside walls and basements, elevating long-term cancer risks. You can test your home with an inexpensive kit or have a professional do it.
- **Camera Lenses** - It has been reported that certain old Leica camera lenses coloured yellow owe their appearance to the presence of the radioactive element, Thorium.
- **Pottery** - Some older pottery such as the Fiesta Ware brand often found in antique stores is glazed with Uranium oxide. When broken, the dust can emit Alpha particles of radiation.
- **Furniture** - More recently, certain metal objects in the home are reported to be partly made of spent radioactive material.

Do not consider that all types of a certain materials or objects contain radioactivity or emit radiation; for example, some smoke detectors and old watches contain radioactivity, but not all do. And these radioactivity-containing elements don't pose a radiation hazard to you unless you were to eat them—and eat a lot of them!

1. a) F,                      b) T,                                      c) T,                                      d) F                      e) T
2. a) T,                      b) T,                                      c) F,                                      d) F,                      e) T
3. a) F,                      b) T,                                      c) F,                                      d) F,                      e) T
4. B,                      5 C,                                      6 B,                                      7 B,                      8.E,
- 9.B                      9. B                                      c. 10. D

a)400

c)Carbon -14,age



Type of Emission	Mass	Charge	Penetrating power	Ionization ability
Alpha	$6.66 \times 10^{-27} \text{ kg}$	$2^+$	5 cm of air	Yes
Beta	$9.31 \times 10^{-31} \text{ kg}$	$\beta^-$ negative $\beta^+$ positive	3 - 6 mm of Aluminium	Yes
Gamma	None	None	30 cm of lead	Yes

a) What are the properties of alpha radiation?

Alpha particles are made up from 2 protons and 2 neutrons. They have a charge of +2 and a relative mass of 4. They are highly ionizing but not very penetrating. They are affected by electric and magnetic fields.

b) How do you calculate the half-life from a graph?	Choose a point on the Y-axis and then halve the number of un-decayed nuclei from the Y-axis and count the corresponding amount of time on X-axis.
c) What is the difference between contamination and irradiation?	An object or a person would be contaminated if unwanted radioactive particles get on them or into them. An object or a person would be irradiated if exposed to radiations
d) How should radioactive samples be handled safely?	Always point away from yourself and others, never handle sources with your fingers: use tongs, only remove sources from their lead lined box when in use and do not eat or drink when using radioactive sources.

14. a)  $x = 82$  and  $y = {}_{-1}^0e$       b)  $x = 214$  and  $y = 84$

c)  $x = 226$  and  $y = 88$       d)  $x = {}_2^4He$  and  $y = 84$       e)  $x = {}_1^3H$

15. a)  $x = 83$  since  ${}_{-1}^0e$  is by definition a  $\beta^-$  particle, the reaction  $\beta^-$  decay.

b)  $x = 82$  and  $y = 206$  The reaction is  $\gamma$  decay, since 2 protons and 2 neutrons are emitted.

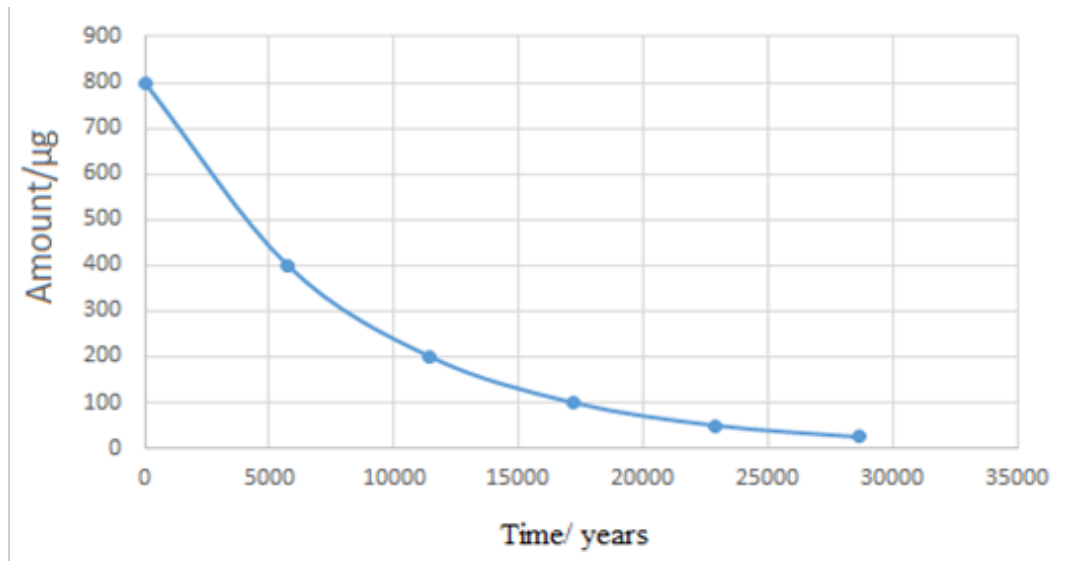
c)  $x = {}_{-1}^0e$  The increase by 1 in the atomic number and the lack of change in the mass number together indicate that a proton appeared, therefore this is a  $\beta^-$  decay.

d)  $x = 88$  and  $y = 226$ , since the process is decay, neither the atomic number nor the atomic mass number is changed.

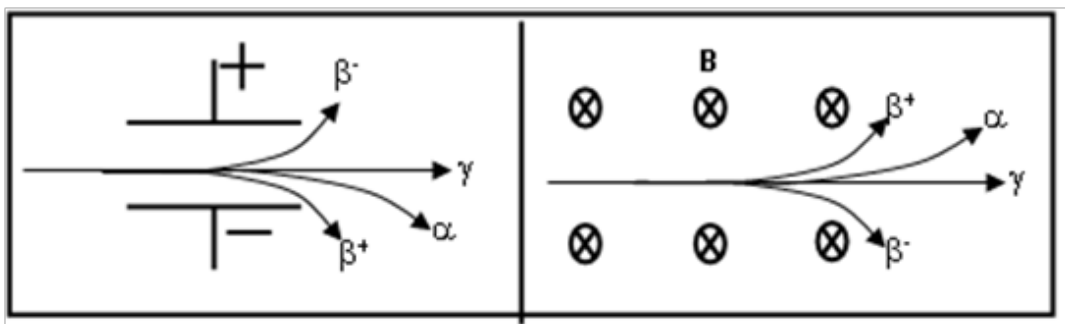
16. After 5730 years the amount of carbon-14 remaining will be one-half the original amount or 400  $\mu\text{g}$  in amount 5730 years it will be one-half as much again. This reasoning allows you to make the calculation summarized in the table below and construct a plot.

Time (years)	0	5730	11460	17190	22920	28650
Amount ( $\mu\text{g}$ )	800	400	200	100	50	25

Graph of isotope of carbon-14 against its half-life



17 a. The charged particles are deflected and follow a curved path in an electric or magnetic field. The  $\gamma$  particles are uncharged and hence are not affected. The  $\alpha$  are charged, but are very heavy and are less deflected than the  $\beta$



b) The  $\gamma$  particle is the most penetrating because it has neither mass nor charge, hence it interacts relatively weakly with matter.

c) The  $\alpha$  particle has the highest ionizing power, with the largest charge ( $+2e$ ), but are not very penetrating.

d)  $\beta$  and electrons are exactly the same, they were named  $\beta$  before it was known that they were electrons.  $\beta^+$  are positrons, or positively charged electrons. They have the same mass as an electron, and the same magnitude of charge, but are positive.

e) X-rays and  $\gamma$  rays are both photons, they have no charge and no mass.  $\gamma$  Rays have higher energy (and higher frequency) than x-rays, and both are higher energy than photons of visible light.

18.a) Background radiation comes from many sources; from outer space, from the earth and from inside our bodies. Radiation from outer space, called cosmic radiation, comes from exploding stars and from the Sun and includes penetrating gamma rays and fast moving nuclear particles. The rocks and soils on earth contain small quantities of radioactive uranium, thorium and potassium-40 with their daughter products. The radioactivity levels in granite areas are higher due to a greater concentration of these elements. Indeed, the natural background activity is 2 to 3 times higher than the average background radiation in these areas. Small traces of naturally occurring isotopes (potassium-40 and carbon-14) are present inside all of our bodies!

b) The lungs generally receive the highest dose of radioactivity, from airborne radioisotopes such as radon-222 gas. The lungs exchange more material with the environment than any other organ. Smokers may have a much higher dosage rate than non-smokers as many cigarettes use tobacco which is dried in the open air and accumulates radon dust which settles on it.




c) The background radiation at higher altitudes is greater because of a higher cosmic radiation. The atmosphere acts as a shield and attenuates (reduces) the cosmic radiation reaching the earth considerably. Thus as one goes to higher altitudes, the 'filtering' action of the atmosphere is reduced. For example, the mean dose rate at sea level is 0.2 mSv/year whereas the dose rate at 4 000 m is 1 mSv/year (one millisieverts per year). This is the reason that pilots and flight attendants have a higher exposure to radiation than most other people as they spend a lot of time at high altitudes.



19.a) The process of  $\alpha$  decay can be modelled as a particle in a potential well (the nucleus) escaping from the well.  $\alpha$  Decay is possible because the potential energy well is not infinitely deep. When the potential energy well is not infinite the wave function of the trapped particle extends beyond the walls, and hence the probability of its existing outside the well, which is equal to the square of the wave function, is non-zero. This process of a particle escaping the well is called tunnelling.

b) The higher the energy of the emitted  $\alpha$  particles for a given element the shorter the half-life. The probability of tunnelling increases with increasing energy of the trapped particle (the  $\alpha$  particle), hence the higher the energy, the greater the probability of decay, the more decays per unit time and the shorter the half-life. (The tunnelling probability also depends on the barrier height.)

c) A nucleus can change its charge by capturing an electron from one of the inner orbitals, turning a proton into a neutron. In the process a tiny uncharged particle called a neutrino is emitted.

## 4.8 End Unit Assessment

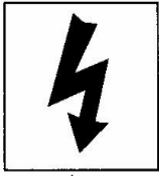
Types of compounds +description	Symbol	Risks	Precautions
<p>Compressed gas</p> <p>Material that is normally gaseous and kept in a pressurized container.</p>		<p>Could explode due to pressure</p> <p>Could explode if heated or dropped</p>	<p>Ensure container is always secured</p> <p>Store in a designated area</p> <p>Do not drop or allow to fall</p>
<p>Flammable combustible materials</p> <p>Material that continue to burn when exposed to a flame or near an ignition source</p>		<p>May ignite spontaneously</p> <p>May release flammable products when exposed to water</p>	<p>Ensure container is always secured</p> <p>Avoid flames and sparks</p> <p>Avoid heating</p> <p>Ensure that electrical sources are secured</p>
<p>Toxic materials immediate and severe</p> <p>Poisons and fatal materials that cause severe and immediate harm</p>		<p>Fatal if ingested or inhaled</p> <p>May be absorbed through the skin</p> <p>Small volumes have a toxic effect</p>	<p>Avoid breathing dust or vapors</p> <p>Avoid contacts with skin or eyes</p> <p>Wear protective clothing and face and eye protection.</p> <p>Work in a well-ventilated area and wear breathing protection</p>

<p>Bio hazardous infectious materials</p> <p>Infectious agents or biological toxin causing a serious disease and death</p>		<p>May cause anaphylactic shock</p> <p>Includes viruses, yeasts, moulds, bacteria and parasites that affect humans</p> <p>Includes fluids containing toxic products</p> <p>Includes cellular components</p>	<p>Avoid forming aerosols</p> <p>Avoid breathing vapors</p> <p>Avoid contamination of people and/or area</p> <p>Store in a designated areas</p> <p>Special training is required to handle materials</p> <p>Work in a designated biological areas with appropriate engineering control</p>
<p>Corrosive materials</p> <p>Materials which react with metals and living tissue</p>		<p>Eye and skin irritation on exposure</p> <p>Severe burns/tissue damage on longer exposure</p> <p>Lung damage if inhaled</p> <p>May cause blindness if contact with eyes</p>	<p>Wear body, hand, eye protection</p> <p>Use breathing apparatus</p> <p>Work in a well-ventilated area</p> <p>Avoid all direct body contact</p> <p>Ensure protective equipment is appropriate</p> <p>Use appropriate storage containers</p>

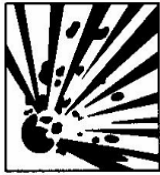
## 4.9 Additional activities

### 4.9.1 Remedial activities

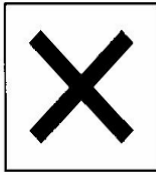
1. Which sign is used to indicate the presence of radioactive materials?



A



B



C



D



E

2. The activity of radioactive source is measured in
  - a. Joules
  - b. Becquerel
  - c. Sieverts
  - d. Grays
  - e. Watts
3. Which of the following choices lists the four known types of forces in nature in order of decreasing strength?

Electromagnetic, strong nuclear, weak nuclear, gravitational

Strong nuclear, gravitational, weak nuclear, electromagnetic

Strong nuclear, weak nuclear, electromagnetic, gravitational

Strong nuclear, electromagnetic, gravitational, weak nuclear

Strong nuclear, electromagnetic, weak nuclear, gravitational

4. The fact that the binding energy per nucleon is roughly a constant over most of the range of stable nuclei is a consequence of the fact that the nuclear force is
  - a. Short range.
  - b. Long range.
  - c. Weak.
  - d. Strong
  - e. Repulsive
5. The interaction that describes the forces among nucleons that hold nuclei together is
  - a. The electromagnetic interaction.
  - b. The weak nuclear interaction.
  - C. The strong nuclear interaction.
  - d.The gravitational interaction
  - e. None of these is correct.



(c) The atomic number of lead is 82; hence there are 82 protons in the nucleus and 82 electrons in the atom. The number of neutrons is  $206 - 82 = 124$ .

9. Average atomic weight  $\frac{0.9889 \times 12 + 0.0111 \times 13}{1.000} = 12.011$

#### 4.9.2. Consolidation activities

1. In one type of radioactive decay, an atom of Uranium ( $m=234.03714$  u) decays to an atom of thorium ( $m = 228.02873$  u) plus an atom of helium ( $m=4.00260$  u) where the masses given are in atomic mass units ( $1 \text{ u} = 1.6605 \times 10^{-27} \text{ kg}$ ). Calculate the energy released in this decay.
2. When two moles of hydrogen and one mole of oxygen react to form two moles of water, the energy released is 484 kJ. How much does the mass decrease in this reaction?
3. Calculate the total binding energy and the binding energy per nucleon for  ${}_{26}^{56}\text{Fe}$ , the most common isotope of iron.
4. What is the binding energy of the last neutron in  ${}_{6}^{13}\text{C}$ ?

#### Answer:

1. The initial mass is  $m = 232.03714$  u, and after the decay the mass is  $228.02873 \text{ u} + 4.00260 \text{ u} = 232.03133$  u, so there is a decrease in mass of  $0.00581$  u. This mass which is equal to  $(0.00581 \text{ u})(1.66 \times 10^{-27} \text{ kg}) = 9.64 \times 10^{-30} \text{ kg}$  is changed into energy.

$$\text{We have } \Delta E = \Delta mc^2 = (9.64 \times 10^{-30} \text{ kg})(3.00 \times 10^8 \text{ m/s})^2 = 8.68 \times 10^{-13} \text{ J}$$

Since  $1 \text{ MeV} = 1.60 \times 10^{-13} \text{ J}$ , the energy released is  $5.4 \text{ MeV}$

2. Using Einstein's equation, we have for the change in mass  $\Delta m$ :

$$\Delta \ddot{u} = \frac{\Delta E}{\ddot{u}} = \frac{(-4884 \times 10^{-3} \text{ J})}{(3.00 \times 10^8 \text{ m/s})} = -5.38 \times 10^{-12}$$

The initial mass of the system is  $0.002 \text{ kg} + 0.016 \text{ kg} = 0.018 \text{ kg}$ .

Thus the change in mass is relatively very tiny and can be neglected.

3. We subtract the mass of a  ${}_{26}^{56}\text{Fe}$  atom from the total mass of 26 hydrogen atoms and 30 neutrons. Then we convert mass units to energy units, finally we divide by  $A=56$ , the total number of nucleons.  ${}_{26}^{56}\text{Fe}$  has 26 protons and 30 neutrons whose separate masses are

$$26({}_1^1\ddot{u}) = 26(1.007825) = 26.20345 \quad \text{includes 26 electrons}$$

$$30\ddot{u}_n = 30(1.008665) = 30.25995$$

The sum is  $56.46340$  u therefore the mass defect is  $\Delta m = 0.52846$  u.

The total binding energy is thus  $E_b = (0.52846 u)(931.5 \text{ MeV} / u) = 492.26 \text{ MeV}$

And the binding energy per nucleon is  $\frac{E_b}{A} = \frac{492.26 \text{ MeV}}{56} = 8.79 \text{ MeV}$

4. We subtract the mass of  ${}^1_0\text{n}$  from the masses of the atom with one less neutron,  ${}^{12}_6\text{C}$ , and a free electron.

The mass of  ${}^{13}_6\text{C} = 12.00000 u$

The mass of  ${}^1_0\text{n} = 1.008665 u$

The total is  $13.008665 u$

Subtract the mass of  ${}^{13}_6\text{C}$  we get  $13.008665 u - 13.003355 u = 0.005310 u$

The energy produced is  $(931.5 \text{ MeV}/u)(0.005310 u) = 4.95 \text{ MeV}$ .

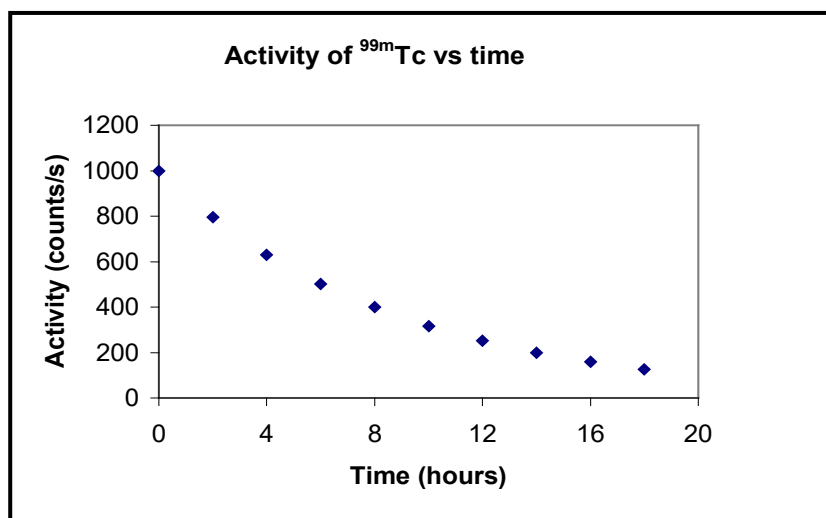
That is, it would require  $4.95 \text{ MeV}$  input energy to remove one electron from  ${}^{13}_6\text{C}$

#### 4.9.3. Extended activities

1. Show that if two ions of the same charge and velocity but different masses pass through a uniform magnetic field, the radii of the path are proportional to the masses. (This is the principle of mass spectrograph). Find an expression for  $\Delta m$  if  $\Delta r$  is a change in radius.
2. Technetium is used to image the brain, thyroid, lungs, liver, spleen, kidney, gall bladder, and skeleton and blood pool. It is the most commonly used radioisotope in medical imaging. The graph below is for a sample of  ${}^{99m}\text{Tc}$ .

Using the graph find:

- 1.a. What is the half-life of this sample?
- b. What is the decay constant for the sample?



2.  $^{133}_{54}\text{Xe}$  is a radioactive gas which is used in studies of lung function. It has a decay constant  $\lambda = 1.51 \times 10^{-11} \text{ s}^{-1}$ . You have just taken delivery of a 4.0 MBq sample for an experiment you wish to conduct.
- What is the half-life of  $^{133}_{54}\text{Xe}$  in seconds and in days?
  - What will be the activity of your sample in 15.93 days? In 18 days?

The experiment you wish to conduct requires an activity of at least 3.0 MBq.

- How long do you have before finding a volunteer subject?
  - What mass of  $^{133}_{54}\text{Xe}$  did you initially acquire?
3. Nuclear power is used in many places in the world. There are over 400 nuclear power plants currently in operation, over 100 of which are in the USA, providing 20% of the electricity consumed in that country. These plants use uranium fuel ( $^{235}_{92}\text{U}$  enriched with 3%  $^{235}_{92}\text{U}$ ) to produce electricity. It is the fission of the  $^{235}_{92}\text{U}$  nuclei which provides the majority of the thermal energy that is used to generate the power.
- Complete the following decay equation:  $^{235}_{92}\text{U} + n \rightarrow ^{93}_{37}\text{Rb} + ^{141}_{55}\text{Cs} + \underline{\hspace{2cm}}$
  - Use the data in the table below to find the energy released in this reaction.
  - How many decays per second would it take to run a 60W light globe?
  - If a power plant only converts 10% of the excess mass into useful energy, how many decays per second would you need?

Useful masses:

Particle	$^{235}_{92}\text{U}$	$^{93}_{37}\text{Rb}$	$^{141}_{55}\text{Cs}$	$^4_2\alpha$		
Mass (amu)	235.04392	92.92172	140.91949	4.002603	0.000545	0.0000000

- $\lambda = 1.660566 \times 10^{-27}$
- Electromagnetic Radiations from mobile towers can have multi-faceted harmful effects on human body. Using research on internet, investigate different effects caused by mobile towers in your region while exposed near them.

## Answers

1. a) we can write the following relations:

$$\frac{m_1 v^2}{r_1} = \ddot{u} \quad (1)$$

$$\frac{m_2 v^2}{r_2} = \ddot{u} \quad (2)$$

By equating equation (1) and equation (2) and simplify, we get  $\frac{m_1}{m_2} = \frac{r_1}{r_2} \Rightarrow r \propto m$

b) Let us then take equations (2)-(1). We get.

$$(m_2 v^2 - m_1 v^2) = (r_2 - r_1) qvB$$

Hence  $\Delta mv = \Delta r qB \Leftrightarrow \Delta m = \frac{qB}{v} \Delta r$

2.a. The half-life,  $T_{1/2}$ , is given by,  $T_{1/2} = \frac{0.693}{\lambda} = \frac{0.693}{1.51 \times 10^{-6} \text{ s}^{-1}} = 458\,940 \text{ s} = 5.31 \text{ days}$

b. After 15.93 days, this is 3 half-lives.

The activity reduces by two for each half life, after 1st half life activity = 2 MBq, after 2nd half-life activity = 1 MBq, and after 3rd half-life activity = 0.5 MBq.

Hence the activity after 15.93 days (i.e., 3 half-lives) is 0.5 MBq

After 18 days, one must use the relationship,  $A = A_0 e^{-\lambda t}$  Now  $\lambda = 1.51 \times 10^{-6} \text{ s}^{-1}$

and  $t = 18 \text{ days} = 18 \times 24 \times 3600 \text{ s} = 1.56 \times 10^6 \text{ s}$

Hence  $A = A_0 e^{-\lambda t} = 4 \times 10^6 \times e^{-2.35} = 3.8 \times 10^5 \text{ Bq}$

c. Again we use  $A = A_0 e^{-\lambda t}$

Here we are given the activity after a certain time, A, as 3 MBq. The initial activity is 4 MBq and one needs to find the value of the time, t:

$$3 = 4e^{-\lambda t} \quad \text{or} \quad 0.75 = e^{-1.51 \times 10^{-6} t}$$

As t is in the exponent part of the equation, one needs to find the logarithm of both sides; in this case, the natural log of both sides is the more appropriate. Note that the time, t, will be expressed in seconds since  $\lambda$  is given in s<sup>-1</sup>.

$$\ln(0.75) = -1.51 \times 10^{-6} t \quad \text{and} \quad -0.288 = -1.51 \times 10^{-6} t$$

Hence,  $t = 190\,518 \text{ s} = 52.9 \text{ hours} = 2.2 \text{ days}$

d. By definition, 1 g of radium-226 has an activity of  $3.7 \times 10^{10} \text{ Bq}$ .

That is, it has a specific activity of  $3.7 \times 10^{10} \text{ Bq/g}$ . If we have a radionuclide of shorter half-life and smaller atomic mass, then it will have (in direct proportion) a greater specific activity than Ra-226. (Note for Ra-226,  $T_{1/2} = 1600 \text{ years}$  and  $A_R = 226$ ).

Hence, the specific activity of any nuclide, X, of half-life  $T_x$  and atomic mass  $A_x$  is given by,

$$\text{Specific activity} = 3.7 \times 10^{10} \times \frac{226}{A_x} \times \frac{1600 \text{ years}}{T_x (\text{years})}$$

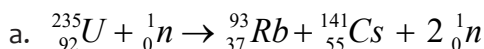
The only restriction with units is that both half-lives should be in the same units of time. In our case,  ${}_{54}^{133}\text{Xe}$  has a half-life of 5.31 days and has an atomic mass of 133. Hence;

$$\text{Specific activity of } {}_{54}^{133}\text{Xe} = 3.7 \times 10^{10} \times \frac{226}{133} \times \frac{1600 \times 365 \text{ days}}{5.31 \text{ days}} = 6.9 \times 10^{15} \text{ Bq} \cdot \text{g}^{-1}$$

That is, 1 g of  ${}_{54}^{133}\text{Xe}$  has an activity of  $6.9 \times 10^{15}$  Bq, or  $1/6.9 \times 10^{15}$  g has an activity of 1 Bq. Hence 4 MBq (initial activity) will have a mass of  $4 \times 10^6 / 6.9 \times 10^{15}$  g, which is  $5.8 \times 10^{-10}$  g.

This very small mass is the amount of pure Xe-133 gas which is mixed with the non-radioactive (Xe 131) part.

### 3. Energy from nuclear reactions.



b. The energy released is given by  $Q = m_i c^2 - m_f c^2$

$$Q = (235.043924 \text{ u} + 1.00866501 \text{ u}) - (92.92172 \text{ u} + 140.91949 \text{ u} + 2 \times 1.00866501 \text{ u}) c^2 = 2.9 \times 10^{11} \text{ J}.$$

To run a 60 W light globe we need 60 J in one second. The number of decays, n, is:

$$n = \frac{60 \text{ J}}{2.9 \times 10^{-11} \text{ J}} = 2.068 \times 10^{12} = 3 \times 10^{12}.$$

c. A power plant only converts 10% of the excess mass into useful energy, so we only get the energy from one in every ten decays, hence we need

$$10 \times 3 \times 10^{12} = 3 \times 10^{13} \text{ decays}.$$

### 5. Headache, Nausea, Brain Tumours, Dizziness, Depression, Paralysis, Insomnia, Muscles Pain, Alzheimer, Infertility, Miscarriage...

# UNIT 5: APPLICATIONS OF OPTICAL FIBER IN TELECOMMUNICATION SYSTEMS

## 5

### 5.1 Key Unit Competence

Differentiate optical fiber transmission and other transmitting systems.

### 5.2 Prerequisite knowledge and skills

The success of this unit 6 relies partly on the mastery of knowledge and skills acquired in Physics (Unit 1 and unit 2, S4& Unit 11, S5 Advanced Level) and other subjects in previous grades or units such as Physics of Ordinary Levels (Unit 13, S1, unit 14, S2, Unit 12 and Unit 13, S3).

### 5.3 Cross-Cutting Issues to be addressed

The following cross cutting should be addressed in this unit. Depending on the situation, they should appear at the beginning, through the lesson or at the end of the lesson

**Inclusive education** (The teacher must promote education for all while teaching). Regardless of physical appearance and abilities, learners should be treated equally. This makes all learners to be involved in teaching and learning process. They find out that they are all of great importance.

**Peace and value Education** (This is the respect of others views and thoughts during class discussions). Remember that someone's idea is very important. It may be correct or not but what is important is to build on that idea.

**Gender education** (equal opportunity of boys and girls in the lesson participation). Care should be taken that both Sexes are given equal opportunities.

**Standardization culture** (Be aware of radiations that do not harm our health). The teacher puts emphases on different types of optical fiber and shows their standards so that learners are aware of the best types they should use in real life.

**Financial education:** The teacher should show the role of optical fiber in telecommunication how it is efficient in order to encourage learners to save their money while using internet connectivity.

**Environment sustainability:** be aware of materials in optical fiber that harm our environment.

## 5.4 Guidance on the introductory activity

This activity aims at capturing students' attention and minds towards the new concept of optical fiber.

- Divide your students into groups (Grouping may depend on the nature of your class or number of learners you have). Always take care of learners with any kind of disability while making groups (hearing, reading, seeing, etc.).
- Tell the learners to open the introductory activity in the learner's book. Give them clear information about the activity.
- Ask learners to observe and read the text below the figure before answering questions. While learners are doing this activity, you move around, guide or answer to the questions of slow learners. You may mark the working of those who have finished.
- When everyone has finished the activity, invite some member(s) of group(s) to present their findings to the whole class. Guide the presentation.
- Ask other groups to present what others did not raise or mention.
- Note some misconceptions and misunderstanding so that they will be corrected and harmonised in the lesson. Together with students harmonize the points and make a summary on the board. Give to learners the opportunity to write the main points in their notebooks.
- Harmonize the lesson by linking what have discussed and the summary of the lesson.
- Summarize your lesson by linking this concept to real life situations.

## Possible answers of the introductory activity

1. Figure 6.1 has three images: On image A, there are bundles of optical fiber installation. It is probably in one of the towns of Rwanda. On figure B, the activities of fiber installation are ongoing. Two parts of fiber optics will be connected together. Part C is either the receiver or emitter of fiber optical signals. It is called transducer.
2. Internet for All" project is a Rwandan policy to connect the whole country to available internet connectivity by using fiber optics
3. Challenges are: digital skills gap, limited infrastructure, lack of capital, unskilled people to exploit internet to maximum...
4. Transfer of information, internet connectivity and communication.
5. Used in surgery, used as a source of light, used to transport laser ray

## 5.5 List of lessons

S/ No	Lesson Title	Learning Objectives	Periods
1	Introductory activity and Principles of Operations of Optical Fibers	<ul style="list-style-type: none"> <li>• Explain the functioning of optical fiber</li> <li>• Identify and explain the components of optical fiber system</li> </ul>	4
2	Types of Optical Fibers	<ul style="list-style-type: none"> <li>• List and explain the functioning of different types of optical fiber</li> <li>• Describe telecommunication system</li> </ul>	2
3	Mechanism of Attenuation	<ul style="list-style-type: none"> <li>• Explain attenuation and Solve problem related to attenuation giving answers in decibels</li> <li>• Describe functions of amplifiers in optical fiber transmission</li> <li>• Describe noise production in optical fiber</li> </ul>	3
4	Optical Transmitter and Optical Receiver	<ul style="list-style-type: none"> <li>• Explain the major role of optical transmitter and optical receiver</li> <li>• Analyse the difference between optical transmitter and optical receiver.</li> </ul>	3
5	Uses of Optical Fibres	<ul style="list-style-type: none"> <li>• Distinguish optical fiber and other telecommunication systems</li> <li>• Recognize the importance of fiber optics in communication</li> </ul>	2

	Advantages and Disadvantages of Optical Fibres	<ul style="list-style-type: none"> <li>• Appreciate significance of optical fiber telecommunication system</li> <li>• Acknowledge reshaping of signals transmitted along an optical fiber reduces noise effects</li> </ul>	2
6	Evaluation		2

## LESSON 1: Principles of Operations of Optical Fibers

### a) Introduction:

Through guided discovery, assist learners to the figure on learner's book. You can make a recap using Units of Physics mentioned above on Prerequisite Knowledge. You can use probing questions techniques to remind the learners the laws of reflection and refraction of light.

### b) Teaching resources

Textbooks

### c) Learning Activities

#### Activity 5.1 Investigating the stable and unstable nucleus

This activity aims to capture students' attention and minds them towards the concept of optical fiber. Therefore, the following guidelines should help the teacher to monitor the lesson efficiently.

- Divide your students into groups, accordingly. Tell the learners to open and read the activity 6.2 in the learner's book.
- Instruct learners to observe fig.6.2 and read the questions and answer them by writing in their notebooks. Give them the time to reflect on their prior knowledge (thinking time).
- While students are doing this activity, you move around and mark the work of those who have finished.
- When everyone is done, invite some groups to present their findings to the whole class. Make sure that you are developing generic competences in your learners: cooperation, critical thinking, etc.
- Inquire from other students or groups whether their answers correspond to the ones discussed. If not, invite them for the presentation of new ideas.

- Together with students harmonize the points discussed and make a summary on the board. Linking to the summary and what have been discussed in class, this will be the opportunity for the teacher to correct misconceptions met during presentation.
- Allow learners to write the main points in their notebooks. Make summative assessment to make sure that learning objectives have been achieved.
- Link this lesson to real life. You should talk about cross-cutting issues to be addressed in this lesson like peace education.

## Possible answers

1. The term critical means an angle of incidence beyond which rays of light passing through a denser medium to the surface of a less dense medium are no longer refracted but totally reflected. When the angle of incidence is critical angle, the angle of refraction is 90°.
2. Total internal reflection is caused by the differences in optical media. The medium of incidence is denser than the medium of refraction.
3. Uses of total internal reflection
  - i. Reflecting prisms. In optical instruments, right-angled prisms are widely used to divert the course of light rays. As the total internal reflection takes place within them, the loss of light energy can be kept to a minimum. So, the prisms are preferred to mirrors for the purpose of reflection.
  - ii. Mirage: On hot summer days or in the deserts, patches of water appear to us, some miles in front of us, only to find none when we approach them. This phenomenon is caused by the total internal reflection. The air layers on the ground become hot and less dense in these places and light, when comes down has to pass through these less-dense layers. At a certain point, the light exceeds the critical angles and the total internal reflection takes place on a vast scale, creating the illusive puddles of water.
  - iii. The sparkles inside diamonds are cause by total internal reflection. Diamond is well-known for its toughness. It has a large refractive index compared with the air. Therefore, when light enters a diamond, the possibility of it being subjected to total internal reflection is very high, that in turn causes sparkles.
  - iv. Optic fibres revolutionized the communication that we take for granted today. This device with a thin flexible glass fibre with a coating, carries light through a distance of kilometres and kilometres, with a very little loss of its energy. This is possible because of total internal reflection
  - v. Medical uses - the endoscope

## Checking my progress

- 1-a,
- 2-D,
- 3-B
4. We know that the critical angle is given by  $\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) = \sin^{-1}\left(\frac{1}{1.33}\right) = 48.8^\circ$

The critical angle for light travelling from water to air is  $48.8^\circ$

5.  $n_1(\sin \theta_1) = n_2(\sin \theta_2)$  and  $(0.1)(\sin 30) = n_2(\sin 20)$  Then  $n_2 = 1.46$

and  $n_1(\sin \theta_1) = n_2(\sin \theta_2)$

Therefore  $\theta_2 = 48^\circ$

a.  $\sin n_c = \frac{n_2}{n_1} \Rightarrow \sin n_c = \frac{1}{2.42} \Rightarrow n_c = 24.4^\circ$

b. (i) Refraction occurs

(ii) Total internal reflection occurs and light reflects back in at  $24.4^\circ$

## Lesson 2: Types of Optical Fibers

### a) Introduction

In this lesson, you are going to guide learners to discover types of optical fiber using research. You can use remind them how to use books or search engines on internet while making a scientific research.

### b) Teaching resources:

Textbooks library or internet

### c) Learning Activities

#### Activity 5.2 Investigating the types of optical fibers

The activity aims to capture students' attention and develop critical thinking and collaboration on learners. The learners will be encouraged to make a scientific research using different resources in order to get information about types of optical fibers.

- Divide your class into groups according to the number of learners you have.
- Assign each group a task to be carried out. Give them instructions or guidelines of the research.
- Supervises them while working to avoid laziness or misconduct in the lesson.
- Ask them to write a report on what they found.
- When they finish (after a reasonable time for this activity), invite them to re-join their class and make presentation. Each group present its findings.

- From the presentations of learners, help them to summarize the content based on the facts of optical fiber. Write the summary and ask learners to copy it in their notebooks.
- Remember to conclude your lesson by connecting it to real life situation

### Possible answer

There are three types of optical fibers: Monomode, multimode and multipurpose optical fiber. Multimode are classified into step-index multimode type and graded index multimode type. Multipurpose fiber optics are Polarization-maintaining and Photonic-crystal fiber.

Monomode fibers use a straight transmission called one mode. Multimode fiber optics use light that travels through the fiber following different light paths called “modes”.

Multipurpose fiber optics are used either as fiber optic sensors or as diffracting materials of light

### Checking my progress

1. False      2. H      3. C

#### 4. Match the words of column A to their meaning of column B

Column A	Column B
Multimode fiber	The core is only 5µm in diameter, and the only one straight path for transmission.
Photonic-crystal fiber	Is commonly used in fiber optic sensors due to its ability to maintain the polarization of the light
Graded index multimode type	Light travels through the fiber following different light paths called “modes
Mono mode fiber	The refractive index of the glass varies continuously from a higher value at the Centre of the fiber to a low value at the outside,
Polarization-maintaining fiber	Such fiber uses diffraction effects instead of or in addition to total internal reflection, to confine light to the fiber’s core.

1→c      2→ e      3→d      4→ a      5→b

## Lesson 3: Mechanism of Attenuation

### a) Introduction

In this lesson, you are going to guide learners to answer to questions related to the provided activity. In this activity, learners will discover defects or power loss of optical fiber and how this problem may be handled. The teacher must create a good climate of learning and teaching.

### b) Teaching resources: Textbooks

### c) Learning Activities

#### Activity 5.3 Light transmission analysis in optical fiber

The activity aims to capture students' attention and develop critical thinking and collaboration on learners. The learners will be encouraged to respond actively in their respective groups.

- Divide your class into groups according to the number of learners you have.
- Ask learners to open their books on activity 6.3 and read the questions on figure provided. Supervises them while working to avoid laziness or misconduct in the lesson.
- Ask them to rise a hand if they have finished. Mark their responses.
- When all of them finish (after a reasonable time for this activity), invite them to do presentation. Each group present its findings.
- From the presentations of learners, help them to summarize the content based on the facts of optical fiber. Together with students develop the summary and ask learners to copy it in their notebooks.
- Remember to conclude your lesson by connecting it to real life situation and emphasize on cross-cutting issues.

#### Possible answer

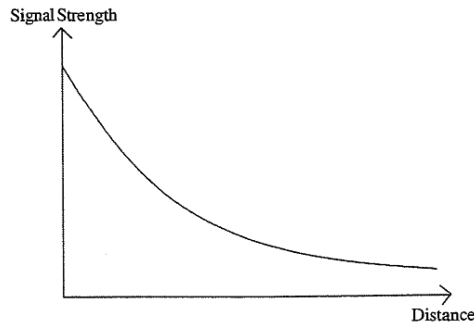
1. No some amount of energy are scatted away and do no reach the destination.
2. Poor optical fiber, absorption, leakage in fiber optics, bad connectors used, impurities in the glass fiber, low refractive index and so on.
3. Use of different devices such as Repeaters, Regenerators and Optical Amplifiers

#### Checking my progress

1. False
2. True
3. True

## Answers

- Attenuation is the measure of the rate of loss of signal strength along the length of the fiber.
- Energy is lost by the scattering and absorption of the light rays as they travel through the glass fiber.
- After each km, it retains 95% of the signal strength it had at the beginning of that km. this leads to an exponential decay curve.



## Lesson 4: Optical Transmitter and Optical Receiver

### a) Introduction:

Through guided discovery, assist learners to the figure on learner's book. You can make a recap using Units of Physics mentioned above on Prerequisite Knowledge. You can use probing questions techniques to remind the learners the laws of reflection and refraction of light.

### b) Teaching resources: Textbooks

### c) Learning Activities

### Activity 5.4 Investigating the signal sources and signal receiver for optic fibers

This activity aims to capture students' attention and minds them towards the concept of optical fiber. Therefore, the following guidelines should help the teacher to monitor the lesson efficiently.

- Divide your students into groups, accordingly. Tell the learners to open and read the activity 5.4 in the learner's book.
- Instruct learners to observe fig.5.4 and read the questions and answer them by writing in their notebooks. Give them the time to reflect on their prior knowledge (thinking time).
- While students are doing this activity, you move around and mark the work of those who have finished.

- When everyone is done, invite some groups to present their findings to the whole class. Make sure that you are developing generic competences in your learners: cooperation, critical thinking, etc.
- Inquire from other students or groups whether their answers correspond to the ones discussed. If not, invite them for the presentation of new ideas.
- Together with students harmonize the points discussed and make a summary on the board. Linking to the summary and what have been discussed in class, this will be the opportunity for the teacher to correct misconceptions met during presentation.
- Allow learners to write the main points in their notebooks. Make summative assessment to make sure that learning objectives have been achieved.
- Link this lesson to real life. You should talk about cross-cutting issues to be addressed in this lesson like peace education, financial education, and environment sustainability.

## Possible answers

1. It is generated by a transmitter. It is composed by a coder and light emitting diode (LED). LEDs transmit information in the form of light.
2. They are modulated at high frequency.
3. The most commonly used optical transmitters are semiconductor devices such as **light-emitting diodes** (LEDs) and **laser diodes**. The main component of an optical receiver is a photo detector (photodiode) which converts the infrared light signals into the corresponding electrical signals by using photoelectric effect before they are processed by the decoder for conversion back into information.

## Lesson 5: Uses of Optical Fibres

### a) Introduction

In this lesson, you are going to guide learners to answer to questions related to the provided activity.

### b) Teaching resources: Textbooks

### c) Learning Activities

### Activity 5.5 Light transmission analysis in optical fiber

The activity aims to bring students' attention and develop critical thinking and collaboration on learners. The learners will be encouraged to respond actively in their respective groups.

- Divide on the method to use in the lesson into groups according to the number of learners you have.

- Ask learners to open their books on page 50 and read the questions on figure provided. Supervises them while working to avoid laziness or misconduct in the lesson.
- Ask them to raise a hand if they have finished. Mark their responses.
- When all of them finish (after a reasonable time for this activity), invite them to do presentation. Each group present its findings.
- From the presentations of learners, help them to summarize the content based on the facts of optical fiber. Write the summary and ask learners to copy it in their notebooks.
- Remember to conclude your lesson by connecting it to real life situation and emphasize on cross-cutting issues.

### **Possible answer**

1. No some amount of energy are scatted away and do no reach the destination.
2. Poor optical fiber, absorption, leakage in fiber optics, bad connectors used, impurities in the glass fiber, low refractive index and so on.
3. Use of different devices such as Repeaters, Regenerators and Optical Amplifiers

### **Checking my progress**

d) A and B

## **Lesson 6: Advantages and Disadvantages of Optical Fibres**

### **a) Introduction:**

Through guided discoveries, give guidelines to learners in order to carry out research on library or on internet.

### **b) Teaching resources: Textbooks, library and internet**

### **c) Learning Activities**

### **Activity 5.6 Investigating the signal sources and signal receiver for optic fibers**

This activity aims to capture students' attention and minds them towards the concept of advantages and disadvantages of optical fiber. Therefore, the following guidelines should help the teacher to monitor the lesson efficiently.

- Divide your students into groups, accordingly. Tell the learners to open and read the activity 6.6 in the learner's book.

- Instruct learners to read the questions and answer them by writing in their notebooks all information from found either by using internet or library. Use the available resources.
- While students are doing this activity, you supervise and assist your learners to encourage them.
- When every group is done, invite some groups to present their findings to the whole class. Make sure that you are developing generic competences in your learners: cooperation, critical thinking, etc.
- Inquire from other students or groups whether their answers correspond to the ones discussed. If not, invite them for the presentation of new ideas.
- Together with students harmonize the points discussed and make a summary on the board. Linking to the summary and what have been discussed in class, this will be the opportunity for the teacher to correct misconceptions met during presentation.
- Allow learners to write the main points in their notebooks. Make summative assessment to make sure that learning objectives have been achieved.
- Link this lesson to real life. You should talk about cross-cutting issues to be addressed in this lesson like peace education, financial education, and environment sustainability.

