Physics

Senior High

Grade 12

Teacher Guide

Standards-Based

Papua New Guinea
Department of Education

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Contents

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Acronyms

AAL	Assessment As Learning
AFL	Assessment For Learning
AOL	Assessment Of Learning
BoS	Board of Studies
CDD	Curriculum Development Division
CP	Curriculum Panel
CRS	Classroom Response System
DA	Diagnostic Assessment
HOD	Head of Department
IHD	Integral Human Development
MTDG	Medium Term Development Goals
NGO	Non-Government Organisation
PBA	Performance Based Assessment
PNG	Papua New Guinea
SAC	Subject Advisory Committee
SBC	Standards-Based Curriculum
SBE	Standards-Based Education
SCG	Subject Curriculum Group
SRS	Student Response System
STEAM	Science, Technology, Engineering, Arts and Mathematics
STEM	Science, Technology, Engineering and Mathematics

Secretary's Message

The aims and goals of the SBC identify the important knowledge, skills, values, and attitudes that all students are expected to acquire and master in order to effectively function in society and actively contribute to its development, students' welfare and enable them to acquire and apply 21st century knowledge, skills, values, and attitudes in their life after Grade 12.

Physics is a significant curriculum framework for teaching children and enabling them to progressively develop proficiency on fundamental ideas of, Science as Inquiry, Fluid Mechanics, Thermal Physics, Waves, Electromagnetism and Atomic and Nuclear Physics. This curriculum addresses Physics skills and processes of sensitive, moral, ethical and environmental issues in the physical world and global awareness.

Thus, students will be able to make informed decisions, problem – solving and management knowledge, skills, values and attitudes in Physics. This will enable them to function effectively in the work and higher education environments as productive and useful citizens of a culturally diverse and democratic society in an interdependent world.

Physics teachers are expected to effectively plan, teach, and assess these knowledge, skills, values, and attitudes. The teacher guide describes what teachers are expected to know and do to enable all their students to effectively learn and demonstrate the expected levels of proficiency in all the grade level Physics knowledge, skills, values and attitudes, and attain the national content standards.

I approve and commend this Grade 12 Physics Teacher Guide to be used by teachers in all Senior High Schools throughout Papua New Guinea.

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UKE. W KOMBRA, PhD
Secretary for Education

Introduction

Physics aims to develop and instill in students the ability in questioning, researching and critical scientific thinking. It does this by giving students particular ways of looking at the world and by emphasising the importance of evidence in forming conclusions. Physics education develops students' confidence to initiate and manage change to meet personal, vocational and societal needs. Physics education assists students to be active citizens by providing the understandings they need to be informed contributors to debates about sensitive, moral, ethical and environmental issues.

The study of Physics enhances scientific knowledge, processes and values have the potential to help students build a more productive and ecologically-sustainable environment and responsible decision making in their local, national and global communities.

Physics aims to provide a meaningful pedagogical framework for teaching and learning essential and in demand knowledge, skills, values, and attitudes that are required for the preparation of students for careers, higher education and citizenship in the 21^{st} Century.

Students should be prepared to gather and understand information, analyze issues critically, learn independently or collaboratively, organize and communicate information, draw and justify conclusions, create new knowledge, and act ethically.

Students' employability will be enhanced through the study and application of STEAM principles. STEAM is an integral component of the core curriculum. All students are expected to study STEAM and use STEAM related skills to solve problems relating to both the natural and the physical environments. The aim of STEAM education is to create a STEAM literate society. It is envisioned that the study of STEAM will motivate students to pursue and take up academic programs and careers in STEAM related fields. STEAM has been embedded in the Physics curriculum. Equal opportunities should be provided for all students to learn, apply and master STEAM principles and skills.

Time allocation for Physics is **240** minutes per week. Teachers are urged to fully utilise the allocated time.

Structure of the Teacher Guide

There are four main components to this teacher guide. They provide essential information on what all teachers should know and do to effectively implement the Chemistry curriculum.

Part 1 provides generic information to help the teachers to effectively use the teacher guide and the syllabus to plan, teach and assess students' performance and proficiency on the national content standards and grade-level benchmarks. The purpose of the teacher guide, syllabus and teacher guide alignment, and the four pillars of PNG SBC, which are morals and values education, cognitive and high level thinking, and 21st Century thinking skills, STEAM, and core curriculum. These are explained to inform as well as guide the teachers so that they align SBE/SBC aims and goals, overarching and SBC principles, content standards, grade-level benchmarks, learning objectives and best practice when planning lessons, teaching, and assessing students.

Part 2 provides information on the strands, units, topics and learning objectives. How topics and learning objectives are derived is explained to the teachers to guide them to use the learning objectives provided for planning, instruction and assessment. Teachers are encouraged to develop additional topics and learning objectives to meet the learning needs of their students and communities where necessary.

Part 3 provides information on SBC planning to help guide the teachers when planning SBC lessons. Elements and standards of SBC lesson plans are described as well as how to plan for underachievers, use evidence to plan lessons, and use differentiated instruction, amongst other teaching and learning strategies.

Part 4 provides information on standards-based assessment, inclusive of performance assessment and standards, standards-based evaluation, standards-based reporting, and standards-based monitoring. This information should help the teachers to effectively assess, evaluate, report and monitor demonstration of significant aspects of a benchmark.

The above components are linked and closely aligned. They should be connected to ensure that the intended learning outcomes and the expected quality of education standards are achieved. The close alignment of planning, instruction and assessment is critical to the attainment of learning standards.

Purpose of the Teacher Guide

This teacher guide describes what all teachers should know and do to effectively plan, teach, and assess Grade 12 Physics content to enable all students to attain the required learning and proficiency standards. The overarching purpose of this teacher guide is to help teachers to effectively plan, teach, assess, evaluate, report and monitor students' learning and mastery of national and grade-level expectations. That is, the essential knowledge, skills, values and attitudes (KSVAs) described in the content standards and grade-level benchmarks, and their achievement of the national and grade-level proficiency standards.

Ample information with thorough guidelines is provided for the teacher to use to achieve the essential KSVAs embedded in the set national content standards and grade level benchmarks.

Thus, the teacher is expected to;

- understand the significance of aligning all the elements of Standards-Based Curriculum (SBC) as the basis for achieving the expected level of education quality,
- effectively align all the components of SBC when planning, teaching, and assessing students' learning and levels of proficiency,
- effectively translate and align the Physics syllabi and teacher guide to plan, teach and assess different Physics units and topics, and the KSVAs described in the grade-level benchmarks,
- understand the Physics national content standards, grade-level benchmarks, and evidence outcomes,
- effectively make sense of the content (KSVAs) described in the Physics national content standards and the essential components of the content described in the grade-level benchmarks,
- effectively guide students to progressively learn and demonstrate proficiency on a range of Physics skills, processes, concepts, ideas, principles, practices, values and attitudes,
- confidently interpret, translate and use Physics content standards and benchmarks to determine the learning objectives and performance standards, and plan appropriately to enable all students to achieve these standards,
- embed the core curriculum in their Chemistry lesson planning, instruction, and assessment to permit all students to learn and master the core KSVAs required of all students,

- provide opportunities for all students to understand how STEAM has and continues to shape the social, political, economic, cultural, and environment contexts and the consequences, and use STEAM principles, skills and process,

- integrate cognitive skills (critical, creative, reasoning, decision-making, and problem-solving skills), high level thinking skills (analysis, synthesis and evaluation skills), values (personal, social, work, health, peace, relationship, sustaining values), and attitudes in lesson planning, instruction and assessment,

- meaningfully connect what students learn in Chemistry with what is learnt in other subjects to add value and enhance students' learning so that they can integrate what they learn and develop in-depth vertical and horizontal understanding of subject content,

- formulate effective SBC lesson plans using learning objectives identified for each of the topics,

- employ SBC assessment approaches to develop performance assessments to assess students' proficiency on a content standard or a component of the content standard described in the grade-level benchmark and

- effectively score and evaluate students' performance in relation to a core set of learning standards or criteria, and make sense of the data to ascertain students' status of progress towards meeting grade-level and nationally expected proficiency standards, and use evidence from the assessment of students' performance to develop effective evidence-based intervention strategies to help students' making inadequate or slow progress towards meeting the grade-level and national expectations to improve their learning and performance.

How to use the Teacher Guide

The Teacher Guide provides essential information about what the teacher needs to know and do to effectively plan, teach and assess students learning and proficiency on learning and performance standards. The different components of the teacher guide are closely aligned with SBC principles and practice, and all the other components of PNG SBC. It should be read in conjunction with the syllabus in order to understand what is expected of teachers and students to achieve the envisaged quality of education outcomes.

The first thing teachers should do is to read and understand each of the sections of the teacher guide to help them understand the key SBC concepts and ideas, alignment of PNG SBC components, alignment of the syllabus and teacher guide, setting of content standards and grade-level benchmarks, core curriculum, STEAM, curriculum integration, essential knowledge, skills, values and attitudes, strands, units and topics, learning objectives, SBC lesson planning, and SBC assessment. A thorough understanding of these components will help teachers meet the teacher expectations for implementing the SBC curriculum, and therefore the effective implementation of Grades 11 and 12 Physics Curriculum. Based on this understanding, teachers should be able to effectively use the teacher guide to do the following:

Determine Lesson Objectives and Lesson Titles

Units, topics and learning objectives have been identified and described in the Teacher Guide and Syllabus. Learning objectives are derived from topics that are extracted from the grade-level benchmarks. Lesson titles are deduced from the learning objectives. Teachers should familiarise themselves with this process as it is essential for lesson planning, instruction and assessment. However, depending on the context and students' learning abilities, teachers would be required to determine additional lesson objectives and lesson titles. Teachers should use the examples provided in this teacher guide to formulate additional lesson objectives and lesson titles to meet the educational or learning needs of their students. What is provided here is not exhaustive.

Benchmark → **Unit** → **Topic** → **Learning Objectives** → **Lesson Titles** → **Lesson Objectives**

Identify and Teach Grade Appropriate Content

Grade appropriate content has been identified and scoped and sequenced using appropriate content organisation principles. The content is sequenced using the spiraling sequence principles. This sequencing of content will enable students to progressively learn the essential knowledge, skills, values and attitudes as they progress further into their schooling. What students learn in previous grades is reinforced and deepens in scope with an increase in the level of complexity and difficulty in the content and learning activities.

It is important to understand how the content is organised so that grade appropriate content and learning activities can be selected, if not already embedded in the benchmarks and learning objectives, to not only help students learn and master the content, but ensure that what is taught is rigorous, challenging, and comparable.

Integrate the Core Curriculum in Lesson Planning, Instruction and Assessment

Teachers should use this teacher guide to help them integrate the core curriculum – values, cognitive and high level skills, 21st Century skills, STEAM principles and skills, and reading, writing, and communication skills in their lesson planning, instruction and assessment. All students in all subjects are required to learn and master these skills progressively through the education system.

Integrate Cognitive, High Level, and 21st Century Skills in Lesson Planning, Instruction and Assessment

Teachers should integrate the cognitive, high level and 21st Century skills in their annual teaching programs, and give prominence to these skills in their lesson preparation, teaching and learning activities, performance assessment, and performance standards for measuring students' proficiency on these skills. Science addresses the skills and processes of sensitive, moral, ethical and environmental issues in the physical world and global industries. Thus, students will be able to make informed decisions, problem – solving and management knowledge, skills, values and attitudes in Science. This enables them to function effectively in the work and higher education environments as productive and useful citizens of a culturally diverse and democratic society in an interdependent world.

In addition, it envisaged all students attaining expected proficiency levels in these skills and will be ready to pursue careers and higher education academic programs that demand these skills, and use them in their everyday life after they leave school at the end of Grade 12. Teachers should use the teacher guide to help them to effectively embed these skills, particularly in their lesson planning and in the teaching and learning activities as well as in the assessment of students' application of the skills.

Integrate Science Values and Attitudes in Lesson Planning, Instruction and Assessment

In sciecne, students are expected to learn, promote and use work, relationship, peace, health, social, personal, family, community, national and global values in the work and study environments as well as in their conduct as community, national and global citizens. Teachers should draw from the information and suggestions provided in the syllabus and teacher guide to integrate values and attitudes in their lesson planning, instruction, and assessment. They should report on students' progression towards internalizing different values and attitudes and provide additional support to students who are yet to reach the internalization stage to make positive progress towards this level.

Integrate Science, Technology, Engineering, Arts and Mathematics (STEAM) Principles and Skills in Lesson Planning, Instruction and Assessment

Teachers should draw from both the syllabus and teacher guide in order to help them integrate STEAM principles and skills, and methodologies in their lesson planning, instruction and assessment. STEAM teaching and learning happens both inside and outside of the classroom. Effective STEAM teaching and learning requires both the teacher and the student to participate as core investigators and learners, and to work in partnership and collaboration with relevant stakeholders to achieve maximum results. Teachers should use the syllabus, teacher guides and other resources to guide them to plan and implement this and other innovative and creative approaches to STEAM teaching and learning to make STEAM principles and skills learning fun and enjoyable and, at the same time, attain the intended quality of learning outcomes.

Identify and Use Grade and Context Appropriate, Innovative, Differentiated and Creative Teaching and Learning Methodologies

SBC is an eclectic curriculum model. It is an amalgam of strengths of different curriculum types, including behavioural objectives, outcomes, and competency. Its emphasis is on students attaining clearly defined, measurable, observable and attainable learning standards, i.e., the expected level of education quality. Proficiency (competency) standards are expressed as performance standards/ criteria and evidence outcomes, that is, what all students are expected to know (content) and do (application of content in real life or related situations) to indicate that they are meeting, have met or exceeded the learning standards. The selection of grade and contextually appropriate teaching and learning methodologies is critical to enabling all students to achieve the expected standard or quality of education. Teaching and learning methodologies must be aligned to the content, learning objective, and performance standard in order for the teacher to effectively teach and guide students towards meeting the performance standard for the lesson. They should be equitable and socially inclusive, differentiate, student-centred, and lifelong. They should enable STEAM principles and skills to be effectively taught and learned by students. Teachers should use the teacher guide to help them make informed decisions when selecting the types of teaching and learning methodologies to use in their teaching of the subject content, including STEAM principles and skills.

Plan Standards-Based Lessons

SBC lesson planning is quite difficult to do. However, this will be easier with more practice and experience over time. Effective SBC lesson plans must meet the required standards or criteria so that the learning objectives and performance standards are closely aligned to attain the expected learning outcomes. Teachers should use the guidelines and standards for SBC lesson planning and examples of SBC lesson plans provided in the teacher guide to plan their lessons. When planning lessons, it is important for teachers to ensure that all SBC lesson planning standards or criteria are met. If standards are not met, instruction will not lead to the attainment of intended performance and proficiency standards. Therefore, students will not attain the national content standards and grade-level benchmarks.

Use Standards-Based Assessment

Standards-Based Assessment has a number of components. These components are intertwined and serve to measure evaluate, report, and monitor students' achievement of the national and grade-level expectations, i.e., the essential knowledge, skills, values and attitudes they are expected to master and demonstrate proficiency on. Teachers should use the information and examples on standards-based assessment to plan, assess, record, evaluate, report and monitor students' performance in relation to the learning standards.

Make informed Judgments About Students' Learning and Progress Towards Meeting Learning Standards

Teachers should use the teacher guide to effectively evaluate students' performance and use the evidence to help students to continuously improve their learning as well as their classroom practice.

It is important that teachers evaluate the performance of students in relation to the performance standards and progressively the grade-level benchmarks and content standards to make informed judgments and decisions about the quality of their work and their progress towards meeting the content standards or components of the standards. Evaluation should not focus on only one aspect of students' performance. It should aim to provide a complete picture of each student's performance. The context, inputs, processes, including teaching and learning processes, and the outcomes should be evaluated to make an informed judgment about each student's performance, Teachers should identify the causal factors for poor performance, gaps in students learning, gaps in teaching, teaching and learning resource constraints, and general attitude towards learning. Evidence-based decisions can then be made regarding the interventions for closing the gaps to allow students to make the required progress towards meeting grade-level and national expectations.

Prepare Students' Performance Reports

Reporting of students' performance and progress towards the attainment of learning standards is an essential part of SBC assessment. Results of students' performance should be communicated to particularly the students and their parents to keep them informed of students' academic achievements and learning challenges as well as what needs to be done to enable the students' make positive progress towards meeting the proficiency standards and achieve the desired level of education quality. Teachers should use the information on the reporting of students' assessment results and the templates provided to report the results of students' learning.

Monitor Students' Progress Towards Meeting the National Content Standards and Grade-Level Benchmarks

Monitoring of student's progress towards the attainment of learning standards is an essential component of standards-based assessment. It is an evidence-based process that involves the use of data from students' performance assessments to make informed judgements about students' learning and proficiency on the learning standards or their components, identify gaps in students' learning and the causal factors, set clear learning improvement targets, and develop effective evidence-based strategies (including preplanning and re-teaching of topics), set clear timeframes, and identify measures for measuring students' progress towards achieving the learning targets.

Teachers should use the teacher guide to help them use data from students' performance assessments to identify individual students' learning weaknesses and develop interventions, in collaboration with each student and his/her parents or guardians, to address the weaknesses and monitor their progress towards meeting the agreed learning goals.

Develop additional Benchmarks

Teachers can develop additional benchmarks using the examples in the teacher guide to meet the learning needs of their students and local communities. However, these benchmarks will not be nationally assessed as these are not comparable. They are not allowed to set their own content standards or manipulate the existing ones. The setting of national content standards is done at the national level to ensure that required learning standards are maintained and monitored to sustain the required level of education quality.

Avoid Standardisation

The implementation of Science curriculum must not be standardised. SBC does not mean that the content, lesson objectives, teaching and learning strategies, and assessment are standardised. This is a misconception and any attempt to standardise the components of curriculum without due consideration of the teaching and learning contexts, student's backgrounds and experiences, and different abilities and learning styles of students will be counterproductive. It will hinder students from achieving the expected proficiency standards and hence, high academic standards and the desired level of education quality. That is, they should not be applied across all contexts and with all students, without considering the educational needs and the characteristics of each context. Teachers must use innovative, creative, culturally relevant, and differentiated teaching and learning approaches to teach the curriculum and enable their students to achieve the national content standards and grade-level benchmarks. And enable all students to experiencesuccess in learning the curriculum and achieve high academic standards.

What is provided in the syllabus and teacher guide are not fixed and can be changed. Teachers should use the information and examples provided in the syllabus and the teacher guide to guide them to develop, select, and use grade, context, and learner appropriate content, learning objectives, teaching and learning strategies, and performance assessment and standards. SBC is evidence-based hence decisions about the content, learning outcomes, teaching and learning strategies, students' performance, and learning interventions should be based on evidence. Teaching and learning should be continuously improved and effectively targeted using evidence from students' assessment and other sources.

Syllabus and Teacher Guide Alignment

A teacher guide is a framework that describes how to translate the content standards and benchmarks (learning standards) outlined in the syllabus into units and topics, learning objectives, lesson plans, teaching and learning strategies, performance assessment, and measures for measuring students' performance (performance standards). It expands the content overview and describes how this content identified in the content standards and their components (essential KSVAs) can be translated into meaningful and evidence-based teaching topics and learning objectives for lesson planning, instruction and assessment. It also describes and provides examples of how to evaluate and report on students' attainment of the learning standards, and use evidence from the assessment of students' performance to develop evidence-based interventions to assist students who are making slow progress towards meeting the expected proficiency levels to improve their performance.

This subject comprises of the Syllabus and Teacher Guide. These two documents are closely aligned, complimentary and mutually beneficial.
They are the essential focal points for teaching and learning the essential Physics knowledge, skills, values and attitudes.

Syllabus	Teacher Guide
Outlines the ultimate aim and goals, and what to teach and why teach it	**Describes how to plan, teach, and assess students' performance**
• Overarching and SBC principles • Content overview • Core curriculum • Essential knowledge, skills, values and attitudes • Strands and units • Evidence outcomes • Content standards and grade-level benchmarks • Overview of assessment, evaluation, and Reporting	• Determine topics for lesson planning, instruction and assessment • Formulate learning objectives • Plan SBC lesson plans • Select teaching and learning strategies • Implement SBC assessment and evaluation • Implement SBC reporting and monitoring

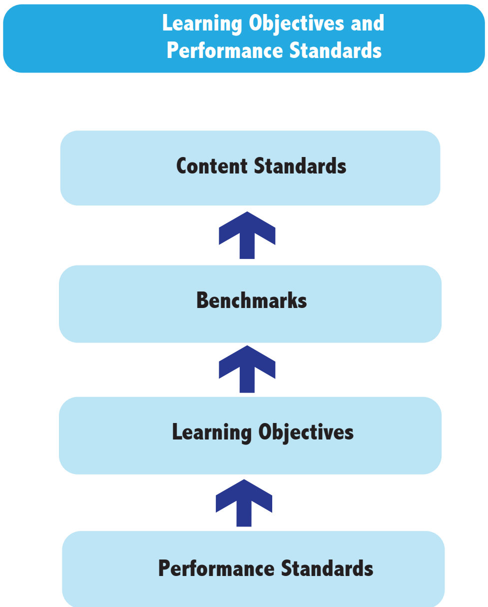
The syllabus outlines the ultimate aim and goals of SBE and SBC, what is to be taught and why it should be learned by students, the underlying principles and articulates the learning and proficiency standards that all students are expected to attain. On the other hand, the teacher guide expands on what is outlined in the syllabus by describing the approaches or the how of planning, teaching, learning, and assessing the content so that the intended learning outcomes are achieved.

This teacher guide should be used in conjunction with the syllabus. Teachers should use these documents when planning, teaching and assessing Grade 12 content.

Teachers will extract information from the syllabus (e.g., content standards and grade-level benchmarks) for lesson planning, instruction and is for measuring students' attainment a content standard as well as progress to the next grade of schooling.

Learning and Performance Standards Alignment

Content Standards, Benchmarks, Learning Objectives, and Performance Standards are very closely linked and aligned. There is a close linear relationship between these standards. Students' performance on a significant aspect of a benchmark (KSVA) is measured against a set of performance standards or criteria to determine their level of proficiency using performance assessment. Using the evidence from the performance assessment, individual student's proficiency on the aspect of the benchmark assessed and progression towards meeting the benchmark and hence the content standard are then determined.



Effective alignment of these learning standards and all the other components of PNG SBE and SBC (ultimate aim and goals, overarching, SBC and subject-based principles, core curriculum, STEAM, and cognitive, high level, and 21st Century skills) is not only critical but is also key to the achievement of high academic standards by all students and the intended level of education quality. It is essential that teachers know and can do standards alignment when planning, teaching, and assessing students' performance so that they can effectively guide their students towards meeting the grade-level benchmarks (grade expectations) and subsequently the content standards (national expectations).

Learning and Performance Standards

Standards-Based Education (SBE) and SBC are underpinned by the notion of quality. Standards define the expected level of education quality that all students should achieve at a particular point in their schooling. Students' progression and achievement of education standard(s) are measured using performance standards or criteria to determine their demonstration or performance on significant aspects of the standards and therefore their levels of proficiency or competency. When they are judged to have attained proficiency on a content standard or benchmark or components of these standards, they are then deemed to have met the standard(s) that is, achieved the intend level of education quality.

Content standards, benchmarks, and learning objectives are called learning standards while performance and proficiency standards (evidence outcomes) can be categorised as performance standards. These standards are used to measure students' performance, proficiency, progression and achievement of the desired level of education quality. Teachers are expected to understand and use these standards for lesson planning, instruction and assessment.

Content Standards

Content standards are evidence-based, rigorous and comparable regionally and globally. They have been formulated to target critical social, economic, political, cultural, environment, and employable skills gaps identified from a situational analysis. They were developed using examples and experiences from other countries and best practice, and contextualized to PNG contexts.

Content standards describe what (**content - knowledge, skills, values, and attitudes**) all students are expected to know and do (how well students must learn and apply what is set out in the content standards) at each grade-level before proceeding to the next grade. These standards are set at the national level and thus cannot be edited or changed by anyone except the National Subject-Based Standards Councils.

Content Standards;

- are evidenced-based,
- are rigorous and comparable to regional and global standards,
- are set at the national level,
- state or describe the expected levels of quality or achievement,
- are clear, measurable and attainable,
- are linked to and aligned with the ultimate aim and goals of SBE and SBC and overarching and SBC principles,
- delineate what matters, provide clear expectations of what students should progressively learn and achieve in school, and guide lesson planning, instruction, assessment,
- comprise knowledge, skills, values, and attitudes that are the basis for quality education,
- provide teachers a clear basis for planning, teaching, and assessing lessons and
- provide provinces, districts, and schools with a clear focus on how to develop and organise their instruction and assessment programs as well as the content that they will include in their curriculum.

Benchmarks

Benchmarks are derived from the content standards and benchmarked at the grade-level. Benchmarks are specific statements of what students should know (i.e., essential knowledge, skills, values or attitudes) at a specific grade-level or school level. They provide the basis for measuring students' attainment of a content standard as well as progress to the next grade of schooling.

Grade-level benchmarks;

- are evidenced-based,
- are rigorous and comparable to regional and global standards,
- are set at the grade level,
- are linked to the national content standards,
- are clear, measurable, observable and attainable,
- articulate grade level expectations of what students are able to demonstrate to indicate that they are making progress towards attaining the national content standards,
- provide teachers a clear basis for planning, teaching, and assessing lessons,
- state clearly what students should do with what they have learned at the end of each school-level,
- enable students' progress towards the attainment of national content standards to be measured, and
- enable PNG students' performance to be compared with the performance of students in other countries.

Approach for Setting National Content Standards and Grade-Level Benchmarks

Strands → Content Standards → Grade -Level Benchmark

Development of Additional Benchmarks

Teachers should develop additional benchmarks to meet the learning needs of their students. They should engage their students to learn about local, provincial, national and global issues that have not been catered for in the grade-level benchmarks but are important and can enhance students' understanding and application of the content. However, it is important to note that these benchmarks will not be nationally examined as they are not comparable. Only the benchmarks developed at the national level will be tested. This does not mean that teachers should not develop additional benchmarks. An innovative, reflect, creative and reflexive teacher will continuously reflect on his/her classroom practice and use evidence to provide challenging, relevant, and enjoyable learning opportunities for his/her students to build on the national expectations for students. Teachers should follow the following process when developing additional grade-level benchmarks.

Benchmark Development Process

Determine what needs to be taught (essential knowledge, skills, values and attitudes) → Determine if what is to be taught will contribute towards the achievement of the national content standard → Formulate benchmarks following the sequence of benchmarks already developed for the content standard

Learning Objectives

Learning or instructional Objectives are precise statements of educational intent. They are formulated using a significant aspect or a topic derived from the benchmark, and is aligned with the educational goals, content standards, benchmarks, and performance standards. Learning objectives are stated in outcomes language that describes the products or behaviours that will be provided by students. They are stated in terms of measurable and observable student behaviour. For example, students will be able to identify the properties of waves.

