PHYSICS FOR TTC

TUTOR'S GUIDE

YEAR 3

OPTION: SME

FOREWORD

Dear tutor,

Rwanda Basic Education Board is honoured to present tutor's guide for Physics Year Three of TTC which serves as a guide to competence-based teaching and learning to ensure consistency and coherence in the learning of Physics subject. The Rwandan educational philosophy is to ensure that Student-teachers 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 tutor's pedagogical approaches, the assessment strategies and the instructional materials available. We paid special attention to the activities that facilitate the learning process in which Student-teachers can develop ideas and make new discoveries during concrete activities carried out individually or with peers. With the help of the tutor, Student-teachers 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 tutor. 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 Student-teacher where concepts are mainly introduced by an activity, situation or scenario that helps the Student-teacher to construct knowledge, develop skills and acquire positive attitudes and values.

In addition, such active learning engages student-teachers 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 and learning materials.
- Organize group discussions for student-teachers considering the importance of social constructivism suggesting that learning occurs

- more effectively when the student-teacher works collaboratively with more knowledgeable and experienced people.
- Engage Student-teachers through active learning methods such as inquiry methods, group discussions, research, investigative activities and group and individual work activities.
- Provide supervised opportunities for Student-teachers 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 Student-teachers' contributions in the class activities.
- Guide Student-teachers 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 tutor'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 tutor's guide 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 the teaching guidance for each concept given in the Student-Teacher's book.

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

I wish to sincerely appreciate all people who contributed towards the development of this tutor's guide, particularly REB staff who organized the whole process from its inception. Special gratitude goes to teachers, illustrators and designers who diligently worked to successful completion of this tutor's guide. Any comment or contribution would be welcome for the improvement of this tutor's guide for the next edition.

Dr. MBARUSHIMANA Nelson

Director General, REB

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I wish to express my appreciation to all the people who played a major role in development of this Physics Tutor's Guide for Year Three of TTC. It would not have been successful without active participation of different education stakeholders.

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Finally, my word of gratitude goes to the Rwanda Basic Education Board staff particularly those from the Curriculum, Teaching and Learning Resources Department who were involved in the whole process of in-house textbook writing.

Joan MURUNGI,

Head of Curriculum, Teaching and Learning Resources Department

Contents

PART I. GENERAL INTRODUCTION

1.0. About the tutor's guide

This book is a tutor's guide for Physics subject, Year Three in TTC. It is designed to accompany Student-teacher's book and intends to help tutors in the implementation of competence based curriculum specifically Physics syllabus.

As the name says, it is a guide that tutors can refer to when preparing their lessons. Tutors may prefer to adopt the guidance provided but they are also expected to be more creative and consider their specific classes' contexts and prepare accordingly.

1.1 The structure of the guide

This section presents the overall structure, the unit and sub-heading structure to help tutors 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 Student-teachers with special educational needs, active 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 tutor 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.

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/topics within a subject and interconnections between different subjects. The tutor 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; tutors 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 Student-teacher's book. This section of the tutor's guide provides guidance on how to conduct this activity and related answers. Note that Student-teachers may not be able to find the right solution but they are invited to predict possible solutions or answers. Solutions are provided by Student-teachers 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.

- **End of each unit**

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

- Summary of the unit which provides the key points of content developed in the Student-teacher's book.
- Additional information which provides additional content compared to the Student-teacher's book for the tutor to have a deeper understanding of the topic.
- End unit assessment which provides answers to questions of the end unit assessment in the Student-teacher's book 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 Student-teacher (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 tutor 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. Tutors are encouraged to replace the suggested teaching aids by the available ones in their respective schools and based on learning environment.

- **Learning activity**

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 Student-teacher's book.

- **Exercises/application activities**

This provides questions and answers for exercises/ application activities.

1.2 Methodological guidance

1.2.1 Developing competences

Since 2015 Rwanda shifted from a knowledge based to a competence based curriculum for pre-primary, primary and general secondary education. For TTCs, it is in 2019 that the competence based curriculum was embraced. This called for changing the way of learning by shifting from tutor centered to a Student-teacher centered approach. Tutors are not only responsible for knowledge transfer but also for fostering Student-teacher's learning achievement, and creating safe and supportive learning environment. It implies also that a Student-teacher has to demonstrate what he/she is able to do using the knowledge, skills, values and attitude acquired in a new or different or given situation.

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 Student-teacher can do rather than what Student-teachers know. Student-teachers 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 disseminated in Student-teacher-cantered rather than the traditional didactic approach. The Student-teachers are evaluated against set standards to achieve before moving on.

In addition to specific subject competences, Student-teachers also develop generic competences which are transferable throughout a range of learning areas and situations in life. Below are examples of how generic competences can be developed in Physics:

Generic competence	**Examples of activities that develop generic competences**
Critical thinking	- Describe the relationship and interdependence of sciences - Observe, record, interpret data recorded during experiments - Identify and use the applications of Physics concepts to solve problems of life and society
Research and Problem solving	- Research using internet or books from the library - Design a project for making bioplastics - Design a questionnaire for data collection during field visit
Innovation and creativity	- Create an experiment procedure to prove a point - Develop a graph to illustrate information - Design a data collection survey/ questionnaire - Conduct experiments with objectives, methodology, observations, results, conclusions - Identify local problems and ways to resolve them
Cooperation, Personal and Interpersonal management and life skills	- Work in Pairs - Small group work - Large group work

Communication	- Organise and present in writing and verbally a complete and clear report of an experiment - Observe, record, interpret the results of a measurement accurately. - Select and use appropriate formats and presentations, such as tables, graphs and diagrams.
Lifelong learning	Exploit all opportunities available to improve on knowledge and skills. Reading scientific journals to keep updated.

1.2.2. Addressing cross cutting issues

Among the changes in the competence based curriculum is the integration of cross cutting issues as an integral part of the teaching learning process as they relate to and must be considered within all subjects to be appropriately addressed. 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 cross cutting issues may seem specific to particular learning areas or subjects but the tutor needs to address all of them whenever an opportunity arises. In addition, Student-teacher 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 on how cross-cutting issues can be addressed in Physics:

Cross-cutting issues	Examples on how to integrate the cross-cutting issues
Inclusive education	Involve all Student-teachers in all activities without any bias. Eg: Allow a Student-teacher with physical disability (using wheelchair) to take notes or lead the team during an experiment.

Gender	Involve both girls and boys in all activities: No activity is reserved only to girls or boys. Tutor should ensure equal participation of both girls and boys during experiments as well as during cleaning and tidying up related activities after experiments.
Peace and Values Education	During group activities, debates and presentations, the tutor will encourage Student-teachers to help each other and to respect opinions of colleagues.
Standardization culture	- Some lessons involve carrying out experiments. Instruction should be clear for Student-teachers to always check if they are not using expired chemicals or defective apparatus. - In addition, when performing experiments Student-teachers have to record data accurately. - For tasks involving calculations, they have to always present accurate results.
Environment and sustainability	- In order to avoid the environment pollution, before, during or after experiments Student-teachers avoid throwing away chemicals anywhere; special places or appropriate containers should be used. - Student-teachers also have to be aware of the impacts of the use of hydrocarbons as fuels, halogenoalkanes, and plastics on the environment.
Financial Education	When performing experiments, Student-teachers are encouraged to avoid wasting chemicals by using the quantities that are just required. They are required to also avoid spoiling equipment and other materials…

1.2.3 Attention to special educational needs specific to each subject

In the classroom, Student-teachers learn in different way depending to their learning pace, needs or any other special problem they might have. However, the tutor has the responsibility to know how to adopt his/her methodologies and approaches in order to meet the learning need of each Student-teacher in

the classroom. Also tutor must understand that Student-teachers with special needs need to be taught differently or need some accommodations to enhance the learning environment. This will be done depending on the subject and the nature of the lesson.

In order to create a well-rounded learning atmosphere, tutor needs to:

- Remember that Student-teachers 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).
- Maintain an organized classroom and limits distraction. This will help Student-teachers with special needs to stay on track during lesson and follow instruction easily.
- Vary the pace of teaching to meet the needs of each Student-teacher. Some Student-teachers process information and learn more slowly than others.
- Break down instructions into smaller, manageable tasks. Student-teachers with special needs often have difficulty understanding long-winded or several instructions at once. It is better to use simple, concrete sentences in order to facilitate them understand what you are asking.
- Use clear consistent language to 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-teacher 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-teacher. Both Student-teachers will benefit from this strategy
- Use multi-sensory strategies. As all Student-teachers learn in different ways, it is important to make every lesson as multi-sensory as possible. Student-teachers with learning disabilities might have difficulty in one area, while they might excel in another. For example, use both visual and auditory cues.

Below are general 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-teacher is unique with different needs and that should be handled differently.

Strategy to help Student-teachers with developmental impairment:

- Use simple words and sentences when giving instructions.
- Use real objects that the Student-teacher can feel and handle, rather than just working abstractly with pen and paper.
- Break a task down into small steps or learning objectives. The Student-teacher should start with an activity that s/he can do already before moving on to something that is more difficult.
- Gradually give the Student-Teacher less help.
- Let the Student-teacher work in the same group with those without disability.

Strategy to help Student-teachers with visual impairment:

- Help Student-teachers 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-teachers has some sight, ask them what they can see. Get information from parents/caregivers on how the Student-teacher manages their remaining sight at home.
- Make sure the Student-teacher has a group of friends who are helpful and who allow the Student-teachers to be as independent as possible.
- Plan activities so that Student-teachers work in pairs or groups whenever possible.

Strategy to help Student-teachers with hearing impairment:

- Strategies to help Student-teachers with hearing disabilities or communication difficulties
- Always get the Student-teacher's attention before you begin to speak.
- Encourage the Student-teacher 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 Student-teachers to also use them.
- Keep background noise to a minimum.

Strategies to help children with physical disabilities or mobility difficulties:

- Adapt activities so that Student-teacher who use wheelchairs or other mobility aids, or other Student-teachers who have difficulty moving, can participate.
- Ask parents/caregivers to assist with adapting furniture e.g. The height of a table may need to be changed to make it easier for a Student-teacher to reach it or fit their legs or wheelchair under.
- Encourage peer support friends can help friends.
- Get advice from parents or a health professional about assistive devices.

1.2.4 Guidance on assessment

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

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 Student-teachers' learning and tutor'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 plays a big role in teaching and learning process. The tutor should encourage individual, peer and group evaluation of the work done in the classroom and uses appropriate competence-based assessment approaches and methods.

In Year Three textbook, formative assessment principle is applied through application activities that are planned in each lesson to ensure that lesson objectives are achieved before moving on. At the end of each unit, the end unit assessment is formative when it is done to give information on the progress of Student-Teachers and from there decide what adjustments need to be done. Assessment standards are taken into consideration when setting tasks.

Summative assessment

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

1.2.5. Student-teachers' 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 Student-teachers' needs, abilities and learning styles.

There are mainly four different learning styles as explained below:

a) Active and reflective Student-teachers

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

b) Sensing and intuitive Student-teachers

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

c) Visual and verbal Student-teachers

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

d) Sequential and global Student-teachers

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

1.2.6. Teaching methods and techniques that promote the active learning

The different Student-teacher learning styles mentioned above can be catered for, if the tutor uses active learning whereby Student-teachers are really engaged in the learning process.

What is Active learning?

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

The role of the tutor in active learning

- The tutor engages Student-teachers 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 Student-teachers to develop different competences by giving tasks which enhance critical thinking, problem solving, research, creativity and innovation, communication and cooperation.
- Tutor supports and facilitates the learning process by valuing Student-teachers' contributions in the class activities.

The role of Student-teachers in active learning

Student-teachers 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 Student-teacher engaged in active learning:

- Communicates and shares relevant information with other Student-teachers through presentations, discussions, group work and other Student-teacher-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:

A) Practical work/ experiments:

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

Practical work is vital in learning Physics; this method gives the Student-teacher 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 Student-teachers: observation, recording and report writing, manipulation, measuring, planning and designing.

A practical lesson/Experiment is done in three main stages:

- **Preparation of experiment:** Checking materials to ensure they are available and at good state; try the experiment before the lesson; think of safety rules and give instructions to lab technician if you have any.
- **Performance of experiment:** Sitting or standing arrangement of Student-teachers; 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.

In some cases, demonstration by the tutor is recommended when for example the experiment requires the use of sophisticated materials or very expensive materials or when safety is a major factor like dangerous experiments and it needs specific skills to be learnt first.

In case your school does not have enough laboratory materials and chemicals, experiments can be done in groups but make sure every Student-teacher participates. You can also make arrangements with the neighbouring science school and take your Student-teachers there for a number of experiments.

B) Research work

Each Student-teacher or group of Student-teachers is given a research topic. They have to gather information from internet, available books in the library or ask experienced people and then the results are presented in verbal or written form and discussed in class.

C) Project work

Physics tutors are encouraged to sample and prepare project works and engage their Student-teachers in, as many as possible. Student-teachers in groups or individually, are engaged in a self-directed work for an extended period of time to investigate and respond to a complex question, problem, or challenge. The work can be presented to classmates or other people beyond the school. Projects are based on real-world problems that capture Student-teachers' interest. This technique develops higher order thinking as the Student-teachers acquire and apply new knowledge in a problem-solving context.

D) Field trip

One of the main aims of teaching Physics in Rwanda is to apply its knowledge for development. To achieve this aim we need to show to Student-Teachers the relationship between classroom science lessons and applied sciences. This helps them see the link between science principles and technological applications.

To be successful, the field visit should be well prepared and well exploited after the visit:

Before the visit, the tutor and Student-teachers:

- agree on aims and objectives
- gather relevant information prior to visit
- brainstorm on key questions and share responsibilities
- discuss materials needed and other logistical and administrative issues
- discuss and agree on accepted behaviours during the visit
- Visit the area before the trip if possible to familiarise yourself with the place

After the visit

When Student-teachers come back from trip, the tutor should plan for follow-up. The follow-up should allow Student-teachers to share experiences and relate them to the prior science knowledge. This can be done in several ways; either: Student-teachers write a report individually or in groups and give to the tutor for marking. The tutor then arranges for discussion to explain possible misconceptions and fill gaps. Or Student-teachers write reports in groups and display them on the class notice board for everyone to read.

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 Student-teachers are involved in the learning process. Below are those main parts and their small steps:

1) Introduction

Introduction is a part where the tutor makes connection between the current and previous lesson through appropriate technique. The tutor opens short discussions to encourage Student-teachers to think about the previous learning experience and connect it with the current instructional objective. The tutor 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 Student-teachers' findings, exploitation, synthesis/summary and exercises/application activities, explained below:

- **Discovery activity**

Step 1

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

- **Presentation of Student-teachers' productions**
  - In this episode, the tutor invites representatives of groups to present the Student-teachers' productions/findings.
  - After three/four or an acceptable number of presentations, the tutor decides to engage the class into exploitation of the Student-teachers' productions.

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

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

The tutor 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

- Tutor guides Student-teachers to make the connection of what they learnt to real life situations. At this level, the role of tutor 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, Student-teachers work individually on the task/activity. The tutor avoids intervening directly. In fact, results from this assessment inform the tutor on next steps for the whole class and individuals. In some cases, the tutor can end with a homework assignment.

PART II: SAMPLE LESSON PLAN

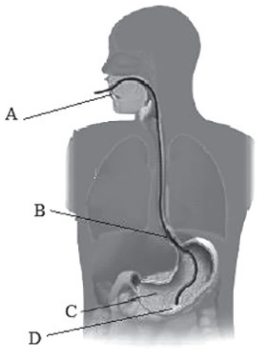
The tutor's guide provides more than one lesson plan taking into consideration the type of lesson in the subject (E.g.: one per main topic/theme) using the CBC format.

Competence – based Lesson Plan

School Name: .....……. Teacher's name:.....

Term	**Date**	**Subject**	**Class**	**Unit N°**	**Lesson N°**	**Duration**	**Class size**
----	.../.../ ...	Physics	Y 3	7	4 of 5	80 min	35
Type of Special Educational Needs to be catered for in this lesson and number of learners in each category				Learners with visual difficulties: **1 student-teacher (*).**			
Unit title	Medical Imaging						
Key Unit Competence	To generate the processes in medical imaging.						
Title of the lesson	Endoscopy Imaging						
Instructional Objective	Using given figure (Endoscopy exam from learner book), learners will be able to describe endoscopy imaging properly.						
Plan for this Class (location: in / outside)	Classroom or outside.						
Learning Materials (for all learners)	Computers, projector and student-teacher's book.						

References	1. Physics for TTC, Student-Teacher's book year 3, REB 2020. 2. Medical Physics : Imaging, JEAN POPE, September 1998.		
Timing for each step	**Description of teaching and learning activity**		**Generic competences** and **Cross cutting issues** to be addressed **+ a short explanation**
	Through performing activity 7.4 from student-teacher book, learners will name the given figure, know how endoscopy exam is taken and is performed and then recognize their advantages and disadvantages.		
	Teacher's activities	**Learners' activities**	
Introduction 10min	Through brainstorming, Motivate the learners by asking them some questions about : - Specific purpose(s) of medical imaging techniques. - Medical imaging applied for digestive system **Note:** Make sure that the student-teacher **(*)** is sit near the teacher and/or near the screen /or near the chalkboard so that he/she can see clearly information given by the teacher.	Learners recall the specific purpose of medical imaging techniques They try to think medical imaging applied for digestive system Individually, they give their thoughts.	**Generic competences** Communication, cooperation, critical thinking through responding the questions. **Cross-cutting issues** - Peace and value education: assigning work peacefully - Inclusive education: involvement and engagement of all learners. - Gender: recognize male and female in performing tasks.

Development of the lesson 60 min	Using group work techniques (or other technique) ask learner perform the following activity. "The picture below shows the procedure that enables doctor to examine the lining of esophagus and stomach. Examine it well and answer the following question.  1. Draw the picture and name the labelled letters A, B, C and D. 2. How do you call the examination technique taken by a doctor? 3. How can we examine inside the stomach by using light rays?	Perform the activity in group (or using other method indicated by teacher). During discussion, leaners tried to answer the activity Hint: 1. A. Month, B. endoscope, C. stomach, D. light 2. Endoscopy exam. 3. The surgery firstly insert the endoscope (contain light and camera) through the mouth and esophagus then into stomach. He/she move light in all corner of the stomach. 4. During an upper endoscopy, an endoscope is easily passed through the mouth up to stomach. It is a flexible tube with a light and camera attached to it, used by specialist to view pictures of the digestive tract on a monitor.it can also be passed into the large intestine (colon) through the rectum to examine the area of the intestine.	**Generic competences** Critical thinking skills through group discussions and facilitate each other. Communication and cooperation through team spirit. Creativity through drawing and labelled picture **Cross-cutting issues** **Gender education**: both Sexes are treated equally. **Peace and value Education**: through respect others view and thoughts during discussions. **Inclusive education** through caring and make involvement of student-teacher **(*)** in the activity.

	4. How is endoscopy performed? 5. What do you think are the advantages and disadvantages of this technique?'' Note: Make sure that the student-teacher (*) is involved in the activity and their fellow student – teacher's assigned roles to him/her. Ask some group(s) to present their finding. Confirm the correct answer(s)	5. advantages: It is very safe, cost effective and has low risk, etc. Disadvantages: patient may have infection, bleeding then technically difficult procedure, etc. Present the results in plenary and write on the board.(using a power presentation where possible) Validate the discussed points and noting them down in their notebooks.	Standardization culture: through awareness of endoscope machines that do not harm human health.

Conclusion 10 min	Summary Harmonize, and then generalize deduction of endoscopy with the real life. Assessment / Evaluation Verify using different methods the level of attainment of the learning outcomes and mark the student-teacher' performance. You may ask questions. NOTE: Remember student-teacher (*)	Give the summary on endoscopy imaging and make a connection of endoscopy with the real life. Student-teacher answer the questions 1. Discuss different functions of endoscope in medicine. 2. What are some of negative effects of using endoscopy?	Generic competences Critical thinking skills while summing up. Lifelong learning through connection of the topic with real life. Cross-cutting issues Gender education: both sexes have equal opportunities to participate in the activities. Peace and value Education: through listening carefully, answer to the questions and the summary. Inclusive education through remembering student-teacher (*) in the assessment.
Teacher self-evaluation			

UNIT 1

SOUND WAVES

1.1 Key unit competence:

Analyse the effects of sound waves in elastic medium

1.2 Prerequisite (knowledge, skills, attitudes and values)

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.

- Simple harmonic motion (Unit 3, year 2)
- Propagation of mechanical waves (Unit 4, year 2)

1.3 Cross cutting issues to be addressed

Inclusive education (promote education for all while teaching):

Regardless of physical appearance and abilities student-teachers should be treated equally. This makes the student-teachers to find out that they are all of great importance.

Gender education (equal opportunity of boys and girls in the lesson participation). Care should be taken that both Sexes are given equal opportunities while in classes. This should be integrated in all lessons in this unit.

Environment sustainability: During delivering different lessons within this unit, Student's teachers should know that use of old vehicles like motorcycle, cars and others that burn fuel in their engines is not good as they lead to pollution.

"Our environment is our life"

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 that do not harm our environment) eg old engines. Whenever you are doing any practical lesson be mindful of this culture. Hence, the measure of quantity that should be applied is good culture to know in order to avoid the dangers in time of use.

1.4 Guidance on 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 student-teachers you have.
- Tell the Student-teachers to open the introductory activity in the student-teacher's book.
- Instruct Student-teachers to re-write the questions and answer them following the instructions from student-teacher's book.
- While Student-teachers 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 Student-teachers).
- Together with students harmonize the points and make a summary on the board. Allow student-teachers 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.

Answers for the introductory activity

1. a) i) You will be able to hear high pitched sound and your friend will hear low pitched sound. This is because, you will be near the source and your friend is far away the source.

ii) Yes. This is because sound made by flute is different from that made by guitar (Can explain this using quality of sound/timber).

The two sounds have different pitch.

b) 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; rook musicians can also suffer hearing loss.

2. There will be variations in sound heard.
   a) As you come close, you will hear high pitched sound
   b) as you go away/recede, there is reduction in intensity of sound heard.

3. In such rooms there is reflection of sound, reverberation which results into interference of sound hence not able to get clearly for our ears to hear sound clearly.

1.5 List of lessons

#	Lesson title	Learning objectives	Number of Periods
1	Production of stationary sound waves	Perform an experiment to produce sound waves. Explain sound waves production	6
2	Characteristics and properties of sound waves	Explain application Snell's law in waves Apply Snell's law in sound waves. Explain the diffraction of waves Explain the Principle of superposition of waves Illustrate diffraction of sound waves. Interpret the Principle of superposition for sound waves	6
3	Characteristics of musical notes	Appreciate the application of sound waves Recognize applications of diffraction of waves in life Acquire ability to logically and systematically analysis sound wave phenomena Adapt scientific method of thinking applicable to wave phenomena.	2
4	The Doppler Effect and its applications	Explain Doppler's effect in sound waves Analyze Doppler's effect in sound waves Solve problems concerning Doppler's effect	5
5	**End unit assessment**		2

Lesson 1: PRODUCTION OF STATIONARY SOUND WAVES

a) Learning objectives

- Perform an experiment to produce sound waves.
- Explain sound waves production

b) Teaching resources

- Textbooks (Student teacher's book and all reference books in student teachers book), internet and real materials which produce sound waves like flute, guitar…….
- Videos, animation and simulations about sound waves
- (https://phet.colorado.edu/en/simulation/legacy/sound).

c) Prerequisites/Revision/Introduction

Student teachers need to have a recap about formation of stationary waves found in integrated science in year 1 and physics in year 2.

d) Learning activity 1.1

- **Guidance on activity 1.1**

This activity aims at making student-teachers how sound can be produced

- Put your students in groups.
- Instruct student-teachers to read the questions and relate them to Fig 1.2
- Tell the students to attempt the questions in their notebooks.
- As student-Teachers 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 student-Teachers or groups whether their answers correspond to the ones discussed
- Together with students harmonize the points and make a summary on the board. Allow Student-teachers to write the main points in their notebooks

- Using student-teachers work, explain harmonics in pipes,
- Link this lesson to real life like rhythm heard after drumming.

Answers for activity 1.1

1) One student use guitar to produce sound while the other uses a flute to produce the sound.
2) The sound will be the same because the sound is not depending on the length of the flute.
3) The sound will be the same but the frequency may be different because the frequency of sound depends on the length of the flute.

Answers for application activity 1.1

1. In a tube with two open ends $f_1 = \frac{v}{2L}$ hence $\lambda = \frac{v}{f_1} = 2L$

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

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 cm

3. a) To get destructive interference the difference between the distances to the loudspeakers should be, n = 1, 3, 5... There will be destructive interference at $\frac{\lambda}{2}$, at $\frac{3\lambda}{2}$ and at $\frac{5\lambda}{2}$, $\frac{n\lambda}{2}$

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

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

$\frac{3\lambda}{2} = 0.5\,m \Leftrightarrow \lambda = \frac{1}{3}\,m$ and then $f_2 = \frac{v}{\lambda} = \frac{343}{1/3} = 1\,029\,Hz$.

Similarly, doing $\frac{5\lambda}{2} = 0.5\,m \Leftrightarrow \lambda = \frac{1}{5}\,m$ we get $f_3 = \frac{v}{\lambda} = \frac{343}{1/5} = 1\,715\,Hz$

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 cm = $^3/_4\lambda$ therefore, λ= 17.6 cm = 0.176 m

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

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

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

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

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

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

The sound propagation velocity in this string is then $v = \lambda_1 f_1 = 1.28 \times 330 = 420\ m/s$
When pressing the string, the string tension do not varies, and the propagation velocity v is also 422 m/s.

The new string length L2 is obtained using $L_2 = \frac{\lambda_2}{2} = \frac{v}{2f_2} = \frac{422}{2 \times 350} = 0.603\ m$.
The difference $64\ cm - 60.3\ cm = 3.7\ cm$ is the distance from the first fret to the nut.

9. 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.

10. The relation between string tension T, mass m, length L and string wave velocity *v* is

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

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

Replacing T = 520 N and $\mu = 4\times10^{-3}\ kg/m$, we get $v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{520}{4\times10^{-3}}} = 361\ m/s$.

The wavelength associated to the fundamental frequency is: $\lambda = 2L = 2\times0.6 = 1.2\ m$.

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

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

Lesson 2: CHARACTERISTICS AND PROPERTIES OF SOUND WAVES

a) Learning objectives

In this lesson students-teachers will be able to

- Explain application Snell's law in waves
- Apply Snell's law in sound waves.
- Explain the diffraction of waves
- Explain the Principle of superposition of waves
- Illustrate diffraction of sound waves.
- Interpret the Principle of superposition for sound waves.

b) Teaching resources

- Textbooks (Student's book and all reference books in students' book), internet and real materials which produce sound waves like flute, guitar……..
- Projectors, computer, videos, animation and simulations for example: (https://phet.colorado.edu/en/simulations/category/physics/sound-and-waves)

c) Prerequisites/Revision/Introduction

- Through guided discovery, assist Student-teachers to describe all the characteristics of sound waves. You can make a recap using propagation of mechanical waves (Unit 4 year 2).
- You can ask them questions like, why is not possible to hear someone that is far away from you? etc.

d) Learning activity 1.2

Guidance on learning activity 1.2:

This activity aims at capturing students' attention and minds towards characteristics and properties of sound waves.

- Divide your students into groups tell the student-teachers to open the activity 1.2 in the student-teacher's book.
- Instruct student-teachers to read the scenario in the activity 1.2 in the student-teachers 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 student-teachers 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.

Answers for activity 1.2

This activity is for about the review on waves and sound wave properties as discussed in year 2

a) **Sound** is associated with our sense of hearing and, therefore, with the physiology of our ears that intercept the sound and the psychology of our brain which interprets the sensations that reach our ears. Sound waves are longitudinal mechanical waves that can travel through solids, liquids, or gases.

- **Reflectio**n of waves is the bouncing off when sound hits an interface
- **Refraction** of waves is the change in direction of waves as they pass from one medium to another
- **Diffraction** is the name given to the phenomenon in which a wave spreads out as it passes through a small aperture or around an obstacle

- **Interference** occurs when two or more waves traveling through the same medium overlap and combine together.
- Laws governing reflection: Incident pulse, reflected pulse and normal at the point of incident, all lie in the same plane; The angle of incident and the angle of reelection are equal
- Laws governing refraction of sound waves: Incident pulse, refracted pulse and normal at the point of incident, all lie in the same plane. The ratio of the sine of the angle of incident to the angle of refraction is constant.

b), c), d) and e): The tutor will judge the answer of the student teacher and harmonize. For more information see additional information for tutor.

e) Answer for application activity 1.2

1. C 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:

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \Leftrightarrow k = 4\pi^2 f^2 m = (2\pi \times 15\ Hz)^2 (3.0 \times 10^{-4} kg) = 2.7\ N/m$$

b) The total mass is now $0.10\ g\ +\ 0.30\ g\ =\ 0.4\ g$. We could substitute $m = 4.0 \times 10^{-4}\ kg$ into $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = 13\ Hz$

7. The total distance covered by the sound wave as it travels from dolphin to target and back is

$\Delta S = 2 \times 110\ m = 220\ m$.

From equation $v = \frac{\Delta s}{\Delta t}$, we have, for 25°C water $\Delta t = \frac{\Delta s}{v} = \frac{220}{1533} = 0.14\ s$

8. From $v = \sqrt{\frac{T}{\mu}}$, we must increase the tension by a factor of 4.

9. a) Using $\lambda = \frac{c}{f}$ then the range of the wavelengths of audible sound in air lie between

$\lambda = \frac{343}{20} = 17.2\ m$ and $\lambda = \frac{343}{20000} = 17.2\ mm$

b) Using $f = \frac{c}{\lambda}$ then the frequencies of visible light lie between

$f = \frac{3.00 \times 10^8}{400 \times 10^{-9}} = 7.50 \times 10^{14}\ Hz$ and $f = \frac{3.00 \times 10^8}{700 \times 10^{-9}} = 4.29 \times 10^{14}\ Hz$

c) The wavelength of these waves in air $\lambda = \frac{v}{f} = \frac{343}{23} = 14.9\ m$

d) The required frequency sound for a good scan $f = \frac{\lambda}{f} = \frac{1500}{1.0 \times 10^{-9}} = 15 \times 10^{11}\ Hz$

Lesson 3: CHARACTERISTICS OF MUSICAL NOTES

a) Learning objectives

- Appreciate the application of sound waves
- Recognize applications of diffraction of waves in life
- Acquire ability to logically and systematically analysis sound wave phenomena
- Adapt scientific method of thinking applicable to wave phenomena.

b) Teaching resources

Textbooks (Student teacher's book and all reference books in student teachers' book), internet, projectors, and real materials of music which produce sound waves like a guitar, a whistle,

a drum, etc.

- Computer, projector videos, animation and simulations for example: (https://phet.colorado.edu/en/simulations/category/physics/sound-and-waves)

c) Prerequisites/Revision/Introduction

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

d) Learning activity 1.3

Guidance on learning activity 1.3

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 student-teachers to read the questions carefully and brainstorm them in their groups.
- 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 student-teachers make a summary (use student's work/ findings)
- Linking to the summery 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.

Answers for activity 1.3

1) The sound of a whistle is different from the sound of a drum. The whistle makes a high sound. The drum makes a low sound.
2) If the same note is sounded on the violin and then on the piano, an untrained listener can tell which instrument is being used, without seeing it. We would never mistake a piano for flute. We say that the quality or timbre of note is different in each case. The manner in which an instrument is played strongly influences the sound quality.

e) Answers for application activity 1.3

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 λ, the first distance d of the minimum amplitude position or node from the wall is:

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

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

The antinodes are midway between the nodes. So maximum amplitude of vibration is obtained: $A_{\max} = \frac{nd}{2}$ from the wall.

