PHYSICS

FOR
ASSOCIATE NURSING PROGRAM

TEACHER'S BOOK

S5

FOREWORD

Dear Teacher,

Rwanda Basic Education Board is honored to present to you this Physics Book for Senior five 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 you achieve full potential at every level of education which will prepare you to be well integrated in society and exploit employment opportunities.

The government of Rwanda emphasizes the importance of aligning teaching and learning materials with the syllabus to facilitate your learning process. Many factors influence what you learn, how well you learn and the competences you acquire. Those factors include the instructional materials available among others. Special attention was paid to the activities that facilitate the learning process in which you can develop your ideas and make new discoveries during concrete activities carried out individually or with peers.

In competence-based curriculum, learning is considered as a process of active building and developing knowledge and meanings by the learner where concepts are mainly introduced by an activity, a situation or a scenario that helps the learner to construct knowledge, develop skills and acquire positive attitudes and values.

For effective use of this textbook, your role is to:

- Work on given activities which lead to the development of skills
- Share relevant information with other learners through presentations, discussions, group work and other active learning techniques such as role play, case studies, investigation and research in the library, from the internet or from your community;
- Participate and take responsibility for your own learning;
- Draw conclusions based on the findings from the learning activities.

I wish to sincerely extend my appreciation to REB staff who organized the editing process of this book. Special gratitude goes to the lecturers, teachers, illustrations and designers who diligently worked to successful completion of this book. Any comment or contribution would be welcome for the improvement of this textbook for the next edition.

Dr. Nelson MBARUSHIMANA
Director General, REB

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Joan MURUNGI,

Head of Department of Curriculum, Teaching and Learning Resources

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Introduction

PHYSICS AND SOCIETY

The purpose of this teacher guide is to help teachers to implement the Physics syllabus of senior five according to unit planning, lesson planning and lesson delivery to develop the learners' competences and skills. It is designed to stimulate teachers to create meaningful teaching programs and lessons by enabling them to choose relevant and purposeful activities and teaching activities. It will encourage teachers to research and look for new and challenging ways of fecilitating students' learning in Physics.

The teacher guide supports the syllabus. The syllabus states the key unit competences to develop, links to other subjects, assessment criteria, learning outcomes for the subject and units, and outlines the content and skills that students will learn.

Rationale of teaching and learning physics

PHYSICS AND SOCIETY

Physics is one of the natural science subjects and contributes significantly to global socioeconomic transformation through its discoveries. These have led to development of new technologies in all fields of production and are beneficial to mankind. Applications of Physics knowledge is evident in industries, engineering, transportation (automobiles, trains, flights etc), medicine and Information and Communication Technology (ICT).

Physics significantly contributes to the advancement of new technologies that arise from theoretical breakthroughs. For example, advances and understanding of electromagnetism or nuclear physics has led to the development of new products which have dramatically transformed the modern society. Some of the discoveries based on Physics knowledge include televisions, computers, electrical appliances, nuclear weapons, advancements in thermodynamics and mechanics which have led to mass industrialization.

Physics is the key to the Rwandan education ambition of developing a knowledge-based society since it promotes science and technology which are necessary for learners to be competent both at regional and global job markets. This new curriculum will address gaps in the current Rwanda Education system which lacks of appropriate skills and attitudes provided by the current education system.

PHYSICS AND LEARNERS

Physics is a worthwhile subject because it prepares students for the real world of work by providing career pathways in mechanical and construction engineering, information and communication technology and other related fields. Physics provides skills that guide the construction of theories and laws that help to explain natural phenomena and enable management of environment.

It also provides answers to problems modern society by empowering students, make them to be creative and innovative, leading to independent approaches of solving daily life problems. Through physics, students explore the laws and rules that govern all the natural phenomena associated with the subject observed in the universe.

Methods, Strategies, Attitudes and Techniques

This section addresses the methods, strategies, attitudes and techniques recommended in the program. While they are different from the concepts, these elements are important in the development of competencies.

METHODS

Methods require special attention. They should not be applied in isolation, but in learning and evaluation situations in which several of them are combined. The ability to apply a combination of different methods is an indicator of proficiency.

Five methods are presented here: modeling, observation, analysis, experimentation and the empirical methods.

MODELING

Modeling consists in constructing a representation of an abstract situation, one that is difficult to observe or impossible to see. This representation can be a text, a drawing, a mathematical formula, a chemical equation, a software program or a scale model. Over time, the model becomes more refined and complex. It may be valid only for a certain amount of time and in a specific context and in many cases, it can be modified or rejected. It is also important to consider the context in which it was created. A model must help learners understand a given reality, explain certain properties of that reality and predict new observable phenomena.

OBSERVATION METHOD

The observation method is an active process intended to help the observer/ learner interpret facts on the basis of his or her predetermined criteria and generally accepted criteria within a given field. In light of the information collected, learners gain a new understanding of the facts, which is inextricably linked to the context in which the observations were made. In his or her interpretation and organization of information, the learner reinterprets the physical world on the basis of his or her assumptions and the conceptual schemes that are an integral part of what he or she brings to the observation process. All observations involve a theoretical model established by the observer.

ANALYSIS

The elements that determine or make up a phenomenon, an object or a system, as well as the interactions between these elements, can be identified through analysis. Analysis also leads to the identification of structural and functional components, which can in turn be analyzed, and to the determination of their hierarchical or interdependent connections. In some cases, this method involves using a broader understanding of a system to determine the function of its parts and the relationships between them, thereby making it possible to highlight the dynamics of a complex system and examine its behaviour over time. This aspect of the analytical method is particularly useful in studying phenomena and applications.

EXPERIMENTAL METHOD

The experimental method begins with the formulation of preliminary explanations. Then learners can begin looking for an answer and defining the framework of the experiment. It then becomes necessary to develop an experimental procedure in order to identify a certain number of variables to be manipulated. The aim of the procedure is to identify and compare observable or quantifiable elements and check them against the initial hypotheses. Moving back and forth between the different stages of the experimental method raises new questions and allows students to formulate new hypotheses, adjust the experimental procedure and take the limitations of the experiment into account.

EMPIRICAL METHOD

The empirical method involves field research without any manipulation of variables. Its spontaneity does not detract from the methodology involved (for example, a sample survey is an empirical approach that leaves nothing to chance). Often based on intuitive models, this method sometimes provides a way of exploring and representing the elements of a problem. Often, it can lead to a number of preliminary ideas, hypotheses and theories, as well as new techniques and possible avenues for other research projects.

Source: Québec Education Program - Physics

The role of the teacher

Teachers play a fundamental role in helping their students develop competencies. The support they provide must relate to the three aspects of every competency: the mobilization of resources in a specific context, the availability of resources and the ability to reflect on the process involved. Teachers must offer learning and evaluation situations that promote the development of the target competencies, support the students' learning progress and evaluate their level of competency development.

The role of learners

Although the teacher sets the pedagogical framework, it is important for the students to be fully engaged in the learning process. Only they can make the necessary connections between their previous knowledge and the new concepts they must assimilate, and they must also adapt their knowledge to the concepts to be learned, and vice versa.

It is important for students to use appropriate techniques when handling equipment and substances. If they use verification or control instruments, they must take into account possible errors in their measurements, whether caused by the instrument, the user or the environment. They must record their measurements using an appropriate number of significant figures and analyze their results based on a certain margin of error. At all times, they must comply with safety standards and handle equipment and substances with care. When in doubt, they must ask the teacher or laboratory technician to ensure that they are working safely and using the equipment and substances correctly.

Learning Outcomes

Expected outcomes are summarized in table I.

Table I: Learning outcomes

Learning Outcomes	Very high achievement	Very high Achievement	Satisfactory Achievement	Low Achievement	Belowminimum standard
1. Demonstrate understanding of fundamental physics principles and models	Demonstrates extensive knowledge and understands a wide range of physics principles and models	Demonstrates sound knowledge and understanding of physics principles and models	Adequate demonstration of knowledge of physics principles and models	Demonstrates limited knowledge of physics principles and models	Has failed to demonstrate understanding of fundamental physics principles and models
2. Apply scientific inquiry and reasoning skills to find solutions to problems	Highly creative and innovative in conducting investigations using scientific methodologies to find solutions to problems	Sound inquiry and reasoning skills in conducting investigations using scientific methodologies in finding solutions to problems	Adequate inquiry and reasoning skills with fair idea of using scientific methodologies in finding solutions to problems	Demonstrates limited inquiry and reasoning skills in problem solving using scientific methodologies	Has failed to demonstrate scientific inquiry and reasoning skills in solving problems using scientific methodologies
3. Communicate scientific data and information	Highly efficient and innovative in communicating	Very good in communicating scientific data and	Adequate competency in communicating information	Limited competency in communicating information	Has failed to achieve competency in

from investigations and laboratory work in different ways	information and scientific data from investigations and laboratory work	information from investigations and laboratory work	and scientific data from investigations and laboratory work	and scientific data from investigations and laboratory work	communicating information and scientific data from investigations and laboratory work
4. Analyse and interpret data and information	Excellent analysis and interpretation of data and information	Very good in analysing and interpreting data and information	Adequate analysis and interpretation of data and information	Demonstrates limited ability in analysing and interpreting data and information	Has failed to demonstrate ability to analyse and interpret data and information
5. Analyse and evaluate developments in physics from the past and present and its impact on people and the environment; and use the information to support and make informed decisions	Makes informed decisions based on excellent analysis and evaluation of developments in physics and their impact on society	Makes informed decisions based on sound analysis and evaluation of developments in physics and their impact on society	Makes decisions based on adequate analysis and evaluation of developments in physics and their impact on society	Makes decisions based on limited analysis and evaluation of developments in physics and their impact on society	Makes decisions based on poor analysis and evaluation of developments in physics and their impact on society

6. Relate relevant traditional knowledge, beliefs, and skills to principles and concepts of physics	Displays excellent ability to perceive and effectively correlate traditional knowledge, belief concepts of physics.	Can effectively perceive and correlate traditional knowledge, belief and skills to principles and concepts of physics	Can adequately perceive and correlate traditional knowledge, belief and skills to principles and concepts of physics	Shows limited ability in perceiving and correlating traditional knowledge, belief and skills to principles and concepts of physics	Is not able to perceive and correlate traditional knowledge, belief and skills to principles and concepts of physics

Source: physics upper secondary education teacher guide, Department of Education, Papua New Guinea. ISBN 978-9980-9925-4-3

Knowledge and Understanding

When preparing and teaching physics, the teacher should think and pinpoint some requirements to meet some expected outcomes. Students are expected to:

- understand phenomena, facts and patterns, principles, concepts, laws, theories and models in physics;
- learn vocabulary, terminology and conventions in physics;
- acquire knowledge of techniques and skills specific to the study of physics;
- group and organise physical knowledge and understanding, and apply them to familiar and unfamiliar situations; and
- develop an understanding of technological applications of physics and of their social implications.

Skills and Processes

Physics teachers must strive to provide opportunities for students to develop life skills. Student activities are designed to address the content knowledge that general science strands usually ignore. There are many skills students develop through interactive science. So students are expected to:

- develop scientific thinking and problem-solving skills;

- acquire an analytical mind to critically evaluate physics-related issues;
- communicate scientific ideas and values in meaningful and creative ways with appropriate use of diagrams, symbols, formulae, equations and conventions, as well as verbal means;
- acquire practical skills such as how to manipulate apparatus and equipment, carry out given procedures, analyse and present data, draw conclusions and evaluate experimental procedures;
- make careful observations, ask relevant questions, identify problems and formulate hypotheses for investigation;
- plan and conduct scientific investigations individually or collaboratively with appropriate instruments and methods, collect quantitative and qualitative data with accuracy, analyse and present data, draw conclusions and evaluate evidence and procedures;
- develop study skills to improve the effectiveness and efficiency of learning; and develop abilities and habits that are essential to life-long learning

Values and Attitudes

Students are expected to:

- develop positive values and attitudes such as curiosity, honesty, respect for evidence, perseverance and tolerance of uncertainty through the study of physics;
- develop a habit of self-reflection and the ability to think critically;
- be willing to communicate and comment on issues related to physics, and demonstrate an open-mindedness towards the views of others;
- be aware of the importance of safety for themselves and others, and be committed to safe practices in their daily life;
- appreciate the achievements made in physics and recognise their limitations;
- be aware of the social, economic, environmental and technological implications of achievements in physics; and
- recognise the importance of life-long learning in our rapidly changing knowledge-based society.

Competences to develop

INTEGRATION OF COMPETENCES

A competence-based curriculum takes learning to higher levels by providing Challenging and engaging learning experiences which require deep thinking rather than just memorisation. Its focus is on what young people can do rather than just on what they know.

There are two categories of competences in a competence-based curriculum: Basic competences and generic competences.

Basic Competences

Basic competences are main, key or vital competences identified basing on expectations and aspirations reflected in the national policy documents. It is on the basis of descriptors of these competences that are built into the learners profile in each level of education, subjects to be taught and learning areas.

Basic competences are listed in the diagram below

- Literacy
- Numeracy
- ICT
- Citizenship and National Identity
- Entrepreneurship and Business Development
- Science and Technology
- Communication in the official languages

These have all been identified as competences with particular relevance to Rwanda on account of its history and context.

Literacy and numeracy are basic to accessing learning in other subjects.

Competence in ICT can be developed through the use of ICT across the subjects. One of the nation's great strengths is its unity in terms of both its population and its sense of purpose. The focus on citizenship and national identity is important in this respect.

There is a key drive to ensure that Rwandans actively create employment opportunities rather than having a mindset of relying on others. Hence entrepreneurship and business development is regarded as basic.

The impact of science and technology increasingly affects all aspects of life and therefore should be considered a basic aspect of subjects across the curriculum.

Generic Competences

Generic competences involve and promote the development of the higher order thinking skills. In doing so they boost subject learning as well as being highly valuable in themselves. They are seen as generic competences because they apply across all curricula, and can be developed in all the subjects studied.

Developing competences

Competences cannot be taught directly like subject knowledge. They are acquired over time through the cumulative effect of a competence approach to learning. They require students to practice and employ the generic competences throughout the subjects that they study. They require teachers to adopt approaches that encourage and enable students to think critically, to carry out research, to solve problems, to be creative and innovative, to communicate, to co-operate and to become life-long leaners.

The subject content provides a necessary context for students to develop the competences, and the basic and generic competences help deepen students' understanding of the subject and build students' ability to apply their subject learning

Generic Competences

The generic student competences that will be developed within all subjects are:

- Critical thinking
- Creativity and innovation
- Research and problem solving
- Communication
- Co-operation, interpersonal relations and life skills
- Life long learning

These generic competences help students deepen their understanding of subjects and apply their subject learning in a range of situations. They therefore contribute to the development of subject competence.

As students develop these generic competences they also acquire the set of skills that employers look for in their employees, so the competences help prepare students for the world of work.

The generic competences are also vital for enabling students to become life long learners who can adapt to our fast-changing world and the uncertain future. Competence in a subject requires a learner to have achieved an appropriate level in terms of all two categories of competence.

Higher Order Thinking Skills (HOTS)

Higher Order Thinking Skills (HOTS) are central to a competence-based curriculum because they develop the understanding that enables learning to be applied effectively.

As the table below shows, Knowledge and Understanding learning objectives relate to memorisation and explanation -the lower levels of learning. Skills learning objectives use more challenging, active verbs so that learners are required to think more deeply and to develop higher order thinking skills.

It is important to highlight the fact that knowledge and understanding are no less

important in a competence-based curriculum. High levels of knowledge and understanding are crucial for a successful knowledge-based economy. It is through the focus on competences and higher order thinking skills in a competence-based curriculum that learners' skills and abilities are developed and, as a consequence, their knowledge and understanding are deepened.

There must be opportunities in subjects for students to develop and to apply basic skills and cross cutting issues where possible. Subject syllabi must focus on what learners need to be able to do as well as on subject knowledge. Basic competences are developed through application of subject learning. The generic competences help the development of the higher order thinking skills so both will deepen subject learning and be valuable in themselves.

Assessment

Competence based assessment is an assessment process in which the learner is confronted with a complex situation related to their everyday life and asked to put into practice what has been learned(knowledge, skills and attitude) in order to resolve or overcome this situation. In competence based assessment the evidence collected is then used as the basis on which judgments are made concerning the learner's progress towards the satisfaction of fixed performance criteria.

Assessment is an integral part of the teaching learning process. One of the major purposes of assessment is to measure the extent to which learning objectives and competences have been achieved and to identify which schools and learners need pedagogical advice and strategic intervention.

Coherence

It is essential that the assessment measures are coherent across ages and schools so that learners can be confident that the standards being applied to their work are compatible with standards across the country. To achieve this level of confidence in the design on the assessment the marking or grading must be trustworthy, delivering reliable and valid tests and examinations.

Recognition of achievement

Assessments must examine or measure what learners know and can do, and how far they succeed, avoiding focusing on what they are unable to do. Assessments must allow for learners to show their knowledge and skill in appropriate ways which may vary with learner, topic and competency.

Accessible, equitable and fair

Assessments must offer equal opportunities to learners to succeed, and be adaptable to learners' circumstances. Assessments must be accessible to all learners in terms of the forms of questioning and testing. Accessibility involves particular attention to the language demands for learners, especially those for whom English is an additional language.

Support progression

Assessments should yield information about aspects of learners' performance which can then be used to diagnose strengths and weaknesses, and next steps for learners.

Formative assessments which are relevant to the current learning should provide evidence which teachers can use to feedback to learners. Competencies, which include knowledge, skills and attitudes, should be assessed in the context of practical application in order for progress to be identified and supported.

Fit for purpose

The methods and forms of assessment should vary, according to such factors as the domains being assessed, the age of the learners, the language in which the assessment is made. The use of the results of assessments affects the forms used, in both formal and informal contexts

Valid

Any assessment must assess what it sets out to measure and be clear about what is being assessed, including such aspects as memory, processes, application. In order to be valid the forms of assessment vary with what is being assessed.

Reliable

Formal assessments and examinations must be consistent in the results they produce over time and for all learners. In examinations, as far as possible, sources of inconsistency, such as item production, marking and linguistic barriers must be eliminated.

Transparent and accountable

Learners, teachers and parents must understand the purposes, forms and uses of assessments that schools make. Schools should make the results of assessments available to learners and parents. Stakeholders and policy makers should take into account the results of assessments nationally when making decisions.

Types of Assessment

Formative assessment (Continuous assessment)

Formative assessment is a crucial element of teaching and learning. The goal of formative assessment is to monitor student learning to provide ongoing feedback that teachers can use to improve their teaching and by students to improve their learning.

More specifically, formative assessments help:

- Learners identify their strengths and weaknesses and target areas that need work;
- Teachers in recognizing where students are struggling and address problems immediately.

Constructive feedback is a vital component of assessment for formative purposes.

Formative assessment involves using both formal and informal methods to check whether learning is taking place. They are given throughout the school year at classroom and school level in order to have a complete picture of the learners' progress and achievements in subject concepts and in competencies. They help teachers to develop appropriate instructional strategies to improve on the teaching-learning process. Formative assessments use one or a combination of the following: observation, pen and paper and oral questioning to measure the areas below:

a) Knowledge and understanding

Evidence of acquisition of knowledge and understanding is through testing mastery of subject concepts and subject competencies and how they are applied in a specific skill area.

b) Practical skills

Evidence of the ability to perform and accomplish a given task is measured through aptitude and or practical tests and evaluation of the final outcome of learning.

c) Attitude and values

Assessing the behavioral approach towards a given task or a situation.

d) Generic competencies

Assessing the steps the learner goes through to perform a given task and the reasoning behind it. Through formative assessment, the logic behind each step and skills utilized to overcome each challenge can be measured.

Competence based assessment measures a learner's ability to confront a complex situation common in daily life and to practice what has been learned (knowledge, skills and attitude) in order to resolve or overcome this situation. The evidence is then used as a basis to determine the learner's progress towards satisfaction of fixed performance criteria.

Summative assessment (assessment of learning)

Summative assessments are used to evaluate student learning, skill acquisition, and academic achievement at the conclusion of a defined instructional period—typically at the end of a project, unit, course, semester, program, or school year. Generally speaking, summative assessments are defined by three major criteria:

The tests, assignments, or projects are used to determine whether students have learned what they were expected to learn. In other words, what makes an assessment "summative" is not the design of the test, assignment, or self-evaluation, per se, but the way it is used—i.e., to determine whether and to what degree students have learned the material they have been taught.. This assessment should have an integrative aspect whereby a student must be able to show mastery of all competencies.

Cross-cutting issues

The curriculum reflects the significance of connections between different subject areas, integrating them across years and cycles. Cross-cutting issues are integrated across learning areas appropriately. They are all important for students to learn about, but they are not confined to one subject. The cross-cutting issues, which have been integrated in the curriculum are described below:

Comprehensive Sexuality Education

The primary goal of a school based Comprehensive Sexuality Education curriculum is to equip children, adolescents, and young people with knowledge, skills and values in an age appropriate and culturally gender sensitive manner so as to enable them to make responsible choices about their sexual and social relationships, explain and clarify feelings, values and attitudes, and promote and sustain risk reducing behavior.

Environment and sustainability

Integration of Environment, Climate Change and Sustainability in the curriculum focuses on and advocates for the need to balance economic growth, society well-being and ecological systems. Learners need basic knowledge from the natural sciences, social sciences, and humanities to understand to interpret principles of sustainability.

Financial Education

The integration of Financial Education into the curriculum is aimed at a comprehensive Financial Education programme as a precondition for achieving financial inclusion targets and improving the financial capability of Rwandans so that they can make appropriate financial decisions that best fit the circumstances of one's life.

Gender

Gender will be understood in schools beginning with family complementarities, gender roles and responsibilities, the need for gender equality and equity, gender stereotypes, gender sensitivity, gender mainstreaming, gender-blind/ gender-unaware.

Genocide Studies

Rwandan children should know about the genocide perpetrated against the Tutsi alongside the Holocaust and other genocides. They should know what caused the genocide in Rwanda, its planning and execution, how it was stopped and what the consequences have been. Rwandan children should take part in fighting genocide ideology and genocide denial. Rwandan students will remember the genocide, which is a means to protect the memory of those that were lost.

Peace and Values Education

Peace and Values Education (PVE) is defined as education that promotes social cohesion, positive values, including pluralism and personal responsibility, empathy, critical thinking and action in order to build a more peaceful society.

Standardisation Culture

Standardisation Culture in Rwanda will be promoted through formal education and plays a vital role in terms of health improvement, economic growth, industrialization, trade and general welfare of the people through the effective implementation of Standardization, Quality Assurance, Metrology and Testing.

Inclusive Education

Inclusion is based on the right of all learners to a quality and equitable education that meets their basic learning needs, and understands the diversity of backgrounds and abilities as a learning opportunity.

Required materials

Table II shows a list of materials that should be available to be used in teaching physics as indicated unit wise.

Table II: physics requirement list

Weeks	Term	Unit	Unit title	Essential requirements for activities and assessment
1 - 3	1	1	Wave and Particle nature of light	Glass and Perspex prisms, ray box kits, Light source, Evacuated glass tube, small metal plate (photocell), Battery, Ammeter, Black and white bodies and electronic microscope.

4 - 6	1	2	Simple harmonic motion	Ripple tanks, ropes, springs, String, bob, fixed point, springs and masses, Ripple tank, microphone, loudspeaker, cathode ray oscilloscope.
6 - 8	1	3	Forced oscillations and resonance of a system	
8 - 11	1	4	Propagation of mechanical waves.	
11 - 13	2	5	Complex electrical circuit.	Pieces of paper, ammeters, voltmeters, galvanometers, ohm meters, dry cells, light bulbs, resistors, dry cell holders, switches, resistance boxes, Wheatstone bridges (slide wire form or resistor form), potentiometers (slide wire type), resistance wires (nichrome) of different diameters and lengths, metre ruler, copper wire leads
13 - 16	2	6	Fossil and non fossil fuel and power production	Radioactive decay data, waste materials (like banana peels, cow dung, and others), closed containers,

16 - 18	2	7	Electric field potential and gravitational potential.	Perspex rulers, electroscopes, ebonite and glass rods, silk and fur materials, pieces of paper, ammeters, voltmeters, galvanometers
18 - 21	2	8	Motion in Orbits	Large Rubber or plastic sheet Heavy round object, lighter objects, such as tennis balls
21 - 24	2-3	9	Atomic models and photoelectric effect.	Electric heaters, power supply, cathode ray oscilloscope, photo cells, TV screen,
24 - 26	3	10	Analog and digital signals	Activity sheets and supporting resources (including film clips!)
26 - 29	3	11	Mobile phone and radio communication.	Loud speakers, fixed phone, mobile phone, charts
29 - 31	3	12	Relativity concepts and postulates of special relativity	Activity sheets and supporting resources
31 - 34	3	13	Interference of light waves.	Diffraction gratings

34 - 36	3	14	Stellar distance and radiation	Activity sheets and supporting resources

Scheme of work and unit plan

The scheme is the breakdown of syllabus into teachable units for a specifically given time frame. For example week, month or term. In other words it is the amount of materials the teacher prepares and intends to teach during a stipulated period of time.

The reflective teacher has to plan a scheme of work in advance for the coverage of subject's topics or concepts as drafted in the syllabus. It's basically the teacher's own personal plan of what he /she intends to teach over a period of time following certain aims, methods and activities. So this scheme should include the unit plans of all units in the syllabus. Unit plan should include dates and number of lesson per week, unit titles and lesson titles, learning objectives, teaching methods and techniques, evaluation procedures, resources, references and observations of each week. Table III of this guide is a unit plan of unit 1 in senior five physics syllabus.

Content Map

Units	Number of Periods	Introduction	Classroom organization	Equipment required	Activities	Competence practiced	Language Practice	Vocabulary Acquisition
Units 1	21	Light is a complex phenomenon that is classically explained with a simple model based on rays and wave-fronts. An excellent comparison of the wave and particle theories involves the differences that occur when light is reflected from a smooth,	Group discussion	Glass and Perspex prisms, ray box kits, Light source, Evacuated glass tube, small metal plate (photocell), Battery, Ammeter, Black and white bodies and		Critical thinking skills, Co-operation, interpersonal management and life skills, Lifelong learning, literacy, use of ICT tools, communication skills		Quantum mechanics, Planck's quantum theory, work function, threshold frequency, photoelectrons, Blackbody, x-rays,

		specular surface, such as a mirror. This unit is interesting but the teacher needs to give concrete examples and explanations to delete any confusions.		electronic microscope.				
Units 2	17	A lot of things in nature repeat themselves over and over again as time passes. Think of an example like our own planet orbiting the sun. Every 365 days it completes a single	Group discussion	Ripple tanks, ropes, springs, String, bob, fixed point, springs and masses, Ripple tank, microphone, loudspeaker, cathode		Critical thinking, Creativity and innovation, Communication, Co-operation, interpersonal management and life skills,		Periodic Time, Frequency, simple harmonic equation, Energy conservation, Superposition.

		revolution around the sun. It’s been doing this for millions of years, and will continue to do it on the same schedule for millions of years. There are many interesting facts of simple harmonic motion in our everyday life of which learners should know.		ray oscilloscope,		science and technology		
Unit 3	17	This unit involves derivation of expressions using the knowledge of differential	Group discussion			Critical thinking, communication, cooperation, i		**Oscillations, Damping, resonance**

		equations. It is better to remind the learners that they should apply the knowledge gained in mathematics –differential equations and trigonometry- in this unit.				nterpersonal management and life skills, numeracy, literacy.		
Unit 4	17	The term wave is clearly understood as the disturbance that leads to the transfer of energy from one point to another. This involves oscillation of	Group discussion			Critical thinking skills, Research and problem-solving, Creativity and innovation, Communication,		Propagation, wave, superposition of harmonics, Electric field, magnetic field, reflection, refraction, Electromagnetic, interference, diffraction, Young double slit

		individual molecules and atoms about fixed points and interchange of energy occurs between neighbouring molecules or atoms. This should be made clear to learners to avoid any misunderstandings. In a wave, the energy of a vibration is moving away from the source in the form of a disturbance within the				Co-operation, interpersonal management and life skills, Lifelong learning, Literacy, use of ICT tools, science and technology.		

		surrounding medium						
Unit 5	17	Generally speaking, network analysis is any structured technique used to mathematically analyze a circuit (a "network" of interconnected components). Quite often the technician or engineer will encounter circuits containing multiple sources of power or component configurations	Group discussion	pieces of paper, ammeters, voltmeters, galvanometers, ohmmeters, dry cells, light bulbs, resistors, dry cell holders, switches, resistance boxes, Wheatstone bridges (slide wire form or resistor form),		Critical thinking, Creativity and innovation, Research and problem-solving, ICT and science and technology		**Circuit, potential difference, Sign conventions, Kirchhoff's laws,network of resistors, Potentiometer**

		which defy simplification by series/parallel analysis techniques. In those cases, he or she will be forced to use other means. This chapter presents a few techniques useful in analyzing such complex circuits. Mathematical techniques to solve for multiple unknowns (called “simultaneous equations” or “systems”) can be applied to		potentiometers (slide wire type), resistance wires (nichrome) of different diameters and lengths, metre rules, copper wire leads				

		basic Laws of circuits to solve net works.						
Unit 6	18	Fossil fuel power plants burn carbon fuels such coal, oil or gas to generate steam that drives large turbines that produce electricity. These plants can generate electricity reliably over long periods of time. However, by burning carbon fuels they produce large amounts	Group discussion	Radioactive decay data, waste materials (like banana peels, cow dung, and others), closed containers,		Critical thinking, Lifelong learning, Communication, Co-operation, interpersonal management and life skills		Fossil fuel , non-renewable energy, coal storage, electricity, fission, Nuclear, Explosion, Global Warming, Pollution, Radioactive Wastes

Warming, Pollution, Radioactive Wastes		carbon dioxide, which causes climate change. This unit explains the types of these fossil fuels and explains non-fossil fuels and how they are used in power production and even the use in making atomic bombs. We should understand the need for this content and special attention is needed on how to avoid the negative						

		results that may erupt when using these fuels.						
Unit 7	18	It is useful if students can recognise that fields are part of the model to explain forces acting at a distance and that they recognise how diagrams are used to represent the strength of these fields. Students will have some qualitative ideas about gravitational and electric fields, when	Group discussion	Perspex rulers, electroscopes and ebonite and glass rods, silk and fur materials, pieces of paper, ammeters, voltmeters, galvanometers		Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy		**electric field and gravitational field, electrostatic force, equipotential, electricdipole, thermionic emission, Trajectory, electron deflection, electrodynamics**

		they meet the idea of gravity and electrostatics. Useful demonstrations and videos can be used to clearly explain the concepts.						
Unit 8	18	From a conceptual standpoint, orbital motion involves giving something enough horizontal velocity so that, by the time gravity pulls it down, it has traveled far enough to have Earth's surface curve	Group discussion	Large Rubber or plastic sheet		Critical thinking, Research and problem-solving, Communication, Co-operation, interpersonal management and life skills, Lifelong		Planets, Gravitational force, Centripetal force, satellite, orbit, Cosmic velocity

Heavy round object, lighter objects, such as tennis balls		away from it. As a result, it stays above the surface. An object in orbit is essentially falling around the Earth but going so fast it never hits it.				learning, numeracy, ICT, science and technology		
Unit 9	20	Atoms consist of several particles called subatomic particles like the proton, electron, neutron, positron, neutrino, meson, etc and these form the basis of particle physics which is domto-	Group discussion	Electric heaters, power supply, cathode ray oscilloscope, photo cells, TV screen,		Critical thinking, Communication, Co-operation, interpersonal management and life skills, Lifelong learning, numeracy, ICT,		**Structure of atom, planetary model, electron, spectrallines, Fluorescence, Phosphorescence, photoelectriceffect**

		inating in today's research in different domains. It is important to realise that a lot of what we know about the structure of atoms has been developed over a long period of time. This is often how scientific knowledge develops, with one person building on the ideas of someone else. We are going look at how our modern understanding				science and technology		

		of the atom has evolved over time.						
Unit 10	18	In today's world, many different types of signals that carry information that help us to communicate surround us, helping us communicate every day. The two types of signals that are used to transport information are analog and digital. Most communication uses both types of	Group discussion	Activity sheets and supporting resources (including film clips!)		Critical thinking, Creativity and innovation		**Communication system, transmission, Bandwidth, Analogue signal, digital technology**

		communication system, transmission, Bandwidth, Analogue signal, digital technology	signals. Therefore, we need a way to be able to use each type efficiently, to ensure the information reaches its destination. This unit discusses digital and analog signals and the use in modern communication.					
Unit 11	18	Like all other radio communication applications, mobile	Group discussion	Loud speakers, fixed phone,		Critical thinking, Creativity and		Radio communication, Transmitter, Digital communication,

		telephony uses radio waves to carry the information, like voice, text and images, through the air. Radio waves are a kind of electromagnetic fields (EMF) that are also called radio frequency fields or radio frequency energy. Electromagnetic fields are present in our every day life, both naturally and from man-made sources.		mobile phone, charts		innovation, Communication, Co-operation, interpersonal management and life, Life-long learning, Literacy, ICT, science and technology		Analog communication, Sampling, Quantization, Coding, cellular network, Handoffs

		Radio waves travel with the speed of light. They consist of an electric and a magnetic component, which vary periodically in time.						
Unit 12	17	Along with quantum mechanics, relativity is central to modern physics. In particular, relativity provides the basis for understanding cosmic processes and the geometry of the universe itself.	Group discussion	Activity sheets and supporting resources		Critical thinking, Research and problem-solving, Communication, Co-operation, interpersonal management and life skills, Lifelong learning,		**Relativity, frames of reference, dilation, Momentum,Galilean equation of transformation**

						ICT, Literacy, science and technology		
Unit 13	17	When two or more waves interact and combine, they interfere with one another. But interference is not necessarily bad: waves may interfere constructively, resulting in a wave larger than the original waves. Or, they may interfere destructively, combining in such a way	Group discussion	Diffraction gratings		Critical thinking, Research and problem-solving, Communication, Co-operation, interpersonal management and life skills, Lifelong learning, numeracy, Literacy, ICT, science and technology		**Interference, electromagnetic radiation, Electromagnetic spectrum, Reflection, Absorption, Transmission, Scattering, Coherence, monochromaticity, Fringe**

		that they form a wave smaller than the original ones. Even so, destructive interference may have positive effects: without the application of destructive interference to the muffler on an automobile exhaust system, for instance, noise pollution from cars would be far worse than it is. Other examples of interference, both constructive and						

		destructive, can be found wherever there are waves: in water, in sound, in light. This unit details the interference of light.						
Unit 14	18	Stars vary in their effective temperature and colour. A hot star radiates more energy per second per metre surface area than a cooler star. Does this then mean that a hot star is going to appear	Group discussion	Activity sheets and supporting resources		Critical thinking, Research and problem-solving, Communication, Co-operation, interpersonal management and life skills, Lifelong		**Solar system, Brightness-magnitude scale, Dwarfs, Hertzsprung-Russel diagram, parallax, luminosity**

		brighter to us than a cooler one? The answer to this actually depends on a few factors. These included in this unit.				learning, Literacy, ICT, science and technology		

TSCHEME OF WORK: PHYSICS S5 PCB

Academic year: …2017 Term: …1st ……… School: …………….. Subject: Physics…

Teacher's name: ……. Class+Combination:…5PCB,PCM,MPG,MPC………Numberofperiodperweek: …7……

Dates & number of lessons (periods)ina week	Units + Key Unit Competences	Lessons + Evaluation	Learning objectives	Teaching methods&Evaluation procedurestechniques	Resources&References	Observations
From January 09 (Mo) to January 13 (Friday) **(7 lessons)**	Unit 1: Wave and Particle nature of light Key Unit competences: By the end of this unit the learner should be able to analyse the nature of light	**Lesson 1:** Introduction **Lesson 2:** Planck's quantum theory **Lesson 3:** Photon theory of light **Lesson 4:** Photoelectric effect 1 **Lesson 5:** Photoelectric effect 2 **Lesson 6:** Assessment 1	By the end of these lessons, using practical examples and derivations learners will be able to explain Planck's quantum theory, photon theory of light and photoelectric effect clearly	Group work discussions. Question and answer Guided discovery Experimentation Questioning (oral) Exercises Quizzes Group work presentations	Research on internet Using libraries Laboratory equipments Teachers in the same department Flip charts Abott, A. (1989). Physics. chicago: Heinman Educational Publisher Nelkon, M., & Parker, H. (1995). Adanced Level Physics. London: Heinemann. Tom, D. (2000). Advanced Physics. London: Hodder Education. Roger A.	The lessons were successfully taught. because learners were able to

		Lesson 7: Activities on photoelectric effect			Freedman and William J. Kaufmann III, (2008): Stars and galaxies. Universe, Third Edition, W.H. Freeman and Company	Realize applications of photoelectric effects in science domains.
From January 16 (Monday) to January 20 (Friday) **(7 lessons)**	**Unit 1: Wave and Particle nature of light** **Key Unit competences:** By the end of this unit the learner should be able to analys the nature of light	**Lesson 8:** Applications of photoelectric effect **Lesson 9:** Wave theory of light **Lesson 10:** Properties of waves **Lesson 11:** Assessment 2 **Lesson 12:** Black body radiation	By the end of these lessons, using real life examples learners will be able to explain wave theory of light, properties of waves, black body radiation, Compton effect and mass energy relation of the photon clearly.	Group work discussions. Question and answer Guided discovery Experimentation Questioning (oral) Exercises Quizzes Group work presentations	Research on internet Using libraries Laboratory equipments Teachers in the same department Flip charts	

		Lesson 13: Energy, mass and momentum relation. **Lesson 14:** Compton effect.			Roger A. Freedman and William J. Kaufmann III, (2008): Stars and galaxies. Universe, Third Edition, W.H. Freeman and Company	The lessons were successfully taught. because learners were able to Explain the relationship between energy, mass and momentum of photon and differentiate electron microscope and Compton effect as applied in medicine

January 23 (Monday) to January 27 (Friday) **(7 lessons)**	**Unit 1:** **Wave and Particle nature of light** **Key Unit competences:** By the end of this unit the learner should be able to analyse the nature of light	**Lesson 15:** Photon interaction **Lesson 16:** Wave-particle duality of light **Lesson 17:** The principle of complementarities **Lesson 18**: Wave nature of matter **Lesson 19:** Electron microscope: T	By the end of these lessons, with examples learners will be able to explain photon interaction, wave-particle duality of light, the principle of complementarities, wave nature of matter and electron microscope clearly.	Group work discussions. Question and answer Guided discovery Experimentation Questioning (oral) Exercises Quizzes Group work presentations	Research on internet Using libraries Laboratory equipments Teachers in the same department Flip charts Abott, A. (1989). Physics. chicago: Heinman Educational Publisher Nelkon, M., & Parker, H. (1995). Adanced Level Physics. London: Heinemann. Tom, D. (2000). Advanced Physics. London: Hodder	

			EM **Lesson 20:** Electron micro-scope: SEM **Lesson 21:** Assessment 3		Education. Roger A. Freed-man and William J. Kaufmann III, (2008): Stars and galaxies. Universe, Third Edition, W.H. Freeman and Company	
		Evaluation		**Evaluationproce-dures** This should be based on the results of assessment I, assessment II and assessment III		Most of stu-dents were successful in this unit.