Performance Standards

Performance Standards are concrete statements of how well students must learn what is set out in the content standards, often called the **“be able to do”** of “what students should know and be able to do.” Performance standards are the indicators of quality that specify how competent a students’ demonstration or performance must be. They are explicit definitions of what students **must do to demonstrate proficiency or competency at a specific level on the content standards**.

Performance standards;

- measure students’ performance and proficiency (using performance indicators) in the use of a specific knowledge, skill, value, or attitude in real life or related situations,
- provide the basis (performance indicators) for evaluating, reporting and monitoring students’ level of proficiency in use of a specific knowledge, skills, value, or attitude,
- are used to plan for individual instruction to help students not yet meeting expectations (desired level of mastery and proficiency) to make adequate progress towards the full attainment of benchmarks and content standards, and
- are used as the basis for measuring students’ progress towards meeting grade-level benchmarks and content standards.

Proficiency Standards

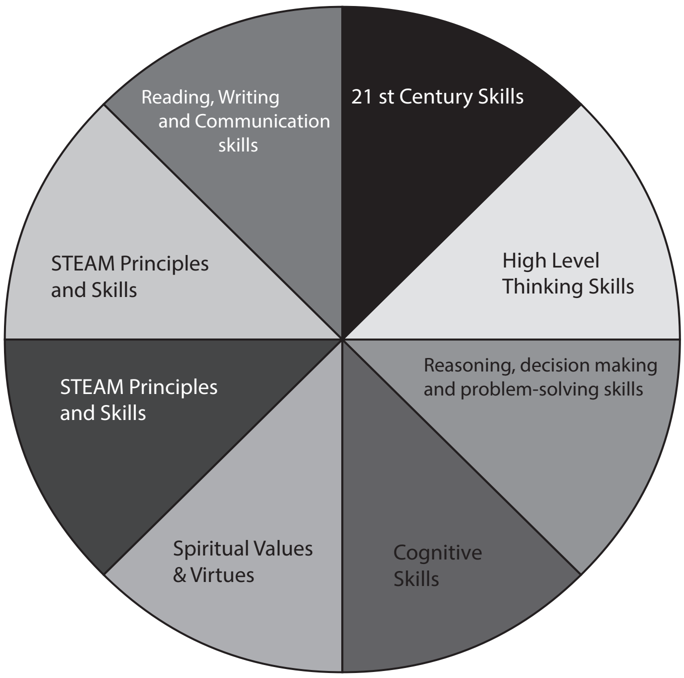
Proficiency standards describe what all students in a particular grade or school level can do at the end of a strand, or unit. These standards are sometimes called evidence outcomes because they indicate if students can actually apply or use what they have learned in real life or similar situations. They are also categorized as benchmarks because that is what all students are expected to do before exiting a grade or are deemed ready for the next grade.

Core Curriculum

A core set of common learnings (knowledge, skills, values, and attitudes) are integrated into the content standards and grade-level benchmarks for all subjects. This is to equip all students with the most essential and in-demand knowledge, skills, and dispositions they will need to be successful in modern/ postmodern work places, higher-education programs and to be productive, responsible, considerate, and harmonious citizens. Common set of learnings are spirally sequenced from Preparatory - Grade 12 to deepen the scope and increase the level of difficulty in the learning activities so that what is learned is reinforced at different grade levels.

The core curriculum includes:

- cognitive (thinking) skills (refer to the syllabus for a list of these skills),
- reasoning, decision-making and problem-solving skills,
- high level thinking skills (analysis, synthesis and evaluation skills),
- 21st Century skills, (refer to appendix 2)
- reading, writing and communication skills,
- STEAM principles and skills,
- essential values and attitudes (core personal and social values, and sustaining values), and
- spiritual values and virtues.



The essential knowledge, skills, values and attitudes comprising the core curriculum are interwoven and provide an essential and holistic framework for preparing all students for careers, higher education and citizenship.

All teachers are expected to include the core learnings in their lesson planning, teaching, and assessment of students in all their lessons. They are expected to foster, promote and model the essential values and attitudes as well as the spiritual values and virtues in their conduct, practice, appearance, and their relationships and in their professional and personal lives. In addition, teachers are expected to mentor, mould and shape each student to evolve and possess the qualities envisioned by society.

Core values and attitudes must not be taught in the classroom only; they must also be demonstrated by students in real life or related situations inside and outside of the classroom, at home, and in everyday life. Likewise, they must be promoted, fostered and modeled by the school community and its stakeholders, especially parents. A holistic approach to values and attitudes in teaching, promoting and modeling is critical to students and the whole school community to internalise the core values and attitudes and making them habitual in their work and school place, and in everyday life. Be it work values, relationship values, peace values, health values, personal and social values, or religious values, teachers should give equal prominence to all common learnings in their lesson planning, teaching, assessment, and learning interventions. Common learnings must be at the heart of all teaching and extra-curricular programs and activities.

Science, Technology, Engineering, Arts and Mathematics

STEAM education is an integrated, multidisciplinary approach to learning that uses science, technology, engineering, arts and mathematics as the basis for inquiring about how STEAM has and continues to change and impact the social, political, economic, cultural and environmental contexts and identifying and solving authentic (real life) natural and physical environment problems by integrating STEAM-based principles, cognitive, high level and 21st century skills and processes, and values and attitudes.

Physics is focused on both goals of STEAM rather than just the goal of problem-solving. This is to ensure that all students are provided opportunities to learn, integrate, and demonstrate proficiency on all essential STEAM principles, processes, skills, values and attitudes to prepare them for careers, higher education and citizenship.

Objectives

Students will be able to:

(i) Examine and use evidence to draw conclusions about how STEAM has and continues to change the social, political, economic, cultural and environmental contexts.
(ii) Investigate and draw conclusions on the impact of STEAM solutions to problems on the social, political, economic, cultural and environmental contexts.
(iii) Identify and solve problems using STEAM principles, skills, concepts, ideas and process.
(iv) Identify, analyse and select the best solution to address a problem.
(v) Build prototypes or models of solutions to problems.
(vi) Replicate a problem solution by building models and explaining how the problem was or could be solved.
(vii) Test and reflect on the best solution chosen to solve a problem.
(viii) Collaborate with others on a problem and provide a report on the process of problem solving used to solve the problem.
(ix) Use skills and processes learned from lessons to work on and complete STEAM projects.
(x) Demonstrate STEAM principles, skills, processes, concepts and ideas through simulation and modelling.
(xi) Explain the significance of values and attitudes in problem-solving.

STEAM is a multidisciplinary and integrated approach to understanding how science, technology, engineering, arts and mathematics shape and are shaped by our material, intellectual, cultural, economic, social, political and environmental contexts. And for teaching students the essential in demand cognitive, high level and 21st century skills, values and attitudes, and empower them to effectively use these skills and predispositions to identify and solve problems relating to the natural and physical environments as well as the impact of STEAM-based solutions on human existence and livelihoods, and on the social, political, economic, cultural, and environmental systems.

STEAM disciplines have and continue to shape the way we perceive knowledge and reality, think and act, our values, attitudes, and behaviours, and the way we relate to each other and the environment. Most of the things we enjoy and consume are developed using STEAM principles, skills, process, concepts and ideas. Things humans used and enjoyed in the past and at present are developed by scientists, technologists, engineers, artists and mathematicians to address particular human needs and wants. Overtime, more needs were identified and more products were developed to meet the ever changing and evolving human needs. What is produced and used is continuously reflected upon, evaluated, redesigned, and improved to make it more advanced, multipurpose, fit for purpose, and targeted towards not only improving the prevailing social, political, economic, cultural and environmental conditions but also to effectively respond to the evolving and changing dynamics of human needs and wants. And, at the same time, solutions to human problems and needs are being investigated and designed to address problems that are yet to be addressed and concurred. This is an evolving and ongoing problem-solving process that integrates cognitive, high level, and 21st Century skills, and appropriate values and attitudes.

STEAM is a significant framework and focal point for teaching and guiding students to learn, master and use a broad range of skills and processes required to meet the skills demands of PNG and the 21st Century. The skills that students will learn will reflect the demands that will be placed upon them in a complex, competitive, knowledge-based, information-age, technology-driven economy and society. These skills include cognitive (critical, synthetic, creative, reasoning, decision-making, and problem-solving) skills, high level (analysis, synthesis and evaluation) skills and 21st Century skills (see Appendix 4). Knowledge-based, information, and technology driven economies require knowledge workers not technicians. Knowledge workers are lifelong learners, are problem solvers, innovators, creators, critical and creative thinkers, reflective practitioners, researchers (knowledge producers rather than knowledge consumers), solutions seekers, outcomes oriented, evidence-based decision makers, and enablers of improved and better outcomes for all.

STEAM focuses on the skills and processes of problem solving. These skills and processes are at the heart of the STEAM movement and approach to not only problem solving and providing evidence-based solutions but also the development and use of other essential cognitive, high level and 21st Century skills. These skills are intertwined and used simultaneously to gain a broader understanding of the problems to enable creative, innovative, contextually relevant, and best solutions to be developed and implemented to solve the problems and attain the desired outcomes. It is assumed that by teaching students STEAM-based problem-solving skills and providing learning opportunities inside and outside the classroom will motivate more of them to pursue careers and academic programs in STEAM related fields thus, closing the skills gaps and providing a pool of cadre of workers required by technology, engineering, science, and mathematics-oriented industries.

STEAM Problem-Solving Processes

Problem-solving involves the use of problem-solving methods and processes to identify and define a problem, gather information to understand its causes, draw conclusions, and use the evidence to design and implement solutions to address it. Even though there are many different problem-solving methods and approaches, they share some of the steps of problem-solving, such as;

- identifying the problem,
- understanding the problem by collecting data,
- analyse and interpret the data,
- draw conclusions,
- use data to consider possible solutions,
- select the best solution,
- test the effectiveness of the solution by trialling and evaluating it, and
- review and improve the solution.

STEAM problem solving processes go from simple and technical to advance and knowledge-based processes. However, regardless of the type of process used, students should be provided opportunities to learn the essential principles and processes of problem solving and, more significantly, to design and create a product that addressed a real problem and meets a human need.

The following are some of the STEAM problem solving processes.

1. Engineering and Technology Problem Solving Methods and Approaches

Engineering and technology problem-solving methods are used to identify and solve problems relating to the physical world using the design process. The following are some of the methods and approaches used to solve engineering and technology related problems.

Parts Substitution

It is the most basic of the problem-solving methods. It simply requires the parts to be substituted until the problem is solved.

Diagnostics

After identifying a problem, the technician would run tests to pinpoint the fault. The test results would be used either as a guide for further testing or for replacement of a part, which also need to be tested. This process continues until the solution is found and the device is operating properly.

Troubleshooting

Troubleshooting is a form of problem solving, often applied to repair failed products or processes.

Reverse Engineering

Reverse engineering is the process of discovering the technological principles underlying the design of a device by taking the device apart, or carefully tracing its workings or its circuitry. It is useful when students are attempting to build something for which they have no formal drawings or schematics.

Divide and Conquer

Divide and conquer is the technique of breaking down a problem into sub-problems, then breaking the sub-problems down even further until each of them is simple enough to be solved. Divide and conquer may be applied to all groups of students to tackle sub-problems of a larger problem, or when a problem is so large that its solution cannot be visualised without breaking it down into smaller components.

Extreme Cases

Considering “extreme cases” – envisioning the problem in a greatly exaggerated or greatly simplified form, or testing using extreme condition – can often help to pinpoint a problem. An example of the extreme-case method is purposely inputting an extremely high number to test a computer program.

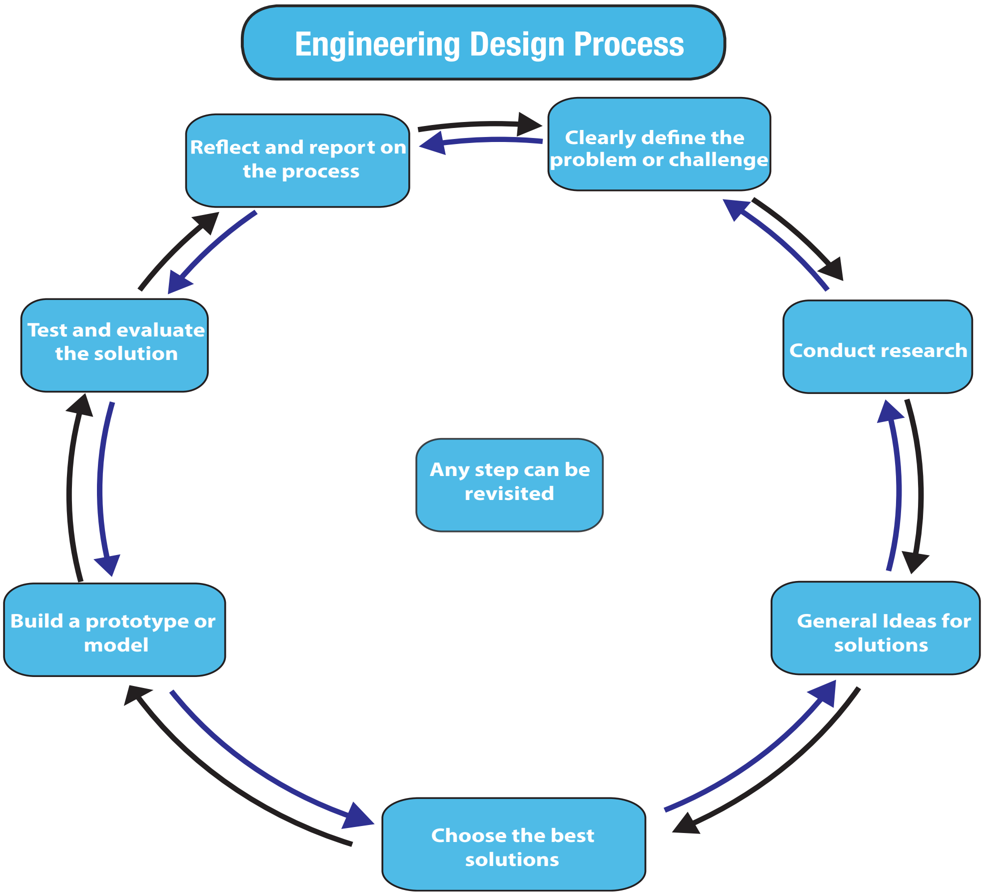
Trial and Error

The trial and error method involve trying different approaches until a solution is found. It is often used as a last resort when other methods have been exhausted.

2. Engineering Design Process

Technological fields use the engineering design process to identify and define the problem or challenge, investigate the problem, collect and analyse data, and use the data to formulate potential solutions to the problem, analyse each of the solutions in terms of its strengths and weaknesses, and choose the best solution to solve the problem. It is an open-ended problem-solving process that involves the full planning and development of products or services to meet identified needs. It involves a sequence of steps such as the following:

1. Analyse the context and background, and clearly define the problem.
2. Conduct research to determine design criteria, financial or other constraints, and availability of materials.
3. Generate ideas for potential solutions, using processes such as brainstorming and sketching.
4. Choose the best solution.
5. Build a prototype or model.
6. Test and evaluate the solution.
7. Repeat steps as necessary to modify the design or correct faults.
8. Reflect and report on the process.



STEAM-Based Lesson planning

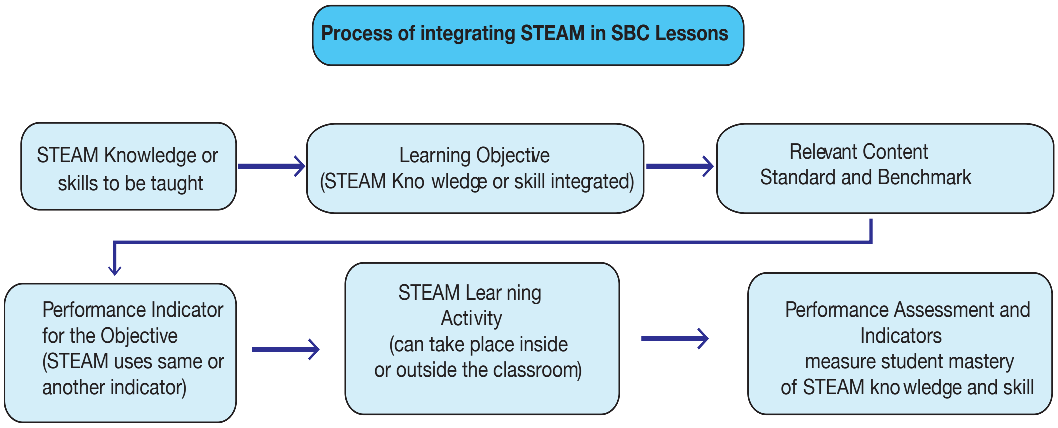
Effective STEAM lesson planning is key to the achievement of expected STEAM outcomes. STEAM skills can be planed and taught using separate STEAM-based lesson plans or integrated into the standards-based lesson plans. To effectively do this, teachers should know how to write effective standards and STEAM-based lesson plans.

An example of a STEAM-based lesson plan is provided in the Appendix. Teachers should use this to guide them to integrate STEAM content and teaching, learning and assessment strategies into their standards-based lesson plans.

Knowing how to integrate STEAM problem-solving skills, principles, values and attitudes as well as STEAM teaching, learning, and assessment strategies into standards-based lesson plans is essential for achieving the desired STEAM learning outcomes. When integrating STEAM problem-solving skills into the standards-based lesson plans, teachers should ensure that these skills are not only effectively aligned to the learning objective and performance standards, they must also be effectively taught and assessed.

Teachers are expected to integrate the essential STEAM principles, processes, skills, values and attitudes described in the grade 12 benchmarks when formulating their standards-based lesson plans. Opportunities should be provided inside and outside of the classroom for students to learn, explore, model and apply what they learn in real life or related situations. These learning experiences will enable students to develop a deeper understanding of STEAM principles, processes, skills, values and attitudes and appreciate their application in real life to solve problems.

Process for Integrating STEAM Principles and Problem-Solving Skills into Standards-Based Lessons



Teachers should follow the steps given below when integrating STEAM problem-solving principles and skills into their standards-based lesson plans.

Step 1: Identify the STEAM knowledge or skill to be taught (From the table of KSVAs for each content standard and benchmark). This could already be captured in the learning objective stated in the standards-based lesson plan.

Step 2: Develop and include a performance standard or indicator for measuring student mastery of the STEAM knowledge or skill *(e.g.* level of acceptable competency or proficiency) if this is different from the one already stated in the lesson plan.

Step 3: Develop student learning activity (An activity that will provide students the opportunity to apply the STEAM knowledge or skill specified by the learning objective and appropriate statement of the standards). Activity can take place inside or outside of the classroom, and during or after school hours.

Step 4: Develop and use performance descriptors (standards or indicators) to analyse students' STEAM related behaviours and products (results or outcomes), which provide evidence that the student has acquired and mastered the knowledge or skill of the learning objective specified by the indicator(s) of the standard(s).

STEAM Teaching Strategies

STEAM education takes place in both formal and informal classroom settings. It takes place during and after school hours. It is a continuous process of inquiry, data analysis, making decisions about interventions, and implementing and monitoring interventions for improvements.

There are a variety of STEAM teaching strategies. However, teaching strategies selected must enable teachers to guide students to use the engineering and artistic design processes to identify and solve natural and physical environment problems by designing prototypes and testing and refining them to effectively mitigate the problems identified. The following are some of the strategies that could be used to utilise the STEAM approach to solve problems and coming up with technological solutions.

- *Inquiry-Based Learning*
- *Problem-Based Learning*
- *Project-based learning,*
- *Collaborative Learning*

Collaborative learning involves individuals from different STEAM disciplines and expertise in a variety of STEAM problem solving approaches working together and sharing their expertise and experiences to inquire into and solve a problem.

Teachers should plan to provide students opportunities to work in collaboration and partnership with experts and practitioners engaged in STEAM related careers or disciplines to learn first-hand about how STEAM related skills, processes, concepts, and ideas are applied in real life to solve problems created by natural and physical environments. Collaborative learning experiences can be provided after school or during school holidays to enable students to work with STEAM experts and practitioners to inquiry and solve problems by developing creative, innovative and sustainable solutions. Providing real life experiences and lessons, e.g., by involving students to actually solve a scientific, technological, engineering, or mathematical, or Arts problem, would probably spark their interest in a STEAM career path. Developing STEAM partnerships with external stakeholders e.g., high education institutions, private sector, research and development institutions, and volunteer and community development organizations can enhance students' learning and application of STEAM problem solving principles and skills.

Some examples of STEAM-related partnership experiences may include:

- *Participatory Learning*
- *Group-Based Learning*
- *Task Oriented Learning*
- *Action Learning*
- *Experiential Learning*
- *Modelling*
- *Simulation*

STEAM Learning Strategies

Teachers should include in their lesson plans STEAM learning activities. These activities should be aligned to principle or a skill planned for students to learn and demonstrate proficiency at the end of the lesson to expose students to STEAM and giving them opportunities to explore STEAM-related concepts, they will develop a passion for it and, hopefully, pursue a job in a STEAM field. Providing real life experiences and lessons, e.g., by involving students to actually solve a scientific, technological, engineering, or mathematical, or arts problem, would probably spark their interest in a STEAM career path. This is the theory behind STEAM education.

STEAM-Based Assessment

STEAM-based assessment is closely linked to standards-based assessment where assessment is used to assess students' level of competency or proficiency of a specific knowledge, skill, value, or attitude taught using a set of performance standards (indicators or descriptors). The link also includes the main components such as the purpose, the assessment principles and assessment strategies and tools.

In STEAM-based assessment, assessments are designed for what students should know and be able to do. In STEAM learning, students are assessed in a variety of ways including portfolios, project/problem-based assessments, backwards design, authentic assessments, or other student-centered approaches.
When planning and designing the assessment, teachers should consider the authenticity of the assessment by designing an assessment that relates to a real world task or discipline specific attributes such as simulation, role play, placement assessment, live projects and debates. These tasks should make the activity meaningful to the student, and therefore be motivating as well as developing employability skills and discipline specific attributes.

Effective STEAM-Based Assessment Strategies

The following are the six assessment tools and strategies to impact teaching and learning as well as help teachers foster a 21st Century learning environment in their classrooms.

1. *Rubrics*
2. *Performance-Based Assessments (PBAs)*
3. *Portfolios*
4. *Student self-assessment*
5. *Peer-assessment*
6. *Student Response Systems(SRS).*

Although the list does not include all innovative assessment strategies, it includes what we think are the most common strategies, and ones that may be particularly relevant to the educational context of developing countries in this 21st Century. Many of the assessment strategies currently in use fit under one or more of the categories discussed. Furthermore, it is important to note that these strategies also connect in a variety of ways.

1. Rubrics

Rubrics are both a tool to measure students' knowledge and ability as well as an assessment strategy. A rubric allows teachers to measure certain skills and abilities not measurable by standardized testing systems that assess discrete knowledge at a fixed moment in time. Rubrics are also frequently used as part of other assessment strategies including; portfolios, performances, projects, peer-review and self-assessment which are also elaborated in this section.

2. Performance-Based Assessments

Performance-Based Assessments (PBA), also known as project-based or authentic assessments, are generally used as a summative evaluation strategy to capture not only what students know about a topic, but if they have the skills to apply that knowledge in a "real-world" situation. By asking them to create an end product. PBA pushes students to synthesize their knowledge and apply their skills to a potentially unfamiliar set of circumstances that is likely to occur beyond the confines of a controlled classroom setting.

The implementation of performance-based assessment strategies can also impact other instructional strategies in the classroom.

3. Portfolio Assessment

Portfolios are a collection of student work gathered over time that is primarily used as a summative evaluation method. The most salient characteristic of the portfolio assessment is that rather than being a snapshot of a student's knowledge at one point in time (like a single standardized test), it highlights student effort, development, and achievement over a period of time; portfolios measure a student's ability to apply knowledge rather than simply regurgitate. They are considered both student-centred and authentic assessments of learning.

4. Self-assessment

While the previous assessment tools and strategies listed in this report generally function as summative approaches, self-assessment is generally viewed as a formative strategy, rather than one used to determine a student's final grade. Its main purpose is for students to identify their own strengths and weakness and to work to make improvements to meet specific criteria. Self-assessment occurs when students judge their own work to improve performance as they identify discrepancies between current and desired performance". In this way, self-assessment aligns well with standards-based education because it provides clear targets and specific criteria against which students or teachers can measure learning.

Self-assessment is used to promote self-regulation, to help students reflect on their progress and to inform revisions and improvements on a project or paper. In order for self-assessment to be truly effective four conditions must be in place: the self-assessment criteria is negotiated between teachers and students, students are taught how to apply the criteria, students receive feedback on their self-assessments and teachers help students use assessment data to develop an action plan.

5. Peer assessment

Peer assessment, much like self-assessment, is a formative assessment strategy that gives students a key role in evaluating learning. Peer assessment approaches can vary greatly but, essentially, it is a process for learners to consider and give feedback to other learners about the quality or value of their work. Peer assessments can be used for variety of products like papers, presentations, projects, or other skilled behaviours. Peer assessment is understood as more than only a grading procedure and is also envisioned as teaching strategy since engaging in the process develops both the assessor and assessee's skills and knowledge.

6. Student Response System

Student response system (SRS), also known as classroom response (CRS), audience response system (ARS) is a general term that refers to a variety of technology-based formative assessment tools that can be used to gather student-level data instantly in the classroom. Through the combination of hardware, (voice recorders, PC, internet connection, projector and screen) and software.

Teachers can ask students a wide range of questions (both closed and open ended), where students can respond quickly and anonymously, and the teacher can display the data immediately and graphically. The use of technology also includes a use of video which examines how a range of strategies can be used to assess students' understanding.

The value of SRS comes from teachers analyzing information quickly and then devising real-time instructional solutions to maximize student learning. This includes a suggested approach to help teachers and trainers assess learning.

Curriculum Integration

What is Curriculum Integration?

Curriculum integration is making connections in learning across the curriculum. The ultimate aim of curriculum integration is to act as a bridge to increase students' achievement and engage in relevant curriculum. (Susan M. Drake and Rebecca C. Burns)

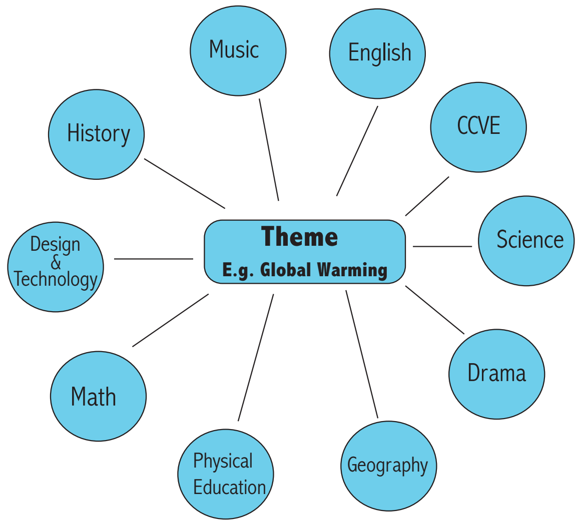
Teachers must develop intriguing curriculum by going beyond the traditional teaching of content based or fragmented teaching to one who is knowledge based and who should be perceived as a 21st Century innovative educator. Curriculum integration is a holistic approach to learning thus curriculum integration in PNG SBC will have to equip students with the essential knowledge, skills, values and attitudes that are deemed 21st Century.