3. Sound intensity $I = \frac{P}{A} = \frac{0.5 \times 10^{-4}}{4\pi 5^2} = 1.6 \times 10^{-8}\ W/m^2$

4. Intensity level $\beta = 10 \log \frac{I}{I_o} = 10 \log \frac{10^{-9}}{10^{-12}} = 30\ dB$

5. a. False, density, b. False, pitch, c. True

6. $L = \beta = 10 \log \frac{I}{I_0} = \frac{1.0 \times 10^{-10}}{1.0 \times 10^{-12}} = 10 \log 100 = 20\ dB$

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.

Lesson 4: THE DOPPLER EFFECT AND ITS APPLICATIONS

a) Learning objectives

- Explain Doppler's effect in sound waves
- Analyze Doppler's effect in sound waves
- Solve problems concerning Doppler's effect

b) Teaching resources

- Textbooks (Student's book and all reference books in students' book), internet
- Projectors, computer, video, real materials like guitar and drums.

c) Prerequisites/Revision/Introduction

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

d) Learning activity 1.4

Guidance on the learning activity 1.4

- Decide on the method to use in this lesson (You can use group work, individual or whole class)
- Tell student-teacher to open their books to activity 1.4
- Instruct them to read the instructions of the questions and attempt the questions in this activity
- Call some student-teacher (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 student-teachers, come up with a summary and note down major points to the board and allow student-teachers to write some important concepts in their notebooks.
- To concretize your lesson, together with student-teachers do examples 1.9 to 1.11 in the student-teacher's book (This will help you to assess the mastery and acquisition of concepts by student-teachers).

Answers for activity 1.4

1. Sound are used in Radar, Medical imaging, Astronomy,… as describe in student-teacher book, section 1.4.2
2. The sound heard decreases due to the relative motion of the source of the wave and the observer.
3. The sound heard increases due to the relative motion of the source of the wave and the observer.
4. Doppler's principle explains why, if a source of sound of a constant pitch is moving toward an observer, the sound seems higher in pitch, whereas if the source is moving away it seems lower. This change in pitch can be heard by an observer listening to the whistle of an express train from a station platform or another train

e) Answers for application activity 1.4

1. C

2. In medicine, the Doppler Effect can be used to measure the direction and speed of blood flow in arteries and veins. This is used in echocardiograms and medical ultrasonography and is an effective tool in diagnosis of vascular problems.

   In astronomy, Doppler Effect is used to measure the speed at which stars and galaxies are approaching or receding from us, in a mechanism named red shift or blue shift. Redshift happens when light seen coming from an object that is moving away is proportionally increased in wavelength, or shifted to the red end of the spectrum. Vice versa occurs with blue shift. Since blue light has a higher frequency than red light, the spectral lines of an approaching astronomical light source exhibit a blue shift and those of a receding astronomical light source exhibits a redshift.

3. 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.

4. 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.

   b) The new frequency f_r detected by the observer:

$$f_r = f_s \frac{v + v_o}{v - v_s} = 1000 \frac{340}{340 - 33.5} = 1109.3\ Hz$$

c) **Astronomy**

Doppler Effect is used to measure the speed at which stars and galaxies are approaching or receding from us, in a mechanism named red shift or blue shift. Redshift happens when light seen coming from an object that is moving away is proportionally increased in wavelength, or shifted to the red end of the spectrum. Vice versa occurs with blue shift. Since blue light has a higher frequency than

red light, the spectral lines of an approaching astronomical light source exhibit a blue shift and those of a receding astronomical light source exhibits a redshift.

Medical imaging

In medicine, the Doppler Effect can be used to measure the direction and speed of blood flow in arteries and veins. This is used in echocardiograms and medical ultrasonography and is an effective tool in diagnosis of vascular problems.

Radar

The Doppler Effect is used to measure the velocity detected objects where a radar beam is fired at a moving target. For example, the police use radar to detect a speeding vehicle. Radio waves are fired using a radar gun at the moving vehicle. The velocity is calculated using the difference between the emitted frequency and the reflected frequency. In a similar way, Doppler radar is used by weather stations to calculate factors like wind speed and intensity

Echolocation

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.

Other, echocardiography, communication, exploration for oil and minerals,

1.6 Summary of the unit

Sound Waves

- Sound is a disturbance of matter (a pressure wave) that is transmitted from its source outward. Hearing is the perception of sound.
- Sound can be modelled in terms of pressure or in terms of displacement of molecules.
- The human ear is sensitive to frequencies between 20 Hz and 20 kHz.

Speed of Sound

- The speed of sound depends on the medium and the state of the medium.
- In a fluid, because the absence of shear forces, sound waves are longitudinal. A solid can support both longitudinal and transverse sound waves.

- the speed of sound v is the same for all frequencies and wavelengths of sound in air and it is related to air temperature T by $v = v_o\sqrt{\frac{T}{T_0}}$

Sound Intensity

- Intensity $I = \frac{P}{A}$ is the same for a sound wave as was defined for all waves, where P is the power crossing area A. The SI unit for I is watts per meter squared.

- Sound intensity level in units of decibels (dB) is $\beta = 10\log\frac{I}{I_o}$ where $I_o = 10^{-12}\ W/m^2$ is the threshold intensity of hearing.
- The perception of frequency is pitch. The perception of intensity is loudness and loudness has units of phons.

Normal Modes of a Standing Sound Wave

- Unwanted sound can be reduced using destructive interference.
- Sound has the same properties of interference and resonance as defined for all waves.
- In air columns, the lowest-frequency resonance is called the fundamental, whereas all higher resonant frequencies are called overtones. Collectively, they are called harmonics.

Sources of Musical Sound

- Some musical instruments can be modelled as pipes that have symmetrical boundary conditions: open at both ends or closed at both ends. Other musical instruments can be modelled as pipes that have anti-symmetrical boundary conditions: closed at one end and open at the other.
- Some instruments, such as the pipe organ, have several tubes with different lengths. Instruments such as the flute vary the length of the tube by closing the holes along the tube. The trombone varies the length of the tube using a sliding bar.
- String instruments produce sound using a vibrating string with nodes at each end. The air around the string oscillates at the frequency of the string. The relationship for the frequencies for the string is the same as for the symmetrical boundary conditions of the pipe, with the length of the pipe replaced by the length of the string and the velocity replaced by $v = \sqrt{\frac{T}{\mu}}$

Beats

- When two sound waves that differ in frequency interfere, beats are created with a beat frequency that is equal to the absolute value of the difference in the frequencies.

The Doppler Effect

- The Doppler Effect is an alteration in the observed frequency of a sound due to motion of either the source or the observer.
- The actual change in frequency is called the Doppler shift.
- a single Doppler effect equation that covers all cases of both source and observer in motion: $f_r = f_o \dfrac{v \pm v_o}{v \mp v_s}$

1.7 Additional information for the tutor

Another way to analyze the vibrations in a uniform tube is to consider a description in terms of the ***pressure* in the air**, shown in Figs. 1.1 and 1.1. Where the air in a wave is compressed, the pressure is higher, whereas in a wave expansion (or rarefaction), the pressure is less than normal. We call a region of increased density a ***compression***; a region of reduced density is a ***rarefaction***. The wavelength is the distance from one compression to the next or from one rarefaction to the next.

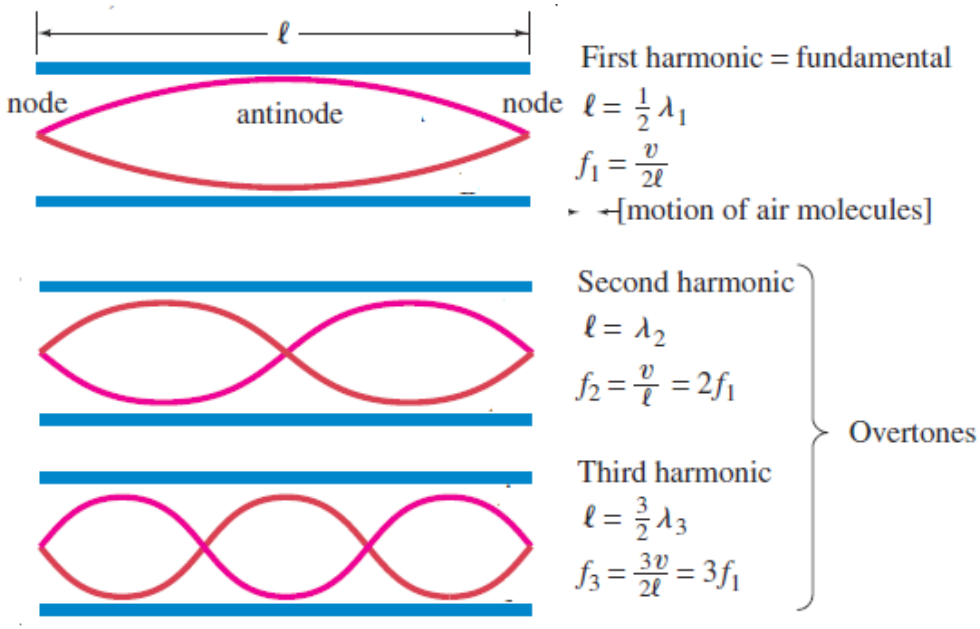


Fig.1. 1 Pressure variation in the air: Graphs of the three simplest modes of vibration (standing waves) for a uniform tube open at both ends ("open tube").

The open end of a tube is open to the atmosphere. Hence the pressure variation at an open end must be a *node*: the pressure does not alternate, but remains at the outside atmospheric pressure. If a tube has a closed end, the pressure at that closed end can readily alternate to be above or below atmospheric pressure. Hence there is a pressure *antinode* at a closed end of a tube. There can be pressure nodes and antinodes within the tube.

Some of the possible vibrational modes in terms of pressure are shown in Fig.1.1 for an open tube, and in Fig.1.2 for a closed tube.

Pipe organs use both open and closed pipes, with lengths from a few centimetres to 5 m or more. A flute acts as an open tube, for it is open not only where you blow into it, but is open also at the opposite end. The different notes on a flute are obtained by shortening the length of the vibrating air column, by uncovering holes along the tube (so a displacement antinode can occur at the hole). The shorter the length of the vibrating air column, the higher the fundamental frequency.

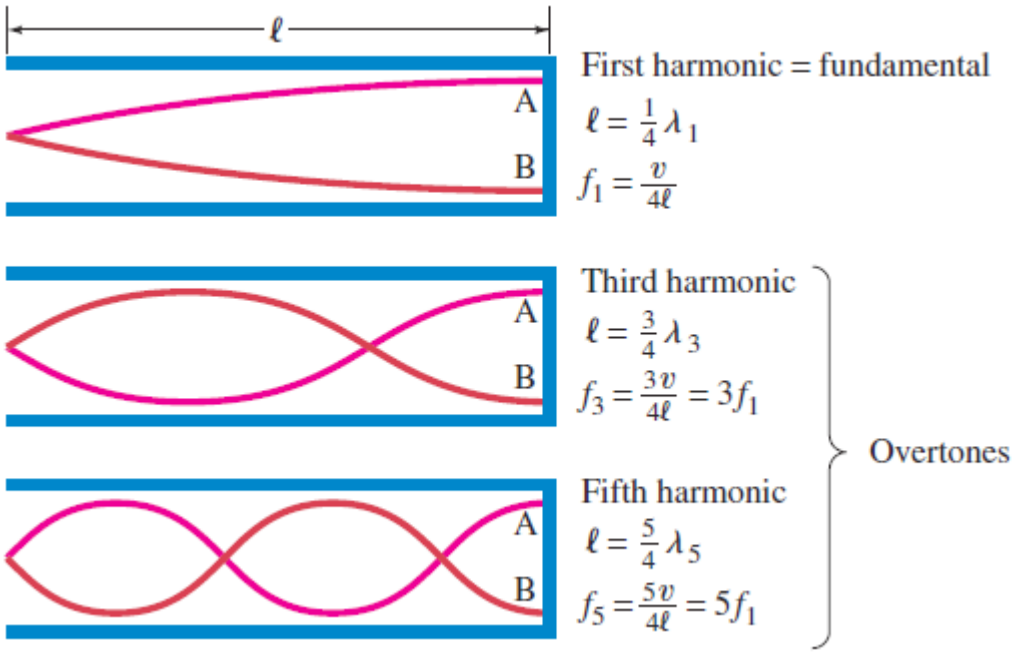


Fig.1. 2 Modes of vibration (standing waves) for a tube closed at one end ("closed tube")

GUIDANCE ON SKILLS LAB 1

This activity aims at making use of knowledge he acquired from the unit and apply it in coming up with solutions of problems we have in the society.

- As stated in student-teachers' book, Students are required to design any musical instrument of their choice.

- Tell them to come up with ideas (of what they are to design) to you so that you can recommend them to continue with what they are planning to design.
- Give them enough time to design the instrument of their choice in a given period of time described by you.
- Keep inspecting their progress over time.
- When they are done designing their instruments, give them time to present (and even play them) in the class even describing science behind the operation of the instruments.
- When they are done, make sure that all instruments are collected and kept in a special room so that they can be used in future classes.
- Make sure you appreciate (using any method of your choice) so that these student-teachers are motivated.

1.8 Answers for end unit 1 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°.

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 $v_s = 5.00\ m/s$, $f_s = 40.0\times10^3\ Hz$, $f_r = 40.4\times10^3\ Hz$ and $v = 340\ m/s$

Detection by the insect: The bat (source) move toward the insect (detector) which is moving away the bat: $f_r' = f_s \dfrac{v - v_o}{v - v_s}$

Detection of echo by bat: In the echo back to the bat, the insect acts as a source of sound, emitting at the frequency f_r' we just calculated. So now the moth is the source (moving away) and the bat is the detector (moving toward): $f_r = f_r' \frac{v + v_s}{v + v_o}$

We get $f_r = f_s(\frac{v - v_o}{v - v_s})(\frac{v + v_s}{v + v_0}) \Rightarrow \mathrm{v}_o = 3.31\, m/s$

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

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

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

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

19. Use $f_r = f_s \frac{v + v_o}{v} \Leftrightarrow 518 \frac{343 + v_o}{343} \Rightarrow v_o = 25.8\, m/s$. **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 nose 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 safety.

Regulations are not needed to reduce noise pollutions 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 (Questions and answers)

1.9.1 Remedial 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

   A. The string's tension has been dramatically increased.

   B. The string can vibrate with much larger amplitude.

   C. 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. 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?

7. Standing sound waves are produced in a pipe that is 1.20 m long. For the fundamental and first two overtones, determine the locations along the pipe (measured from the left end) of the displacement nodes and the pressure nodes if the pipe is closed at the left end and open at the right end.

Answer

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. 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.

7. 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.1.28. Location of the displacement nodes (N) measured from the closed end:

- fundamental 0
- 1st overtone 0, 0.80 m
- 2nd overtone 0, 0.48 m, 0.96 m

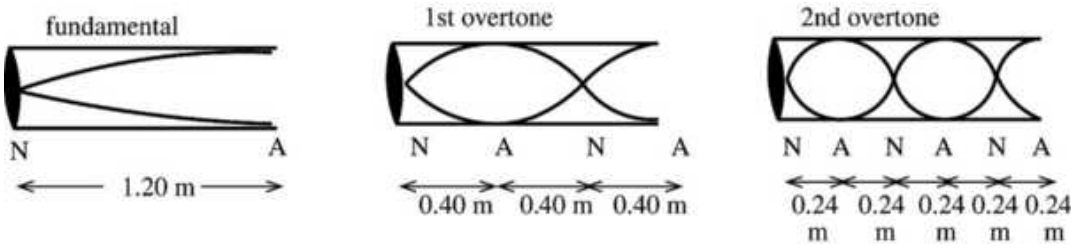


Fig.1. 3 Standing waves produced by pipe open at one end and closed at the other end

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

2nd overtone 0.24 m, 0.72 m, 1.20 m.

1.9.2 Consolidation activities

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. Murenzi 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?

Answer

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 $v = \lambda f$, 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.

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

From equation of $v = \frac{\Delta s}{\Delta t}$, we have, for 25°C water and $\Delta t = \frac{\Delta s}{v} = \frac{220}{1533} = 0.14\ s$

1.9.3 Extended activities

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.
    a) Draw the first three harmonics of vibration on the string below, and calculate the wavelength and frequency for each**.**
    b) What is the velocity of the waves on this string?
    c) 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?

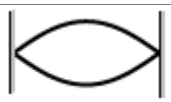
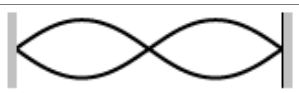
17. **The Human Voice.** The human vocal tract is a pipe that extends about 17 cm from the lips to the vocal folds (also called “vocal cords”) near the middle of your throat. The vocal folds behave rather like the reed of a clarinet, and the vocal tract acts like a stopped pipe. Estimate the first three 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.)

Answer

14. From $v = \sqrt{\frac{T}{\mu}}$, 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**.**

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

b. Use $v = f\lambda = 110 \times 1.29 = 141.9 = 142$

c. The new length of the string is 0.645 m - 0.215 m = 0.430 m

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

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

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.

(a) For an open pipe the successive harmonics are $f_n = nf_o$ where n = 1,2,3,

For a stopped pipe the successive harmonics are $f_n = nf_o$ where n =1, 3, 5, ...

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

$f_n = nf_o = 1372\ Hz$ and $f_{n+1} = (n+1)f_o = 1764\ Hz$.

Subtract the first equation from the second: $(n+1)f_0 - nf_o = 1364 - 1372$

This gives $f_o = 392\ Hz$. 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

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

Subtracting one equation from the other gives $2f_0 = 392\ Hz$ and $f_0 = 196\ Hz$.

Then $n = \frac{1372}{196} = 7$ so $7f_0 = 1372\ Hz$ and $9f_0 = 1764\ Hz$.

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) $f_0 = 196\ Hz$.

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

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.

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

UNIT 2

CLIMATE CHANGE AND GREENHOUSE EFFECT

2.1 Key Unit Competence

Evaluate the environmental survey conducted on climate change and greenhouse effect.

2.2 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.

- Black body radiation (in unit 2 year 2)
- Energy Sources in Rwanda.
- Environmental problems such as Noise, pollution, Ozone depletion and Global warming.
- Composition, Structure and dynamics of the atmosphere.

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

- Inclusive education (promote education for all while teaching). Regardless of physical appearance and abilities student-teachers should all be treated equally. This makes the student-teachers 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.
- Standardization culture (Be aware of machines that do not harm our environment)

2.4 Guidance on the introductory activity

This activity aims at capturing students' attention and minds towards climate change and greenhouse effect.

- Inform student-teachers that they are to discuss this activity by themselves under your guidance.
- You may split your class into groups (if it is a mixed school make sure that your groups have boys and girls) and tell them to start working on the introductory activity.
- Give student-teachers like 20 minutes 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. In case there are some word/concepts that need to be explained or clarified in the questions, try to help them
- Invite some groups to present their findings to the whole class. Students can use power point presentations. Remember to attend any student that needs a special attention.
- Ask student-teachers 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 student-teachers' findings and deductions
- Let the student-teachers note down important points and notes in their notebooks for future reference and revision purposes.

Answers for the introductory activity

a) By radiation.

This energy is used for

i) Photosynthesis by plants

ii) Provides human beings Vitamin D

iii) Gives Natural light for vision

iv) Drying our crops, clothes and others

v) Helps in the process of rain formation and others. You can accept student's ideas that answer this part.

b) No! Human absorb this energy and radiate after being used.

Also, plants do not maintain this energy forever instead after being used it is emitted.

c) A black body: This is a body that absorb radiations that fall on it. However, a perfect black body absorb all radiations that fall on it and reflect none.

d) i) Its surface temperature would change affecting the climate of that body, may be if it is a planet

ii) Once the energy is reflected, it means that there will distribution of this energy in its atmosphere. Leading to average distribution of temperature with its surface and its atmosphere.

iii) Yes. Since these radiations lead to variations in the temperature, there is a possibility of change in the climate of that planet (objects)

There is also a possibility of these radiations being retained in the atmosphere in case there are elements that may stop these radiations from continuing. Such elements include accumulation of green gases in the atmosphere.

e) Concentration of these gases in the atmosphere leads to changes (specifically rise) in temperature.

f) This has led to climate change. Man has done the following to minimize the changes

- Planting trees
- Good methods of farming
- Use of electric/charged engines not those that emit carbon dioxide.
- Stop burning bushes, etc

2.5 List of Lessons

#	Lesson Tittle	Learning Objectives	Number of Periods
1	Climate Change	- Explain the concept of climate change - Explain causes of climate change	4
2	Solar and black body radiations.	- Analyze the concept of black body. - Explain the nature of black body radiation and its emissivity. - State Stefan-Boltzmann law and apply it to emission rates from different surfaces. - Evaluate and discuss the intensity of sun's radiation reaching the earth - Evaluate concept of emissivity and relate it to emission rates for different surfaces - Explain how earth's albedo varies independent of season and latitude.	3
3	Greenhouse effects and its impact on climate change	- Describe Greenhouse effect - Appreciate the usefulness of energy from greenhouse in supporting plant life	4
4	Climate change mitigation	- Carry out Investigation on Greenhouse effect - Explain the climate change mitigation	2
5	End Unit Assessment		2

Lesson 1: CLIMATE CHANGE

a) Learning objectives

Explain the concept of climate change
Explain causes of climate change

b) Teaching resources

Textbooks (Student's book and all reference books in students' book), internet
Projectors, videos about Climate change

c) Prerequisites/Revision/Introduction

Knowledge about effect of temperature on gases

Effects of radiations on a surface.

d) Learning activity 2.1

Guidance on activity 2.1

This Activity aims at making student-teachers discover and analyze concepts about climate change

- Tell Student-teachers to open their books (in the Student-teacher's book) to activity 2.1
- Decide on the methodology to use in this lesson. You can group your student-teachers, 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.
- Move around and see the progress and how student-teachers are progressing with their discussion. During this period, you can assist students with problems or who needs special attention.
- Select some of them to share their deductions to the whole class and allow questions from students if any. Create a good ground for student-teachers to discuss.
- Make a summary (using student-teacher findings) and tell student-teachers to write down important ideas in their books.

- You can summarize this activity by making student-teachers to be aware that climate is changing, and something must be done (by them) to avoid such changes. It's their responsibility as good citizens of Rwanda.

Answers for learning activity 2.1

a) Change the temperature of the earth's surface and its atmosphere that results into change in its climate.

b) High concentrations of intensity of radiations in the atmosphere leads to the increase in the temperature of the atmosphere.

c) The incidence can be controlled by

- Conserving the nature that reduce the rate of carbon concentration in air
- Reducing use of devices that emit carbon dioxide gases
- And other well discussed points. Let student-teachers discuss their findings and harmonize these points.

d) Floods, prolonged dry seasons, rise in temperatures, change in humidity. Students should fully explain these points.

e) Afforestation, good methods of farming and all practices that aims at conserving the nature.

e) Answers for the application activity 2.1

1. a) Weather means to change in atmospheric conditions for a short period of time

   b) Climate refers to change in atmospheric conditions for a long period

   c) Climate change refers to variation in the climate of a given region/area/ place

   d) Humidity is the amount of Water vapor in the atmosphere

   e) Temperature is the degree of hotness or coldness of an area or a body.

2. Factors that have led to climate change in Rwanda
   - Poor methods of farming
   - Deforestation
   - Bush burning
   - Toxic gases from industries and engines of vehicles.
   - Volcanic activity.

3. Different areas in same region may have different climatic conditions due to

- Different amount of water vapor in its atmosphere
- Different vegetation cover
- Different activities taking place in those regions like farming, industrialization and other infrastructures etc.

Lesson 2: SOLAR AND BLACKBODY RADIATIONS

a) Learning objectives

- Analyze the concept of black body.
- Explain the nature of black body radiation and its emissivity.
- State Stefan-Boltzmann law and apply it to emission rates from different surfaces.
- Evaluate and discuss the intensity of sun's radiation reaching the earth
- Evaluate concept of emissivity and relate it to emission rates for different surfaces
- Explain how earth's albedo varies independent of season and latitude.

b) Teaching resources

- Textbooks (Student's book and all reference books in students' book), internet
- Projectors, videos animation and simulation about black body radiations (https://phet.colorado.edu/en/simulations/category/physics/light-and-radiation).

c) Prerequisites/Revision/Introduction

- Students must revise Unit 2 year 2 about black body radiations.

d) Learning activity 2.2

Guidance on Activity 2.2

This activity introduces makes student-teachers discover and analyze concepts about solar and black body radiations

- Tell the student-teachers to turn to activity 2.2.

- Divide them into groups (you can use any technique depending on what you want to achieve at the end of the lesson)
- Instruct them to read the questions under that activity and re-write the questions to their note books.
- Give them like 25 minutes to attempt the question
- While they are doing the work, you can move around marking and helping students who need special attention.
- When everyone is done, invite 3 or 4 students (or students depending on the time you have) to present their answers to whole class. They can use power point to present.
- Together with student-teachers make harmonization and come to the general conclusion of answers of each question as given in the answers below.
- Let student-teachers note down important information in their notebooks for future reference.

Answers for activity 2.2

a) Radiation

b) No. This is because some of the radiations are absorbed within the medium while others is reflected. This reduces the intensity of heat reaching the observer.

c) Factors that affect intensity of radiations received by the earth.

- **The shape of the earth**: The earth has a spherical shape and therefore the sunlight is more spread out near the poles because it is hitting the earth at an angle, as opposed to hitting the earth straight-on at the equator.
- **The earth's rotation**: all areas are not consistently exposed to sunlight. Areas that are experiencing 'night time' are not receiving a lot of the sun's power; therefore, the time of the day or night will affect the solar constant.
- **The angle of the surface to the horizontal at that particular location**: When the Sun is directly overhead, its rays strike Earth perpendicular to the ground and so deliver the maximum amount of energy. When the Sun is lower in the sky, a sunbeam strikes the ground at an angle and so its energy is "spread out" over a larger area

d) Among other factors, the following are some of the factors that affect the absorption of radiations by the earth include the following:

- **Clouds**. The atmosphere is usually covered with clouds that usually pass over the earth's surface. This leads to reduction or increase in the temperature of the earth's surface. This is because these clouds may absorb or reflects back sun's light to the free space. However, this depends on the distance from which the clouds are from earth's surface. When sun's radiation is reflected, the earth's surface is cooled and when it is absorbed the earth is warmed.
- **Oceans** While observing from the space, you will find out that water bodies appear differently from land surfaces. They appear darker and therefore absorb more sun's radiations than land. However, some of the radiations heating the water surface (ocean) may be carried away by the currents while others may form water vapor.
- **Thick vegetation covers or forested areas.** Places covered with vegetation absorb a lot of sun's radiation. This is because the vegetation cover provides a dark surface which absorbs more radiations than the bare land.
- **Surface albedo.** Different surfaces appear differently. Light coloured surfaces absorb different amounts of radiations than dark coloured surfaces. Snow covered areas are highly reflective. They thus absorb less amounts of energy (Sun's radiation). The snow cover reduces the heating effect of the earth's surface. However, if temperatures reduce, the snow cover reduces leading to the absorption of radiation by the exposed ground surface.

e) They are called blackbodies.

e) Answers for the application activity 2.2

1a. The Sun's spectral output is composed of approximately 9% ultraviolet (and shorter) wavelengths, 41% visible light, and about 50% infrared radiation.

b. The solar energy that reaches the top of Earth's atmosphere is more or less constant. It does vary a little as Earth revolves annually around the Sun, and because of changes in solar activity

c. No. Different wavelengths of light interact differently with water and aerosols in the atmosphere. Some wavelengths are preferentially transmitted, some are scattered, and other wavelengths are absorbed.

2. a. Absorption reduces the amount of solar radiation that reaches Earth's surface. On average, about 15% of incoming solar radiation is absorbed by atmospheric molecules such as water vapor, oxygen and small particulates (aerosols).

   b. Scattering of solar radiation within the atmosphere also accounts for a reduction of energy reaching Earth.

   c. Combining the percentages of incoming energy absorbed (18%) and scattered (26%) by the atmosphere plus clouds, the overall effect is that nearly half (18% + 26% = 44%) of the energy entering the atmosphere doesn't make it through to Earth's surface.

3. a. Albedo is the fraction of the reflected solar radiation to the incident solar radiation. Clouds have a high albedo, meaning they reflect a much greater percentage of the incoming light than does vegetation.

   b. The insolation (incoming solar energy) received daily depends primarily on:

   - The angle of the Sun above the horizon (solar elevation angle, solar incidence angle),
   - The length of time the surface is exposed to the Sun, and
   - Atmospheric conditions. The higher the sun in the sky and the longer a surface is exposed to the sun, the more insolation. The clearer the sky, the more insolation. As Earth revolves around the Sun over the course of a year, its orbital and tilt geometry cause seasonal and latitudinal variations in insolation.

   c. Generally, equatorial regions experience less fluctuation in daily insolation throughout the year. Further from the equator, seasonal differences are more pronounced. Polar regions experience many more hours of sunlight than darkness in their respective summer, and many more hours of darkness than sunlight in their respective winter. On the equator, however, there is a nearly constant 12 hour of sunlight throughout the year. Moreover, the distance light has to pass through the atmosphere near the equator is less than the distance it passes through near the poles.

4. a) A blackbody is a body which absorbs all the radiations incident upon it
   b) Stefan-Boltzmann law

The law states that, "the power per unit area radiated by a surface of a black body is directly proportional to the forth power of its temperature".

$$P = e\sigma AT^4$$

While

Wien's displacement law It states that "the maximum wavelength of the emitted energy from a blackbody is inversely proportional to its absolute temperature".

c) From $\lambda_{\max} T = b$

$5.2\times10^{-7}T = 2.9\times10^{-3}$

$T = 5576.9K \approx 6000K$

Hence proved

5. a) The formula used is $\lambda_{\max} T = b$

Since $6.85\times10^{-7}T = 2.9\times10^{-3}$ gives $T = 4233.576 \simeq 4.23\times10^{3}\ K$

Which is the Value of B2.

b) Using $L = e\sigma AT^4$

and $L = 0.039\times10^{27}\ W, \sigma = 5.67\times10^{-9}\ m^{-2}K^{-4}, T = 4.23\times10^{3}$

$$A = \frac{0.039\times10^{27}}{5.67\times10^{-8}\times[4.23\times10^{3}]^4} = 0.2\times10^{19}$$

Hence D2 is about 0.2 as expected

Lesson 3: GREENHOUSE EFFECTS AND ITS IMPACT ON CLIMATE CHANGE

a) Learning objectives

- Describe Greenhouse effect
- Appreciate the usefulness of energy from greenhouse in supporting plant life

b) Teaching resources

- Textbooks (Student's book and all reference books in students' book), internet
- Projectors,computer, videos and animation about greenhouse effect (https://phet.colorado.edu/en/simulation/legacy/greenhouse)

c) Prerequisites/Revision/Introduction

- Knowledge about green gases.
- Knowledge about blackbody radiations

d) Learning activity 2.3

Guidance on learning activity 2.3

This activity introduces student-teachers to greenhouse effect

- Tell student-teachers to observe the figure in this activity in the learner's book.
- Decide the methodology to use in this lesson. (You can use individual or groups).Care must be taken, while deciding the methods, student-teachers with special needs should be catered for.
- Tell them to read the questions in the activity 2.3
- Leave the student-teachers to copy the questions and attempt them by themselves. (This can take like 20 minutes)
- While student-teachers are doing this work, you can move around marking and guiding student-teachers where there might be a problem.
- When they are done and you are also done with marking, invite some students to discuss their answers and observations to the whole class. Make sure they use power point presentations.
- Together with student-teachers summarize what you have discussed and note down important points on the board and let them put them in their findings.
- Link what you have discussed to impact of greenhouse effect, global warming and climate change mitigation
- Allow student-teachers to note down important information in their notebooks.