Lesson plan

A lesson plan is a teacher's detailed description of the course of instruction, r 'learning trajectory' for a lesson. A daily lesson plan is developed by a teacher to guide class learning. Proper classroom planning will keep teachers organized and on track while teaching, thus allowing them to teach more and help students reach objectives more easily. The better prepared the teacher is, the more likely she/he will be able to handle whatever unexpectedly happens in the lesson.

LESSON PLANNING:

- provides a coherent framework for smooth efficient teaching.
- helps the teacher to be more organized.
- gives a sense of direction in relation to the syllabus.
- helps the teacher to be more confident when delivering the lesson.
- provides a useful basis for future planning.
- helps the teacher to plan lessons which cater for different students.
- Is a proof that the teacher has taken a considerable amount of effort in his/her teaching.

In this guide, table IV is a format of the lesson plan and is flexible for some changes about which the teacher feels more comfortable according to the teaching and learning situation and the content to teach. But in making changes the teacher should bear in mind that this Lesson plan should be detailed and structured systematically to make lesson delivery perfect and easy.

Table IV: Lesson Plan with guidelines

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

Term	**Date**	**Subject**	**Class**	**Unit N**	**Lesson N**	**Duration**	**Class size**
I	25 /01/ 2017	Physics	S.5	1	1 of 24	40 minutes	30
TypeofSpecialEducationalNeedstobecateredforinthislessonandnumberoflearners in each category				Number of learners with impairment and the type of impairment e.g. one student has hearing impairment			
Unit title	Wave and particle nature of light						
KeyUnitCompetence	By the end of this unit the learner should be able to analysis the nature of light						
Title of the lesson	**Introduction to the theory of quantum mechanics**						
Instructional Objective	With the help of real life examples, learners will be able to explain the theory of quantum mechanics clearly						
Plan for this Class (location:in/outside)	In class						
Learning Materials (for all learners)	Flip charts, audio-visual materials						
References	• Abott, A. (1989). Physics. Chicago: Heinman Educational Publisher • Nelkon, M., & Parker, H. (1995). Adanced Level Physics. London: Heinemann. • Tom, D. (2000). Advanced Physics. London: Hodder Education.						

Timing for each step	Description of teaching and learning activity By viewing documentary videos learners will be able to understand the quantum theory correctly.		Generic competences and Cross cutting issues to be addressed + a short explanation
	Teacher's activities	**Learner's activities**	
Steps and Timing			
INTRODUCTION: (5 minutes)	Begin the lesson asking learners the opening question and allow them to react on it. **Give them the worksheet** **Theteachertrystoanswer questions.**	Let the learners responde to the questions and suggest possible answers according to their understanding.	Critical thinking is developed through responding to the questions. Communication skills are developed in responding/ answering to the questions. Peace and values are addressed through reespecting each other in asnwering questions.

Development of the lesson **(30minutes)**	The teacher displays the documentary videos about quatium theory and lets the learners watch. The teacher provides questions related to quatium theory, and schedule the presentation after the discussions in their respective groups.	Learners watch the documentary videos displayed Learners share ideas and suggest possible answers, then prepare for the for presentation. Learners make presentation about the findings of their discussions.	Through watching vides, critical thinking is developed. Co-operation and communication skills are developed through sharing ideas and presentation. Genddear is addressed in group making and presentation. Peace and value is addressed through team work spirit.
	Perform an activity and presentation of the results with assist learner in their groups. Appreciate and give comments on the presentation.	Carry out different measurements and record the values obtained. Present their work in front of other groups.	
	Gives summary on the work presented.	✓ Write down the comments of the facilitator in their note books	
Conclusion (5 min)	Teacher provides and justifies the expected answers.	Write down the answers and comments about the answers being provided.	Critical thinking through recognition of responces of the challanges in the lesson.
Teacher self-evaluation	Collect materials given and rearrange the class room		

UNIT 1

Wave and Practical Nature of Light

KNOW THIS

Light is a complex phenomenon that is classically explained with a simple model based on rays and wave-fronts. An excellent comparison of the wave and particle theories involves the differences that occur when light is reflected from a smooth, specular surface, such as a mirror. This unit is interesting but the teacher needs to give concrete examples and explanations to delete any confusions.

Key unit competence

Analyse the nature of light

Unit description

This unit involves theories which the learner should understand and master. It would be helpful to carry out some demonstrations and presentations using projected videos and other IT tools to explain some principles deeply. This unit deals with;

1.1 Planck's quantum theory
1.2 Photon theory of light
1.3 Photoelectric effect
1.4 Wave theory of monochromatic light
1.5 Properties of a light wave
1.6 Blackbody radiation
1.7 Energy, mass and momentum of a photon
1.8 Compton effect
1.9 Photon interactions
1.10 Wave-particle duality of light
1.11 The principle of complementarities
1.12 The wave nature of matter
1.13 Electron microscope

Summary of Knowledge, Skills, Attitudes and Values

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

Knowledge	Skills	Attitudes and value
State Planck's quantum theory.	Explain the wave theory of light and state its limitations	Appreciate the importance of light waves in life.
Explain the photon theory of light and photoelectric effect.	Describe phenomena of black-body radiation.	Realize applications of photoelectric effects in science domains.
Explain the relationship between energy, mass and momentum of photon.	Evaluate properties of light as a wave.	Recognize the value of analyzing light energy.
	Describe photon interactions and the wave nature of matter.	
	Investigate the theory of wave-particle duality.	
	Describe electron microscope and Compton Effect as applied in medicine.	

Learning objectives

By the end of this unit learners will be able to;

- explain the Planck's quantum theory and apply it to other theories.
- explain photoelectric effect and use it to derive and apply Einstein's photoelectric equation.
- derive the Compton shift using the scattering principle of obstructed photon.

SCOPE AND SEQUENCE

This unit will be delivered in 21 lessons each of 40 minutes.

Unit 1: Wave and Particle nature of light

Lesson 1	Lesson 2	Lesson 3	Lesson 4
This lesson should cover: Introduction	**This lesson should cover:** Planck's quantum theory	**This lesson should cover:** Photon theory of light	**This lesson should cover:** Photoelectric effect 1
Lesson 5	**Lesson 6**	**Lesson 7**	**Lesson 8**
This lesson should cover: Photoelectric effect 2	**This lesson should cover:** Assessment 1	**This lesson should cover:** Activities on photoelectric effect	**This lesson should cover:** Applications of photoelectric effect
Lesson 9	**Lesson 10**	**Lesson 11**	**Lesson 12**
This lesson should cover: Wave theory of light	**This lesson should cover:** Properties of waves	**This lesson should cover:** Assessment 2	**This lesson should cover:** Black body radiation
Lesson 13	**Lesson 14**	**Lesson 15**	**Lesson 16**
This lesson should cover: Energy, mass and momentum relation	**This lesson should cover:** Compton effect	**This lesson should cover:** Photon interaction	**This lesson should cover:** Wave-particle duality of light
Lesson 17	**Lesson 18**	**Lesson 19**	**Lesson 20**
This lesson should cover: The principle of complementarities	**This lesson should cover:** Wave nature of matter	**This lesson should cover:** Electron microscope: TEM	**This lesson should cover:** Electron microscope: SEM
Lesson 21			
This lesson should cover: Assessment 3			

LESSON DEVELOPMENT

Lesson 1	**Title: Introduction**
Learning objectives	By the end of this lesson using real life examples, learners will be able to explain the theory of quantum mechanics clearly.
Key words	Quantum mechanics
Cross-cutting issues to discuss	Gender, peace and values.
Competence developed	Critical thinking skills, Co-operation, interpersonal management and life skills, Lifelong learning, literacy, use of ICT tools, communication skills
Attention to special educational need children	Special care should be given to learners with hearing and visual impairments since the lesson is more theoretical and needs the use of audio-visual instruments.
Lesson 2	**Title: Planck's quantum theory**
Learning objectives	By the end of this lesson, using Planck's quantum theory hypothesis, learners will be able to explain the variation of the photon's energy with frequency accurately.
Key words	Planck's quantum theory, Planck's constant, photon
Cross-cutting issues to discuss	Gender, peace and values.
Competence developed	Critical thinking, Co-operation, interpersonal management and life skills, Life long learning, literacy, communication skills
Attention to special educational need children	Special attention is needed for learners with intellectual difficulties which highly arise when dealing with calculations.

Lesson 3	**Title: Photon theory of light**
Learning objectives	By the end of this lesson, using real life examples, learners will be able to explain the photon theory of light clearly.
Key words	Photons, Photon theory of light.
Cross-cutting issues to discuss	Gender, peace and values.
Competence developed	Critical thinking skills, Co-operation, interpersonal management and life skills, Life long learning, literacy, use of ICT tools, communication skills
Attention to special educational need children	Special care should be given to learners with hearing and visual impairments since the lesson is more theoretical and needs the use of audio-visual instruments.
Lesson 4	**Title: Photoelectric effect 1**
Learning objectives	By the end of this lesson, using the hypothesis of Einstein learners will be able to explain and derive the Einstein's photoelectric equation easily.
Key words	Photoelectric equation, work function, threshold frequency, threshold wavelength, kinetic energy
Cross-cutting issues to discuss	Gender, peace and values.
Competence developed	Co-operation, interpersonal management and life skills, Life long learning, literacy, use of ICT tools, communication skills
Attention to special educational need children	The lesson should be developed using audio-visual instruments so that learners with hearing and visual impairment can be considered.

Lesson 5	**Title: Photoelectric effect 2**
Learning objectives	By the end of this lesson, using Einstein's photoelectric equation learners will be able to solve calculations dealing with photoelectric effect and graphically interpret them accurately.
Key words	Photoelectric equation, work function, threshold frequency, threshold wavelength, kinetic energy, stopping potential
Cross-cutting issues to discuss	Gender, peace and values.
Competence developed	Critical thinking skills, Co-operation, interpersonal management and life skills, Lifelong learning, literacy, communication skills, numeracy.
Attention to special educational need children	Intellectual, developmental, speech and language disabilities should be taken care of.
Lesson 6	**Title: Assessment 1**
Learning objectives	By the end of this assessment using knowledge and skills gained in previous lessons, learners will be able to relate the content with the real life experiences.
Key words	Quantum mechanics, Planck's quantum theory, Planck's constant, photon, Photon theory of light, Photoelectric equation, work function, threshold frequency, threshold wavelength, stopping potential
Cross-cutting issues to discuss	Gender, peace and values.
Competence developed	Critical thinking, problem solving.

Attention to special educational need children	Printed papers should be clear to make it easy for learners with visual impairment to read.
Lesson 7	**Title: Activities on photoelectric effect**
Learning objectives	By the end of this lesson practically, learners will be able to explain photoelectric effect clearly.
Key words	Photoelectric effect, stopping potential, work function, threshold wavelength and frequency, graphical presentation.
Cross-cutting issues to discuss	Gender, peace and values.
Competence developed	Critical thinking skills, Research and problem-solving, Creativity and innovation, Communication, Co-operation, interpersonal management and life skills, Lifelong learning, Literacy, use of ICT tools, science and technology.
Attention to special educational need children	Special care should be taken for learners with visual, intellectual, developmental, physical and hearing impairments.
Lesson 8	**Title:Applicationsofphotoelectric effect**
Learning objectives	By the end of this lesson using practical and real life examples, learners will be able to explain and apply the theory of photoelectric effect properly.
Key words	Photoelectric effect, anode, cathode, photoelectrons, photons, photocells, current.
Cross-cutting issues to discuss	Gender, peace and values.

Competence developed	Critical thinking skills, Research and problem-solving, Creativity and innovation, Communication, Co-operation, interpersonal management and life skills, Lifelong learning, Literacy, use of ICT tools, science and technology.
Attention to special educational need children	Special attention is taken for learners with visual, hearing and developmental disabilities.
Lesson 9	**Title: Wave theory of light**
Learning objectives	By the end of this lesson, theoretically learners will be able to explain the wave theory of light properly.
Key words	Wave theory, Wavelets, Wave front, Wave normal, Primary source and Secondary source.
Cross-cutting issues to discuss	Gender, peace and values.
Competence developed	Critical thinking skills, Communication, Co-operation, interpersonal management and life skills, Lifelong learning, Literacy, use of ICT tools, science and technology.
Attention to special educational need children	Special attention is given to learners with visual, hearing and developmental disabilities.
Lesson 10	**Title: Properties of waves**
Learning objectives	By the end of this lesson graphically and using examples, learners will be able to state and explain the properties of waves properly.
Key words	Wavelength, amplitude, periodic time, frequency, phase angle
Cross-cutting issues to discuss	Gender, peace and values.

Competence developed	Critical thinking skills, Communication, Co-operation, interpersonal management and life skills, Life long learning, Literacy.
Attention to special educational need children	Special attention is given to learners with visual, hearing and developmental disabilities.
Lesson 11	**Title: Assessment 2**
Learning objectives	By the end of this assessment using knowledge and skills gained in previous lessons, learners will be able to relate the content with the real life experiences.
Key words	Photoelectric effect, work function, threshold wavelength and frequency, photoelectrons, photons, Wavelets, Wave theory, properties of waves.
Cross-cutting issues to discuss	Gender, peace and values.
Competence developed	Critical thinking, problem solving.
Attention to special educational need children	Printed papers should be used to make it easy for learners with visual impairment to read.
Lesson 12	**Title: Black body radiation**
Learning objectives	By the end of this lesson using practical examples, learners will be able to explain the black body radiation clearly.
Key words	Blackbody, emission of electromagnetic waves, temperature
Cross-cutting issues to discuss	Gender, peace and values.
Competence developed	Critical thinking skills, Communication, Co-operation, interpersonal management and life skills, Lifelong learning, Literacy, science and technology.

Attention to special educational need children	Special attention is given to learners with visual, hearing and developmental disabilities.
Lesson 13	**Title:Energy,massandmomentum relation**
Learning objectives	By the end of this lesson mathematically, learners will be able to derive the mathematical relation between mass, energy and momentum of the photon clearly.
Key words	Energy, mass and momentum of a photon
Cross-cutting issues to discuss	Gender, peace and values.
Competence developed	Criticalthinkingskills,Co-operation, interpersonal management and life skills, Lifelong learning, literacy, communication skills, numeracy.
Attention to special educational need children	Special attention is needed for learners with intellectual difficulties which highly arise when dealing with calculations, developmental, hearing and visual impairments.
Lesson 14	**Title: Compton effect**
Learning objectives	By the end of this lesson with derivations, learners will be to explain the scattering of the photon and electron emission properly,
Key words	x-rays, scattering, Compton effect, Compton shift,
Cross-cutting issues to discuss	Gender, peace and values.
Competence developed	Criticalthinkingskills,Co-operation, interpersonal management and life skills, Lifelong learning, literacy, communication skills, numeracy.
Attention to special educational need children	Special attention is given to learners with visual, hearing and developmental disabilities.

Lesson 15	**Title: Photon interaction**
Learning objectives	By the end of this lesson using examples learners will be able to explain different kinds of photon interactions properly.
Key words	Photon interactions, Coherent Scattering, Photoelectric Effect, Compton Interaction, Pair Production, Photodisintegration
Cross-cutting issues to discuss	Gender, peace and values.
Competence developed	Critical thinking skills, Co-operation, interpersonal management and life skills, Lifelong learning, literacy, communication skills.
Attention to special educational need children	Special attention is given to learners with visual, hearing and developmental disabilities since audio visual instruments can be used in lesson delivery.
Lesson 16	**Title: Wave-particle duality of light**
Learning objectives	By the end of this lesson, simple examples learners will be able to explain the wave particle nature of light properly.
Key words	Interference, diffraction, polarization, Planck's hypothesis, photoelectric experiment, black body experiment
Cross-cutting issues to discuss	Gender, peace and values.
Competence developed	Critical thinking skills, Co-operation, interpersonal management and life skills, Lifelong learning, literacy, communication skills.

Attention to special educational need children	Special attention is given to learners with visual, hearing and developmental disabilities since audio visual instruments can be used in lesson delivery.
Lesson 17	**Title: The principle of complementarities**
Learning objectives	By the end of this lesson, theoretically learners will be able to explain the principles of complementarities clearly.
Key words	Principle of complementarities
Cross-cutting issues to discuss	Gender, peace and values
Competence developed	Critical thinking skills, Co-operation, interpersonal management and life skills, Lifelong learning, literacy, communication skills.
Attention to special educational need children	Special care is given to learners with hearing and visual impairments.
Lesson 18	**Title: Wave nature of matter**
Learning objectives	By the end of this lesson theoretically, learners will be able to explain the wave nature of matter.
Key words	Wave nature of matter, Broglie wavelength
Cross-cutting issues to discuss	Gender, peace and values.
Competence developed	Critical thinking skills, Co-operation, interpersonal management and life skills, Lifelong learning, literacy, communication skills.
Attention to special educational need children	Special care is given to learners with hearing and visual impairments.

Lesson 19	**Title: Electron microscope: TEM**
Learning objectives	By the end of this lesson, with clear examples learners will be able to explain the working mechanism of transmission electron microscope properly.
Key words	Transmission electron microscope, fluorescent screen, cathode, anode, electron beam
Cross-cutting issues to discuss	Gender, peace and values
Competence developed	Critical thinking skills, Co-operation, interpersonal management and life skills, Lifelong learning, literacy, communication skills.
Attention to special educational need children	Care is taken for learners with visual, physical and hearing impairments.
Lesson 20	**Title: Electron microscope: SEM**
Learning objectives	By the end of this lesson, with clear examples learners will be able to explain the working mechanism of scanning electron microscope properly.
Key words	Scanning electron microscope, Detectors, back scattered electrons, TV screen
Cross-cutting issues to discuss	Gender, peace and values
Competence developed	Critical thinking skills, Co-operation, interpersonal management and life skills, Lifelong learning, literacy, communication skills.
Attention to special educational need children	Care is given to learners with visual, physical and hearing impairments.

Lesson 21	**Title: Assessment 3**
Learning objectives	By the end of this assessment, using knowledge and skills gained in previous lessons, learners will be able to relate the content with the real life experiences.
Key words	Blackbody, electromagnetic waves, Energy, mass and momentum of a photon, Compton effect, Compton shift, Coherent Scattering, Photo-electric Effect, Compton Interaction, Pair Production, Photo-disintegration, Wave-particle duality of light, Principle of complementarities, Wave nature of matter, de-Broglie wavelength, electron microscope.
Cross-cutting issues to discuss	Gender, peace and values.
Competence developed	Critical thinking, problem solving.
Attention to special educational need children	Printed papers should be used to make it easy for learners with visual impairment to read.

Main contents and concepts to emphasise

Quantum mechanics is the system of laws which governs the behaviour of matter on the atomic scale. So Quantum mechanics is required to analyze the behaviour of molecules, atoms, and nuclei.

Planck's quantum theory arose out of the inability of the classical physics to explain the experimentally observed distribution of energy in the spectrum of a black body.

$$E = nhf = \frac{nhc}{l}$$

The **photon theory** of light suggests that all light comes from a radiating source and is transmitted as tiny particles, or photons as they are now called.

According to Einstein's theory, an electron is ejected from the metal by a collision with a single photon. Energy of the photon is used as stated in the famous **Einstein photoelectric equation**

$$hf = W_o + K.E_{\max}$$

Photoelectric emission is the phenomenon of emission of electrons from the surface of metals when the radiations of suitable frequency and suitable wavelength fall on the surface of the metal.

Work function is the minimum energy required to set free an electron from the binding forces on the metal surface.

The **Threshold Frequency** is defined as the minimum frequency of incident light required for the photo electric emission.

Stopping potential is the potential difference applied until no electron reaches the anode and no current flows.

$$V_s = \frac{h}{e}(f - f_o)$$

Wave theory of monochromatic light: If light consists of undulations in an elastic medium it should diverge in every direction from each new centre of disturbance, and so, like sound, bend round all obstacles and obliterate the shadow.

A **wave:** is any disturbance that results into the transfer of energy from one point to another point.

Primary source: The geometrical center or axis of the actual source of light which is either a point or a line is called the primary source.

Wavelets: All points lying on small curved surfaces that receive light at the same time from the same source (primary or secondary) are called wavelets.

Secondary source: Any point on a wavelet, acts as the source of light for further propagation of light. It is called a secondary source.

Wave front: The envelope of all wavelets in the same phase- having received light from sources in the same phase at the same time is called a wave front.

Wave normal: The normal at any point drawn outward on a wave front is called the wave normal. Further propagation of light occurs along the wave normal. In isotropic media the wave normal coincides with the 'ray of light'.

A **black body** is a theoretical object that absorbs 100% of the radiation that hits it and re-radiates energy which is characteristic of this radiating system or body only.

The mass, energy and momentum of a photon are related according to equations;

$$E = mc^2 \quad P = \frac{E}{c} \qquad \text{(where } m \text{ is the mass defect)}$$

Compton effect says that when x-rays are projected on the target, they are scattered after hitting the target and change the direction in which they were moving. The Compton shift for the photon is given by

$$l' - l = \frac{h}{mc}(1 - \cos f)$$

Photon interactions: Because photons are electrically neutral, they do not steadily lose energy via coulombic interactions with atomic electrons, as the charged particles. Photon interactions include; Coherent Scattering, Photoelectric Effect, Compton Interaction, Pair Production and Photodisintegration.

Wave-particle duality of light: According to different experiments and properties, light behaves as waves as well as particles.

Principle of complementarities: Both properties of light of being a wave and a particle are necessary for gaining complete knowledge of the phenomena; They are complementary to each other but at the same time they also exclude each other.

The wave nature of matter: It is important to realize that the attribution of a wavelength to a massive particle implies that it should behave as a wave under some conditions.

Electron microscope: is an instrument that uses one or several lenses to form an enlarged (magnified) image. The most common electron microscopes are Transmission Electron Microscope (TEM) and Scanning Electron Microscope (SEM).

SOLUTION TO ACTIVITIES

Possible solutions to the Opening question

(*a*) Sarah's potential energy increases because she is climbing up the ladder and thus her height from the ground increases.

(*b*) The potential energy of Jovia is greater than that of Peter because of her height above peter.

(*c*) As Jovia slides down, her potential energy decreases and will be zero the moment she reaches the ground.

(*d*) Mr. John is assisting the kids to climb the ladder.

The kid's energy and potential are not enough to make her reach the top of the ladder.

From the learners' book, the electron is shown interacting with light and subsequently dissipating the excess energy it receives from the light by doing work in an external circuit. The electric current flows through external circuit via terminals F and B. The sequence involved is analogous to the children playing on the slide with the help of Mr. John.

SOLUTION TO APPLICATION ACTIVITY 1.1

1. The comprehensive theory incorporating the wave and quantum aspects of a particle together is dealt with what is called "quantum mechanics".
2. Planck believed that radiation is composed of energy bundles only in the vicinity of the emitter and once emitted, the radiation energy spreads as waves.
3. There four postulates of Planck theory:
   (a) The matter is composed of a large number of oscillating particles. These oscillators have different frequencies.
   (b) The radiant energy which is emitted or absorbed by the blackbody is not continuous but discontinuous in the form of small discrete packets of energy and each such packet of energy is called a 'quantum'. In case of light, **the quantum** of energy is called a **'photon'**.
   (c) The energy of each quantum is directly proportional to the frequency (f) of the radiation, the energy of the oscillations of atoms within molecules cannot have just any value; instead each has energy which is a multiple of a minimum value related to the frequency of oscillation by

$$E = hf = \frac{hc}{\lambda}$$

Where

- $h = 6.63\times 10^{-34}\ J\cdot s = 4.136\times 10^{-15}\ eV\cdot m$ is the Planck's constant and E the energy of a particle;

- λ is the wavelength and f the frequency of the corresponding wave

- $hc = (6.63\times 10^{-34}\ J\cdot s)(3.00\times 10^{8}\ m/s) = 1\,240\ eV\cdot nm$

(d) The oscillator emits energy, when it moves from one quantized state to the other quantized state. The oscillator does not emit energy as long as it remains in one energy state. The total amount of energy emitted or absorbed by a body will be some whole number quanta.

Hence $E = nhf$

4. $E = hf = 6.63 \times 10^{-34} \times 4.69 \times 10^{14} = 3.11 \times 10^{-19} J$

$$Number\ of\ quanta = \frac{1.3 \times 10^{-2}}{3.11 \times 10^{-19}} = 4.18 \times 10^{16}$$

5. (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.

6. (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.

7. Photon momentum $p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}\ J.s}{650 \times 10^{-9}\ m} = 1.02 \times 10^{-27}\ kg.m/s$

Energy of a single photon $E = pc$

$$E = (1.02 \times 10^{-27}\ kg\ \ m/s)(3 \times 10^{8}\ m/s) = 3.06 \times 10^{-19}\ J = 1.91\, eV$$

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

$$\frac{5.00 \times 10^{-3}}{3.06 \times 10^{-19}} = 1.63 \times 10^{16}\ photons/s$$

8. a) Energy of photon $E = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34}\ J.s)(3 \times 10^{8}\ m/s)}{589 \times 10^{-9}\ m} = 3.38 \times 10^{-19}\ J$

b) From energy of photon

$$E = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34}\ J.s)(3 \times 10^{8}\ m/s)}{1240 \times 10^{-9}\ m} = 1.6 \times 10^{-19}\ J = 1.0\, eV$$

SOLUTION TO ACTIVITIES

ACTIVITY 1-1

(a) The amplitude of the wave is 2.08 cm
(b) The wavelength of the wave is 6 cm
(c) Point A is called the trough.

ACTIVITY 1-2

V	T	A	O	I	W	A	T	X	O	W	O	O	D	R	O	P	S	S	E	A	S	U	P	T	S
S	C	A	T	T	E	R	I	N	G	A	C	A	N	U	M	B	E	P	H	X	D	E	E	X	Z
A	M	X	Q	Q	I	Y	P	H	O	T	O	D	I	S	I	N	T	E	G	R	A	T	I	O	N
O	W		A	B	D	C	O	U	L	O	M	B	I	C	L	X	U	E	F	A	C	H	P	L	P
E	L	E	C	T	R	O	N	A	T	E	P	U	I	O	N	I	P	D	S	Y	J	O	O	S	O
S	X	I	N	C	O	H	E	R	E	N	T	O	S	D	Q	Z	T	M	D	U	H	M	L		O
U	O	P	O	T	S	M	L	E	P	R	O	D	U	C	T	I	O	N	U	S	O	S	F	X	S
A	I	N	T	E	R	A	C	T	I	O	N	L	T	I	T	T	L	K	O	T	S	O	X	D	Z
O	S	M	C	O	S	U	N	M	O	D	I	F	I	E	D	I	P	H	O	T	O	N	T	P	L

MORE ACTIVITIES

Light of a set frequency is shone onto a plate of Sodium. Electrons are ejected towards to the top plate, which is connected to the negative of a variable power supply. The voltage is increased until the current decreases to zero, and the voltage was recorded. The frequency was changed and the experiment repeated.

The following results were obtained.

Frequency × 10^{14}(Hz)	Stopping voltage (V)
5.3	0.45
6.9	1.0
7.75	1.3
8.25	1.6
9.9	2.4
11.9	3.15

(a) Plot this experimental data for Sodium
(b) Use your graph to determine values for Planck's constant, the Threshold Frequency and the Work Function for the metal.

SOLUTION TO EXERCISE 1.2

1. $E_{rest} = mc^2$

   $E_{rest} = 9.11 \times 10^{-31}$ kg × $(3.00 \times 10^8 \text{ m s}^{-1})^2$

   $= 8.2 \times 10^{-14}$ J.

2. Energy in eV is energy in joules divided by 1.6×10^{-19} *J/eV*

   $$E = \frac{8.2 ^{\text{\textasciiacute}}\ 10^{-34}\ J}{1.60 ^{\text{\textasciiacute}}\ 10^{-19}\ J/eV} = 0.51\,MeV$$

3. 0.51 MeV since electrons and positrons have identical mass.
4. 1.02 MeV. Two particles, each of rest energy 0.51 MeV, are annihilated.
5. 0.51 MeV each. The two photons share the total 1.02 MeV.
6. 1.02 MeV. The photon has to create the rest energy of two particles, each 0.51 MeV.
7. Approximately 10^4 pairs. Each pair requires approximately

   $1\,MeV = 1 ^{\text{\textasciiacute}}\ 10^6\ eV$ and $10GeV = 10 \times 10^9\ eV$ is available.

SOLUTION TO APPLICATION ACTIVITY 1.3

MORE ACTIVITIES

1. Clearly analyzing the images of Fig.1-4, answer the questions that follow;

Fig.1.4. Behavior of light

(*a*) When particles hit a surface, what do you expect to see? (Bounce, reflection)

(*b*) When particles enter a surface, what do you expect to see? (They slow down, change direction, etc)

(*c*) Can you visualize reflection and refraction as particles?

(*d*) If in a dark room there is a single bulb on the wall and we put a partition in front of the light, will the room be completely dark behind the partition?

(*e*) What happens in the light bulb case? How is the light spread in the room? Can light (travelling in a straight line) bend around the partition?

(*f*) If you imagine waves of light, how would you explain this (think of waves of water)?

(*g*) Now what is your conclusion about the theory of light?

SOLUTION TO ACTIVITIES

(*a*) We see reflection and/or refraction.

(*b*) They slow down or move faster depending on the nature of the surface and they then change direction.

(*c*) Yes, if the partition is big then we can see the room completely dark. If this partition is small the room will not be completely dark behind the partition.

(*d*) In the light bulb case, light spreads out in all directions like particles being emitted out. It spreads in the room by disturbance that reads to the transfer of energy form a point to a point. Yes. Light can bend around the partition.

END UNIT ASSESSMENT

1. Answer: $E = 3.07 \times 10^{-19}$ J, $f = 4.57 \times 10^{14}$ Hz
2. 1.6×10^{30} s^{-1} [Hint number of photons = $\dfrac{\text{energy/unit time}}{\text{energy/photon}}$]
3. Phenomena like interference, laws of refraction, reflection, simultaneous refraction and reflection, double refraction etc can be explained on the basis of this theory.

   According to Huygens, theory, the velocity of light in denser medium is less than velocity of light in a rarer medium as was experimentally proved by Foucault.

   [Note: for rest of the questions see notes]

4 a) $\lambda = \dfrac{h}{mv} = \dfrac{6.63 \times 10^{-34}\ J.s}{0.05\ kg \times 40\ m/s} = 3.3 \times 10^{-34}\ m$

b) $K = \dfrac{p^2}{2m} = \dfrac{h^2}{2m\lambda^2} \Rightarrow \lambda = \dfrac{h}{\sqrt{2mK}} = \dfrac{6.63 \times 10^{-34}\ J.s}{\sqrt{2(9.11 \times 10^{-19}\ kg)(13.6 \times 1.6 \times 10^{3} \times 1.6 \times 10^{-19}\ J)}} = 0.33\ nm$

c. $\lambda = \frac{h}{\sqrt{2mqV}} = \frac{6.63\times 10^{-34}\ J.s}{\sqrt{2(9.11\times 10^{-19}\ kg)(100\times 10^{3}\times 1.6\times 10^{-19}\ J)}} = 3.885\times 10^{-12}\ m$

5. $\lambda = \frac{h}{mv} = \frac{6.63\times 10^{-34}\ J.s}{(0.175\ kg)(23.6\ m)} = 1.60\times 10^{-34}\ m$

6. $K = \frac{hc}{\lambda} - \phi = \frac{(6.63\times 10^{-34}\ J.s)(3\times 10^{8}\ m/s)}{200\times 10^{-9}\ m}\left(\frac{1\ eV}{1.6\times 10^{-19}\ J}\right) - 5.01\ eV = 1.21\ eV$

$V_s = \frac{K}{e} = \frac{1.21\ eV}{e} = 1.21\ V$

7. $K = \frac{hc}{\lambda} - \frac{hc}{\lambda_o} = (6.63\times 10^{-34})(3\times 10^{8})\left(\frac{1}{200\times 10^{-9}} - \frac{1}{440\times 10^{-9}}\right) = 5.42\times 10^{-19}\ J = 3.38\ eV$

$V_s = \frac{K}{e} = \frac{3.38\ eV}{e} = 3.38\ V$

8. Let's assume an average wavelength in the middle of the visible spectrum $\lambda = 500\ nm$

The energy of each photon is $E = hf = \frac{hc}{\lambda}$. Only 3% of the 100 W power is emitted as visible light, or $P = 100\times 3\% = 3\ W$

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 $P = 3\ J/s$ $P = Nhf$ is where N is the number of photons emitted per second and

Hence $N = \frac{P\lambda}{hc} = \frac{(3\ J/s)(500\times 10^{-9}\ m)}{(6.63\times 10^{-34}\ J.s)(3\times 10^{8}\ m/s)} = 8\times 10^{18}\ photons/s$.

9) (i) Photoelectric effect Compton effect

(ii) Reflection of light refraction of light interference of light

10. (a) Photoelectric effect is the emission of electrons from the surface of a metal when light of suitable frequency / energy shines on it

b) ***Einstein's photoelectric law*** $hf = \phi + \frac{1}{2}mv^2$

c) Photons (of light) / quanta / packets (or bundles) of energy all of energy from one photon is given to one electron energy must be greater than work function of metal for P.E.E. to occur / for electron to escape

d) ***Application of the photoelectric effect***: sound track in film, photography, counters, photocell, burglar alarm, automatic doors, etc.

UNIT

2

Simple Harmonic Motion

KNOW THIS

A lot of things in nature repeat themselves over and over again as time passes. Think of an example like our own planet orbiting the sun. Every 365 days it completes a single revolution around the sun. It's been doing this for millions of years, and will continue to do it on the same schedule for millions of years. There are many interesting facts of simple harmonic motion in our everyday life of which learners should know.

Key unit competence

Analyze energy changes in simple harmonic motion.