There are three approaches that PNG SBC will engage to foster conducive learning for all its children whereby they all can demonstrate proficiency at any point of exit. Adapting these approaches will have an immense impact on the lives of these children thus they can be able to see themselves as catalyst of change for a competitive PNG. Not only that but they will be comparable to the world standards and as global citizens.

Engaging these three approaches in our curriculum will surely sharpen the knowledge and ability of each child who will foresee themselves as assets through their achievements thus contribute meaningfully to their country. They themselves are the agents of change. Integrated learning will bear forth a generation of knowledge based populace who can solve problems and make proper decisions based on evidence. Thus, PNG can achieve its goals like the Medium Term Development Goals (MTDG) and aims such as the Vision 2050 for a happy, healthy and wealthy society whereby, all its citizens should have access and fair distribution to income, shelter, health, education and general goods and services improving the general standard of living for PNG in the long run.

1. (i) Multidisciplinary Approach

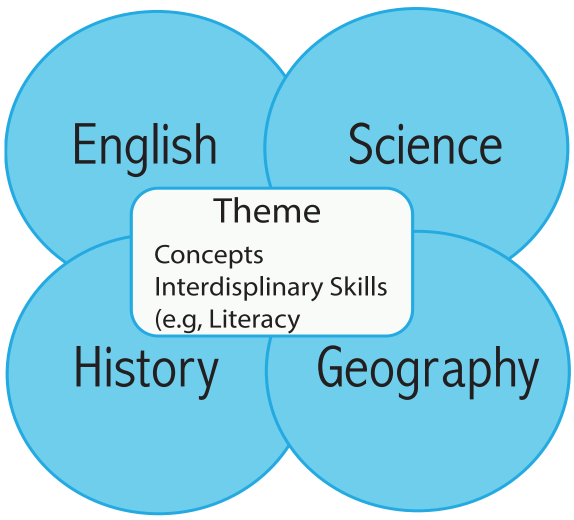
In this approach learning involves a theme or concept that will be taught right across all subject area of study by students. That is, content of a particular theme will be taught right across all subjects as shown in the diagram below. For instance, if the theme is global warming, subject areas create lessons or assessment as per their subjects around this theme. Social Science will address this issue, Science and all other subject likewise.



1. (ii) Interdisciplinary Approach

This approach addresses learning similarly to the multidisciplinary approach of integrated learning whereby learning takes place within the subject area. However, it is termed interdisciplinary in that the core curriculum of learning is interwoven into each subject under study by the students. For instance; in Social Science under the strand of geography students write essay on internal migration however, apart from addressing the issues of this topic, they are to apply the skill of writing text types in their essay such as argumentative essay, informative, explanatory, descriptive, expository and narrative essay while writing their essay. They must be able to capture the mechanics of English skills such as grammar, punctuation and so forth. Though these skills are studied under English they are considered as core skills that cut across all subjects under study. For example; if Science students were to write about human development in biology then the application of writing skills has to be captured by the students in their writing. It is not seen as an English skill but a standard essential skill all students must know and do regardless.

Therefore, essential knowledge, skills, values and attitudes comprising the core curriculum are interwoven and provide an essential and holistic framework for preparing all students for careers, higher education and citizenship in this learning.



2. Intradisciplinary approach

This approach involves teachers integrate sub disciplines within a subject area. For instance, within the subject Social Science, the strands (disciplines) of geography, environment, history, political science and environment will all be captured studying a particular content for Social Science. For example, under global warming, students will study the geographical aspects of global warming, environmental aspect of global warming and likewise for history, political science and economics. Thus, children are well aware of the issues surrounding global warming and can address it confidently at each level of learning.

3. Trans disciplinary Approach

In this approach learning goes beyond the subject area of study. Learning is organized around students' questions and concerns. That is, where there is a need for change to improve lives, students develop their own curriculum to effect these need. The trans-disciplinary approach addresses real-life situations thus giving the opportunity to students to attain real life skills. This learning approach is more to do with Project–Based Learning also referred to as problem-based learning or place- based learning.

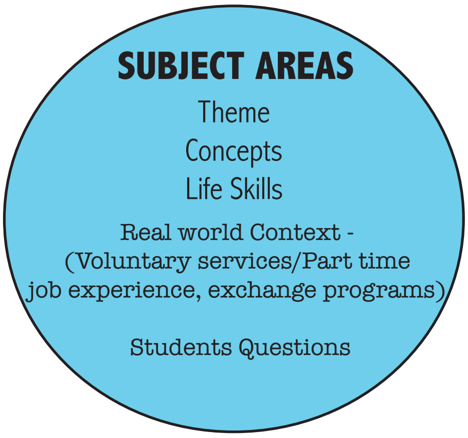
Below are the three steps to planning project based curriculum.

1. Teachers and students select a topic of study based on student interests, curriculum standards, and local resources.
2. The teacher finds out what the students already know and helps them generate questions to explore. The teacher also provides resources for students and opportunities to work in the field
3. Students share their work with others in a culminating activity. Students display the results of their exploration and review and evaluate the project.

For instance; students may come up with slogans for school programs such as 'Our culture – clean city for a healthier PNG'. The main aim could be to curb betel nut chewing in public areas especially around bus stops and local markets. Here, students draw up their own instructions and criteria for assessment which is; they have to clean the nearest bus stop or local market once a week throughout the year. They also design and create posters to educate the general public as their program continues. They can also involve the town council and media to assist them especially to carry out awareness.

Studies have proven that Project based-programs have led to the following:

- Students go far beyond the minimum effort
- Make connections among different subject areas to answer open-ended questions
- Retain what they have learnt
- Apply learning to real-life problems
- Have fewer discipline problems
- Lower absenteeism



These integrated learning approaches will demand for teaches to be proactive in order to improve students learning and achievements. In order for PNG Standards-Based Curriculum to serve its purpose fully, these three approaches must be engaged for better learning for the children of Papua New Guinea now and in the future.

Essential Knowledge, Skills, Values and Attitudes and Scientific Thinking Process

Students' level of proficiency and progression towards the attainment of content standards will depend on their mastery and application of essential knowledge, skills, values, and attitudes in real life or related situations. Provided here are examples of different types of knowledge, processes, skills, values, and attitudes that all students are expected to learn and master as they progress through the grades. These are expanded and deepen in scope and the level of difficulty and complexity are increased to enable students to study in-depth the subject content as they progress from one grade to the next.

These knowledge, skills, values and attitudes have been integrated into the content standards and benchmarks. They will also be integrated into the performance standards. Teachers are expected to plan and teach essential knowledge, skills, values and attitudes in their lessons, and assess students' performance and proficiency, and progression towards the attainment of content standards.

Types of Knowledge

There are different types of knowledge. These include;	
• Public and private (privileged) knowledge • Specialised knowledge • Good and bad knowledge • Concepts, processes, ideas, skills, values, attitudes • Theory and practice • Fiction and non-fiction • Traditional, modern, and postmodern knowledge	• Subject and discipline-based knowledge • Lived experiences • Evidence and assumptions • Ethics and Morales • Belief systems • Facts and opinions • Wisdom • Research evidence and findings • Solutions to problems

Types of Processes

There are different types of processes. These include;	
• Problem-solving • Logical reasoning • Decision-making • Reflection	• Cyclic processes • Mapping (e.g. concept mapping) • Modelling • Simulating
Science Inquiry processes include: • Gathering information • Analysing information • Evaluating information • Making judgements • Taking actions	

Types of Skills

There are different types of skills. These include:

1. Cognitive (Thinking) Skills

Thinking skills can be categorized into **critical thinking** and **creative thinking** skills.

i. Critical Thinking Skills

A person who thinks critically always evaluates an idea in a systematic manner before accepting or rejecting it. Critical thinking skills include;	
• Attributing • Comparing and contrasting • Grouping and classifying • Sequencing • Prioritising • Analysing	• Detecting bias • Evaluating • Metacognition (Thinking about thinking) • Making informed conclusions.

ii Creative Thinking Skills

A person who thinks creatively has a high level of imagination, able to generate original and innovative ideas, and able to modify ideas and products. Creative thinking skills include;	
• Generating ideas • Deconstruction and reconstruction • Relating • Making inferences • Predicting • Making generalisations • Visualizing	• Synthesising • Making hypothesis • Making analogies • Invention • Transformation • Modeling • Simulating

2. **Reasoning Skills** - Reason is a skill used in making a logical, just, and rational judgment.

3. **Decision-Making Skills** - Decision-making involves selection of the best solution from various alternatives based on specific criteria and evidence to achieve a specific aim.

4. **Problem Solving Skills –** These skills involve finding solutions to challenges or unfamiliar situations or unanticipated difficulties in a systematic manner.

5. Literacy Skills

A strong emphasis must be placed on various types of literacy, from financial to technological, from media to mathematical, from content to cultural. Literacy may be defined as the ability of an individual to use information to function in society, to achieve goals and to develop her or his knowledge and potential. Teachers emphasize certain aspects of literacy over others, depending on the nature of the content and skills they want students to learn.

The following literacy skills are intended to be exemplary rather than definitive	
• Listens, read, write, and speak with comprehension and clarity • Define and apply discipline-based conceptual vocabulary • Describe people, places, and events, and the connections between and among them • Arrange events in chronological sequence • Differentiate fact from opinion • Determine an author's purpose • Determine and analyse similarities and differences • Analyse cause and effect relationships • Explore complex patterns, interactions and relationships • Differentiate between and among various options	• Listens, read, write, and speak with comprehension and clarity • Define and apply discipline-based conceptual vocabulary • Describe people, places, and events, and the connections between and among them • Arrange events in chronological sequence • Differentiate fact from opinion • Determine an author's purpose • Determine and analyse similarities and differences • Analyse cause and effect relationships • Develop an ability to use and apply abstract principals • Explore and/or observe, identify, and analyse how individuals and/or societies relate to one another

6. High Level Thinking Skills - These skills include analysis, synthesis, and evaluation skills.

i *Analysis Skills* – Analysis skills involve examining in detail and breaking information into parts by identifying motives or causes, underlying assumptions, hidden messages; making inferences and finding evidence to support generalisations, claims, and conclusions.

Key Words				
Analyse	Differences	Find	List	Similar to
Appraise	Discover	Focus	Motivate	Simplify
Arrange	Discriminate	Function	Omit	Take part in
Assumption	Discussion	Group	Order	Test for
Breakdown	Distinction	Highlight	Organize	Theme
Categorize	Distinguish	In-depth	Point out	
Cause & effect	Dissect	Inference	Research	
Choose	Divide	Inspect	See	
Classify	Establish	Isolate	Select	
Comparing	Examine	Investigate	Separate	

ii *Synthesis Skills* – Synthesis skills involve changing or creating something new, compiling information together in a different way by combining elements in a new pattern proposing alternative solutions.

i. *Evaluation Skills* – Evaluation skills involve justifying and presenting and defending opinions by making judgments about information, validity of ideas or quality of work based on set criteria.

Types of Values

Personal engagement and civic engagement strategies help young people to acquire and apply skills and dispositions that will prepare them to become competent and responsible citizens.

1. Personal Values (importance, worth, usefulness, etc.)

Core values	Sustaining values
• Sanctity of life • Truth • Aesthetics • Honesty • Human • Dignity • Rationality • Creativity • Courage • Liberty • Affectivity • Individuality	• Self-esteem • Self-reflection • Self-discipline • Self-cultivation • Principal morality • Self-determination • Openness • Independence • Simplicity • Integrity • Enterprise • Sensitivity • Modesty • Perseverance

2. Social Values

Core Values	Sustaining Values
• Equality • Kindness • Benevolence • Love • Freedom • Common good • Mutuality • Justice • Trust • Interdependence • Sustainability • Betterment of human kind • Empowerment	• Plurality • Due process of law • Democracy • Freedom and liberty • Common will • Patriotism • Tolerance • Gender equity and social inclusion • Equal opportunities • Culture and civilisation • Heritage • Human rights and responsibilities • Rationality • Sense of belonging • Solidarity • Peace and harmony • Safe and peaceful communities

Types of Attitudes

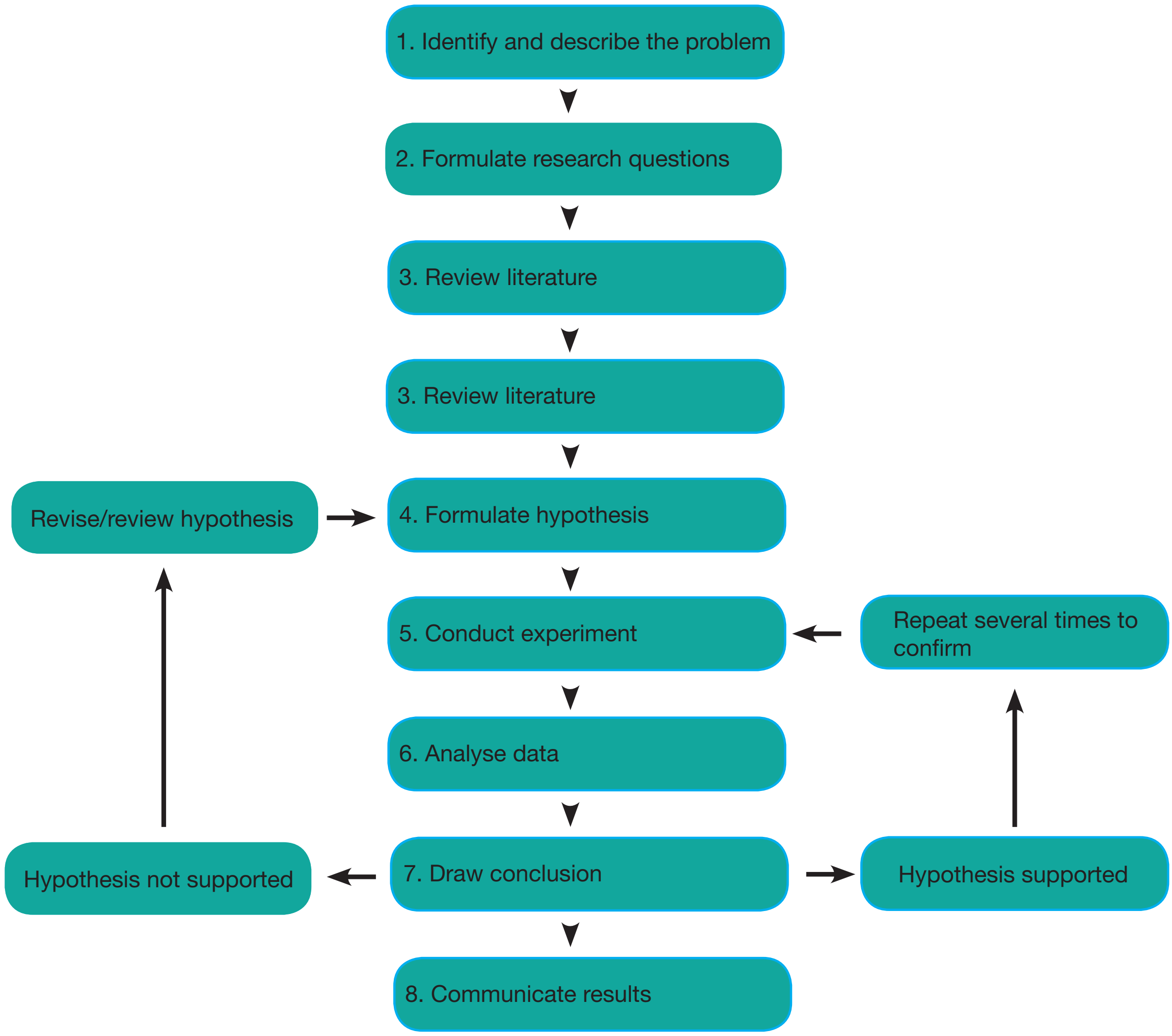
Attitudes - Ways of thinking and behaving, points of view	
• Optimistic • Participatory • Critical • Creative • Appreciative • Empathetic • Caring and concern • Positive • Confident • Cooperative	• Responsible • Adaptable to change • Open-minded • Diligent • With a desire to learn • With respect for self, life, equality and excellence, evidence, fair play, rule of law, different ways of life, beliefs and opinions, and the environment.

Scientific Thinking Process

Scientists engage in scientific inquiry by following key science practices that enable them to understand the natural and physical world and answer questions about it. Science students must become proficient at these practices to develop an understanding of how the scientific enterprise is conducted. These practices include skills from daily life and school studies that students use in a systemic way to conduct scientific inquiry. There are six (6) basic science process skills science students have to master before they apply the science inquiry problem-solving approach. The process skills that are at the heart of the scientific inquiry and problem-solving process are:

- Observation
- Communication
- Classification
- Measurement
- Inference
- Prediction

The science practices are fundamental to all science disciplines. The eight (8) steps that are fundamental to scientific inquiry are outlined below. The steps in the process vary, depending on the purpose of the inquiry and the type of questions or hypothesis created.



The steps above should be taught and demonstrated by students separately and jointly before they implement the inquiry process. Students should be guided through every step of the process so that they can explain them, their importance and use the steps and the whole process proficiently to identify, investigate and solve problems. A brief explanations and examples of each step are provided below to assist teachers plan and teach each step. Students should be provided with opportunities to practice and reflect on each step until they demonstrate the expected level of proficiency before moving on to the next step.

Step 1: Identify and describe the problem

Problems are identified mainly from observations and the use the five senses – smell, sight, sound, touch and taste. Students should be guided and provided opportunities to identify natural and physical environment problems using their five senses and describe what the problem is and its likely causes.

Example: *Observation*

- When I turn on a flashlight using the on/off switch, light comes out of one end.

Step 2: Formulate research question

After the problem is identified and described, the question to be answered is then formulated. This question will guide the scientist in conducting research and experiments.

Example: *Question*

- What makes light comes out of a flash light when I turn it on?

Step 3: Review literature

It is more likely that the research problem and question have already been investigated and reported by someone. Therefore, after asking the question, the scientist spends some time reading and reviewing papers and books on past research and discussions to learn more about the problem and the question ask to prepare her for his own research. Conducting literature review helps the scientist to better understand his/her research problem, refine the research question and decide on experiment/research approach before the experiment is conducted.

Example: *Literature review*

- The scientist may look in the flashlight's instruction manual for tips or conduct online search on how flashlights work using the manufacturer's or relevant websites. Scientist may even analyse information and past experiments or discoveries regarding the relationship between energy and light.

Step 4: Formulate hypothesis

With a question in mind, the researcher decides on what he/she wants to test (The question may have changed as a result of the literature review).
The research will clearly state what he/she wants to find out by carrying out the experiment. He/She will make an educated guess that could answer the question or explain the problem. This statement is called a hypothesis. A hypothesis guides the experiment and must be testable.

Example: *Hypothesis*

- The batteries inside a flashlight give it energy to produce light when the flashlight is turned on.

Step 5: Conduct experiment

This step involves the design and conduct of experiment to test the hypothesis. Remember, a hypothesis is only an educated guess (a possible explanation), so it cannot be considered valid until an experiment verifies that it is valid.

Example: *Experimental Procedure*

- Remove the batteries from the flashlight, and try to turn it on using the on/off switch.
  Result: The flashlight does not produce light
- Reinsert the batteries into the flashlight, and try to turn it on using the on/off switch.
  Result: The flashlight does produce light.
- Write down these results

In general, it is important to design an experiment to measure only one thing at a time. This way, the researcher knows that his/her results are directly related to the one thing he/she changed. If the experiment is not designed carefully, results may be confusing and will not tell the researcher anything about his/her hypothesis.

Researchers collect data while carrying out their experiments. Data are pieces of information collected before, during, or after an experiment. To collect data, researchers read the measuring instruments carefully. Researchers record their data in notebooks, journals, or on a computer.

Step 6: Analyse data

Once the experiment is completed, the data is then analysed to determine the results. In addition, performing the experiment multiple times can be helpful in determining the credibility of the data.

Example: *Analysis*

- Record the results of the experiment in a table.
- Review the results that have been written down.

Step 7: Draw conclusions

If the hypothesis was testable and the experiment provided clear data, scientist can make a statement telling whether or not the hypothesis was correct. This statement is known as a conclusion. Conclusions must always be backed up by data. Therefore, scientists rely heavily on data so they can make an accurate conclusion.

If the data supports the hypothesis, then the hypothesis is considered correct or valid. If the data does not support the hypothesis, the hypothesis is considered incorrect or invalid.

Example: *Valid Hypothesis*

- The flashlight did not produce light without batteries. The flashlight did produce light when batteries were inserted.

Therefore, the hypothesis that batteries give the flashlight energy to produce light is valid, given that no changes are made to the flashlight during the experiment.

Example: *Invalid Hypothesis*

- The flashlight did NOT produce light when the batteries were inserted. Therefore, the hypothesis that batteries give the flashlight energy to produce light is invalid.

In this case, the hypothesis would have to be modified to say something like, "The batteries inside a flashlight give it energy to produce light when the batteries are in the correct order and when the flashlight is turned on." Then, another experiment would be conducted to test the new hypothesis.
An invalid hypothesis is not a bad thing! Scientists learn something from both valid and invalid hypotheses. If a hypothesis is invalid, it must be rejected or modified. This gives scientists an opportunity to look at the initial observation in a new way. They may start over with a new hypothesis and conduct a new experiment. Doing so is simply the process of scientific inquiry and learning.

Step 8: Communicate findings

Scientists generally tell others what they have learned. Communication is a very important component of scientific progress and problem solving. It gives other people a chance to learn more and improve their own thinking and experiments. Many scientists' greatest breakthroughs would not have been possible without published communication or results from previous experimentation.

Every experiment yields new findings and conclusions. By documenting both the successes and failures of scientific inquiry in journals, speeches, or other documents, scientists are contributing information that will serve as a basis for future research and for solving problems relating to both the natural and physical worlds. Therefore, communication of investigative findings is an important step in future scientific discovery and in solving social, political, economic, cultural, and environmental problems.

Example: *Communication of findings*

- Write your findings in a report or an article and share it with others, or present your findings to a group of people. Your work may guide someone else's research on creating alternative energy sources to generate light, additional uses for battery power, etc.

Teaching and Learning Strategies

Scientific teaching emphasises and embraces the use of cognitive, reasoning, decision-making, problem solving and higher level thinking skills to teach to enhance students' understanding of inter-disciplinary concepts and issues in relation to environment, geography, history, politics and economic within PNG and globally. It aims to provide a meaningful pedagogical framework for teaching and learning essential and in demand knowledge, skills, values, and attitudes that are required for the preparation of students for careers, higher education and citizenship in the 21st Century.

Students must be prepared to gather and understand information, analyse issues critically, learn independently or collaboratively, organize and communicate information, draw and justify conclusions, create new knowledge, and act ethically.

These teaching and learning strategies will help teachers to;

- familiarize themselves with different methods of teaching in the classroom
- develop an understanding of the role of a teacher for application of various
- methods in the classroom

Successful teachers always keep in view that teaching must "be dynamic, challenging and in accordance with the learner's comprehension. He/she does not depend on any single method for making his/her teaching interesting, inspirational and effective".

A detailed table of Teaching and Learning Strategies are outlined below:

STRATEGY	TEACHER	STUDENTS
CASE STUDY Used to extend students' under-standing of real life issues	Provide students with case studies related to the topic of the lesson and allow them to analyse and evaluate.	Study the case study and identify the problem addressed. They analyse the problem and suggest solutions supported by con-ceptual justifications and make presentations. This enriches the students' existing knowledge of the topic.
DEBATE A method used to increase students' interest, involvement and participation	Provide the topic or question of debate on current issues affect-ing a bigger population, clearly outlining the expectations of the debate. Explain the steps involved in debating and set a criteria/standard to be achieved.	Conduct researches to gather supporting evidence about the selected topic and summarising the points. They are engaged in collaborative learning by delegating and sharing tasks to group members. When debating, they improve their communication skills.

DISCUSSION The purpose of discussion is to educate students about the process of group thinking and collective decision.	The teacher opens a discussion on certain topic by asking essential questions. During the discussion, the teacher reinforces and emphasises on important points from students responses. Teacher guide the direction to motivate students to explore the topic in greater depth and the topic in more detail. Use how and why follow-up questions to guide the discussion toward the objective of helping students understand the subject and summarise main ideas.	Students ponder over the question and answer by providing ideas, experiences and examples. Students participate in the discussion by exchanging ideas with others.
GAMES AND SIMULATIONS **Encourages motivation and creates a spirit of competition and challenge to enhance learning**	Being creative and select appropriate games for the topic of the lesson. Give clear instructions and guidelines. The game selected must be fun and build a competitive spirit to score more than their peers to win small prices.	Go into groups and organize. Follow the instructions and play to win
OBSERVATION Method used to allow students to work independently to discover why and how things happen as the way they are. It builds curiosity.	Give instructions and monitor every activity students do	Students possess instinct of curiosity and are curious to see the things for themselves and particularly those things which exist around them. A thing observed and a fact discovered by the child for himself becomes a part of mental life of the child. It is certainly more valuable to him than the same fact or facts learnt from the teacher or a book. Students Observe and ask essential questions Record Interpret
PEER TEACHING & LEARNING (power point presentations, pair learning) Students teach each other using different ways to learn from each other. It encourages; team work, develops confidence, feel free to ask questions, improves communication skills and most importantly develop the spirit of inquiry.	Distribute topics to groups to research and teach others in the classroom. Go through the basics of how to present their peer teaching.	Go into their established working groups. Develop a plan for the topic. Each group member is allocated a task to work on. Research and collect information about the topic allocated to the group. Outline the important points from the research and present their findings in class.