Answers for activity 2.3

a) A greenhouse is a structure that makes sunlight to warm surfaces inside an enclosed structure

b) i) Greenhouse gases

ii) When these gases Accumulate in the atmosphere, they form a layer that stops radiations from the earth from being dispersed hence absorbed or

reflected back to the earth leading to the change in the temperature of the earth's atmosphere hence global warming

c) - Afforestation

- Sensitizing people on conserving Nature
- Advocating for Good methods of farming
- Limiting Carbon Emissions like advocating to using gas instead of charcoal

Accept learner's Ideas that are like the above suggestions

e) Answers for the application activity 2.3

1. Greenhouse Effect: *Greenhouse effect* is the process by which thermal radiation from the sun is prevented from leaving the atmosphere and then re-radiated in different directions.

While Global warming is the long-term rise in the average temperature of the Earth's climate system.

2. This is because the greenhouse gases in the atmosphere act the same way as the glass panels of a greenhouse, which allow sunlight through and trap heat inside. Hence greenhouse.

3. Rising atmospheric concentrations of CO_2, CH_4, and CFCs indicates the possibility of additional warming of the global climate. The panel refers to warming due to increased atmospheric concentrations of greenhouse gases as "greenhouse warming." Measurements of atmospheric CO_2, show that the 1990 concentration of 353 parts per million by volume is about one-quarter larger than the concentration before the Industrial Revolution. This makes people to be worried that there are high chances of temperature increase if action is not taken

4. a) Carbon dioxide gas.

b) Factors for rise in emissions of carbon

- Industrialization
- Emission of carbon from vehicles and other engines

c) Using alternative energy sources like use of solar panels, Electric/ chargeable vehicles, creating carbon sinks.

d) Yes, it's a good idea! This is because when these gases Accumulate in the atmosphere, they form a layer that stops radiations from the earth from being dispersed hence absorbed or reflected back to the earth leading to the change in the temperature of the earth's atmosphere hence global warming. And this is bad!

Carbon dioxide that may be necessary for nature (Photosynthesis) can be got from the sun.

Lesson 4: CLIMATE CHANGE MITIGATION

a) Learning objective

- To differentiate internal energy and total energy of a system

b) Teaching resources

- Textbooks (Student-teachers book and all reference books in student-teachers' book), internet

c) Prerequisites/Revision/Introduction

- Knowledge about greenhouse effect

d) Learning activity 2.4

Guidance on learning activity 2.4

This activity introduces climatic change mitigation

- Tell student-teachers to turn to activity 2.4 in the learner's book.
- Divide student-teachers into groups or chose any method that can suit your class and helps the learner to attempt the activity. Ensure that student-teachers with special needs are catered for while deciding the method to use.
- Tell student-teachers to read the questions and copy them to their notebooks. They should first analyze the text at the start of the questions.
- Give student-teachers like 20 minutes to read and internalize the text
- While moving around mark student-teachers' work.
- After marking invite some members to discuss or present their answers to the whole class. They can use power point presentations.

- Ask student-teachers (rest of the class) whether their answers correspond to the discussed ones
- Connect/link student-teachers' ideas with climate change mitigation. You can use student's book notes.

Answers for activity 2.4

a) I strongly support the plans of the government. Because these plans will fight all that may cause our climate to change. Like controlling carbon dioxide concentrations in the atmosphere that may lead to global warming.

Note!! Student teachers must support this idea! Try to make those that may want to oppose the idea, the relevance of conservation of nature.

b) A student teacher must give all activities that aims at conserving nature and reducing carbon emissions.

The student teacher may suggest that he/she has done the following

- Planting trees
- Stop burning bushes
- Using good methods of farming like use of terraces, mulching etc

c)
- Use of electric/rechargeable vehicles
- Advocating for afforestation and re-afforestation
- Encouraging farmers to use advanced/good methods of farming, etc

e) Answers for application activity 2.4

1. A well written essay with the following features (Everything should be focused to climate change mitigation in Rwanda)
   - Heading
   - Introduction
   - Body
   - Conclusion. The passage should be well punctuated, and in good English.
   - References

2. For this question, Students are to do research about climate change mitigation. The findings may be different depending where the students had their research work from.

Accept all relevant information about climate change mitigation

2.6 Summary of the unit.

- **Climate** is the "**average weather**," or more rigorously, as the **statistical description in terms of the mean and variability of relevant quantities over a period** ranging from months to thousands of years.
- Climate change can be observed over a longer period.
- Climate change refers to any significant change in the climate parameters such as temperature, precipitation, or wind patterns.
- The source of the energy injected into our atmosphere is from the sun, which is continually shedding part of its mass by radiating waves of electromagnetic energy and high energy particles into space.
- This constant emission represents all the energy available to the earth. The amount of energy received at the top of the atmosphere is mainly affected by four factors: **solar output**, **the sun–earth distance, the altitude of the sun, and day length.**
- Solar energy originates from nuclear reactions within the sun's hot core (16 $x10^6$ K) and is transmitted to the sun's surface by radiation and hydrogen convection.
- The annually changing distance of the earth from the sun produces seasonal variations in solar energy received by the earth.
- The altitude of the sun also affects the amount of solar radiation received at the surface of the earth. The greater the sun's altitude, the more concentrated is the radiation intensity
- The length of daylight also affects the amount of radiation that is received. Obviously, the longer the time the sun shines the greater is the quantity of radiation that a given portion of the earth will receive.
- A black body. This a body that absorbs all radiations that fall on it.
- *Albedo:* This is the measure of reflection on a surface
- *Radiation:* This is the process in which energy is transferred by means of electromagnetic waves.
- Mitigation refers to using new technologies and renewable energies, making older equipment more energy efficient, or **changing** management practices or consumer behavior.
- Climate Change Mitigation**:** This refers to efforts to reduce or prevent emission of greenhouse gases.

- The greenhouse effect**:** This is a process by which thermal radiation from a planetary surface is absorbed by atmospheric greenhouse gases, and is re-radiated in all directions

2.7 Additional information for the tutor

Blackbody:

It's possible that you realize a black body in real practice. Construct a box made of a thermally conductive material, such as metal. The box should be completely closed on all sides, so that the inside forms a cavity that does not receive light from the surroundings. Then, make a small hole somewhere on the box. The light coming out of this hole will almost perfectly resemble the light from an ideal blackbody, for the temperature of the air inside the box.

Climate change

a) Climate change

For most people, the expression "climate change" means the alteration of the world's climate that we humans are causing, through fossil fuel burning, clearing forests and other practices that increase the concentration of greenhouse gases (GHG) in the atmosphere. This is in line with the official definition by the United Nations Framework Convention on Climate Change (UNFCCC) that climate change is the change that can be attributed "directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods".

b) Physical evidence for climate change.

Temperature measurements and proxies

The instrumental temperature record from surface stations was supplemented by radiosonde balloons, extensive atmospheric monitoring by the mid-20th century, and, from the 1970s on, with global satellite data as well. The 180/160 ratio in calcite and ice core samples used to deduce ocean temperature in the distant past is an example of a temperature proxy method, as are other climate metrics noted in subsequent categories.

Historical and archaeological evidence

Climate change in the recent past may be detected by corresponding changes in settlement and agricultural patterns. Archaeological evidence, oral history and historical documents can offer insights into past changes in the climate. Climate change effects have been linked to the collapse of various civilizations.

Glaciers are considered among the most sensitive indicators of climate change. Their size is determined by a mass balance between snow input and melt output. As temperatures warm, glaciers retreat unless snow precipitation increases to make up for the additional melt; the converse is also true.

Vegetation

A change in the type, distribution and coverage of vegetation may occur given a change in the climate. Some changes in climate may result in increased precipitation and warmth, resulting in improved plant growth and the subsequent sequestration of airborne CO_2. A gradual increase in warmth in a region will lead to earlier flowering and fruiting times, driving a change in the timing of life cycles of dependent organisms. Conversely, cold will cause plant bio-cycles to lag. Larger, faster or more radical changes, however, may result in vegetation stress, rapid plant loss and desertification in certain circumstances. An example of this occurred during the Carboniferous Rainforest Collapse (CRC), an extinction event 300 million years ago. Now, vast rainforests covered the equatorial region of Europe and America. Climate change devastated these tropical rainforests, abruptly fragmenting the habitat into isolated 'islands' and causing the extinction of many plant and animal species.

Pollen analysis

Palynology refers to the study of contemporary and fossil palynomorphs, including pollen. Palynology is used to infer the geographical distribution of plant species, which vary under different climate conditions. Different species of plants have pollen with distinctive shapes and surface textures, and since the outer surface of pollen is composed of a very resilient material, they resist decay. Changes in the type of pollen found in different layers of sediment in lakes, bogs, or river deltas indicate changes in plant communities. These changes are often a sign of a changing climate. As an example, palynological studies have been used to track changing vegetation patterns throughout the Quaternary glaciations and especially since the last glacial maximum.

Cloud cover and precipitation

Past precipitation can be estimated in the modern era with the global network of precipitation gauges. Surface coverage over oceans and remote areas is relatively sparse, but, reducing reliance on interpolation, satellite clouds and precipitation data has been available since the 1970s. Quantification of climatological variation of precipitation in prior centuries and epochs is less complete but approximated using proxies such as marine sediments, ice cores, cave stalagmites, and tree rings. In July 2016 scientists published evidence of increased cloud cover over polar regions, as predicted by climate models.

Climatological temperatures substantially affect cloud cover and precipitation. For instance, during the Last Glacial Maximum of 18,000 years ago, thermal-driven evaporation from the oceans onto continental landmasses was low, causing large areas of extreme desert, including polar deserts (cold but with low rates of cloud cover and precipitation). In contrast, the world's climate was cloudier and wetter than today near the start of the warm Atlantic Period of 8000 years ago.

Dendroclimatology

Dendroclimatology is the analysis of tree ring growth patterns to determine past climate variations. Wide and thick rings indicate a fertile, well-watered growing period, whilst thin, narrow rings indicate a time of lower rainfall and less-than-ideal growing conditions.

Ice cores

Analysis of ice in a core drilled from an ice sheet such as the Antarctic ice sheet, can be used to show a link between temperature and global sea level variations. The air trapped in bubbles in the ice can also reveal the CO_2 variations of the atmosphere from the distant past, well before modern environmental influences. The study of these ice cores has been a significant indicator of the changes in CO_2 over many millennia and continues to provide valuable information about the differences between ancient and modern atmospheric conditions.

Animals

Remains of beetles are common in freshwater and land sediments. Different species of beetles tend to be found under different climatic conditions. Given the extensive lineage of beetles whose genetic makeup has not altered significantly over the millennia, knowledge of the present climatic range of the different species, and the age of the sediments in which remains are found, past climatic conditions may be inferred.

Sea level change

Global sea level change for much of the last century has generally been estimated using tide gauge measurements collated over long periods of time to give a long-term average. More recently, altimeter measurements — in combination with accurately determined satellite orbits — have provided an improved measurement of global sea level change. To measure sea levels prior to instrumental measurements, scientists have dated coral reefs that grow near the surface of the ocean, coastal sediments, marine terraces, and nearshore archaeological remains.

Guidance on the skills lab 2

Remember the aim of this activity is to make students apply what they have studied.

- Make sure you help student(s) in getting materials needed for the project
- Help student-teacher(s) to locate places where to construct the greenhouse
- Inspect student's progress. You can advise them in case they have difficulties so that they achieve the targeted objective(s)
- Guide student-teachers on how to come up with a wonderful report and on how to make good presentations.
- You can award marks to the students to motivate your student-teachers. For marking you can design your own marking rubric.

2.8 Answers for end unit assessment

1. A 2. B 3. C 4. A

5. D 6. A 7. D 8. B

9. a) Wien's displacement law, states that the wavelength of maximum emission from a blackbody is inversely proportional to its temperature.

From this law it can be deduced that shorter-wavelength (higher-frequency) light corresponds to higher-energy photons, which you would expect from a higher-temperature object

b) i) The graph also shows:

As temperature increases, the total energy emitted increases, because the total area under the curve increases.

It also shows that the relationship is not linear as the area does not increase in even steps. The rate of increase of area and therefore energy increases as temperature increases.

ii) Between 4000 and 7000 K, is visible spectrum from red (long wavelength) to violet of short wavelength. At 4000 K the particles are vibrating with a less energy, hence red. As temperatures increase, the energy of particles increases shifting to particles of higher frequency. Hence changing their color to blue, indigo and then Violet.

iii) This is because the curves represent radiations emitted by a black body at different temperatures. That's whys these curves have different shapes.

10. Weather and climate will affect the intensity of the sun. Some areas are cloudier than others.

Due to Shape of the earth (the earth's spherical shape), the sunlight is more spread out near the poles because it is hitting the earth at an angle, as opposed to hitting the earth straight-on at the equator. There is **also less atmosphere at the equator**, **allowing more sunlight to reach the earth.** Therefore, the intensity varies depending on the geographical latitude of the location.

Due to the earth's rotation, all areas are not consistently exposed to sunlight. Areas that are experiencing 'nighttime' are not receiving a lot of the sun's power, therefore the time of the day or night will affect the solar constant.

The angle of the surface to the horizontal at that particular location.

Planet's albedo, etc.

11. $albedo = \frac{amont\ of\ radiation\ reflected}{amount\ of\ radiation\ incidenton\ surface} = \frac{1500\,W \cdot m^2}{1500\,W \cdot m^2} = 1$

Comment: *The body is totally/highly reflective like a polished surface*

b) **Clouds**. The atmosphere is usually covered with clouds that usually pass over the earth's surface. This leads to reduction or increase in the temperature of the earth's surface. This is because these clouds may absorb or reflects back sun's light to the free space. However, this depends on the distance from which the clouds are from earth's surface. When sun's radiation is reflected, the earth's surface is cooled and when it is absorbed the earth is warmed.

Oceans. While observing from the space, you will find out that water bodies appear differently from land surfaces. They appear darker and therefore absorb more sun's radiations than land. However, some of the radiations heating the water surface (ocean) may be carried away by the currents while others may form water vapor while others. All these affect the rate at which the earth either absorb or reflect the sun's radiation hence affecting its albedo.

Thick vegetation cover or forested areas. Places covered with vegetation absorb a lot of sun's radiation. This is because the vegetation cover provides a dark surface which absorb more radiations than the bare land. This therefore affects the planet's albedo.

Surface albedo. Different surfaces appear differently. Light colored surfaces absorb different amounts of radiations than dark colored surfaces. Snow covered areas are highly reflective. They thus absorb less amounts of energy (Sun's radiation). The snow cover reduces the heating effect of the earth's surface. However, if temperatures reduce, the snow cover reduces leading to the absorption of radiation by the exposed ground surface.

12.a) i) Climate change refers to any significant change in the measures of climate lasting for an extended period of time

ii) Greenhouse Effect: *Greenhouse effect* is the process by which thermal radiation from the sun is prevented from leaving the atmosphere and then re-radiated in different directions.

b) The following are ways how greenhouse effects can be avoided

- High efficiency during power production
- replacing coal and oil with natural gas
- combined heating and power systems (CHP)
- renewable energy sources and nuclear power
- carbon dioxide captures and storage
- Use of hybrid vehicles.

13. At low temperatures a black body emit radiations of short wavelength (Red) that's why her observations indicated red at 1000 K whereas at higher temperatures radiations of high frequency (high energy) are emitted. The mixture of these high frequency radiations is what brings about the body to appear white

14. Not! John is not right. A black body is anybody that absorbs radiations that falls on it. It should be noted that other nonblack objects absorb radiations depending on their surface albedos.

15. Stefan's constant $\sigma = 5.7 \times 10^{-8} Wm^2 K^{-4}$

$Power\ radiated = power\ received = 50\,W$

$P = e\sigma AT^4$

$0.7 \times 5.7 \times 10^{-8} \times 2\pi \times 2.5 \times 10^{-5} \times 0.6 \times T^4 = 50$

Solving gives $T = 1909.7\ K$

16. *Greenhouse effect* is the process by which thermal radiation from the sun is prevented from leaving the atmosphere and then re-radiated in different directions.

Effects

- Greater strength of extreme weather events like: heatwaves, tropical cyclones, floods, and other major storms.
- Increasing number and size of forest fires.
- Rising sea levels (predicted to be as high as two feet by the end of the next century).
- Melting of glaciers and polar ice.
- Increasing acidity in the ocean, resulting in bleaching of coral reefs and damage to oceanic wildlife.

17. These are gases that are found in the atmosphere of the earth that traps the solar radiations. They trap suns radiations leading to increase in temperature hence global Warming.

18. Trees and other vegetation cover use carbon dioxide during their photosynthesis. This leads to absorption of a certain percentage of carbon dioxide in the atmosphere. This reduces the green gases that are problem

19. Climate change mitigation is the process of preventing all these green gases. This is very important as it is aimed at controlling the rise in temperatures of the earth while regulating earth's temperature.

20. The temperature of the temperature of the earth will rise leading to global warming.

21. When an object is heated, its temperature rises as heat is added. The increase in heat is called sensible heat. Similarly, when heat is removed from an object and its temperature falls, the heat removed is also called sensible heat. **Heat that causes a change in temperature in an object is called sensible heat.**

Solids can become liquids (ice to water) and liquids can become gases (water to vapor) but changes such as these require the addition or removal of heat. **The heat that causes these changes is called latent heat**

22.i) Climate feedback: This refers to a process that acts to amplify or reduce direct warming or cooling effects.

ii) Climate lag: This is the change in radiation.

iii) Climate model: This is a quantitative way of representing the interactions of the atmosphere, oceans, land surface, and ice. Models can range from relatively simple to quite comprehensive

23. Any essay in good English with the following

- Heading
- Good introduction
- Well-developed body (Connected to climate change)
- Conclusion.

2.9 Additional Activities

2.9.1 Remedial Activities

1. What natural things affect climate in the long run?

2. What is meant by ‘’atmospheric lifetime” and “sinks”?

3. Do all greenhouse gases have the same effect?

4. a. What happens to most radiation that is absorbed by the surface of Earth?

   b. What is the difference between sensible and latent heat?

   c. Why don’t global temperatures rise because of incoming solar radiation?

5 a. What is the greenhouse effect?

   b. What chemical compounds contribute to greenhouse warming?

   c. Mars and Venus both have high relative concentrations (~95%) of the greenhouse gas CO2 in their atmospheres. Why is Venus so hot while Mars is colder than Earth?

   d. What is global warming?

ANSWERS

1. Natural things affect climate in the long run

- On the geologic time scale, many things affect climate:
- Changes in solar output
- Changes in the earth’s orbital path
- Changes in land and ocean distribution (tectonic plate movements and the associated changes in mountain geography, ocean circulation, and sea level)
- Changes in the reflectivity of the earth’s surface
- Changes in atmospheric concentrations of trace gases (especially CO2 and CH4)

- Changes of a catastrophic nature (such as meteor impacts or extended volcanic eruptions)

2. These concepts can be illustrated by referring to what is called the "carbon cycle." When CO2 is emitted into the atmosphere, it moves among four main sinks, or pools, of stored carbon: the atmosphere, the oceans, the soil, and the earth's biomass (plants and animals). The movement of CO2 among these sinks is not well understood. About 45 percent of the total emissions of CO2 from human activity since preindustrial times is missing in the current accounting of CO2 in the atmosphere, oceans, soil, and biomass. Three possible sinks for this missing CO2 have been suggested. First, more CO2 may have been absorbed into the oceans than was thought. Second, the storage of CO2 in terrestrial plant life may be greater than estimated. Third, more CO2 may have been absorbed directly into soil than is thought. However, there is no direct evidence for any of these explanations accounting for all the missing CO2. CO2 in the atmosphere is relatively "long-lived" in that it does not easily break down into its constituent parts. CH4, by contrast, decomposes in the atmosphere in about 10 years. The greenhouse gas with the longest atmospheric lifetime (except for CO2), CFC-115, has an average atmospheric lifetime of about 400 years. The overall contribution of greenhouse gases to global warming depends on their atmospheric lifetime as well as their ability to trap radiation.

3. Each gas has different radiative properties, atmospheric chemistry, typical atmospheric lifetime, and atmospheric concentration. For example, CFC-12 is roughly 15,800 times more efficient molecule for molecule at trapping heat than CO2. Because CFC-12 is a large, heavy molecule with many atoms.

4. a. Most of the radiation absorbed by Earth's surface is reradiated (emitted) as long wavelength (long wave) radiant energy.

   b. Sensible heat is radiant energy that directly flows between objects or areas due to a temperature difference between them. Latent heat is released or absorbed when water changes state during the processes of evaporation, evapotranspiration, melting, freezing, condensation, and sublimation.

   c. A balance exists between incoming solar energy and Earth system reradiation of long wave radiation back into space.

5. a. The greenhouse effect is the warming of Earth's atmosphere caused by the absorption of long wave energy emitted by the surface of Earth. Atmospheric gases and clouds act like a greenhouse roof to keep heat in the system.

b. Substances that have a significant effect on global warming are water vapor, carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, and liquid water droplets.

c. Venus has greater relative and absolute amounts of carbon dioxide than Earth and Mars. Despite a 95% relative concentration of carbon dioxide, Mars has a much thinner atmosphere overall, so the absolute amount of carbon dioxide is too small to trap the solar insolation reemitted from the surface.

d. Global warming is a consistent trend of increasing global temperatures caused by additional amounts of greenhouse gases accumulating in the atmosphere.

2.9.2 Consolidation Activities

1. Focusing on reducing carbon production to reduce carbon dioxide emissions is argued to be the wrong variable to focus on. Explain what one should focus on?

Answer:

The focus should be on carbon consumption

Feedback:

In a situation where many countries (such as UK) after many years have made little progress towards achieving their Kyoto emissions reduction targets, critics are starting to point out that the situation would be much worse if these countries had not managed to get reduce their carbon production by exporting it to countries like China, by de facto exporting jobs. But the effect is illusionary, because we still import back from countries such as China the goods which we might have produced ourselves. Of course, the reason for exporting the jobs in the first place is to take advantage of low cost production locations. But if we keep consuming as we did before, at a global level nothing is achieved. We need to focus on carbon consumption. Hence 'The focus should be on carbon consumption' is the correct answer; 'It is impossible to achieve' is not true, as carbon production can be reduced at an aggregate level; 'It has nothing to do with carbon dioxide emissions' is simply wrong, as it is very much to do with carbon dioxide emissions; while 'The focus should be on carbon elimination' is merely a red herring; it does not mean anything.

2. What do we mean when we say "think globally, act locally" in relation to environmental problems?

Answer:

While these problems, as we experience them in relation to sustainability issues, are produced by processes operating at a global level, we all have a role to play in our local context in making individual and collective responses, as communities and companies, which will help ameliorate the effects of these problems

Feedback:

There is a little bit of truth in each of the three incorrect alternatives. International negotiations have a crucial role to play, but local responses are also crucial and are not simply related to self-protection measures. Equally, a global perspective of research and thought on environmental issues is crucial, but the results and implications generated from this apply at a range of spatial levels, not just the local. The essential aspect of the phrase or adage in the question is that we need a global perspective on environmental issues so that we can focus correctly on what we can do at a local level to respond.

2.9.3 Extended Activities.

1. a. What general mechanism is responsible for redistributing heat energy in Earth systems?

   b. What drives atmospheric circulation?

   c. Explain simply how atmospheric circulation develops.

2. a. Are the oceans or the atmosphere more efficient at storing energy? Explain.

   b. Explain what effect ocean heat capacity has on global temperatures.

   c. Give an example of how atmosphere and ocean systems affect each other.

3. a. Explain how humans can affect land surface albedos.

   b. Explain how the loss of land vegetation might modify local climates.

   c. What impact have humans had on concentrations of greenhouse gases? Give a specific example

ANSWERS

1. a. The circulation of the atmosphere and oceans redistributes heat from areas of surplus to areas of deficit.

   b. The heat differential between tropical and polar areas (generated by latitudinal differences in insolation) drives atmospheric circulation.

c. Equatorial areas are heated more than polar areas; the warming equatorial air rises as it gets less dense. The rising tropical air gets replaced by cooler, denser air moving down from the poles by a process known as convection. Due to the rotation of Earth and the resulting Coriolis force, several circulating cells in each hemisphere are generated.

2. a. Oceans are more efficient at storing energy, due to the tremendous volume of water in the oceans and water's capacity to hold heat.

b. The oceans impart a moderating effect on global temperatures.

c. The El Niño-Southern Oscillation (ENSO) that occurs periodically in the southern Pacific Ocean is an example of how ocean circulation and atmospheric circulation interact. Changing moisture budgets, altered winds and decreased coastal upwelling become part of a chain of energy redistribution that affects global climate patterns.

3. a. Albedo can be changed by modifying land surfaces. In general, presence of vegetation cover reduces albedo, while bare soil and concrete increase albedo. Moisture tends to lower albedos, lack of moisture raises albedos.

b. When vegetation is removed from a surface the localized radiation budget change. Though the surface albedo usually increases and hence relatively more insolation is reflected and less absorbed, the localized area may become hotter overall due to less shading and less evaporative cooling as a result of reduced transpiration. The reverse may be true at times when vegetation is not transpiring; for example, during winter forested areas absorb more insolation and act as wind breaks, and thus may be warmer than cleared areas.

c. Anthropogenic forces have increased atmospheric concentrations of methane (rice cultivation, raising sheep and cattle, gas mining, trash landfills), carbon dioxide (consumption of fossil fuels, biomass burning), and chlorofluorocarbons (refrigerants, solvents, aerosol propellants.

UNIT 3

APPLICATIONS OF OPTICAL FIBER IN COMMUNICATION SYSTEM

3.1 Key unit competence:

Evaluate the application optic fibre transmission and other transmitting systems

3.2 Prerequisite (knowledge, skills, attitudes and values)

The success of this unit 3 relies partly on the mastery of knowledge and skills acquired in Physics (Unit 8, year 2) and other subjects in previous grades or units such as Physics of Ordinary Levels (Unit 13, S3).

3.3 Cross cutting issues to be addressed

- **Inclusive education** (promote education for all while teaching):
- Regardless of physical appearance and abilities student-teacher should be treated equally. This makes the student-teacher to find out that they are all of great importance.
- **Gender education** (equal opportunity of boys and girls in the lesson participation). Care should be taken that both Sexes are given equal opportunities while in classes. This should be integrated in all lessons in this unit while teaching.
- **Environment sustainability**: During delivering different lessons within this unit, Student-teacher's teachers should know that while doing demonstrations like illustrating black bodies using hot objects may give rise to carbon emissions that are dangerous. This should be avoided
- **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.

3.4 Guidance on introductory activity

This activity aims at capturing student-teacher'' attention and minds towards the new concept of optical fibre in telecommunication system.

- Divide your student-teacher' into groups (Grouping may depend on the nature of your class or number of student-teacher you have). Always take care of student-teacher with any kind of disability while making groups (hearing, reading, seeing, etc.).
- Tell the student-teacher to open the introductory activity in the student-teacher's book. Give them clear information about the activity.
- Ask student-teacher to observe and read the text bellow the figure before answering questions. While student-teacher are doing this activity, you move around, guide or answer to the questions of slow student-teacher. You may mark the working of those who have finished. Make sure you help student-teacher' who require special attention.
- When everyone has finished the activity, invite some member(s) of group(s) to present their findings to the whole class. Guide the presentation. Student-teacher may use power point presentation during presentation
- Ask other groups to present what others did not raised or mentioned.
- Note some misconceptions and misunderstanding so that they will be corrected and harmonised in the lesson. Together with student-teacher' harmonize the points and make a summary on the board.
- Give to student-teacher 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.

Answers for the introductory activity

1. Fig.3.1 in Student-Teacher's book has three images: On image A, there are bundles of optical fibers. It is probably in one of the town of Rwanda.

   On figure B, the activities of fiber installation are on-going. Two parts of fiber optics will be connected together.

   Part C is either the receiver or emitter/server of fiber optical signals. It is called transducer.

2 Transfer of information, internet connectivity and communication.

3 For gigabits and beyond gigabits transmission of data, the fiber optic communication is the ideal choice. This type of communication is used to transmit voice, video, telemetry and data over long distances and local area networks or computer networks without repeaters.

4. Challenges are: digital skills gap, limited infrastructure, lack of capital, unskilled people to exploit internet on maximum…

3.5 List of lessons

#	Lesson title	Learning objectives	Number of Periods
1	*Optical fiber*	- Explain functioning of optic fibre - Identify and explain the components in optic fibre system.	4
2	Principle of operation of optical fibers	- Describe telecommunication system - Recognise the importance of fibre optics in communication	4
3	Mechanism of attenuation and light scattering	- Explain attenuation in optical fiber - Describe functions of amplifies in optical fiber transmission	2
4	Optical fiber communication	- Identify parts of a block diagram of telecommunication system. - Construct, analyse and judge block diagrams of a telecommunication system. - Describe noise production in optical fibre - Appreciate significance of optical fibre telecommunication system. - Distinguish optical fibre and other telecommunication systems - Outline the function of a microphone and antenna	6
5	End Unit Assessment		2

Lesson 1: OPTICAL FIBRE

a) Learning objective

- Explain functioning of optical fibre
- Identify and explain the components in optical fibre system.

b) Teaching resources

- Internet and textbooks, and any source of light.
- Videos on nature and properties of light but connected to fiber optics.

c) Prerequisites/Revision/Introduction

- Student-teachers need to know the Nature, characteristics and propagation of light. Remember, these student-teacher studied light in S1 unit 13, S2 unit 14 and S3.
- Try to give them a recap/overview so that they can connect/link what they studied in O'level to this unit.

d) Learning activity 3.1

Guidance on activity 3.1

The activity aims to capture student-teachers attention and develop critical thinking and collaboration on student-teachers through doing research. The Student-teacher will be encouraged to make a scientific research using different resources in order to get information about types of optical fibres.

- Divide your class into groups according to the number of student-teacher you have. In case you have student-teacher that require special attention, put them into consideration
- Give them instructions or guidelines of the research on how to do the research. They can use computer laboratory with internet connection.
- 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 using power point presentation.
- From the presentations of Student-teachers help them to summarize the content based on the facts of optical fibre. Write the summary and ask student-teacher to copy it in their notebooks.
- Remember to conclude your lesson by connecting it to real life situation. Like how internet is transmitted. If you have fibre connection at you school, you can refer to it. You can ask the computer science teacher to assist in case he/she has time.

Answer for activity 3.1

a) 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.

b)

- 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

e) Answers for aplications activity 3.1

1. True 2. H 3. C 4. Refer to the content

5) 1 → C 2 → E 3. → D 4 → A 5. → B

Lesson 2: PRINCIPLE OF OPERATION OF OPTICAL FIBRES

a) Learning objectives

- Describe telecommunication system
- Recognise the importance of fibre optics in communication

b) Teaching resources

- Textbooks and online resources like video, animation and models.

c) Prerequisites/Revision/Introduction

- Student-teachers need to know how light is reflected and refracted
- Student-teachers need to be aware of how signals are transmitted
- They can also link this concept to unit 12 in S1 and 13 in S2 and 13 in S3

d) Learning activity 3.2

Guidance on activity 3.2

This activity aims to capture student-teachers attention and minds them towards the concept of optical fibre. Therefore, the following guidelines should help the tutor to monitor the lesson efficiently.