Unit description

We have already studied the most common types of motion in level four: linear and rotational motion. We developed the concepts of work, energy, and momentum for these types of motion. To complete our study of classical mechanics we must finally examine the complicated case of oscillations. Unlike the other types of motion we have studied, oscillations generally do not have constant acceleration, are many times chaotic and require far more advanced mathematics to handle. As such, we give a complete treatment to the subject as possible, concentrating on the kinds of oscillations that are easiest to examine. This unit covers;

2.1 Kinematics of Simple Harmonic Motion

2.2 Equation of Simple Harmonic motion

2.3 Solution of a Simple Harmonic motion equation

2.4 Simple Harmonic oscillators

- 2.4.1 Simple Pendulum
- 2.4.2 Mass on a Coil Spring
- 2.4.3 Torsion Pendulum
- 2.4.4 Compound pendulum
- 2.4.5 Liquid in a U-tube

2.5 Kinetic and Potential energy of an oscillating system

2.6 Energy changes in an oscillating system
2.7 Energy conservation in oscillating systems
2.8 Superposition of harmonics of same frequency and same direction
2.9 Superposition of harmonics of same frequency and opposite direction

Summary of knowledge, skills, attitudes and values

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

Knowledge	Skills	Attitudes and value
Explain kinematics and simple harmonic motion	**Distinguishkinematics and simple harmonic motion**	**Appreciatetheimportance of simple harmonic motion in life.**
Describe examples of simpleharmonicoscillators.	**Analyse examples of simple harmonic motion oscillators.**	**Acquirescientificreasoning and attitude forinterpretingsimple harmonic motion.**
Explaintheequations ofsimpleharmonicmotion.	**Derive equations of simple harmonic motion.**	**Acquire aptitude to logically and systematicallypursuesimple harmonicmotionsituations**
Explainenergychange andconservationinoscillating systems.	**Analyseenergychangesandconservationin oscillating systems.**	**Adaptscientificmethodofthinkingapplicable in all areas of life.**
Explainsuperposition of harmonics of same frequency.	**Analysesuperposition of harmonics of frequency.**	**Acquireknowledgefor analysing and modellingphysicalprocesses.**
		Enjoyobservingbodies undergoingsimpleharmonic motion

Learning objectives

By the end of this lesson, learners will be able to;

- determine the periodic time of an oscillating mass by practically and by calculation accurately.
- derive and apply the equation of simple harmonic motion correctly
- determine the periodic time of the simple pendulum correctly.

SCOPE AND SEQUENCE

This unit will be delivered in 20 lessons each of 40 minutes.

Unit 2: Simple Harmonic motion			
Lesson 1	**Lesson 2**	**Lesson 3**	**Lesson 4**
This lesson should cover: Kinematics of Simple Harmonic Motion	**This lesson should cover:** Equation of Simple Harmonic motion and its solution	**This lesson should cover:** Simple Pendulum	**This lesson should cover:** Determination of acceleration due to gravity using a simple pendulum bob
Lesson 5	**Lesson 6**	**Lesson 7**	**Lesson 8**
This lesson should cover: Mass on a Coil Spring	**This lesson should cover:** Assessment 1	**This lesson should cover:** Determination of acceleration due to gravity using a spiral spring.	**This lesson should cover:** Torsion Pendulum
Lesson 9	**Lesson 10**	**Lesson 11**	**Lesson 12**
This lesson should cover: Compound pendulum	**This lesson should cover:** Liquid in a U-tube	**This lesson should cover:** Kinetic and Potential energy of an oscillating system	**This lesson should cover:** Assessment 2
Lesson 13	**Lesson 14**	**Lesson 15**	**Lesson 16**
This lesson should cover: Energy changes in an oscillating system	**This lesson should cover:** Energy conservation in oscillating systems	**This lesson should cover:** superposition of harmonics of same frequency and same direction	**This lesson should cover:** superposition of harmonics of same frequency and opposite direction
Lesson 17			
This lesson should cover: assessment 3			

Suggested Answers to the Introductory Activity.

a) In each case, when the mass is displaced and then released, it will move up and down. In other words, it will oscillate. This oscillatory motion is periodic and displacement keeps reducing until the mass returns to its rest position.

b) Child's swing

Pendulum bob

Liquid in U-Tube

Shock absorbers etc

c) Engineering like in shock absorbers

Recreational like the Canopy in Nyungwe National Park.

LESSON DEVELOPMENT

Lesson 1	**Title:KinematicsofSimpleHarmonicMotion**
Learning objectives	By the end of this lesson, practically and by calculations learners will be able to determine the periodic time of an oscillating mass accurately.
Key words	Periodic Time, Frequency, Amplitude, Angular velocity, Linear acceleration, Linear velocity
Cross-cutting issues to discuss	Gender, peace and values
Competence developed	Critical thinking, Creativity and innovation, Communication, Co-operation, interpersonal management and life skills, science and technology
Attention to special educational need children	Special attention is given to gifted and talented learners and those with visual, physical and developmental impairments.
Lesson 2	**Title:EquationofSimpleHarmonicmotion and its solution**
Learning objectives	By the end of this lesson, by derivation and calculations, learners will be able to derive and apply the equation of simple harmonic motion correctly.

Key words	Equation of simple harmonic equation, solution of simple harmonic equation
Cross-cutting issues to discuss	Gender equality, peace and values
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy
Attention to special educational need children	Since the lesson involves a number of calculations, special attention is needed for learners with hearing impairment and gifted and talented learners.
Lesson 3	**Title: Simple Pendulum**
Learning objectives	By the end of this lesson, by derivation and calculations, learners will be able to determine the periodic time of the simple pendulum correctly.
Key words	Simple Pendulum, bob, acceleration due to gravity, periodic time
Cross-cutting issues to discuss	Gender equality, peace and values
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy
Attention to special educational need children	This lesson is more practical, so special attention is needed for learners with physical and developmental impairments.
Lesson 4	**Title: Determination of acceleration due to gravity using a simple pendulum bob**
Learning objectives	By the end of this lesson, practically using a simple pendulum, learners will be able to determine acceleration due to gravity correctly.
Key words	Acceleration due to gravity, simple pendulum, periodic time
Cross-cutting issues to discuss	peace and values
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy, innovation and creativity.

Attention to special educational need children	This lesson is more practical, so special attention is needed for learners with physical impairments.
Lesson 5	**Title: Mass on a Coil Spring**
Learning objectives	By the end of this lesson, by derivation and calculations, learners will be able to calculate the periodic time of an oscillation of spring properly.
Key words	Spring, mass, periodic time, simple harmonic motion
Cross-cutting issues to discuss	Gender, pace and values
Competence developed	Critical thinking, communication, cooperation, numeracy
Attention to special educational need children	Special attention is given to learners with developmental impairment.
Lesson 6	**Title: Assessment 1**
Learning objectives	By the end of this assessment, using knowledge and skills gained from lesson 1 to lesson 5, learners will be able to relate the content with the real life experiences.
Key words	Periodic Time, Frequency, Amplitude, Angular velocity, Linear acceleration, Linear velocity, Equation of simple harmonic motion, Simple Pendulum,
Cross-cutting issues to discuss	Gender equality, peace and values.
Competence developed	Critical thinking, problem solving.
Attention to special educational need children	Printed papers should be given to make it easy for learners with visual impairment to read.
Lesson 7	**Title:Determinationofaccelerationdue to gravity using a spiral spring.**
Learning objectives	By the end of this lesson practically, learners will be able to derive the expression of periodic time of a oscillation accurately.
Key words	Periodic time, spring, acceleration due to gravity, the mass

Cross-cutting issues to discuss	Gender, peace and values
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy, innovation and creativity.
Attention to special educational need children	This lesson is more practical, so special attention is needed for learners with physical and developmental impairments.
Lesson 8	**Title: Torsion Pendulum**
Learning objectives	By the end of this lesson by derivation and calculations, learners will be able to calculate the periodic time of an oscillating torsion pendulum accurately.
Key words	Torsion pendulum, moment of inertia , periodic time
Cross-cutting issues to discuss	Gender, peace and values
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy
Attention to special educational need children	Special attention is needed for learners with physical and developmental impairments.
Lesson 9	**Title: Compound pendulum**
Learning objectives	By the end of this lesson, by derivation and calculations, learners will be able to calculate the periodic time of an oscillating compound pendulum accurately.
Key words	Rigid body, compound pendulum, periodic time.
Cross-cutting issues to discuss	Gender, peace and values
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy
Attention to special educational need children	Special attention is needed for learners with physical and developmental impairments.
Lesson 10	**Title: Liquid in a U-tube**

Learning objectives	By the end of this lesson, by derivation and calculations, learners will be able to calculate the periodic time of an oscillating liquid in a U-tube accurately.
Key words	U-shaped tube, Excess pressure, Newton's Second law of motion, periodic time
Cross-cutting issues to discuss	Gender, peace and values
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy
Attention to special educational need children	Special attention is needed for learners with physical and developmental impairments.
Lesson 11	**Title: Kinetic and Potential energy of an oscillating system**
Learning objectives	By the end of this lesson, by calculations and derivations, learners will be able to determine the values of kinetic energy and potential energy of an oscillating particle accurately.
Key words	Kinetic energy and potential energy.
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability.
Competence developed	Critical thinking, communication, cooperation, interpersonal management and life skills, numeracy, literacy.
Attention to special educational need children	Special attention is paid to gifted and talented learners and learners with developmental and physical impairments.
Lesson 12	**Title: Assessment 2**
Learning objectives	By the end of this assessment using knowledge and skills gained from lesson 7 to lesson 11, learners will be able to relate the content with the real life experiences.

Key words	Periodic time, torsion pendulum, rigid body, compound pendulum, U-shaped tube, Kinetic energy and potential energy.
Cross-cutting issues to discuss	Gender, peace and values.
Competence developed	Critical thinking, problem solving.
Attention to special educational need children	Printed papers should be given to make it easy for learners with visual impairment to read.
Lesson 13	**Title: Energy changes in an oscillating system**
Learning objectives	By the end of this lesson, by derivation and using real life examples learners will be able to explain energy changes in an oscillating system clearly.
Key words	Energy changes and Energy conservation
Cross-cutting issues to discuss	Environment and sustainability.
Competence developed	Critical thinking, communication, cooperation, interpersonal management and life skills, numeracy, literacy.
Attention to special educational need children	Special attention is paid to gifted and talented learners and learners with developmental and physical impairments.
Lesson 14	**Title:Energyconservationinoscillating systems**
Learning objectives	By the end of this lesson, using examples, learners will be able to explain the principle of conservation of energy clearly.
Key words	Conservation of energy
Cross-cutting issues to discuss	Environment and sustainability.
Competence developed	Critical thinking, communication, cooperation, interpersonal management and life skills, numeracy, literacy.
Attention to special educational need children	Special attention is given to gifted and talented learners and learners with developmental impairment

Lesson 15	**Title:superpositionofharmonicsofsame frequency and same direction**
Learning objectives	By the end of this lesson, using derivation and calculations learners will be able to calculate the displacement of the resultant oscillation of harmonics of the same frequency and same direction correctly.
Key words	Superposition, harmonics, displacement, frequency.
Cross-cutting issues to discuss	Environment and sustainability
Competence developed	Critical thinking, communication, cooperation, interpersonal management and life skills, numeracy, literacy.
Attention to special educational need children	Special attention is given to gifted and talented learners, and learners with developmental impairment
Lesson 16	**Title:superpositionofharmonicsofsame frequency and opposite direction**
Learning objectives	By the end of this lesson, using derivation and calculations, learners will be able to calculate the displacement of the resultant oscillation of harmonics of the same frequency and opposite directions correctly.
Key words	Superposition, harmonics, displacement, frequency.
Cross-cutting issues to discuss	Environment and sustainability
Competence developed	Critical thinking, communication, cooperation, interpersonal management and life skills, numeracy, literacy.
Attention to special educational need children	Special attention is given to gifted and talented learners, and learners with developmental impairment
Lesson 17	**Title: Assessment 3**

Learning objectives	By the end of this assessment using knowledge and skills gained from lesson 1 to lesson 16, learners will be able to relate the content with the real life experiences.
Key words	Periodic Time, Frequency, Amplitude, Angular velocity, Linear acceleration, Linear velocity, Equation of simple harmonic equation, solution of simple harmonic equation, Simple Pendulum, the bob, acceleration due to gravity, periodic time, periodic time, Spring, torsion pendulum, moment of inertia, rigid body, compound pendulum, U-shaped tube, Excess pressure, Second Newton's law of motion, Kinetic energy, potential energy. Energy changes and Energy conservation Superposition of harmonics
Cross-cutting issues to discuss	Gender, peace and values.
Competence developed	Critical thinking, problem solving.
Attention to special educational need children	Printed papers should be clear to make it easy for learners with visual impairment to read.

MAIN CONTENTS AND CONCEPTS TO EMPHASISE

Simple Harmonic Motion: Any motion that repeats itself with equal time intervals is called periodic motion with the force F acting on an object is directly proportional to the displacement x from a fixed point and is always towards this point.

Periodic Time is the time taken for the particle to complete one oscillation.

Frequency is defined as how many oscillations occur in one second.

$$f = \frac{1}{T}$$

Amplitude is the maximum displacement of the particle from its resting position.

Angular velocity (w): is the rate of change of angular displacement with time.

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

Linear velocity (ν): is the rate of change of linear displacement with time.

$$\nu = \pm\omega\sqrt{A^2 - x^2}$$

Linear acceleration of a particle is the rate of change of linear velocity of that particle with time.

$$a = -\omega^2 x$$

The **equation of simple harmonic** motion is derived based on the conditions necessary for simple harmonic motion;

$$\frac{d^2x}{dt^2} + \omega^2 x = 0$$

Solution of a Simple Harmonic motion equation;

$$x(t) = A\sin(\omega t + \Phi)$$

A simple pendulum executes S.H.M and its period is given by;

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

The **extension of the spiral spring** (caused by attached mass 'in') which obeys Hooke's law is directly proportional to the extending tension. The periodic time of oscillation caused by releasing the mass is given by;

$$T = 2\pi\sqrt{\frac{m}{k}} \text{ (Where } k \text{ is spring constant)}$$

In a torsion pendulum, an extended body is suspended by a light wire and is rotated about the wire about the axis of rotation to execute a simple harmonic motion with period;

$$T = 2\pi\sqrt{\frac{I}{K}}$$

Where I is moment of inertia of the rod and K is the spring constant

For a **Compound pendulum**, any rigid body suspended from a fixed support constitutes a physical pendulum that oscillates with a periodic time given by;

$$T = 2\pi\sqrt{\frac{I}{Mgd}}$$

Where I is the rotational inertia of pendulum about axis is suspension M is pendulum mass, is distance between suspension point and centre of mass, g is acceleration due to gravity.

Any compound pendulum behaves like a simple pendulum if its effective length is equal to;

$$l = \frac{1}{Md}$$

A U-shaped tube is filled with a liquid and liquid on one side of a U-tube is depressed by blowing gently down that side, the level of the liquid will oscillate and execute simple harmonic motion with period given by;

$$T = 2\pi\sqrt{\frac{h}{g}}$$

Kinetic energy of an oscillating object is given by;

$$K.e = \frac{1}{2}m\omega^2 A^2 - \frac{1}{2}m\omega^2 x^2$$

The potential energy of the oscillating object is given by;

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

The total energy of any oscillating object is always constant and is given by;

$$E = \frac{1}{2}m\omega^2 A^2$$

Superposition of harmonic oscillations always gives the displacement of the resultant wave equal to the sum of individual displacements.

SOLUTION OF A SIMPLE HARMONIC MOTION EQUATION

To solve the equation of simple harmonic motion in the student's book, we need to find the auxiliary quadratic equation (A.Q,E).

$$\frac{d^2x}{dt^2} + \omega^2 x = 0$$

The solutions of equations of a simple harmonic motion in

$$\Rightarrow x(t) = A\cos(\omega t + \Phi)$$
$$\Rightarrow x(t) = A\sin(\omega t + \Phi)$$

Torsion Pendulum

In a torsional pendulum, an extended body is suspended by a light wire. The body is rotated about the wire as the axis of rotation. The upper end of the wire remains fixed with the support and the lower end of the wire is rotated through an angle with the body, thus a twist θ is produced in the wire.

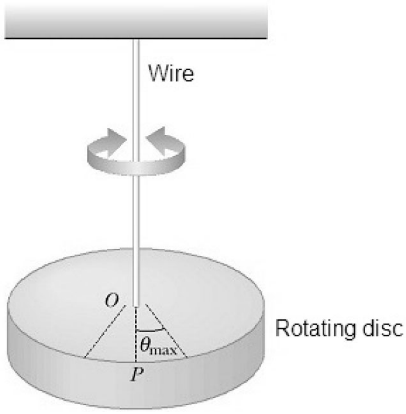


Fig.2-1; Torsional pendulum

Any twisting of the wire is inevitably associated with mechanical deformation. The wire resists such deformation by developing a restoring torque . The twisted wire exerts a restoring torque on the body to bring it back to its original position i.e. θ = 0.

The restoring torque is proportional to the angle of deformation. This is valid for small angles;

$$\tau_1 \, \alpha \, \theta$$

$$\tau_1 = -K\theta$$

Where and is called the torsion constant or torque constant.

The rotational equation of rotational motion is;

$$\tau_2 = I\alpha$$

Where is the moment of inertia of the disc and is angular acceleration of the system. Driving and restoring torque are equal but act in opposite direction.

$$\therefore \; -K\theta = I\alpha$$

$$\alpha = -\frac{K}{I}\theta$$

But and are constants.

$$\alpha = \frac{d^2\theta}{dt^2} = -\frac{Mgd}{I}\theta$$

This means that torsion pendulum executes simple harmonic motion.

So, comparing equation 2-12 in student's book and equation 2-10 n this guide gives;

$$W^2 = \frac{K}{I}$$

$$W = \sqrt{\frac{K}{I}}$$

$$\frac{2p}{T} = \sqrt{\frac{K}{I}}$$

$$T = 2p\sqrt{\frac{I}{K}}$$

Equation 2-11 is an expression for the periodic time of the torsion pendulum.

Compound pendulum

Any rigid body suspended from a fixed support constitutes a physical pendulum. The mo $\tau_1 = -K\theta$ ch a system can be followed very nearly in the same way as that of a simple pendulum. The distance of the center of mass of the body from the fixed suspension point acts as the effective length of the pendulum and the total mass being the mass of the particle situated at the center of the body. This system can now be treated in exactly the same way as a simple pendulum.

Consider an extended body of mass M with a hole drilled through it. Suppose that the body is suspended from the peg which passes through the hole such it is free to swing from side to side as shown on Fig.2-2. The setup is known as a compound pendulum.

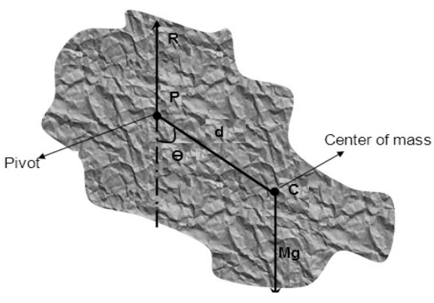


Fig.2-2; Compound pendulum

The restoring torque acting on the body when rotated through an angle θ is given by;

$$\tau_1 = -Mgd\sin\theta$$

For small angles measured in radians;

$$\sin\theta = \theta$$

$$\tau_1 = -Mgd\theta$$

The negative sign means that restoring torque opposes the driving torque. The driving torque is given by equation 2-9. Then equating equation 2-9 and equation 2-13 gives;

$$I\alpha = -Mgd\theta$$

$$\alpha = -\left(\frac{Mgd}{I}\right)\theta$$

Where is constant. Which means that a compound pendulum executes simple harmonic motion.

Comparing equation 2-12 in student's book and equation 2-14 derived in this guide will give;

$$\omega^2 = \frac{Mgd}{I}$$

$$\omega = \frac{2\pi}{T} = \sqrt{\frac{Mgd}{I}}$$

$$T = 2\pi\sqrt{\frac{I}{Mgd}}$$

Comparing equation 2-11 and equation 2-15, we conclude that a compound pendulum behaves like a simple pendulum with an effective length;

$$l = \frac{I}{Md}$$

SOLUTIONS OF APPLICATION ACTIVITY 2.1

1.(a) $a = \frac{F}{m} = \frac{0.05\,N}{0.1\,kg} = 0.5\,m\ \ s^{-2}$ for 100 g read as 0.1 kg

(b) s = w^2s and w = $\frac{2p}{T}$

so $T = 2p\sqrt{\frac{A}{a}} = 2p\sqrt{\frac{20^{\bar{}}\ 10^{-3}\ m}{0.5\ m.s^{-2}}} = 1.3\ s$

2. $x = A$ sin wt

n = Aw cos wt

a = –w^2 Asin wt

$P = mv = mA$w cos wt

$F = ma$ = –mw^2 Asin wt

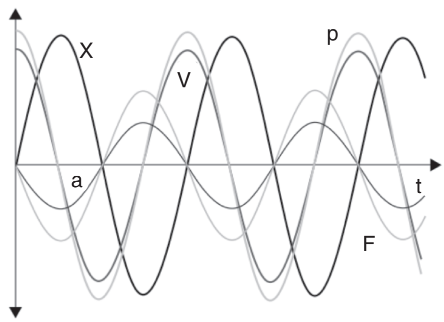


Fig.2-1; Wave forms

3. (a) A = 8.00 cm   w = 0.250 Hz

$x = A$ sin(wt + Φ)

n = A wcos(wt + Φ)

A at t = 0, n = 1.24 m/s

This gives $f = \cos^{-1}(\frac{1.24}{0.25^{\bar{}}\ 8}) = 0.669\ rad$

$x = A$sin(0.25t + 0.669)

n = 2cos(0.5pt + 0.469p)

(b) Initial displacement is the value of x at t = 0

x_0 = 8cos0.669 = 6.28 cm

SOLUTIONS OF APPLICATION ACTIVITY 2.2

1. (a) $x = \frac{F}{x} = \frac{mg}{x} = \frac{5.0\,\text{kg} \times 10\,\text{N kg}^{-1}}{500\,\text{N m}^{-1}} = 0.1\,\text{m}$

(b) w = $\frac{2p}{T}$ and $T = 2p\sqrt{\frac{m}{k}}$

So $\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{500\,\text{N m}^{-1}}{5.0\,\text{kg}}} = 10\,\text{rad s}^{-1}$

(c) The time taken from maximum displacement to equilibrium position is $t = \frac{T}{4}$

as $T = \frac{2p}{W} = \frac{2p}{10\,rad\ \ s^{-1}}$ hence $t = \frac{T}{4} = \frac{2p}{4\bar{\ }10\,rad\ \ s^{-1}} = 0.16\,s$

(d) $v_{max} = 2\pi fA = \omega A = 10\text{ rad s}^{-1} \times 0.10\text{ m} = 1.0\text{ m s}^{-1}$

e) With two unknowns, this requires the use of simultaneous equations. Initially

$$T = 2\text{p}\sqrt{\frac{l}{g}} = 4.2\,s$$

When the length is shorter

$$2p\sqrt{\frac{l - 1.0\text{ m}}{g}} = 3.7\text{ s.}$$

Dividing one equation by the other

$$\frac{\sqrt{\frac{l}{g}}}{\sqrt{\frac{l-1.0\text{ m}}{g}}} = \frac{4.2\text{ s}}{3.7\text{ s}}.$$

This gives $\frac{l}{l - 1.0\text{ m}} = \left(\frac{4.2}{3.7}\right)^2 = 1.29$

$$l = 1.29(l - 1.0\text{ m}) = 1.29l - 1.29\text{ m}$$

and $0.29l = 1.29\text{ m}$

so $l = \frac{1.29\text{ m}}{0.29} = 4.5\text{ m.}$

f) Since $T = 2\text{p}\sqrt{\frac{l}{g}}$

$$g = \frac{4\text{p}^2 l}{T^2} = \frac{4\text{p}^2(4.5\,m)}{(4.2\,s)^2} = 10\,m\,s^{-2}$$

2. Simple harmonic oscillators work because the force acts in the opposite direction to the displacement. As the pendulum moves away from the

area immediately below the peg it is hanging on, the force no longer acts in the opposite direction to the displacement.

3. Assumption:- the angular displacement is very small.

4. $g = (2\pi f)^2 l = (2\pi)^2 (0.819)^2 (0.371) = 9.824 m/s^2$

5. $x = A\cos(wt + f)$

$\therefore \dfrac{A}{2} = A\cos f$

$\cos f = \dfrac{1}{2}$

$f = 60°$

$-\dfrac{1}{2}A = A\cos(Wt + 60^0)\ \text{Û}\ -\dfrac{1}{2} = \cos(Wt + \dfrac{p}{3})$

$-\dfrac{2p}{T}t + \dfrac{p}{3} = \dfrac{2p}{3}\ \text{Û}\ t = \dfrac{T}{6} = \dfrac{12}{6} = 2\ s$

6.

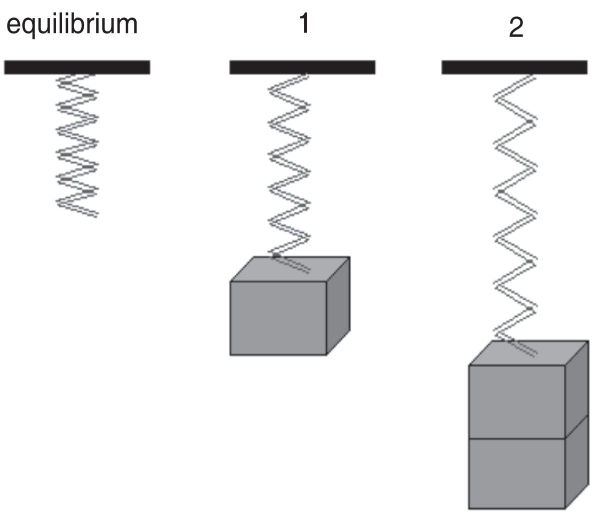


Fig.2-2; Helical springs

$L_0 = 500\ mm = 0.5\ m$

$L_1 = 850\ mm = 0.85\ m$

$m_1 = 250g = 0.25\ kg$

$m_2 = 0.5\ kg$

$x_{1max} = 120\ mm = 0.12\ m$

$x_{2max} = ?$

$A_2 = ?$

From hooke's law,

$F = kx$ and frequency, $f_0 = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

(a) spring constant

$ke = mg$

$e = L_1 - L_0 = 0.85 - 0.5 = 0.35\ m$

$$k = \frac{mg}{e} = \frac{0.25 \times 9.8}{0.35} = 7N/m$$

(b) See notes

(c) Amplitude: If the spring is pulled down by 120 mm,

$x_{1\max} = 0.12\ m$

(d) Frequency and period (does not depend upon amplitude)

$$f_1 = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi}\sqrt{\frac{7}{0.250}} = 0.84\ Hz$$

$$T_1 = \frac{1}{f_1} = 1.2\ s$$

(e) $e_2 = \frac{mg}{k} = \frac{0.5 \times 9.8}{7} = 0.7\ m$

$L_2 = e_2 + L_0 = 0.7 + 0.5 = 1.2\ m$

(f) $T_1 = 2\pi\sqrt{\frac{m_1}{k}}$ and $T_2 = 2\pi\sqrt{\frac{m_2}{k}}$

$$\frac{T_2}{T_1} = \sqrt{\frac{m_2}{m_2}} = \sqrt{\frac{0.500}{0.250}} = \sqrt{2} = 1.4$$

SOLUTIONS FOR APPLICATION ACTIVITY 2.3

a. The PE and KE when x = 0.100 m

Potential energy

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

$$E_p = \frac{1}{2}x100x0.1^2 = 0.5\ J$$

Kinetic Energy,

$$E_K = \frac{1}{2} mW^2 (a^2 - x^2)$$

$$E_K = \frac{1}{2} \times 0.5 \times (14.14)^2 (0.2^2 - 0.1^2) = 1.5\ J$$

b. The mechanical energy of the system
From

$$Mechanical\ Energy, E = \frac{1}{2} mW^2 a^2$$

$$and\ K = mW^2$$

$$E = \frac{1}{2} Ka^2$$

$$E = \frac{1}{2} x100x(0.2)^2 = 2\ J$$

c. The maximum velocity

$$V_{max} = Wa$$

Finding

$$W = \sqrt{\frac{k}{m}}$$

$$W = \sqrt{\frac{100}{0.5}} = 14.14\ rad/s$$

Therefore.

$$V_{max} = 14.14x0.2 = 2.83\ m/s$$

SOLUTIONS TO ACTIVITIES

MORE ACTIVITIES

1. This aim of this activity is to determine the period of Oscillation of a bifilar suspension

Required materials

Two retort stands/clamps/bosses, two metre rulers, stop watch, two lengths of cotton thread (about 50 cm).

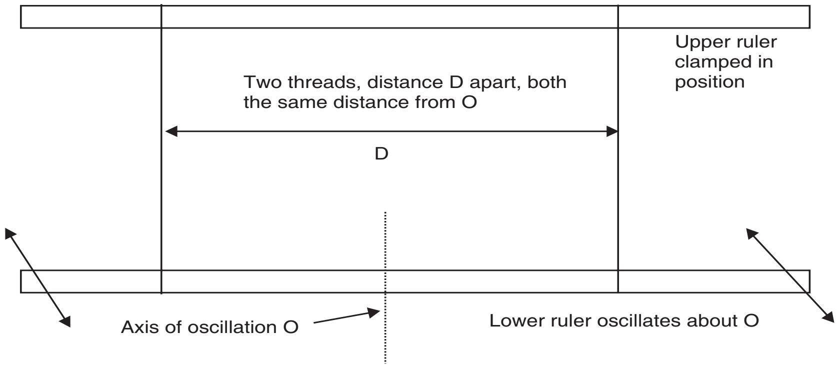


Fig.2-3; Bifilar suspension

Procedure

(a) Set up the apparatus as shown above with two lengths of thread of equal lengths (approximately 30 cm). Do not tie the threads too tightly as you will need to vary the distance **D** during the experiment.

(b) Set the distance $D = 60\ cm$ between the two threads.

(c) Set the lower ruler into oscillation in such a way that it oscillates about a vertical axis at O.

(d) Use your stop-watch to record the time **t** for 10 complete oscillations. Calculate the time **T** for one oscillation.

(e) Repeat procedures 2 to 4 for values of D = 55, 50, 45, 40, 35 cm.

(f) Record your results in a suitable table including the values of $\log T$ and $\log D$.

(g) Plot a graph of $\log T$ against $\log D$

(h) Calculate the gradient, **m** and calculate the value **c** of $\log T$ for $\log D = 0$.

(i) The period of a bifilar suspension is expected to be given by an equation of form: $T = aD^b$

Where **a** = a constant that depends on the other physical properties of the set up (e.g. the mass of the lower rule).

(j) Express the above equation (in procedure 9) as $\log T = b.z + p$.

(k) Calculate the values of **a** and **b.**

2. This activity aims at determining the acceleration due to gravity

Required materials

Spring, tall retort stand/clamp, set of 100g masses with holder, long pin, small piece of plasticine, stop watch, one metre rule.

Procedures

(a) Hang the spring vertically from a stand and attach the optical pin pointer onto the end of the spring using a small piece of plasticine. Clamp the metre rule vertically next to the spring as shown below:

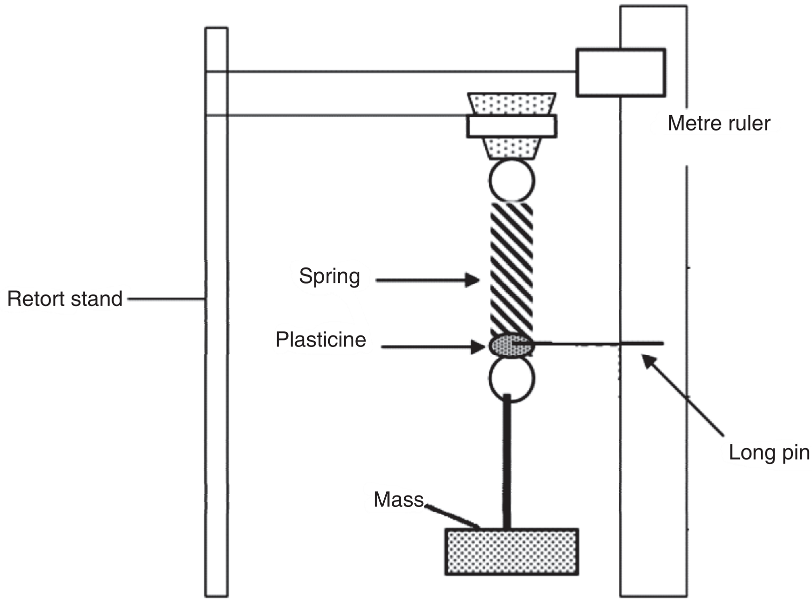


Fig.2-4; Oscillation of a mass on spring

(b) Note the initial level **A** of the optical pin against the rule.

(c) Hang a mass, m = 200 kg and then note the new pin level **B** and so calculate the spring extension, x in metres.

(d) Now displace this mass from its equilibrium position and release. Measure the time **t** for **10** oscillations.

(e) Finally calculate the period **T** for one oscillation.

(f) Repeat stages 3 to 5 for the values of m = 0.300 kg, 0.400 kg, 0.500 kg, 0.600 kg , 0.700 kg

(g) Tabulate your results in a suitable table including the values of T^2.

(h) Plot the following graphs:

(i) Graph 1: mass, m against extension, x.

(ii) Graph 2: $\mathbf{T}^2$ against m.

Both graphs should be on different graph papers.

(i) Calculate the slope G_1 of Graph 1.

(j) Calculate the slope G_2 of Graph 2.

(k) Calculate the value of acceleration due to gravity g from $g = \dfrac{4p^2}{G_1G_2}$

(l). The extension, x caused by a mass, **m** of weigh mg are related by: $mg = kx$. Find the value of k.

(m) (i) How, if at all, would your graphs and results be different if you were to perform this experiment on the moon?

(ii) Show how the expression $g = \dfrac{4p^2}{G_1G_2}$ is obtained from $T = 2p\sqrt{\dfrac{m}{k}}$ and $mg = kx$

ANSWER FOR END UNIT ASSESSMENT

1.a) By comparing this equation with General equation for simple harmonic motion: $x = A\cos(Wt + j\ )$

We see that $A = 4.00\ m$, and $W = p\ rad/s$. Therefore, $f = \dfrac{p}{2p} = 0.500\ Hz$ and

$$T = \frac{1}{f} = 2\ s$$

(b) $x = (0.400\ m)\cos(pt + \dfrac{p}{4})\ \square\ \text{v} = \dfrac{dx}{dt} = -4.00p\sin(pt + \dfrac{p}{4})$

$$a = \frac{dv}{dt} = -4.00p^2\cos(pt + \frac{p}{t})$$

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

$$x = (4.00\ m)\cos(p + \frac{p}{t}) = -2.83\ \text{m}$$

$$v = -(4.00\ m)p\sin(p + \frac{p}{t}) = 8.89\ \text{m/ s}$$

$$a = -(4.00\ m)p^2\cos(p + \frac{p}{t}) = 27.9\ \text{m/ s}^2$$

(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 to and a varies between $-4.00\pi\ m/s$ to $+4.00\pi\ m/s$

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 $t = 1.00\ s$ is $x_i = (4.00\ m)\cos\dfrac{\pi}{4} = 2.83\ \text{m}$

In part (c), we found that the xcoordinate $t = 1.00\ s$ is $x_f = (4.00\ m)\cos(\pi + \dfrac{\pi}{t}) = -2.83\ \text{m}$; therefore, the displacement between $t = 0\ s$ and $t = 1.00\ s$ is $\Delta x = x_f - x_i = -5.66\ m$

(f) $\Delta x = -5.66\ m$

2. (a) 1.26s (b) 0.25 m/s
   (c) 1.25 m/s^2 (d) $-(1.25m/s)^2\cos 5.00t$

3. (a) $F = kx \Leftrightarrow k = \dfrac{F}{x} = 200\ N/m$

   (b) $\omega = 2\pi f = \sqrt{\dfrac{g}{l}} \Leftrightarrow l = \dfrac{g}{4\pi^2 f^2} = \dfrac{9.81}{4\pi^2(0.5)^2} = 0.994$

4. Solving Equation of period for the length gives

$$T = 2\pi\sqrt{\frac{l}{g}} \Leftrightarrow l = \frac{gT^2}{4\pi^2} = \frac{9.80 \times 1^2}{4\pi^2} = 0.248\ m$$

Thus, the meter's length would be slightly less than one fourth its current length

5. (a) Period decreases. (b) Period increases. (c) No change.
6. No, the equilibrium position of the pendulum will be shifted (angularly) towards the back of the car. The period of oscillation will increase slightly, since the restoring force (in the reference frame of the accelerating car) is reduced.
7. $T = 2\pi\sqrt{\dfrac{l}{g}} \Leftrightarrow g = \dfrac{4\pi^2 l}{T^2} = \dfrac{4\pi^2(75.00 \times 10^{-2}\ \text{m})}{(1.7357\ s)^2} = 9.81\ m/s^2$

UNIT 3

Forced Oscillations and Resonance of a System

KNOW THIS

This unit involves derivation of expressions using the knowledge of differential equations. It is better to remind the learners that they should apply the knowledge gained in mathematics –differential equations and trigonometry- in this unit.

Key unit competence

Analyze the effects of forced oscillations on systems.