PERFORMANCE-RELATED TASKS (dramatization, song/lyrics, wall magazines) Encourages creativity and take on the overarching ideas of the topic and are able to recall them at a later date	Students are given the opportunity to perform the using the main ideas of a topic. Provide the guidelines, expectations and the set criteria	Go into their established working groups. Being creative and create dramas, songs/lyrics or wall magazines in line with the topic.
PROJECT (individual/group) Helps students complete tasks individually or collectively	Teacher outline the steps and procedures of how to do and the criteria	Students are involved in investigations and finding solutions to problems to real life experiences. They carry out researches to analyse the causes and effects of problems to provide achievable solutions. Students carefully utilise the problem-solving approach to complete projects.
USE MEDIA & TECHNOLOGY to teach and generate engagement depending on the age of the students	Show a full movie, an animated one, a few episodes form documentaries, you tube movies and others depending on the lesson. Provide questions for students to answer before viewing	Viewing can provoke questions, debates, critical thinking, emotion and reaction. After viewing, students engage in critical thinking and debate

Strands, Units and Topics

Table of strand, units and topics

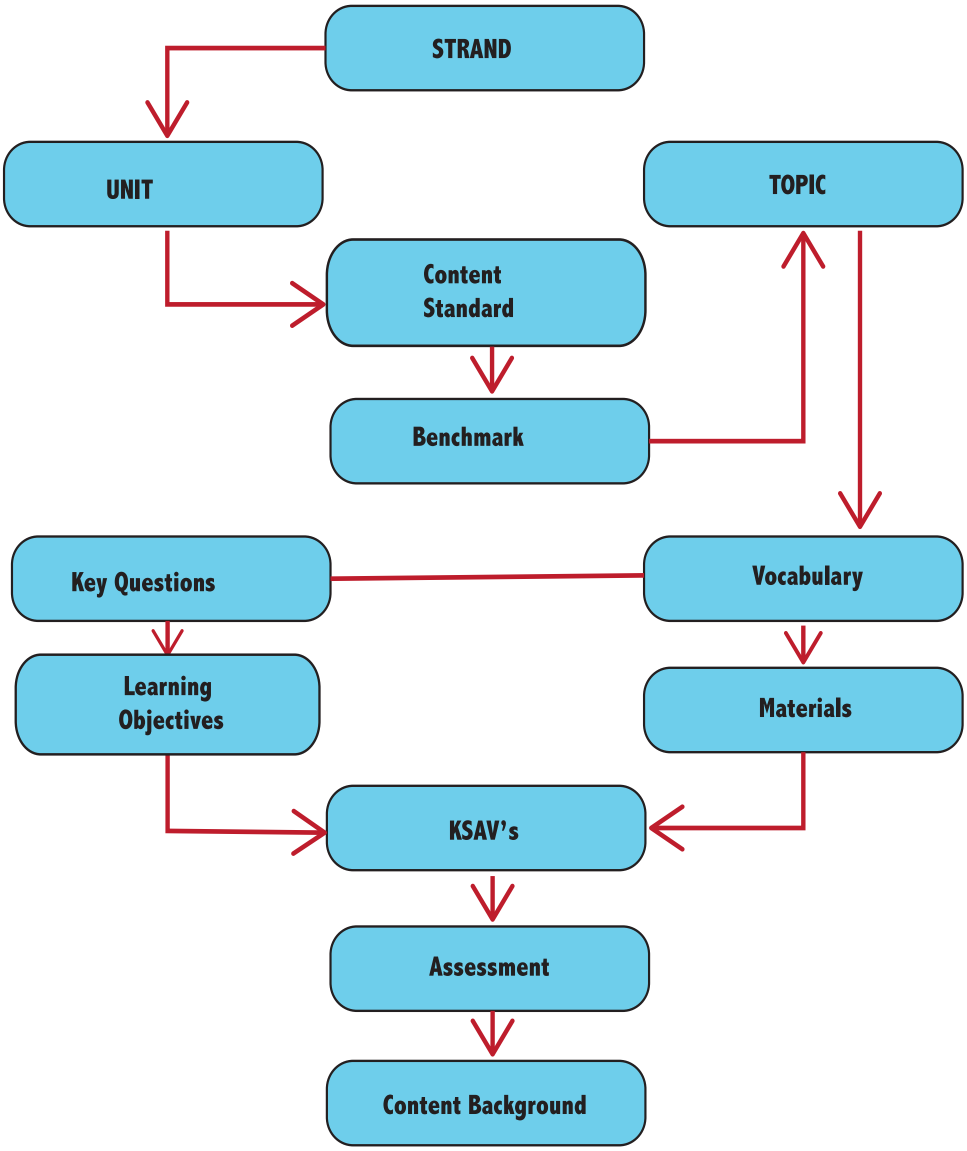
The table below outlines the contents of Grade 12 Physics in strands, units, topics and with the suggested lesson tittles to be in an academic year.
Teachers are provided with what will be taught under each of the four strands in a year. This overview will guide the teachers on how to plan their teaching programs for a school year in each term.

Strand	Unit	Topic	Lesson Title
Physical Science	Fluid Mechanics	Pressure and Density	Fluids in Physics: Definition and Characteristics
			What Is Density? - Explanation & Examples
			Specific Gravity (Definition and calculation)
			Atmospheric Pressure: Definition and Units and measurement.
		Static Fluid	Transmission of pressure in fluid (Pascal's Principle)
			Hydraulic Hoist (Application of Pascal's principle)
			Upthrust/Buoyancy force (Archimedes' Principle)
			Torricelli's Theorem
			Surface tension and Capillary action
		Fluid Dynamics	Fluid mass and Flow Rate
			Continuity Equation
			Bernoulli's Principle: Definition and Examples
			Bernoulli's Equation: Formula, Examples & Problems
			Viscosity and Laminar Flow: definition and examples
			Turbulent flow: definition and examples
			Predict Whether an Object Will Float or Sink: Understanding Density (Practical lesson)
		Heat and Temperature	Temperature Units, Converting Between Kelvins and Celsius
			Temperature measuring instruments
			Heat: Difference between temperature
	Thermal Physics	Heat transfer and capacity	Calorimetry: Measuring Heat Transfer and Heat Capacity
			Heat Transfer & Phase Changes
			Specific heat capacity of water
			Latent heat
			Thermal Expansion & Heat Transfer (Linear, volume and area expansion)
			Heat transfer (radiation, conduction and convection)
		Temperature in quantity of gas	The Kinetic Molecular Theory: Properties of Gases
			The Ideal Gas Law and the Gas Constant
			Using the Ideal Gas Law: Calculate Pressure and Volume
			Using the Ideal Gas Law: Calculate Temperature and Quantity of a Gas
			Boltzmann Constant and Planck's Principal

		Laws of Thermodynamics	The Zeroth Law of Thermodynamics
			First Law of Thermodynamics: Law of Conservation of Energy
			Second Law of Thermodynamics: Entropy and Systems
			Efficiency & the Carnot Cycle: Equations & Examples
	Waves	Wave Motion	Types of Waves (Transverse and Longitudinal Waves)
			Characteristics of Waves (λ, f, A, T and v)
			Reflection and Transmission of waves (phase reversal)
			Superposition of waves (Standing or Stationary waves)
			Nodes and Antinodes
		Water waves	The ripple tank
			Generating waves using ripple tank (Practical)
			Reflection and refraction of water waves
			Diffraction of water waves
			Interference of water waves (constructive and destructive interference and path difference)
		Light and Electromagnetic Spectrum	Diffraction and interference of light, constructive and destructive interference of light and bandwidth.
			Diffuse and Regular reflection
			Reflection Law and Snell's Law
			Light and Colour and The electromagnetic spectrum
			Radio waves and micro waves
			Infrared waves, Ultraviolet radiation, x-rays and gamma rays
		Sound Waves	Transmission of sound, (compression and rarefaction)
			Properties of sound in vacuum, solid and liquid
			Speed, pitch, loudness and quality of sound
			Ultrasonic waves
			Resonance and Beats
	Electromagnetism	Magnetic Fields and Forces	Magnetic Force: Definition, Poles & Dipoles
			What is a Magnetic Field?
			How Magnetic Fields Are Created
			How Magnetic Forces Affect Moving Charges
		Electromagnetic induction and Power Transmission	Electromagnetic Induction: Definition & Variables that Affect Induction
			Electromagnetic Induction: Conductor to Conductor & Transformers
			Transformers (examples and operating..)
			Power transmission (Power loss and voltage drop across transmission lines)
		Laws of Electromagnetism	Faraday's Law of Electromagnetic Induction: Equation and Application
			The Biot-Savart Law: Definition & Examples
			Ampere's Law: Definition & Examples
			Maxwell's Equations: Definition & Application

		Electric Motors and Generators	Electric Motors & Generators: Converting Between Electrical and Mechanical Energy
			AC motors and their parts
			DC motors and their parts
			Uses of AC and DC motors
			AC and DC generators
			Examples and uses of AC and DC generators
	Atomic and Nuclear physics	Atomic Physics	Atomic Structure (protons and nuclear number, isotopes)
			Planck's Constant: Formula & Application
			The Bohr Model and Atomic Spectra
			Wave-Particle Duality & the Davisson-Germer Experiment
			Heisenberg Uncertainty Principle: Definition & Equation
		Photons	Energy & Momentum of a Photon: Equation & Calculations
			Electron Cloud: Definition, Model & Theory
		Radioactive Decay	Nuclear Physics: Nuclear Force & Binding Energy
			Types of Radioactive Decay and Their Effect on the Nucleus
			Balancing Nuclear Equations & Predicting the Product of a Nuclear Reaction
			Alpha, beta and gamma decay
			Half-life: Calculating Radioactive Decay and Interpreting Decay Graphs
		Nuclear Reactions	Mass-Energy Conversion, Mass Defect and Nuclear Binding Energy
			Fusion, Fission, Carbon Dating, Tracers & Imaging: Applications of Nuclear Physics
			Disintegration Energy in Nuclear Physics: Definition & Formula
			Nuclear Reaction: Definition & Examples (Nuclear reactor)
			Applications of Nuclear Physics (Safety and Hazards)
			Applications of Nuclear Physics (Medical, industry and agriculture)

In this section, the content is arranged into topics, benchmarks together with the essential, knowledge, skills, attitudes and values. Learning objectives are provided for each topic in the units for the teacher to utilize in developing their lesson objectives.



Grade 12 Physics

Teaching Content

Strand 1: Science as Inquiry

Unit: Fluid Mechanics **Topic :** Quantities and Measurement

Content Standard 12.1.1	Students will be able to explain the nature and the processes of scientific inquiry and use the modes of scientific inquiry and habits of mind to investigate and interpret the world around them.
Benchmark 11.2.3.2	Identify appropriate quantities, their units and measurement methods using the metric system.

Key question(s):

- What is Physics?
- What are Physical Quantities?
- What are Standard and Derived SI Units?
- How do we convert them in different units?

Vocabulary:

Partial pressure, Diffusion, Effusion, Atmospheric pressure, Effervescence

Learning Objective(s)

By the end of the topic, students can:

- define physics and list the SI Standard Quantities
- differentiate between Standard units and Derived Units

Materials

Various measuring devices that can be found in the school, for example; meter rulers, galvanometer, voltmeter, ammeter, balance, tape measure, vernier caliper, micrometre screw gauge, etc.…

Knowledge	Skills	Attitudes and Values
• Demonstrate understanding of fundamental physics principles and models.	• Collecting, observing and analysing data from measurements. • Conduct investigations using equipment • Estimating, predicting and interpreting data. • Communicating scientific data.	• Being precise and accurate. • Making true judgements.

Assessment

- Students can be able to differentiate between standard and derived units
- Students can be able to convert standard and derived SI units

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

Refer to Gr 11 teacher guded to review content background on measuring instruments and physical quantities.

Strand 2: Physical Science

Unit: Fluid Mechanics **Topic:** Pressure and Density

Content Standard 12.2.1	Students will be able to explain and examine the structure and properties of fluids at rest and in motion
Benchmark 12.2.1.1	Explain density and pressure in solids

Key question(s):

- What are pressure and density?
- What is Specific Gravity?

Vocabulary:

pres pressure, density, specific gravity sure, density, specific gravity

Learning Objective(s)

By the end of the topic, students can:

- State the Characteristics of Fluids
- Explain density (in solids and liquids) and specific gravity and specify their units.

Materials

Diagrams of pressure and density measuring devices

Knowledge	Skills	Attitudes and Values
• Density = Mass/Volume The unit of Density is kgm^{-3} • Pressure is the force applied per unit area. P = F/A • Constant Atmospheric pressure is 101 325 Pascal or 760mmHg	• Explain static and dynamic fluid principles and applications. • Explain density and pressure in solids and liquids • Define pressure and solve problems involving pressure	• Appreciate the understanding of pressure in solids and liquids • Appreciative and questioning in investigating • Critical in solving problems involving pressure

Assessment

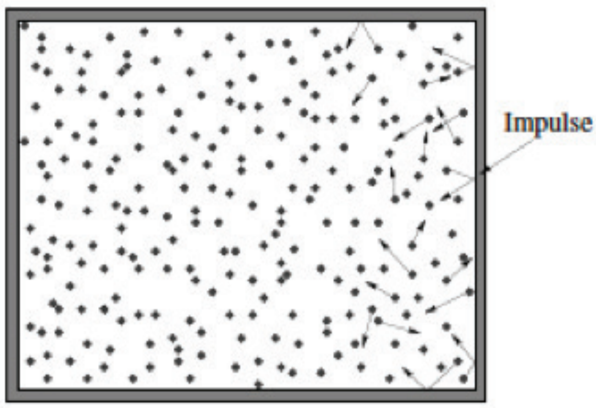
- Identify and explain the pressure properties in solids, liquids and gases using their properties.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

General Fluid Properties

Fluids are the generic name given to two states of matter, liquids and gases characterized by a lack of long-range order and a high degree of mobility at the molecular scale. Let us begin by visualising fluids microscopically, since we like to build our understanding of matter from the ground up.



A large number of atoms or molecules are confined within in a "box", where they bounce around each other and the walls. They exert a force on the walls equal and opposite the force the walls exert on them as the collisions more or less elastically reverse the particles' momenta perpendicular to the walls.

Pressure

When considering fluids, to describe the forces that confine and act on the fluids in terms of pressure, defined to be the force per unit area with which a fluid pushes on a confining wall or the confining wall pushes on the fluid:

$$P = \frac{F}{A}$$

Pressure gets its own SI units, which clearly must be Newton's per square metre. We give these units their own name, Pascal's:

$$1\,Pascal = \frac{Newton}{metre^{2}}$$

A Pascal is a tiny unit of pressure whereas a Newton is not very big, recall (one kilogram weighs roughly ten Newton's or 2.2 pounds) so a Pascal is the weight of a quarter pound spread out over a square metre. Writing out "Pascal" is a bit cumbersome and you'll see it sometimes abbreviated Pa (with the usual power-of-ten modifications, kPa, MPa, GPa, mPa and so on).
A more convenient measure of pressure in our everyday world is a form of the unit called a bar:

$$1bar = 10^{5}\ Pa = 100kPa$$

The symbol atm stands for one standard atmosphere. The connection between atmospheres, bars, and pascals is:

$$1\,standard\ atmosphere = 101.325kPa = 1013.25mbar$$

The extra significant digits therefore refer only to a fairly arbitrary value (in pascals) historically related to the original definition of a standard atmosphere in terms of "millimeters of mercury" or torr:

$$1\ standard\ atmosphere = 760.00mmHG = 760.00torr$$

Density

As we have done from almost the beginning, let us note that even a very tiny volume of fluid has many, many atoms or molecules in it, at least under ordinary circumstances in our everyday lives. True, we can work to create a vacuum – a volume that has relatively few molecules in it per unit volume, but it is almost impossible to make that number zero – even the hard vacuum of outer space has on average one molecule per cubic meter or thereabouts. We live at the bottom of a gravity well that confines our atmosphere – the air that we breathe – so that it forms a relatively thick soup that we move through and breathe with order of Avogadro's Number (6×10^{23}) molecules per liter – hundreds of billions of billions per cubic centimeter.

We could just count molecules in these tiny volumes, but the properties of oxygen molecules and helium molecules might well be very different, so the molecular count alone may not be the most useful quantity. Since we are interested in how forces might act on these small volumes, we need to know their mass, and thus we define the density of a fluid to be:

$$p = \frac{dm}{dv}$$

The mass per unit volume we are all familiar with from our discussions of the center of mass of continuous objects and moments of inertia of rigid objects.

The principle of flotation states that:

A floating object displaces its own weight of fluid in which it floats

Specific Gravity

The specific gravity of a substance may be defined as the ratio of the density of the substance to the density of water.

$$SG = \frac{Density\ of\ subs\tan ce}{density\ of\ water}$$

The SG of an object which floats in water may be determined approximately by noting what fraction of its volume is under the surface as it floats.

Unit: Fluid Mechanics **Topic:** Static

Benchmark 12.2.1.2	Describe static and dynamic fluid principle and applications

Key question(s):

- How can we explain transmission of fluids in Density, Carpilary action, Pascal's Principle?
- What is a hydraulic hoist and how does it function?

Vocabulary:

Density, Carpilary action, Surface tension

Materials

Diagrams of pressure and density measuring devices

Learning Objective(s)

By the end of the topic, students can:

- Explain how pressure is transmitted in fluids.
- Explain and give examples of hydraulic hoists.

Knowledge	Skills	Attitudes and Values
• Pascal's principle in fluid • Fluid pressure calculation • Pressure in solids is a function of the applied force and the area of surface to which the force is applied	• Explain pressure in solids and liquids. • State the Pascal's principle in fluids and hydraulic hoist	• Appreciate the application of pressure transmission in modern mechanisms.

Assessment

- Students can be able to explain the transmission of pressure in fluids and give some examples of mechanisms that pressure to do work.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

The **pressure** exerted by a **static fluid** depends only upon the depth of the fluid, the density of the **fluid,** and the acceleration of gravity. The most remarkable thing about this expression is what it does not include. The **fluid pressure** at a given depth does not depend upon the total mass or total volume of the liquid.

Static Fluid Pressure

The pressure exerted by a static fluid depends only upon the depth of the fluid, the density of the fluid, and the acceleration of gravity.

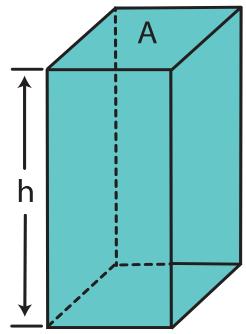
The pressure in a static fluid arises from the weight of the fluid and is given by the expression

$$\infty = m/V = \textit{fluid density}$$

$$P_{\textit{static fluid}} = \infty gh \textit{ where } \quad g = \textit{acceleration of gravity}$$

$$h = \textit{depth of fluid}$$

The pressure from the weight of a column of liquid of area A and height h is

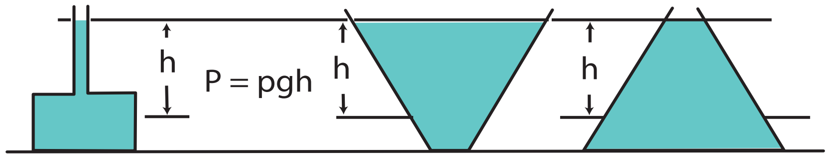


$V = hA = \text{volume}$

$\text{weight} = mg$

Static fluid pressure does not depend on the shape, total, or surface area of the liquid.

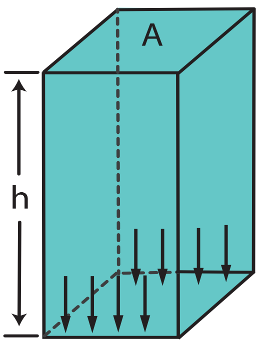
$$\text{Presure} = \frac{\text{weight}}{\text{area}} = \frac{mg}{A} = \frac{pVg}{A} = pgh$$



The most remarkable thing about this expression is what it does not include. The fluid pressure at a given depth does not depend upon the total mass or total volume of the liquid. The above pressure expression is easy to see for the straight, unobstructed column, but not obvious for the cases of different geometry which are shown.

Because of the ease of visualizing a column height of a known liquid, it has become common practice to state all kinds of pressures in column height units, like mmHg or cm H_2O, etc. Pressures are often measured by manometres in terms of a liquid column height.

Fluid Pressure Calculation



Pressure at depth h:
$P = pgh$

Fluid column height in the relationship

Pressure Difference $\textbf{\textit{Pressure Difference}} \rightarrow \Delta P = P_2 - P_1 = pgh$

is often used for the measurement of pressure. After entering the relevant data, any one of the highlighted quantities below can be calculated by

$$\textbf{\textit{Pressure Difference}} \rightarrow \Delta P = P_2 - P_1 = pgh$$

Note that this static fluid pressure is dependent on density and depth only; it is independent of total mass, weight, volume, etc. of the fluid.

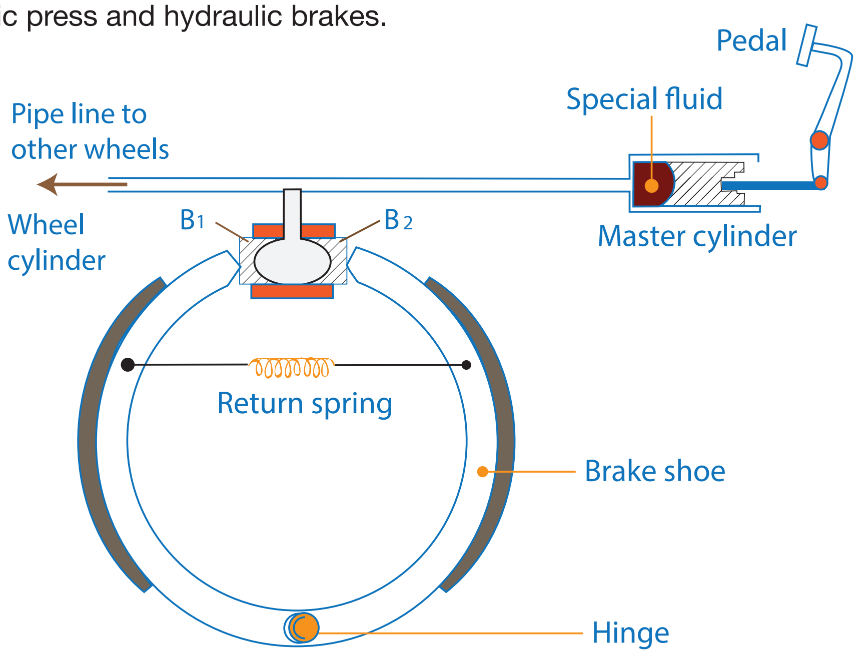
Pascal's Law

Pascal's law states that pressure applied to an enclosed liquid, is transmitted equally to every part of the liquid.

This can be demonstrated using a glass vessel as shown in figure above. When force is applied to the piston the pressure exerted on the water is transmitted equally throughout the water so that water comes out of all the holes with equal force.

When pressure is applied at a point in a confined fluid, it is transmitted equally in all directions.

Hydraulic devices like hydraulic press and car brakes are based on the above principle.
The transmission of power is made use of in hydraulic machines where a small force applied at one point is made to exert a much larger force at some other point. This principle is made use of in the working of a hydraulic press and hydraulic brakes.



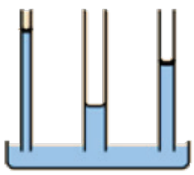
Hydraulic brake system

This system of braking is shown in figure above. A cylinder having two opposed pistons expands the brake shoes. These are forced outwards by liquid under pressure conveyed by a pipe from the master cylinder. The brake pedal works the piston of the master cylinder. When pressure on pedal is released, the brake shoe pull-off springs force the wheel piston back into the cylinders and the liquid is returned to the master cylinder. A very important advantage of this system is that the pressure set up in the master cylinder is transmitted equally to all four-wheel cylinders so that the braking effort is equal on all the wheels.

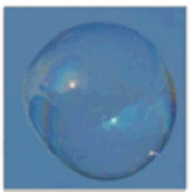
Surface Tension

The cohesive forces between liquid molecules are responsible for the phenomenon known as surface tension. The molecules at the surface do not have other like molecules on all sides of them and consequently they cohere more strongly to those directly associated with them on the surface. This forms a surface "film" which makes it more difficult to move an object through the surface than to move it when it is completely submersed.

Surface tension is typically measured in dynes/cm, the force in dynes required to break a film of length 1 cm. Equivalently, it can be stated as surface energy in ergs per square centimetre. Water at 20°C has a surface tension of 72.8 dynes/cm compared to 22.3 for ethyl alcohol and 465 for mercury.

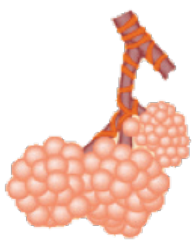


Surface tension and capillarity



Surface tension and bubbles

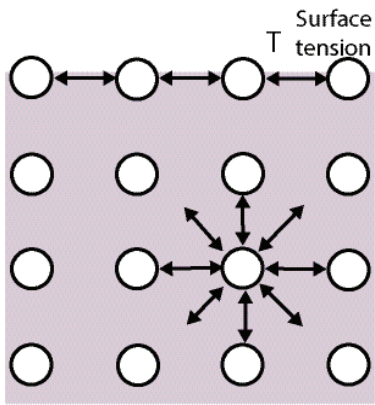
Surface tension and droplets



Alveoli of lungs

Other surface tension examples.

Cohesion and Surface Tension



The cohesive forces between molecules down into a liquid are shared with all neighbouring atoms. Those on the surface have no neighbouring atoms above and exhibit stronger attractive forces upon their nearest neighbours on the surface. This enhancement of the intermolecular attractive forces at the surface is called surface tension.

Surface Tension of Water

The surface tension of water is 72 dynes/cm at 25°C . It would take a force of 72 dynes to break a surface film of water 1 cm long. The surface tension of water decreases significantly with temperature as shown in the graph. The surface tension arises from the polar nature of the water molecule.

Hot water is a better cleaning agent because the lower surface tension makes it a better "wetting agent" to get into pores and fissures rather than bridging them with surface tension. Soaps and detergents further lower the surface tension.

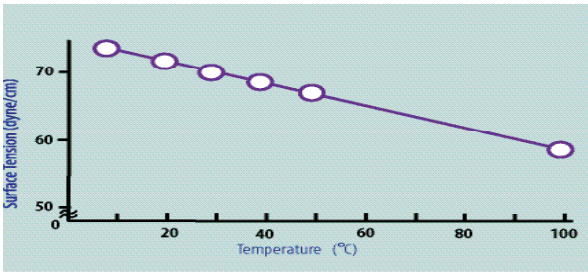


Figure Surface Tension of Water

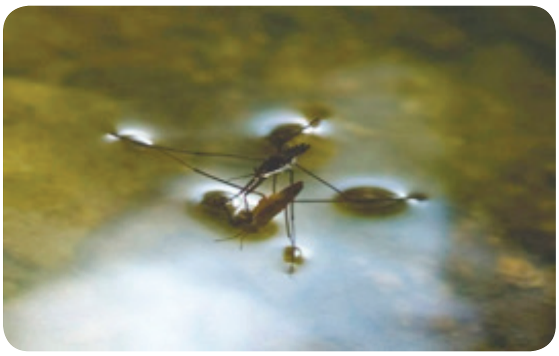
Cohesion and Adhesion

Molecules in the liquid state experience strong intermolecular attractive forces. When those forces are between like molecules, they are referred to as cohesive forces. For example, cohesive forces hold the molecules of a water droplet together, and the especially strong cohesive forces at the surface constitute surface tension.

When the attractive forces are between unlike molecules, they are said to be adhesive forces. The adhesive forces between water molecules and the walls of a glass tube are stronger than the cohesive forces lead to an upward turning meniscus at the walls of the vessel and contribute to capillary action.

The attractive forces between molecules in a liquid can be viewed as residual electrostatic forces and are sometimes called van der Waals forces or van der Waals bonds.