- Divide your student-teachers into groups, accordingly. Tell the student-teachers to open and read the activity 3.2 in the student-teacher's book.
- Instruct student-teachers to observe the figure of activity 3.2, read the questions of that activity and answer them by writing in their notebooks. Give them the time to reflect on their prior knowledge (thinking time).
- While student-teachers 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 student-teachers: cooperation, critical thinking, etc.
- Inquire from other student-teachers' or groups whether their answers correspond to the ones discussed. If not, invite them for the presentation of new ideas.

- Together with student-teachers 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 tutor correct misconceptions met during presentation.
- Allow student-teachers 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.

Answers for activity 3.2

1. A: Undeviated ray (Normal ray), B: Refracted ray, C: glazing ray and D: reflected ray.
2. Refractions of light at different angle of incident
3. The critical angle, 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 900.
4. Total internal reflection is caused by the differences in optical media. The medium of incidence is denser than the medium of refraction
5. Communication (in fibre optics), in medicine (Endoscopy)

e) Answers for Applications activity 3.2

1. A, 2.D, 3. B

4. We know that the critical angle is given by $\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) = \sin^{-1}\left(\frac{1}{1.33}\right) = 48.8^0$

The critical angle for light travelling from water to air is 48.8^0

5 a). $\sin\theta_C = \frac{1}{2.42} \Leftrightarrow \theta_C = 24.4^0$

Since 28° is greater than θ_C, total internal reflection will occur, there is no refraction.

b. $\sin\theta_C = \frac{1.33}{2.42} \Leftrightarrow \theta_C = 33.3^0$

Since 28° is less than θ_C some light will undergo refraction into the water

6. $n_1(\sin\theta_1) = n_2(\sin\theta_2)$ and $(1.33)(\sin 57.5) = 1.5(\sin\theta_2)$ Therefore

7. (a) $\sin n_c = \frac{n_2}{n_1} \Rightarrow \sin n_c = \frac{1}{2.42} \Rightarrow n_c = 24.4^0$

(b) (i) Refraction occurs

(ii) Total internal reflection occurs, and light reflects back in at 24.4°

Lesson 3: MECHANISM OF ATTENUATION AND LIGHT SCATTERING

a) Learning objective

- Explain attenuation in optic fibre

b) Teaching resources

- Textbooks, internet, projectors and simulations about attenuation and light scattering

c) Prerequisites/Revision/Introduction

- Student-teachers need to first review the previous lesson.
- Student-teachers need to know interaction of particles when they meet
- What happens to particles energy after interactions?

d) Learning activity 3.3

Guidance on the learning activity 3.3

This activity aims at making students discover mechanism of attenuation and light scattering as applied in optical fibre.

- Divide your class into groups according to the number of student-teacher you have, or you can decide on the method you had planned (in your lesson plan) to use.
- Make sure you help student-teachers who requires special attention
- Ask student-teachers to open their books on activity 3.3 and read and internalise the questions. 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. They can use power point to do their presentation.
- From the presentations of student-teachers, help them to summarize the content based on the facts of optical fibre.
- Together with student-teachers develop the summary and ask student-teacher to copy it in their notebooks.

Answers for activity 3.3

a. No, some amount of energy is scatted away and do no reach the destination.

b. Poor optical fiber, absorption, leakage in fiber optics, bad connectors used, impurities in the glass fiber, low refractive index and so on.

c. Use of different devices such as Repeaters, Regenerators and Optical Amplifiers

Note: Make sure you mind about Special educational need. In case you have a student-teacher who needs special attention/care.

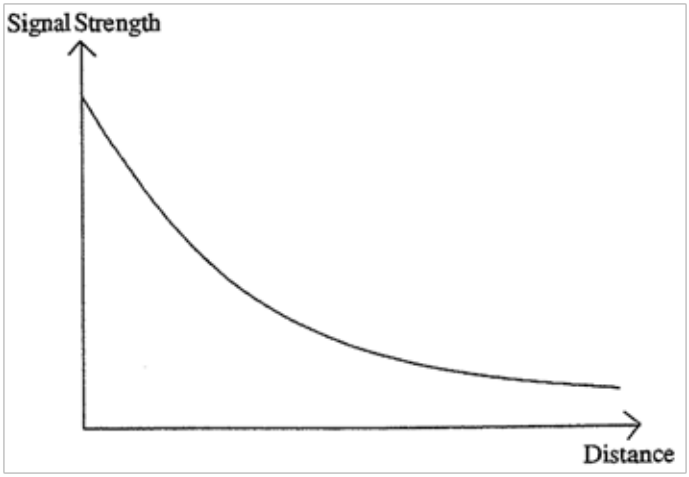
e) Answers for application activity 3.3

1. A. False B. True C. True

2. a) Attenuation is the 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 20 km $ie\, n = 20$, the signal strength $P = P_o(1-r)^n = P_0(1-0.05)^n = 0.36P_0$ where P_0 is the original signal strength

Lesson 4: OPTICAL FIBER COMMUNICATION

a) Learning objectives

- Identify parts of a block diagram of telecommunication system.
- Construct analyse and judge block diagrams of a telecommunication system.
- Describe noise production in optic fibre
- Appreciate significance of optic fibre telecommunication system.
- Distinguish optical fibre and other telecommunication systems
- Outline the function of a microphone and antenna.

b) Teaching resources

- Internet and textbooks, and any source of light for example LED and Laser, simulations (please use this website (https://phet.colorado.edu/en/simulations/category/physics) for physics simulations.
- Animation, models and videos on optical fiber communication.

c) Prerequisites/Revision/Introduction

- Through guided discovery, assist student-teacher to the figure on student-teacher'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 student-teacher the laws of reflection and refraction of light.

d) Learning activity 3.4

Guidance on learning activity 3.4

The activity aims to capture student-teachers attention on optical fibre communication.

- Divide your class into groups according to the number of student-teachers you have.
- Ask student-teachers to open their books on activity 3.4 and read and attempt the questions. 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 student-teachers, help them to summarize the content based on the facts of optical fibre communication.
- Together with student-teachers develop the summary and ask student-teacher to copy it to their notebooks.

Answers for Activity 3.4

1. Light source
2. Electromagnetic waves
3. See block diagram of optical fiber communication in Student-teacher's book under section

e). Answers for application activity 3.4

1. B, C, F 2.A 3.D 4).A False B. False

5. **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.

6. Transmitter is the first stage of the optical fiber communication system. It consists of a light source which converts electric signals into light signals and a focusing lens is used to focus the light beam into the optical fiber. Both Lasers and LEDs can be used as a light source. Lasers have more power than LEDs, but its characteristics vary with changes in temperature.

Optical receiver receives light signals which it converts back to electrical signals. Receiver uses a *photocell* or **photodiode** to detect the light and convert it to proportional electric signals, which is capable of measuring magnitude, frequency and phase of the optic field. This type of communication uses the wave lengths near to the infrared band that are just above the visible range.

Two types of photo detectors are mainly used for optical receiver in optical communication system: PN photo diode and avalanche photo diode. Depending on the application's wavelengths, the material composition of these devices vary. These materials include silicon, germanium, InGaAs, etc

Both LED and Laser can be used as light sources based on the application.

3.6. Summary of the unit 3

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 drawing 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 fibre-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 fibre, 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

3.7 Additional information for the tutor

Types of optical fiber losses

Optical beam power traveling along the fiber decreases exponentially with distance. There are different optical fiber losses mechanisms (fiber loss mechanisms):

a) Rayleigh scattering

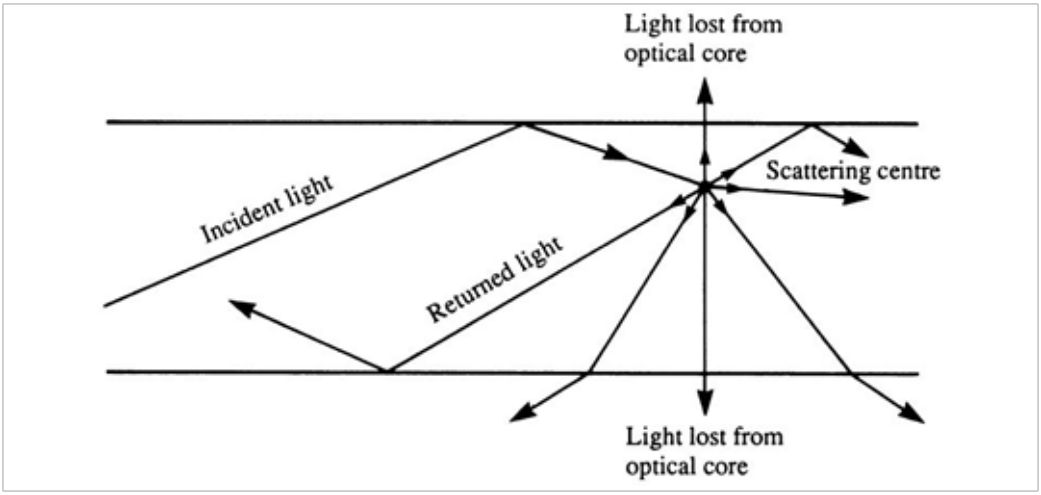


Fig.3. 1: Light scattering in optical fiber

The propagation of light through the core of an optical fiber is based on total internal reflection of the light wave. Rough and irregular surfaces, even at the molecular level, can cause light rays to be reflected in random directions as it is illustrated on Fig.3.2. This is called diffuse reflection or scattering, and it is typically characterized by wide variety of reflection angles.

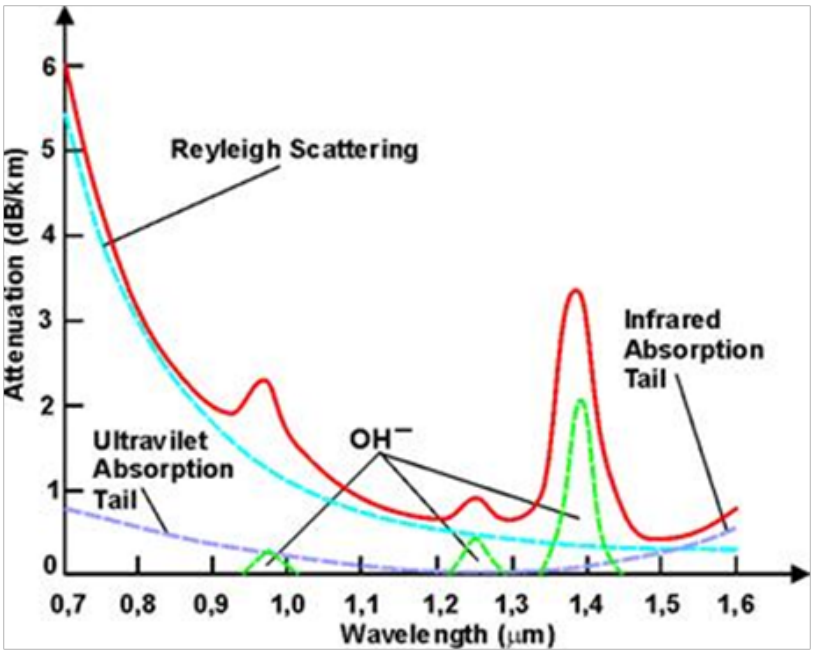


Fig.3. 2 Spectral attenuation of a silica optical fiber

Light scattering depends on the wavelength of the light being scattered.

Thus, limits to spatial scales of visibility arise, depending on the frequency of the incident light-wave and the physical dimension (or spatial scale) of the scattering center, which is typically in the form of some specific micro-structural feature. Since visible light has a wavelength of the order of one micrometer (one millionth of a meter) scattering centers will have dimensions on a similar spatial scale. Thus, attenuation results from the incoherent scattering of light at internal surfaces and interfaces.

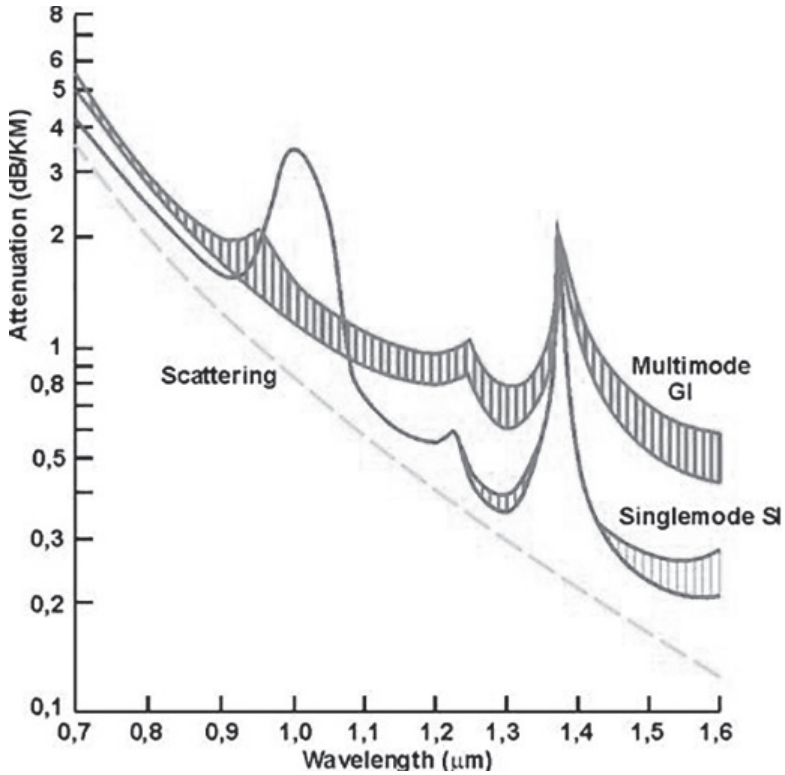


Fig.3. 3 Attenuation of the single mode step index (SM SI) and multimode graded index (MM GI) silica glass fibers as a function of a wavelength.

Rayleigh scattering is a wavelength dependent process that depends on material in homogeneities smaller than wavelength.

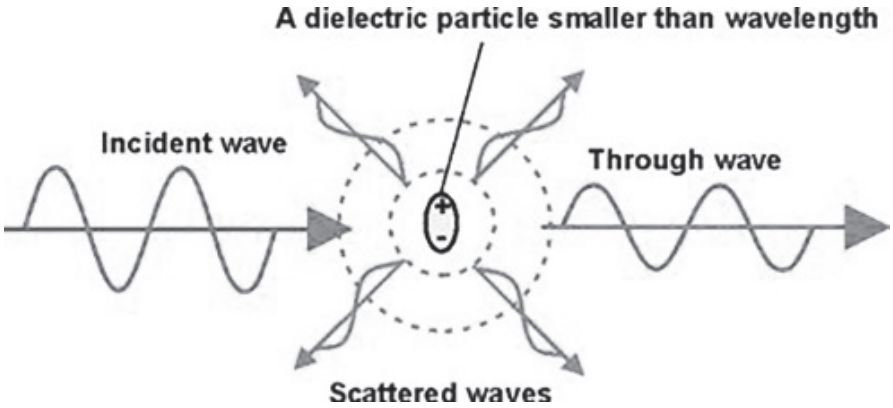


Fig.3. 4 Illustration of Rayleigh scattering effect.

Rayleigh scattering strongly depends on a wavelength: $\alpha \propto \frac{1}{\lambda^4}$

Rayleigh scattering losses can be expressed as: $\alpha_R = 1.7(\frac{0.85}{\lambda})^4$

Rayleigh attenuation restricts the use of fibers at short wavelength. The Rayleigh scattering defines the fundamental limit of reachable fiber attenuation. Within optical windows the Rayleigh scattering is the most significant attenuation mechanism.

GUIDANCE ON SKILLS LAB 3

Remember that this activity is to make student-teacher' analyse how a signal can be transmitted through a medium

- Tell student-teachers the main objective of this activity
- Assist student-teachers to get required materials for the success of the activity as required/stated in student-teachers book
- Assist the student-teachers (if needed) to set up the experiment as stated in the student-teacher's book
- Make sure you guide the student-teachers to follow the set instructions in the student-teacher's book.
- Assist student-teachers to make a report about the outcomes of the experiment and for them to check whether the set objectives have been achieved.

- Appreciate your student-teachers for the work done so that they can be motivated for what they did. This makes student-teachers to find physics applicable and enjoyable.

3.8. Answers for end unit 3 assessment

1. D

2. (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

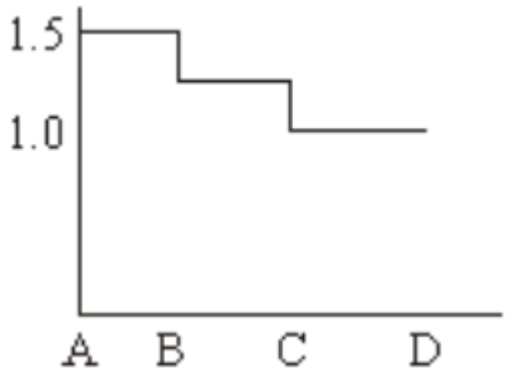
Do not allow not symmetrical

(b) $\sin\theta_C = \frac{1.49}{1.52} \Rightarrow \theta_C = 79^0$

3. (a) (i) Core. So that total internal reflection can occur

(ii) Using equation in 1 (c), the critical angle is 79.4^0

(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.

4. The transmission distance of a fiber-optic communication system has traditionally been limited by fiber attenuation and by fiber distortion.

- **Repeaters**: Repeaters convert the signal into an electrical signal, and then use a transmitter to send the signal again at a higher intensity than was received, thus counteracting the loss incurred in the previous segment. They mostly used to be installed about once every 20 km.

- **Regenerators:** Optical fibers link, in common with any line communication system, have a requirement for both jointing and termination of the transmission medium. When a communications link must span at a larger distance than existing fiber-optic technology is capable of, the signal must be regenerated at intermediate points in the link by optical communications repeaters called regenerators. An optical regenerator consists of optical fibers with special coating (doping). The doped portion is pumped with a laser. When the degraded signal comes into the doped coating, the energy from the laser allows the doped molecules to become lasers themselves. The doped molecules then emit a new strong light signal with the same characteristics as the incoming weak signal. Basically, the regenerator is a laser amplifier for the incoming signal.

- **Optical Amplifiers:** Another approach is to use an optical amplifier which amplifies the optical signal directly without having to convert the signal into the electrical domain. It is made by doping a length of fiber with the rare-earth mineral erbium and pumping it with light from a laser with a shorter wavelength than the communications signal (typically 980 nm). Amplifiers have largely replaced repeaters in new installations.

5. (a) 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.

6. 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 50-200μm in the case of multimode fiber and 10μm 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

7. (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.

8. 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.

3.9. Additional activities (Questions and answers)

3.9.1 Remedial activities

1. The principle called total internal reflection explains why light is not guided in an optical fiber.

   A. True

   B. False

2. The symbol for refractive index is:

   A. n C. M

   B. c D. None of the above

3. Do fibers have losses?

4. Can fibers be bent at right angles? Why?

Answer

1. B 2. A

3. 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. 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.

3.9.2 Consolidation activities

5. Prepare a comparative table between a multimode and a single mode fiber optics

Answer

5.

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

3.9.3 Extended activities

6. Make a study of the following diagram of optical fiber below and discuss its functioning

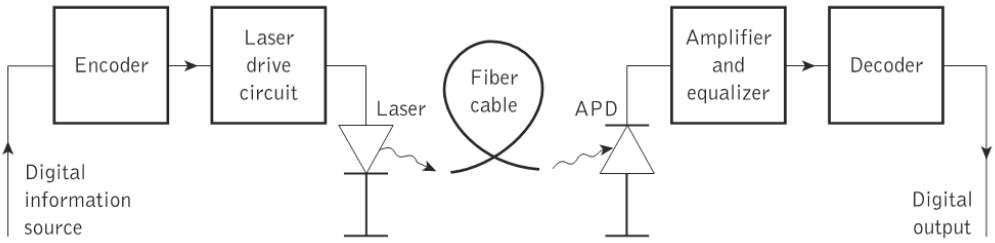


Fig.6. 1 A digital optical fiber link using a semiconductor laser source and an avalanche photodiode (APD) detector

7. When the mean optical power launched into an 8 km length of fiber is $120\ \mu W$, the mean optical power at the fiber output is $3\ \mu W$. 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

6. 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.

7. (a) The overall signal attenuation in decibels through the fiber is:

Signal attenuation $\alpha = 10\log\frac{P_1}{P_o} = 10\log\frac{120\times10^{-6}}{3\times10^{-6}} = 16.0\ dB$

(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:

The signal attenuation of the total length L is $\alpha_{dB}L = 16.0\ dB$

Then $\alpha_{dB} = \frac{16.0\ dB}{8\ km} = 2.0\ dB/km$

c) As $\frac{\alpha}{L} = 2.0\ dB/km$, then the loss incurred along 10 km of the fiber is given by $\alpha = 2\times10 = 20\ dB$

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 $\alpha = 20 + 9 = 29\ dB$

To obtain a numerical value for the input/output power ratio, the relation

Signal attenuation $\alpha = 10\log\frac{P_1}{P_o} \Leftrightarrow \frac{P_1}{P_o} = 10^{\frac{\alpha}{10}}$

Hence $\frac{P_i}{P_o} = 10^{\frac{29}{20}} = 794.3$

UNIT 4

NATURE OF PARTICLES AND THEIR INTERACTIONS

4.1 Key unit competence:

Classify the nature of particle and their interactions

4.2 Prerequisite (knowledge, skills, attitudes and values

The success of this unit relies partly on the mastery of knowledge and skills acquired in Chemistry (Electron configurations of atoms and ions) and other related subjects in previous grades

4.3 Cross cutting issues to be addressed

- **Inclusive education** (promote education for all while teaching):
- Regardless of physical appearance and abilities Student-teachers should be treated equally. This makes the Student-teachers to find out that they are all of great importance.
- **Gender education** (equal opportunity of boys and girls in the lesson participation). Care should be taken that both Sexes are given equal opportunities while in classes. This should be integrated in all lessons in this unit.
- **Environment sustainability**: During delivering different lessons within this unit, Student-Teacher's teachers should know that use of old vehicles like motorcycle, cars and others that burn fuel in their engines is not good as they lead to pollution.

"Our environment is our life"

- **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. Care should be taken to use standard materials while doing practical like standard meter rule, masses and others. Hence, the measure of quantity that should be done using standard equipment.

4.4 Guidance on introductory activity

This activity aims at capturing Student-Teachers' attention and minds towards this concept

- Divide your Student-Teachers into groups (Where possible, mix equally the number of girls to number of boys. If there are student-teachers 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 Student-Teachers to open the introductory activity in the Student-Teacher's book.
- Instruct Student-Teachers to re-write the questions and answer them following the instructions from Student-Teacher's book.
- While Student-Teachers 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 Student-Teachers).
- Together with Student-Teachers harmonize the points and make a summary on the board. Allow Student-Teachers 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

Answers for introductory activity

a) Proton, electron, neutrons, Photons, muon, hadrons …

b) No, some are heavier than others due to their internal structure

c) These particles interact each other. By electric charge if they are charged, or by gravitational force if they are massive particle

d) We can classifier by particle by mass, by interaction, by charge, by spin…

4.5 List of lessons

#	Lesson title	Learning objectives	Number of Periods
1	Fundamental particles	- Explain the concept of an antiparticle - Point out fundamental interactions by exchange of particles	5
2	Classification of particles	- Explain classification of elementary particles - Explain classes of particles by spin - Classify and describe particles by spin. - Appreciate application of elementary particles	5
3	Fundamental forces and interactions	- Interpret concept of an antiparticle. - Outline fundamental interactions by exchange of particles. - Explain the concepts of matter and antimatter. Describe elementary particles.	3
4	End unit assessment		2

Lesson 1: FUNDAMENTAL PARTICLES

a) Learning objectives

- Explain the concept of an antiparticle
- Point out fundamental interactions by exchange of particles

b) Teaching resources

- Internet and textbooks (Use all reference books in Student-Teacher's book)

- Projectors, computer, videos, animation and simulations about fundamental particles (https://phet.colorado.edu/en/simulations/category/chemistry)

c) Prerequisites/Revision/Introduction

- Through guided discovery, assist Student-Teachers 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 Student-Teachers questions about elementary particles and four fundamental forces and their unification

d) Learning activity 4.1

Guidance on the learning activity 4.1

This lesson focuses on making Student-Teachers understand apply the concept of fundamental particles

- Tell Student-Teachers to write down the question in their notebooks.
- While in groups, let the Student-Teachers brainstorm the question together.
- Tell them to write their suggestions on a paper/their note books
- As Student-teachers are discussing, move around and see the progress of their discussions.
- 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 on the board. They can have a power point presentation if they are able to prepare it.
- 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 characteristics and discuss with other Student-Teachers.
- Connecting to what Student-Teachers have presented, guide Student-Teachers to comprehensively review an atom. And link the discussion in a way that you are able to discuss, the electron and photon, neutron, neutrino, positron and other antiparticles.
- Let them note down (in their textbooks) for future reference.

Answers for activity 4.1

a). An **atom** is the smallest constituent unit of ordinary matter that constitutes a chemical element.

b). An atom itself is made up of three tiny kinds of particles called subatomic particles: protons, neutrons, and electrons.

c). subatomic particles

e) Answers for application activity 4.1

1. A 2.C 3.B 4.B 5.A 6.D

Lesson 2: CLASSIFICATION OF PARTICLES

a) Learning objectives

- Explain classification of elementary particles
- Explain classes of particles by spin
- Classify and describe particles by spin.
- Appreciate application of elementary particles

b) Teaching resources

- Text books (all reference books in Student-Teachers' book), Projectors, computer and internet.
- Models, videos and simulations about classification of particles specifically elementary particles(https://phet.colorado.edu/en/simulations/category/chemistry)

c) Prerequisites/Revision/Introduction

This lesson requires Student-Teachers to have had knowledge and skills about fundamental particles (discussed) in the previous lesson.

d) Learning activity 4.2

Guidance on learning activity 4.2

- Divide Student-Teachers into groups (you can decide the method to use depending on your lesson plan and the nature of your class) and tell them to turn to activity 4.2
- Let them brainstorm the questions in the activity while noting their suggestions in their notebooks.
- You can move around and mark their work. In case there is a Student-Teacher with a problem try to guide and help him or her.
- Call one or two groups or individuals to present the work to the whole class.
- Let other Student-Teachers contrast their findings to the result presented, hence, assist them to draw a suitable conclusion. And let them note down important information in their notebooks for future reference.

Answers for activity 4.2

(a) to (c) . **Particles** have various intrinsic properties, including electric charge, mass, color charge, and spin. Quarks are the only elementary particles in the Standard Model of Particle Physics to experience all four fundamental interactions, also known as *fundamental forces* (electromagnetism, gravitation, strong interaction, and weak interaction), as well as the only known particles whose electric charges are not integer multiples of the elementary charge.

e) Answers for application activity 4.2

1. C 2. B 3. A 4. C 5. B 6. D 7. B 8. B 9. B
10. A.

11. (*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 = ½ 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.

12. 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 muon; the tauon, and the three types of neutrino. While Hadrons are the class of particles that chiefly interacts through the strong nuclear force; contains neutron, the proton, the pion, and other particles of large mass.

c) Meson: the elementary particle originally predicted to be responsible for the string nuclear force; now a class of particles. While baryon number is a property of elementary particles; quarks have a baryon number of $\frac{1}{2}$

13. 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).

14. 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).

Lesson 3: FUNDAMENTAL FORCES AND INTERACTIONS

a) Learning objectives

- Interpret concept of an antiparticle.
- Outline fundamental interactions by exchange of particles.
- Explain the concepts of matter and antimatter. Describe elementary particles.

b) Teaching resources

- Textbooks and internet.
- Projectors, videos, simulation(https://phet.colorado.edu/en/simulations/category/physics and https://phet.colorado.edu/en/simulations/category/chemistry)

c) Prerequisites/Revision/Introduction

Student-Teachers should have knowledge about the force that exists between two masses (Newton's law of gravitation) and charges (coulomb's law of electrostatics)

a) Learning activity 4.3

Guidance on activity 4.3

This activity aims at capturing Student-Teachers' attention and minds towards fundamental forces interaction of particles

- Decide the method of teaching and tell them to turn to the activity 4.2 in the Student-Teacher's book.
- Tell them to brainstorm the questions either as in groups or class depending on the method you applied.
- While Student-Teachers are brainstorming/discussing this activity, you move around and assist those that may have contradiction
- 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 Student-Teachers harmonize the points and make a summary on the board. Allow Student-Teachers 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 fundamental forces and interaction of particles. (You can use work in Student-teachers' book).

Answers for activity 4.3

a) The **intrinsic strengths** of the forces can be compared relative to the *strong* force, here considered to have *unit strength* (i.e., = 1.). In these terms, the *electromagnetic* **force** has an intrinsic strength of (1/137). The *weak* **force** is a billion times weaker than the **strong force**. The weakest of them all is the *gravitational* **forc**e. This may seem strange, since it is strong enough to hold the massive Earth and planets in orbit around the Sun!

We can compare the relative strengths of the electromagnetic *repulsion* and the gravitational *attraction* between two protons of unit charge using Newton's law of gravitation that that the gravitational force between two bodies a distance ***r*** apart is

$$F_G = G\frac{Mm}{r^2}$$

We see now what is meant by *intrinsic* **strength**. It is given by the magnitude of the universal force constant, in this case, *G,* independent of the masses or distances involved.

In similar terms, the electromagnetic force between two particles is proportional to the product of the two charges (*Q* and *q*) and inversely to the distance ***r*** squared:

$$F_G = k\frac{Qq}{r^2}$$

b) Answers for application activity 4.3

1. 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.

2. E

3. By 1940, the recognized forces of nature (*fundamental* **forces)** were four:
   - *gravitational forces* between objects, mediated by graviton
   - *electromagnetic forces* between electric charges, mediated by photon
   - strong force *(nuclear force)* between subatomic particles, mediated by gluon
   - *weak forces* that arise in certain radioactive decay processes, mediated by the $W^{\pm}$ and Z^{0} bosons

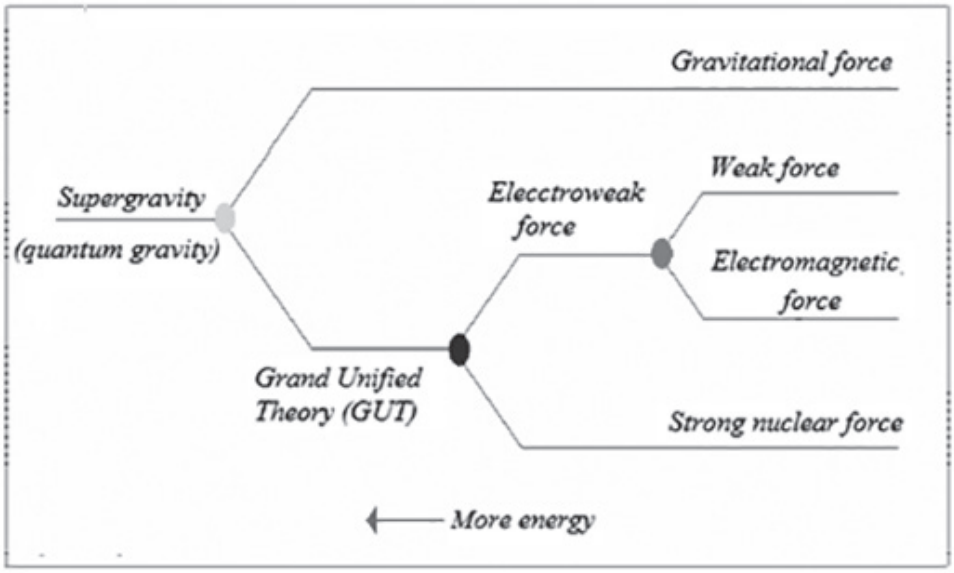
4. Positron is an antimatter particle; proton is a matter particle

   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

5.