Unit Description

This unit involves writing trigonometric differential equations of different systems and finding their solutions. This unit requires learners to have the mathematical knowledge of differential equations of the first and second order. The unit will deeply deal with

- 3.0 Introduction
- 3.1 Damped oscillations
- 3.2 Equation of Damped oscillations
- 3.3 The solution of equation of damping
- 3.4 Types of damped oscillations
  - 3.4.1 Under damping oscillation
  - 3.4.2 Over damped oscillation
  - 3.4.3 Critically damped oscillation
- 3.5 Natural frequency of a vibration and forced oscillation
- 3.6 Equation of forced oscillation and its solution
- 3.7 Variation of forced frequency on graph at amplitude close to natural frequency of vibration
- 3.8 Resonances
- 3.9 Applications and examples of resonance in everyday life
  - 3.9.1 A washing machine
  - 3.9.2 Breaking the glass using the voice
  - 3.9.2 Breaking the bridge

3.9.3 Musical instruments

3.9.4 Tuning circuit

3.9.5 Microwave ovens

3.9.6 Magnetic Resonance Imaging (MRI)

3.10 Effect of resonance on a system

Summary of Knowledge, Skills, Attitudes and Values

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

Knowledge	**Skills**	**Attitudes and value**
Define damping	Perform experiments to demonstrate damping of oscillating systems	Appreciate applications of damped oscillators in life
Outline types of damped oscillations	Analyse damped oscillators.	Acquire scientific attitudes for interpreting the resonance
Explain examples of damped oscillators	Analyse natural vibration and forced oscillation	Acquire ability to systematically analyse cases of simple harmonic motion
Explain natural vibration and forced oscillation	Analyse graphically forced oscillations	Acquire knowledge for analysing and modelling physical processes
Describe resonance and give examples	Describe graphically the variation of forced oscillations	
	Describe resonance and give examples	
	Describe applications of resonance	

Learning objectives

By the end of this unit learners will be able to

- explain the concept of oscillating systems and relate it to the real life situations.
- solve equations of different types of damped oscillations and derive the expression for displacement for each.
- explain resonance, state its conditions and explain its applications in everyday life.

SCOPE AND SEQUENCE

This unit will be delivered in 17 lessons each of 40 minutes.

Unit 3: Forced oscillations and resonance of a system			
Lesson 1	**Lesson 2**	**Lesson 3**	**Lesson 4**
This lesson should cover: Introduction	**This lesson should cover:** damped oscillators	**This lesson should cover:** Equation of damped oscillations	**This lesson should cover:** The solution of equation of damping and under damping oscillation
Lesson 5	**Lesson 6**	**Lesson 7**	**Lesson 8**
This lesson should cover: Over damped oscillation and Critically damped oscillation	**This lesson should cover:** Assessment 1	**This lesson should cover:** Damping Activity Natural frequency of a vibration and forced oscillation.	**This lesson should cover:** Equation of forced oscillation
Lesson 9	**Lesson 10**	**Lesson 11**	**Lesson 12**
This lesson should cover: Solution of the equation of forced oscillation	**This lesson should cover:** Variation of forced frequency on graph at	**This lesson should cover:** Condition for resonance	**This lesson should cover:** Assessment 2

	amplitude close to natural frequency and resonance		
Lesson 13	**Lesson 14**	**Lesson 15**	**Lesson 16**
This lesson should cover: Applications of resonance: A washing machine, Breaking the glass using the voice	**This lesson should cover:** Applications of resonance; Breaking the bridge, Musical instruments	**This lesson should cover:** Applications of resonance; Microwave ovens, Magnetic Resonance Imaging (MRI)	**This lesson should cover:** Effect of resonance on systems
Lesson 17			
This lesson should cover: Assessment 3			

LESSON DEVELOPMENT

Lesson 1	**Title: Introduction**
Learning objectives	By the end of this lesson, using examples, learners will be able to explain the concept of oscillating systems clearly.
Key words	Oscillations, oscillatory systems , guitar string , bridges, swing
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking, communication, cooperation, interpersonal management and life skills, numeracy, literacy
Attention to special educational need children	Special attention is given to gifted and talented learners and learners with any impairment

Lesson 2	**Title: Damped oscillators.**
Learning objectives	By the end of this lesson, using real life examples, learners will be able to explain applications of oscillating systems in everyday life properly.
Key words	Irreversible energy loss, Damping, Shock Absorber, Electrical Meters, musical instrument , paper cone, loud speaker
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking, communication, cooperation, interpersonal management and life skills, numeracy, literacy
Attention to special educational need children	Special attention is given to gifted and talented learners and learners with developmental impairment
Lesson 3	**Title:EquationofDampedoscillations**
Learning objectives	By the end of this lesson, by derivations and using calculations, learners will be able to derive the differential equation of damped oscillations accurately.
Key words	differential equation, auxiliary quadratic equation , damped angular frequency
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking, communication, cooperation, interpersonal management and life skills, numeracy, literacy
Attention to special educational need children	Special attention is given to gifted and talented learners and learners with developmental impairment

Lesson 4	**Title: The solution of equation of damping; under damping oscillation**
Learning objectives	By the end of this lesson, by derivation and calculation, learners will be able to solve the equation of damped oscillations and derive the expression for displacement for under-damped oscillation accurately.
Key words	natural damping
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking, communication, cooperation, interpersonal management and life skills, numeracy, literacy.
Attention to special educational need children	Special attention is given to gifted and talented learners and learners with developmental impairment
Lesson 5	**Title: Over damped oscillation and Critically damped oscillation**
Learning objectives	By the end of this lesson, by derivation and calculation, learners will be able to solve the equation of damped oscillations and derive the expression for displacement for over-damped and critically damped oscillation accurately.
Key words	Over damping, critical damping, decay constant, damping coefficient
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking, communication, cooperation, interpersonal management and life skills, numeracy, literacy.
Attention to special educational need children	Special attention is given to gifted and talented learners and learners with developmental impairment
Lesson 6	**Title: Assessment 1**

Learning objectives	By the end of this assessment, using knowledge and skills gained from lesson 1 to lesson 5, learners will be able to relate the content with the real life experiences.
Key words	Oscillations, oscillatory systems , guitar string , bridges, swing, irreversible energy loss, Damping, Shock Absorber, Electrical Meters, musical instrument , paper cone, loud speaker, differential equation, auxiliary quadratic equation , damped angular frequency, natural damping, Over damping, Critically damped, decay constant, damping coefficient
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking, problem solving.
Attention to special educational need children	Printed papers should be used to make it easy for learners with visual impairment to read.
Lesson 7	**Title:Natural frequency of a vibration and forced oscillation.**
Learning objectives	By the end of this lesson, learners will be able to analyse damping and theoretically explain natural frequency of a vibration and forced oscillation clearly.
Key words	mean value, oscillator, uncertainty
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking, communication, cooperation, interpersonal management and life skills, numeracy, literacy.

Attention to special educational need children	Special attention is given to gifted and talented learners and learners with developmental impairment
Lesson 8	Title: Equation of forced oscillation
Learning objectives	By the end of this lesson learners will be able to derive the differential equation of forced oscillation.
Key words	Natural frequency, forced oscillation, restoring force
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking, communication, cooperation, interpersonal management and life skills, numeracy, literacy.
Attention to special educational need children	Special attention is paid to gifted and talented learners, and learners with developmental impairment
Lesson 9	**Title:Solutionoftheequationofforced oscillation**
Learning objectives	By the end of this lesson learners will be able to solve the differential equation of forced oscillation.
Key words	homogeneous equation , steady state solution, displacement
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking, communication, cooperation, interpersonal management and life skills, numeracy, literacy
Attention to special educational need children	Special attention is given to gifted and talented learners and learners with developmental impairment

Lesson 10	**Title: Variation of forced frequency on graph at amplitude close to natural frequency**
Learning objectives	By the end of this lesson, using real life examples, learners will be able to explain the variation of forced frequency and amplitude of oscillation and theoretically explain the concept of resonance accurately.
Key words	forced frequency and natural frequency of vibration, amplitude, applied force, resonance
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking, communication, cooperation, interpersonal management and life skills, numeracy, literacy.
Attention to special educational need children	Special attention is paid to gifted and talented learners and learners with developmental impairment
Lesson 11	**Title: Condition for resonance**
Learning objectives	By the end of this lesson, by derivation, learners will be able to state the condition of resonance clearly.
Key words	Maximum amplitude, condition for resonance
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking, communication, cooperation, interpersonal management and life skills, numeracy, literacy
Attention to special educational need children	Special attention is paid to gifted and talented learners, and learners with developmental impairment

Lesson 12	**Title: Assessment 2**
Learning objectives	By the end of this assessment, using knowledge and skills gained from lesson 6 to lesson 11, learners will be able to relate the content with the real life experiences.
Key words	mean value, oscillator, uncertainty, natural frequency, forced oscillation, restoring force, homogeneous equation , steady state solution, displacement, resonance
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking, problem solving
Attention to special educational need children	Printed papers should be used to make it easy for learners with visual impairment to read.
Lesson 13	**Title: Applications of resonance: A washing machine, Breaking the glass using the voice**
Learning objectives	By the end of this lesson, using theoretical principles, learners will be able to explain the applications of resonance in real life clearly.
Key words	washing machine
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking, communication, cooperation, interpersonal management and life skills, numeracy, literacy.
Attention to special educational need children	Special attention is given to gifted and talented learners, and learners with developmental impairment

Lesson 14	**Title: Applications of resonance; Breaking the bridge, Musical instruments**
Learning objectives	By the end of this lesson, using theoretical principles, learners will be able to explain the applications of resonance in real life clearly.
Key words	Bridge, Musical instruments
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking, communication, cooperation, interpersonal management and life skills, numeracy, literacy
Attention to special educational need children	Special attention is given to gifted and talented learners, and learners with developmental impairment
Lesson 15	**Title: Applications of resonance; Microwaveovens,MagneticResonance Imaging (MRI)**
Learning objectives	By the end of this lesson, using theoretical principles, learners will be able to explain the applications of resonance in real life clearly.
Key words	Microwave ovens, Magnetic Resonance Imaging (MRI)
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking, communication, cooperation, interpersonal management and life skills, numeracy, literacy
Attention to special educational need children	Special attention is given to gifted and talented learners and learners with developmental impairment

Lesson 16	**Title: Effect of resonance on a system**
Learning objectives	By the end of this lesson, using real life examples, learners will be able to explain the effects of resonance on systems clearly.
Key words	Resonance
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking, communication, cooperation, interpersonal management and life skills, numeracy, literacy
Attention to special educational need children	Special attention is given to gifted and talented learners and learners with developmental impairment
Lesson 17	**Title: Assessment 3**
Learning objectives	By the end of this assessment using knowledge and skills gained from lesson 1 to lesson 16, learners will be able to relate the content with the real life experiences.
Key words	Damping, shock absorber, electrical meters, damped angular frequency, natural damping , over damping, critical damping, decay constant, damping coefficient, natural frequency, forced oscillation, applications of resonance
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking, problem solving
Attention to special educational need children	Printed papers should be provided to make it easy for learners with visual impairment to read.

MAIN CONTENTS AND CONCEPTS TO EMPHASISE

Damping is a dissipating force that is always in the opposite direction to the direction of motion of the oscillating particle and is represented by equation;

$$m\frac{d^2x}{dt^2} + b\frac{dx}{dt} + kx = 0$$

The solution of this equation depends on the type of damping, given as

For Under-damping oscillation: $x(t) = e^{-\frac{b}{2m}t}(C_1\cos\omega_d t + C_2\sin\omega_d t)$

For Over damped oscillation: $x(t) = e^{-\frac{b}{2m}t}(C_1 e^{\omega_d t} + C_2 e^{-\omega_d t})$

For Critically damped oscillation: $x(t) = e^{-\frac{bt}{2m}}(C_1 + C_2 t)$

The **natural frequency** of an object is the frequency of oscillation when released. e.g. a pendulum.

A forced oscillation is where an object is subjected to a force that causes it to oscillate at a different frequency than its natural frequency. It is represented by differential equation:

$$m\frac{d^2x}{dt^2} + b\frac{dx}{dt} + kx = F_0\cos\omega t$$

Resonance occurs when an object capable of oscillating, has a force applied to it with a frequency equal to its natural frequency of oscillation. Resonance occurs when angular frequency of oscillation is related to natural angular frequency according to equation;

$$\omega = \sqrt{\omega_0^2 - \gamma^2}$$

In real life, resonance is applied in;

- A washing machine
- Breaking the glass using the voice
- Breaking the bridge
- Musical instruments
- Tuning circuit
- Microwave ovens
- Magnetic Resonance Imaging (MRI)

ANSWER FOR END UNIT ASSESSMENT

1. $y = -2\cos 5t + 2\sqrt{3}\sin 5t \quad \omega_o = 5 \quad A = 4 \quad \varphi = -\frac{2\pi}{3}$
2. $y = 3\cos 10t$, $\omega_0 = 10$, $A = 3$, $\varphi = 0$
3. $y = -5\cos\left(\frac{t}{2}\right) - 10\sin\left(\frac{t}{2}\right)$, $\omega_0 = \frac{1}{2}$, $A = 5\sqrt{5}$, $\varphi = \pi + \tan^{-1}2$

4. $A = \dfrac{F_0}{m\sqrt{(\omega_0^2 - \omega_e^2)^2 + 4\delta^2\omega_e^2}}$ with $c = 2\delta m = 0$, $A = \pm \dfrac{F_0}{m(\omega_0^2 - \omega_e^2)}$

Thus $\omega_e^2 = \omega_0^2 \pm \dfrac{F_0}{mA} = \dfrac{k}{m} \pm \dfrac{F_o}{mA} = \dfrac{6.30}{0.150} \pm \dfrac{1.70}{0.150 \times 0.44}$

This yields: $\omega_e = 8.23\ rad/s$ or. $\omega_e = 8.23\ rad/s$

Then $f_e = \dfrac{\omega_e}{2\pi}$ gives either $f_e = 1.31\ Hz$ or $f_e = 0.641\ Hz$

5. The frequency if undamped would be

$$\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{2.05 \times 10^4}{10.6}} = 44.0\ rad/s$$

With damping:

$$\omega_d = \sqrt{\omega_o^2 - (\frac{c}{2m})^2} = \sqrt{44.0^2 - (\frac{3}{2 \times 10.6})^2} = 44.0\ rad/s$$

$$f = \frac{\omega_d}{2\pi} = \frac{44.0}{2\pi} = 7.0\ Hz$$

6. **Equation of forced oscillation**: $\ddot{x} + 2\delta\dot{x} + \omega_o^2 x = \dfrac{F_e}{m}\cos\omega_e t$

The damping constant: $\delta = \dfrac{c}{2m} = \dfrac{0.5}{2 \times 0.5} = 0.5\ rad/s$

The amplitude of resonant

$$A_r = \frac{F_e}{m\sqrt{(\omega_o^2 - \omega_e^2)^2 + (2\delta\omega_e)^2}} = \frac{F_e}{2m\delta\omega_o} = \frac{F_e}{c\omega_o} = \frac{0.1}{0.5\sqrt{\frac{50}{0.5}}} = 0.02\ m$$

7.Equation of forced oscillation: $\ddot{x} + 2\delta\dot{x} + \omega_o^2 x = \dfrac{F_e}{m}\cos\omega_e t$

The damping constant: $\delta = \dfrac{b}{2m} = \dfrac{0.5}{2 \times 0.5} = 0.5\ rad/s$

The amplitude of resonant

$$A_r = \frac{F_e}{m\sqrt{(\omega_o^2 - \omega_e^2)^2 + (2\delta\omega_e)^2}} = \frac{F_e}{2m\delta\omega_o} = \frac{F_e}{c\omega_o} = \frac{0.1}{0.5\sqrt{\frac{50}{0.5}}} = 0.02\ m$$

UNIT
4

Propagation of Mechanical Waves

KNOW THIS

The term wave is clearly understood as the disturbance that leads to the transfer of energy from one point to another. This involves oscillation of individual molecules and atoms about fixed points and interchange of energy occurs between neighbouring molecules or atoms. This should be made clear to learners to avoid any misunderstanding. In a wave, the energy of a vibration is moving away from the source in the form of a disturbance within the surrounding medium.

Key unit competence

Evaluate the propagation of mechanical waves.

Unit description

This unit involves many derivations and graph representation. Clear demonstrations are needed to make learners clearly understand the content. This unit deals with;

- 4.0 Introduction
- 4.1 The concept of waves
- 4.2 Terms used and characteristics of waves
- 4.3 Types of waves
  - 4.3.1 Mechanical waves
  - 4.3.2 Electromagnetic waves
- 4.4 Properties of waves
  - 4.4.1 Reflection
  - 4.4.2 Refraction
  - 4.4.3 Interference
  - 4.4.4 Diffraction
- 4.5 Young's double slit experiment
- 4.6 Wave on a vibrating string
- 4.7 Applications of waves

Summary of Knowledge, Skills, Attitudes and Values

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

Knowledge	Skills	Attitudes and value
Explain wave concept	Describe wave properties and their characteristics	Appreciate applications of wave interference in life
Explain the terms amplitude, frequency displacement, wavelength and wave phase	Classify waves as longitudinal and transverse, mechanical and electromagnetic waves	Recognize importance of resonance in designing musical instruments
Explain the terms transverse and longitudinal waves	Observe and describe nodes and antinodes in stationary waves	Appreciate the sound systems on the studio
Explain the terms progressive and stationary waves	Explain conditions necessary for interference to occur	Appreciate application of acoustics in a radio studio
Explain phase of vibration	Describe interference fringes (constructive interference and destructive interference)	Develop positive attitude of curiosity, honesty, respect for evidence, perseverance and tolerance while solving wave related problems
Explain reflection, refraction, diffraction and interference of waves.	Apply the equation of two superimposed progressive waves	
Explain Young's double slit experiment		

Learning objectives

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

- explain the concept and characteristics of waves properly
- explain the types of waves properly
- derive and apply the progressive wave equation clearly

- analyse the superposition of harmonics of the same frequency clearly
- to analyse standing waves clearly
- analyse examples of mechanical waves properly
- explain the concept of electromagnetic waves
- explain the reflection of waves
- explain the refraction of waves
- explain interference of waves clearly
- explain the diffraction behaviour of waves clearly
- the positions of fringes on the screen accurately
- explain the behaviour of waves in vibrating strings and applications of waves properly

SCOPE AND SEQUENCE

This unit will be delivered in 20 lessons each of 40 minutes.

Unit 4: Propagation of Mechanical Waves			
Lesson 1	**Lesson 2**	**Lesson 3**	**Lesson 4**
This lesson should cover: Classroom demonstration	**This lesson should cover:** The concept of waves, Terms used and characteristics of waves	**This lesson should cover:** Types of waves	**This lesson should cover:** Equation of a progressive wave
Lesson 5	**Lesson 6**	**Lesson 7**	**Lesson 8**
This lesson should cover: Principle of superposition	**This lesson should cover:** Assessment 1	**This lesson should cover:** Stationary waves	**This lesson should cover:** Examples of mechanical waves
Lesson 9	**Lesson 10**	**Lesson 11**	**Lesson 12**
This lesson should cover: Electromagnetic waves	**This lesson should cover:** Reflection of waves	**This lesson should cover:** Refraction of waves	**This lesson should cover:** Assessment 2

Lesson 13	Lesson 14	Lesson 15	Lesson 16
This lesson should cover: Interference of waves	**This lesson should cover:** Diffraction	**This lesson should cover:** Young's double slit experiment	**This lesson should cover:** Wave on a vibrating string and Applications of waves
Lesson 17			
This lesson should cover: Assessment 2			

LESSON DEVELOPMENT

Lesson 1	**Title: Classroom Demonstration**
Learning objectives	By the end of this lesson, practically, learners will be able to explain the concept of waves clearly.
Key words	Disturbance, propagation of waves, medium, groups, the concept of waves
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking skills, research and problem-solving, creativity and innovation, communication, co-operation, interpersonal management and life skills, lifelong learning, literacy, use of ICT tools, science and technology
Attention to special educational need children	Special care should be given to learners with visual, intellectual, developmental, physical and hearing impairments and also gifted and talented learners.
Lesson 2	**Title:TheConceptofWaves,termsused and characteristics of waves**

Learning objectives	By the end of this lesson, with examples, learners will be able to explain the terms, concept and characteristics of waves properly.
Key words	Concept of waves, period, frequency wavelength, wave speed , amplitude, phase difference, wave number, intensity, wavefront
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking skills, research and problem-solving, creativity and innovation, communication, co-operation, interpersonal management and life skills, lifelong learning, literacy, use of ict tools, science and technology.
Attention to special educational need children	Special care should be given to learners with visual, intellectual, developmental, physical and hearing impairments and also gifted and talented learners.
Lesson 3	**Title: Types of Waves**
Learning objectives	By the end of this lesson, using real life examples, learners will be able to explain the types of waves properly.
Key words	Mechanical waves, Progressive waves, Longitudinal waves, Transverse waves
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking skills, research and problem-solving, creativity and innovation, communication, co-operation, interpersonal management and life skills, lifelong learning, literacy, use of ICT tools, science and technology.

Attention to special educational need children	Special care should be given to learners with visual, intellectual, developmental, physical,and hearing impairments and also gifted and talented learners.
Lesson 4	Title: Equation of a progressive wave
Learning objectives	By the end of this lesson, by derivation, learners will be able to derive and apply the progressive wave equation clearly.
Key words	Displacement, wave function
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking skills, research and problem-solving, creativity and innovation, communication, co-operation, interpersonal management and life skills, lifelong learning, literacy, use of ICT tools, science and technology.
Attention to special educational need children	Special care should be taken of learners with visual, intellectual, developmental, physical and hearing impairments and also gifted and talented learners.
Lesson 5	**Title: Principle of Superposition**
Learning objectives	By the end of this lesson, by calculations learners will be able to analyse the superposition of harmonics of the same frequency clearly.
Key words	Displacement, superposition of harmonics
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competences developed	Critical thinking skills, research and problem-solving, creativity and innovation, communication, co-operation, interpersonal management and life skills, lifelong learning, literacy, use of ICT tools, science and technology.

Attention to special educational need children	Special care should be given to learners with visual, intellectual, developmental, physical and hearing impairments and also gifted and talented learners.
Lesson 6	**Title: Assessment 1**
Learning objectives	By the end of this assessment, using knowledge and skills gained in previous lessons, learners will be able to relate the content with the real life experiences.
Key words	Concept of waves, period, frequency, wavelength, wave speed , amplitude, phase difference, wave number mechanical waves, progressive waves, longitudinal waves, transverse waves, superposition of harmonics
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking, problem solving
Attention to special educational need children	Printed papers should be used to make it easy for learners with visual impairment to read.
Lesson 7	**Title: Stationary Waves**
Learning objectives	By the end of this lesson, using real life examples, learners will be able to analyse standing waves clearly.
Key words	Nodes, antinodes
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking skills, research and problem-solving, creativity and innovation, communication, co-operation, interpersonal management and life skills, Lifelong learning, Literacy, use of ICT tools, science and technology.

Attention to special educational need children	Special care should be given to learners with visual, intellectual, developmental, physical and hearing impairments and also gifted and talented learners.
Lesson 8	**Title: Examples of Mechanical Waves**
Learning objectives	By the end of this lesson, theoretically and practically, learners will be able to analyse examples of mechanical waves properly.
Key words	Sound waves, water waves, ocean waves, earthquake waves, body waves, surface waves
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking skills, research and problem-solving, creativity and innovation, communication, co-operation, interpersonal management and life skills, lifelong learning, literacy, use of ICT tools, science and technology.
Attention to special educational need children	Special care should be given to learners with visual, intellectual, developmental, physical and hearing impairments and also gifted and talented learners.
Lesson 9	**Title: Electromagnetic Waves**
Learning objectives	By the end of this lesson, using real life applications, learners will be able to explain the concept of electromagnetic waves clearly.
Key words	Electric field, magnetic field
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability

Competence developed	Critical thinking skills, research and problem-solving, creativity and innovation, communication, co-operation, interpersonal management and life skills, lifelong learning, literacy, use of ICT tools, science and technology.
Attention to special educational need children	Special care should be given to learners with visual, intellectual, developmental, physical and hearing impairments and also gifted and talented learners.
Lesson 10	**Title: Reflection of Waves**
Learning objectives	By the end of this lesson, using mathematical proofs and drawings, learners will be able to explain the reflection behaviour of waves clearly.
Key words	Wavefronts, laws of reflection
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking skills, research and problem-solving, creativity and innovation, communication, co-operation, interpersonal management and life skills, lifelong learning, literacy, use of ICT tools, science and technology.
Attention to special educational need children	Special care should be given to learners with visual, intellectual, developmental, physical and hearing impairments and also gifted and talented learners.
Lesson 11	**Title: Refraction of Waves**
Learning objectives	By the end of this lesson, using mathematical proofs and drawings, learners will be able to explain the refraction behaviour of waves clearly.
Key words	Wavefronts, laws of refraction
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability

Competences developed	Critical thinking skills, research and problem-solving, creativity and innovation, communication, co-operation, interpersonal management and life skills, lifelong learning, literacy, use of ICT tools, science and technology.
Attention to special educational need children	Special care should be given to learners with visual, intellectual, developmental, physical and hearing impairments and also gifted and talented learners.
Lesson 12	**Title: Assessment 2**
Learning objectives	By the end of this assessment, using knowledge and skills gained in previous lessons, learners will be able to relate the content with the real life experiences.
Key words	Nodes, antinodes, Electromagnetic waves, Examples of mechanical waves, Reflection of waves, Refraction of waves
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking, problem solving
Attention to special educational need children	Printed papers should be used to make it easy for learners with visual impairment to read.
Lesson 13	**Title: Interference of Waves**
Learning objectives	By the end of this lesson, using real life examples, learners will be able to explain interference of waves clearly.
Key words	Constructive interference, destructive interference
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability

Competence developed	Critical thinking skills, research and problem-solving, creativity and innovation, communication, co-operation, interpersonal management and life skills, lifelong learning, literacy, use of ICT tools, science and technology.
Attention to special educational need children	Special care should be given to learners with visual, intellectual, developmental, physical and hearing impairments and also gifted and talented learners.
Lesson 14	**Title: Diffraction**
Learning objectives	By the end of this lesson, using drawings and practical analysis, learners will be able to explain the diffraction behaviour of waves clearly.
Key words	Fresnel's diffraction, Fraunhofer diffraction
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking skills, research and problem-solving, creativity and innovation, communication, co-operation, interpersonal management and life skills, lifelong learning, literacy, use of ICT tools, science and technology.
Attention to special educational need children	Special care should be given to learners with visual, intellectual, developmental, physical and hearing impairments and also gifted and talented learners.
Lesson 15	**Title: Young's Double Slit Experiment**
Learning objectives	By the end of this lesson, using calculations, learners will be able to locate the positions of fringes on the screen accurately.
Key words	Fringe separation, slit separation
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability

Competences developed	Critical thinking skills, research and problem-solving, creativity and innovation, communication, co-operation, interpersonal management and life skills, lifelong learning, literacy, use of ICT tools, science and technology.
Attention to special educational need children	Special care should be given to learners with visual, intellectual, developmental, physical and hearing impairments and also gifted and talented learners.
Lesson 16	**Title: Wave on a Vibrating String and Applications of Waves**
Learning objectives	By the end of this lesson, using examples, learners will be able to explain the behaviour of waves in vibrating strings and applications of waves properly.
Key words	Waves in strings
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking skills, research and problem-solving, creativity and innovation, communication, co-operation, interpersonal management and life skills, lifelong learning, literacy, use of ICT tools, science and technology.
Attention to special educational need children	Special care should be given to learners with visual, intellectual, developmental, physical and hearing impairments and also gifted and talented learners.
Lesson 17	**Title: Assessment 3**
Learning objectives	By the end of this assessment, using knowledge and skills gained in all lessons of the unit, learners will be able to relate the content with the real life experiences.

Key words	The concept of waves, characteristics of waves, Types of waves, wave equation, Principle of superposition, Nodes, antinodes, properties of waves, Young's double slit experiment, Waves in strings
Cross-cutting issues to discuss	Gender, peace and values, environment and sustainability
Competence developed	Critical thinking, problem solving
Attention to special educational need children	Printed papers should be used to make it easy for learners with visual impairment to read.

MAIN CONTENTS AND CONCEPTS TO EMPHASISE

Waves can be thought of as a disturbance in a medium that transfers energy from one place to another.

The **period** T of the wave is the time it takes for one wavelength of the wave.

The **frequency** f is the number of wavelengths that pass a point in space in one second.

The **wavelength** λ is the horizontal distance in space between two nearest points that are oscillating in phase

The **wave speed** v is the speed at which the wave advances.

Phase difference (phase angle) is the angular difference between two points on the wave or between two waves.

The **wave number** also called the **propagation number** k is the spatial frequency of a wave.

The **Intensity** of a wave or the power radiated by a source are proportional to the square of the amplitude.

Wavefront is a line or surface in the path of the wave motion on which the disturbance at every point have the same phase.

Mechanical waves are waves produced by the disturbance in a material medium.

A **progressive** wave consists of a disturbance moving from one point to another.

Longitudinal wave propagates through some medium in the direction of travel of the disturbance.

In **Transverse waves**, the direction of disturbance is perpendicular to the direction of travel of the wave.

Equation of a progressive wave is given by;

$$y_P = A\sin\left(\omega t - \frac{2\pi x}{\lambda}\right)$$

Principle of superposition states that the resultant displacement at any time is the vector sum of the individual displacements.

Stationary waves are waves which seem to be at rest.

The positions of nodes are x = $\frac{m\lambda}{4}$ where m = 1,3,5,7,9,...

The positions of antinodes are $x = \frac{n\lambda}{2}$ where n = 0,1,2,3,4,5,6,...

Electromagnetic waves are disturbances in form of varying electric and magnetic fields.

All kinds of waves reflect, refract, interfere and also spread around the obstacle.

Other than the superposition of waves meeting at a point, other **conditions for interference** are;

- The sources of the waves must be coherent, which means they emit identical waves with a constant phase difference.
- The waves should be monochromatic - they should be of a single wavelength.

A **bright fringe** is obtained when the path difference is given by $x = \frac{n\lambda D}{a}$ where n = 0,1,2,3,4,...

A **dark fringe** is obtained when the path difference is given by $x = \frac{m\lambda D}{2a}$ where m = 1,3,5,7,...

SOLUTION TO ACTIVITIES

Class Demonstration

Possible Solutions

(a) Their raised, then lowered, arms were the disturbance

(b) up and down

(c) around the circle

(d) the push

(e) around the ring

(f) around the ring

ACTIVITY 4-1

Conclusion

The student will hear a clear sound when the spoon is struck. The vibrations of the spoon propagate up the string and into the student's head. Bone, especially around the temples and outer ear, resonates readily in response to sound.

Note: The bone in front of your ear is the most resonant bone in the body, so it is ideal for transmitting vibrations and hearing sound. The vibrations from the spoon are transmitted easily through the string and your skull, which you hear as a sound.

ANSWER TO APPLICATION ACTIVITY 4.1

1. a) wavelength
   b) x
   c) y
   d) wave number
   e) speed
   f) higher
   g) amplitude
   h) progressive wave

2.

										e	p	e	e	d		
												l				
											p	e	r	i	o	d
					t	r	o	u	g	h		cc				
						e						t				
						f						r				
d						l						o				
i				a		e						m				
s				m	e	c	h	a	n	i	c	a	l			
p				p		t						g				
l				l		i						n				
a				i		o						e				
c	r	e	s	t		n			p	h	o	t	o	n	s	
e				u								i				
m				d					f	o	r	c	e			
e		i	n	e	r	t	i	a								
n																
t																

ACTIVITY 4-2

Answer:

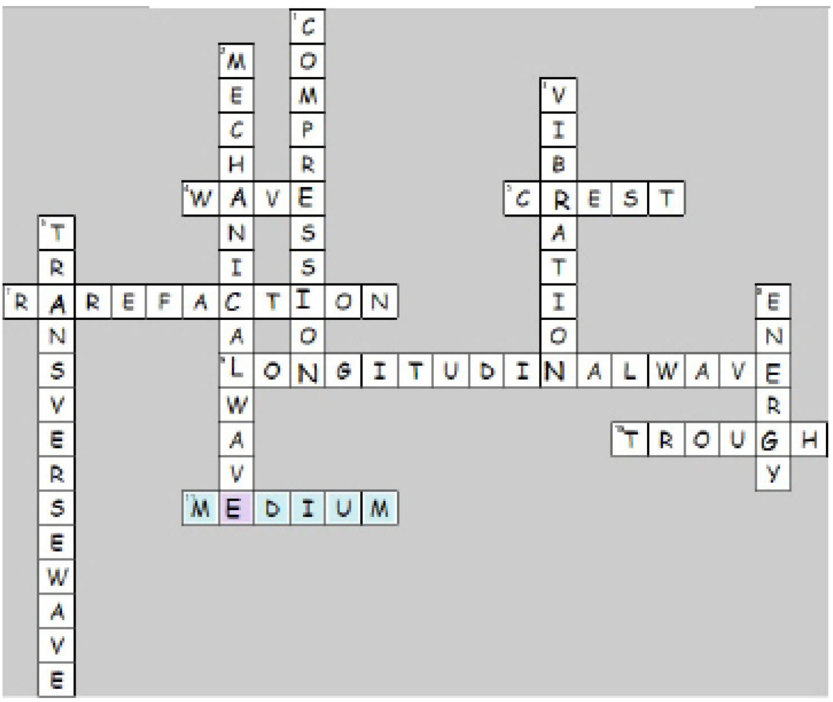
Across

1. speed
3. period
4. trough
9. mechanical
10. crest
11. photons
12. force
13. inertia

Down

2. electromagnetic
5. reflection
6. medium
7. displacement
8. amplitude

APPLICATION ACTIVITY 4.2



SOLUTIONS TO END UNIT ASSESSMENT.

1. One method for producing a sinusoidal wave on a string. The left end of the string is connected to a blade that is set into oscillation. Every element of the string, such as that at point P, oscillates with simple harmonic motion in the vertical direction.

Using **Angular frequency** Equations, we find that

$$\omega = \frac{2\pi}{T} = 2\pi f = 2\pi(5.00) = 31.4\ rad/s$$

Using **Speed of sinusoidal wave** Equations, we find that

$$k = \frac{\omega}{v} = \frac{31.4}{20.0} = 1.57\ rad/s$$

Because $A = 12.0\ cm = 0.120\ m$ we have

$$y = A\sin(\omega t - kx) = (0.120)\sin(31.4t - 1.57x)$$

2. (a) amplitude: 3.0 mm, (b) Frequency: 60 Hz,
(c) Wavelength: 2. 00 cm, (d) Speed:1.2 m/s, (e) period:0.017 s.

3. a) the nth resonance frequency: $f_n = nf_o = 252$

The next higher resonance frequency: $f_{n+1} = (n+1)f_o = 336$

Solving equ (a) and (b) we get $\frac{n}{n+1} = \frac{252}{356} \Leftrightarrow n = 3$

Hence the fundamental frequency is $f_o = \frac{f}{n} = \frac{252}{3} = 84\ Hz$

b) The wavelength of fundamental frequency $\lambda = 2L = 6\ m$

The wave speed: $v = \lambda f = 6\ m \times 256\ Hz = 504\ m/s$

The tension in the string;

$$v = \sqrt{\frac{T}{\mu}} \Leftrightarrow T = \mu v^2 = (0.002\,5\ kg/m)(504\ m/\text{s}) = 635\ \text{N}$$

4. Fundamental frequency:

$$f_o = \frac{1}{2 \times 400 \times 10^{-3}}\sqrt{\frac{120 \times 400 \times 10^{-3}}{1.2 \times 10^{-3}}} = 250\ Hz$$

Third harmonic $f_2 = 3f_0 = 3 \times 250\ Hz = 750\ H$

5. (a) The wave number k, period T, angular frequency ω, and speed v of the wave are: $k = \frac{2\pi}{\lambda} = \frac{2\pi}{40.0} = 0.157\ rad/cm$

$$T = \frac{1}{f} = \frac{1}{8.00} = 0.125\ s$$

$$\omega = 2\pi f = 2\pi \times 8.00 = 50.3\, rad/s$$

$$v = \lambda f = 40.0 \times 8.00 = 320\, cm/s$$

(b) Because A = 15.0 cm and because y = 15.0 cm at x = 0 and t = 0, on substitution, it becomes

$$y_m = A\sin(\omega t - kx + \phi) \Rightarrow 15.0 = 15.0\sin\phi \Leftrightarrow \sin\phi = 1 \Leftrightarrow \phi = \frac{\pi}{2}\, rad$$

Hence the wave function is of the form:

$$y = A\sin(\omega t - kx + \frac{\pi}{2}) = A\sin(\omega t - kx + \frac{\pi}{2})$$

Substituting the values for *A*, *k*, and into this expression, we obtain

$$y = 1.5\sin(50.3t - 0.157x + \frac{\pi}{2}) = 15.0\cos(50.3\,t - 0.157\,x)$$

UNIT 5

Interference of Light Waves

KNOW THIS

When two or more waves interact and combine, they interfere with one another. These waves may interfere constructively, resulting in a wave larger than the original waves. They may also interfere destructively, combining in such a way that they form a wave smaller than the original ones. Destructive interference also has some positive effects: without the application of destructive interference to the muffler on an automobile exhaust system, for instance, noise pollution from cars would be far worse than it is. Other examples of interference, both constructive and destructive, can be found wherever there are waves: in water, in sound, in light. This unit discusses the interference of light in detail.

