PHYSICS FOR TTC

TUTOR'S GUIDE

YEAR 2

OPTION: SME

Kigali, 2019

FOREWORD

Dear tutor,

Rwanda Education Board is honoured to present tutor's guide for Physics year two 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 learners achieve full potential at every level of education which will prepare them to be well integrated in society and exploit employment opportunities.

In line with efforts to improve the quality of education, the government of Rwanda emphasizes the importance of aligning teaching and learning materials with the syllabus to facilitate their learning process. Many factors influence what they learn, how well they learn and the competences they acquire. Those factors include the relevance of the specific content, the quality of 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 teacher. In competence-based curriculum, learning is considered as a process of active building and developing of knowledge and understanding, skills and values and attitude by the learner where concepts are mainly introduced by an activity, situation or scenario that helps the learner to construct knowledge, develop skills and acquire positive attitudes and values.

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

- Plan your lessons and prepare appropriate teaching and learning materials.

- Organize group discussions for student-teachers considering the importance of social constructivism suggesting that learning occurs more effectively when the learner 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 book.

Even though this tutor's guide contains the Answers for 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. NDAYAMBAJE Irénée

Director General of Rwanda Education Board

ACKNOWLEDGEMENT

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 two of TTC. It would not have been successful without active participation of different education stakeholders.

I owe gratitude to different Universities and schools in Rwanda that allowed their staff to work with REB in the in-house textbooks production project. I wish to extend my sincere gratitude to lecturers, teachers and all other individuals whose efforts in one way or the other contributed to the success of writing of this tutor's guide. Special acknowledgement goes to teachers, tutors, illustrators and designers who participated in production of this tutor's guide.

Finally, my word of gratitude goes to the Rwanda 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 two in TTC. It is designed to accompany student teacher 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 for questions of the end unit assessment in the student-teacher's book and suggests additional questions and related Answers for assess the key unit competence.
- Additional activities**:** It includes 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 activities**

  This section provides a short description of the methodology and any important aspect to consider. It provides also Answers for 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 teacher centered to a learner 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 learner can do rather than what learners 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 learner-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 crosscutting 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. An example: 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 equipments 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-teachercan 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 learners; slow, average and gifted learners 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 two 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 teacher teachers' needs, abilities and learning styles.

There are mainly four different learning styles as explained below:

a) Active and reflective learners

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

b) Sensing and intuitive learners

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

c) Visual and verbal learners

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

d) Sequential and global learners

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

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, learners 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 learners in active learning

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

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

Some active techniques that can be used in Physics

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

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 learners' 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. Orstudent-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-teachers'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

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

Term	Date	Subject	Class	Unit Nº	Lesson Nº	Duration	Class size
Term I	… /…/ ….	PHYSICS	Year 2 SME	1	1 of 4	80 min	….
Type of Special Educational Needs to be catered for in this lesson and number of learners in each category				**1student with visual difficulties.**			

Unit title	**Applications of thermodynamics laws.**
Key Unit Competence	To evaluate applications of first and second laws of thermodynamics in real life.
Title of the lesson	Internal energy and total energy of a system.
Instructional Objective	Through group discussions, learners will be able to analyse internal and total energy of a system accurately.
Plan for this Class (location: in / outside)	Classroom or Laboratory
Learning Materials (for all learners)	A pumped ball, a syringe, a flask with hot water, Source pan with cover and source of heat, Laboratory thermometer.
References	1. Breithaupt, J. (2000), *Understanding Physics For Advanced Level* (4, Ed.) Ellenborough House, Italy: Stanley Thorners; 2. Abbot, A. F., & Cockcroft, J. (1989). *Physics.* (5, Ed.) Heinemann: Educational Publishers. 3. Student's book SME Year two unit 1.

Timing for each step	**Description of teaching and learning activity**	**Generic competences and**
	Description of teaching and learning activity Through performing an experiment of heating/boiling water in a	

<table>
<tr><td></td><td colspan="2">closed pan, the learners will realise internal energy of a system with Tutor’s guide.</td><td rowspan="2">Cross cutting issues to be addressed
+
a short explanation</td></tr>
<tr><td></td><td>Teacher activities</td><td>Learner activities</td></tr>
<tr><td>Introduction

10min</td><td>Motivate the learners by asking them some questions like how food gets ready when it is heated and what is the significance of putting food and drinks in flasks, and others.
Form small groups with recognition of the group leaders, secretary and time keeper and let them brainstorm on the given questions.
Make sure that the student-teacher with visual difficulties sits in front so that he/she can see on the board clearly.
Moderate the presentations and correct different ideas from student-teachers.
Possible answers:
Given in the textbook
Facilitating the student-</td><td>Recall how temperature changes the internal energy of a system.
They try to think how energy is transmitted throughout a system and then discuss the question and take position.
Individually, they give their thoughts.
Predictions:
When you heat food, you are transferring energy into it by placing it in contact with surroundings that have a higher temperature. So the temperature is transmitted throughout the whole system leading to food getting ready.
The main aim of putting food in flask is to keep them at required temperatures and preserve them from microbes.
Discover the objectives of the lesson
<u>Prediction</u>
To differentiate internal energy and total energy of a system</td><td>Communication, cooperation, critical thinking through responding to questions.
Gender is addressed in forming groups.</td></tr>
</table>

	teachers to think about the lesson title of the day.		
Development of the lesson 55min	Lead the process of examining learners' predictions. Give an opportunity to the learner to suggest how to verify their predictions. Light the source of heat (Either a stove, Bunsen burner or any other source of heat). Guide the groups to observe and take note of what is happening as water is heated. Guide them in measuring temperature using laboratory thermometer. Schedule the presentations of sample groups to discuss on the observations and difficulties involved in performing the activity. After the experiment, summarize the feedback	Student-teachers start heating water in a closed/covered pan. Observe and note temperature changes. Learners discuss on how heat is transferred in liquids and how change in temperature leads to energy changes in the system. Notice their predictions during discussions. Present the results in plenary and write them on the board. Compare the results with different predictions Student-teachers notice the feedback of the discussed points in their notebooks (about the experiment that is done) and attempt the activity assigned to them (Activity 1.1 in the learner's book) Present the results and write on the chalk board	Peace and value through co-operation in performing work. Gender recognition in forming groups and assigning duties in performing tasks. Peace and value, inclusive education through co-operation in discussions and assigning duties in performing tasks. Through

	based on student-teachers' ideas and let them attempt application activity 1.1 in the student's book to assess their understanding. Mark student-teachers' work.		performing tasks student-teacher develops critical thinking and analytical skills.
Conclusion 15 min	Summarize the the feedback after marking student-teachers'work trying to relate the ideas with real life situations. Assessment/Homework Verify using different methods the level of attainment of the learning outcomes You may ask questions like, 1) Differentiate heat from thermal energy. 2) Discuss the meaning of internal energy of a system.	Correct their results and write the home work in their note books. Apply the gained skills to answer questions and different tasks related to internal energy of a system given by the tutor.	Critical thinking and analytical skills
Teacher self-evaluation	Successfully taught or partially taught.		

PART III: UNIT DEVELOPMENT

UNIT 1: APPLICATIONS OF THERMODYNAMICS LAWS

1.1 Key unit competence:

Evaluate applications of first and second laws of thermodynamics in real life

1.2 Prerequisite (knowledge, skills, attitudes and values)

- Student-teachers should know working principal of flasks.
- Student-teachers should have knowledge on heat transfer. From O'level physics S.1 unit 9, S.2 unit 10, and S.3 unit 6.

1.3 Cross cutting issues to be addressed

- **Inclusive education** (promote education for all in teaching and learning process):

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

- **Gender education** (equal opportunities of boys and girls in the learning process). It is very important to give both Sexes equal opportunities in teaching and learning process. This should be integrated in all lessons of this unit.
- **Environment sustainability**: During delivering of different lessons within this unit, Student- 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). For example: Old engines. Whenever you are doing any practical lesson be mindful of this culture in selecting appropriate measuring instruments. Hence, the measurement 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 intends to introduce applications of thermodynamics laws to student-teachers and captures student-teacher's attention to realize how the unit is applicable in real life.

- Decide on the method and technique to use. Make sure that the method chosen makes student-teachers get involved in brainstorming the questions in the activity. You may decide student-teachers to be in small groups (reasonable number depending on the size of your class), individual and others. The choice is yours. Make sure you take care of students with special educational needs.

- Guide them to read and interpret the questions. In case there are new words in the questions, try to explain them.

- Depending on the level of understanding of your students, give them appropriate time to answer the questions in their notebooks. In case they were in groups, let each group come up with their findings and present to the whole class.

- Decide the method of assessing/correcting the activity. You may decide either to mark or discuss the answers in the class with any other student in the class.

- Harmonize the work discussed/done in the class adding relevant information that will enable you to link students' answers/findings to the whole unit. You can allow students to note down information you think is relevant to the unit.

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

1.5 List of lessons

#	Lesson title	Learning objectives	Number of Periods
1	Internal energy and total energy of a system	- Differentiate internal energy and total energy of a system	3
2	Work done by expanding gas	- Explain the work done by expanding gas	3
3	First law of thermodynamics	- State the first law of thermodynamics - Point out laws of thermodynamics to isothermal, isochoric and Isobaric and adiabatic processes - Solve problems related to thermodynamic processes	5
4	Second law of thermodynamics: Adiabatic process, Carnot cycle.	- State the second law of thermodynamics - Solve problems related to Carnot cycle and adiabatic process - Apply law of thermodynamics to explain the principle of a Carnot engine, diesel engine and refrigerator - Solve problems related to Carnot and diesel engine, and refrigerators - Determine and evaluate the efficiency of heat engines - Explain thermodynamic processes in heat engines - Analysis efficiency of heat engines - Discuss impact of heat engine on climate	11
5	End unit assessment		2

Lesson 1: Internal energy and total energy of a system

a) Learning objective

- To differentiate internal energy and total energy of a system

b) Teaching resources

- Textbooks (Student-teacher's book and all reference books in student-teacher's book), internet
- Projectors, videos about energy changes in Simple Harmonic Motion

c) Prerequisites/Revision/Introduction

- Knowledge about effect of temperature on gases.
- Kinetic theory of matter as learnt in year 1 in unit 8.

d) Learning activities

Guidance for learning activity 1.1 in learners' book

This activity intends to test student-teacher's impact of temperature on the energy of a system.

- Chose appropriate method to use in your class. Student-teachers can do this activity either in groups, as individual or class discussion.

- Let the student-teachers turn to activity 1.1 and under your supervision let them read and interpret the questions. (This still depend on the mythology you chose)

- Leave them to brainstorm the questions and they can either write their suggested answers in their exercise books or do presentations in case of group work.

- Decide the method of correcting their work

- Together with student-teachers, harmonize /summarize the discussion and in case student-teachers need to note down some important information in their notebooks

- You can give your student-teachers assignment about the next concept. Make sure you give all instructions on how you want these student-teachers do assignment.

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

Answers for Activity 1.1

a) Since the room's temperature increased, internal energy of the room increased which is then absorbed by the body. This is because you are in that environment. This can be best explained zeroth law. If two bodies are in thermal contact, there will always be flow of heat from hot region to cold region.

b) Heat can be transmitted by radiation, conduction and convection. Therefore, heat can also be transmitted via roofing by conduction, walls (by conduction). Therefore, it's possible to find the room hot though closed through walls roofings etc.

c) No. Since there will be high exchange of energy from the room to outside.

d) Pressure and temperature changes. Because:

Pressure is due to the interaction/collision of air particles and this changes with the change in temperature and temperature is rose since there was absorption of energy may be from the sun since it was on a hot day and the major source of heat is sun, therefore the rate of interaction of particles will increase leading to rise in temperature. Therefore, pressure increases,

Volume remains constant since the walls of the room are fixed and stiff. The force applied by air particles is not enough to make walls move.

Answers for the Application activity 1.1

1. i) Heat refers to the total internal energy of a system. However, in thermodynamics, heat only denotes heat exchange or a form of energy transfer between different temperatures,

   ii) Internal energy is the sum of potential energy of the system and
   the system's kinetic energy. The change in internal energy (ΔU) of a reaction is equal to the heat gained or lost (enthalpy change) in a reaction when the reaction is run at constant pressure.

OR: In thermodynamics, the internal energy of a system is the total energy contained within the system.

2. The internal energy of a system can be increased by introduction of **matter**, by **heat,** or by doing **thermodynamic work** on the system
3. In an engine, in a refrigerator and in steam engine

All these changes are intended to do some work.

There will be flow of heat from hot end to cold end. (First law of thermodynamics)

Lesson 2: Work done by expanding gas

a) Learning objective

In this lesson student-teachers will be able to explain the work done by expanding gas

b) Teaching resources

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

- Projectors, videos

c) Prerequisites/Revision/Introduction

- Knowledge about effect of temperature on gases.
- Kinetic theory of matter as learnt in year1in unit 8.

d) Learning activities 1.2

Guidance to learning activity 1.2:

This activity is aims at making student-teachers to think and explore concepts on work done by the gas.

- Chose appropriate method to use in your class. Student-teachers can do this activity either in groups, as individual or class discussion.

- Let the student-teachers turn to activity 1.2 and under your supervision let them read and interpret the questions. (This still depend on how you have planned to deliver your lesson.)

- Leave them to discuss the questions and they can either write their suggested answers in their exercise books or do presentations in case of group work.

- Decide the method of correcting their work

- Together with student-teachers, make a summary of the discussion and in case students need to note down some important information in their notebooks

- You can give your student-teachers assignment about the next concept. Make sure you give all instructions on how you want these student-teachers do assignment.

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

Answers for Activity 1.2

a) Gas does work if there is volume change.

From $W = P\Delta V$ it implies that work is done if $\Delta V > 0$

b) No the walls cannot be displaced because the force exerted by these forces on to the wall is negligible in a such way that fixed and stiff walls cannot be displaced.

c) In case the walls of a container are elastic, the following may occur when a gas expands,

- Volume changes/increases
- There is a change in pressure
- There is a change in temperature.

Answers for Application activity 1.2

1. Depending on the nature, a gas may expand (if there is volume change) and do work. This is for elastic and thin surfaces. But for fixed and stiff wall, the work done is always zero since the particles cannot exert enough force to make particles of be displaced.
2. Expansion of gases may lead the shape of the container to be deformed (deformation) which may result to either increase or decrease size. This can be minimized by making containers with strong walls that can’t be affected by pressure changes that may rise due to temperature changes.

3 a) $W = P\Delta V = P(V_2 - V_1) = 6.4\times10^5\ J$

b) $W = P(V_2 - V_1) = \dfrac{3PV}{4} = -4.8\times10^5\ J$

4. Work done by a gas: $W = P\Delta V = \mathrm{PAd} = 3.0\times10^2\ J$

Lesson 3: First law of thermodynamics and applications

a) Learning objectives

- State the first law of thermodynamics
- Point out laws of thermodynamics to isothermal, isochoric and Isobaric and adiabatic processes
- Solve problems related to thermodynamic processes

b) Teaching resources

- Textbooks (Student-teacher’s book and all reference books in student-teacher’s book), internet

- Projectors

c) Prerequisites/Revision/Introduction

- Student-teachers need to know about effect of temperature on a system

- Kinetic theory of matter as learnt in year1in unit 8.

d) Learning activities 1.3

Guidance on learning activity 1.3

This activity makes learners to think and analyze and discover first law of thermodynamics.

- Tell student-teachers to turn to activity 1.2 in the student-teacher’s book

- Depending on the nature and size of your class, decide the methodology to use (it may be group work, individual or class activity)

- Tell student-teachers to copy the questions into their notebooks and give them some time to attempt or discuss the questions.

- 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 first of law of thermodynamics and applications

- Together with student-teachers make a summary about student-teachers’ findings/answers.

Possible Answers for the learning activity.

1. Heat from the source reaches the container by radiation and transmitted to water by conduction and then by convection in the water.

Thus, water absorbs heat/energy and as a result its energy/heat increases, and it is then transmitted through the whole liquid. The liquid can boil if heated up to boiling point and after boiling, water evaporates. The vapor may exert pressure on to the cover as a result; the cover may be pushed away due to pressure exerted by vapor

Note: This is open, the question doesn't show whether heating was continued or stopped after a short.

Accept any explanation that shows energy changes.

2. Transmission of heat (by convection) in the liquid leads to change of internal energy. This transfer of heat/energy may lead to increase in temperature hence increase in pressure inside the container, hence displacement of the container.
3. Student-teachers deduction should lead to derivation of $\Delta U = Q - W$

Where ΔU is the change in internal energy

Q is the heat supplied to the system

W is the work done by the system

Which is the equation of first law of thermodynamics

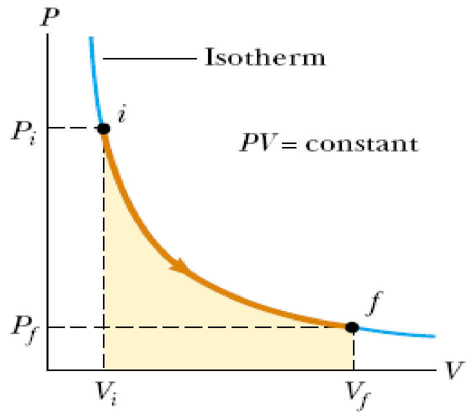
4. a) 100 ^{o}C

b) Water boils at a constant temperature. Thus, even if extra heat is supplied, the temperature doesn't change. This is isothermal process.

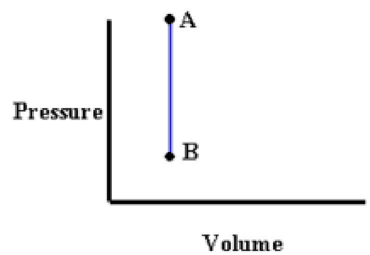
c) Isothermal process. Because this is the process which takes place at a constant temperature.

Answers for application activity 1.3

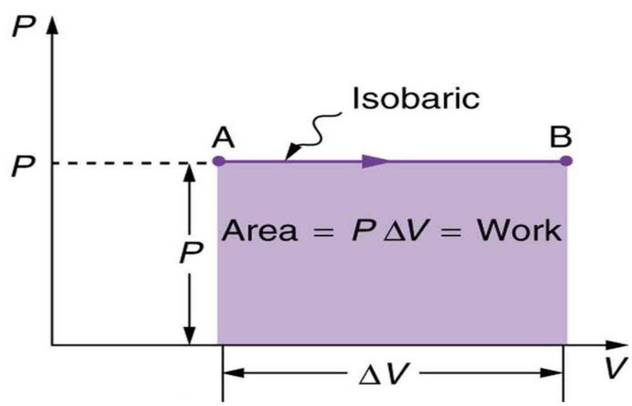
1.a) Isothermal process: This thermodynamic process that takes place at a constant temperature.



b) Isovolumetric process: This thermodynamic process that takes place at a constant volume.



c) Isobaric process: This thermodynamic process that takes place at a constant pressure.



2 a) P-V curve for the processes

b)
$$P_1V_1 = P_2V_2 \Leftrightarrow 1.0325\ x\ 10^5 \times 2 = P_2 \times 6$$
$$P_2 = \frac{1.0325\ x\ 10^5 \times 2}{6} \Leftrightarrow P_2 = 3.4x\ 10^4\ Pa$$

c) During Isobaric $W = P(V_f - V_i)$

$$W = 1.0325 \times 10^5 (4-2) = 2.65 \times 10^5 \ J$$

During Isothermal, $W = RT \ln(\frac{V_f}{V_i})$

$$W = 8.314x298 \ln(\frac{4}{2}) = 1717.3 \ J$$

d) $W = 8.314x298 \ln(\frac{2}{4}) = -1717.3 \ J$

The negative signifies that work is done on to the gas/system.

3a) i) Reversible isothermal change is the change that takes place at a constant temperature but can go back to the initial states.

Thus, if a system at P_2V_2 can still undergo the same change (at constant temperature) to P_1V_1.Such processes are referred to as ***Reversible isothermal change.***

ii) Conditions to achieve a reversible isothermal change.

The gas must be contained in a thin –walled heat conducting vessel/container in good thermal contact with a constant temperature bath.

The process must be carried out slowly to allow time for heat exchange to take place.

Lesson 4: Second law of thermodynamics and application

a) Learning objective

- State the second law of thermodynamics
- Solve problems related to Carnot cycle and adiabatic process

- Apply law of thermodynamics to explain the principle of a Carnot engine, diesel engine and refrigerator
- Solve problems related to Carnot and diesel engine, and refrigerators
- Determine and evaluate the efficiency of heat engines
- Explain thermodynamic processes in heat engines
- Analysis efficiency of heat engines
- Discuss impact of heat engine on climate

b) Teaching resources

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

- Projectors

c) Prerequisites/Revision/Introduction

- Student-teachers need to be aware of operation of some of devices used in daily life like refrigerators, thermos flask, Engines and others

- Student-teachers need to know about effect of temperature on a system

- Kinetic theory of matter as learnt in S1 unit 8.

d) Learning activities

Guidance on the learning Activity 1.4:

- This lesson emphasizes on the practical applications of second law of thermodynamics and applications.

- Tell learners to open their books (Learners book) to learners' activity 1.4

- Decide on the methodology to use in this lesson. You can group your learners; they can do it as a class or individual.

- Instruct them to read and interpret the questions and the picture of the refrigerator. Allow them to attempt/discuss the questions.

- You may move around to see the progress of the students

- Select some student-teachers to share their Answers for the whole class and allow questions from students if any. Create a favorable environment for learners to discuss.

- Together with student-teachers' ideas, link their Answers for the practical applications of second law of thermodynamics.

- Make a summary (using student-teachers' findings) and tell learners 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.

Expected Answers for the activity.

a) It works by transferring heat from the inside of the fridge to its external environment (including food and drinks) so that the inside of the fridge is cooled to a temperature below the room temperature.
b) The heat is conducted away from a drink by low temperatures inside the refrigerator.

e) Answers for application activity 1.4

1. C.
2. E.
3. From efficiency, $e = \frac{W}{\theta_H} = \frac{9200}{22 \times 100 \times 4.186} = 0.999 = 99.9\%$
4. From the efficiency of heat Engine, $e = \frac{W}{\theta_H} = \frac{|\theta_H| - |\theta_C|}{\theta_H} = \frac{3200}{8200} = 0.39 = 39\%$

5. a) When the freezer is placed on top, the cold air produced from it is denser than the warmer air in the bottom. So cold air being dense sinks down and the warm air is forced to rise up so when the warm air rises up it and gets cold in the freezer.

b) Evaporation causes cooling because the process requires heat energy. The energy is taken away by the molecules when they convert from liquid into gas, and this **causes cooling** on the original surface.

Or. Evaporation causes cooling because during evaporation the particle of the liquid absorb energy from the surroundings to regain the energy lost during evaporation. The absorption of heat from the surrounding makes the surrounding cool.

6. $\mathrm{COP} = \dfrac{T_{\mathrm{L}}}{T_{\mathrm{H}} - T_{\mathrm{L}}}$

$$\mathrm{COP} = \frac{258}{303 - 258} = 5.73$$

7. $\mathrm{COP} = \dfrac{T_{\mathrm{L}}}{T_{\mathrm{H}} - T_{\mathrm{L}}}$

$$5 = \frac{T_{\mathrm{L}}}{302 - T_{\mathrm{L}}} \Leftrightarrow 1510 - 5T_{\mathrm{L}} = T_{\mathrm{L}}$$

$$1510 = 6T_{\mathrm{L}} \Leftrightarrow T_{\mathrm{L}} = 251.6\ K = -21.4^{0}C$$

1.6 Summary of the unit

Until about 1850, the fields of thermodynamics and mechanics were considered to be two distinct branches of science, and the law of conservation of energy seemed to describe only certain kinds of mechanical systems.

However, mid-nineteenth-century experiments performed by the Englishman James Joule and others showed that there was a strong connection between the transfer of energy by heat in thermal processes and the transfer of energy by work in mechanical processes.

Today we know that internal energy, which we formally define in this chapter, can be transformed to mechanical energy. Once the concept of energy was generalized from mechanics to include internal energy, the law of conservation of energy emerged as a universal law of nature.

This unit focuses on the concept of internal energy, the processes by which energy is transferred, the first law of thermodynamics, and some of the important applications of the first law. The first law of thermodynamics is a statement of conservation of energy.

It describes systems in which the only energy change is that of internal energy and the transfers of energy are by heat and work. Furthermore, the first law makes no distinction between the results of heat and the results of work. According to the first law, a system's internal energy can be changed by an energy transfer to or from the system either by heat or by work.

It states that the change in internal energy of a system is equal to the heat added to the system minus the work done by the system. Therefore, the law stated gives mathematical treatment of internal energy of a system shown below. Hence the first law of thermodynamics.

$$\Delta U = Q - W$$

The second law of thermodynamics is a statement about which processes occur in nature and which do not. It can be stated in a variety of ways, all of which are equivalent. One statement is that: **"Heat can flow spontaneously from a hot object to cold object; heat will not flow spontaneously from a cold object to a hot object"**.

Heat engines: a heat engine takes heat Q_H from a source, converts part of it to work W, and discards the remainder $|Q_C|$ at lower temperature. The thermal efficiency e of a heat engine measures how much of the absorbed heat is converted to work.

$$e = \frac{W}{Q_H} = 1 + \frac{Q_C}{Q_H} = 1 - \left|\frac{Q_C}{Q_H}\right|$$

Refrigerators: a refrigerator takes heat Q_C from a colder place, has a work input $|W|$, and discards heat $|Q_H|$ at a wormer place. The effectiveness of the refrigerator is given by its coefficient of performance K.

$$K = \frac{|Q_C|}{|W|} = \frac{|Q_C|}{|Q_H| - |Q_C|}$$

1.7 Additional Information for tutor

Steam engine (external combustion engines)

Most engines used in modern society are heat engines. This includes steam electric power generators, automobiles, trucks, many locomotives, refrigerators, air conditioners, heat pumps. The first recorded heat engine was that made by Hero of Alexander in AD 50.

The first major step toward the mechanization of society was the invention of the steam engine by James Watt in 1765/1769. He greatly improved Newcomer’s steam engine, making it smaller, more efficient, and more powerful—and effectively turning steam engines into more practical and affordable machines. Watt's work led to stationary steam engines that could be used in factories and compact, moving engines that could power steam locomotives.

Scottish clergyman Robert Stirling (1790–1878) invented a very clever engine that has two cylinders with pistons powering two cranks driving a single wheel. One cylinder is kept permanently hot (heated by an external energy source that can be anything from a coal fire to a geothermal energy supply) while the other is kept permanently cold.

The engine works by shuttling the same volume of gas (permanently sealed inside the engine) back and forth between the cylinders through a device called a **regenerator**, which helps to retain energy and greatly increases the engine's efficiency. Stirling engines don't necessarily involve combustion, though they're always powered by an external heat source.

For instance, in a typical process by which a power plant produces electricity, coal or some other fuel is burned outside the engine in steam boiler **(Fig.11.1)**, and the high-temperature gases produced are used to convert liquid water to steam. This steam is directed at the blades of a turbine, setting it into rotation. The mechanical energy associated with this rotation is used to drive an electric generator.

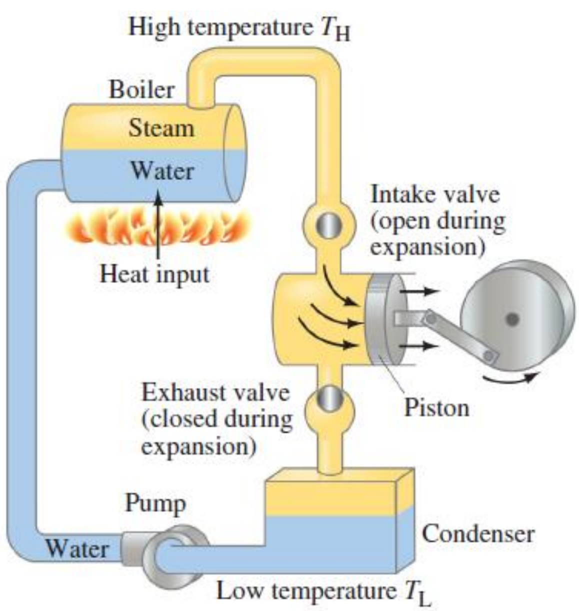


Fig.1. 1Steam engine is an external combustion heat engine that performs mechanical work using steam as its working fluid.

The Stirling engine was developed in 1816 by Robert Stirling. This engine, long neglected, is now being developed for use in automobiles and spacecraft. A Stirling engine delivering 5000 hp (3.7 MW) has been built. Because they are quiet, Stirling engines are used on some military submarines.

The ***Stirling cycle*** is similar to the Otto cycle, except that the compression and expansion of the gas are done at constant temperature, not adiabatically as in the Otto cycle. The Stirling cycle is used in ***external* combustion engines** (in fact, burning fuel is not necessary; *any* way of producing a temperature difference will do—solar, geothermal, ocean temperature gradient, etc.), which means that the gas inside the cylinder is not used in the combustion process.

Heat is supplied by burning fuel steadily outside the cylinder, instead of explosively inside the cylinder as in the Otto cycle. For this reason Stirling-cycle engines are quieter than Otto-cycle engines, since there are no intake and exhaust valves (a major source of engine noise). While small Stirling engines are used for a variety of purposes, Stirling engines for automobiles have not been successful because they are larger, heavier, and more expensive than conventional automobile engines.

GUIDANCE ABOUT 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-teacher's book, Student-teachers are required to design a refrigerator using stated materials in the student's book (Pot, Charcoal, cotton cloth, water etc)
- Guide the student-teachers to get the stated materials. Remember that this project can be accomplished over a relatively long period of time. Do not stress them to complete the work in a short period.
- Provide the internet for doing a research on how it is made.
- When student-teachers are done in getting materials make sure that each student-teacher get a separate place (around the school) where one can place his/her setup for a proper follow-up.
- Keep inspecting and advising student-teachers where necessary (to a student-teacher that needs help). Encourage those who are not making it.
- You can award marks to all presented/done projects. This will help you to know that your students have understood and can apply the unit.

Note in case there is a student-teacher that requires special attention; please make sure assistance is provided

1.8 END UNIT ASSESSMENT (answers)

1. The maximum possible efficiency is the idealized Carnot efficiency. We must use kelvin temperatures. We first change the temperature to kelvins by adding 273 to the given Celsius temperatures:

$T_H = 500 + 273 = 773\ K \qquad T_C = 270 + 273 = 543\ K$

Thus $\eta = 1 - \frac{T_C}{T_H} = 1 - \frac{543}{773} = 30\%$

Only about 30 % of the energy added by heat is used by the engine to do work.

2. The efficiency of the engine is: $\eta = 1 - \frac{Q_C}{Q_H} = 1 - \frac{4}{9} = 56\%$

The maximum possible efficiency is given by the Carnot efficiency: $\eta = 1 - \frac{T_C}{T_H} = 1 - \frac{225}{376} = 40\%$

So the manufacturer's claims violate the second law of thermodynamics and cannot be believed.

3. The heat added to the system is $Q = 2500\ J$

The work W done *by* the system is $W = -1800\ J$.

Hence we apply the first law of thermodynamics, to our system

$\Delta U = Q - W = 2500\ J - (-1800\ J) = 4300\ J$

4. $W_{BC} = P_B(V_C - V_B) = 3.00 \times 10^5 (0.400 - 0.0900) = 94.2\ \text{kJ}$

$Q=(U_C-V_B)+\mathrm{W}\Leftrightarrow(\mathrm{U}_C-U_B)=100-94.2=5.79\text{ kJ}$

Since T is constant, $U_D-U_C=0$

$W_{DA}=P_D(V_A-V_D)=1.00\times10^5(0.200-1.20)=-101\text{ kJ}$

$U_A-U_D=-150+101.3=-48.7\ kJ$

Now, $(U_B-U_A)+(\mathrm{U}_C-U_B)+(U_D-\mathrm{U}_C)+(\mathrm{U}_A-U_D)=0$

$(\mathrm{U}_B-U_A)=-(5,79+0-48.7)=42.9\text{ kJ}$

5. $Q=W+\Delta U\Leftrightarrow U_f=Q-W+U_i=33-26+27=34\ J$

6. $W_{net}=W_{AB}+W_{BC}+W_{CD}+W_{DA}$

$$W_{net}=\int_{V_1}^{V_B}PdV+\int_{V_B}^{V_C}P_2dV+\int_{V_C}^{V_2}PdV+\int_{V_2}^{V_1}P_1dV$$

$$W_{net}=\int_{V_1}^{V_B}\frac{RT_1dV}{V}+P_2\left(V_C-V_B\right)+\int_{V_C}^{V_2}\frac{RT_2dV}{V}+P_1\left(V_1-V_2\right)$$

$$W_{net}=RT_1\ln\frac{V_B}{V_1}+P_2\left(V_C-V_B\right)+RT_2\ln\frac{V_2}{V_C}+P_1\left(V_1-V_2\right)$$

For isothermal process: $P_1V_A=P_2V_B\ and\ P_2V_C=P_1V_D$ so only the logarithmic terms do not counsel out.

Also, $\frac{V_B}{V_1}=\frac{V_B}{P_2}\,and\,\frac{V_2}{V_C}=\frac{P_2}{P_1}$

$$W_{net}=RT_1\ln\frac{P_1}{P_2}+RT_2\ln\frac{P_2}{P_1}=RT_1\ln\frac{P_1}{P_2}-RT_2\ln\frac{P_1}{P_2}=\left(RT_1-RT_2\right)\ln\frac{P_1}{P_2}=\left(RT_2-RT_1\right)\ln\frac{P_2}{P_1}$$

Moreover $P_1V_2 = RT_2$ *and* $P_1V_1 = RT_1$

$$W_{net} = P_1\left(V_2 - V_1\right)\ln\frac{P_2}{P_1}$$

1.9 Additional activities (Questions and answers)

1.9.1 Remedial activities

1. Choose the best answer: In practice a diesel engine can have greater operating efficiency because

  a. the efficiency of the Otto engine decreases after a ceratin compression ratio
  b. for the same compression ratio $\eta_d < \eta_o$
  c. the compression ratio of a diesel engine can be increased to a greater value than for an Otto engine
  d. the presence of the spark plug lowers efficiency.

2. Choose the best answer: In a Carnot cycle

  a. Work done during adiabatic expansion is less than work done during adiabatic compression
  b. Work done by working substance during adiabatic expansion is greater than work done during adiabatic compression.
  c. work done during adiabatic expansion is equal to work done during adiabatic compression
  d. Work done during adiabatic expansion is equal to the heat absorbed from the source.

1.9.2 Consolidation activities

3. Air at 20.0 °C in the cylinder of a diesel engine is compressed from an initial pressure of 1.00 atm and volume of 800.0 cm^3 to a volume of 60.0 cm^3. Assume that air behaves as an ideal

gas with $\gamma = 1.4$ and that the compression is adiabatic. Find the final pressure and temperature of the air.

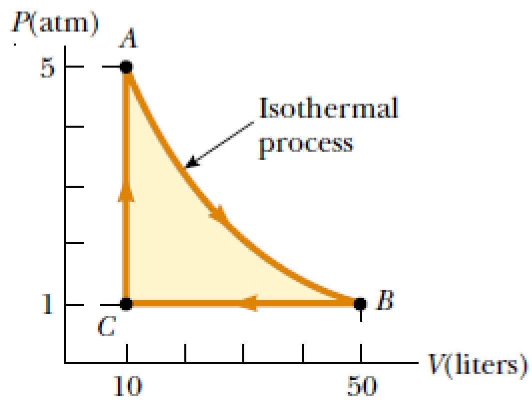
4. A typical dorm room or bedroom contains about 2500 moles of air. Find the change in the internal energy of this much air when it is cooled from 35.0^0 to 26.0^0 at a constant pressure of 1.00 atm. Treat the air as an ideal gas with $\gamma = 1.4$

1.9.3 Extended activities

5. The highest theoretical efficiency of a certain engine is 30%. If this engine uses the atmosphere, which has a temperature of 300 K, as its cold reservoir, what is the temperature of its hot reservoir?

If the heat engine absorbs 837 J of energy from the hot reservoir during each cycle, how much work can it perform in each cycle?

6. A 1.00 mol sample of an ideal monatomic gas is taken through the cycle shown in Figure below. The process *AB* is a reversible isothermal expansion. Calculate (a) the net work done by the gas, (b) the energy added to the gas by heat, (c) the energy exhausted from the gas by heat, and (d) the efficiency of the cycle.



Answers

1. c. the compression ratio of a diesel engine can be increased to a greater value than for an Otto engine

2. c. work done during adiabatic expansion is equal to work done during adiabatic compression

3. We find that $P_f = P_i(\frac{V_i}{V_f})^{\gamma} = 1.00(\frac{800.0}{60.0})^{1.40} = 37.6\ atm$

Because $PV = nRT$ is valid during any process and because no gas escapes from the cylinder,

$$\frac{P_iV_i}{T_i} = \frac{P_fV_f}{T_f} \Leftrightarrow T_f = \frac{P_fV_f}{P_iV_i}T_i = \frac{37.6\times 60.0}{1.00\times 800.0}\times 293 = 826\ K = 553\ {}^0C$$

The high compression in a diesel engine raises the temperature of the fuel enough to cause its combustion without the use of spark plugs.

4. $\gamma = \frac{C_p}{C_v} = \frac{C_v + R}{C_v} = 1 + \frac{R}{C_v} \Leftrightarrow C_v = \frac{R}{\gamma - 1} = 20.79\ J/mol\cdot K$

$$\Delta U = nC_v\Delta T = (250)(20.79)(26.0 - 35.0) = -4.68\times 10^5\ J$$

5. We use the Carnot efficiency to find T_h: $\eta = 1 - \frac{T_C}{T_H} \Leftrightarrow T_H = \frac{T_C}{1-\eta} = \frac{300}{1-0.30} = 430\ K$

The work performed: $\eta = \frac{W}{Q_H} \Leftrightarrow W = 0.30\times 837 = 251\ J$

6. a) for the isothermal process AB, the work on the gas is

$$W_{AB} = -P_AV_A\ln\frac{V_B}{V_A} = -5(1.013\times 10^5\ \text{Pa})(10.0\times 10^{-3}\ m^3)\ln\frac{50.0}{10.0} = -8.15\times 10^3\ J$$

(b) since AB is an isothermal process, $\Delta U = 0$ and $Q_{AB} = -W_{AB} = 8.15\times 10^3\ J$

For an ideal monoatomic gas, $c_v = \frac{3R}{2}$ and $c_p = \frac{5R}{2}$

$$T_B = T_A = \frac{P_B V_B}{nR} = \frac{1.013\times10^5 \times 50.0\times10^{-3}}{R} = \frac{5.05\times10^3}{R}$$

$$W_{BC} = -P_B \Delta V = (1.013\times10^5 \text{ Pa})(10.0\times10^{-3}\ m^3) = 4.05\times10^3\ J$$

$W_{CA} = 0$ and $W = -W_{AB} - W_{BC} = 4.11\times10^3\ J = 4.11\times10^3\ J$

Also $T_c = \frac{P_c V_c}{nR} = \frac{(1.013\times10^5)(10.0\times10^{-3})}{R} = \frac{101\times10^3}{R}$

$$Q_{CA} = nc_v \Delta T = 1.00\times\frac{3R}{2}\times\frac{(5.05\times10^3 - 1.01\times10^{-3})}{R} = 6.08\ kJ$$

So the total energy absorbed by heat is $Q_{AB} + Q_{CA} = 8.15\ kJ + 6.08\ kJ = 14.2\ kJ$

c) $Q_{CA} = nc_p \Delta T = \frac{3nR\Delta T}{2} = \frac{5P_B V_{BC}}{2}$

$$Q_{BC} = \frac{5}{2}(1.013\times10^5)[(10.0 - 50.0)\times10^{-3}] = -10.1\ kJ$$

d) $e = \frac{W}{Q} = \frac{W}{Q_{AB} + Q_{CA}} = \frac{4.11\times10^3}{1.42\times10^4} = 28.9\%$

UNIT 2: WAVE AND PARTICLE NATURE OF LIGHT

2.1 Key unit competence:

Compare the nature of light

2.2 Prerequisite (knowledge, skills, attitudes and values)

- Student-teachers need to know the Nature, characteristics and propagation of light. Remember, these student-teachers studied light in S_1 unit 13, S_2 unit 14 and S_3.
- Try to give them a recap/overview so that learners can connect/link what they studied in O'level to this unit.