## Possible answers:

### Advantages

**Capacity:** Optical fibres carry signals with much less energy loss than copper cable and with a much higher bandwidth.

**Size and weight:** Optical fiber cables are much lighter and thinner than copper cables with the same bandwidth.

**Security:** Optical fibres are much more difficult to tap information from undetected; a great advantage for banks and security installations.

Running costs: copper system consumes far more electrical power than fiber, simply to carry the signals.

### Disadvantages

**Price:** In spite of the fact that the raw material for making optical fibres, sand, is abundant and cheap, optical fibres are still more expensive per metre than copper.

**Special skills:** Optical fibres cannot be joined together (spliced) as an easily as copper cable and requires additional training of personnel and expensive precision splicing and measurement

## Checking my progress

1. See the answers in activity above
2. False

## 5.6 Summary of the Unit

An optical fiber (fiber optics) is a medium for carrying information from one point to another in the form of light. It uses a flexible, transparent fiber made by silica glass or plastic and has a diameter slightly thicker than that of a human hair.

The underlying main physics concept behind the functioning of an optical fiber is a phenomenon known as **total internal reflection**.

There are three main types of Optical Fibers: **Monomode** (or single mode), **Multimode** and **special purpose** optical fibers.

In fiber optics, attenuation also known as **transmission loss**, is the reduction in intensity of the light beam (or signal) as it travels through the transmission medium.

Attenuation can be caused by several factors both extrinsic and intrinsic and can be reduced by using regenerators, amplifiers, etc.

The process of communicating using fiber-optics involves the following basic steps:

- Creating the optical signal involving the use of a transmitter, usually from an electrical signal.
- Relaying the signal along the fiber, ensuring that the signal does not become too distorted or weak.
- Receiving the optical signal.
- Converting it into an electrical signal.

Optical fibres offer huge communication capacity in the communications industry and In medicine Although there are many benefits to using optical fibres, there are also some disadvantages such as lack of skilled people and high cost

## 5.7 Additional information for the teacher

### 5.7.1. Acceptance angle

Having considered the propagation of light in an optical fiber through total internal reflection at the core–cladding interface, it is useful to enlarge upon the geometric optics approach with reference to light rays entering the fiber. Since only rays with a sufficiently shallow grazing angle (i.e. with an angle to the normal greater than  $\phi_c$ ) at

the core–cladding interface are transmitted by total internal reflection, it is clear that not all rays entering the fiber core will continue to be propagated down its length.

The geometry concerned with launching a light ray into an optical fiber is shown in Figure 6.1, which illustrates a meridional ray A at the critical angle  $\phi_c$  within the fiber at the core–cladding interface. It may be observed that this ray enters the fiber core at an angle  $\theta_a$  to the fiber axis and is refracted at the air–core interface before transmission to the core–cladding interface at the critical angle. Hence, any rays which are incident into the fiber core at an angle greater than  $\theta_a$  will be transmitted to the core–cladding interface at an angle less than  $\phi_c$  and will not be totally internally reflected.

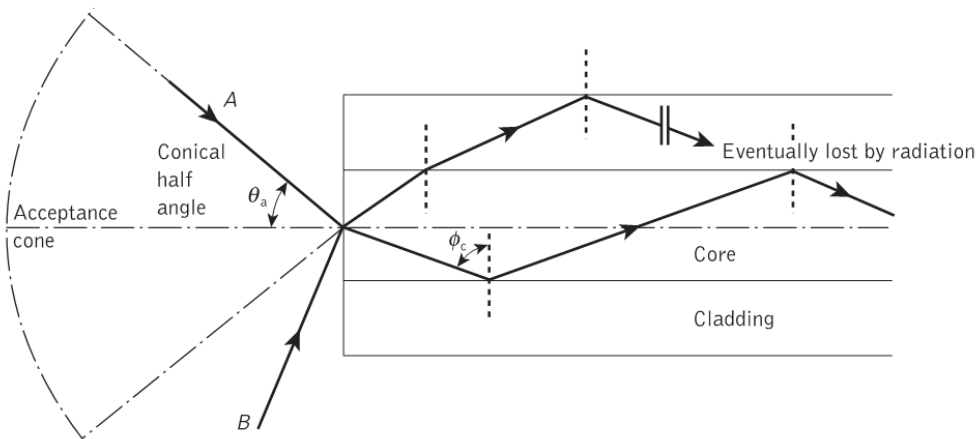


Fig.5. 1 The acceptance angle  $\theta_a$  when launching light into an optical fiber

This situation is also illustrated in Figure 6.1, where the incident ray B at an angle greater than  $\theta_a$  is refracted into the cladding and eventually lost by radiation. Thus for rays to be transmitted by total internal reflection within the fiber core they must be incident on the fiber core within an **acceptance cone** defined by the conical half angle  $\theta_a$

Hence  $\theta_a$  is the maximum angle to the axis at which light may enter the fiber in order to be propagated, and is often referred to as the acceptance angle ( $\theta_a$  is sometimes referred to as the maximum or total acceptance angle) for the fiber. **Invalid source specified.**

If the fiber has a regular cross-section (i.e. the core–cladding interfaces are parallel and there are no discontinuities) an incident meridional ray at greater than the critical angle will continue to be reflected and will be transmitted through the fiber. From symmetry considerations it may be noted that the output angle to the axis will be equal to the input angle for the ray, assuming the ray emerges into a medium of the same refractive index from which it was input.

### 5.7.2. Numerical aperture

The acceptance angle for an optical fiber was defined in the preceding section. However, it is possible to continue the ray theory analysis to obtain a relationship between the acceptance angle and the refractive indices of the three media involved, namely the core, cladding and air. This leads to the definition of a more generally used term, the numerical aperture of the fiber. It must be noted that within this analysis, as with the preceding discussion of acceptance angle, we are concerned with meridional rays within the fiber. Fig.6.2 shows a light ray incident on the fiber core at an angle  $\theta_1$  to the fiber axis which is less than the acceptance angle for the fiber  $\theta_a$ . The ray enters the fiber from a medium (air) of refractive index  $n_0$ , and the fiber core has a refractive index  $n_1$ , which is slightly greater than the cladding refractive index  $n_2$ .

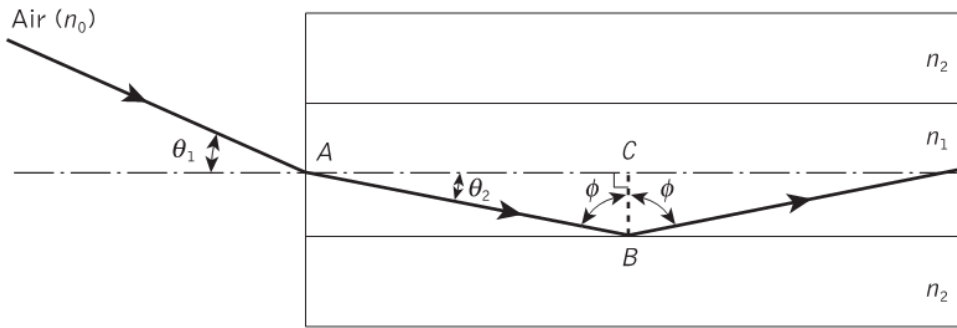


Fig.6. 2

Assuming the entrance face at the fiber core to be normal to the axis, then considering the refraction at the air–core interface and using Snell’s law given by  $n_0 \sin \theta_1 = n_1 \sin \theta_2$ .

Considering the right-angled triangle ABC indicated in Figure 2.5, then:  $\phi = \frac{\pi}{2} - \theta_2$  where  $\phi$  is greater than the critical angle at the core–cladding interface. Hence the equation

$$n_0 \sin \theta_1 = n_1 \sin \theta_2 \text{ becomes: } n_0 \sin \theta_1 = n_1 \cos \phi$$

Using the trigonometrical relationship,  $\sin^2 \phi + \cos^2 \phi = 1$  the equation above can be written in The form:

$$n_0 \sin \theta_1 = n_1 (1 - \sin^2 \phi)^{\frac{1}{2}} \quad (*)$$

When the limiting case for total internal reflection is considered,  $\phi$  becomes equal to the critical angle for the core–cladding interface and is given by  $\sin \phi_c = \frac{n_2}{n_1}$ . Also in this limiting case  $\theta_1$  becomes the acceptance angle for the fiber  $\theta_a$ . Combining these limiting cases into (\*) gives

$$n_0 \sin \theta_1 = (n_1^2 - n_2^2)^{\frac{1}{2}} \quad (**)$$

Equation (\*\*), apart from relating the acceptance angle to the refractive indices, serves as the basis for the definition of the important optical fiber parameter, the numerical aperture (NA). Hence the NA is defined as:  $NA = n_0 \sin \theta_1 = (n_1^2 - n_2^2)^{\frac{1}{2}}$

Since the NA is often used with the fiber in air where  $n_0$  is unity, it is simply equal to  $\sin \theta_a$ .

It may also be noted that incident meridional rays over the range  $0 \leq \theta_1 \leq \theta_a$  will be propagated within the fiber.

The NA may also be given in terms of the relative refractive index difference  $\Delta$  between the core and the cladding which is defined as:

$$\Delta = \frac{n_1^2 - n_2^2}{2n_1^2} \approx \frac{n_1 - n_2}{n_1} \text{ for } \Delta \ll 1$$

Hence combining the equation of numerical aperture and the equation of relative refractive index difference, we can write:

$$NA = n_1 (2\Delta)^{\frac{1}{2}}$$

The relationships given in equations above for the numerical aperture are a very useful measure of the light-collecting ability of a fiber. They are independent of the fiber core diameter and will hold for diameters as small as 8  $\mu\text{m}$ . However, for smaller diameters they break down as the geometric optics approach is invalid. This is because the ray theory model is only a partial description of the character of light. It describes the direction a plane wave component takes in the fiber but does not take into account interference between such components. When interference phenomena are considered it is found that only rays with certain discrete characteristics propagate in the fiber core. Thus the fiber will only support a discrete number of guided modes. This becomes critical in small-core-diameter fibers which only support one or a few modes.

**Ex1:** A silica optical fiber with a core diameter large enough to be considered by ray theory analysis has a core refractive index of 1.50 and a cladding refractive index of 1.47.

Determine: (a) the critical angle at the core–cladding interface; (b) the NA for the fiber; (c) the acceptance angle in air for the fiber.

### Solution:

(a) The critical angle  $\phi_c$  at the core–cladding interface is given by  $\phi_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) = 78.5^\circ$

(b)  $NA = (n_1^2 - n_2^2)^{\frac{1}{2}} = (1.50^2 - 1.47^2)^{\frac{1}{2}} = 0.30$

(c) the acceptance angle in air is  $\theta_a = \sin^{-1} NA = \sin^{-1}(0.30) = 17.4^\circ$

**Ex2:** A typical relative refractive index difference for an optical fiber designed for long distance transmission is 1%. Estimate the NA and the solid acceptance angle in air for the fiber when the core index is 1.46. Further, calculate the critical angle at the core–

cladding interface within the fiber. It may be assumed that the concepts of geometric optics hold for the fiber.

### Solution:

Since  $\Delta = 0.01$ , the NA is given by:  $NA = n_1(2\Delta)^{\frac{1}{2}} = 1.46(0.02)^{\frac{1}{2}} = 0.21$

For small angles the solid acceptance angle in air  $\zeta$  is given by:

$$\xi \approx \pi\theta_\alpha^2 = \pi \sin^2 \theta_\alpha = \pi(NA)^2$$

$$\xi \approx \pi \times 0.04 = 0.13 \text{ rad}$$

For the relative refractive index  $\Delta$  gives  $\Delta \approx \frac{n_1 - n_2}{n_1} = 1 - \frac{n_2}{n_1}$

Hence,  $\frac{n_2}{n_1} = 1 - \Delta = 1 - 0.01 = 0.99$

The critical angle at the core-cladding interface is

$$\phi_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) = \sin^{-1} 0.99 = 81.9^\circ$$

## 5.8 End unit assessment

1. (a) (i) Coherent – used to transfer / transmit image (out of body)

Coherent – same fiber arrangements at both ends of bundle

Allow same relative position, do not allow symmetrical

(ii) Non-coherent – used to transfer light into body (to illuminate)

Non-coherent – random fiber arrangement along bundle

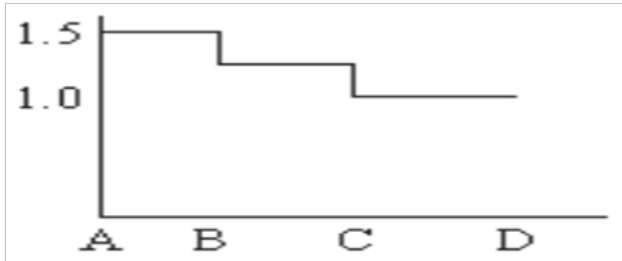
Do not allow not symmetrical

$$(b) \sin \theta_c = \frac{1.49}{1.52} \Rightarrow \theta_c = 79^\circ$$

2. (a) (i) Core. So that total internal reflection can occur

(ii) Using equation in 1 (c), the critical angle is  $79.4^\circ$

(b)



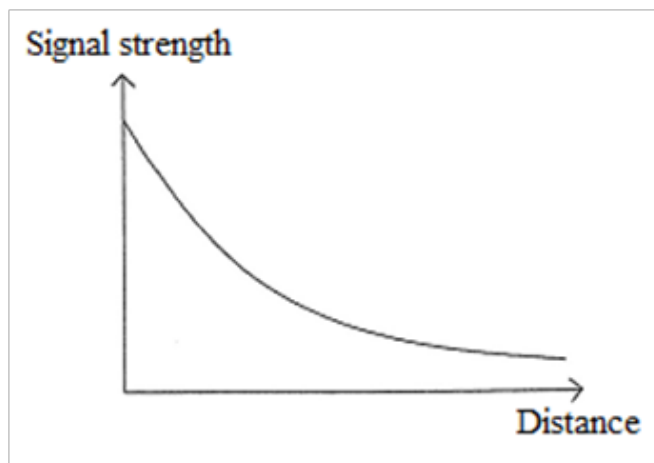
$n$  (constant) = 1.5 from A to B, slight decrease and constant from B to C

At C,  $n$  decreases to 1, remains at 1 from C to D.

3.a) Attenuation is a measure of the rate of loss of signal strength along the length of the fiber.

b) Energy is lost by the scattering and absorption of the light rays as they travel through the glass fiber.

c) After each km it retains 95% of the signal strength it had at the beginning of that km. This leads to an exponential decay curve.



After 35 km, the signal strength is  $= 0.95^{35} \times A = 0.166A$  (where  $A$  is the original signal strength).

4a) Length of cable about 5000 km (estimation)  $t = \frac{s}{v} = \frac{5 \times 10^6}{2 \times 10^8} = 0.025s$

(b) Path of microwave about 86 000 km is  $t = \frac{8.6 \times 10^7}{3 \times 10^8} = 0.28s$

(c) The delay using the optical fiber is not noticeable. Remembering that the signal delay there and back would be double the value estimated, this would be noticeable with a satellite link.

## 5.9 Additional activities

### 5.9.1 Remedial activities

1. The principle called total internal reflection explains why light is not guided in an optical fiber.
  - a. True
  - b. False
3. The symbol for refractive index is:
  - c.n
  - b. c
  - d. M
  - d) &
  - e. None of the above
3. Do fibers have losses?

### Answer

All things in the universe are inefficient. This means that when a measured amount of something enters a system, less comes out than originally went in. If you pour a liter of water into one end of a pipe, you will always get less than a liter out of the other end. If you apply a voltage to the extreme of one wire, no matter how you do it, you will get a lesser value at the other end.

Fiber optics are no exception, the light entering one end encounters all kinds of obstacles and flaws, resulting in losses; from 2 to 10% for every running meter.

4. Can fibers be bent at right angles? Why?

### Answer

No. All fibers must be bent with a radius, which will not alter the internal architecture of the fiber. For every type and size of fiber, there is a minimum radius of curvature, specified and recommended by the manufacturer. Bending fiber optics at right angles will cause the conductor to shatter in the case of glass, and be permanently damaged in all other types.

### 5.9.2 Consolidation activities

1. Prepare a comparative table between a multimode and a single mode fiber optics
2. Write in your own words the description of step index fiber and graded index fiber

#### Answers 1.

1.

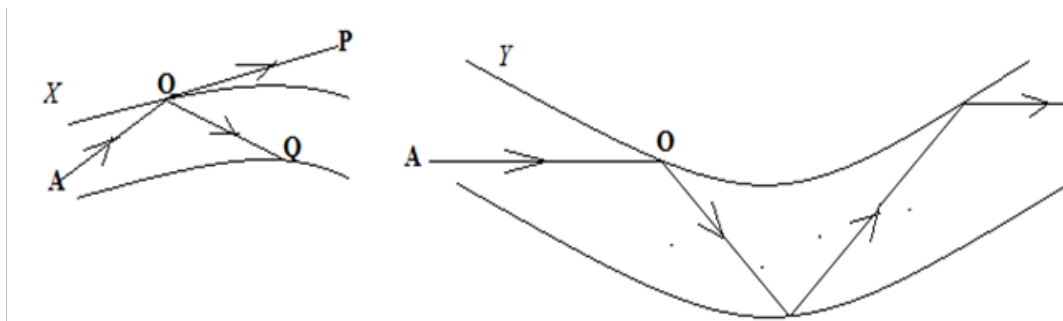
Multimode fiber	Single mode
Low cost sources	High cost sources
Low cost connectors	High cost connectors
Lower installation cost	Higher installation cost
Higher fiber cost	Lower fiber cost
Higher loss, lower bandwidth	Lower loss, high bandwidth
Distance up to 2 km	Distance to 60 km

2. The teacher should mark this activity by considering the information given in the table bellow

Step index fiber	Graded index fiber
The refractive index of the core is uniform throughout and undergoes on abrupt	The refractive index of the core is made to vary gradually such that it is maximum at the centre of the core
The diameter of the core is about 50-200 $\mu\text{m}$ in the case of multimode fiber and 10 $\mu\text{m}$ in the case of single mode	The diameter of the core is about 50 in the case of multimode fiber
The path of light propagation is zig-zag in manner	The path of the light is helical in manner
Attenuation is more for multimode step index fiber but for single mode, it is very less.  Explanation: When a ray travels through the longer distances, there will be some difference in reflected angles. Hence high angle rays arrive later than low angle rays causing dispersion resulting in distorted output.	Attenuation is less.  Explanation: here the light ray travel with different velocity in different paths because of their different refractive indices. At the outer edge it travels faster than near the centre. But almost all the rays reach the exit at the same time due to helical path. Thus there no dispersion

### 5.9.3 Extended activities

1. One kind of optical fiber consists of two very very thin rods one inside the other.



- i. Explain why only a small amount of light is piped through the fiber in X.
  - ii. Why does the light travel along the fiber in Y without losing its intensity.
  - iii. State how the inner and outer surfaces differ in their refractive indices.
  - iv. Why is a fiber coated with a layer of plastic?
  - v. State two applications of optical fibers.
2. Do fiber optics transmit radiations?
  3. Make a study of the following diagram of optical fiber below and discuss its functioning

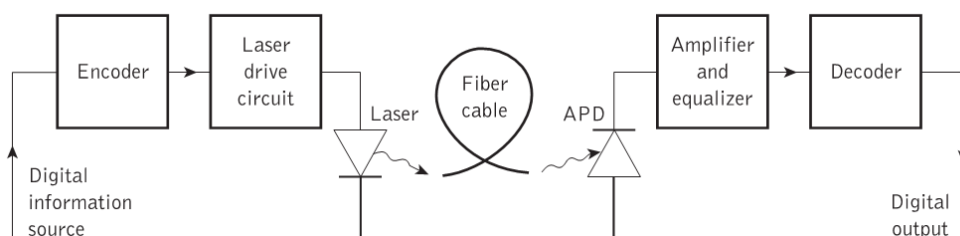


Fig.5. 3 A digital optical fiber link using a semiconductor laser source and an avalanche photodiode (APD) detector

4. When the mean optical power launched into an 8 km length of fiber is  $120 \mu\text{W}$ , the mean optical power at the fiber output is  $3 \mu\text{W}$ . Determine:
  - a. The overall signal attenuation or loss in decibels through the fiber assuming there are no connectors or splices;
  - b. The signal attenuation per kilometre for the fiber.

- c. The overall signal attenuation for a 10 km optical link using the same fiber with splices at 1 km intervals, each giving an attenuation of 1 dB;
- d. The numerical input/output power ratio in (c).

## Answer

1. (i) In X, The ray is incident at O at a small angle (less than the critical angle). Most of the light is refracted along OP: only a small amount is reflected along OQ.  
 (ii) In Y, the ray is incident at an angle of incidence which is greater than the critical angle and total internal reflection occurs. The ray continues throughout the fiber and all the ray is piped along the curved path.  
 (iii) The inner surface has a slightly higher refractive index than the outer surface, since it is a slightly denser medium.  
 (iv) To protect it from damage by preventing it from becoming scratched.
2. Light is a radiation; therefore, the answer is yes. Some fibers, depending on the nature of the materials from which they are made, transmit one band of radiation more or less wide or restricted.

Generally, the fibers used for lighting transmit little or no ultraviolet, a very small amount of infrared and variable quantities of the visible light frequencies.

Heat is a radiation on the infrared region and does not transmit well on standard lighting fibers. To put an example; the amount of heat that will build up inside a case with a volume of one cubic meter of air, is only one degree in 24 hours, from a 5mm diameter PMMA light guide powered by a 150 W metal halide illuminator

3. The figure above shows a block schematic of a typical digital optical fiber link. Initially, the input digital signal from the information source is suitably encoded for optical transmission. The laser drive circuit directly modulates the intensity of the semiconductor laser with the encoded digital signal. Hence a digital optical signal is launched into the optical fiber cable. The avalanche photodiode (APD) detector is followed by a front-end amplifier and equalizer or filter to provide gain as well as linear signal processing and noise bandwidth reduction. Finally, the signal obtained is decoded to give the original digital information.
4. (a) The overall signal attenuation in decibels through the fiber is:

$$\text{Signal attenuation } 10 \log_{10} \frac{P_i}{P_0} = 10 \log_{10} \frac{120 \times 10^{-6}}{3 \times 10^{-6}} = 16.0 \text{ dB}$$

(b) The signal attenuation per kilometre for the fiber may be simply obtained by dividing the result in (a) by the fiber length which corresponds to it where:

$$\text{The signal attenuation of the total length L is } \alpha_{dB} = \frac{16.0 \text{ dB}}{8 \text{ km}} = 2.0 \text{ dBkm}^{-1}$$

$$\text{Then } \alpha_{dB} = \frac{16.0 \text{ dB}}{8 \text{ km}} = 2.0 \text{ dBkm}^{-1}$$

c) As  $\alpha_{dB} = 2.0 \text{ dB km}^{-1}$ , then the loss incurred along 10 km of the fiber is given by

$$\alpha_{dB} L = 2 \times 10 = 20 \text{ dB}$$

d) However, the link also has nine splices (at 1 km intervals) each with an attenuation of 1 dB. Therefore, the loss due to the splices is 9 dB. Hence, the overall signal attenuation for the link is: Signal attenuation = 20 + 9 = 29 dB

To obtain a numerical value for the input/output power ratio, the relation

Signal attenuation  $10 \log_{10} \frac{P_i}{P_0}$  can be equal to  $\frac{P_i}{P_0} = 10^{\frac{\text{total attenuation in dB}}{10}}$

Hence

$$\frac{P_i}{P_0} = 10^{\left(\frac{29}{10}\right)} = 794.3$$

### 6.1 Key unit competence:

Analyze block diagram of telecommunications

### 6.2 Prerequisite knowledge and skills

The success of this unit relies partly on the mastery of knowledge and skills acquired in Physics (Unit 10 and 11, S5 Advanced Level) and (unit 13, S3 Ordinary level).

### 6.3 Cross-Cutting Issues to be addressed

**Inclusive education** (The teacher must promote education for all while teaching). Regardless of physical appearance and abilities learners should be treated equally. This makes all learners to be involved in teaching and learning process. They find out that they are all of great importance.

**Peace and value Education** (This is the respect of others views and thoughts during class discussions). Remember that someone's idea is very important. It may be correct or not but what is important is to build on that Idea.

**Gender education** (equal opportunity of boys and girls in the lesson participation). Care should be taken that both Sexes are given equal opportunities.

**Environment sustainability:** During delivering different lessons within this unit, let learners be familiar with des advantages of system communication. This led to the recognition of the awareness on them and learners will be responsible for the world around them and they will acquire knowledge, skills, attitude and values which will enable them to deal with the environment change issues.

### 6.4 Guidance on the introductory activity

This activity aims at capturing students' attention and minds towards this concept. The activity should not take more than ten minutes.

- Divide your students into groups (Grouping may depend on the nature of your class or number of learners you have). Always take care of learners with any kind of disability while making groups.

- Give them clear instructions about the activity.
- While students are doing this activity, you move around, guide slow learners and mark their working.
- When everyone has finished the activity, invite some member(s) or group(s) to discuss their findings to the whole class.
- Ask other members whether their answers correspond to the discussed points and if there is any point that is different from what have been raised to mention it.
- Note some misconceptions and misunderstanding so that they will be corrected and harmonised in the lesson. Together with students harmonize the points and make a summary on the board. Give to learners the opportunity to write the main points in their notebooks.
- Harmonize the lesson by linking what have discussed and the summary of the lesson.
- Summarize your lesson by linking this concept to real life situations.

## 6.5 List of Lessons

S/ No	Lesson Title	Learning Objectives	Periods
1	Operating principle of microphone	Outline the function of a microphone	2
2	Channels of signal transmission	Identify types channels	3
3	Carrier wave and modulator	Concept of carrier wave modulation	2
4	Oscillator, radio frequency amplifier and power amplifier	Differentiate oscillator, modulator and power amplifier Describe terms applied in telecommunications systems	3
5	Antennas	Outline the function of antenna	2

6	Block diagrams of telecommunication	Identify parts of a block diagram of telecommunication system  Describe terms applied in telecommunication systems  Construct, analyse and judge block diagrams of telecommunication system  Realise that parts of a telecommunication system are dependent	2
7	End unit assessment		2

## Lesson 6.1: Operating principle of microphone

### a) Introduction:

Through guided discovery, assist learners to discuss about mobile communication. You can make a recap using Units mentioned above on Prerequisite Knowledge. You can use probing questions techniques to remind the learners mobile communication.

### b) Teaching resources:

Internet and textbooks, and other available resources

### c) Learning Activities:

#### Activity 6.1 investigating what is a microphone

This activity aims to capture students' attention and minds them towards investigating what is a microphone. Therefore, the following guidelines should help the teacher to monitor the lesson efficiently.

- Divide your students into groups, accordingly. Tell the learners to open and read the activity 6.1 in the learner's book.
- Instruct learners to observe the figure 6.1 and read the questions and answer them by writing in their notebooks. Give them the time to reflect on their prior knowledge (thinking time).
- While students are doing this activity, you move around and mark the work of those who have finished.
- When everyone is done, invite some member(s) or group(s) to present their findings to the whole class. Make sure that you are developing generic competences in your learners: cooperation, communication, critical thinking, etc.

- Inquire from other students or groups whether their answers correspond to the ones discussed
- Together with students harmonize the points discussed and make a summary on the board. Linking to the summary and what have been discussed in class, this will be the opportunity for the teacher to correct misconceptions met during presentation.
- Allow learners to write the main points in their notebooks. Make summative assessment to make sure that learning objectives have been achieved.
- Link this lesson to real life. You should talk about cross-cutting issues to be addressed in this lesson like peace education.

## Possible answers

4. The **function of a telephone** is to make and receive a call. It helps people to communicate and exchange either oral or written information land, undersea and in air. At the top of a telephone cell, there is a loudspeaker pressed against the air. At the bottom, there is a microphone near the mouth. Coming out of the handset, wrapped inside a single thick, coiled cable are two pairs copper wires. One pair is an output: it takes outgoing **electrical signals** from the microphone to the telephone system. The other pair is an output: it takes incoming signals from the telephone to the loudspeaker. The microphone and loudspeaker work in similar but opposite ways: The microphone contains a flexible piece of plastic called a diaphragm an iron coil attached to it and a magnet nearby. When you speak into the mouthpiece, the sound energy in your voice makes the diaphragm. Vibrate, moving the coil nearer to the farther the magnet. This generates an electric current in the coil corresponding to the sound of your voice: If you talk loud, a big current is generated, if you talk softly, the current is smaller. Thus a microphone is thought to be an energy converting device: It turns the sound energy in your voice into electrical energy using a device called Transducer. The loudspeaker in a phone works in magnetism to convert the electrical energy back into sound energy you can hear. In some phones, the loudspeaker and the microphone units are virtually identical, just wired up in opposite ways.
5. **The functions of a microphone:** Basically a microphone has a diaphragm which moves when pressures sound moves pushes it. This movement can be converted into proportional voltage using several possible transducers. A transducer is device which receives electrical, mechanical or acoustic waves from one medium and converts them into related waves for a similar or different medium. Thus, it can be said that a microphone is a transducer that converts acoustic energy (sound vibrations) into electrical energy.

The function of a speaker: To understand the working principle of a speaker, we need to understand first the concept of a sound. A sound is a vibration in air particles. When a sound source generates a sound, it generally makes a vibration in its surrounding air particles which finally to our eardrum. Generally a speaker is device that produces

vibrations in air particles in order to generate sound by converting the voltage or current into sound vibrations in the air by moving the diaphragm of the speaker.

## **Lesson 6.2: Channels of signal transmission**

### **a) Introduction:**

Through guided discovery, assist learners to discuss about signal transmission. You can make a recap using Units mentioned above on Prerequisite Knowledge (10, 11). You can use probing questions techniques to remind the learners the transmission of signals

### **b) Teaching resources:**

Internet and textbooks and available resources

### **c) Learning Activities**

#### **Activity 7.2: Investigating signal transmission**

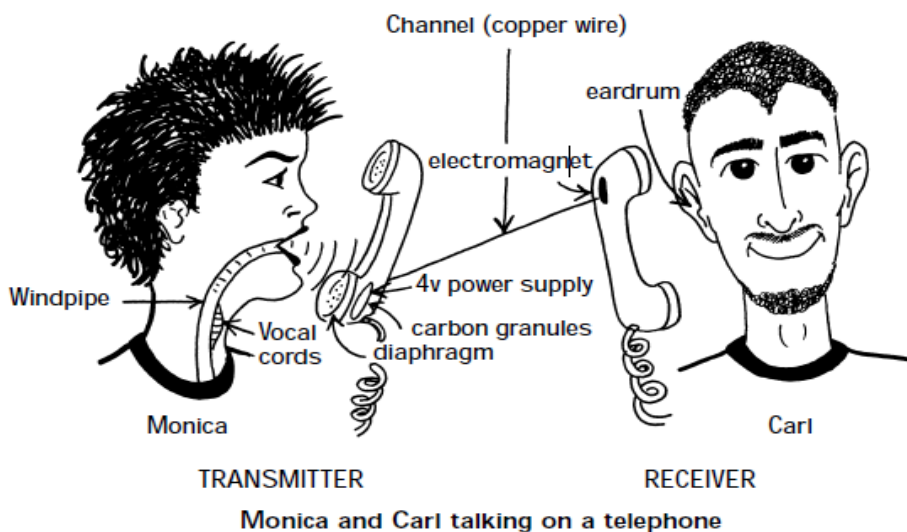
This activity aims to capture students' attention and minds them towards investigating investing signal transmission. Therefore, the following guidelines should help the teacher to monitor the lesson efficiently.

- Decide on the method of teachers to use in this lesson.
- Give the instructions to students and read the questions and answer them by writing in their notebooks. Give them the time to reflect on their prior knowledge (thinking time).
- While students are doing this activity, you move around and mark the work of those who have finished.
- When everyone is done, invite some member(s) or group(s) to present their findings to the whole class. Make sure that you are developing generic competences in your learners: cooperation, communication, critical thinking, etc.
- Inquire from other students or groups whether their answers correspond to the ones discussed
- Together with students harmonize the points discussed and make a summary on the board. Linking to the summary and what have been discussed in class, this will be the opportunity for the teacher to correct misconceptions met during presentation.
- Allow Students to write the main points in their notebooks. Make summative assessment to make sure that learning objectives have been achieved.
- Link this lesson to real life. You should talk about cross-cutting issues to be addressed in this lesson like peace education.

## Possible answers

Example of how the voice can be transmitted from transmitter to receiver

The transmitter consists of Monica (who is talking) and the transmitting (bottom) end of the telephone. Monica speaks, and her vocal cords vibrate. This causes vibrations in the air, which travel through and out her mouth, and then travel to the bottom end of the telephone. Inside the bottom end of the telephone is a diaphragm. When the vibrations of the air arrive at this diaphragm, it, like an eardrum, begins to vibrate. Directly behind the diaphragm are a bunch of carbon granules. These granules are part of an electrical circuit, which consists of a 4-V source, copper wire, and the carbon granules. The carbon granules act as a resistor (with variable resistance) in the circuit. When the diaphragm is pushed back by the vibrating air, it causes the carbon granules (right behind it) to mash together. In this case, the granules act like a low-resistance resistor in the circuit. Hence, the current flowing through the electric circuit is high. When the diaphragm is popped out by the vibrating air, it causes the carbon granules (right behind it) to separate out. In this case, those carbon granules are acting like a high-resistance resistor in the electrical circuit. Hence, the current flowing through the circuit is low. Overall, vibrations in the diaphragm (its “pushing back” and “popping out”) cause the same vibrations (frequencies) to appear in the current of the electrical circuit (via those carbon granules). The channel is a copper wire. The vibrating current generated by the transmitter is carried along this wire to the receiver.



**The receiver** consists of two parts: the receiving (top) part of the telephone, and Carl's ear. The current, sent along the copper wire, arrives at the top end of the telephone. Inside this top end is a device called an electromagnet and right next to that is a diaphragm. The current, containing all of Monica's talking frequencies, enters into the electromagnet. This electromagnet causes the diaphragm to vibrate with all of Monica's talking frequencies. The vibrating diaphragm causes vibrations in the air, and

these vibrations travel to Carl's ear. His eardrum vibrates, and these vibrations cause electrical signals to be sent to his brain, which interprets this as Monica's sound. (Nasar, 2001)

#### **d) Checking my progress**

1.D

2. Used for radio broadcasting of voice and music to shortwave listeners over very large areas; sometimes entire continents or beyond.

Used for military communication,

Used for Diplomatic communication,

3. The part of the medium frequency radio band used mainly for Amplitude Modulation radio broadcasting. It is the original radio broadcasting band, in use since the early 1920's

4. Distinguish between Amplitude modulation and frequency modulation

In amplitude modulation (AM), the amplitude of the high frequency carrier wave is made to vary in proportion to the amplitude of the audio signal as shown in fig....

In frequency modulation (FM), the frequency of carrier wave is made to change in proportion to the audio signal's amplitude as shown in fig....

### **Lesson 6.3: Carrier wave and modulator**

**a) Prerequisites/Revision/Introduction:**

**b) Teaching resources:**

Internet and textbooks and other available resources

**a. Learning Activities**

#### **Activity 6.3: Modulation techniques**

This activity aims at making students how sound can be produced

- Put your students in groups.
- Instruct learners to read the questions and relate them to Fig 7.6
- Tell the students to attempt the questions in their notebooks.
- When students are doing this activity; you move around and mark their work.
- when everyone is done and you are done, invite some member(s) or group(s) to discuss their findings to the whole class.

- Inquire from other students or groups whether their answers correspond to the ones discussed
- Together with students harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks

### **Possible answers:**

This system can be applied in a number of applications such as:

- When a spokesperson uses a microphone conveying a speech to the audience
- When a journalist or a radio/ television presenter is on a scene in studio or a stage presenting a show
- When someone is talking on a telephone. It concerns a calling person and a person being called

When recording an art product in studio (producers)

#### **d. Checking my progress**

1. A) AM
2. Analog and digital signals are used to transmit information, usually through electric signals. In analog and digital signals are technologies, the information such as any audio or video, is transformed into electric signals. . The difference between analog and technologies is that in analog, the information is transmitted into electric pulses of varying amplitude. In digital, translation of information is into binary format (0 or 1).
3. The carrier wave in telecommunication is defined as the continuous electromagnetic radiation, of constant amplitude and frequency, that is given out by a transmitter and it is modulated in direct proportion to the signal, such as the voice or music that is to be transmitted.
4. The purpose of the carrier is:
  - To transmit the information through space as an electromagnetic wave (as in radio communication).
  - To allow several carriers at different frequencies to share a common physical transmission medium by division multiplexing examples cable television.

## **Lesson 6.4: Oscillator, radio frequency amplifier and power amplifier**

### **a) Introduction:**

Through questioning, learners revise the transmission of signals learned in the previous lessons.

## b) Teaching resources:

Internet and textbooks

## c) Learning activities

This activity aims at capturing students' attention and minds towards the recap on the previous lessons.

- Divide learners into groups.
- Where possible, take your students in a computer lab and instruct them to investigate the uses of oscillator and radio frequency amplifier in the telecommunication. You can instruct them how to find them in the search engine.
- While students are doing this activity, you move around and mark their attention and assist them if there is any problem about searching on internet.
- When every group is done; invite groups (s) (like 2 groups) to discuss and present their findings to the whole class. Here, a group should choose one to represent their finding. Where possible, when two groups are to represent, one should be represented by a girl another by a boy or a learner with impairment.
- Inquire from other students or groups whether their answers correspond to the ones discussed in their groups.
- Together with students harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks. Then linking to the summary and what have been discussed in class.

## Possible answers:

1. A radio frequency is any of the electromagnetic wave frequencies which is in the extend range from around 20 kHz to 300GHz. Is used in telecommunication to increase the amplitude signal
2. An oscillator is an electronic circuit that produces a periodic, oscillating electric signal, a sine or square wave. They are used in telecommunication to convert direct current from a power supply to an alternating current signal. Most signals generated by oscillators are used in broadcasting radio and television transmission
3. They are used in devices which generate clock signals that regulate the computers and quartz clocks in i devices able to produce electronic beeps (electronic beepers) and video games. They are used as sources of carrier signals which are used to modulate and help the original signal to reach the destination.

## d) Checking my progress

1. (a) Audio Frequency (AF) oscillators (frequency range is 20 Hz to 20 kHz)  
(b) Radio Frequency (RF) oscillators (frequency range is 20 kHz to 30 MHz)

- (c) Video Frequency oscillators (frequency range is dc to 5 MHz)
  - (d) High Frequency (HF) oscillators (frequency range is 1.5 MHz to 30 MHz)
  - (e) Very High Frequency (VHF) oscillators (frequency range is 30 MHz to 300 MHz)
2. Electronic circuits that produce a periodic waveform on its output with only the DC supply voltage as an input
  3. a: Microphone                      b: Oscillator      c: Audio frequency  
     d: Radio frequency              e: Antenna              f: Amplifier

## Lesson 6.5: Antennas

### a) Introduction:

Through brainstorming, teacher invites different learners to review on the previous lessons.

### b) Teaching resources:

Internet, textbooks, flipcharts and other available resources.

### c) Learning Activities:

- Instruct learner to observe fig 6.13 from learner book and answer questions of activity 6.5
- In group(s), let learners discuss and answer that activity on flipcharts.
- Authorize group representatives to present their findings.
- Complete the ideas that are incomplete and confirms correct answers.
- Correct the false ideas and confirms correct answers.
- Harmonize learner's ideas.

### Possible answers:

1. Wire antennas and Reflector antennas
2. Aperture antennas, Array antennas, Isotropic antennas, Biconical dipole antenna, Biconical dipole antenna, Micro strip antennas, etc
3. After a radio frequency (RF) signal has been generated in a transmitter, an antenna must be used to radiate this signal through the space to a receiver. The transmitter signal energy is sent into the free space by the transmitting antenna while the radio frequency signal is then picked up from the space by receiving antenna.

The RF energy is transmitted into the space in the form of electromagnetic field. As the travelling electromagnetic field arrives at the receiving antenna, the voltage is induced into the antenna as it is the conductor. This RF voltages induced into the receiving antenna are then passed into the receiver and converted back into the transmitter RF information.

#### **d) Checking my progress**

- 1. An antenna** is an electrical device connected (often through a transmission line) to the receiver or transmitter which converts electric power into radio waves, and vice versa
- 2. Array antenna**
- The Array antennas Yagi-Uda antennas or micro-strip patch arrays or aperture arrays, slotted waveguide arrays

#### **Aperture antennas**

The aperture antennas are horn antennas and waveguide opening and they are usually used in aircrafts and space crafts.

### **Lesson 6.6: Block diagrams of telecommunication**

#### **a) Introduction:**

Through guided discovery, assist learners to discuss different parts of block diagram of telecommunication.

You can make a recap using Unit 10: analog and digital signals( S5) and unit 11: Mobile phone and radio communication (S5).

#### **b) Teaching resources:**

Internet and textbooks.

#### **c) Learning Activities**

#### **Activity 6.6: investigating communication system**

This activity aims at capturing students' attention and minds towards terms applied in telecommunication

- Divide learners into groups.
- Where possible, take your students (in a period of 10 to 15 min) in a computer lab and instruct them to search about block diagram of telecommunication. You can instruct them write in the search engine “ Telecommunication system”
- While students are doing this activity, you move around and mark their attention and assist them if there is any problem about searching on internet.

- When every group is done; invite some groups (s) to discuss and present their findings to the whole class. Here, a group should choose one to represent their findings. Where possible, when two groups are to represent, one should be represented by a girl another by a boy or a learner with impairment.
- Inquire from other students or groups whether their answers correspond to the ones discussed in their groups.
- Together with students harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks. Then linking to the summary and what have been discussed in class.

### **Possible answer:**

the communication system, as the system that conveys information from one point to another via physical channels that propagate electromagnetic, acoustic, particle density or other waves. The communication system provided in the illustration (fig 6. 18) has the main parts which are:

**Input transducer:** this device turns the sound energy in a voice into electrical energy transforming it into an input signal to be fed to the transmitter. This signal must be modulated and encoded. The transmitter converts the input signal to transmitter signal suited for the transmitting after using modulation and using an encoder it. Here the signal is affected by various process take place in the channel within which the signal will be fed to transmission

- **Transmission channel:** medium that bridges the distance from the source to the destination. It can be either wired or wires.
- **The receiver** is a device that converts the received signal in a form appropriate for output transducer after amplifying, filtering, demodulating and decoding it.
- **Output transducer:** it converts the output signal into a desired message form. It is corresponding to the original signal from the source, though sometimes through the transmitting channel, it can be subjected to various transmission impairments such as:
  1. Attenuation which is the decrease of the signal strength in the channel
  2. Distortion of the signal waveform due to the linearity, frequency response, overloads, directional response channel.
  3. Noise which random natural signal, most of the time unwanted signal added to the original or transmitted signal, sometimes produced by characteristics of the channel such as linearity, frequency response, overloads and the surrounding environment. Once added to the original, they contaminate it.
  4. Interference to the original signal due to signals from human sources, machinery, power lines, digital switching circuits, coupling circuits.

#### d) Checking my progress

1. Power amplifier in simple radio transmitter provides the necessary electrical power to operate the transmitter
2. a. physical time-variable quantity usually in smooth and continuous form.  
b. ordered sequence of symbols selected from finite set of elements
3. Block diagram of simple radio receiver (is drawn in learner book)

### 6. 6 Summary of the Unit

**Telecommunication** in real life is the **transmission** of signs, signals, text messages, writings, images and sounds and other types of data of any nature by wire, radio, optical or other electromagnetic systems of communication. Telecommunication occurs when the exchange of information between communicating participants includes the use of signs or other technologically based materials such as telephone, TV set, radio receiver, radio emitter, computer, and so on. All can be done either mechanically, electrically or electronically.