Key unit competence

By the end of the unit the learner should be able to perform experiment on interference of light waves.

Unit description

In Physics, the net effect of the combination of two or more wave trains moving on intersecting or coincident paths is that of the addition of the amplitudes of the individual waves at each point affected by more than one wave. The concepts of interference in this unit are explained through numerous calculations and diagrams. The unit deals with;

13.0 Introduction

13.1. Nature of electromagnetic waves

- 13.1.1 Producing electromagnetic waves
- 13.1.2 Electromagnetic Radiation
- 13.1.3 Electromagnetic spectrum
- 13.1.4 Radiation Interaction with the Earth
- 13.1.5 Radiation Interaction with the Atmosphere
- 13.1.6 Atmospheric Absorption of electromagnetic waves

13.2 Conditions for interference to occur, given two sources of light

13.3. Principle of superposition

13.4. Interference patterns of two coherent point sources of light
13.5. Double-slit experiment
13.6. Intensity distribution of fringe pattern

Summary of Knowledge, Skills, Attitudes and Values

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

Knowledge	Skills	Attitudes and value
Explain the nature of electromagnetic waves	Analyse conditions for interference to occur for given two sources	Appreciate the importance of light waves in life
Explain regions of the electromagnetic spectrum	Explain and describe the principle of superposition	Acquire scientific techniques, reasoning and attitudes in analyzing electromagnetic waves
Explain dispersion of EM waves	Analyse interference pattern produced by two coherent point sources	Acquire scientific reasoning and attitudes in interpreting the concepts of interference
Explain dispersion of EM waves in relation to refractive index and wavelength	Carry out an investigation on double-slit experiment	Acquire ability to logically and systematically pursue a particular liner of thought
Distinguish between transmission, absorption and scattering of radiation.	Derive Young's equation for double slit interference	Acquire knowledge for analysing and modelling physical processes
Identify examples of transmission, absorption and scattering of Em radiation	Draw intensity distribution for fringe pattern	

	Solve problems involving two interfering sources of light	

Learning objectives

By the end of this unit, the learners should be able to;

- explain the concept of wave interferences and their applications in our daily life.
- explain the interaction of electromagnetic radiation with the earth.

SCOPE AND SEQUENCE

This unit will be delivered in 17 lessons each of 40 minutes.

Unit 13: Interference of light waves

Lesson 1	Lesson 2	Lesson 3	Lesson 4
This lesson should cover: Introduction	**This lesson should cover:** Nature of electromagnetic waves	**This lesson should cover:** Producing electromagnetic waves	**This lesson should cover:** Electromagnetic Radiation
Lesson 5	**Lesson 6**	**Lesson 7**	**Lesson 8**
This lesson should cover: Assessment 1	**This lesson should cover:** Concept of Electromagnetic spectrum	**This lesson should cover:** Electromagnetic spectrum	**This lesson should cover:** Radiation Interaction with the Earth
Lesson 9	**Lesson 10**	**Lesson 11**	**Lesson 12**
This lesson should cover: Radiation Interaction with the Atmosphere	**This lesson should cover:** Atmospheric Absorption of electromagnetic waves	**This lesson should cover:** Assessment 2	**This lesson should cover:** Conditions for interference to occur given two sources of light
Lesson 13	**Lesson 14**	**Lesson 15**	**Lesson 16**

This lesson should cover: Principle of superposition	**This lesson should cover:** Interference patterns of two coherent point sources of light	**This lesson should cover:** Double-slit experiment	**This lesson should cover:** Intensity distribution of fringe pattern
Lesson 17			
This lesson should cover: Assessment 3			

LESSON DEVELOPMENT

Lesson 1	**Title: Introduction**
Learning Objectives	By the end of this lesson, using reallife examples the learners will be able to explain the concept of interference properly.
Key words	Interference of light waves
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Research and problem solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, numeracy, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is needed to the the learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties, specific and general learning difficulties and gifted and talented the learners
Lesson 2	**Title: Nature of electromagnetic waves**
Learning Objectives	By the end of this lesson, using examples the learners will be able to explain the nature of electromagnetic waves clearly.
Key words	Electric fields and magnetic fields

Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, numeracy, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is needed to the learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties, specific and general learning difficulties and gifted and talented learners
Lesson 3	**Title: Producing electromagnetic waves**
Learning Objectives	By the end of this lesson, the concepts of electric and magnetic fields the learners will be able to explain how electromagnetic waves are produced clearly.
Key words	charged particles, electric field, magnetic field
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, numeracy, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is needed to the learners with Intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties, specific and general learning difficulties and gifted and talented the learners
Lesson 4	**Title: Electromagnetic Radiation**
Learning Objectives	By the end of this lesson, using examples the learners will be able to explain the nature of electromagnetic radiations clearly.
Key words	electromagnetic radiation

Cross-cutting issues to be discussed	Gender, Peace and Values Education
Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, numeracy, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is given to the learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties, specific and general learning difficulties and gifted and talented learners
Lesson 5	**Title: Assessment 1**
Learning Objectives	By the end of this assessment using knowledge and skills gained in lessons 1 to 4, the learners will be able to relate the content with the real-life experiences.
Key words	Interference of light waves, Electric fields and magnetic fields, charged particles, electromagnetic radiation
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinning and problem solving
Attention to special educational need children	Special attention is given to the learners with visual impairment
Lesson 6	**Title: Concept of Electromagnetic spectrum**
Learning Objectives	By the end of this lesson, using examples the learners will be able to explain the concept of electromagnetic waves clearly.
Key words	Electromagnetic spectrum, wavelength
Cross-cutting issues to discuss	Gender equality, Peace and Values Education

Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, numeracy, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is given to the learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties, specific and general learning difficulties and gifted and talented learners
Lesson 7	**Title: Electromagnetic spectrum**
Learning Objectives	By the end of this lesson, using examples the learners will be able to explain the spectrum of electromagnetic waves clearly.
Key words	Frequency, wavelength
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, numeracy, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is given to the learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties, specific and general learning difficulties and gifted and talented learners
Lesson 8	**Title: Radiation Interaction with the Earth**
Learning Objectives	By the end of this lesson, using examples the learners will be able to explain the interaction of electromagnetic radiation with the earth clearly.
Key words	Reflection, Absorption, Transmission
Cross-cutting issues to discuss	Gender, Peace and Values Education

Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, numeracy, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is given to the learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties, specific and general learning difficulties and gifted and talented learners
Lesson 9	**Title: Radiation Interaction with the Atmosphere**
Learning Objectives	By the end of this lesson, using examples, the learners will be able to explain the interaction of electromagnetic radiation with the atmosphere clearly.
Key words	Scattering
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, numeracy, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is given to the learners with Intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties, specific and general learning difficulties and gifted and talented learners
Lesson 10	Title: Atmospheric Absorption of electromagnetic waves
Learning Objectives	By the end of this lesson, using examples the learners will be able to explain the atmospheric absorption of electromagnetic waves clearly.

Key words	Ozone, Carbon dioxide, Water Vapour
Cross-cutting issues to discuss	Gender equality, Peace and Values Education
Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, numeracy, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is given to the learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties, specific and general learning difficulties and gifted and talented learners
Lesson 11	Title: Assessment 2
Learning Objectives	By the end of this assessment using knowledge and skills gained in lessons 6 to10, the learners will be able to relate the content with the real-life experiences.
Key words	Electromagnetic spectrum, wavelength, Frequency, Reflection, Absorption, Transmission, Scattering, Ozone, Carbon Dioxide, Water Vapour
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking and problem solving
Attention to special educational need children	Special attention is to given the learners with visual impairment
Lesson 12	**Title: Conditions for interference to occur given two sources of light**
Learning Objectives	By the end of this lesson, using examples the learners will be able to explain the conditions necessary for interference to occur clearly.
Key words	Coherent sources, monochromatic waves
Cross-cutting issues to discuss	Gender, Peace and Values Education

Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, numeracy, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is needed to the learners with Intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties, specific and general learning difficulties and gifted and talented learners
Lesson 13	Title: Principle of superposition
Learning Objectives	By the end of this lesson, using examples the learners will be able to explain the principle of superposition clearly.
Key words	Displacement
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, numeracy, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is given to the learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties, specific and general learning difficulties and gifted and talented learners
Lesson 14	**Title: Interference patterns of two coherent point sources of light**
Learning Objectives	By the end of this lesson, using examples, learners will be able to explain the interference patterns of two coherent point sources of light clearly.
Key words	Young's double slits, coherent sources
Cross-cutting issues to discuss	Gender, Peace and Values Education

Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, numeracy, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is given to the learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties, specific and general learning difficulties and gifted and talented learners
Lesson 15	**Title: Double-slit experiment**
Learning Objectives	By the end of this lesson, mathematically, the learners will be able to describe the conditions for dark and bright fringes clearly.
Key words	Fringe separation
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, numeracy, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is given to the learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties, specific and general learning difficulties and gifted and talented learners
Lesson 16	**Title: Intensity distribution of fringe pattern**
Learning Objectives	By the end of this lesson, mathematically the learners will be able to describe the variation of intensity distribution of fringe pattern clearly.
Key words	Intensity, fringe pattern

Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, numeracy, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is given to the learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties, specific and general learning difficulties and gifted and talented learners
Lesson 17	**Title: Assessment 3**
Learning Objectives	By the end of this assessment using knowledge and skills gained in lessons 11 to 16, the learners will be able to relate the content with the real-life experiences.
Key words	Coherent sources, monochromatic waves, Displacement, Young's double slits, Fringe separation, Intensity, fringe pattern
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinning and problem solving
Attention to special educational need children	Special attention is given to the learners with visual impairment

Guidance to the introductory Activity.

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

- Tell students to turn to the introductory activity in the learner's book.
- Suggest on the methodology to use in this lesson. Choice may depend on the nature of your class. Remember that this activity intends to trigger learners' attention about interference of light waves.
- Guide them to attempt the questions in this activity. Make sure they have enough time to discuss the questions.
- When they are done ask them to present their answers to the whole class.

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

Possible answers to the introductory activity.

a) Minimum is as a result of regions of minimum intensity meeting regions of maximum intensity leading to formation of dark fringes hence destructive interference.

Maximum regions are due to reinforcement of regions of light wave leading to increase in energy. A bright fringe is formed thus constructive interference.

b) Meeting of light waves.
c) Interference of Light waves.
d) Application of light waves-In LASER construction, measuring of wavelength of light (using young's double slit experiment)

Answers for the application activity 5.2

1. The path difference for destructive interference

$$\Delta x = (2n+1)\frac{\lambda}{2}$$

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**

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

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** $x_n = \dfrac{n\lambda D}{d}$

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

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

<u>MAIN CONTENTS AND CONCEPTS TO EMPHASISE</u>

Nature of electromagnetic waves

Electromagnetic waves are transverse waves that transfer electrical and magnetic energy.

In other words electromagnetic waves have electric and magnetic fields varying perpendicularly.

Producing electromagnetic waves

Electromagnetic waves are produced by charged particles and every charged particle has an electric field surrounding it. The electric field produces electric forces that can push or pull on other particles.

Electromagnetic Radiation

All forms of electromagnetic radiation consist of mutually perpendicular oscillating electric and magnetic fields. Because the various kinds of electromagnetic radiations have the same speed (c), they differ in only wavelength and frequency.

Electromagnetic spectrum

Electromagnetic energy travels in waves and spans a broad spectrum from very long radio waves to very short gamma rays.

From memory you should be able to list the parts in order of energy (relate how that relates to frequency and wavelength) and know how they are produced, detected and their dangers and uses — a rough idea of their approximate wavelength is also useful!.

Radiation Interaction with the Earth

Radiation that is not absorbed or scattered in the atmosphere can reach and interact with the Earth's surface. There are three forms of interaction that can take place when energy strikes, or is incident upon the surface. These are: absorption (A); transmission (T) and reflection (R).

Radiation Interaction with the Atmosphere

The Earth's atmosphere acts as a filter to remove radiation such as cosmic rays, gamma rays, x-rays, UV rays, and large portions of the electromagnetic spectrum through the process of absorption and scattering by gases, water vapour, and particulate matter (dust).

Atmospheric Absorption of electromagnetic waves

In addition to the scattering of EM radiation, the atmosphere also absorbs electromagnetic radiation. The three main constituents which absorb radiation are Ozone, Carbon dioxide, and Water Vapour.

Conditions for interference to occur with two sources of light

- The sources of the waves must be coherent, which means they emit identical waves with a constant phase difference.
- The waves should be monochromatic - they should be of a single wavelength.

Principle of superposition

The principle states that when two or more than two waves superimpose over each other at a common particle of the medium then the resultant displacement (y) of the particle is equal to the vector sum of the displacements (y_1 and y_2) produced by individual waves, i.e. $\vec{y} = \vec{y_1} + \vec{y_2}$

Double-slit experiment

Monochromatic light (single wavelength) falls on two narrow slits S_1 and S_2 which are very close together and acts as two coherent sources, when waves coming from two coherent sources superimposes on each other, an interference pattern is obtained on the screen.

A bright fringe is obtained when the path difference is a whole number of wavelength.

$$r_2 - r_1 = n\mathrm{l} \qquad \text{where } n = 0, 1, 2, 3, 4, \ldots$$

A dark fringe is obtained when the path difference is an odd value of half wavelength.

$$r_2 - r_1 = \frac{m}{2}\mathrm{l}$$

$$x = \frac{m\lambda D}{2d}$$

Where m = 1, 3, 5, 7, ...

Intensity distribution of fringe pattern

Assuming that the two waves have the same amplitude E_0, we can write the magnitude of the electric field at a point let say P due to each wave separately as;

$E_1 = E_0 \sin \omega t$ and $E_2 = E_0 \sin(\omega t + \Phi)$

Since $I \propto E_p^2$, we can write the average light intensity at point P as;

$$I = I_{max} \cos^2\left(\frac{\Phi}{2}\right)$$

$$I = I_{max} \cos^2\left(\frac{\pi d \sin\theta}{\lambda}\right)$$

Guidance for the End of Unit assessment

This activity has no direct answers. Base on learners' deductions and make a general conclusion.

Make sure to harmonize learners' suggestions/ideas/answers

Solutions to End Unit assessment

1. $d = 5.0 \times 10^{-4}$ m $\lambda = 5.89 \times 10^{-7}$ m

   $d \sin\theta = m\lambda \Rightarrow \sin\theta = m\lambda/d \Rightarrow \theta = \sin^{-1}(m\lambda/d)$

   $m = 1$, $\theta_1 = 0.0675°$ $m = 2$, $\theta_2 = 0.135°$

   $\tan\theta = h/l$, $y_1 = h$, $\tan\theta = y_1/l \Rightarrow y_1 = l \tan\theta = 2 \times \tan(0.0675)$

   y_1(Height of lower fringe) = 0.00236 m

   y_2(Height of upper fringe) = 0.00472 m

   Δy = 0.00236 m

   Where Δy = Difference between two fringe locations.

2. $\tan\theta = h/l \Rightarrow \theta = \tan^{-1}(h/l) = 0.430°$

   Now that θ is known, you can use the formula with $m = 3$ to find the wavelength.

   $d \sin\theta = m\lambda$

   $\Rightarrow \lambda = d \sin\theta/m = 2.0 \times 10^{-4} \times \sin(0.430°)/3$

$= 5.00 \times 10^{-7}$ m

3. First find the angle:

   tan q = y/L

   $\Rightarrow$ q = $\tan^{-1}(y/L) = \tan^{-1}(1.73/11.2)$

   = 8.78°

   Find the wavelength

   d sin q = ml $\Rightarrow$ l = d sin q/m = 6.8 × sin(8.78°)/1 = 1.04 km

4. d = 247m

   l = 5.44m

   ml = d sin q $\Rightarrow$ sin q = ml/d $\Rightarrow$ q = $\sin^{-1}$(ml/d)

   q = $\sin^{-1}(1 \times 5.44/247)$ = 1.262°

UNIT 6

Complex Electrical Circuit

KNOW THIS

Generally speaking, network analysis is any structured technique used to mathematically analyze a circuit (a "network" of interconnected components). Quite often the technician or engineer will encounter circuits containing multiple sources of power or component configurations which defy simplification by series/parallel analysis techniques. In those cases, he or she will be forced to use other means. This chapter presents a few techniques useful in analyzing such complex circuits. Mathematical techniques to solve for multiple unknowns (called "simultaneous equations" or "systems") can be applied to basic laws of circuits to solve networks.

Key unit competence

By the end of the unit, the learner should be able to construct and to analyze a complex electrical circuit.

Unit description

This unit deals with:

5.1 Kirchhoff's laws
5.2 Design of complex and simple electric circuits
5.3 Resistors and electromotive forces in series and parallel complex circuits.
5.4 Simple potentiometer circuits
5.5 Comparison of e.m.f.s
5.6 Measurement of internal resistance of a cell
5.7 Measurement of current by Potentiometer
5.8 Advantages and disadvantages of potentiometer

Summary of Knowledge, Skills, Attitudes and Values

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

Knowledge	Skills	Attitudes and Values
State and explain Kirchhoff's laws.	Carry out investigation on measurement of voltage and electrical current.	Appreciate application of Kirchhoff's laws in designing complex circuits.

Distinguish between simple and complex circuits.	Evaluate complex circuits using Kirchhoff's laws.	Enjoy applying Kirchhoff's laws in complex electrical circuits.
Identify mixture of parallel and series connections in complex circuit.	Analyze the electrical current flowing in a complex circuit.	Adapt scientific skills in analyzing complex circuits to avoid overloads.
Explain applications of Kirchhoff 's laws to complex circuits.	Design complex electrical circuit.	
Outline measuring instruments for voltage and electrical current.	Perform an experiment using simple potentiometer circuits.	
Explain advantages and disadvantages of potentiometer.	Solve problems involving complex circuit and potentiometer.	

Learning objectives

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

- analyse complex electrical circuits well.
- use Kirchhoff's laws in circuit analysis accurately.
- analyse simple potentiometer circuits clearly.

SCOPE AND SEQUENCE

This unit will be taught in 18 lessons as distributed below;

Unit 5: Complex electrical circuit			
Lesson 1	**Lesson 2**	**Lesson 3**	**Lesson 4**
This lesson should cover: Introduction	**This lesson should cover:** Kirchhoff's laws	**This lesson should cover:** Kirchhoff's Current Law	**This lesson should cover:** Kirchhoff's Voltage Law

Lesson 5	Lesson 6	Lesson 7	Lesson 8
This lesson should cover: Uses of Kirchhoff's laws	**This lesson should cover:** Assessment 1	**This lesson should cover:** Design of complex and simple electric circuits	**This lesson should cover:** Applications of Kirchhoff's laws in circuit analysis
Lesson 9	**Lesson 10**	**Lesson 11**	**Lesson 12**
This lesson should cover: Simple potentiometer circuits	**This lesson should cover:** Comparison of e.m.f.s	**This lesson should cover:** Assessment 2	**This lesson should cover:** Measurement of internal resistance of a cell
Lesson 13	**Lesson 14**	**Lesson 15**	**Lesson 16**
This lesson should cover: Activity 2	**This lesson should cover:** Measurement of current by Potentiometer	**This lesson should cover:** Activity 3	**This lesson should cover:** Advantages and disadvantages of potentiometer
Lesson 17			
This lesson should cover: Assessment 3			

LESSON DEVELOPMENT

Lesson 1	Title: Introduction
Learning objectives	By the end of this lesson, with examples, learners will be able to define and calculate branch currents accurately.
Key words	complex circuit configuration, combination circuit, potential difference.

Cross-cutting issues to discuss	Gender, peace and values, standardization culture and environment for sustainability.
Competence developed	Critical thinking, creativity and innovation, research and problem-solving, ICT and science and technology
Attention to special educational need children	Special attention is given to learners with physical disabilities.
Lesson 2	**Title: Kirchhoff's laws**
Learning objectives	By the end of this lesson, practically learners will be able to analyse complex electrical circuits well.
Key words	Kirchhoff's Circuit Laws and Sign Conventions
Cross-cutting issues to discuss	Gender, Peace and Values Education Standardization Culture
Competence developed	Critical thinking, creativity and innovation, research and problem-solving, ICT and science and technology
Attention to special educational need children	Special attention is given to learners with physical disabilities, gifted learners and learners with developmental disabilities.
Lesson 3	**Title: Kirchhoff's Current Law**
Learning objectives	By the end of this lesson, using Kirchhoff's current law learners will be able to calculate loop currents and branch currents correctly.
Key words	Junction Rule, current, schematic diagram

Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education, Financial Education, Standardization Culture
Competence developed	Critical thinking, Communication, Cooperation, interpersonal management and life skills and numeracy
Attention to special educational need children	Special attention is given to learners with Intellectual Challenges, Developmental Challenges, Speech and Communication Difficulties and Gifted and Talented
Lesson 4	**Title: Kirchhoff's Voltage Law**
Learning objectives	By the end of this lesson, using Kirchhoff's voltage law, learners will be able to analyse circuits loops and calculate voltage drops and branch currents correctly.
Key words	loop of a closed circuit, Kirchhoff's Loop Rule
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education, Financial Education, Standardization Culture
Competence developed	Critical thinking, creativity and innovation, cooperation, interpersonal management and life skills, communication, numeracy, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, gifted and talented learners
Lesson 5	**Title: Uses of Kirchhoff's laws**

Learning objectives	By the end of this lesson, using examples, learners will be able to list the use of Kirchhoff's laws in real life situations.
Key words	Uses of Kirchhoff's laws
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education, Financial Education, Standardization Culture
Competence developed	Critical thinking, Creativity and innovation, Cooperation, interpersonal management and life skills, communication, numeracy, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, gifted and talented learners
Lesson 6	**Title: Assessment 1**
Learning objectives	By the end of this assessment, using knowledge and skills gained in lessons 1 to 5, learners will be able to relate the content with the real life experiences.
Key words	complex circuit configuration, combination circuit, potential difference, Kirchhoff's Circuit Laws, sign conventions, current, schematic diagram, loop of a closed circuit, uses of Kirchhoff's laws
Cross-cutting issues to discuss	Environment and Sustainability, Gender, Peace and Values Education, Standardization Culture
Competence developed	Critical thinking, problem solving

Attention to special educational need children	Special attention is given to learners with visual difficulties, behavioural difficulties, emotional difficulties, learners with health challenges.
Lesson 7	**Title:Designofcomplexandsimple electric circuits**
Learning objectives	By the end of this lesson, using different electrical components and theories, learners will be able to design complex electrical circuits properly.
Key words	series and parallel network of resistors, complex and simple electric circuits.
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education, Standardization Culture
Competence developed	Critical thinking, creativity and innovation, communication, cooperation, interpersonal management and life skills, science and technology.
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties, gifted and talented learners.
Lesson 8	**Title: Applications of Kirchhoff's laws in circuit analysis**
Learning objectives	By the end of this lesson, by calculations learners will be able to use Kirchhoff's laws in circuit analysis accurately.

Key words	Branch currents, loop currents, voltage drops.
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education, Standardization Culture, Financial Education.
Competence developed	Critical thinking, Creativity and innovation, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, lifelong learning, ICT, entrepreneurship and business development, science and technology
Attention to special educational need children	Intellectual challenges, speech and communication difficulties, behavioural difficulties
Lesson 9	**Title:Simplepotentiometercircuits**
Learning objectives	By the end of this lesson, by calculations and derivations, learners will be able to analyse simple potentiometer circuits clearly.
Key words	potential difference, voltage divider, the balance point
Cross-cutting issues to discuss	Environment and sustainability, Gender , Peace and Values Education, Standardization Culture, Financial Education
Competence developed	Critical thinking, Creativity and Innovation Communication, Cooperation, interpersonal management and life skills, ICT, science and technology

Attention to special educational need children	Intellectual challenges, speech and communication difficulties, gifted and talented learners
Lesson 10	**Title: Comparison of e.m.f.s**
Learning objectives	By the end of this lesson, by calculations learners will be able to compare e.m.f.s accurately.
Key words	standard cell, e.m.f.s
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education, Standardization Culture, Financial Education
Competence developed	Critical thinking, creativity and innovation, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, ICT, entrepreneurship and business development, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication, gifted and talented learners
Lesson 11	**Title: Assessment 2**
Learning objectives	By the end of this assessment, using knowledge and skills gained in lessons 7 to 10, learners will be able to relate the content with the real life experiences.
Key words	series and parallel network of resistors, complex and simple electric circuits, Branch currents, loop currents, voltage drops, voltage divider, the balance point, standard cell, e.m.f.s

Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education, Standardization Culture, Financial Education
Competence developed	Critical thinking, problem solving
Attention to special educational need children	Special attention is given to learners with visual difficulties, behavioural difficulties, emotional difficulties, learners with health challenges
Lesson 12	**Title: Measurement of internal resistance of a cell**
Learning objectives	By the end of this lesson, by derivations and calculations, learners will be able to calculate and measure internal resistance of the cell accurately.
Key words	internal resistance, balance point
Cross-cutting issues to discuss	Environment and sustainability, Gender, Peace and Values Education, Standardization Culture, Financial Education
Competence developed	Critical thinking, Creativity and innovation, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, ICT, entrepreneurship and business development, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication, gifted and talented learners

Lesson 13	**Title: Activity 2**
Learning objectives	By the end of this activity, practically using a potentiometer learners will be able to measure the e.m.f of an unknown cell accurately.
Key words	e.m.f of an unknown cell
Cross-cutting issues to discuss	Environment and sustainability, Gender , Peace and Values Education, Standardization Culture, Financial Education
Competence developed	Critical thinking, Creativity and innovation, Research and problem-solving, Communication, Co-operation, interpersonal management and life skills, ICT, entrepreneurship and business development, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication, gifted and talented, difficulties in handling equipments
Lesson 14	**Title: Measurement of current by Potentiometer**
Learning objectives	By the end of this lesson, by derivations and calculations, learners will be able to calculate current in a potentiometer accurately.
Key words	Measurement of current, balance point

Cross-cutting issues to discuss	Environment and sustainability, Gender , Peace and Values Education, Standardization Culture, Financial Education
Competence developed	Critical thinking, Creativity and innovation, Research and problem-solving, Communication, Co-operation, interpersonal management and life skills, ICT, entrepreneurship and business development, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication, gifted and talented learners
Lesson 15	**Title: Activity 3**
Learning objectives	By the end of this activity, practically using a potentiometer learners will be able to measure the e.m.f of an unknown cell accurately.
Key words	e.m.f of an unknown cell
Cross-cutting issues to discuss	Environment and sustainability, Gender , Peace and Values Education, Standardization Culture, Financial Education
Competence developed	Critical thinking, Creativity and innovation, Research and problem-solving, Communication, Co-operation, interpersonal management and life skills, ICT, entrepreneurship and business development, science and technology

Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication, gifted and talented, difficulties in handling equipments
Lesson 16	**Title: Advantages and disadvantages of potentiometer**
Learning objectives	By the end of this lesson, with examples learners will be able to list advantages and disadvantages of potentiometer well.
Key words	Potentiometer
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Research and problem-solving, Lifelong learning, Communication, Co-operation, interpersonal management and life skills, Literacy, Citizenship and national identity, entrepreneurship and business development
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication, gifted and talented learners
Lesson 17	**Title: Assessment 3**
Learning objectives	By the end of this assessment using knowledge and skills gained in lessons, 1 to 16 learners will be able to relate the content with the real life experiences.

Key words	complex circuit configuration, combination circuit, potential difference, Kirchhoff's laws
Cross-cutting issues to discuss	Environment and sustainability, Gender , Peace and Values Education, Standardization Culture, Financial Education
Competence developed	Critical thinking, problem solving
Attention to special educational need children	Special attention is given to learners with visual difficulties, behavioural difficulties, emotional difficulties, learners with health challenges

MAIN CONTENTS AND CONCEPTS TO EMPHASISE

Kirchhoff's laws

There are two Kirchhoff's laws:

Kirchhoff's Current Law states that *"the algebraic sum of the currents flowing at a node or junction in an electric circuit is zero"*.

Kirchhoff's Voltage Law states that *"the algebraic sum of the potentials around a closed electric circuit is zero"*.

To solve the resistor circuits using Kirchhoff's rules

1. Define the various currents
    - Can either define branch (segment) currents for each element in the circuit
    - Or can define loop currents for each loop in the circuit
2. If using branch currents, use Kirchhoff's Junction Rule to look for interdependent currents. This allows for reducing the number of variables being solved for.
3. Use Loop Rule to define voltage equations for each loop, using previously defined currents.
4. Solve set of simultaneous equations using algebraic manipulation.

    A simple potentiometer is a device used for taking a number of electrical measurements. It is a piece of resistance wire, usually a meter long, fixed between two points A and B with a cell of output voltage, V, connected between the two ends

SOLUTIONS TO ACTIVITIES

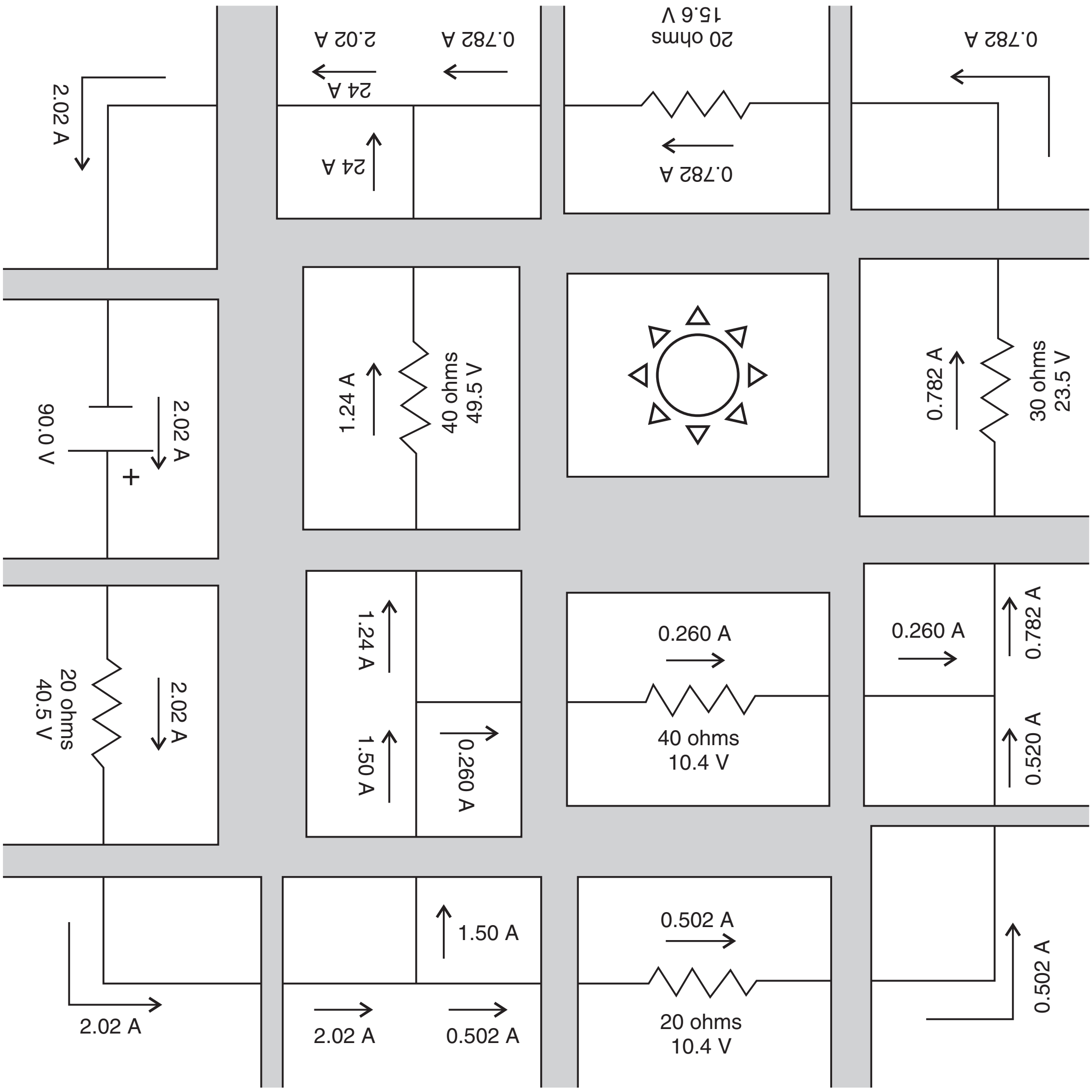
Opening questions

1. The current outside the branches of a combination circuit is everywhere the same. The current inside the branches is always less than that outside of the branches. When comparing the current of two parallel-connected resistors, the resistor with the least resistance will have the greatest current. The current within a single branch will be the same above and below the resistor.
   (a) The current at location A is **equal to** the current at location B.
   (b) The current at location B is **greater than** the current at location E.
   (c) The current at location G is **less than** the current at location F.
   (d) The current at location E is **greater than** the current at location G.
   (e) The current at location B is **greater than** the current at location F.
   (f) The current at location A is **equal to** the current at location L.
   (g) The current at location H is **less than** the current at location I.
2. The voltage drop across a resistor is dependent upon the current in the resistor and the resistance of the resistor. In situations in which the current is the same for both resistors (such as for series-connected resistors), the resistor with the greatest resistance will have the greatest voltage drop.
   (a) The electric potential difference (voltage drop) between points B and C is **greater than** the electric potential difference (voltage drop) between points J and K.
   (b) The electric potential difference (voltage drop) between points B and K is **greater than** the electric potential difference (voltage drop) between points D and I.
   (c) The electric potential difference (voltage drop) between points E and F is **equal to** the electric potential difference (voltage drop) between points G and H.
   (d) The electric potential difference (voltage drop) between points E and F is **equal to** the electric potential difference (voltage drop) between points D and I.

(e) The electric potential difference (voltage drop) between points J and K is **greater than** the electric potential difference (voltage drop) between points D and I.

(f) The electric potential difference between points L and A is **equal to** the electric potential difference (voltage drop) between points B and K.

Activity 5-1



Answer for Application activity 6.2

1. $e = 1.12\,V$
2. $l = 67.2\;cm$

ANSWERS TO END OF UNIT QUESTION

4. $I_1 = \frac{1}{1100}A,\qquad I_2 = \frac{4}{275}A,\qquad I_3 = -\frac{3}{220}A$
5. $I_1 = 4.75\,A,\qquad I_2 = -3.50\,A,\qquad I_3 = 8.25\,A$
6. $I = 0.286\,A\qquad V = 11.44\,V$
7. $I = 2.5\,A$
8. $I_1 = \frac{26}{13}A\qquad I_2 = -1\,A\qquad I_3 = 1\,A$
9. We apply the loop rule to the three loops shown:

$$I_3 - I_1 - (I_1 - I_3) = 0 \qquad (1)$$

$$-I_2 - 2(I_2 + I_3) + 13 = 0 \qquad (2)$$

$$-I_1 - I_3 + I_2 = 0 \qquad (3)$$

Solving these equation we get: $I_1 = 6\,A$, $I_2 = 5\,A$, $I_3 = -1\,A$

The total current through the network is $I_1 + I_2 = \mathbf{1}\;A$ and the potential drop across it is equal to the battery emf, 13 V. The equivalent resistance of the network is therefore

$$R_{eq} = \frac{13}{11} = 1.2\,\mathrm{W}$$

$$V_{ab} = -4\,\acute{}\,2 + 7\,\acute{}\,1 = -1\,V$$

10: We apply KVL to the three loops in turn.