2.3 Cross cutting issues to be addressed

Inclusive education (promote education for all in teaching and learning process):

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

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'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 "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.

2.4 Guidance on introductory activity

This activity aims at capturing students' attention and minds towards the concept of wave and particle nature of light.

- Divide your students into groups (Grouping may depend on the nature of your class or number of learners you have). Always take care of learners with any kind of educational need while making groups (hearing, reading, seeing, etc.).
- Tell the learners to open the introductory activity in the learner's book. You may give them a brief introduction about the activity
- Ask learners to interpret the pictures in the activity before answering questions. While learners are doing this activity, you move around, guide the slow learners. You may mark the working of those who have finished.
- When everyone has finished the activity, invite some member(s) of group(s) to present their findings to the whole class. Guide the presentation. They can use power point.
- Note some misconceptions and misunderstanding (if any) so that they are corrected and harmonised in the lesson. Together with students harmonize the points and make a summary on the board. Give to learners the opportunity to write the main points in their notebooks.
- Summarize your lesson by linking this concept to real life situations and to concept of wave and particle nature of light.

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

Expected answers for the introductory activity

1a) The one putting on black/dark cloth, because black bodies are good absorbers of radiations.

b) The black cloth will dry faster. Reason stated in a) above.

c) White shirts and blouses are preferred because, they do not absorb a lot of radiations/energy hence students may not be heated up because of the radiations that may be absorbed.

For black blouses or shirts, they can absorb a lot of radiations making students heated the more which is a disturbance to them while in class.

2. a) Silvered foil reflect radiations and thus prevents these radiations from penetrating into the product which would affect the suitable temperature of the product.

b) This is because black painted room can confine heat, leading the room to be hotter.

c) As explained above, a black roofed house would appear hotter than a white roofed house. Because black roofed would absorb more radiation into the house than a white one.

2.5 List of lessons

#	**Lesson title**	**Learning objectives**	**Number of Periods**
1	Nature and properties of light	- Explain the wave theory of light and state its limitations - Evaluate properties of light as a wave - Appreciate the importance of light waves in life - State Planck's quantum theory - Explain the photon theory of light - Explain the relationship between energy, mass and momentum of photon	8
2	Blackbody radiation	-Describe phenomena of black-body radiation	2
3	Compton effect	- Explain Compton effect - Solve problems relating to Compton effect	4
4	End Unit Assessment		2

Lesson 1: Nature and properties of light

a) Learning objective

- Explain the wave theory of light and state its limitations
- Evaluate properties of light as a wave
- Appreciate the importance of light waves in life
- State Planck's quantum theory
- Explain the photon theory of light
- Explain the relationship between energy, mass and momentum of photon

b) Teaching resources

- Internet and textbooks, and any source of light.
- Videos on nature and properties of light

c) Prerequisites/Revision/Introduction

- Student-teachers need to know the Nature, characteristics and propagation of light. Remember, these student-teachers studied light in S_1 unit 13, S_2 unit 14 and S_3.
- Try to give them a recap/overview so that learners can connect/link what they studied in O'level to this unit.

d) Learning activity 2.1

Guidance to learning activity 2.1:

The activity aims to capture student-teachers' attention and develop critical thinking and collaboration in learners. The learners are encouraged to work together to answer the questions in the activity 2.1.

- Decide on the methodology to use while students are attempting this activity.

- Give them clear guidelines on how to attempt these questions. Reflect on your lesson plan.

- Facilitate your students/your class while they are attempting the questions.

- When they finish (after a reasonable time for this activity), you may either decide to mark their work

- Harmonise by letting other students to give their suggestions while complementing and adding to their views.

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

Answer for activity 2.1

a) It implies that the quantity is not continuous hence discrete.

b) No.

These are some of characteristics of light.

Light has energy

Light has momentum

c) Extraordinarily small

e) Answers for Aplications activity 2.1

1. (*D*) only light behaves as both a particle and a wave. De Broglie postulated, and experiments have confirmed, that in addition to light, electrons and protons (and many other particles) have both wave and particle properties that can be observed or measured.

2. (*D*) Both electrons and photons have momentum that is related to their wavelength by $p = \frac{h}{\lambda}$.

Young's double-slit experiment demonstrated diffraction with light, and later experiments demonstrated electron diffraction. Therefore, all three statements are correct.

3. The photon has energy $E = \dfrac{hc}{\lambda}$

$$E = \frac{(6.63\times10^{-34}\ J.s)(3\times10^{8}\ m/s)}{450\times10^{-9}\ m} = \frac{4.42\times10^{-19}\ J}{1.6\times10^{-19}\ J/eV} = 2.8\,eV$$

4. a) Photon momentum $p = \dfrac{h}{\lambda} = \dfrac{6.63\times10^{-34}\ J.s}{650\times10^{-9}\ m} = 1.02\times10^{-27}\ kg.m/s$

b) Energy of a single photon $E = pc$

$$E = (1.02\times10^{-27}\ kg.m/s)(3\times10^{8}\ m/s) = 3.06\times10^{-19}\ J = 1.91\,eV$$

The laser pointer emits energy at the rate of 5.00 mW, so it emits photons at the rate of

$$\frac{5.00\times10^{-3}}{3.06\times10^{-19}} = 1.63\times10^{16}\ Photons/s$$

5. Energy of photon $E = \dfrac{hc}{\lambda} = \dfrac{(6.63\times10^{-34}\ J.s)(3\times10^{8}\ m/s)}{589\times10^{-9}\ m} = 3.38\times10^{-19}\ J$

Lesson 2: Blackbody radiation

a) Learning objective

-Describe phenomena of black-body radiation

b) Teaching resources

- Textbooks and internet.
- Black colored objects
- Source of heat/radiation

b) Prerequisites/Revision/Introduction

- Student-teachers need to know how heat is transferred
- They can link this concept to unit 9 in S1 and

d) Learning activities 2.2

Guidance of the learning activity 2.2

This activity aims at realizing the nature of black body and its characteristics.

- Help student-teachers to get the required materials to perform/do the activity. You may ask them to bring the clothes talked about in the question a day before the lesson.
- Guide the student-teachers to follow the instructions/questions as set in the activity.
- Assist them to make constructive deductions/conclusions connected to lesson/black body radiation.
- Use student-teachers' findings to define a black body and its characteristics.

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

Answers for the activity 2.2

A black body is anybody that absorbs all radiations that falls on it and reflects none.

When its temperature increases, a black body stores a lot of energy.

Answers for applications activity 2.2

1. D 2.B

3. We assume the star emits radiation as a blackbody, and solve for in Wien's law:

$$\lambda_p = \frac{2.90\times10^{-3}\ m\cdot K}{T} = \frac{2.90\times10^{-3}\ m\cdot K}{3.25\times10^{4}\ K} = 89.2\ nm$$

The peak is in the UV range of the spectrum, and will be way to the left in Fig. 1.1. In the visible region, the curve will be descending, so the shortest visible wavelengths will be strongest. Hence the star will appear bluish (or blue-white).

Lesson 3: Compton Effect

a) Learning objective

- Explain Compton effect
- Solve problems relating to Compton effect

b) Teaching resources

- Textbooks, internet, projectors and simulations about Compton Effect

c) Prerequisites/Revision/Introduction

- Student-teachers need to know interaction of particles when they meet
- What happens to particles energy after interactions?

d) Learning activities

Guidance to the learning activity 2.3

- Let the learner(s) brainstorm the questions on activity 2.3
- Have sample group present their work to the class.
- Check student-teachers' responses to review the student-teachers' 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.

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

Answers for the activity 2.3

a) The particle separate and may lose energy

b) In electron microscope (You can briefly explain to students how electron microscope operates)

c) -To know the properties/behaviors of light.

-Any suggestion that explain the need to analyze the behavior of light.

e) Answers for application activities 2.3

1. For the scattering angle, $\theta = 30^0$ is given by $\Delta\lambda = \lambda_C(1-\cos\theta) = 2.43(1-\cos 30) = 0.32\ pm$

This gives the scattered wavelength of the scattered X-ray: $\lambda' = \lambda + \Delta\lambda = 71 + 0.325 = 71.325\ pm$

The largest Compton shift occurs at the angle θ when $1-cos\ \theta$ has the largest value, which is for the angle $\theta = 180^0$ given by $\Delta\lambda_{\max} = \lambda_C(1-\cos\theta) = 2.43(1-\cos 180) = 4.86\ pm$

2. $\lambda_1 = \dfrac{hc}{E_1} = \dfrac{(6.63\times10^{-34}\ J\cdot s)(3.0\times10^{8}\ m/s)}{(5.5\times10^{6}\ eV)(1.6\times10^{-19}\ J/eV)} = 2.26\times10^{-13}\ m$

$$\lambda_2 = \lambda_1 + \frac{h}{m_e c}(1-\cos\theta) = 2.26\times10^{-13}\ m + \frac{6.63\times10^{-34}\ J\cdot s)(1-\cos 60)}{(9.11\times10^{-31}\ kg)(3.00\times10^{8}\ m/s)} = 1.44\times10^{-12}\ m$$

$$E_2 = \frac{hc}{\lambda_1} = \frac{(6.63\times10^{-34}\ J\cdot s)(3.0\times10^{8}\ m/s)}{(1.44\times10^{-12}\ m)(1.6\times10^{-19}\ J/eV)} = 0.87\ MeV$$

2.6. Summary of the unit

The behaviour of a single photon was predicted by the wave theory. The electromagnetic wave predicts the probability that a photon will register at a certain position on a detecting surface at a given instant. Light is not just a wave and not just a particle but exhibits a “wave–particle duality.”

Understanding both the wave and the particle properties of light is essential for a complete understanding of light; the two aspects of light complement each other.

When light passes through space or through a medium, its behaviour is best explained using its wave properties; when light interacts with matter, its behaviour is more like that of a particle.

The wave–particle model of light has superseded Newton's particle theory and Maxwell's electromagnetic theory, incorporating elements of both.

A particle of nonzero mass has a wavelike nature, including a wavelength λ, found by de Broglie to equal $\lambda = \frac{h}{mv}$

Electron microscopes use the principles of quantum mechanics and matter waves to achieve very high magnifications, in some cases exceeding 2 million times.

A blackbody of a given temperature emits electromagnetic radiation over a continuous spectrum of frequencies, with a definite intensity maximum at one particular frequency. As the temperature increases, the intensity maximum shifts to progressively higher frequencies.

Planck proposed that molecules or atoms of a radiating blackbody are constrained to vibrate at discrete energy levels, which he called quanta. The energy of a single quantum is directly proportional to the frequency of the emitted radiation, according to the relationship $E = hf$ where h is Planck's constant.

Photoelectrons are ejected from a photoelectric surface when the incident light is above a certain frequency f_0, called the threshold frequency. The intensity (brightness) of the incoming light has no effect on the threshold frequency. The threshold frequency is different for different surfaces.

The cut-off potential is the potential difference at which even the most energetic photoelectrons are prevented from reaching the anode. For the same surface the cut-off potential is different for each frequency, and the higher the frequency of the light, the higher the cut-off potential.

The energy of light is transmitted in bundles of energy called photons, whose energy has a discrete, fixed amount, determined by Planck's equation, $E = hf$.

In the Compton Effect, high-energy photons strike a surface, ejecting electrons with kinetic energy and lower-energy photons. Photons have momentum whose magnitude is given by

$$p = \frac{h}{\lambda}$$

Interactions between photons and matter can be classified into reflection, the photoelectric effect, the Compton Effect, changes in electron energy levels within atoms, and pair production

2.7 Additional Information for tutor

Compton Effect

The photoelectric effect and Einstein's theories about light having a particle nature caused a lot of scientists to start to re-examine some basic ideas, as well as come up with some new ones.

- Based on a lot of Einstein's work (including his Special Theory of Relativity), physicists predicted that these photons should have momentum, just like other particles do.
- The tough part is explaining and proving this in a reasonable way, since you don't exactly feel light hammering you into the floor.
- The momentum that the light photons have must be very small, and not based on the common way of calculating momentum using p = mv (since light has no rest mass).
- Instead the formula was based on the wavelength and frequency of the light, just like Planck's formula.

$$p = \frac{h}{\lambda} = \frac{hf}{c}$$

Be careful to only use these formulas if you are doing something involving the momentum of photons

In 1923 A.H. Compton started shooting high frequency x-rays at various materials and found that his results seemed to support the idea of photons having momentum. In one setup he shot the high frequency x-rays at a piece of graphite.

- If light was a wave, we would expect the x-rays to come out the other side with their wavelength smaller
- Basically we can explain this as the waves squishing when they hit the graphite, like a ball squishing when it hits the ground.

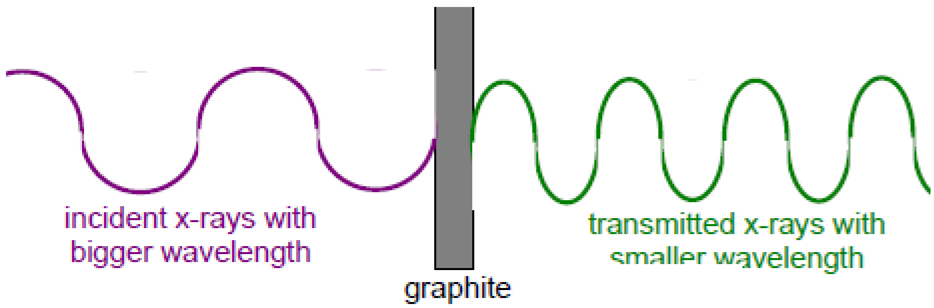


Fig.2. 1 The bigger wavelength x-rays shot at a piece of graphite.

Instead, Compton found that the x-rays scattered after hitting the target, changing the *direction* they were moving and actually getting a *longer* wavelength.

- Remember, longer wavelength means smaller frequency.
- Since $E = hf$, the scattered photons had less energy! Somehow, the x-ray photons were losing energy going through the graphite. So where'd the energy go?

- Compton found that electrons were being thrown off the target at an angle.
- Compton was able to explain all he was seeing (which became known as the **Compton Effect**) by using:
    - The conservation of energy (the energy the photon lost had to go somewhere).
    - The photon theory of light (to figure out the momentum of the photons).
    - The conservation of momentum (to explain the angles things were shooting off at).

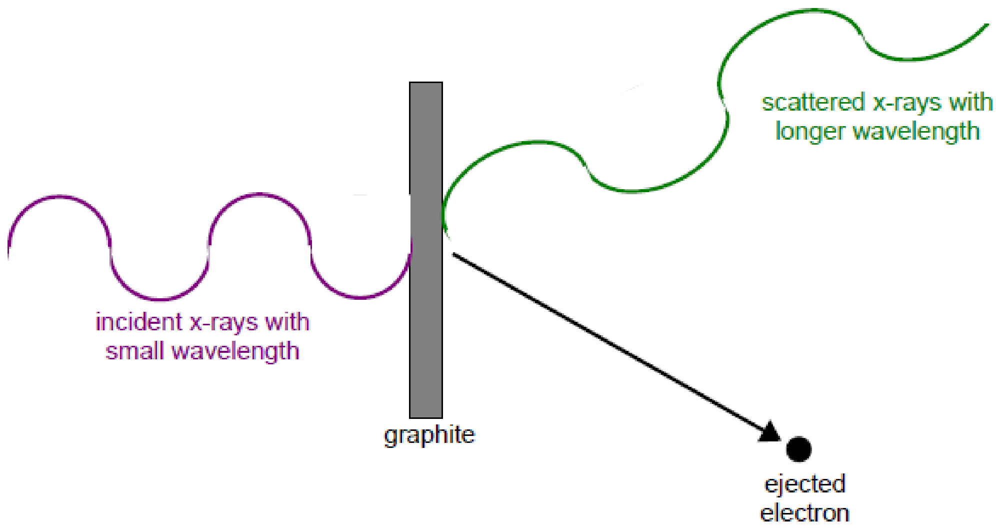


Fig.2. 2 The small wavelength x-rays shot at a piece of graphite.

If we looked at this in terms of momentum, we'd need to be careful about using the correct momentum equations for each part.

● **Incident x-rays**

The original x-rays have a small wavelength, and the formula $p = \frac{h}{\lambda}$ shows us that this mean it has a lot of momentum.

● **Scattered x-rays**

The x-rays that made it through have a bigger wavelength, so $p = \frac{h}{\lambda}$ means it has less momentum.

● **Ejected electrons**

We would calculate the electron's momentum using a classic $p = mv$ calculation.

Compton found that if he did all the calculations, using the ideas of treating **light like photons** (to figure out their momentum) and **conservation of momentum** in a 2D collision, the numbers worked beautifully.

- In fact, it's almost spooky just how perfectly the numbers worked out. It was basically a 100% perfect conservation of momentum.
- This showed that the particle model of light with all its talk about photons must be correct.
- This was a turning point in the particle theory of light, when the majority of physicists started to really believe the wave-particle duality of light was probably correct. But you might also be saying to yourself "Hey, we've seen this all before… it's just the photoelectric effect!" That would be wrong.

"In Photoelectric Effect, High frequency EMR hits metal there is conservation of energy occurs while in Compton Effect, High frequency EMR hits non-metal, there is Conservation of momentum occurs

After looking at the data he got from his experiments, Compton also found that he could predict the exact change in the wavelength between the incident and scattered x-rays.

- His formula was based on the wave-particle duality of light, as well as the angle of the scattered x-ray.

$$\Delta\lambda = \frac{h}{mc}(1-\cos\theta)$$

Where

- $\Delta\lambda$ = change in wavelength between incident and scattered (m)
- h = Planck's Constant
- m = mass of electron (kg)
- c = speed of light
- θ = scattered x-ray's angle

GUIDANCE ABOUT SKILLS LAB 2

This is an activity that aims at making student-teachers put in practice what they have achieved and mastered in this unit. It will help you to evaluate student-teacher's appreciation for this unit.

- As stated in student-teacher's book, Student-teachers are required to compare absorption rates for different colored surfaces so that they can realize the concept of black body radiation.
- Help student-teachers to get the required materials as stated in learners' book. They include: Silvered surfaces, Black colored surface (painted, red, blue and green) and laboratory thermometers.
- Try to guide them to set up the materials as set in the activity. It's ok to adjust the arrangement and timing as long as the same results can be achieved.
- Facilitate them to attempt the activity while providing conducive environment to the learners so that activity is done effectively.
- Check whether different groups or individuals have relatively similar values. Assist learners to make general conclusion.
- Note in case there is a student **that requires special attention, please make sure assistance is provided.**

2.8. END UNIT ASSESSMENT (answers)

1. Light demonstrates characteristics of both waves and particles. Diffraction, interference, and polarization are wave characteristics and are demonstrated, for example, in Young's double-slit experiment. The photoelectric effect and Compton scattering are examples of experiments in which light demonstrates particle characteristics. We can't say that light is a wave or a particle, but it has properties of each.

2. In the photoelectric effect, the photons (typically visible frequencies) have only a few eV of energy, whereas in the Compton Effect, the energy of the photons (typically X-ray frequencies) is more than 1000 times greater and their wavelength is correspondingly smaller. In the photoelectric effect, the incident photons eject electrons completely out of the target material,

while the photons are completely absorbed (no scattered photons). In the Compton Effect, the photons are not absorbed but are scattered from the electrons.

3. The proton will have the shorter wavelength, since it has a larger mass than the electron and therefore a larger momentum for the same speed ($\lambda = \frac{h}{p}$).

4. We say that electrons have wave properties since we see them act like waves when they are diffracted or exhibit two-slit interference. We say that electrons have particle properties since we see them act like particles when they are bent by magnetic fields or accelerated and fired into materials where they scatter other electrons.

5. Both a photon and an electron have properties of waves and properties of particles. They can both be associated with a wavelength and they can both undergo scattering. An electron has a negative charge and has mass, obeys the Pauli Exclusion Principle, and travels at less than the speed of light. A photon is not charged, has no mass, does not obey the Pauli Exclusion Principle, and travels at the speed of light.

6. $K = hf = (6.63\times10^{-34})(7.06\times10^{14}) = 4.68\times10^{-19}\ J = 2.92\,eV$

7. The range of energy is from $E_1 = hf_1 = 5.23\times10^{-19}\ J$ to $E_2 = hf_2 = 3.31\times10^{-16}\ J$

8. a) We want $\Delta\lambda = \lambda' - \lambda = 1.0\%$ of 0.124 nm that is $\Delta\lambda = \lambda' - \lambda = 1.24\times10^{-12}\ m$

Using the value $\lambda_C = \frac{h}{mc} = 2.426\times10^{-12}\ m$ we find $\cos\phi = 1 - \frac{\Delta\lambda}{\lambda_c} = 0.4889 \Rightarrow \phi = 60.7^0$

b) For $\Delta\lambda = \lambda' - \lambda = 0.050\%$ of 0.124 nm, that is $\Delta\lambda = \lambda' - \lambda = 6.2\times10^{-14}\ m$

Using the value $\frac{h}{mc} = 2.426\times10^{-12}\ m$ we find $\cos\phi = 1 - \frac{\Delta\lambda}{2.426\times10^{-12}} = 0.9744 \Rightarrow \phi = 13.0^0$

2.9. Additional activities (Questions and answers)

2.9.1 Remedial activities

1. UV light causes sunburn, whereas visible light does not. Suggest a reason.

2. Why do we say that light has wave properties? Why do we say that light has particle properties?

2.9.2 Consolidation activities

3. Why do we say that electrons have wave properties? Why do we say that electrons have particle properties?

4. What are the differences between a photon and an electron? Be specific: make a list.

2.9.3 Extended activities

5. Use conservation of momentum to explain why photons emitted by hydrogen atoms have slightly less energy than that predicted by Eq.: $hf = E_f - E_i$

6. Match list I with list II and select the correct answer using the code given below the lists

List I	List II
A. Explanation of the photoelectric effect	1. J.J. Thomson
B. Discovery of a comet	2. Robert millikan
C. Measurement of the electronic charge	3. Einstein
D. Thermoelectricity	4. Edmund halley
	5. Seebeck

i. A-3, B-2, C-4, D-5
ii. A-5, B-1, C-4, D-3
iii. A-5, B-4, C-4, D-3
iv. A-3, B-4, C-2, D-5

7. X-rays of wavelength 0.140 nm are scattered from a very thin slice of carbon. What will be the wavelengths of X-rays scattered at (*a*) 0°, (*b*) 90°, (*c*) 180°?

Answers for additional activities

1**.** Individual photons of ultraviolet light are more energetic than photons of visible light and will deliver more energy to the skin, causing burns. UV photons also can penetrate farther into the skin and, once at the deeper level, can deposit a large amount of energy that can cause damage to cells.

2. Light demonstrates characteristics of both waves and particles. Diffraction, interference, and polarization are wave characteristics and are demonstrated, for example, in Young's double-slit experiment. The photoelectric effect and Compton scattering are examples of experiments in which light demonstrates particle characteristics. We can't say that light IS a wave or a particle, but it has properties of each.

3. We say that electrons have wave properties since we see them act like waves when they are diffracted or exhibit two-slit interference. We say that electrons have particle properties since we see them act like particles when they are bent by magnetic fields or accelerated and fired into materials where they scatter other electrons.

4. Both a photon and an electron have properties of waves and properties of particles. They can both be associated with a wavelength and they can both undergo scattering. An electron has a negative charge and has mass, obeys the Pauli Exclusion Principle, and travels at less than the speed of light. A photon is not charged, has no mass, does not obey the Pauli Exclusion Principle, and travels at the speed of light.

5. When a photon is emitted by a hydrogen atom as the electron makes a transition from one energy state to a lower one, not only does the photon carry away energy and momentum, but to conserve momentum, the atom must also take away some momentum. If the atom carries away some momentum, then it must also carry away some of the available energy, which means that the photon takes away less energy than Eq. $hf = E_f - E_i$ predicts.

6.iv

7. (a) For $\varphi = 0^0$, and $\cos\varphi = 1$. The Compton equation gives $\lambda' = \lambda = 0.140\ nm$

This makes sense since for $\varphi = 0^0$ there really isn't any collision as the photon goes straight through without interacting.

(b) For $\varphi = 90^0$; we get $\lambda' = \lambda + \dfrac{h}{m_e c} = 0.140\ nm + \dfrac{6.63\times10^{-34}\ J\cdot s}{(9.11\times10^{-31}\ kg)(3.00\times10^{8}\ m/s)} = 0.142\ nm$

That is, the wavelength is longer by one Compton wavelength ($\dfrac{h}{m_e c^2} = 0.0024\ nm$ for an electron).

(c) For $\varphi = 180^0$ which means the photon is scattered backward, returning in the direction from which it came (a direct "head-on" collision), $\cos\varphi = -1$ and $1 - \cos\varphi = 2$

So $\lambda' = \lambda + \dfrac{h}{m_e c}(1-\cos\theta) = 0.140\ nm + \dfrac{2\times6.63\times10^{-34}\ J\cdot s}{(9.11\times10^{-31}\ kg)(3.00\times10^{8}\ m/s)} = 0.145\ nm$

UNIT 3: SIMPLE HARMONIC MOTION.

3.1. Key Unit competence:

Illustrate and explain energy changes in simple harmonic motion

3.2 Prerequisite (knowledge, skills, attitudes and values

Student-teachers should be aware of concepts about waves. They can refer to Physics year 1 unit 7. Learners should be aware of concepts about circular motion

3.3 Cross cutting issues to be addressed

Inclusive education (promote education for all while teaching):

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

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. 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.

3.4 Guidance on introductory activity

This activity aims at bringing/capture student-teachers' attention about simple harmonic motion. Remember that this unit uses principles of waves that they studied inPhysics in unit 7, in year Two.

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

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

Note: in case there is a student that requires special attention, please make sure assistance is provided

Expected answers for the introductory activity.

a) i) Oscillatory motion

ii) Circular motion

b) In i) it is to and fro movement of the child in the swing. The child reaches a certain point and returns back while retracing the path taken while in ii) Pupils will move around a fixed point at the centre of the merry-Go round.

c) Potential energy-Kinetic energy -Potential energy

d) -To be able to analyse motion of different systems

- Be able to solve different motions like damping system in a vehicle that is intended to reduce number of vibrations of a vehicle after passing a hump.
- Be able design systems of some behaviours like of a given constant.

3.5 List of lessons

#	Lesson title	Learning objectives	Number of Periods
1	Kinematics of simple harmonic motion	- Explain kinematics of simple harmonic motion - Solve problems related to kinematics of simple harmonic motion - Derive equations of simple harmonic motion - Explain the equations of simple harmonic motion - Solve problems applying equations of simple harmonic motion	6
2	Simple harmonic oscillators	- Describe examples of simple harmonic oscillators and point out examples of simple harmonic motion oscillators	4
3	Energy changes and conservation in oscillating	- Explain energy change and conservation in oscillating systems	3

	systems	- Illustrate energy changes and conservation in oscillating systems	
4	End unit assessment		2

Lesson 1: Kinematics of simple harmonic motion

a) Learning objective

- Explain kinematics of simple harmonic motion
- Solve problems related to kinematics of simple harmonic motion
- Derive equations of simple harmonic motion
- Explain the equations of simple harmonic motion

Solve problems applying equations of simple harmonic motion

b) Teaching resources

- Internet and textbooks (Use all reference books in student-teacher's book)
- Projectors, videos

c) Prerequisites/Revision/Introduction

The success of this unit relies partly on the mastery of knowledge and skills acquired in Wave studied in year 1 in Physics, and other related subjects in previous grades.

d) Learning activities 3.1

Guidance to the learning activity 3.1

This learning activity focuses on making students to explore kinematics in SHM and derive equations in SHM

- Divide your class into different groups (Choice is yours about methodology depending on the type of your class). In case you have this swing at your college, you can elaborate the motion clearly. Or you can demonstrate it using a swinging Pendulum bob.
- Instruct them to answer/attempt the questions in the students' book.
- While student-teachers are doing/attempting/discussing the questions, move around and inspect how work is being done.
- Invite 2 or 3 (or any number of groups depending on how many you had formed) to present their findings (They can use power point in case they have one that is prepared). Let them discuss by themselves.
- Ask other groups members of the class to contrast their finding to those presented by the groups on show whether they have different findings/answers/suggestions from what others have presented.
- Connecting to what learners have presented, guide learners to explain what SHM is and how it is related to other kinds of motion.

Note: In case there is a student that requires special attention, please make sure assistance is provided

Answers for the activity 3.1.

a) It is an oscillatory motion. Because there is to and fro movement of the child in the swing.
b) As he passes through the centre.
c) -Length of the swing

-Force applied to the boy while being set into motion. (This affects the amplitude attained by the boy while swinging)

-The angle the boy/ body is making with the vertical before being displaced.

d) No! Because there are other external forces acting on the system. These include

-Force due to gravity

-Air resistances.

e) Answers for application activity 3.1

1. a) Simple Harmonic motion can be defined as a special type of periodic motion in which acceleration is directed towards a fixed point and directly proportional to the displacement of the body from that fixed point.

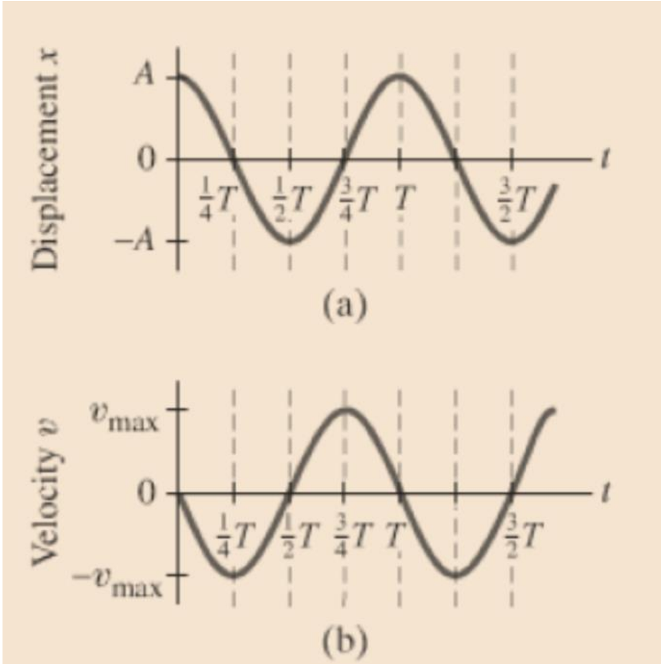
b) Characteristics of a body executing SHM.

i) It is periodic
ii) Its acceleration is directly proportional to the displacement from a fixed point
iii) Its acceleration is always directed towards a fixed point
iv) Mechanical energy is always conserved

c) The equations of displacement and velocities may either be represented by a sine curve or a cosine curve depending on where the body starts from. So, a student can give/state a cosine or a sine curve.

i) Displacement can be given by: $x = a\sin\omega t$ or $x = a\cos\omega t$

ii) Velocity can be given by $V = a\omega\cos\omega t$ or $V = -a\omega\sin\omega t$



2. From equation $x(m) = 0.20\sin 3.0t,$

$$x(m) = 0.20\sin 3.0t, \textit{when } x = 5x10^{-2}\,m$$

$$5\times10^{-2} = 0.20\sin 3.0t$$

$$3.0t = \sin^{-1}(\frac{5x10^{-2}}{0.2})$$

$$3.0t = 14.48$$

$$t = 4.8s$$

$$v = \frac{d}{dt}(0.2\sin 3.0t)$$

$$v = 0.6\cos 3.0t \textit{ when } t = 4.8$$

$$v = 0.6\cos(3.0\times4.8) = 0.58\,m/s$$

Acceleration $a = -\omega^2(a\sin\omega t)$

$$a = -3^2\times0.2\sin(3.0\times4.8)$$

$$a = -1.8\sin(14.4) = -0.45\,m/s$$

The negative indicates that the body the body starts to decelerate as it passes through the center/equilibrium.

3. First use $v = \pm\omega\sqrt{x_0^2 - x^2}$ to find the angular velocity ω:

$$\omega = \frac{v}{\sqrt{x_o^2 - x^2}} = \frac{2\pi}{T} \Leftrightarrow T = \frac{2\pi\sqrt{x_o^2 - x^2}}{v}$$

$$T = \frac{2\times 3.14\sqrt{(0.47m)^2 - (0.23m)^2}}{2.15} = 1.2\sec$$

4. (a) Using the equation for velocity: $4 = -\omega\sqrt{r^2 - x^2}$

When x = 3 cm, the velocity is v = 4 cm/s and when x = 4 cm the velocity is v = 3 cm/s

We have: $3 = -\omega\sqrt{r^2 - 3^2}$ and $4 = -\omega\sqrt{r^2 - 4^2}$

Squaring and dividing these equations we get; $\frac{16}{9} = \frac{r^2 - 9}{r^2 - 16}$ hence $r = \pm 5\ cm$

(b) Substituting for r in one of the velocity equations we find $\omega = 1\ rad/s$ and $T = \frac{2\pi}{\omega} = 2\pi\ s$

(c) At equilibrium position x = 0 then the velocity is $v = \pm\omega\sqrt{r^2 - x^2} = \pm\omega r = \pm 5\ cm/s$

5. $E_T = \frac{1}{2}m\omega^2 A^2 = 117.0377168\ J$

$$P.E = \frac{1}{2}m\omega^2 x^2 \Leftrightarrow E_x = \frac{1}{2}m(2\pi f)^2 x^2 = \frac{1}{2}1.83(2\pi\times 10.0)^2(0.13)^2 = 60.985J$$

Lesson 2: Simple harmonic oscillators

a) Learning objective.

- Describe examples of simple harmonic oscillators and point out examples of simple harmonic motion oscillators

b) Teaching resources

- Text books (all reference books in students' book), internet.
- Projectors, videos

c) Prerequisites/Revision/Introduction

This lesson requires students to have had knowledge and skills about oscillatory motion. Like experience on the canopy found in Nyungwe Forest.

d) Learning activity 3.2

Guidance on learning activity 3.2

Through guided discovery, assist learners to develop their skills and attitudes in solving problems related to oscillatory motion.

- Make student-teachers turn to learning activity 3.2
- Let them interpret the kind of the chair relating to the scenario of a seat in the compound of a certain hotel.
- Divide learners into small groups and let them brainstorm and answer the questions. You may any method not only grouping method.
- Check student-teachers' work and let one or two groups present the work to the whole class.
- Let other learners contrast their findings to the result presented, hence, assist them to draw a suitable conclusion connected to simple harmonic oscillators.

Note: In case there is a student that requires special attention, please make sure assistance is provided.

Answers for the activity 3.2.

a) Simple pendulum, other examples student-teacher can state include mass on helical spring, liquid in U-tube, oscillating cylinder,.

b) Factors that may affect the number of oscillations made by the swinging seat.

-The spring constant it is attached to.

-Mass of a person seated to it.

b) The seat will swing differently since the spring may not have the same constant as the elastic rope.

c) The difference was due to the difference in masses.

e) Answers for application activity 3.2

1. B.

Reason: It is pulled down 10 cm therefore the maximum displacement from the equilibrium (amplitude) is 10 cm. To travel from the displacement to the equilibrium position is a quarter of the whole cycle (**A** to **midpoin**t to**-A** to **midpoint** to **A** (again)). Therefore, period is 2.0 s

2. B

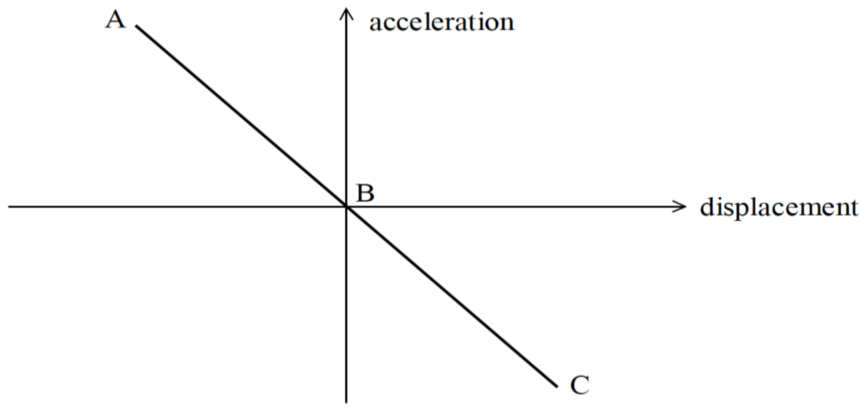
3. D

4. a) Simple Harmonic motion can be defined as a special type of periodic motion in which acceleration is directed towards a fixed point and directly proportional to the displacement of the body from that fixed point.

Or: the force/acceleration is proportional to the displacement from the equilibrium position/Centre; the force/acceleration is directed towards the equilibrium position/center / the force/acceleration is in the opposite direction to the displacement;

c) and c)

It is a straight line through the origin; with negative gradient;



5. (a) $f = \frac{1}{T} = 0.588\,Hz$ (b) $k = 4\pi^2 f^2 m = 0.68\,N/m$ (c) $v_{\max} = \omega A = 0.44\,m/s$

(d) $a_{\max} = \omega^2 A = 1.6\,m/s^2$ (e) $v = \omega\sqrt{A^2 - x^2} = \frac{2\times 3.14}{1.70}\sqrt{\left(12\times 10^{-2}\right)^2 - \left(6\times 10^{-2}\right)^2} = 0.38\,m/s$

(f) $a = -\omega^2 x = -\left(\frac{2\pi}{1.70}\right)^2 \times 6\times 10^{-2} = 0.82\,m/s^2$

Lesson 3: energy changes and conservation in oscillating systems

a) Learning objective

-Explain energy change and conservation in oscillating systems

-Illustrate energy changes and conservation in oscillating systems

b) Teaching resources

- Textbooks and internet.
- Projectors, videos

c) Prerequisites/Revision/Introduction

This lesson requires student-teachers to know Energy changes in any moving system ie Mechanical energy, potential energy, and kinetic energy. You can connect this unit to unit 9 in S.2.

d) Learning activity 3.3

Guidance on learning Activity 3.3

This lesson aims at making student-teachers recall energy changes in moving objects and relate it to oscillatory motion.

- Tell student-teachers to turn to activity 3.3 in student-teacher's book
- Suggest on the methodology to use in this lesson. Choice may depend on the nature of your class.
- Instruct them to discuss questions in this activity.
- Leave the learners to perform the activity by themselves. Give them enough time to work out the questions.
- Call some members or groups to present their findings.
- Let the learners connect the discussed Answers for what they have.
- Together with students, consolidate and come to a common understanding on changes in energy in SHM

Note: In case there is a student that requires special attention, please make sure assistance is provided.