**A message** is information put in an appropriate form for transmission. Each message contains information. A message can be either analog message (a physical time-variable quantity usually in smooth and continuous form) and a digital message (an ordered sequence of symbols selected from finite set of elements)

**An antenna or aerial** is an electrical device connected to the receiver or transmitter which converts electric power into radio waves, and vice versa. It is usually used with a radio transmitter or radio receiver

**Input transducer** is a device that turns the sound energy in a voice into electrical energy transforming it into an input signal to be fed to the transmitter. This signal must be modulated and encoded.

Thus, modulation is the process by which some characteristics such as amplitude, frequency, and phase of a carrier are varied in accordance with a modulating wave while encoding is the process of coding the message and change it in the language understandable by the transmitter. The oscillators are sources of carrier signals which are used to modulate and help the original signal to reach the destination. Normally, the resulting signal must be raised at a level that will permit it to reach its destination. This operation is accomplished by **amplifiers**.

**An amplifier** is an electronic device which can increase the amplitude or the power of the input signal to its input parts, without the needs of modifying the form of that signal.

**A transmitter is a device that** converts the input signal to transmitted signal suited for the transmitting channel after using a modulator and using an encoder it. Here the signal can be affected by various phenomena which take place in the channel within which the signal will be fed for transmission.

1. **Transmission channel** is a medium that bridges the distance from source to the destination. It can be either wired or wireless. E. g: fiber optics, coaxial cables, waveguide, atmosphere
2. **The receiver** is device that convert the received signal in a form appropriate for the output transducer after amplifying, filtering, demodulating and decoding it.
3. **Output transducer** it converts the output electrical signal into a desired message form. This message must correspond to the original signal from the source, though sometimes through the transmitting channel, it might have been subjected to various transmission impairments such as:
  - a. Attenuation which is the decrease of the signal strength in the channel
  - b. Distortion of the signal waveform due to the linearity, frequency response, overloads, directional response channel
  - c. Noise which is any random natural signal, most of the time unwanted signal added to the original or transmitted signal, sometimes produced by characteristics of the channel such as linearity, frequency response, overloads, directional response and the surrounding environment. Once added to the original, they contaminate it.
  - d. Interference to the original signal due to signals from human sources, machinery, power lines, digital switching circuits, coupling circuits.

To be able to reuse the receive the message which was sent from the source, the receiver should be able to demodulate and decode it using a demodulator and a decoder. Thus, demodulation is the reverse process of modulation, which is used to get back the original message signal while decoding is the reverse process of encoding to retrieve the original message and make it human understandable message. At the transmission and the reception, we use antennas. Antennas are the devices which convert radio frequencies signals or electrical signals into electromagnetic or wave signals or vice versa. Functionally, antennas are devices used to send information in form of electromagnetic wave signals to communicate in wireless or unguided ways.

## 6.7 Additional Information

### Telecommunication and society

The societal importance of telecommunications is well accepted and broadly understood, reflected in its near ubiquitous penetration and use. Noted below are some of the areas of impact:

- Telecommunication provides a technological foundation for societal communications.

Communication plays a central role in the fundamental operations of a society from business to government to families. In fact, communication among people is the essence of what distinguishes an organisation, community, or society from a collection of individuals. Communication from web browsing to cell phone calling to instant messaging has become increasingly integrated into how we work, play and live.

- Telecommunications enable participation and development. Telecommunications plays an increasingly vital role in enabling the participation and development of people in communities.
- Telecommunications provides vital infrastructure for national security. From natural disaster recovery, to homeland security, to communication of vital intelligence to continued military superiority, telecommunication plays a pivotal role.

It is difficult to predict the impact of telecommunications technologies, services and applications that have not yet been invented. For example, in the early days of research and development into the internet in the late 1960s, who could have foreseen the full impact of the internet's which widespread use today?

## 6.8 End Unit Assessment

1. A.
2. C.
3. a) Amplifier      b) Modulator
4. System in which information is transmitted from one physical location, A, to a second Physical location, B

System which allows this information to be sent beyond the range of usual vocal or visual communications.

5. Draw a labelled diagram showing the elements of radio transmitter see LB
6. Digital systems of communication are transmitted in data bits (zeros and one), so

they are not subjected interference, the way the signal leaves the transmitter (or the station for that matter) it is exactly the way you receive it. Since it is digital, the signal is either on or off. Unlike analog where it could be on with lots of interference from anything including distance from the transmitter, mountains etc.

- Power consumption of digital transmitter is very low and enables provision of mobile TV services
- They provide sharper, cleaner, and more detailed images than analog pictures
- There is the possibility of delivering interactive video and data services

## 7. Examples:

- Improvement of total factor productivity, particularly in those industries that are ICT-intensive but also in Those that are not creation/ relocation of enterprises relocation of enterprises based on the availability of high capacity telecommunications networks (as one of many infrastructure factors) and quality of life (driven by availability of networks in schools, hospitals, public administration etc)
- Employment creation of employment as a result of relocation of companies searching for labour cost arbitrage.
- Creation of qualified self-employment resulting from the availability of communication networks
- Creation of employment in manufacturing and installation of telecommunications equipment economic growth increase in efficiency of industries with high transaction costs (retail distribution, finance etc...)
- Consumer surplus generated by the availability of new telecommunications services.....

## 6.9 Additional activities (Questions and Answers)

### 6.9.1 Remedial activities

1. In amplitude modulation, the .....of carrier is varied according to the strength of the signal
  - a. amplitude
  - b. Frequency
  - b. Phase
  - d. None of the above
2. Over modulation ( amplitude) occurs when signal amplitude is.....carrier amplitude
  - a. Equal to
  - b. Greater than
  - c. Less than
  - d. None of the above

3. Demodulation is done.....
  - a. Receiving antenna      b. Transmitter
  - c. Radio receiver          d. Transmitting antenna
4. As the modulation level is increased, the carrier power.....
  - a. Is increased              b. Remains the same
  - c. Is decreased              d. none of the above
5. In radio transmission, the medium of transmission.....
  - a. Space                      b. an antenna
  - c. Cable                      d. None of the above
6. Man made noise are.....variations
  - a. Amplitude                b. Frequency
  - c. Phase                      d. both phase and frequency
7. In TV transmission, picture signal is.....modulated
  - a. Frequency                b. Phase
  - c. Amplitude                d. none of the above
8. In a radio receiver, noise is generally developed at....
  - a. . IF stage                  b. Receiving antenna
  - c. audio stage                d. RF stage
9. When the modulating the modulating signal controls the frequency of the carrier, we get.
  - a. Phase modulation      b. amplitude modulation
  - c. Frequency modulation   d. May be any of the above

**Answer**

- |      |      |      |      |      |
|------|------|------|------|------|
| 1. A | 2. B | 3. C | 4. B | 5. A |
| 6. A | 7. C | 8. D | 9. C |      |

### 6.9.2 Consolidation activities

10. With a block diagram explain the following elements of telecommunication system

Transmitter and Receiver

11. What is the meaning of the term attenuation in communication system?

12. What does the term transducer mean in communication system?

### Answer

10. A transmitter is an electronic device used in telecommunications to produce radio waves in order to transmit or to send data with the aid of an antenna.

A receiver is a device that converts the received signal in a form appropriate for the output transducer after amplifying, filtering, demodulating and decoding it.

11. The loss of strength of a signal while propagating through a medium.

12. A device that converts signals to electrical form or vice-versa.

### 6.9.3 Extended activities

13. Modulation allows us to send a signal over a band pass frequency range. If every signal gets its own frequency range, then we can transmit multiple signals simultaneously over a single channel, all using different frequency ranges. Another reason to modulate a signal is to allow the use of a smaller antenna

# Unit 7: NATURE OF PARTICLES AND THEIR INTERACTIONS

# 7

## 7.1 Key unit competence

Analyse the nature of particle and their interactions

## 7.2 Prerequisite knowledge and skills

The success of this unit relies partly on the mastery of knowledge and skills acquired in Chemistry S4 (Unit 2: Electron configurations of atoms and ions) and other related subjects in previous grades

## 7.3 Cross-Cutting Issues to be addressed

- **Inclusive education** (promote education for all while teaching). Regardless of physical appearance and abilities learners should be treated equally. This makes the learners to find out that they are all of great importance. Regarding to this unit, you can show learners that as small elementary particle in reaction together, they create matter or energy through their interaction, thus, as students all, regardless of their physical ability, in a team they can make the society beautiful
- **Gender education** (equal opportunity of boys and girls in the lesson participation). Care should be taken that both Sexes are given equal opportunities. In this unit, we have seen baryons and mesons together, they form hadrons at equal proportion, thus as male and female working together with equity, they build their society.
- **Environment sustainability:** During delivering different lessons within this unit, let learners be familiar with the application and importance of skills and knowledge obtained about elementary particles.

## 7.4 Guidance on the introductory activity

This activity aims at capturing students' attention and minds towards this concept

- Divide your students into groups (Where possible, mix equally the number of girls to number of boys. If there are students with impairment, let them take the lead of groups during doing activity). The choice of method to use may depend on size, type and time of the lesson
- Tell the learners to open the introductory activity in the learner's book.

- Instruct learners to re-write the questions and answer them following the instructions from learner's book.
- While students are doing this activity, you move around and mark their work.
- When everyone is done and you are done, invite some member(s) or group(s) to present and discuss their findings to the whole class.
- Ask other members whether their answers correspond to the discussed points and if there is any point that is different from what have been raised to mention it. You can talk about those points (in a discussion together with other students).
- Together with students harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks. And then linking to the summary and what have discussed in class, emphasize on the main types of elementary particles. You can take some minutes and explain them.
- Summarize your lesson by linking this concept to real life situations

## 7.5 List of Lessons

S/ No	Lesson Title	Learning Objectives	Periods
1	Elementary particles	<ul style="list-style-type: none"> <li>• Describe elementary particles</li> <li>• Describe elementary particles</li> <li>• Appreciate application of elementary particles</li> </ul>	3
2	Classification of elementary particles.	<ul style="list-style-type: none"> <li>• Explain classification of elementary particles</li> <li>• Explain classes of particle by spin</li> <li>• Classifier and describe particles by spin</li> <li>• Acquire scientific techniques for identifying elementary particles</li> </ul>	4
3	Particle and anti particle  Pauli's exclusion principle	<ul style="list-style-type: none"> <li>• Explain the concept of antiparticle</li> <li>• Interpret concepts of an antiparticle</li> <li>• State Pauli's exclusion Principle</li> <li>• Analyse Pauli's exclusion principle</li> </ul>	3

4	Fundamental interactions by particle exchange	<ul style="list-style-type: none"> <li>• Outline fundamental interactions by exchange of particles</li> <li>• Analyse fundamental interactions by exchange of particles</li> </ul>	2
6	Uncertainty principle and particle creation	<p>Explain uncertainty principle for time , energy and particle creation</p> <p>Discuss uncertainty principle for time and energy in the context of particle</p>	2
5	Matter and antimatter (pair production and annihilation)	<ul style="list-style-type: none"> <li>• Explain the concepts of matter and antimatter</li> <li>• Acquire scientific attitudes of reasoning to interpret elementary particle phenomenon</li> </ul>	2
6	End unit assessment		2

## Lesson 7.1: Elementary particles

### a) Introduction:

- Through guided discovery, assist learners to describe main types of elementary particles.
- You then guide them to find explanations about elementary particles, the four fundamental forces and their unification
- You can ask learners questions about elementary particles and four fundamental forces and their unification

### b) Teaching resources

Internet and textbooks, and other available resources

### c) Learning Activities:

#### Activity 7.1 Investigate the presence of smaller particles

This activity aims to capture students' attention and minds them towards the presence of small particles. Therefore, the following guidelines should help the teacher to monitor the lesson efficiently.

- Decide on the method of teaching to use. Tell the learners to open and read the activity 7.1 in the learner's book.
- Give the instructions to learners and read the questions and answer them by writing in their notebooks. Give them the time to reflect on their prior knowledge (thinking time).
- While students are doing this activity, you move around and mark the work of those who have finished.
- When everyone is done, invite some member(s) or group(s) to present their findings to the whole class. Make sure that you are developing generic competences in your learners: cooperation, communication, critical thinking, etc.
- Inquire from other students or groups whether their answers correspond to the ones discussed
- Together with students harmonize the points discussed and make a summary on the board. Linking to the summary and what have been discussed in class, this will be the opportunity for the teacher to correct misconceptions met during presentation.
- Allow learners to write the main points in their notebooks. Make summative assessment to make sure that learning objectives have been achieved.
- Link this lesson to real life. You should talk about cross-cutting issues to be addressed in this lesson like peace education.

### **Possible answers**

4. Elementary particle is any of the particles of which matter and energy are composed or which mediate the fundamental forces of nature. In particle physics, it is a particle whose substructure is unknown thus it is unknown whether it is composed of other particles
5. There are three main types of elementary particles are: Gauge bosons, leptons and hadrons

#### **d. Checking my progress**

1. A.
2. i) **Gauge bosons**                      ii) **Leptons and quarks**
3. A.
4. The study of the fundamental constituents of matter and their interactions

## Lesson 7.2: Classification of elementary particles

### a) Introduction:

- Through guided discovery, assist learners to describe different types of elementary particles and how to classify elementary particles based on the properties
- You then guide them to find explanations about types of elementary particles and their classification. You can make a recap using the lesson 1 of this unit.
- You can ask learners questions about elementary particles and their classifications

### b) Teaching resources:

Internet and textbooks and available resources

### c) Learning Activities

#### Activity 7.2: Classes of elementary particles

This activity major focuses on classification of elementary particles.

Make groups (or you can vary the method depending on the type of your class)

instruct learners to read instructions carefully brainstorm the questions and then write them in their notebooks and then attempt the questions.

Invite some group(s) to present their findings to the whole class and allow others to give their Points in case they are different from what have been discussed.

Together with learners make a summary (use student's work/findings) linking to the summary you made with students, explain clearly types of elementary particles and their classification.

### Possible answers

1.

- **Gauge bosons:** The particles in the gauge boson category include the photon, which carries the electromagnetic force
- **Leptons:** comprise three charged particles, each existing in both a positive and a negative form the electron, the muon, the tau and neutrinos of three corresponding types the electron neutrino, the muon neutrino, and the tau neutrino.
- **Hadrons:** they include the neutron, the proton, the pion, and other particles with larger rest masses. Hadrons are further divided by mass and spin into the mesons and the heavier baryons.

2. There are three properties that describe an elementary particle 'mass,' 'charge' and 'spin'

### 7.2.3 Checking my progress

1. Elementary particles can be classified by their properties “mass, Spin and charge”
2. D.
3. D
4. Elementary particle is any of the particles of which matter and energy are composed or which mediate the fundamental forces of nature. In particle physics, it is a particle whose substructure is unknown thus it is unknown whether it is composed of other particles.

## Lesson 7.3: Particle and anti particle

### a) Introduction:

Through brainstorming, teacher invites different learners to review on the previous lessons.

### b) Teaching resources:

Internet and textbooks and available resources

### c) Learning Activities

This activity aims at capturing students’ attention and minds towards the recap on the lesson 2 Classification of elementary particles.

- Decide on the methodology of teaching to use in this lesson.
- Where possible, take your students in a computer lab and instruct them to search about the concept of particle and antiparticle. You can instruct them write in the search engine “particle and antimatter”.
- Divide While students are doing this activity, you move around and mark their attention and assist them if there is any problem about searching on internet.
- When every group is done; invite groups (s) (like 2 groups) to discuss and present their findings to the whole class. Here, a group should choose one to represent their finding. Where possible, when two groups are to represent, one should be represented by a girl another by a boy or a learner with impairment.
- Inquire from other students or groups whether their answers correspond to the ones discussed in their groups.

Together with students harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks. Then linking to the summary and what have been discussed in class, take a step and explain intensively the need to know about particle, antiparticle and Pauli’s exclusion principle.

## Activity 7.3: What is antiparticle?

### Possible answers

An **antiparticle** is a particle of antimatter corresponding to a give particle in every respect except that charge and certain other discrete properties charge sign. The positron, for example, is the antiparticle the electron. In collision between a particle and its antimatter counterpart, both are annihilated.

#### d) Checking my progress

1. An antiparticle (its definition in learner book)
2. The principle of Pauli's exclusion states that two or more identical fermions cannot occupy the same quantum state within a quantum system simultaneously.
3. 'No two particles, fermions (electrons) can be in the same quantum state'. As the Pauli's exclusion principle suggests, if any two particles for examples electrons are found be sharing the same state, any one particle will be excluded from sharing state.

## Lesson 7.4: Fundamental interactions by particle exchange

### a) Introduction:

Through brainstorming, learners revise the elementary particles in the previous lessons.

### b) Teaching resources:

Internet, textbooks and other available resources

### c) Learning activities

Decide on the method to use in this lesson (You can use group work, individual or whole class)

- Tell learners to open their books to activity 7.4
- Instruct them to read the instructions of the questions and attempt the questions in this activity
- Call some student(s) or group(s) to present their findings to the whole class. Under your guidance
- Explain their findings about antiparticles in the whole class.
- Together with students, come up with a summary and allow learners to write some important concepts in their notebooks.

## 7.4 Possible answers:

In particle physics:

1. Gravitational force is responsible for the motion of the planets and Stars in the Universe
2. The electroweak interaction is the unified description of two of the four known fundamental interactions of nature: electromagnetic and the weak interaction
3. Strong force is an attractive between protons and neutrons that keep the nucleus together.
4. Weak force is the mechanism of interaction between sub-atomic particles that causes radioactive decay and thus plays an essential role in nuclear fission (meaning is responsible for radioactive decay of certain nuclear

### 7.4.2 Checking my progress

1. B
2. By 1940, the recognized forces of nature (fundamental forces) were four:  
Gravitational forces between objects,  
Electromagnetic forces between electric charges,  
Strong force (nuclear force) between subatomic particles,  
Weak forces that arise in certain radioactive decay processes

## Lesson 7.5: Uncertainty principle and particle creation

### a) Introduction:

Through guided discovery, assist learners to discuss about uncertainty principle for time and energy in the context of particle creation. You can make a recap using the previous lessons.

### b) Teaching resources:

Internet, textbooks and other available resources

### c) Learning Activities

- Decide on the method to use in this lesson (You can use group work, individual or whole class) Tell learners to open their books to activity 8.5
- Instruct them to read the instructions of the questions and attempt the questions in this activity

- Call some student(s) or group(s) to present their findings to the whole class. Under your guidance
- Explain uncertainty principle and derive its equation.
- Together with students, come up with a summary and note down major points to the board and allow learners to write some important concepts in their notebooks.

### Activity 7.5: Investigation of particle creation and position

#### Possible answers:

Particle creation meaning, high energy particle from accelerator can collide to produce new particles. They can produced by nuclear reaction. No, we can't know exactly the position and momentum of particle uncertainty principle

#### 7.5 Checking my progress

The Uncertainty principle.

a.  $\Delta x \Delta p \geq \frac{\hbar}{2}$  where  $\hbar = \frac{h}{2\pi} = 1.055 \times 10^{-34} \text{ J} \cdot \text{s}$

The Heisenberg uncertainty principle says that no matter how precise your measurements, the more you know about one variable the less it is possible to know about the other, and the product of the two uncertainties is always greater than or equal to Planck's constant,  $\hbar = \frac{h}{2\pi} = 1.055 \times 10^{-34} \text{ J} \cdot \text{s}$ .

All experiments involve some uncertainty due to inaccuracies in measurements; these uncertainties are also often called "errors". In a first year physics experiment these uncertainties are enormous compared to that from the uncertainty relation, so it can be ignored in the first year laboratory.

The uncertainty principle places no limit on how accurately you can measure the position or velocity of an object. It limits how much you can know about position and momentum simultaneously, the more you know about one, the less you can know about the other.

2. a) The electron could be anywhere within the region,  $\Delta x = 5.000 \times 10^{-11} \text{ m}$ ;

so we take as its position uncertainty. For a given value of the uncertainty in momentum is minimum when the product  $\Delta x \cdot \Delta p \geq \frac{h}{4\pi}$

$$\text{Hence } \Delta p = \frac{h}{4\pi\Delta x} = \frac{6.23 \times 10^{-34}}{4\pi(5.00 \times 10^{-11})} = 0.992 \times 10^{-24} \text{ kgm/s}$$

b) We can rewrite the non relativistic expression of kinetic energy

$$K = \frac{1}{2}mv^2 = \frac{p^2}{2m} = \frac{(0.992 \times 10^{-24} \text{ kg m/s})^2}{2 \times 9.11 \times 10^{-31}} = 5.4 \times 10^{-19} \text{ J} = 3.375 \text{ eV}$$

## **Lesson 7.6: Matter and antimatter (pair production and annihilation)**

### **a) Introduction:**

Through guided discovery, assist learners to discuss about the concepts of matter and antimatter. You can make a recap using the previous lesson 8.2

### **b) Teaching resources:**

Internet and textbooks.

### **c) Learning Activities**

#### **Activity 7.7: Describing the matter and antimatter**

### **Possible answers:**

1. Matter is defined as substance that has inertia and occupies physical space. In modern physics, it consists of various types of particles, each with mass and size. Examples: the electron, the proton and the neutron then combinations of these particles form atoms.
2. Antimatter and give examples of antimatter particles. Examples A positron is the antiparticle of the electron. Antiproton is the antiparticle of proton
3. Pair production is the creation of an elementary particle and its antiparticle from neutral boson. Examples Include creating an electron and a positron, a muon and antimuon, or proton and an antiproton.
4. The processes in which a particle and antiparticle unite, annihilate each other, and produce one or more photons.

### **d. Checking my progress**

1. D
2. Annihilation
3. When antimatter meets matter (we assume that their particles are of the same type) the process annihilation occurs, and energy is released
4. Antimatter is the same as matter in every way, looks the same and behaves the same, except its particles have electrical charges opposite to matter.. Examples: electrons are negatively charged, while a positron is positively charged.

## 7. 6 Summary of the Unit

Elementary particles have been organized into groups according to their fundamental properties, including mass, spin and charge. One classification scheme treated particles as gauge bosons, leptons, and Hadrons.

- **Gauge bosons** the class of particles that interact through the electroweak force and contains the photon and the W boson and Z boson.
- **Leptons** the class of particles that interact through the weak nuclear force and contains the electron, the muon, the tauon and the three types of neutrino.
- **Hadrons** the class of particles that chiefly interact through the strong nuclear force and contains the neutron, the proton, the pion and other particles of large mass
- **Baryons** are assumed to consist of three quarks, and mesons to consist of a quark and an antiquark.

**Meson:** the elementary particle originally predicted to be responsible for the strong nuclear force and now a class of particle

There are four fundamental forces or interactions:

- Gravity
- The weak force is responsible for the radioactive decay of unstable nuclei and for interactions of neutrinos and other leptons with matter.
- Electromagnetic force
- Strong force binds quarks together and holds nucleons (protons and neutrons) in nuclei.

Antiparticle is a subatomic particle identical to another subatomic particle in mass but opposite to it in electric and magnetic field (such as sign of charge) that when brought together with its counterpart produces mutual annihilation.

**Pauli's exclusion principle** states that no more than one particle can occupy any quantum state.

**Heisenberg uncertainty principle:** we cannot measure the momentum and position of an object simultaneously to better than an uncertainty given by

$$\Delta x \Delta p \geq \frac{\hbar}{2}$$

Not that, in a similar way, the energy of an object can be uncertain, even not conserved, for a very short period of time, according to

**Matter** is a substance that has mass and takes up a space by having a volume. This includes atoms and anything made up of these but not other energy phenomena or waves such as light or sound

to  $\Delta E \Delta t \geq \frac{\hbar}{2}$  where  $\hbar = \frac{h}{2\pi} = 1.055 \times 10^{-34} \text{ J} \cdot \text{s}$ .

**Antimatter** is a material composed of the antiparticle to the corresponding particle or ordinary particles. In theory a particle and its antiparticle have the same mass as one another but opposite electric charge and other differences in quantum numbers.

**Pair production** is the creation of an elementary particle and its antiparticle from neutral boson. Examples Include creating an electron and a positron, a muon and antimuon, or proton and an antiproton.

**Annihilation** is the processes in which a particle and antiparticle unite, annihilate each other, and produce one or more photons.

## 7.7 Additional Information

### 1. Classifications of hadrons

Spin	Mesons									Baryons			
Spin	0				1					1/2			
Name	Pion	Kaon	Anti-Kaon	eta	rho	Hyper-Kaon	Antihyperkaon	Omega	Sigma	Proton	Xi	Lambda	
Charge	1,0,-1	1,0	0,-1	0	1,0	0,-1	0	0	1,0,-1	1,0	0,-1	0	
Strangeness	0	1	-1	0	0	1	-1	0	-1	0	-2	-1	

### 2. Particle physics

Protons, electrons, neutrons, neutrinos and even quarks are often featured in news of scientific discoveries. All of these, and a whole “zoo” of others, are tiny sub-atomic particles too small to be seen even in microscopes. While molecules and atoms are the basic elements of familiar substances that we can see and feel, we have to “look” within atoms in order to learn about the “elementary” subatomic particles and to understand the nature of our Universe. The science of

This study is called Particle Physics, Elementary Particle Physics or sometimes High Energy Physics (HEP).

Atoms were postulated long ago by the Greek philosopher Democritus, and until the beginning of the 20th century, atoms were thought to be the fundamental indivisible building blocks of all forms of matter. Protons, neutrons and electrons came to be regarded as the fundamental particles of nature when we learned in the 1900's through the experiments of Rutherford and others that atoms consist of mostly empty space with electrons surrounding a dense central nucleus made up of protons and neutrons.

The central nucleus contains protons and neutrons which in turn contain quarks. Electron clouds surround the nucleus of an atom. The science of particle physics surged forward with the invention of particle accelerators that could accelerate protons or electrons to high energies and smash them into nuclei to the surprise of scientists, a whole host of new particles were produced in these collisions.

**By the early 1960s**, as accelerators reached higher energies, a hundred or more types of particles were found. Could all of these then be the new fundamental particles?

Confusion reigned until it became clear late in the last century, through a long series of experiments and theoretical studies, that there existed a very simple scheme of two basic sets of particles: the **quarks** and **leptons** (among the leptons are electrons and neutrinos), and a set of fundamental forces that allow these to interact with each other. By the way, these “forces” themselves can be regarded as being transmitted through the exchange of particles called **gauge**

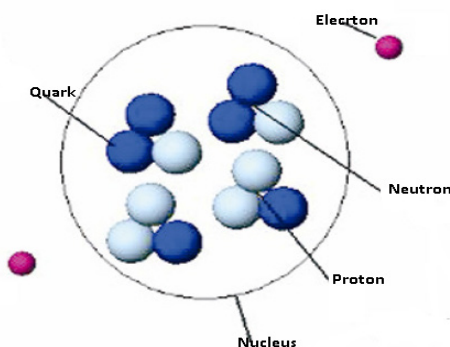


Fig.7. 1The structure of an atom

**Bosons.** Example of these is the photon, the quantum of light and the transmitter of the electromagnetic force we experience every day.

## 7.8 End unit assessment

### 7.8.1 Multiple choices

1. A. (The positron is a particle of matter with the same mass as an electron but an opposite charge. It is a form of antimatter because, when a positron encounters, the two completely annihilate to yield energy’).

2. C
3. C (All of the fundamental forces act on a variety of objects, including our bodies. Although the strong and weak forces are very short range, the electromagnetic force is a long-range force, just like gravity. One reason we notice the “weak” gravity force more than the electromagnetic force is that most objects are electrically neutral, so they do not have significant net electromagnetic forces on them. It is true that the gravitational force between people and other objects of similar size is too small for us to notice, but due to the huge mass of the Earth, we are always aware of the influence of the Earth’s gravitational force on us)

### 7.8.2 Structured questions

4. A = Leptons      B = Baryons

5. (a) (i)

- Positron is an antimatter particle; proton is a matter particle
- Positron is a lepton; proton is a hadron
- Positron has a smaller rest mass than a proton
- Positron is not composed of other particles; proton is made up of quarks

ii) Proton path has greater radius of curvature than positron

(iii) Radius of curvature  $r = \frac{Be}{mv}$ , where v, B and e are constant therefore r proportional to m mass of proton (m) is (much) greater than mass of positron at same speed

6. Rest mass of electron  $m_0 = 0.51 \text{ MeV}$  therefore total energy available

$$E = 2.2 + 2 \times 0.51 = 3.22 \text{ MeV}$$

Gamma photons produced have average energy  $\bar{E} = \frac{3.2}{2} = 1.6 \text{ MeV}$

### 7.8.3 Essay question

**$\pi$  meson (pion)** is a particle that can be positive, negative, or neutral.

A  $\pi^+$  or  $\pi^-$  meson has a mass of 273 electrons. A neutral meson has a mass of 264 electro masses.

A muon ( $\mu$ ) is a particle having a mass of 207 electron masses. It formed in the decay of a  $\pi^+$  or  $\pi^-$  meson and can be either positive or negative. It becomes just like a heavy electron

decay of a  $\pi$  A neutrino is a neutral particle of almost zero rest mass that is emitted in beta and in  $\pi^+$  or  $\pi^-$  meson decays. Six kinds of a neutrinos are known, three of which are antineutrinos.



**Answer 4. a.**

5. Which of the following particles interacts with itself

- a. Neutrino
- b. Photon
- c. Gluon

**Answer 5.c**

6. Which of the four fundamental forces has the shortest range?

- a. Strong
- b. Weak
- c. Electromagnetism
- d. Gravity

**Answer: 6. b.**

7. Lepton number is

- a. Violated in weak interactions
- b. Violated in strong interactions
- c. Conserved only in electromagnetic interaction
- d. Conserved for all forces
- e. Conserved only in weak interaction

**Answer: 7. d.**

8. State the Heisenberg uncertainty principle?

Answer: (is in a learner's book. lesson 8.5)

9. Elementary particles that interact by the weak force are called:

- a) Pion
- b) muon
- c) Neutron
- c) Proton
- d) W boson

**Answer: 9.b**

#### 7.9.2 Consolidation activities

10. What happens when antimatter collides with its matter?

Answer: they annihilate resulting into formation of energy.

11. What is meant by the following terms: pair production and annihilation?

**Answer:** (is in a learner's book: lesson 7.6)

12. The uncertainty of the x-component of the electron's position is 0.05 nm. Use the position momentum Uncertainty principle to find:

The uncertainty in the momentum.

Then use the Classical expressions for the momentum and kinetic energy to estimate the electron's kinetic energy,

Compare it to the ground-state kinetic energy predicted by the Bohr mode. Find the uncertainty in the gamma-ray energies. (Take the time needed for the gamma rays to be emitted to be )

$$a) \Delta x \Delta p \geq \frac{\hbar}{2} \text{ so } \Delta p \geq \frac{\hbar}{2\Delta x} = \frac{6.626 \times 10^{-34}}{4\pi \times 5.00 \times 10^{-9}} = 1 \times 10^{-24} \text{ kg} \cdot \text{m} / \text{s}$$

$$b) k = \frac{1}{2}mv^2 = \frac{p^2}{2m} = \frac{(1 \times 10^{-24} \text{ kgm} / \text{s})^2}{2 \times 9.11 \times 10^{-31}} = 5.488 \times 10^{-19} \text{ J} = 3.43 \text{ eV}$$

$$c) \Delta E \Delta t \geq \frac{\hbar}{2} \Leftrightarrow \Delta E = \frac{\hbar}{2\Delta t} = \frac{1. \times 10^{-24}}{2 \times 1 \times 10^{-12}} = 3 \times 10^{-4} \text{ eV}$$

### 7.9.3 Extended activities

1. In which of the four force interactions does each of the following particles play a role?
- a) Electron    b) positron    c) proton    d) neutron    e) neutrino

#### Answers :

- a) electromagnetic, weak and gravity  
 b) electromagnetic, weak and gravity  
 c) weak, strong, and gravity  
 d) electromagnetic, weak, strong and gravity  
 e) Weak

2. Why does pair production need a nucleus?

**Answer:** ' the photon must be a nucleus in order to satisfy conservation of momentum, as an electron-positron pair producing in free space cannot both satisfy conservation of energy and momentum. Because of this, when pair production occurs, the atomic nucleus receives some recoil'.

### 8.1 Key Unit Competence

Organize the properties and basic principles of quarks.

### 8.2 Prerequisite knowledge and skills

The success of this unit relies partly on the mastery of knowledge and skills acquired in Physics (Unit 7: Nature of particle and their interaction, S6), in Chemistry S4 (Unit 2: Electron configurations of atoms and ions) and other related subjects in previous grades.

### 8.3 Cross-Cutting Issues to be addressed

- **Inclusive education** (promote education for all while teaching). Regardless of physical appearance and abilities learners should be treated equally. This makes the learners to find out that they are all of great importance. Regarding to this unit, you can show learners that as small elementary particle in reaction together, they create matter or energy through their interaction, thus, as students all, regardless of their physical ability, in a team they can make the society beautiful. (You should not this after providing summary at the end of the lesson 4)
- **Gender education** (equal opportunity of boys and girls in the lesson participation). Care should be taken that both Sexes are given equal opportunities. In this unit, we have seen that quarks and antiquarks together, they form meson at equal proportion, thus as male and female working together with equity, they build their society.
- **Environment sustainability:** During delivering different lessons within this unit, let learners be familiar with the application and importance of skills and knowledge obtained about formation of matter, properties and principles of quarks as elementary particles.

## 8.4 Guidance on the introductory activity

- This activity aims at capturing students' attention and minds towards this concept
- Decide the method to use in this lesson (Where possible, mix equally the number of girls to number of boys. If there are students with impairment, let them take the lead of groups during doing activity)
- Tell the learners to open the introductory activity in the learner's book.
- Instruct learners to re-write the questions and answer them following the instructions from learner's book.
- While students are doing this activity, you move around and mark their work.
- When everyone is done and you are done, invite some member(s) or group(s) to present and discuss their findings to the whole class.
- Ask other members whether their answers correspond to the discussed points and if there is any point that is different from what have been raised to mention it. You can talk about those points (in a discussion together with other students).
- Together with students harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks. And then linking to the summary and what have discussed in class, emphasize on the types of quarks. You can take some minutes and explain them.
- Summarize your lesson by linking this concept to real life situations if you can find one like a fruit ant is seeds (eg: papaya)

### Possible answers of the introductory activity.

During this introductory activity, let learners present their upbringing about the about quarks and elementary particles in general, and then find out the hub of their curiosity about quarks. The summary of the introductory question provided in the LB

5. As regarded from unit 8, we have seen that electrons are composed by leptons; protons and neutron are composed by quarks and photons. Let students bring back their background knowledge about elementary particles that they may know.
6. When a charged particle penetrates in matter, it will interact with the electrons and nuclei present in the material through the electromagnetic force. For instance, if the particle has 1 MeV or more as energy, as is typical in nuclear phenomena, the energy is large compared to the binding energy of the electrons in the atom. Any charged particle undergoing acceleration will emit electromagnetic radiation. If a high-energy charged particle deviates from its trajectory due to a collision with a nucleus, this collision is necessarily accompanied by electromagnetic radiation. The emission is strongly peaked in the direction of flight of the charged particles (Blemstrahlung).

## 8.5 List of lessons

S/No	Lesson Title	Learning Objectives	Periods
1	Types of quarks	<p>List types of quarks, identify quarks, antiquarks and hadrons (baryons and mesons)</p> <p>Identify quarks, antiquarks and hadrons (baryons and mesons)</p> <p>Explain types of quarks</p> <p>Explain quarks as components of proton and neutron.</p> <p>Adapt scientific thinking about particle elements</p>	4
2	Baryon number and the law of conservation	<p>Define baryon number and state the law of conservation of baryon number.</p> <p>Interpret the baryon number and apply the law of conservation of baryon number.</p> <p>Formulate the spin structure of hadrons (baryon and mesons)</p>	4
3	Spin structures of hadrons (hadrons and mesons)	<p>Identify the spin structure of hadrons (baryons and mesons)</p> <p>Formulate the spin structure of hadrons (baryon and mesons)</p> <p>Acquire knowledge of analyzing and modeling behavior of quarks.</p>	4
4	Color in forming of bound states of quarks.	<p>Explain how colour forms bound states of quarks.</p> <p>Explain colour of quarks and gluons</p>	2
5	Colour as component of quarks and gluons.	<p>State colours of quarks and gluons.</p> <p>Explain colour of quarks and gluons</p> <p>Acquire ability to logically and systematically pursue a line of thoughts.</p>	2
6	Evaluation		2

## Lesson 1: Types of quarks (4 periods)

### a) Introduction:

- Through guided discovery, assist learners to describe different types of elementary particles.
- You then guide them to find explanations about quarks and their types as well as introduce their properties. You can make a recap using Unit 7: Nature of particle and their interaction (S6) and from chemistry Unit 2: Electron configurations of atoms and ions (S4).
- You can ask learners questions about elementary particles and quarks as well as referred to unit 8 (S6) and unit 2 of chemistry S4.

### b) Teaching resources

- Internet
- Fruit (avocado, papaya, etc)
- Text books

### c) Learning Activities

#### Activity 8.1: Investigating about elementary particles

- This activity aims at capturing students' attention and minds towards the recap on elementary particles.
- Divide your students into groups or any method that is appropriate for your class.
- Instruct learners to discuss about the prerequisite unit 7 about elementary particles; then let them answer to questions in activity 8.1 in the learners book
- While students are doing this activity, you move around and mark their attention.
- When every group is done; invite groups (s) (like 2 groups) to discuss and present their findings to the whole class. Here, a group should choose one to represent their finding. Where possible, when two groups are to represent, one should be represented by a girl another by a boy or a learner with impairment.
- Inquire from other students or groups whether their answers correspond to the ones discussed in their groups.
- Together with students harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks. Then linking to the summary and what have been discussed in class, take a step and explain intensively the need to know about elementary particles as well as quarks.
- Suggested answer to activity 8.1

There are three main groups of elementary particles:

- **Gauge bosons:** The particles in the gauge boson category include the photon, which carries the electromagnetic force, and the  $W^\pm$  and Z bosons, which carry the weak nuclear force.

- **Leptons:** comprise three charged particles, each existing in both a positive and a negative form the electron, the muon, the tau (also called the tauon) and neutrinos of three corresponding types **the electron neutrino, the muon neutrino, and the tau neutrino.**
  - **Hadrons:** they include the neutron, the proton, the pion, and other particles with larger rest masses. Hadrons are further divided by mass and spin into the mesons and the heavier baryons.
2. **Quarks** are types of elementary particles and a fundamental constituent of matter. Quarks combine to form composite particles called hadrons, the most stable of which are protons and neutrons, the components of atomic nuclei. They are particles that interact chiefly through the strong nuclear force
  3. The study of elementary particles plays a major role of opening our curiosity to know about the origin of matter and energy or how interaction between them may produce matter, energy or both of them.

### Activity 8.2: Investigating quark particles

This activity aims at capturing students' attention and minds towards the recap on elementary particles especially about quarks and types of quarks.

- Decide the method to use in this lesson
- Where possible, take your students to computer lab and instruct them to search about the concept of quarks. You can instruct them write in the search engine like "Types of quarks".
- While students are searching on internet, you move around and mark their attention or assist them where some groups may be distracted on internet.
- When every group is done; invite groups (s) (like 2 groups) to discuss and present their findings to the whole class. Here, a group should choose one to represent their findings. Where possible, when two groups are to represent, one should be represented by a girl another by a boy or a learner with impairment.
- Inquire from other students or groups whether their answers correspond to the ones discussed in their groups.
- Together with students harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks. Then linking to the summary and what have been discussed in class, take a step and explain intensively the need to know about types of and their properties.

### Suggested answer to activity 8.2

Quarks are elementary particle and fundamental constituent of matter. Quarks combine to form composite particles called **hadrons**, the most stable of which are **protons** and **neutrons**, the components of atomic nuclei. Due to a phenomenon

known as **color confinement**, quarks are never directly observed or found in isolation; they can be found only within hadrons, such as **baryons** (of which protons and neutrons are examples) and mesons.

There are six types of quarks, known as flavors: up, down, strange, charm, top, and bottom

**d) i. Suggested answer to checking my progress 8.1.3**

1. (C) Each hadron consists of a proper combination of a few elementary components called **quarks**.
2. (A) Which of the following is not conserved in a nuclear reaction? **Nucleon number**.
3. (A) The first antiparticle found was **the positron**.
4. (B) The proton, neutron, electron, and the photon are called **fundamental particles**.
5. (D) The exchange particle of the electromagnetic force is the **photon**.
6. (B) Particles that interact by the strong force are called **hadrons**.
7. (B) At the present time, the elementary particles are considered to be the **leptons and quarks**.
8. (B) The electron and muon are both **leptons**.
9. (A) Particles that make up the family of hadrons are **baryons and mesons**.
10. (A) It is not possible for a particle to be both a lepton and a baryon. A lepton is an elementary particle, not composed of quarks, while baryons are made up of three quarks.
  - (b) Yes, it is possible for a particle to be both a baryon and a hadron. All baryons are spin =  $\frac{1}{2}$  hadrons.
  - (c) No, it is not possible for a particle to be both a meson and a quark. A meson is made up of two quarks.
  - (d) No, it is not possible for a particle to be both a hadron and a lepton. A lepton is an elementary particle, while a hadron is made up of three quarks.
11. (A) Fermions: according to the standard model, the particles from which all matter is composed; subdivided into leptons and quarks while Bosons: according to the standard model, the particles responsible for the fundamental forces of nature.

(b) Leptons: the class of particles that interact through the weak nuclear force; contains the electrons, the muons; the tauons, and the three types of neutrino. While

Hadrons: the class of particles that chiefly interacts through the strong nuclear force; contains neutron, the proton, the pions, and other particles of large mass.

(c) Meson: the elementary particle originally predicted to be responsible for the strong nuclear force; now a class of particles. While baryon number is a property of elementary particles; quarks have a baryon number of  $\frac{1}{3}$ .

12. An electron takes part in the electromagnetic interaction (it is charged), the weak interaction, and the gravitational interaction (it has mass). A neutrino takes part in the weak interaction and the gravitational interaction (it has a small mass). A proton takes part in the strong interaction (baryon), the electromagnetic interaction (it is charged), the weak interaction, and the gravitational interaction (it has mass).

### Suggested answer to checking my progress 8.1.3

1. (C) A proton is made up of two **up quarks** and a **down quark**
2. (B) Particles that are not affected by strong nuclear force are **leptons**
3. (A) Particle which explains about mass of matter is called Higgs boson
4. There are six types of quarks, known as flavors: up, down, strange, charm, top, and bottom. Up and down quarks have the lowest masses of all quarks. The heavier quarks rapidly change into up and down quarks through a process of particle decay (the transformation from a higher mass state to a lower mass state). Because of this, up and down quarks are generally stable and the most common in the universe, whereas strange, charm, bottom, and top quarks can only be produced in high energy collisions (such as those involving cosmic rays and in particle accelerators).

**Notice to all lessons:** Remember the essence of this activity (checking my progress) is to master and apply what they have already acquired from the previous lessons of the unit and activities provided.

- Assign this activity as homework/exercise/ group work/ Assignment or any depending on what you want to achieve.
- Make sure you check or mark the activity when students are done with the work.
- Give them feedback and invite some members to discuss their findings to the whole class.
- Together with students harmonize and make a summary and tell your students to write down key points in their notebooks.

## **Lesson 2: Baryon number and the law of conservation (4 periods)**

### **a) Introduction**

- Through guided discovery, assist learners to describe the properties of quarks and then define the baryon number of quarks.

You then guide them to find explanations about quarks and their types as well as introduce their properties. You can make a recap using Unit 7: Nature of particle and their interaction (S6) and from chemistry Unit 2: Electron configurations of atoms and ions (S4) as well as the lesson 1 of this unit.

- You can ask learners questions about types of quarks and then their baryon numbers.

### **b) Teaching resources**

- Internet
- Text books

### **c) Learning Activities**

#### **Activity 9.3: Investigating about particle's baryon numbers.**

This activity aims at capturing students' attention and minds towards the recap on baryon numbers of elementary particles.