Surface Tension and the Water Strider



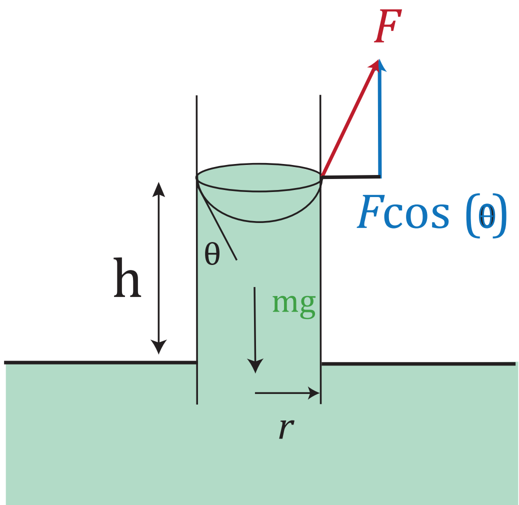
This interesting insect can freely run along the surface of a quiet pond. Its tiny mass and the geometry of its legs allow it to be supported by the high surface tension of water.

Adhesion and surface tension together can produce capillary action. Capillary action occurs when the adhesion to the walls is stronger than the cohesive forces between the liquid molecules. Adhesion of water to the walls of a vessel results in an upward force on the liquid at the edges. The surface tension keeps the surface intact, so the whole liquid surface is dragged upward.

The maximum height to which the liquid will rise through capillary action is given by:

$$h = 2\,F\,\cos\theta\,/\,(mgr)$$

Then the weight of the risen liquid is balanced by the surface tension.



Unit: Fluid Mechanics **Topic:** Static Fluid

Benchmark 12.2.1.2	Describe static and dynamic fluid principle and applications

Key question(s):

- What is flow rate?
  Density, Capillary action,
- How is the continuity equation used?
  Surface tension
- How is Bernoulli's principle derived?

Vocabulary:

Density, Carpilary action, Surface tension

Learning Objective(s)

By the end of the topic, students can:

- Explain the principles of fluid dynamics
- Use Bernoulli's equation to solve problems.

Materials

Diagrams of laminar and turbulent flow and a diagram to derive Bernoulli's equation.

Knowledge	Skills	Attitudes and Values
• Flow rates and equation of continuity • Bernoulli's Equation • Viscosity and Laminar • Turbulent flow. • Floating and density	• Find flow rates using equation of continuity. • Use Bernoulli's Equation to solve problems • Explain the relationship between viscosity and laminar	• Appreciate the understand and the Bernoulli's equation • Optimistic and questioning in investigating principles of floatation and density.

Assessment

- Students can differentiate between laminar and turbulent flow.
- Students can derive Bernoulli's equation step by step.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

In physics and engineering, **fluid dynamics** is a subdiscipline of **fluid** mechanics that describes the **flow** of **fluids**—liquids and gases. It has several subdisciplines, including aerodynamics (the study of air and other gases in motion) and hydrodynamics (the study of liquids in motion).

What is flow?

The movement of liquids and gases is generally referred to as "flow," a concept that describes how fluids behave and how they interact with their surrounding environment — for example, water moving through a channel or pipe, or over a surface. Flow can be either steady or unsteady. In his lecture notes, "Lectures in Elementary Fluid Dynamics" (University of Kentucky, 2009) J. M. McDonough, a professor of engineering at the University of Kentucky, writes, "If all properties of a flow are independent of time, then the flow is steady; otherwise, it is unsteady." That is, steady flows do not change over time. An example of steady flow would be water flowing through a pipe at a constant rate. On the other hand, a flood or water pouring from an old-fashioned hand pump are examples of unsteady flow.

Flow can also be either laminar or turbulent. Laminar flows are smoother, while turbulent flows are more chaotic. One important factor in determining the state of a fluid's flow is its viscosity, or thickness, where higher viscosity increases the tendency of the flow to be laminar. Patrick McMurtry, an engineering professor at the University of Utah, describes the difference in his online class notes, "Observations About Turbulent Flows" (University of Utah, 2000), stating, "By laminar flow we are generally referring to a smooth, steady fluid motion, in which any induced perturbations are damped out due to the relatively strong viscous forces. In turbulent flows, other forces may be acting the counteract the action of viscosity."

Laminar flow is desirable in many situations, such as in drainage systems or airplane wings, because it is more efficient and less energy is lost. Turbulent flow can be useful for causing different fluids to mix together or for equalising temperature. According to McDonough, most flows of interest are turbulent; however, such flows can be very difficult to predict in detail, and distinguishing between these two types of flow is largely intuitive.

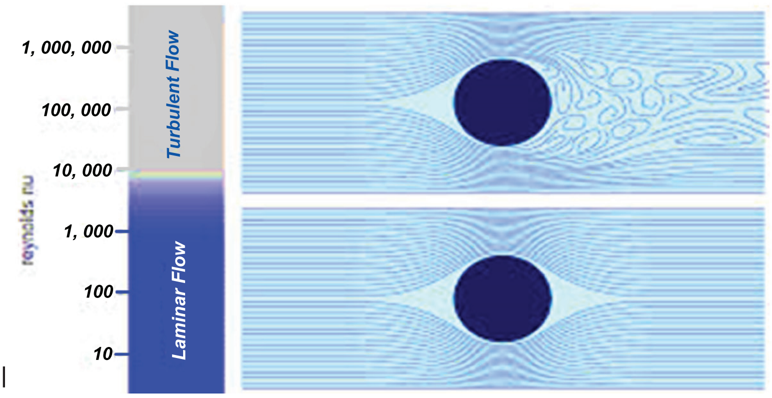


Figure: Tuerlant l

Bernoulli's Equation

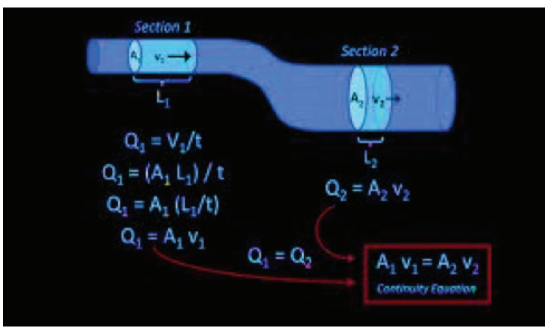
Bernoulli's Equation tells us how much the pressure within a moving fluid increases or decreases as the speed of the fluid changes.

$$P_a + \frac{1}{2}pv_a^2 + pgh_a = P_b + \frac{1}{2}pv_b^2 + pgh_b$$

Where;

- a is the first point along the pipe
- b is the second point along the pipe
- P is static pressure in newton per metre squared
- ρ is density in kilograms per metre cubed
- v is the velocity in metres per second
- g is gravitational acceleration in metres per second squared
- h is height in metres

Continuity Equation



Unit: Thermal Physics **Topic:** Heat and Temperature

Content Standard 12.2.2	Students will be able to examine and explain the structure properties of fluids at rest and in motion.
Benchmark 12.2.2.1	Define heat and temperature and calculate the efficiency of energy transfer within physical systems

Key question(s):

- What is the difference between heat and temperature?
- How do we convert from Kelvin, Celsius and Fahrenheit?
- What instrument are used to measure temperature?

Vocabulary:

Heat, temperature

Learning Objective(s)

By the end of the topic, students can:

- Differentiate between heat and temperature.
- Describe specific heat and its units.

Materials

Temperature measuring devices (or diagrams)

Knowledge	Skills	Attitudes and Values
• Definition of heat and its units • Specific and latent heat • Heat capacity and specific heat capacity • Effeciency of energy transfer	• Explain and give examples of heat and temperature.	• Appreciate the ways in which heat is transferred

Assessment

- Define heat and temperature and calculate the efficiency of energy transfer within physical systems

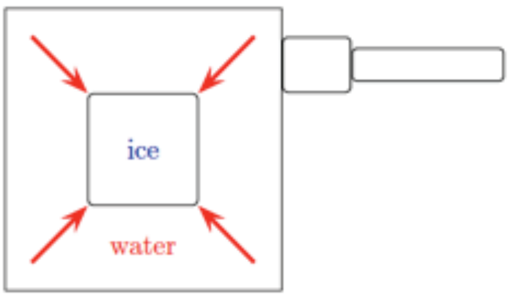
Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

Heat is a form of energy. The term ‘heat’ is used to describe the energy transferred through the heating process.

Temperature is a measure of the average kinetic energy of the particles in a body.

It should now be clear that heat is nothing more than energy on the move. It can be carried by atoms, molecules or electromagnetic radiation but it is always just transport of energy. This is very important when we describe movement of heat, as we will do in the following sections. `Cold’ is not a physical thing. It does not move from place to place, it is just the word for a lack of heat, just like dark is the word for an absence of light.



A heat flow diagram showing the heat flowing from the warmer water into the cooler ice cube.

Temperature scales

Scale	Symbol	Definition
Fahrenheit	°F	Temperature at which an equal mixture of ice and salt melts =0°F Temperature of blood =96°F
Celsius	°C	Temperature at which water freezes=0°C Temperature at which water boils =100°C
Kelvin	K	Absolute zero is 0K Triple point of water is 273.15K

It turns out that the freezing point of water, 0± C, is equal to 273: 15 K. So, in order to convert from Celsius to kelvin need to subtract 273.15.

Unit: Thermal Physics — **Topic:** Heat Transfer and Capacity

Benchmark 12.2.2.1	Define heat and temperature and calculate the efficiency of energy transfer within physical systems

Key question(s):

- How is heat transferred from different mediums?
- What is change of state?
- What is heat capacity and latent heat?

Vocabulary:

Heat Capacity, Latent Heat

Learning Objective(s)

By the end of the topic, students can:

- Solve examples and problems on the amount of heat required to change temperature and phase of a substance.

Materials

Temperature measuring devices (or diagrams)

Knowledge	Skills	Attitudes and Values
• Heat transfer by means of conduction, convection and radiation. • Thermal conductors and insulators	• Explain how heat is transferred from one body to another.	• Appreciate the ways in which heat is transferred

Assessment

- Research the nature of solids, liquids and gases by examining their molecular structures.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

The Caloric Theory

The most accepted notion of heat was one that associated it with a fluid known as caloric. Noted chemist Antoine Lavoisier reasoned that there were two forms of **caloric** - the kind that was **latent** or stored in combustible materials and the kind that was **sensible** and observable through a temperature change.

Heat transfer by Conduction

Conduction is the primary mode of heat transfer in solid. When one end of a solid is heated, you are not able to observe molecular motion in the heated solid, but you can intuitively that the molecules that make up solid are in violent motion colliding with each other. The molecules in contact or near the heat source are acquiring higher energies than their near neighbors farther away from the source. Collisions between the more energetic molecules and the molecules with less energy lead to transfer of energy from the molecules nearer the hot end of the solid to those at the cool end of the solid. In time the whole solid gets hot.

Heat transfer by Conduction

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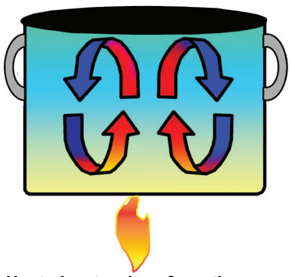
Heat transfer by Convection

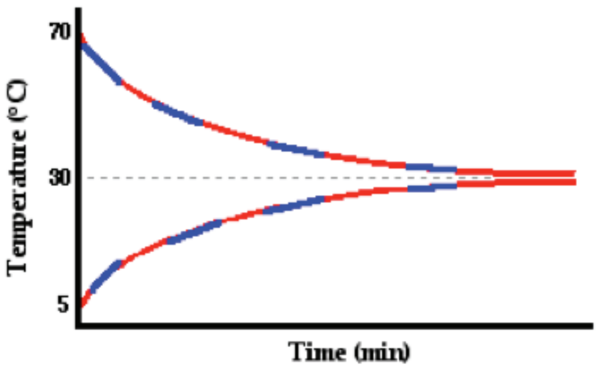
- Heat transfer through solids occurs by conduction. This is primarily due to the fact that solids have orderly arrangements of particles that are fixed in place. Liquids and gases are not very good conductors of heat.
- Heat typically does not flow through liquids and gases by means of conduction. Liquids and gases are fluids; their particles are not fixed in place; they move about the bulk of the sample of matter.
- **Convection** is the process of heat transfer from one location to the next by the movement of fluids. The moving fluid carries energy with it. The fluid flows from a high temperature location to a low temperature location.



Heated water rises from the bottom to the top of the pot. Cold water replaces the rising water.

Heat Transfer by Radiation

A final method of heat transfer involves radiation. Radiation is the transfer of heat by means of **electromagnetic waves**. To radiate means to send out or spread from a central location. Whether it is light, sound, waves, rays, flower petals, wheel spokes or pain, if something radiates then it protrudes or spreads outward from an origin. The transfer of heat by radiation involves the carrying of energy from an origin to the space surrounding it. The energy is carried by electromagnetic waves and does not involve the movement or the interaction of matter. Thermal radiation can occur through matter or through a region of space that is void of matter (i.e., a vacuum). In fact, the heat received on Earth from the sun is the result of electromagnetic waves traveling through the void of space between the Earth and the sun.
Graph showing changes in water temperature



The blue lines represents the slopes at various times.
The slope decreases over the course of the experiment.

In the graphs in the previous page, the slope of the line represents the rate at which the temperature of each individual sample of water is changing. The temperature is changing because of the heat transfer from the hot to the cold water. The hot water is losing energy, so its slope is negative. The cold water is gaining energy, so its slope is positive

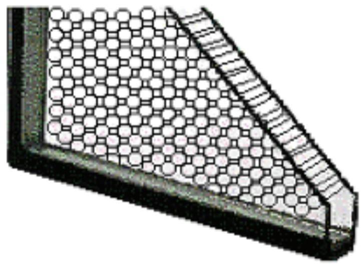
Variables that are affected in the process of heat transfer

1. Material

The first variable that we have identified as affecting the rate of conductive heat transfer is the temperature difference between the two locations. The second variable of importance is the materials involved in the transfer. The effect of a material upon heat transfer rates is often expressed in terms of a number known as the thermal conductivity

2. Area

Another variable that affects the rate of conductive heat transfer is the area through which heat is being transferred.



A window can be thought of as consisting of a countless number of tiny columnar rods through which heat is conducted. Larger windows consist of a greater number of rods.

3. Thickness or Distance

A final variable that affects the rate of conductive heat transfer is the distance that the heat must be conducted.

Let's consider the transfer of heat through a glass window from the inside of a home with a temperature of $\mathbf{T_1}$ to the outside of a home with a temperature of $\mathbf{T_2}$. The window has a surface area **A** and a thickness d. The thermal conductivity value of the window glass is k. The equation relating the heat transfer rate to these variables is

$$\textbf{Rate} = \mathbf{k \cdot A \cdot (T1 - T2)/d}$$

The units on the rate of heat transfer are Joule/second, also known as a Watt. This equation is applicable to any situation in which heat is transferred in the same direction across a flat rectangular wall.

Specific Heat Capacity

The ***specific heat capacity*** refers to the amount of heat required to cause a unit of mass (say a gram or a kilogram) to change its temperature by 1°C Heat capacities are listed on a *per gram or per kilogram* basis. Occasionally, the value is listed on a per mole basis, in which case it is called the **molar heat capacity**. The fact that they are listed on a per amount basis is an indication that the quantity of heat required to raise the temperature of a substance depends on how much substance there is.

Specific Heat Capacity
Joule/gram/°C

Molar Heat Capacity
Joule/mole/°C

Specific heat capacities provide a means of mathematically relating the amount of thermal energy gained (or lost) by a sample of any substance to the sample's mass and its resulting temperature change. The relationship between these four quantities is often expressed by the following equation.

Q = m•C•wT

Where **Q** is the quantity of heat transferred to or from the object, **m** is the mass of the object, **C** is the specific heat capacity of the material the object is composed of, and w**T** is the resulting temperature change of the object.

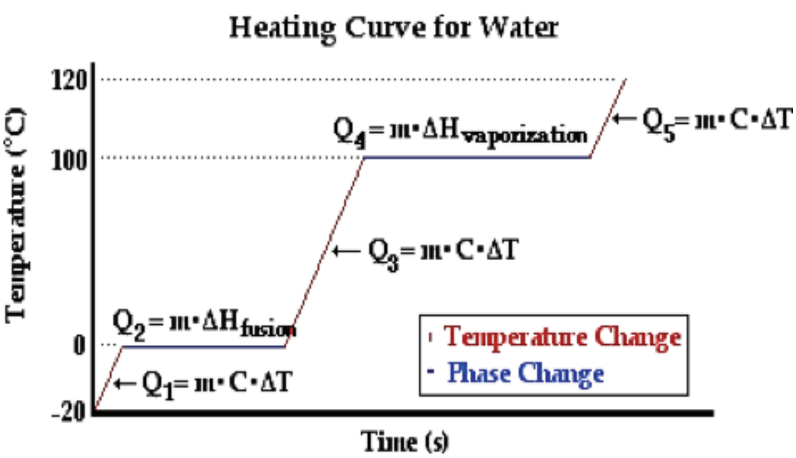
Table of Heat and Changes of state

Process	Change of State
Melting	Solid to Liquid
Freezing	Liquid to Solid
Vaporization	Liquid to Gas
Condensation	Gas to Liquid
Sublimation	Solid to Gas
Deposition	Gas to Solid

The **heat of fusion** is the energy change associated with the solid-liquid state change
The heat of vaporization is the energy associated with the liquid-vapour(gas) change

1. For melting and freezing: $Q = m \cdot \Delta H_{fusion}$
2. For vaporization and condensation: $Q = m \cdot \Delta H_{vaporization}$

Graph showing Heating and Cooling curves of Water



The quantity of heat transferred to the water in $Q1$, $Q3$, and $Q5$ is related to the mass of the sample and the temperature change by the formulae
Q = m•C•w**T.** And the quantity of heat transferred to the water in Q_2 and Q_4 is related to the mass of the sample and the heat of fusion and vaporization by the formulae **Q = m•**w**H** $_{fusion}$ ($Q2$) and **Q = m•**w**H** $_{vaporization}$ (Q 4). So now, we will make an effort to calculate the quantity of heat required to change 50.0 grams of water from the solid state at -20.0°C to the gaseous state at 120.0°C.

Unit: Thermal Physics **Topic:** Temperature in Quantity of Gases

Benchmark 12.2.2.2	Research the nature of solids, liquids and gasses by examining their molecular structures.

Key question(s):

- What are the ideal gas laws and gas constants?
- How can we use gas laws to calculate Temperature, Pressure and Volume?
- What are Boltzmann Constant and Planck's Principle?

Vocabulary:

Ideal gas, Plank's constant

Learning Objective(s)

By the end of the topic, students can:

- Use ideal gas laws and kinetic molecular theory to determine the temperature in a certain quantity of gases.

Materials

Diagrams of gas particles in a fixed volume at certain temperatures.

Knowledge	Skills	Attitudes and Values
• Kinetic Molecular Theory • State Properties of Gases • Use Ideal Gas to solve problems • Boltzmann Constant and Planck's Principle	• Explain how to determine the temperature in a quantity of gas.	• Appreciative and questioning in investigating Kinetic theory and properties of gases • Appreciate the understanding of Boltzmann Constant and Planck's

Assessment

- Research the nature of solids, liquids and gases by examining their molecular structures.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

Ideal Gas Law which is usually written as:

$$p \cdot V = n \cdot R \cdot T$$

p	:	pressure (Pa)
V	:	Volume (m^3)
n	:	number of mols (mol)
R	:	gas konstant $(J/molK)$
T	:	temperature (K)

where p = pressure, V = volume, n = number of moles, T = kelvin temperature and R the ideal gas constant.

Ideal gas 1: We solve the ideal gas equation for the volume

V =nRT/p

Ideal gas 2: pV = nRT

Another value which is sometimes convenient is 0.08206 dm3 atm/mol K.
R is related to the Boltzmann-constant as:

R=N_o×k_B

Ideal gas 1: We solve the ideal gas equation for the volume

V =nRT/p

Ideal gas 2: pV = nRT

Kinetic theory of gases
The kinetic-molecular theory of gases can be stated as four postulates:

- A gas consists of particles (atoms or molecules) in continuous, random motion.
- Gas molecules influence each other only by collision; they exert no other forces on each other.
- All collisions between gas molecules are perfectly elastic; all kinetic energy is conserved.
- The average energy of translational motion of a gas particle is directly proportional to temperature.

deal gas 1: We solve the ideal gas equation for the volume

V =nRT/p

Another value which is sometimes convenient is 0.08206 dm3 atm/mol K.
R is related to the Boltzmann-constant as:

$$R = N_o \times k_B$$

Where N_O is the number of molecules in a mol of a substance, i.e. 6.022¢1023 and kB is1.308¢10^{-23} J/K is valid for one single particle.

Ideal gas 1: We solve the ideal gas equation for the volume

$$V = nRT/p$$

Ideal gas 2: pV = nRT

Kinetic theory of gases

The kinetic-molecular theory of gases can be stated as four postulates:

1. A gas consists of particles (atoms or molecules) in continuous, random motion.
2. Gas molecules influence each other only by collision; they exert no other forces on each other.
3. All collisions between gas molecules are perfectly elastic; all kinetic energy is conserved.
4. The average energy of translational motion of a gas particle is directly proportional to temperature.

Unit: Thermal Physics **Topic:** Laws of Thermodynamics

Benchmark 12.2.2.3	Deduce and apply the laws of thermodynamics to solve problems involving thermodynamics.

Key question(s):

- What is Zeroth Law of Thermodynamics?
- What is the Law of Energy Conservation?
- What does Energy Efficiency mean?

Vocabulary:

Thermodynamics

Learning Objective(s)

By the end of the topic, students can:

- Apply the laws of thermodynamics to answer questions involving thermodynamics.

Materials

Diagrams of gas particles in a fixed volume at certain temperatures.

Knowledge	Skills	Attitudes and Values
• Law of Conservation of Energy • Laws of Thermodynamics' • Zeroth's Law of Thermodynamics	• Explain thermodynamics laws and apply it mathematically.	• Sceptical and questioning in investigating law of conservation of Energy and Energy Efficiency

Assessment

- Deduce and apply the laws of thermodynamics to solve problems involving thermodynamics.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

The first law of thermodynamics

The first law of thermodynamics refers to the conservation of different types of energy which are states that:

Energy cannot be created or destroyed but is just transformed from one form into another.

There are two ways of transferring energy to a system, heat and work. This transfer causes a change in the internal energy of the system.

Internal energy is defined as the sum of the kinetic energy and the potential energy of interaction of the molecules of a system. For an ideal gas, this can be identified with the kinetic energy of the gas molecules.

¢E = ¢Q ¡ ¢W (First law of thermodynamics)

The second law of thermodynamics

The second law of thermodynamics has many equivalent statements, among them being the flow of heat from hot to cold, the efficiency of thermal (Carnot) engines, entropy,
One statement relates to the spontaneity of processes. In terms of entropy, the second law can be stated as:

In a spontaneous process, the entropy of the Universe increases

The third law of thermodynamics

The entropy of a perfect crystal at absolute zero is exactly equal to zero.
The entropy change of a system undergoing reversible, isothermal changes tends to zero as TT tends to zero.

It is impossible in a finite number of steps to reduce the entropy of a system to its T=0T=0 value.

The Zeroeth Law of Thermodynamics

In our chapter on electric circuits, we learned that a difference in electric potential between two locations causes a flow of charge along a conducting path between those locations. As long as an electric potential difference is maintained, a flow of charge will exist. Now in this chapter we learn a similar principle related to the flow of heat. A temperature difference between two locations will cause a flow of heat along a (thermally) conducting path between those two locations. As long as the temperature difference is maintained, a flow of heat will occur. This flow of heat continues until the two objects reach the same temperature. Once their temperatures become equal, they are said to be at thermal equilibrium and the flow of heat no longer takes place.

This principle is sometimes referred to as the **zeroeth law of thermodynamics.** This principle became formalized into a law after the first, second and third laws of thermodynamics had already been discovered.

Unit: Waves **Topic:** Wave Motion

Content Standard 12.2.3	Students will be able to analyse and apply the properties, types and patterns of waves in energy transfer.
Benchmark 12.2.3.1	Analyse and compare transverse and longitudinal waves and their properties.

Key question(s):

- What are longitudinal and transverse waves?
- What are the characteristics of waves?

Vocabulary:

Transverse wave, longitudinal wave.

Learning Objective(s)

By the end of the topic, students can:

- Define the types of waves and explain their characteristics

Materials

Rope, long spring,

Knowledge	Skills	Attitudes and Values
• Transverse waves are waves that each point on the wave vibrates at right angles to the direction of the wave. • Longitudinal waves are those in which the points on the wave vibrate parallel to the direction of the wave.	• Explain the wave phenomena in the physical and natural world.	• Appreciate the applications of waves in the physical and natural world.

Assessment

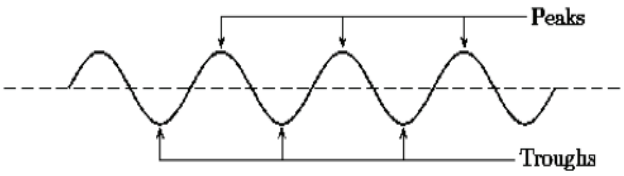
- Analyse and compare transverse and longitudinal waves using their properties.

Teacher to develop assessment rubric on the assessment tasks mentioned above using samples provided in the assessment section

Content Background

What are waves?

Waves are disturbances that propagate through a medium. Waves can be viewed as an energy transfer rather than the movement of a particle. Particles form the medium through which waves propagate but they are not the wave. This will become clearer later. Let's consider one case of waves, water waves. Waves in water consist of moving peaks and troughs. A peak is a place where the water rises higher than when the water is still and a trough is a place where the water sinks lower than when the water is still. A single peak or trough we call a pulse. A wave consists of a train of pulses. So waves have peaks and troughs. This could be our first property for waves. The following diagram shows the peaks and troughs on a wave.

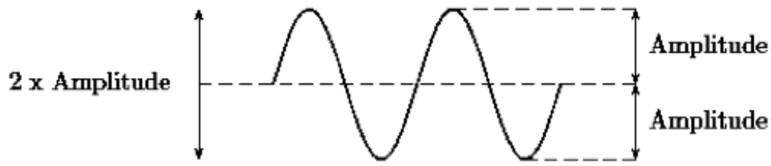


In physics we try to be as quantitative as possible. If we look very carefully we notice that the height of the peaks (crests) above the level of the still water is the same as the depth of the troughs below the level of the still water. The size of the peaks and troughs is the same.

Characteristics of Waves

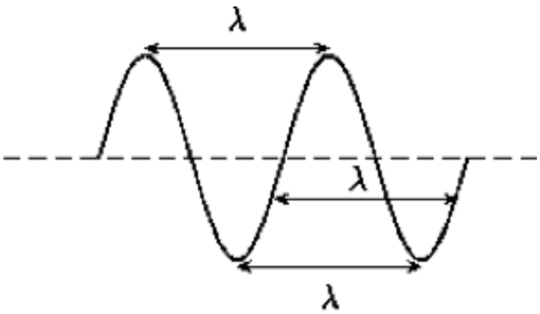
Amplitude

The characteristic height of a peak and depth of a trough is called the amplitude of the wave. The vertical distance between the bottom of the trough and the top of the peak is twice the amplitude. We use symbols agreed upon by convention to label the characteristic quantities of the waves. Normally the letter A is used for the amplitude of a wave. The units of amplitude are metres (m).