Answers for the activity 3.3

With explanations, explain how energy changes from Potential energy, to kinetic energy and back to potential energy.

d) Answers for application activity 3.3

1. Answers about the passage.

a) B
b) A
c) B
d) B
e) B

2. From $T = 2\pi\sqrt{\frac{L}{g}}$

$$2 = 2\pi\sqrt{\frac{l}{9.81}} \Leftrightarrow \frac{4}{4\pi^2} = \frac{l}{9.81}$$
$$l = \frac{4\times 9.81}{4\pi^2} = 1\,m$$

Mass has no effect on the period of a pendulum, its only length that affects the period from the formula.

Thus, from $T = 2\pi\sqrt{\frac{L}{g}}$

$$T = 2\pi\sqrt{\frac{2\times 1}{9.81}} = 2.8\,s$$

Thus, the new period becomes 2.8 seconds.

3. From kinetic energy $K = \frac{1}{2}m\omega^2(\mathrm{A}^2 - x^2)$

When $x = A/2$.

$$K = \frac{1}{2}m\omega^2\left[A^2 - \left(\frac{A}{2}\right)^2\right]$$
$$K = \frac{3}{4}\left(\frac{A^2m\omega^2}{2}\right)$$

This shows that the remaining KE is $\frac{3}{4}$ of the total mechanical energy.

4. i) 80 mJ read from the graph

   ii) From

$$Mechanical\ energy, \mathrm{E}_M = \left(\frac{A^2m\omega^2}{2}\right)$$
$$80\times10^{-3} = \frac{(4\times10^{-2})^2\times0.4\times\omega^2}{2}$$
$$\omega = 15.8\ rad/s$$

$$V_{\max} = \omega A = 15.8\times4\times10^{-2} = 0.63\ m/s$$

   iii) Amplitude=4cm (read from the graph)

   From the equation

$$E_p = \frac{1}{2}m\omega^2.x^2$$

$$E_p = \frac{1}{2}\times4\times15.8^2\times2\times10^{-2}$$

$$E_p = 9.986 = 10J$$

   v) The period of the motion

From $T = \frac{2\pi}{\omega} = \frac{2\pi}{15.8}$

$T = 0.4\, s$

3.6. Summary of the unit

Simple harmonic motion occurs when the force acting on an object or system is directly proportional to its displacement x from a fixed point and is always directed towards this point:

$$F = -kx$$

If the object moves with SHM, the variation of the **displacement** x with time t is a sine relation given by: $x = A\sin(\omega t + \varphi)$

Velocity: $v = \frac{dx}{dt} = A\omega\cos(\omega t + \varphi)$

The **acceleration is given:** $v = -A\omega^2 \sin(\omega t + \varphi) = -\mathrm{x}\,\omega^2$

The **period** T of the motion is the time to make a complete to-and-fro movement or cycle.

The period is given by $T = \frac{2\pi}{\omega}$

The **frequency** f of a simple harmonic motion is the number of complete (to-and-fro) oscillations per second. $f = \frac{1}{T}$

Differential equation of SHM is given by $a = \frac{d^2x}{dt} \Rightarrow \frac{d^2x}{dt} + \omega^2 x = 0$

When two waves travel through a medium, their combined effect at any point can be found by the principle of superposition.

3.7. Additional Information for tutor

Superposition of SHM with the same frequency

When two waves travel through a medium, their combined effect at any point can be found by the principle of superposition. This states that: *"The resultant displacement at any point is the sum of the separate displacements due to the two waves i.e. if two or more waves move in the same linear medium, the net displacement of the medium (that is, the resultant wave) at any point equals the algebraic sum of all the displacements caused by the individual waves*."

Linear medium is, one in which the restoring force acting on the particles of the medium is proportional to the displacement of the particles

Let us apply this principle to two sinusoidal waves traveling in the same direction in a linear medium. If the two waves are traveling to the right and have the same frequency, wavelength, and amplitude but differ in phase, we can express their individual wave functions as

$$y_1 = A\sin(kx - \omega t) \qquad \text{and} \quad y_2 = A\sin(kx - \omega t + \varphi)$$

To simplify this expression, we use the trigonometric identity $\mathrm{sina} + \mathrm{sinb} = 2\cos\frac{a-b}{2}\sin\frac{a+b}{2}$

If we let $a = kx - \omega t$ and $b = kx - \omega t + \varphi$, we find that the resultant wave function y reduceds to

$$y = y_1 + y_2 = 2A\cos\frac{\varphi}{2}\sin(kx - \omega t + \frac{\varphi}{2})$$

The resultant wave function *y* also is sinusoidal and has the same frequency and wavelength as the individual waves, since the sine function incorporates the same values of *k* and ω that appear in the original wave functions. The amplitude of the resultant wave is $2A\cos\frac{\varphi}{2}$,

Waves that obey this principle are called **linear waves**. In the case of mechanical waves, linear waves are generally characterized by having amplitudes much smaller than their wavelengths.

Waves that violate the superposition principle are called **nonlinear waves** and are often characterized by large amplitudes.

One consequence of the superposition principle is that two traveling waves can pass through each other without being destroyed or even altered. For instance, when two pebbles are thrown into a pond and hit the surface at different places, the expanding circular surface waves do not destroy each other but rather pass through each other. The complex pattern that is observed can be viewed as two independent sets of expanding circles. Likewise, when sound waves from two sources move through air, they pass through each other.

Now let consider some cases:

Let $y_1 = r_1 \sin \omega t$ and $y_2 = r_2 \sin \omega t$ therefore $y = y_1 + y_2 = (r_1 + r_2)\sin \omega t$

Let $y_1 = r_1 \sin \omega t$ and $y_2 = r_2 \sin(\omega t \pm \frac{\pi}{2})$ therefore $y = y_1 + y_2 = r \sin(\omega t \pm \phi)$

where $r = \sqrt{r_1^2 + r_2^2}$ and $\tan \phi = \frac{r_2}{r_1}$

Let $y_1 = r_1 \cos \omega t$ and $y_2 = r_2 \sin \omega t$ therefore $y = y_1 + y_2 = r \cos(\omega t - \phi)$

Where $r = \sqrt{r_1^2 + r_2^2}$ and $\tan \phi = \frac{r_2}{r_1}$

Let $y_1 = r_1 \sin \omega t$ and $y_2 = r_2 \sin(\omega t + \varphi)$ therefore $y = y_1 + y_2 = r \sin(\omega t + \phi)$

Where $r = \sqrt{r_1^2 + r_2^2 + 2r_1 r_2 \cos \varphi}$ and $\tan \phi = \frac{r_2 \sin \varphi}{r_1 + r_2 \cos \varphi}$

Let $y_1 = r_1 \sin(\omega t + \phi)$ and $y_2 = r_2 \sin(\omega t + \varphi)$ therefore $y = y_1 + y_2 = r \sin(\omega t + \psi)$

where $r = \sqrt{r_1^2 + r_2^2 + 2r_1 r_2 \cos(\varphi - \phi)}$ and $\tan \psi = \frac{r_1 \sin \varphi + r_2 \sin \phi}{r_1 \cos \varphi + r_2 \cos \phi}$

Example 3.1

1. Determine the resultant of superposition of two oscillations described by $y_1 = \sqrt{2}\cos(t+\frac{\pi}{2})$ and $y_2 = \sqrt{2}\cos(t+\frac{2\pi}{3})$

Answer:

$$y = y_1 + y_2 = 2\sqrt{2}\cos(t+\frac{\pi}{6}) + \sqrt{2}\cos(t+\frac{2\pi}{3}) = 2\sqrt{2}\cos\frac{2\pi}{3}\sin(t+\frac{7\pi}{6})$$

2. Find initial phase and amplitude for simple harmonic motion represented by an equation $y = 3\cos\omega t + 4\sin\omega t$**.**

Answer

$$y = 3\cos\omega t + 4\sin\omega t = 3\sin(\omega t - \frac{\pi}{2}) + 4\sin\omega t = A\sin(\omega t + \varphi)$$

Where $A = \sqrt{3^2 + 4^2 + 2\times 3\times 4\cos(\frac{\pi}{2} - 0)} = 5$

$$\tan\varphi = \frac{3\sin(-\frac{\pi}{2}) + 4\sin 0}{3\cos(-\frac{\pi}{2}) + 4\cos 0} = \frac{-3}{4} \Rightarrow \varphi = 0.9316\,rad = 36^0 52'$$

GUIDANCE ABOUT SKILLS LAB 3

This is an experiment that aims at making students analyze and apply some of the concepts they have acquired in this unit. Not this activity can be well done in laboratory.

- Provide all the necessary materials as set in the question (1 Full set of retort stand,4 masses of 50 g each,1 spring)

- Guide learners in setting up the experiment as set in the activity. In case you have a student with any educational need, please make sure you help him or her.
- Guide them through instructions/questions so that they can do the work perfectly.
- Help them to have a suitable table of results with their values recorded in it.
- The table of results should be columnar like the one shown below.

M/kg	t/s	T/s	T/s^2
-	-	-	-

- Guide learners in plotting the graph. All the rules in plotting a graph should be respected.
- You can check student's work see whether the expected results are obtained.

  Remember that you may leave students to work on their own, since this is aimed at checking student's ability to apply what they have studied.

3.8. End unit assessment (answers)

1. First use $v = \pm\omega\sqrt{x_0^2 - x^2}$ to find the angular velocity ω:

$$\omega = \frac{v}{\sqrt{x_o^2 - x^2}} = \frac{2\pi}{T} \Leftrightarrow T = \frac{2\pi\sqrt{x_o^2 - x^2}}{v}$$

$$T = \frac{2\times 3.14\sqrt{(0.47m)^2 - (0.23m)^2}}{2.15} = 1.2\,\text{sec}$$

2. The object's kinetic energy is $K = \frac{1}{2}mv^2 = \frac{1}{2}m\omega^2 A^2 \sin^2(\omega t + \varphi)$,

Its potential energy is elastic potential energy. The elastic potential energy stored in a spring displaced a distance x from its equilibrium position is $U = \frac{1}{2}kx^2$.

The object's potential energy therefore is $U = \frac{1}{2}kx^2 = \frac{1}{2}m\omega^2 x^2 = \frac{1}{2}\mathrm{m}\,\omega^2\,\mathrm{A}^2\cos^2(\omega t + \varphi)$

The total mechanical energy of the object is

$$E = K + U = \frac{1}{2}m\omega^2 A^2 \sin^2(\omega t + \varphi) + \frac{1}{2}m\omega^2 A^2 \cos^2(\omega t + \varphi) = \frac{1}{2}m\omega^2 A^2$$

The energy E in the system is proportional to the square of the amplitude: $E = \frac{1}{2}kA^2$

It is a continuously changing mixture of kinetic energy and potential energy.

For any object executing simple harmonic motion with angular frequency ω , the restoring force $F = -m\omega^2 x$ obeys Hooke's law, and therefore is a conservative force. We can define a potential energy $U = \frac{1}{2}m\omega^2 x^2$, and the total energy of the object is given by $E = \frac{1}{2}m\omega^2 A^2$

3. a) By comparing this equation with General equation for simple harmonic motion:
$x = A\cos(\omega t + \varphi)$

We see that $A = 4.00\ m$, and $\omega = \pi\ rad/s$. Therefore, $f = \frac{\pi}{2\pi} = 0.500\ Hz$ and $T = \frac{1}{f} = 2\ s$

b) $x = (0.400\ m)\cos(\pi t + \frac{\pi}{4}) \Rightarrow \mathrm{v} = \frac{dx}{dt} = -4.00\pi\sin(\pi t + \frac{\pi}{4})$

$$a = \frac{dv}{dt} = -4.00\pi^2\cos\left(\pi t + \frac{\pi}{4}\right)$$

c) Noting that the angles in the trigonometric functions are in radians, we obtain, at t = 1.00 s,

$$x = (4.00\ m)\cos\left(\pi + \frac{\pi}{4}\right) = -2.83\ \mathrm{m}$$

$$v = -(4.00\ m)\pi \sin\left(\pi + \frac{\pi}{4}\right) = 8.89\ \text{m/s}$$

$$a = -(4.00\ m)\pi^2 \cos\left(\pi + \frac{\pi}{4}\right) = 27.9\ \text{m/s}^2$$

d) In the general expressions for v and a found in part (b), we use the fact that the maximum values of the sine and cosine functions are unity. Therefore, v varies between $-4.00\pi\ m/s$ to $+4.00\pi\ m/s$ and a varies between $-4.00\pi^2\ m/s^2$ to $+4.00\pi^2\ m/s^2$

Thus, $v_{\max} = 4.00\pi = 12.6\ \text{m/s}$ and $a = 4.00\pi^2 = 39.5\ \text{m/s}^2$

We obtain the same results using $v_{\max} = \omega A$ and $a_{\max} = \omega^2 A$

where. $A = 4.00\ m$, and $\omega = \pi\ rad/s$

e) The x coordinate at $t = 0\ s$ is $x_i = (4.00\ m)\cos\frac{\pi}{4} = 2.83\ \text{m}$

In part (c), we found that the x coordinate $t = 1.00\ s$ is $x_f = (4.00\ m)\cos\left(\pi + \frac{\pi}{4}\right) = -2.83\ \text{m}$;

therefore, the displacement between $t = 0\ s$ and $t = 1.00\ s$ is $\Delta x = x_f - x_i = -5.66\ m$

f) $\varphi = \frac{9}{4}\pi\ rad$.

4. (a) The displacement as a function of time is $x = (5\ cm)\cos(2t + \frac{\pi}{6})$.

Here $\omega = 2Hz$, $\varphi = \frac{\pi}{6} rad$, and A = 5 cm. The displacement at t = 0 is

$x(0) = 5\cos(\frac{\pi}{6}) = 4.33\ cm$

(b) The velocity at t = 0 is $v(t) = -\omega A \sin(\omega t + \varphi) = -2 \times 5 \sin\frac{\pi}{6} = -5\ cm/s$.

The acceleration at t = 0 is $a(0) = -\omega^2 A \cos(\omega t + \phi) = -4 \times 5 \cos\frac{\pi}{6} = -17.3\ cm/s^2$

(c) The period of the motion is $T = \frac{2\pi}{\omega} = \frac{2\pi}{2} = \pi\ s$ and the amplitude is 5 cm

5. If we assume the clock ticks once per cycle, then the period T = 1.0 s. We solve equation for L

$$L = \frac{T^2 g}{4\pi} = 0.25\,m$$

To find the period: $T = 2\pi\sqrt{\frac{l}{g}} = 2\pi\sqrt{\frac{1.0}{9.2}} = 2.01\,s$

6. (a) The period is $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{1}{25}} = 1.26\,s$

(b) The angular speed is $\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{25}{1}} = 5\ rad/s$.

The maximum speed is $v_{max} = \omega A = 5 \times 3 = 15$ cm/s.

The maximum acceleration of the particle is $a_{max} = \omega^2 A = 0.75$ m/s^2

(c) At time t = 0 the particle is at position x = -3 cm i.e. $-3 = 3\cos(0 + \varphi) \Leftrightarrow \cos\varphi = -1 \Rightarrow \varphi = \pi$

$x(t) = A\cos(\omega t + \varphi) = 3\cos(5t + \pi) = 3\cos 5t$,

$v(t) = -\omega A \sin(\omega t + \varphi) = 15\cos 5t$,

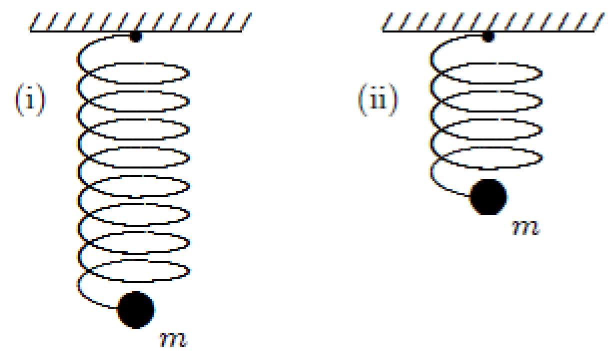
$a(t) = -\omega^2 A \cos(\omega t + \varphi) = 0.75\cos 5t$.

3.9. Additional activities (Questions and answers)

3.9.1 Remedial activities

This test contains 10 multiple choice questions, each of which has only one correct answer. If you answer a question correct, you score 5 points. If you answer a question wrong, you lose 2 points. If you do not attempt a question, you score 0 points.

1. A simple harmonic oscillator consists of a particle of mass m and an ideal spring with spring constant k. Particle oscillates as shown in (i) with period T. If the spring is cut in half and used with the same particle, as shown in (ii), the period will be:



A. 2T
B. √2T
C. T/√2
D. T
E. T/2

2. An object on the end of a spring is set into oscillation by giving it an initial velocity while it is at its equilibrium position. In the first trial the initial velocity is v_0 and in the second it is $4v_0$. In the second trial:

A. the amplitude is half as great and the maximum acceleration is twice as great
B. the amplitude is twice as great and the maximum acceleration is half as great
C. both the amplitude and the maximum acceleration are twice as great
D. both the amplitude and the maximum acceleration are four times as great
E. the amplitude is four times as great and the maximum acceleration is twice as great

3. If the length of a simple pendulum is doubled, its period will:

A. halve
B. be greater by a factor of √2
C. be less by a factor of √2
D. double
E. remain the same

4. A simple pendulum has length L and period T. As it passes through its equilibrium position, the string is suddenly clamped at its midpoint. The period then becomes:

A. 2T
B. T
C. T/2
D. T/4
E. none of these

5. One of the two clocks on the earth is controlled by a pendulum and other by a spring. If both the clocks are taken to the moon, then which clock will have the same time period on the earth?

(A) Spring clock, (B) pendulum clock, (C) both, (D) non.

6. A simple pendulum has a time period T_1 when on the earth's surface, and T_2 when taken to a height R above the earth's surface where R is the radius of the earth. The value of $\frac{T_2}{T_1}$ is:

(A) 1 (B) √2 (C) 4 (D) 2

7. If a simple harmonic motion is represented by $\frac{d^2x}{dt^2} + \alpha x = 0$, its time period is

(A) $\frac{2\pi}{\alpha}$ (B) $\frac{2\pi}{\sqrt{\alpha}}$ (C) $2\pi\sqrt{\alpha}$ (D) $2\pi\alpha$

8. Which of these periodic motions are SHM?

A. A child swinging on a playground swing at a small angle
B. A record rotating on a turntable
C. An oscillating clock pendulum

9. In order to double the period of a simple pendulum

A. Its length should be doubled
B. Its length should be quadrupled
C. The mass of its bob should be doubled
D. The mass of its bob should be quadrupled

10. A pendulum clock is set to give correct time at the sea level. The clock is moved to a hill station at an altitude h above sea level. In order to keep correct time on the hill station which one of the following adjustments is required?

A. The length of the pendulum has to be reduced
B. The length of the pendulum has to be increased
C. The mass of the pendulum has to be increased
D. The mass of the pendulum has to be reduced

3.9.2 Consolidation activities

11. A mass-spring system oscillates with amplitude of 3.5 cm. If the force constant of the spring of 250 N/m and the mass is 0.5 kg, determine

(a) The mechanical energy of the system,
(b) the maximum speed of the mass, and
(c) the maximum acceleration

12. What happens to the period of a simple pendulum if the pendulum's length is doubled? What happens to the period if the mass of the suspended bob is doubled?

13. A "second's pendulum" is one that moves through its equilibrium position once each second. (The period of the pendulum is precisely 2 s.) The length of a second's pendulum is 0.992 7 m at Tokyo, Japan and 0.994 2 m at Cambridge, England. What is the ratio of the free-fall accelerations at these two locations?

3.9.3 Extended activities

14. Can the amplitude *A* and phase constant ϕ be determined for an oscillator if only the position is specified at $t = 0$? Explain.

15. A metal pendulum is attached to a clock. The clock keeps correct time at $20^{\circ}\mathrm{C}$. Explain the reading of the clock at $40^{\circ}\mathrm{C}$

16. A 0.500 kg glider, attached to the end of an ideal spring with force constant k = 450 N/m, undergoes SHM with amplitude of 0.040 m. compute (a) the maximum speed of the glider; (b) the speed of the glider when it is at x = -0.015 m; (c) the magnitude of the maximum acceleration of the glider; (d) the acceleration of the glider at x = -0.015 m;

Answers for the additional activities

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

11. (a) We have $m = 0.5\,kg$, $A = 0.035\,m$, $k = 250\,N/m$, $\omega^2 = \dfrac{k}{m} = 500\,s^{-2}$, $\omega = 22.36\,rad/s$.

The mechanical energy of the system is $E = \dfrac{1}{2}kA^2 = 0.153J$

(b) The maximum speed of the mass is $v_{\max} = \omega A = 0.78\,m/s$

(c) The maximum acceleration is $a_{\max} = \omega^2 A = 17.5\,m/s^2$

12. We have $T_i = 2\pi\sqrt{\dfrac{L_i}{g}}$ and $T_f = 2\pi\sqrt{\dfrac{L_f}{g}} = 2\pi\sqrt{\dfrac{2L_f}{g}} = \sqrt{2}T_i$

The period gets larger by 2 times. Changing the mass has no effect on the period of a simple pendulum.

13. The period in Tokyo is $T_c = 2\pi\sqrt{\dfrac{L_T}{g_T}}$

And the period in Cambridge is $T_c = 2\pi\sqrt{\dfrac{L_c}{g_c}}$

We know that $T_T = T_c = 2.00\,s$

For which, we see $\frac{T_T}{g_T} = \frac{L_c}{g_c} \Leftrightarrow \frac{L_T}{L_c} = \frac{g_T}{g_c} = \frac{0.9927}{0.9942} = 0.998$

14. No. It is necessary to know both the position and velocity at time zero.

15. The clock loses time. This is because expansion with the rise in temperature, of the size of the pendulum

16. The maximum speed is at $x = 0$ and the maximum magnitude of acceleration is at $x = \pm A$

(a) For $x = 0, \frac{1}{2}mv_{\max}^2 = \frac{1}{2}kA^2$ *and* $v_{\max} = A\sqrt{\frac{k}{m}} = (0.040m)\sqrt{\frac{450\,N/m}{0.500kg}} = 1.20\,m/s$

(b) $v_x = \pm\sqrt{\frac{k}{m}(A^2 - x^2)} = \pm\sqrt{\frac{450\,N/m}{0.500kg}\left((0.04m)^2 - (0.015m)^2\right)} = \pm 1.11m/s$

The speed is $v = 1.11m/s$

(c) For $x = \pm A, a_{\max} = \frac{k}{m}A = \left(\frac{450\,N/m}{0.500kg}\right)(0.040m) = 36\,m/s^2$

(d) $a_x = -\frac{k}{m}x = \left(\frac{450\,N/m}{0.500kg}\right)(-0.015m) = +13.5\,m/s^2$

UNIT 4: PROPAGATION OF MECHANICAL WAVES

4.1. Key Unit competence:

Evaluate the propagation of mechanical waves

4.2 Prerequisite (knowledge, skills, attitudes and values)

Students should be aware of concepts about waves. They can refer to SME year 1 unit 7.

4.3 Cross cutting issues to be addressed

- **Inclusive education** (promote education for all in the learning process):

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

- **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 even if they may want to have water waves. They should not play in water bodies. Save the environment, save the future.

- **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 demonstration of water waves on a ripple tank.

4.4 Guidance on introductory activity

This activity aims at capturing students' attention and minds towards interference of waves. Mind you these students have idea about superposition. This will help them to understand interference of waves.

- Tell student-teachers to open student-teacher's book directly to unit 4 and then switch on to the introductory Activity.

- Inform student-teachers that they are to do the activity 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) and tell them to start working on the introductory activity. Or decide any appropriate method to use depending on the nature of your class.

- Let them interpret the diagram in the introductory diagram

- Give student-teachers enough time to work by themselves brainstorming/ discussing the questions. In this period, you can move around overseeing what students are doing. Leave them to work by themselves.

- Invite some groups to present their findings to the whole class. You can explain new terms used and clarify points where 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 learners' findings and deductions. Let them write key points in their notebooks. But the key points should be answering the questions and related to mechanical waves.

Note: In case there is a student-teacher that requires special attention, please make sure assistance is provided.

Expected answers for the introductory activity.

b) This question is open, and it depends on the intensity of light, size of slits and distance from the light source to the slits. Therefore, any other that supports idea should be accepted. It may be: either dark fringes, bright fringes or blurred.

c) -Intensity of light that affects the wavelength of the incident light.

-Distance between the slits and the screen

-Size of the slits.

d) No! Because the images/fringes depend on the intensity of light which is not the same in this case.

e) Once the size of the slits is increased, the images become blurred and not clear.

f) We do not ordinarily observe the wave behavior for light because no clear investigation done compared to that of Thomas Young that classifies the detailed behaviors of wave.

g) -Can be applied in determination of focal length of a lens. (Light experiment in determination of focal length of lenses in O'level)

- Determining the wavelength of light.

- In entertainment (in production of colored fringes that are entertaining)

4.5 List of lessons

#	Lesson title	Learning objectives	Number of Periods
1	**Interference of waves**	- Outline the applications of interference of Waves	6

		- Explain the applications of interference of waves	
2	**Stationary waves**	- Observe and describe nodes and antinodes in stationary waves - Distinguish nodes from antinodes - Outline the applications of stationary waves - Appreciate the sound systems on the studio	6
3	End unit assessment		2

Lesson 1: Interference of waves

a) Learning objective

- Outline the applications of interference of Waves

- Explain the applications of interference of Waves

b) Teaching resources

– Textbooks/internet.
– Projectors, videos (Simulations about interference of waves).
– https://phys.libretexts.org/Ancillary_Materials/Visualizations_and_Simulations/PhET_Simulations/PhET%3A_Wave_Interference

c) Prerequisites/Revision/Introduction

Since this unit is about interference of waves, learners need to remember the superposition of waves from unit 7 in Physics (SME). Try to link this to what they studied in Year 1

d) Learning activities 4.1

Guidance to learning activity 4.1

This lesson aims at introducing interference of waves and its applications.

- Tell student-teachers to turn to activity 4.1 in student-teacher's book
- Suggest on the methodology to use in this lesson. Choice may depend on the nature of your class. Remember that this is a practical lesion. Where learners need to do an experiment.
- Instruct them to do the experiment. Make sure you provide all the necessary equipment
- Leave the learners to perform the experiment by themselves. Give them enough time to work out the experiment
- When they are done ask them to answer the questions in the activity. You may ask them different questions related to the questions but arising from the experiment

Note: in case there is a student-teacher that requires special attention, please make sure assistance is provided.

Answers for the learning activity

d) The observations differ depending on how the disturbance is applied.

Possible suggestions:

i) Ripples propagating backwards and forward crossing one another.

ii) Completely water being displaced

e) Interference of waves.

f) In light waves, sound waves.

Answers for the application activity 4.1

1. The path difference for destructive interference

$\Delta x = (2n+1)\dfrac{\lambda}{2}$ where n=0,1,2, 3,…..

λ is wavelength of the wave

The path difference for constructive interference

$\Delta x = n\lambda$ where n=0,1,2,3,…..

λ is wavelength of the wave

2. When light passes from a less dense medium to a dense medium its wavelength changes (reduces). And by definition, the separation of fringes depends on the wavelength hence for this case the fringe separation will reduce.

3. If monochromatic light in Young's interference experiment is replaced by white light, then the waves of each wavelength form their separate interference patterns. i.e., the waves of all colours reach at mid-point M in same phase. Therefore, the central fringe is white.

Thus Light of different colours/wavelength may separate after passing through the slit leading formation of different colours of different wavelength. Hence distinct fringes may not be formed on the screen.

4. From $m\lambda = d\sin\theta$ and $m = 2$

$m\lambda = d\sin\theta$ and d is the slit separation

$2\lambda = 0.03mm\sin 2.15 = 0.00056\,mm$

5. From $\lambda = d\sin\theta$ and d is the slit separation

$\lambda = 0.03\sin 10 = 5.2\times 10^{-3}m$

6. From $x_n = \dfrac{n\lambda D}{d}$

$$x_n = \frac{(n_5 - n_1)\lambda D}{d} = \frac{(5-1)6.2\times 10^{-17}\times 0.8}{d}$$

$d = 7.94\times 10^{-14}m$

Lesson 2: Stationary waves

a) Learning objective

- Observe and describe nodes and antinodes in stationary waves.
- Distinguish nodes from antinodes.
- Outline the applications of stationary waves.
- Appreciate the sound systems on the studio.

b) Teaching resources

– Text books (all reference books in student-teacher’s book) and internet.
– Projectors, videos (Use the link that gives the simulations given in the lesson title 2)

c) Prerequisites/Revision/Introduction

Since this unit is about interference of waves, learners need to remember the superposition of waves from unit 7 in Physics (SME). Try to link this to what they studied in Year 1

d) Learning activities

Guidance to learning activity 4.2

- This activity introduces student-teachers to principal of stationary waves that is due to interference of waves.
- Divide your class into small groups, and let student-teachers follow the working procedures to obtain the results.
- Let the learner(s) perform the activity 4.2 using their prior knowledge about superposition/interference of waves.
- Tell them to study and interpret the diagram in the activity. This will help them to answer the proceeding questions
- Have sample group present their work to the class.
- Check student-teachers’ responses to review the student-teachers' plans and ideas to continue the discussion with a brief brainstorming of the concepts using student-teachers’ works and book.

• Comment on student-teachers' responses written in their notebooks and give them the summary of expected feedback based on their findings.

Note: In case there is a student-teacher that requires special attention, please make sure assistance is provided.

Answers for activity 4.2

a) Meeting of the water ripples lead to the shape indicated in the figure.

b) They would appear single curved waves/ripples propagating forward. (nothing interfering them)

c) The resultant waves are stationary waves, vibrating about fixed position without transferring energy from one point to another.

Answers for application activity 4.2

1. Displacement node is a region of zero displacement on a stationary wave. In another way, displacement node is a region of maximum pressure on a stationary wave.

Displacement antinode is a region of maximum displacement on a stationary wave. In another way, displacement node is a region of minimum pressure on a stationary wave.

2. **Characteristics of stationary waves**

- The wave shape does move
- Neighboring points have different amplitudes
- Neighboring points have the same phase
- It store energy
- Formed when two waves interfere

3. Check solutions for a) and b) are proved in Student-teacher for integrated science (unit 7 in year 1- SME).

4. The wave is $y = 8\sin(40\pi t + 0.8\pi x)$

To get a stationary wave, add the two waves, $y = 8\sin(40\pi t - 0.8\pi x) + y = 8\sin(40\pi t + 0.8\pi x)$

$$y = 2\times 8\sin(40\pi t)\cos(0.8\pi x) = 16\sin(40\pi t)\cos(0.8\pi x)$$

Amplitude $A = 16\cos 0.8\pi x$

Velocity $V = \frac{d}{dt}(A\sin 40\pi t) = 40\pi A\cos 40\pi t$

$V = 40\pi(16\cos 0.8\pi x)\cos 40\pi t = 640\pi[\cos 0.8\pi x\cos 40\pi t]$

4.6. Summary of the unit

A **wave** is a disturbance or deformation of the medium it is in; that travels through space or matter in regular pattern, usually by the transfer of energy from one point to another, often with no permanent displacement of the particles of the medium.

A wave whose source vibrates with SHM is called a **sinewave**: $y = A\sin(\omega t + \varphi)$

The world is full of waves, the three main types being mechanical waves, matter waves and electromagnetic waves. In the case of mechanical waves, some physical medium is being disturbed— in our pebble and beach ball example, elements of water are disturbed. Electromagnetic waves do not require a medium to propagate; some examples of electromagnetic waves are visible light, radio waves, television signals, and X-rays.

Waves are divided into types according to the direction of the displacements in relation to the direction of the motion of the wave itself: If the vibration is parallel to the direction of motion, the wave is known as a longitudinal wave. The transverse wave is a wave, in which the vibrations are at right angles to the direction of motion.

The wavelength λ of a sinusoidal waveform traveling at constant speed v is given by: $\lambda = \frac{v}{\lambda}$

All waves can be reflected due to change of speed and diffracted (they spread through openings comparable to their wavelength). Interference occurs where two waves overlap at a place produce constructive interference but a crest and a trough produce destructive interference.

The progressive wave equation is given by: $y_m = A\sin(\omega t \pm kx) = A\sin 2\pi(\frac{t}{T} \pm \frac{x}{\lambda})$

In a progressive wave, neighboring points are out of phase with each other.

A stationary or standing wave is one in which some points are permanently at rest (nodes), others between these points are vibrating with varying amplitude and the maximum amplitude is midway between the nodes (antinodes)

4.7. Additional Information for tutor

Types of wave

In mathematics and science, a **wave** is a disturbance or deformation of the medium it is in; that travels through space or matter in regular pattern, usually by the transfer of energy from one point to another, often with no permanent displacement of the particles of the medium.

For example, what happen when you drop a pebble into a pond? The disturbance created by the pebble generates water waves that travel away from the disturbance, if you were carefully examine the motion of a leaf floating near the disturbance, you would see that the leaf moves up and dawn and back and forth about its original position.

However, the leaf does not undergo any net displacement from the motion of the wave. The leaf's motion indicates the motion of the water's particles. The molecules of water move locally, like the leaf does, but they do not travel across the pond. That is, the water wave moves from one place to another, but the water itself is not carried with it. Only the wave of energy moves outward.

Fig.4. 1Interference patterns produced by outward spreading waves from many drops of liquid falling into a body of water

The very existence of waves is a consequence of the medium's tendency to be at rest. Once energy is transmitted to the medium, conservation of energy requires that if the medium is to come to rest at one place, it must move the energy somewhere else. That movement is the wave; we say that the wave "propagates" through the medium.

The wave concept is abstract. When we observe what we call a water wave, what we see is a rearrangement of the water’s surface. Without the water, there would be no wave. A wave traveling on a string would not exist without the string. Sound waves could not travel through air if there were no air molecules. With mechanical waves, what we interpret as a wave corresponds to the propagation of a disturbance through a medium.

A wave allows energy to be transferred from one point to another, some distance away without any particle of a medium travelling between the two points.

A wave whose source vibrates with SHM is called a **sinewave**:

$$y = A\sin(\omega t + \varphi)$$

Waves are of three main types: Mechanical wave, electromagnetic wave and matter wave. Much of what we discuss in this unit applies to waves of all kinds. However, for specific examples we shall refer to mechanical waves.

1. Mechanical waves

Mechanical waves are wave that can transfer energy through matter e.g. sound, seismic and water waves, wave trains. The matter through which mechanical waves travel is called the **medium**. All mechanical waves require (1) some source of disturbance, (2) a medium that can be disturbed, and (3) some physical mechanism through which elements of the medium can influence each other.

Mechanical Waves are divided into two types according to the direction of the displacements in relation to the direction of the motion of the wave itself.

(a) Longitudinal wave

If the vibration is parallel to the direction of motion, the wave is known as a longitudinal wave. The longitudinal wave is always mechanical because it results from successive compressions (state of maximum density and pressure) and rarefactions (state of minimum density and pressure) of the medium. Sound waves produced in wind musical instruments (trumpet, flute, clarinet, pipe organ,….) typify this form of wave motion.

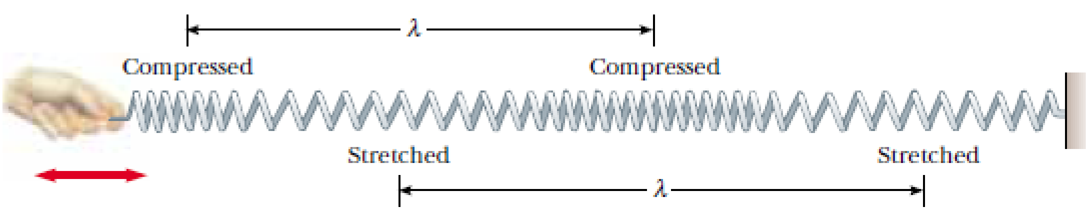


Fig.4. 2Longitudinal waves along a stretched spring. The displacement of the coils is in the direction of the wave motion. Each compressed region (region of high particle density) is followed by a stretched region (region of low particle).

(b) Transverse wave

The transverse wave is a wave in which the vibrations are at right angles to the direction of motion. A transverse wave may be mechanical, such as the wave projected in a taut string or it may be electromagnetic, such as light, X ray, or radio waves.

For a transverse wave, the wavelength is the distance between two successive crests or troughs. For longitudinal waves, it is the distance from compression to compression or rarefaction to rarefaction. The actual motion of the particles has been indicated by small arrows in the diagram

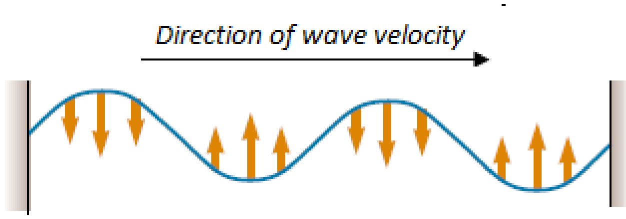


Fig.4. 3 Energy has been transferred, although no material moved from left to right

Some mechanical wave motions, such as waves on the surface of a liquid, are combinations of both longitudinal and transverse motions, resulting in the circular motion of liquid particles.

A slinky spring can be used to demonstrate that two common waves:

- If the end of the spring is moved from side to side or up and down, a wave of side-to-side or up-to-down displacement will travel along the spring. Waves like those in which the displacements of the spring are perpendicular to the direction of travel of the waves are called **transverse waves**.

- If the end of the spring is moved back and forth, along the direction of the spring itself, a wave of back-and-forth displacement will travel along the spring. Waves like those in which the displacements are parallel to the direction of travel of the waves are called **longitudinal waves**.

The speed of longitudinal wave depends only on the physical properties of the place in which the wave travels:

$$v = \sqrt{\frac{T}{\mu}}$$

Where F is the tension in Newton and $\mu = \frac{m}{l}$ is the linear mass in in kg/m

2 Matter Waves

If we perform the double slit diffraction experiment using a beam of electrons instead of light, we still get a diffraction pattern. The interpretation of this is that **matter travels as a wave**. Thus "matter acts as both a particle and as a wave."

If we can sometimes consider an electron to be a wave, what is its wavelength? Louis de Broglie postulated that all particles with momentum have a wavelength

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

Where $h = 6.63 \times 10^{-34}\ J \cdot s$ is Planck's constant (energy of a photon divided by its frequency), and p is the magnitude of the momentum of the particle.

The matter waves describe the wavelike characteristics of atomic-level particles.

For mechanical waves, the speed of the wave is a property of the medium, speed does not depend on the size or shape of the wave.

3 Electromagnetic waves

Electromagnetic waves are waves that can carry energy without using matter. Electromagnetic wave is a disturbance in electric and magnetic fields that caries energy through space at the speed of light. Electromagnetic wave is transverse.

That is, the electric and magnetic field vectors associated with electromagnetic waves are perpendicular to the direction of wave propagation

Electromagnetic Waves include visible light, ultraviolet radiation, infrared radiation, gamma rays, X-rays, and radio waves. All electromagnetic waves travel through a vacuum at the same speed: $c = 3\times10^{8}\ m/s$

GUIDANCE ABOUT SKILLS LAB 4

In this activity, Learners are to show the skills attained from this unit. According to the activity, they are to construct a ripple tank an experiment that is used to study water waves.

This device is not common in most schools and tutors and student-teachers rarely use it. Thus, it is from this skill that student-teachers will solve this problem.

- Facilitate these learners to get materials to design the ripple tank.
- Facilitate them in conducting a research using internet or library for more information.
- You may always inspect their progress and advise where necessary.
- Help those students with any problem (SEN) so that all of your students achieve the objectives of this activity.
- Allow them/some groups/individuals to present their project. They can present the theory behind the functioning of this device using PowerPoint or normal boards and even the operation and working of the device.
- In case there some individuals that are not making it, ask others that have tried it, to help them
- Help the students to keep the working devices for future use.