- Decide on the method of teaching to use in this lesson.
- Where possible, take your students (in a period of 10 to 15 min) in a computer lab and instruct them to search about the concept baryon number of elementary particles. You can instruct them write in the search engine “Baryon number of elementary particles”.
- Instruct learners to discuss about the types of quarks; then let them present their findings about activity 8.3.
- While students are doing this activity, you move around and mark their attention and assist them if there is any problem about searching on internet.
- When every group is done; invite groups (s) (like 2 groups) to discuss and present their findings to the whole class. Here, a group should choose one to represent their finding. Where possible, when two groups are to represent, one should be represented by a girl another by a boy or a learner with impairment.
- Inquire from other students or groups whether their answers correspond to the ones discussed in their groups.
- Together with students harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks. Then linking to the summary and what have been discussed in class, take a step and explain intensively the need to know about elementary particles as well as quarks.

### c. Suggested answer to activity 8.3

Baryon number is a property of elementary particles; e.g: quarks have a baryon number of  $\frac{1}{3}$  **Baryon number** is a generalization of nucleon number; it can be conserved in nuclear reaction and decays. All nucleons are defined to have baryon number  $B=+1$ , and all antinucleons (antiprotons, antineutrons) have  $B=-1$ . All other types of particles, such as photons, mesons, and electrons and other leptons have  $B=0$

### d) Suggested answer to checking my progress about 8.2

1. Particle interactions have been observed to conserve the number of baryons present; hence the introduction of another quantum number, the baryon number, and the law of conservation of baryon number. Quarks are assigned a baryon number of  $\frac{1}{3}$ , since three quarks are required to construct a baryon.

The law of baryon of conservation state that:

“The total baryon number before a particle interaction equals the total baryon number after”

$$2. (a) p + p \rightarrow p + \bar{p} + n + p$$

On the left hand side, we have,  $B=+1+1=+2$ ,

the right hand side gives  $B = +1 - 1 + 1 + 1=+2$

Hence, the baryon number is conserved.

$$(b) p + p \rightarrow p + \pi^+$$

On the left hand side, we have  $B=+1+1=+2$ , the right hand side  $B=+1+0=+1$ .

Hence, the baryon number is not conserved.

## Lesson 3: Spin structures of hadrons (baryons and mesons) (4 periodes)

### a) Introduction

- Through guided discovery, assist learners to describe spin structure of hadrons.
- You then guide them to find explanations about quarks and their types as well as introduce their properties. You can make a recap using lesson 1 and 2 of this unit .
- You can ask students questions about hadrons, and their properties as well as their spin structures.

### b) Teaching resources

- Internet
- Text books

## c) Learning Activities

### Activity 8.4: Investigating the spin structure of elementary particles

This activity aims at capturing students' attention and minds towards the recap on quarks, baryon numbers and spin structure of hadrons.

- Decide the method of teaching to use in this lesson.
- Where possible, take your students (in a period of 15 to 20 min) in a computer lab and instruct them to search about the concept spin structure of hadrons. You can instruct them to write in the search engine "Spin structure of hadrons". Remember to tell them to note the source of information they are getting from internet.
- While students are doing this activity, you move around and mark their attention.
- When every group is done; invite groups (s) (like 2 groups) to discuss and present their findings to the whole class. Here, a group should choose one to represent their finding. Where possible, when two groups are to represent, one should be represented by a girl another by a boy or a learner with impairment.
- In an open discuss, inquire from other students or groups whether their findings correspond to the ones discussed in their groups.
- Together with students harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks. Then linking to the summary and what have been discussed in class, take a step and explain intensively the need to know about baryon number and spin structure of hadrons.

### Suggested answer to activity 8.4

Although no isolated quarks have been found, more than two hundred of their bound states have been discovered, all with integer electric charges. The reason for this is closely associated with a new degree of freedom that exists for quarks, but not for leptons, called color. There exist in simple quark model only three types of quark bound states that are allowed. These are the baryons, which have half-integer spin and are assumed to be bound states of three quarks ( $3q$ ); the antibaryons, which are their antiparticles and assumed to be bound states of three antiquarks ( $3\bar{q}$ ); and the mesons, which have integer spin and are assumed to be bound states of a quark and an antiquark ( $q\bar{q}$ ). Some examples of baryons and mesons that we shall meet later in this unit, together with their quark compositions are summarized in the learner's book (see Table 8.6 and 8.7 from LB)

d) Suggested answer to checking my progress for 8.3

1. (a) Anti-kaon ( $\bar{\kappa}$ )  
(b) pi minus ( $\bar{\pi}$ )

(c) sigma zero ( $\Sigma^0$ )

(d) sigma plus ( $\Sigma^+$ )

2. (a) For  $\bar{B}^0 = \bar{b}u$ , we have

$$\text{Charge: } -\frac{1}{3} - \frac{2}{3} = -1$$

$$\text{Spin: } 1/2 - 1/2 = 0 \text{ Spin:}$$

$$\text{Baryon number: } \frac{1}{3} - \frac{1}{3} = 0$$

$$\text{Strangeness: } \frac{1}{2} - \frac{1}{2} = 0$$

$$\text{Charm: } 0 + 0 = 0$$

$$\text{Bottomness: } -1 + 0 = -1$$

$$\text{Topness: } 0 + 0 = 0$$

(b) Because  $B^+$  is the antiparticle of  $B^-$ ,  $B^+ = \bar{b}u$ . The  $B^0$  still must have a bottom quark, but must be neutral. Therefore  $B^0 = \bar{b}d$ . Because  $\bar{B}^0$  is the antiparticle to  $B^0$ , we must have  $\bar{B}^0 = b\bar{d}$

3. (a) The neutron has a baryon number of 1, so there must be three quarks. The charge must be 0, as must be the strangeness, the charm, the bottomness and the topness. Thus  $n = uud$

(b) The antineutron is the anti particle of the neutron, so  $\bar{n} = \bar{u}\bar{u}\bar{d}$

(c) The  $\Lambda^0$  has a strangeness of -1, so it must contain an "s" quark. It is a baryon, so it must contain three quarks. And it must have charge, charm, bottomness, and topness equal to 0. Thus  $\Lambda^0 = uds$

(d) The  $\bar{\Sigma}^0$  has a strangeness of 0 so it must contain an  $\bar{s}$  quark. It is a baryon, so it must contain three quarks. And it must have charge, charm, bottomness, and topness equal to 0. Thus  $\bar{\Sigma}^0 = \bar{u}\bar{d}\bar{s}$

## Lesson 4: Color in forming of bound states of quarks (2 periods).

### a) Introduction

- Through guided discovery, assist learners to describe different types of elementary particles.
- You then guide them to find explanations about color forming of bound state in theories of elementary particles as well as their properties. You can make a recap using lesson 2 and lesson 3
- You can ask learners questions about color charge property in particle theories and quarks as well during the activity 8.5.

### b) Teaching resources

- Internet
- Text books

## c) Learning Activities

### Activity 8.5: Investigating about what bound state is.

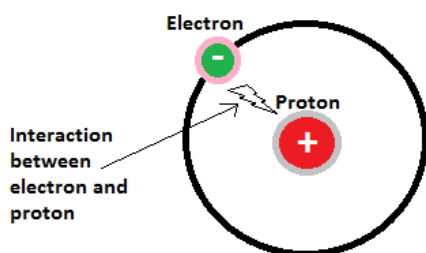
This activity aims at capturing students' attention and minds towards the recap on properties of elementary particles as well as defining the color in forming bound state.

- Chose the appropriate method to use in this lesson.
- Instruct learners to discuss about the prerequisite unit 2 of chemistry S4 about electronic configuration and then tell them to describe the electronic structure of a hydrogen atom.
- While students are doing this activity, you move around and mark their attention on activity.
- When every group is done; invite groups (s) to discuss and present their findings to the whole class. Here, a group should choose one to represent their finding. Where possible, when two groups are to represent, one should be represented by a girl another by a boy or a learner with impairment.
- Inquire from other students or groups whether their answers correspond to the ones discussed in their groups.
- Together with students harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks. Then linking to the summary and what have been discussed in class, take a step and explain intensively the need to know about properties of elementary particles especially color charge property.
- **Notice:** At the end of this lesson you should note in your conclusion; the inclusive education as mentioned above in section 8.3.

### Suggested answer to activity 8.5

The hydrogen atom configuration shows that the proton which is located at centre while electron moves around it at a speed of about 1% the speed of light on the outer shells. The proton is heavy while the electron is light .This is the simplest example of what physicists call a “bound state”. The word “state” basically just meaning a thing that hangs around for a while, and the word “bound” meaning that it has components that are bound to each other, as spouses are bound in marriage.

### d) Suggested answer to checking my progress for 8.4



## Hydrogen atom

The proton and electron exchange information via a gauge boson, in this case, a virtual photon. This is how the electromagnetic interactions are mediated.

2. (a) Color is a property assigned to quarks, keeping them in different quantum states to avoid violation of Pauli Exclusion Principle.

(b) Gluons are hypothetical chargeless massless particles believed to carry the strong nuclear force.

(c) Quantum chromodynamics (QCD) is a theory that describes the strong interaction in terms of gluon exchanges on the part of quarks and antiquarks.

## Lesson 5: Colour as component of quarks and gluons (2 periods)

### a) Introduction

- Through guided discovery, assist learners to describe colour as component of quarks and gluons.
- You then guide them to find explanations about color and color as component of quarks as well as to introduce their properties. You can make a recap using lesson 4 about color in forming of bound state.
- You can ask learners questions about color properties of elementary particles and color as component of quarks and gluons.

### b) Teaching resources

- Internet
- Text books

### c) Learning Activities

#### Activity 8.6: Investigating the origin of color

- This activity aims at capturing students' attention and minds towards the recap on color in forming of bound state of matter energy interaction, thus, the color as component of quarks and gluons.
- Chose the appropriate method to use in this lesson.
- Using a scenario of heating a metal, and instruct learners to discuss about the prerequisite knowledge and skills about color properties of hadrons; then let them answer to questions in activity 9.6 in the learners book.
- While students are doing this activity, you move around and mark their attention.
- When every group is done; invite groups (s) (like 2 groups) to discuss and present their findings to the whole class. Here, a group should choose one to represent their finding. Where possible, when two groups are to represent, one should be represented by a girl another by a boy or a learner with impairment if any.

- With other groups, assist them to contrast the presented answers correspond to the ones discussed in their groups.
- Together with students harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks. Then linking to the summary and what have been discussed in class, take a step and explain intensively the need to know about color as component of quarks and gluons..

### Suggested answer to activity 8.6

1. When a metal is heated, the energy of electrons increases. As the energy increases, the photons that are emitted fall in the wavelength of the visible spectrum. Initially, the metal is emitting infra red radiation invisible the naked eye, when the emitted photons get more energy; they reach the red region of visible light spectrum. Persistent heating will take you to more colors in the spectrum i.e Red → Orange → Yellow → White.
2. Atoms continuously emit and absorb photons. The fact that you can see means that something made of matter - the Sun or light bulb - emitted photons which bounced off the matter you are looking at and interacted with the matter of your eye to create another energy signal which travelled down the matter of your optic nerve to produce a cascade of matter/energy interactions in your brain. Just about everything that happens is an interaction between matter and energy.
3. Color charge is a property of quarks and gluons that is related to the particles' strong interactions in the theory of quantum chromodynamics. The color charge of quarks and gluons is completely unrelated to everyday meaning of color. The term color and labels red, green and blue became popular simply because of loose analogy to primary colors.

Particles have corresponding antiparticles. A particle with red, green or blue charge has corresponding antiparticle on which the color charge must be anticolor or red, green and blue respectively, for the color charge to be conserved in particle – antiparticle creation and annihilation.

### Suggested answers for Checking my progress (Section 9.6 of LB)

#### 1. (A) Red, green and blue

2. (a) Gluons are composed by a color and anticolor (eg. Red-antiblue)

(b) The quark–antiquark pairs of mesons have canceling color and anticolor (for example, blue and antiblue), so mesons also have no net color]

(c) A baryon always contains one red, one green, and one blue quark, so the baryon itself has no net color]

## 8.6 Unit summary

- An antiparticle has the same mass as a particle but opposite charge. Certain other properties may also be opposite: for example, the antiproton has baryon number (nucleon number) opposite to that of the proton.
- In all nuclear and particle reactions, the following conservation laws hold: momentum, angular momentum, mass-energy, electric charge, baryon number and lepton numbers.
- Certain particles have a property called strangeness, which is conserved by the strong force but not by the weak force. The properties charm, bottomness and topness also are conserved by strong force but not by the weak.
- Just as the electromagnetic force can be said to be due to an exchange of photons, the strong nuclear force was first thought to be carried by mesons that have rest mass, but recent theory says the force is carried by massless gluons.
- The W and Z particles carry the weak force. These fundamental force carriers (photon, W and Z, gluons) are called gauge bosons
- Other particles can be classified as either leptons or hadrons. Leptons participate in the weak and electrically charged electromagnetic interactions. Hadrons, which today are considered to be made up of quarks, participate in the strong interactions as well. The hadrons can be classified as mesons, with baryon number zero, and baryons, with nonzero baryon number.
- Quarks and leptons are the fundamental building blocks of matter
- Standard model of elementary particles considers quarks as the basic building blocks of the hadrons. The six quark “flavors” are called up, down, strange, charmed, bottom, and top.
- It is expected that there are the same number of quarks as leptons (six each), and that quarks and leptons are the truly elementary particles with the gauge bosons ( $\gamma, W, Z, gluons$ .)
- Quarks are said to have color, and according to quantum chromodynamics (QCD), the strong color force acts between their color charges and is transmitted by gluons.
- Electroweak theory views the weak and electromagnetic forces as two aspects of a single underlying interaction. QCD plus the electroweak theory are referred to as the standard model

Grand unified theory of forces suggests that at very short distances ( $10^{-32}m$ ) and very high energy, the weak, electromagnetic, and strong forces appear as a single force, and the fundamental difference between quarks and leptons disappears.

## 8.7 Additional information

### 8.7.1 Quark flavor and color

Quarks are  $-1/2$  spin particles (fermions) which come in various species, referred to as flavors. Different quark flavors have been given somewhat whimsical names, as shown in Figure below Fig.9.1. In addition to the curious names, two other things in Fig.9.1 should strike you as odd: the enormous disparity of masses of different quarks, spanning five orders of magnitude, and the fact that quarks have fractional charge (in units of  $|e|$ ). The quark masses listed in this table must be interpreted with some care, as isolated quarks are never observed experimentally. The mass, or rest energy, of observed particles which are bound states of quarks (like the proton) largely reflects the binding energy of the quarks, and is not just the sum of the intrinsic quark masses. Nevertheless, it is remarkable that quark masses vary over such a wide range, from a few MeV to hundreds of GeV. The three lightest quark flavors, denoted u, d and s, have masses which are small relative to the proton mass; the three heavy flavors, c, b and t, have masses which are comparable or large relative to the proton mass.

Along with quarks, there are also antiquarks, denoted  $\bar{u}$ ,  $\bar{d}$ ,  $\bar{s}$  etc., with the same masses but opposite electric charge as their partner. (So, for example, the antiquark has charge  $-1/2$  and then has charge  $+1/2$ .)

mass	$\approx 2.4 \text{ MeV}/c^2$	$\approx 1.275 \text{ GeV}/c^2$	$\approx 172.44 \text{ GeV}/c^2$
charge	$2/3$	$2/3$	$2/3$
spin	$1/2$	$1/2$	$1/2$
	<b>u</b>	<b>c</b>	<b>t</b>
	up	charm	top
<b>QUARKS</b>	$\approx 4.8 \text{ MeV}/c^2$	$\approx 95 \text{ MeV}/c^2$	$\approx 4.18 \text{ GeV}/c^2$
	$-1/3$	$-1/3$	$-1/3$
	$1/2$	$1/2$	$1/2$
	<b>d</b>	<b>s</b>	<b>b</b>
	down	strange	bottom

Fig.8. 1 Standard model of quarks

Quarks have an additional attribute, analogous to but different from electric charge, which is termed color charge. The color charge of a quark can have three possible values which may be denoted as red, green, or blue. These names are simply labels for different quantum states of the quark. Antiquarks carry opposite electric and color charge as the corresponding quarks; color states of antiquarks can be called anti-red, anti-green or anti-blue. Since quarks (and antiquarks) have spin  $1/2$ , so they can also be labeled by their spin projection, or  $\uparrow$ , along any chosen spin quantization axis. Hence, for each quark flavor, there are really six different types of quark, distinguished by the color (red, blue, green) and spin projection (up, down).

### 8.7.2 Baryon number

Baryon number, denoted B, is defined as the total number of baryons minus the number of antibaryons, similar to the definition of lepton number L. Since baryons are bound states of three quarks, and antibaryons are bound states of three antiquarks, baryon number is the same as the number of quarks minus antiquarks, up to a factor of three,

$$B = (\# \text{ baryons}) - (\# \text{ antibaryons}) = \frac{1}{3} (\# \text{ quarks}) - (\# \text{ antiquarks})$$

All known interactions conserve baryon number. High energy scattering processes can change the number of baryons, and the number of antibaryons, but not the net baryon number. For example, in proton-proton scattering, the reaction  $p + p \rightarrow p + p + n + \bar{n}$  can occur, but not  $p + p \rightarrow p + p + n + n$

### 8.7.3 Hadrons

All hadrons are considered to be made up of combination of quarks, and their properties are described at their quark content. Mesons consist of a quark-antiquark pair. Baryons, on the other hand, consist of three quarks. For example, a neutron  $n = ddu$ , whereas an antiproton is  $\bar{p} = \bar{u}\bar{u}\bar{d}$  (See Table 9.7 from LB).

Strange particle all contains an s or quark, whereas charmed particles contain a c or quark. A few of these hadrons are list in the Table 9.1 below.

Category	Particle	Anti-particle	Spin	Baryon number B	Strangeness S	Charm c	Bottomness b	Principle decay mode
Mesons	$D^+$	$D^-$	0	0	0	+1	0	K + others, e + others
	$D^0$	$\bar{D}^0$	0	0	0	+1	0	K + others, $\mu$ or e + others
	$D_s^+$	$D_s^-$	0	0	+1	+1	0	K + others
	$J/\psi$	self	1	0	0	0	0	Hadrons, $e^+e^-$ , $\mu^+\mu^-$
	$Y$	self	1	0	0	0	0	Hadrons, $\mu^+\mu^-$ , $e^+e^-$ , $\tau^+\tau^-$
	$B^-$	$B^+$	0	0	0	0	-1	$D^0$ + others
	$B^0$	$\bar{B}^0$	0	0	0	0	-1	$D^0$ + others
Baryons	$\Lambda_c^+$	$\Lambda_c^-$	$\frac{1}{2}$	+1	0	+1	0	Hadrons (e.g. $\Lambda$ + others)
	$\Sigma_c^{++}$	$\Sigma_c^{--}$	$\frac{1}{2}$	+1	0	+1	0	$\Lambda_c^+\pi^+$
	$\Sigma_c^+$	$\Sigma_c^-$	$\frac{1}{2}$	+1	0	+1	0	$\Lambda_c^+\pi^0$
	$\Sigma_c^0$	$\bar{\Sigma}_c^0$	$\frac{1}{2}$	+1	0	+1	0	$\Lambda_c^+\pi^-$
	$\Lambda_c^0$	$\bar{\Lambda}_c^0$	$\frac{1}{2}$	+1	0	0	-1	$J/\psi\Lambda^0, \Lambda_c^+\pi^+\pi^-\pi^-$

Fig.8. 1Some constituents of hadrons

After the quark theory was proposed, physicists began looking for these fractionally charged particles, but direct detection has not been successful. Current models suggest that quarks may be so tightly bound together that they may not ever exist singly in the Free State. But observations of very high energy electrons scattered off protons suggest that protons are indeed made up of constituents.

### 8.8 End unit assessment solution (2 periods)

- (C) A proton is made up of two **up quarks and a down quark** and a strange quark and an anti-strange quark
- (B) Particles that are unaffected by strong nuclear force are **leptons**
- (A) Particle which explains about mass of matter is called **Higgs boson**
- (E) A conservation law that is not universal but applies only to certain kinds of interactions is conservation of : **strangeness**
- (E) In quantum electrodynamics (QED), electromagnetic forces are mediated by: **the exchange of virtual photons.**
- (A) Conservation laws that describe events involving the elementary particles include the conservation of (**all of these are correct**).
- (D) The conservation law violated by the reaction  $p \rightarrow \pi^0 + e^+$  is the conservation of **lepton number and baryon number.**
- (B) Particles that participate in the strong nuclear interaction are called **hadrons**
- (C) Current thought is that all matter is composed of **six quarks and six leptons.**

**Tau, boson, lepton, electron, quark, meson, lambda, alpha, beta, gamma, x ray, gauge boson, neutrino, baryon, color, proton, neutron, kaon, tau, muon, spin.**

(A)

- Has charge  $+\frac{2}{3}e + \frac{2}{3}e + \frac{2}{3}e = +2e$
- Has charge  $+\frac{2}{3}e + \frac{2}{3}e - \frac{1}{3}e = +1e$
- Has charge  $+\frac{2}{3}e - \frac{1}{3}e - \frac{1}{3}e = 0$
- Has charge  $-\frac{1}{3}e - \frac{1}{3}e - \frac{1}{3}e = -1e$

(B)

- Proton has charge  $+1e$  so could be
- Neutron has charge  $0$  so could be
- $\Delta^-$  has charge  $-1e$  so could be

- iv.  $\Delta^{++}$  has charge  $+2e$  so could be
- v. A down quark, charge  $-1/3e$  changes to an up quark, charge  $+2/3e$ , so the charge carried away must be if charge is to be conserved.

(C)

- i.  $u\bar{u}$  has charge  $+\frac{2}{3}e - \frac{2}{3}e = 0$
- ii.  $d\bar{d}$  has charge  $-\frac{1}{3}e + \frac{1}{3}e = 0$
- iii.  $u\bar{d}$  has charge  $+\frac{2}{3}e + \frac{1}{3}e = 1e$
- iv.  $d\bar{u}$  has charge  $-\frac{1}{3}e - \frac{2}{3}e = -1e$
- v. The  $\pi^+$  with charge  $+1e$  could be  $u\bar{d}$
- vi. The  $\pi^-$  with charge  $-1e$  could be  $d\bar{u}$

The neutral  $\pi^0$  could be either or both of  $u\bar{u}$  and  $d\bar{d}$ . In fact it is an equal mixture of the two.

12. (a) To conserve charge, the missing particle must be neutral. To conserve baryon number, the missing particle must be a meson. To conserve strangeness, charm, topness, and bottomness, the missing particle must be made of up and down quarks and antiquarks only. With all this information, the missing particle is  $\pi^0 = u\bar{u} + d\bar{d}$ .

(b) This is a weak interaction since one product is a lepton. To conserve charge, the missing particle must be neutral. To conserve the muon lepton number, the missing particle must be an antiparticle in the muon family. With this information, the missing particle is  $\bar{\nu}_\mu$ .

Baryon number:  $0 + 1 = 1 + 0 + 0$

Baryon number is conserved.

Lepton number:  $0 + 0 = 0 + 1 - 1$   
conserved.

Lepton number is

Strangeness:  $0 + 0 = 0 + 0 + 0$   
conserved.

Strangeness is

The reaction is possible, via the weak interaction.

13. (a) Baryon number is violated  $1 \rightarrow 0 + 0$

(b) The reaction can occur

(c) Baryon number is violated  $1 + 1 \rightarrow 1 + 0$

(d) This reaction can occur

(e) This reaction can occur

(f) Violates baryon number:  $0 \rightarrow 0+1$  and violate muon-lepton number  $0 \rightarrow -1+0$

## 8.9 Additional activities

### 8.9.1 Remedial activities and answers

1. The strong nuclear force between a neutron and a proton is due to

a) the exchange of  $\pi$  mesons between the neutron and the proton.

b) the conservation of baryon number.

c) the beta decay of the neutron into the proton.

d) the exchange of gluons between the quarks within the neutron and the proton.

e) Both (A) and (D) at different scales.

2. Electrons are still considered fundamental particles (in the group called leptons). But protons and neutrons are no longer considered fundamental; they have substructure and are made up of

A. pions.

C. quarks

E. photons

B. leptons.

D. bosons.

3. Which of the following will interact via the weak nuclear force only?

A. Quarks.

C. Neutrons

E. Electrons

G. Higgs boson.

B. Gluons.

D. Neutrinos.

F. Muons.

4. Is it possible for a particle to be both

A. a lepton and a baryon?

C. a meson and a quark?

B. a baryon and a hadron?

D. a hadron and a lepton?

Explain.

### Solutions to remedial activities

1. (e) A common misconception is that the strong force is a result of just the exchange of  $\pi$  mesons between the protons and neutrons. This is correct on the scale of the nucleons. However, when the quark composition of the protons, neutrons, and  $\pi$

mesons is considered at the elementary particle scale, it is seen that the transfer is due to the exchange of gluons. Therefore, both answers can be considered correct at different scales. Students who answer (d) should be given credit for their answer as well.

2. (c) Pions are not fundamental particles and are made up of quark and antiquark pairs. Leptons and bosons (including photons) are fundamental particles, but are not a constituent of protons and neutrons. Protons and neutrons are composed of up and down quarks.

3. (d) Quarks, gluons, neutrons, and the Higgs boson interact through the strong force. Electrons and muons are charged particles and interact through the electromagnetic force. Neutrinos only interact through the weak force.

4. (a) No. Leptons are fundamental particles with no known internal structure. Baryons are made up of three quarks.

(b) Yes. All baryons are hadrons.

(c) No. A meson is a quark–antiquark pair.

(d) No. Hadrons are made up of quarks, and leptons are fundamental particles.

### 8.9.2 Consolidation activities

6. A student claims to have observed a decay of an electron into two neutrinos, travelling in opposite directions. What conservation laws would be violated by this decay?

Solution to consolidation activity

6. Several conservation laws are violated.

- Conservation of electric charge is violated because the negative charge of the electron has disappeared.
- Conservation of electron-lepton number is also violated because there is one lepton before the decay and two afterward. If both neutrinos were electron-neutrino, electron-lepton number conservation would be violated in the final state. However, if one of the product neutrinos were other than an electron-neutrino, then another lepton conservation law would be violated, because no other leptons were in the initial state.

Other conservation laws are obeyed by this decay.

- Energy can be conserved—the rest energy of the electron appears as the kinetic energy (and possibly some small rest energy) of the neutrinos.
- The opposite directions of the velocities of the two neutrinos allows for conservation of momentum.

- Conservation of baryon number and conservation of other lepton number are also upheld in this decay.

### 8.9.3 Extended activities

7. Which of the following reactions are possible, and by what interaction could they occur? For those forbidden, explain why.

a.  $\pi^- + \bar{u} \rightarrow \pi^0 + \pi^0$

b.  $K^- + p \rightarrow \Lambda^0 + \pi^0$

c.  $K^+ + n \rightarrow \Sigma^+ + \pi^0 + \gamma$

d.  $K^+ \rightarrow \pi^0 + \pi^0 + \pi^+$

e.  $\pi^+ \rightarrow e^+ + \nu_e$

8. Which of the following reactions are possible, and by what interaction could they occur? For those forbidden, explain why

a.  $\pi^{\pm} + p \rightarrow K + \Sigma$

b.  $\pi^{\pm} + p \rightarrow K + \Sigma$

c.  $\pi^- + p \rightarrow \Lambda^0 + K^0 + \pi^0$

d.  $\pi^{\pm} + p \rightarrow K + \Sigma$

e.  $\pi^- + \bar{u} \rightarrow \pi^+ + \bar{\nu}_e$

### Solution to extended activities 8.9.3

7. (a) For the reaction  $\pi^- + \bar{u} \rightarrow \pi^0 + \pi^0$ , the conservation laws are as follows:

Charge:  $-1 + 1 \neq 0 + 1 + 0$  charge is not conserved. Also we note that the reactants would have to have significant kinetic energy to be able to create the  $K^0$

(b) For the  $K^- + p \rightarrow \Lambda^0 + \pi^0$ , the conservation laws are as follows:

Charge:  $-1 + 1 = 0 + 0$

Charge is conserved

Spin:  $0 \llcorner \frac{1}{2} \quad \frac{1}{2} \quad 0$

Spin conserved

Baryon number:  $0 \llcorner 1 \quad 1 \quad 0$

Baryon number is conserved

Lepton number:  $0 \llcorner 0 \quad 0 \quad 0$

Lepton number is conserved

Strangeness:  $-1 + 0 = -1 + 0$

Strangeness is conserved

The reaction is possible, via the strong interaction.

(c) For the reaction  $\pi^+ + p \rightarrow \pi^0 + p + \pi^+$ , the conservation laws are as follows:

Charge: $1 + 0 = 1 + 0 + 0$	Charge is conserved
Spin: $\frac{1}{2} + \frac{1}{2} = \frac{1}{2} + \frac{1}{2} + \frac{1}{2}$	Spin is conserved
Baryon number: $0 + 1 = 1 + 0 + 0$	Baryon number is conserved
Lepton number: $0 + 0 = 0 + 0 + 0$	Lepton number is conserved
Strangeness: $1 + 0 \neq 0 + 0 + 0$	Strangeness is not conserved

The reaction is not possible via the strong interaction because strangeness is not conserved. It is possible via the weak interaction

d) For the reaction  $K^+ \rightarrow \pi^0 + \pi^+$ , the conservation laws are as follows:

Charge: $1 \rightarrow 0 + 1$	Charge is conserved.
Spin: $0 \rightarrow 0 + 0$	Spin is conserved.
Baryon number: $0 \rightarrow 0 + 0$	Baryon number is conserved.
Lepton number: $0 \rightarrow 0 + 0$	Lepton number is conserved
Strangeness: $1 \rightarrow 0 + 0$	Strangeness is not conserved

This reaction is possible, via the weak interaction.

e) For  $\pi^+ \rightarrow e^+ + \nu_e$  the reaction, the conservation laws are as follows:

Charge: $1 = 1 + 0$	Charge is conserved.
Spin: $0 = -\frac{1}{2} + \frac{1}{2}$	Spin is conserved
Baryon number: $0 = 0 + 0$	Baryon number is conserved.
Lepton number: $0 = -1 + 1$	Lepton number is conserved.
Strangeness: $0 = 0 + 0$	Strangeness is conserved.

The reaction is possible, via the weak interaction.

8. (a) For the reaction  $\pi^- + p \rightarrow K^+ + \Sigma^-$ , the conservation laws are as follows:

Charge: $-1 + 1 = 1 - 1$	Charge is conserved
Spin: $0 \rightarrow \frac{1}{2} + 0 + \frac{1}{2}$	Spin is conserved
Baryon number: $0 \rightarrow 1 + 0 + 1$	Baryon number is conserved

$$\text{Lepton number: } 0 \approx 0 \quad 0 \quad 0$$

Lepton number is conserved

$$\text{Strangeness: } 0 \approx 0 \quad 1 \quad 1$$

Strangeness is conserved

The reaction is possible, via the strong interaction.

(b) For the reaction  $\pi^+ + p \rightarrow K^+ + \Sigma^+$ , the conservation laws are as follows:

$$\text{Charge: } 1 \approx 1 \quad 1 \quad 1$$

Charge is conserved

$$\text{Spin: } 0 \approx \frac{1}{2} \quad 0 \quad \frac{1}{2}$$

Spin is conserved

$$\text{Baryon number: } 0 \approx 1 \quad 0 \quad 1$$

baryon number is conserved

$$\text{Lepton number: } 0 \approx 0 \quad 0 \quad 0$$

Lepton number is conserved

$$\text{Strangeness: } 0 \approx 0 \quad 1 \quad 1$$

Strangeness is conserved

The reaction is possible, via the strong interaction.

(c) For the reaction  $\pi^- + p \rightarrow \Lambda^0 + K^- + \pi^-$ , the conservation laws are as follows:

$$\text{Charge: } -1 + 1 = 0 + 0 + 0$$

Charge is conserved

$$\text{Spin: } \frac{1}{2} + \frac{1}{2} = \frac{1}{2} + \frac{1}{2} + 0$$

Spin is conserved

$$\text{Baryon number: } 0 + 1 = 1 + 0 + 0$$

Baryon number is conserved

$$\text{Lepton number: } 0 + 0 = 0 + 0 + 0$$

Lepton number is conserved

$$\text{Strangeness: } 0 + 0 = 1 - 1 + 0$$

Strangeness is conserved

The reaction is possible, via the strong interaction.

(e) For the reaction  $\pi^- + \bar{u} \rightarrow \bar{d} + e^- + \bar{\nu}_e$ , the conservation laws are as follows:

$$\text{Charge: } -1 + 1 = 1 - 1 + 0$$

Charge is conserved

$$\text{Spin: } 0 + \frac{1}{2} = \frac{1}{2} + \frac{1}{2} - \frac{1}{2}$$

Spin is conserved

$$\text{Baryon number: } 0 + 1 = 1 + 0 + 0$$

Baryon number is conserved

$$\text{Lepton number: } 0 + 0 = 0 + 1 - 1$$

Lepton number is conserved

$$\text{Strangeness: } 0 + 0 = 0 + 0 + 0$$

Strangeness is conserved

The reaction is possible, via the strong interaction.

**Note** that we did not check mass conservation, because in a collision, there is always some kinetic energy brought into the reaction. Thus the products can be heavier than the reactants.

## 9.1 Key Unit Competence

Analyze and evaluate the effects of x-rays.

## 9.2 Prerequisite knowledge and skills

The success of this unit relies partly on the mastery of knowledge and skills acquired in Physics (Unit 1, unit 5 of S6 and Unit 9 of S5), and other related subjects in previous grades.

## 9.3 Cross-Cutting Issues to be addressed

- **Inclusive education** (promote education for all while teaching):  
Regardless of physical appearance and abilities learners should be treated equally. This makes the learners to find out that they are all of great importance. In spite of their physical ability, learners with impairment as normal learners should be aware of the uses and dangers of x rays. This should be addressed at the end of lesson 1
- **Gender education** (equal opportunity of boys and girls in the lesson participation). Care should be taken that both Sexes are given equal opportunities. Girls and boys should be aware of x-rays about their uses and dangers. This should be at the end of lesson 2.
- **Environment sustainability:** During delivering different lessons within this unit, let learners be familiar with the application and importance of skills and knowledge x rays, their production, uses and danger and then the dangers they make cause to the environment when used in a wrong manner.
- **Peace and value Education** (respect others view and thoughts during class discussions). Remember that someone's idea is very important. It may be correct or Not but what is important is to build on that Idea. It is in this case that radiologist or other x rays users, may use them for their odd purposes to kill or cause cancer to someone. Therefore, remind the learners that the uses of x rays are for good not for our immoral needs.

- Standardization culture (Be aware of machines that do not harm our environment). The x rays are in the ranges of hard and soft x rays. Hence, the measure of quantity that should be applied is good culture to know in order to avoid the dangers in time of use.

## 9.4 Guidance on the introductory activity

This activity aims at capturing students' attention and minds towards this concept of x rays, their production, uses and dangers

- Divide your students into groups (Where possible, mix equally the number of girls to number of boys. If there are students with impairment, let them take the lead of groups during doing activity)
- Tell the learners open the Learn Book to the introductory activity of the unit 10 and then instruct them to re-write the questions and answer them following the instructions from learner's book.
- While students are doing this activity, you move around and mark their attention on working activity.
- When every group is done, invite some group(s) to present and discuss their findings to the whole class. You may choose two or three groups to present their findings while others follow.
- Ask other groups' members whether their answers correspond to the discussed points and if there is any points that are different from what have been raised; tell them to mention it. You can talk about those points (in a discussion together with students).
- Together with students harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks. And then linking to the summary and what have discussed in class, emphasize on the x rays production, uses and dangers. You can take some minutes and explain them.
- Summarize your lesson by linking this concept to real life situations like when someone goes to hospital for radiology or for a scan.

### Possible answers of the introductory activity.

During this introductory activity, let learners present their upbringings about the radiations, and then find out the hub of their curiosity about x rays radiation production, uses and dangers. The summary of the introductory question is provided in the Learn Book.

## 9.5 List of lessons

S/ No	Lesson Title	Learning Objectives	Periods
1	Production of x-rays	<ul style="list-style-type: none"> <li>• Explain the production of x rays</li> <li>• Describe and explain the production of x rays</li> <li>• Recognize how the intensity and the quality of x rays can be controlled</li> </ul>	2
2	Properties of x-rays	<ul style="list-style-type: none"> <li>• State the properties of x rays</li> <li>• Analyze the effects of x rays</li> <li>• Appreciate the uses and the dangers of x rays</li> </ul>	2
3	The origins and characteristic features of an x-ray spectrum	<ul style="list-style-type: none"> <li>• Draw and describe an x ray spectrum</li> <li>• Explain the origin and characteristic features of an x rays spectrum.</li> <li>• Analyze the origin and characteristic feature of x rays spectrum</li> <li>• Recognize the continuous and characteristic feature wavelength limit</li> </ul>	4
4	Application of x-rays	<ul style="list-style-type: none"> <li>• Outline the application of x rays in medicine, industry and scientific research</li> <li>• Analyze application of x rays in medicine, industries, research and forensic science.</li> <li>• Appreciate the uses of x rays in medicine, industry and scientific research.</li> </ul>	4
5	Problems involving accelerating potential and minimum wavelength.	<ul style="list-style-type: none"> <li>• Solve problems involving accelerating potential and minimum wave length of x rays.</li> <li>• Acquire ability pursue thinking related to dangers of x rays.</li> <li>• Appreciate the application based on x rays</li> </ul>	4
6	Evaluation	<ul style="list-style-type: none"> <li>- End unit assessment</li> <li>- Summative assessment</li> </ul>	4

## Lesson 1: Production of x-rays

### a) Introduction

Through guided discovery, assist learners to describe the process of x ray production experiment. You can make a recap using the cathode rays production (Physics S5: unit)

You can ask them questions like, what are the uses of cathode rays produced.

### b) Teaching resources

Textbooks, Cathode ray television (CRT) set

### c) Learning Activities

#### Activity 9.1

This activity aims at capturing students' attention and minds towards this concept of x ray production and its properties.

- Decide the method of teaching and tell them to open on the activity 10.1 in the learner's book.
- Instruct learners to read the scenario in the activity 10.1 in the learner's book and explain by writing in their notebooks about their observations.
- While students are doing this activity, you move around and mark their work.
- When every group is done, invite some member(s) or group(s) to discuss their findings to the whole class.
- Inquire from other groups' members whether their answers correspond to the ones discussed from presenting groups.
- Together with students harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks.
- Linking to the summary and what have been discussed in class, take a step and explain intensively about the x ray production.
- Link this lesson to real life like the photography of radiology at hospital, uses of CRT TV.

### d) Suggested answer to activity 9.1

1. **X-rays** are short wavelength electromagnetic radiations produced when fast moving electrons strike matter. X-rays are a form of electromagnetic radiation, as are radio waves, infrared radiation, visible light, ultraviolet radiation and microwaves.
2. X-rays are produced when rapidly moving electrons that have been accelerated through a potential difference of the order of  $10^3$  to  $10^6$  V strike a metal target. Electrons are 'boiled off' from the heated cathode by thermionic emission and are accelerated toward the Anode (the target) by a large potential difference  $V_h$ .

- X-ray radiation has become an indispensable imaging tool in medical science.
- X rays are also much used in scientific research, in security, checking cargo and luggage at airport.
- In the study of crystal structures (crystallography)

### e) Suggested answer to checking my progress 9.1.4

1. X-rays are when fast-moving electrons strike matter.
2. Hard and soft X-rays. Hard x-rays are produced by high accelerating potential. They have high penetrating power and short wavelength while soft x-rays are produced by lower accelerating potential, have relatively low penetrating power and relatively long wavelength
3. The answer is that a German physicist, Wilhelm Roentgen, discovered a new form of radiation in 1895. He called it X-radiation because he didn't know what it was (x to mean unknown).
4. X-rays take a given position in the electromagnetic spectrum and have uses which are different from other electromagnetic radiations.
5.
  - They have a very short wavelength (about the same size as the diameter of an atom.
  - They cause ionization (adding or removing electrons in atoms and molecules)
  - They affect photographic film in the same way as visible light (turning it black)
  - They are absorbed (stopped) by metal and bone.

### Suggested answer to activity 9.2

- 1
  - They have a very short wavelength (about the same size as the diameter of an atom.
  - They cause ionization (adding or removing electrons in atoms and molecules)
  - They affect photographic film in the same way as visible light (turning it black)
  - They are absorbed (stopped) by metal and bone.
2. X-rays are produced when rapidly moving electrons that have been accelerated through a potential difference of the order of  $10^3$  to  $10^6$  V strike a metal target. Electrons are 'boiled off' from the heated cathode by thermionic emission and are accelerated toward the Anode (the target) by a large potential difference  $V_h$ ; while

The photoelectric effect relates to the following phenomena: if a metal surface is illuminated by visible or ultraviolet light radiation, electrons are released provided that the frequency of the radiation exceeds a critical threshold.

## Lesson 2: The origins and characteristic features of an x-ray spectrum

### a) Introduction

Through guided discovery, assist learners to discover the effect of x rays and then the characteristic feature of x ray spectrum. You can make a recap using knowledge, skills and values obtained in unit 9 of S5.

You can ask them questions like: what is electromagnetic radiation? Or ask them to draw the electromagnetic spectrum diagram according to their wavelength. (This can take like 2 minutes)

### b) Teaching resources

Internet and textbooks

### c) Learning activity

This lesson focuses on making students understand apply the concept of x ray spectrum and its characteristics.

- Decide on the method to use in this lesson
- Instruct them to follow instructions as stated in the activity from Learner book depends on the type of your class.
- During the learners are doing the activity, move around and mark the learners' attention but make sure to let the learners to perform the activity.
- Invite 2 or 3 (or any number of groups depending on how many you had formed) to present their findings. Let them discuss by themselves.
- Ask other groups members of the class to contrast their finding to those presented by the groups on show whether they have different findings from what others have presented. Then tell them to mention the other missing points and discuss with other students.
- Connecting to what learners have presented, guide learners to describe briefly the characteristic spectrum of x rays.
- Linking to the summary and what have been discussed in class, take a step and explain intensively about the characteristic spectrum of x rays while students are taking notes.

### Example problem

Calculate the minimum wavelength of X-rays emitted when electrons accelerated through 30 kV strike a target.

$$f = \frac{1.602 \times 10^{-19} \times 30000}{6.626 \times 10^{-34}} = 7.25 \times 10^{18} \text{ Hz}$$

Therefore, the wavelength  $\lambda_{\min} = \frac{c}{f} = 4.14 \times 10^{-11} \text{ m} = 0.0414 \text{ nm}$

## Lesson 3: Application of x-rays

### a) Introduction

Through guided discovery, assist learners to discover different applications of x rays. You can make a recap using; knowledge, skills and values found in unit 5 of S6.

### Guidance on lesson 3

- Divide learners into groups and time when you are teaching this lesson
- Take learners in computer lab and instruct them search for the activity 10.4 provided.
- Introduce the activity and let the learner(s) perform the activity while you are moving around to mark their attention.
- Learners brainstorm on their results and write the work in their notebook.
- Check students' work and let one or two groups present the work to the whole class.
- Let other learners contrast their findings to the result presented, hence, assist them to draw a suitable conclusion.
- Comment on students' responses written in their notebooks and the presentation, and give them the expected feedback summarizing their work.

### b) Teaching resources

Internet and textbooks

### c) Learning activity

This lesson focuses on taking student at a level of analyzing and evaluating the uses of x rays in real life, i.e the application of x rays. This would be summarized in the following activity 9.4 guided as follow:

#### Activity 9.4:

- Divide your class into groups due to the type of your class.
- Instruct learners to search on internet due to activity 10.4 provided in the LB.
- Let the learner(s) perform the activity using their prior knowledge about production and properties of X rays and write the ideas in the note book.
- Tell one or two sample groups to present their findings to the whole class.
- Check student's responses to review the students' plans and ideas to continue the discussion with a brief brainstorming of the concepts using student's work and book.
- Let other non presenting groups bring additional to what have been presented and then assist them contrast the new upbringings to the presented ones.