4.6. Summary of the unit

Particle other than photon are classified as hadrons or leptons.

Hadrons interact primarily through the strong force. They have size and structure and hence are not elementary particles. There are two types of hadrons, **baryons** and **mesons**. Mesons have a baryon number of 0 and have either zero or integer spin. Baryons, which generally are the most massive particles, have nonzero baryon numbers and spins of ½ or 3/2. The neutron and proton are examples of baryons.

Leptons have no structure or size and are considered truly elementary particles. Leptons interact only through the weak and electromagnetic forces. they are six leptons: electron, muon, tau and their associated neutrinos: electron-neutrino, muon-neutrino and tau-neutrino.

All hadrons are composed of smaller units known as **quarks**, which have fractional electric charges and baryon numbers of 1/3 and come in six flavors: **u**p, **d**own, **t**op, **b**ottom, **s**trange, **c**harm. Each baryon contains three quarks, and each meson contains one quark and one antiquark. Quarks have a property called **color** and strong force between quarks is referred to as the **color force**.

An antiparticle and particle have the same mass but opposite electric charge, and other properties may also have opposite values, such as lepton number and baryon number.

Quarks and leptons have an intrinsic angular momentum called *spin*, equal to a half-integer (½) of the basic unit and are labeled as *fermions*.

The decay of strange particles provides our first example of a *conditional conservation law*, one that is obeyed in some interactions and not in others. By contrast, several conservation laws are obeyed in *all* interactions. These include the familiar conservation laws; energy, momentum, angular momentum, and electric charge. These are called *absolute conservation laws.* Baryon number and the three lepton numbers are also conserved in all interactions. Strangeness is conserved in strong and electromagnetic interactions but *not* in all weak interactions.

4.7. Additional information for the tutor

The COLOR theory

The attractive interactions among quarks are mediated by massless spin 1 bosons called **gluons** in much the same way that photons mediate the electromagnetic interaction or that pions mediated the nucleon–nucleon force in the old Yukawa theory.

Quarks and leptons have an intrinsic angular momentum called *spin*, equal to a half-integer (1/2) of the basic unit and are labeled as *fermions*. Fermions obey the exclusion principle on which the Fermi-Dirac distribution function is based. This would seem to forbid a **baryon** having two or three quarks with the same **flavour** and same spin component. For example, the proton has

two u quarks and one d quark, and an omega (Ω) particle (a baryon) has three s quarks. To avoid this difficulty, it is assumed that each of the six quark (**u, d, s, c, b,** and **t**) comes in three varieties referred as **flavor**, which are called *color.* According to theory, each flavor of quark can have one of three colors, usually designated **Red, green, and blue**. The exclusion principle applies separately to each color.

Fig.4. 1 Colour property assigned to quarks, keeping them in different quantum states to avoid violation of the Pauli Exclusion Principle

A **baryon** always contains one red, one green, and one blue quark, so the baryon itself has no net color.

Each **gluon** has a color–anticolor combination (for example, blue–antired) that allows it to transmit color when exchanged, and color is conserved during emission and absorption of a gluon by a quark. The gluon-exchange process changes the colors of the quarks in such a way that there is always one quark of each color in every baryon. The color of an individual quark changes continually as gluons are exchanged.

Each quark is assumed to carry a *color charge*, analogous to electric charge, and the strong force between quarks is referred to as the **color force**. This theory of the strong force is called **quantum chromodynamics,** to indicate that the

force acts between color charges (and not between, say, electric charges). The strong force between two hadrons is considered to be a force between the quarks that make them up, as suggested in Fig.4.2

Similar processes occur in **mesons** such as pions. The quark–antiquark pairs of mesons have canceling color and anticolor (for example, blue and antiblue), so mesons also have no net color. Mesons are white or corless

Fig.4. 2 (a) The force between two quarks holding them together as part of a proton, for example, is carried by a gluon, which in this case involves a change in color. (b) Strong interaction $n + p \rightarrow n + p$ *with the exchange of a charged* π *meson (+ or -) depending on whether it is considered moving to the left or to the right)*

Suppose a pion initially consists of a blue quark and an antiblue antiquark. The blue quark can become a red quark by emitting a blue–antired virtual gluon. The gluon is then absorbed by the antiblue antiquark, converting it to an antired antiquark (Fig. 4.3).

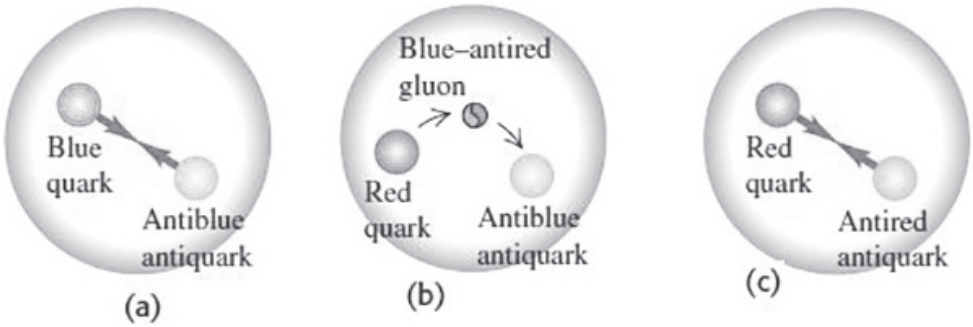


Fig.4. 3 (a) A pion containing a blue quark and an antiblue antiquark. (b) The blue quark emits a blue–antired gluon, changing to a red quark. (c) The gluon is absorbed by the antiblue antiquark, which becomes an antired antiquark. The pion now consists of a red–antired quark–antiquark pair. The actual quantum state of the pion is an equal superposition of red–antired, green–antigreen, and blue–antiblue pairs.

Color is conserved in each emission and absorption, but a blue–antiblue pair has become a red–antired pair.

Such changes occur continually, so we have to think of a pion as a superposition of three quantum states: blue–antiblue, green–antigreen, and red–antired. In terms of quarks and gluons, these mediating virtual mesons are quark–antiquark systems bound together by the exchange of **gluons**.

4.8. Answers for end unit 4 assessment

1. (*B*, *E*, *F*, *G*) Atoms are not fundamental, because they are made up of protons, neutrons, and electrons. Protons and neutrons are not fundamental, as they are made up of quarks. The fundamental particles are leptons (including electrons), quarks, and gauge bosons (including the photon and Higgs boson).

2. (A) Unlike the electron, the positron has positive charge and a negative lepton number. Unlike the charge and lepton number, the mass of the positron has the same sign (and magnitude) as the mass of the electron.

3. (E) A common misconception is that the strong force is a result of just the exchange of ϖ 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 ϖ 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. Student-Teachers who answer (*d*) should be given credit for their answer as well.

4. (*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.

5. C 6.B

7. Positively charged electron // anti-electron

8.
   (a)True, they have half-integer spin
   (b) True, hadrons include both baryons and mesons.
   (c)False, hadrons include both baryons and mesons.
   (d) False, are 0 spin particles
   (e)False, they are elementary particles
   (f) True, the typical ratio of their decay is of the order of 10^{14} at **ordinary energies.**
   (g) False, the electron interacts with the proton via the weak interaction and the gravitational interaction).

4.9. Additional activities

4. 9.1 Remedial activities

1. The gluon is the force carrier for

   A. Weak force C. The fifth force

   B. Gravity D. Strong force E. electromagnetic force

2. Fundamental or elementary particles are particles that aren't made up of small particles. What is the most common types of fundamental particle in the universe?

   A. Atom C. Neutrino

   B. Meson D. Quarks

3. What are the fundamental particles of an atom?

   A. Quarks, gluons and electrons

   B. Protons, neutrons and electrons

   C. The nucleus and electron orbit

   D. An atom cannot be broken down into anything small than itself

4. Which of the following particles interacts with itself

   A. Neutrino

   B. Photon

   C. Gluon

5. Which of the four fundamental forces has the shortest rang?

   A. Strong C. Electromagnetism

   B. Weak D. Gravity

Answer

1. D 2. C

3. a. Atoms are made up of fundamental particle called **Quarks, gluons** and **electrons**. Quarks and gluons make up protons and neutrons, which find in nucleus of an atom. Each proton and neutron consists of three quarks held together by gluons, which transmit the strong force. Electrons, which orbit around the nucleus, are the third type of fundamental particles in an atom.

4. C 5. B.

4.9.2 Consolidation activities

6. What happens when antimatter collides with matter?

Answer

6. Antimatter is the same as matter in every, looks the same, behaves the same, except its particles have electrical charges opposite to matter for example electrons are negatively charged while a positron is positively charged. It mains the positron is 'antiparticle' of the electron.

4.9.3 Extended activities

7. In which of the four force interactions does each of the following particles play a role?

   a) Electron c) proton

   b) positron d) neutron e) neutrino

8. Why does pair production need a nucleus?

Answer

7. a**)** Electromagnetic, weak and gravity

   b) Electromagnetic, weak and gravity

   c) Weak, strong, and gravity

   d) Electromagnetic, weak, strong and gravity

   e) Weak

8. 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'.

UNIT 5

X-RAYS AND ITS EFFECTS

5.1 Key Unit Competence

Suggest and criticize possible effects of X-rays

5.2 Prerequisite knowledge and skills

The success of this unit relies on understanding the nature and characteristics of electromagnetic waves.

5.3 Cross-Cutting Issues to be addressed

- **Inclusive education** (promote education for all while teaching):
- Regardless of physical appearance and abilities student-teachers should be treated equally. This makes the student-teachers to find out that they are all of great importance. In spite of their physical ability, student-teachers with impairment as normal student-teachers should be aware of the uses and dangers of x rays.
- **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.
- **Environment sustainability**: During delivering different lessons within this unit, let student-teachers 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 student-teachers 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.

5.4 Guidance on the introductory activity

This activity aims at capturing student-teachers' attention and minds towards this concept of x rays, their production, uses and dangers

- Divide your student-teachers 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 Student-teachers open the student-teachers' Book to the introductory activity of the unit 5 and then instruct them to re-write the questions and answer them following the instructions from student-teacher's book
- While student-teachers 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 student-teachers harmonize the points and make a summary on the board. Allow student-teachers to write the main points in their notebooks. And then linking to the summary and what have discussed in class, emphasize on the uses of **x rays, production, 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.

Answers for the introductory activity.

1. **These services offers imaging:** This allows a technician to get detailed information about structural or disease-related changes

2. The different types of radiations include: X-rays and Laser.

3. X-rays are produced when fast moving electrons strike matter.

4. Refer to properties of X-rays in Students book.

5. In mining (Detection of minerals)

In research

In agriculture

In crystallography. For Explanations, refer to student's book under lesson 5.3 in student-teachers book in applications and dangers of X-rays

6. Refer to student's book in Lesson 5.3 under dangers of X-rays in student-teacher's book

7. The following are some of the recommendations one should offer to avoid dangers caused by X-rays.

   (i) Protective suits and wears such as gloves and eye glasses made of *lead* are used always when handling these radiations. These shields protect the workers from X-ray exposure.

   (ii) Workers who operate equipment's that use X-rays must wear special badges which detect the amount of radiation they are exposed to.

   (iii) Food and drinks are not allowed in places where X-radiations are present.

   (iv) Experiments that involve these radiations (X-rays) substances should be conducted in a room surrounded by thick concrete walls or lead shields.

   (v) Equipment that use X-rays should be handled using remote-controlled mechanical arms from a safe distance.

5.5 List of lessons

S/ No	Lesson Title	Learning Objectives	Periods
1	Production of x-rays	- Explain the production of x-rays - Describe and explain the production of x-rays - Recognize how the intensity and the quality of x-rays can be controlled	5
2	Properties of x-rays and Characteristic features on X-ray spectrum	- State the properties of x rays - Analyse the effects of x rays - Draw X-ray spectrum - Identify the origins and characteristic features of X-ray spectrum.	6
3	Application and Dangers of x-rays	- Outline the application of x rays in medicine, industry and scientific research - Analyse application of x rays in medicine, industries, research and forensic science. - Appreciate the uses of x rays in medicine, industry and scientific research. - Suggest the possible dangers of X-rays. - Appreciate the uses and the dangers of x rays	5
4	End unit Assessment		2

Lesson 1: PRODUCTION OF X-RAYS

a) Learning objectives

- Explain the production of x-rays
- Describe and explain the production of x-rays
- Recognize how the intensity and the quality of x-rays can be controlled

b) Teaching resources

- Textbooks, internet, video, simulations, Cathode ray television (CRT) set

c) Prerequisites/Revision/Introduction:

Through guided discovery, assist student-teachers to describe the process of x ray production experiment.

d) Learning activity 5.1

Guidance on learning activity 5.1

This activity aims at capturing students' attention and minds towards this concept of x ray production.

- Decide the method of teaching and tell them to open on the activity 5.1 in the learner's book.
- Instruct student-teachers to read the scenario/text in the activity 5.1 in the learner's book
- While student-teachers 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 student-teachers harmonize the points and make a summary on the board. Allow student-teachers 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. (You can use work in student-teachers' book)

- Link this lesson to real life like in the photography of radiology at hospital, uses of CRT TV.

Answer to activity 5.1

1. These electrons need to be accelerated so that their energy is greater to overcome anything that would stop them from reaching the target.

They need to be decelerated so that all their kinetic energy is converted into other forms as which includes production of X-rays. Thus, deceleration of electrons produces x rays

2. Changing the energy of bombarding electrons changes the quality of X-rays produced. For example, weak targeted electrons would give rise to production of soft (Less energetic X-rays) while strong/energetic electrons lead to production of hard X-rays

3. It is possible with all the required materials and trained personnel to produce the X-rays. And Even there are some places in this country where X-rays are produced; e.g some laboratories and hospitals.

Answers for the application activity 5.1

1 & 2 a). Refer to the student teachers' book in concept 5.1.1.

2 b) i) Soft X-rays.

ii) Hard X-rays

Lesson 2: PROPERTIES OF X-RAYS AND CHARACTERISTIC FEATURES OF AN X-RAY SPECTRUM

a) Learning objectives

- State the properties of x rays
- Analyse the effects of x rays
- Draw X-ray spectrum
- Identify the origins and characteristic features of X-ray spectrum.

b) Teaching resources

- Internet, textbooks, online videos, animations and simulations

c) Prerequisites/Revision/Introduction

Through guided discovery, assist student-teachers to discover the properties of x rays and then the characteristic feature of x ray spectrum.

You can ask them questions like: what is electromagnetic radiation? Or ask them to draw the electromagnetic spectrum diagram according to their wavelength.

Learning activity 5.2

Guidance on the activity 5.2

This lesson focuses on making students understand apply the concept of x-ray spectrum and its characteristics.

- Tell student-teachers to write down the question in their notebooks.
- While in groups, let the student-teachers brainstorm the question together.
- Tell them to write their suggestions on a paper
- As student teachers are discussing, move around and see the progress of their discussions.
- 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 on the board.
- 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 characteristics and discuss with other students.
- Connecting to what student-teachers have presented, guide student-teachers to describe briefly the characteristic of x rays.
- Let them note down (in their textbooks) for future reference.

Answers for activity 5.2

The following are the main properties of X-rays:

- X-rays can penetrate through most substances. However, their penetrating power is different.
- X-ray can produce fluorescence in different substances.
- X-rays can blacken photographic plate. The degree of blackening depends upon the intensity of x-rays incident upon the plate. Thus, X-ray intensity can be measured with the help of photographic plates.

- X-rays ionize the gas through which they travel. The ionizing power depends on the intensity of the x-ray beam. Thus, X-ray intensity can also be measured by measuring their ionizing power.
- X-rays are not deflected by electric or magnetic fields. This proves that unlike cathode rays or positive rays they are not a beam of charged particles.
- X-rays travels on a straight line like ordinary light.
- X-ray are both reflected and refracted.
- X-rays can be diffracted with the help of crystalline substances. They can also be polarized.

Answers to application activity 5.2

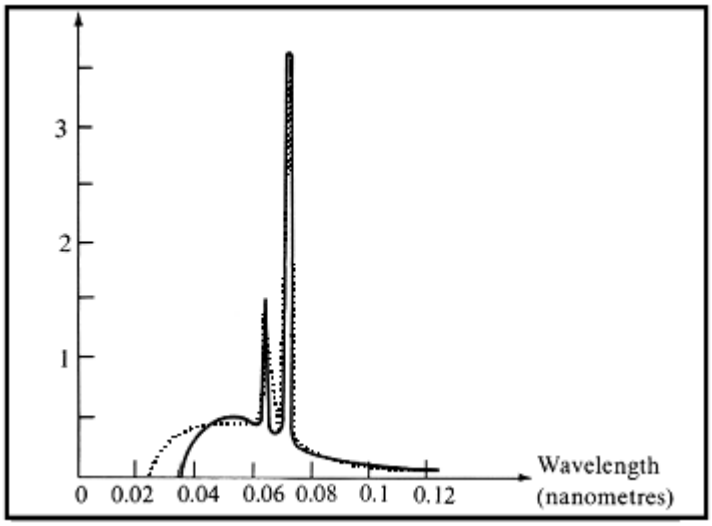
1. Refer to answers for activity 5.2

2. 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 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.



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 Figure above

3. (i) $E = eV = 1.602\times10^{-19}\times10^{4} = 1.602\times10^{-15} J = 10^{4}\ eV$

(ii) $\lambda_{mim} = \dfrac{hc}{eV} = \dfrac{3\times10^{8}\times6.67\times10^{-34}}{1.602\times10^{-19}\times10^{4}} = 1.25\times10^{-10}\ m$

(iii) $E_{\max} = \dfrac{hc}{\lambda_{\min}} = \dfrac{3\times10^{8}\times6.67\times10^{-34}}{1.25\times10^{-10}} = 602\times10^{-15}\ J$

Lesson 3: APPLICATION AND DANGERS OF X-RAYS

a) Learning objectives.

- Outline the application of x rays in medicine, industry and scientific research
- Analyse application of x rays in medicine, industries, research and forensic science.

- Appreciate the uses of x rays in medicine, industry and scientific research.
- Suggest the possible dangers of X-rays.
- Appreciate the uses and the dangers of x rays

b) Teaching resources

- Internet, textbooks, scenario, demonstration, field visit or case study, online simulations (https://phet.colorado.edu/) and animation or video

c) Prerequisites/Revision/Introduction

Through guided discovery, assist student-teachers to discover different applications and dangers of x rays.

This lesson focuses on taking student at a level of analysing and evaluating the uses of x rays in real life, i.e the applications and dangers of x rays.

a) Learning activity 5.3

Guidance on activity 5.3

- Divide student-teachers into groups and tell them to open activity 5.3
- Let them brainstorm the questions in the activity.
- Let them write their suggestions into their notebooks
- You can move around and mark their work. In case there is a student with a problem try to guide and help him or her.
- Call one or two groups or individuals to present the work to the whole class.
- Let other student-teachers contrast their findings to the result presented, hence, assist them to draw a suitable conclusion.

Answers for activity 5.3

1. 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. The following are some of the precautions that should be taken to avoid dangers that may be caused due to exposure of X-rays
   - Protective suits and wears such as gloves and eye glasses made of *lead* are used always when handling these radiations. These shields protect the workers from X-ray exposure.

- Workers who operate equipment's that use X-rays must wear special badges which detect the amount of radiation they are exposed to.
- Food and drinks are not allowed in places where X-radiations are present.
- Experiments that involve these radiations (X-rays) substances should be conducted in a room surrounded by thick concrete walls or lead shields.
- Equipment that use X-rays should be handled using remote-controlled mechanical arms from a safe distance.

Answers for application activity 5.3

The questions **1, 2,** and **3** requires student teachers to explain how X-rays are used in different fields, Dangers, and precautions

Refer to Student-teacher's book on 5.3.1 and 5.3.2 for answers.

5. 6 Summary of the unit

- **X-RAYS NATURE:** X-rays with energies ranging from about to 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 of electromagnetic wave (velocity of photon) with frequency and wavelength is given by the relation: $c = \lambda v$
- Each photon has an energy E, which is proportional to its frequency:

  $$E = hf = \frac{hc}{\lambda}$$
- Where, $c = 2.99792458\ m/s \approx 3.0 \times 10^{8}\ m/s$ *and* $h = 6.63 \times 10^{-34}\ J.s$ is the Plank constant. The momentum p is given by, 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 n 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.

5.7 Additional information for Tutor

5.7.1 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}Å to 100 Å; conventional X-ray spectroscopy is largely confined to the region of about 0.1 Å to 25 Å. (1 Å$=1\times10^{-10}m$)

X-ray spectroscopy is a form of optical spectroscopy that utilizes emission, absorption, scattering, fluorescence, and diffraction of X-ray radiation

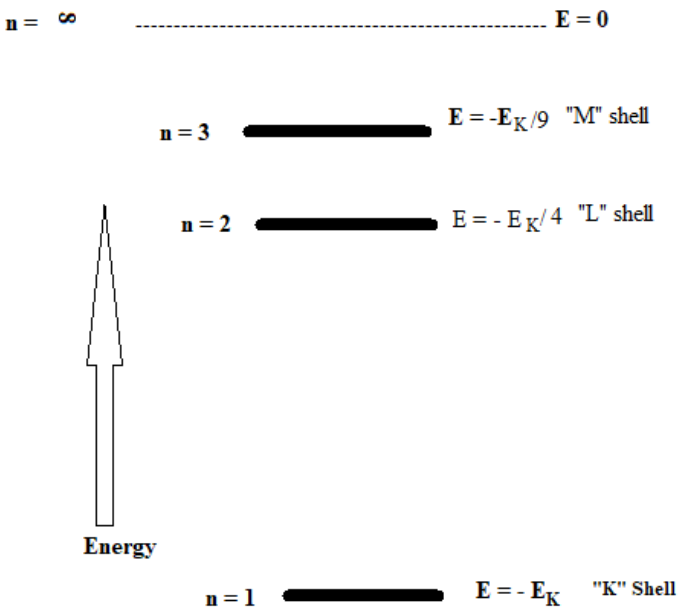
The basics: X-rays are short-wavelength (hence, high frequency, and hence, relatively high energy) electromagnetic radiation. Two ways to produce X-rays:

- Deceleration of high-energy electrons

- Electronic transitions involving inner-orbital electrons

Approximate wavelength range: 10^{-4} nm - 10 nm and the wavelength range used in conventional applications: 0.01 nm to 2.5 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 sodium, 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 atom. However, for X-ray emissions of importance in elemental analysis, a simplified treatment is enough and the diagram below is useful.

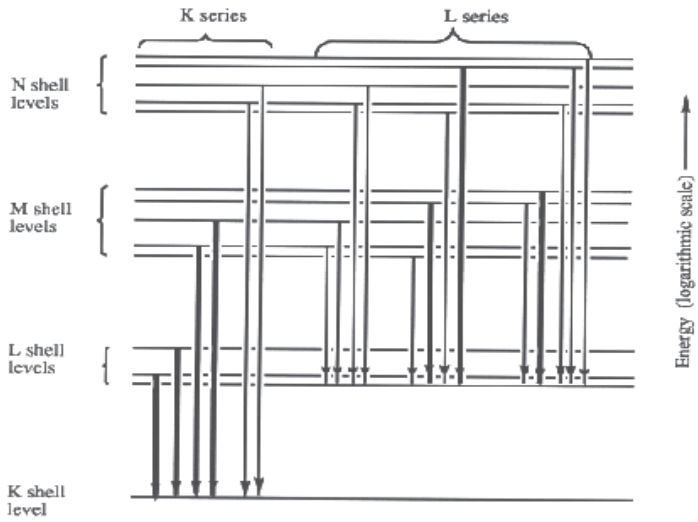


Fig.5. 1 Partial energy level diagram showing common transitions leading to X–radiation. The most intense lines are indicated by the widest arrows.

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/Å for Intense X–ray Emission Lines

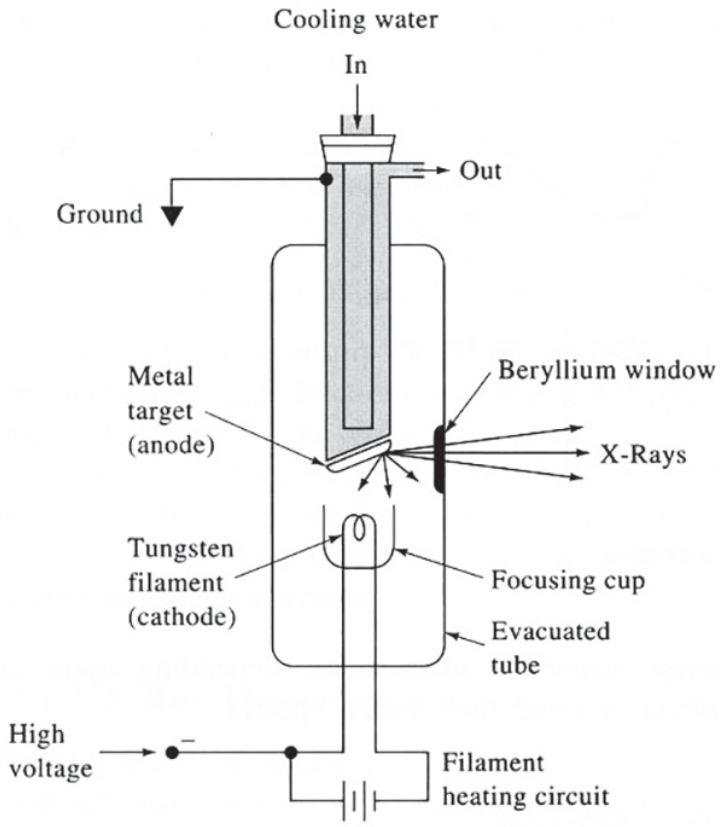
Element	K Series		L Series	
	a1	b1	a1	b1
Na	11.909	11.617	–	–
K	3.742	3.454	–	–
Cr	2.290	2.085	21.714	21.323
Rb	0.926	0.829	7.318	7.075
Cs	0.401	0.355	2.892	1.282
W	0.209	0.184	1.476	1.282
U	0.126	0.111	0.911	0.720

(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.

5.7.2 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:

1) 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:

$$hf_{\max} = \frac{hc}{\lambda_{\min}} = eV$$

where, $f_{\max}$ 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.

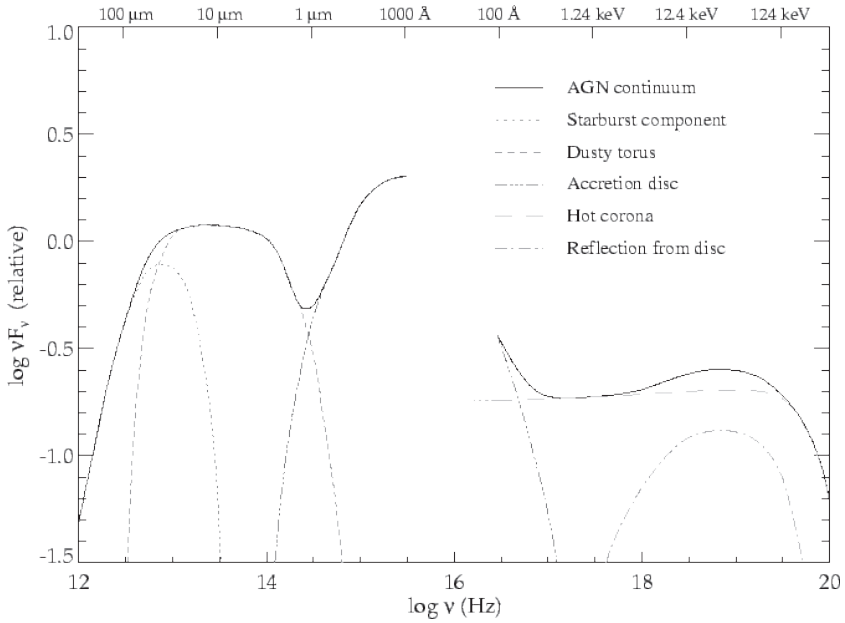


Fig.5. 2 Schematic representation of an AGN continuum spectrum including a possible source for each emission component.

Line Spectra from Electron Beam Source

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 colour, 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 colour.

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.

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 accepts the

energy of ultraviolet photons and emits 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 colour, which is what we observed. The spectral lines of krypton indicate another red light, however, we observed a cool blue colour. Argon's prominent lines also imply a red colour, which does not match the observed lavender-purple colour. 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:

$$hf_{\max} = \frac{hc}{\lambda_{\min}} = eV$$

Where

- P_0 incident beam power,
- P transmitted beam power,
- x path length in cm

We can rewrite this to take into account the density of the sample:

$$\ln \frac{P_0}{P} = Mx$$

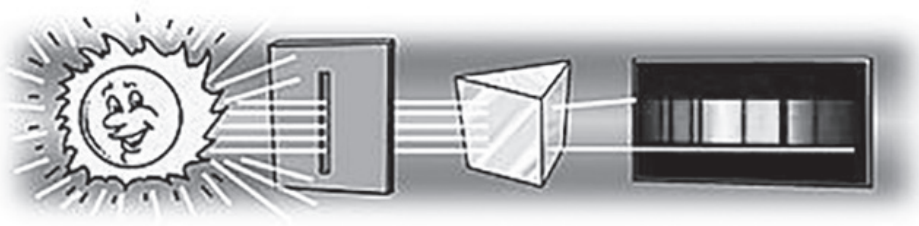
where M is the mass absorption coefficient.

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:

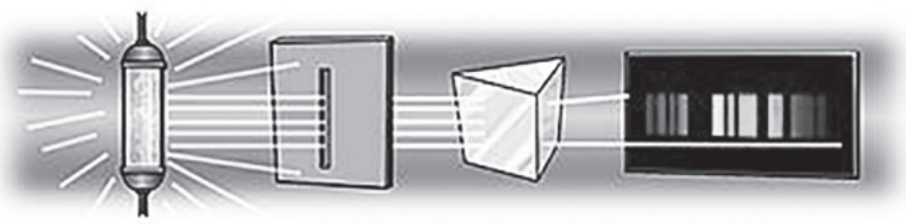
So $M_{tot} = W_{AA} + W_{BB} + ... + W_{nn}$

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.



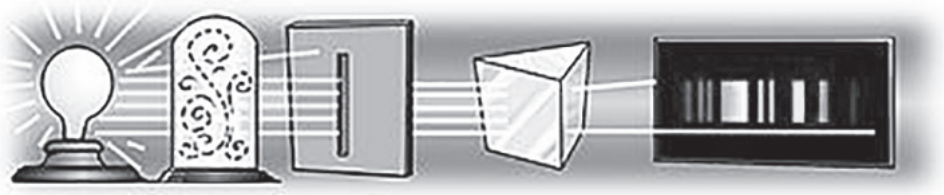
Dark lines? That's the opposite of what we've been talking about. You've been telling me that different elements create a series of bright lines at certain wavelengths.

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.)

GUIDANCE ON SKILLS LAB

This activity aims at making student teachers to appreciate what they have been studying in this unit.

- Help students teachers to organise their trip to the nearest hospital. You can call the administration of the hospital of interest so that they can prepare for your student teachers.
- On the day of going, make sure that all your student teachers are in school uniform for proper recognition and you have to accompany them.
- You may also set guiding questions to supplement the questions in the Student-teacher's book.
- Tell them to be disciplined and focused as they receive explanations from the experienced laboratory technician.