4.8. END UNIT ASSESSMENT (answers)

1. There is a constructive interference of the sound waves at point P and Q. since is the first maximum after P, where AP = BQ, it follows that: $AQ - BQ = \lambda$ where λ is = 90º so

$$AQ = \sqrt{BQ^{2} - AB^{2}} = 2.60\ m$$

From $AQ - BQ = \lambda \Rightarrow \lambda = 0.20\ m$ Wave speed $v = \lambda f = 340\ m/s$

2. Using the equation of constructive interference: $\lambda = \frac{d\sin\theta}{m} = \frac{dx}{mD}$

Then for violet light: $\lambda_{violet} = \frac{(5.0\times10^{-4}\ m)(2.0\times10^{-3}\ m)}{1\times2.5\,m} = 400\ nm$

For red light: $\lambda_{violet} = \frac{(5.0\times10^{-4}\ m)(3.5\times10^{-3}\ m)}{1\times2.5\,m} = 700\ nm$

3. $d = \frac{n\lambda D}{x} = \frac{4(5.89\times10^{-7}\ m)(1.60\ m)}{16\times10^{-3}\ m} = 0.236\ nm$

4. The condition for dark fringes, or destructive interference, is given by: $d\sin\theta = (m+\frac{1}{2})\lambda$

$0.05\sin\theta = (m+\frac{1}{2})(500\times10^{-9}) \Leftrightarrow \theta = \arcsin(2m+1)(50\times10^{-7})$

Then, substitute in m = 0, 1 and 2 to gain corresponding values of θ (in°):

- For $n=0$ then $\theta = \arcsin(1\times50\times10^{-7}) = 0.0003$
- For $n=1$ then $\theta = \arcsin(3\times50\times10^{-7}) = 0.0009$
- For $n=2$ then $\theta = \arcsin(5\times50\times10^{-7}) = 0.0014$

5. No.

4.9. Additional activities (Questions and answers)

4.9.1 Remedial activities

1. How do transverse waves differ from longitudinal waves?

2. Both longitudinal and transverse waves can propagate through a solid. A wave on the surface of a liquid can involve both longitudinal and transverse motion of elements of the medium. On

the other hand, a wave propagating through the volume of a fluid must be purely longitudinal, not transverse. Why?

3. In a longitudinal wave in a spring, the coils move back and forth in the direction of wave motion. Does the speed of the wave depend on the maximum speed of each coil?

4. A sinusoidal transverse wave is traveling on a string. Any point on the string:

A. moves in the same direction as the wave
B. moves in simple harmonic motion with a different frequency than that of the wave
C. moves in simple harmonic motion with the same angular frequency as the wave
D. moves in uniform circular motion with a different angular speed than the wave
E. moves in uniform circular motion with the same angular speed as the wave

4.9.2 Consolidation activities

5**.** Sound waves are

A. Transverse waves characterized by the displacement of air molecules.
B. Longitudinal waves characterized by the displacement of air molecules.
C. Longitudinal waves characterized by pressure differences.
D. Both (*B*) and (*C*).
E. (*A*), (*B*), and (C).

6. Choose the best answer: A "wave front" is a surface of constant:

A. Phase C. frequency
B. wavelength D. amplitude E. speed

7. a) Define and state the unit of each the following quantities: Amplitude, Period, Frequency, and Velocity

b) Explain how a water wave travels when there is a source of disturbance at one point.

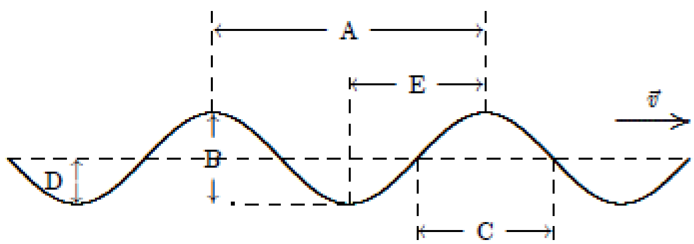
4.9.3. Extended activities

8. Calculate the frequency of a radio wave of wavelength 150 m. The velocity of all electromagnetic waves in free space is $c = 3 \times 10^8\ m/s$

9. A sinusoidal wave is traveling toward the right as shown.

a) Which letter correctly labels the amplitude of the wave?

b) Which letter correctly labels the wavelength of the wave?



Answer for additional activities

1. The difference is in the direction of motion of the elements of the medium. In longitudinal waves, the medium moves back and forth parallel to the direction of wave motion. In transverse waves, the medium moves perpendicular to the direction of wave motion.

2. Longitudinal waves depend on the compressibility of the fluid for their propagation. Transverse waves require a restoring force in response to sheer strain. Fluids do not have the underlying structure to supply such a force. A fluid cannot support static sheer.

A viscous fluid can temporarily be put under sheer, but the higher its viscosity the more quickly it converts input work into internal energy. A local vibration imposed on it is strongly damped, and not a source of wave propagation.

3. The wave speed is independent of the maximum particle speed. The source determines the maximum particle speed, through its frequency and amplitude. The wave speed depends instead on properties of the medium.

4. C

5. D

6. A

7. a) amplitude: maximum displacement from equilibrium position. SI unit of amplitude is m

The **period** T, is the time in s it takes for complete cycle of an oscillation of a wave. The **period** is the time between two peaks.

The number of complete cycles the ride swings through in a unit of time is the ride's **frequency**. The **frequency** is the number of peaks per unit time. The SI unit of frequency is Hz (Hertz).

The **propagation speed of a wave** (denoted v) is the rate at which a given peak of the wave travels. The SI unit of speed is m/s

b) The water wave moves from one place to another, but the water itself is not carried with it. Only the wave of energy moves outward.

8. For wave, $\lambda = \frac{c}{f} \Leftrightarrow f = \frac{c}{\lambda} = \frac{3\times 10^{8}\ m/s}{150\,m} = 2\ MHz$

9. a) The amplitude of the wave is D b) The wavelength of the wave is A

UNIT 5: FOSSIL, NON FOSSIL FUEL AND POWER PRODUCTION

5.1. Key unit competence:

Justify the effects of fossil and non-fossil fuel in power production

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

The learner will be equipped with knowledge acquired in different courses done in ordinary level and in SME year 1 like Elements and fission in Chemistry, Energy in the Word and Rwanda in Physics S3 Ordinary level, Data presentations and interpretations in Geography.

5.3 Cross cutting issues to be addressed

Inclusive education (promote education for all in teaching and learning process):

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

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-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.

Note: Environmental sustainability, financial education, Peace and values education, Inclusive education and gender education and others that can be judged by the Tutor

5.4 Guidance on introductory activity

- The Tutor asks student-teachers to open Learner's Book and read carefully the questions given on introductory activity of unit 5.
- The Tutor will guide Student-teachers in their discussions. The activity should be done in groups, in pairs or individually depending on the size of the class.
- Learners should share their findings in groups or pairs before presentation in front of the whole class. The Student-teachers should not answer all questions.
- If this happen, the Tutor will help them to get the answer as the lesson is ongoing.

5.5 List of lessons

#	Lesson title	Learning objectives	Number of Periods
1	Fossil fuel and non-fossil fuel	- Outline historical and geographical reasons for use of fossil fuels. - Distinguish fossil fuel and non-fossil fuel.	2
2	Transportation and storage of fossil fuels.	Outline advantages and disadvantages associated with the transportation and storage of fossil fuels	2
3	Environmental problems of fossil fuels	Explain environmental problems associated with recovery of fossil fuels after use in power stations.	3
4	Problems associated with the production of nuclear power.	Point out Problems associated with the production of nuclear power	3
5	Safety issues and risks of nuclear power	- Outline safety issues and risks of nuclear power. - Apply knowledge attained to identify safety issues and risks of nuclear power.	2
6	End unit assessment		2

Lesson 1: Fossil fuel and non-fossil fuel

a) **Learning objective**

- Outline historical and geographical reasons for use of fossil fuels
- Distinguish fossil fuel and non-fossil fuel

b) **Teaching resources**

Search internet, Scientific Journals and Computer simulations.

c) **Prerequisites/Revision/Introduction**

Elements and fission in Chemistry will serve as prerequisites knowledge of Student Teachers. The Tutor introduces his/her lesson by asking questions about energy in the World studied in Physics S3 Ordinary level.

d) Learning activity 5.1

Guidance to learning activity 5.1

- The Tutor asks Student -Teachers to open Learner's Book and read carefully the questions given on learning activity 5.1

- The Tutor will ensure that learners with special needs if any are all engaged in the activity.

- The Tutor will guide Student-teachers in their discussions.
- The activity should be done in groups, in pairs or individually depending on the size of the class.
- Student-teachers should share their findings in groups or pairs before presentation in front of the whole class.
- Student-teachers will write their presentation on the board.
- The Tutor harmonizes presentations focusing on the content of the lesson and cross cutting issues related to the lesson.

Answers for activity 5.1

1) Energy used at home when

(i) cooking food are: fire wood, charcoal, gas, electricity

(ii) Candle, kerosene lamp, electricity

(iii) Electric iron, charcoal iron

2) Petroleum oil and diesel oil. These forms of energy are imported. They are fossil fuel

3) Solar energy

4) Solar energy can be used forever but petroleum and diesel oil should be depleted if they are used anarchically.

d) **Answers for Application activities 5.1**

1) Burning diesel oil in a car to generate mechanical energy is an example

2) (i) Solar panel energy, wind energy, geothermal energy, hydroelectric power energy, etc.

(ii) Non-fossil fuels are considered to be extremely important for power creation. This is because they are usually renewable energy sources that could be tapped for hundreds of years and not run out. In addition, energy production using non fossil-based fuels usually generates much less pollution.

3) Fossil fuels are hydrocarbons, primarily coal, fuel oil or natural gas, formed from the remains of dead plants and animals. In common dialogue, the term ‘fossil fuel’ also includes hydrocarbon-containing natural resources that are not derived from animal or plant sources.

Coal, oil and natural gas are called ‘**fossil fuels**’ because they have been formed from the fossilized remains of prehistoric plants and animals. Fossil fuels are non-renewable energy source since they take millions of years to form.

4) Before steam engines were invented, heavy industry depended on mechanical water power to grind flour, saw wood, and so forth. Industrialization led to a higher rate of energy usage. Fossil fuel led to development and it played a crucial rule as energy sources, inputs for agriculture, and feed stocks for chemical manufacture. The Industrial Revolution marked a big change for people of the world. Many of the agriculture based societies that used human and animal labor forces switched to use machines to do work. Coal was commonly used in the early era of

industrialization until internal combustion engine and the automobile were invented. Oil and gas became the most common fossil fuel people used

Lesson 2: Transportation and storage of fossil fuels

a) Learning objective

Outline advantages and disadvantages associated with the transportation and storage of fossil fuels

b) Teaching resources

Search internet, Library, Journals and computer simulations

c) Prerequisites/Revision/Introduction

The Tutor introduces his/her lesson by asking questions about the previous lesson. He should exploit also skills leant in S_1 Unit 6, S_3 unit 4 related to energy.

d) Learning activity 5.2

Guidance to learning Activity 5.2

- The Tutor asks Student-teachers to read activity 5.2 on Student teacher's book.
- The Tutor must provide activities for learners with special needs if any.
- They observe clearly and try to answer to the questions during about five minutes.
- Student-teachers should work in groups of 4 depending on the size of the class.
- The Tutor gives guidance in different groups accordingly.
- After answering questions, the Tutor helps Student-teachers to develop the lesson of the day as Prepared in the lesson plan.
- The development of cross cutting issues in this lesson is important.

Answers for activity 5.2

a) In Rwanda we should have fossil fuel like Natural gas and oil since our neighboring countries like Uganda have. Geographically, we are located in the same region. Researches must be conducted to prove this.

b) In Rwanda we use: Natural gas and refined oil.

c) They come outside by Importation. We use Land transportation from Kenya or Tanzania. This method is costly to the country because of long distances, insecurity and accidents in the road, taxes, etc.

d) (i) Big stock of oil and gas should be important if there is a lack of these fuels in importation of them. In the case when our country lacks funds, we should use stored fuels.

(ii) In the case of insecurity, stocks of fossil fuel can serve as terrorist attacks.

The consequences of an accident would be absolutely devastating both for human beings and the nature.

Answers for Application activities 5.2

1. a) The majority of oil transported by maritime means reaches their destination.

b) Oil depots are usually situated close to oil refineries or in locations where marine tankers containing products can discharge their cargo.
c) Rail transport is the most attractive for long-term, long-distance, high-volume movements of coal.
d) Pipelines require less right-of-way, much less labor, and about half of the steel and other supplies required for other transport methods.
e) Taller and wider stockpiles reduce the land area required to store a set tonnage of coal.
f) Transport of coal on barges is highly cost-efficient.
g) Transportation by gas pipelines are less costly and are thus more common.

2. Crude oil is transported by waterways or land ways in pipelines.
3. - Even though pipelines are useful, in certain cases the construction of gas pipelines is technically impossible or too expensive, for example to bring Nigerian gas to Europe, or to take gas from Qatar to Japan.

-Because natural gas expands more, it is costly to build equipment of transport and storage for natural gas than oil.

Lesson 3: Environmental problems of fossil fuels

a) Learning objective

Explain environmental problems associated with recovery of fossil fuels after use in power stations.

b) Teaching resources

- Search Internet, Library, Internet simulations.
- Projectors, videos

c) Prerequisites/Revision/Introduction

The Tutor exploits skills leant by Student Teachers in S_1 Unit 6 and S_3 Unit 4 Ordinary Level related to energy.

d) Learning activity 5.3

Guidance to the learning activity 5.3

- Using a scenario of environmental degradation in their region or elsewhere they know, the Tutor should introduce his lesson by asking short answer questions on it.
- After that, The Tutor asks Student-teachers to read activity 5.3 in Student-teacher's book.
- Ensure that all learners are fully engaged in this activity of about six minutes. The lesson must be inclusive.
- They observe clearly and try to answer to the questions. They should work in groups of 4 depending on the size of the class.
- The Tutor is a facilitator in this activity.
- After answering questions, the Tutor develops his lesson using answers of the Student-teachers.

Answers for learning activity 5.3

1. Smokes, rivers, factory, mountains, people, animals.

2. The source of energy used in the factory is coal.
3. The environment is quietly polluted because the smokes from the factory are damaging the atmosphere. Also wastes from the factory are polluting rivers and lakes which have negative impacts on aquatic living things and on human being.
4. When wastes from the factory pollute water, they affect aquatic animals. The people need to use the water in their daily life like drinking, fishing, etc and thus being affected. In his respiration the human being will be affected by contaminated air. Also, gaseous smokes from the factory will destroy ozone layer.
5. - To avoid harmful wastes on the environment,
   - To avoid gaseous smokes to the human being
   - To avoid acidic gases destroying ozone layer.

e) **Answers for Application activities 5.4**

Regardless their eminent role in industrialization era, the following show that fossil fuels are harmful to human being and environment in general when they are badly handled.

1. Climate Change and Global Warming

Global warming occurs when carbon dioxide from power plant is accumulated in the atmosphere.

2. Hole in the Ozone Layer

The World is facing a serious confrontation as the emissions of chlorofluorocarbons and other destructive gases are causing ozone holes to appear in the stratospheric ozone layer. As a consequence, the concentration of detrimental ultraviolet radiation is increasing at ground level and jeopardizing humans, crops and ecosystems.

3. Acid rain

The wind carries the acidic compounds into the air, and they later fall to the ground in either dry or wet form. They form an acidic 'rain' which can destroy vegetation.

4. Air Pollution

Air pollution is the release of excessive amounts of harmful gases (e.g. methane, carbon dioxide, Sulphur dioxide, nitrogen oxides) as well as particles (e.g. dust of tyre, rubber, and lead from car exhausts) into the atmosphere.

5. Changes in Food Supply

Changing weather affects the agricultural industry and the human food supply. Carbon emissions contribute to increasing temperatures and decreasing precipitation, changing the growing conditions for food crops in many areas.

6. Water Pollution

Sewage is the household waste water. Many detergents contain phosphates which act as plant fertilizers. When these phosphates and the sewerage reach rivers, they help water plants to grow in abundance, reducing the dissolved oxygen in the river water. The result is death of aquatic animals due to suffocation by the algal blooms.

7. Population Explosion

It is the rapid increase in population in developing countries causing famine, and also in developed countries causing more demand for energy and with that, it increases pollution and destruction of the environment.

Lesson 4: Problems associated with the production of nuclear power

a) Learning objectives

- Point out Problems associated with the production of nuclear power

b) Teaching resources

- Search internet, Library, Journals and computer simulations
- Projectors, videos

c) Prerequisites/Revision/Introduction

Energy in the World studied in Geography Ordinary level serve as prerequisite knowledge. The lesson one studied previously will serve as introduction of the new lesson.

d) Learning activity 5.4

Guidance to the learning activity 5.4

- The Tutor asks Student-teachers to open Learner's book and observe the figure 5.4 in activity 5.4 and read carefully the related questions.
- The Tutor must ensure that all learners are included, especially those with special needs.
- He asks them to provide answers in small groups if possible. The use of ICT tools is an advantage.
- The activity should be done in small groups, in pairs or individually depending on the class size and textbooks.
- Student-teachers should share their findings in groups or pairs before presentation in front of the whole class.
- The Tutor helps Student-teachers to harmonize presentations focusing on the content of the lesson. Remember to develop cross cutting issues met in the lesson.

Answers for learning activity 5.4

i) There is a factory which ejects pollutants smokes in the atmosphere.

ii) No, it does not. It looks like an industry producing different forms of energy.

iii) They should be using coal as combustible material.

iv) The problem of radioactive wastes is unsolved. The waste from nuclear energy is extremely dangerous and it has to be carefully looked after for several thousand years (10,000 years according. During the operation of nuclear power plants, radioactive waste is produced, which, in turn, can be used for the production of nuclear weapons.

e) **Answers for Application activity 5.4**

1) (i) **Nuclear fuel** is any material that can be consumed to derive nuclear energy.

(ii) **Nuclear fission** is a process, by which a heavy nucleus splits into two or more simpler pieces. This process releases a lot of energy.

2) The problem of radioactive waste, high risks of accidents, Nuclear power plants could be preferred targets for terrorist attacks, generation of country conflicts.

Lesson 5: Safety issues and risks of nuclear power

a) Learning objective

- Outline safety issues and risks of nuclear power
- Apply knowledge attained to identify safety issues and risks of nuclear power

b) Teaching resources

- Search internet, Library, Journals and computer simulations
- Projectors, videos

d) Prerequisites/Revision/Introduction

The Tutor exploits skills leant by Student-teachers in S_3 Unit 4 Ordinary Level related to energy problems in the World. Previous lessons will be serving as introduction and/or prerequisite knowledge.

Learning activity 5.5

Guidance to the learning activity 5.5

- The Tutor introduces his/her lesson by using a scenario of industries in Rwanda that produces energy so that Student-teachers brain storm on it.
- He asks them to read activity 5.5 in Student-teacher book. They observe clearly and try to answer to the questions.
- They should work individually then share in pairs before a reasonable number of Student-teachers' presents to the whole class.
- ICT tools should be used if available.
- The Tutor guide and correct misconception when necessary.

- Slow learners and ones with special needs must be assisted by the Tutor to make his lesson inclusive.

- Tutor helps Student-teachers to develop the lesson of the day as Prepared in the lesson plan, making a link of the lesson with real life situation.

Answers for activity 5.5

1. Rwanda has a need to use nuclear power because we need sufficient sources of electrical energy to run our factories for further development, rather than using fossils fuels which destroys our environment. Nuclear power energy should also be used in different sectors like in agriculture, in medicine, etc.
2. Nuclear power is a non-fossil fuel
3. It should generate nuclear radiations when not handled correctly; it can also be the sources of accidents due to overheating when uncontrolled efficiently.
4. List of proposals to avoid environmental problems in Rwanda today and in the future:

- Take measures to avoid accident that result in core damage from overheating in nuclear power plant when constructed.

- To isolate the wastes from human contact

- To use new technologies for Carbon capture and storage which is a way to prevent carbon dioxide building up in the atmosphere?

- Find a way of Shifting from fossil fuels to 100% clean renewable energy.

Answers for application activities 5.5

Refer to the content of point 5.5 in student teachers book

5.6 Summary of the unit

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

Types of Fossil Fuels

– Coal

– Natural Gas

– Oil (Petroleum)

Energy production using fossil fuels

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

Nuclear fuel and nuclear fission

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

Controlled fission (power production)

When a fission reaction leads to a new fission reaction, which leads to another one and so on, it is called controlled fission. The amount of heat required is controlled by raising and lowering the rods in the reactor.

Uncontrolled fission (nuclear weapons)

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

Problems associated with the production of nuclear power

a) Problem of radioactive waste.

b) High risks.

c) Targets for terrorist attacks.

d) Nuclear weapons.

e) Uranium is a scarce resource.

f) Illusion to build new nuclear power plants.

Environmental problems of fossil fuels

1. Climate Change / Global Warming and Greenhouse Effect

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

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

2. Hole' in the Ozone Layer

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

3. Acid Rain

When gases, such as sulphur dioxide and nitrogen oxides react with water in the atmosphere to form sulphuric acid and nitric acid, they form an acidic 'rain' which can destroy vegetation.

4. Air Pollution

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

Other environmental problems of fossil fuels include:

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

5.7 Additional Information for tutor

Dangers of coal as fossil fuel on the human body

During combustion, some of the carbon remains unburned, and some other materials in coal and oil are not combustible; these come off as very small solid particles, called particulates, which are typically less than one ten thousandth of an inch in diameter, and float around in the air for many days. Smoke is a common term used for particulates large enough to be visible.

Some of the organic compounds formed in the combustion process attach to these particulates, including some that are known to cause cancer. Coal contains trace amounts of nearly every element, including toxic metals like beryllium, arsenic, cadmium, selenium, and lead, and these are released in various forms as the coal burns.

All of the above pollutants are formed and released directly in the combustion process. Sometime after their release, nitrogen oxides may combine with hydrocarbons in the presence of sunlight to destroy ozone layer, one of the most harmful pollutants.

Let us summarize some of the known health effects of these pollutants:

- Sulfur dioxide is associated with many types of respiratory diseases, including coughs and colds, asthma, bronchitis, and emphysema. Studies have found increased death rates from high sulfur dioxide levels among people with heart and lung diseases.
- Nitrogen oxides can irritate the lungs, cause bronchitis and pneumonia, and lower resistance to respiratory infections such as influenza; at higher levels it can cause pulmonary edema.
- Carbon monoxide bonds chemically to hemoglobin, the substance in the blood that carries oxygen to the cells, and thus reduces the amount of oxygen available to the body tissues. Carbon monoxide also weakens heart contractions, which further reduces oxygen supplies and can be fatal to people with heart disease. Even at low concentrations it can affect mental functioning, visual acuity, and alertness.
- Particulates, when inhaled, can scratch or otherwise damage the respiratory system, causing acute and/or chronic respiratory illnesses. Depending on their chemical composition, they can contribute to other adverse health effects. For example, benzo-a-pyrene, well recognized as a cancer-causing agent from its effects in cigarette smoking, sticks to surfaces of particulates and enters the body when they are inhaled.

- Ozone irritates the eyes and the mucous membranes of the respiratory tract. It affects lung function, reduces ability to exercise, causes chest pains, coughing, and pulmonary congestion, and damages the immune system.
- Volatile organic compounds include many substances that are known or suspected to cause cancer. Prominent among these is a group called polycyclic aromatic, which includes benzo-a-pyrene mentioned above.
- Toxic metals have a variety of harmful effects. Cadmium, arsenic, nickel, chromium, and beryllium can cause cancer, and each of these has additional harmful effects of its own. Lead causes neurological disorders such as seizures, mental retardation, and behavioral disorders, and it also contributes to high blood pressure and heart disease. Selenium and tellurium affect the respiratory system, causing death at higher concentrations.

It is well recognized that toxic substances acting in combination can have much more serious effects than each acting separately, but little is known in detail about this matter. Information on the quantities of air pollutants required to cause various effects is also very limited. However, there can be little doubt that air pollution is a killer.

GUIDANCE ON SKILLS LAB 5

After studying this unit, the Tutor is asked to sensitize Student teachers on the benefits of environmental protection. He then assigns a task to each Student asking them to prepare Project works on Environmental protection as indicated in the Student teacher's books. The Tutor is allowed to assists, advices and corrects project works before his Student teachers present them to beneficiaries of the Projects. It is advisable to make the follow up of the presentations of the projects. The copies of the projects will be marked and kept in portfolio of each student.

5.8 END UNIT ASSESSMENT (Answers)

1. a) False b) True c)True d) True e) False
2. 1-B, 2-E, 3-G, 4-A, 5-F, 6-C, 7-D
3. a)
4. D

5. A
6. D
7. (a) advantages of non-fossil fuel

It is safe, abundant, and clean to use when compared to fossil fuels.

Multiple forms of renewable energy exist.

It provides the foundation for energy independence.

Renewable energy is stable.

It is a technology instead of a fuel.

(b) Disadvantages of Renewable energy

Not every form of renewable energy is commercially viable.

Many forms of renewable energy are location-specific.

Many forms of renewable energy require storage capabilities.

8. In Rwanda, there are different ways of protecting environment. Referred to Word Economic Forum, 2019 we should underline the following measures:

1. Plastic bags

Rwanda's mission to maintain a clean and healthy environment has been going since 2008 when it banned the use of non-biodegradable plastic bags and packaging materials. To date, Rwandans use only bags made from paper, cloth, banana leaves and papyrus, among other biodegradable materials.

It has made a difference. The plastic-bag ban has earned the country a reputation as one of the cleanest countries in Africa. In 2008, Rwanda's capital, Kigali, was declared one of the cleanest cities in Africa by UN Habitat. It also created opportunities for entrepreneurs who invested in alternative packaging materials (cloths, papers, banana leaves and papyrus).

2. Forest cover

To achieve its goal of increasing forest cover to 30% of total land area by 2020, Rwanda has embarked on massive reforestation and tree-planting drive, and new measures such as agro-forestry and training schemes in forest management are being implemented. These efforts, along with the plastic-bag ban, earned the nation a Future Policy Award from World Future in 2011.

3. Restoration

Rwanda's commitment to conserve the environment has also been seen through the protection and restoration of degraded ecosystems such as wetlands, lakes and natural forests.

Forests such as Nyungwe, Gishwati and Mukura have been restored and upgraded into national parks. The promotion of these parks, home to a vast variety of flora and fauna, has contributed to the growth of the tourism sector that is currently the principal generator of foreign currency, with US$ 304.9 million and US$ 318 million revenue in 2014 and 2015 respectively.

Located in the northern part of Rwanda, Rugezi wetland (which had dried up because of human activities and climate change) was rehabilitated in 2005. Its restoration led to the recovery of water levels, increased hydropower production in Burera and Ruhondo lakes and a boost for the country's fishing sector. For this, Rwanda received a Green Globe Award in 2010.

4. The Green Fund

As one of the most vulnerable nations to climate change, Rwanda is acutely aware of the challenges that lie ahead. Therefore, to achieve its vision of a low-carbon and climate-resilient economy by 2050, Rwanda has established the Green Fund, a ground-breaking investment fund, the largest of its kind in Africa.

The fund supports the best public and private projects that have the potential for transformative change and that support Rwanda's commitment to building a green economy. The fund has mobilized around $100 million to date and is a leading example of the impact that well-managed climate financing can have.

5. Green politics

For a country to achieve sustainable development, environmental sustainability must be taken into consideration. This applies to policies, legislation and programs alike. Over the past years, the government has taken measures to ensure national development is in harmony with the protection of the environment

5.9. Additional activities (Questions and answers)

5.9.1 Remedial activities

1. Use the following terms to complete the diagram below: factories, acid rain, ozone depletion, rapid population growth, burning fossil fuel, global warming, motor vehicles and power plants.

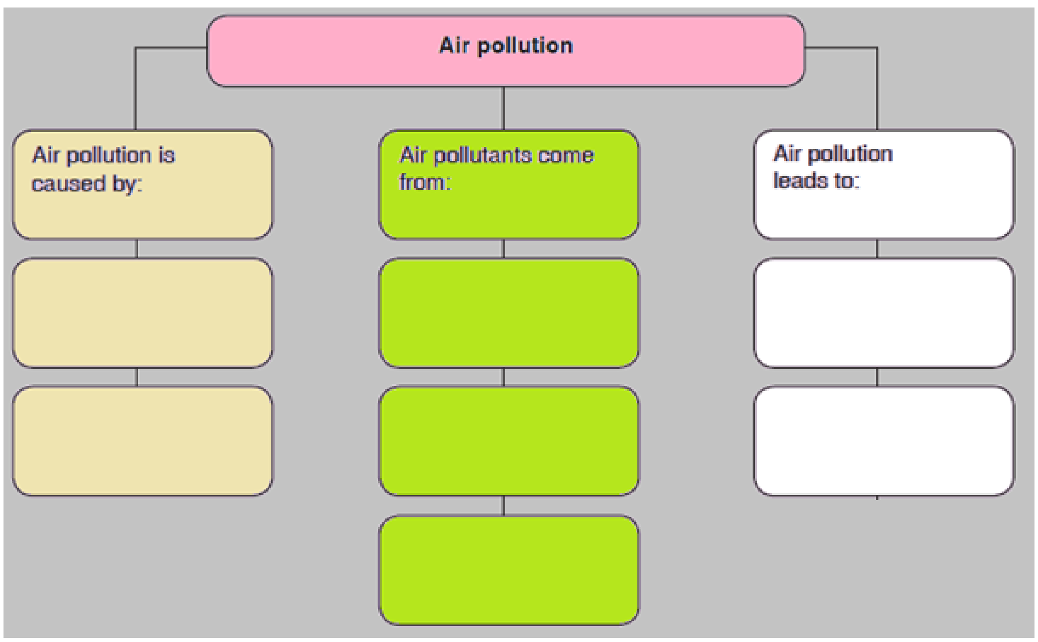


Fig.5. 1 Diagram

2. Crossword puzzle: Fill the missing words in the crossword puzzle given below.

Down

1. __________ _________ refers to the rise in the world's average temperature due to air pollution.
2. _________ _______ are gases in the atmosphere that absorb and emit radiation, causing the greenhouse effect.
3. ______________ is a mixture of smoke and fog in the atmosphere.
4. ____________ ________is a non-renewable source of energy formed from the remains of dead plants and animals.

Across

5. ______ _____ is the reduction of the amount of ozone
6. The water sources and the land are polluted by ______ ________ when exhaust gases dissolve in the rain.

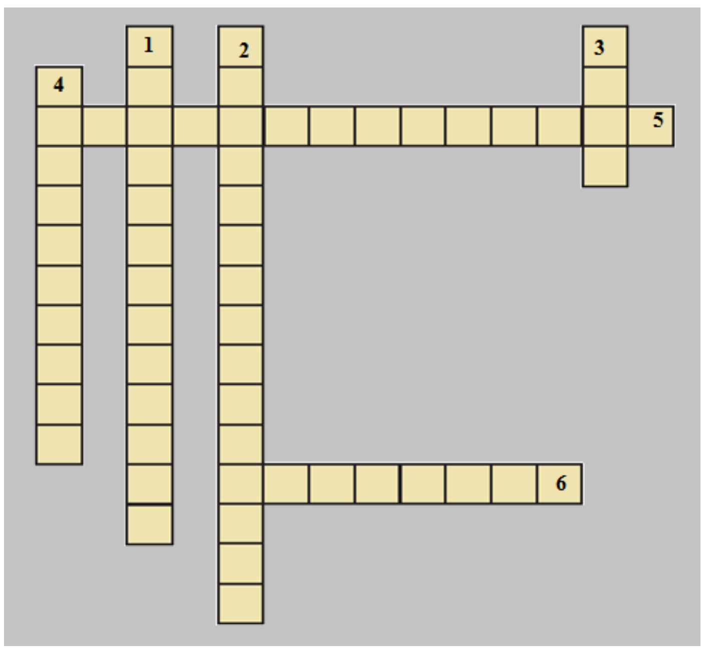


Fig.5. 2 Crossword puzzle

3. Outline advantages and disadvantages of coal as fossil fuel.

5.9.2. Consolidation activities

1. Why should solar energy be harnessed to take care of our electric power needs?
2. How do we confirm that the 'greenhouse effect' is real?
3. How does acid rain destroy forests and fish?

4. Is it possible to eliminate the air pollution from coal burning?

5. Radioactivity can harm us by radiating from sources outside our bodies, by being taken in with food or water or by being inhaled into our lungs. But we consider only one of these pathways. Why is it so?

5.9.3 Extended activities

Background Information

During combustion, some of the carbon remains unburned, and some other materials in coal and oil are not combustible; these come off as very small solid particles, called particulates, which are typically less than one ten thousandth of an inch in diameter, and float around in the air for many days. Smoke is a common term used for particulates large enough to be visible. Some of the organic compounds formed in the combustion process attach to these particulates, including some that are known to cause cancer.

Question: Using search Internet, find out other diseases caused by pollutants suggested above.

Answers of additional activities

a) Remedial activities

1. Air pollution is caused by: rapid population growth, global warming.

Air pollutants come from: power plants, burning fossil fuel and factories.

Air pollution leads to: Ozone depletion, global warming.

2. **Down**

1. Global warming

2. Greenhouse gases

3. Smog

4. Fossil fuel

Across

5. Ozone depletion

6. Acid rain

2)

#	Advantages	Disadvantages
Coal	1. Large quantities. 2. Well-distributed. 3. Converted into synthetic liquid fuels and gases. 4. Yields far more energy than renewable sources. 5. Safer than nuclear power. 6. Longer life span than oil or gas. 7. Feedstock for organic chemicals.	1. Causes Acid rain and global warming. 2. Not so readily transported. 3. Mining is dangerous. 4. Leaves solid residue and releases toxic gases in air, causing pollution.

b) Consolidation activities

1. Solar energy is non-polluting source of energy and has enormous capacity of producing energy fulfilling increasing needs of modern society.

2. Global warming and climate change conform that the greenhouse effect is real.

3. Acid rain changes the PH of water bodies that destroy planktons and fish. Acid rain burns leaf of plants and also changes PH of soil and destroy fertility. This leads to destruction of forest.

4. Burning of coal always produces air pollution.

5. We consider the first one because it is very dangerous compared to others. The principal risks associated with nuclear power arise from health effects of radiation, which can be caused due to contact with nuclear wastes. This radiation consists of sub-atomic particles travelling at or near the velocity of light (186,000 miles per second). They can penetrate deep inside the human body where they can damage biological cells and thereby initiate a cancer. If they strike sex cells, they can cause genetic diseases in progeny.

c) Extended activities

Some of the findings are the following:

- Sulfur dioxide is associated with many types of respiratory diseases, including coughs and colds, asthma, bronchitis, and emphysema. Studies have found increased death rates from high sulfur dioxide levels among people with heart and lung diseases.
- Nitrogen oxides can irritate the lungs, cause bronchitis and pneumonia, and lower resistance to respiratory infections such as influenza; at higher levels it can cause pulmonary edema.
- Carbon monoxide bonds chemically to hemoglobin, the substance in the blood that carries oxygen to the cells, and thus reduces the amount of oxygen available to the body tissues. Carbon monoxide also weakens heart contractions, which further reduces oxygen supplies and can be fatal to people with heart disease. Even at low concentrations it can affect mental functioning, visual acuity, and alertness.
- Particulates, when inhaled, can scratch or otherwise damage the respiratory system, causing acute and/or chronic respiratory illnesses. Depending on their chemical composition, they can contribute to other adverse health effects. For example, benzo-a-pyrene, well recognized as a cancer-causing agent from its effects in cigarette smoking, sticks to surfaces of particulates and enters the body when they are inhaled.
- Ozone irritates the eyes and the mucous membranes of the respiratory tract. It affects lung function, reduces ability to exercise, causes chest pains, coughing, and pulmonary congestion, and damages the immune system.
- Volatile organic compounds include many substances that are known or suspected to cause cancer. Prominent among these is a group called polycyclic aromatic, which includes benzo-a-pyrene mentioned above.
- Toxic metals have a variety of harmful effects. Cadmium, arsenic, nickel, chromium, and beryllium can cause cancer, and each of these has additional harmful effects of its own. Lead causes neurological disorders such as seizures, mental retardation, and behavioral disorders, and it also contributes to high blood pressure and heart disease. Selenium and tellurium affect the respiratory system, causing death at higher concentrations.

UNIT 6: MOTION IN ORBITS

6.1. Key unit competence

Apply Newton's law of gravitation and Kepler's laws in explaining planetary motion

6.2 Prerequisite (knowledge, skills, attitudes and values

The learner will be equipped with knowledge and skills related to Newton's laws of Motion acquired in different courses done in ordinary level in Physics S1, S2 and S3.

6.3 Cross cutting issues to be addressed

Inclusive education (promote education for all in teaching and learning process):

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

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-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.

Peace and values education, gender education and inclusive education are some of the examples of cross cutting issues to be addressed in this lesson. This list is not exhaustive.

6.4 Guidance on introductory activity

- The Tutor introduces his/her lesson by a simple dialogue and questions about Newton's laws of motion to capture Student-teachers' attention.
- He then asks Student-teachers to open Learner's Book and read carefully the questions given on introductory activity of unit 6.
- The Tutor will guide and encourage Student-teachers in their discussions. Make sure that the discussions are inclusive.
- The activity should be done in small groups, in pairs or individually depending on the size of the class.
- Student-teachers should share their findings in small groups or pairs before presentation in front of the whole class.
- The use of ICT tools is very important when the materials are available
- If the Student-teachers are not able to respond accurately to the questions, the Tutor will support them by using simpler questions to make understandable the content.
- The lesson ends by rising out different cross cutting issues met in the lesson.

6.5 List of lessons

#	Lesson title	Learning objectives	Number of Periods
1	Newton's law of gravitation	- State Newton's law of gravitation - Apply Newton's laws of gravitation to explain the	3

		universe and solar system.	
2	Kepler's laws of planetary motion	- State and explain Kepler's law of planetary motion - Apply knowledge of Kepler's laws of planetary motion - Explain universe and solar system - Explain orbits and period of rotation of planets around the sun - Explain acceleration due to gravity near earth's surface - Explain Variation of gravity above and below the earth surface.	8
3	Satellites and Rockets.	- State principles of satellites and rockets - Explain the applications of satellites in real life	5
4	End unit assessment		2

Lesson 1: Newton's law of gravitation

a) Learning objective

- State Newton's law of gravitation
- Apply Newton's laws of gravitation to explain the universe and solar system.

b) Teaching resources

- Search internet, Library, Journals and computer simulations
- Projectors, videos

c) Prerequisites/Revision/Introduction

Student-teachers have skills on Newton's laws of motion learnt in S1 Unit 4 and S2 Unit 3. In Year 1, they have learnt Circular motion. This will help them to understand motion of planets around the sun.

d) Learning activities 6.1

Guidance to the learning activity 6.1:

- The Tutor asks Student-teachers to open Learner's Book and read carefully the questions given on activity 6.1.
- The Tutor will facilitate Student-teachers in their discussions in order to discover correct answers.
- The activity should be done in small groups, in pairs or individually depending on the size of the class.
- If Student-teachers are working individually, let them share in pairs their findings before presentation.
- The Tutor harmonizes presentations by focusing on the content of the lesson.