- Comment on students' responses written in their notebooks, and give them the summary of expected feedback based on their findings.
- Linking to the summary and what have been discussed in class, take a step and explain intensively about different application of x rays while student are taking notes.
- Link this lesson to real life like the use of X rays at hospitals, at airport, in checking cargo, in industry, etc.

### **Suggested answers to activity 9.4**

1. As provided in LB, the uses of x rays are various. They are applied in medicine (imaging), in industry, in security like checking luggage at airport, checking cargo in transport, etc
2.
  - Because X rays can kill living cells, they must be used with extreme care. When improperly used they can cause severe burns, cancer, leukemia, and cataracts. They can speed aging, reduce immunity to disease, and bring about disastrous changes in the reproductive cells.
  - Lead screens, sheets of lead-impregnated rubber, and leaded glass are used to shield patients and technicians from undesired radiation.
  - The effect of X radiation is cumulative. That is, a number of minor doses over a number of years is equivalent to a large dose at one time. Etc.

### **d. Suggested answers to checking my progress 9.3**

1. For medical applications, x-rays are usually generated in vacuum tubes by bombarding a metal target with high-speed electrons and images produced by passing the resulting radiation through the patient's body on to a photographic plate or digital recorder to produce a radiograph, or by rotating both source and detector
2. The uses of X rays should be quantified to given dose for the safety of others because X rays can cause damage to living tissues when one uses and extreme dose. As x-ray photons are absorbed in tissues, their energy breaks molecular bonds and creates highly reactive free radicals (such as neutral H and OH), which in turn can disturb the molecular structure of proteins and especially genetic material. Young and rapidly growing cells are particularly susceptible, which is why x-rays are useful for selective destruction of cancer cells. When improperly used they can cause severe burns, cancer, leukemia, and cataracts. They can speed aging, reduce immunity to disease, and bring about disastrous changes in the reproductive cells.

## **Lesson 4: Problems involving accelerating potential and minimum wavelength**

### **a) Introduction**

Through guided discovery, assist learners to develop their skills and attitudes in solving problems related to the accelerating potential and minimum wave length of produced x rays from x ray tube. You can make a recap using; knowledge, skills and values found in unit 5 and unit 10 of S6; unit 9 of physics in S5.

### **Guidance on lesson 4**

- Divide learners into groups
- Instruct learners to use prior knowledge from unit 1 and unit 5 of Physics S6, and then tell them to solve the activity provided in the LB on activity 9.5.
- Introduce the activity and let the learner(s) perform the activity while you are moving around to mark their attention.
- Learners brainstorm on their results and write their findings in their notebook.
- Check students' work and let one or two groups present the work to the whole class.
- Let other learners contrast their findings to the result presented, hence, assist them to draw a suitable conclusion.
- Comment on students' responses written in their notebooks and the presentation, and give them the expected feedback summarizing their work.

### **b) Teaching resources**

Internet and textbooks

### **c) Learning activity**

This activity focuses on taking student at a level of analyzing and evaluating the skills acquired in solving problems related to accelerating potential and minimum wavelength of x rays. This would be summarized in the following activity 10.5 guided as follow:

#### **Activity 9.5:**

- Decide on the method to use depending on the type of your class.
- Instruct learners in their groups to work on activity 10.5 provided in the LB.
- Let the learner(s) perform the activity using their prior knowledge about production and properties of X rays and write the ideas in the note book.
- Tell one or two sample groups to present their findings to the whole class.
- Check student's responses to review the students' plans and ideas to continue the discussion with a brief brainstorming of the concepts using student's work and book.

- Let other non presenting groups bring additional to what have been presented and then assist them to contrast the new upbringings to the presented ones.
- Comment on students' responses written in their notebooks, and give them the summary of expected feedback based on their findings.
- Linking to the summary and what have been discussed in class, take a step and explain intensively about solving problems related to x rays while student are taking notes.
- Link this lesson to real life like the use of setting a project about construction of x rays apparatus.

### Suggested answers to activity 9.5

i.  $P = VI = (30 \times 10^3)(2.0 \times 10^{-3}) = 60 \text{ W}$

ii.  $I = Ne \Leftrightarrow N = \frac{I}{e} = \frac{2 \times 10^{-3}}{1.602 \times 10^{-19}} = 1.25 \times 10^{16}$  where N is the number of electrons striking the target per second

iii.  $\frac{1}{2}mv^2 = eV \Leftrightarrow v = \sqrt{\frac{2(1.602 \times 10^{-19})(3 \times 10^4)}{9.11 \times 10^{-31}}} = 1.03 \times 10^8 \text{ m/s}$

iv.  $\lambda_{\min} = \frac{hc}{eV} = \frac{(6.67 \times 10^{-34})(3 \times 10^8)}{(1.602 \times 10^{-19})(3 \times 10^4)} = 4.2 \times 10^{-11} \text{ m} = 0.42 \text{ nm}$

### d) Suggested answers to checking my progress about section 9.4

1. Energy E is expressed by Einstein's relation of  $E = mc^2$  where m is mass and c is the speed of light. If this relationship is utilized, considering SI unit that expresses mass in kg,

$$E = (1 \times 10^{-3})(2.998 \times 10^8)^2 = 8.988 \times 10^{13} \text{ J}$$

The atomic weight per mole (molar mass) for carbon is 12.011 g. Thus, the number of atoms included in 1 g

Carbon is calculated as  $\frac{6.022 \times 10^{23}}{12.011} = 5.01 \times 10^{22}$  because the numbers of atoms are included in one mole of carbon is the Avogadro's number  $6.022 \times 10^{23}$ . Therefore, the energy release per carbon atom can be estimated as:

$$\frac{8.99 \times 10^{13}}{5.01 \times 10^{22}} = 1.79 \times 10^{-9} \text{ J}$$

2. The work W, if electric charge Q (coulomb, C) moves under voltage V is expressed by  $W = QV$ . When an electron is accelerated under 1V of difference in potential, the energy obtained by the electron is called 1 eV. Since the elementary charge e is

$$1 \text{ eV} = 1.602 \times 10^{-19} \text{ C} \times 1 \text{ V} = 1.602 \times 10^{-19} \text{ J}$$

Electric field E can be expressed with  $E = \frac{V}{d}$ , where the distance, d, between electrodes

and the applied voltage being  $V$ . The force  $F$  on the electron with elementary charge  $e$  is given by;  $F = eE$

Here, the unit of  $F$  is Newton. Acceleration  $a$  of electrons is given by the following equation in which  $m$  is the mass of the electron

$$1. \quad E = \frac{10 \text{ kV}}{10^{-2} \text{ m}} = 10^6 \text{ V / m}$$

$$2. \quad F = 1.602 \times 10^{-19} \text{ C} \times 10^6 \text{ V} = 1.602 \times 10^{-13} \text{ N}$$

$$3. \quad a = \frac{eE}{m} = \frac{1.602 \times 10^{-19}}{9.11 \times 10^{-31}} = 1.76 \times 10^{17} \text{ m / s}^2$$

3. An X-ray probe has a greater energy than an electron probe for the same wavelength. Wavelength of light emitted from the probe,  $\lambda = 1 \text{ \AA} = 10^{-10} \text{ m}$

The kinetic energy of the electron is given as:  $E = \frac{1}{2}mv^2 \Leftrightarrow m_e v = \sqrt{2Em_e}$

Where  $v = \text{Velocity of electron}$ ,  $p = \text{Momentum}(p) \text{ of the electron}$

According to the de Broglie principle, the de Broglie wavelength is given as:

$$\lambda = \frac{h}{p} = \frac{h}{m_e v} = \frac{h}{\sqrt{2Em_e}} \Leftrightarrow E = \frac{h^2}{2\lambda^2 m_e} = \frac{(6.67 \times 10^{-34})^2}{2(10^{-10})^2 (9.11 \times 10^{-31})} = 2.44 \times 10^{-17} \text{ J} = 152.42 \text{ eV}$$

Energy of a photon,

$$E' = \frac{hc}{\lambda} \text{ eV} = \frac{6.67 \times 10^{-34} \times 3 \times 10^8}{10^{-10} \times 1.602 \times 10^{-19}} = 1.25 \times 10^4 \text{ eV} = 12.5 \text{ keV}$$

Hence, a photon has a greater energy than an electron for the same wavelength.

## 9. 6 Unit Summary

- X-RAYS NATURE: X-rays with energies ranging from about 100 eV to 10 MeV are classified as electromagnetic waves, which are only different from the radio waves, light, and gamma rays in wavelength and energy. X-rays show wave nature with wavelength ranging from about 10 nm to  $10^3$ nm.
- According to the quantum theory, the electromagnetic wave can be treated as particles called photons or light quanta.
- The propagation velocity  $c$  of electromagnetic wave (velocity of photon) with frequency  $\nu$  and wavelength  $\lambda$  is given by the relation:  $c = \lambda\nu$
- Each photon has an energy  $E$ , which is proportional to its frequency:

$$E = hf = \frac{hc}{\lambda}$$

Where,  $c = 299792458 \text{ m / s}$  ( $c \approx 2.998 \times 10^8 \text{ m / s}$  and  $h = 6.6260 \times 10^{-34} \text{ J.s}$  and

$h = 6.6260 \times 10^{-34} \text{ J}\cdot\text{s}$  is the Planck constant. The momentum  $p$  is given by  $mv$ , the product of the mass  $m$ , and its velocity  $v$ . The de Broglie relation for material wave relates wavelength to momentum:

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

- **FACTORS CONTROLLING THE X-RAY BEAM:** The x-ray beam emitted from an x-ray tube may be modified to suit the needs of the application by altering the beam exposure length (timer), exposure rate (mA), beam energy (kVp and filtration), beam shape (collimation), and target-patient distance (long or short cone).
- **BREMSSTRAHLUNG RADIATION:** Bremsstrahlung interactions, the primary source of x-ray photons from an x-ray tube, are produced by the sudden stopping, breaking or slowing of high-speed electrons at the target. Most high speed electrons have near or wide misses with the nuclei. In these interactions, a negatively charged high speed electron is attracted toward the positively charged nucleus and loses some of its velocity. This deceleration causes the electron to lose some kinetic energy, which is given off in the form of a photon. The closer the high speed electron approaches the nuclei, the greater is the electrostatic attraction on the electron, the braking effect, and the greater the energy of the resulting Bremsstrahlung photon.
- **CHARACTERISTIC RADIATION:** Characteristic radiation occurs when an electron from the filament displaces an electron from an inner-shell of the tungsten target atom, thereby ionizing the atom. When this happens, another electron in an outer-shell of the tungsten atom is quickly attracted into the void in the deficient inner-shell.
- **THE DIFFRACTION OF X-RAYS** of wavelength  $\lambda$  by reflection from a crystal is described by the Bragg equation. Strong reflections are observed at grazing angles  $\phi$  (where  $\phi$  is the angle between the face of the crystal and the reflected beam) given by  $m\lambda = 2d \sin \phi$

Where  $d$  is the distance between reflecting planes in the crystal, and  $m = 1, 2, 3, ..$ , is the order of reflection.

- **OPTICAL PATH LENGTH:** In the same time that it takes a beam of light to travel a distance  $d$  in a material of index of refraction  $n$ , the beam would travel a distance  $nd$  in air or vacuum. For this reason,  $nd$  is defined as the optical path length of the material.

## 9.7 Additional information

### 9.7.1 X-Ray Spectrometry

X-Rays are short wavelength electromagnetic radiation produced by the deceleration

of high energy electrons or by electronic transitions of electrons in the inner orbital of atoms. The wavelength range of X-rays is from about  $10^{-5}\text{\AA}$  to  $100\text{\AA}$ ; conventional X-ray spectroscopy is largely confined to the region of about  $0.1\text{\AA}$  to  $25\text{\AA}$ .

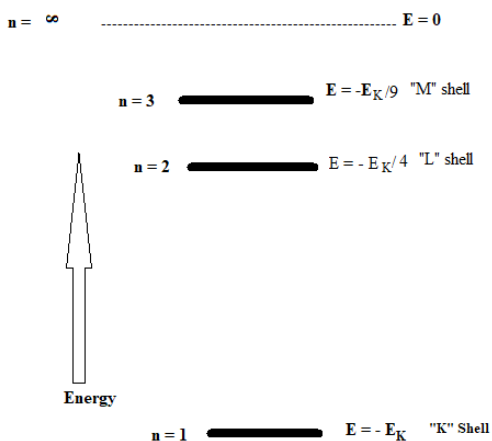
X-ray spectroscopy is a form of optical spectroscopy that utilizes emission, absorption, scattering, fluorescence, and diffraction of X-ray radiation

**The basics:** X-rays are short-wavelength (hence, high frequency, and hence, relatively high energy) electromagnetic radiation. Two ways to produce X-rays:

- Deceleration of high-energy electrons
- Electronic transitions involving inner-orbital electrons

Approximate wavelength range:  $10^{-4}\text{ nm} - 10\text{ nm}$  and the wavelength range used in conventional applications:  $0.01\text{ nm}$  to  $2.5\text{ nm}$

X-rays are the shortest wavelength, i.e., highest energy, electromagnetic radiation associated with electronic transitions in atoms. Calculation of the energy states of an atom is in general, very difficult, except of course in the particular case of the hydrogen atom, where the problem is readily soluble and the results, shown schematically below, are very well known.



An important feature of the above diagram is that the differences in orbital energies decrease as they themselves increase. This means that the energy required for excitation, or given out on relaxation of an electron from a higher orbital to a lower orbital is greater when "inner" orbitals are involved and least when "outer" orbitals are involved.

Except for light elements (say, those preceding Na) the innermost orbitals are not significantly influenced by bonding interactions involving the atom and, hence, their energies may be regarded as characteristic of that atom regardless of its state of combination. Inner orbital transitions involve X-rays, and it is for this reason that X-ray

spectrometry can be a form of atom detection and, hence, of non-destructive chemical analysis.

The energy level diagram for any atom is considerably more complex and depends in detail upon the particular atom. However, for X-ray emissions of importance in elemental analysis, a simplified treatment is sufficient and the diagram below is useful.

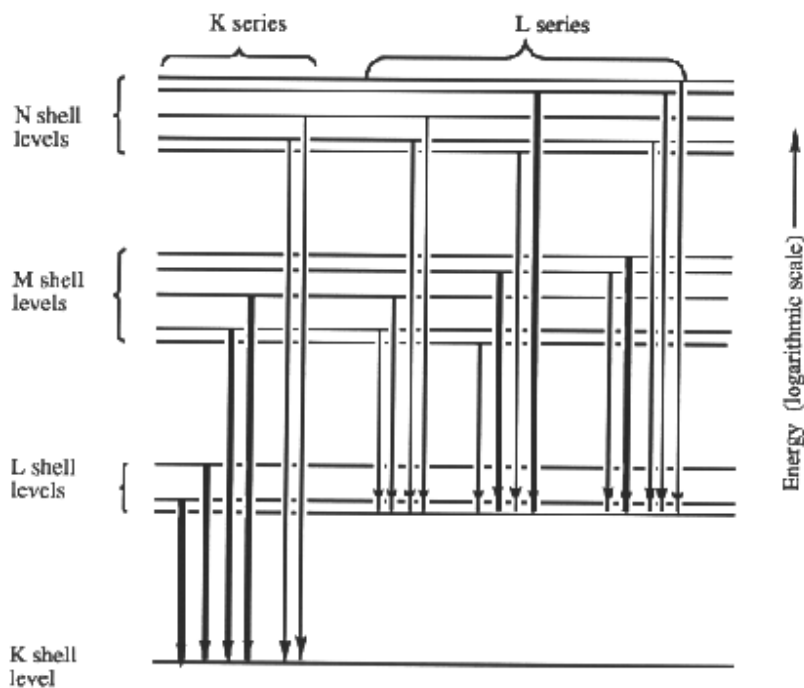


Fig. 9. 1 Partial energy level diagram showing common transitions leading to X-radiation. The most intense lines are indicated by the widest arrows.

The orbital shells for which the principal quantum number  $n = 1, 2, 3$ , etc. are labelled the K, L, M, etc. and, hence, emissions due to a higher energy electron entering these shells are said to form the K, L, M, etc. series of lines. Generally, only the K and L series of X-rays are of analytical utility and the wavelengths of these lines for a selection of elements spanning the Periodic Table are shown below.

Wavelengths/ $\text{\AA}$  for Intense X-ray Emission Lines

Element	K Series		L Series	
	a1	b1	a1	b1
Na	11.909	11.617	–	–
K	3.742	3.454	–	–
Cr	2.290	2.085	21.714	21.323

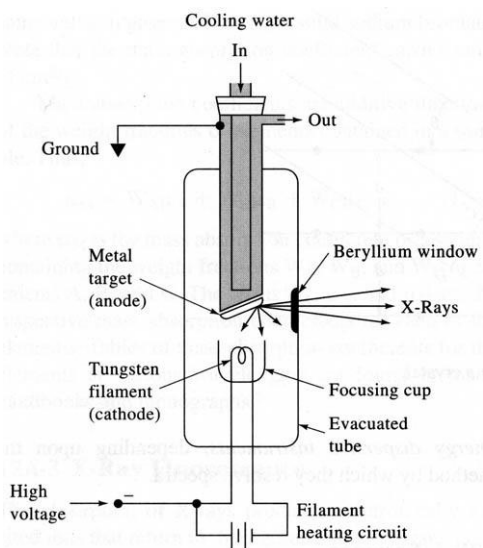
Rb	0.926	0.829	7.318	7.075
Cs	0.401	0.355	2.892	1.282
W	0.209	0.184	1.476	1.282
U	0.126	0.111	0.911	0.720

(Note that all possible electronic transitions are not of equal probability, i.e., the nature of a spectrum depends on specific selection rules, so that the complexity of a spectrum is not as great as might be expected from first consideration of an energy level diagram.)

The fact that the wavelength of a line of given type decreases as the atomic number of the element increases is rather important in that it means that an X-ray from a given element must be able to cause inner shell ionization and, hence, emission of radiation of lower energy from any lighter element.

### 9.7.2 X RAY PRODUCTION, PROPERTIES AND SPECTRUM

Below is a schematic of an X-ray tube.



X-ray sources can emit two forms of X-rays:

- 10) continuous (white radiation or Bremsstrahlung - “Bremsstrahlung” refers to radiation arising from the deceleration of particles)
- 2) discontinuous (line)

## Electron beam sources

In electron beam sources, X-rays are produced by heating a cathode to produce high-energy electrons; these electrons are energetic enough to ionize off the cathode and race towards a metal anode (the target) where, upon collision, X-rays are given off from the target material in response to the colliding electrons. By varying the conditions, one can obtain either a continuous spectrum or a discontinuous spectrum.

The reaction between the electron beam and the target material involves deceleration of the electron and ejection of a target photon and emission of X-rays. The energy lost by the electron as it smashes into the target material is equal to the energy of the ejected photon. Since any given electron can be retarded differently by the same target material, a range of photon energies are possible. The maximum photon energy corresponds to total stopping of the electron and is given by:

$$h\nu_0 = \frac{hc}{e} = Ve$$

where,  $\nu_0$  is the maximum frequency,  $V$  = accelerating voltage,  $e$  = electron charge. This is the Duane-Hunt law.

## Electron beam source line spectra characteristic

1. Elements with  $Z > 23$  exhibit two spectral series: a K line (corresponding to shorter wavelengths) and an L line (corresponding to relatively longer wavelengths). Elements with  $Z < 23$  exhibit only the K series
2. As  $Z$  increases, so too does the minimum amount of energy required for excitation; For all but the lightest elements, the X-ray line spectra are independent of either physical or chemical states. This is because the electrons involved in the transition are not participating in any chemical bonds.

## Continuum Spectra from Electron Beam Sources

In an X-ray tube, electrons produced at a heated cathode are accelerated toward a metal anode by a potential as great as 100kV; upon collision, part of the energy of the electron beam is converted into X-Rays. Under some conditions only a continuum spectrum is results. The continuum X-Ray spectrum is characterized by a well-defined, short wavelength limit, which is dependent upon the accelerating voltage but independent of the target material. The continuum radiation from an electron beam source results from collisions between the electrons of the beam and the atoms of the target material.

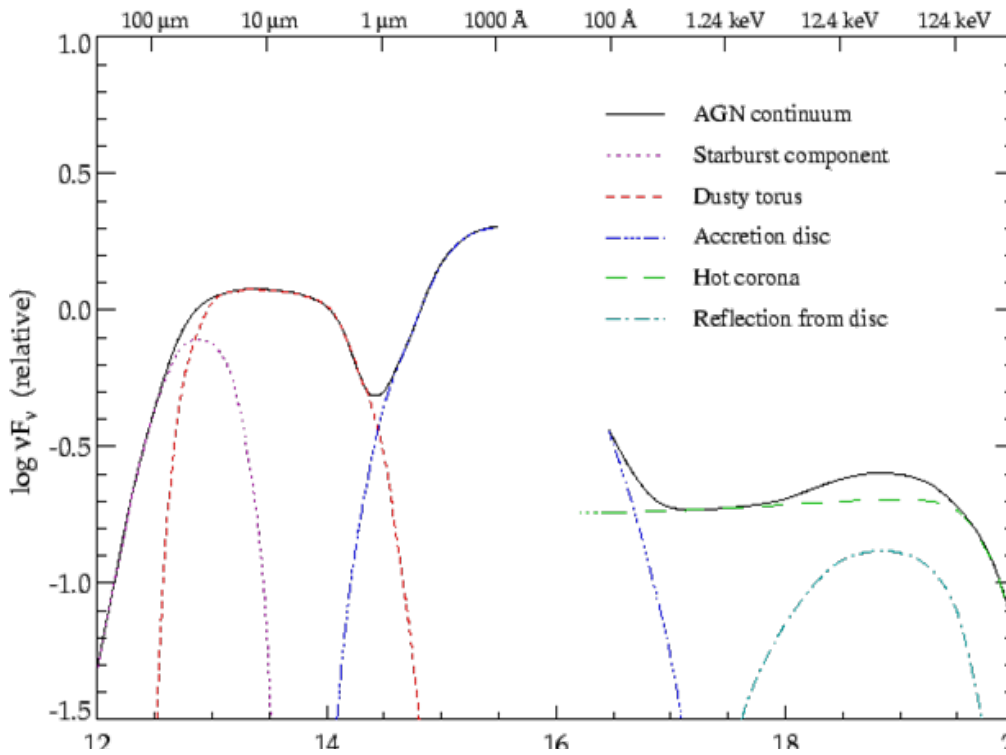
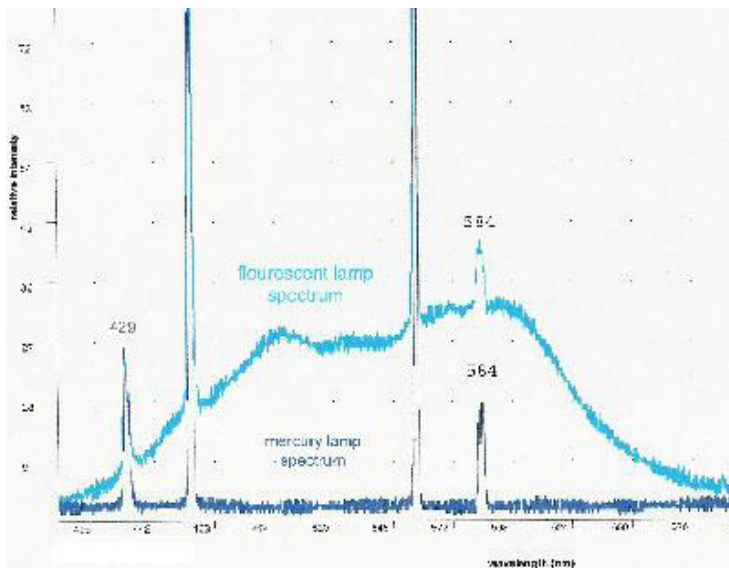


Fig. 9. 2 Schematic representation of an AGN continuum spectrum including a possible source for each emission component.

### Line Spectra from Electron Beam Sources...

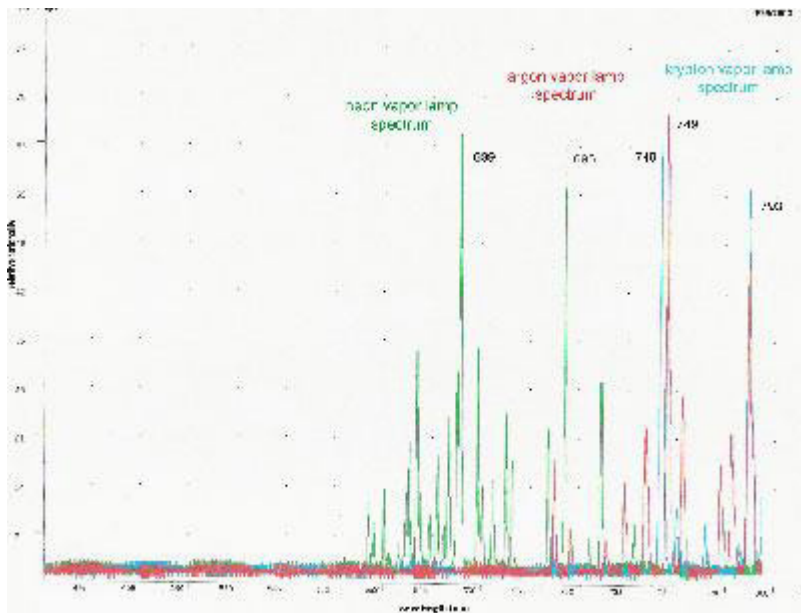
Bombardment of a molybdenum target produces intense emission lines. The emission behavior of molybdenum is typical of all elements having atomic numbers greater than 23, that is, the X-Ray line spectra are similar when compared with ultraviolet emission and consist of two series of lines.

Line spectra are composed of distinct lines of color, or in the case of our graphs, sharp peaks of large intensity at a particular wavelength. Line spectra are characteristic of elements and compounds when excited (energized) under certain conditions. These spectra helped develop the current atomic theories. Line spectra thus provide a “fingerprint” unique to each element, and as with continuous spectra, the combination of the prominent lines in the spectrum produce the observe light color.

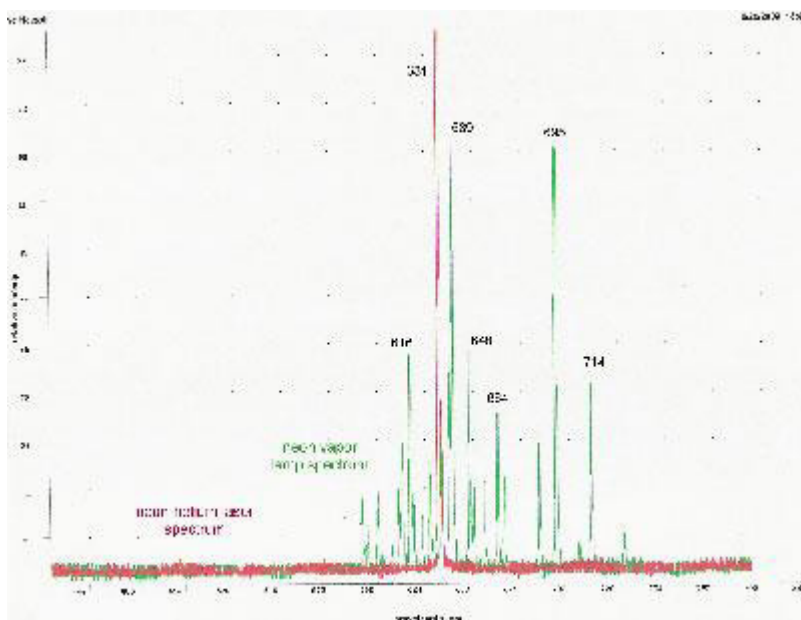


The fluorescent lamp's spectrum is a mixture of line and continuous spectra. Because of the exact correlation with the principal mercury vapor lines and the fluorescent lamp's lines, we can conclude that a major component of the fluorescent lamp is mercury vapor. But what produced the continuous portion of the fluorescent spectrum?

A phosphor is a substance that can accept energy in one form and emit the energy in the form of visible light. Fluorescent lights are produced by coating the inside surface of the glass tube with phosphor particles, which accept the energy of ultraviolet photons and emit visible photons. In the case of my lamp, the phosphor coating emitted relatively high intensities of light ranging from blue to yellow in color, demonstrated by the continuous peaks between about 480 nm and 600 nm. Because it is not an atomic source, we should not expect line spectra from the phosphor particles, and so attribute the continuous portion of the plot to the activity of the phosphor. The presence of the continuous spectra also tells us that the mercury vapor is emitting light in the ultraviolet range, which is beyond the scope of our spectrophotometer to detect directly.



These three elemental vapor spectra clearly illustrate line spectra. Examining the prominent lines of neon, I would expect the light to be a deep red-orange color, which is what we observed. The spectral lines of krypton indicate another red light, however, we observed a cool blue color. Argon's prominent lines also imply a red color, which does not match the observed lavender-purple color. I hypothesize that the difference is because our spectrophotometer doesn't detect or plot the very short blue visible wavelengths (near ultra-violet), which would combine with the red lines in the spectrum to produce the blue and lavender-blue light seen from krypton and argon vapor lamps.



A neon-helium laser produces a red laser beam, which is correlated on the spectral graph with a single, sharp peak in the red portion of the spectrum. Because of this single peak, we can refer to the laser as an extremely monochromatic light source. Careful examination of the graph reveals a minor peak on the neon vapor spectra at the same wavelength of the laser beam, which indicates the neon component of the neon-helium laser.

## Absorption

Absorption of X-ray radiation follows Beer's law like the absorption of other forms of electromagnetic radiation. For X-ray work, Beer's law looks like:

$$\ln \frac{P_0}{P} = x$$

Where

$P_0$  incident beam power,

$P$  transmitted beam power,

$\ln$  linear absorption coefficient (similar to molar absorptivity),

$x$  path length in cm

We can rewrite this to take into account the density of the sample:

$$\ln \frac{P_0}{P} = Mx$$

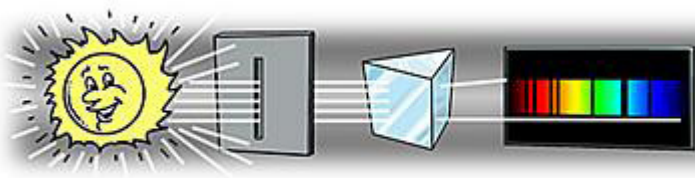
where  $M$  is the mass absorption coefficient.

Using the mass absorption coefficient, you don't need to worry about the physical or chemical state of the sample.

And, mass absorption coefficients have the additional convenience of being additive functions of their weight fractions of sample components:

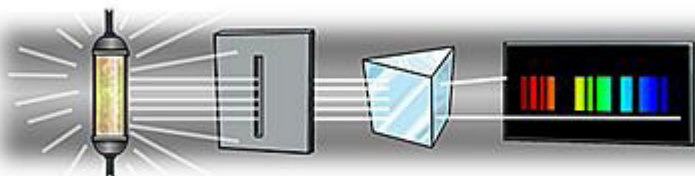
$$\text{So } M_{tot} = W_A + W_B + \dots + W_n$$

Like many important scientific discoveries, Fraunhofer's observation of spectral lines was a complete accident. Fraunhofer wasn't looking for anything of the sort; he was simply testing some new state-of-the-art prisms he had made. When sunlight was sent through a thin slit and then through one of the prisms, it formed a rainbow-colored spectrum, just as Fraunhofer had expected but, much to his surprise, the spectrum contained a series of dark lines.



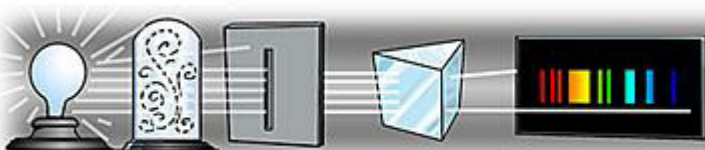
Dark lines? That's the opposite of what we've been talking about. You've been telling me that different elements create a series of bright lines at certain wavelengths.

That's what happens when an element is heated. In terms of the Bohr model, heating the atoms gives them some extra energy, so some of their electrons can jump up to higher energy levels. Then, when one of these electrons drops back down to a lower level, it emits a photon --at one of that element's special frequencies, of course. And those photons create the bright lines in the spectra you showed me.



Exactly that's called an emission spectrum. But there is another way in which elements can produce spectra. Suppose that instead of a heated sample of some element, you have the element in the form of a relatively cool gas. Now let's say that a source of white light-- containing all visible wavelengths--is shining behind the gas. When photons from the light source make their way through this gas, some of them can interact with the atoms--provided that they have just the right frequency to bump an electron of that element up to a higher energy level. Photons at those particular frequencies are thus absorbed by the gas. However, as you noted before, the atoms are "transparent" to photons of other frequencies.

So all those other frequencies would come through okay. Then the spectrum of light that had been through the gas would just have some gaps in it, at the frequencies that were absorbed.



That's right. The spectrum with these missing frequencies is called an absorption spectrum. (Note that the dark lines in an absorption spectrum appear at exactly the same frequencies as the bright lines in the corresponding emission spectrum.)

## 9.8 End unit assessment solutions

1. Solution to question 1 is summarized in the table below:

i.	ii	iii	iv	v
C	B	A	D	A

2. X-ray production-characteristic radiation and bremsstrahlung:

a) X-rays are produced by bombarding a target material with high energy electrons. If the incident electron interacts or collides with an atom in the target then it will lose some of its kinetic energy. This energy can be emitted as an x-ray. The broad range of x-ray wavelengths is the bremsstrahlung (“braking radiation”). It arises from the sudden decelerations of the electrons as they strike the target. Since there will be a range of magnitudes of accelerations, there will be a range of x-ray energies. The sharp spikes in the spectrum are the characteristic radiation. These x-ray wavelengths are characteristic of the particular atoms in the target. Some of the bombarding electrons cause electrons within the target atoms to be promoted to higher energy levels. When these electrons drop down again to lower levels, they release energy in the form of photons. The photons have an energy which is the difference in energy between two electron shells in the target atoms.

b) If the incident electron gives up all its kinetic energy in a single interaction a photon with the highest possible energy will be produced. This maximum energy corresponds to the minimum wavelength,  $\lambda_{\min}$ . It is impossible to get an x-ray with higher energy (shorter wavelength) than that originally possessed by the incident electron. This is an important clue to the photon nature of x-rays, more collisions will produce more photons, but not higher energy photons, in the same way that increasing the intensity of the incident light in the photoelectric effect will increase the photo-current, but not the stopping voltage.

c) If the accelerating voltage was increased, the cut-off wavelength would decrease (dotted line in figure) as each incident electron would carry more energy allowing higher energy x-rays to be produced. The characteristic peaks would not change as these correspond to x-rays emitted when electrons move from one energy level to another in the target atom. These energy levels will not change, hence the characteristic peaks will not change. The characteristics x-rays are characteristic of the target material.

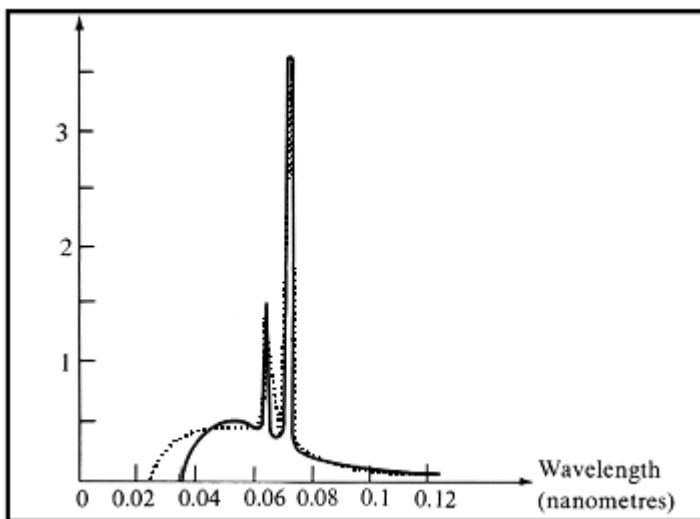


Fig.9.3

d) If the target was changed the cut-off wavelength would remain the same. The characteristic peaks would change as these depend on the electron energy levels of the target material, see Fig.10.3

3. (i)  $E = eV = 1.602 \times 10^{-19} \times 10^4 = 10^4 \text{ eV}$

(ii) de Broglie relation:  $\lambda = \frac{h}{\sqrt{2eVm_e}} = \frac{6.67 \times 10^{-34}}{\sqrt{2(10^4) \times 1.602 \times 10^{-19} (9.11 \times 10^{-31})}} = 1.23 \times 10^{-11} \text{ m}$

(iii)  $\lambda_{\min} = \frac{hc}{eV} = \frac{3 \times 10^8 \times 6.67 \times 10^{-34}}{1.602 \times 10^{-19} \times 10^4} = 1.25 \times 10^{-10} \text{ m}$

(iv)  $E_{\max} = \frac{hc}{\lambda_{\min}} = \frac{3 \times 10^8 \times 6.67 \times 10^{-34}}{1.25 \times 10^{-10}} = 602 \times 10^{-15} \text{ J}$

4. According to Bragg's law  $n\lambda = 2d \sin \theta$  and  $n = 1$

therefore,  $\lambda = 2d \sin \theta = \frac{\lambda}{2 \sin \theta} = \frac{1.2 \times 10^{-10}}{2 \times \sin 12^\circ} = 2.89 \times 10^{-10} \text{ m}$

5. Check answer on activity 10.5

6.  $h = \frac{E}{f_{\max}} = \frac{E \lambda_{\min}}{c} = \frac{4.8 \times 10^{-15} \times 4.1 \times 10^{-11}}{2.998 \times 10^8} = 6.56 \times 10^{-34} \text{ J} \cdot \text{s}$

7.  $n\lambda = 2d \sin \theta = 1$

$\lambda = 2d \sin \theta = 2 \times 2.82 \times 10^{-10} \times \sin 10^\circ = 9.79 \times 10^{-11} \text{ m}$

8. As  $\lambda = \frac{h}{p} = \frac{h}{m_e v} \Leftrightarrow v = \frac{h}{m_e \lambda}$  then  $K = \frac{1}{2} m_e v^2 = \frac{1}{2} \frac{h^2}{m_e \lambda^2}$  also  $eV = K$

9.

10. A tungsten target ( $Z = 74$ ) is bombarded by electrons in an x-ray tube. The K, L, and M atomic x-ray energy levels for tungsten are -69.5, -11.3 and -2.30 keV, respectively.

a) The energy levels are given as negative values because these are the values of electrical potential energy when a free electron is taken as the reference at 0 eV. In other words, they are the energies required to totally remove the electron from that energy level. It is rather like the gravitational potential energy down the bottom of a hole when the surface of the earth is taken as the reference of zero.

b) The minimum kinetic energy of the bombarding electrons is the energy required for the transition:

$k_{\alpha}$  line is from the transition from  $n = 2$  to  $n = 1$  energy level,  $E = (69.5 - 11.3) = 58.2$  keV

$k_{\beta}$  line is from the transition from  $n = 3$  to  $n = 1$  energy level,  $E = (69.5 - 2.3) = 67.2$  keV

c) The minimum values of the accelerating potential are 58.2 keV and 67.2 keV, respectively.

$$d) \lambda = \frac{hc}{E} = \frac{6.67 \times 10^{-34} \times 3 \times 10^8}{58.2 \times 10^3 \times 1.602 \times 10^{-19}} = 2.1 \times 10^{-11} \text{ m}$$

$$\lambda = \frac{hc}{E} = \frac{6.67 \times 10^{-34} \times 3 \times 10^8}{67.2 \times 10^3 \times 1.602 \times 10^{-19}} = 1.8 \times 10^{-11} \text{ m}$$

11.

A: High potential

B: Applied voltage source

C: Hot water out from cooling the target

D: Cold water in to cool the target (Anode)

E: The anode (Target)

F: The cathode. Hot filament, the source of

electron

G: Beam of electron towards the anode

H: X rays produced

## 9.9 Additional activities

### 9.9.1 Remedial activities and answers

1. Choose the correct answer for the following questions.

ii. Scattered x-ray beams approach detector screen

A. perpendicularly

B. parallel

C. anti-parallel

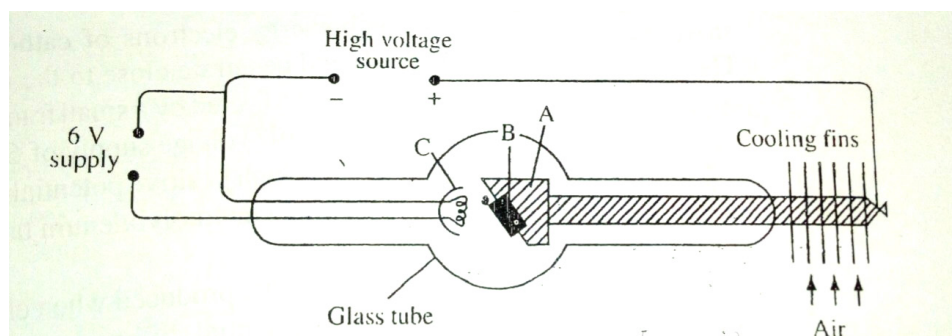
D. at an angle

- ii. Type of x-rays used to detect break in bone is
- hard
  - soft
  - both A and B
  - moderate
- iii. Intensifier screens reduces patient's exposure to x-rays by a factor of
- 500-600
  - 1000-2000
  - 100-500
  - 10-100
- iv. Contrast media consist of elements with
- lower atomic number
  - higher atomic number
  - metalloids
  - inert gases
- v. A good x-ray source should produce x-rays of narrow beam and
- parallel x-rays
  - perpendicular x-rays
  - anti-parallel x-rays
  - anti-perpendicular x-rays

**Answer:**

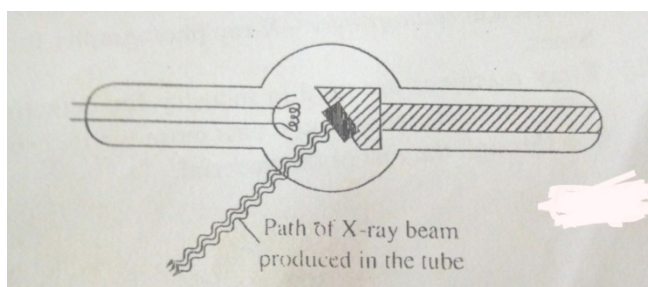
i	ii	iii	iv	v
D	A	C	B	A

The figure below shows the structure and circuit of a modern x rays tube



- b) Indicate on the diagram the path of the x-ray beam supplied by the tube.
- c) Name the part marked C and state its function
- d) Name the metals used in parts A, B and state why there are suitable for use in the tube
- e) Why are cooling fins necessary?
- f) Describe how the x rays are produced.
- g) What is the speed of x rays?
- h) What are hard and soft x rays?
- i) Briefly describe two uses of x rays
- j) In which way do x rays differ from gamma rays.
- k) Explain why people are advised against exposing themselves to x rays unless it is absolutely unavoidable.

Answer:



- b) C is a concave focusing cathode which helps electrons to focus on a spot on target B
- c) A copper anode as it is a good conductor of heat; conducts heat away from the target;
- d) B- Molybdenum or tungsten has a very high melting point and does not melt when heated.
- e) The cooling fins remove much of the heat conducted along the thick copper rod A.