For loop 1: $-24 + 10(i_1 - i_2) + 12(i_1 - i_3) = 0\;\hat{U}\;\; 11i_1 - 5i_2 - 6i_3 = 12$ **a)**

For loop 2: $24i_2 + 4(i_2 - i_3) + 10(i_2 - i_1) = 0\;\hat{U}\;\; -5i_1 + 19i_2 - 2i_3 = 0$ *b)*

For loop 3: $4i_0 + 12(i_3 - i_1) + 4(i_3 - i_2) = 0$

But at node A, $i_0 = i_1 - i_2$ so that

$$4(i_1 - i_2) + 12(i_3 - i_1) + 4(i_3 - i_2) = 0\;\hat{U}\;\; -i_1 - i_2 + 2i_3 = 0 \qquad \text{c)}$$

Solving these equations we get: $i_1 = 2.25\,A$, $i_2 = 0.75\,A$, $i_3 = 1.5\,A$

thus $i_0 = i_1 - i_2 = 1.5\,A$

11. For loop: $-15 + 5i_1 + 10(i_1 - i_2) + 10 = 0\;\hat{U}\;\; 3i_1 - 2i_2 = 1$ a)

For loop 2: $6i_2 + 4i_2 + 10(i_2 - i_1) - 10 = 0 \Leftrightarrow i_1 - 2i_2 = -1$ (b)

Using the substitution method, we substitute Eq. (a) into Eq. (b), and we get :

$I_1 = i_1 = 1\,A \quad I_2 = i_2 = 1\,A \quad I_3 = i_1 - i_2 = 0$

To use Cramer's rule, we cast Eqs. (a) and (b) in matrix form as

$$\begin{bmatrix} 3 & -2 \\ 1 & -2 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} 1 \\ -1 \end{bmatrix}$$

We obtain the determinants: $\Delta = \begin{vmatrix} 3 & -2 \\ 1 & -2 \end{vmatrix} = -4$

$$\Delta_1 = \begin{vmatrix} 1 & -2 \\ -1 & -2 \end{vmatrix} = -4 \qquad \Delta_2 = \begin{vmatrix} 3 & 1 \\ 1 & -1 \end{vmatrix} = -4$$

Thus $i_1 = \frac{\Delta_1}{\Delta} = \frac{-4}{4} = 1\,A \qquad i_2 = \frac{\Delta_2}{\Delta} = \frac{-4}{4} = 1\,A$

12. The 45.0 Ω and 15.0 Ω resistors are in parallel, so first reduce them to a single equivalent resistance. Then find the equivalent series resistance of the circuit.

$$R_{eq} = \frac{45.0 \times 15.0}{45.0 + 15.0} = 11.5\,\Omega$$

The total equivalent resistance is

$$R_{eq} = 18.0 + 11.5 + 3.26 = 32.5\,\Omega$$

Ohm's law gives $I = \frac{25.0\,V}{32.5\,\Omega} = 0.769\,A$

4. From Ohm's law: $V = \varepsilon - ri = 20 - 2 \times 1.0 = 18\,V$

Using again Ohm's law: $R = \frac{V}{i} = \frac{18}{1.0} = 18\,\Omega$

5. a) From Ohm's law: $i = \dfrac{n\varepsilon}{R + nr} = \dfrac{10 \times 2.2}{21 + 10 \times 0.1} = 1\ A$

b) Using again Ohm's law: $V = n(\varepsilon - ri) = 10(2.2 - 0.1 \times 1) = 21\ V$

6. Emf is pd across a generator in open circuit: $\varepsilon = 52\ V$

With load: $V = \varepsilon - ri \Rightarrow r = \dfrac{\varepsilon - V}{i} = \dfrac{50 - 48.8}{80} = 0.04\ \Omega$

$V = \varepsilon - ri = 52 - 0.04 \times 20 = 51.2\ V$

The circuit appears complicated until we realize that the 45.0 Ω and 15.0 Ω resistors are in parallel

Activity 5-2

A. Parallel Circuit: A circuit with two or more branches for current to flow
B. Conductor: Material that electrons can move through
C. Electric Current: Flow of electrons through a conductor
D. Complex Circuit: Made up of series and parallel circuits
E. Switch: A device to break a circuit
F. Insulator: Poor conductor of electricity
G. Ampere: Unit for measuring rate of electron flow in a circuit
H. Electric Charge: Having too many or too few electrons
I. Battery: A temporary source of electric current
J. Power: Rate at which a device converts electrical energy to another form of energy
K. Circuit: Path of electric conductors
L. Static Electricity: Electric charge built up in one place
M. Electroscope: Device that detects electric charges
N. Resistance: Opposition to the flow of electricity
O. Series Circuit : Electric current where current flows through all parts of the circuit
P. Volt: Unit to measure Electric Potential

UNIT 7

Electric potential and gravitational potential

KNOW THIS

It is useful if students can recognise that fields are part of the model to explain forces acting at a distance and that they recognise how diagrams are used to represent the strength of these fields. Students will have some qualitative ideas about gravitational and electric fields, when they meet the idea of gravity and electrostatics. Useful demonstrations and videos can be used to clearly explain the concepts.

Key Unit Competence

Analyze electric field and gravitational potential.

Unit description

This unit involves the use of mathematical derivations which needs the knowledge of integration and graphical illustrations. Learners should clearly analyse these graphics and derive necessary expressions. This unit deals with:

7.0. Introduction
7.1. Electric field and electric potential due to a point charge
7.2. Electric potential energy and potential difference
7.3. Equipotential Lines and Surfaces
7.4. Potential due to electric dipole
7.5. Conservation of electrical energy
7.6. Cathode ray tube
7.7. TV and computer monitors
7.8. Trajectory of a charge moving in a cathode ray tube
7.9. Electrodynamics
7.10. Gravitational field and gravitational potential
7.11. Escape velocity for a planet
7.12. Energy conservation in gravitational fields

Summary of Knowledge, Skills, Attitudes and Values

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

Knowledge	Skills	Attitudes and value
Explain electric potential and electric potential energy	Derive an expression for electric potential for one or more point charges.	Appreciate underlining assumptions applied in derivation of escape speed
State the relation between equipotential surface and electric field lines	Describe and sketch field patterns of equipotential surfaces due to one or two point charges	Appreciate the effects of electric field in a cathode tube of television set and computer monitor
Define gravitational potential and gravitational potential energy	Analyze relation between equipotential surfaces and electric field lines	
	Describe and sketch the trajectory of a charge moving in cathode ray tube	
	Derive an expression for gravitational potential due to one or more point masses	
	Derive an expression for escape speed for a planet	
	Compare electric and gravitational fields	
	Analyze work done in moving a point charge between two points in an electric field independent of the path	

Learning objectives

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

- list the properties of an electric and gravitational fields and the variation of potentials properly.
- explain the working mechanism of a cathode ray tube, TV tubes and computer monitors properly.
- explain the everyday applications of electric and magnetic fields.

SCOPE AND SEQUENCE

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

Unit 7: Electric field potential and gravitational potential

Lesson 1	**Lesson 2**	**Lesson 3**	**Lesson 4**
This lesson should cover: Introduction	**This lesson should cover:** Electric field and electric potential due to a point charge	**This lesson should cover:** Electric potential energy	**This lesson should cover:** Potential difference
Lesson 5	**Lesson 6**	**Lesson 7**	**Lesson 8**
This lesson should cover: Equipotential Lines and Surfaces	**This lesson should cover:** Potential due to electric dipole	**This lesson should cover:** Assessment 1	**This lesson should cover:** Conservation of electrical energy
Lesson 9	**Lesson 10**	**Lesson 11**	**Lesson 12**
This lesson should cover: Cathode ray tube	**This lesson should cover:** TV and computer monitors	**This lesson should cover:** Trajectory of a charge moving in a cathode ray tube I	**This lesson should cover:** Trajectory of a charge moving in a cathode ray tube II

Lesson 13	Lesson 14	Lesson 15	Lesson 16
This lesson should cover: Assessment 2	**This lesson should cover:** Electrodynamics	**This lesson should cover:** Gravitational field and Gravitational potential	**This lesson should cover:** Escape velocity for a planet
Lesson 17	**Lesson 18**		
This lesson should cover: Energy conservation in gravitational fields	**This lesson should cover:** Assessment 3		

LESSON DEVELOPMENT

Lesson 1	**Title: Introduction**
Learning objectives	By the end of this lesson, with examples learners will be able to list the properties of an electric field properly.
Key words	Concept of electric field and gravitational field.
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners

Lesson 2	**Title: Electric field and electric potential due to a point charge**
Learning objectives	By the end of this lesson, mathematically, learners will be able to explain the difference between electric field and electric potential clearly.
Key words	Electric potential, point charge, electrostatic force
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and ented learners
Lesson 3	**Title: Electric potential energy**
Learning objectives	By the end of this lesson, mathematically, learners will be able to calculate electric potential energy accurately.
Key words	Electric potential energy, conservative gravitational force
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy
Attention to special educational need children	Special attention is given to learners with, intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners

Lesson 4	**Title: Potential difference**
Learning objectives	By the end of this lesson, mathematically, learners will be able to calculate potential difference accurately.
Key words	Electric potential difference
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy
Attention to special educational need children	Special attention is given to learners with, intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 5	**Title: Equipotential Lines and Surfaces**
Learning objectives	By the end of this lesson, mathematically learners will be able to explain the equipotential points and surfaces clearly.
Key words	equipotential surface, equipotential lines
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy
Attention to special educational need children	Special attention is given to learners with, intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners

Lesson 6	**Title:Potentialduetoelectricdipole**
Learning objectives	By the end of this lesson, with examples learners will be able to explain the change in potential due to an electric dipole clearly.
Key words	Electric dipole
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 7	**Title: Assessment 1**
Learning objectives	By the end of this assessment, using knowledge and skills gained in lessons 1 to 6 lessons, learners will be able to relate the content with the real life experiences.
Key words	Concept of electric field and gravitational field, Electric potential, point charge, electrostatic force, electric potential energy, conservative gravitational force, Electric potential difference, equipotential surface, equipotential lines, electric dipole
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, problem-solving
Attention to special educational need children	Visual Difficulties

Lesson 8	**Title: Conservation of electrical energy**
Learning objectives	By the end of this lesson, mathematically, learners will be able to explain the variation of electric potential energy and kinetic energy properly.
Key words	Electric charge, kinetic energy, potential energy
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy
Attention to special educational need children	Special attention is given to learners with, intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 9	**Title: Cathode ray tube**
Learning objectives	By the end of this lesson, using the diagram, learners will be able to explain the working mechanism of a cathode ray tube properly.
Key words	CRT, thermionic emission, electron gun, cathode rays
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy
Attention to special educational need children	Special attention is needed to learners with, intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners

Lesson 10	**Title: TV and computer monitors**
Learning objectives	By the end of this lesson, using the diagram, learners will be able to explain the working mechanism of TV and computer monitors properly.
Key words	Color screens, scanning
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy
Attention to special educational need children	Special attention is given to learners with, intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 11	**Title:Trajectoryofachargemoving in a cathode ray tube I**
Learning objectives	By the end of this lesson, using the diagram, learners will be able to explain the parabolic motion of a charged particle in an electric field clearly.
Key words	Trajectory
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy
Attention to special educational need children	Special attention is given to learners with, Intellectual Challenges, Developmental Challenges, Speech and Communication Difficulties and Gifted and Talented learners

Lesson 12	**Title:Trajectoryofachargemoving in a cathode ray tube II**
Learning objectives	By the end of this lesson, mathematically learners will be able to explain the parabolic motion of a charged particle in an electric field clearly.
Key words	Horizontal and vertical motion of a charge in electric field, electron deflection
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 13	**Title: Assessment 2**
Learning objectives	By the end of this assessment, using knowledge and skills gained in lessons 7 to 12 lessons, learners will be able to relate the content with the real life experiences.
Key words	Electric charge, kinetic energy, potential energy, CRT, thermionic emission, electron gun, cathode rays, Colour screens, scanning, Trajectory, Horizontal and vertical motion of a charge in electric field, electron deflection
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, problem-solving
Attention to special educational need children	Visual Difficulties

Lesson 14	**Title: Electrodynamics**
Learning objectives	By the end of this lesson, using the concept of electric and magnetic fields, learners will be able to explain the concept of electrodynamics clearly.
Key words	classical electrodynamics
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 15	**Title: Gravitational field and Gravitational potential**
Learning objectives	By the end of this lesson, mathematically, learners will be able to explain the variation of gravitational potential in a gravitational field clearly.
Key words	Gravitational field, gravitational potential
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners

Lesson 16	**Title: Escape velocity for a planet**
Learning objectives	By the end of this lesson, mathematically, learners will be able to explain the meaning and the value of escape velocity accurately.
Key words	Escape velocity
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy
Attention to special educational need children	Special attention is given to learners with, intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 17	**Title: Energy conservation in gravitational fields**
Learning objectives	By the end of this lesson, mathematically, learners will be able to explain the conservation of energy in a gravitational field.
Key words	Kinetic and potential energy
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, numeracy
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 18	**Title: Assessment 3**

Learning objectives	By the end of this assessment, using knowledge and skills gained in lessons 14 to 17 lessons, learners will be able to relate the content with the real life experiences.
Key words	Classical electrodynamics, gravitational field, gravitational potential, Escape velocity, kinetic and potential energy
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, problem-solving
Attention to special educational need children	Visual Difficulties

MAIN CONTENTS AND CONCEPT TO EMPHASISE

Electric field and electric potential due to a point charge

The direction of electric field is taken to be the direction of the force it would exert on a positive test charge.

$$Potential\ V = \frac{Work\ done}{Unit\ charge} \qquad \text{Or} \qquad Potential\ V = \frac{Energy\ to\ be\ applied}{Unit\ charge}$$

$$V = -\frac{q}{4\mathrm{pe}_0 r}$$

Electric potential energy and potential difference

The work done by a conservative force in moving an object between any two positions is independent of the path taken. Hence we define the potential energy for electrostatic force mathematically as;

$$Potential\ Energy\ U = Work\ done\ on\ a\ charge$$

And the change in electrical energy between two points A and B is given by;

$$\mathrm{D}U = \frac{q^2}{4\mathrm{pe}_0\mathrm{e}_r}\left(\frac{1}{r_A} - \frac{1}{r_B}\right)$$

$$U_B - U_A = -\,qED$$

Equipotential Lines and Surfaces

An equipotential surface is the one on which all points are at the same potential. An *equipotential surface must be perpendicular to the electric field* at any point.

Potential due to electric dipole

Unlike electric field lines, which start and end on electric charges, equipotential lines and surfaces are always continuous and never end.

Conservation of electrical energy

At the instant at which the field is applied, the motionless test charge has zero kinetic energy, and its electric potential energy is at a maximum. Then, the charge accelerates, and its kinetic energy (from motion) increases as its potential energy decreases. The sum of energies is always constant.

$$E_{pot} + E_{kin} = \text{constant}$$

Cathode ray tube

The CRT is a vacuum tube in which a beam of electrons is accelerated and deflected under the influence of electric or magnetic fields.

These electrons, if left undisturbed, travel in a straight-line path until they strike the screen of the CRT which is coated with a material that emits visible light when bombarded with electrons.

TV and computer monitors

In TV and computer monitors, the CRT electron beam sweeps over the screen in the manner of carefully synchronized voltages applied to the deflection plates and is called scanning.

Trajectory of a charge moving in a cathode ray tube

The equation of motion of a charge in a field is calculated by considering vertical and horizontal displacements and is given by;

$y = ax^2$ where $a = \dfrac{Ve}{2mdv^2}$

This equation shows that when electron is in the field, its path is parabolic and is called the *equation of trajectory*.

The vertical deflection D of electron on the screen from initial direction of motion can be obtained by using equation;

$$D = \frac{Velz}{mdv^2}$$

Electrodynamics

When the velocities of the charged particles under consideration become comparable with the speed of light, corrections involving the theory of relativity must be made; this branch of the theory is called relativistic electrodynamics.

Gravitational potential

The gravitational potential V at a point is defined numerically as equal to work done in taking a uniform mass from infinity to that point.

$$V = -\frac{GM_e}{R}$$

Escape velocity for a planet

If the rocket is fired from the surface of the earth with velocity v such that it just escapes from the influence of the earth's gravitational pull then this velocity is called *escape velocity*.

$$v = \sqrt{2gR_e}$$

$$v = \sqrt{2 \times 9.8 \times 6.4 \times 10^6}\ \sqrt{2gR_e}$$

$$= 11.2 \times 10^3\ m/s = 11.2\ km/s$$

Energy conservation in gravitational fields

Conservation of energy tells us that the total energy of the system is conserved, and in this case, the sum of kinetic and potential energy must be constant. This means that every change in the kinetic energy of a system must be accompanied by an equal but opposite change in the potential energy.

Total energy $E = K + U$

$$E = -\frac{GM_e m}{2r}$$

SOLUTION TO ACTIVITIES

SOLUTION FOR APPLICATION ACTIVITY 7.1

1.(a) For the positive charge,

$$V = \frac{kq}{r} = \frac{(9.0\times 10^{9}\ N\ m^{2}/C)(20\times 10^{-6}\ C)}{0.50\ m} = 3.6\times 10^{5}\ V$$

(b) For the negative charge,

$$V = \frac{kq}{r} = \frac{(9.0\times 10^{9}\ N\ m^{2}/C)(-20\times 10^{-6}\ C)}{0.50\ m} = -3.6\times 10^{5}\ V$$

2. The absolute electric potential at the origin due to the first charge is

$$V_1 = \frac{kq_1}{x_1} = \frac{(8.988\times 10^{9}\ N\ m^{2}/C^{2})(6.0\times 10^{-6}\ C)}{5.1\times 10^{-2}\ m} = 1.06\times 10^{6}\ V$$

Likewise, the absolute electric potential at the origin due to the second charge is

$$V_2 = \frac{kq_2}{x_2} = \frac{(9.988\times 10^{9}\ N\ m^{2}/C^{2})(-5.0\times 10^{-6}\ C)}{3.4\times 10^{-2}\ m} = -1.32\times 10^{6}\ V$$

The net potential V at the origin is simply the algebraic sum of the potentials due to each charge taken in isolation.

Thus, $V = V_1 + V_2 = 1.06\times 10^{6}\ V - 1.32\times 10^{6}\ V = -2.64\times 10^{5}\ V$

The work W which we must perform in order to slowly moving a charge from infinity to the origin is simply the product of the charge and the potential difference V between the end and beginning points.

Thus, $W = q_3V = (2.64\times 10^{5}\ V)(-7.0\times 10^{-6}\ C) = 1.85\ J$

3. (a) Since the charges are equal and placed symmetrically $F = 0$

(b) Since $F = qE = 0$ then $E = 0$

(c) $V = 2\frac{kq}{r} = \frac{2(8.99\times 10^{9}\ N.m^{2}.C^{-2})(2.00\times 10^{-6}\ C)}{0.800\ m} = 45.0\ kV$

SOLUTION FOR APPLICATION ACTIVITY 7.2

1. $k.e = 3.2\times 10^{-6}\ J$ $\quad e = 1.6\times 10^{-19}\ C$ $\quad D = 2.1\ cm = 2.1\times 10^{-2}\ m$

$d = 5mm = 5\times 10^{-3}\ m$

$$k.e = \frac{1}{2}mv^2$$

$$mv^2 = 2k.e = 2 \times 3.2 \times 10^{-6} = 6.4 \times 10^{-6}\ kgm^2/s^2$$

$$z = \frac{1}{2} + 20 = 1 + 20 = 21\ cm$$

From $\quad D = \dfrac{V\ elz}{dmv^2}$

$$V = \frac{dmv^2 D}{elz} = \frac{5\times10^{-3}\times6.4\times10^{-6}\times2.1\times10^{-2}}{1.8\times10^{-19}\times2\times10^{-2}\times21\times10^{-2}} = 1.0\times10^{12}V$$

2. $V = 12V,\quad l = 4 \times 10^{-2}\ cm,\ v = 1.0 \times 10^6\ m/s$

$$q = \tan^{-1}\left(\frac{Vel}{dmv^2}\right) = \tan^{-1}\left(\frac{12\times1.8\times10^{11}\times4\times10^{-2}}{(1.0\times10^6)^2\times4\times10^{-2}}\right) = 65.26^0$$

SOLUTION FOR ACTIVITY 7.3

1. Let m represent the asteroid's mass and M represent Earth's mass ($M_e = 5.98\times 10^{24}\ kg$). The asteroid is initially at distance $10R_e$ and finally at distance R_e where $R_e = 6.37\times 10^6\ m$ is Earth's radius

Because we are to neglect the effects of the atmosphere on the asteroid, the mechanical energy of the asteroid–Earth system is conserved during the fall. Thus, the final mechanical energy (when the asteroid reaches Earth's surface) is equal to the initial mechanical energy. With kinetic energy K and gravitational potential energy U, and we can write this as

$$K_i + U_i = K_f + U_f \Rightarrow \frac{1}{2}mv_i^2 - \frac{GMm}{10R_e} = \frac{1}{2}mv_f^2 - \frac{GMm}{R_e} \Rightarrow v_f = \sqrt{v_i^2 + \frac{2GM}{R_e}(1-\frac{1}{10})}$$

Substituting known values, we find

$$v_f = \sqrt{(12\ m/s)^2 + \frac{2(6.67\times10^{-11}\ m^3/s^2\ kg^2)(5.98\times10^{24}\ kg)}{6.37\times10^6\ m}(1-\frac{1}{10})} = 16\ km/s$$

2. (a) The orbital radius must be

$$R = R_e + h = 6.37\times10^6 0.350\times10^6 = 6.72\times10^6\ m$$

From the orbital energy,

$$E = \frac{GMm}{2R} = \frac{(6.67\times10^{-11}\ N\ m^2/\mathrm{kg}^2)(5.98\times10^{24}\ kg)(7.20\ kg)}{2(6.72\times10^6\ m)} = 2.14\times10^8\ J$$

(b) On the launch pad, the ball is not in orbit

Thus

$$E_0 = U_o = -\frac{GMm}{R_e} = \frac{(6.67´\ 10^{-11}\ N\ \ m^2/\mathrm{kg}^2)(5.98´\ 10^{24}\ kg)(7.20\ kg)}{6.37´\ 10^6\ m} = -4.51´\ 10^8\ J$$

The increase in the mechanical energy of the ball from launch pad to orbit is

$$DE = E - E_o = 2.37´\ 10^6\ J$$

3. $F_G = \dfrac{GM_e m}{(R_e + R_e)^2} = \dfrac{GM_e m}{R_e^2} = \dfrac{mg_e}{4} = \dfrac{(2\,000\ kg)(59.80\ m/s^2)}{4} = 4\,900\ J$

The spacecraft is twice as far from the Earth's center as when it is at the surface of the Earth. Therefore, since the force of gravity decreases as the square of the distance the force of gravity F_G on the satellite will be only one-fourth its weight at the Earth's surface

ANSWER TO END OF UNIT QUESTION

1. $\mathrm{F} = \dfrac{4\sqrt{2}\,\mathrm{Gm}^2}{\mathrm{a}^2}$
2. $\Rightarrow\ x = \dfrac{1}{2}$
3. $\vec{F} = \vec{F}_{\mathrm{AC}} + \vec{F}_{\mathrm{AB}} = 1.67 \times 10^{-9}\,(\hat{i} + \hat{j})\ \mathrm{N}$
4. $V = 2.1 \times 10^4\ volts$
5. (a) $U_{el} = 2.6\ mJ$ (b) $U_{el} = 0.50\ mJ$
6. $V_{\text{bottom}} = 1.33 \times 10^6\ m/s$
7. (*a*) $F = 33.8$ mN at 60° above the
   (*b*) $W_{AB} = 23.7$ mJ
   (*c*) D$EPE = 23.7$ mJ
   (*d*) D$V = -\,8.40\ V$

UNIT 8

Motion in Orbits

KNOW THIS

From a conceptual standpoint, orbital motion involves giving something enough horizontal velocity so that, by the time gravity pulls it down, it has travelled far enough to have Earth's surface curve away from it. As a result, it stays above the surface. An object in orbit is essentially falling around the Earth but going so fast that it never hits it.

Key unit competence

By the end the learner should be able to evaluate Newton's law of gravitation and apply Kepler's laws of planetary motion.

Unit description

This unit outlines the existing proofs of certain periodic orbits. Starting with the problem of two bodies a condition for existence of periodic orbits in a rotating coordinate system is derived. So learners should be familiar with mathematical derivations and their applications. This unit deals with:

8.1. Introduction
8.2. Newton's law of gravitation
8.3. Kepler's laws of planetary motion
8.4. Verification of Kepler's third law of planetary motion
8.5. Acceleration due to gravity at the surface of the earth
8.6. Variation of acceleration due to gravity with height
8.7. Variation of gravity with depth
8.8. Variation in g Due to Rotation of Earth
8.9. Variation of gravity g Due to Shape of Earth
8.10. Rockets
8.11. Spacecraft Propulsion
8.12. Satellites
    8.12.1. Orbital Velocity of Satellite
    8.12.2. Time Period of Satellite
    8.12.3. Height of Satellite

8.12.4. Geostationary Satellite
8.12.5. Angular Momentum of Satellite
8.12.6. Energy of Satellite
8.13. Types and applications of Satellite Systems
8.14. Cosmic velocity (first, second and third)
8.14.1. The first cosmic velocity
8.14.2. Second cosmic velocity (escape velocity)
8.14.3. The third cosmic velocity

Summary of knowledge, skills, attitudes and values

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

Knowledge	Skills	Attitudes and value
Explain Newton's law of gravitation	Apply Newton's laws of gravitation to explain the universe and solar system	Appreciate the importance of earth orbital motion to human life
Explain acceleration due to gravity near earth's surface	Apply knowledge of Kepler's laws of planetary motion	Acquire knowledge of planetary motion and use it to explain planet motion
Explain principles of satellites and rockets	Analyze and explain orbits and period of rotation of planets around the sun	Acquire capacity to observe the universe and identify planets
Explain universe and solar system	Evaluate the work done in gravitation fields	
State and explain Kepler's law of planetary motion	Describe the work done in gravitation and explain cosmic velocities	
	Solve problems related to gravitation, planetary motion and cosmic velocities	

	Relate the orbital motion of the earth to seasons and other phenomena such as eclipse	

Learning objectives

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

- use the Newton's law of gravitational motion to calculate the period and velocity of satellites in different orbits.
- apply Kepler's laws in different mathematical analysis.

SCOPE AND SEQUENCE

This unit will be delivered in 20 lessons each of 40 minutes.

Unit 8: Motion in Orbits			
Lesson 1	**Lesson 2**	**Lesson 3**	**Lesson 4**
This lesson should cover: Introduction and Newton's law of gravitation	**This lesson should cover:** Kepler's laws of planetary motion	**This lesson should cover:** Verification of Kepler's third law of planetary motion	**This lesson should cover:** Acceleration due to gravity at the surface of the earth
Lesson 5	**Lesson 6**	**Lesson 7**	**Lesson 8**
This lesson should cover: Variation of acceleration due to gravity with height	**This lesson should cover:** Variation of gravity with depth	**This lesson should cover:** Variation in g due to rotation of Earth	**This lesson should cover:** Variation of gravity g due to Shape of Earth
Lesson 9	**Lesson 10**	**Lesson 11**	**Lesson 12**
This lesson should cover: Rockets and Spacecraft Propulsion	**This lesson should cover:** Assessment 1	**This lesson should cover:** Orbital Velocity of Satellite	**This lesson should cover:** Time Period of Satellite

Lesson 13	Lesson 14	Lesson 15	Lesson 16
This lesson should cover: Height of Satellite	**This lesson should cover:** Geostationary Satellite	**This lesson should cover:** Angular Momentum of Satellite and Energy of Satellite	**This lesson should cover:** Types and applications of Satellite Systems
Lesson 17	**Lesson 18**		
This lesson should cover: Cosmic velocity (first, second and third)	**This lesson should cover:** Assessment 2		

LESSON DEVELOPMENT

Lesson 1	**Title: Introduction and Newton's law of gravitation**
Learning objectives	By the end of this lesson, using the concept of rotational motion, learners will be able to state the Newton's law of gravitation and mathematically apply it.
Key words	universal law of gravitation, gravitational force
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, research and problem-solving, communication, co-operation, interpersonal management and life skills, lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with, developmental challenges, speech and communication difficulties and gifted and talented learners.

Lesson 2	**Title:Kepler's laws of planetary motion**
Learning objectives	By the end of this lesson, using diagrams and mathematical expressions, learners will be able to state Kepler's laws of planetary motion properly.
Key words	Ellipses, sun, focus, areas, periods of time, revolution of planets
Cross-cutting issues to discuss	Gender, peace and values education
Competence developed	Critical thinking, Research and problem-solving, communication, co-operation, interpersonal management and life skills, lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 3	**Title:Verification of Kepler's third law of planetary motion**
Learning objectives	By the end of this lesson, mathematically learners will be able to verify Kepler's third law of planetary motion accurately.
Key words	Gravitational force, Centripetal force
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, research and problem-solving, communication, co-operation, interpersonal management and life skills, lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 4	**Title:Acceleration due to gravity at the surface of the earth**
Learning objectives	By the end of this lesson, mathematically learners will be able to calculate the acceleration due to gravity at the surface of the earth accurately.
Key words	acceleration due to gravity

Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, research and problem-solving, communication, co-operation, interpersonal management and life skills, lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 5	**Title: Variation of Acceleration Due to gravity with Height**
Learning objectives	By the end of this lesson, mathematically learners will be able to verify the variation of acceleration due to gravity above the surface of the earth accurately.
Key words	acceleration due to gravity, height
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, research and problem-solving, communication, co-operation, interpersonal management and life skills, lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 6	**Title: Variation of Gravity with Depth**
Learning objectives	By the end of this lesson, mathematically learners will be able to verify the variation of acceleration due to gravity below the surface of the earth accurately.
Key words	acceleration due to gravity, depth
Cross-cutting issues to discuss	Gender, Peace and Values Education

Competence developed	Critical thinking, research and problem-solving, communication, co-operation, interpersonal management and life skills, lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 7	**Title: Variation in g Due to Rotation of Earth**
Learning objectives	By the end of this lesson, mathematically learners will be able to verify the variation of acceleration due to gravity due to the rotation of the earth accurately.
Key words	acceleration due to gravity, centrifugal force
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, research and problem-solving, communication, co-operation, interpersonal management and life skills, lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 8	**Title:Variationofgravity g DuetoShape of Earth**
Learning objectives	By the end of this lesson, mathematically learners will be able to verify the variation of acceleration due to gravity due to the shape of the earth accurately.
Key words	acceleration due to gravity, ellipses
Cross-cutting issues to discuss	Gender, Peace and Values Education

Competence developed	Critical thinking, research and problem-solving, communication, co-operation, interpersonal management and life skills, lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 9	**Title:RocketsandSpacecraftPropulsion**
Learning objectives	By the end of this lesson, using Newton's laws of motion, learners will be able to explain the motion of rockets and spacecraft propulsion properly.
Key words	Rocket, Spacecraft Propulsion
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, research and problem-solving, communication, co-operation, interpersonal management and life skills, lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 10	**Title: Assessment 1**
Learning objectives	By the end of this assessment, using knowledge and skills gained in lessons 1 to 9, learners will be able to relate the content with the real life experiences.
Key words	universal law of gravitation, gravitational force, ellipses, sun, focus, areas, periods of time, revolution of planets, gravitational force, centripetal force, acceleration due to gravity, height, depth, centrifugal force, rocket, spacecraft propulsion

Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, problem-solving
Attention to special educational need children	Special attention is given to learners with Visual difficulties
Lesson 11	**Title: Orbital Velocity of Satellite**
Learning objectives	By the end of this lesson, using Newton's law of gravitational motion, learners will be able to calculate the velocity of a satellite accurately.
Key words	Satellite, Communication, Orbital Velocity
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, research and problem-solving, communication, co-operation, interpersonal management and life skills, lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 12	**Title: Time Period of Satellite**
Learning objectives	By the end of this lesson, using Newton's law of gravitational motion, learners will be able to calculate the period of a satellite accurately.
Key words	planetary motion, periodic time
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, research and problem-solving, communication, co-operation, interpersonal management and life skills, lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with, developmental challenges, speech and communication difficulties and gifted and talented learners

Lesson 13	**Title: Height of Satellite**
Learning objectives	By the end of this lesson, using Newton's law of gravitational motion, and mathematical derivations, learners will be able to calculate the height of a satellite in space accurately.
Key words	height of satellite
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, research and problem-solving, communication, co-operation, interpersonal management and life skills, lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 14	**Title: Geostationary Satellite**
Learning objectives	By the end of this lesson, using Newton's law of gravitational motion, learners will be able to explain mathematically the behaviour of a geostationary satellite.
Key words	geostationary satellite
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, research and problem-solving, communication, co-operation, interpersonal management and life skills, lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with developmental challenges, speech and communication difficulties and gifted and talented learners

Lesson 15	**Title: Angular Momentum of Satellite and Energy of Satellite**
Learning objectives	By the end of this lesson, using Newton's law of gravitational motion and mathematical derivations, learners will be able to calculate the angular momentum of a satellite accurately.
Key words	Angular momentum and energy of satellite
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, research and problem-solving, communication, co-operation, interpersonal management and life skills, lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 16	**Title:TypesandapplicationsofSatellite Systems**
Learning objectives	By the end of this lesson, using Newton's law of gravitational motion, learners will be able to explain the types of satellites and their applications.
Key words	Geo-stationary earth orbit, Medium earth orbit, Low earth orbit, Highly elliptical orbit
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, research and problem-solving, communication, co-operation, interpersonal management and life skills, lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with developmental challenges, speech and communication difficulties and gifted and talented learners

Lesson 17	**Title: Cosmic velocity (first, second and third)**
Learning objectives	By the end of this lesson, using Newton's law of gravitational motion, learners will be able to calculate the first, second and third cosmic velocities accurately.
Key words	Cosmic velocity, gravitational force, centripetal force
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Research and problem-solving, communication, co-operation, interpersonal management and life skills, lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 18	**Title: Assessment 2**
Learning objectives	By the end of this assessment, using knowledge and skills gained in lessons 10 to 17, learners will be able to relate the content with the real life experiences.
Key words	Satellite, Communication, Orbital Velocity planetary motion, periodic time, height of satellite, geostationary satellite, Angular momentum and energy of satellite, Geo-stationary earth orbit, Medium earth orbit, Low earth orbit, Highly elliptical orbit, Cosmic velocity, gravitational force, centripetal force
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, problem-solving
Attention to special educational need children	Special attention is needed to learners with Visual difficulties

MAIN CONTENTS AND CONCEPTS TO EMPHASISE

"Together with learners, discuss what happens when two massive objects are brought together. Then relate learners' discussion to Newton's law of gravitation"

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 m_1 and m_2 is directly proportional to the product of masses and inversely proportional to the square of their mean distance apart."

$$F = \frac{Gm_1m_1}{r^2}$$

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 peiods 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.

Verification of Kepler's third law of planetary motion

Gravitational force of attraction of the sun and the planet

$$F_1 = \frac{Gm_1m_2}{R^2}$$

Centripetal force is responsible for keeping the planet moving in a circular motion around the sun.

$$F_2 = \frac{m_2 n^2}{R}$$

If $F_1 = F_2$ we get;

$$R^3 = kT^2$$

which is true that $R^3 \alpha \, T^2$

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 it's average value is taken to be 9.8 m/s^2 on earth.

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;

$$g' = g\left(\frac{R}{R+h}\right)^2$$

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;

$$g' = \frac{4}{3}\pi\rho G(R-d)$$

The depth d is measured from the surface of the earth.

Variation in g Due to Rotation of Earth

As the earth rotates, a body placed on its surface moves along the circular path and hence experiences centrifugal force, due to it, the apparent weight of the body decreases.

By solving, the acceleration due to gravity is given by;

$$g' = g - \omega^2 R\cos^2 \lambda$$

Variation of gravity g Due to Shape of Earth

The value of acceleration due to gravity will vary depending on someone's position at the surface of the earth as;

At equator $\quad g_e = \frac{GM}{R_e^2}$

At poles $\quad g_p = \frac{GM}{R_p^2}$

Rockets and spacecraft

A rocket is a device that produces thrust by ejecting stored matter. Spacecraft propulsion is characterized 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

$$\nu = R\sqrt{\frac{g}{R+h}}$$

Time Period of Satellite

The period of a satellite is given by;

$$T = 2\pi\sqrt{\frac{R}{g}}\left(1+\frac{h}{R}\right)^{3/2}$$

Height of Satellite

The height at which a satellite is launched is given by;

$$h = \left(\frac{T^2 g R^2}{4\pi^2}\right)^{1/3} - R$$

Geostationary Satellite

The satellite which appears stationary relative to earth is called geostationary or geosynchronous satellite, *e.g.*, communication satellite.

Angular Momentum of Satellite

The angular momentum of a satellite is given by;

$$L = \sqrt{m^2 GMr}$$

It is seen that angular momentum of satellite depends on both the mass of orbiting and central body as well as the radius of orbit.

Energy of Satellite

When a satellite revolves around a planet in its orbit, it possesses both potential energy (due to its position against gravitational pull of earth) and kinetic energy (due to orbital motion).