Wavelength

Look a little closer at the peaks and the troughs. The distance between two adjacent (next to each other) peaks is the same no matter which two adjacent peaks you choose. So there is a fixed distance between the peaks. Looking closer you'll notice that the distance between two adjacent troughs is the same no matter which two troughs you look at. But, more importantly, it is the same as the distance between the peaks. This distance that is a characteristic of the wave is called the wavelength. Waves have a characteristic wavelength. The symbol for the wavelength is λ. The units are metres (m).



The wavelength is the distance between any two adjacent points that are in phase. Two points in phase are separate by an integer (0, 1, 2, 3...) number of complete wave cycles. They don't have to be peaks or trough but they must be separated by a complete number of waves.

Period

Now imagine you are sitting next to a pond and you watch the waves going past you. First one peak then a trough and then another peak. If you measure the time between two adjacent peaks you'll find that it is the same. Now if you measure the time between two adjacent troughs you'll find that it's always the same, no matter which two adjacent troughs you pick. The time you have been measuring is the time for one wavelength to pass by. We call this time the period and it is a characteristic of the wave. Waves have a characteristic time interval that we call the period of the wave and denote with the symbol T. It is the time it takes for any two adjacent points that are in phase to pass a fixed point. The units are seconds (s).

Frequency

There is another way of characterising the time interval of a wave. We timed how long it takes for one wavelength to pass a fixed point to get the period. We could also turn this around and say how many waves go by in 1 second. We can easily determine this number, which we call the frequency and denote f. To determine the frequency, how many waves go by in 1s, we work out what fraction of waves goes by in 1 second by dividing 1 second by the time it takes T. If a wave takes 1/2 a second to go by then in 1 second two waves must go by 1÷1/2=2. The unit of frequency is the Hz or s^{-1}. Waves have a characteristic frequency.

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

f : frequency (Hz or s^{-1})
T : period (s)

Speed

Now if you are watching a wave go by you will notice that they move at a constant velocity. The speed is the distance you travel divided by the time you take to travel that distance. This is excellent because we know that the waves travel a distance, in a time T. This means that we can determine the speed.

$$v = \frac{\lambda}{T}$$

v : speed ($m.s^{-1}$)
λ : wavelength (m)
T : period (s)

There are a number of relationships involving the various characteristic quantities of waves. A simple example of how this would be useful is how to determine the velocity when you have the frequency and the wavelength. We can take the above equation and substitute the relationship between frequency and period to produce an equation for speed of the form

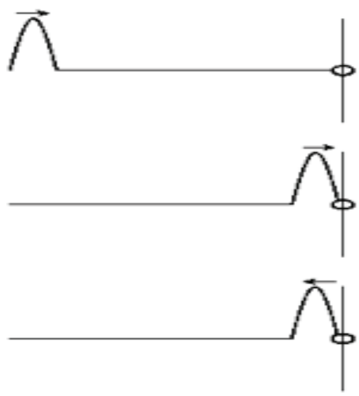
$$v = \frac{\lambda}{T}$$

v : speed ($m.s^{-1}$)
λ : wavelength (m)
T : period (s)

Phase shift of reflected wave

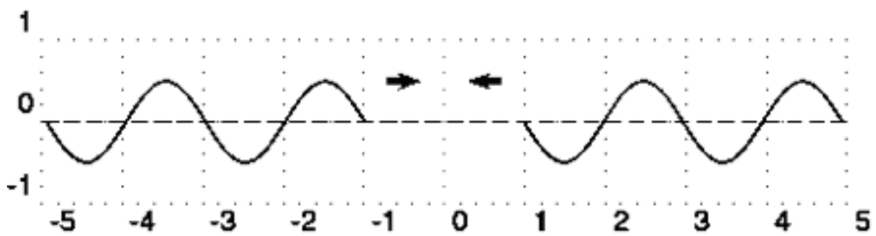
When a wave is reflected from a denser medium it undergoes a phase shift. That means that the peaks and troughs are swapped around. The easiest way to demonstrate this is to tie a piece of string to something. Stretch the string out flat and then flick the string once so a pulse moves down the string. When the pulse (a single peak in a wave) hits the barrier that the string is tide to it will be reflected. The reflected wave will look like a trough instead of a peak. This is because the pulse had undergone a phase change. The fixed end acts like an extremely dense medium.

If the end of the string was not fixed, i.e. it could move up and down then the wave would still be reflected but it would not undergo a phase shift. To draw a free end we draw it as a ring around a line. This signifies that the end is free to move.

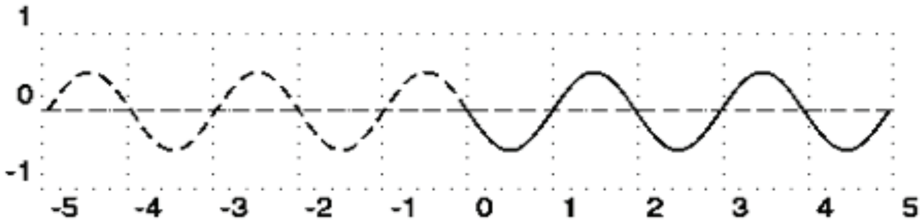


Standing Waves

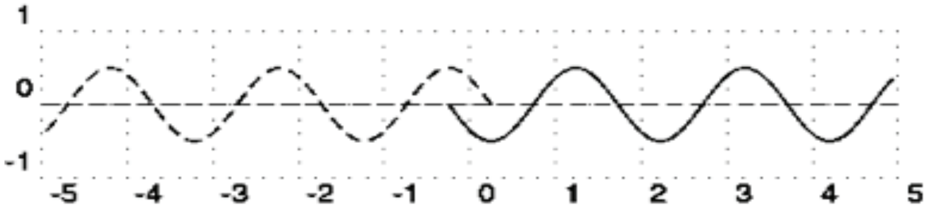
When two waves move in opposite directions, through each other, interference takes place. If the two waves have the same frequency and wavelength then a specific type of constructive interference can occur: standing waves can form. Standing waves are disturbances that don't appear to move; they look like they stay in the same place even though the waves those from them are moving. Let's demonstrate exactly how this comes about. Imagine a long string with waves being sent down from either end. The waves from both ends have the same amplitude, wavelength and frequency as you can see in the picture below:



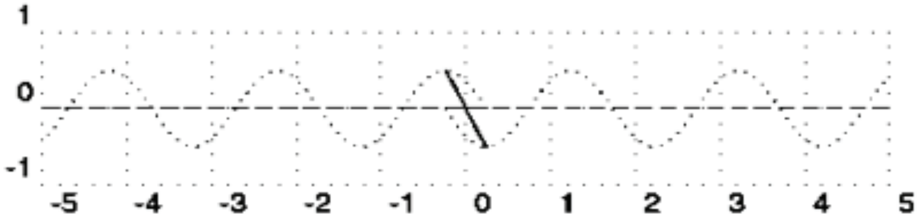
To stop from getting confused between the two waves we'll draw the wave from the left with a dashed line and the one from the right with a solid line. As the waves move closer together when they touch both waves have amplitude of zero:



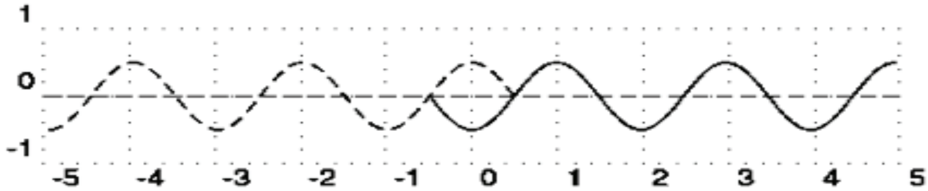
If we wait for a short time the ends of the two waves move past each other and the waves overlap. Now we know what happens when two waves overlap, we add them together to get the resulting wave.



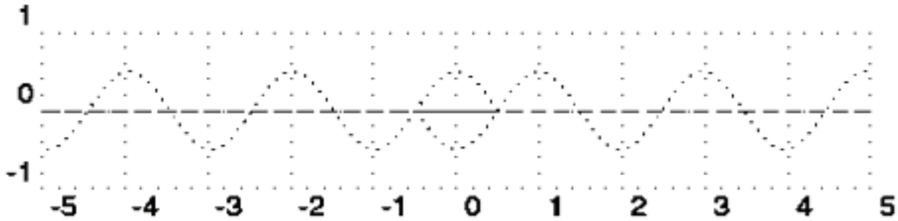
Now we know what happens when two waves overlap, we add them together to get the resulting wave. In this picture we show the two waves as dotted lines and the sum of the two in the overlap region is shown as a solid line:



The important thing to note in this case is that there are some points where the two waves always destructively interfere to zero. If we let the two waves move a little further we get the picture below:

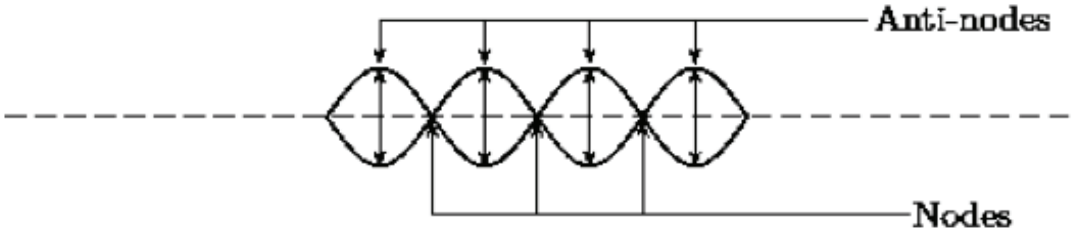


Again we have to add the two waves together in the overlap region to see what the sum of the waves looks like.



Node and Anti-node

A node is a place where the two waves cancel out completely as two waves destructively interfere in the same place. An anti-node is a place where the two waves constructively interfere.
Important: The distance between two anti-nodes is only 1/2 λ¸ because it is the distance from a peak to a trough in one of the waves forming the standing wave. It is the same as the distance between two adjacent nodes. This will be important when we workout the allowed wavelengths in tubes later. We can take this further because halfway between any two anti-nodes is a node. Then the distance from the node to the anti-node is half the distance between two anti-nodes. This is half of half a wavelength which is one quarter of a wavelength, 1/4 λ.



Unit: Waves **Topic:** Water Waves

Benchmark 12.2.3.2	Research the nature of matter and energy, forms of energy, including waves and energy transformations.

Key question(s):

- What are the properties of water waves?
- How does constructive and destructive interference occur?

Vocabulary:

Transverse wave, longitudinal wave.

Learning Objective(s)

By the end of the topic, students can:

- Define the types of waves and explain their characteristics

Materials

Rope, long spring,

Knowledge	Skills	Attitudes and Values
• When two waves reinforce each other, constructive interference is said to have occurred • When a crest from one source meets a trough from another source, two waves cancel each other and destructive interference takes place.	• Explain how waves build up in the physical world (ocean waves) • Explain the process of how waves cancel each other in the ocean.	• Appreciate the importance of wave interference in the physical world.

Assessment

- Describe constructive and destructive interference using the wave properties of water.

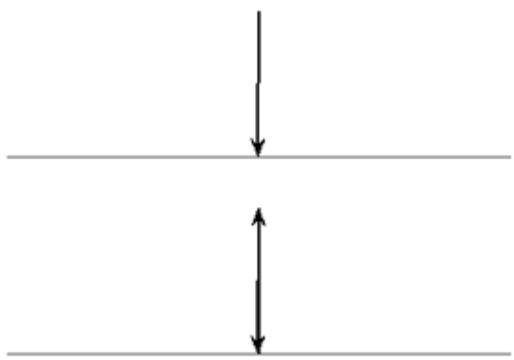
Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

Reflection

When waves strike a barrier they are reflected. This means that waves bounce off things. Sound waves bounce off walls, light waves bounce off mirrors, radar waves bounce off planes and this can explain how bats can fly at night and avoid things as small as telephone wires. The property of reflection is a very important and useful one.

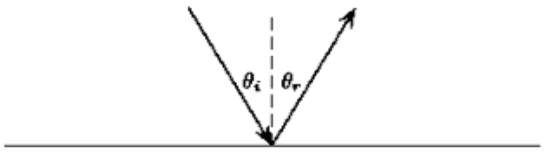
When waves are reflected, the process of reflection has certain properties. If a wave hits an obstacle at a right angle to the surface then the wave is reflected directly backwards at the right angle.



If the wave strikes the obstacle at some other angle then it is not reflected directly backwards.
The angle that the waves arrives at is the same as the angle that the reflected waves leave at.
The angle that waves arrives at or is incident at equals the angle the waves leaves at or is reflected at.
Angle of incidence equals angle of reflection θi = θr

$$\theta_i = \theta_r$$

θ_i : angle of incidence
θ_r : angle of reflection

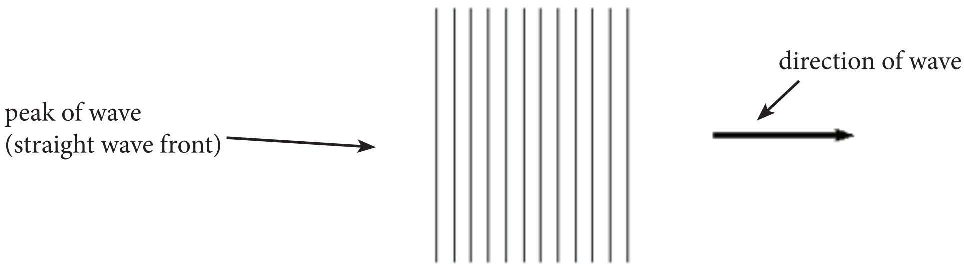


Diffraction

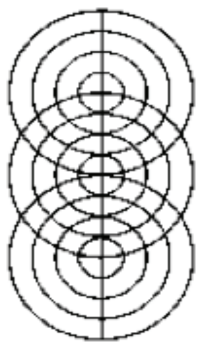
One of the most interesting, and also very useful, properties of waves is diffraction. When a wave strikes a barrier with a hole, only part of the wave can move through the hole. If the hole is similar in size to the wavelength of the wave diffraction occurs. The waves that come through the hole no longer looks like a straight wave front. It bends around the edges of the hole. If the hole is small enough it acts like a point source of circular waves.
This bending around the edges of the hole is called diffraction. To illustrate this behavior we start with Huygens's principle.

Huygens's Principle

Huygens's principle states that each point on a wavefront acts like a point source or circular waves. The waves emitted from each point interfere to form another wavefront on which each point forms a point source. A long straight line of points emitting waves of the same frequency leads to a straight wave front moving away. To understand what this means let's think about a whole lot of peaks moving in the same direction. Each line represents a peak of a wave.



If we choose three points on the next wave front in the direction of motion and make each of them emit waves isotropically (i.e. the same in all directions) we will get the sketch below:



What we have drawn is the situation if those three points on the wave front were to emit waves of the same frequency as the moving wave fronts. Huygens principle says that every point on the wave front emits waves isotropically and that these waves interfere to form the next wave front.

What we have drawn is the situation if those three points on the wave front were to emit waves of the same frequency as the moving wave fronts. Huygens principle says that every point on the wave front emits waves isotropically and that these waves interfere to form the next wave front.

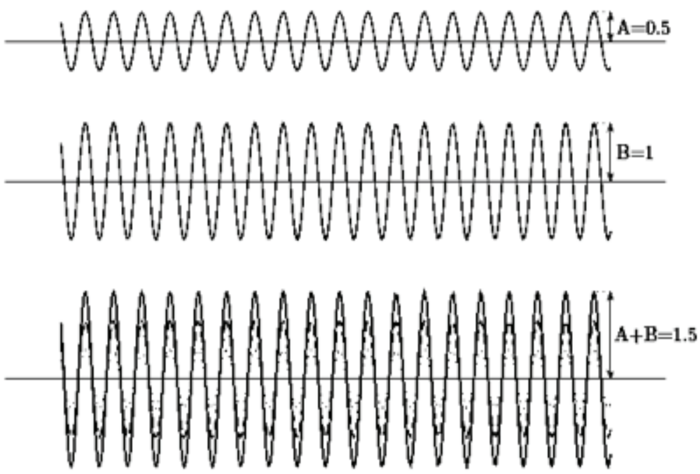
Dispersion

Dispersion is a property of waves where the speed of the wave through a medium depends on the frequency. So if two waves enter the same dispersive medium and have different frequencies they will have different speeds in that medium even if they both entered with the same speed.

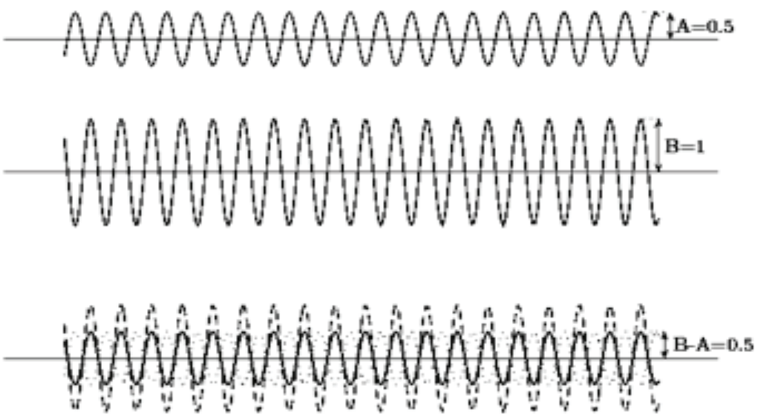
Interference

If two waves meet interesting things can happen. Waves are basically collective motion of particles. So when two waves meet they both try to impose their collective motion on the particles. This can have quite different results.

If two identical (same wavelength, amplitude and frequency) waves are both trying to form a peak then they are able to achieve the sum of their efforts. The resulting motion will be a peak that has a height, which is the sum of the heights of the two waves. If two waves are both trying to form a trough in the same place then a deeper trough is formed, the depth of which is the sum of the depths of the two waves. Now in this case the two waves have been trying to do the same thing and so add together constructively. This is called **constructive interference.**



If one wave is trying to form a peak and the other is trying to form a trough then they are competing to do different things. In this case they can cancel out. The amplitude of the resulting wave will depend on the amplitudes of the two waves that are interfering. If the depth of the trough is the same as the height of the peak nothing will happen. If the height of the peak is bigger than the depth of the trough a smaller peak will appear and if the trough is deeper than a less deep trough will appear. This is **destructive interference.**



Unit: Waves **Topic:** Light and Electromagnetic

Benchmark 12.2.3.3	Explain and provide examples of electromagnetic radiation and sound using a wave model.

Key question(s):

- How does a light wave behave?
- What is an electromagnetic spectrum?

Vocabulary:

Electromagnetic Spectrum,

Learning Objective(s)

By the end of the topic, students can:

- Determine how light travels through different mediums
- Interpret electromagnetic spectrum.

Materials

Light ray (diagram), electromagnetic spectrum diagram

Knowledge	Skills	Attitudes and Values
• When light travels from one medium to another it changes direction, except when it is incident normally on the separating surface	• Explain how light behaves through different mediums • Explain how to spear a fish in the water seen from the above	• Understand the importance of characteristics of light in the physical world

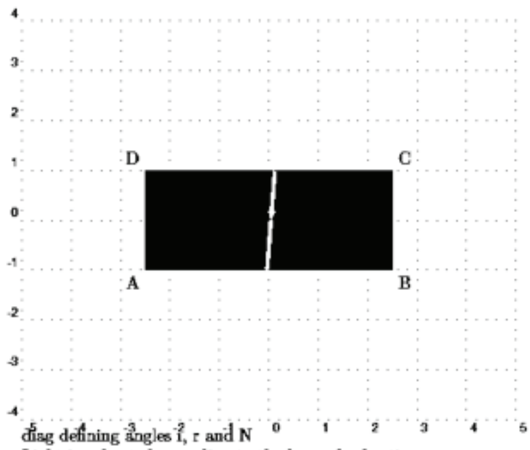
Assessment

- Students can be able to investigate the behavior of light rays when traveling through different mediums.
- Describe the electromagnetic spectrum.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

When light travels from one medium to another it changes direction, except when it is incident normally on the separating surface. The change of direction is caused by the change in the velocity of the light as it passes from one medium to the other.



diag defining angles i, r and N
Light is refracted according to the laws of refraction:

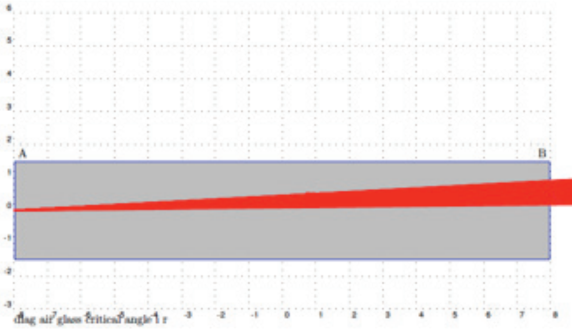
Laws of Refraction

Laws of Refraction:
sin i /sin r is a constant for two given media (Snell's Law)
The incident ray, the normal and the refracted ray are all in the same plane

Sin i /sin r is known as the refractive index (n)

Total Internal Reflection

This can only happen when light is travelling into a less dense medium
Refection numbers are n1 = 2 and n2 = 1:



When light travels from glass to air it is refracted away from the normal as shown above. As the angle of incidence is increased the angle of refraction eventually reaches 90° as in b. If the angle of incidence is increased further beyond this value, total internal reflection occurs as in c. The critical angle c is the angle of incidence corresponding to the angle of refraction of 90°.

From the above the refractive index from air to glass
n=sin90/sin c = 1/sin c
Also sin c = 1 / n = 2/3 in the case of glass.
Sin c = 0.6667 => critical angle for glass is 41° to 49°

Total internal reflection has some very useful properties eg
diag prism for turning light 180° and
daig prism for turning light 90°

The size of the final image in a pair of binoculars depends on the distance travelled by the light within the binoculars. By using two prisms this distance can be increased without increasing the length of the binoculars.

The Electromagnetic Spectrum

These are transverse waves. They can travel through empty space. They travel at the speed of light.
Short wavelength and Long wavelength

Dangers
Microwaves kill living cells. Ultraviolet light causes skin cancer and also can kill living cells.

Uses

- Radio waves are used in TV's and radios.
- Microwaves are used to heat food; and are also used to transmit signals to satellites and back to earth. Infrared light is used to asses heat loss from buildings, weather forecasting, locating survivors in earthquakes and in TV remote controls.
- Visible light is used in fibre optics.
- Ultraviolet light produces vitamins in the skin if it is in small doses.
- X-Rays are used to look at bones inside your body, my body and everybody's body. g-rays are used to treat cancer.

Unit: Waves **Topic:** : Sound Waves

Benchmark 12.2.3.3	Explain and provide examples of electromagnetic radiation and sound using a wave model.

Key question(s):

- What are the characteristics of sound waves?
- How is sound transmitted from one medium to another?

Vocabulary:

Pitch, Tone, Loudness,

Learning Objective(s)

By the end of the topic, students can:

- Describe the characteristics of sound
- Determine how sound travels through different mediums.

Materials

Different mediums, e.g. wood, rope, iron rod etc. that transmit sound.

Knowledge	Skills	Attitudes and Values
• Sound travels through different mediums at different speed. • The speed of sound in at sea level, at a temperature of 21°C and under normal atmosphere condition is 344 ms^{-1}	• Explain how sound travels through different mediums • Explain pitch, loudness and tone of a sound produced	• Appreciate how musicians create melodious sound using pitch, loudness and tone

Assessment

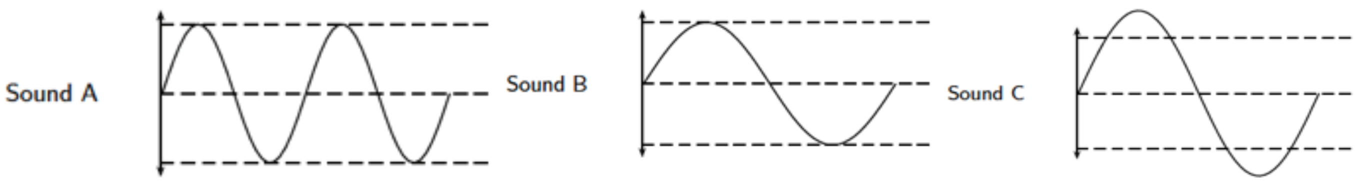
- Explain and provide examples of electromagnetic radiation and sound using a wave model.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

Characteristics of a Sound Wave

Since sound is a wave, we can relate the properties of sound to the properties of a wave. The basic properties of sound are: pitch, loudness and tone.



Sound B has a lower pitch (lower frequency) than Sound A and is softer (smaller amplitude) than Sound C.

Pitch

The frequency of a sound wave is what your ear understands as pitch. A higher frequency sound has a higher pitch, and a lower frequency sound has a lower pitch. Sound A has a higher pitch than sound B. For instance, the chirp of a bird would have a high pitch, but the roar of a lion would have a low pitch. The human ear can detect a wide range of frequencies. Frequencies from 20 to 20 000 Hz are audible to the human ear. Any sound with a frequency below 20 Hz is known as an infrasound and any sound with a frequency above 20 000 Hz is known as an ultrasound.

Table below lists the ranges of some common animals compared to humans.

	lower frequency (Hz)	upper frequency (Hz)
Humans	20	20 000
Dogs	50	45 000
Cats	45	85 000
Bats		120 000
Dolphins		200 000
Elephants	5	10 000

Loudness

The amplitude of a sound wave determines its loudness or volume. A larger amplitude means a louder sound, and a smaller amplitude means a softer sound. In Figure 15.1 sound C is louder than sound B. The vibration of a source sets the amplitude of a wave. It transmits energy into the medium through its vibration. More energetic vibration corresponds to larger amplitude. The molecules move back and forth more vigorously.
The loudness of a sound is also determined by the sensitivity of the ear. The human ear is more sensitive to some frequencies than to others. Loudness thus depends on both the amplitude of a sound wave and its frequency whether it lies in a region where the ear is more or less sensitive.

Tone

Tone is a measure of the quality of the sound wave. For example, the quality of the sound produced in a particular musical instrument depends on which harmonics are superposed and in what proportions. The harmonics are determined by the standing waves that are produced in the instrument.

The quality (timbre) of the sound heard depends on the pattern of the incoming vibrations, i.e. the shape of the sound wave. The more irregular the vibrations, the more jagged is the shape of the sound wave and the harsher is the sound heard.

Speed of Sound

The speed of sound depends on the medium the sound is travelling in. Sound travels faster in solids than in liquids, and faster in liquids than in gases. This is because the density of solids is higher than that of liquids, which means that the particles are closer together. Sound can be transmitted more easily.
The speed of sound also depends on the temperature of the medium. The hotter the medium is, the faster its particles move and therefore the quicker the sound will travel through the medium. When we heat a substance, the particles in that substance have more kinetic energy and vibrate or move faster.

Sound can therefore be transmitted more easily and quickly in hotter substances.
Sound waves are pressure waves. The pressure of the medium through which it is travelling will therefore influence the speed of sound. At sea level the air pressure is higher than high up on a mountain. Sound will travel faster at sea level where the air pressure is higher than it would at places high above sea level.