- f) X rays are produced when high energy electrons of cathode rays strike the atoms of heavy metals and penetrate close to nucleus. The hot cathode, C emits electrons when heated by a small transformer connected to a.c mains. It has very low voltage supply of 6 V. Copper anode A is maintained at very high positive potential relative to cathode C, so that electrons reach the molybdenum target B, with a high energy. The whole tube is evacuated and x rays are produced when electrons collide with molybdenum target. The potential difference across the electrodes accelerates the electrons to the speed necessary to produce the x rays only. Only a small fraction of the kinetic energy of the electrons becomes x ray radiation; the rest is absorbed by the target which becomes hot. A cooling device, the fins are required to conduct away this heat.
- f) Their speed is  $C = 3 \times 10^8 \text{ m/s}$ . X rays are electromagnetic waves and therefore have the speed of light in vacuum.
- g) X rays have wavelengths range between 10 nm to 0.001 nm. Soft x rays produced at low voltage and they have low penetrating power, low energy and long wavelength. Short wavelength x rays are referred to as hard x rays. They are produced at high voltage and have high penetrating power.
- h)
- i. X rays pass through matter of low density but are absorbed far more by matter of high density. Hence they penetrate tissue of flesh but are absorbed by denser matter such as bones. So they are used in radiography (x ray photography for study of bones)
  - ii. X ray machines are used in industry for detecting flaws and defects in steel plates. X rays pass more easily through the flows than through the rest of the material.
  - iii. Recently developed x ray microscopes have made it possible to study the arrangement of the molecules of crystalline substances e.g the structure of wool to improve fibre.
  - iv. X rays have harmful killing effects on normal living cells and are dangerous to health. Hence all x rays apparatus are always surrounded by lead shields which absorb stray radiation. Most x rays are absorbed by about 1 mm thick lead. However, very hard x rays are used in hospitals to destroy cancered cells
- i) X rays differ from gamma rays in that gamma rays originate from the nuclei of atoms while X rays are as a result of fast moving electrons being decelerated by a metal which they hit.
- j) X rays are dangerous to us because our bodies can absorb the energy from x ray radiation. When our bodies absorb the x rays energy, ions are produced in the body. These ions can change or destroy living cells. The damage to the body's living cells

can stop them from functioning and multiplying, which may lead to cancer, leukaemia, and hereditary defects in children and / or death. People are therefore advised against exposing themselves to x rays unless it is absolutely unavoidable.

3. How much the radiographer increase the:

- i. Intensity?
- ii. Energy of x rays produced by an x rays tube?

**Answer**

i. The intensity of x rays can either be increased by:

- Increasing the current on the filament or
- Increasing the tube voltage

ii. Increase the tube voltage

4. State the energy transformation that take place during x ray production in an x ray tube.

**Answer:**

Electrical energy is converted to heat energy in the filament cathode. The heat energy is then converted to kinetic energy of moving electrons. Upon reaching the anode, the kinetic energy is converted to x rays and heat energy.

5. (a) Calculate the wavelength of x rays whose energy is 9.5 keV.

(b) Comment on the quality of the x rays in (a)

**Answer:**

$$(a) \lambda = \frac{hc}{E} = \frac{6.67 \times 10^{-34} \times 3 \times 10^8}{(95 \times 10^3 \times 1.602 \times 10^{-19})} = 1.3 \times 10^{-10} \text{ m} = 0.13 \text{ nm}$$

(b) The x rays are of high quality. Quality of x rays in the penetrating power of x rays. X rays of short wavelength like that in (a) above are of high quality since their penetrating power is high

### 9.9.2 Consolidation activities

6. What are the advantages do rotating anode x ray tubes have over fixed target x ray tube?

**Answer:**

Rotating anode x ray tube have an advantage of producing high intensity x rays since heat loading on the target is reduced by the rotation of anode as compared to the fixed anode tubes.

7. Determine the tube voltage of an x ray tube which is 1.5 % efficient if it produces x rays whose minimum wavelength is  $1.8 \times 10^{-10}$  m.

**Answer:**

$$E = \frac{hc}{\lambda} = \frac{6.67 \times 10^{-34} \times 3 \times 10^8}{1.8 \times 10^{-10}} = 1.1 \times 10^{-14} \text{ J} = 6.95 \text{ keV}$$

$$\text{The total energy of electrons emitted } E_t = \frac{100E}{1.5} = \frac{100 \times 1.1 \times 10^{-14}}{1.5} = 7.33 \times 10^{-14} \text{ J}$$

$$E_t = eV \Leftrightarrow V = \frac{E_t}{e} = \frac{7.33 \times 10^{-14}}{1.602 \times 10^{-19}} = 457.76 \text{ kV}$$

6 (a) Calculate the electrons produced per minute by the cathode of an x ray tube which has a current of 40 mA flow through it.

Determine the maximum frequency of the x rays so produced if the tube voltage is 80 kV and the tube is 2%.

**Answer:**

6. (a) Calculate the electrons produced per minute by the cathode of an x ray tube which has a current of 40 mA flow through it.

(a) Determine the maximum frequency of the x rays so produced if the tube voltage is 80 kV and the tube is 2%.

Answer:

$$(a) \text{ Total charge } Q = It = (40 \times 10^{-3})(60) = 2.4 \text{ C}$$

Number of electrons

$$N_e = \frac{Q}{e} = \frac{2.4}{1.602 \times 10^{-19}} = 1.5 \times 10^{19}$$

$$(b) \text{ Energy per electron } E = \frac{2.4 \times 80000}{1.5 \times 10^{19}} = 1.28 \times 10^{-14} \text{ J}$$

Efficiency of the tube  $\eta = \frac{2}{100}$  of E

$$\text{Hence } f = \frac{\eta E}{h} = \frac{2 \times 1.28 \times 10^{-14}}{100 \times 6.67 \times 10^{-34}} = 3.843 \times 10^{17} \text{ Hz}$$

### 9.9.3 Extended activities.

1. How and what are some uses of x-rays in medicine?

**Answer:**

Depending on the images needed, the X-Ray technician will ask you to lie, sit, or stand in several positions during the process. You will be asked to hold your breath and remain still while the images are being taken. This provides the clearest images possible-Rays can be used to Diagnose: Conditions Affecting the Lungs, Enlarged Heart, Fractures, Infections, Blood Clots, Swallowed Items, Pneumonia, Foreign Bodies, Obstructions, etc.

## 10.1 Key Unit Competence

By the end of the unit, learners should be able to analyse the applications of LASER

## 10.2 Prerequisite knowledge and skills

The success of this unit rely on the mastery of knowledge, skills acquired in physics in previous grades or units as indicated below.

- Wave and particle nature of light (Unit 1 S.5)
- Effects of X-rays (Unit 9 S.6)
- Black body radiation (in unit1 S.5)

## 10.3 Cross-Cutting Issues to be addressed

- Standardization culture (Be aware of equipment that do not emit electromagnetic radiations)

## 10.4 Guidance on the introductory activity.

This activity aims at capturing students' attention and minds towards this concept

- Tell students that they are to discuss (by themselves) under your guidance.
- Split your class into groups (if it is a mixed school make sure that your groups have boys and girls) in case it is mixed and tell them to start working on the introductory activity.
- Give students enough time to work by themselves brainstorming the questions. In this period, you can move around overseeing what students are doing. Leave them to work by themselves.
- Invite some groups to present their findings to the whole class. You can explain new terms used and clarify points where students had problems
- Ask students from different groups to judge whether, what have been discussed correspond to the questions.

- Together with students, make a summary of what have been discussed using learners' findings and deductions
- Ask learners to identify the practical applications of electromagnetic waves Specifically lasers

Possible answers of the introductory activity.

- Electromagnetic waves are waves that do not necessarily need a material medium for transmission.
- Do not require a material medium for transmission
  - They move with high speed approximately to speed of light in vacuum (Speed of light  $c = 3 \times 10^8$  m/s)
  - Because of high speed (high energy), some of them penetrate matter
  - Like any other waves, electromagnetic waves suffer reflection, refraction, interference,
  - Diffraction absorption, scattering and many others
  - They are transverse waves
  - Electromagnetic waves are produced by accelerating charge.
  - The frequency of all electromagnetic waves remains unchanged but the wavelength can change
  - when it travels from one medium to another.
  - The energy carried by electric and magnetic fields of electromagnetic fields are equal.
  - Their energy can be quantised.
- Accelerating charges produce varying electric and magnetic fields. Changing electric fields results into changing magnetic that leads to production of current. This interplay between magnetic and electric fields leads to production of electromagnetic waves
- NO. Different types of electromagnetic waves have different energy depending on where they originate and the medium they propagate through.
- Electromagnetic waves can be regarded as stream of energy. Using different examples of electromagnetic waves, we can discuss the positive uses of these waves

## **X-rays.**

- i. Treating cancer
- ii. Investigation structure of metals
- iii. Detect broken bones, punctures in broken pipes etc
- iv. To study the structure of crystals and properties of Atoms.

For more information refer to S.6 unit 9

## **LASER LIGHT**

- i. Punching small holes on a surface of a material
- ii. Laser surgery
- iii. Used as a level
- iv. For security purposes
- v. They are used in scientific research
  - Electromagnetic waves can be used to transfer information
  - Gamma rays can be used to kill living organisms and sterilize medical equipment
  - Micro wave oven converts electromagnetic energy with low frequency into electromagnetic energy with very high frequency that is easily absorbed by food and converted into heat.
- vi. From LASER meaning **Light Amplifier by Stimulated Emission of Radiation**, it implies that laser itself is an electromagnetic radiation under visible part of radiation possessing all the characteristics of electromagnetic waves. Therefore, Lasers are part of electromagnetic waves.

## 10.5 List of lessons

S/ No	Lesson Tittle	Learning Objectives (Adapted from syllabus)  By the end of the Lesson(s) Learners should be able to:	Suggested Number of Periods
1	Introductory Activity	Have a general over view of the unit and connect electromagnetic waves to laser light.	2
2	Laser Concept	Analyse the mechanism to produce LASER beam	3
3	Laser Structure	Analyse the structure of a laser	3
4	Properties of lasers	Explain: monochromatic, coherent sources of light, stimulated emission of light and spontaneous emission of light.	3
5	Applications and dangers of Lasers	Analyse applications and dangers of LASER beam	4
6	End unit assessment.	To apply knowledge and understanding acquired from the concepts learnt.	2

### Lesson 10.1: Concept of laser.

#### a) Prerequisites/Revision/Introduction:

Through guided discovery, assist learners to discover what a laser is and how it can be produced. You can make a recap using;

- Propagation of mechanical waves (Unit 4 S.5) particularly on electromagnetic wave
- Wave and particle nature of light (Unit 1 S.5)
- Production of X-rays (Unit 9 S.6)

Questions like,

Put in full L.A.S.E.R. and defining all the terms in the word LASER should be posed to students

How is laser produced? (This can take like 2 minutes).

**b) Teaching resources: Internet and textbooks, Laser pointers (if you have any at your school)**

**c) Learning Activities:**

This lesson focuses on making students understand and apply the concept laser production

- Tell students to turn to activity 11.1 in students' book and interpret the picture
- Divide your class into different groups (Choice is yours about methodology depending on the type of your class)
- Instruct them to re-write questions to their notebooks.
- Leave the learners to perform the activity by themselves. Give them enough time to work out the questions.
- Invite 2 or 3 (or any number of groups depending on how many you had formed) to present their findings. Let them discuss by themselves
- Ask other members of the class to whether they have similar answers from what others have presented.
- Together with students, consolidate and come to a common understanding of different questions in the Activity.

**Expected results of the activity:**

- a. A **laser** is created OR produced when the electrons in atoms in special glasses, crystals, or gases absorb energy from an electrical current or another laser and become "excited."
- b. **Yes.** This is because the atoms need extra source of energy so that they can absorb that energy and jump to another energy levels (Excited state). Therefore, energy sources like electricity is necessary to provide energy to the atoms so that they can be excited.
- c. **Laser** is formed when atoms are in excited states. It does not happen in ground state since particles in this level have minimum or Zero energy, hence in ground state atoms cannot radiate any radiation.

**Answers to Activity 10.2**

- i. Absorption is a process in which a photon from a pump source is destroyed and the atom which was at the ground state is promoted to the excited state

- ii. Stimulated emission is the process in which an atom is demoted to the ground state, and the electric field is left with  $n + 1$  photons
  - iii. Spontaneous emission is a process in which an atom drop to a lower level by emitting a photon of radiation
2. In excited states, electrons have a lot of energy than in ground state. Therefore an electron emits or radiates energy when it leaves the excited states.

$$3. E = hf$$

Where

$E$  is energy radiated

$h$  is planks constant

and  $f$  frequency of emitted radiation

4. Population inversion is the process of increasing excited electrons in higher energy levels.

## Lesson 10.2: Laser Structure

### a) Prerequisites/Revision/Introduction:

Students need to be knowing what a laser is and how it is produced

In brief, ask learners in brief to describe the structure of a laser light basing on what they know.

### b) Teaching resources: Internet and textbooks,

### c) Learning Activities

### Activity 10.3

This activity makes learners to think and analyse the structure of laser light.

- Tell students to turn to activity 10.2 in the learner's book
- Depending on the nature and size of your class, decide the methodology to use (it may be group work, individual or class activity)
- Tell students to copy the questions into their notebooks and give them some time to attempt or discuss the questions. This may take up like 40 minutes.
- Call some students (may be a group or individual depending on the methodology you used) to make a presentation about their answers/findings.
- Ask other students whether they agree with what have been discussed by their fellow students. You can harmonize if there is any problem

- Link learner's findings and notes to the structure of a laser
- Together with students make a summary about structure of laser. Compile the outcomes and let learners write them in their Notebooks.

### Expected answers on this activity 10.3.

- a. laser system consists of three important parts: Active medium or amplifying medium, the energy source referred to as the pump or pump source and the optical resonator consisting of mirrors or system of mirrors.

For more explanations refer to students' book.

- b. Parts are different. This is because at different points, the beam has different energy. Like in pumping mechanism, energy is supplied. This means that the parts cannot resemble.

### Answers to checking my Progress 10.1.6

1. The laser is a device that uses the ability of some substances to absorb electromagnetic energy and re-radiate it, as a highly focused beam of monochromatic and synchronized wavelength radiation.
2. LASER stands for Light Amplifier by Stimulated Emission of Radiation.
3. A laser is created OR produced when the electrons in atoms in special glasses, crystals, or gases absorb energy from an electrical current or another laser and become "excited."
4. Refer to Activity 10.2 part (no 4)
5.  $E = hf = 6.63 \times 10^{-34} \times 10^{10}$   
 $E = 6.65 \times 10^{-24} J$
6. a) Active medium or amplifying medium, The pump and Optical resonator  
 b). Plane mirror resonator, Confocal resonator, Concentric resonator, Spherical-plane resonator and Concave-convex resonator. Diagrams discussed in learner's book.

## Lesson 3: Properties of lasers

### a) Prerequisites/Revision/Introduction:

Students need to be knowing the concept of laser.

Learners have ever seen different examples of light. Let them list the different examples and their characteristics / properties.

## **b) Teaching resources: Internet, textbooks laser pointer (if you have any)**

### **Activity 10.4**

This activity aims at making learners discover the properties of laser light.

- Tell learners to copy down the questions to their Notebooks and attempt them.
- Move around and mark students' books.
- Take time after marking and let the learners raise their answers (you can pick any number (for each question) of students depending on the time you have)
- Together with learners make a summary of correct points on the board and tell learners to correct themselves where they went wrong and write correct points to their notebooks.

### **Expected answers of this activity**

- a. Monochromatic, Coherent, collimation (Directionality). For explanations refer to learners' book.
- b. Different kinds of lasers are different since they are produced by different sources with different energy. Example Gas laser may not be equally similar as solid lasers. This means that the degree of Coherence, monochromaticity, and directionality differs depending on the type of laser.

The output is determined by the spectral emission properties of the gain medium and the modes supported by the cavity.

### **Answers to Checking my progress 10.2.4**

1.b

2.a

3. Under monochromaticity, laser light is produced with similar or one wavelength. This is a condition for coherence. Also, collimation is a property that allows light to stay in one direction which can also be achieved when light have one wavelength. Hence the three terms are connected.

4. In holography, the temporal coherence (in laser) length determines the maximum depth of the object in a reflection hologram, and the spatial coherence length determines the lateral size. Holography, which is based on interference between light beams, long coherence length enables taking holograms of large bodies, which require greater depth of field. Both the light reflected from the near part of the body, and the light reflected from the far part of the body, will still be coherent with the reference beam.

5. Collimation or Directionality. This is because laser light is highly directional.

## Lesson 4: Applications and dangers of Lasers

### a) Prerequisites/Revision/Introduction:

Students need to be knowing all the properties of laser light and laser production.

Learners now know what a laser is and what makes up laser light. Let them give real applications and dangers of misuse of laser light.

### b) Teaching resources: Internet, textbooks laser pointer (if you have any)

### c) Learning Activities

This lesson emphasizes on the practical applications and dangers of misuse of laser light.

- Tell learners to open their books (Learners book) to activity 10.6
- Decide on the methodology to use in this lesson. You can group your learners, they can do it as a class or individual.
- Instruct them to read the activity first and then re-write the questions to their notebooks.
- Allow them to attempt the questions.
- Move around and mark their work.
- Select some students to share their answers to the whole class and allow questions from students if any. Create a favourable environment for learners to discuss.
- Together with student's ideas, link their answers to the practical applications of laser light.
- Make a summary (using student's findings) and tell learners to write down important ideas in their books.

## Answers to the Activity 10.6

- In Cutting metals (welding)
  - As a level in construction
  - Laser Surgery in hospitals
  - They are used in military and law enforcement devices for marking targets and measuring range and speed.
  - Laser lighting displays use laser light as an entertainment medium.
  - And many others discussed in learners' book.
- Accept all learner's idea if a student answers the question.
- In hospitals, Industries construction, Security section, etc

## Activity 10.6

This activity makes students to be aware of dangers of misuse of laser light.

- Tell learners to open activity 11.6 in the learner's book.
- Divide learners into groups or chose any method that can suit your class and helps the learner to attempt the activity
- Tell learners to read the questions and copy them to their notebooks.
- Give students favourable to work on the activity given
- While moving around mark students work.
- After marking invite some members to discuss or present their answers to the whole class
- Ask learners (rest of the class) whether their answers correspond to the discussed ones
- Invite some students to present about their answers. React on their findings by concretizing what may be missing or not discussed comprehensively.
- Consolidate your lesson by making a summary from learners'suggestions and tell students to note down important points in their notebooks.

## Expected answers to the activity 10.6

- a. Yes.
- b. Because long exposure of these radiations cause skin burn, skin cancer, affects eyes, Affect cells of a human being resulting into mutation.
- c. Because of their high energy, this makes them to have high penetrating power. Therefore, they can penetrate matter hence harmful.

## Activity 10.7

This activity makes learners discover precautions that one can take to avoid side effects of laser light

- Tell learners to open activity 10.7 in the learner's book.
- Divide learners into groups or chose any method that can suit your class and helps the learner to attempt the activity
- Tell learners to read the question and copy it to their notebooks.
- Give students like 30 minutes to work on the activity given
- While moving around mark students work.
- After marking invite some members to discuss or present their answers to the whole class

- Ask learners (rest of the class) whether their answers correspond to the discussed ones
- Consolidate your lesson by making a summary from learners' suggestions and tell students to note down important points in their notebooks.

### **Possible answers to activity 10.7**

- a. The protective wear are intended to shield them from incoming radiations that are harmful. (Accept any learner's idea that is that is connected to the reasoning stated)
- b. This question requires all the preventive measures against laser radiation. Some of them are listed below.
  - i. For any one working in places where there are incidences of being exposed to laser light, one should wear protective clothes, glasses and shoes so that there is no direct exposure of these radiations on to the body.
  - ii. One should minimize the time of working with lasers.
  - iii. Areas that are exposed to these radiations should be warning signs and labels so that one can be aware of places/areas where laser light is used.
  - iv. Safe measures like Use of remote control should be used to avoid direct exposure of these radiations (LASER light).
  - v. People should be given trainings on how to handle lasers.
  - vi. There should also access restrictions to laboratories that use laser

All discussed in learners' book

### **Answers to checking my progress 10.3.4**

#### 1. Negative effects of lasers

- Lasers can cause damage in biological tissues, both to the eye and to the skin, by the following mechanisms.
- Thermal damage -burns occur when tissues are heated to the point where denaturation of proteins occurs.
- Photochemical damage -where light triggers chemical reactions in tissue.

#### 2. Ways of preventing dangers caused by lasers. Discussed in Activity 11.5

3. Depends on the student's idea. But the biggest percentage should be a YESS since the useful in most of the activities. As discussed in in the uses of lasers.

4. Consider student's idea. But depending on the positive uses of these radiations, man should continue using laser light. But the answer should bear a scientific support.

## 10.6 Summary of the Unit

The term LASER is an acronym for Light Amplification by Stimulated Emission of Radiation.

Laser emits electromagnetic radiation by the process of optical amplification based on stimulated emission of photons.

### Components of a Laser

A laser consists of

- An optical cavity,
- A pumping system (energy source) and
- An appropriate lasing medium.

### Characteristics of Lasers

- Monochromatic—laser consist of mostly single wavelength rather than different wavelengths.
- Coherent—wavelengths in a laser beam are in phase. The wave crests and troughs are parallel to each other.
- Collimated—very narrow, travel in the same direction. Because of these properties intense power is produced at a small point of concentration.

### Types of Lasers

Lasers can be classified by the type of lasing material in the optical cavity.

- Solid state lasers make use of a crystalline lasing material. e.g., ruby or neodymium-YAG (yttrium aluminum garnet) lasers.
- Gas lasers uses pure gas or mixture of gases. e.g., carbon dioxide and helium-neon.
- Semiconductor/diode lasers employ n-type and p-type semiconducting element materials.
- Liquid/dye lasers employ organic dye in a liquid solution or suspension as lasing media.
- Excimer lasers (the name is derived from the terms excited and dimers) use gases such as chlorine and fluorine mixed with inert gases such as argon, krypton or xenon.

## Effects of Laser

Biological Effects: Lasers can cause damage in biological tissues, both to the eye and to the skin, by the following mechanisms.

- Thermal damage -burns occur when tissues are heated to the point where denaturation of proteins occurs.
- Photochemical damage -where light triggers chemical reactions in tissue.

Preventive measures of the effects of Lasers

### Warning sign to be posted at the entrance.

- Warning lights to be provided outside the laser room to warn visitors when the laser is in operation.
- Materials that can cause specular reflection must not be kept in the laboratory.
- Laser safety glasses must be used if the permissible exposure limits for the laser are exceeded.
- Secure optical components to the table to prevent stray reflections from misaligned optics.
- Users must never view the beam at the level of the horizontal plane where they are passing.
- Watches and jewelry must not be used in the laboratory.
- Alignment of beams and optical components must be performed at a reduced beam power whenever possible

Amplification and Population Inversion When favourable conditions are created for the stimulated emission, more and more atoms are forced to give up photons thereby initiating a chain reaction and releasing vast amount of energy, this results in rapid build-up of energy of emitting one particular wavelength (monochromatic light), traveling coherently in a precise, fixed direction. This process is called amplification by stimulated emission. The number of atoms in any level at a given time is called the population of that level. Normally, when the material is not excited externally, the population of the lower level or ground state is greater than that of the upper level. When the population of the upper level exceeds that of the lower level, which is a reversal of the normal occupancy, the process is called population inversion. This situation is essential for a laser action. For any stimulated emission, it is necessary that the upper energy level or met stable state should have a long-life time, i.e., the atoms should pause at the met stable state for more time than at the lower level. Thus, for laser action, pumping mechanism (exciting with external source) should be from a such, as to maintain a higher population of atoms in the upper energy level relative to that in the lower level.

## 10.7 Additional Information

### The Einstein Coefficients

The Einstein Coefficients Laser activity may occur in the case of nonequilibrium, as we will see later. Before dealing with this situation, let us start by considering the case of equilibrium between the radiation field and an ensemble of atoms in the walls of a cavity. This will lead to the Einstein derivation of Planck's radiation law. The atoms will be described in the framework of Bohr's model of the atom, allowing the electron to occupy only discrete energy levels. For the derivation of the radiation law, the consideration of just two of those levels is sufficient. They shall be indexed by 1 and 2 and shall be populated such that for the total number of atoms

$$N_1 + N_2 = N \text{ holds.}$$

This  $N_2$  means that of the atoms are in the excited state with energy  $E_2$  and  $N_1$  atoms are in the ground state with energy  $E_1$ . Transitions between the states shall be possible by emission or absorption of photons of the appropriate energy.

Consider an assembly of atoms at an absolute temperature T in which the atoms may be in different energy levels.

If  $n_0$  is number of atoms per unit volume in the ground state ( $E=0$ ), then the number of atoms  $n$  per unit volume in excited state E is given by Boltzmann distribution law

$$n = n_0 e^{-\frac{E}{kT}} \text{ where } k = 1.38 \times 10^{-23} \text{ J / K, } E = \text{energy of a photon}$$

### 10.8 End of Unit Assessment answers.

- |       |       |       |       |       |       |
|-------|-------|-------|-------|-------|-------|
| 1. b  | 2. a  | 3. b  | 4. b  | 5. a  | 6. b  |
| 7. a  | 8. a  | 9. b  | 10. b | 11. c | 12. d |
| 13. f | 14. b | 15. a | 16. c | 17. c |       |

18.a) Laser radiation is a light characterized by an extremely high degree of (1) monochromaticity,

(2) coherence, (3) directionality, and (4) brightness.

Or: The laser is a device that uses the ability of some substances to absorb electromagnetic energy and re-radiate it, as a highly focused beam of monochromatic and synchronized wavelength radiation.

19. (a) Coherence. Wavelengths in a laser beam are in phase. The wave crests and troughs are parallel to each other.

Monochromaticity. Here laser consist of mostly single wavelength rather than different wavelengths.

Collimation. This is where very narrow beam of light, travel in the same direction. Because of these properties intense power is produced at a small point of concentration.

20.a) Spontaneous Absorption of light. This process involves the atom initially at an excited state, in the presence of  $n$  photons in some resonant mode. After the stimulated emission event, the atom is demoted to the ground state, and the electric field is left with  $n + 1$  photons

Spontaneous Emission. In general, when an electron is in an excited energy state, it must eventually decay to a lower level, giving off a photon of radiation. This event is called “spontaneous emission,” and the photon is emitted in a random direction and a random phase.

Population inversion. Population inversion: This is the process of increasing excited electrons in higher energy levels. This is the redistribution of atomic energy levels that takes place in a system so that laser action can occur. (For diagrams refer student’s book)

b) This question needs applications or uses of laser light

In laser Surgery

- Used in welding
- Used as a level in construction
- In formation of 3D diagrams
- In scientific research
- Others discussed in Student’s book.

c) Though laser light is very important in different activities, it can also cause harm if mis-used In what ways is laser light harmful.

This question requires side effects of lasers. Some of them are listed below.

- Cause skin cancer
- Cause skin burn
- Affect eyes

## 10.9 Additional activities

### 10.9.1 Remedial activities:

1.The following are properties of laser. Which one is a unique property of laser?

- a. Directional
- b. Speed
- c.Coherence
- d. Wavelength

Answer: c

Explanation: Coherence is an important characteristic of laser beam because in laser beams, the wave trains of same frequency are in phase/ Due to high coherence it results in an extremely high power.

2.Among the following, which one of the following is an example of optical pumping?

- a. Ruby laser
- b. Helium -neon laser
- c.Semiconductor laser
- d. Dye laser

Answer: a

Explanation: The atoms of Ruby are excited with the help of photons emitted with the help of photons emitted by an external optical source. The atoms absorb energy from photos and raises to excited state. Therefore, Ruby laser is an example of optical pumping.

3.When laser light is focused on an area for a long time, then that particular area alone will be heated. True or false?

- a. True
- b. False

Answer: a

a. Explanation: Laser beam has very high intensity, directional properties and coherence. When it is focused on a particular area for a long time, then the area alone will be heated and the other area will remain as such. This is called thermal effect.

4. Calculate the wavelength of radiation emitted by an LED made up of a semiconducting material with band gap energy 2.8eV.

- a. 2.8Å
- b. 4,3308 Å
- c. 5548.4 Å
- d. 4430.8 Å

Answer: d

Explanation:  $E = hc / \lambda$

Therefore,  $\lambda = hc / E$

$$\lambda = 4430.8 \text{ \AA}$$

5. Estimate the number of photons, from green light of mercury ( $\lambda = 4961 \text{ \AA}$ ), required to do one joule of work.

- a.  $4524.2 \times 10^{18} / \text{m}^3$
- b.  $2.4961 \times 10^{18} / \text{m}^3$
- c.  $2.4961 / \text{m}^3$
- d.  $2.4961 / \text{m}^3$

Answer: b

Explanation:  $E = hc / \lambda$

$$E = 4.006 \times 10^{-19} \text{ Joules}$$

$$\text{Number of photons required} = (1 \text{ Joule}) / (4.006 \times 10^{-19})$$

$$N = 2.4961 \times 10^{18} / \text{m}^3$$

$$\text{Number of photons required} = (1 \text{ Joule}) / (4.006 \times 10^{-19})$$

$$N = 2.4961 \times 10^{18} / \text{m}^3$$

6. The following are types of lasers. Which one of the following can be used for generation of laser pulse?

- a. Ruby laser
- b. Carbon laser
- c. Heliumneon laser
- d. Nd- YAG laser

Answer: d

Explanation: Since Nd YAG laser has a higher thermal conductivity than other solid state lasers, it lends itself for generation of laser pulses at a higher pulse repetition rate or a quasi-continuous wave operation.

7. Which of the following is a condition to achieve population inversion?

- a. To excite most of the atoms
- b. To bring most of the atoms to ground state
- c. To achieve stable condition
- d. To reduce the time of production of laser

Answer: a

Explanation: When population inversion is achieved, the majority of atoms are in the excited state. This causes amplification of the incident beam by stimulated emission. Thus the laser beam is produced.

8. Laser can be termed as non-material knife. True or false?

- a. False

Answer: b

Explanation: In laser surgery, without knife, bloodless operation, cutting tissues etc can be made, hence laser is called non material knife.

9. DVD uses laser. True or false?

- a. True
- b. False

Answer: a

Explanation: A DVD player contains a laser. By moving the lens longitudinally, different depths can be reached in the disc. To make room for a lot of information on every disc, the beam has to be focused on as small an area as possible. This cannot be done with any other light source.

10. Which of the following is used in atomic clocks?

- a. Laser
- b. Quartz
- c. Maser
- d. Helium

Answer: c

Explanation: Before laser maser was used. It stood for microwave amplification by stimulated emission of radiation. This was based of Albert Einstein's principle of stimulated emission. It was used in atomic clock.

11. Which of the following can be used in vibrational analysis of structure?

- a. Maser
- b. Qwarts
- c. Electrical
- d. Laser

Answer: d

Explanation: Laser can be used in vibrational analysis of structure. This is because when a structure under test begins to vibrate a distinctive pattern begins to emerge.

#### 10.9.2 Consolidation

1. Which of the following are the three most common laser level types?

- (a) Rotary Laser;
- (b) Line Laser;
- (c) Power Laser;
- (d) Dot Laser;
- (e) Cordless Laser

2: **True or False:** Rotary laser levels project a beam of light  $360^\circ$  allowing the user to establish a horizontal or vertical plane?

3: **True or False:** Rotary laser levels are recommended for outside use only?

4: **True or False:** An important feature of an exterior rotary laser level is a high rotational speed of the laser level beam.

5: **Yes or No:** Can you see a rotary laser level beam outside in daylight or in bright ambient light?

6: What are three commonly required accessories for exterior lasers?

- a. A detector/receiver that detects the laser level beam when the human eye cannot;
- b. A bucket to stand on;
- c. A grade rod to measure changes in the elevation;
- d. A tripod to hold the laser level from;
- e. Joe the helper

**7: True or False**

Using a rotating laser level outside requires two people to operate?

**8: Which of the following applications can be performed with an exterior laser?**

- (a) Excavating;
- (b) Rough and Fine Grading;
- (c) Alignment of concrete forms;
- (d) Setting up drainage;
- (e) All the above

**9: True or False**

Interior laser levels can have red, blue, green or yellow laser level beams?

10: How much more visible to the human eye are green beam laser levels than red beam lasers?

- (a) 2%;
- (b) It isn't more visible;
- (c) 10%;
- (d) 400%

**11: True or False**

Interior laser levels typically have a variable speed control?

**12: What is the advantage of the scan mode feature on an interior laser?**

13: What are the most common accessories used with interior lasers?

- (a) Tripod;
- (b) Grade Rod;
- (c) Ceiling Mount;
- (d) Detector;
- (e) Target

**14: Which of the following applications can be performed with an interior laser?**

- (a) Acoustical ceilings;
- (b) Drywall installation;
- (c) Level floors;
- (d) Level cabinets;
- (e) All the above

**Q15: Can the same laser level be used inside and outside?**

16: What are the two primary advantages of a self-leveling laser level over a manually leveled laser?

**17: True or False**

Dot laser levels project dots either vertically, horizontally or at right angles allowing the end user to establish plumb lines or right angles.

**18: Can a dot laser level beam be seen outside in the daylight?**

**19: A dot laser level can be used for which of the following applications?**

- (a) Installing sprinkler systems;
- (b) Machinery installation;
- (c) Installing electrical outlets and switches;
- (d) Squaring batter boards;
- (e) All the above

**20: True or False**

A line laser level projects lines either vertical, horizontal or vertically and horizontally simultaneously.

**21: Can line laser level beams be seen outside in daylight or in bright ambient light?**

**22: What are the two most commonly used accessories with line lasers?**

- (a) Grade Rod;
- (b) Detector/Receiver;
- (c) Ceiling Mount;
- (e) Tripod

**23: Which of the following applications can be done with a line laser?**

- (a) Sprinkler installation;
- (b) Track lighting;
- (c) Install windows;
- (d) Install chair railing;
- (e) All of the above

**24: True or False**

Optical instruments are used to establish grades and elevations as well as establish straight lines?

**25: True or False**

Establishing elevations using an optical instrument is a one-person operation?

**26: The following are operations that can be done using laser. Which one of the following can be done using an optical instrument?**

- (a) Landscaping;
- (b) Controlling concrete pours;
- (c) Leveling deck floors;
- (d) Contour farming;
- (e) All the above

**27: What are the two most commonly used accessories used with an optical instrument?**

- (a) Tripod;
- (b) Detector;
- (c) Tape Measure;
- (d) Grade Rod

## Answers

1. A, B & D
2. True
3. False, rotary laser levels are recommended for outside and inside applications
4. True, exterior laser levels typically rotate very quickly to send as many signals to the detector/receiver as possible.
5. No, you will not be able to see a rotary laser level beam outside. A detector/receiver must use to detect the rotating laser level beam.
6. A, C & D
7. False, one of the primary benefits of using a rotating laser level is that it only takes one person to operate.
8. E - All the above
9. False, interior laser levels have green or red laser level beams only.
10. D, Green beam laser levels are 400% brighter to the human eye than red beam lasers.
11. True, the slower the rotation speed the more visible the beam is. The faster the rotation speed the more of a chalk line effect can be seen.
12. Using the scan mode feature on an interior laser level concentrates the 360° beam to a specific 30° or 60° area. By narrowing the angle of the laser level beam, it makes the laser level beam even more visible to the human eye.
13. C & E, A ceiling mount that is designed to hold the laser level on perimeter wall angle when installing an acoustical ceiling. A laser level target with reflective tape on the back also helps the operator see the laser level beam.
14. E - All the above
15. Yes, versatile laser levels with variable speed can be used outside at their fastest rotation speed with a detector and at a slower speed inside so the operator can see the beam.
16. a) Faster set up. Using a self-leveling laser level is much quicker to set up on a tripod, level and begin working. A manually leveled laser level requires the operator to adjust the leveling screws to level the laser.  
b) An out of level indicator. If a self-leveling laser level is moved out of its self-leveling range, an audible and visual alert signal will activate. There is no out of level indicator on manually leveled lasers.
- 17: True, a two-dot laser level is designed to give the operator a plumb point between floor and ceiling. A three-dot laser level is designed to give the operator plumb and level. A five-dot laser level provides the operator plumb, level and right angles.

18: Yes, because the laser level beam is concentrated into a dot, a dot laser level beam can be seen outside in the daylight.

19: E - All the above

20: True - some laser levels are designed to project a vertical and horizontal line simultaneously while other line laser levels are designed to project one, two, three or four lines individually.

21: No, a line laser level beam cannot be seen outside in the daylight. To use a line laser level outside in the daylight, the line laser level must have a “pulse” feature and be used with a line laser level detector/receiver.

22: B & E, A line laser level detector/receiver when the line laser level is being used outside. The line laser level must have a “pulse” feature. Light Duty Tripod - Light Duty Tripod. The operator puts the laser level on the platform and sets the platform and laser level beam to any desired height.

23: E - All the above

24: True

25: False, it takes two people to establish elevations using an optical instrument. One person to look through the instrument and take the elevation reading off the grade rod and one person to hold the grade rod at the desired location

26: E - All the above

27: A & D, A tripod to hold the optical instrument. A grade rod to measure changes in elevation.

## 11.1 Key Unit Competence.

Analyze the processes in medical imaging.

## 11.2 Prerequisite knowledge and skills

The successes of this unit rely partly on the mastery of knowledge, skills acquired in physics and other subjects in previous grades or unit or experience in real life related to the medical imaging as indicated below:

- Oscillation and wave (unit 3, S5)
- Sound intensity (unit 1, S6)
- Radioactive decay (unit 5, S6)
- X-ray in medicine (unit 9, S6).

## 11.3. Cross-Cutting Issues to be addressed

- Gender (both boys and girls are treated equally in the lesson participation). Care should be taken that both Sexes are given equal opportunities.
- Peace and value Education: (respect others view and thoughts during class discussions). Remember that someone's idea is very important. It may be correct or Not but what is important is to build on that Idea.
- Standardization culture (Be aware of machines or others materials that do not harm our environment).
- Inclusive education (promote education for all while teaching): Regardless of physical appearance and abilities learners should be treated equally. This makes the learners to find out that they are all of great importance. In spite of their physical ability, learners with impairment as normal learners should be aware of the uses of medical imaging techniques.
- Environment sustainability: During delivering different lessons within this unit, let learners be familiar with the application and importance of skills medical imaging, uses and benefits and risks of them.

## 11.4 Guidance on the introductory activity

This activity aims at capturing students' attention and minds towards this concept of medical imaging, their function, uses and effects.

- Divide your students into groups (Where possible, mix equally the number of girls to number of boys. If there are students with impairment, let them take the lead of groups during doing activity)
- Tell the learners open their books (L B) the introductory activity of the unit 12 and then instruct them to observe the photo and answer them following the instructions from learner's book.
- While students are doing this activity, you move around and mark their attention on working activity.
- When every group is done, invite some group(s) to present and discuss their findings to the whole class. You may choose two or three groups to present their findings while others follow.
- Ask other groups' members whether their answers correspond to the discussed points and if there is any points that are different from what have been raised; tell them to mention it. You can talk about those points (in a discussion together with students).
- Together with students harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks. And then linking to the summary and what have discussed in class, emphasize on the concept of medical imaging, their function, uses and effects.
- You can take some minutes and explain them.
- Summarize your lesson by linking this concept to real life situations like when someone goes to hospital for radiography, echography or for a scan.
- Possible answers of the introductory activity.
- During this introductory activity, let learners present their upbringings about the radiography, echography and nuclear magnetic resonance then find out the hub of their curiosity about x rays radiation production, uses and function. The summary of the introductory question is provided in the LB.

## 11.5 List of Lessons

S/ No	Lesson Title	Learning objective( adapted from syllabus)  By the end of the Lesson(s) Learners should be able to:	Suggested number of periods
1	x- ray imaging	<ul style="list-style-type: none"> <li>• Identify advantages and disadvantages of x- ray imaging , radiography and mammography</li> <li>• Explain the basic functioning principles of x- ray imaging , radiography and mammography</li> <li>• Acquire knowledge in analysing and modelling physical processes involved in medical imaging</li> </ul>	4
2	Ultrasound scan	<ul style="list-style-type: none"> <li>• Explain the medical imaging using ultrasound scan</li> <li>• Identify advantages and disadvantages of medical imaging using ultrasound scan. Explain the function of MRI.</li> <li>• Enjoy the use of ultrasound scan in medical imaging.</li> </ul>	4
3.	Endoscopy	<ul style="list-style-type: none"> <li>• Explain the basic functioning principles of endoscopy.</li> <li>• Identify the benefits of endoscopy</li> </ul>	3

4	Magnetic resonance imaging(MRI)	<ul style="list-style-type: none"> <li>• Explain the basic functioning principles of MRI</li> <li>• Explain the hazard associated with medical resonance imaging</li> <li>• Acquire knowledge in analysing and modelling physical processes involved in MRI</li> </ul>	4
5	Assessment		2

## Lesson 1: x-ray imaging

### a) Introduction

Through guided discovery, learners should be able to explain the basic functioning principles of x-ray imaging, radiography and mammography then suggest the advantage and disadvantage of them.

You can make a brief introduction using unit 10 in Senior six. You can ask them questions that are related to x-rays, effects and its applications especially in medicine.

### b) Teaching resources

Textbooks, Internet.

### c) Learning Activities

- These activities majorly focus on X-rays in radiography and mammography.
- Tell students to turn to activity 12.1 in students' book
- Divide your class into different groups (Decide on the method to use in this lesson depending on the type of your class and time of the day)
- Instruct them to re-write questions to their notebooks.
- Leave the learner perform the activity by themselves. Give them enough time to work out the questions.
- Invite some members or groups to present their findings. Let them discuss by themselves
- Ask other members of the class to whether they have similar answers from what others have presented.

- Together with students, consolidate and come to a common understanding of different questions in the Activity.

Note: There are more 2 activities under this part. (They are 12.1, 12.2,). Tell them to work out these activities in their time. You can also tell students to do some of these activities during their class time.

### **Suggested answer for all activities.**

#### **Activity 11.1:**

- 2.A (x-ray sources), B (ray coming from sources), C (human's body), D (Screen), E (image given by X-rays).
- 3.the X-rays emerging from the source pass through the body and are detected on the photographic film or fluorescent screen, the rays travel in a very nearly straight lines through the body with minimal deviation since at X-ray wavelengths there is a little diffraction or refraction. there is absorption (and scattering) however and the difference in absorption by different structures in the body is what gives rise to the image produced by the transmission and darker the film.
- 4.Radiology is defined as the branch of medicine that encompasses not only imaging techniques, such as x-rays, but also treatments, such as radiation therapy while radiography focused on the use of x-rays.

#### **Activity 11.2:**

- Problem: breast symptoms
  - Causes: hormone use, whether you have a family or personal history of breast cancer, and if there's a possibility of being pregnant.
  - If possible, obtain copies of your prior mammograms and make them available to your radiologist on the day of your exam.
- d) Advise: You may be asked to wear a gown. Don't wear deodorant, talcum powder or lotion under your arms or on your breasts as these may appear on the mammogram and interfere with correct diagnosis.

### **Suggested answers for checking my progress**

- 1.The applications of Multidetector CT are:
  - CT angiography: coronary, cerebral, carotid, pulmonary, renal, visceral, peripheral
  - Cardiac CT, including CT coronary angiography and coronary artery calcium scoring

- CT colography (virtual colonoscopy), CT cholangiography, CT enterography
- Brain perfusion scanning
- Planning of fracture repair in complex areas: acetabulum, foot and ankle, distal radius and carpus.
- Display of complex anatomy for planning of cranial and facial reconstruction surgery

2. The types of x-ray imaging used in mammography are:

**Digital mammography** also called full-field digital mammography (FFDM): is a mammography system in which the x-ray film is replaced by electronics that convert x-rays into mammographic pictures of the breast. These systems are similar to those found in digital cameras and their efficiency enables better pictures with a lower radiation dose.

**Computer-aided detection (CAD)** systems search digitized mammographic images for abnormal areas of density, mass, or calcification that may indicate the presence of cancer. The CAD system highlights these areas on the images, alerting the radiologist to carefully assess this area.

**Breast tomosynthesis**, also called three-dimensional (3-D) mammography and digital breast tomosynthesis (DBT): is an advanced form of breast imaging where uses three-dimensional image set.