(1) Potential energy : $U = mV = \dfrac{-GMm}{r}$

(2) Kinetic energy : $K = \dfrac{1}{2}m\nu^2 = \dfrac{GMm}{2r}$

Total energy $(E) = \dfrac{-GMm}{2r}$ = constant

Types and applications of Satellite Systems

- GEO (Geo-stationary earth orbit)
- MEO (medium earth orbit)
- LEO (Low earth orbit) and
- HEO (Highly elliptical orbit)

COSMIC VELOCITY

The first cosmic velocity

$$n_1 = 7900\ m/s$$

Second cosmic velocity

This is also called the escape velocity $n_2 = 11200\ m/s$

Third cosmic velocity

The third cosmic velocity is the initial velocity which a body has to have to leave the Solar System and its value is given by;

$$n_3 = 16.7\ km/s$$

SOLUTIONS OF ACTIVITIES

Answer for application activity 8.2

1. Kepler's third law

   $T^2 \propto R^3$

   $$\therefore \frac{T_{Neptune}}{T_{Saturn}} = \left(\frac{T_{Neptune}}{R_{Saturn}}\right) = \left(\frac{10^{13}}{10^{12}}\right)^{3/2} = 10\sqrt{10}$$

2. We know $g = \frac{GM}{R^2} = \frac{GM}{(D/2)^2} = \frac{4GM}{D^2}$

   If mass of the planet = M_0 and diameter of the planet = D_0. Then

   $$g = \frac{4GM_0}{D_0^2}$$

3. Weight of the body at height R,

$$W' = W\left(\frac{R}{R+h}\right)^2 = W\left(\frac{R}{R+\frac{R}{2}}\right)^2 = W\left(\frac{2}{3}\right)^2 = \frac{4}{9}W = \frac{4}{9}\times 72 = 32N.$$

4. Acceleration due to gravity at depth d,

$$g' = g\left[1-\frac{d}{R}\right] = g\left[1-\frac{100}{6400}\right] = 9.8\left[1-\frac{1}{64}\right] = 9.8\times\frac{63}{64} = 9.66\,m/s^2$$

5. If $F \propto \dfrac{1}{R^n}$

$$\text{Then ; } v \,\mu\, \frac{1}{\sqrt{R^{n-1}}} \qquad \text{here } n = 1 \;\backslash\; v \,\mu\, \frac{1}{\sqrt{R^{1-1}}} \,\mu\, R^0$$

6. Orbital radius of satellite $r_s = 4r_c$ (given)

From Kepler's law

$T \propto r^{3/2}$

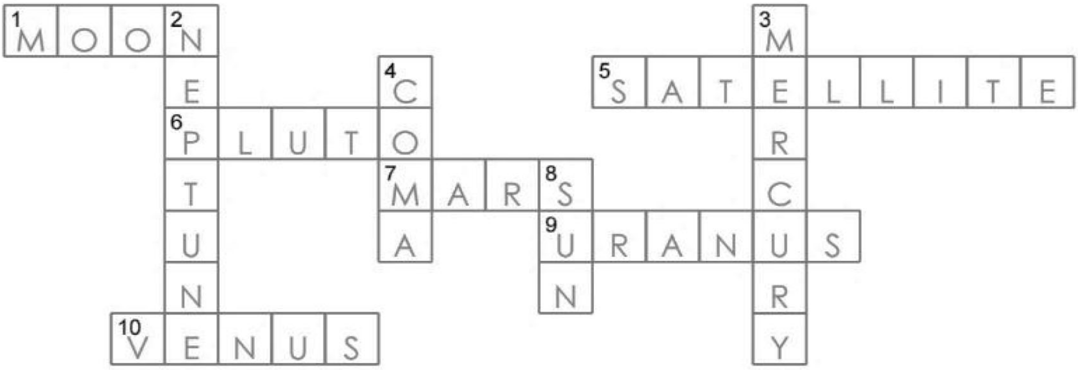
$$\therefore \frac{T_s}{T_c} = \left(\frac{r_s}{s_c}\right)^{3/2} = (4)^{3/2}$$

$\Rightarrow T_s = 8T_c = 8 \times 1$ day $= 8$ days.

Answer for application activity 8.3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A	A	A	X	P	O	T	E	N	T	I	A	L	O	R	K	O
B	Q	C	V	I	Y	O	F	U	O	D	S	T	W	O	R	K
C	A	S	C	C	B	X	D	Y	O	H	X	L	I	T	A	I
D	S	A	O	E	Q	T	K	I	N	E	T	I	C	A	D	S
E	P	T	S	C	L	G	R	Y	O	I	L	W	I	T	I	V
F	S	E	M	Z	Y	E	N	E	R	G	Y	B	O	I	U	E
G	P	L	I	O	P	A	R	O	B	H	R	H	P	O	S	L
H	A	L	C	K	N	R	V	A	I	T	E	A	R	N	C	O
I	C	I	D	E	E	T	M	O	T	I	O	N	V	Q	X	C
J	E	T	Z	P	W	H	I	G	A	I	V	O	T	I	Y	I
L	C	E	I	L	T	O	B	O	L	F	O	R	C	E	T	T
M	R	S	G	E	O	S	T	A	T	I	O	N	A	R	Y	Y
N	A	X	M	R	N	X	Q	Z	O	R	O	C	K	E	T	S
O	F	I	W	R	O	P	R	O	P	U	L	S	I	O	N	O
P	T	P	L	A	N	E	T	A	R	Y	D	O	X	B	B	S

Answer for application activity 8.4



Any constructive meaningful sentence constructed by students having any one of the words identified.

ANSWERS OF END OF UNIT QUESTIONS

1. $\dfrac{T_1}{T_2} = \dfrac{1}{2\sqrt{2}}$

2. $R = 1.87 \times 10^6\ m.$

3. $\dfrac{H_{planet}}{H_{earth}} = \dfrac{g_{earth}}{g_{planet}} = 100\ m$

4. $x = \dfrac{9D}{10}$

5. $d = \left(\dfrac{n-1}{n}\right)R$

6. n = 1.02 km /sec = 1km/s (Approx.)

7. $T = 27 \times 2\pi\sqrt{\dfrac{R}{g}}$

8. $\dfrac{T_1}{T_2} = \dfrac{1}{2\sqrt{2}}.$

UNIT 9

Atomic models and photo-electric effect

KNOW THIS

Atoms consist of several particles called subatomic particles like the proton, electron, neutron, positron, neutrino, meson etc. These form the basis of particle physics which is dominating in today's research in different domains. It is important to realise that a lot of what we know about the structure of atoms has been developed over a long period of time. This is often how scientific knowledge develops, with one person building on the ideas of someone else. We are going to look at how our modern understanding of the atom has evolved over time.

Key unit competence

By the end of this unit, the learner should be able to evaluate the atomic model and photoelectric effect

Unit description

This unit investigates students understanding of the photoelectric effect which is an important part of the atomic structure. This Unit describes at a very introductory level the fundamentals of quantum mechanics and needs understanding some basic concepts in chemistry. It deals with;

9.0 Introduction
9.1 Structure of atom
9.2 Rutherford's atomic model
9.3 Bohr's atomic model
9.4 Energy levels and spectral lines of Hydrogen
9.5 Thermionic emission (thermo electronic emission)
9.6 Applications of cathode rays
  9.6.1 Cathode ray oscilloscope
  9.6.2 TV tubes
9.7 Fluorescence and phosphorescence
9.8 Photoelectric emission laws'
9.9 Photoelectric effect
9.10 Factors affecting photoelectric emission

9.11 Photon, work function and Plank constant

9.12 Einstein's equation photoelectric effect

9.13 Application of photoelectric effect (photo emissive and photovoltaic cells)

9.14 Compton effect

Summary of knowledge, skills, attitudes and values

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

Knowledge	Skills	Attitudes and value
Recall duality nature of light	Evaluate excitation and ionization of an atom.	Appreciate the difference between fluorescent and phosphorescent materials.
Explain the structure of the atom	Analyse electric current production when sun radiation shines a metal surface	Appreciate the use of solar and photocells in real life
Explain atomic radiation spectra	Investigate electron deflection in electric and magnetic fields in cathode tubes	Appreciate the use of cathode ray tube in television to display images
Explain evidence of energy levels in atom.	Distinguish fluorescent and phosphorescent materials	Recognize the types of rays using cathode ray oscilloscope (C.R.O)
Identify factors influencing thermionic emission	Evaluate applications of photoelectric effect.	Appreciate the importance of emitted rays
Explain how C.R.O and T.V. tubes function	Explain why Compton effect fails when light is considered as a wave	
Explain the photoelectric effect		
Explain factors affecting photoelectric emission		

Explain functioning of photo cells (photo emissive and photovoltaic cells)		

Learning Objectives

By the end of this unit, learners should be able to;

- describe different atomic models by explaining their concepts and drawbacks.
- explain the photoelectric effect and its applications in everyday life.

SCOPE AND SEQUENCE

This unit will be delivered in 22 lessons each of 40 minutes.

Unit 9: Atomic models and photoelectric effect			
Lesson 1	**Lesson 2**	**Lesson 3**	**Lesson 4**
This lesson should cover: Structure of atom	**This lesson should cover:** Rutherford's atomic model	**This lesson should cover:** Bohr's atomic model	**This lesson should cover:** Bohr's Orbits
Lesson 5	**Lesson 6**	**Lesson 7**	**Lesson 8**
This lesson should cover: Energy levels and spectral lines of Hydrogen	**This lesson should cover:** Thermionic emission	**This lesson should cover:** Cathode ray oscilloscope	**This lesson should cover:** TV tubes
Lesson 9	**Lesson 10**	**Lesson 11**	**Lesson 12**
This lesson should cover: Fluorescence and phosphorescence	**This lesson should cover:** Assessment 1	**This lesson should cover:** Photoelectric emission laws'	**This lesson should cover:** Photoelectric effect

Lesson 13	Lesson 14	Lesson 15	Lesson 16
This lesson should cover: Factors affecting photoelectric emission	**This lesson should cover:** Photon, work function and Planck's constant	**This lesson should cover**: Einstein's equation photoelectric effect	**This lesson should cover:** Stopping potential and photoelectric effect
Lesson 17	**Lesson 18**	**Lesson 19**	**Lesson 20**
This lesson should cover: Application of photoelectric effect	**This lesson should cover:** Compton Effect 1	**This lesson should cover:** Compton Effect 2	**This lesson should cover:** Assessment 2

LESSON DEVELOPMENT

Lesson 1	**Title: Structure of atom**
Learning objectives	By the end of this lesson, learners will be able to explain the structure of an atom clearly.
Key words	Structure of atom, plum pudding model
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, Lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 2	**Title: Rutherford's atomic model**
Learning objectives	By the end of this lesson, using diagrams, learners will be able to explain the Rutherford's model of the atom clearly.

Key words	Rutherford's planetary model of the atom
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, communication, co-operation, interpersonal management and life skills, lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 3	**Title: Bohr's atomic model**
Learning objectives	By the end of this lesson, learners will be able to explain the Bohr's model of the atom clearly.
Key words	hydrogen atom, Bohr's postulates
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, Lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 4	**Title: Bohr's Orbits**
Learning objectives	By the end of this lesson, mathematically learners will be able to analyse Bohr's orbital radius and speed accurately.
Key words	Radius of orbit, Speed of electron

Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, communication, co-operation, interpersonal management and life skills, lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 5	**Title:Energylevelsandspectrallinesof Hydrogen**
Learning objectives	By the end of this lesson, using diagrams, learners will be able to explain Energy levels and spectral lines of Hydrogen atom clearly.
Key words	Energy levels, spectral lines of Hydrogen
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, communication, co-operation, interpersonal management and life skills, lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 6	**Title: Thermionic emission**
Learning objectives	By the end of this lesson, using examples learners will be able to explain the concept of thermionic emission clearly.
Key words	Thermionic emission, discharge of electrons
Cross-cutting issues to discuss	Gender, Peace and Values Education

Competence developed	Critical thinking, communication, co-operation, interpersonal management and life skills, lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 7	**Title: Cathode ray oscilloscope**
Learning objectives	By the end of this lesson, using diagram, learners will be able to explain the working principle of the Cathode Ray Oscilloscope clearly.
Key words	C.R.O tube, deflecting the beam
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, Lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 8	**Title: TV tubes**
Learning objectives	By the end of this lesson, using the concept of cathode rays, learners will be able to explain the working of TV tubes clearly.
Key words	The picture tube, phosphor stripes, electron guns
Cross-cutting issues to discuss	Gender, Peace and Values Education

Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, Lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 9	**Title:Fluorescenceandphosphorescence**
Learning objectives	By the end of this lesson, learners will be able to explain the difference between fluorescence and phosphorescence clearly.
Key words	Fluorescence, Phosphorescence
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, Lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 10	**Title: Assessment 1**
Learning objectives	By the end of this assessment using knowledge and skills gained in lessons 1 to 9, learners will be able to relate the content with the real life experiences.

Key words	Structure of atom, plum pudding, Rutherford's planetary model of the atom hydrogen atom, Bohr's postulates, Radius of orbit, Speed of electron, Energy levels, spectral lines of Hydrogen, Thermionic emission, discharge of electrons, C.R.O tube, deflecting the beam, The picture tube, phosphor stripes, electron guns, Fluorescence, Phosphorescence
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, problem solving
Attention to special educational need children	Special attention is given to learners with visual difficulties
Lesson 11	**Title: Photoelectric emission laws'**
Learning objectives	By the end of this lesson, learners will be able to state the laws of photoelectric emission clearly.
Key words	The photo current, intensity of light, kinetic energy, frequency
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, Lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 12	**Title: Photoelectric effect**
Learning objectives	By the end of this lesson, using the photon theory, learners will be able to explain the concept of photoelectric effect clearly.
Key words	Photoelectric emission

Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, Lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 13	**Title: Factors affecting photoelectric emission**
Learning objectives	By the end of this lesson, learners will be able to explain the factors affecting photoelectric emission clearly.
Key words	Intensity of Light, Frequency, Number of Photoelectrons, Kinetic Energy of Photoelectrons
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, Lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 14	**Title: Photon, work function and Planck constant**
Learning objectives	By the end of this lesson, learners will be able to define the photon, work function and Planck's constant clearly.

Key words	Photon, work function, Planck constant
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, Lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 15	**Title:Einstein'sequationphotoelectric effect**
Learning objectives	By the end of this lesson, mathematically, learners will be able to explain and apply the Einstein's equation of photoelectric effect clearly.
Key words	Photoelectric emission, Work function, Threshold Frequency
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, Lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 16	**Title: Stopping potential and photoelectric effect**

Learning objectives	By the end of this lesson, learners will be able to explain the effect of stopping potential on photoelectric emission clearly.
Key words	Stopping potential and photoelectric effect
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, Lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 17	**Title:Applicationofphotoelectriceffect**
Learning objectives	By the end of this lesson, learners will be able to explain the applications of photoelectric effect in everyday life clearly.
Key words	photovoltaic cells
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, Lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 18	**Title: Compton Effect 1**
Learning objectives	By the end of this lesson, using the diagram learners will be able to explain the concept of Compton Effect clearly.

Key words	The energy conservation, The photon scattering, Compton Effect
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, Lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 19	**Title: Compton Effect 2**
Learning objectives	By the end of this lesson, mathematically, learners will be able to explain the concept of Compton Effect, derive and apply the expression for the Compton shift clearly.
Key words	Compton shift
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, Communication, Co-operation, interpersonal management and life skills, Lifelong learning, numeracy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 20	**Title: Assessment 2**
Learning objectives	By the end of this assessment, using knowledge and skills gained in lessons 11 to 19, learners will be able to relate the content with the real life experiences.

Key words	The photo current, intensity of light, kinetic energy, Photoelectric emission, Frequency, Photon, work function, Planck's constant, Threshold Frequency, Stopping potential, photovoltaic cells, Compton Effect, Compton shift
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competence developed	Critical thinking, problem solving
Attention to special educational need children	Special attention is given to learners with visual difficulties

MAIN CONTENTS AND CONCEPTS TO EMPHASISE

Structure of atom

An atom is a sphere in which are embedded positively charged particles called protons and negatively charged particles called electrons.

Rutherford's atomic model

Rutherford performed experiments on the scattering of alpha particles by extremely thin gold foils. From these experiments born a new model of the atom called Rutherford's planetary model of the atom. The following conclusions were made

- Most of the mass and all of the charge of an atom concentrated in a very small region is called atomic nucleus.
- Nucleus is positively charged and it's size is of the order of $10^{-15}m \approx 1$ Fermi.
- In an atom there is maximum empty space and the electrons revolve around the nucleus in the same way as the planets revolve around the sun.

Bohr's atomic model

Bohr's model is based on the following postulates:-

- Each electron moves in a circular orbit centered the nucleus.
- The centripetal force needed to the electron moving in a circle is provided by electrostatic force of attraction between the nucleus and electrons.

- The angular momenta of electrons are whole number multiples of $\frac{h}{2p}$ where h is the Planck's constant. i.e. $p = \frac{nh}{2p} = mvr$.
- When electron moves in its allowed orbit, it doesn't radiate energy. The atom is then stable, such stable orbits are called stationary orbits.
- When an electron jumps from one allowed orbit to another, it radiates energy. The energy of radiation equals energy difference between levels.

$$hf = e_i = e_f$$

Energy levels and spectral lines of Hydrogen

When hydrogen atom is excited, it returns to its normal unexcited (or ground state) state by emitting the energy it had absorbed earlier. Transition from different orbits cause different wavelengths, these constitute spectral series which are characteristic of the atom emitting them.

The spectral lines arising from the transition of electron forms a spectra series. Mainly there are five series and each series is named after it's discover as Lyman series, Balmer series, Paschen series, Bracket series and Pfund series.

Thermionic emission

Thermionic emission or discharge of electrons from heated materials is widely used as a source of electrons in conventional electron tubes (e.g., television picture tubes) in the fields of electronics and communications.

Applications of cathode rays

- Cathode ray oscilloscope
- TV tubes

Fluorescence and phosphorescence

Fluorescence is the emission of light by a substance that has absorbed light or other electromagnetic radiation.

Phosphorescence is a specific type of photoluminescence related to fluorescence. Unlike fluorescence, a phosphorescent material does not immediately re-emit the radiation it absorbs.

$$V_s = \frac{h}{e}\left(f - f_o\right)$$

Photoelectric effect

The photoelectric effect is the emission of electrons from the surface of a metal when electromagnetic radiation (such as visible or ultraviolet light) shines on the metal.

Photoelectric emission laws'

Law 1: The photo current is directly proportional to the intensity of light and is independent of frequency.

Law 2: The kinetic energy of the photo electrons is directly proportional to frequency and is independent of intensity.

Law 3: Photoelectric effect does not happen when the incident frequency is less than a minimum frequency (threshold frequency).

Law 4: There is no time lag between the incidence of photon and emission of electrons or photoelectric process is an instantaneous.

Factors affecting photoelectric emission

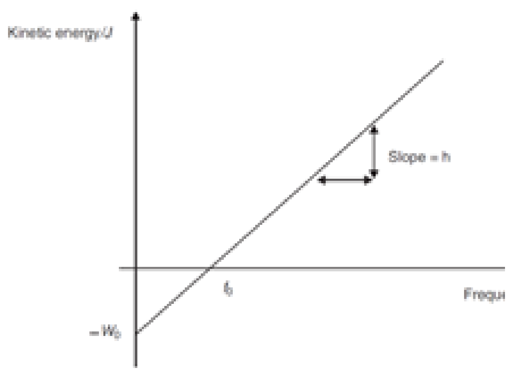
- Intensity of Light:
- Frequency:
- Number of Photoelectrons
- Kinetic Energy of Photoelectrons

Einstein's equation

Einstein suggested that the energy of the incident radiation hf was partly used to free electrons from the binding forces on the metal and the rest of the energy appeared as kinetic energy of the emitted electrons and his famous equation is;

$$hf = W_0 + K_{max}$$

From this equation,we can plot a graph of kinetic energy against frequency as shown below.

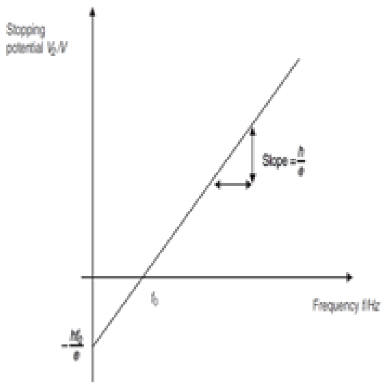


From the graph,it can be deduced that the slope of the graph yields plunks constant.

If the reverse potential difference applied on the circuit is increased until no electron reaches the anode, no current flows and this applied potential is called a stopping potential. This changes the Einstein's photoelectric equation to;

$$V_s = \frac{h}{e}\left(f - f_o\right)$$

Emphasize use of the graph below to interpret the equation above



The slope multiplied by electronic charge gives plunk's constant.

Application of photoelectric effect

Photoelectric effect is applied in photoelectric cells or simply photocells. These cells change light energy into electric current. Photoelectric cell makes use of photoelectric effect and hence converts light energy into electrical energy. The strength of the current depends on the intensity of light falling on the cathode.

Compton effect

Compton effect says that when x-rays are projected on the target, they are scattered after hitting the target and change the direction they were moving.

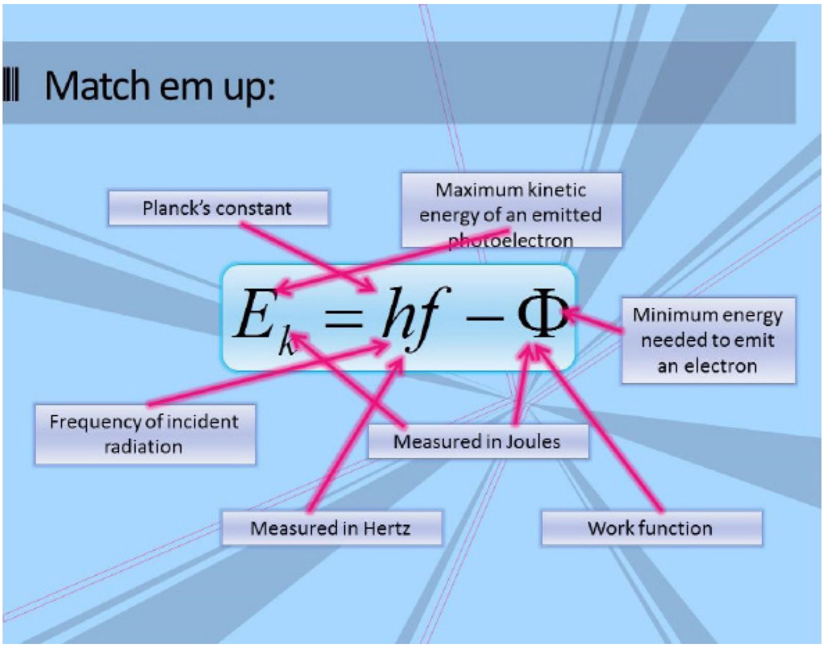
The Compton equation (or Compton shift) is given by;

$$\lambda' - \lambda = \frac{h}{mc}(1 - \cos\phi)$$

SOLUTIONS OF ACTIVITIES

ACTIVITY 3-2

3.



APPLICATION ACTIVITY 3.2

4. (a) Equation 1-8 in the student's book is $V_s = \frac{h}{e}(f - f_o)$

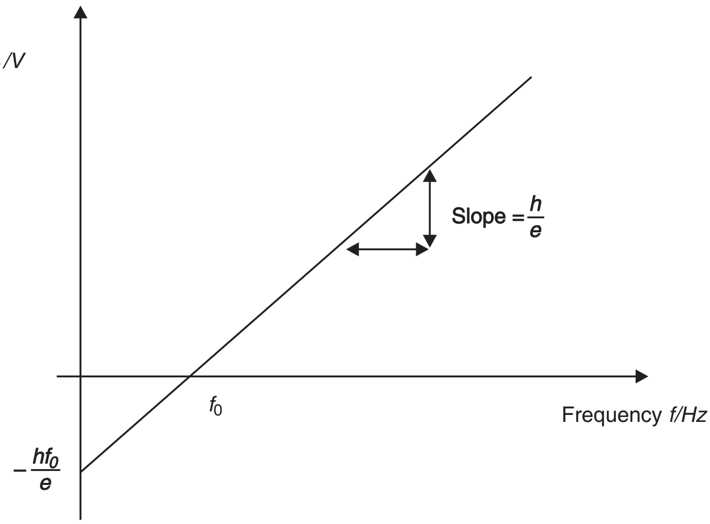
The only variables we have are the stopping potential V_s and the radiation frequency f_i. So the equation takes the form y = $ax + b$ where

$y = V_s$

$a = \frac{h}{e}$

$b = \frac{hf_0}{e}$

And its plot is a straight line as shown below



9.1 Determination of Planck's constant 1

Planck's constant $h = e \times slope$

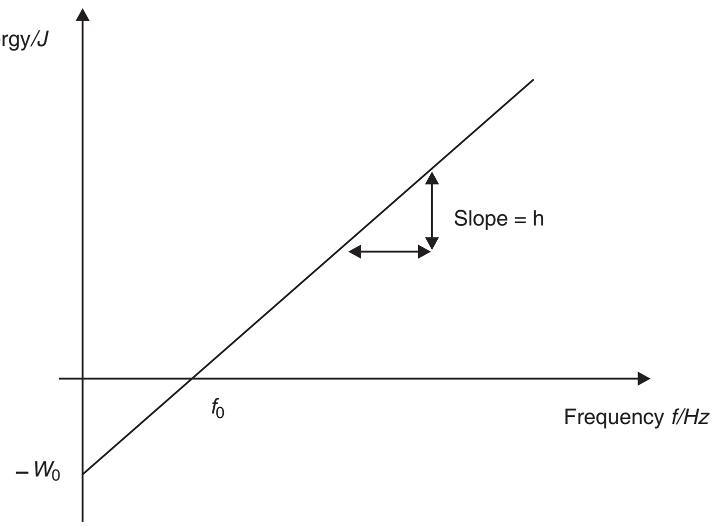
(b) As $K.e._{max} = hf - W_0$

The only variables we have are the kinetic energy $K.e_{max}$ and the radiation frequency f_i. So the equation takes the form $y = ax + b$ where

$y = K.e_{max}$

$a = h$

$b = -W_0$



9-2; Determination of Planck's constant 2

ACTIVITY 9-3

(a) The slope of the line is $\frac{\mathrm{D}E}{\mathrm{D}f} = 6.63 \times 10^{-34}$ J/Hz.

(b) Intercept on vertical intercept is $-1.04 \times 10^{-19} J$.

(c) Equation of the line is $E = 6.63 \times 10^{-34} f - 1.04 \times 10^{-19}$.

(d) The vertical intercept is the work function.

(e) The value of the slope of the line is the Planck's constant.

(f) The Einstein photoelectric equation is $K.e_{max} = hf - \Phi$.

SOLUTIONS OF EXERICISE 9-1

1.

Metal	Work Function / eV	Work Function / J	Frequency used / Hz	Maximum KE of ejected electrons / J
Sodium	2.28	3.65×10^{-19}	6×10^{14}	0.35×10^{-19}
Potassium	2.30	3.68×10^{-19}	6×10^{14}	0.32×10^{-19}
Lithium	2.90	4.64×10^{-19}	$1. \times 10^{15}$	1.99×10^{-19}
Aluminium	4.10	6.56×10^{-19}	1.04×10^{15}	0.35×10^{-19}
Zinc	4.30	6.88×10^{-19}	1.2×10^{15}	1.12×10^{-19}
Copper	4.60	7.36×10^{-19}	1×10^{15}	0

For copper 1×10^{15} Hz is below the threshold frequency so no electrons are ejected.

2. a) $E = hf = 6.63 \times 10^{-34} \times 1.61 \times 10^{15} = 1.07 \times 10^{-18} J$

b) $W_0 = hf - eV_s$

$= 1.07 \times 10^{-18} - 1.6 \times 10^{-19} \times 3$

$= 5.9 \times 10^{-19} J$

c) $\frac{1}{2}mv^2_{max} = eV_s$

$$v_{max} = \sqrt{\frac{2eV_s}{m}}$$

$$= \sqrt{\frac{2\times1.6\times10^{-19}\times3}{9.11\times10^{-31}}}$$

$$=1.02\times10^{6} m/s$$

ANSWERS OF END OF UNIT QUESTIONS

1. The English scientist Thomson suggested that the atom, which is a neutral particle, was made of positive charge with 'lumps' of negative charge embedded in it - rather like the plums in a pudding. For this reason it was known as the Plum Pudding theory of the atom.

   Rutherford explained it this way. He knew that the alpha particles carried a positive charge so he said that the positive charge of the atom was concentrated in one place that he called the nucleus, and that the negatively charged particles, the electrons, were in orbit around the nucleus. Most of the mass was in the nucleus
2. Rutherford's prediction using the idea of Coulomb law repulsion was verified by experiment. It also enables experimental values of nuclear charge to be obtained, i.e. atomic number.
3. They would not have been repelled so it is unlikely that any would 'bounce back'. Some could be absorbed by the nucleus.
4. The charge on the nucleus is much smaller so deflection would be smaller.
5. Small, massive and positive.
6. a) $3.52x10^{33}\ eV$ b) $2.08 \times 10^{-19}J$
7. a) l = 0.017 A° b) $\frac{Dl}{l} = 41.2\%$
8. a) 60.7^0 b) 13.0^0
9. a) Energy of the photon $4.74 \times 10^{-19}J$ = E = $2.9eV$ b) $0.246eV$
10. Total Energy = Energy of positron + Energy of a electron

    Total Energy = $(K + mc^2) + (K + mc^2) = E + E$

    b) E=0.511MeV each, l = $2.43 \times 10^{-12}m$, $f = 1.24 \times 10^{20}\ Hz$
11. Hint $\left[p = \frac{h}{l}\right] P = 1.33 \times 10^{-27} Kg.m/s$

    b) n = 1460 m/s

    c) Energy of electron $E = 6.02 \times 10^{-6}eV$, Energy of the photon $2.48eV$
12. a) n = $4.36 \times 10^6\ m/s$ b) $54.0eV$

UNIT 10

Analog and Digital Signals

KNOW THIS

In today's world, many different types of signals carry information that help us to communicate around us. The two types of signals that are used to transport information are analog and digital signals. Most communication uses both types of signals. Therefore, we need a way to be able to use each type efficiently, to ensure the information reaches its destination. This unit discusses digital and analog signals and their use in modern communication.

Key unit competence

To be able to differentiate analog from digital signals.

Unit description

This unit is more theoretical but engages the learners by using real-life examples in the use of digital and analog signals. This unit explains the block diagram of Information Transmission in a communication system and the Elements of Communication. It also discusses the advantages of digital technology and finally gives the basic knowledge on Logic Gates.

10.0. Introduction
10.1. Information transmission in a communication system
10.2. Communication Terms and Concepts
10.3. Elements of communication
10.4. Types of information and requirements
10.5. Simplex transmission
10.6. Half-duplex communications
10.7. Full-duplex communications
10.8. Bandwidth and signal Frequency
10.9. Analogue signal system
    10.9.1. Example of an analogue electronic system
10.10. Analog signals
10.11. Advantages and disadvantages of analog signals

10.12. Digital signals
10.13. Advantages of digital technology
10.14. Comparing digital and analog signals
10.15. Logic gates

Summary of Knowledge, Skills, Attitudes and Values

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

Knowledge	Skills	Attitudes and value
Explain types of information used in communication.	Explain terms used in communication systems	Appreciate advantages of digital over analog system
Differentiate digital and analogue system of communication	Analyse analogue and digital systems	Enjoy converting natural numbers to digital system
Identify and explain simplex, duplex and multiplex in communication	Evaluate and advantages and disadvantages of digital and analog	
State advantages of digital system over analogue. System	Differentiate simplex from duplex communication systems	
State laws of digital numbers and their representation.	Judge which is the best system to use Solve problems involving digital numbers	

Learning Objectives

By the end of this unit, the learners should be able to;

- explain the transmission of information in a communication system.
- explain with examples the use of digital and analog signals in everyday applications.

SCOPE AND SEQUENCE

This unit will be taught in 15 lessons as distributed below;

Unit 10: Analog and digital signals

Lesson 1	Lesson 2	Lesson 3	Lesson 4
This lesson should cover: Information transmission in a communication system	**This lesson should cover:** Communication Terms and Concepts	**This lesson should cover:** Elements of communication	**This lesson should cover:** Types of information and requirements
Lesson 5	**Lesson 6**	**Lesson 7**	**Lesson 8**
This lesson should cover: Simplex transmission	**This lesson should cover:** Half-duplex communications	**This lesson should cover:** Full-duplex communications	**This lesson should cover:** Bandwidth and signal Frequency
Lesson 9	**Lesson 10**	**Lesson 11**	**Lesson 12**
This lesson should cover: Analog signal system	**This lesson should cover:** Assessment 1	**This lesson should cover:** Example of an analogue electronic system	**This lesson should cover:** Analog signals
Lesson 13	**Lesson 14**	**Lesson 15**	**Lesson 16**
This lesson should cover: Advantages and disadvantages of analog signals	**This lesson should cover:** Digital signals	**This lesson should cover:** Advantages of digital technology	**This lesson should cover:** Comparing digital and analog signals
Lesson 17	**Lesson 18**		
This lesson should cover: Logic gates	**This lesson should cover:** Assessment 2		

LESSON DEVELOPMENT

Lesson 1	**Title: Information Transmission in a Communication System**
Learning Objectives	By the end of this lesson, using real-life examples, the learners will be able to explain the block diagram of information transmission in a communication system clearly.
Key words	Communication system, transmitting end propagation medium, receiving end
Cross-cutting issues to discuss	Gender, Peace and Values Education, Standardization Culture
Competences developed	Critical thinking, Creativity and innovation Communication, Research and problem-solving, Cooperation, interpersonal management and life skills, Lifelong learning, Literacy, ICT, science and technology
Attention to special educational need children	Special attention is given to the learners with intellectual challenges, developmental challenges, hearing difficulties, speech and communication difficulties, and gifted and talented learners
Lesson 2	**Title: Communication Terms and Concepts**
Learning Objectives	By the end of this lesson, using real-life examples, the learners will be able to explain the terms and concepts in a communication system clearly.
Key words	Communicator, Message, Code, Channels, Medium, Noise, Environment, Feedback, Levels
Cross-cutting issues to be discussed	Gender, Peace and Values Education, Standardization Culture

Competences developed	Critical thinking, Creativity and innovation Communication, Research and problem-solving, Cooperation, interpersonal management and life skills, Lifelong learning, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is given to the learners with intellectual challenges, developmental challenges, hearing difficulties, speech and communication difficulties and gifted and talented learners
Lesson 3	**Title: Elements of communication**
Learning Objectives	By the end of this lesson, using real-life examples, the learners will be able to explain the elements of communication.
Key words	Sender, Receiver, Message, Channel, Feedback
Cross-cutting issues to discuss	Gender, Peace and Values Education, Standardization Culture
Competences developed	Critical thinking, Creativity and innovation Communication, Research and problem-solving, Cooperation, interpersonal management and life skills, Lifelong learning, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, hearing difficulties, speech and communication difficulties and gifted and talented learners.