- Make sure you tell them to note down important information as they are explaining for them.
- Remind them that they are to do a comprehensive report. Help them in doing that report if need be.
- Mark their reports and grade them.
- Make sure that they harmonise their findings and connect them to what they have covered in this unit.

5.8 Answers for end unit 5 assessment

1. Solution to question 1 is summarized in the table below:

i.	ii	iii	iv	v
C	B	A	D	A

2.

i) $P = VI = (30\times10^{3})(2.0\times10^{-3}) = 60\,W$

ii) $I = Ne \Leftrightarrow N = \frac{I}{e} = \frac{2\times10^{-3}}{1.602\times10^{-19}} = 1.25\times10^{16}$ where N is the number of electrons stricking the target per second

iii) $\frac{1}{2}mv^{2} = eV \Leftrightarrow v = \sqrt{\frac{2(1.602\times10^{-19})(3\times10^{4})}{9.11\times10^{-31}}} = 1.03\times10^{8}\ m/s$

$$\lambda_{\min} = \frac{hc}{eV} = \frac{(6.67\times10^{-34})((3\times10^{8})}{(1.602\times10^{-19})(3\times10^{4})} = 4.2\times10^{-11}\ m = 0.42\ nm$$

3. $$h = \frac{E}{f_{\max}} = \frac{E\lambda_{\min}}{c} = \frac{4.8\times10^{-15}\times4.1\times10^{-11}}{2.998\times10^{8}} = 6.56\times10^{-34}\ J\cdot s$$

4. $$\lambda_{mim} = \frac{hc}{eV} = \frac{3\times10^{8}\times6.63\times10^{-34}}{1.602\times10^{-19}\times20\times10^{3}} = 6.21\times10^{-11}\ m$$

5. 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_α line is from the transition from n = 2 to n = 1 energy level, E = (69.5 – 11.3) = 58.2 keV

k_β 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) $$\lambda = \frac{hc}{E} = \frac{6.67\times10^{-34}\times3\times10^{8}}{58.2\times10^{3}\times1.602\times10^{-19}} = 2.1\times10^{-11}\ m$$

$$\lambda = \frac{hc}{E} = \frac{6.67\times10^{-34}\times3\times10^{8}}{67.2\times10^{3}\times1.602\times10^{-19}} = 1.8\times10^{-11}\ m$$

6.

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

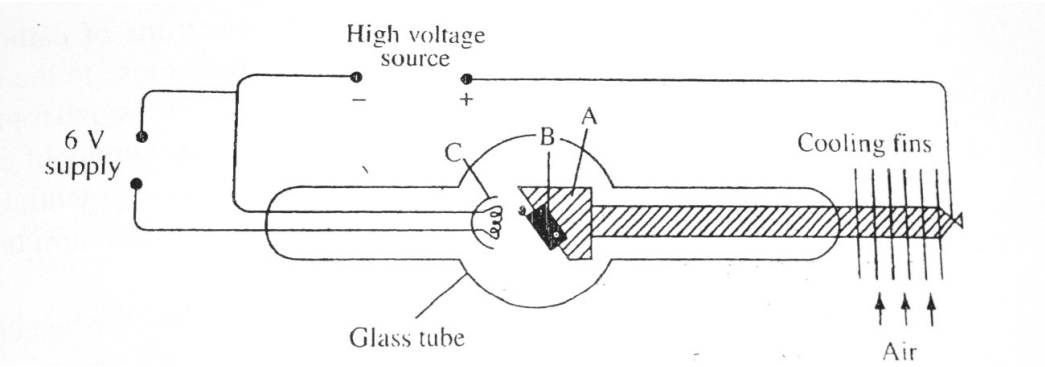
G: beam of electron towards the anode

H: X rays produced

5.9 Additional activities

5.9.1 Remedial activities and answers

1. The figure below shows the structure and circuit of a modern x rays tube



(a) Indicate on the diagram the path of the x-ray beam supplied by the tube.

(b) Name the part marked C and state its function

(c) Name the metals used in parts A, B and state why there are suitable for use in the tube

(d) Why are cooling fins necessary?

(e) Describe how the x rays are produced.

(f) What is the speed of x rays?

(g) What are hard and soft x rays?

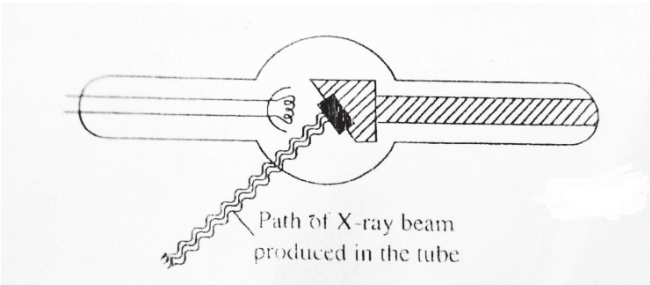
(h) Briefly describe two uses of x rays

(i) In which way do x rays differ from gamma rays.

(j) Explain why people are advised against exposing themselves to x rays unless it is unavoidable.

Answer:

a)



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;

B- Molybdenum or tungsten has a very high melting point and does not melt when heated.

d) The cooling fins remove much of the heat conducted along the thick copper rod A.

e) 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 . 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 unavoidable.

2. How does the radiographer increases 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

3. 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.

4. (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) $\lambda = \frac{hc}{E} = \frac{6.67\times10^{-34}\times3\times10^{8}}{(95\times10^{3}\times1.602\times10^{-19}} = 1.3\times10^{-10}\ m = 0.13\ nm$

(b) The x rays are of high quality. Quality od 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

5.9.2 Consolidation activities

5. 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.

6. Determine the tube voltage of an x ray tube which is 1.5 % efficient if it produces x rays whose minimum wavelength is $1.8\times10^{-10}\,m$

Answer:

$$E=\frac{hc}{\lambda}=\frac{6.67\times10^{-34}\times3\times10^{8}}{1.8\times10^{-19}}=1.1\times10^{-14}\ J=6.95\ keV$$

The total energy of electrons emitted $E_t=\frac{100E}{1.5}=\frac{100\times1.1\times10^{-14}}{1.5}=7.33\times10^{-14}\ J$

$$E_t=eV\Leftrightarrow V=\frac{E_t}{e}=\frac{7.33\times10^{-14}}{1.602\times10^{-19}}=7457.76\ kV$$

7. (a) Calculate the electrons produced per minute by the cathode of an x ray tube which has a current of 40 mA flow drought it.

(a) Determine the maximum frequency of the x rays so produced if the tub voltage is 80 kV and the tube is 2%.

Answer:

(a) Total charge $Q=It=(40\times10^{-3})(60)=2.4\ C$

Number of electrons $N_e=\frac{Q}{e}=\frac{2.4}{1.602\times10^{-19}}=1.5\times10^{19}$

(b) Energy per electron $E=\frac{2.4\times80000}{1.5\times10^{19}}=1.28\times10^{-14}\ J$

Efficiency of the tube $\eta=\frac{2}{100}$ of E

Hence $f=\frac{\eta E}{h}=\frac{2\times1.28\times10^{-14}}{100\times6.67\times10^{-34}}=3.843\times10^{17}\ Hz$

5.9.3 Extended activities.

8. Calculate the energy released per carbon atom when 1 g of carbon is totally converted to energy. Use $N_A = 6.022 \times 10^{23}, N_A = Avogadros\ Number$,Mass of $C-12 = 12.011g$

Answer

The Energy E, is expressed by Einstein's relation $E = mc^2$

Thus $E = 1 \times 10^{-3}(3.0 \times 10^8)^2 = 9.0 \times 10^{13} J$

The atomic weight per mole (molar mass) of carbon is 12. 011g.Thus, the number of atoms included in 1g of carbon is

$$\frac{1}{12.011} \times 6.022 \times 10^{23} = 5.01 \times 10^{22}$$

Therefore, energy release per carbon atom is calculated as

$$\frac{9.0 \times 10^{13}}{5.01 \times 10^{22}} = 1.79 \times 10^{-9}\ J$$

9. X-rays are generated by making the electrically charged particles (electrons) with sufficient kinetic energy in vacuum collide with cathode. The resultant X-rays can be divided into two parts: Continuous X-rays and characteristic X-rays. The wavelength distribution and the intensity of continuous X-rays are usually depending on the applied voltage. A clear limit is recognized on the short wavelength side.

   a) Estimate the speed of electron before collision when applied voltage is 30 000 V and compare it with the speed of light in vacuum.

   b) In addition, obtain the relation of the shortest wavelength limit of X-rays generated with applied Voltage V, when the electron loses all energy in a single collision.

Answers

a) From

$$KE = eV$$

$$ev = \frac{mv^2}{2} = v^2 = \frac{2ev}{m}$$

$$v^2 = \frac{2\times1.602\times10^{-19}\times3\times10^4}{9.11\times10^{-31}}, v = \sqrt{\frac{2\times1.602\times10^{-19}\times3\times10^4}{9.11\times10^{-31}}}$$

$$v = 1.002\times10^8 m/s$$

Therefore, the speed of an electron before impact is about one-third of speed of light in air/Vacuum.

b) $V_{Min} = \frac{c}{V_{Max}} = \frac{hc}{eV} = \frac{6.63\times10^{-34}\times3.0\times10^8}{1.6\times10^{-19}V} = \frac{12.4\times10^{-7}}{V}m$

10. Calculate

(a) Strength of the electric field E,

(b) Force on the electron F,

(c) Acceleration of electron when a voltage of 10 kV is applied between two electrodes of X-ray tube separated by an interval of 10 mm.

SOLUTIONS

Solution: The work $W = Vq$

$$W = 1.602\times10^{-19}\times10^4 = 1.602\times10^{-15} J$$

The electric field E can be calculated from $F = eE$

From second Newton's law of motion, $F = ma$

Therefore $a = \frac{F}{m} = \frac{eE}{M}$

a) $E = \frac{10kV}{10mm} = \frac{10^4}{10^{-2}} = 10^6 V/m$

b) $F = eE = 1.602\times10^{-19}\times10^6 = 1.602\times10^{-13} N$

c) $a = \frac{eE}{m} = \frac{1.602\times10^{-19}\times10^6}{9.109\times10^{-31}} = 1.76\times10^{17} ms^{-2}$

UNIT 6

LASER AND ITS EFFECTS

6.1 Key Unit Competence

Point out effects of LASER beam

6.2 Prerequisite knowledge and skills

The success of this unit relies on the mastery of knowledge, skills acquired in physics in previous grades or units as indicated below.

- Wave and particle nature of light (Unit 2 year 2)
- Effects of X-rays (Unit 5)
- Black body radiation (in unit 2 year 2)

6.3 Cross-Cutting Issues to be addressed

- Standardization culture (Be aware of equipment that do not emit electromagnetic radiations)
- Laser may have negative effect on nature and thus, Experiments involving laser should be in protected place NOT to harm the ENVIRONMENT.

6.4 Guidance on the introductory activity.

This activity aims at capturing student-teachers attention and minds towards the LASERS

- Tell students-teachers 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 student-teachers enough time to work by themselves brainstorming the questions. In this period, you can move around overseeing what student-teachers 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 student teachers had problems

- Ask student teachers from different groups to judge whether, what have been discussed correspond to the questions.
- Together with student teachers, make a summary of what have been discussed using student-teachers' findings and deductions.
- Let student-teachers write the summary (discussed work by all the work) into their notebooks for future reference.

Answers for the introductory activity.

a) LASER light is produced by stimulating a material's electrons to give out the laser light or radiation.

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.

b) Characteristics of LASER light.

Do not require a material medium for transmission

- They move with high speed approximately to speed of light in vacuum (Speed of light c = $3x10^8$ 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 quantized.

c) Uses of LASERS in different fields.

Refer to 6.3.1(applications of lasers in student-teachers book)

d) Refer to 6.3.2 (Dangers of lasers in student -teacher's book)

e) Refer to 6.3.3 (Precautions measures to avoid negative effects of lasers)

6.5 List of lessons

#	Lesson Tittle	Learning Objectives	Number of Periods
1	Production of laser	- Define a LASER beam - Analyze the mechanism to produce LASER beam - Analyze the structure of a laser	3
2	Properties of LASER beam	- Explain: monochromatic, coherent sources of light, stimulated emission of light and spontaneous emission of light. - Generate a LASER light as a source of coherent light	3
3	Applications and dangers of Lasers	- Analyze applications and dangers of LASER beam	2
4	End unit assessment.		2

Lesson 1: PRODUCTION OF LASER

a) Learning objectives

- Define a LASER beam
- Analyze the mechanism to produce LASER beam
- Analyze the structure of a laser

b) Teaching resources:

Internet, textbooks, Laser pointers (if you have any at your school), Videos, animation and simulations about Laser

(https://phet.colorado.edu/en/simulations/category/physics/light-and-radiation)

c) Prerequisites/Revision/Introduction:

Through guided discovery, assist student-teachers to discover what a laser is and how it can be produced. You can make a recap using;

- Wave and particle nature of light.
- Production of X-rays (in unit 5)

d) Learning Activity 6.1

Guidance on activity 6.1

This lesson focuses on making student teachers understand and apply the concept laser production

- Tell student-teachers to turn to activity 6.1 in student-teacher's book
- 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 student-teachers 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. They can use PowerPoint.
- Ask other members of the class to whether they have similar answers from what others have presented.
- Together with student-teachers, consolidate and come to a common understanding of different questions in the activity.

Answers for activity 6.1:

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.

d) As electrons absorb energy, they jump from ground state to excited state. Hence the number of electrons in the ground state reduces as those in excited state increases.

e) Answers for application activity 6.1.

1. **LASER** stands for *Light Amplifier by Stimulated Emission of Radiation*.

2. 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.

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. 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-teachers' book)

5. 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 student-teachers' book.

6. i) Stimulated absorption: During the process of spontaneous absorption, a photon from the source is destroyed and the atom which was at the ground state is promoted to the excited state with application of external source of energy.

   ii) Stimulated Emission: **This** occurs when a photon strikes an atom that is in excited state and makes the atom emit another photon

   iii) 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.

   iv) 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.

Lesson 2: PROPERTIES OF LASERS

a) Learning objectives

- Explain: monochromatic, coherent sources of light, stimulated emission of light and spontaneous emission of light.
- Generate a LASER light as a source of coherent light

b) Teaching resources:

- Internet, textbooks laser pointer (if you have any)

c) Prerequisites/Revision/Introduction:

- Student-teachers need to know the concept of laser.
- Student-teachers have ever seen different examples of light. Let them list the different examples and their characteristics / properties.

d) Learning Activity 6.2

Guidance to learning activity 6.2

This activity aims at making student-teachers discover the properties of laser light.

- Tell student-teachers to copy down the questions to their notebooks and attempt them.
- Move around and mark student-teachers' works.
- Take time after marking and let the student-teachers raise their answers (you can pick any number (for each question) of student teachers depending on the time you have.
- Together with student-teachers make a summary of correct points on the board and tell student-teachers to correct themselves where they went wrong and then they write correct points to their notebooks.

Answers for activity 6.2

a) Monochromatic, Coherent, collimation (Directionality). For explanations refer to student-teachers' 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.

e) Answers for application activity 6.2

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. 3D images are formed using a single LASER beam. The beam is split into two beams by a special lens. When the two LASER beams intersect, they create an interference pattern that results into a 3D image.
5. Collimation or Directionality. This is because laser light is highly directional.
6. Refer to 6.2 properties of LASER beam in student-teacher's book
   i) Monochromaticity. Here laser consist of mostly single wavelength rather than different wavelengths.
   ii) b) Coherence. Wavelengths in a laser beam are in phase. The wave crests and troughs are parallel to each other.
   iii) 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.

Lesson 3: APPLICATIONS AND DANGERS OF LASERS

a) Learning objective

- Analyze applications and dangers of LASER beam

b) Teaching resources

- Internet, textbooks , laser pointer (if you have any)

c) Prerequisites/Revision/Introduction:

- Student-teachers need to know all the properties of laser light and laser production.
- A student-teacher now knows what a laser is and what makes up laser light. Let them give real applications and dangers of misuse of laser light.

d) Learning Activity 6.3

Guidance on learning activity 6.3

This lesson emphasizes on the practical applications and dangers of misuse of laser light.

- Tell student-teachers to open their books (Student-teachers' book) to activity 6.3
- Decide on the methodology to use in this lesson. You can group your student-teachers or 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 student-teachers to share their answers to the whole class and allow questions from students if any. Create a favorable environment for student-teachers to discuss.
- Together with student-teachers link their answers to the practical applications of laser light.
- Make a summary (using student-teachers findings) and tell them to write down important ideas in their books.

Answers for activity 6.3

a) - 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.

b) And many others discussed in student-teachers' book. Accept all student-teachers' idea if a student answers the question.

c) In hospitals, Industries construction, Security section, etc.

e) Answers for application activity 6.3

1a) i) Applications of laser light in daily life.

Refer to student's book under concept 6.3.1

ii) 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.

iii) Ways of preventing dangers caused by lasers.

Refer to student's book under concept 6.3.3

2. Depends on the student's idea. The positive side outweighs the negative side. A reason why they are used in different activities/fields. As discussed, in in the uses of lasers.
3. 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.

4. i) Types of Lasers:

Gas lasers, Solid state laser, Metal state lasers, Dye lasers, Free electron Lasers.

ii) Examples of Lasers

6.6 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 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.

6.7 Additional information for the tutor

The Einstein Coefficients

The Einstein Coefficients Laser activity may occur in the case of nonequilibrium. 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

$N_1 + N_2 = N \; holds$

This means that N_2 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

$\imath = n_0 e^{(-\frac{E}{kT})} \; where \; K = 1.38x10^{-23} / k, E = energy \; of \; a \; photon.$

GUIDANCE ON SKILLS LAB

This activity is aimed at making student-teachers to analyze how a LASER is produced and used.

- Together with class leaders, write a letter to the leaders of nearest laboratory informing them that you want to visit. Keep following up until

your request is accepted. Make sure you send topic of discussion to technician that is to handle your students.

- Prepare your student-teachers for the visit. Alert them to go with pens and books because they are to write important information from the presentation.
- Guide them on how to ask questions as the technician is presenting.
- When you are done with the visit, make sure you return back to school in time and tell the students that they have to compile what they learnt from the laboratory. Let them know that you will mark their work and inform them the deadline for submission of their work.
- Collect the work through their class leaders and mark it. When you are done with marking make sure you get time and clarify misconception if any.
- Tell them that they are to keep their work for future reference.

6.8 Answers for end 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	1 2) d
13) f	14) b	15) a	16) c	17) c	

18 a) 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.

b) Solid state lasers, Gas lasers, Dye lasers, Chemical Lasers, Metal vapor lasers, and Free-electron lasers.

For Explanations, Refer 6.3.1 in Student-teachers book

19. a) 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 teacher's book.

b) 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

6.9 Additional activities

6.9.1 Remedial activities:

1. The following are properties of laser. Which one is a unique property of laser?

   A. Frequency B. Speed

   C. Coherence D. Wavelength

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

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

4. Calculate the wavelength of radiation emitted by an LED made up of a semiconducting material with band gap energy 2.8eV.

   A. $2.8\times10^{-10}m$

   B. $4.3308\times10^{-10}m$

   C. $5548.4\times10^{-10}m$

   D. $4430.8\times10^{-10}m$

5. Estimate the number of photons, from green light of mercury ($\lambda = 4961`\times10^{-10}m$), required to do one joule of work.

   A. $4524.2\times10^{18}/m^3$

   B. $2.4961\times10^{18}/m^3$

   C. $2.4961/m^3$

   D. 2.4961/m

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 dioxide laser

C. Helium neon laser D. Nd- YAG laser

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

8. Laser can be termed as non-material knife. True or false?

A. False

B. True

9. DVD uses laser. True or false?

A. True

B. False

10. Which of the following is used in atomic clocks?

A. Laser B. Quartz

C. Maser D. Helium

11. Which of the following can be used in vibrational analysis of structure?

A. Maser B. Quarts

C. Electrical waves D. Laser

ANSWERS TO REMIDIAL ACTIVITIES

1. 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. 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. 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. D. **Explanation:** $E = \frac{hc}{\lambda}$

Therefore, $\lambda = \frac{hc}{E}$

$\lambda = 4430.8 \times 10^{-10} m$

5. B,: $E = \frac{hc}{\lambda}$

$E = 4.006 \times 10^{-19} J$

Number of photons required $= \frac{(1\,joule)}{4.006 \times 10^{-19}} = 2.5 \times 10^{18} m^{-3}$

6. 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. 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. B. **Explanation:** In laser surgery, without knife, bloodless operation, cutting tissues etc can be made, hence laser is called non-material knife.

9. 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. 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. 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.

6.9.2 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° 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

15. 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 then 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 make 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.

6.9.3 Extended activities

1. A LASER peripheral iridotomy is a procedure is a procedure for treating eye condition known as narrow angle glaucoma, in which the pressure build up in the eye can lead to loss of vision. A neodymium YAG laser (Wavelength =1044 nm) is used in the procedure to punch a tiny hole in the peripheral iris, thereby relieving in pressure build up. In one application the laser delivers $4.0\times10^{-3}\ J$ of energy to the iris in creating the hole. How many photons does the LASER deliver?

2. A LASER is used in eye surgery to weld the detached retina back into place. The wavelength of the laser beam is 614 nm and the power is1.6 W. During the surgery, the laser beam is turned on for 0.060 s. During this time,

how many photons are emitted by the laser?

3. Fusion is the process by which the sun produces energy. One experimental technique for creating controlled fusion utilizes a solid state laser that emits a wavelength 1050 nm and can produce a power of $1.01\times10^{14}\ W$ for a pulse duration of $1.1\times10^{-11}\ s$ .In contrast ,the helium/neon laser used at the checkout counter in a bar code scanner emits a wavelength of 635 nm and produces a power about $1.01\times10^{-3}\ W$ .How long (in days) would the helium neon laser have to operate to produce the same number of photons that the solid-state laser produces $1.1\times10^{-11}\ s$?

SOLUTIONS

1. From $E=\dfrac{nhc}{\lambda}\Leftrightarrow n=\dfrac{\lambda E}{hc}=\dfrac{1044\times10^{-9}\times4\times10^{-3}}{6.63\times10^{-34}\times3\times10^{8}}=2.1\times10^{16}$

Thus, there are $n=2.1\times10^{16}\ photons$

2. From $E=nhf=\dfrac{nhc}{\lambda}$

And $P=\dfrac{E}{t},\mathrm{E}=Pt$

Thus $Pt=\dfrac{nhc}{\lambda}$

$$n=\frac{\lambda Pt}{hc}=\frac{614\times10^{-9}\times1.6\times0.060}{6.63\times10^{-34}\times3\times10^{8}}=2.96\times10^{17}$$

$n=2.96\times10^{17}\ particles$

3. From $n=\dfrac{\lambda Pt}{hc}=\dfrac{1050\times10^{-9}\times1.01\times10^{14}\times0.060}{6.63\times10^{-34}\times3\times10^{8}}=3.2\times10^{31}\ particles$

For the second case $3.2\times10^{31}=\dfrac{635\times10^{-9}\times1.01\times10^{-3}t}{6.63\times10^{-34}\times3\times10^{8}}$

$$t=\frac{3.2\times10^{31}\times6.63\times10^{-34}\times3\times10^{8}}{635\times10^{-9}\times1.01\times10^{-3}}=9.924\times10^{15}\ s$$

Time t in days $t=\dfrac{9.924\times10^{15}}{60\times60\times24}=1.15\times10^{11}\ days$

UNIT 7

MEDICAL IMAGING

7.1 Key unit competence

Generate the processes in medical imaging.

7.2 Prerequisite (knowledge, skills, attitudes and values):

Student- teachers should be aware of the concept of x-rays and its effects in medicine.

7.3 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 student-teachers should be treated equally. This makes the student-teachers to find out that they are all of great importance. In spite of their physical ability, student-teachers with impairment as normal student-teachers should be aware of the uses of medical imaging techniques.

Environment sustainability: During delivering different lessons within this unit, let student-teachers be familiar with the application and importance of skills medical imaging, uses and benefits and risks of them.

7.4 Guidance on introductory activity

This activity aims at capturing student teachers attention and minds towards this concept of medical imaging, their function, uses and effects.

- Divide your student-teachers into groups (Grouping may depend on the nature of your class or number of student-teachers you have). Always take care of student-teachers with any kind of educational need while making groups (hearing, reading, seeing, etc.).
- Tell the student-teachers to open the introductory activity in the learner's book. You may give them a brief introduction about the activity
- Ask student-teachers to interpret the pictures in the activity before answering questions. While student-teachers are doing this activity, you move around, guide the slow student-teachers. 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. They can use power point.
- Note some misconceptions and misunderstanding (if any) so that they are corrected and harmonised in the lesson. Together with student teachers harmonize the points and make a summary on the board. Give to student-teachers the opportunity to write the main points in their notebooks.
- Summarize your lesson by linking this concept to real life application of medical imaging techniques.

Note: Make sure you mind about Special educational need. In case you have a student-teacher who needs special attention/care.

Answers for the introductory activity

1. A. Photo of chest obtained after radiography diagnosis,

   B. treatment of pregnant woman where the doctor show image of her internal part in order to see unborn baby.

   C. doctor are treating the line of esophagus

   D. treatment of patient through Magnetic Resonance Imaging (MRI) machine.

Note: the student-teachers should suggest other alternative answers suitable to this activity.

2. Techniques used are:

   A. x-rays B. ultrasound

   C. endoscopy D. Magnetic Resonance Imaging (MRI)

3. The answer for question 3 and 4 are on note (seen 7.2 ultrasonic imaging, 7.3 x-rays imaging, 7.4 endoscopy, 7.6 Magnetic Resonance Imaging (MRI) from learner's book)

7.5 List of lessons

#	Lesson title	Learning objectives	No of periods
1	Concept of medical imaging	- Describe the concepts used in medical imaging. - Outline specific purposes imaging techniques	1
2	Ultrasonic imaging	- Explain the basic function of ultrasound. - Explain the risks and benefits associate to ultrasound imaging. - Identify advantages and disadvantages of ultrasound imaging	3
3	X-ray imaging	- Explain the working principle of X-ray imaging(radiography, mammography and CT-scan) - Evaluate the application of x-ray imaging.	4
4	Endoscopy	- Describe how the endoscopy is performed	2
5	Magnetic Resonance Imaging(MRI)	- Explain physics concepts used in MRI - Explain the function of MRI scan. - Explain the advantage and disadvantage of MRI. - Acquire knowledge in analysing and modelling physical processes involved in medical imaging.	2
5	End Unit Assessment		2

Lesson 1: CONCEPT OF MEDICAL IMAGING

a) Learning objectives

- Describe the concepts used in medical imaging.
- Outline specific purposes imaging techniques

b) Teaching resources

- Internet and textbooks.
- Videos on medical imaging
- Computer, projector, etc

c) Prerequisites/Revision/Introduction

- Student-teachers should know the x-rays and its applications in medicine and propagation of sound wave.
- They should connect/link what they know with medical imaging.

d) Learning activity 7.1

Guidance on learning activity 7.1

The activity aims to capture student-teachers' attention and develop critical thinking and collaboration in student-teachers. The student-teachers are encouraged to work together to answer the questions in the activity 7.1.

This lesson focuses on making student-teachers understand the concepts of medical imaging.

- Tell student-teachers to open their books (student's book) to learning activity 7.1
- Decide on the methodology to use in this lesson. You can group your student-teachers (or use other techniques), they can do it as a class or individual.
- Instruct them to read the activity first and then re-write it to their notebooks.
- Allow them to attempt the questions.
- Move around and mark their work.
- Select some student-teachers to share their answers (during a presentation) to the whole class and allow questions from students if any (They can use power point where possible). Create a good ground for student-teachers to discuss.

- Together with student-teacher, link their answers to real life experience related to medical imaging
- Make a summary and tell student-teachers to write down important ideas in their books.

Note: Make sure you mind about Special educational need. In case you have a student-teacher who needs special attention/care.

Answer for activity 7.1

a) If the child swallow a coin and get safely to his/her stomach, the doctor may recommend an X-ray or ultrasound see where the coin is.

b) After located it, without operating him/her, the following techniques should be applied:

The doctor should give the drugs that will relax the muscles and let coin to pass into stomach and go out. This will be treated endoscopically or using x-ray.

If the coin is causing pain or damage to the bowels or esophagus. This may be treated by upper endoscopy to remove the object without puncturing the bowels or esophagus.

Answers for application activity 7.1

1. Medical imaging refers to the technique and process of producing visual representations of the interior areas inside the human body (function of some organs or tissues) to diagnose medical problems and monitor treatment
2. The main methods of imaging used in modern medicine include:
    - Radiography: is often used when we want images of bone structures to look for breakages.
    - A mammography (or mammogram) is an X-ray of the breast. It's a screening tool used to detect and diagnose breast cancer.
    - Magnetic resonance imaging, MRI scanners are often used to take images of the brain or other internal tissues, particularly when high-resolution images are needed.
    - Nuclear medicine: is used when you need to look inside the digestive or circulatory systems, such as to look for blockages. It uses radioactive materials that are injected or swallowed.
    - Ultrasound: is used to study the development of fetus in the mother's womb and to take images of internal organs when high resolution is not needed.

- Endoscopy: Endoscopy is a nonsurgical procedure used to examine a person's digestive tract. Using an endoscope, which is a flexible tube with a light and camera attached to it.
- Elastography: also called liver **elastography**, is a type of imaging test that checks the liver for fibrosis. Fibrosis is a condition that reduces blood flow to and inside the liver. This causes the buildup of scar tissue. Left untreated, fibrosis can lead to serious problems in the liver
- Photoacoustic imaging: refers to the hybrid imaging technology based on the photoacoustic effect. When non-ionizing lazer pilse are delivered to the tissues, some of the energy is converted to the heat which cause a rapid thermoelastic expansion and generation of an ultrasound wave.
- Tomography: is imaging by sections or sectioning, through the use of any kind of penetrating wave. The method is used in radiology, archaeology, biology, atmospheric science, geophysics, oceanography, plasma physics, materials science, astrophysics, quantum information, and other areas of science. It is a technique for displaying a representation of a cross section through a human body or other solid object using x-rays.
- Echocardiography: is an ultrasound of heart. It is a test that uses sound waves to produce live images of your heart. Its image is an echocardiogram. This test allows the doctor to monitor how the patient's heart and its valves are functioning.

3. Specific purpose of those methods:

Magnetic resonance imaging involves radio waves and magnetic fields to look at the organs and other structures in the body. The procedure requires an **MRI scanner**, which is, simply put, a large tube that contains a massive circular magnet. This magnet creates a powerful magnetic field that aligns the protons of hydrogen atoms in the body. Those protons are then exposed to radio waves, causing the protons to rotate. When the radio waves are turned off, the protons relax and realign themselves, emitting radio waves in the recovery process that can be detected by the machine to create an image.

Nuclear medicine is a rather general term that involves any medical use of radioactive materials. But in terms of imaging, it usually refers to the use of radioactive tracers, which are radioactive materials that are injected or swallowed so that they can travel through the digestive or circulatory system. The radiation produced by the material can then be detected to create an image of those systems.

Ultrasound utilizes high-frequency sound waves, which are reflected off tissue to create images of organs, muscles, joints, and other soft tissues. It›s kind of like shining a light on the inside of the body, except that this light travels through

the skin layers and can only be viewed using electronic sensors.

Radiography is often used when we want images of bone structures to look for breakages.