The speed of sound in air, at sea level, at a temperature of 21 ^{o}C and under normal atmospheric conditions is 344 $m.s^{-1}$.

Intensity of Sound

Intensity is one indicator of amplitude. Intensity is the energy transmitted over a unit of area each second.

Intensity is defined as:

$$Intensity = \frac{energy}{time \times area} = \frac{power}{area}$$

By the definition of intensity, we can see that the units of intensity are:

$$\frac{Joules}{sm^2} = \frac{Watts}{m^2}$$

The unit of intensity is the decibel (symbol: dB). This reduces to an SI equivalent of $W \times m^{-2}$.
The threshold of hearing is 10^{-12} $W.\ m^{-2}$. Below this intensity, the sound is too soft for the ear to hear.
The threshold of pain is 1.0 $W \times m^{-2}$. Above this intensity a sound is so loud it becomes uncomfortable for the ear.

Notice that there is a factor of 1012 between the thresholds of hearing and pain. This is one reason we define the decibel (dB) scale.

The intensity in dB of a sound of intensity I, is given by:

$$\beta = 10 \log \frac{1}{1_0} \qquad I_0 = 10^{-12} W.m^{-12}$$

In this way we can compress the whole hearing intensity scale into a range from 0 dB to 120 dB.

Examples of sound intensities

Source	Intensity (dB)	Times greater than hearing threshold
Rocket Launch	180	10^{18}
Jet Plane	140	10^{14}
Threshold of Pain	120	10^{12}
Rock Band	110	10^{11}
Subway Train	90	10^{9}
Factory	80	10^{8}
City Traffic	70	10^{7}
Normal Conversation	60	10^{6}
Library	40	10^{4}
Whisper	20	10^{2}
Threshold of hearing	0	0

Ultrasound

Ultrasound is sound with a frequency that is higher than 20 kHz. Some animals, such as dogs, dolphins, and bats, have an upper limit that is greater than that of the human ear and can hear ultrasound.

The most common use of ultrasound is to create images, and has industrial and medical applications. The use of ultrasound to create images is based on the reflection and transmission of a wave at a boundary. When an ultrasound wave travels inside an object that is made up of different materials such as the human body, each time it encounters a boundary, e.g. between bone and muscle, or muscle and fat, part of the wave is reflected and part of it is transmitted. The reflected rays are detected and used to construct an image of the object.

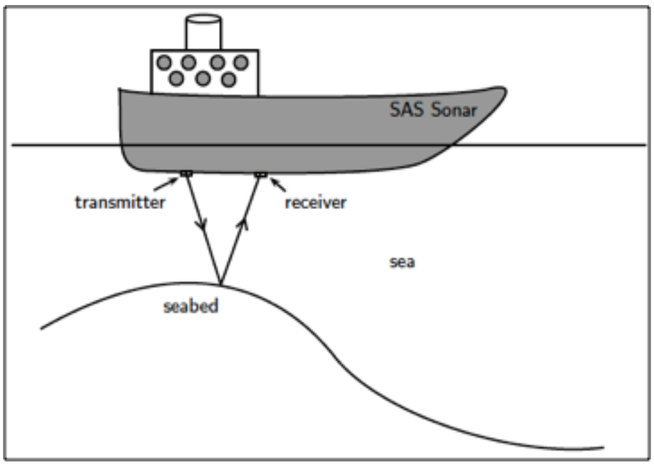
Ultrasound in medicine can visualise muscle and soft tissue, making them useful for scanning the organs, and is commonly used during pregnancy. Ultrasound is a safe, non-invasive method of looking inside the human body.

Ultrasound sources may be used to generate local heating in biological tissues with applications in physical therapy and cancer treatment. Focused ultrasound sources may be used to break up kidney stones.

Ultrasonic cleaners, sometimes called supersonic cleaners, are used at frequencies from 20-40 kHz for jewelry, lenses and other optical parts, watches, dental instruments, surgical instruments and industrial parts. These cleaners consist of containers with a fluid in which the object to be cleaned is placed. Ultrasonic waves are then sent into the fluid. The main mechanism for cleaning action in an ultrasonic cleaner is actually the energy released from the collapse of millions of microscopic bubbles occurring in the liquid of the cleaner.

SONAR

Ships on the ocean make use of the reflecting properties of sound waves to determine the depth of the ocean. A sound wave is transmitted and bounces off the seabed. Because the speed of sound is known and the time lapse between sending and receiving the sound can be measured, the distance from the ship to the bottom of the ocean can be determined; this is called sonar, which stands for **S**ound **N**avigation And **R**anging.



Unit: Electromagnetism	Topic: Magnetic Field and Forces
Content standard 12.2.4	Students will be able to examine and evaluate electromagnetism properties and concepts and derive equations to find magnetic field strength and voltage induced in AC and DC motors and generators.
Benchmark 12.2.4.1	Invetigate how magnetic materials and electric currents (moving electric charges) are sourced of magnetic fields and are subject to forces arising from the magnetic fields of other sources.

Key question(s):

- What is magnetic force?
- What does a magnetic field look like?
- How does a magnetic field or force influence a moving charge?

Vocabulary:

Magnetic Field, Magnetic Flux

Learning Objective(s)

By the end of the topic, students can:

- Determine how light travels through different mediums
- Interpret electromagnetic spectrum.

Materials

Electromagnetic field diagrams.

Knowledge	Skills	Attitudes and Values
• Gain understanding of magnetic field and force and its influence on a moving charge.	• Be able to apply the knowledge obtained to solve problems associated with the topic.	• Appreciate the topic and apply in real life situation.

Assessment

- Explain magnetic fields and forces using diagrams and its influence on a moving charge.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

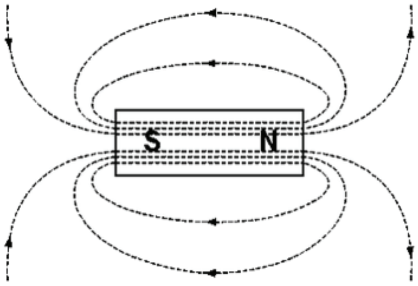
Content Background

Magnetic Fields and Forces

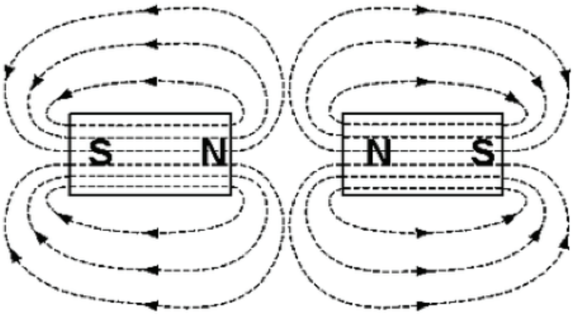
A Magnet is an object that produces a Magnetic Field. It can be formed of a permanent magnet or an electromagnet. The history of magnetism begins some thousands of years ago. In a region of Asia Minor known as Magnesia rocks were found that could attract each other. The rocks were called ‘magnets’ after their place of discovery.

Magnets come in many shapes but no matter what their shapes are, each magnet has a North Pole and a South Pole.

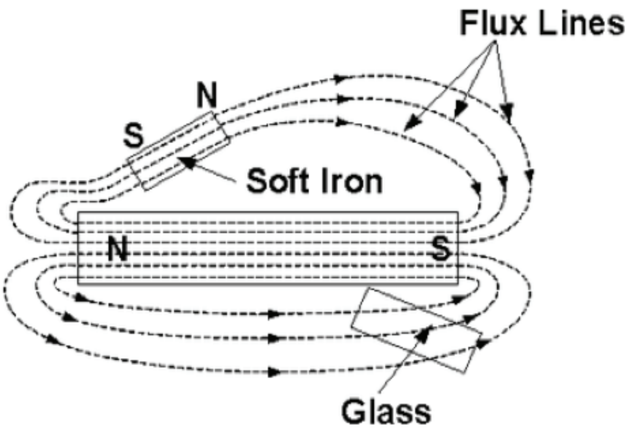
A Magnetic Field is said to exist in a region if a (Magnetic) Force can be exerted on a Magnet. Magnetic Field Lines (Flux Lines) are imaginary lines representing the direction and strength of the Magnetic Field. They go from the North Pole to the South Pole outside the Magnet, and go from the South Pole to the North Pole inside the Magnet. The density of the Magnetic Field Lines is higher near the Poles, and the Magnetic Force is stronger there and is shown in the figure below.



A Magnet attracts or repels other Magnets, depending on their mutual orientation of North and South Poles. When placing like Poles of two Magnets together, the Magnets repel each other as shown below.

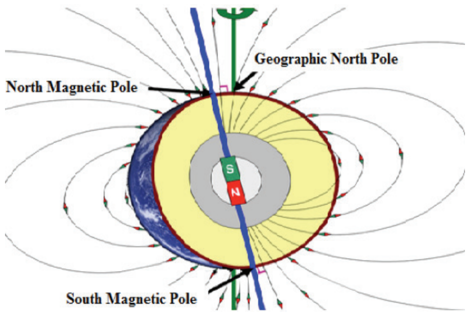


Aside from that, magnets attract other magnetic materials like iron, nickel and cobalt. The Magnetic Field exerts a Magnetic Force on these materials. See diagram below.



Note that other non-metallic materials like glass do not interact with the magnetic field.

A Compass is a navigational instrument of finding directions on the earth. It consists of a thin piece of a Magnet in needle shape, which is balanced on a nearly frictionless pivot point. The Earth Geographical North Pole is actually the Magnetic South Pole, which attracts the North Pole of the Compass, making it points north. See image below.



A magnetic field is a vector field that describes the magnetic influence of electric charges in relative motion and magnetized materials. Magnetic fields are observed in a wide range of size scales, from subatomic particles to galaxies. In everyday life, the effects of magnetic fields are often seen in permanent magnets, which pull on magnetic materials (such as iron) and attract or repel other magnets, as we have seen in the preceding paragraphs. Magnetic fields surround and are created by magnetized material and by moving electric charges (electric currents) such as those used in electromagnets. Magnetic fields exert forces on nearby moving electrical charges and torques on nearby magnets. In addition, a magnetic field that varies with location exerts a force on magnetic materials. Both the strength and direction of a magnetic field vary with location. As such, it is an example of a vector field.

Magnetic Force

The magnetic field B is defined from the Lorentz Force Law, and specifically from the magnetic force on a moving charge.

The implications of this expression include:

1. The force is perpendicular to both the velocity v of the charge q and the magnetic field B.

2. The magnitude of the force is $F = qvB \sin y$ where y is the angle < 180 degrees between the velocity and the magnetic field. This implies that the magnetic force on a stationary charge or a charge moving parallel to the magnetic field is zero.

3. The direction of the force is given by the right hand rule. The force relationship above is in the form of a vector product.

Unit: Electromagnetism **Topic:** Electromagnetic Induction and Power

Benchmark 12.2.4.2	Examine the relationship between magnetic field changes and the production of electric fields, which results in the inducement of currents in nearby conductors.

Key question(s):

- What is electromagnetic induction and its practical applications?

Vocabulary:

Induction, conduction and radiation

Learning Objective(s)

By the end of the topic, students can:

- Investigate and explain electromagnetic induction
- Describe various application areas such as transformers and even in power transmission.

Materials

Diagram of electromagnetic induction example.

Knowledge	Skills	Attitudes and Values
• Gain understanding of electromagnetic induction. • Be able to realize the concept being used in application such as transformers and power generation and transmission.	• Be able to apply the knowledge obtained to solve problems and issues associated with electromagnetic induction and power.	• Appreciate electromagnetic induction and power and apply in real life situation.

Assessment

- Explain electromagnetic induction and power and its applications in electrical appliances.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

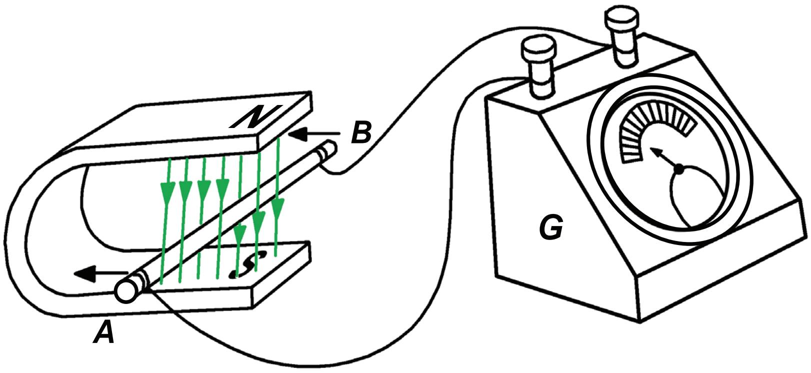
Electromagnetic induction

When the north pole of a bar magnet is moved into the coil of wire, the needle of the galvanometer is seen to be deflected to the right. When the bar magnet is stationary, however, the needle returns to its zero position. When the bar magnet is removed from the coil, the needle is deflected to the left. Thus, whenever the magnet moves, a current is produced in the coil. In other words and EMF id **induced** in the coil. A similar result can be obtained by moving a coil of wire over a stationary magnet.

When Faraday conducted this experiment, he found that the strength of the induced current and hence the EMF was increased by:

- Moving the coil or magnet faster
- Increasing the strength of the magnet
- Increasing the number of turns of wire in the coil

A current can also be induced in a wire when it moves in a magnetic field. The figure below shows a ling copper wire connected to a galvanometer. Part of the wire, AB, is in a magnetic field. If AB moves (at right angles across the magnetic field lines), a current is induced in the wire. A forward movement produces a current in the opposite direction to a backward movement. There is no current induced if the wire is stationary or moves parallel to the field. The faster the movement of the wire, the greater is the level of EMF which is produced.



Suppose that the length of the wire in the figure above is L and it moves at speed v through the field of strength B. The force F on the charge in the wire is

$$F = qvB \sin\theta$$

Where θ is the angle between the direction of the charge motion and the magnetic field. The work done in moving the charge a distance L is given by:

$$W = F \text{ x } L = qvB \sin\theta \text{ x } L$$

We also know that

$$W = p.d. \text{ x } q = EMF \text{ x } q \qquad EMF = \frac{W}{q} = \frac{qBLv \sin\theta}{q}$$

Hence $EMF = BLv \sin\theta$

$$\text{if } \theta = 90^0, \text{ then } \sin\theta = 1 \text{ and } EMF = BLv$$

The direction of the induced current can be found from the left hand induced current rule.

Lenz's Law

The induced current is in such a direction as to oppose the charge producing it.

Unit: Electromagnetism **Topic:** Laws of electromagnetism

Benchmark 12.2.4.2	Examine the relationship between magnetic field changes and the production of electric fields, which results in the inducement of currents in nearby conductors.

Key question(s):

- What are the laws of electromagnetism?
- How can we apply the laws of electromagnetism in electromagnetic study?

Vocabulary:

Induction, conduction and radiation

Learning Objective(s)

By the end of the topic, students can:

- Explain Faraday's law, Biot-savart law, Ampere's law and Maxwell's equation.

Materials

Diagram showing electromagnetic flux.

Knowledge	Skills	Attitudes and Values
• Know when and where appropriate to apply the laws covered in this topic.	• Be able to apply the knowledge obtained to solve problems and issues associated with the topic.	• Appreciate the topic and apply in real life situation.

Assessment

- Students can be able to explain the relationship between magnetic field changes and the production of electric fields, which results in the inducement of currents in nearby conductors.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

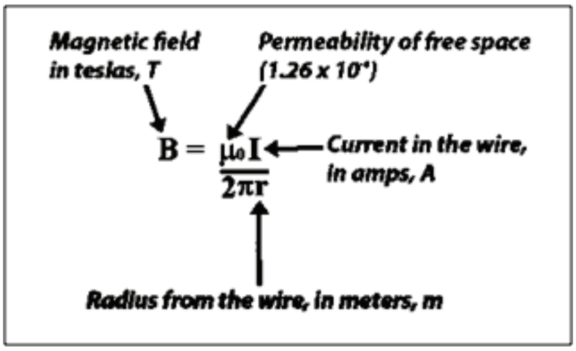
Consider a rectangular coil of area A placed at right angles to a magnetic field of strength **B**. A EMF can be induced in the coil by: changing the field strength, changing the area of the coil or rotating the coil about an axis perpendicular to the field. Faraday found that the induced EMF varied with the change in the amount of magnetic field in a given area. The number of lines of magnetic field cutting a given area is called the ***magnetic flux*** (symbol Φ).

When the area is perpendicular to the filed, $\Phi = BA$
The unit for magnetic flux is the weber (Wb). ***One Wb=1*** $T \times m^2$

Faraday's first law of induction
The EMF induced in a conductor is directly proportional to the rate of change of magnetic flux

The Bio-Savart Law

The Bio-Savart Law is an equation that describes the magnetic field created by a current-carrying wire and allows you to calculate its strength at various points.



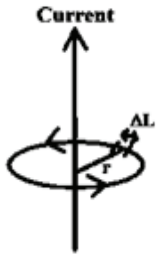
Ampere's Law

Ampere's law states that:

'For any closed loop path, the sum of the length elements times the magnetic field in the direction of the length element is equal to the permeability time the electric current enclosed in the loop'

Ampere's Law:

$$\sum B\Delta L = \mu_0 I$$



Maxwell's Law

Maxwell's equations describe how electric charges and electric currents create electric and magnetic fields. Further, they describe how an electric field can generate a magnetic field, and vice versa. Maxwell's equations are a set of four different equations that form the theoretical basis for describing classical electromagnetism:

1. Gauss' law: Electric charges produce an electric field. The electric flux across a closed surface is proportional to the charge enclosed.
2. Gauss' law for magnetism: There are no magnetic monopoles. The magnetic flux and Faraday's law quantitative across a closed surface is zero.
3. Faraday's law: time-varying magnetic fields produce an electric field
4. Ampere's Law: Steady currents and time-varying electric fields (the latter due to Maxwell's correction) produce a magnetic field.

Unit: Electromagnetism **Topic:** Electric Motors and Generators.

Benchmark 12.2.4.3	Investigate how voltage is induced by a changing magnetic field in AC and DC motors and generators.

Key question(s):

- How does DC motor and generators work?
- How does AC motor and generators work?
- What are some of the applications of Electric motors and generators?

Vocabulary:

Direct current (DC), alternating current (AC)

Learning Objective(s)

By the end of the topic, students can:

- Describe how AC and DC motors and generators work.

Materials

Diagram showing AC and DC motors and generators.

Knowledge	Skills	Attitudes and Values
• Know the working principle behind the AC motors and generators. • Know the working principle behind the DC motors and generators. • Understand how the DC devices differ from the AC counterpart.	• Be able to apply the knowledge obtained to solve problems and issues associated with the topic. • Knowing the principles of operation and the difference which enables you to make the best choice for your application.	• Appreciate the topic and apply in real life situation.

Assessment

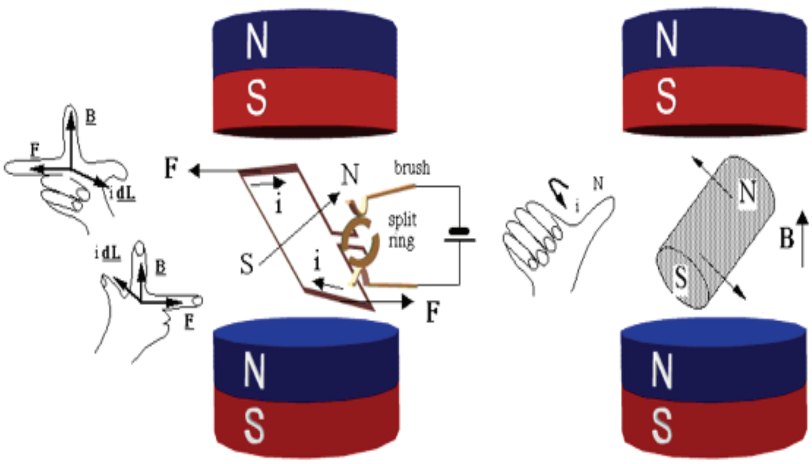
- Investigate and explain how voltage is induced by a changing magnetic field in AC and DC motors and generators.

Teacher to develop assessment rubric on the assessment task mentioned above.

Content Background

DC Motors

A simple DC motor has a coil of wire that can rotate in a magnetic field. The current in the coil is supplied via two brushes that make moving contact with a split ring. The force exerted on the current – carrying wires creates a torque on the coil.



The force F on a wire of length L carrying a current I in a magnetic field Band I, which would be 90^{o} if the field were uniformly vertical. The direction of F comes from the right hand rule as shown above. The two forces shown here are equal and opposite, but they are displaced vertically, so the exert a torque. The force on the other two side of the coil act along the same line and so they exert no torque.

The coil can also be considered as a magnetic dipole, or a little electromagnet, as indicated by the arrows SN: curl the fingers of your right hand in the direction of the current, and your thumb is the North Pole. In the sketch at right, the electromagnet formed by the coil of the rotor is represented as a permanent magnet, and the same torque (North attracts south) is seen to be that acting to align the central magnet.

Note that the **brushes** on the **split ring.** When the plane on the rotating coil reaches horizontal, the brushes will break contact (not much is lost, because this is the point of zero torque, the forces act inwards). The angular momentum of the coil carries it past this break point and the current then flows in the opposite direction, which reverses the magnetic dipole. After passing the break point, the rotor continues to turn anticlockwise and starts to align in the opposite direction.
The torque generated over a cycle varies with the vertical separation of the two forces. It therefore depends on the sine of the angle between the axis of the coil and field. However, because of the split ring, it is always in the same sense.

DC Generators

Now a DC motor is also a DC generator. The coil, split ring, brushes and magnet are exactly the same hardware as the motor above, but the coil is being turned, which generates an emf.
If you use a mechanical energy to rotate the coil (N turns, are A) at uniform angular velocity ω in the magnetic field **B**, it will produce a sinusoidal emf in the coil. Let θ be the angle between **B** and the normal to the coil, so the magnetic flux φ is NABcosθ.

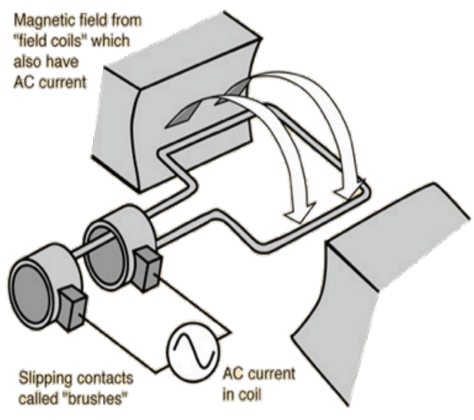
$$emf = -\frac{d\varphi}{dt} = -\left(\frac{d}{dt}\right)(NBA\cos\theta)$$
$$= NBA\sin\theta\left(\frac{d\theta}{dt}\right) = NBAw\ \sin wt$$

As in the DC motor, the ends of the coil connect to a split ring, whose two halves are connected by the brushes. Note that the brushes and the split ring rectify the emf produced: the contacts are organized so that the current will always flow in the same direction, because when the coil turns, past the dead spot, where the brushes meet the gap in the ring, the connections between the ends of the coil and external terminals are reversed. The emf here(neglecting the dead spot, which conveniently happens at zero volts) is NBAω sin ωt

AC Motors

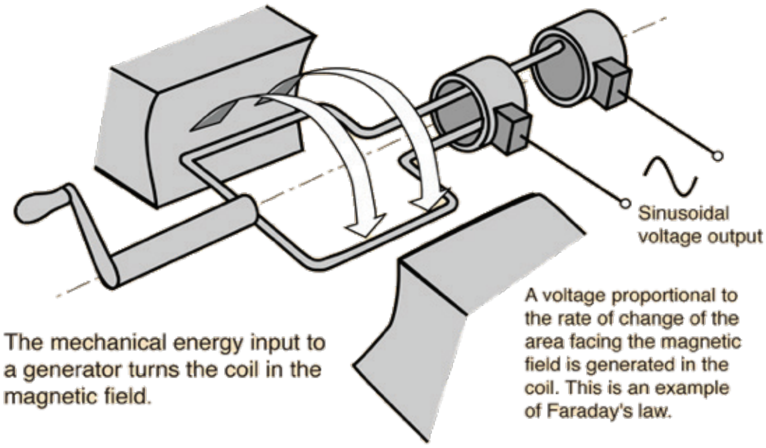
As in the DC motor case, a current is passed through the coil, generating a torque on the coil. Since the current is alternating, the motor will run smoothly only at the frequency of the sine wave. It is a synchronous motor. More common is the induction motor, where electric current is induced in the rotating coils rather than supplied to them directly.

One of the drawbacks of this kind of AC motor is the high current which must flow through the rotating contacts. Sparking and heating at those contacts can waste energy and shorten the lifetime of the motor. In common AC motors the magnetic field is produced by an electromagnet powered by the same AC voltage as the motor coil. The coils which produce the magnetic field are sometimes referred to as the ‘stator’, while the coils and the solid core which rotates is called the ‘armature’. In a AC motor the magnetic field is sinusoidally varying, just as the current in the coil varies.



AC Generator

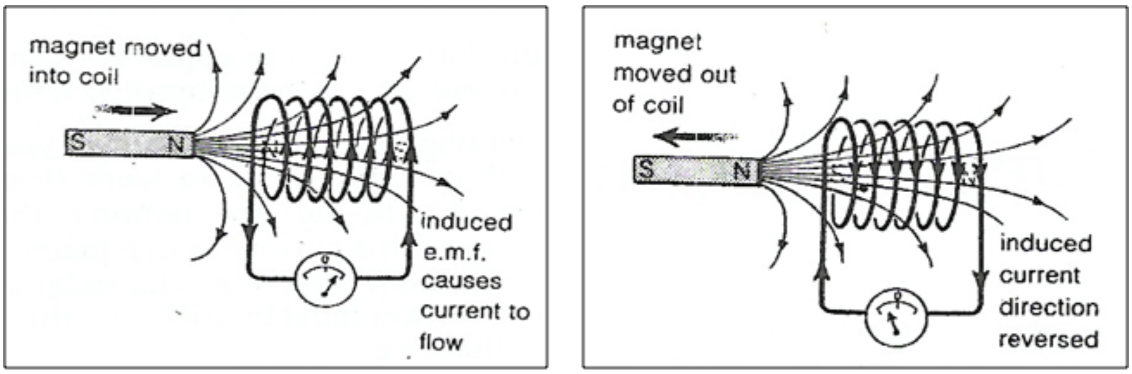
The turning of a coil in the magnetic field produces motional emfs in both sides of the coil which add. Since the component of the velocity perpendicular to the magnetic field changes sinusoidally with the rotation, the generated voltage is sinusoidal or AC. This process can be described in terms of Faraday's law when you see that the rotation of the coil continually changes the magnetic flux through the coil and therefore generates a voltage.



Lens law states that; an induced current always flows in a direction such that it opposes the change producing it.

Say, if the north pole of the bar magnet is move into the coil then the side of the coil facing it will become north pole thus causing the current in the coil to move upwards (using right hand grip/screw rule for solenoid). When the bar magnet is move out, the same side of coil that was initially acting as north pole will now become south pole thus causing the current to move downwards (using right hand grip/screw rule for solenoid).