Answers for learning activity 6.1

a) There is no interaction between two stones. If any it is very weak.
b) There is a week force of attraction between two stones. This is because they are small and the distance between them is small so that the force cannot be felt.

c) In general, the attractive force between two bodies is negligible if their masses are relatively small and are separated by a small distance.

d) If bodies are relatively big enough, they have considerable interaction between them compared to smaller ones. Examples: interaction between Earth and sun, Earth and moon, sun and planets…

e) Answers for application activities 6.1

1. $F = \dfrac{Gm_1m_2}{r^2}$ where m is mass and G is gravitational constant

$$F = \frac{6.67\times10^{-11}\times8\times8}{0.5^5}$$

$$F = 1.7\times10^{-8}\,N$$

2. Solving this problem, all we have to do is put the above values for mass and distance into the general gravity formula below:

$$F_G = G\frac{m_A m_B}{r^2} \text{ and } F_G = \frac{6.67\times10^{-11}\times10\times20}{(0.1)^2}$$

$$F_G = 0.000\,133\,4\,N$$

3. (a) The mass does not change. It remains constant everywhere. Thus it has $4.0\,kg$ on the planet and on the earth.

(b) The weight on the planet is $W_p = mg_p = 4.0\,kg\times2.0\,m/s^2 = 8.0\,N$

On the Earth, $W_e = mg_e = 4.0\,kg\times9.8\,m/s^2 = 39.2\,N$

Lesson 2: Kepler's laws of planetary motion

a) Learning objectives

- State and explain Kepler's law of planetary motion
- Apply knowledge of Kepler's laws of planetary motion

- Explain universe and solar system
- Explain orbits and period of rotation of planets around the sun
- Explain acceleration due to gravity near earth's surface
- Explain Variation of gravity above and below the earth surface.

b) Teaching resources

- Search internet, Library, Journals and computer simulations
- Projectors, videos

d) Prerequisites/Revision/Introduction

Student-teachers have skills in conservation of Mechanical energy learnt in S2 Unit 9 and Newton's laws of motion and gravitation of planetary motion studied in lesson one above in this unit. Circular motion studied in Year Two will help Student-teachers to understand motion of planets around the sun. However the tutor should introduces his lesson by revising Lesson 1 of this Unit.

d) Learning activities 6.2

Guidance to the learning activity 6.2

- The Tutor asks Student-teachers to open Learner's Book and read carefully the questions given on activity 6.2.
- The Tutor will guide Student-teachers in their discussions. The activity should be done in small groups, in pairs or individually depending on the size of the class.
- Student-teachers should share their findings in groups or pairs before presentation in front of the whole class by using ICT tools like computer and projector.
- The Tutor harmonizes presentations focusing to the content of the lesson and together with them give the summary of expected feedback based on their findings and write the summary in their notebooks.

- **Note:** In case there is a student-teacher that requires special attention, please make sure assistance is provided

Answers for learning activities 6.2

a) All planets are rotating around the sun. Their trajectories are elliptical
b) No, each planet has its own path
c) The largest body is the sun
d) Yes, there is a gravitational force between the sun and other planets. This is because planets cannot escape from their respective orbits.
e) The force keeps the planets in their orbit, so that they remain in orbit in their motion

e) Answers for Application activities 6.2

1. **A is true.** When the planet passes nearer to sun, it moves fast and vice versa. Hence, the time taken in travelling *DAB* is less than that for *BCD*.

2. a) $G = 6.67\times10^{-11}Nm^2kg^{-2}$, $mass\ of\ Mars\ (M) = 6.37\times10^{23}kg$ and $r = 3.40\times10^6 m$

$$g = \frac{GM}{r^2} = \frac{6.67\times10^{-11}\times6.37\times10^{23}}{\left(3.40\times10^6\right)^2}$$

$$g = 3.68N/kg$$

The magnitude of gravitational field strength on the surface of Mars is $g = 3.68N/kg$

b) The required ratio is $\frac{g_{Mars}}{g_{Eath}} = \frac{3.68}{9.80} = 0.375$

The ratio of the magnitudes of the gravitational field strengths is 0.375:100. This means that the gravitational field strength on the surface of Mars is 37.5% of the gravitational field strength on the surface of Earth

3. Given that

$g = 9.80 N/kg \quad G = 6.67\times10^{-11} Nm^2kg^{-1}$, $r = 6.38\times10^6 m$ $mass\ of\ the\ Earth(m) = ?$

$$g = \frac{GM}{r^2}$$

$$M = \frac{gr^2}{G} \Leftrightarrow M = \frac{(9.80\ N/kg\times(6.38\times10^6\ \mathrm{m})^2}{6.67\times10^{-11} m^2kg^{-2}}$$

$M = 5.98\times10^{24} kg$ The mass the Earth is $5.98\times10^{24} kg$

4. (i) The gravitational field strength at the given point is

$$g = \frac{GM_E}{r^2} = \frac{(6.7\times10^{-11})(6\times10^{24})}{\left[(1.0+6.4)\times10^6\right]^2}$$

$g = 7.3N\ kg^{-1}$

(ii) On the surface of the Earth $g = \dfrac{GM}{R^2}$

$$g = \frac{(6.7\times10^{-11})(6\times10^{24})}{(6.4\times10^6)^2}$$

$g = 9.8\ Nkg^{-1}$

5. $g = \dfrac{GM}{r^2} = \dfrac{\left(6.67\times10^{-11} N.m^2.kg^{-2}\right)\left(5.98\times10^{24}\ kg\right)}{\left(6\,380\,000\ m + 8\,850\ m\right)^2} = 9.77\ m/s^2$

6. a) The escape velocity is

$$v_e = \sqrt{\frac{2GM}{R}} = \sqrt{\frac{2\times\left(6.67\times10^{-11} N.m^2.kg^{-2}\right)\left(5.98\times10^{24}\ kg\right)}{6380000\,m}} = 11.2\times10^3\ m/s$$

The kinetic energy of the space craft is $K = \dfrac{1}{2}mv_e^2 = \dfrac{1}{2}\times5\,000\times\left(11.2\times10^3\right)^2 = 3.14\times10^{11}\ J$

b) From Equation $v_e = \sqrt{\dfrac{2GM}{R}}$, the mass of the object moving with the escape speed does not appear. Thus, the escape speed for the 1 000 kg spacecraft is the same as that for the 5 000 kg spacecraft. The only change in the kinetic energy is due to the mass, so the 1 000 kg spacecraft will require one fifth of the energy of the 5 000 kg spacecraft:

$$K = \frac{1}{2}\frac{m}{5}v_e^2 = \frac{3.14\times10^{11}}{5}J = 6.28\times10^{10}J$$

Lesson 3: Satellites and Rockets.

a) Learning objective

- State principles of satellites and rockets
- Explain the applications of satellites in real life

b) Teaching resources

- Search internet, Library, Journals and computer simulations
- Projectors, videos

c) Prerequisites/Revision/Introduction

All skills learnt in Lessons 1 and 2 of this unit will serve as prerequisite knowledge for the new lesson. The tutor is advised to introduce his/her lesson by revising them with hi/her Students.

d) Learning activities 6.3

Guidance to the learning activity 6.3

- Invite student-teachers to perform exercises provided in activity 6.3
- Request student-teachers to answer questions asked and brainstorm.
- Encourage student-teachers to think in critical and innovative way.
- Provide activities of slow learners and those with special education needs to make the lesson enjoyable and inclusive.
- Let student-teachers observe the images and think critically where are used in our daily life activities.

- The activity should be done in small groups, in pairs or individually depending on the size of the class.

-Student-teachers should perform presentation in front of the whole class by using ICT tools like computer and projector.

- The Tutor harmonizes presentations focusing to the content of the lesson. Cross cutting issues are explained in this lesson.

Answers for learning activity 6.3

1. If the balloon goes forward, the air goes backward (in opposite direction).
2. The balloon's direction changes. Because of the weight of water is greater than the weight of the balloon, there will not be action and reaction forces. Then the balloon will fall dawn.
3. The rocket on the figure above moves forward as the exhausts move backward as did air balloon. It is applying Newton's 3rd law of motion: law of action and reaction.
4. (i) They use Rocket engines

   (ii) Artificial satellites are used to give information related to: weathering, astronomy, military, navigation, radio and television, Internet.

e) Answers for application activities 6.3

1. **Across:** 1. Moon, 5. Satellite, 6. Pluto, 7.Mars, 9. Uranus, 10 Venus

   Down: 2. Neptune, 3mercury, 4. Coma, 8. Sun.

2. (i) Astronomy is the study of celestial objects such as stars, planets, galaxies, natural satellites, comets, etc. The satellites that are used to study or observe the distant stars, galaxies, planets, etc. are called astronomical satellites.

   (ii) They are mainly used to find the new stars, planets, and galaxies. It captures the high-resolution images of the distant stars, galaxies, planets etc. Hubble space telescope is an example of astronomical satellite.

3.

(a) The radius of the orbit is $r = h + R_E = 7.80\ \times 10^5 m + 6.38 \times 10^6 m = 7.16 \times 10^6 m$

$$v = \sqrt{\frac{M_E G}{r}} = \sqrt{\frac{\left(6.673 \times 10^{-11} N.m^2.kg^{-2}\right)\left(5.97 \times 10^{24}\ kg\right)}{7.16 \times 10^6\ m}} = 7.46 \times 10^3\ m/s$$

(b) $T = \dfrac{2\pi r}{V} = \dfrac{2\pi\left(7.16 \times 10^6 m\right)}{\left(7.46 \times 10^3\ m/s\right)} = 6030s = 1.68h$

6.6. Summary of the unit

Newton's law of gravitation

This is also called the universal law of gravitation or inverse square law. It states that "the gravitational force of attraction between two masses m1 and m2 is directly proportional to the product of masses and inversely proportional to the square of their mean distance apart."

$$F_g = G\frac{m_1 m_2}{r^2}$$

Kepler's laws of planetary motion

1st Law: This law is called the law of orbits and states that planets move in ellipses with the sun as one of their foci. It can also be stated that planets describe ellipses about the sun as one focus.

2nd Law: This is called the law of areas and states that the line joining the sun and the planet sweeps out equal areas in equal periods of time.

3rd Law: The law of periods states that the square of the periods T of revolution of planets are proportional to the cubes of their mean distances R from the sun.

$$\frac{T_1^2}{T_2^2} = \frac{R_1^3}{R_2^3}$$

Verification of Kepler's third law of planetary motion

Comparison between Gravitational force of attraction of the sun and the planet and the Centripetal force responsible for keeping the planet moving in a circular motion around the sun allows to write $F_G = F_C \Leftrightarrow \frac{GMm}{r^2} = \frac{mv^2}{r} \Leftrightarrow v = \sqrt{\frac{GM}{r}}$ (*)

Also $v = \frac{2\pi r}{T}$

Substituting v from equation this value in equation (*), we get $\sqrt{\frac{GM}{r}} = \frac{2\pi r}{T} \Leftrightarrow T = 2\pi\sqrt{\frac{r^3}{GM}}$ which is true that $T^2 \propto R^3$.

Acceleration due to gravity at the surface of the earth

At the surface of the earth acceleration due to gravity is given by $g = \frac{GM}{R^2}$.This value is constant and its average value is taken to be 9.8 m/s^2.

Variation of acceleration due to gravity with height

The acceleration due to gravity at a point above the surface of the earth is given by $g' = \frac{GM}{(R+h)^2}$

Alternatively, this value should be found using $g' = g\left(\frac{R}{R+h}\right)^2$

This value decreases as you move further from the surface of the earth.

Variation of gravity with depth

At a point below the surface of the earth, acceleration due to gravity is given by $g' = \frac{4}{3}\pi\rho G\left(R-d\right)$

The depth d is measured from the surface of the earth. The value of acceleration due to gravity increases as we move towards the surface. At centre of earth $g = 0$.

Rockets and spacecraft

A rocket is a device that produces thrust by ejecting stored matter. Spacecraft Propulsion is characterized in general by its complete integration within the spacecraft (e.g. satellites).

Satellites

A satellite is an artificial body placed in orbit round the earth or another planet in order to collect information or for communication.

Orbital Velocity of Satellite

The orbital velocity is given by $v = \sqrt{\frac{gR^2}{R+h}}$ *or* $v = R\sqrt{\frac{g}{R+h}}$

Time Period of Satellite

The period of a satellite is given by $T = \frac{2\pi r}{v} = 2\pi\sqrt{\frac{(R+h)^3}{gR^2}}$

Height of Satellite

The height at which a satellite is launched is given by $h = (\frac{T^2 gR^2}{4\pi^2}) - R$

Application of Satellites

Satellites that are launched in to the orbit by using the rockets are called man-made satellites or artificial satellites. Artificial satellites revolve around the earth because of the gravitational force of attraction between the earth and satellites.

Unlike the natural satellites (moon), artificial satellites are used in various applications. The various applications of artificial satellites include: Weather forecasting, Navigation, Astronomy, Satellite phone, Satellite television, Military satellite, Satellite internet and Satellite radio.

6.7. Additional information for tutor

Weightlessness

Weightlessness is the feeling we experience when unsupported. An astronaut orbiting the Earth in a space vehicle with its rocket motors off is said to be weightless. If weight means the pull of the Earth on a body, then the statement, although commonly used, is misleading.

A body is not truly weightless unless it is outside the earth's (or any other) gravitational field, i.e. at a place where $g = 0$. In fact it is gravity which keeps an astronaut and his vehicle in orbit. To appreciate what experiencing the sensation of weightlessness means we will consider similar situations on Earth.

We are aware of our weight because the ground or whatever supports us exerts an upward push on us as a result of downward push our feet exert on the ground. It is this upward push which makes us feel the force of gravity.

When a lift suddenly starts upwards the push of the floor on our feet increases and we feel heavier. On the other hand if the support is reduced we seem to be lighter. In fact we judge our weight from the upward push exerted on us by the floor. If our feet are completely unsupported we experience weightlessness.

Passengers in a lift that has a continuous downward acceleration equal to g would get the same acceleration as the lift. There is no upward push on them and so no sensation of weight is felt.

An astronaut in space vehicle is not unlike a passenger in a freely falling lift. The astronaut is moving with constant speed along the orbit, but since he is travelling in a circle he has a centripetal acceleration of the same value as that of the space vehicle and equal to g at that height.

The walls of the vehicle exert no force on the astronaut; he is unsupported, the physiological sensation of weight disappears and he floats about weightless. Similarly, any object released in the rock does not fall. Anything not in use must be firmly fixed and liquid will not pour.

Summing up, to be strictly correct we should not use the term weightless unless by weight we mean the force exerted on (or by) a body by (or on) its support, and generally we do not.

Also, it is important to appreciate that although weightless a body still has mass and it would be just as difficult to push it in space as on earth. An astronaut floating in an orbiting vehicle could still be injured by hitting a hard but weightless object.

Cosmic velocities

1. Parking orbits

A satellite of the Earth having orbital time period same as that of the Earth, i.e., 24 hours and moving in equatorial plane is called a **geo-stationary** (or **geo-synchronous**) satellite as it appears stationary when viewed from the Earth. Such satellites are used for such purposes as cable TV transmission, for weather forecasting, and as communication relays

a) Determine the height above the Earth's surface such a satellite must orbit and (b) such a satellite's speed

Answer

a) The only force on the satellite is gravity, so we apply the equation $\frac{GM_{sat}M_E}{R^2} = M_{sat}\frac{v^2}{R}$

The Satellite revolves around the Earth with the same period that the earth rotates on its axis, namely once in 24 h. Thus the speed of the satellite must be $v = \frac{2\pi R}{T} = \frac{2\pi R}{86400}$

We put this into the first equation above and obtain $\frac{GM_E}{R^2} = \frac{(2\pi R)^2}{T^2 R}$

We solve for R and we find R = 4.23×10^7 m or 42300 km from the Earth's centre. We subtract the earth's radius of 6380 km to find that the satellite must orbit about 36000 km (about 6 r_E) above the Earth's surface.

b) We solve equation $G\frac{M_E}{R^2} = \frac{v^2}{R} \Rightarrow v = 3070 m/s$ **(1st *cosmic velocity*)**

The **speed** of the satellite in geostationary orbit (parking orbit) is called **1st *cosmic velocity***

We get the same result if we use $v = \frac{2\pi R}{T}$

We get also the same result if we apply the Kepler's third law: we must compare the satellite to some other object that orbits Earth. The simplest choice is the Moon because we know its period and distance. The Moon's period is about T_M = 27 d and its distance from the Earth about $r_{ME} = 380000 km$.

The period of the weather satellite needs to be $T_{Sat} = 1$ so that it stays above the same place on the Earth.

Hence, $\frac{r_{sat}}{r_{ME}} = \left(\frac{T_{sat}}{T_M}\right)^{2/3} \Leftrightarrow \frac{r_{sat}}{r_{ME}} = \left(\frac{1}{27}\right)^{2/3} = \frac{1}{9}$

c) What if the satellite motion were taking place at height **h** above the surface of another planet more massive than the Earth but of the same radius? Would the satellite be moving at a higher or a lower speed than it does around the Earth?

Answer

If the planet pulls downward on the satellite with more gravitational force due to its larger mass, the satellite would have to move with a higher speed to avoid moving toward the surface.

This is consistent with the predictions of Equation: $v = \sqrt{\frac{GM}{R}}$, which shows that because the speed v is proportional to the square root of the mass of the planet, as the mass increases, the speed also increases.

2. Earth Satellite

A **satellite** is an object revolving around a planet under the effect of its gravitational field. Its orbital motion depends on the gravitational attraction of the planet and the initial conditions.

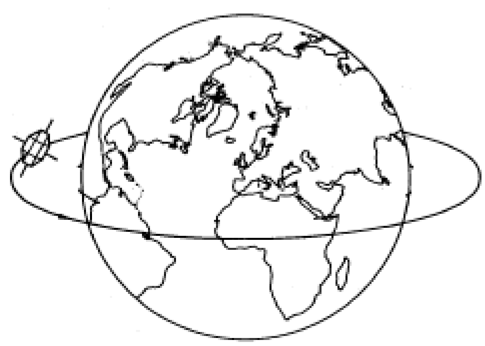


Fig.6. 1 A satellite revolving around the Earth

Satellite can be **natural** or **artificial**. The **Moon** is a natural satellite of the Earth. It moves around the Earth once in 27.3 days in an approximate circular orbit of radius $3.85 \times 10^5\ km$. **Sputnik** was the first artificial satellite put into its orbit by Russia in 1957. India has launched its first satellite Aryabhatta on April 19, 1975.

Satellites are used for scientific, engineering, commercial, spying and military applications

The satellite is carried by a rocket to the desired height and released horizontally with a high velocity, so that it remains moving in a nearly circular orbit. The horizontal velocity that has to be imparted to a satellite at the determined height so that it makes a circular orbit around the planet is called **orbital velocity**.

Satellite can be launched from the earth's surface to circle the earth. They are kept in their orbit by gravitation attraction of the earth. Consider a satellite of mass m which just circles the earth of mass M close to its surface in an orbit; then if r_e is the radius of the earth:

$$\frac{mv^2}{r_E} = G\frac{Mm}{r^2{}_E} \Leftrightarrow \frac{mv^2}{r_E} = mg \Rightarrow v = \sqrt{r_E g} = 8\, km/s$$ **(2nd*cosmic velocity)***

The period in the orbit is $T = \frac{2\pi r_E}{v} = 5\,000\ s = 83\min$

With this velocity a satellite can describe a circular orbit close to the earth's surface. With velocity greater than 8 km/s but less than 11.2 km/s; a satellite describes an elliptical orbit round the earth.

3. Escape velocity:

The speed that a projectile, space probe, or similar object must reach in order to escape the gravitational influence of the earth or celestial body to which it is attract.

Suppose an object of mass m is projected vertically upward from the Earth's surface with an initial speed $v_i = u$.

The initial mechanical energy is $KE_i + PE_i = \frac{1}{2}mv_i^2 - \frac{GM_E m}{R_E}$

We neglect air resistance and assume that the initial velocity is just large enough to allow the object to reach infinity with a velocity of zero. We call this value of v_i the escape velocity v_e

When the object is at an infinite distance from the Earth, its kinetic energy is zero because v_f and the gravitational potential energy is zero because our zero level of potential energy was selected at $r = \infty$

Hence the total mechanical energy is zero and the law of conservation of energy gives:

$$\frac{1}{2}mv_i^2 - \frac{GM_E m}{R_E} = 0 \Rightarrow v_e = \sqrt{\frac{2GM_E}{R_E}} = 11.2\ km/s$$

3rd cosmic *velocity*

With an initial velocity of $u = 11.2\ km/s$ a rock will completely escape from the gravitational attraction of the earth.

GUIDANCE ON SKILLS LAB 6

- At the end of this unit, the Tutor give an activity of skills lab in which Student-teachers are advised to make research on internet using YouTube browser
- They will be searching how to fabricate a propeller jet using local materials.
- The Tutor will give them instructions as indicated in learner's book.
- The activity will be done during the weekend and Student Teachers will present their findings the next week.
- The assistance and advices of the Tutor are needed here and this will help him to mark any progress of his/her student-teachers.

6.9. ANSWERS FOR END UNIT ASSESSMENT (Answers)

1. Because g is the same for all objects near the Earth's surface. The larger mass needs a larger force to give it just the same acceleration.
2. Solving this problem, all we have to do is put the above values for mass and distance into the general gravity formula below:

$$F_g = G\frac{m_A m_B}{r^2} \quad \text{and} \quad F_g = \frac{(6.67\times10^{-11})\times10\times20}{(0.01)^2} = 0.000133\ N$$

Therefore, the two objects are attracted toward one another with a force of 0.000 1334 N, just in opposite directions.

3. For this problem, we will need two more pieces of information: the mass of the earth (because we want to calculate the gravitational attraction between the 10 kg object and the earth) is $m_e = 5.98\times10^{24}\,kg$ and the radius of the earth is about $r = 6.378\times10^6\ m$ (the distance, r is measured from the center of one object to the center of the other object.

Now that we have everything need to solve this problem, all we have to do is put the appropriate values for mass and distance into the general gravity formula:

$$F_G = G\frac{m_e m_B}{r^2} = \frac{(6.67\times10^{-11})\times10\times5.98\times10^{24}\,kg}{(6.378\times10^6\ m)^2} = 98.1\ N$$

So, we find that the gravitational attraction between the 10 kg object and the earth is 98.1 N

4. Mass of person $(\mathrm{m_1}) = 50\ \mathrm{kg}$ and mass of person $(m_2) = 75\ kg$

Distance between them $(\mathrm{r}) = 0.50\ \mathrm{m}$

Gravitational force $(\mathrm{F}_G) = ?$ $\quad F_G = G\frac{m_1 m_2}{r^2} = 6.67\times10^{-11}\frac{50\times75}{(0.5)^2}$

$$= 100\times10^{-11}\ N$$

The magnitude of gravitational force each exerts on the other is $100\times10^{-11}\,N$

5. a) The Sun-Earth distance is $1.496\times10^{11}\,m$ and the Earth-Moon distance is $3.84\times10^8\ m^3$, so the distance from the Sun to the Moon during a solar eclipse is

$$1.496\times10^{11}\ m - 3.84\times10^8\ m = 1.492\times10^{11}\ m$$

The mass of the Sun, Earth, and Moon are, $M_m = 1.99\times10^{30}\ kg$, $M_E = 5.98\times10^{24}\ kg$ and $M_m = 7.36\times10^{22}\ kg$

We have $F_{SM} = G\dfrac{m_S m_M}{R_{SM}^2} = (6.67\times10^{-11})\dfrac{(1.99\times10^{30})(7.36\times10^{22})}{(1.492\times10^{11})^2} = 4.39\times10^{20}\ N$

b) $F_{EM} = G\dfrac{m_E m_M}{R_{EM}^2} = (6.67\times10^{-11})\dfrac{(5.98\times10^{24})(7.36\times10^{22})}{(3.84\times10^{8})^2} = 1.99\times10^{20}\ N$

c) $F_{ES} = G\dfrac{m_E m_S}{R_{ES}^2} = (6.67\times10^{-11})\dfrac{(1.99\times10^{30})(5.98\times10^{24})}{(1.496\times10^{11})^2} = 3.55\times10^{22}\ N$

6. $M = \dfrac{gr^2}{G} = \dfrac{(9.81\,m/s^2)(6.37\times10^6\ m)^2}{6.67\times10^{-11}\ N.m/kg^2} = 6.0\times10^{24}\ kg$

$M = 6.0\times10^{24}\ kg$ Mass of the earth is $M = 6.0\times10^{24}\ kg$

7. *On the moon,* m_1 *weighs* $\dfrac{1}{6}(9.8\ N)$

$W_1 = G\dfrac{m_1 m_2}{r^2}$. Therefore, $W_1 = \dfrac{1}{6}(9.8) = 6.67\times10^{-11}\dfrac{1\times m_2}{(1.738\times10^6)^2}$

$m_2 = \dfrac{(9.8)(1.738\times10^6)^2}{(6)(6.67\times10^{-11})} = 7.4\times10^{22}\ kg$

8. (a) $F = mg = 1.00\,kg\times5.42\times10^{-9}\ N/kg = 5.42\times10^{-9}\ N$

(b) $F = mg = 8.91\times10^5\ kg\times5.42\times10^{-9}\ N/kg = 4.83\times10^{-3}\,N$

6.10. Additional activities (Questions and answers)

6.10.1 Remedial activities

The discovery of "Universal Gravitation" is associated with:

A. Robert Hook

B. Isaac Newton
C. James Joule
D. Max Plank
E. Christian Huygens

2. Two objects with equal masses of 1 kg each are separated by a distance of 1 m. The gravitational force between

A. Slightly less than G

B. Slightly greater that G

C. Equal to G

D. Half as much of G

E. Twice as much of G

3. Two objects, one with a mass of m and one with a mass of 4m are attracted to each other by a gravitational force. If the force on 4m is F, what is the force on mass m in terms of F?

A. 16F B. 4F C. F D. ¼ F E. 1/16 F

4. A hypothetical planet has a mass of four times that of the Earth and radius of twice that of the Earth? What is the acceleration due to gravity on the planet in terms of the acceleration on the Earth?

A. g, B. $\frac{g}{2}$, C. $\frac{g}{4}$, D. 2g, E. $\frac{g}{8}$

5. Two objects are attracted to each other by a gravitational force F. If each mass is tripled and the distance between the objects is cut in half, what is the new gravitational force between the objects in terms of F?

6. A rocket moves away from the surface of Earth. As the distance r from the center of the planet increases, what happens to the force of gravity on the rocket?

A. The force increases directly proportional to r

B .The force increases directly proportional to r^2

C. The force doesn't change

D. The force becomes zero after the rocket loses the contact with Earth

E. The force decreases inversely proportional to $\frac{1}{r^2}$

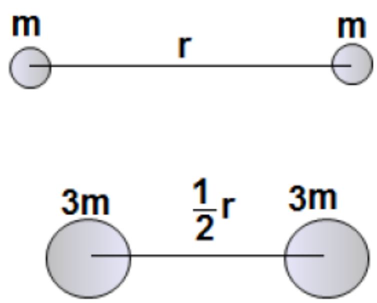


Fig.6. 2 Objects attracting one another

A. 24 F B. 36 F C. 16 F D. 1/16 F E. 1/24 F

8. A satellite is orbiting a planet of mass M with an orbital radius r. Which of the following represents the orbital velocity of the satellite?

A. $v=\sqrt{\frac{GM}{R}}$ B. $v=\sqrt{\frac{GM}{r^2}}$ C. $v=\sqrt{\frac{GM}{r}}$ D. $v=\sqrt[3]{\frac{GM}{r}}$ E. $v=\sqrt{\frac{GM}{r^3}}$

9. A satellite is orbiting a planet with an orbital radius r. Which of the following diagrams represents the direction of the velocity and acceleration of the satellite?

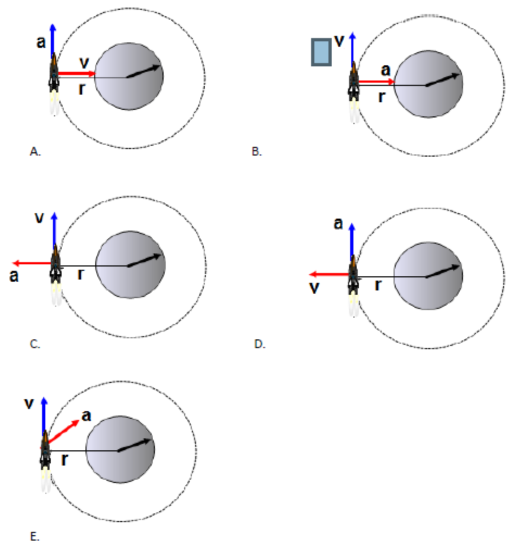


Fig.6. 3 A satellite orbiting a planet

10. An object with a mass of 48 kg measured on Earth is taken to the Moon. What is the weight of the object on the Moon's surface if the acceleration due to gravity on Moon is one-sixth of that on Earth?

A. 8 N B. 48 N C. 288 N D. 480 N E. 80 N

6.10.2. Consolidation activities

1. Determine the magnitude of the gravitational field strength at a point

   a) 1000km above the surface of the earth,
   b) On the surface of the Earth

$$G = 6.7\times10^{-11}\ N.m^{-2}.kg^{-2},\ M_e = 6.0\times10^{24}\ kg,\ R_e = 6.4\times10^{6} m$$

2. At the surface of a certain planet, the gravitational acceleration g has a magnitude of $2.0\ m/s^2$. A 4.0kg brass ball is transported to this planet. Give:

a) The mass of the brass ball on the earth and on the planet

b) The weight of the brass ball on the earth and on the planet

3. The mass of the Earth is 81 times that of the moon and the distance from the centre of the Earth to that of the moon is about 4×10^5 km. Calculate the distance from the centre of the Earth where the resultant gravitational force becomes zero when a spacecraft is launched from the Earth to the moon.

6.10.3. Extended activities

1. Planet X and Earth have the following properties:

	Earth	Planet X
Mass	2M	M
Density	P	P

Determine the gravitational field strength on the surface of the Planet (Gravitational field strength on Earth's surface $= 9.8\ N/kg$)

2. Determine height, from the surface of the Earth, which an object must travel through so that the gravitational field strength change by 1.0%.

(Radius of the earth $= 6\ 400 km$)

3. What is the change in gravitational potential energy of a 64.5-kg astronaut, lifted from Earth's surface into a circular orbit of altitude 4.40×10^2 km?

Answers for Additional activities

a) Remedial activities

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

b) Consolidation activities

1. The gravitational field strength at the given point is $g = \dfrac{GM}{r^2}$

$$= \frac{(6.7\times10^{-11})(6\times10^{24})}{\left[(0.001+6.4)\times10^{6}\right]^2}$$

$$= 9.811\ Nkg^{-1}$$

c) On the surface of the Earth, $g = \dfrac{GM}{R^2}$

$$= \frac{(6.7\times10^{-11})(6\times10^{24})}{(6.4\times10^{6})^2}$$

$$= 9.814\ Nkg^{-1}$$

2. a) The mass of an object cannot change therefore mass remains as $4.0\ kg$

b) $weight = mg(on\ the\ Earth)$

$mass(m) = 4.0\ kg$

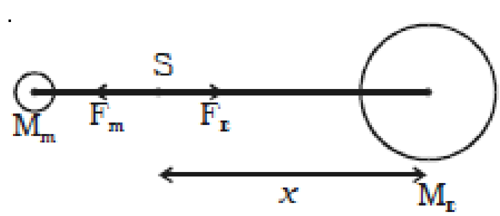
$g = 10.0\ m/s^2$

$then\ weight = 4.0\times10.0 = 40.0\ N$

On the planet

$w = mg = 4.0\times2.0 = 8.0\ N$

3.



Let the mass of the spacecraft be m. The gravitational force on the spacecraft at S due to the Earth is opposite in direction to that of the moon. Suppose the spacecraft S is at a distance x from the center of the Earth and at a distance of $(4\times10^5 - x)$ from the moon.

$$\frac{GM_E m}{x^2} = \frac{GM_m m}{(4\times10^5 - x)^2} \Leftrightarrow \frac{M_E}{M_m} = \frac{x^2}{(4\times10^5 - x)^2} \Leftrightarrow x = 3.6\times10^5 km$$

The resultant gravitational force is zero at a distance of 3.6×10^5 km from the center of the Earth. The resultant force on S due to the Earth acts towards the Earth until 3.6×10^5 km is reached. Then it acts towards the moon.

d) Extended activities

1. Earth:

$$g_E = \frac{GM_E}{R_E^2} \quad \text{..................(1)}$$

Planet:

$$g = \frac{GM}{R^2} \quad \text{......................(2)}$$

Taking (2) over (1):

$$\frac{g}{g_E} = (\frac{M}{M_E})(\frac{R_E}{R})^2$$

But $M = \rho V = \rho(\frac{4}{3}\pi R^3)$

$$\frac{M_E}{M} = (\frac{\rho_E}{\rho})(\frac{R_E}{R})^3$$

$$2 = (1)\left(\frac{R_E}{R}\right)^3$$

$$\frac{R_E}{R} = 1.26$$

$$\frac{g}{g_E} = (\frac{1}{2})(1.26)^2 = 0.794$$

$g = 0.794(9.8) = 7.8\ Nkg^{-1}$

2. On Earth's surface,

$g = \dfrac{GM}{R}$ Where R is the radius of the Earth.

At a height r from the center of the Earth, $g' = \dfrac{GM}{r}$

$$\frac{\Delta g}{g} = \frac{g - g'}{g}$$

$$= 1 - \frac{g'}{g} = 1 - \left(\frac{R}{r}\right)^2$$

$$= \left(\frac{R}{r}\right)^2 = 1 - \frac{1}{100} = 0.990$$

$$\frac{R}{r} = 0.995 \Rightarrow r = \frac{R}{0.995}$$

But $r = R + h$ where h is the required height.

$$R + h = \frac{R}{0.995} \Rightarrow h = \frac{0.005(6400km)}{0.995} = 32km$$

3. $r_2 = r_E + 4.40 \times 10^2 km$

$$= 6.38 \times 10^6 m + 4.40 \times 10^5 m$$

$$r_2 = 6.82 \times 10^6 m$$

On the surface of earth, $E_{g1} = -\dfrac{GM_E m}{r_E}$

$$= -\frac{(6.67 \times 10^{-11}\ \mathrm{Nm^2kg^{-2}})(5.98 \times 10^{24}\ \mathrm{kg})(64.5kg)}{6.38 \times 10 \times 10^6 m}$$

$$E_{g1} = -4.03 \times 10^9 J$$

In orbit, $E_{g2} = -\dfrac{GM_E m}{r_2}$

$$= -\frac{(6.67\times10^{-11}\,N.m^2.kg^{-2})(5.98\times10^{24}\ kg)(64.5\,kg)}{6.82\times10^6\ m}$$

$$E_{g2} = -3.77\times10^9\,J$$

$$\triangle E = E_{g2} - E_{g1}$$

$$= (-3.77\times10^9\,J) - (-4.03\times10^9)$$

$$\Delta E_g = 2.6\times10^8\,J$$

The change in gravitational potential energy is $\Delta E_g = 2.6\times10^8\,J$

UNIT 7: ATOMIC MODELS AND PHOTOELECTRIC EFFECT

7.1 Key Unit competence:

Interpret the atomic model and photoelectric effect and solve related problems

7.2 Prerequisite (knowledge, skills, attitudes and values

Through guided discovery, assist learners to remember the nature of an atom (From Chemistry in O'level). You can make a recap using;

- Motion of objects in a circular orbit.
- Circular motion

7.3 Cross cutting issues to be addressed

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

- **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.
- **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.

Working together in groups

Having a strong bond of love like the way particles are bonded or attracted to one another.

7.4 Guidance on introductory activity

This activity aims at capturing student-teachers' attention and minds towards Atomic models and photoelectric effect.

- Tell student-teachers that they are to discuss (by themselves) under your guidance.
- Split your class into groups (if it is a mixed school makes sure that your groups have boys and girls) 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 students are doing. Leave them to work by themselves.
- Invite some small groups to present their findings to the whole class. You can explain new terms used and clarify points where student-teachers had problems. Link this concepts/problem to structure of an atom in Chemistry.
- Ask student-teachers from different small 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 learners' findings and deductions.
- You can ask learners to note down important information discussed in the class.

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

Expected answers for the introductory activity.

1. a) Like an atom, the balls are like electrons around the nucleus.

b) Like an atom, particles(electrons) are revolving around the nucleus

c) The energy is released / absorbed when an electron jumps from higher/lower energy level.

2. a) They used models because, the suggestions/findings were not the final instead some of their findings was open to be criticized.

b) Rutherford's atomic model.

Simpson's model

Bohr's atomic model. For explanations refer to student's book.

7.5 List of lessons

#	**Lesson title**	**Learning objectives**	**Number of Periods**
1	Bohr model of the atom and energy levels	- Explain energy levels - Explain Bohr's atomic model - Explain Formation of spectral lines	6
2	Photoelectric Effect	- Explain the photoelectric effect. - Explain how C.R.O and T.V. tubes function. - Outline factors affecting photoelectric emission. -Explain functioning of photo cells	5

		(photo emissive and photovoltaic cells) - Illustrate electric current production when sun radiation shines a metal surface. - Distinguish fluorescent and phosphorescent materials - Point out applications of photoelectric effect. - Solve problems using Einstein's equation photoelectric effect	
3	Thermionic emission	Identify factors influencing thermionic emission.	4
	End unit assessment		2

Lesson 1: Bohr model of the atom and energy levels

a) Learning objective

-Explain energy levels

-Explain Bohr's atomic model

-Explain Formation of spectral lines

b) Teaching resources

- Search internet, Library, Journals and computer simulations
- Projectors, videos

c) Prerequisites/Revision/Introduction

Through guided discovery, assist learners to discuss the structure of an atom

- You can use idea of planetary motion in this series Year 2 unit 6 to relate the motion of electrons around the nucleus so that you can relate it to motion of planets around the sub.

d) **Learning activities 7.1**

Guidance to the learning activity 7.1

This lesson focuses on making student-teachers understand atomic models and energy levels.

- Tell student-teachers to open their books (student-teacher's book) to learning activity 7.1
- Decide on the methodology to use in this lesson. In small groups or learners can also 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 for the whole class and allow questions from student-teachers if any. Create a good ground for learners to discuss.
- Together with student-teachers' ideas, link their Answers for atomic models.
- Make a summary (using student-teachers' findings about Rutherford's limitations and energy of an electron while in energy level) and tell learners to write down important ideas in their books.

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

Answers for the learning activity 7.1

a) Corrections to be made on Rutherford's model.

These are Bohr's Postulates.

- Electrons were present in orbits outside the nucleus and execute circular motion around the nucleus under the influence of the Coulomb attraction between the electron and nucleus and in accordance with the laws of classical physics.
- The electron can occupy only certain **allowed orbits** or **stationary states** for which the orbital angular momentum, L, of the electron is an integral multiple of Planck's constant divided by 2π.

$L_n = mv_n r_n = \frac{nh}{2\pi}$ that is $L_n = mv_n r_n = n\hbar$

where $\hbar = \frac{h}{2\pi} = \frac{6.63 \times 10^{-34}\ J \cdot s}{2\pi} = 1.055 \times 10^{-34}\ J \cdot s$

- An electron in such a stationary state **does not radiate electromagnetic energy**.
- Energy is emitted or absorbed by an atom when an electron moves from one stationary state to another. The difference in energy between the initial and final states is equal to the energy of the emitted or absorbed photon and is quantized according to the Planck relationship:

$\Delta E = E_f - E_i = hf$ [From student's book]

b) Electrons have fixed amounts of energy while they are in Stationary orbits

c) i) The electron gains (absorbs) energy once it jumps from one energy level to another.

ii) Once an electron drops from one energy level to another, it loses energy ($E = hf$)

e**) Answers for Application activities 7.1**

1. An electron executes circular motion around the nucleus under the influence of the Coulomb attraction between the electron and nucleus and in accordance with the laws of classical physics.