Lesson 2: ULTRASONIC IMAGING

a) Learning objectives

- Explain the basic function of ultrasound.
- Explain the risks and benefits associate to ultrasound imaging.
- Identify advantages and disadvantages of ultrasound imaging

b) Teaching resources

- Internet and textbooks.
- Videos on ultrasound imaging
- Computer, projector, etc

c) Prerequisites/Revision/Introduction

- Student-teachers should be aware on sound wave.
- They should connect/link what they know with ultrasonic imaging.

d) Learning activity 7.2

Guidance on learning activity 7.2:

The activity aims to capture student-teachers' attention and develop critical thinking and collaboration in student-teachers. The student-teachers are encouraged to work together to answer the questions in the activity 7.2.

This lesson focuses on making student-teachers understand how the sound waves propagate.

- Tell student-teachers to open their books (student teachers book) to learning activity 7.2
- Decide on the methodology to use in this lesson. You can group your student-teachers; they can do it as a class or individual.
- Instruct them to read the activity first and then re-write it to their notebooks.
- Allow them to attempt the questions.
- Move around and mark their work.

- Select some student-teachers to share their answers to the whole class and allow questions from student-teachers if any (They can use power point where possible). Create a good ground for student-teachers to discuss.
- Together with student-teacher, link their answers to real life experience related to ultrasound imaging.
- Make a summary (application of ultrasound) and tell student-teachers to write down important ideas in their books.

Note: Make sure you mind about Special educational need. In case you have a student-teacher who needs special attention/care.

Answer for activity 7.2

a) The doctor used ultrasound because it is used to study the development of Mutesi's fetus and is the one which is used to create an image of internal body structures such as tendons, muscles, joints, blood vessels, and internal organs. Its objective is often to find a source of a disease or to exclude pathology.

b) Ultrasound imaging uses ultra-high-frequency sound waves to produce cross-sectional images of the body. The sound wave travels to the human body, some are reflected directly and others are scattered before return to the transducer as echoes.

The reflected ultrasound pulses detected by the transducer need to be amplified in the scanner or ultrasonic probe. The echoes that come from deep within the body are more attenuated than those from the more superficial parts and therefore required more amplification. The information is stored in a computer and displayed on a video (television) monitor.

c) Yes, because ultrasound is useful way of examining many of the body's internal organs including but not limited to the following: (Heart and blood vessels, including the abdominal aorta and its major branches. liver, gallbladder, spleen, pancreas, kidneys, bladder, uterus, ovaries, and unborn child fetus) in pregnant patients) so most of people have some of the above listed parts, in case they feel pain, the ultrasound is needed.

Answers for application activity 7.2

1. a) $\alpha = \dfrac{(Z_{soft} - Z_{air})^2}{(Z_{soft} + Z_{air})^2} = \dfrac{(1.63\times10^6 - 430)^2}{(1.63\times10^6 + 430)^2} = 0.998 = 99.8\%$

b) $\alpha = \dfrac{(Z_{soft} - Z_{bone})^2}{(Z_{soft} + Z_{bone})^2} = \dfrac{(1.63\times10^6 - 5.6\times10^6)^2}{(1.63\times10^6 + 5.6\times10^6)^2} = 0.301 = 30.1\%$

Or

$\alpha = \dfrac{(Z_{soft} - Z_{bone})^2}{(Z_{soft} + Z_{bone})^2} = \dfrac{(1.63\times10^6 - 7.78\times10^6)^2}{(1.63\times10^6 + 7.78\times10^6)^2} = 0.427 = 42.7\%$

The percentage varies between 30% and 43%.

2. The purposes of ultrasound are:
   - An ultrasound scan is used to examine internal body structures.
   - Ultrasound imaging sends out (emits) high-frequency sound waves, directed at the tissue being examined, and recording the reflected sound or echoes to create an image.
   - An ultrasound scan is generally non-invasive.
   - Common reasons for ultrasound scanning include investigations of a person's abdominal and pelvic organs, musculoskeletal and vascular systems, and to check fetal development during pregnancy

3. Ultrasound 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.

4. 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.

Lesson 3: X-RAYS IMAGING

a) **Learning objectives**

- Explain the working principle of X-ray imaging(radiography, mammography and CT-scan)
- Evaluate the application of x-ray imaging.

b) **Teaching resources**

- Internet and textbooks.
- Videos on medical imaging using x-rays
- Computer, projector, etc

b) **Prerequisites/Revision/Introduction**

- Student-teachers should know x-rays and its effects in medicine.
- They should link the concepts with unit 5 that they have learnt.

d) **Learning activity 7.3**

Guidance on the learning activity 7.3

This activity aims at realizing the use of x-rays in medicine.

- Depending on the nature and size of your class, decide the methodology to use (it may be group work or other techniques, individual or class activity)
- Tell student-teachers to copy the questions into their notebooks, then after let them to attempt or discuss the questions.
- Move around and mark their work
- Call some student-teachers (may be a group or individual depending on the methodology you used) to make a presentation about their answers/findings.
- Ask other student-teachers 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 x-rays imaging.
- Together with student-teachers make a summary about x-rays imaging. Compile the outcomes and let student-teachers write them in their Notebooks.

Note: Make sure you mind about Special educational need. In case you have a student-teacher who needs special attention/care.

Answers for activity 7.3

1. a) The doctor has been getting that image after using x-ray imaging.

In medical applications, x-rays are usually generated in vacuum tubes by bombarding a metal target with high-speed electrons (x-rays are form of electromagnetic radiation like visible light) and images produced by passing the resulting radiation through the patient's body onto a photographic plate or digital recorder and it also pass through the x-ray detector on the other side of the patient to produce a radiograph so an image will be formed and that presents the shadows formed by the objects inside the body.

b) Devices like camera cannot give such image because camera emit radiation in form of light which has energy that can't penetrate in the human bodies.

2. a) You can detect whether the girl have breast cancer probably yes or no.

If yes, the doctor orders a mammogram for checking her any cancer or changes, it's known as a screening mammogram. If the girl have a lump or any other symptom of breast cancer, or breast implants the doctor will probably need a diagnostic mammogram. When the doctor obtain copies of your prior mammograms and make them available to her radiologist to get views of the breast from multiple positions and magnify the area of cancer.

If no, the doctor have to be sure that the girl is pregnant / breastfeeding or not. In general the girl will not be able to receive screening mammography so the doctor can order other method such as ultrasound or give her the pharmaceutical products where possible.

b) The methods of X-ray imaging techniques that may be used to examine breast problems in Mammography; here The mammograms are non-invasive procedure used as screening tool to detect early breast in women no symptoms. They can also be used to detect and diagnose breast disease in women experiencing symptoms like lump, pain, skin dimpling or nipple discharge.

Answers for applications activity 7.3

1. The advantages and disadvantages of CT-Scan are:

advantages	Disadvantages
- Widely available - Quick exam. - CT-Scan give a good contrast images - High spatial resolution - Images scored in a computer memory. - Etc	- Very expensive - Poor soft-tissue contrast. - Higher radiation exposure. - Involves exposure to ionizing radiation(gamma-rays) - Radiation material may cause allergic injection-site reactions in some people. - Etc.

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 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.

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 you pregnant? Or breastfeeding? or have you a physical disability? Etc.

6. A biopsy is the only test that can determine if a suspected tissue area is cancerous.

7. Reasons why people do not attend breast screening (screening mammography) are:
   - They are too busy.
   - They feel fit and health and do not think they are at risk of cancer 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

Lesson 4: ENDOSCOPY

a) **Learning objective**

- Describe how the endoscopy is performed

b) **Teaching resources**

- Textbooks, internet, Computer
- Projectors and simulations about endoscopy.

c) **Prerequisites/Revision/Introduction**

- Student-teachers should know line of esophagus, small and large intestines.

d) **Learning activity 7.4**

Guidance on the learning activity 7.4

- Tell student-teachers to open their books (student teacher's book) to learning activity 7.4
- Choose on the methodology to use in this lesson. You can group your student-teachers (or use other techniques) they can do it as a class or individual.
- Initiate them to read the activity first and then re-write it to their notebooks.
- Allow them to do activity and move around then after mark their work.
- Have sample group present their work to the class. (They can use power point where possible)
- Check student-teacher's responses to review their ideas to continue the discussion with a brief brainstorming of the concepts using student's work.
- Comment on student teachers' responses written in their notebooks and give them the expected feedback.
- Together with student-teachers, link their answers to real life experience related to endoscopy
- Make a summary (Use of endoscopy) and tell student-teachers to write down important ideas in their books..

Note: Make sure you mind about Special educational need. In case you have a student-teacher who needs special attention /care.

Answers for learning activity 7.4

1. A. Mouth, B: Endoscope, C: Stomach, and D: Light
2. Endoscopy Exam
3. Procedure used to examine inside the stomach by using light rays, the surgery firstly insert the endoscope (contain light and camera) through the mouth and esophagus then into stomach. He/she move light in all corner of the stomach.
4. Endoscopy is a nonsurgical procedure used to examine a person's digestive tract. Using an endoscope, which is a flexible tube with a light and camera attached to it, the specialist can view pictures of your digestive tract on a monitor. During an upper endoscopy, an endoscope is easily passed through the mouth and throat and into the esophagus, allowing the specialist to view

the esophagus, stomach, and upper part of the small intestine. Similarly, endoscopes can be passed into the large intestine (colon) through the rectum to examine this area of the intestine.

5. Advantages

- Complete visualization of the entire stomach or digestive tract.
- It is very safe and effective tool in diagnosis
- Does not leave any scar because it uses natural body openings.
- It is cost effective and has low risk
- They are generally painless.
- Can do therapeutic interventions

Disadvantages

- Bleeding
- Perforation (tear in the gut wall)
- Infection
- Reaction to sedation (action of administering a sedative drug to produce a state of calm or sleep.
- Technically difficult procedure
- Very time consuming (Procedure can take > 3 hours)
- Patient may need to be admitted to the hospital
- Higher risk of small bowel perforation

Answers for application activity 7.4

1. Endoscope
2. Function of endoscope:

Endoscope is a flexible tube with a light and camera attached to it that is used by doctor to see images in the line of esophagus or in the area of intestine. That image had to be projected on the screen.

During upper endoscopy, the endoscope pass through the mouth, and esophagus to see inside stomach and upper part of small intestine.

It can also be pass into large intestine through rectum to examine the area of intestine

3. Both colonoscopy and gastroscopy uses endoscope

Colonoscopy	Gastroscopy
Upper endoscopy Used to see the line of esophagus	Lower endoscopy Used to see the area of intestine

4. Negative effect of using endoscopy are:
   i. Bleeding
   ii. Perforation (tear in the gut wall)
   iii. Infection.
   iv. Etc.

Lesson 5: MAGNETIC RESONANCE IMAGING (MRI)

a) Learning objectives

- Explain Physics concepts used in MRI.
- Explain the function of MRI scan.
- Explain the advantages and disadvantages of MRI.
- Acquire knowledge in analysing and modelling physical processes involved in medical imaging.

b) Teaching resources

Textbooks, internet, computer, projectors and video about magnetic resonance imaging and simulation (https://phet.colorado.edu/en/simulations/category/physics/light-and-radiation).

c) Prerequisites/Revision/Introduction

Student-teachers should have knowledge about the electromagnetic waves and other medical imaging techniques.

d) Learning activity 7.5

Guidance on the learning activity 7.5

- Let the learner(s) brainstorm the questions on activity 7.5
- Have sample group present their work to the class. (They can use power point where possible)

- Check student-teachers responses to review their ideas to continue the discussion with a brief brainstorming of the concepts using student's work.
- Comment on student-teachers responses written in their notebooks and give them the expected feedback.
- Together with student teachers link their answers to real life experience related to magnetic resonance imaging(MRI)
- Make a summary (use of MRI) and tell student-teachers to write down important ideas in their books.

Note: Make sure you mind about Special educational need. In case you have a student-teacher who needs special attention /care.

Answers for activity 7.5

i) The Magnetic Resonance Imaging uses a powerful magnet which produce a strong magnetic field that forces protons in the body to align with that field. When the radiofrequency field is turned off, the MRI machine sensors are able to detect the energy released as the protons realign with the magnetic field. This machine 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.

ii) 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.

iii) Yes, because no risk that pregnancy woman can experienced due to the absence of ionization that MRI have

iv) Advantages of MRI in clinical practice include:

1. Excellent soft tissue contrast and characterization
2. Lack of ionizing radiation.
3. Noninvasive machine.
4. Lack of artefact from adjacent bones, e.g. pituitary fossa

Disadvantages of MRI:

1. High capital and running costs.
2. Image selected and interpretation is complex.

3. Examination can be difficult for some people who are claustrophobic
4. The examination is noisy and takes long.
5. Hazards with implants, particularly pacemakers.
6. Practical problems associated with large superconducting magnets.

e) Answers for application activity 7.5

1. Some benefits of MRI are:

- Excellent soft tissue contrast resolution
- Ability to obtain direct transverse, sagittal coronal and oblique images.
- Does not use ionization radiation
- Doesn't produce bone/ air artefacts.

Limitations of MRI are:

- Longer imaging time.
- High cost
- Complexity of the equipment and scan acquisition
- Inability to demonstrate calculation or cortical bone detail.
- Dangerous for patients with metallic devises places within the body
- Difficult to be performed on claustrophobie patients
- Movement during scanning may cause severe burns if mishandled.

2. The meaning of relaxation in the context of MRI is an interactions happening at near-collisions between nuclei give rise to the magnetization constantly approaching the equilibrium size.

3. 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.

4. NMR stand for ''Nuclear Magnetic Resonance''.

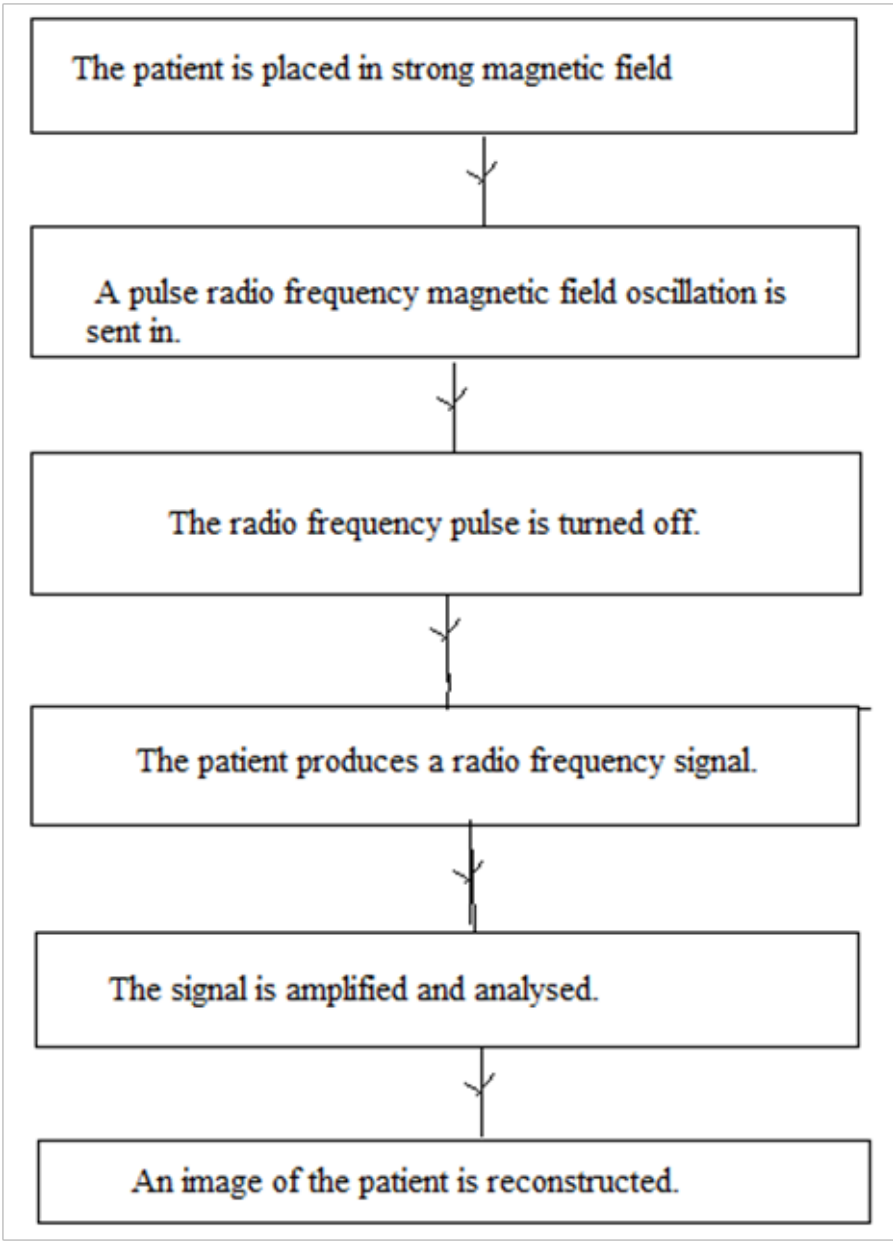
The role of the three terms are:

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.

5. Basic steps in the formation of MRI image are:



7.6. Summary of the unit

- **Medical imaging** is a technique and process of producing visual representations of the interior areas inside the human body (function of some organs or tissues) to diagnose medical problems and monitor treatment.
- **Types of medical imaging are:** Radiography, Mammography, Magnetic resonance imaging. Nuclear medicine, Ultrasound, etc
- **Specific purposes of imaging techniques.**

Ultrasound is used to study the development of fetus in the mother's womb and to take images of internal organs when high resolution is not needed.

Radiography is often used when we want images of bone structures to look for breakages.

MRI scanners are often used to take images of the brain or other internal tissues, particularly when high-resolution images are needed.

Nuclear medicine is used when you need to look inside the digestive or circulatory systems, such as to look for blockages. It uses radioactive materials that are injected or swallowed.

- Mammography is a specialized medical imaging that uses low-dose X-rays to investigate the internal structure of the breast.
- A mammography exam, called a mammogram.
- **Form of MRI**: Diffusion-weighted imaging, Perfusion-weighted imaging, Magnetic resonance spectroscopy.

Medical imaging technique	Advantages	disadvantages
Scintigraphy/ radionuclide imaging	Most case the whole body is analysed.	Generally poor resolution compared with other imaging techniques. Radiation risks due to the administered radionuclide. Can be invasive, sometimes requiring an injection into the bloodstream.

ULTRASOUND IMAGING	No known harmful effects of diagnostic ultrasound. Clear examination of soft tissues Real time imaging means required quick procedure. It is noninvasive Lack of ionizing radiation.	Cannot penetrate bone, so the adult skeletal system and head cannot be imaged. Clarity of image is poorer than in many other techniques. It cannot be used in areas that contain gas (such as lungs) Longtime scanning and required greater skills and experience to produce a clear results.
Radiography	Short exposure. Large area image. Low cost. Low radiation exposure. Excellent contrast and spatial resolution.	Use of high radiation dose. Sensitive variation in exposure Less sensitive to detect early osseous changes. Lack of depth resolution.
Mammography	Non-invasive procedure. Minimum hazard of radiation. Increase in cancer detection rate. Improved positive predictive values for recall and biopsy.	May increase radiation dosage patient receivers. May require new equipment / training for techs and radiologist Is inconclusive.
Computer tomography scan	Images can be scored in a computer memory. High spatial resolution. Widely available and Quick exam. CT-Scan give a good contrast images	Risk to the patient because of the high radiation dose. Very expensive. Not commonly used to image painful joints modality Poor soft-tissue contrast. Higher radiation exposure.

Endoscopy	It is cost effective and has low risk. They are generally painless. Can do therapeutic interventions. Allows for ampling/ biopsying of small bowel mucosa.	Bleeding. Perforation. Infection. Reaction to sedation. Technically difficult procedure. Very time consuming.
Magnetic Resonance Imaging	Excellent soft tissue contrast. Lack of ionizing radiation. Noninvasive machine. Lack of artefact from adjacent bones.	High capital and running costs. Image selected and interpretation is complex. Examination can be difficult for some people who are claustrophobic. The examination is noisy and takes long. Hazards with implants, particularly pacemakers

Scintigraphy refers to the use of gamma radiation to form images following the injection of various radiopharmaceuticals.

- The most commonly used radionuclide in clinical practice is technetium, written in this text as ^{99}mTc, gallium citrate (^{67}Ga), thallium (^{201}Tl), indium (^{11}In) and iodine (^{131}I).

7.7 Additional information for the tutor

7.7.1. Nuclear medicine (scintigraphy)

a) Physics of scintigraphy and terminology

Scintigraphy refers to the use of gamma radiation to form images following the injection of various radiopharmaceuticals. The key word to understanding of scintigraphy is radiopharmaceutical. 'Radio' refers to the radionuclide, i.e. the emitter of gamma rays.

The most commonly used radionuclide in clinical practice is technetium, written in this text as ^{99}mTc, where 99 is the atomic mass, and the 'm' stands for metastable. Metastable means that the technetium atom has two basic energy

states: high and low energy states. As the technetium transforms from the high-energy state to the low-energy state, it emits a quantum of energy in the form of a gamma ray, which has energy of 140 keV. Other commonly used radionuclides include gallium citrate (^{67}Ga), thallium (^{201}Tl), indium (^{11}In) and iodine (^{131}I).

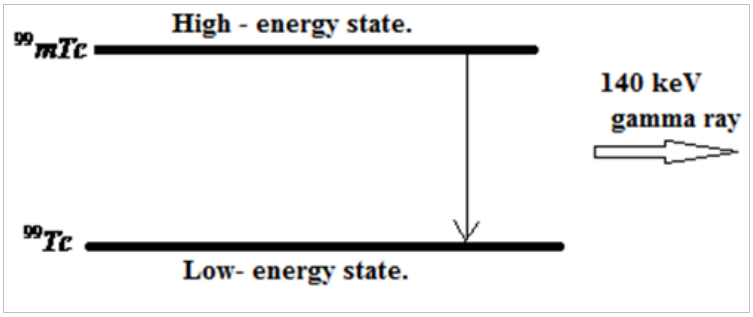


Fig7.12: Gamma ray production. The metastable atom ^{9}mTc passes from a high-energy to a low-energy state and releases gamma radiation with a peak energy of 140 keV.

Basic functioning of radionuclide scan

A **radionuclide** scan is a way of **imaging** bones, organs and other parts of the body by using a small dose of a radioactive chemical. There are different types of **radionuclide** chemical. The one used depends on which organ or part of the body need to be scanned.

A radionuclide (sometimes called a radioisotope or isotope) is a chemical which emits a type of radioactivity called gamma rays. A tiny amount of radionuclide is put into the body, usually by an injection into a vein. Sometimes it is breathed in, or swallowed, or given as eye drops, depending on the test.

Gamma rays are similar to X-rays and are detected by a device called a gamma camera. The gamma rays which are emitted from inside the body are detected by the gamma camera, are converted into an electrical signal and sent to a computer. The computer builds a picture by converting the differing intensities of radioactivity emitted into different colors or shades of grey.

However, radionuclide imaging techniques do not depict structural anatomy like ultrasound, X-ray computed tomography (XCT) or conventional radiographs. It is the only established noninvasive technique available to investigate organ physiology, although recently Nuclear magnetic resonance (NMR) imaging technique has shown its capability to probe organ physiology and anatomy without ionizing radiation.

Radionuclide scans do not generally cause any after effects. Through the natural process of radioactive decay, the small amount of radioactive chemical in your body will lose its radioactivity over time. Although the levels of radiation used in the scan are small, patients may be advised to observe special precautions.

b. Limitations and disadvantages of scintigraphy

The main advantages of scintigraphy are its high sensitivity and the fact that the functional information is provided as well as anatomical information. However it has some disadvantages that are listed below:

i. Generally poor resolution compared with other imaging techniques.

ii. Radiation risks due to the administered radionuclide

iii. Can be invasive, sometimes requiring an injection into the bloodstream

iv. Disposal for radioactive waste, including that from patients, requires special procedures.

v. Relatively high costs associated with radiotracer production and administration.

7.7.2. OBSERVED SOUND INTENSITY AND EAR RESPONSE

a) 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.

The ear consists of three main parts: the outer ear, the middle ear and the inner ear. In the outer ear, sounds 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.

b. 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 figure below.

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.

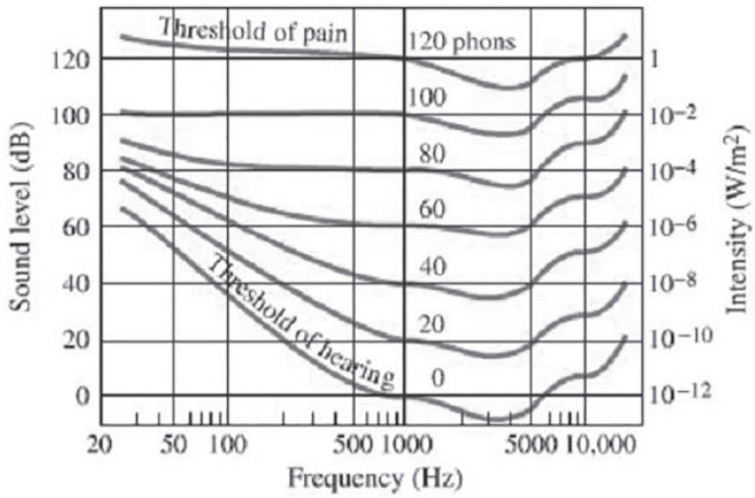


Fig.7. 2 Loudness in phons

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.

a) Sound Intensity Level

The human ear responds *logarithmically* to sound intensity: Loudness = Sound *Intensity* Level,

$$L = \beta = 10 \log \frac{I}{I_0}$$

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

- $I_0 = 1.0 \times 10^{-12}\ W/m^2$ 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.

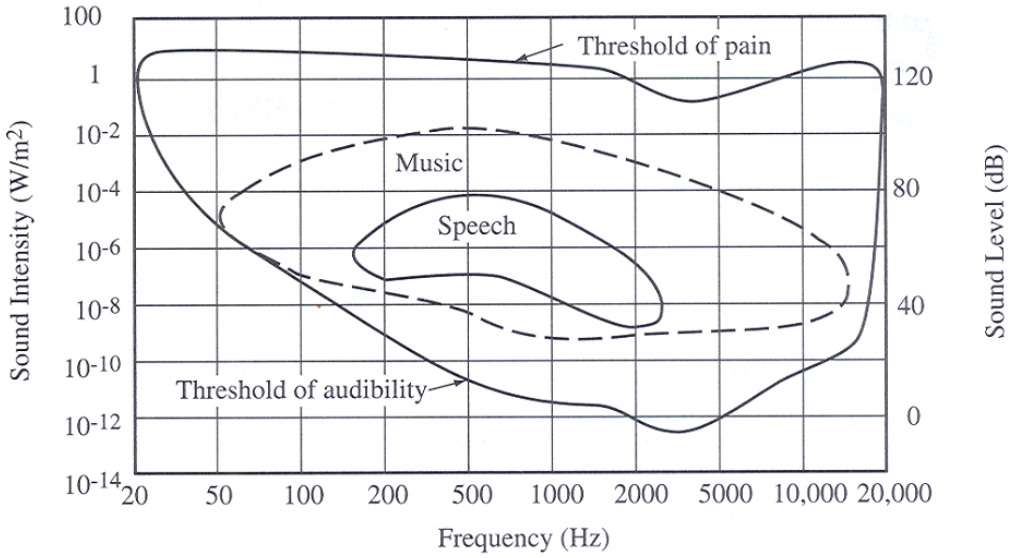


Fig.7. 3 The range of human hearing: Sound Intensity, Sound Level versus Frequency

EXAMPLE:

1. The sound level of sound whose intensity is
$a) I = 1.0 \times 10^{-10}\ \mathrm{W}/m^2 \quad b) I = 1.0 \times 10^{-11}\ \mathrm{W}/m^2$. What will be the sound level?

Answer

$$L = B = 10Log\frac{I}{I_0}$$

$$a) L = 10Log\frac{1.0\times10^{-10}}{1.0\times10^{-12}} = 10Log100 = 20dB$$

$$b) L = 10Log\frac{1.0\times10^{-11}}{1.0\times10^{-12}} = 10Log10 = 10dB$$

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.

Guidance on skills lab 7

- This activity aims at capturing teachers attention and minds towards the working functions of medical imaging machine such as ultrasound machine, x-ray machine, endoscopy and Magnetic Resonance Imaging machine.
- This skills lab will be carried out to the nearest hospital where the laboratory technician or the doctor give more clarification based on (the question from learner book) the functions and uses of these machines
- The student-teachers write the summary of the explanations and then ask other questions that help them to understand more.
- After leaving the hospital, student-teachers make a comprehensive report and compare the information got from the hospital to the one they have learnt in this unit.
- Present their findings (in the report) to the class and to the tutor.

Note: Make sure you mind about Special educational need. In case you have a student who needs special attention/care.

7.8. Answers for end unit 7 assessment

1. B 2. C 3. C 4. C 5. B

6. The missing words are underlined.

A. The best human ears can respond to frequencies from about 20Hz to almost 20,000Hz. This frequency is called the **audible range.**

B. A **variety of instruments** can be passed through the endoscope that allows the surgeon to treat many abnormalities with little or no discomfort, remove swallowed objects

C. Equipment is safe, easy to handle, can be operated and be portable. This in one of the **advantage** of ultrasound

D. When the pulse of ultrasound is sent into the body and meets a boundary between two media, most of the wave is reflected and a strong **echo** is recorded.

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. Lack of **ionizing** radiations one of the advantages of MRI.

7. A. True B. False C. False D. True E. False

8. i) The magnitude of the acoustic impedance of each material are:

$$Z_1 = \rho_1 \times v_1 = 900 \times 1500 = 1350000 kg\ m^{-2} s^{-1}$$

$$Z_2 = \rho_2 \times v_2 = 1000 \times 1550 = 1550000 kg\ m^{-2} s^{-1}$$

ii) $$I_r = I_i \times \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2} = 1.0 \times \frac{(1550000 - 1350000)^2}{(1550000 + 1350000)^2} = 0.0048\ W\ m^{-2}$$

iii) The values of intensity of reflection coefficient

$$\alpha = \frac{I_r}{I_i} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2} = \frac{0.0048}{1.0} = 0.5\%$$

iv) The intensity of the wave transmitted into the second material is given by

$$I_i - I_r = 1.0 - 0.0048 = 0.9952\ W\ m^{-2}$$

9. $d = 5.6\ cm = 56 \times 10^{-3} m$, $Velocity\ v = 1.5 km\ s^{-1} = 1500 m/s$

The time is given by $56 \times 10^{-3} m \times 25 \times 10^{-4} s/m = 14 \times 10^{-5} s$

$$d = \frac{vt}{2} = \frac{1500 \times 14 \times 10^{-5}}{2} = 0.105 m = 10.5 cm$$

10. Similarities: all are medical imaging uses to detect the diagnostic of a patient.

Endoscopy	Radionuclide
- Use light - see in the stomach (lining of esophagus)	- Use ultrasound - see inside the body

11. 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

12. Areas of the body can be imaged by ultrasound because 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.)

13. 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.

14. 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)

7.9. Additional activities (Questions and answers)

7.9.1 Remedial activities

1-2: choose the correct answer.

1. Scintigraphy refers to the use of:

   Gamma radiation to form images

   X- ray radiation to form images

   X- rays and gamma radiations to form images

   None of radiation to form images.

2. The radionuclide in clinical practice are

   Technetium

   Thallium

   Gallium

   ALL of them

3. State the applications of Multidetector CT .

Answer

1. A 2. D

3. 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.

7.9.2 Consolidation activities

4. What are the factors affecting the attenuation of ultrasound?

5. a)What do sonar stand for?

   b) What is sonar used?