3. It is necessary to compress the breast in exam of mammography because the following reasons:

- Visualize whether all of the tissue of the breast.
- Spread out the tissue so that small abnormalities are less likely to be hidden by overlying breast tissue.
- Allow the use of a lower x-ray dose since a thinner amount of breast tissue is being imaged.
- Hold the breast still in order to minimize blurring of the image caused by motion.
- Reduce x-ray scatter to increase sharpness of picture.

## Lesson 2: Ultrasound scan

### a) Introduction

Through guided discovery, learners should be able to explain the basic functioning principles of ultrasound scan and their benefits

You can make a brief introduction using unit 1 in senior six. You can ask them questions that are related to the sound and its application in medicine

## b) Teaching resources

Textbooks, Internet.

## c) Learning Activities

The activities are focused medical imaging used sound such as sonography and echography

### Activity 11.3

This activity aims at capturing students' attention and minds towards the concept of echography

Divide your students into groups and tell them to open on the activity 12.3 in the learner's book.

Instruct them to re-write questions to their notebooks.

While students are doing this activity, you move around and mark their work.

When every group is done, invite some member(s) or group(s) to discuss their findings to the whole class.

Inquire from other groups' members whether their answers correspond to the ones discussed from presenting groups.

Together with students harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks.

Linking to the summary and what have been discussed in class, take a step and explain reasons for scanning.

Link this lesson to real life

**Note:** Note: There are more 3 activities under this part. (They are 12.3, 12.4,12.5). Tell them to work out these activities in their time. You can also tell students to do some of these activities during their class time

## Suggested answer for all Activities

### Activity 11.3

- a. yes
- b. It is recommended for the diagnostic treated by a doctor
- c. Yes, as far is known. It should be used only when there is a good clinical reason and applicable for a normal pregnancy means that when this period provide the information.

d. a normal pregnancy means that when this period provide the information, the patient should have careful clinical examination either positive pregnancy test and moral pregnancy I a period where a patient know that is getting pregnancy in mindset and grows as normal but the patient did not getting any positive pregnancy test.

e. Reasons for scanning during a normal pregnancy are:

To see age of foetus, position of foetus, development of foetus etc

#### **Answer for activity 11.4**

- a. Radionuclide refers to a way of imaging bones, organs and other parts of the body by using a small dose of a radioactive chemical
- b. A radionuclide is used which collects in areas where there is a lot of bone activity (where bone cells are breaking down or repairing parts of the bone). So a bone scan is used to detect areas of bone where there is cancer, infection, or damage
- c. Comparison of accuracy of scintimammography and x-ray mammography in the diagnosis of primary breast cancer in patients selected for surgical biopsy means that The scintimammography may have a role in the diagnosis of primary breast cancer when X-ray mammography is unhelpful

#### **Answer for activity 11.5**

- a. It varies (take some hour or minutes) depending on the part being scanned.
- b. It help physician to scan and obtain the image.
- c. The quantities to consume or not consume the chemical should be indicated by the doctor.
- d. As patient or as patient assistant, you should report immediately to the doctor.

#### **Suggested answers for checking my progress**

1. Ultrasound Ultrasounds are high-frequency sound waves above the human ear's audible range: that is with frequency sound waves greater than 20 KHz. They can be used to scan for birth defects in unborn babies and defects in manufactured equipment, while infrasounds are low-frequency below normal hearing. Infrasound can be used to track animals and monitor seismic activity.
2. The combination of conventional two-dimensional US imaging with Doppler US is known as Duplex US.
3. Ultrasound should be used in a prudent manner, only to provide medical benefit to the patient. The use of ultrasound to only view the fetus, obtain a picture of the fetus, or determine the fetal gender without a medical indication is inappropriate and contrary to responsible medical practice

4. Many physicians believe that the possible risks and cost of scanning every clinically normal pregnancy are not justified by the benefits for patient. This decision to scan or not to scan a normal pregnancy must be made by the physician and each patient. There are no universally accepted guidelines at present
5. The ultrasound is a non invasive procedure that, when used properly, has not demonstrate fatal harm. The long term effects of repeated ultrasound exposures on the fetus are not fully known. It is recommended that ultrasound only be used if medically indicated.
6. No it does not mean there is a problem. The heartbeat may not be detected for reasons that include: tipped uterus, larger abdomen, or inaccurate dating with last menstrual period. Heartbeats are best detected with transvaginal ultrasounds early in pregnancy. Concern typically develops if there is no fetal heart activity in an embryo with a crown-rump length greater than 5mm. If you receive an ultrasound exam after week 6, your healthcare provider will begin to be concerned if there is no gestational sac.

## **Lesson 3: Endoscopy**

### **a. Introduction**

Through guided discovery, learners should be able to explain the basic functioning principles of endoscopy and their benefits

### **b. Teaching resources**

Textbooks, Internet.

### **c. Learning Activities**

The activities are focused medical imaging called endoscopy

#### **Activity 11.6**

This activity aims at capturing students' attention and minds towards the concept of endoscopy

Divide your students into groups and tell them to open on the activity 12.6 in the learner's book.

Instruct them to re-write questions to their notebooks.

While students are doing this activity, you move around and mark their work.

When every group is done, invite some member(s) or group(s) to discuss their findings to the whole class.

Inquire from other groups' members whether their answers correspond to the ones discussed from presenting groups.

Together with students harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks.

Linking to the summary and what have been discussed in class, take a step and explain reasons why using endoscopy.

Link this lesson to real life

**Note:** Tell them to work out this activity in their time. You can also tell students to do it during their class time

### **Suggested answer activity**

- a. Overall, endoscopy is very safe.
- b. Few potential complications, which may include:
  - Perforation (tear in the gut wall)
  - Reaction to sedation.
  - Infection
  - Bleeding, etc
- c. Your internist or family doctor may perform sigmoidoscopy in their office. However, all of the other endoscopy procedures are usually performed by gastroenterology specialists (gastroenterologists). Other specialists such as gastrointestinal surgeons also can perform many of these procedures.
- d. Gut Preparation. Examining the upper digestive tract (upper endoscopy or ERCP) requires nothing more than fasting for 6-8 hours prior to the procedure. To examine the colon, it must be cleared of stool. Therefore, a laxative or group of laxatives is given on the day before the procedure.

Sedation. For most examinations with an endoscope, a sedative is provided. This increases the comfort of the individual undergoing the examination. The sedative, which is administered via an injection into the vein, produces relaxation and light sleep. There are usually few if any recollections of the procedure. Patients wake up within an hour, but the effects of the medicines are more prolonged, so it is not safe to drive until the next day.

- The stomach should be completely empty. You should have nothing to eat or drink for approximately 8 hours before the examination.
- It is best to inform your surgeon of ALL your current medications as well as allergies to medications a few days prior to the examination.
- if you have any major diseases, such as heart or lung disease that may require special attention during the procedure, discuss this with your surgeon.

## Lesson 4: MRI

### a) Introduction

Through guided discovery, learners should be able to explain the basic functioning principles of MRI and their benefits

### b) Teaching resources

Textbooks, Internet.

### c) Learning Activities

The activities are focused principle of MRI.

### Activity 11.7

This activity aims at capturing students' attention and minds towards the concept of MRI

Divide your students into groups and tell them to open on the activity 12.7 in the learner's book.

Instruct them to re-write questions to their notebooks.

While students are doing this activity, you move around and mark their work.

When every group is done, invite some member(s) or group(s) to discuss their findings to the whole class.

Inquire from other groups' members whether their answers correspond to the ones discussed from presenting groups.

Together with students harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks.

Linking to the summary and what have been discussed in class, take a step and explain the principle of MRI.

Link this lesson to real life

**Note:** Tell them to work out this activity in their time. You can also tell students to do it during their class time

## Suggested answer activity

- iv. MRI is a medical imaging technique uses magnetic properties.
- v. It is used to help diagnose or monitor treatment for a variety of conditions within the chest, abdomen and pelvis, brain and spinal cord, bones and joints ,breasts ,heart and blood vessels , internal organs, such as the liver, womb or prostate gland, etc.
- vi. MRI is so powerful, it is for any treatment as other used for and has the biggest benefit of MRI compared with other imaging techniques (such as CT scans) is, there's no risk of ionizing radiation.
- vii. Yes, because no risk that pregnancy woman can experienced due to the absence of ionization that MRI have

## Suggested answer for checking my progress.

1.What is mean by relaxation in the context of MRI?

Answer: Interactions happening at near-collisions between nuclei give rise to the magnetization constantly approaching the equilibrium size.

2.Name two reasons why the hydrogen nucleus is the most popular one imaged in MRI

Answer: Two reasons that the hydrogen nucleus is the most popular one imaged in MRI are:

- Hydrogen is abundance in the body.
- It gives the strongest MRI signals.

3.What does NMR stand for? Explain carefully the role of the three terms involved

### ANSWERS:

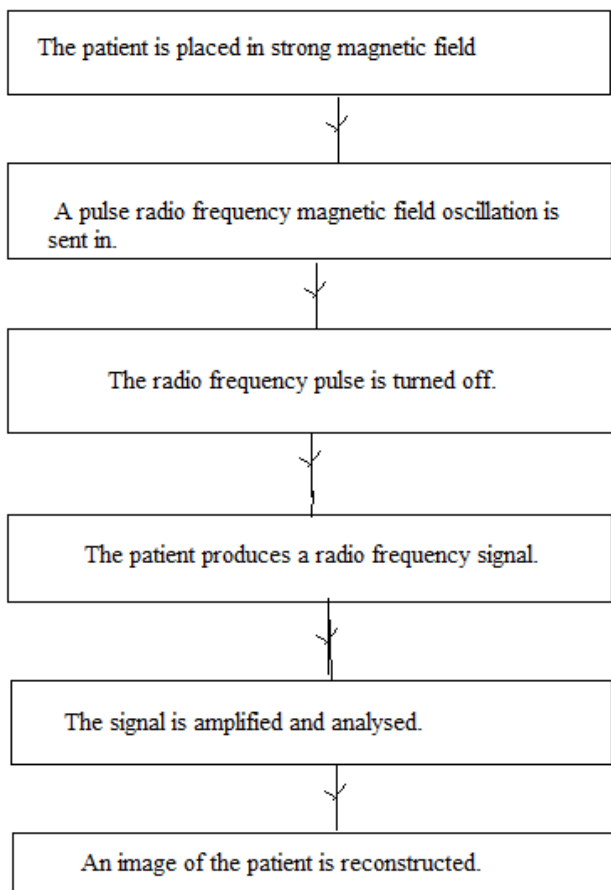
NMR stand for “Nuclear Magnetic Resonance”.

**Nuclear:** The nuclei of many body atoms behave like tiny bars magnets.

**Magnetic:** when in a strong magnetic field, these tiny bars magnets align with the field, although not perfectly. They rotate or process around the field direction with a particular frequency that falls in the radio frequency range.

**Resonance:** if the body receives a short pulse of radio frequency magnetic field oscillations, those nuclei with a frequency exactly matching the incoming frequency resonate and absorb energy. When the pulse ends, the body nuclei re-emit this energy, inducing a radio frequency signal in receiver coils outside the body.

4. Basic steps in the formation of MRI image are:



### 11.6 SUMMARY

Radiology is defined as the branch of medicine that uses radioactive compounds and electromagnetic radiation or sound waves in the diagnosis and treatment of diseases.

The technicians or technologists who operate the equipment are called radiographers

Mammography is specialized medical imaging that uses low-dose x-rays to see inside the breasts.

A mammogram is an exam of mammography.

Computer Tomography is an imaging technique whereby cross-sectional images are obtained with the use of X-rays.

Duplex ultrasound is a combination of conventional two-dimensional US imaging with Doppler US.

The term computed tomography is often used to refer to X-ray CT.

Gastroscopy is a procedure that enables your surgeon to examine the lining of the esophagus.

The most sensitive imaging test available for the diagnosis of acute cerebral infarction is Diffusion-weighted imaging.

Endoscopy using light

MRI used magnetic properties, in MRI they use Nuclear, Magnetic and Resonance

Nuclear: The nuclei of many body atoms behave like tiny bars magnets.

Magnetic: when in a strong magnetic field, these tiny bars magnets align with the field, although not perfectly. They rotate or precess around the field direction with a particular frequency that falls in the radio frequency range.

Resonance: if the body receives a short pulse of radio frequency magnetic field oscillations, those nuclei with a frequency exactly matching the incoming frequency resonate and absorb energy. When the pulse ends, the body nuclei re-emit this energy, inducing a radio frequency signal in receiver coils outside the body.

Scintigraphy refers to the use of gamma radiation to form images following the injection of various radiopharmaceuticals.

## 11.7 Additional information

### Observed sound intensity and ear response

#### Description of the ear

The human ear is a remarkably sensitive detector of sound. Mechanical detectors of sound can barely match the ear in detecting low intensity sounds. The ear has a function of transforming the vibrational energy of waves into electrical signals that are carried to the brain by ways of nerves as does a microphone.

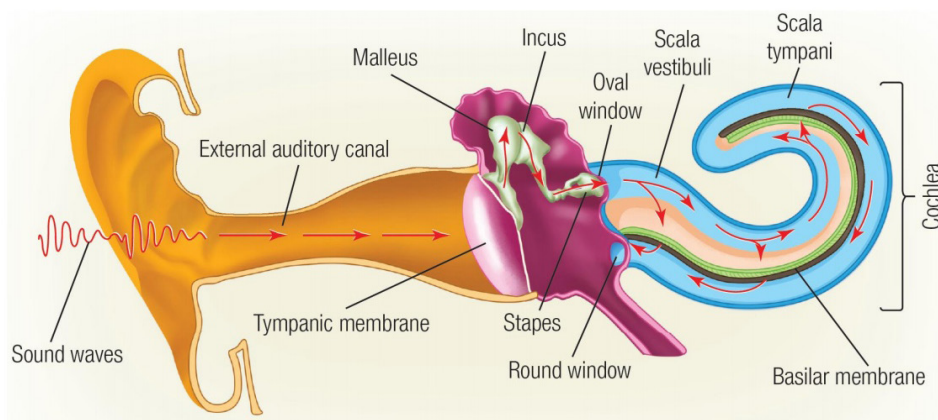


Fig.11. 1 Flow of acoustic energy: Outer ear, Middle ear, Inner ear

The ear consists of three main parts: the outer ear, the middle ear and the inner ear.

In the outer ear, sound waves from the outside travel down the ear canal to the eardrum which vibrates in response to the colliding waves.

The inner ear consists of three small bones known as the hammer, anvil and stirrup which transfer the vibrations of the eardrum to the inner ear at the oval window.

The function of the inner ear is to transduce vibration into nervous impulses. While doing so, it also produces a frequency (or pitch) and intensity (or loudness) analysis of the sound. Nerve fibres can fire at a rate of just under 200 times per second. Sound level information is conveyed to the brain by the rate of nerve firing, for example, by a group of nerves each firing at a rate at less than 200 pulses per second. They can also fire in locked phase with acoustic signals up to about 5 kHz. At frequencies below 5 kHz, groups of nerve fibres firing in lock phase with an acoustic signal convey information about frequency to the brain. Above about 5 kHz frequency information conveyed to the brain is based upon the place of stimulation on the basilar membrane. As an aside, music translated up into the frequency range above 5 kHz does not sound musical. (Hallowell, Davis; Richard, S., 1970)

This delicate system of levers, coupled with the relatively large area of the eardrum compared to the area of the oval window, results in pressure being amplified by a factor of about 40. The inner ear consists of the semicircular canals, which are important for controlling balance, and the liquid filled cochlea where the vibrational energy of sound waves is transformed into electrical energy and sent to the brain.

### **Logarithmic response of the ear versus intensity**

The ear is not equally sensitive to all frequencies. To hear the same loudness for sounds of different frequencies requires different intensities. Studies done over large numbers of people have produced the curves shown on Fig.12.3.

On this graph, each curve represents sounds that seemed to be equally loud. The number labelling each curve represents the loudness level which is numerically equal to the sound level in dB at 1000 Hz. The units are called phons.

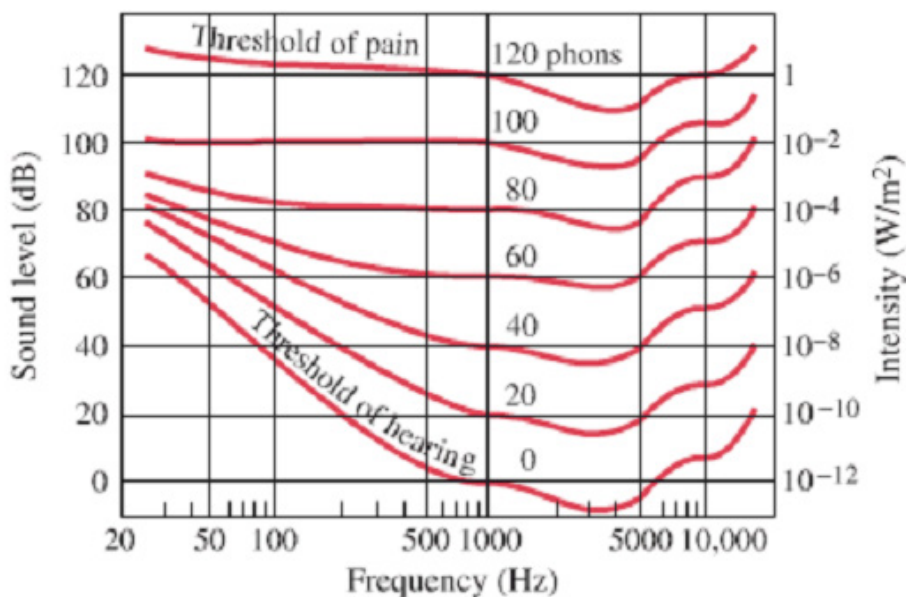


Fig.11. 2 Loudness in phons

Example: The curve labelled 40 represents sounds that are heard by an average person to have the same loudness as 1000 Hz sound with a sound level of 40 dB. From this 40 phon curve, we see that a 100 Hz tone must be at a level of about 62 dB to be perceived as loud as a 1000 Hz tone of only 40 dB.

Two aspects of any sound are immediately evident to human listener: loudness and the pitch. Each refers to a sensation in the consciousness of the listener. But to each of these subjective sensations there corresponds a physically measurable quantity.

Loudness refers to the intensity in the sound wave. Intensity is related to the energy transported by a wave per unit time across a unit area perpendicular to the energy flow. Intensity is proportional to the square of the wave amplitude.

### Sound Intensity Level

The human ear responds logarithmically to sound intensity: Loudness = Sound Intensity Level,

$$L = \beta = 10 \log \frac{I}{I_0} \quad (12.01)$$

Because of this relationship between the subjective sensation of loudness and the physically measurable quantity intensity, sound intensity levels are usually specified on a logarithmic scale. The unit of this scale is a bel, after the inventor Alexander Graham Bell.

Where

- $I_0 = 1.0 \times 10^{-12} \text{ W / m}^2$  is the intensity of a chosen reference level (minimum intensity audible to a good ear which is threshold of hearing)
- the logarithm is to the base 10.

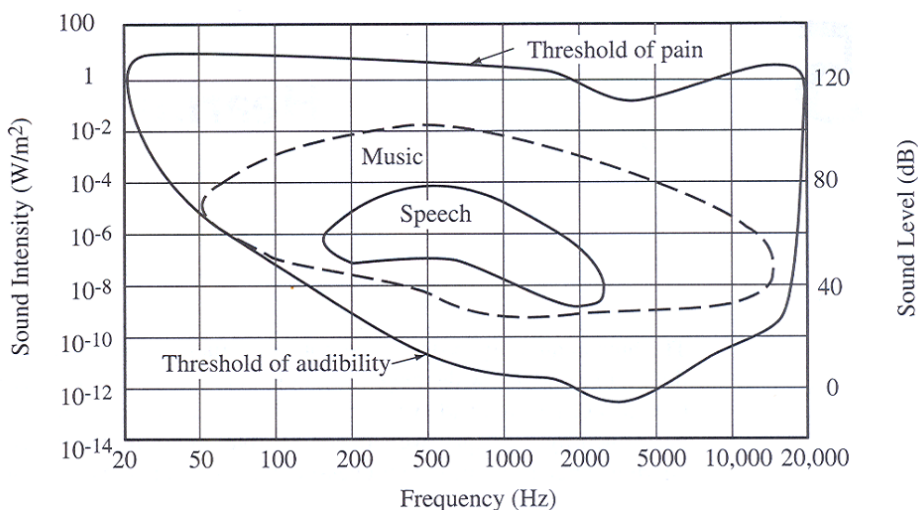


Fig.11. 3 The range of human hearing: Sound Intensity, Sound Level versus Frequency

### Example 12.1

1. The sound level of sound whose intensity is  $I = 1.0 \times 10^{-10} \text{ W / m}^2$  what will be the sound level?

Answer

$$L = \beta = 10 \log \frac{I}{I_0} = \frac{1.0 \times 10^{-10}}{1.0 \times 10^{-12}} = 10 \log 100 = 20 \text{ dB}$$

Notes – The sound level at the threshold of hearing is 0 dB.

An increase in intensity by a factor of 10 corresponds to a sound level of increase of 10 dB; an increase in intensity by a factor of 100 corresponds to a sound level of 20 dB.

**Specific acoustic impedance:** A medium tends to oppose the passage of sound waves through it, rather like an electrical circuit resists to flow of current through it. Just as the term electrical impedance is used to describe the opposition of a medium to the flow of sound waves. It is a measure of the way the molecules of the medium move in response to acoustic pressure.

The specific acoustic impedance  $Z$  of a medium is given by

$$Z = \rho v$$

Where  $\rho$  the density of the medium and  $v$  is the velocity of sound in medium

Substances	$\rho$ ( $kg / m^3$ )	$v$ ( $m / s$ )	$Z$ ( $kg / m^2 \cdot s$ )
<b>Air</b>	1.29	$3.31 \times 10^2$	430
<b>Water</b>	$1.00 \times 10^3$	$14.8 \times 10^2$	$1.48 \times 10^6$
<b>Fat</b>	$0.92 \times 10^3$	$14.5 \times 10^2$	$1.33 \times 10^6$
<b>Muscle</b>	$1.04 \times 10^3$	$15.8 \times 10^2$	$1.64 \times 10^6$

Table 12. 1 Values  $\rho, v$  and  $Z$  for Various Substances

The intensity of sound is correlated to energy  $E$  (J) per time and area [ $m^2$ ]

$$I = \frac{E}{t \times A} \quad (12.01)$$

The mechanical energy of a sound wave with frequency and speed necessary to move from single molecule by maximum distance  $A_0$  is:

$$: \frac{1}{2} m v^2 \text{ and } E = 2\pi^2 m A_0^2 f^2$$

As the speed  $v^2 = (2\pi f)^2 A_0^2$  and  $m = \rho \times v$

The total intensity of sound can be expressed in terms of density  $\rho$

$$I = \frac{1}{2} \rho v A^2 (2\pi f)^2 \quad (12.03)$$

The product of density and speed of sound is a material constant and is called the acoustic impedance  $Z$ .

$$I = \frac{1}{2} \frac{P^2}{Z} \quad (12.04)$$

Audible sound intensities at  $\approx 1000\text{Hz}$  range from  $10^{-12} \text{ w} / \text{m}^2$  (quiet) to  $1 \text{ w} / \text{m}^2$  (loud)

### Example 11.2

1. What is the displacement range for air molecules correspond to the audible intensity range at an average frequency

Answer:

$$A_{\text{Loud}} = \frac{1}{2\pi f} \left( \frac{2 \times I}{Z} \right)^{\frac{1}{2}} = \frac{1}{6280} \sqrt{\frac{2 \times 1}{430}} = 1.1 \times 10^{-5} \text{ m} = 10 \mu\text{m}$$

This displacement corresponds to size of a cell.

$$A_{\text{quiet}} = \frac{1}{2\pi f} \left( \frac{2 \times I}{Z} \right)^{\frac{1}{2}} = \frac{1}{6280} \sqrt{\frac{2 \times 10^{-12}}{430}} = 1.1 \times 10^{-11} \text{ m} = 10 \text{ pm}$$

This displacement corresponds to size of an atom.

The intensity of sound is directly related to the pressure change:  $I \propto P^2$

$$\alpha = 10 \log \left( \frac{I}{I_0} \right) = 10 \log \left( \frac{P}{P_0} \right)^2 = 20 \log \left( \frac{P}{P_0} \right)$$

Audible intensities are referenced to lowest audible intensity  $I_0 = 10^{-12} \text{ W / m}^2$

$$P_0 = \sqrt{I_0 \cdot 2 \cdot Z} = 3 \cdot 10^{-5} \text{ Pa}$$

The most intense sound which can be heard without inflicting pain or damage is  $I = 1 \text{ W / m}^2$  this corresponds to intensity in decibels:

$$10 \log \frac{10^{12}}{1} = 120 \text{ dB}$$

$$120 \text{ dB} = 20 \log \frac{P}{P_0} \Leftrightarrow \frac{P}{P_0} = 10^6 \text{ Pa} \Leftrightarrow P = 30 \text{ Pa}$$

### Example 12.3

1. Intensity levels of can cause damage of the ear drum diaphragm. What is the displacement and pressure of the diaphragm at such an intensity adopting an average frequency of FF? With

Answer

$$10 \log \frac{I}{I_0} = 160 \text{ dB}$$

$$\log \frac{I}{I_0} = 16 \Leftrightarrow I = 10^{-12} \times 10^{16} = 10^4 \text{ W / m}^2$$

$$A = \frac{1}{2\pi f} \sqrt{\frac{2 \times I}{Z}} = \frac{1}{2\pi \times 1000} \sqrt{\frac{2 \times 10^4}{1.64 \times 10^6}} = 1.76 \times 10^{-5} \text{ m}$$

The pressure is

$$P = \sqrt{I \cdot 2 \cdot Z} = \sqrt{10^4 \times 2 \times 1.64 \times 10^6} = 1.8 \times 10^5 \text{ Pa}$$

### Thermography

Functional testing, able to detect physiological changes, cannot pinpoint the exact location of suspicious area. In thermography there are no radiation, non-invasive, no risk, can be used as often as necessary to observe the effectiveness of treatment over time. It uses infrared detectors to detect heat and increased vascularity that may be

related to angiogenesis. Thermography can detect physiological changes many years prior to any other method of screening, very sensitive to fast growing aggressive tumors, hormonal activity in the breast will affect thermographic imaging but not to the point of abnormality.

## **Types of Brain Imaging Techniques**

Brain imaging techniques allow doctors and researchers to view activity or problems within the human brain, without invasive neurosurgery. There are a number of accepted, safe imaging techniques in use today in research facilities and hospitals throughout the world.

### **1. FMRI**

Functional magnetic resonance imaging, or fMRI, is a technique for measuring brain activity. It works by detecting the changes in blood oxygenation and flow that occur in response to neural activity – when a brain area is more active it consumes more oxygen and to meet this increased demand blood flow increases to the active area. fMRI can be used to produce activation maps showing which parts of the brain are involved in a particular mental process.

### **2. CT**

Computed tomography (CT) scanning builds up a picture of the brain based on the differential absorption of X-rays. During a CT scan the subject lies on a table that slides in and out of a hollow, cylindrical apparatus. An x-ray source rides on a ring around the inside of the tube, with its beam aimed at the subjects head. After passing through the head, the beam is sampled by one of the many detectors that line the machine's circumference. Images made using x-rays depend on the absorption of the beam by the tissue it passes through. Bone and hard tissue absorb x-rays well, air and water absorb very little and soft tissue is somewhere in between. Thus, CT scans reveal the gross features of the brain but do not resolve its structure well.

### **3. PET**

Positron Emission Tomography (PET) uses trace amounts of short-lived radioactive material to map functional processes in the brain. When the material undergoes radioactive decay a positron is emitted, which can be picked up by the detector. Areas of high radioactivity are associated with brain activity.

### **4. EEG**

Electroencephalography (EEG) is the measurement of the electrical activity of the brain by recording from electrodes placed on the scalp. The resulting traces are known as an electroencephalogram (EEG) and represent an electrical signal from a large number of neurons.

EEGs are frequently used in experimentation because the process is non-invasive to the research subject. The EEG is capable of detecting changes in electrical activity in the brain on a millisecond-level. It is one of the few techniques available that has such high temporal resolution.

## 5. MEG

Magnetoencephalography (MEG) is an imaging technique used to measure the magnetic fields produced by electrical activity in the brain via extremely sensitive devices known as SQUIDs. These measurements are commonly used in both research and clinical settings. There are many uses for the MEG, including assisting surgeons in localizing a pathology, assisting researchers in determining the function of various parts of the brain, neurofeedback, and others.

## 6. NIRS.

Near infrared spectroscopy is an optical technique for measuring blood oxygenation in the brain. It works by shining light in the near infrared part of the spectrum (700-900nm) through the skull and detecting how much the reemerging light is attenuated. How much the light is attenuated depends on blood oxygenation and thus NIRS can provide an indirect measure of brain activity.

## 11. 8 End unit assessment

### Part II:

1.a                      2. d                      3. C                      4. D                      5. b

6. Write the missing word or words on the space before each number.

- A. The term computed tomography is often used to refer to X-ray CT.
- B. Gastroscopy is a procedure that enables your surgeon to examine the lining of the esophagus.
- C. The most sensitive imaging test available for the diagnosis of acute cerebral infarction is Diffusion-weighted imaging.
- D. Array of photomultiplier tubes to transform the flashes into amplified electrical pulses inside the body.
- E. Transducers used are different depending on the age of a patient, one has 5 MHz and other 3.5 MHz.

- F. Hydrogen nuclei (also called protons) behave as small compass needles that align themselves parallel to the field.
- G. In nuclear magnetic resonance there are appearance three words: nuclear, magnetic and resonance.
- H.Examination can be claustrophobic, noisy and long is one of the disadvantages of MRI.

7. a. True      b. False      c. False      d. True      e. False

8. similarities: all are medical imaging uses to detect the diagnostic of a patient.

Endoscopy	Radionuclide
Use light	Use ultrasound
see in the stomach (lining of esophagus)	see inside the body

9. The advantages of MRI in clinical practice are:

- Excellent soft tissue contrast and characterization
- Lack of artefact from adjacent bones, e.g. pituitary fossa
- Multiplanar capabilities
- Lack of ionizing radiation

10. There are no known harmful effects associated with the diagnostic use of ultrasound. Widespread clinical use of diagnostic ultrasound for many years has not revealed any harmful effects. Although the possibility exists that such biological effects may be identified in the future, current data indicate that the benefits to patients of the prudent use of diagnostic ultrasound outweigh the risks if any, that may be present. However, a prudent and conservative approach is recommended in which diagnostic ultrasound is to be used only for medical benefit and with minimal exposure.

11. Ultrasound is a safe and non-invasive diagnostic tool that can be used to examine many parts of the body, most commonly soft tissue. It is used extensively in the female pelvis (both obstetrical and gynecological), the abdomen (kidneys, liver and gallbladder), and for cardiac diagnosis.

Another type of ultrasound, Doppler, is used in vascular diagnosis to assess blood flow. Other areas, such as the brain, eyes, thyroid, breast, prostate, and testicles, can be imaged by ultrasound as well. (It's also frequently used during your prenatal appointments to hear your baby's heartbeat.)

12. Ultrasound is widely known for its use in first-, second-, and third-trimester pregnancy. The most common reason for having an ultrasound examination during pregnancy is to help the doctor determine when your baby is due, or to make sure the baby is growing as it should. A doctor may also request an ultrasound examination to determine the baby's position, to see if you are carrying twins or triplets, or to detect a birth defect.

13. The major advantages of MDCT over conventional CT scanning are:

Increased speed of examination.

Rapid examination at optimal levels of intravenous contrast concentration

14. It is necessary to compress the breast in exam of mammography because the following reasons:

- visualize whether all of the tissue of the breast.
- Spread out the tissue so that small abnormalities are less likely to be hidden by overlying breast tissue.
- Allow the use of a lower x-ray dose since a thinner amount of breast tissue is being imaged.
- Hold the breast still in order to minimize blurring of the image caused by motion.

### **Essay question:**

The discussion will be focused on the following MRI applications:

- Abnormal body water presence (swelling, infection, bleeding, cysts).
- Head and spine (tumours, rupture discs.)
- Joints (ruptured tendons, worn cartilage).
- Abdomen (tumours and diseased tissue in the liver, pancreas, bladder and kidney).
- Fluid flow (Blocked blood vessels, heart studies).

## **11.9 Additional activities**

### 11.9.1 Remedial activities

Multiple choices: choose the correct answer.

1. One of the medical imaging using X-ray is:

- a. CT Scan
- b. endoscopy

c. thermography

d. both of them

2. Mammography is used to detect:

a. Brain diseases

b. Baby disease

c. Breast diseases

d. None of them

3. A radionuclide scan may be done for one reason:

a. A radionuclide is used to collect the areas where the infrared are synchronised.

b. A radionuclide is used to collect in areas where there is a lot of bone activity.

c. A radionuclide is used to collect the areas where gamma camera are produced image

d. A radionuclide is used to collect information from the exam of lining of esophagus.

4. The medical imaging techniques used sounds are:

a. Radionuclide

b. Radiography

c. Mammography

d. Endoscopy

5. Magnetic Resonance Imaging uses:

a. x-rays

b. Light

c. Magnetization

d. both of them

6. Describe tomography as medical imaging techniques.

### 11.9.2 Consolidation activities

1. Observe the figure below and answer the following questions:

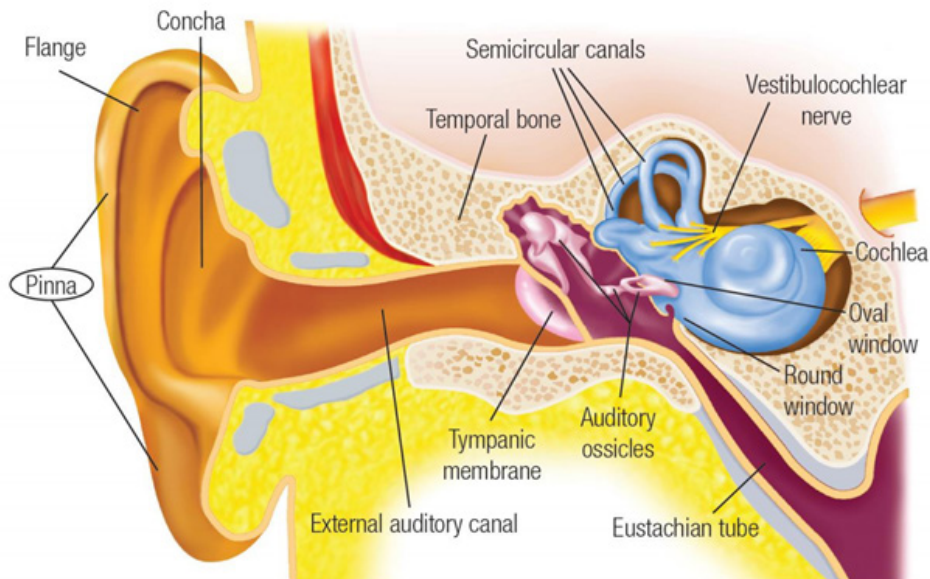


Fig.11. 4The anatomy of the ear

- The figure above is among the parts of human body. What is the name of it?
  - Divide that figure into three main parts and investigate the role of each part.
  - Explain the propagation of sound wave in these three parts.
  - Do you think that a normal person can hear sound waves of different frequencies? Justify your answer.
- Outline the application of ultrasound scan?
  - Why an ultrasound is performed?
  - How endoscopy is different from mammography?
  - If you are getting a mammogram for the first time, what are the specific questions you are expected to be asked by a doctor.
  - Is the mammography specific for women only? Explain.
  - What does a biopsy mean?
  - Explain reasons why people do not attend breast screening (screening mammography)

## Suggested answer for additional activities

Answer for Remedial activities:

1.a    2. c                    3. B                    4. A                    5. c

2. Thermography refers to functional testing, able to detect physiological changes, cannot pinpoint the exact location of suspicious area. In thermography there are no radiation, non-invasive, no risk, can be used as often as necessary to observe the effectiveness of treatment over time. It uses infrared detectors to detect heat and increased vascularity that may be related to angiogenesis while tomography

Suggested answer for consolidation activities.

1.a. Ear

b. Outer Ear, Middle Ear and Inner Ear.

- i. The outer ear transmits sound waves to the tympanic membrane via external auditory canal. The outer portion is lined with hairy skin containing sweat glands and oily sebaceous glands which together form ear wax.
- ii. The middle ear is an air filled space connected to the back of the nose by a long, thin tube called the Eustachian tube. The middle ear space houses three little bones, the hammer, anvil and stirrup (malleus, incus and stapes) which conduct sound from the tympanic membrane to the inner ear.
- iii. The inner ear consists of the cochlea which transduces vibration to a nervous impulse and the vestibular labyrinth which houses the organ of balance.

d. The outer and middle ears serve to amplify the sound signal on its passage from the exterior to the inner ear by about 30 dB. The function of the inner ear is to transduce vibration into nervous impulses. While doing so, it also produces a frequency (or pitch) and intensity (or loudness) analysis of the sound. Sound level information is conveyed to the brain by the rate of nerve firing, for example, by a group of nerves each firing at a rate at less than 200 pulses per second. They can also fire in locked phase with acoustic signals up to about 5 kHz.

e. No, all kinds of sounds can not be heard by a human being. The frequency range of human hearing is generally considered as 20 Hz to 20 000 Hz. The upper range varies greatly among individuals and decreases with age and noise exposure. The amplitude of our sensation ranges from the threshold of hearing (~0 dB) to thresholds of discomfort and pain (above 140 dB).

2. US scanning is applicable to:

- Solid organs including liver, kidneys, spleen and pancreas
- Urinary tract

- Obstetrics and gynaecology
- Small organs including thyroid and testes
- Breast
- Musculoskeletal system.

3. Most people associate ultrasound scans with pregnancy. These scans can provide an expectant mother with the first view of her unborn child. However, the test has many other uses.

Your doctor may order an ultrasound if you're having pain, swelling, or other symptoms that require an internal view of your organs. An ultrasound can provide a view of the: Bladder, brain (in infants), eyes, gallbladder, kidneys, liver, ovaries, pancreas, spleen, thyroid, testicles, uterus, Blood vessels, etc.

An ultrasound is also a helpful way to guide surgeons' movements during certain medical procedures, such as biopsies.

4. Endoscopy An ultrasound scan, sometimes called a sonogram, is a procedure that uses high-frequency sound waves to create an image of part of the inside of the body. It does not use X-rays. While mammography is used X-rays to create images of the breast. These images are called mammograms

5. If you are getting a mammogram for the first time, you are expected to be asked by a doctor some specific questions for example are: do you have breast implants? Are pregnant? Or breastfeeding? or have a physical disability?

6. No, the mammography is not specific for women only because the mammogram is an X-ray picture of the breast. Breast cancer or breasts that have signs or symptoms of disease for any person. Not only women even the men can have those signs or symptoms and be exposed in front of a mammogram.

7. A biopsy is the only test that can determine if a suspected tissue area is cancerous.

8. Reasons why people do not attend breast screening (screening mammography) are:

- They are too busy.
- They feel fit and healthy and do not think they are at risk of developing breast cancer.
- They are afraid of receiving a breast cancer diagnosis if they do opt for scanning.
- They are deterred because they have had a false positive result in the past.
- Prior experiences proved painful.
- They did not get a reminder.
- They believe mistakes can be made with the results

## 12.1 Key Unit Competence

Analyze the use of radiation in medicine.

## 12.2 Prerequisite knowledge and skills

The learner will use the knowledge acquired in unit five in senior six to interpret and analyze clearly concepts related to radiation in medicine.

NB: The unit must be carefully discussed with clear emphasis on the basics of radiation therapy for cancer treatment in medicine. Explain clearly all the concepts about radiation in medicine and its effects based on the learning objectives of the unit.

## 12.3 Cross-Cutting Issues to be addressed

- **Standardization culture:** Through health improvement by absorbing standard doses of radiation and using radiation dosimeter.
- **Environment and sustainability:** Discussing the need of sustainable future in Rwanda, ensuring that the interactivity of radiation and application of physics in medicine is clearly integrated in medical treatment.
- **Financial education:** Through taking dosage in the recommended time to avoid the risks of disease multiplying that would lead to spending more money in the treatment.
- **Peace and value:** Assigning work to groups to enhance co-operation and team working spirit among learners.
- **Inclusive education:** All activities given should be recognizing the capabilities of the learners.
- **Gender:** Recognize male and female in structuring activities and performing tasks.

## 12.4 List of lessons

S/No	Lesson Title	Learning Objectives(Adapted from syllabus)  By the end of the Lesson(s) Learners should be able to:	Suggested Number of Periods
1	Radiation dose	<ul style="list-style-type: none"> <li>• Explaining clearly the sources of radiation.</li> <li>• Classifying the types of radiation.</li> <li>• Explaining the effects of radiation exposure on human body and radiation dosage.</li> <li>• Solving problems involving measurement of ionizing radiation.</li> </ul>	5
2	Biological effect	<ul style="list-style-type: none"> <li>• Explain clearly concepts on deterministic effects and stochastic effects involved in radiation dosimetry.</li> </ul>	4
3	Concept of balanced risk.	<ul style="list-style-type: none"> <li>• Explain clearly and evaluate the balance risks of ionizing radiation in medical treatment.</li> </ul>	4
4	Physical half-life, biological half-life and effective half-life.	<ul style="list-style-type: none"> <li>• Explain clearly terms used in half-life and performing calculations related to half-lives.</li> </ul>	2
6	End unit assessment	<ul style="list-style-type: none"> <li>• Evaluate the concepts covered in the unit.</li> </ul>	2

## Structure of a lesson

### LESSON 12.1: Radiation in medicine

#### a) Prerequisites/Revision/Introduction:

Through guided discovery, assist learners to interpret and discuss discovered concepts about the sources of radiation and its application in medicine.

**b) Teaching resources:** Textbooks and internet.

#### c) Learning Activities:

This lesson focuses in making students understand the classification of radiation and select the kind of radiation mostly used in medical treatment.

#### Guidance in activity 12.1

- This activity introduces students to know the types of radiation and its application in medical treatment.
- Divide your class into groups, and let students interpret the activity to obtain the results.
- Let the learner(s) perform the activity using their prior knowledge about radiation and its application in medical treatment and write the ideas in the note book.
- Have sample group present the work to the class.
- Check students' responses to review the students' ideas to continue the discussion with a brief brainstorming of the concepts using student's work and textbook.
- Comment on students' responses written in their notebooks, and give the summary of expected feedback based on their findings.

#### Expected feedback

- f. Ionizing radiation-is one consisting of particles, X-rays or gamma rays with sufficient energy to cause ionization in the medium through with it passes. whereas non-ionizing radiation-refers to any type of electromagnetic radiation that does not carry enough energy to ionize atoms or molecules.
- g. The kind of radiation used in medical treatment is ionizing radiation. Because they have a high penetrating power.
- h. **It is ionizing radiation.** This is because the main source of exposure to ionizing radiation is the radiation used during medical exams such as X-ray or computed tomography scans. However, the amounts of radiation used are so small that the risk of any damaging effects is minimal.

Even when radiotherapy is used to treat cancer, the amount of ionizing radiation used is so carefully controlled that the risk of problems associated with exposure is tiny.

### Guidance in activity 12.2

- This activity support students to learn more types of ionizing radiation and select the one with high penetrating power based on the interpretation of the figure.
- Let the learners brainstorm about the questions in their respective groups and write the answers in their notebooks.
- Check students' ideas and summarize their thoughts in giving the feedback.

### Expected answers of activity 2.

- a. A-represent alpha, B-represent beta, C-represent gamma and x-rays.
- b. C is the one with high penetrating power because it goes through the hand and it is absorbed by concrete.
- c. Man-made forms of radiation are used in X-rays, cancer treatment, nuclear facilities and nuclear weapons.
- d. High doses of radiation therapy are used to destroy cancer cells. Side effects occur because radiation therapy can also damage healthy cells and tissues near the treatment area.