The electron can occupy only certain **allowed orbits** or **stationary states** for which the orbital angular momentum, L, of the electron is an integral multiple of Planck's constant divided by 2π.

An electron in such a stationary state **does not radiate electromagnetic energy**.

Energy is emitted or absorbed by an atom when an electron moves from one stationary state to another. The difference in energy between the initial and final states is equal to the energy of the emitted or absorbed photon and is quantized according to the Planck relationship:

$\Delta E = E_f - E_i = hf$

2. a) Using $\frac{1}{\lambda} = -R_h\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = 1.097\times10^7\left(\frac{1}{1^2} - \frac{1}{2^2}\right) \Leftrightarrow \lambda = 121.5\, nm$

This wavelength lies in the ultraviolet region.

The frequency of photon emitted: $f = \frac{c}{\lambda} = \frac{3.00\times10^8}{121.5\times10^{-9}} = 2.47\times10^{15}\ Hz$

b) $\frac{1}{\lambda} = -R_h\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = 1.097\times10^7\left(\frac{1}{1^2} - \frac{1}{3^2}\right) \Leftrightarrow \lambda = 102.6\, nm$

3. a) $\lambda = \frac{h}{mv} = \frac{6.63\times10^{-34}}{0.05\times40} = 3.3\times10^{-34}\ m$

b) $K = \frac{1}{2}mv = \frac{p^2}{2m} \Leftrightarrow K = \frac{h^2}{2m\lambda^2} \Leftrightarrow \lambda = \frac{h}{\sqrt{2mK}} = \frac{6.63\times10^{-34}}{\sqrt{2(9.1\times10^{-31})(13.6\times1.6\times10^{-19})}} = 0.33\, nm$

c) $\lambda = \frac{h}{\sqrt{2mqV}} = \frac{6.63\times10^{-34}}{\sqrt{2(9.1\times10^{-31})(100\times10^3\times1.6\times10^{-19})}} = 3.885\times10^{-12}\ m$

4. (*B*) The momentum of a photon is inversely proportional to its wavelength. Therefore, doubling the momentum would cut the wavelength in half.

5. i) Energy of radiation:

$$\Delta E = -E_0\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = -2.18\times10^{-8}\left(\frac{1}{5^2} - \frac{1}{2^2}\right) = 458\times10^{-11}\ J$$

$$\Delta E = (458\times10^{-11}\ J/atom)(6.02\times10^{23}\ atoms/mol)\left(\frac{1\,kJ}{1000\ J}\right) = 2.76\times10^{9}\ kJ/mol$$

ii) Frequency: $\Delta E = hf \Leftrightarrow f = \frac{\Delta E}{h} = \frac{458\times10^{-11}}{6.63\times10^{-34}} = 69\times10^{13}\ Hz$

iii) Wavelength: $\Delta E = \frac{hc}{\lambda} \Leftrightarrow \lambda = \frac{hc}{\Delta E} = \frac{6.63\times10^{-34}\times3.00\times10^{8}}{458\times10^{-11}} = 43.4\times10^{-15}\ m$

Lesson 2: Photoelectric effect

a) Learning objectives

- Explain the photoelectric effect.

- Explain how C.R.O and T.V. tubes function.

- Outline factors affecting photoelectric emission.

-Explain functioning of photo cells (photo emissive and photovoltaic cells)

- Illustrate electric current production when sun radiation shines a metal surface.

- Distinguish fluorescent and phosphorescent materials

- Point out applications of photoelectric effect.

- Solve problems using Einstein's equation photoelectric effect

b) Teaching resources

- Search internet, Library, Journals and computer simulations
- Projectors, videos

c) Prerequisites/Revision/Introduction

This lesson requires knowledge and skills from working principle of solar panels. And black body radiation that is to say emission and absorption of energy.

Energy conversion. That is from light energy to other forms of energy

d) Learning activities 7.2

Guidance on learning activity 7.2

The photo in this activity was taken from Rwamagana District. It is meant to introduce to student-teachers how electricity can be generated by a process of photoelectric effect.

- Decide on the method to use (As planned in your lesson plan)
- Let student-teachers turn to activity 7.2 in student-teacher's book. You can ask whether there is any one with solar panel at their home.
- Allow student-teachers to give their views about the working and operation of solar panels.
- Let them give their suggestions but connected to the questions asked in the activity.
- Use student-teachers' ideas to make a general explanation about solar panels.

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

Answers for learning activity 7.2

Most of the questions are open ended question. Accept any answer that answers the question.

a) Solar panels are devices that converts solar energy into electric energy.
b) Operation of solar panels

A solar panel consists of Photovoltaic cells which absorbs light radiations and converts it into electric energy. You can make a comprehensive research from any reliable source either from internet or textbooks

c) Areas like Musanze and Gicumbi do not receive a lot of sunshine and these panels' works efficiently when they absorb radiations of high energy. Therefore in such areas, they will not operate efficiently because of their cold climate.

d) Yes! Light is an electromagnetic carrying Energy $E = hf$ .Without energy, then atoms in the panel wouldn't absorb anything. Hence remaining not excited.

e) Answers for application activities 7.2

1 a) Threshold frequency: $f_o = \dfrac{\phi}{h} = \dfrac{(2.3\times1.6\times10^{-19})}{6.63\times10^{-34}} = 5.6\times10^{14}\ Hz$

b) Kinetic energy $K = E-\phi \Leftrightarrow \dfrac{1}{2}mv^2 = hf-\phi \Leftrightarrow v = \sqrt{\dfrac{2(\frac{hc}{\lambda}-\phi)}{m}} = 2.5\times10^5\ m/s$

c) Stopping voltage:

$$V_s = \frac{K}{e} = \frac{\frac{hc}{\lambda}-\phi}{e} = \frac{\frac{(6.63\times10^{-34}\ \mathrm{J.s})(3\times10^8\ \mathrm{m/s})}{5\times10^{-7}\ m} - 2.3\,eV(1.6\times10^{-19}\ J/eV)}{1.6\times10^{-19}\ J/eV} = 0.18\,V$$

d) The longest wavelength: $\lambda = \dfrac{hc}{\phi} = 5.4\times10^{-7}\ m$

2. Let's assume an average wavelength in the middle of the visible spectrum $\lambda = 500\ nm$. The energy of each photon is $E = hf = \dfrac{hc}{\lambda}$. Only 3% of the 100 W power is emitted as visible light, or $P = 100\times3\% = 3\,W$

The number of photons emitted per second equals the light output of divided by the energy of each photon. The energy emitted in one second $P = 3\ J/s$ is $P = Nhf$ where N is the number of photons emitted per second and $f = \dfrac{c}{\lambda}$

Hence $N_0 = \frac{P\lambda}{hc} = \frac{(500\times10^{-9}\ m)(3\ J/s)}{(6.63\times10^{-34}\ J.s)(3.00\times10^{8}\ m/s)} = 8\times10^{18}$ photons emitted per second

3. $E = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34}\ J.s)(3\times10^{8}\ m/s)}{450\times10^{-9}\ m} = 4.42\times10^{-19}\ J = 2.76\,eV$

4. (*A*) A higher work function requires more energy per photon to release the electrons. Blue light has the shortest wavelength and therefore the largest energy per photon.

5. (*B*) The blue light has a shorter wavelength and therefore more energy per photon. Since the beams have the same intensity (energy per unit time per unit area), the red light will have more photons.

Lesson 3: Thermo-electronic emission /thermionic emission

a) Learning objective

- Explain the production of cathode rays and their properties.
- Analyze applications of cathode rays.
- Identify factors influencing thermionic emission

b) Teaching resources

– Search internet, Library, Journals and computer simulations
– Projectors, videos

c) Prerequisites/Revision/Introduction

Learners will use the knowledge acquired in unit 2 about Black body radiation to interpret and analyse clearly concepts.

d) Learning activities 7.3

Guidance to the learning activity 7.3

- This activity introduces student-teachers to know how particles are emitted thermionically.
- Divide your class into small groups, and let student-teachers read and interpret the questions.
- Let the learner(s) perform the activity using their prior knowledge about photoelectric effect.
- Have sample group present their work to the class. They can use power point presentation
- Check student's responses to review the student-teachers' plans and ideas to continue the discussion with a brief brainstorming of the concepts using student's work and book.
- Comment on students' responses written in their notebooks and give them the summary of expected feedback based on their findings.

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

Answers for activity 7.3

a) When the surface is connected to electricity, particles absorb electric energy and become excited hence becomes accelerated.

b) Properties of emitted particles.

- They travel in straight lines and they carry negative charge.
- They are deflected by electric and magnetic fields.
- Cathode rays cause fluorescence on striking certain materials.
- They have energy and momentum.
- Cathode rays are capable of ionizing gas atoms if the potential difference is large and the gas pressure is not high.
- Depending on their energy, cathode rays can penetrate thin sheets of paper or metal foils.
- When cathode rays are stopped suddenly, they produce X-rays.
- They affect photographic plates.

c) If disconnected, the particles decelerate, and finally comes to rest. Hence ejection of particles stops.

e) Answers for Application activities 7.3

1. One cycle spans 4 divisions. The period is therefore: $T = 4\ div(\frac{50\ \mu s}{div}) = 200\ \mu s$

And the frequency is $f = \frac{1}{T} = \frac{1}{200 \times 10^{-6}} = 5\ kHz$

The vertical height above the horizontal axis encompasses 2 divisions.

Therefore, $V_m = 2\ div(\frac{0.1V}{div}) = 0.2\ V$

2(a) To obtain a spot trace on a typical C.R.O. screen:

(i) Switch on the C.R.O.

(ii) Switch the time base control to off. This control is calibrated in time per centimetres—for example, 5 ms/cm or 100 μs/cm.

Turning it to zero ensures no signal is applied to the X-plates.

The Y-plate input is left open-circuited.

(iii) Set the intensity, X-shift and Y-shift controls to about the mid-range positions.

(iv) A spot trace should now be observed on the screen. If not, adjust either or both of the X and Y-shift controls. The X shift control varies the position of the spot trace in a horizontal direction whilst the Y-shift control varies its vertical position.

(v) Use the X and Y-shift controls to bring the spot to the centre of the screen and use the focus control to focus the electron beam into a small circular spot.

(b) To obtain a continuous horizontal trace on the screen the same procedure as in (a) is initially adopted. Then the time base control is switched to a suitable position, initially the millisecond time base range, to ensure that the repetition rate of the saw tooth is sufficient for the persistence of the vision time of the screen phosphor to hold a given trace.

7.6. Summary of the unit

Rutherford's model proposed that the atom consists of a small, extremely dense positive nucleus that contains most of its mass; the atom's volume is mostly empty space; and the Coulomb force holds the electrons in orbit.

Further work on a scattering revealed that Coulomb's law, $F_E = \frac{kq_1q_2}{r^2}$, applies to the electric force between small charged particles even at distances smaller than the size of atoms; the positive charge on the nucleus is the same as the atomic number.

Balmer devised a simple empirical equation from which all of the lines in the visible spectrum of hydrogen could be computed:

$$\frac{1}{\lambda} = R_h\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

His equation allowed the energy levels for hydrogen to be predicted as $E_n = -\frac{13.6}{n^2}$

The work of Franck and Hertz, and the analysis of emission and absorption spectra had confirmed that there are discrete, well-defined internal energy levels within the atom.

Bohr proposed that atoms only exist in certain stationary states with certain allowed orbits for their electrons. Electrons move in these orbits with only certain amounts of total energy, called energy levels of the atom.

Bohr made the following three postulates regarding the motion of electrons within atoms:

1. There are a few special electron orbits that are “allowed,” each characterized by a different specific electron energy.
2. When moving in an allowed stationary orbit, an electron does not radiate energy.
3. Electrons may move from a higher-energy orbit to a lower-energy orbit, giving off a single photon. Similarly, an atom can only absorb energy if that energy is equal to the energy difference between a lower stationary state and some higher one.

Bohr combined classical mechanics with quantum wave mechanics to produce a satisfactory model of the atomic structure of hydrogen.

The lone electron of a hydrogen atom normally resides in the ground state (n = 1). By absorbing energy from photons, however, or from collisions with high-speed particles, it may be boosted up to any of the excited states (n = 2, 3, 4 ...). Once in an excited state, the electron quickly moves to any lower state, creating a photon in the process.

Bohr’s model was quite successful in that it provided a physical model of the hydrogen atom, matching the internal energy levels to those of the observed hydrogen spectrum, while also accounting for the stability of the hydrogen atom.

Bohr’s model was incomplete in that it broke down when applied to many electron atoms.

A continuous spectrum given off by a heated solid is caused by the interactions between neighbouring atoms or molecules. An emission spectrum or line spectrum is emitted from electrically “excited” gases.

An absorption spectrum occurs when some of the light from a continuous spectrum is absorbed upon passing through a gas. Atoms absorb light of the same frequencies that they emit.

The Franck–Hertz experiment showed that the kinetic energy of incident electrons is absorbed by mercury atoms but only at discrete energy levels.

An atom is normally in its ground state. The excited states or energy levels are given by the discrete amounts of energy the atom can internally absorb.

Ionization energy is the maximum energy that can be absorbed internally by an atom, without triggering the loss of an electron.

In the emission spectrum, the energy of the emitted photon equals the change in the internal energy level: $E_p = E_f - E_i$

When a photon is absorbed, its energy is equal to the difference between the internal energy levels: $E_p = E_f - E_i$

7.7. Additional Information for tutor

Hydrogen like Atoms

We can extend the Bohr model to other one-electron atoms, such as singly ionized helium He^+ , doubly ionized lithium Li^{2+} and so on. Such atoms are called ***hydrogen like* atoms**. In such atoms, the nuclear charge is not *e* but Ze where *Z* is the *atomic number,* equal to the number of protons in the nucleus. The effect in the previous analysis is to replace e^2 everywhere by Ze^2

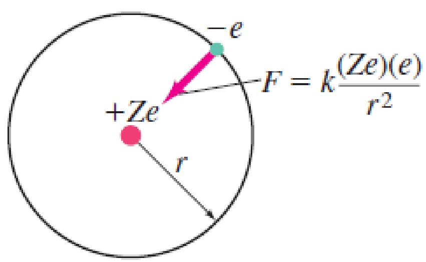


Fig.7. 1 Electric force keeps the negative electron in orbit around the positively charged nucleus.

An electron in a circular orbit of radius *r* (Fig.7.1) would have a centripetal acceleration produced by the electrical force of attraction between the negative electron and the positive nucleus. This force is given by Coulomb's law,

$$F = \frac{k(Ze)(e)}{r^2}$$

Where $k = \frac{1}{4\pi\varepsilon_o} = 8.89 \times 10^9 \ N.m^2 / C^2$

The charge on the electron is -e and that on the nucleus is +Ze where Ze is the charge on the nucleus, +e is the charge on a proton, Z is the number of protons in the nucleus called **atomic number**,

In Newton's second law, $F_{net} = ma$ we substitute Coulomb's law for F and $a = \frac{v^2}{r_n}$ for a particular allowed orbit of radius and obtain $\frac{kZe^2}{r_n^2} = \frac{mv^2}{r_n} \Leftrightarrow r_n = \frac{kZe^2}{mv^2}$

and then substitute for v from $v = \frac{nh}{2\pi m r_n}$) and solve for r_n (it appears on both sides, so we cancel one of them) and find for an atom with $Z \neq 1$,

The orbital radii as $r_n = \frac{n^2h^2}{4\pi^2 kme^2 Z} = \frac{n^2 r_o}{Z}$

The potential energy of the electron is given by $U = -eV = -\frac{kZe^2}{r_n}$

The kinetic energy: $K = \frac{1}{2}mv^2$

The total energy for an electron in the n^{th} orbit of radius r_n is the sum of the kinetic and potential energies:

$$E_n = \frac{mv^2}{2} - \frac{kZe^2}{r_n}$$

When we substitute v from $v = \frac{nh}{2\pi m r_n}$, we obtain the energies of the larger orbits in atom with $Z \neq 1$ are given by $E_n = -\frac{ke^2 Z^2}{2r_0 n^2} = \frac{-(13.6\,eV)Z^2}{n^2} = -\frac{Z^2 E_o}{n^2}$

For an atom with $Z \neq 1$ we can write the wavelengths in the lines spectrum:

$$\frac{1}{\lambda} = -R_h Z^2 \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Example 7.1

Singly ionized helium, He^+ , a hydrogen like system, ha one electron in the 1 s orbit when the atom is in its ground state.

(a) Find the energy of the system in the ground state and the radius of the ground state orbit

(b) determine the ionization energy of the He^+

(c) calculate the maximum wavelength a photon can have to cause ionization

(d) compares the energy levels for H and for He which has $Z = 2$

Answer

(a) The energy of the system in the ground state: $E_1 = -\frac{Z^2 E_o}{n^2} = -\frac{2^2 \times 13.6}{1^2} = -54.4\,eV$

The radius of grounded state: $r_n = \frac{n^2 r_o}{Z} = \frac{1^2 \times 0.0529}{2} = 0.0265\,nm$

(b) the ionization energy is $\Delta E = E_f - E_1 = 0 - (-54.4\,eV) = 54.4\,eV$

(c) The maximum wavelength photon $\lambda = \frac{hc}{\Delta E} = \frac{(6.63 \times 10^{-34}\ J.s)(3.00 \times 10^8\ m/s)}{(54.4\,eV)(1.6 \times 10^{-19}\ J/\mathrm{eV})} = 22.8\,nm$

If $\lambda > 22.8\,nm$ ionization cannot occur.

(d) Figure 7.2 compares the energy levels for H and for He which has $Z = 2$

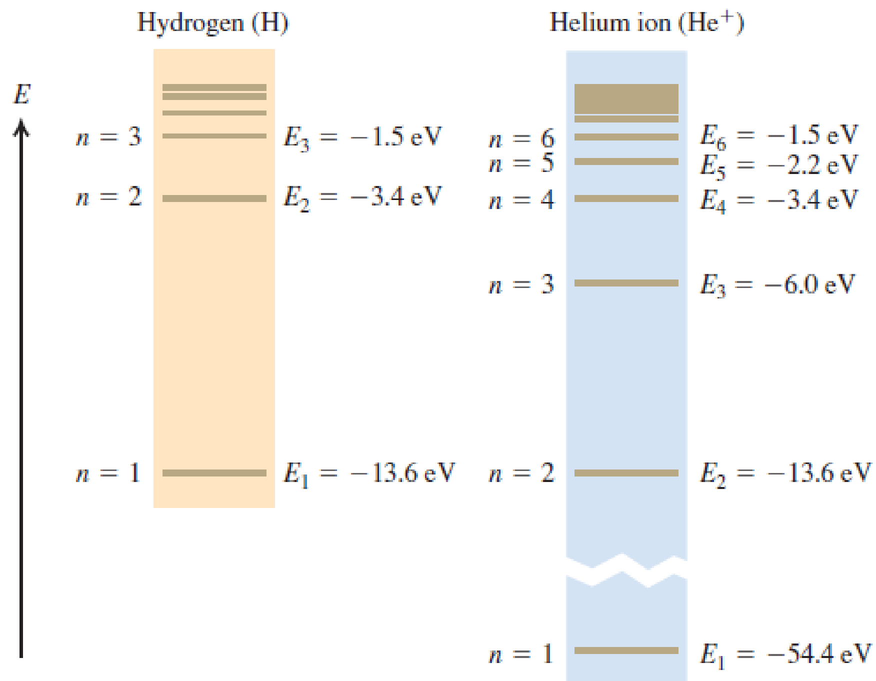


Fig.7. 2 Energy levels of H and He^{+}

GUIDANCE ABOUT SKILLS LAB 7

This task is aimed at making learners realize and apply knowledge and skills attained from what they have covered in this unit (specifically photoelectric effect)

- Assist learners to get materials so that they can perform the experiment as stated in the student's book.
- You may guide them (depending on the nature of your class) on how to make the set up as shown and instructed in student's book.
- You can make a follow up and see the progress and still you may assist some of the learners who need special care.
- Try to find out whether the objective (of demonstrating photoelectric effect is achieved). This can be measured from the results/outputs/reports from the students.

7.8. END UNIT ASSESSMENT (Answers)

1. A 2. D 3. A

4. In Rutherford's planetary model of the atom, the Coulomb force (electrostatic force) keeps the electrons from flying off into space. Since the protons in the center are positively charged, the negatively charged electrons are attracted to the center by the Coulomb force and orbit the center just like the planets orbiting a sun in a solar system due to the attractive gravitational force.

5. At room temperature, nearly all the atoms in hydrogen gas will be in the ground state. When light passes through the gas, photons are absorbed, causing electrons to make transitions to higher states and creating absorption lines.

These lines correspond to the Lyman series since that is the series of transitions involving the ground state or $n = 1$ level. Since there are virtually no atoms in higher energy states, photons corresponding to transitions from $n \geq 2$ to higher states will not be absorbed.

6. (*a*) The Bohr model successfully explains why atoms emit line spectra; it predicts the wavelengths of emitted light for hydrogen; it explains absorption spectra; it ensures the stability of atoms (by decree); and it predicts the ionization energy of hydrogen.

(*b*) The Bohr model did not give a reason for orbit quantization; it was not successful for multi electron atoms; it could not explain why some emission lines are brighter than others; and it could not explain the "fine structure" of some very closely spaced spectral lines.

7. The two main difficulties of the Rutherford model of the atom were that (1) it predicted that light of a continuous range of frequencies should be emitted by atoms and (2) it predicted that atoms would be unstable.

8. Even though hydrogen only has one electron, it still has an infinite number of energy states for that one electron to occupy, and each line in the spectrum represents a transition between two of

those possible energy levels. So there are many possible spectral lines. And seeing many lines simultaneously would mean that there would have to be many hydrogen atoms undergoing energy level transitions—a sample of gas containing many H atoms, for example.

9. No. At room temperature, virtually all the atoms in a sample of hydrogen gas will be in the ground state. Thus, the absorption spectrum will contain primarily the Lyman lines, as photons corresponding to transitions from the n =1 level to higher levels are absorbed.

Hydrogen at very high temperatures will have atoms in excited states. The electrons in the higher energy levels will fall to all lower energy levels, not just the n =1 level. Therefore, emission lines corresponding to transitions to levels higher than n =1 will be present as well as the Lyman lines. In general, you would expect to see only Lyman lines in the absorption spectrum of room temperature hydrogen, but you would find Lyman, Balmer, Paschen, and other lines in the emission spectrum of high-temperature hydrogen.

10. 1. J. J. Thomson 2. Niels Bohr 3. Ancient Greeks and Dalton 4. Rutherford 5. Marie and Pierre Curie

11. The closely spaced energy levels in Fig. above correspond to the different transitions of electrons from one energy state to another—specifically to those that start from closely packed high energy levels, perhaps with n = 10 or even higher.

12. On average, the electrons of helium are closer to the nucleus than are the electrons of hydrogen. The nucleus of helium contains two protons (positive charges) so attracts each electron more strongly than the single proton in the nucleus of hydrogen. (There is some shielding of the nuclear charge by the “other” electron, but each electron still feels an average attractive force of more than one proton’s worth of charge.)

13. The Balmer series spectral lines are in the visible light range and could be seen by early experimenters without special detection equipment. It was only later that the UV (Lyman) and IR (Paschen) regions were explored thoroughly, using detectors other than human sight.

14. (*a*) continuous (*b*) line, emission (*c*) continuous (*d*) line, absorption (*e*) continuous with absorption lines (like the Sun)

15. It is possibl e for the de Broglie wavelength ($\lambda = h/p$) of a particle to be bigger than the dimension of the particle. If the particle has a very small mass and a slow speed (like a low-energy electron or proton), then the wavelength may be larger than the dimension of the particle. It is also possible for the de Broglie wavelength of a particle to be smaller than the dimension of the particle if it has a large momentum and a moderate speed (like a baseball). There is no direct connection between the size of a particle and the size of the de Broglie wavelength of a particle. For example, you could also make the wavelength of a proton much smaller than the size of the proton by making it go very fast.

16. Bohr model of the atom,

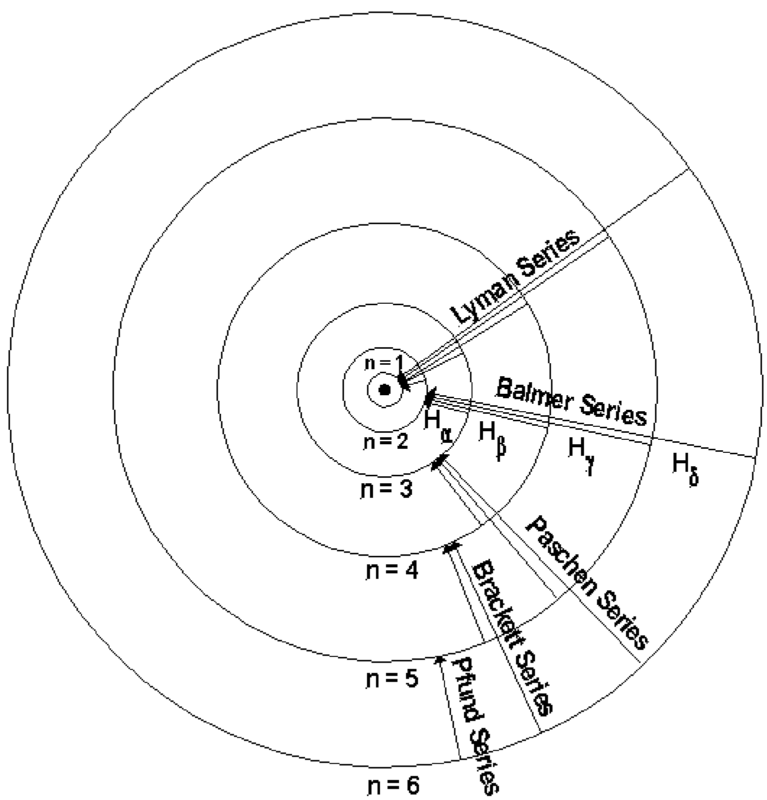


Fig.7. 3. Spectra series of Hydrogen atom

7.9. Additional activities (Questions and answers)

7.9.1 Remedial activities

1. (a) In a cathode ray tube, electrons emitted from a cathode are attracted towards an anode by means of a large potential difference. If the anode-cathode potential difference is 2200 V, calculate the kinetic energy, in J, and speed of each electron just before impact at the anode.

(b) (i) If an electron of this energy was to impinge on a fluorescent screen, calculate the shortest wavelength of the electromagnetic radiation subsequently emitted and explain why this is a minimum value.

(ii) Calculate the de Broglie wavelength of an electron with the same energy as that hitting the screen previously.

2. (a) Determine the wavelength of the second Balmer line (n = 4 to n = 2 transition).

   (b) Determine likewise the wavelength of the second Lyman line, and
   (c) The wavelength of the third Balmer line

Answer

1. (a) $K = W_{done} = qV = (1.6\times10^{-19}\ C)(2\,200\,V) = 3.5\times10^{-16}\ J$

$$K = \frac{1}{2}mv^2 = 3.5\times10^{-16}\ J \text{ hence } v = \sqrt{\frac{2K}{m}} = \sqrt{\frac{2\times3.5\times10^{-16}\ J}{9.1\times10^{-31}\ kg}} = 2.8\times10^{7}\ m/s$$

(b) (i) Al the KE goes to one photo: $fh = K$

$$\lambda = \frac{c}{f} = \frac{ch}{K} = \frac{(6\cdot63\times10^{-34}\ J\cdot s)(3\times10^{8}\ m)}{3.5\times10^{-16}\ J} = 5.7\times10^{-10}\ m$$

(ii) $\lambda = \dfrac{h}{mv} = \dfrac{6\cdot63\times10^{-34}\ J\cdot s}{(9\cdot1\times10^{-31}\ kg)(2.8\times10^{7}\ m/s)} = 2.6\times10^{-11}\ m$

2.

(a) For jump from $n = 4$ to $n = 2$, we have

$$\lambda = \frac{(1.24\times10^3 eV.\text{nm})}{E_4 - E_2} = \frac{(1.24\times10^3 eV.\text{nm})}{[-0.85eV - (-3.4eV)]} = 486\,nm$$

(b) For the jump from $n = 3$ to $n = 1$, we have

$$\lambda = \frac{(1.24\times10^3 eV.\text{nm})}{E_3 - E_1} = \frac{(1.24\times10^3 eV.\text{nm})}{[-1.5eV - (-3.4eV)]} = 102\,nm$$

(c) The energy of the $n = 5$ level is

$$E_5 = \frac{-(13.6eV)}{5^2} = -0.54\,eV$$

For the jump from $n = 5$ to $n = 2$, we have

$$\lambda = \frac{(1.24\times10^3 eV.\text{nm})}{E_5 - E_2} = \frac{(1.24\times10^3 eV.\text{nm})}{[-0.54eV - (-3.4eV)]} = 434\,nm$$

7.9.2. Consolidation activities

1. Which of the following is necessarily true?

A. Red light has more energy than violet light.

B. Violet light has more energy than red light.

C. A single photon of red light has more energy than a single photon of violet light.

D. A single photon of violet light has more energy than a single photon of red light.

E. None of the above.

F. A combination of the above (specify)

2. If a photon of energy E ejects electrons from a metal with kinetic energy K, then a photon with energy $E/2$

A. Will eject electrons with kinetic energy $\frac{K}{2}$.

B. Will eject electrons with an energy greater than $\frac{K}{2}$.

C. Will eject electrons with an energy less than $\frac{K}{2}$.

D. Might not eject any electrons.

3. Determine the wavelength of an electron that has been accelerated through a potential difference of 100 V.

Answers

1. (*D*) A common misconception is that violet light has more energy than red light. However, the energy is the product of the energy per photon and the number of photons. A single photon of violet light has more energy than a single photon of red light, but if a beam of red light has more photons than the beam of violet light, then the red light could have more energy.

2. (*D*) The energy of the photon $E = K + \phi$. If the energy of the photon is $E > 2\phi$, then cutting the photon energy in half will still allow electrons to be emitted. However, if the work function is $\phi > \frac{E}{2}$, then no electrons would be emitted if the photon energy were cut in half.

3. If the kinetic energy is much less than the rest energy, we can use the classical formula, and then apply conservation of energy

$$K = \frac{1}{2}mv^2 = eV \Leftrightarrow v = \sqrt{\frac{2\times100\times1.6\times10^{-19}}{9.11\times10^{-31}}} = 5.6\times10^6 \; m/\text{s}.$$

To find the de Broglie wavelength $\lambda = \frac{h}{mv} = \frac{6.63\times10^{-27}}{9.11\times10^{-31}\times5.9\times10^6} = 0.12 \; nm$

b) As a particle travels faster, does its de Broglie wavelength **decrease**, increase, or remain the same?

7.9.3. Extended activities

1. Find the longest and shortest wavelengths of the Balmer series and determine its energy.

2. What are the shortest and longest wavelengths in the Paschen series of hydrogen?

3. An electron in the hydrogen atom makes a transition from the $n=2$ energy state to the ground state corresponding to $n=1$ **(Lyman line)**

(a) Find the wavelength and frequency of the emitted photon.

(b) What is the wavelength of photon emitted by hydrogen when the electron makes a transition from the $n_i = 3$e to $n_f = 1$ state?

1. To give the largest wavelength λ , the right-hand side of the Rydberg equation must be as small as possible. This means that n_i and n_f should differ by unity or when $n_i = 2$, as it does for the Balmer series, then $n_f = 3$

$$\frac{1}{\lambda} = -R_h(\frac{1}{n_f^2} - \frac{1}{n_i^2}) = 1.097\times10^7(\frac{1}{2^2} - \frac{1}{3^2}) \Leftrightarrow \lambda = 656\,nm$$

This wavelength is in the red region of the visible spectrum.

The energy of this photon is: $E = \frac{hc}{\lambda_{\max}} = \frac{(6.63\times10^{-34}\ J\cdot s)(3\times10^8\ m/s)}{656.3\times10^{-9}\ m} = 3.03\times10^{-19}\ J = 1.89\,eV$

The shortest with $\frac{1}{n} = 0 \Rightarrow n = \infty$

$$\frac{1}{\lambda} = -R_h(\frac{1}{n_f^2} - \frac{1}{n_i^2}) = 1.097\times10^7(\frac{1}{2^2} - 0) \Leftrightarrow \lambda = 365\,nm$$

This wavelength is in the ultraviolet region and corresponds to the series limit. The energy of this photon is $E = \dfrac{hc}{\lambda_{\max}} = \dfrac{(6.63\times10^{-34}\ J\cdot s)(3\times10^{8}\ m/s)}{364.6\times10^{-9}\ m} = 5.45\times10^{-19}\ J = 34\,eV$

2. The longest wavelength occurs for $n_i = 3$ and $n_f = 4$

$$\frac{1}{\lambda} = -R_h\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = 1.097\times10^{7}\left(\frac{1}{3^2} - \frac{1}{4^2}\right) \Leftrightarrow \lambda = 1880\,nm$$

The shortest wavelength occurs for $n_f = \infty$ and is given by

$$\frac{1}{\lambda} = -R_h\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = 1.097\times10^{7}\left(\frac{1}{3^2} - \frac{1}{\infty^2}\right) \Leftrightarrow \lambda = 820\,nm$$

3. a) To obtain λ with $n_i = 2$ and $n_f = 1$ we can use

$$\frac{1}{\lambda} = -R_h\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = 1.097\times10^{7}\left(\frac{1}{1^2} - \frac{1}{2^2}\right) \Leftrightarrow \lambda = 121.5\,nm$$

This wavelength lies in the ultraviolet

The frequency of photon emitted: $f = \dfrac{c}{\lambda} = \dfrac{3.00\times10^{8}}{121.5\times10^{-9}} = 2.47\times10^{15}\ Hz$

b) $\dfrac{1}{\lambda} = -R_h\left(\dfrac{1}{n_f^2} - \dfrac{1}{n_i^2}\right) = 1.097\times10^{7}\left(\dfrac{1}{1^2} - \dfrac{1}{3^2}\right) \Leftrightarrow \lambda = 102.6\,nm$

UNIT 8: ANALOG AND DIGITAL SIGNALS IN TELECOMMUNICATION SYSTEMS

8.1 Key Unit competence

Evaluate the application of analog and digital signals in telecommunication systems

8.2 Prerequisite (knowledge, skills, attitudes and values)

The Student-teachers have acquired skills and knowledge in ordinary level in S_2 Unit 14 of electronics and in S_3 Unit 14 of telecommunication.

8.3 Cross cutting issues to be addressed

Peace and values education, sustainable environment, gender education, Inclusive education are different cross cutting issues to be addressed in this unit. However, the tutor is allowed to develop others depending on the situation of the class.

8.4 Guidance on introductory activity

This activity aims at capturing student-teachers' attention and minds towards the concept of Analogue and Digital Signals in Telecommunication System.

- Divide your students into groups (Grouping may depend on the nature of your class or number of learners you have).
- Always take care of slow students and any student-teachers with any kind of educational need while making groups (hearing, reading, seeing, etc.).
- Tell the learners to open the introductory activity in the learner's book. You may give them a brief introduction about the activity.
- Ask learners to interpret the pictures in the activity before answering questions. While learners are doing this activity, you move around, guide the slow learners. You may mark the working of those who have finished.
- When everyone has finished the activity, invite some member(s) of group(s) to present their findings to the whole class. Guide the presentation. They may present using PowerPoint.
- 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 learners the opportunity to write the main points in their notebooks.
- Harmonize the lesson by linking what have discussed and the summary of the lesson.
- Summarize your lesson by linking the concepts of analogue and digital signals in telecommunication system to real life situations.

8.5 List of lessons

#	Lesson title	Learning objectives	Number of Periods
1	Telecommunication terms and concepts	- Explain types of information used in communication - Explain terms used in communication systems - Identify and explain simplex, duplex and multiplex in Communication - Distinguish simplex from duplex communication systems.	5
2	Analog and digital signal systems	- Differentiate digital and analogue system of communication - State laws of digital numbers and their representation - Point out advantages and disadvantages of digital and analogue - Judge which system best to use in communication systems.	8
3	Mobile communication systems	- Differentiate telephone and radio transmission	2
4	Radio transmission and reception (AM, FM, PM)	- Identify and explain modulations used in communication - Differentiate terms AM, FM and PM radio transmission operations	3
5	End unit assessment		2

Lesson 1: Types of information and requirements

a) Learning objectives

- Explain types of information used in communication
- Explain terms used in communication systems
- Identify and explain simplex, duplex and multiplex in Communication
- Distinguish simplex from duplex communication systems

b) Teaching resources

- Search internet, Library, Journals and computer simulations
- Projectors, videos

c) Prerequisites/Revision/Introduction

- Students Teachers have a need to know Telecommunication terms and concepts. Remember, these students studied telecommunication in S3 unit 13.
- The Tutor introduces his/her lesson by giving a recap/overview so that Students can connect/link what they studied in Ordinary Level to this unit.

d) Learning activity 8.1

Guidance on the learning activity 8.1

The learning activity 8.1 aims at capturing student-teachers' attention and develops critical thinking and collaboration in them. The Student-teachers are encouraged to work together to answer the questions in the activity given.

- Decide on the methodology to use while students are attempting this activity.
- Give them clear guidelines on how to attempt these questions. Reflect on your lesson plan.
- Facilitate your student-teachers while they are attempting the questions.
- When they finish (after a reasonable time for this activity), you may either decide to mark their work.

- Harmonise by letting other student-teachers to give their suggestions while complementing and adding to their views. Remember to put emphasize on cross cutting issues addressed in this lesson.
- Let student-teachers write summary of important concepts in their note books.

Answers for learning activity 8.1

1. The two people are speaking using telephones
2. It depends. Both the sender and the receiver are interchanging the role, because a receiver must wait to receive, and the sender will wait for the feedback of the message.
3. The information being transmitted is good because interlocutors are smiling.
4. There are instructional, command, advisory, answers, historical and predictive information.
5. They are using wire telephones. They are digital telephones

Answers for Application activities 8.1

1. A 2. B 3. A

4. - Simplex transmission is a single one-way base band transmission

- Half-duplex transmission is an improvement over simplex transmission because the traffic can travel in both directions.

- Full-duplex transmission operates like a two-way, two-lane street. Traffic can travel in both directions at the same time.

5. Frequency range and time period over which channel remains constant is referred as coherence bandwidth and coherence time respectively

Lesson 2: Analogue signal system

a) Learning objective

- Differentiate digital and analogue system of communication
- State laws of digital numbers and their representation

- Point out advantages and disadvantages of digital and analogue
- Judge which system best to use in communication systems

b) Teaching resources

Textbooks, Internet simulations, Search internet, phones, Radio set, a computer set.

c) Prerequisites/Revision/Introduction

Student-teachers have learnt a lot in Telecommunication terms and concepts in the previous lesson. Also they have studied telecommunication in S3 unit 13.

The Tutor introduces his/her lesson by giving a recap/overview so that Student-teachers can connect/link what they studied and the new lesson.

d) Learning activity 8.2

Guidance to the learning Activity 8.2

The activity 8.2 aims at capturing student-teachers' attention and minds towards the concept of Analogue and Digital Signals.