6. What do you think are the contraindication for MRI Scan?

Answer

4. The factors affecting the attenuation of ultrasound are:
    - The wave simply "spreads out" and suffers an "inverse square law type" reduction in intensity.
    - The wave is scattered away from its original direction
    - The wave is absorbed in the medium
    - 5. a) sonar stands for" sound navigation ranging'.

b) Sonar is a technique that is used sound propagation (usually underwater as in submarine navigation) to navigate communicate with or detect objects on or under the surface of the water.

It is used to measure the depth of water and used to create image of internal body structure as tendons, muscles, joints, blood vessels, internal organism.

6. The contraindication to MRI scan are:
    - Patient who have implanted medical devices (pacemakers or defibrillators, cochlear implants, cerebral aneurysm clips).
    - Patient who have iron fragments in their eyes.
    - Implantable Pediatric Sternum Device. A new implanted sternal device system for pediatric patients.
    - MR-incompatible prosthetic heart valves.
    - Contrast allergy.
    - Body weight (**MRI** tables have specific weight limitations)

7.9.3 Extended activities

7. For radionuclide imaging, it is advisable for the patient to consume a small quantity of radionuclide, or it is injected into a vein in your arm.

How long does it take?

What is the purpose of those radionuclide chemicals?

Assuming the patient has already consumed the radionuclide for him/her to be scanned and wants to take another scan on another part of the body, will the patient be required to take another dose of the nuclide?

You as a student, what advices can you give to a patient who develops allergies after taking the radio nuclear chemical?

8. Distinguish ultrasound from infrasound?

9. Explain clearly the real life application of ultrasound.

Answer

7. For radionuclide imaging, it is advisable for the patient to consume a small quantity of radionuclide, or it is injected into a vein in your arm.

   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.

8. Difference between ultrasound and infrasound is shown in table below.

Ultrasound	Infrasound
is sound waves with frequencies higher than the upper audible It is used for scanning	is sound that is lower in frequency than 20 Hz it is used by animals to communicate

9. Real life application of ultrasound.

Ultrasonic refers to the study of the applications of sound waves that are at a higher frequency than the range which humans can hear. Such waves are used in many fields such as navigations, medicine, imaging, cleaning, communication, mixing etc.

a) cleaning:

Ultrasound is used to clean substances like glass, ceramics, metals etc. It is also used to remove grease and oil from the surface of such materials. Big industries use ultrasound to clean their machines and other apparatus. It is also used to remove oil and other lubricants from aircraft and even automobiles.

b) Detection of cracks:

Ultrasound is used to detect cracks in metallic compounds, and this is mainly used during the construction of huge bridges, buildings and other structures. The ultrasound waves produce distinctive echo patters when it hits the structure, and through software analysis, you can easily find out if there is a crack in the metal structure.

c) Echocardiography:

Echocardiography is often known as Cardiac echo which is basically the sonogram of the heart. The procedure is used for the diagnosis of heart diseases. Echocardiography is one of the most widely used diagnostic tests by cardiologists. You get information about the size of the heart, location, pumping capacity etc.

d) Ultrasonography:

Using ultrasound, you can also get the images of other internal body structures such as organs, muscles and joints. The images that are got from ultrasound are known as sonograms. The images are got when the ultrasound echoes off the tissue and these echoes are recorded and displayed on the screen as an image.

e) Sonar:

Sound navigation and ranging have been one of the most popular methods which are used when they go underwater. SONAR makes it easy to communicate or detect object that are under the surface of the water. SONAR is also used for robot navigations in the air and studies are going on to use ultrasound waves for atmospheric navigation.

f) Echolocation:

Echolocation is when sound waves and echoes are used to determine if there are any objects in the space. Bats use the method of Echolocation to move from one place to another as they cannot see. They send out waves, and when the waves hit an object, it returns and signals them to move in another direction. Based on the nature of the echo bats will be able to determine the size and shape of the object that is in front of them.

UNIT 8

RADIATIONS AND MEDICINE

8.1 Key unit competence:

Categorize hazards and safety precautions of radiation in medicine

8.2 Prerequisite (knowledge, skills, attitudes and values):

Student - teachers should be aware of the concept of x-rays and its effects in medicine.

They should be aware on medical imaging techniques and its real life applications.

8.3 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 chances/ 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 Student-Teachers should be treated equally. This makes the Student-Teachers to find out that they are all of great importance. In spite of their physical ability, Student-Teachers with impairment as normal Student-Teachers should be aware on radiation and use of medical imaging techniques.

Environment sustainability: During delivering different lessons within this unit, let Student-Teachers be familiar with the application and importance of skills radiation and medicine, uses and benefits and risks of them.

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.

8.4 Guidance on introductory activity

This activity aims at capturing Student-teachers attention and minds towards this concept of radiation in medicine, radiation dose, uses, effects and dangers of radiation exposure to human body.

- Divide your Student-teachers into groups (Grouping may depend on the nature of your class or number of Student-Teachers you have). Always take care of Student-Teachers with any kind of educational need while making groups (hearing, reading, seeing, etc.).
- Tell the Student-teachers to open the introductory activity in the Student-teacher's book. You may give them a brief introduction about the activity
- Ask Student-teachers to interpret the pictures in the activity before answering questions. While Student-teachers are doing this activity, you move around, guide the slow Student-teachers. 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. They can use power point where possible
- Note some misconceptions and misunderstanding (if any) so that they are corrected and harmonised in the lesson. Together with Student-Teachers harmonize the points and make a summary on the board. Give to Student-Teachers the opportunity to write the main points in their notebooks.
- Summarize your lesson by linking this concept to real life application of radiation in medicine by focusing on the symptoms, effects and jeopardy of radiation exposure to human body

Answers for the introductory activity

a) The difference between artificial source of radiation and natural source of radiation is shown in table below:

Artificial source of radiation: Are man-made radiation which are exposed to the public. Those radiations are coming from medical procedure such as diagnostic x-rays, nuclear medicine and radiation therapy.

Natural source of radiation

Some are coming from three sources such as Cosmic, terrestrial and internal radiation

Cosmic radiation include: sun, atmosphere, earth

Charged particles from the sun and stars interact with the earth's atmosphere and magnetic field to produce a shower of radiation, typically beta and gamma radiation. The dose from cosmic radiation varies in different parts of the world due to differences in elevation and to the effects of the earth's magnetic field.

Terrestrial Radiation found in **soil, water** and **vegetation.**

Radioactive is in the soil, water, and vegetation. Low levels of uranium, thorium, and their decay products are found everywhere. Some of these materials are ingested with food and water, while others, such as radon, are inhaled. The dose from terrestrial sources also varies in different parts of the world. Locations with higher concentrations of uranium and thorium in their soil have higher dose levels.

Internal radiations include (Potassium-40, Carbo-14, and Lead-210).

In addition to the cosmic and terrestrial sources, all people also have radioactive potassium-40, carbon14, lead-210, and other isotopes inside their bodies from birth. The variation in dose from one person to another is not as great as the variation in dose from cosmic and terrestrial sources. The average annual dose to a person from internal radioactive material is about 40 millirems/year.

a) The major types of source of radiation mostly preferred to be used in medicine are X-rays or radiation therapy

b) Yes.

c) The answers of this sub question is on note 8.2(from Student-Teacher book)

8.5 List of lessons

#	Lesson title	Learning objectives	No of periods
1.	Radiation dose	- Explain radiation dosimetry. - Explain the terms: exposure, absorbed dose, quality factor (relative to biological effectiveness) and dose equivalent - Differentiate the terms: exposure, absorbed dose, quality factor (relative to biological effectiveness) and dose equivalent as used in radiation dosimetry	6
2	Hazards and safety precautions when handling radiations.	- Outline hazards and safety precautions to be taken when handling radiations - State the concept of balanced risk. - Explain hazards and safety precautions when handling radiations - Describe the concept of balanced risk	4
3	Basics of radiation therapy for cancer treatment	- Outline the basics of radiation therapy for cancer treatment - Analyse the basics of radiation therapy for cancer	2
4	End Unit Assessment		**2**

Lesson 1: RADIATION DOSE

a) Learning objectives

- Explain radiation dosimetry.
- Explain the terms: exposure, absorbed dose, quality factor (relative to biological effectiveness) and dose equivalent
- Differentiate the terms: exposure, absorbed dose, quality factor (relative to biological effectiveness) and dose equivalent as used in radiation dosimetry

b) Teaching resources

- Internet, textbooks and Simulations (https://phet.colorado.edu/en/simulations/category/physics/light-and-radiation).
- Videos on radiation dose,
- Computer, projector, etc..

c) Prerequisites/Revision/Introduction

- Student-teachers should know the x-rays and its applications in medicine
- Student-teachers should know medical imaging techniques
- They should connect/link what they know with radiation.

d) Learning activity 8.1

Guidance on learning activity 8.1

The activity aims to capture Student-teachers' attention and develop critical thinking and collaboration in Student-Teachers. They are encouraged to work together to answer the questions in the activity 8.1.

This lesson focuses on making Student-teachers understand the concepts of radiation.

- Tell Student-teachers to open their books (Student-teacher's book) to learning activity 8.1
- Decide on the methodology to use in this lesson. You can group your Student-teachers (or use other techniques), they can do it as a class or individual.

- Instruct them to read the activity first and then re-write it to their notebooks.
- Allow them to attempt the questions.
- Move around and mark their work.
- Select some Student-teachers to share their answers during a presentation to the whole class (They can use power point where possible) and allow questions from Student-teachers if any. Create a good ground for Student-Teachers to discuss.
- Together with Student-teacher link their answers to real life experience related to radiation
- Make a summary and tell Student-teachers to write down important ideas in their books.

Note: Make sure you mind about Special educational need. In case you have a Student-teacher who needs special attention/care.

Answer for activity 8.1

a) The ability of the radiation to penetrate through matter is expressed in terms of penetration power. The more you the penetration power the greater dangerous they are. In general alpha Particle makes them less able to penetrate matter, gamma travel much farther than alpha.

b) No, any amount of radiation can't be applied because The amount of radioactive material to be managed shall be such that the subject receives the minimum radiation dose with which it is practical to perform the study without putting at risk the benefits to be obtained by the study. Under no circumstances may the radiation dose to any adult differs from a single one. The amount of radiation takes into account the dose and relative radio sensitivity of organs/ the part which is going to be examined, the age, sex of patient and the time you are received that dose.

c) The common radiation used in hospital is: ionization radiation (including x-rays and gamma rays).

d) Effects of radiation to human body are: radiation sickness and sometime cancer for a long-time exposure.

e) The precautions are taken reduce the risk include: keeping radioactive sources shielded and wearing protective clothing

Answers for application activity 8.1

1.

Ionization radiation	non-ionization radiations
- Ionization refers to a radiation that carries sufficient energy to release electrons from atoms or molecules, in that way ionizing them. - It is made up of energetic subatomic particles, ion or atoms that moving at high speeds. - It is used X-ray radiography or computed tomography scans. - Example:x-rays, gamma-rays.	- *Non-ionizing radiation* is any type of electromagnetic *radiation* that does not carry enough energy to *ionize* atoms or molecules. - Example: visible light, microwaves, ultraviolet (UV) radiation, infrared radiation, radio waves, radar waves, mobile phone signals, etc - etc

2. 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) Radiation dose is a quantity of the energy measured which is deposited in matter by ionizing radiation per unit mass.

   c) The quality factor of a radiation type 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.

3. A measure of the risk of biological harm is the dose of radiation received by tissue.

Lesson 2: HAZARDS AND SAFETY PRECAUTIONS WHEN HANDLING RADIATIONS

a) Learning objectives

- Outline hazards and safety precautions to be taken when handling radiations
- State the concept of balanced risk.
- Explain hazards and safety precautions when handling radiations
- Describe the concept of balanced risk

b) Teaching resources

- Internet and textbooks.
- Videos on radiation dose,
- Computer, projector, etc.

c) Prerequisites/Revision/Introduction

- Student-Teachers should know x-rays and its effects in medicine.
- Student-Teachers should know medical imaging techniques.
- Student-Teachers should know the concept radiation

d) Learning activity 8.2

Guidance on learning activity 8.2:

The activity aims to capture Student-teachers' attention and develop critical thinking and collaboration in Student-teachers. The Student-teachers are encouraged to work together to answer the questions in the activity 8.2.

This lesson focuses on making Student-teachers understand unintended events happened during radiation exposure, jeopardy and preventive measures to be taken.

- Tell student-teachers to open their books (Student-Teacher's book) to learning activity 8.2
- Decide on the methodology to use in this lesson. You can group your student-teachers; they can do it as a class or individual.
- Instruct them to read the activity first and then re-write it to their notebooks.

- Allow them to attempt the questions.
- Move around and mark their work.
- Select some student-teachers to share their answers to the whole class (They can use power point where possible) and allow questions from student-teachers if any. Create a good ground for Student-Teachers to discuss.
- Together with student-teachers link their answers to real life experience related to medical imaging.
- Make a summary (hazards and safety precaution of radiation) and tell Student-Teachers to write down important ideas in their books.
- **Note:** Make sure you mind about Special educational need. In case you have a Student-Teacher- teacher who needs special attention / care.

Answer for activity 8.2

1.a) Radiation accident is an unintended event that as or may have adverse consequences or potential consequences of which are not negligible from the point of view of protection or safety.

b) Radiation accident includes:

- Operating error
- Human error
- Equipment failure
- Unintended deviation
- Any diagnostic exposure appears to be greater than intended or doubling doses /dose repeatedly and exceeding the established guidance level.
- Any the repeated treatment delivered to either the wrong patient or wrong tissue.
- Using wrong pharmaceutical or with a dose or dose fractionation different from what is indicated by medical practitioner. This may lead to the acute secondary effects.

c) Effect of radiation exposure

Short term exposure radiation	Long-term exposure radiation
Rises your risk of cancer	Cause radiation sickness, burns cancer, cardiovascular disease, gastrointestinal system and sometimes death.

a) safety precaution:

Damage by radiation is irreversible. Once the cells are damaged, they do not repair themselves. Until now, there is no way for medicine to do this, so it is important for someone who has been exposed to seek medical help as soon as possible.

Possible treatments include:

- Removing all clothing,
- Rinsing with water and soap.
- Use of potassium iodide (KI) to block thyroid uptake if a person inhales or swallows too much radioiodine
- Prussian blue, given in capsules, can trap cesium and thallium in the intestines and prevent them from being absorbed. This allows them to move through the digestive system and leave he body in bowel movements.
- Filgrastim, or Neupogen, stimulates the growth of white blood cells. This can help if radiation has affected the bone marrow.

Depending on exposure, radiation can affect the whole body. For cardiovascular, intestinal, and other problems, treatment will target the symptoms.

Instructions for reducing unnecessary exposure to radiation include:

- keeping out of the sun around midday and using a sunscreen or wearing clothes that cover the skin
- making sure any CT scans and x-rays are necessary, especially for children
- letting the doctor know if you are or may be pregnant before having an x-ray, PET, or CT scan

2. I can advise him to pass this imaging because effects of radiations 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. So the Doctor knows this, and he/she will use low radiation dose.

Answers for application activity 8.2

1. Balanced risks refers to weighing the radiation risks due to X-rays, CT-Scans or another imaging at very high doses or radiations. Here you balance the benefits and risks.
2. The life time 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.

3. 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).

4. 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.

5. 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.

6. For reducing radiation exposure, there are 3 principals: time, distance, and shielding.

   a) Time: Radiation exposure can be accumulated over the time of exposure. In C-arm fluoroscopy-guided interventions, the time spent for checking C-arm fluoroscopy-guided interventions is relative to the time exposure. The longer exposure time, the more radiation exposure to the pain physician. For reducing the usage of time, the physician has to improve his/her skills in intervention and the radiographer has to check the X-ray at the correct location, and at the right moment without blurred image.

b) **Distance:** the greater distance from radiation source can reduce the radiation exposure the amount of radiation exposure is not inversely proportional to the distance from radiation source, but it is inversely proportional to the square of the distance i.e. double the distance from the radiation source can reduce the radiation exposure not to $\frac{1}{2}$ but to $\frac{1}{4}$.

c) **Shielding:** There are many shielding devices such as caps, lead glasses, thyroid protectors, aprons, radiation reducing gloves, and so on, for radiation safety during C-arm fluoroscopy-guided interventions. Reducing the time of radiation exposure, a greater distance from radiation sources, and the use of shielding devices for radiation protection are important.

Lesson 3: BASICS OF RADIATION THERAPY FOR CANCER TREATMENT

a) Learning objectives

- Outline the basics of radiation therapy for cancer treatment
- Analyse the basics of radiation therapy for cancer.

b) Teaching resources

- Internet and textbooks.
- Videos on radiation dose
- Computer, projector, etc

c) Prerequisites/Revision/Introduction

- Student-teachers should know x-rays and its effects in medicine.
- Student-teachers should know medical imaging techniques.
- Student-teachers should be aware of the hazards, safety precaution when handling radiation.

d) Learning activity 8.3

Guidance on the learning activity 8.3

This activity aims at realizing the radiation therapy for cancer treatment.

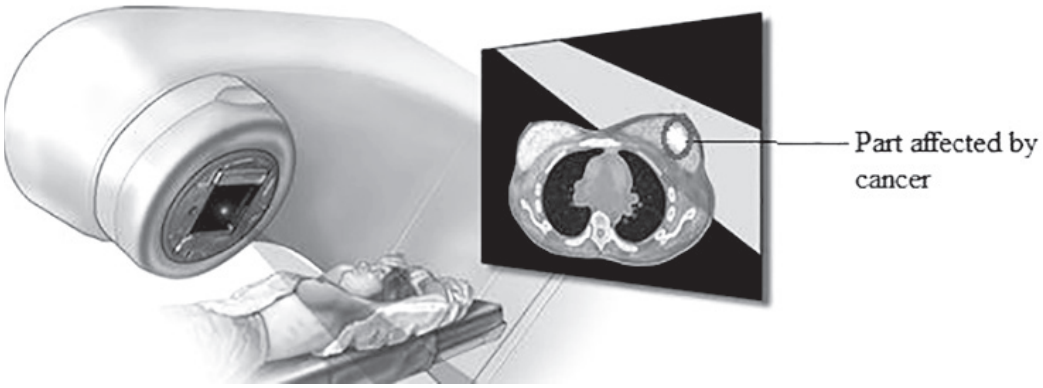
- Tell Student-teachers to open their books (Student-teacher's book) to learning activity 8.3
- Choose on the methodology to use in this lesson. You can group your Student-teachers (or use other techniques) they can do it as a class or individual.

- Initiate them to read the activity first and then re-write it to their notebooks.
- Allow them to do activity and move around then after mark their work.
- Have sample group present their work to the class. (They can use power point where possible)
- Check Student-teachers' responses to review their ideas to continue the discussion with a brief brainstorming of the concepts using Student-teacher's work.
- Comment on Student-teachers' responses written in their notebooks and give them the expected feedback.
- Make a summary (radiotherapy for cancer treatment) and tell Student-teachers to write down important ideas in their books.

Note: Make sure you mind about Special educational need. In case you have a Student-teacher who needs special attention/care.

Answers for activity 8.3

i)



ii) No, Breast Cancer is one of the most prevalent and common forms of Cancers. Some condition largely effects women only, while in a very few rare cases it also affects certain men

iii) External beam radiation therapy delivers radiation using a linear accelerator (device uses high energy x-rays or electrons to conform to a tumor's shape and destroy cancer cells.

Internal radiation therapy, called brachytherapy or seed implant, involves placing radioactive source inside the patient.it is coming from radiation source placed in seeds, needles or thin plastic tube that are put in or near the tissue. Radioactive source in form of a liquid is injected or swallowed by patient.

For the above figure the doctor opt the external beam radiation therapy.

Answers for application activity 8.3

1) Radiation therapy is used to treat many type of cancer. It can be used to cure cancer, control the growth or spread of cancer and to provide comfort by alleviating the symptoms cancer can sometimes cause.
2) It is used to kill cancer cells or stop them from growing or spreading in the body.
3) Each radiation therapy treatment takes about 10 minutes. It is usually delivered in five days.
4) In the early stage, radiation therapy can help reduce the size of a tumor before surgery or kill remaining cancer cells afterward. In the later stages, it may help relieve pain as part of palliative care. One form of radiation treatment involves using a machine that produces a beam of radiation.

8.6. Summary of the unit

- Ionization radiation refers to a radiation that carries sufficient energy to release electrons from atoms or molecules, in that way ionizing them.
- Radiation therapy also called radiotherapy.
- **Non-ionizing radiation** is any type of electromagnetic radiation that does not carry enough energy to ionize atoms or molecules.
- **Radiation dosemetry** is a measurement of radiation received by a patient/person.
- Radiation dosimeter is a device that measures dose uptake of external ionizing radiation.
- Effects of long term exposure are: radiation sickness, cancer, etc
- **Deterministic effects**: These effects are observed after **large absorbed doses** of radiation and are mainly a consequence of radiation induced cellular death.
- **Stochastic effects:** They are effects associated with long term, low level (**chronic**) exposure to radiation.
- Safety precautions for handling radiations include Shortening the time of exposure, increasing distance from a radiation source and shielding
- **Radiation therapy** (also called radiotherapy) refers to the cancer treatment which uses high dose of radiation to kill cancer cells and tumors.
- **Cancer** is the name given to a range of diseases where there is malignant tumour.

8.7 Additional information for the tutor

8.7.1 The half-lives: physical, biological, and effective

The *half-life* is a characteristic property of each radioactive species and is independent of its amount or condition. The effective *half-life* of a given isotope is the time in which the quantity in the body will decrease to *half* as a result of both radioactive decay and biological elimination.

There are three half-lives that are important when considering the use of radioactive drugs for both diagnostic and therapeutic purposes. While both the **physical** and **biological** half-lives are important since they relate directly to the disappearance of radioactivity from the body by two separate pathways (radioactive decay, biological clearance), there is no half-life as important in humans as the **effective half-life.**

The half-life takes into account not only elimination from the body but also radioactive decay. If there is ever a question about residual activity in the body, the calculation uses the effective half-life; in **radiation dosimetry** calculations, the only **half-life** that is included in the equation is the effective half-life.

a) Physical half Lives

Physical half-life is defined as 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. The physical half-life is designated T_p or more commonly $T_{1/2}$.

By default, **the term $T_{1/2}$** refers to the physical half-life and T_p is used when either or both of the other two half-lives are included in the discussion.

$$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

where λ is the radioactive constant of the radio substance

There are a few things to note about the T_p :

▪ The T_p can be measured directly by counting a sample at 2 different points in time and then calculating what the half-life is.

▪ For example, if activity decreases from 100% to 25% in 24 hours, then the half-life is 12 hours since a decrease from 100% to 50% to 25% implies that 2 half-lives have elapsed.

The **physical half-life** is unaffected by anything that humans can do to the isotope. High or low pressure or high or low temperature has no effect on the decay rate of a radioisotope.

b) Biological half lives

Biological Half-life is defined as 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. It is typically designated T_b. There are a few things to note about the T_b :

- For radioactive compounds, we have to calculate the T_b because the mass of the isotope is usually on the nanogram scale and, when distributed throughout the body, and especially in the target organ, concentrations are in the pictogram/ml range, much too small to measure directly.

- For non-radioactive compounds, we can measure the T_b directly. For example, assuming that a person is not allergic to penicillin, we could give 1 000 mg of the drug and then measure the amount present in the blood pool and in the urine since we administered such a large amount of the drug.

- T_b is affected by many external factors. Perhaps the two most important are hepatic and renal function. If kidneys are not working well, we would expect to see a high background activity on our scans.

- Each individual organ in the body has its own T_b and the whole body also has a T_b representing the weighted average of the T_b of all internal organs and the blood pool. It is therefore very important to have a frame of reference. For example, do you need to know the T_b of the drug in the liver or in the whole body?

- All drugs have a T_b , not just radioactive ones. Drug package inserts often refer to the half-time of clearance of a drug from the blood pool or through the kidneys.

- Since the whole body has a T_b representing the weighted average of the T_b of all internal organs, it will almost never equal that of an internal organ.

c) Effective half lives

Effective half-life is defined as 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.

It is designated T_e can be measured directly. For example, one can hold a detection device 1 m from the patient's chest and count the patient multiple times until the reading decreases to half of the initial reading.

The patient is permitted to use the rest room between readings as needed, so both elimination and decay are taking place. The half-life being measured in this case is the T_e and T_e is affected by the same external factors that affect T_b since T_e is dependent upon T_b.

$$T_e = \frac{T_p \cdot T_b}{T_p + T_b}$$

Where

- T_p: physical half-life
- T_b: biological half-life

Example 8.1

For a Xe-133 for pulmonary ventilation study, where $T_p = 5.3\,\text{days}$ and $T_b = 15s$, calculate the effective half-life of Xe.

Answer:

$$T_e = \frac{T_p \cdot T_b}{T_p + T_b} = \frac{457920 \times 15}{457920 + 15} = 15\,s$$

8.7.2 IONIZATION RADIATION VERSUS NON-IONIZATION RADIATION

The table below shows how the ionization radiations differs from non-ionization radiations

Description	Ionization radiation	Non ionization radiation
meaning	Radiation that has enough energy to remove electrons from atoms or molecules as it pass through matter.	Radiation that does not carry enough energy to remove electron from atoms or molecules.
examples	x-ray, gamma rays, cosmic rays	Light, microwaves , infrared, lasers, radio waves, ultraviolet and radar
frequencies	Higher frequency and short wavelength	Lower frequency and short wavelength
types	X-RAYS Nuclear	Near ultraviolet radiation 'visible light, infrared, microwave, radio waves, very low frequency (VLF), Extremely low frequency (ELF), Thermal radiation, Black-body radiation.
Sample sources	Nuclear energy production, Certain medical imaging studies. Concentrated UV Light	Microwave Computers Tablets WiFi Networks Cell Phones Bluetooth Devices Power Lines
effects	Some of these rays in excess can be harmful. These are used for medical purposes	These rays aren't directly harmful. in fact, our lives depend heavily on these for survival
Ions	Interaction with matter can produce charged particles called IONS	Cannot produce ions

energy	Higher energy electromagnetic waves (gamma) or heavy particles (beta and alpha).	Lower energy electromagnetic waves. Not enough energy to pull electron from orbit, but can excite the electron

8.7.3 Most common Types of cancer

1) Breast cancer: A cancer that forms in the cells of the breasts.
2) Prostate cancer: A cancer in a man's prostate, a small walnut-sized gland that produces seminal fluid.
3) Basal cell cancer: A type of skin cancer that begins in the basal cells.
4) Skin cancer (melanoma): The most serious type of skin cancer.
5) Colon cancer: A cancer of the colon or rectum, located at the digestive tract's lower end.
6) Lung cancer: A cancer that begins in the lungs and most often occurs in people who smoke.
7) Leukemia: A cancer of blood-forming tissues, hindering the body's ability to fight infection.
8) Lymphoma: A cancer of the lymphatic system.

Note that: Cancer can be treated by **surgery**, **chemotherapy**, **radiation therapy**, hormonal **therapy**, targeted **therapy** (including **immunotherapy** such as monoclonal antibody **therapy**) and synthetic lethality.

Guidance on skills lab 8

This activity aims at capturing Student-teachers' attention and minds towards the explanation of invited medical doctor that has expertise in radiation and medicine.

- This skill lab will be carried out at school. Where the invited medical doctor give more clarification based on the points of discussion that has been sent before (these points are mentioned in Student-Teacher's book).
- During discussion, Student-teachers note something from explanations and then ask other questions that help them to understand more.
- Compare what the doctor explained to what you have been discussing in this unit.

- Develop a comprehensive report including all what you have been studying and information from the doctor.
- Present your findings (in the report) to the class and to the tutor. (They can use power point where possible).
- Submit your report to your tutor for marking or checking.(it may be sent through email)

Note: Make sure you mind about Special educational need. In case you have a Student-teacher who needs special attention/care.

8.8. Answers for end unit 8 assessment

1. The severity of signs and symptoms of radiation sickness depends on how much radiation you've absorbed. How much you absorb depends on the strength of the radiated energy, the time of your exposures, and the distance between you and the source of radiation.

Possible symptoms are:

- Nausea and vomiting
- Diarrhea
- Headache
- Fever
- Weakness
- Hair loss
- Low blood pressure
- Dizziness and disorientation
- Infection
- Bloody vomit and stools from internal bleeding

The complication of radiation sickness can contribute to both short-term and long-term mental health problems, such as grief, fear and anxiety about:

i) Experiencing a radioactive accident or attack

ii) Mourning friends or family who haven't survived

iii) Dealing with the uncertainty of a mysterious and potentially fatal illness

iv) Worrying about the eventual risk of cancer due to radiation exposure

2. Radiation sickness is resulting from excessive exposure to ionization radiation. they are 2 types of radiation: non-ionization and ionization radiation came from light, radio waves, microwaves and radar

3. No, Radiation cannot be spread from person to person. Small amount of quantities of radiation materials occur naturally in the air, water, plants and our bodies. People can also get near the contact of radiation through medical procedures like x-rays and other cancer treatments.
4. 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.

5. 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.
6. 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.

7. 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.
8. 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).

8.9. Additional activities (Questions and answers)

8.9.1 Remedial activities

1. What is the risk of radiation exposure?
2. In case of long radiation exposure how can a person be treated?
3. What are the symptoms of radiation exposure?

Answer for Remedial activities

1. Exposure to very high levels of radiation, such as being close to an atomic blast, can cause acute health effects such as skin burns and acute radiation syndrome (“radiation sickness»). It can also result in long-term health effects such as cancer and cardiovascular disease.
2. In case of long radiation exposure we firstly do the treatment for internal contamination. Some treatments may reduce damage to internal organs caused by radioactive particles. Medical personnel would use these treatments only if you›ve been exposed to a specific type of radiation. These treatments include the following: Potassium iodide (ThyroShield, Iosat)

3. Symptoms of radiation sickness may include:
   a. Weakness, fatigue, fainting, confusion.
   b. Bleeding from the nose, mouth, gums, and rectum.
   c. Bruising, skin burns, open sores on the skin, sloughing of skin.
   d. Dehydration.
   e. Diarrhea, bloody stool.
   f. Fever.
   g. Hair loss.
   h. Inflammation of exposed areas (redness, tenderness,

8.9.2 Consolidation activities

4. What is the most dangerous type of radiation to living matter? Give reason.
5. Explain what happens when radiation interacts with matter?

Answer for consolidation activities

4. The most dangerous type of radiation to living matter is Gamma rays. Due to their high penetration power, they can damage bone and internal organs.

5. When the x-rays or gamma rays are directed into an object, some of the photons interact with the particles of matter and their energy can be absorbed by depositing its energy or be scattered or deflected from its original direction and deposit part of its energy; both are with electrons.

8.9.3 Extended activities

6. Many people are experienced in many activities; those activities can expose people to source of radiation. What are these?

7. Explain the basic methods used to treat a patient with cancer.

Suggested answer for extended activities

6. These activities may include:
   - Watching television
   - Flying in an airplane
   - Passing through a security scanner
   - Using a microwave or cell phone.

Note that: Smokers have a higher exposure than non-smokers, as tobacco contains a substance that can decay to become polonium 210.

Astron Wuts have the highest exposure of anyone. They may be exposed to 25 rads in one Space Shuttle mission.

7. There are four basic methods and treatment for any one patient may involve two or more of them
   - Surgery: if the tumour is easily located, it may simply be removed.
   - Chemotherapy: the patient is given dose of cell destroying drugs.
   - Hormone therapy: some hormone dependent tumour can be treated by altering the hormone balance within the body.
   - Radiotherapy: tumour cells are destroyed with high-energy radiation, either gamma-rays from a radioactive source or x-rays.

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