### Guidance in activity 12.3

- Introduce the activity and let the learner(s) perform the activity reviewing the concepts about radiation dosimetry and why it is very important to wear a dosimeter.
- Learners brainstorm on their results and write the work in their notebook.
- Check learners' responses and let one group present the work.
- Comment on learners' responses written in their notebooks and the presentation, and give them the expected feedback summarizing their work.

### Expected feedback:

- i. **Dosimeter** is a device that is used to measure exposures from x-ray, gamma ray and high energy beta particles.
- j. **Dosimeters** are issued by people following a review of badge application forms. The Radiation Safety Office will determine if badges are required following an assessment of the applicant's work scenario relative to radiation source use.

### Guidance in activity 12.4

- Introduce the activity and let the learner(s) perform the activity reviewing the concepts about symptoms of radiation exposure and its effects when exposed to the human body.
- Learners brainstorm and discuss on the steps taken to minimize the effects of radiation exposure.
- Comment on learners' responses written in their notebooks and the presentation, and give them the expected feedback summarizing their work.

#### **Expected feedback:**

- a. Nausea (feeling sick) and vomiting, Spontaneous bleeding, Bloody diarrhoea, Sloughing of skin, Hair loss, Severe fatigue, Mouth ulcers.
- b. In most cases, a large acute exposure to radiation causes both immediate (see radiation sickness) and delayed effects (cancer or death), can cause sickness or even death within hours or days. Such acute exposures are extremely rare.
- c. These are common side effects when a person undergoes radiation treatment for cancer: Hair loss, Stomach upset, nausea, vomiting, diarrhoea, Low white blood cells (leucopenia), Red and itchy skin at the site of the radiation, Sore mouth or mouth ulcers (oral mucositis)
- d. There is always a risk of damage to cells or tissue from being exposed to any amount of ionizing radiation. Over time, exposure to radiation may cause cancer and other health problems. But in most cases, the risk of getting cancer from being exposed to small amounts of radiation is small.
- e. The exposed individual is removed from the source of radiation. Antiemetic may be used to treat nausea and vomiting, Antibiotics may be administered to prevent secondary infections caused by immune system deficiency, In the event of damaged bone marrow tissue due to radiation exposure, blood transfusions and a bone marrow transplant may also be required, If only part of the body has been exposed to radiation rather than the whole body, treatment may be easier because humans can withstand radiation exposure in large amounts to non-vital body parts, Potassium iodide is administered to prevent thyroid cancer in cases of exposure to radioactive iodine, The bisphosphonates (used to treat osteoporosis) have also shown promise as treatments for reducing the harmful effects of radiation exposure.

### Guidance in activity 12.5

- Introduce the activity and let the learner(s) brainstorm and perform the activity reviewing the concepts about the safe level of radiation exposure and its annual limit.
- Comment on learners' responses written in their notebooks and the presentation, and give them the expected feedback summarizing their work.

### **Expected feedback:**

- The average exposure in the United States, from natural sources of radiation (mostly cosmic radiation and radon), is 300 millirems per year at sea level. Radiation exposure is slightly higher at higher elevations- thus the exposure in averages 400 millirems per year.
  - a) Persons under the age of 18 years are also limited to 0.5rem/year. The dose limit to non-radiation workers and members of the public are two percent of the annual occupational dose limit. Therefore, a non-radiation worker can receive a whole body dose of no more that 0.1 rem/year from industrial ionizing radiation.

### **Guidance in activity 12.6**

- Introduce the activity and let the learner(s) perform the activity reviewing the concepts about absorbed dose, measure of the risk of biological harm and how ionizing radiation is exposed to natural sources of radiation.
- Learners brainstorm and summarize their discussions in their notebooks.
- Comment on learners' responses written in their notebooks after the presentation of sample groups, and give the expected feedback summarizing their work.

### **Expected feedback:**

- a. Absorbed dose is a measure of the energy deposited in a medium by ionizing radiation. In the SI system of units, the unit of measure is joules per kilogram, and its special name is gray (Gy).
- b. A measure of the risk of biological harm is the dose of radiation received by tissue.
- c.
  - because the body can more easily repair damage from radiation that is spread over a large area than that which is concentrated in a small area.
  - We receive internal exposure from radioactive elements which we take into our bodies through food and water, and through the air we breathe. In addition, we have radioactive elements (Potassium 40, Carbon 14, Radium 226) in our blood or bones.
  - we are exposed to varying amounts of radiation from sources such as dental and other medical X-rays, industrial uses of nuclear techniques and other consumer products such as aluminized watches, ionization smoke detectors, etc.

## **Lesson 12.2: Problems involving radiation dosimetry.**

### **1 Prerequisites/Revision/Introduction:**

This lesson requires knowledge and skills obtained in unit thirteen in senior six.

Let the learners take a review by discussing concepts about the application of radiation to get more description about radiation dosimetry.

**2. Teaching resources:** Internet and textbooks.

**3. Learning Activities:**

### **Guidance in activity 12.7**

- The teacher introduce the activity and let the learner(s) perform the activity reviewing the concepts about risks involved in using ionizing radiation in medicine, nature of radiation induced biological effects and the classification of effects of radiation.
- Learners brainstorm and summarize their discussions about questions using textbook in their notebooks.
- Comment on learners' responses written in their notebooks after the presentation of sample groups, and give the expected feedback summarizing their work.

### **Expected feedback:**

1. Yes.

- Benefit to patients from medical uses of radiation has been established beyond doubt.
- Modern diagnostic radiology assures faster, more precise diagnosis and enables monitoring of a large proportion of diseases.
- It has been estimated that in about one half of cases, radiological procedures (plain film radiography, fluoroscopy, computed tomography) have a substantial impact on the speed of diagnosis.
- Nuclear medicine uses radioactive substances, called radiopharmaceuticals, in the diagnosis and treatment of a range of diseases.
- Radiation therapy uses ionizing radiation for treatment.
- The magnitude of risk from radiation is dose-related with higher amounts of radiation being associated with higher risks.
- The undisputed health benefits of diagnostic X-ray and nuclear medicine diagnostics may be accompanied by a generally small risk (probability) of deleterious effects.

- This fact has to be taken into account while using ionizing radiation sources in diagnosis.
- Large amounts of radiation are required in radiation therapy; the risk of radiation-related adverse effects is measurably higher.
- Too low an amount of radiation in diagnosis will result in either an image that does not have enough information to make a diagnosis and in radiation therapy, not delivering enough radiation will result in increased mortality because the cancer being treated will not be cured.
- The frequency or intensity of biological effects is dependent upon the total energy of radiation absorbed (in joules) per unit mass (in kg) of a sensitive tissues or organs. This quantity is called absorbed dose and is expressed in gray (Gy).

4.

- Cells can be killed by radiation during cellular division chromosomal aberrations due to radiation may result in loss of part of the chromosomal DNA which results in cell death.
- Surviving cells may carry changes in the DNA at a molecular level (mutations).
- DNA damage also can result from the direct interaction of ionizing particles with the DNA double helix (rarely).

5. There are two basic categories of the biological effects that may be observed in irradiated persons.

These are 1) due largely to cell killing (deterministic) and 2) mutations which may result in cancer and hereditary effects (stochastic or probabilistic).

Effects due to cell killing have a practical threshold dose below which the effect is not evident but in general when the effect is present its severity increases with the radiation dose.

The threshold doses is not an absolute number and vary somewhat by individual. Effects due to mutations (such as cancer) have a probability of occurrence that increases with dose, it is currently judged that there is not a threshold below which the effect will not occur and finally the severity of the effects is independent of the dose.

**Thus a cancer caused by a small amount of radiation can be just as malignant as one caused by a high dose.**

**Deterministic effects:** These effects are observed after large absorbed doses of radiation and are mainly a consequence of radiation induced cellular death. They occur only if a large proportion of cells in an irradiated tissue have been killed by radiation, and the loss cannot be compensated by increased cellular proliferation.

**Stochastic effects:** As mentioned above, irradiated and surviving cells may become modified by induced mutations (somatic, hereditary). These modifications may lead to two clinically significant effects: malignant neoplasms (cancer) and hereditary mutations.

### Guidance in activity 12.8

- The teacher introduce the activity and let the learner(s) perform the activity reviewing the concepts about magnitude of the risks for cancer ,hereditary effects, typical doses from medical diagnostic procedures and the situations when diagnostic radiological investigations to be avoided.
- Learners brainstorm the concepts stated above and summarize their discussions trying to answering the questions in their notebooks.
- Comment on learners' responses written in their notebooks after the presentation of sample groups, and give the expected feedback summarizing their work.

### Expected feedback:

1.The lifetime value for the average person is roughly a 5% increase in fatal cancer after a whole body dose of 1 Sv .

A statistically significant increase in cancer has not been detected in populations exposed to doses of less than 0.05 Sv.

Hereditary effects as a consequence of radiation exposure have not been observed in humans. No hereditary effects have been found in studies of the offspring and grandchildren of the atomic bomb survivors. However, as based on animal models and knowledge of human genetics, the risk of hereditary deleterious effects have been estimated to not be greater than 10% of the radiation induced carcinogenic risk.

2.No. All living organisms on this planet, including humans, are exposed to radiation from natural sources. An average yearly effective dose from this so-called natural background, amounts to about 2.5 mSv. This exposure varies substantially geographically (from 1.5 to several tens of mSv in limited geographical areas).

3.Various diagnostic radiology and nuclear medicine procedures cover a wide dose range based upon the procedure.

Doses can be expressed either as absorbed dose to a single tissue or as effective dose to the entire body which facilitates comparison of doses to other radiation sources. The doses are a function of a number of factors such as tissue composition, density and thickness of the body.

4.Yes.

- The quality assurance and quality control in diagnostic radiology and nuclear medicine play also a fundamental role in the provision of appropriate, sound radiological protection of the patient.

- There are several ways that will minimize the risk without sacrificing the valuable information that can be obtained for patients' benefit. Among the possible measures it is necessary to justify the examination before referring a patient to the radiologist or nuclear medicine physician.
- Repetition should be avoided of investigations made recently at another clinic or hospital.
- Failure to provide adequate clinical information at referral may result in a wrong procedure or technique being chosen by radiologist or nuclear medicine specialist.

5. Yes.

- There are well-established views -not always respected - which indicate that in some circumstances radiography or fluoroscopy does not contribute anything to patients' management. This applies to situations when a disease could not have progressed or resolved since the previous investigation, or the data obtained could not influence patients' treatment.
- Most common examples of unjustified examinations include: routine chest radiography at admission to a hospital or before surgery in absence of symptoms indicating cardiac or pulmonary involvement (or insufficiency).

### **Guidance in activity 12.9**

- This activity introduces students to know the special diagnostic procedures to be considered and ways of reducing radiation risks during performance of diagnostic procedure.
- Let the learner(s) brainstorm with their prior knowledge about the concepts stated above and try to answer questions in their note books.
- Have sample group present their work to the class.
- Check student's responses to review students' ideas to continue the discussion with a brief brainstorming of the concepts using student's work and book.
- Comment on students' responses written in their notebooks, and summarize their work in the expected feedback.

### **Expected feedback:**

1.

- While all medical uses of radiation should be justified, it stands to reason that the higher the dose and risk of a procedure, the more the medical practitioner should consider whether there is a greater benefit to be obtained. There are radiological procedures that deliver doses at the upper end of the scale.

2. Yes.

- Both the fetus and children are thought to be more radiosensitive than adults. Diagnostic radiology and diagnostic nuclear medicine procedures (even in combination) are extremely unlikely to result in doses that cause malformations or a decrease in intellectual function. The main issue following in-utero or childhood exposure at typical diagnostic levels (<50 mGy) is cancer induction.
- Before a diagnostic procedure is performed it should be determined whether a patient is, or may be, pregnant, whether the fetus is in the primary radiation area and whether the procedure is relatively high dose (e.g. barium enema or pelvic CT scan).
- For children, dose reduction is achieved by using technical factors specific for children and not using routine adult factors. In diagnostic radiology care should be taken to minimize the radiation beam to only the area of interest.
- Because children are small, in nuclear medicine the use of administered activity lower than that used for an adult will still result in acceptable images and reduced dose to the child.

3.

- The most powerful tool for minimizing the risk is appropriate performance of the test and optimization of radiological protection of the patient. These are the responsibility of the radiologist or nuclear medicine physician and medical physicist
- The basic principle of patients' protection in radiological X-ray investigations and nuclear medicine diagnostics is that necessary diagnostic information of clinically satisfactory quality should be obtained at the expense of a dose as low as reasonably achievable, taking into account social and financial factors.
- Among the procedures that should be avoided are: 1) fluoroscopy and photofluorography for screening for tuberculosis in children and adolescents (only normal radiographs should be made instead at this age). 2) Fluoroscopy without electronic image intensification.
- It should be emphasized, that radiological interventional procedures lead to higher doses to patients than normal diagnostic investigations.

### **Guidance in quick check1**

- Let the learner(s) brainstorm with their prior knowledge about radiation and try to respond by writing the answer in the notebook.
- Check students' answers and comment on students' responses written in the notebooks, and give them the expected feedback.

### **Expected feedback:**

Each one is a source of radiation to some degree.

## Expected feedback:

- a. A Doctor (radiation oncologist) is the one involved in my radiation treatment.
- b. Before you begin receiving radiation therapy, your radiation oncology team will carefully design your plan to make sure that you receive safe and accurate treatment.
  - Special computers are also used to monitor and double-check the treatment machines to make sure that the proper treatment is given.
  - The medical physicist will work with the team to develop an extensive safety and quality assurance plan to ensure that every patient receives the correct treatment in the safest possible way, each and every time.
- c. Treatment will be carefully planned to focus on the cancer while avoiding healthy organs in the area. Throughout your treatment, members of your team check and recheck your plan through repeat imaging and radiation patient chart review.
- d. The team will meet with you at least weekly to assess your progress and monitor any unexpected side effects that are occurring.
- e. Medical Error-These are mistakes done in the medical treatment whereas side effect- These are the negative consequence that occurs due to medical error and normal treatment.
- f. Shortening the time of exposure, increasing distance from a radiation source and shielding.

## Answer for 12.2.4 checking my progress

1.

- a. **Background radiation** refers to the ionizing radiation from high energy particles or rays that we are unavoidably exposed to in our daily lives, which gives each of us a small but continuous dose of ionizing radiation.
- b. Part of background radiation is due to the electromagnetic radiation spectrum, and this includes 'ionizing' components such as X-radiation (X-rays) and gamma rays, and 'non-ionizing' components such as visible light and radio waves.
- c. X-rays, gamma rays and some other high energy particles are called 'ionizing radiation' because they can deposit enough energy into a body tissue to change its molecules or proteins by ejecting an electron from an atom.

The sources of ionizing radiation in our environment are cosmic rays from the universe, naturally occurring radioactive substances in the food and water we eat and drink, the air we breathe, in the ground, in building materials, and so on.

We are all weakly radioactive due to the presence of radioactive elements in our bodies (such as potassium 40 and carbon 14), and this contributes to our background radiation exposure.

Background radiation is most commonly given in units of millisievert (mSv), which both measures and combines the radiation dose and the consequent risk delivered by an exposure.

The amount of background radiation varies widely in different parts of the world due to the radioactivity of the soil, latitude, height above sea level and lifestyle.

2. These risks are difficult to accurately measure, but it has been shown that the risk of developing cancer is slightly increased if you have been exposed to additional ionizing radiation above background levels.

The risks are not the same for all people; females are slightly more sensitive to the effects of ionizing radiation compared with males.

Children are also more sensitive, as the cells that make up their growing tissues and organs are dividing more rapidly. Children also live longer, so the effects of radiation have more time to become visible.

Some people have genetic differences that predispose them to the effects of ionizing radiation. There are other risks from high exposures to ionizing radiation, but these are not expected at the dose levels used in diagnostic imaging.

3. Your decision should be made in close consultation with your referring doctor. Ask your doctor about the procedure and how it will help to provide information about your symptoms or the presence of disease or injury.

Ask your doctor about the risks of the procedure and what the risks would be of not having the procedure; that is, if your doctor needs the information in order to identify and plan the most appropriate treatment.

Although there is a small risk of harm from ionizing radiation, there could be a greater risk of not having the information.

It might also be as beneficial to you to confirm the absence of disease or injury as it is to confirm its presence.

4. X-rays, CT scans, nuclear medicine studies, MRI and ultrasound each have a greater or lesser ability to scan and provide an image of specific parts of the body and/or to identify the presence or absence of certain conditions or disease.

MRI and ultrasound studies are usually used in preference to other imaging tests when it is possible to do so. Your referring doctor will consider which imaging procedure is most appropriate depending on the type of information required and your medical history.

## **Lesson 12.3: Safety precautions in handling radiations**

### **3.1 Prerequisites/Revision/Introduction:**

The lesson uses the concepts in radioactivity radiations from unit 5 in senior six.

Building on the previous lesson, let the learners brainstorm on the safety precautions in handling radiations.

**3.2 Teaching resources:** Textbooks and Internet

**3.3 Learning Activities:**

#### **Guidance in activity 13.10**

- The activity introduces learners to know the procedures that must be in place for safe treatment.
- Let the learner(s) brainstorm with their prior knowledge about the safety procedures in handling radiations and try to answer questions in their note books.
- Have sample group present their work to the class.
- Check student's responses to review students' ideas to continue the discussion with a brief brainstorming of the concepts using student's work and book.
- Comment on students' responses written in their notebooks, and summarize their work in the expected feedback.

#### **Guidance in activity 12.11**

- Introduce the activity and let the learner(s) brainstorm with their prior knowledge about soil texture and write their ideas in the note book.
- Check student's responses to review the students' ideas and continue the discussion with a brief brainstorming of the concepts in student's work.
- Comment on students' responses written in their notebooks, and give them the expected feedback.

### **12.6 Unit Summary**

- Basic types of radiation are ionizing and non-ionizing radiations.
- Ionizing radiation: This is a radiation that carries enough energy to liberate electrons from atoms or molecules, thereby ionizing them.
- The main source of exposure to ionizing radiation is the radiation used during medical exams such as X-ray radiography or computed tomography scans. The amounts of radiation used are so small that the risk of any damaging effects is minimal.

- Radiotherapy is used to treat cancer, the amount of ionizing radiation used is so carefully controlled that the risk of problems associated with exposure is tiny. Natural sources of radiation include cosmic radiation, radon radiation in the body, solar radiation and external terrestrial radiation. Man-made forms of radiation are used in X-rays, cancer treatment, nuclear facilities and nuclear weapons.
- Non-ionizing radiation: It refers to any type of electromagnetic radiation that does not carry enough energy to ionize atoms or molecules. High levels of UV-radiation can cause sunburn and increase the risk of skin cancer developing.
- An important characteristic of the various ionizing radiations is how deeply they can penetrate the body tissues.
- Due to their charge and mass, alpha particles interact strongly with matter, and can only travel a few centimeters in air.
- Due to their smaller mass, they are able to travel further in air, up to a few meters, and can be stopped by a thick piece of plastic, or even a stack of paper.
- The depth to which beta particles can penetrate the body depends on the energy.
- When you take beta emitters into the body, they will irradiate internal tissues and then become a much more serious hazard.
- Having no mass or charge, gamma radiation can travel much farther through air than alpha or beta, losing (on average) half its energy.
- X-rays are similar to gamma radiation, with the primary difference being that they originate from the electron cloud.
- X-Rays are longer-wavelength and lower energy than gamma radiation.
- Neutron radiation occurs when neutrons are ejected from the nucleus by nuclear fission and other processes.
- The amounts of radiation received are referred to as doses, and the measurement of such doses is known as dosimetry.
- Dosimeters are used to monitor your occupational dose from radioactive material or radiation-producing equipments. Most individuals working with X-ray producing equipment in the hospital will be issued a dosimeter.
- Dosimeters are not suitable for measuring exposures to low energy beta particles or alpha particles.
- Long-term exposure to small amounts of radiation can lead to gene mutations and increase the risk of cancer, while exposure to a large amount over a brief period can lead to radiation sickness.
- Exposure is a measure of the ionization produced in air by x-rays or  $\gamma$  rays, and it is defined in the following manner.
- Exposure is defined the total charge per unit mass of air.
- The SI unit for exposure is coulomb per unit mass (C/kg).
- The unit of absorbed dose is specified in terms of the amount of energy deposited by radiation in 1 kg of material. This unit is the Gray, abbreviated Gy.

- An absorbed radiation dose of 1 Gray corresponds to the deposition of 1 joule of energy in 1 kg of material.
- More biological damage is caused for the same physical dose.
- Quality factors are used to compare the biological effects from different types of radiation. The quality is expressed in terms of the Quality Factor (Q).
- The quality factor of a radiation type : It is defined as the ratio of the biological damage produced by the absorption of 1 Gy of that radiation to the biological damage produced by 1 Gy of X or gamma radiation.
- The unit of Equivalent dose H is the sievert (Sv).
- An equivalent dose of one sievert represents that quantity of radiation dose that is equivalent, in terms of specified biological damage, to one gray of X or gamma rays.
- Most of the radiation instruments we use to measure doses or dose rates reads in mSv or  $\mu$ Sv.
- The effects of radiation at high doses and dose rates are reasonably well documented.
- A very large dose delivered to the whole body over a short time will result in the death of the exposed person within days.
- At lower doses and dose rates, there is a degree of recovery in cells and in tissues.
- The optimization of patients' protection is based on a principle that the dose to the irradiated target (tumor) must be as high as it is necessary for effective treatment while protecting the healthy tissues to the maximum extent possible.
- The threshold doses are not an absolute number and vary somewhat by individual.
- A cancer caused by a small amount of radiation can be just as malignant as one caused by a high dose.
- Large absorbed doses of radiation and are mainly a consequence of radiation induced cellular death.
- The frequency or intensity of biological effects is dependent upon the total energy of radiation absorbed (in joules) per unit mass (in kg) of a sensitive tissues or organs
- A cancer caused by a small amount of radiation can be just as malignant as one caused by a high dose.
- Animal models and knowledge of human genetics, the risk of hereditary deleterious effects have been estimated to not be greater than 10% of the radiation induced carcinogenic risk.
- Exposure to an amount of radiation all at once or from multiple exposures in a short period of time.

- In most cases, a large acute exposure to radiation causes both immediate (radiation sickness) and delayed effects (cancer or death), can cause sickness or even death within hours or days. Such acute exposures are extremely rare.
- Radiation risks refer to all excess cancers caused by radiation exposure (incidence risk) or only excess fatal cancers (mortality risk).
- Acute health effects occur when large parts of the body are exposed to a large amount of radiation.
- The large exposure can occur all at once or from multiple exposures in a short period of time.
- Shortening the time of exposure, increasing distance from a radiation source and shielding are the basic countermeasures (or protective measures) to reduce doses from external exposure.
- The less time that people are exposed to a radiation source, the less the absorbed dose  
Distance: The farther away that people are from a radiation source, the less the absorbed dose.
- Balancing risks are often summarized in the following :
- The demand for imaging, especially computed tomography, that has increased vastly over the past 20 years
- An estimated 30% of computed tomography tests that may be unnecessary
- Ionizing radiation that may be associated with cancer.
- The risks of radiation exposure that is often overlooked and patients are seldom made aware of these risks
- The requesting doctor who must balance the risks and benefits of any high radiation dose imaging test, adhering to guideline recommendations if possible
- Difficult cases that should be discussed with a radiologist, ideally at a clinic radiological or multidisciplinary team meeting.
- Physical half-life: It is the period of time required to reduce the radioactivity level of a source to exactly one half its original value due solely to radioactive decay.
- Biological Half-life: It is the period of time required to reduce the amount of a drug in an organ or the body to exactly one half its original value due solely to biological elimination.
- Effective half-life: It is the period of time required to reduce the radioactivity level of an internal organ or of the whole body to exactly one half its original value due to both elimination and decay.

## 12.7 Additional Information:

### 1. RADIATION DOSE

- i. **Absorbed dose- external radiation:** There are a number of different quantities that can be used to express the general concept of “dose”. The basic quantity is “absorbed dose” which is the energy deposited by ionising radiation in a medium per unit mass of the irradiated material. The SI unit for absorbed dose is the gray (Gy). The previous special unit was the rad (1 Gy = 100 rad).
- ii. **Dose equivalent:** To take account of the different biological effectiveness of different types of radiation, the quantity “dose equivalent” has been defined. This is obtained by multiplying the absorbed dose (Gy) by a quality factor (or relative biological effectiveness) for the type of radiation concerned.

It is unusual for the whole body to be uniformly irradiated so that the dose equivalent in all organs and tissues is the same. However, for most types of work it is adequate to make the simplifying assumption that a personal dosimeter worn on the trunk measures a representative “dose” for the whole body. This applies where an individual is only exposed to external radiation. It may also be necessary to wear extremity dosimeters.

- iii. **(iii) Committed dose - internal radiation:** If a radioactive substance is taken into the body (injection, inhalation, inoculation), it begins to irradiate the tissues around it until it has been eliminated by metabolism or radioactive decay. The “committed dose equivalent” from a single intake of a radioactive substance is the total dose equivalent that an organ or tissue is “committed” to receive in this way in the following 50 years. This takes into account the radiological half-life of the material and its biological properties.
- iv. **(iv) Annual limits on intake:** Annual limits on committed dose equivalent, or committed effective dose equivalent, are used to define limits on the amount of radioactive substance which may be taken in during the year - i.e. the quantity of an isotope which if taken into the body would result in an exposure equivalent to the dose limit.

### Relationship between activity and dose

Radiation dose is a measure energy transfer from the source to the target material. One gray is equivalent to 1 joule of radiation energy per kg of irradiated matter. Since, simplistically, a source emits radiation of certain energies in MeV (one MeV =  $1.6 \times 10^{-13}$  J), then if the activity of the source is known, the energy output can be calculated.

### 2. BIOLOGICAL EFFECTS OF RADIATION

When ionising radiation passes through **biological tissue**, most of the energy deposited (>99%) goes into the production of heat. The rise in temperature is very small, that is to say 5 Sv of radiation energy applied to soft tissue would raise the temperature.

Important effects arise from the remaining 1% of the energy, which causes ionization of the atoms in the tissue. This ionization causes chemical changes through the breakage of chemical bonds and these changes lead to a range of damaging effects. The following sections explain how different radiation doses effect cells and describe how this cellular damage manifests itself in injury to the body.

## Effects on Cells

Living systems are made up of cells. Cells can be thought of as “chemical factories” in which molecules carry out the tasks that keep cells working. These are vital to the continued working and replication of cells. Damage to these kinds of molecules can have serious consequences. Recovery may be possible by the manufacture of replacement molecules or the simple reversal of the damaging chemical changes by some biological repair system.

Pregnant women and children are especially sensitive to radiation exposure. The cells in children and fetuses divide rapidly, providing more opportunity for radiation to disrupt the process and cause cell damage

**Note:** There are basically three levels of damage that can occur to an individual cell described below:

**Massive damage:** The cell may be killed immediately, or at least be made incapable of carrying out its normal function.

### Intermediate damage:

The cell cannot divide, but is otherwise unaltered and can still perform all of its other functions. The kind of damage is very important in tissues with rapidly dividing stem cells, as these cells provide a supply of replacement cells for special purposes.

### Minor damage

The result of small to intermediate doses. There are no obvious visible short-term effects on tissues, although some damage can be seen in individual cells.

## 3. RADIATION INJURIES

The cellular damage described in the previously is manifested in a range of detrimental effects. These effects are conventionally divided into deterministic and stochastic effects.

### i. Deterministic effects

These are effects that are expected to occur above a certain threshold dose and are the result of extensive cell damage. Above this threshold, the severity of the effect is then directly dependent on the dose received by the part of the body exposed.

## ii. Stochastic effects

Stochastic effects are those effects where the probability of occurrence is proportional to the level of the **radiation dose** received. It is assumed that there is no threshold below which these effects cannot occur. An increase in dose will raise the probability that the effect will occur in the part of the body that has been irradiated.

### 4. RISKS DUE TO THE EXPOSURE OF RADIOACTIVE ELEMENT

The risk from exposure to a particular radioactive element depends on:

The energy of the radiation it emits.

Its activity (how often it emits radiation).

The rate at which the body metabolizes and eliminates the radionuclide following ingestion or inhalation. The risk that exposure to a radioactive element will cause a particular health effect also depends on whether exposure is internal or external.

Internal exposure is when radioactive material gets inside the body by eating, drinking, breathing or injection (from certain medical procedures). Alpha and beta particles pose a serious health threat if significant quantities are inhaled or ingested. Outside the body, alpha particles are too large to pass through the skin or a thin layer of clothes.

External exposure (also known as direct exposure) is when the radioactive source is outside of your body. X-rays and gamma rays can pass through your body, depositing energy as they go.

## Major sources of public exposure to natural radiation

The United Nations Scientific Committee on the Effects of Atomic Radiation identifies four major sources of public exposure to natural radiation: cosmic radiation, terrestrial radiation, inhalation and ingestion.

### a) Exposure from cosmic radiation

The earth's outer atmosphere is continually bombarded by cosmic radiation. Usually, cosmic radiation consists of fast moving particles that exist in space and originate from a variety of sources, including the sun and other celestial events in the universe.

Cosmic rays are mostly protons but can be other particles or wave energy. Some ionizing radiation will penetrate the earth's atmosphere and become absorbed by humans, which results in natural radiation exposure.

The doses due to natural sources of radiation vary depending on location and habits. Regions at higher altitudes receive more cosmic radiation. The following map shows how levels of cosmic radiation vary with elevations above sea level and longitude and latitude.

## b) Exposure from terrestrial radiation

The composition of the earth's crust is a major source of natural radiation. The main contributors are natural deposits of uranium, potassium and thorium which, in the process of natural decay, will release small amounts of ionizing radiation. Uranium and thorium are “ubiquitous”, meaning they are found essentially everywhere. Traces of these minerals are also found in building materials so exposure to natural radiation can occur from indoors as well as outdoors.

## c) Exposure through inhalation

Most of the variation in exposure to natural radiation results from inhalation of radioactive gases that are produced by radioactive minerals found in soil and bedrock. Radon is an odourless and colourless radioactive gas that is produced by the decay of uranium.

Once released into the air, these gases will normally dilute to harmless levels in the atmosphere but sometimes they become trapped and accumulate inside buildings and are inhaled by occupants. Radon gas poses a health risk not only to uranium miners, but also to homeowners if it is left to collect in the home. On average, it is the largest source of natural radiation exposure.

## Exposure through ingestion

Trace amounts of radioactive minerals are naturally found in the contents of food and drinking water. For instance, vegetables are typically cultivated in soil and ground water which contains radioactive minerals. Once ingested, these minerals result in internal exposure to natural radiation.

These radioactive and non-radioactive elements are used in building and maintaining our bodies. Natural radioisotopes continually expose us to radiation. The human body also contains several radioactive isotopes. The table below contains a list of some of the isotopes naturally found in the body.

## Artificial sources of radiation

- i. **Atmospheric testing:** The atmospheric testing of atomic weapons from the end of the Second World War until as late as 1980 released radioactive material, called fallout, into the air. As the fallout settled to the ground, it was incorporated into the environment. Much of the fallout had short half-lives and no longer exists, but some continues to decay to this day. People and the environment receive smaller and smaller doses from the fallout every year.
- ii. **Medical sources:** Radiation has many uses in medicine. The most well known use is X-ray machines, which use radiation to find broken bones and diagnose disease. X-ray machines are regulated by Health Canada and provincial authorities. Another

example is nuclear medicine, which uses radioactive isotopes to diagnose and treat diseases such as cancer.

**iii. Industrial sources:** Radiation has a variety of industrial uses that range from nuclear gauges used to build roads to density gauges that measure the flow of material through pipes in factories. It is also used for smoke detectors, some glow-in-the dark exit signs, and to estimate reserves in oil fields. Radiation is also used for sterilization which is done by using large, heavily shielded irradiators.

**iv. Nuclear Fuel Cycle:** Nuclear power plants use uranium to drive a chain reaction that produces steam, which in turn drives turbines to produce electricity. Similarly, uranium mines, fuel fabrication plants and radioactive waste facilities release some radioactivity that contributes to the dose of the public.

## Top of Form

### Radiation in Everyday Life

Radioactivity is a part of our earth - it has existed all along. Naturally occurring radioactive materials are present in its crust, the floors and walls of our homes, schools, or offices and in the food we eat and drink. There are radioactive gases in the air we breathe. Our own bodies - muscles, bones, and tissue - contain naturally occurring radioactive elements.

Man has always been exposed to natural radiation arising from the earth as well as from outside the earth. The radiation we receive from outer space is called cosmic **radiation** or **cosmic rays**.

We also receive exposure from man-made radiation, such as X-rays, radiation used to diagnose diseases and for cancer therapy. Fallout from nuclear explosives testing, and small quantities of radioactive materials released to the environment from coal and nuclear power plants, are also sources of radiation exposure to man.

## 12.8 End unit assessment answers

### 12.8.1 Multiple choice

1. Which of the following would reduce the cell damage due to radiation for a lab technician who works with radioactive isotopes in a hospital or lab?
  - a. Increase the worker's distance from the radiation source.
  - b. Decrease the time the worker is exposed to the radiation.
  - c. Use shielding to reduce the amount of radiation that strikes the worker.
  - d. Have the worker wear a radiation badge when working with the radioactive isotopes.



3. Will you take imaging scans regularly during my treatment to verify position of my treatment? Who reviews those scans?
4. People who work around metals that emit alpha particles are trained that there is little danger from proximity or touching the material, but they must take extreme precautions against ingesting it. Why? (Eating and drinking while working are forbidden.)
5. What is the difference between absorbed dose and effective dose? What are the SI units for each?
6. Radiation is sometimes used to sterilize medical supplies and even food. Explain how it works.
7. How might radioactive tracers be used to find a leak in a pipe?
8. Explain that there are situations in which we may or may not have control over our exposure to ionizing radiation.
  - a. When do we not have control over our exposure to radiation?
  - b. When do we have control over our exposure to radiation?
  - c. Why might we want to limit our exposure to radiation when possible?
9. Does exposure to heavy ions at the level that would occur during deep-space missions of long duration pose a risk to the integrity and function of the central nervous system?
10. Radiation protection of ionizing radiation from radiation sources is particularly difficult. Give a reason for this difficulty.

#### 16.5.3 Essay questions

1. I always lock my radioactive material-use rooms. However, renovators came in during the weekend, worked, and left the door open while they were on their lunch break. Am I responsible and how can I prevent this from happening? Debate on the situation above to support your answer.
2. How can I ensure that personnel who work in my lab, but do not use radioactive material, do not violate the security requirements? Debate to support your idea.
3. A Housekeeping staff member opens my radioactive material-use room after working hours and does not lock it when they leave. What should I do? Explain clearly to support your idea.
4. Make a research and predict what steps that can or might be taken to reduce the exposure to radiation (e.g., if living near a radioactive area like an abandoned uranium mine, if finding a radioactive source, or in the event of a nuclear explosion or accident).

## Part III: Essay Questions

23. The outcome depends on students' trial and research and the guidance of the respective teacher giving the students good approach of making and reporting scientific research.

12.8.7 Additional activities (Remedial activities, Consolidation activities, extended activities) and expected answer

### 1. What forms of radioactive material must be secured?

#### Solution:

The following radioactive material must be secured at all times. There are no exempt quantities:

- Stock vials and other containers of radioactive material
- Calibration sources in liquid scintillation vials
- Radioactive material contained in waste
- Sealed sources

### 2. If a room is posted "Caution Radioactive Material," do I have to lock the door even if there is no radioactive material is present in the room?

#### Solution:

A qualified No. However, during a past inspection, an inspector pointed out that this practice could complicate the lab security issue. If use of material is infrequent, and communications are poor, not all individuals working in the lab may be cognizant of all use by other lab members. It is always best to establish a habit of locking a room that is posted for radioactive material use.

### 3. Can an area be locked instead of individual rooms?

#### Solution:

A qualified Yes. If you have a small suite of rooms with limited access and you are able to secure areas such as hallways, suites, and building sections, the rooms within this area may be left unlocked or open. However, the entrances to the secured perimeter must be locked at all times.

### 4. Can a radioactive material workroom across the hall from where I am working be left open if I am moving back and forth between the rooms?

#### Solution:

No. Unless you can control and maintain constant surveillance over the lab that contains radioactive material, this is not permitted. The test is whether you can ensure that no unauthorized individual can enter and remove radioactive material without being challenged.

**5. If I am in an office or other room inside my lab, can I leave the main lab unlocked?**

**Solution:**

No. Unless you can control and maintain constant surveillance over the lab that contains radioactive material, this is not permitted. The test is whether you can ensure that no unauthorized individual can enter and remove radioactive material without being challenged.

**6. Can I leave the door to the lab unlocked or open if all radioactive material (including waste) is locked in a cabinet or refrigerator?**

Solution:Yes.

**7. May I leave the door to my lab open and not under my surveillance if I install an entry alarm system?**

**Solution:**Yes. This is permitted if you can hear the alarm when someone enters the room, and you respond to the alarm by investigating each entry.

**8.Does equipment that contains radioactive material (e.g. freezers and LSC) stored in hallways need to be locked?**

Solution:Yes.

**9. My radioactive material cold room cannot be locked. Can I leave radioactive material in this area unsecured?**

**Solution:**No. The acceptable alternatives are:

- Find a cold room that can be locked. Amend your authorization as required
- Place the radioactive material in a locked cabinet within the cold room
- Have a lock installed on the cold room door
- Prior to installing any lock on any door (cold room, lab door or hallway door) you must contact FP&C to ensure that the lock is an approved type and design. If you install a lock that has not been approved, you will bear the expense of replacing it with a proper type.

**10. All my radioactive material is secured properly and I have empty waste containers in the lab. Do I have to lock the room?**

**Solution:**No.

**11. I have a liquid scintillation counter that has a radioactive sealed source as an integral part of it. Do I have to secure it?**

**Solution:**No. However, the calibration vials and the sample vials must be secured. If you have samples in the LSC, you must either lock the room, lock the unit, or otherwise

maintain immediate control while the material is in the counter.

**12.Are there activity limits below which security rules do not apply?**

Solution:No.

**13.How can I make changes to my security plan?**

**Solution:**The Security Plan you have filed with EHS must be adhered to at all times. You must submit your change in writing, prior to proceeding with any changes to security practices in your areas.

**14.What should I do if I notice an unlocked, unoccupied radioactive room or area that is not under my control?**

Solution:Notify EHS. We also suggest that you immediately notify the responsible PI about the room that was found unsecured.

**15.How can I ensure that personnel who work in my lab, but do not use radioactive material, do not violate the security requirements?**

**Solution:** The security requirements apply to the material, not the people. Therefore, all personnel in your lab must be trained and cognizant of the security requirements for the material in the lab they are working in.

**16.How can I prevent people who do not work in my lab from violating the security rule?**

**Solution:**

- Although these individuals should have received some level of radiation safety training, you should remind them not to leave your room(s) unsecured.
- 
- Non-UVA personnel: These individuals most likely have not received training. You must supervise their activities while they are in your lab or instruct them on security requirements. You are responsible for the actions taken by non-UVA personnel while they are in your lab.

**17.A Housekeeping staff member opens my radioactive material-use room after working hours and does not lock it when they leave. What should I do?**

**Solution:**

- Contact EHS when this happens. All Environmental Services and Facilities Management housekeeping personnel should have received a short course in radiation safety. In addition, you should communicate with the housekeeping staff about safety in your labs.

**18.My lab was broken into during the night. What should I do?**

**Solution:** Immediately call both the UVA Police and EHS to report the break-in.

**19. I always lock my radioactive material-use rooms. However, renovators came in during the weekend, worked, and left the door open while they were on their lunch break. Am I responsible and how can I prevent this from happening?**

**Solution:**

- Supervision of UVA Facilities Management personnel and outside contractors is the responsibility of UVA Facilities Planning and Construction (FP&C). Their managers have received training regarding the requirements for calling the appropriate EHS group for assistance and approvals prior to working in radioactive material-use rooms. However, do not assume that EHS has been notified about work in your radioactive material-use rooms. If you have advance knowledge of renovations or maintenance work, please call EHS and give us the scheduled times and dates.

We will assist FP&C in developing a plan that includes security of your radioactive material-use rooms.

- If lab personnel will not be present during renovation work, instructions should be given to renovators or maintenance personnel to lock the door whenever workers leave the area.

In any case, if you discover that renovators or maintenance personnel have not followed instructions, call EHS so we can contact FP&C and take corrective action.

**20. What are the consequences if I fail to secure a radioactive material room, area or piece of equipment?**

**Solution:** This depends on the circumstances and the past security compliance history for the lab. A report must be filed with EHS and further actions will be determined by the Radiation Safety Committee. Willful violation of the UVA radioactive material security program may lead to suspension or revocation of the authorization to use radioactive material.

**21. Does receiving external-beam radiation make a person radioactive or able to expose others to radiation?**

**Solution:** External-beam therapy does not make a person radioactive in any way. The therapy only affects your cells for the very short time that you are receiving treatment. A person who has received external-beam radiation is unable to contaminate or transfer that radiation to any other person.

**22. How can I be sure that the external-beam radiation machine isn't damaging normal, healthy tissue in my body?**

**Solution:** We have carefully developed methods for calibrating radiation beams and ensuring that they reach the areas they are intended to target. Even when normal tissues near the area undergoing radiation receive small amounts of radiation, it is rare

for long-term damage to occur. Our doctors also know how much radiation healthy tissue can receive without causing irreversible damage. We often use special masks, molds, or casts of body parts to keep you absolutely still during treatment, so that we can aim the radiation beams precisely to the area we want to treat.

**23. Is there any risk that internal radiation implants (brachytherapy) will leak or break free from where they are placed and move around my body?**

**Solution:** With brachytherapy, we use a needle or a catheter to insert radioactive material contained within an impenetrable sealed source such as a seed, pellet, wire, or capsule. As the radioactive isotopes inside the implant decay naturally over time, they emit radiation and damage nearby cancer cells. This radioactivity travels only a certain distance beyond the implant, and eventually deteriorates to the point that the implant no longer gives off any radiation.

The implants are specially tested and sealed to ensure that radioactive material doesn't leak, and we place them in such a way that it's highly unlikely they will move. Also, in the case of brachytherapy for genitourinary cancers, while there is no risk that the implants will come out with semen, we do give patients a strainer to use for 24 to 48 hours after the procedure when urinating, in the rare case that a seed becomes dislodged.

**24. Should I limit contact with anyone while brachytherapy implants are inside my body?**

**Solution:** Most of our safety concerns are related to being in physical contact with children for extended periods of time, since their bodies are undergoing such rapid change and growth and are therefore more vulnerable to abnormal cell changes. Because we vary the radiation dose in each implant as well as the number of implants we insert based on your particular cancer, we provide you with specific advice about precautions to take when you're in close contact with children.

**25. Do prostate seed implants put my sexual partner or the person I sleep next to at risk in any way?**

**Solution:** Prostate seeds are sealed sources. You cannot contaminate another person by being in his or her physical vicinity, during sexual intercourse, or through any other form of intimate contact. Your doctor or a member of the radiation safety staff will discuss any special precautions you should take with sleep arrangements before you leave the hospital. For example, based on such factors as your age and the age of your partner, for a period of time we may ask that you avoid embracing your partner from the back in the "spooning" position through the night.

**26. Do I pose a danger to others after receiving radioactive iodine therapy for thyroid cancer?**

**Solution:** For several days following this therapy, radioactive substances can be emitted through body fluids such as saliva, urine, and sweat. We send patients home with detailed instructions on how to care for themselves for the first few days — from limiting contact with young children and pets to using separate utensils and towels.

**27. I am having an imaging test using radioactive materials. Will I be radioactive after the test?**

**Solution:**Radioactive material will stay in your body for several hours or days depending on the type used and the metabolism of the compound to which it was attached. Eventually, the material decays and your body naturally flushes it out through urine, sweat, and other forms of biological elimination. We make sure the specifics are clear to you before the test, and we may also issue an information card explaining your treatment in the event that you are questioned by someone in airport security, for example.

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