- Divide your student-teachers into small groups (Grouping may depend on the nature of your class, the number of materials you have or number of learners).
- Always take care of slow student-teachers and any student-teacher with any kind of educational need while making groups (hearing, reading, seeing, etc.).
- Help student-teachers to get materials needed in this activity.
- You may give a brief introduction about the activity and distribute the materials in groups.
- Ask learners connect the materials as instructed in the activity 8.2 Learner's Book. While learners are doing this activity, you move around, guide the slow learners. While guiding, it is an opportunity to ask some questions on the activity and mark them.
- When everyone has finished the activity, invite some member(s) of group(s) to present their findings to the whole class. Guide the presentation.

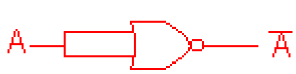
- Note some misconceptions and misunderstanding (if any) so that they are corrected and harmonised in the lesson. Together with students harmonize the points and make a summary on the board. Give to learners the opportunity to write the main points in their notebooks.
- Harmonize the lesson by linking what have discussed and the summary of the lesson.
- Summarize your lesson by linking the concepts of analogue and digital signals in telecommunication system to real life situations.

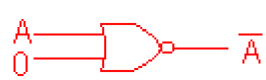
Answers for learning activity 8.2

1. It is getting to the speaker by air medium. They are mechanical waves.
2. Also the message is getting to the audience by means of air as channel. This method is used in mobile phone communication, radio transmitter and radio receiver.
3. The message is converted by the microphone into electrical signals then into electromagnetic waves travelling in air. At the loud speaker, the received electromagnetic waves are connected into electric signals then into sound waves.
4. If this happens, it would be bad. Because our phones would be fixed one. You cannot move with. It will be an analogue period time we shifted from.

d) Answers for Application activities 8.2

1. B
2. D
3. B
4. B
5. Wiring the NOR gate to become an inverter:





6. Truth table

A	B	C	$A+B$	$B.C$	$\overline{A+B}$	$\overline{A+B}+B.C$
0	0	0	0	0	1	1

0	0	1	0	0	1	1
0	1	0	1	0	0	0
0	1	1	1	1	0	1
1	0	0	1	0	0	0
1	0	1	1	0	0	0
1	1	0	1	0	0	0
1	1	1	1	1	0	1

Lesson 3: Mobile communication systems

a) Learning objective

Differentiate telephone and radio transmission

b) Teaching resources

- Mobile phone, radio receiver, search internet and physics textbooks, Library, Journals and computer simulations
- Projectors, videos

c) Prerequisites/Revision/Introduction

Student-teachers studied a bloc diagram of general communication system in S3 ordinary Level Unit 13. Using this prerequisite knowledge and concepts learnt previously, the Tutor should introduce the new lesson easily.

d) Learning activities 8.3

Guidance to the learning activity 8.3

The learning activity 8.3 has a purpose of capturing students' attention and develops critical thinking and problem solving competences in them. The Student-teachers are encouraged to work collaboratively in groups to answer the questions given this activity.

- Decide on the methodology to use while students are attempting this activity.
- Reflect on your lesson plan and give clear instructions in this activity.
- Facilitate your student-teachers while they are attempting the questions.
- When they finish (after a reasonable time for this activity), you may either decide to mark their work.
- Harmonise by letting other student-teachers to give their suggestions while complementing and adding to their views. Let student-teachers write summary in their notebooks. Remember to put emphasize on cross cutting issues addressed in this lesson.

Answers for Learning Activity 8.3

a) There are 3 small cells and one macro cell in the picture.
b) In this figure, there are one big master (antenna Tower or principal Base Station) and three small masters (auxiliary Base Stations).
c) In different cells there are masts which have a role of amplify signals from the major mast.
d) While transmitting network in the targeted area, the area is divided into small portions to facilitate the transmission of network in different users. In fact the network is weak when reaching these small portions. Therefore another small base station must be there to amplify the network so that users get a strong signal network for their mobile phone.
e) In urban areas, the number of cells must be greater than those in rural area because in urban areas there are lots of network increases in demand by users than in rural areas.

e) Answers for Application activities 8.3

1. a) BTS stands for Base Transceiver Station

b) BSC stands for Base Station Control

c) PSTN stands for Public Switched Telephone Network

2a) Cell is the basic geographic unit of a cellular system. **Cells** are base stations transmitting over small geographic areas that are represented as hexagons. Each cell size varies depending on the landscape.

b) Handoff occurs when the mobile unit moves out of the coverage area of a given cell site, the reception becomes weak. At this point, the cell site in use requests a handoff. The system switches the call to a stronger-frequency channel in a new site without interrupting the call or alerting the user. The call continues as long as the user is talking, and the user does not notice the handoff at all.

c) Frequency reuse: Cells with the same number have the same set of frequencies. Here, because the number of available frequencies is 7, the frequency reuse factor is 1/7. That is, each cell is using 1/7 of available cellular channels.

Lesson 4: Radio transmission and reception (AM, FM, PM)

a) Learning objective

- Identify and explain modulations used in communication
- Differentiate terms AM, FM and PM radio transmission operations

b) Teaching resources

– Search internet, Library, Journals and computer simulations
– Projectors, videos

c) Prerequisites/Revision/Introduction

Student-teachers studied a bloc diagram of general communication system in S3 ordinary Level Unit 13. The Tutor should introduce the new lesson easily by using this prerequisite knowledge and concepts learnt previously.

d) Learning activity 8.4

Guidance to the learning activity 8.4

The Student-teachers are encouraged to work together to answer the questions in this activity. The learning activity 8.4 aims at capturing student-teachers' attention and develops critical thinking and collaboration in Student-teachers. Referring to his/her Lesson plan, the Tutor will decide on the methodology to use while student-teachers are attempting this activity.

- Give them clear guidelines on how to attempt these questions. Ensure that all Student-teachers are fully involved: slow student-teachers and ones with special needs.
- Facilitate your student-teachers and engage them in a constructive discussion while they are attempting the questions.
- When they finish (after a reasonable time for this activity), you may should decide to mark their work.
- Harmonise by letting other students to give their suggestions while complementing and adding to their views. Help student-teachers appreciate cross cutting issues addressed in this lesson.

Answers for learning activities 8.4

a) The role of the antenna of the radio receiver is to capture radio signals from the radio emitter station (or from the nearer antenna tower).
b) They come from the radio emitter.
c) The electromagnetic waves are received by the antenna, and then converted into electrical signals and radio frequency to be converted into sound waves by the microphone of the receiver.
d) No she can’t. The microphone which converts electrical signals into sound is damaged.
e) FM stands for Frequency modulation, MW stands for Medium Waves and SW stands for Short Waves.

e) **Answers for application activity 8.4**

1. The process of frequency translation at the transmitter is called **modulation** while the process of recovering the audio-signal at the receiver is called **demodulation**.
2. A power amplifier is an electronic device used to increase the magnitude of voltage/current/power of an input signal. It takes in a weak electrical signal/waveform and reproduces a similar stronger waveform at the output by using an external power source.

3. Different types of analog modulation are: frequency modulation, amplitude modulation and phase modulation.

4. Both FM and AM receivers employ super heterodyne principle. However, the following are the points of differences between the two types of receivers:

(*i*)An FM receiver has two additional stages *that is* limiter and discriminator, which are quite different from an AM receiver.

(*ii*)FM broadcast signals lie in the frequency range between 88 and 108 MHz whereas AM broadcast signals lie in the frequency range from 540 kHz to 1600 kHz.

(*iii*)FM receivers are free from interference and this means that much weaker signals can be successfully handled.

(*iv*) FM bandwidth is about 200 kHz compared to 10 kHz bandwidth for AM.

(*v*) The IF for FM receivers is 10.7 MHz whereas IF for AM receivers are 455 kHz.

8.6. Summary of the unit

Information transmission in a communication system

The signals from information source are added to the carrier in the modulator. The modulated signal is sent along a channel in the propagating medium by a transmitter. The propagation medium is a channel through which information is transmitted. This may be a cable or a free space.

Communication Terms and Concepts

– Communication	Communicator
– Message	Medium
– Noise	Environment
– Feedback	Levels

Elements of communication

- Sender	Receiver
- Message	Channel
- Feedback

Types of information and requirements

- Constructional/creative information
- Operational information
- Communicational information

Simplex transmission

Simplex transmission is a single one-way base band transmission. Simplex channels are not often used because it is not possible to send back error or control signals to the transmit end.

Half-duplex communications

Half-duplex transmission is an improvement over simplex because the traffic can travel in both directions. Full-duplex networking technology increases performance because data can be sent and received at the same time.

Bandwidth and signal Frequency

The bandwidth of a composite signal is the difference between the highest and the lowest frequencies contained in that signal.

Mathematically, the bandwidth is given by:

$$B_W = f_u - f_l$$

$BW = f_{USB} - f_{LSB}$

Where f_u and f_l stand for upper side band and lower side band respectively.

Elements of communication

Analogue signal system

Analogue systems operate with values that vary continuously and have no abrupt transitions between levels.

Analog signals

Analog signal is a continuous signal that contains time varying quantities. An analog signal is a continuous wave denoted by a sine wave and may vary in signal strength (amplitude) or frequency (time).

Digital signals

Unlike analog technology which uses continuous signals, digital technology encodes the information into discrete signal states. Numerous and very successful applications of digital technology include the continuously growing number of PC's, the communication network ISDN as well as the increasing use of digital control stations (Direct Digital Control: DDC).

Advantages of digital technology

• More capacity from the same number of frequencies.
• Consistent voice clarity at low received signal levels near the edge of coverage.
• Data is defined in the standard.
• Secure transmissions.

Logic gates

There are three basic logic gates each of which performs a basic logic function, they are called NOT, AND and OR. All other logic functions can ultimately be derived from combinations of these three.

Concepts of transmission system

In telecommunication, a communication system is a collection of individual communication networks, transmission systems, relay stations, tributary stations, and data terminal equipment (DTE) usually capable of interconnection and interoperation to form an integrated whole.

Principle of cellular radio

The cellular concept is a major breakthrough in solving the problem of spectral congestion and user capacity. It involves dividing the area into small parts called cells. The neighboring base stations are assigned different groups of channels so that the interference between base stations (and the mobile users under their control) is minimized. It offers very high capacity in a limited spectrum allocation without any major technological changes.

Structure of cellular network

An overall cellular network contains a number of different elements from the base transceiver station (BTS) itself with its antenna back through a base station controller (BSC) and a mobile switching center (MSC) to the location registers (HLR and VLR) and the link to the public switched telephone network (PSTN).

The BSC is often co-located with a BTS. The BSC interfaces with the mobile switching centre. This makes more widespread choices about the routing of calls and interfaces to the land line based PSTN as well as the HLR and VLR.

Principle of cellular network

Because the amount of frequency spectrum available for mobile cellular use was limited, efficient use of the required frequencies was needed for mobile cellular coverage. In modern cellular telephony, rural and urban regions are divided into areas according to specific provisioning guidelines.

Modulation techniques

Modulation is a technique used for encoding information into a RF channel. There are a few general types of modulation; Frequency Modulation (FM), Phase Modulation (PM), and Amplitude modulation (AM).

8.7 Additional Information for tutor

Some elements of block diagram of telecommunication

1. **Transmission channel** which is the electric medium that bridges the distance from source to destination
2. **The receiver** to convert the received signal in a form appropriate for the output transducer after amplifying, filtering, demodulating and decoding it
3. **Output transducer** to convert the output electrical signal the desired message form
4. **Modulation** is defined as the process by which some characteristics (i.e. amplitude, frequency, and phase) of a carrier are varied in accordance with a modulating wave.
5. **Encoding** is the process of coding the message and changes it in the language understandable by the transmitter. This operation is realized at the transmitting end
6. **Demodulation** is the reverse process of modulation, which is used to get back the original message signal. Modulation is performed at the transmitting end whereas demodulation is performed at the receiving end.
7. **Decoding** is the reverse process of encoding to retrieve the original message and make it human understandable message. It is realized at the receiving end
8. **Antennas** which are aerials used to transmit and receive the signals.
9. **The oscillators** which are the sources of carrier signals which are used to modulate and help the original signal to reach the destination

10. The signal normally, must be raised at a level that will permit it to reach its destination. This operation is accomplished by **amplifiers**

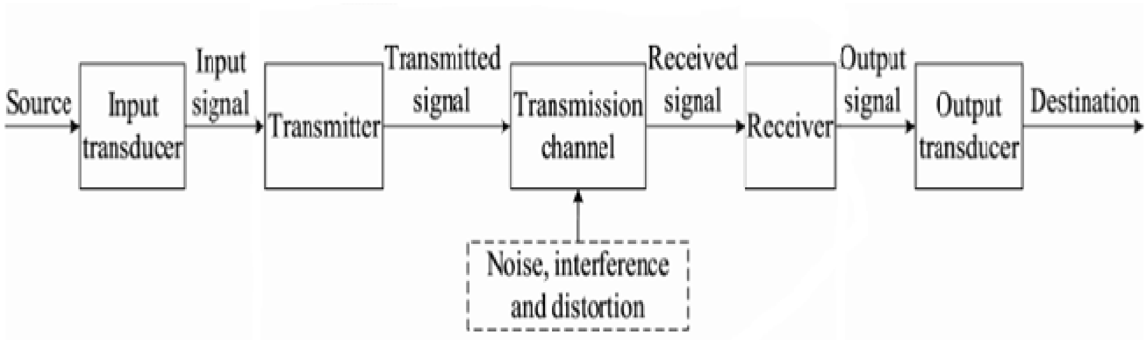


Fig.8. 1 Block diagram of telecommunication

Telecommunication and society

The societal importance of telecommunications is well accepted and broadly understood, reflected in its near ubiquitous penetration and use. Noted below are some of the areas of impact:

- Telecommunication provides a technological foundation for societal communications.

Communication plays a central role in the fundamental operations of a society from business to government to families. In fact, communication among people is the essence of what distinguishes an organisation, community, or society from a collection of individuals. Communication from web browsing to cell phone calling to instant messaging has become increasingly integrated into how we work, play and live.

- Telecommunications enable participation and development. Telecommunications plays an increasingly vital role in enabling the participation and development of people in communities.

- Telecommunications provides vital infrastructure for national security. From natural disaster recovery, to homeland security, to communication of vital intelligence to continued military superiority, telecommunication plays a pivotal role.

It is difficult to predict the impact of telecommunications technologies, services and applications that have not yet been invented. For example, in the early days of research and development into the internet in the late 1960s, who could have foreseen the full impact of the internet's which widespread use today?

GUIDANCE ON SKILLS LAB 8

- At the end of this unit of Analogue and Digital in Telecommunication, the Tutor assigns an activity of skills lab in which Students teachers will conduct a survey to identify different devices used in telecommunication in a chosen village near the school.

- Student-teachers will carry out this activity in pairs if possible.

- The Tutor will give them instructions as indicated in learner's book. He/ She choose a suitable moment to carry out this activity.

- The following chart should be used to collect information.

Device	Number of family	Wireless devices	Non wireless devices	%

- The total number of family will be given by local authorities. They will be helping in this activity.
- The guidance of the Tutor is needed here and this will help him to work hand in hand with local authorities and student teachers.
- After getting information, the student-teachers will present their findings and the Tutor will mark reports of his/her student-teachers.

8.8 END UNIT ASSESSMENT (Answers)

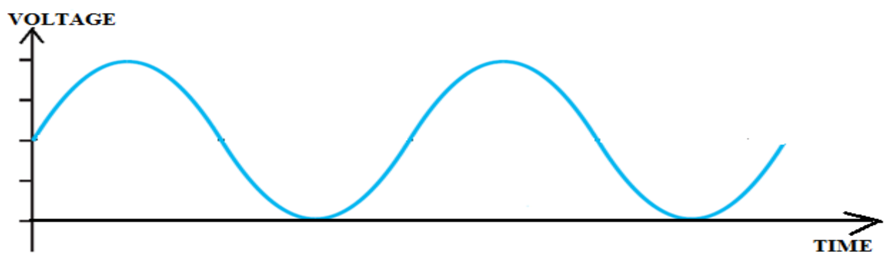
1. (i)
2. (ii)
3. (iii)
4. (i)
5. (ii)
6. (iii)
7. (iii)
8. (i)
9. (ii)
10. (iii)
11. (iv)
12. (i)

13. (ii)		15. (iv)		17. (iii)

14. (i)		16. (i)

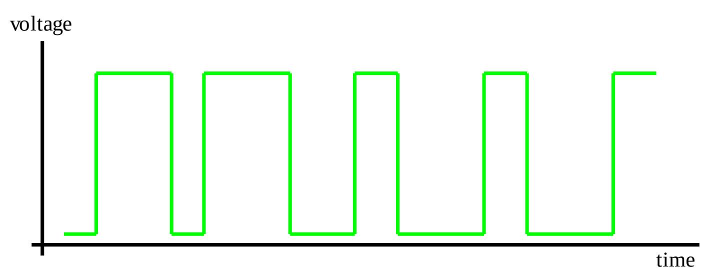
18. **Telecommunication** in real life is the **transmission** of signals and other types of data of any nature by wire, radio, optical or other electromagnetic systems of communication. Telecommunication occurs when the exchange of information between communicating participants includes the use of signs or other technologically based materials such as telephone, TV set, radio receiver, radio emitter, computer, and so on. All can be done either mechanically, electrically or electronically.

19. a) (i)



(ii) Human voice, public address system, analog electronic devices.

b) (i)



(ii) Computers, CDs, DVDs, and other digital electronic devices.

20. a) A is analog clock while B is digital

b) Truth table

A	B	$C=(A\oplus B)$	$D=\left(\overline{A\oplus B}\right)$	$E=(A\odot B)$	$X=(E\oplus D)$
0	0	0	1	0	1
1	0	1	0	0	0
0	1	1	0	0	0
1	1	1	0	1	1

8.9. Additional activities (Questions and answers)

8.10.1 Remedial activities

1. One of the following is used for satellite communication

A. Radio waves C. Microwaves
B. Light waves D. All of these

2. When the modulating signal controls the frequency of the carrier, we get,............

(i) Phase modulation
(ii) Amplitude modulation
(iii) Frequency modulation
(iv) May be any one of the above

3. Modulation refers to a low-frequency signal controlling the ....

(i) amplitude of the carrier
(ii) frequency of the carrier
(iii) phase of the carrier
(iv) may be any of the above

4. The two basic types of signals are analog and:

A. Digilog
B. Digital

C. Vetilog
D. Sine wave

5. A) what do you understand by the term amplifier?

B) Explain different types of Modulation

6. Complete the chart below. Give the correct term or description where it misses.

Terms	Description
1.	A party to whom the sender transmits the message.
2. Channel	
3. Noise	
4.	4. The process of sharing the messages through continuous flow of symbols
5. Code	

8.10.2 Consolidation activities

1. Which of the following characterizes an analog quantity?

A. Discrete levels represent changes in a quantity.
B. Its values follow a logarithmic response curve.
C. It can be described with a finite number of steps.
D. It has a continuous set of values over a given range.

2. Which type of signal is represented by discrete values?

A. Noisy signal
B. Nonlinear
C. Analogue

D. Digital

3. An analog signal continuous in both-------------and-----------------

A. frequency, power
B. Time, amplitude
C. Segments, Packets

4. Analog signals is a measured response to changes in a ---------------

A. Bus
B. Base
C. Physical phenomena
D. Thick net

5. Modulation is defined as:

A. Another method of conveying an analog signal
B. The beginning and ending bits of an analog signal
C. Away to convert analog in to a digital signal
D. A method of marking an analog frequency higher

6. ----------------is both discrete and quantized.

A. Digital signal
B. Analog signal
C. Modulated signal
D. Synchronized signal

7. Analog Circuit do not involve quantization of information into digital format

A. True

B. false

8. Using a table, compare analog and digital signals. In your table, include the following:

Signal transmission, waves, representation, examples and data transmission.

9. Design electrical circuits for AND gate, OR gate and NOT gate.

8.10.3 Extended activities

1. With a block diagram explain the following elements of telecommunication system: Transmitter and Receiver

2. Discus briefly positive impact of telecommunication in development of a country like Rwanda.

8.10.4 Answers for additional activities

A. Answers for remedial activities

1. A	2. (iii)
3. (iv)	4. B

5. A) The amplifier amplifies the modulated carrier wave to increase its power. The more powerful the amplifier, the more powerful the broadcast.

B) A**mplitude modulation** (AM), the amplitude of the high-frequency carrier wave is made to vary in proportion to the amplitude of the audio signal. It is called “amplitude modulation” because the *amplitude* of the carrier is altered (“modulate” means to change or alter).

Frequency modulation (FM), the *frequency* of the carrier wave is made to change in proportion to the audio signal’s amplitude. The mixed signal is amplified further and sent to the transmitting antenna where the complex mixture of frequencies is sent out in the form of electromagnetic waves.

Phase modulation (PM) encodes information as variations in the instantaneous phase of the carrier wave. It is widely used for transmitting radio waves and is an integral part of many digital transmission coding schemes that underlie a wide range of technologies like Wi-Fi, GSM and satellite television. In this type of modulation, the amplitude and frequency of the carrier signal remains unchanged after PM.

6. 1) Receiver

2) The specific mechanism used to transmit the message

3) Interference with the message

4) Communication

5) A suitable system for creating /carrying messages through a specific medium.

B. Answers for consolidation activities

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

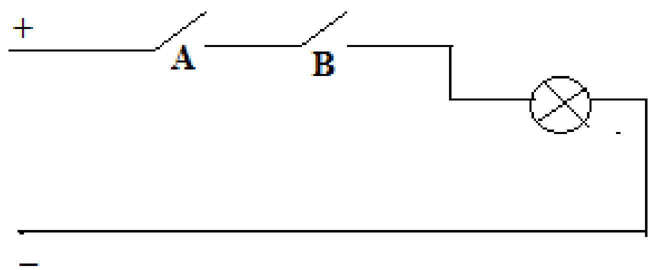
7. True

8. **Comparison between digital and analog signals**

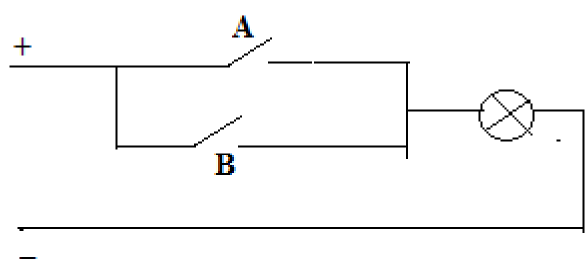
	Analog	**Digital**
Signal	Analog signal is a continuous signal which represents physical measurements.	Digital signals are discrete time signals generated by digital modulation.
Waves	Denoted by sine waves	Denoted by square waves
Representation	Uses continuous range of values to represent information	Uses discrete or discontinuous values to represent information

Example	Human voice in air, analog electronic devices	Computers, CDs, DVDs, and other digital electronic devices.
Data transmissions	Subjected to deterioration by noise during transmission and write/read cycle.	Can be noise-immune without deterioration during transmission and write/read cycle.

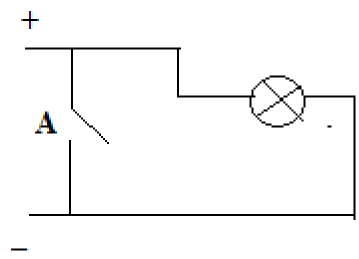
9. a) Circuit for AND gate



b) Circuit for OR gate



c) Circuit for NOT gate



C. Answers for extended activities

1. A transmitter is an electronic device used in telecommunications to produce radio waves in order to transmit or to send data with the aid of an antenna.

A receiver is a device that converts the received signal in a form appropriate for the output transducer after amplifying, filtering, demodulating and decoding it.

2. After discussion, the emphasis will be put on the following points:

- Improvement of total factor productivity, particularly in those industries that are ICT-intensive but also in Those that are not creation/ relocation of enterprises relocation of enterprises based on the availability of high capacity telecommunications networks (as one of many infrastructure factors) and quality of life (driven by availability of networks in schools, hospitals, public administration etc)

- Employment creation of employment as a result of relocation of companies searching for labour cost arbitrage.

- Creation of qualified self-employment resulting from the availability of communication networks.

- Creation of employment in manufacturing and installation of telecommunications equipment economic growth increase in efficiency of industries with high transaction costs (retail distribution, finance etc)

- Consumer surplus generated by the availability of new telecommunications services

UNIT 9: RELATIVITY CONCEPTS AND POSTULATES OF SPECIAL RELATIVITY

9.1. Key Unit competence:

Explain relativity Concepts and postulates of special relativity

9.2 Prerequisite (knowledge, skills, attitudes and values)

- Student-teachers need to be aware why there are changes in observed objects due to relative motion.
- Student-teachers should be aware of difference in the shapes seen by observers at different points in any reference flames.

9.3 Cross cutting issues to be addressed

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

9.4 Guidance to the introductory activity

This activity focuses at introducing relativity concepts and postulates of special relativity.

- Let the student-teachers turn to the introductory activity.
- Depending on the methodology you want to use, you may decide either student-teachers to copy the questions into their notebooks or discuss the questions in groups or the whole class.

- Give them time to brainstorm/answer/discuss the questions either as a group, class or as an individual. This can take some minutes.
- Allow them to present their findings either to the whole class or to the groups or to you depending on the method you used.
- Harmonize student-teachers' findings/answers as the whole class and come to a general understanding as the whole class.
- You can allow learners to note down important notes in their books for future reference.

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

Expected answers for the introductory activity.

a) Yes, Yves will be able to catch the ball because him and the projected ball are in the same reference frames.
b) Vertical motion
c) No. Diana observed a projectile type of motion.
d) No. As observed by Diana, the ball seemed to be moving at 60+5=65 km/s

9.5 List of lessons

#	Lesson title	Learning objectives	Number of Periods
1	Concept of relativity	- Explain frame of reference - Appreciate the significance of frame of reference in life - Explain and Interpret the two postulates of special theory of relativity - State two postulates of the special theory of relativity	7

2	RELATIVISTIC DYNAMICS	- Describe the concept of simultaneity. - Explain space, time, and mass. - Related space, time, and mass.	6
3	End unit assessment		2

Lesson 1: Concept of relativity

a) Learning objectives

- Explain frame of reference
- Appreciate the significance of frame of reference in life
- Explain and Interpret the two postulates of special theory of relativity
- State the two postulates of the special theory of relativity

b) Teaching resources

- Search internet, Library, Journals and computer simulations
- Projectors, videos

c) Prerequisites/Revision/Introduction

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

Unit 2 in S.1 and S.2 because learners need to have knowledge skills about motion.

d) Learning activities 9.1

Guidance to the activity 9.1

This lesson emphasizes on the concepts of relativity and postulates of special relativity.

- Tell learners to open their books (Learners book) to activity 9.1

- Decide on the methodology to use in this lesson. You can group your learners; they can do it as a class or individual.
- Instruct them to read the activity first and then re-write the questions to their notebooks.
- Allow them to attempt the questions.
- Move around and mark their work.
- Select some students to share their Answers for the whole class and allow questions from students if any. Create a favorable environment for learners to discuss.
- Together with student's ideas, link their Answers for Relativity concepts and postulates of special relativity.
- Make a summary (using student-teachers' findings) and tell learners to write down important ideas in their books.

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

Answers for the activity 9.1.

a) No.
b) It is because in accordance to relativity, Shyaka was at rest relative to motion of the car while the observed objects (trees, Stones Mountains etc.) are in motion with respect to the car.
c) This is because the two frames seem to be stationary relative to one another. Hence the speeding car (the one to overtake) will seem to be at rest.

e) Answers for Application activities 9.1

1. In the rest frame,

$$p_i = m_1 v_{1i} + m_2 v_{2i} = 2000 \times 20.0 + 1500 \times 0 = 4.00 \times 10^4 \ kg \cdot m/s$$

$$p_f = (m_1 + m_2) v_f = (2000 + 1500) v_f$$

Since $p_i = p_f \Leftrightarrow v_f = \dfrac{4.00\times 10^4}{2000+1500} = 11.429\, m/s$

In the moving frame, these velocities are all reduced by +10.0 m/s.

$v'_{1i} = v_{1i} - v' = 20.0 - 10.0 = 10.0\, m/s$

$v'_{2i} = v_{2i} - v' = 0 - 10.0 = -10.0\, m/s$

$v'_f = v_f - v' = 11.429 - 10.0 = 1.429\, m/s$

Our initial momentum is then $p'_1 = m_1 v'_{1i} + m_2 v'_{2i} = 2000\times 10.0 + 1500\times(-10.0) = 5\,000\, kg\cdot m/s$

And our final momentum is $p'_f = (m_1 + m_2)v'_f = (2000 + 1500\times 1.429 = 5\,000\, kg\cdot m/s$

2. a) $v = v_T + v_B = 60.0\, m/s$ b) $v = v_T - v_B = 20.0\, m/s$

c) $v = \sqrt{v_T^2 + v_B^2} = \sqrt{20^2 + 40^2} = 44.7\, m/s$

3. The first observer watches some object accelerate under applied forces. Call the instantaneous velocity of the object v_1. The second observer has constant velocity v_{21} relative to the first, and measures the object to have velocity $v_2 = v_1 - v_{21}$.

The second observer measures an acceleration of $a_2 = \dfrac{dv_2}{dt} = \dfrac{dv_1}{dt}$

This is the same as that measured by the first observer. In this non relativistic case, they measure the same forces as well. Thus, the second observer also confirms that $\sum F = ma$.

4. Let the positive *x*-direction be north $v_{Y/E} = 88\, km/h$ and $v_{T/E} = -104\, km/h$

a) The truck's velocity relative to you:

$$v_{T/y} = v_{T/E} + v_{E/Y} = -104\,km/h - 88\,km/hs = -192\,km/h$$

The truck is moving at $192\,km/h$ in the negative *x*-direction (south) relative to you.

b) Your velocity relative to the truck $v_{Y/T} = -v_{T/y} = 192\,km/h$

c) The relative velocities do *not* change after you and the truck pass each other. The relative *positions* of the bodies don't matter. After it passes you the truck is still moving at $192\,km/h$ toward the south relative to you, even though it is now moving away from you instead of toward you.

Lesson 2: Relativistic dynamics.

a) Learning objective

-Describe the concept of simultaneity

-Explain space, time, and mass

-Related space, time, and mass

b) Teaching resources

- Search internet, Library, Journals and computer simulations
- Projectors, videos

c) Prerequisites/Revision/Introduction

Through guided discovery, assist learners to discover what relativistic tendencies are.

- Linear motion (S.1 and S.2 unit 2)

d) Learning activities 9.2

Guidance on learning activity 9.2

This lesson focuses on making student-teachers understand apply the concept of relativistic dynamics.

- Tell student-teachers to turn to activity 9.7 in student-teacher's book and interpret the statement.
- Divide your class into different groups (Choice is yours about methodology depending on the type of your class)
- Leave the learners to perform the activity by themselves. Give them enough time to work out the questions.
- Invite 2 or 3 (or any number of groups depending on how many you had formed) to present their findings. Let them discuss by themselves
- Ask other members of the class to whether they have similar answers from what others have presented.
- Together with student-teachers, consolidate and come to a common understanding of different answers that rose from student-teachers/different groups.

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

Answers for activity 9.2

This question do not have exact answer. Any answer that brings in the concept of relativistic dynamics.

Eg. The day you are busy, time seem to move/fly faster because your brain is working at a faster rate hence making time to fly faster.

e) Answers for Application activities 9.2

1. (*a*) The given 10.0 min time interval is the proper time t_p—starting and finishing the magazine happen at the same place on the spaceship. Earth clocks measure

$$\Delta t = \frac{\Delta t_p}{\sqrt{1-\left(\frac{v}{c}\right)^2}} = \frac{10.00\ \text{min}}{\sqrt{1-\left(\frac{0.75\,c}{c}\right)^2}} = 15.1\ \text{min}$$

(b) In Earth frame, the rocket travels a distance

$$d = vt = (0.75\times 3\times 10^8\ m/s)(15.1\ \text{min}\times 60\ s/\text{min}) = 2.04\times 10^{11}\ m$$

In the space's frame, the Earth is moving away from the spaceship at $0.75\,c$, but the time is only 10.0 min, so the distance is measured to be

$$d = vt = (0.75\times 3\times 10^8\ m/s)(15.1\ \text{min}\times 60\ s/\text{min}) = 1.35\times 10^{11}\ m$$

2. (*a*) Earth observers see the ship as contracted $L = L_p\sqrt{1-\left(\frac{u}{c}\right)^2} = 23\sqrt{1-\left(\frac{0.75\,c}{c}\right)^2} = 15\ m$

(*b*) Earth observers see the launch as dilated (lengthened) in time, as given by

$$\Delta t = \frac{\Delta t_p}{\sqrt{1-\left(\frac{v}{c}\right)^2}} = \frac{28\ \text{min}}{\sqrt{1-\left(\frac{0.75}{c}\right)^2}} = 42\ \text{min}$$

9.6 Summary of the unit

The special theory of relativity is based on the two basic postulates:

- The laws of physics must be the same in all inertial reference frames.

-The speed of light in vacuum has the same value, $c = 3\times10^{8}\ m/s$ in all inertial frames, regardless of the velocity of the observer or the velocity of the source emitting the light.

Three consequences of the special theory of relativity are

- Events that are simultaneous for one observer are not simultaneous for another observer who is in motion relative to the first.

- Clocks in motion relative to an observer appear to be slowed down by a factor $\gamma = \dfrac{1}{\sqrt{1-(\frac{v}{c})^{2}}}$

This phenomenon is known as time dilation.

- The length of objects in motion appears to be contracted in the direction of motion by a factor γ This phenomenon is known as length contraction.

9.7 Additional Information for tutor

The Twin Paradox

Describe how the concept of time dilation leads to the "twin paradox". Different observers' versions of the time taken for a journey at speeds close to the speed of light may be compared. Students should be aware that, since one of the twins makes an outward and return journey, this is no longer a symmetrical situation for the twins

An intriguing consequence of time dilation is the so-called **twin paradox**. Consider an experiment involving a set of twins named Speedo and Goslo. When they are 20 yr old, Speedo, the more adventuresome of the two, sets out on an epic journey to Planet X, located 20 ly from the Earth. (Note that 1 light year (ly) is the distance light travels through free space in 1 year.) Furthermore, Speedo's spacecraft is capable of reaching a speed of 0.95 c relative to the inertial frame of his twin brother back home.

After reaching Planet X, Speedo becomes homesick and immediately returns to the Earth at the same speed 0.95 c. Upon his return, Speedo is shocked to discover that Goslo has aged 42 yr and is now 62 yr old. Speedo, on the other hand, has aged only 13 yr. At this point, it is fair to raise the following question—which twin is the traveler and which is really younger as a result of this experiment?

From Goslo’s frame of reference, he was at rest while his brother traveled at a high speed away from him and then came back. According to Speedo, however, he himself remained stationary while Goslo and the Earth raced away from him and then headed back. This leads to an apparent contradiction due to the apparent symmetry of the observations.

Which twin has developed signs of excess aging?

The situation in our current problem is actually not symmetrical. To resolve this apparent paradox, recall that the special theory of relativity describes observations made in inertial frames of reference moving relative to each other.

Speedo, the space traveler, must experience a series of accelerations during his journey because he must fire his rocket engines to slow down and start moving back toward Earth.

As a result, his speed is not always uniform, and consequently he is not in an inertial frame. Therefore, there is no paradox—only Goslo, who is always in a single inertial frame, can make correct predictions based on special relativity. During each passing year noted by Goslo, slightly less than 4 months elapses for Speedo.

Only Goslo, who is in a single inertial frame, can apply the simple time-dilation formula to Speedo’s trip. Thus, Goslo finds that instead of aging 42 yr, Speedo ages only:

$$\Delta t_p = \frac{\Delta t}{\gamma} = \Delta t\sqrt{1-\left(\frac{v}{c}\right)^2} = 42\sqrt{1-\left(\frac{0.95c}{c}\right)^2} = 13\ yr\ .$$

Thus, according to Goslo, Speedo spends 6.5 yr traveling to Planet X and 6.5 yr returning, for a total travel time of 13 yr, in agreement with our earlier statement.

If the travelling twin maintains a speed of 50 % the speed of light for one year (according to a clocks aboard the spaceship) 1.15 years will have elapsed on Earth. At 99.5 % the speed of light for one year then 10 earth years would pass one spaceship year.

In this example, 42 years would pass on Earth, whereas only 13 years would pass for the astronaut (Goslo) on the trip. Is it just the clocks that would slow down for the astronaut?

No. All processes, including aging and other life processes, run more slowly for the astronaut as measured by an Earth observer. But to the astronaut, time would pass in a normal way.

The astronaut would experience 13 years of normal sleeping, eating, reading, and so on. And people on Earth would experience 42 years of ordinary activity.

What causes time dilation?

Are measurements made in the rod's frame of reference invalid because it is moving? No, all inertial frames of reference are equivalent; none is favoured. In any case, an experimenter on the rod is perfectly entitled to say that it is the laboratory which is moving!

Has the electronics of the rod's clock been affected by its motion? No; the laws of Physics are the same in all inertial frames. Nothing is different about the way the clocks run in the two frames.

Anyway, in the rod's frame it is the laboratory clocks that are moving. So what does cause time dilation? It is the non-independence of space and time, as acknowledged in the term, space-time. The time interval between two events is least when measured in a frame of reference in which the events occur at the same place. It is greater in a frame of reference in which the events occur in different places, and there-fore have to have their times recorded by different clocks

GUIDANCE ABOUT SKILLS LAB 9

This activity aims at making students analyze the effects of relativity in real life. This activity is based on imagination or what students have ever observed in their daily life.

- Make your students try to understand why they are to do this imaginary activity.
- Leave them to research about the guiding questions.
- Your role here is to see whether the activity is well done.

9.8. END UNIT ASSESSMENT (Answers)

1. C 2.C 3.C 4.D 5.E 6.D

7. (a) If an observer were to move along with the muon (the muon would be at rest to this observer), the muon would have a mean life of $T_p = 2.2\times10^{-6}\ s$. To an observer in the lab, the muon lives longer because of time dilation.

From $\Delta t = \dfrac{\Delta t_p}{\sqrt{1-\left(\dfrac{v}{c}\right)^2}} = \dfrac{2.2\times10^{-6}\ s}{\sqrt{1-\left(\dfrac{0.36\,c}{c}\right)^2}} = 2.8\ \mu s$

(b) At a speed of $v = 1.8\times10^{8}\ m/s$, classical Physics would tell us that with a mean life of $2.2\ \mu s$, an average muon would travel $d = vt = (0.60\times3\times10^{8}\ m/s)(2.2\times10^{-6}\ s) = 400\ m$.

But relativity predicts an average distance of $d = vt = (0.60\times3\times10^{8}\ m/s)(2.8\times10^{-6}\ s) = 500\ m$

8. $\Delta t = \dfrac{\Delta t_p}{\sqrt{1-\left(\dfrac{v}{c}\right)^2}} = \dfrac{3.0\ s}{\sqrt{1-\left(\dfrac{0.95\,c}{c}\right)^2}} = 9.6\ s$

That is, a moving pendulum takes longer to complete a period than a pendulum at rest does.

9.9. Additional activities (Questions and answers)

9.9.1 Remedial activities

1. Suppose you are driving your car on a business trip and are traveling at 30 m/s. Your boss, who is waiting at your destination, expects the trip to take 5.0 h. When you arrive late, your excuse is that your car clock registered the passage of 5.0 h but that you were driving fast and so your clock ran more slowly than your boss's clock.

a. If your car clock actually did indicate a 5.0 h trip, how much time passed on your boss's clock, which was at rest on the Earth?

b. If your car is 4.3 m long when it is parked, how much shorter does it appear to a stationary roadside observer as you drive by at 30 m/s?