Lesson 4	**Title: Types of information and requirements**
Learning Objectives	By the end of this lesson, using real-life examples the learners will be able to explain the types of information and their requirements clearly.
Key words	creative information, Operational information, Communication information
Cross-cutting issues to discuss	Gender, Peace and Values Education, Standardization Culture
Competences developed	Critical thinking, Creativity and innovation Communication, Research and problem-solving, Cooperation, interpersonal management and life skills, Lifelong learning, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is given to the learners with, intellectual challenges, developmental challenges, hearing difficulties, speech and communication difficulties and gifted and talented learners
Lesson 5	**Title: Simplex transmission**
Learning Objectives	By the end of this lesson, using real-life examples, the learners will be able to explain the simplex mode of information transmission clearly.
Key words	Simplex transmission
Cross-cutting issues to discuss	Gender, Peace and Values Education, Standardization Culture
Competences developed	Critical thinking, Creativity and innovation Communication, Research and problem-solving, Cooperation, interpersonal management and life skills, Lifelong learning, Literacy, ICT, Science and technology

Attention to special educational need children	Special attention is given to learners with, intellectual challenges, developmental challenges, hearing difficulties, speech and communication difficulties and gifted and talented learners
Lesson 6	**Title: Half-duplex communications**
Learning Objectives	By the end of this lesson, using real-life examples, the learners will be able to explain the half-duplex mode of information transmission clearly.
Key words	Half-duplex
Cross-cutting issues to discuss	Gender, Peace and Values Education, Standardization Culture
Competences developed	Critical thinking, Creativity and innovation Communication, Research and problem-solving, Cooperation, interpersonal management and life skills, Lifelong learning, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is given to learners with, intellectual challenges, developmental challenges, hearing difficulties, speech and communication difficulties and gifted and Talented learners
Lesson 7	**Title: Full-duplex communications**
Learning Objectives	By the end of this lesson, using real-life examples the learners will be able to explain the full-duplex mode of information transmission clearly.
Key words	Full-duplex
Cross-cutting issues to discuss	Gender, Peace and Values Education, Standardization Culture

Competences developed	Critical thinking, Creativity and innovation Communication, Research and problem-solving, Cooperation, interpersonal management and life skills, Lifelong learning, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is given to the learners with intellectual challenges, developmental challenges, hearing difficulties, speech and communication difficulties and gifted and talented learners
Lesson 8	**Title:BandwidthandsignalFrequency**
Learning Objectives	By the end of this lesson, using real-life examples, the learners will be able to explain the bandwidth and signal frequency in a communication system clearly.
Key words	Bandwidth and signal Frequency
Cross-cutting issues to discuss	Gender, Peace and Values Education, Standardization Culture
Competences developed	Critical thinking, Creativity and innovation Communication, Research and problem-solving, Cooperation, interpersonal management and life skills, Lifelong learning, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, hearing difficulties, speech and communication difficulties and gifted and talented learners
Lesson 9	**Title: Analog signal system**

Learning Objectives	By the end of this lesson, using real-life examples, the learners will be able to explain the concept of analog signal system clearly.
Key words	Analog signal
Cross-cutting issues to discuss	Gender, Peace and Values Education, Standardization Culture
Competences developed	Critical thinking, Creativity and innovation Communication, Research and problem-solving, Cooperation, interpersonal management and life skills, Lifelong learning, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is given to the learners with, intellectual challenges, developmental challenges, hearing difficulties, speech and communication difficulties and gifted and talented learners
Lesson 10	**Title: Assessment 1**
Learning Objectives	By the end of this assessment, using knowledge and skills gained from lesson 1 to lesson 9, the learners should be able to relate the content with the real-life experiences.
Key words	Communication system, transmitting end propagation medium, receiving end, Communicator, Message, Code, Channels, Medium, Noise, Environment, Feedback, Levels, Sender, Receiver, Message, Channel, Feedback, creative information, Operational information, Communication information, Simplex transmission, Half-duplex, Full-duplex, Bandwidth and signal Frequency, Analog signal

Cross-cutting issues to discuss	Gender, Peace and Values Education, Standardization Culture
Competences developed	Critical thinking and problem solving
Attention to special educational need children	Special attention is given to the learners with visual impairment
Lesson 11	**Title:Exampleofananaloguelectronic system**
Learning Objectives	By the end of this lesson, the learners will be able to explain examples of analog electronic system clearly.
Key words	Public address system
Cross-cutting issues to discuss	Gender, Peace and Values Education, Standardization Culture
Competences developed	Critical thinking, Creativity and innovation Communication, Research and problem-solving, Cooperation, interpersonal management and life skills, Lifelong learning, Literacy, ICT, Science and technology
Attention to special educational need children	Special attention is given to the learners with, intellectual challenges, developmental challenges, hearing difficulties, speech and communication difficulties and gifted and talented learners
Lesson 12	**Title: Analog signals**
Learning Objectives	By the end of this lesson, using real-life examples, the learners will be able to explain the use of analog signals in information transmission system clearly.
Key words	Analog signals
Cross-cutting issues to discuss	Gender, Peace and Values Education, Standardization Culture

Competences developed	Critical thinking, Creativity and innovation Communication, Research and problem-solving, Cooperation, interpersonal management and life skills, Lifelong learning, Literacy, ICT, science and technology
Attention to special educational need children	Special attention is gives to learners with intellectual challenges, developmental challenges, hearing difficulties, speech and communication difficulties and gifted and talented learners
Lesson 13	**Title:Advantages and disadvantages of analog signals**
Learning Objectives	By the end of this lesson, using real-life examples, the learners will be able to explain advantages and disadvantages of analog signals clearly.
Key words	Analog signals
Cross-cutting issues to discuss	Gender, Peace and Values Education, Standardization Culture
Competences developed	Critical thinking, Creativity and innovation Communication, Research and problem-solving, Cooperation, interpersonal management and life skills, Lifelong learning, Literacy, ICT, science and technology
Attention to special educational need children	Special attention is given to the learners with, intellectual challenges, developmental challenges, hearing difficulties, speech and communication difficulties and gifted and talented learners

Lesson 14	**Title: Digital signals**
Learning Objectives	By the end of this lesson, using real-life examples, the learners will be able to explain the use of digital signals in information transmission system clearly.
Key words	Digital signals
Cross-cutting issues to discuss	Gender, Peace and Values Education, Standardization Culture
Competences developed	Critical thinking, Creativity and innovation Communication, Research and problem-solving, Cooperation, interpersonal management and life skills, Lifelong learning, Literacy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with, intellectual challenges, developmental challenges, hearing difficulties, speech and communication difficulties and gifted and talented learners
Lesson 15	**Title:Advantagesofdigitaltechnology**
Learning Objectives	By the end of this lesson, using real-life examples, the learners will be able to explain the advantages of digital technology clearly.
Key words	digital technology
Cross-cutting issues to discuss	Gender, Peace and Values Education, Standardization Culture
Competences developed	Critical thinking, Creativity and innovation Communication, Research and problem-solving, Cooperation, interpersonal management and life skills, Lifelong learning, Literacy, ICT, Science and technology

Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, hearing difficulties, speech and communication difficulties and gifted and talented learners
Lesson 16	**Title: Comparing digital and analog signals**
Learning Objectives	By the end of this lesson, using real-life examples, the learners will be able to give the similarities and differences between digital and analog signals clearly.
Key words	digital and analog signals
Cross-cutting issues to discuss	Gender, Peace and Values Education, Standardization Culture
Competences developed	Critical thinking, Creativity and innovation Communication, Research and problem-solving, Cooperation, interpersonal management and life skills, Lifelong learning, Literacy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, hearing difficulties, speech and communication difficulties and gifted and talented learners
Lesson 17	**Title: Logic gates**
Learning Objectives	By the end of this lesson, learners will be able to compare logic gates and electrical circuits and give their truth tables accurately.
Key words	OR, AND, NOT, EXOR
Cross-cutting issues to discuss	Gender, Peace and Values Education, Standardization Culture

Competences developed	Critical thinking, Creativity and innovation Communication, Research and problem-solving, Cooperation, interpersonal management and life skills, Lifelong learning, Literacy, ICT, science and technology
Attention to special educational need children	Special attention is given to the learners with intellectual challenges, developmental challenges, hearing difficulties, speech and communication difficulties and gifted and talented learners
Lesson 18	**Title: Assessment 2**
Learning Objectives	By the end of this assessment, using knowledge and skills gained from lesson 10 to lesson 17, learners should be able to relate the content with the real-life experiences.
Key words	public address system, Analog signals, Digital signals, digital technology, OR, AND, NOT, EXOR
Cross-cutting issues to discuss	Gender, Peace and Values Education, Standardization Culture
Competences developed	Critical thinking and problem solving
Attention to special educational need children	Special attention is given to learners with visual impairment

This activity aims at capturing students' 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 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. And let them attempt the questions.

- 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 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.

Suggested answers to the introductory Activity.

a)

- Analog
- Digital signals.

b)

- 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

c) At the point of sending the message, the message is in analog form, that is then transmitted as an electromagnetic wave that is in form of digital signals.The signals then becomes analog when it is processed at the receiving point (in a mobile phone or a computer).

d)

- Radio signal
- Internet signals
- Light signals
- Sound signal
- Current and Voltage

MAIN CONTENTS AND CONCEPTS TO EMPHASISE

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
- Code
- Channels
- Medium
- Noise
- Environment
- Feedback
- Levels

Elements of communication

- Sender
- Receiver
- Message
- Channel
- Feedback

Types of information and requirements

- Constructional/creative information
- Operational information
- Communication 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;

$$BW = F_{USB} - f_{LSB}$$

Where F_{USB} and f_{LSB} stand for upper side band and lower side band respectively.

Analogue signal system

Analogue systems operate with values that vary continuously and have no abrupt transitions between levels. In Rwanda recently analogue systems were replaced by digital systems that provide greater capacity of data transfer and increased reliability and security.

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 net work 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.

Activity 10.1

Term description	
Receiver	1. A party to whom the sender transmits the message
Channel	Specific channel/pipeline used to transmit the message
Noise	Any interference to the message
	The process of sharing the messages through continuous flow of symbols
Code	Means a system suitable for creating/carrying message through specific medium

Activity 10.2

Sender: Anna

Receiver: John

Message: John, are you OK?

Feedback: No. I am a bit tired

Channel: free space

Answers to Activity 10.3

1.B

2.D

3.D

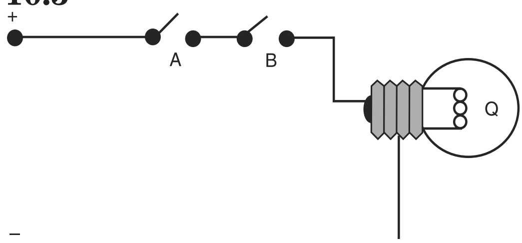
4.A

Answers to Question Exercise 10.4

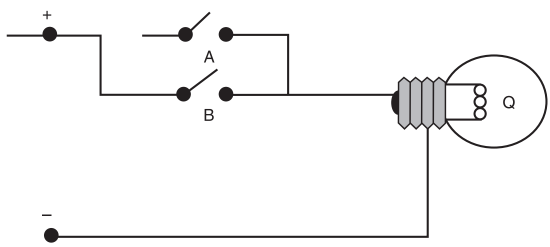
Operation →		OR	AND	EXOR	Decimal
Position →	$1\times2^3=8$	$1\times2^2=4$	$0\times2^1=0$	$1\times2^0=1$	
0	0	0	0	0	=0
0	1	1	0	1	$=8+4+1+0=13$
1	0	1	0	1	=5
1	1	1	1	0	=14

Decimal	MSB	4 binary		LSB
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
10	1	0	1	0
11	1	0	1	1
12	1	1	0	0
13	1	1	0	1
14	1	1	1	0
15	1	1	1	1

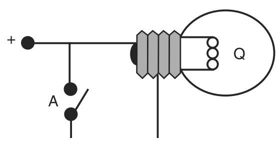
Activity 10.5



Circuit for AND gate



Circuit OR gate



Circuit for NOT gate

SOLUTIONS OF END UNIT ASSESSMENT

Answers for Question 1

1. See the notes about the advantages of transmitting signals in a digital form.

A	B	C	P = A NOR B	Q = B AND C	X = P OR Q
1	1	1	0	1	1
1	1	0	0	0	0
1	0	1	0	0	0
1	0	0	0	0	0
0	1	1	0	1	1
0	1	0	0	0	0
0	0	1	1	0	1
0	0	0	1	0	1

A	B	A OR B	A AND B	A NOR B	(A AND B) OR (A NOR B)
1	1	1	1	0	1
1	0	1	0	0	0
0	1	1	0	0	0
0	0	0	0	1	1

A	B	C	D = A OR B	E = B AND C	F = D OR E	C AND F
1	1	1	1	1	1	1
1	1	0	1	0	1	0
1	0	1	1	0	1	1
1	0	0	1	0	1	0
0	1	1	1	1	1	1
0	1	0	1	0	1	0
0	0	1	0	0	0	0
0	0	0	0	0	0	0

A	B	C	D = A XOR B	E = B AND C	F = D OR E	F XOR C
1	1	1	0	1	1	0
1	1	0	0	0	0	0
1	0	1	1	0	1	1
1	0	0	1	0	1	1
0	1	1	1	1	1	0
0	1	0	1	0	1	1
0	0	1	0	0	0	1
0	0	0	0	0	0	0

UNIT 11

Mobile phone and radio communication

KNOW THIS

Like all other radio communication applications, mobile telephony uses radio waves to carry the information, like voice, text and images, through the air. Radio waves are a kind of electromagnetic fields (EMF) that are also called radio frequency fields or radio frequency energy. Electromagnetic fields are present in our every day life, both naturally and from man-made sources. Radio waves travel with the speed of light. They consist of an electric and a magnetic component, which vary periodically with time.

Key unit competence

By the end of the unit the learner should be able to distinguish mobile phone system from radio system of communication.

Unit description

The purpose of this unit of " Mobile phone and radio communication" is designed to provide students in level 5 the opportunity to explore and to solve problems about the physics of how Mobile phone and radio communication work. This unit is divided into sections which mostly discuss on Concepts of transmission system, Principle of cellular radio, Mobile communication systems and Modulation techniques. It deals with;

11.0 Introduction
11.1 Concepts of transmission system
11.2 Principle of cellular radio
11.3 Structure of cellular network
11.4 Principle of cellular network
11.5 Mobile communication systems
11.6 Modulation techniques
11.7 Post, telegraph and telephone (PTT)

Summary of Knowledge, Skills, Attitudes and Values

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

Knowledge	Skills	Attitudes and value
Recall the concepts of transmission systems	Explain exactly the simple cellular radio principles	Appreciate roles of telephone and radio transmission systems
Differentiate between telephone and radio transmission	Differentiate between the terms AM, FM and PM radio transmission operation	Appreciate types of modulations (AM, FM, and PM) applied in communication systems.
Identify and explain modulations used in communication		

Learning objectives

By the end of this unit, learners should be able to;

- explain the concept and principles of cellular radio network.
- explain the need for cellular system in modern mobile communication.

SCOPE AND SEQUENCE

This unit will be delivered in 15 lessons each of 40 minutes.

Unit 11: Mobile phone and radio communication

Lesson 1	Lesson 2	Lesson 3	Lesson 4
This lesson should cover: Introduction	**This lesson should cover:** Concepts of transmission system	**This lesson should cover:** Limitations of digital communications	**This lesson should cover:** Principle of cellular radio
Lesson 5	**Lesson 6**	**Lesson 7**	**Lesson 8**
This lesson should cover: Structure of cellular network	**This lesson should cover:** Assessment 1	**This lesson should cover:** Principle of cellular network	**This lesson should cover:** Cells and clusters in a network

Lesson 9	Lesson 10	Lesson 11	Lesson 12
This lesson should cover: Cell splitting and frequency reuse	**This lesson should cover:** Handoffs in mobile communication	**This lesson should cover:** Mobile communication systems	**This lesson should cover:** Assessment 2
Lesson 13	**Lesson 14**	**Lesson 15**	**Lesson 16**
This lesson should cover: Need for modulation	**This lesson should cover:** Frequency modulation	**This lesson should cover:** Amplitude modulation	**This lesson should cover:** Phase modulation
Lesson 17	**Lesson 18**		
This lesson should cover: Post, telegraph and telephone (PTT)	**This lesson should cover:** Assessment 3		

LESSON DEVELOPMENT

Lesson 1	Title: Introduction
Learning Objectives	By the end of this lesson, using real-life examples, the learners will be able to explain the need for mobile and radio communication in every day activities clearly.
Key words	Concept of mobile and radio communication
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Creativity and innovation, Communication, Cooperation, interpersonal management and life, Lifelong learning, Literacy, ICT, science and technology

Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties
Lesson 2	**Title:Conceptsoftransmissionsystem**
Learning Objectives	By the end of this lesson, using a block diagram, learners will be able to explain the concept of transmission system clearly.
Key words	Transmitter, Channel, Receiver, Digital communication, Analog communication
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Creativity and innovation, Communication, Cooperation, interpersonal management and life, Lifelong learning, Literacy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties
Lesson 3	**Title: Limitations of digital communications**
Learning Objectives	By the end of this lesson, using real-life examples, the learners will be able to explain the limitations of digital communication clearly.
Key words	Sampling, Quantization, Coding
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Creativity and innovation, Communication, Cooperation, interpersonal management and life, Lifelong learning, Literacy, ICT, science and technology

Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties
Lesson 4	**Title: Principle of cellular radio**
Learning Objectives	By the end of this lesson, using real-life examples, the learners will be able to explain the principle of cellular radio clearly.
Key words	power transmitters, co-channel station
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Creativity and innovation, Communication, Cooperation, interpersonal management and life, Lifelong learning, Literacy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties
Lesson 5	**Title: Structure of cellular network**
Learning Objectives	By the end of this lesson, using real-life examples, the learners will be able to explain the structure of cellular network clearly.
Key words	BTS, MSC, HLR, VLR, PSTN
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Creativity and innovation, Communication, Cooperation, interpersonal management and life, Lifelong learning, Literacy, ICT, science and technology

Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties
Lesson 6	**Title: Assessment 1**
Learning Objectives	By the end of this assessment, using knowledge and skills gained in lessons 1 to 5, learners will be able to relate the content with the real-life experiences.
Key words	Concept of mobile and radio communication, Transmitter, Channel, Receiver, Digital communication, Analog communication, Sampling, Quantization, Coding, power transmitters, co-channel station, BTS, MSC, HLR, VLR, PSTN
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking and problem solving
Attention to special educational need children	Special attention is given to learners with visual impairment
Lesson 7	**Title: Principle of cellular network**
Learning Objectives	By the end of this lesson, using real-life examples, the learners will be able to explain the principle of cellular network clearly.
Key words	principle of cellular network
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Creativity and innovation, Communication, Cooperation, interpersonal management and life, Lifelong learning, Literacy, ICT, science and technology

Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties
Lesson 8	**Title: Cells and clusters in a network**
Learning Objectives	By the end of this lesson, using real-life examples and diagrams, learners will be able to explain the difference in cells and clusters in a network clearly.
Key words	Cells, clusters
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Creativity and innovation, Communication, Cooperation, interpersonal management and life, Lifelong learning, Literacy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties
Lesson 9	**Title: Cell splitting and frequency reuse**
Learning Objectives	By the end of this lesson, using real-life examples and diagrams, learners will be able to explain the need for cell splitting and frequency reuse in a network clearly.
Key words	Cell splitting, frequency reuse
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Creativity and innovation, Communication, Cooperation, interpersonal management and life, Lifelong learning, Literacy, ICT, science and technology

Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties
Lesson 10	**Title: Handoffs in mobile communication**
Learning Objectives	By the end of this lesson, using real-life examples and diagrams, learners will be able to explain the concept of handoffs in a mobile network clearly.
Key words	Handoffs
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Creativity and innovation, Communication, Cooperation, interpersonal management and life, Lifelong learning, Literacy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties
Lesson 11	**Title:Mobilecommunicationsystems**
Learning Objectives	By the end of this lesson, using real-life examples, the learners will be able to explain the concept of mobile communication clearly.
Key words	Mobile communication
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Creativity and innovation, Communication, Cooperation, interpersonal management and life, Lifelong learning, Literacy, ICT, science and technology

Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties
Lesson 12	**Title: Assessment 2**
Learning Objectives	By the end of this assessment, using knowledge and skills gained in lessons 6 to 11, learners will be able to relate the content with the real-life experiences.
Key words	principle of cellular network, Cells, clusters Cell splitting, frequency reuse, Handoffs, Mobile communication
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking and problem solving
Attention to special educational need children	Special attention is given to learners with visual impairment
Lesson 13	**Title: Need for modulation**
Learning Objectives	By the end of this lesson, using examples learners will be able to explain the need for modulation in mobile communication clearly.
Key words	Modulation
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Creativity and innovation, Communication, Cooperation, interpersonal management and life, Lifelong learning, Literacy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties
Lesson 14	**Title: Frequency modulation**

Learning Objectives	By the end of this lesson, using examples, learners will be able to explain the need for frequency modulation in mobile communication clearly.
Key words	Frequency modulation
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Creativity and innovation, Communication, Cooperation, interpersonal management and life, Lifelong learning, Literacy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties
Lesson 15	**Title: Amplitude modulation**
Learning Objectives	By the end of this lesson, using examples, learners will be able to explain the need for amplitude modulation in mobile communication clearly.
Key words	Amplitude modulation
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Creativity and innovation, Communication, Cooperation, interpersonal management and life, Lifelong learning, Literacy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties
Lesson 16	**Title: Phase modulation**

Learning Objectives	By the end of this lesson using examples learners will be able to explain the need for phase modulation in mobile communication clearly.
Key words	Phase modulation
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Creativity and innovation, Communication, Cooperation, interpersonal management and life, Lifelong learning, Literacy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties
Lesson 17	**Title: Post, telegraph and telephone (PTT)**
Learning Objectives	By the end of this lesson, using examples, learners will be able to explain the need for posts, telegraphs and telephone in everyday life clearly.
Key words	Post, telegraph and telephone
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Creativity and innovation, Communication, Cooperation, interpersonal management and life, Lifelong learning, Literacy, ICT, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, developmental challenges, speech and communication difficulties
Lesson 18	**Title: Assessment 3**

Learning Objectives	By the end of this assessment, using knowledge and skills gained in lessons 12 to 17, learners will be able to relate the content with the real-life experiences
Key words	Modulation, Frequency modulation, Amplitude modulation, Phase modulation, Post, telegraph and telephone
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking and problem solving
Attention to special educational need children	Special attention is given to learners with visual impairment

Guidance to the introductory activity and its solutions.

Guidance to learning activity

The introductory activity has a purpose of capturing students' attention and develops critical thinking and problem solving competences in them. The Students 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 students 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. Let students write summary in their notebooks. Remember to put emphasize on cross cutting issues addressed in this lesson.

Possible Answers for Learning Activity

1. There are 3 small cells and one macro cell in the picture.
2. In this figure, there are one big master (antenna Tower or principal Base Station) and three small masters (auxiliary Base Stations).
3. In different cells there are masts which have a role of amplify signals from the major mast.

4. 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.
5. 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.

MAIN CONTENTS AND CONCEPTS TO EMPHASISE

Concepts of transmission system

In telecommunication, a communications system is a collection of individual communications 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 and neighbouring 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 offered 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 centre (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).

SOLUTION TO ACTIVITIES

Expected answers for Activity 11.1

Any sensible story that involves at least 4 equipment given under this activity.

The story may base on

- How they are used
- How they transfer information
- Advantages of using one over another.
- How the equipment have transformed our society
- Etc.

ANSWERS TO THE END OF UNIT QUESTIONS

1. Amplitude modulation, the information signal is used to vary the amplitude of the carrier so that it follows the wave shape of information signal.
2. Modulation is the process of varying one or more properties of a periodic waveform, called the carrier signal
3. Amplitude modulation (AM) (here the amplitude of the carrier signal is varied in accordance with the instantaneous amplitude of the modulating signal) Double-sideband modulation (DSB) ...

   Angle modulation, which is approximately constant envelope.
4. Modulation is extremely necessary in communication system due to thef ollowing reasons :

   (i) Practical antenna length. Theory shows that in order to transmit a wave effectively, thelength of the transmitting antenna should be approximately equal to the wavelength of the wave.

   (ii) Operating range. The energy of a wave depends upon its frequency. The greater the frequencyof the wave, the greater the energy possessed by it. As the audio signal frequencies are small, therefore, these cannot be transmitted over large distances if radiated directly into space. The onlypractical solution is to modulate a high frequency carrier wave with audio signal and permit the transmission to occur at this high frequency (i.e. carrier frequency).

(iii) Wireless communication. One desirable feature of radio transmission is that it should be carried without wires i.e. radiated into space. At audio frequencies, radiation is not practicable because the efficiency of radiation is poor. However, efficient radiation of electrical energy is

possible at high frequencies (> 20 kHz). For this reason, modulation is always done in communication systems.

5. Length of antenna is shortened, signal loss is reduced, ease of radiation, adjustment of bandwidth, shifting signal frequency of the assigned

value. (as discussed in answers above)

6. Frequency modulation is when the frequency of carrier wave is changed in accordance with the intensity of the signal

Guidance to application activity

The Students are encouraged to work together to answer the questions in this activity. The application activity aims at capturing students' attention and develops critical thinking and collaboration in Students. Referring to his/her Lesson plan, the Tutor will decide on the methodology to use while students are attempting this activity.

- Give them clear guidelines on how to attempt these questions. Ensure that all Students are fully involved: slow students and students with special needs.
- Facilitate your students 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 Students appreciate cross cutting issues addressed in this lesson.

Possible Answers for Learning activities

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 microphone of the receiver.

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.

UNIT

12

Relativity concepts and postulates of special relativity

KNOW THIS

When the wavelike nature of light (and other electromagnetic radiation) was discovered at the 18th century, scientists assumed that there must be some kind of substance in which the waves move. They believed that space was filled with such a substance, and called it ether.

In 1887 Albert Michelson and Edward Morley carried out an experiment in which they tried to show the motion of Earth relative to the ether by measuring changes in light speed in different directions. To their astonishment they found no change in the light speed regardless of the relative motion between Earth and the source of light or the ether.

As a result of this experiment known as the Michelson-Morley experiment, the theory of ether, was abandoned by most physicists. In the absence of ether, there was also no absolute reference to determine what is at rest and what is moving in space.

This was where Einstein started his work on relativity. Along with quantum mechanics, relativity is central to modern physics. In particular, relativity provides the basis for understanding cosmic processes and the geometry of the universe itself.

Key unit competence

By the end of this unit the learner should be able to analyse relativity Concepts and postulates of special relativity.

Unit description

The purpose of this unit is to introduce the theory of special relativity in an easily understandable way. It reviews the basic issues in special relativity in a somewhat informal way, without the use of higher mathematics, so that anyone with a basic knowledge of physics can easily understand it. This unit deals with;

12.0 Introduction

12.1 Definition and concept of relativity
12.2 Postulates of special theory of relativity
12.3 Concept of space, time and mass
12.4 Concept of Frame of reference
12.5 Galilean equation of transformation
12.6 Concept of simultaneity

Summary of Knowledge, Skills, Attitudes and Values

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

Knowledge	**Skills**	**Attitudes and value**
Explain space, time, mass and frame of reference	Related space, time and mass	Appreciate the significance of frame of reference.
Explain the two postulates of special theory of relativity State two postulates of the special theory of relativity	Analyse Galilean equation of transformation	Acquire scientific technique and reasoning to analyzing theories and equations.
	Interpret postulates of special theory of relativity	Acquire scientific reasoning and attitudes for interpreting simultaneity
	Describe the concept of simultaneity	Problems on relative velocity and Galilean Equations of transformation
	Create simulations to demonstrate postulates of special relativity	

Learning Objectives

By the end of this unit, learners should be able to;

- explain the concept of general and special relativity.

- explain the concept of the frames of reference and apply it in other theories.

SCOPE AND SEQUENCE

This unit will be delivered in 15 lessons each of 40 minutes.

Unit 12: Relativity concepts and postulates of special relativity

Lesson 1	**Lesson 2**	**Lesson 3**	**Lesson 4**
This lesson should cover: Meaning of relativity	**This lesson should cover:** The concept of relativity	**This lesson should cover:** First postulate of special theory of relativity	**This lesson should cover:** Second postulate of special theory of relativity
Lesson 5	**Lesson 6**	**Lesson 7**	**Lesson 8**
This lesson should cover: Concept of Time dilation	**This lesson should cover:** Time dilation equation	**This lesson should cover:** Assessment 1	**This lesson should cover:** Length contraction
Lesson 9	**Lesson 10**	**Lesson 11**	**Lesson 12**
This lesson should cover: Mass and Momentum	**This lesson should cover:** Mass and energy	**This lesson should cover:** Concept of Frame of reference	**This lesson should cover:** Types of frames of reference
Lesson 13	**Lesson 14**	**Lesson 15**	**Lesson 16**
This lesson should cover: Assessment 2	**This lesson should cover:** Concept of Galilean transformation	**This lesson should cover:** Galilean equation of transformation	**This lesson should cover:** Concept of simultaneity
Lesson 17			
This lesson should cover: Assessment 3			

LESSON DEVELOPMENT

Lesson 1	**Title: Meaning of relativity**
Learning Objectives	By the end of this lesson, learners will be able to define relativity clearly.
Key words	relativity
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, ICT, Literacy, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 2	**Title: The concept of relativity**
Learning Objectives	By the end of this lesson, learners will be able to explain the concept of relativity.
Key words	concept of relativity
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, ICT, Literacy, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties and gifted and talented learners

Lesson 3	**Title: First postulate of special theory of relativity**
Learning Objectives	By the end of this lesson, with examples, learners will be able to state the principle of relativity clearly.
Key words	inertial frames of reference
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, ICT, Literacy, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 4	**Title: Second postulate of special theory of relativity**
Learning Objectives	By the end of this lesson, with examples, learners will be able to explain the Principle of Invariant Light Speed clearly.
Key words	Speed of light
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, ICT, Literacy, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties and gifted and talented learners

Lesson 5	**Title: Concept of Time dilation**
Learning Objectives	By the end of this lesson, with examples, learners will be able to explain the concept of time of dilation clearly.
Key words	Time dilation
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, ICT, Literacy, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 6	**Title: Time dilation equation**
Learning Objectives	By the end of this lesson, mathematically learners will be able to derive and use the equation of time of dilation clearly.
Key words	Time
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, ICT, Literacy, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 7	**Title: Assessment 1**

Learning Objectives	By the end of this assessment using knowledge and skills gained in lessons 1 to 6, learners will be able to relate the content with the real-life experiences.
Key words	Relativity, concept of relativity, inertial frames of reference, Speed of light, Time dilation, Time
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking and problem solving
Attention to special educational need children	Special attention is given to learners with visual impairment
Lesson 8	**Title: Length contraction**
Learning Objectives	By the end of this lesson, mathematically learners will be able to explain length contraction clearly.
Key words	length contraction
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, ICT, Literacy, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 9	**Title: Mass and Momentum**
Learning Objectives	By the end of this lesson, mathematically learners will be able to relate mass and momentum of a particle clearly.
Key words	Mass and Momentum
Cross-cutting issues to discuss	Gender, Peace and Values Education

Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, ICT, Literacy, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties and Gifted and Talented learners
Lesson 10	**Title: Mass and energy**
Learning Objectives	By the end of this lesson, mathematically, learners will be able to derive and use the equation of time of dilation clearly.
Key words	Mass and energy
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, ICT, Literacy, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 11	**Title: Concept of Frame of reference**
Learning Objectives	By the end of this lesson, with examples learners will be able to explain the concept of frames of reference clearly.
Key words	Frame of reference
Cross-cutting issues to discuss	Gender, Peace and Values Education

Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, ICT, Literacy, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 12	**Title: Types of frames of reference**
Learning Objectives	By the end of this lesson, with examples, learners will be able to explain the types of frames of reference clearly.
Key words	Non-inertial, Inertial Frame of Reference
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, ICT, Literacy, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 13	**Title: Assessment 2**
Learning Objectives	By the end of this assessment, using knowledge and skills gained in lessons 7 to 12, learners will be able to relate the content with the real-life experiences.
Key words	length contraction, Mass, Momentum, energy, Non-inertial, Inertial Frame of Reference
Cross-cutting issues to discuss	Gender, Peace and Values Education

Competences developed	Critical thinking and problem solving
Attention to special educational need children	Special attention is given to learners with visual impairment
Lesson 14	**Title:ConceptofGalileantransformation**
Learning Objectives	By the end of this lesson, learners will be able to explain the concept of Galilean transformation clearly.
Key words	inertial frames of references
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, ICT, Literacy, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 15	**Title: Galilean equation of transformation**
Learning Objectives	By the end of this lesson, learners will be able to derive the equation of Galilean transformation clearly.
Key words	space and time coordinates systems
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, ICT, Literacy, science and technology

Attention to special educational need children	Special attention is given to learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 16	**Title: Concept of simultaneity**
Learning Objectives	By the end of this lesson, with examples learners will be able to explain the concept of simultaneity clearly.
Key words	frame of reference
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking, Research and problem-solving, Communication, Cooperation, interpersonal management and life skills, Lifelong learning, ICT, Literacy, science and technology
Attention to special educational need children	Special attention is given to learners with intellectual challenges, hearing difficulties, developmental challenges, speech and communication difficulties and gifted and talented learners
Lesson 17	**Title: Assessment 3**
Learning Objectives	By the end of this assessment, using knowledge and skills gained in lessons 14 to 16, learners will be able to relate the content with the real-life experiences.
Key words	inertial frames of references, Galilean equation of transformation
Cross-cutting issues to discuss	Gender, Peace and Values Education
Competences developed	Critical thinking and problem solving
Attention to special educational need children	Special attention is given to learners with visual impairment

Guidance to the introductory Activity

This lesson emphasizes on the concepts of relativity and postulates of special relativity.

- Tell learners to open their books (Learners book) to the introductory activity
- Decide on the methodology to use in this lesson. You can group your learners, they can do it as a class or individual.
- Instruct them to read the activity first and then re-write the questions to their notebooks.
- Allow them to attempt the questions.
- Move around and mark their work.
- Select some students to share their answers to the whole class and allow questions from students if any. Create a favorable environment for learners to discuss.
- Together with student's ideas, link their answers to Relativity concepts and postulates of special relativity.
- Make a summary (using student's findings) and tell learners to write down important ideas in their books.

Expected answers for this activity.

a) In opposite direction of motion of the car.

b) It is because in accordance to relativity, Shakya 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.

<u>MAIN CONTENTS AND CONCEPTS TO EMPHASISE</u>

Definition and concept of relativity

This is a theory developed by Albert Einstein which says that the way that anything except light moves through time and space depends on the position and movement of someone who is watching. Einstein's special theory of relativity (special relativity) is all about what's relative and what's absolute about time, space, and motion.

Postulates of special theory of relativity

- **First postulate: the Principle of Relativity**

This states that the laws of physics are the same in all inertial frames of reference.

This postulate relates to reference frames. It says that there is no preferred frame and, therefore, no absolute motion.

- **Second postulate: the Principle of Invariant Light Speed**

  This states that speed of light c is a constant, independent of the relative motion of the source and observer.

Concept of space, time and mass

- **Time Dilation**

  Time dilation is the phenomenon where two objects moving relative to each other (or even just a different intensity of gravitational field from each other) experience different rates of time flow. The total time is given by

  $t = \mathrm{g}t_0$

  Where

- **Length Contraction**

  If we turn our light beam clock to face in the direction of motion, time dilation implies length contraction.

Activity

To explain the concept of space, time and mass, gather students in groups of 3 to 5 members and carryout activities found on; *http://aether.lbl.gov/www/classes/p139/exp/gedanken.html*

Concept of Frame of reference

A frame of reference is a set of coordinates that can be used to determine positions and velocities of objects in that frame; different frames of reference move relative to one another.

Types of Frame of Reference

There are two types of frames of reference

- Inertial Frame of Reference
- Non-inertial Frame of Reference

Galilean equation of transformation

The set of equations shown below is known as the Galilean Transformation and enables us to relate a measurement in one inertial reference frame with another.

$x = x' + vt$

$y = y'$

$z = z'$

Concept of simultaneity

The concept of simultaneity says that two events that are simultaneous to one observer are not necessarily simultaneous to a second observer. Both observers are correct in their observations -- there is no best or preferred frame of reference.

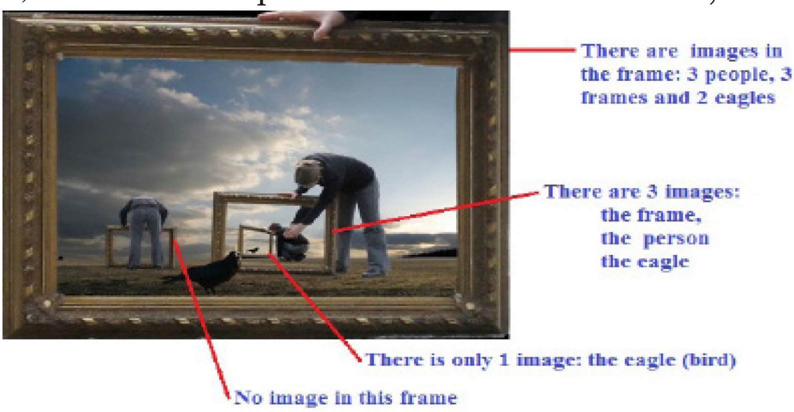
SOLUTIONS TO ACTIVITIES

Activity 12-1

Answer:

a) There are two answers to this question depending on the frame of reference considered. If we narrow the frame to be the seat or position of the passenger, all of them are not moving but if we consider the whole plane, all passengers are moving at the speed of the plane.

b) The answer depends on the frame considered;



Solutions to exercise 12-1

1. $$KE_{rel} = \frac{9.11\times 10^{-31}kg)(3\times 10^{8}m/s)^{2}}{\sqrt{1-(0.1)^{2}}} - (9.11\times 10^{11} - 31kg)(3\times 10^{8}m/s)^{2} = 4.13\times 10^{-16}J$$

$$KE_{cl} = \frac{1}{2}(9.11\times 10^{-31}kg)(0.1\times 10^{8}m/s)^{2} = 4.10\times 10^{-16}J$$

In this case the classical result and the relativistic results are nearly the same.

2. An electron volt is the kinetic energy that an electron would acquire if accelerated through a potential difference of 1 volt. This energy is eV, where $e = 1.6 \times 10^{-19}$ C and V = 1 volt. That is,
   1 eV = (1.6 × 10^{-19} C)(1V) = 1.6 × 10^{-19} J

Then,

$$E_0 = (9.11 \times 10^{-31} kg)(3 \times 10^{8} m/s)^2 = 8.20 \times 10^{-14} J$$

$$= (8.20 \times 10^{-14} J)(1eV / 1.6 \times 10^{-19} J) = 5.11 \times 10^{5} eV = 511keV$$

3. DE = $m_{He3}C^2 + m_D C^2 - m_{He4}C^2 - m_H C^2$

   = 2809.4 + 1876.1 – 3728.4 – 938.8 = 18.3 MeV