2. Moving clocks run slow. Does this result have anything to do with the time it takes light to travel from the clock to your eye?

9.9.1. Consolidation activities

3. Two twins are 25.0 years old when one of them sets out on a journey through space at nearly constant speed. The twin in the spaceship measures time with an accurate watch. When he returns to Earth, he claims to be 31.0 years old, while the twin left on Earth knows that she is 43.0 years old. What was the speed of the spaceship?

4. In relativity, the order of two events in one frame may be reversed in another frame. Does this imply that there exists a frame in which I get off a bus before I get on it?

5. You are in a spaceship sailing along in outer space. Is there any way you can measure your speed without looking outside?

9.9.3. Extended activities

6. If you move at the speed of light, what shape does the universe take in your frame?

7. Two cells that subdivide on Earth every 10.0 s start from on a journey to the sun ($1.50\times10^{11}\ m$ away) in a spacecraft moving at 0.850 c. how many cells will exist when the spacecraft crashes into the sun?

Answers

1. a. Applying time dilation Equation, we find Δt, the time interval measured by your boss, to be

$$\Delta t = \frac{\Delta t_p}{\sqrt{1-\left(\frac{v}{c}\right)^2}} = \frac{5.0}{\sqrt{1-\left(\frac{0.30\,c}{c}\right)^2}} = 5.0\,h + 0.9\,ns$$

Your boss's clock would be only 0.9 ns ahead of your car clock. You might want to try another excuse!

b. The observer sees the horizontal length of the car to be contracted to a length

$$\Delta L = L_p - L = L_p\left[1-\sqrt{1-\left(\frac{u}{c}\right)^2}\right]$$

The roadside observer sees the car's length as having changed by an amount

$$\Delta L = (43\,m)\left[1-\sqrt{1-\left(\frac{30\,m/s}{3.00\times10^8\,m/s}\right)^2}\right] = 2.2\times10^{-14}\ m$$

This is much smaller than the diameter of an atom!

2. No. When we talk about how fast a clock is running in a given frame, we are referring to what the clock actually reads in that frame. It will of course take time for the light from the clock to reach an observer's eye, but it is understood that the observer subtracts off this transit time in order to calculate the time at which the clock actually shows a particular reading. Likewise, other

relativistic effects, such as length contraction and loss of simultaneity, have nothing to do with the time it takes light to reach your eye. They deal only with what really *is*, in your frame.

3. The spaceship clock as seen by the space-twin reads the trip time to be

$\Delta t_p = 31.0 - 25.0 = 6.0\ yr$

The Earth bound twin sees her brother age 6.0 yr but her clocks tell her that a time

$\Delta t = 43..0 - 25.0 = 18.0\ yr$ has passed.

Hence $\Delta t = \gamma \Delta t_p \Leftrightarrow \gamma = \dfrac{\Delta t}{\Delta t_p} = \dfrac{18.0}{6.0} = 3.0$

From which $\gamma = \dfrac{1}{\sqrt{1-\left(\dfrac{v}{c}\right)^2}} \Leftrightarrow v = c\sqrt{1-\dfrac{1}{\gamma^2}} = 2.96\times10^8\ m/s$

4. No. The order of two events can be reversed in another frame only if the events are space-like separated. That is, if $\Delta x > c\Delta t$ in other words, the events are too far apart for even light to get from one to the other). The two relevant events here (getting on the bus, and getting off the bus) are not space-like separated, because the bus travels at a speed less than *c*, of course.

They are time-like separated. Therefore, in all frames it is the case that I get off the bus after I get on it. There would be causality problems if there existed a frame in which I got off the bus before I got on it. If I break my ankle getting off a bus, then I wouldn't be able to make the fast dash that I made to catch the bus is the first place, in which case I wouldn't have the opportunity to break my ankle getting off the bus, in which case I could have made the fast dash to catch the bus and get on, and, well, you get the idea.

5. There are two points to be made here. First, the question is meaningless, because absolute speed does not exist. The spaceship does not have a speed; it only has a speed relative to something else. Second, even if the question asked for the speed with respect to, say, a piece of

stellar dust, the answer would be "no." Uniform speed is not measurable from within the spaceship. Acceleration, on the other hand, is measurable (assuming there is no gravity around to confuse it with).

6. The question is meaningless, because it is impossible for you to move at the speed of light. A meaningful question to ask is: What shape does the universe take if you move at a speed very close to c? The answer is that in your frame everything would be squashed along the direction of your motion. Any given region of the universe would be squashed down to a pancake.

7**.**According to earth observers, with respect to whom the cells are moving, the time taken for the trip to sun is the distance travelled (x) over the sped (v)

$$\Delta t = \frac{x}{v} = \frac{1.50 \times 10^{11}\ m}{(0.850\ c)(2.998 \times 10^{8}\ m)} = 588\ s$$

Because spacecraft clocks are moving with respect to the planet, they appear from earth to run more slowly. The time these clocks read is

$$\Delta t_s = \frac{\Delta t_m}{\gamma} = 310\ s$$

The cells divide according to the spacecraft clock, a clock that is at rest relative to them. They therefore undergo 31 divisions in this time, since they divide each 10.0 s. therefore the total number of cells present on crashing is

$$2^{31} = 2.1 \times 10^{9} \quad cells$$

UNIT 10: STELLAR DISTANCE AND RADIATION

10.1. Key Unit competence:

Explain stellar radiation and stellar distance

10.2 Prerequisite (knowledge, skills, attitudes and values)

- The success of this unit relies partly on the mastery of knowledge, skills acquired in Black body radiation studied in unit two in this year and general structure of the solar system.

10.3 Cross cutting issues to be addressed

- Inclusive education (promote education for all in teaching and learning process). Regardless of physical appearance and abilities learners should all be treated equally. This makes the learners to find out that they are all of great importance.
- Peace and value Education (respect others view and thoughts during class discussions). Remember that someone's idea is very important. It may be correct or Not but what is important is to build on that Idea.
- Gender (equal opportunity of boys and girls in the lesson participation). Care should be taken that both Sexes are given equal opportunities.

10.4 Guidance to the introductory activity

This activity aims at capturing student-teachers' attention and minds towards stellar distance and radiation.

- Divide your student-teachers into small groups (Grouping may depend on the nature of your class or number of learners you have.
- Tell the learners to open the introductory activity in the learner's book.
- Guide learners to re-write the questions and answer them following the instructions from learner'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 students)
- Together with students harmonize the points and make a summary on the board using a power point presentation. Allow learners to write the main points in their notebooks
- In case there is a student-teacher that needs special care, please try to help him or her.

Expected answers for introductory activity

a) The hottest is A. From junior science classes we learn that a blue Bunsen flame is hotter than the orange "safety" flame. This relationship holds true for stars as well.

b)i) ***blackbody***.

ii) Stars are massive spheres of gas, mostly hydrogen and some helium. They produce energy through thermonuclear fusion in their cores. Surface temperature, size and main sequence lifetime of stars

c) Hot objects are brighter than cold objects

d) See 10.1 ***Sun's atmosphere and interior in student-teacher's book.***

10.5 List of lessons

#	Lesson title	Learning objectives	Number of Periods
1	Sun's atmosphere and interior	- Explain sun's interior and atmosphere	4
2	Brightness and magnitude scale	- Identify the stars brightness and magnitude scale - Explain relative positions of	2

		the eight planets and the sun	
3	Types of stars and spectra of stars	- Identify star temperature and color from spectra. - Classify stars and planets. - Point out the existence of constellations - Illustrate star's spectra line	4
4	Stellar distance	- Explain stellar distance and masses	2
	End unit assessment		2

Lesson 1: Sun's atmosphere and interior

a) Learning objective

- Explain sun's interior and atmosphere

b) Teaching resources

- Search internet, Library, Journals and computer simulations
- Projectors, videos

c) Prerequisites/Revision/Introduction

- The success of this concept requires student-teachers in Black body radiation studied in unit two.

d) Learning activities 10.1

Guidance to the learning activity 10.1

This activity aims at capturing student-teachers' attention and minds about sun's atmosphere and interior.

- This is a research work activity. Make sure that student-teachers get the questions to research about.
- Give them guidelines on how to do the research. The findings should aim at studies on sun's interior and atmosphere.
- They can use different resources including internet. Ensure that reliable sources/links are used. Tell them that not all sources provide reliable information.
- When everyone is done and you are done, invite some member(s) or group(s) to discuss their findings from research to the whole class. They can use power point presentations.
- 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 learners to write the main points in their notebooks
- You can build on their findings to introduce your concept "Sun's composition)

Answers for the activity 10.1

Refer to student's book part 10.1.2

e) Answers for Application activities 10. 1

1. D

2. Since the mass of the atoms in the gas is not known $v_1 = \sqrt{\frac{8kT_1}{\pi m}}$ and $v_2 = \sqrt{\frac{8kT_2}{\pi m}}$

$$\frac{v_1}{v_2} = \sqrt{\frac{8kT_1}{\pi m} \times \frac{\pi m}{8kT_2}} = \frac{1}{2} \Leftrightarrow v_2 = 2v_1 = 10\ km/s$$

So the speed of the atoms is doubled when the temperature increases by a factor of four.

3. We can see the photosphere from Earth
4. The atmosphere of the sun is composed of several layers , mainly the photosphere, the chromospheres and the corona
5. See 10.12 Main layers of the sun's atmosphere in Student-Teacher book

6. Mercury is both small (low mass), and close to the Sun, so the thermal speed of the particles in the atmosphere is high and it is relatively easy for molecules to be going fast enough to escape the gravity of Mercury. Recall the escape velocity equation $v_e = \sqrt{\frac{2GM}{R}}$

Lesson 2: Brightness and magnitude scale

a) Learning objectives

- Identify the stars brightness and magnitude scale

- Explain relative positions of the eight planets and the sun

b) Teaching resources

– Search internet, Library, Journals and computer simulations
– Projectors, videos

c) Prerequisites/Revision/Introduction

For student-teachers need to have prior knowledge about black body radiation covered in Unit 2 specifically on how color changes as temperature increases.

d) Learning activities 10.2

Guidance to the learning activity 10.2

This activity aims at capturing student-teachers' attention and minds towards the concept of brightness and magnitude scale of stars.

- Divide your student-teachers into groups (Grouping may depend on the nature of your class or number of learners you have). Always take care of learners with any kind of educational need while making groups (hearing, reading, seeing, etc.).

- Tell the learners to open the activity and read the guidelines in the learner's book. You may give them a brief introduction about the activity

- Let the learners do the activity practically with materials provided by you. (These are torches/sources, meter rule and new dry cells)

- 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 learners the opportunity to write the main points in their notebooks.

-Harmonize the lesson by linking what have discussed and the summary of the lesson.

Answers for the activity 10.2.

Answers are what students observe from the experiment.

e) Answers for Application activities 10.2

1. To convert the observed brightness of a star (the apparent magnitude, m) to an absolute magnitude, we need to know the distance, d, to the star. Alternatively, if we know the distance and the apparent magnitude of a star, we can calculate its absolute magnitude.

2. However, the brightness of a star depends on its composition and how far it is from the planet. Astronomers define star brightness in terms of apparent magnitude (how bright the star appears from Earth) and absolute magnitude (how bright the star appears at a standard distance of 32.6 light years, or 10 parsecs)

3. Stars appear to have a brightness which we express in magnitude. Stars have a wide range of apparent brightness measured here on Earth. The variation in their brightness is caused by both variations in their luminosity and variations in their distance. An intrinsically faint, nearby star can appear to be just as bright to us on Earth as an intrinsically luminous, distant star.

4. Stefan-Boltzmann law $L = 4\pi\sigma(2R)^2T^4 = 4(4\pi\sigma R^2T^4) = 4L_s = 15.2\times10^{26}\ J$.

5. Stefan-Boltzmann law $L = 4\pi\sigma\left(\frac{R}{2}\right)^2(2T)^4 = 4(4\pi\sigma R^2T^4) = 4L_s = 15.2\times10^{26}\ J$

6. From Stefan-Boltzmann law $L = 4\pi\sigma R_s^2T^4$ and $L = 4\pi\sigma R^2T^4$

$$\frac{L}{L_s} = \frac{R^2}{R_s^2} = \frac{100\ L_s}{L_s} \Leftrightarrow R = 10\sqrt{R_s}$$

7. Use the magnitude–distance relation to find the distance to the Virgo cluster:

$$m - M = 5\log\frac{p}{10} \Leftrightarrow p = 10^{\frac{m-M+5}{5}} = 100^{\frac{26.3+5-5}{5}} = 1.8\times10^7\ pc = 18\ Mpc$$

Lesson 3: Types of stars and spectra of stars

a) Learning objective

- Identify star temperature and color from a spectra.
- Classify stars and planets.
- Point out the existence of constellations
- Illustrate star's spectra line

b) Teaching resources

– Search internet, Library, Journals and computer simulations
– Projectors, videos

c) Prerequisites/Revision/Introduction

Student-teachers need to apply knowledge about black bodies and spectrum of light emitted by a black body.

d) Learning activities 10.3

Guidance to learning Activity 10.3

This activity aims at introducing classes of stars.

- Assist learners to interpret questions in this activity.

- You can first discus about the statement "Stars are born, and stars die"

- When everyone is done you can mark them. Invite some member(s) or group(s) to discuss their Answers for the whole class. They can use power point presentations.

- Inquire from other student-teachers or groups whether their answers correspond to the ones discussed.

- Together with student-teachers harmonize the points and make a summary on the board. Allow learners to write the main points in their notebooks

Answers for the activity 10.3

a) At the start, hydrogen start fusing into hydrogen. This leads to the increase in mass, temperature, and Luminosity. Because of these changes, eventually, the star may burn all of its hydrogen and as a result it may explode (that is its death) into other features like new stars, black holes etc.

b) The Size increases. This is due to the fusion of hydrogen into helium. Some stars may not develop if the fusion of hydrogen is low. For more explanations refer to students' book.

e) Answers for Application activities 10.3

1. $t = t_s\left(\frac{M}{M_s}\right)^{-2.5} = 10^{10}\left(\frac{1.5\,M_s}{M_s}\right)^{-2.5} = 1.15\times10^{7}\ yr$

The lifetime of a star 15 times as massive as the Sun is almost a thousand times shorter

2. The energy released $E = Lt = (3.8\times10^{26}\ J/s)(10^{10}\ yr\times3.16\times10^{44}\ s/yr) = 1.2\times10^{44}\ J$

3. Using Wien's law: $T = \frac{2.90\times10^{-3}}{\lambda_m} = \frac{2.90\times10^{-3}}{450\times10^{-9}} = 6640\ K$

The apparent brightness $b = \frac{L}{4\pi r^2} \Leftrightarrow r = \sqrt{\frac{L}{4\pi b}} = \sqrt{\frac{10^{27}}{4\pi(10^{-11})}} = 7.96\times10^{36}\ m$

4. O, B. A, F, G, K, M

5. The spectral type (class) of a star gives us temperature information, but we don't know its luminosity. To get the luminosity, we must know the distance!

Lesson 4: Stellar distance

a) Learning objective

Explain stellar distance and masses

b) Teaching resources

- Search internet, Library, Journals and computer simulations
- Projectors, videos

c) Prerequisites/Revision/Introduction

- Student-teachers need to have knowledge at determining distances between two objects.

- Student-teachers need knowledge about Relativity Covered in this year unit 9.

d) Learning activities 10.4

Guidance on learning activity 10.4

This activity will make student-teachers to discover all the concepts about stellar distance and apply this information to know where these bodies are located.

- Let the learners turn to activity 10.4
- Let the learners discuss the questions individually or as a group depending on the method you employed.
- When they are done discussing, call few to present. Remember to consider mixed ability and gender balance. They can use PowerPoint while presenting.
- Together with student-teachers harmonize and make a summary of key and important information. Give student-teachers time to note down important information in their notebooks.

Answers for learning activity 10.4

Using the laws of Physics as we know them here on Earth, to interpret the electromagnetic radiation emitted by these objects. Radiation is any way in which energy is transmitted through space from one point to another without the need for any physical connection between those locations.

e) Answers for Application activities 10.4

1. $\tan p = p \Leftrightarrow d = \frac{1}{p} = \frac{1}{0.75} = 1.33\ pc$

2. $1\ pc = 3.26\ ly \Rightarrow 8.6\ ly = \frac{8.6 \times 1 pc}{3.26} = 2.6338\ pc$

The parallax angle $p = \frac{1}{d} = \frac{1}{2.68} = 0.379\ pc$

3. The distance in pc is given by $d = \frac{1}{p}$

Star	Measured parallax (arcseconds)	Distance (pc)
Betelelgeuse	0.00507	197.24
Proxima centauri	0.769	1.30
Arcturus (alpha Bootis)	0.09	11.11
Procyon (alpha Canis Minoris)	0.288	3.47
Hadar (beta Centauri)	0.0062	161.29
Rigel (beta Orionis)	0.0042	238.10
Sirius (alpha Canis Majoris)	0.379	2.64
Altair (alpha Aurigae)	0.194	5.15

10.6. Summary of the unit

The Hertzsprung -Russell (H-R) Diagram is a graph that plots stars color (spectral type or surface temperature) vs. its luminosity (intrinsic brightness or absolute magnitude). On it, astronomers plot stars' color, temperature, luminosity, spectral type, and evolutionary stage. This diagram shows that there are 3 very different types of stars:

- Most stars, including the sun, are "**main sequence stars**," fuelled by nuclear fusion converting hydrogen into helium. For these stars, the hotter they are, the brighter. These stars are in the most stable part of their existence; this stage generally lasts for about 5 billion years.

- As stars begin to die, they become **giants** and **supergiants** (above the main sequence). These stars have depleted their hydrogen supply and are very old. The core contracts as the outer layers expand. These stars will eventually explode (becoming a planetary nebula or supernova, depending on their mass) and then become white dwarfs, neutron stars, or black holes (again depending on their mass).
- Smaller stars (like our Sun) eventually become faint **white dwarfs** (hot, white, dim stars) that are below the main sequence. These hot, shrinking stars have depleted their nuclear fuels and will eventually become cold, dark, black dwarfs.

We have discussed various methods to measure the distance to a star, classified into two groups: geometrical methods based on **parallax** and Optical methods based on the star's **luminosity**.

10.7. Additional Information for tutor

Physical stellar Characteristics

There are a number of physical characteristics that vary for each of the different types of star. These include the surface temperature, luminosity (brightness), mass (weight), radius (size), and lifetime, prevalence in the cosmos, and point in the stellar evolutionary cycle.

When considering these physical features, the different kinds of star are usually compared with our nearest stellar companion, the Sun. The following table gives the solar values.

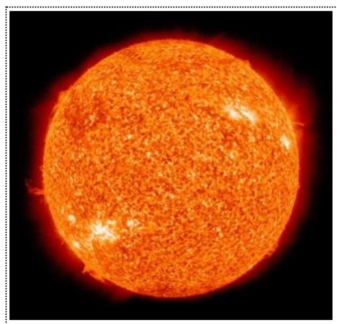


Fig.14. 1 Our star: Sun

Physical Characteristics of Sun

- Lifetime: 10 billion years
- Evolution: middle (4.5 billion years)
- Luminosity: 3.846×10^{26} W
- Temperature: 5 500 °C
- Spectral Type: G (yellow)
- Radius: 695 500 km

- Mass: 1.98×10^{30} kg

Detailed Stellar Properties

I know of 10 different types of stars. They are called **neutron stars**, **black dwarfs**, **white dwarfs**, **brown dwarfs, red dwarfs, yellow dwarfs, blue giants, red giants, blue supergiants and red supergiants**.

1. **Neutron star**

It is the remaining star after a giant star explodes and goes **supernova**. The neutron star can now have up to three times the mass of our sun and it is packed into only a small ball with a radius of around 10 km to 16 km.

Fig.10. 1supernova

- Lifetime: unknown (long)
- Evolution: dead, cooling
- Temperature: < 2 000 000 ºC
- Spectral Types: D (degenerate)
- Luminosity: ~0.000001
- Radius: 5 - 15 km
- Mass: 1.4 - 3.2
- Prevalence: 0.7%

A neutron star is so dense that on earth just one teaspoon full would way a hundred million tonnes! A neutron star is a very small star, perhaps only 20 km across, which is just as heavy as the Sun is now. Its matter is extremely densely-packed together.

When a Giant star collapses as it dies, it causes a huge explosion called a **Supernova**. This explosion, producing vast amounts of cosmic dust and appearing like another nebula in space, ends with the star shrinking or totally disappearing. A neutron star, which spins very fast, gives out huge pulses of radiation. This is why it is known as a Pulsar. If it does completely disappear it becomes a Black Hole, appearing to suck in objects orbiting or approaching close to it.

2. Black dwarf

A **black dwarf** is the stage after a white dwarf. It takes so long for stars to get to this stage that none has probably ever gotten to this stage. Our universe is so young and it will take a few times older than our universe even is for any sun to turn into a black dwarf.

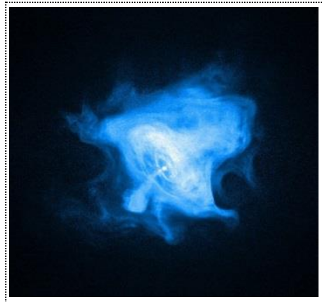


Fig.10. 2 Black dwarf

Our nearest star, Proxima Centauri is a red dwarf and scientists believe that it will take billions of years for it to end it's life cycle and eventually become a white dwarf and then a black dwarf. Black dwarfs are stars that are burnt out and do not have any light or heat anymore. Our Sun will probably become a black dwarf too someday.

- Lifetime: unknown (long)
- Evolution: dead
- Temperature: <-270 °C
- Spectral Types: none
- Luminosity: infinitesimal
- Radius: 0.008 - 0.2
- Mass: 0.1 - 1.4
- Prevalence: ~0%

3. White dwarf

A white dwarf is not really white, its color depends on its temperature, and it can be from violet to deep red. A white dwarf can not be seen without a telescope. Did you know a teaspoon full of white dwarf would way 5 tonnes?

A white dwarf is one of the last stages of a star from when the giant star releases its outer layers of gases and leaves the center or core of the star. The white dwarf is then only about the size of the Earth but still has 3/4 the mass of our Sun.

- Lifetime: 10^{15}- 10^{25} years
- Evolution: dead, cooling
- Temperature: 4 000 – 150 000 ºC
- Spectral Types: D (degenerate)
- Luminosity: 0.0001 - 100
- Radius: 0.008 - 0.2
- Mass: 0.1 - 1.4
- Prevalence: 4%

Fig.10. 3 White dwarf

Stars less than 10 solar masses will shed their outer layers to form planetary nebulae. They will typically leave behind an Earth-sized core of less than 1.4 solar masses. This core will be so dense that the electrons within its volume will be prevented from occupying any smaller region of space (becoming degenerate). This physical law (Pauli's exclusion principle) prevents the stellar remnant from collapsing any further.

The remnant is called a white dwarf, and examples include Sirius B and Van Maanen's star. More than 97% of stars are theorized to become white dwarfs. These super hot structures will remain hot for trillions of years before cooling to become black dwarfs.

4. **Brown dwarf**

A **brown dwarf** is when a star was being created but it didn't get enough mass to become a real star. Instead of staying the same size or expanding it will shrink and cool down and fade. The brightest brown dwarf sometimes resembles a red dwarf.

- Lifetime: unknown (long)
- Evolution: not evolving
- Temperature: 0 – 1 800 °C
- Spectral Types: L, T, Y (after M)
- Luminosity: ~0.00001
- Radius: 0.06 - 0.12
- Mass: 0.01 - 0.08
- Prevalence: unknown (many)

Fig.10. 4 Brown dwarf

Brown dwarfs are substellar objects that never accumulated enough material to become stars. They are too small to generate the heat required for hydrogen fusion. Brown Dwarfs constitute the midpoint between the smallest red dwarf stars and massive planets like Jupiter or white dwarf but smaller than our sun.

They are the same size as Jupiter, but to qualify as a brown dwarf, they must be at least 13 times heavier. Their cold exteriors emit radiation beyond the red region of the spectrum, and to the human observer they appear magenta rather than brown. As brown dwarfs gradually cool, they become difficult to identify, and it is unclear how many exist.

5. Red dwarf

A red dwarf is a low mass star, and since small stars take very long to slowly burn up there fuel they last a very very long time. A red dwarf can live for more than 10 times the present age of our universe, around 200 billion years at its regular rate.

Red dwarfs are the most popular type of sun and make up just over half of all the stars in our entire galaxy! If our Sun was a red dwarf, from earth it wouldn't provide us with daylight it would only give us light like when our sun is rising or setting.

- Lifetime: 73 - 5500 billion years
- Evolution: early, middle
- Temperature: 1 800 – 3 500 °C
- Spectral Types: M
- Luminosity: 0.0001 - 0.08
- Radius: 0.12 - 0.7
- Mass: 0.08 - 0.45
- Prevalence: 73%

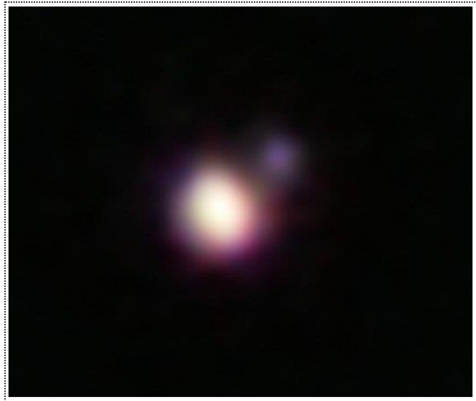


Fig.10. 5 A red dwarf

Our nearest neighbour star Proxima Centauri, Barnard's Star and Gliese 581 are all red dwarfs. They are the smallest kind of main sequence star. Red dwarfs are barely hot enough to maintain the nuclear fusion reactions required to use their hydrogen fuel.

However, they are the most common type of star, owing to their remarkably long lifetime that exceeds the current age of the universe (13.8 billion years). This is due to a slow rate of fusion, and an efficient circulation of hydrogen fuel via convective heat transport.

6. Yellow dwarf

A **yellow dwarf** is a star like our Sun. A yellow star lives around 10 billion years. Eventually a yellow star will bloat into a red giant and it's outer layer will shoot out into space leaving a white dwarf and then later a black dwarf.

- Lifetime: 4 - 17 billion years
- Evolution: early, middle
- Temperature: 5 000 – 7 300 °C
- Spectral Types: G, F
- Luminosity: 0.6 - 5.0
- Radius: 0.96 - 1.4
- Mass: 0.8 - 1.4

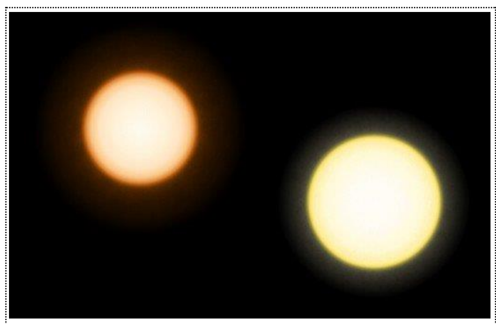


Fig.10. 6 Yellow dwarf

- Prevalence: 10%

The Sun, Alpha Centauri A, and Kepler-22 are yellow dwarfs. These stellar cauldrons are in the prime of their lives because they are burning hydrogen fuel in their cores. This normal functioning places them on the `main sequence', where the majority of stars are found. The designation `yellow dwarf' may be imprecise, as these stars typically have a whiter color. However, they do appear yellow when observed through the Earth's atmosphere.

7. **Blue giant**

A blue giant is a star that was born a giant and later in its life cycle just like a yellow star it will bloat into a bigger star but instead of turning into a red giant it turns into a red supergiant. A blue giant usually lives a pretty short life.

- Lifetime: 3 - 4,000 million years
- Evolution: early, middle
- Temperature: 7 300 – 200 000 °C
- Spectral Types: O, B, A
- Luminosity: 5.0 – 9 000 000
- Radius: 1.4 - 250
- Mass: 1.4 - 265
- Prevalence: 0.7%

Fig.10. 7 Blue giant

Blue giants are defined here as large stars with at least a slight blueish coloration, although definitions do vary. A broad definition has been chosen because only about 0.7% of stars fall into this category.

Not all blue giants are main sequence stars. Indeed, the largest and hottest (O-type) burn through the hydrogen in their cores very quickly, causes their outer layers to expand and their luminosity to increase. Their high temperature means they remain blue for much of this expansion (e.g. Rigel), but eventually they may cool to become a red giant, supergiant or hypergiant.

8. Blue supergiant

Blue supergiants above about 30 solar masses can begin throw off huge swathes of their outer layers, exposing a super-hot and luminous core. These are called Wolf-Rayet stars. These massive stars are more likely to explode in a supernova before they can cool to reach a later evolutionary stage, such as a red supergiant. After a supernova, the stellar remnant becomes a neutron star or a black hole.

It is an expanded blue giant. They are rare and some of the brightest stars in the universe. As the blue supergiant's core reaction speeds up and slows down and the wind changes can change back and forth from a blue supergiant and a red supergiant.

A blue supergiant has fast but rare wind compared to a red supergiant which has a slow wind. Blue supergiants are rarely found with older stars they are found with young stars.

9. Red giant's

A red giant is a star that increases in temperature and implodes and the heat energy it releases causes it to expand. A red giant is a star like our Sun after it expands and cools down and gets a bit dimmer. Once our Sun becomes a red giant it will turn all of our inner planets into cinder.

- Lifetime: 0.1 - 2 billion years
- Evolution: late
- Temperature: 3 000 – 5 000 °C
- Spectral Types: M, K
- Luminosity: 100 - 1000
- Radius: 20 - 100
- Mass: 0.3 - 10
- Prevalence: 0.4%

Aldebaran, Mira and Arcturus are red giants. These stars are in a late evolutionary phase. Red giants would previously have been main sequence stars (such as the Sun) with between 0.3 and 10 solar masses. Smaller stars do not become red giants because, due to convective heat transport, their cores cannot become dense enough to generate the heat needed for expansion. Larger stars become red supergiants or hypergiants.

In red giants, the accumulation of helium (from hydrogen fusion) causes a contraction of the core that raises the internal temperature. This triggers hydrogen fusion in the outer layers of the star, causing it to grow in size and luminosity. Due to a larger surface area, the surface temperature is actually lower (redder). They eventually eject their outer layers to form a planetary nebula, while the core becomes a white dwarf.

10. Red supergiant

Red supergiant is the biggest in size but not in mass or surface temperature or true brightness in the known universe. A red supergiant ends its life it in a super nova. Red supergiant is a star that is in its last phase of its life burning helium. A red supergiant is just a bigger version of a red giant. Red supergiants have no photosphere.

- Lifetime: 3 - 100 million years
- Evolution: late
- Temperature: 3 000 – 5 000 ºC
- Spectral Types: K, M
- Luminosity: 1 000 – 800 000
- Radius: 100 – 1650
- Mass: 10 – 40
- Prevalence: 0.0001%

Betelgeuse and Antares are red supergiants. The largest of these types of stars are called red hypergiants. One of these is 1650 times the size of our Sun (NML Cygni), and is the largest known star in the universe. NML Cygni is 5 300 light years away from the Earth.

Like red giants, these stars have swelled up due to the contraction of their cores, however, they typically evolve from blue giants and supergiants with between 10 and 40 solar masses. Higher mass stars shed their layers too quickly, becoming Wolf-Rayet stars, or exploding in supernovae. Red supergiants eventually destroy themselves in a supernova, leaving behind a neutron star or black hole.

GUIDANCE ABOUT SKILLS LAB 10

This activity is aimed at enhancing the understanding of students about astrophysics through research. It is also aimed at improving research skills amongst students.

- Tell the students to start/do on their research. You can leave them to research by themselves.
- In case there is a student that needs special care, please guide them accordingly.
- Please try to correct their research work and advise those who had difficulties in getting relevant information.

10.8. Answers for end unit assessment 10

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

8. C 9.C

10. Titan is farther from the Sun, so its surface temperature is much lower, about 100 K. With a temperature this low, an object of this size can retain its atmosphere. A secondary consideration is that Titan is geologically active, due to tidal heating. Outgassing geysers, which add more N2 to the atmosphere, are constantly renewing the atmosphere on Titan. The Moon, on the other hand, is geologically dead. The primordial atmosphere has been lost to space, and it has no means to replenish it.

10.9. Additional activities (Questions and answers)

10.9.1 Remedial activities

1**.** How did ancient ship navigators use the Big Dipper at night?

A. Not Sure
B. They used it to find which direction was north
C. They tried to figure out where the big bear was
D. They only used it during the daytime

2. What is the color of the light coming from a Blue Moon?

A. Not Sure
B. The same as it is for a Full Moon
C. Blue
D. The same as it is for a New Moon

3. Stars appears to move from East to West because

A. All stars move from East to West
B. The Earth rotates from West to East
C. The Earth rotates from West to East
D. The background of stars moves from West to East

10.9.2 Consolidation activities

4. What are the characteristics used to classify stars?

5. What is a star in space?

10.9.3. Extended activities

6. Can there be a purple star?

7. How do we know how far away a star is?

Answers

1.B 2.B 3.A

4. Astronomers classify stars according to their physical characteristics. Characteristics used to classify stars include **color**, **temperature**, **size**, **composition**, and **brightness**. Stars vary in their **chemical composition**.

5. Basically, stars are big exploding balls of gas, mostly hydrogen and helium. Our nearest star, **the Sun**, is so hot that the huge amount of hydrogen is undergoing a constant star-wide nuclear reaction, like in a hydrogen bomb.

6. The **star** would therefore appear white — a combination of all colors. Earth's sun emits a lot of green light, but humans see it as white. **Purple stars** are something the human eye won't easily see because our eyes are more sensitive to blue light.

Green and **purple stars** do exist. The color of **stars** depends on their temperatures, and they emit radiation throughout the visible spectrum. But when a star emits peak radiation at a wavelength we define as green, it also emits radiation over the rest of the spectrum. Green is in the middle.

7. The idea of the ladder is to start with nearby objects like **stars**. We can measure their distances using a method called parallax. Back in the 90s a satellite called Hipparcos used parallax to measure the distance to thousands of **stars**. Once you **know how far** away a **star** is you can calculate how bright that **star** is.

BIBLIOGRAPHY

1. Abbot, A. F., & Cockcroft, J. (1989). Physics (5 ed.). Heinemann: Educational Publishers.
2. Atkins, K. R. (1972). Physics-Once over Lightly. New York : New York.
3. BIPM. (2006). The International System of Units (SI) (8 ed.). Sevres, France: International Bureau of Weights and Measures.
4. Breithaupt, J. (2000). Understanding Physics For Advanced Level (4 ed.). Ellenborough House, Italy: Stanley Thorners.
5. Carl, N. (2001). Telecommunications Demystified: A Streamlined Course in Digital Communications (and some Analog) for EE Students and Practicing Engineers. USA: LLH Technology Publishing.
6. Cunningham, W. (2001). Environmental science (6 ed.). McGraw-Hill: McGraw-Hill.
7. Cutnell, J. D., & Johnson, K. W. (1995). Physics. (3 ed.). USA: John Wiley; Sons, Inc.
8. Cutnell, J. D., & Johnson, K. W. (2006). Essentials of Physics. USA: John Wiley&Sons, Inc.
9. Douglass, C., &Giancoli. (1980). PHYSICS, Principles with applications (5 ed.). Prentice Hall.
10. Glencoe. (2005). Physics - Principles and Problems [textbook]. McGraw.
11. Haber-Schaim, U., Cutting, R., Kirkesey, H. G., & Pratt, H. A. (2002). Force, Motion, and Energy. USA: Science Curriculum, Inc.
12. Halliday, Resneck, & Walker. (2007). Fundamentals of Physics (8 ed.). Wiley.
13. Hewitt, P. G., SUCH0CKI, J., & Hewitt, L. A. (1999). Conceptual Physical Science (2 ed.). Addison Wesley Longman.
14. Jones, E. R., & Childers, R. L. (1992). Contemporary College Physics (2 ed.). USA: Addison-Wesley Publishing Company.
15. Jones, E. R., & Childers, R. L. (1992). Contemporary College Physics (2 ed.). USA: Addison-Wesley Publishing Company.
16. Michael, E. B. (1999). Schaum's outline of Theory and Problems of Physics for Engineering and Science. USA: McGRAW-HILL Companies, Inc.

17. Michael, J. P., Loannis, M., & Martha, C. (2006). Science Explorer, Florida Comprehensive Science. Boston: Pearson Prentice Hall.
18. Nelkon, M., & Parker, P. (2001). Advanced level Physics. Edinburgh gate: Heineman.
19. Patrick, T. (2004). Mathematics standard level (3 ed.). Victoria: Ibid Press.
20. Randall, D., & Knight. (2004). Physics for scientists and engineers: Stategic approach (Vol. 3). San Fransisco: Pearson Education, Inc.
21. Randall, D., & Knight. (2008). Physics for scientists and engineers: Stategic approach (2 ed., Vol. 3). San Fransisco: Pearson Education, Inc.
22. Serway, R. A. (1992). Principles of Physics. Orlando, Florida: Saunders College Publishing.
23. Serway, R. A., & Jewett, J. J. (2010). Physics for Scientists and Engineers with Modern Physics (8 ed.).
24. Silver, B., &Ginn, I. (1990). Physical Science. Unit States of America.
25. Stephen, P., & Whitehead, P. (1996). Physics (2 ed.). School Edition.
26. Subranya, K. (1993). Theory and applications of fluid mechanics. Tata McGraw: Hill Companies.
27. Taylor, E., & Wheeler, J. A. (1992). Spacetime Physics: Introduction to Special Relativity (2 ed.). San Francisco: W.H.Freeman& Company, Publishers.
28. Tipler, P. A. (1991). Physics for Scientists and Enginners (3 ed., Vol. 1). USA: Worth Publishers, Inc.
29. Tipler, P. A. (1991). Physics for Scientists and Enginners (3 ed., Vol. 2). USA: Worth Publishers, Inc.
30. Tom, D. (1999). Physics for today and tomorrow (2 ed.). London: John Murray Publisher.
31. Tom, D. (2000). Advanced Physics (5 ed.). H. Kennett.
32. Uichiro, M. (2001). Introduction to the electron theory of metals . Cambridge University Press .
33. Wysession, M., Frank, D., &Yancopoulos, S. (2004). Physical Science. Boston, Massachusetts, Upper Saddle River, New Jersey: Pearson Prentice Hall.

Hypertext books

34. http://astro.unl.ed/naap/pos/animations/keppler.swf
35. http://en.wikibooks.org/w/index.php?title=Physics_Exercises/Kinematics
36. http://en.wikipedia.org/wiki/International_System_of_Quantities
37. http://en.wikipedia.org/wiki/Newton%27s_laws_of_motion
38. http://phet.colorado.edu/en/simulations/category/new
39. http://resources.sargentwelch.com/tag/selective-experiments-in-physics
40. http://scienceworld.wolfram.com/physics/MomentofInertiaRing.html.
41. http://www.answers.com/topic/temperature-conversion
42. http://www.glenbrook.k12.il.us/GBSSCI/PHYS/Class/newtlaws
43. http://www.newworldencylopedia.og/entry/Evangelista_Torricelli
44. http://www.physicsclassroom.com
45. http://www.worldofteaching.com
46. www.youtube.com/user/ignitelearning