The diagrams below illustrated that; when the north pole of bar magnet is moved into and out of the coil.



Changing bar magnet face; if the south pole of the bar magnet is moved into the coil, then the side of the coil facing it will become south pole thus causing the current in the coil to move downwards (using right hand grip/screw rule). When the bar magnet is move out, the same side of coil that was initially acting as south pole will now become north pole thus causing the current to move upwards (using right hand grip/screw rule for solenoid).

The size of the induced e.m.f can be increased by:

- moving the magnet at a higher/faster rate
- using stronger magnet
- increase the number of turns in the coil

Mutual Induction

Mutual induction refers to the change in the current through one coil that will bring about an induced e.m.f in the other.

The figures below show how mutual induction works. If the switch is ON (fig 1), the current flows in the circuit on the left and thus creates magnetic field outwards, that field then produce induced e.m.f on the next (right) circuit. If the switch is OFF (fig 2), the current stops flowing through the left circuit thus causing magnetic field to be weaken (inwards), that causes the induced e.m.f to flow in opposite direction.

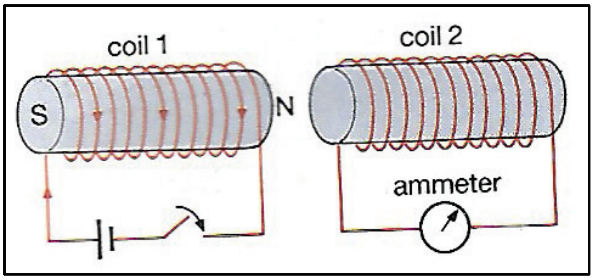


Fig 1

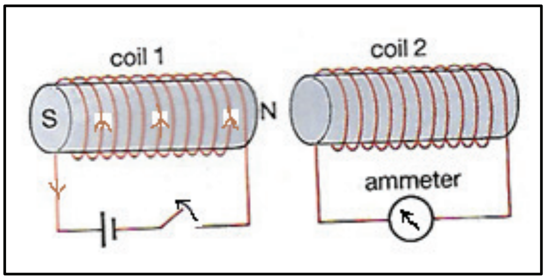


Fig 2

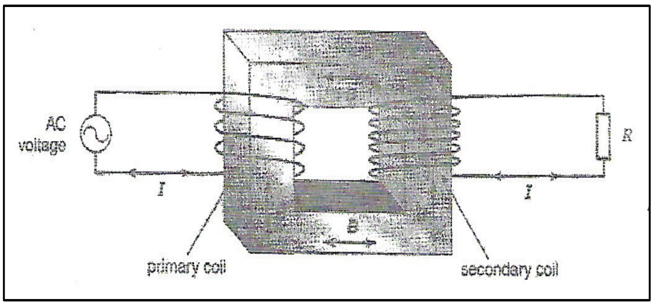
In order to maintain constant induced e.m.f on the right circuit, the switch on the left circuit has to be turned ON and OFF (current changes) every time. The change in the current on the left circuit creates a constant magnetic field outwards and inwards thus producing induced e.m.f on the right circuit.

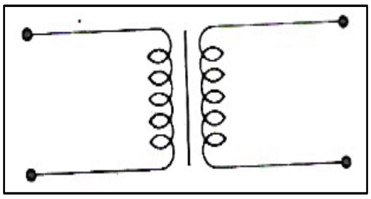
This is the basic of transformer. A transformer makes use of only AC circuit (not DC) because in AC circuit, the current is always changing similar to mutual induction.

Transformer

A transformer is a device in which two multi-turn coils are would around iron core. One coil acts as an input while the other acts as an output. The purpose of a transformer is to produce an output AC voltage that is different from the input AC voltage.

A Transformer





A changing current (I) in the primary coil produces a changing magnetic field (B) in the iron core, which is propagated through the iron core to the secondary coil where the changing magnetic field induces changing e.m.f in the secondary coil.

In a transformer, the iron core transfers the changing magnetic flux produced by AC current in the primary coil to the secondary coil. The changing magnetic flux in the secondary coil induces an alternating voltage producing alternating current. There are two (2) types of transformers:

1. Step-Down Transformer

A step-down transformer has more turns of coil in the primary than the secondary. It produces an output voltage lower in the secondary coil than the primary coil. This means that the primary coil will have more turns of coil and more voltage while secondary coil will have less turns of coil and less voltage.

2. Step-Up Transformer

A step-up transformer has less turns of coil in the primary than the secondary. It produces an output voltage higher in the secondary coil than the primary coil. This means that the primary coil will have less turns of coil and less voltage while secondary coil will have more turns of coil and more voltage.

Assuming that there is no energy loss in the form of heat, the following equation can be used to determine any one of the given unknown:

$$\frac{Voltage\ across\ \sec ondary}{voltage\ across\ primary} = \frac{Number\ of\ turns\ in\ the\ \sec ondary}{Number\ of\ turns\ in\ the\ primary}$$

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

If there is no energy loss when energy is transfered from primary side to the secondary side, then the power in the primary coil is equal to the power in the secondary coil. This happens in an ideal transformer.

An **ideal transformer** does not loss energy and thus power input into the primary is equal to the power output into the secondary.

$$Power\ \mathrm{int}\,o\ the\ primary = Power\ out\ of\ the\ \sec odnary$$

$$P_p = P_s$$

$$I_p V_p = I_s V_s$$

The above equation implies that if a primary coil increases voltage, then it reduces current in the same proportion and vice versa. Power station that needs to supply electricity to longer distance s requires transfer to do that effectively. Voltage has to be increased while current is reduced so that power can be transmitted to long distances. If current is high, power would be lost as heat because of the resistance of the transmitting wire.

In fact most transformers are not perfectly efficient, they waste (loss) some energy as heat through the surroundings and through the resistance of the transmitting power lines (wires).

Therefore, **power loss** can be calculated using this equation on the right:

$$P = IV$$

$$P = I(IR) \ldots\ldots (V = IR)$$

$$P = I^2 R$$

Where;

$P = power\ loss\ (Watts)$

$I = current\ (A)$

$V = voltage\ (V)$

$R = resistance\ (\Omega)$

Unit: Atomic and Nuclear Physics	**Topic:** Atomic Physics
Content Standard 12.2.5	Students will be able to explain and examine the structure, properties and changes of matter as well as sources, uses, conservations and changes of energy.
Benchmark 12.2.5.1	Investigate the structure of matter including atoms, protons and neutrons.

Key question(s):

- How are atoms structured?

Vocabulary:

Proton, neutron, electron

Learning Objective(s)

By the end of the topic, students can:

- Describe atomic structure in conjunction to Bohr's model of the atom.
- Define Heisenberg's uncertainty principle.

Materials

Diagram showing the structure of an atom.

Knowledge	Skills	Attitudes and Values
• The nuclear charge of the atoms of a given element is always the same and is the characteristic of that element.	• Explain how atoms are structured. • Create models of atomic structures.	• Appreciate the functions of atoms in the physical world.

Assessment

- Describe the structure of an atom using its properties.

Teacher to develop assessment rubric on the assessment task mentioned above.

Content Background

The Proton

The existence of positive charge in the atom was known even before the time of Rutherford's experiment. However, it was Rutherford and his colleagues who measured the amount of positive charge in the nuclei of various elements. It was found that:

> ***The nuclear charge of the atoms of a given element is always the same and is the characteristic of that element***

The smallest nuclear charge is that of the hydrogen nucleus. The name **proton** was given to the nuclear particle carrying this unit positive charge. The number of protons in the nucleus of an atom is called its **atomic number, Z**.

Sine the number of positive charges in a neutral atom equals the number of electrons, the mass of the proton has been found to be $1.67\times10^{-27}\ kg$.

Properties of the subatomic particles

In 1932 the English physicist James Chadwick discovered a third subatomic particle, the **neutron.** This particle exists in the nucleus, has no electric charge and is about the size of proton.

Properties of the subatomic particles

Particle	Charge	Mass	Location in the atom
proton	+ 1	1.67×10^{-27} kg	nucleus
neutron	0	1.67×10^{-27} kg	nucleus
electron	- 1	9.11×10^{-31} kg	orbits nucleus

Unit: Atomic and Nuclear Physics **Topic:** Photons

Benchmark 12.2.5.2	Examine how atoms interact by transferring or sharing electrons.

Key question(s):

- What are photons and what are their characteristics in the physical world?

Vocabulary:

Photon

Learning Objective(s)

By the end of the topic, students can:
- Investigate and examine photons and their characteristics.

Materials

Diagram showing the structure of an atom.

Knowledge	Skills	Attitudes and Values
• A photon is the smallest discrete amount or quantum of electromagnetic radiation.	• Describe photons with respect to their particles.	• Appreciate the function of photons in the physical world.

Assessment

- Students identify and explain the characteristics of photons.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

A photon is the smallest discrete amount or quantum of electromagnetic radiation. It is the basic unit of all light. Photons are always in motion, in a vacuum, and travel at a constant speed of 2.998×10^8 m/s.

The photon is sometimes referred to as a ‘quantum’ of electromagnetic energy. Photons are not thought to be made up of smaller particles. They are a basic unit of nature called an elementary particle.

Unit: Atomic and Nuclear Physics **Topic:** : Radioactive Decay

Benchmark 12.2.5.3	Research nuclear reactions and how they produce energy.

Key question(s):

- What are the types of radiation and how are they produced?
- How do radioactive materials decay?

Vocabulary:

Nuclear Transmutation, alpha, beta, gamma

Learning Objective(s)

By the end of the topic, students can:
- Investigate types of radiation.
- Describe radioactive decay

Materials

Chart for diagrams showing radioactive particles.

Knowledge	Skills	Attitudes and Values
• The three main types of radiations are alpha, beta, and gamma.	• Explain the three radiations with their properties and behaviours.	• Appreciate the uses of radiation in daily life situations.

Assessment

- Students to describe nuclear transmutation.
- Students research nuclear reactions and explain how they produce energy.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

Nuclear radiation

All radioactive nuclides have certain features in common.

1. They cause certain compounds to fluoresce.
2. They cause ionization of air molecules.
3. They affect a photographic plate.
4. They can cause damage to the health of living things.
5. They undergo a process of decay

Detection of radioactivity

The instruments used to detect radioactivity are;

- Scintillation counter
- Spark counter
- Geiger-Muller (GM) tube
- Diffusion cloud chamber

Types of radioactivity

Alpha (α) radiation

Alpha radiation is due to positively charged particles being emitted from the nucleus of radioactive atoms. Measurement of their charge to mass ratio (e/m) by J.J. Thompson at the beginning of this century suggested that they were helium nuclei (containing two protons bound to two neutrons). This was confirmed by Rutherford and others.

Alpha particles travel at about 5% of the speed of light. Because of their + 2 charge they tend to attract electrons away from nearby atoms and so cause intense ionization in a gas.

When americium-241 $\left({}^{241}_{95}Am\right)$ emits an alpha particle, it is changed into neptunium-237 $\left({}^{237}_{93}Np\right)$. This alpha decay may be shown by the following equation.

$$ {}^{241}_{95}Am \rightarrow {}^{237}_{93}Np + {}^{4}_{2}H(\propto) $$

In an alpha decay, the atomic number Z of the nucleus decreases by two and the mass number by four. Such a change is called a nuclear transmutation.

Alpha particles have a low power of penetration, traveling only a few centimeters in air. They can be stopped by a sheet of thick paper.
Alpha particles can be detected on a photographic plate, in a cloud chamber and by a spark counter. Only the most energetic can be detected on a GM counter.

Beta (β) radiation

Beta radiation is due to particles being emitted from the nucleus of radioactive atom. Measurement of their mass ratio (e/m) sows that beta particles are fast moving electrons. They are much lighter than alpha particles and have a net charge of - 1. Their speed ranges from 30% to 90% of the speed of light. They are much less ionizing than alpha particles but are far more penetrating. The most energetic beta particles have a range in air of a few meters and are stopped by about 5 mm of aluminum or 1 mm of lead.

In beta decay, a neutron in the nucleus changes into a proton and en electron. Since electrons cannot exist in the nucleus for a long period of time, the electron produced is elected. This results in a nuclear transmutation

Gamma (γ) radiation

Gamma radiation is due to high-energy electromagnetic rays being emitted from the nucleus of an atom. They travel at about the speed of light and have no net charge. It is important to realize that gamma radiation is not due to particles.

The nature of gamma radiation was not established until 1914. Like X-rays, gamma rays are very penetrating, but their ionizing power is very low. They are never completely absorbed but their intensity can be reduced significantly by several centimetres of lead. Their wavelengths are shorter than X-rays.
When a nucleus emits a gamma ray, the nucleus retains the same atomic number Z and mass number A. The gamma ray only carries away energy. After removal of some energy, the nucleus becomes more stable.

$$ {}^{60}_{27}Co^{*} \rightarrow {}^{60}_{27}Co + \gamma $$

(= in excited or unstable state)*

Gamma emission generally occurs after an alpha or beta emission.
Gamma rays can be detected on a photographic plate, in a cloud chamber (straight tracks spreading out from the gamma rays) and by a GM counter.

Radiation Type	Relative ionising power	Relative penetrating power	Range in air	Electric charge	Absorbed by:
Alpha	10 000	1	5 cm	+2	Sheet of paper
Beta	100	100	3 m	– 1	
Gamma	1	10 000	100 m	0	

Radioactive decay

Half-life is the time it takes for half of the nuclei to decay. Rate of decay $\propto$ number of atoms present at time t.

$$i.e. \frac{dN}{dt} \propto N$$

This gives the equation $\frac{dN}{dt} = -\lambda N$ ($\lambda =$ decay constant)

Using calculus, (not shown here) gives $N = N_o e^{-\lambda t}$

Where N_o is the number of atoms present at ***t=0***

It can be shown that the half-life τ is given by: $\tau = \frac{0.6931}{\lambda}$
Thus if τ is large, λ is small; and vice versa.

Examples and uses of radioactive isotopes

Isotopes	Type of emission	Half-life	Uses
$^{14}_{6}C$	β	5730 y	Carbon dating, biological tracing. Produced in atmosphere when cosmic rays collide with N-14.
$^{60}_{27}Co$	β, γ	5.3 y	Sterilization of medical products, plastic modification, industrial radiography, cancer treatment, killing of bacteria
$^{235}_{92}U$	α, γ	7.13×10^{8}y	

Unit: Atomic and Nuclear Physics **Topic:** Nuclear Reactions

Benchmark 12.2.5.3	Research nuclear reactions and how they produce energy.

Key question(s):

- How does nuclear fission differ from nuclear fusion?
- What is a nuclear reactor?
- What are the uses of nuclear energies?

Vocabulary:

Nuclear Fission, Fusion,Nuclear reactor moderator, coulorabic repulsion

Learning Objective(s)

By the end of the topic, students can;

- Differentiate between nuclear fission and fusion
- Determine the parts and functions of nuclear reactor.
- Investigate and explain the uses of nuclear energy in industries.

Materials

Chart for diagrams showing nuclear reactor.

Knowledge	Skills	Attitudes and Values
• The splitting of a heavy nucleus into nuclei of intermediate mass is called nuclear fission • The combination of light nuclei to form a heavier nucleus is called nuclear fusion.	• Create models explaining nuclear fission and fusion	• Have a fair state of notion on the uses of nuclear fission and fusion.

Assessment

- Research nuclear reactions and explain how they produce energy.

Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

Nuclear Fission

The splitting of a heavy nucleus into nuclei of intermediate mass is called nuclear fission. During the fission process neutrons are emitted and a large amount of energy is released. The energy is in the form of the kinetic energy of the fragments, which it converts into heat energy by collisions with other atoms.
One equation for the fission of U-235 is:

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{138}_{56}Ba + ^{95}_{36}Kr + 3^{1}_{0}n + 300MeV$$

The products of the reaction are also radioactive. The neutrons released in the fission of a nucleus can trigger off the fission of other nuclei. In this way, a **chain reaction** occurs, releasing an enormous amount of energy in a short time.
For a chain reaction to occur, the mass of the uranium-235 has to exceed a certain value, called the **critical mass**. The **critical assembly** of uranium is the volume and shape that will sustain a chain reaction.

The neutrons emitted during fission are usually moving too fast to be absorbed by other fissionable nuclei. Hence the neutrons must be slowed down by a suitable material called a moderator (e.g. graphite or heavy water).

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Nuclear Fusion

In fission, a heavy nucleus is split into two to release energy. The reverse process can also produce large amount of energy.

The combination of two light nuclei to form a heavier nucleus is called **nuclear fusion**. For example, two nuclei of hydrofen-2 (deuterium) can be smashed together to form a nucleus of helium-3 and a neutron. The reaction can be written as:

$$ {}_{1}^{2}H + {}_{1}^{2}H \rightarrow {}_{2}^{3}He + {}_{0}^{1}n + 3.3MeV $$

The total energy released in this reaction is less than that of uranium fission, but the energy per nucleon is much greater. In other words, less material is required to produce the energy.

To start the fusion of two nuclei, they must be brought sufficiently close together. It is not easily done as they repel by a large electrical force (coulombic repulsion). A way to bring the nuclei together would be to heat them up to an extremely high temperature (100 million degrees), so that they gain enough kinetic energy to overcome the coulombic repulsion. At these temperatures, however, containment would be difficult because all material would be vaporized and would not hold the plasma.

Nuclear Reactor

A nuclear reactor is a device in which a controlled chain reaction takes place. The world's first commercial power station was opened in 1956 at Calder Hall, England.
In a nuclear power station, fission in a nuclear reactor provides energy to turn water into steam. The steam is used to turn a turbine, which is connected to a generator. The generator produces electricity. Careful control of the chain reaction ensures energy is released at a steady rate. There are many different types of nuclear reactors.
The **pressurized water reactor** (PWR) is the most common reactor type used today. The fuel (uranium oxide enriched with uranium-235) is contained in a steel pressure vessel. Energy released during the fission process heats the water to around 325oC. The heated water is carried in pipes at high pressure (155 atmosphere) to the steam generator. The pressurized water also acts as a moderator to slow down the fission neutrons, thereby maintaining the chain reaction. Boron-steel control rods inserted in the fuel elements are used to control the reaction. The boron absorbs the neutrons, which can cause further fission. The chain reaction and hence the temperature can be controlled by raising or lowering the control rods. In an emergency, all the control rods are lowered to shut down the reactor.

Standards-Based Lesson Planning

What are Standards-Based Lessons?

In a Standards-Based Lesson, the most important or key distinction is that, a student is expected to meet a defined standard for proficiency. When planning a lesson, the teacher ensures that the content and the methods of teaching the content enable students to learn both the skills and the concepts defined in the standard for that grade level and to demonstrate evidence of their learning.

Planning lessons that are built on standards and creating aligned assessments that measure student progress towards standards is the first step teacher must take to help their students reach success. A lesson plan is a step-by-step guide that provides a structure for an essential learning.

When panning a standards-based lesson, teacher instructions are very crucial for your lessons. How teachers instruct the students is what really points out an innovative teacher to an ordinary teacher. Teacher must engage and prepare motivating instructional activities that will provide the students with opportunities to demonstrate the benchmarks. For instance, teacher should at least identify 3-5 teaching strategies in a lesson; teacher lectures, ask questions, put students into groups for discussion and role play what was discussed.

Why is Standards-Based Lesson Planning Important?

There are many important benefits of having a clear and organized set of lesson plans. Good planning allows for more effective teaching and learning. The lesson plan is a guide and map for organizing the materials and the teacher for the purpose of helping the students achieve the standards. Lesson plans also provide a record that allows good, reflective teachers to go back, analyse their own teaching (what went well, what didn't), and then improve on it in the future.

Standards-based lesson planning is vital because the content standards and benchmarks must be comparable, rigorous, measurable and of course evidence based and be applicable in real life that we expect students to achieve. Therefore, teachers must plan effective lessons to teach students to meet these standards. As schools implement new standards, there will be much more evidence that teachers will use to support student learning to help them reach the highest levels of cognitive complexity. That is, students will be developing high-level cognitive skills.

Components of a Standards-Based Lesson Plan

An effective lesson plan has three basic components;

- aims and objectives of the course;
- teaching and learning activities;
- assessments to check student understanding of the topic.

Effective teaching demonstrates deep subject knowledge, including key concepts, current and relevant research, methodologies, tools and techniques, and meaningful applications.

Planning for under-achievers NORMA

Who are underachieving students?
Under achievers are students who fail or do not perform as expected. Underachievement may be caused by emotions (low self-esteem) and the environment (cultural influences, unsupportive family)

How can we help underachievement?

Underachievement varies between students. Not all students are in the same category of underachievement.
Given below a suggested strategies teachers may adopt to assist underachievers in the classroom.

- Examine the Problem Individually

It is important that underachieving students are addressed individually by focusing on the student's strengths.

- Create a Teacher-Parent Collaboration

Teachers and parents need to work together and pool their information and experience regarding the child. Teachers and parents begin by asking questions such as;

- In what areas has the child shown exceptional ability?
- What are the child's preferred learning styles?
- What insights do parents and teachers have about the child's strengths and problem areas?

- Help student to plan every activity in the classroom
- Help students set realistic expectations
- Encourage and promote the student's interests and passions.
- Help children set short and long-term academic goals
- Talk with them about possible goals.
- Ensure that all students are challenged (but not frustrated) by classroom activities
- Always reinforce students

Standards-Based Lesson Planning

The following sample lesson can help teachers to plan effective lessons. Teachers are encouraged to study the layout of the different components of these lessons and follow this design in their preparation and teaching of each lesson. Planning a good lesson helps the teacher in maintaining a standard teaching pattern which should not deviate students learning of the concept from the topic.

Sample Standards-Based Lesson Plan (Integrating STEAM)

Topic: Quantities and Measurement
Lesson Topic: Standard and Derived Units
Grade: **11**
Length of Lesson: 40 minutes

National Content Standard: 12.1.1 Students will be able to explain the nature and the processes of scientific inquiry and use the modes of scientific inquiry and habits of mind to investigate and interpret the world around them.

Grade Level Benchmark: 12.1.1.1. Identify appropriate quantities, their units and measurement methods using the metric system.

Essential Knowledge, Skills, Values, and Attitudes

Knowledge: Fundamental and derived units.
Skills: Evaluating - Reasoning
Values: Precise and accurate in interpreting information or data.
Attitudes: Responsible, truthful and correctness.

STEAM Knowledge and Skill

Knowledge: Reasons for standard and derived units.
Skill: Evaluating - Reasoning

Performance Indicator: Identify the essential processes in deriving units.

STEAM Performance Indicator: As above

Materials: Copies of conversion scales

- **Lesson Objective:** Students will be able to differentiate between Standard units and Derived Units

Essential Questions:

What are standard and derived SI units?'
What STEAM principles and practices can be used to enhance the ability to make conversions and derivations between units?...

Lesson Procedure

Teacher Activities	Student Activities
Introduction	
• Explain what students will learn and how it will be useful. • Connect what they will learn to prior learning or experience.	• Listen to the teacher.
Body	
Modeling	
• Identify and discuss a Standard and Derived units.	• Listen and respond when prompted by the teacher.
Guided Practice	
• Give students a copy of the conversion scale. • Ask students to read the conversion scale and identify one process involved in deriving units from standard units. • Ask students to stop and give a process for deriving units. • Ascertain if students understand what they are supposed to do.	• Read the conversion scale and identify one process involved in deriving units from standard units. • Give one process given in the conversion scale in deriving units from standard units. • Let teacher know if they understand what to do.
Independent Practice	
• Ask students to read the conversion scale and identify one process involved in deriving units from standard units. • Ask students to suggest and defend one process to derive units from standard units.	• Read the conversion scale and identify one process involved in deriving units from standard units. • Suggest and defend one other conversion process to derive units from standard units.
Conclusion	
• Emphasise the reasons given in the conversion scale to derive units from standard units. • Ask students to provide a process given in the process for deriving units.	• Listen to the teacher. • Give reasons to make conversions and their importance, orally

Performance Assessment and Standards

National Content Standard 12.1.1: Students will be able to explain the nature and the processes of scientific inquiry and use the modes of scientific inquiry and habits of mind to investigate and interpret the world around them.

Lesson Topic	Topic	Benchmark	Performance Assessment	
Standard and Derived Units	**Quantities and Measurement**	**12.1.1.1.** Identify appropriate quantities, their units and measurement methods using the metric system.	Student read the conversion scale and identify processes derive units from standard untis.	
	PROFICIENCY RUBRIC			
	Advanced	**Proficient**	**Partially Profi-cient**	**Novice**
	Identify all the processes given in derivation of units from standard units and justified at least one process	Identify all the processes given in the derivation of units from standard units.	Identify more than half of the processes given in deriving units from standard units.	Identify less than half of the processes given in the derivation of units from standard units

STEAM Activity

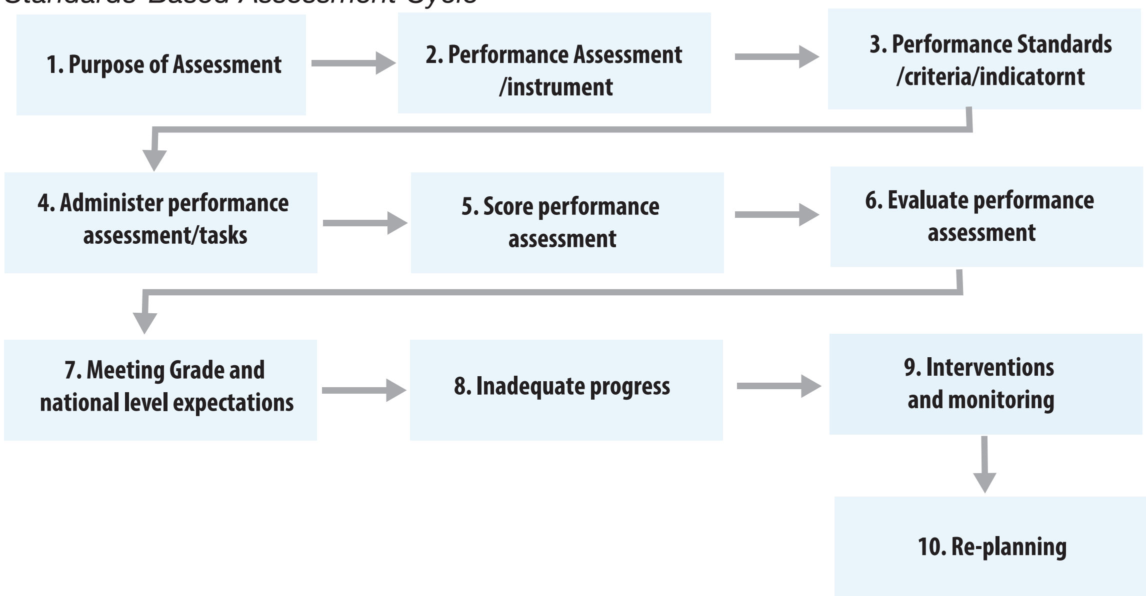
Students create a model of a measuring device that is essential in measuring and can be used in the derivation processes of units.

Assessment, Monitoring and Reporting

What is Standards-Based Assessment (SBA)?

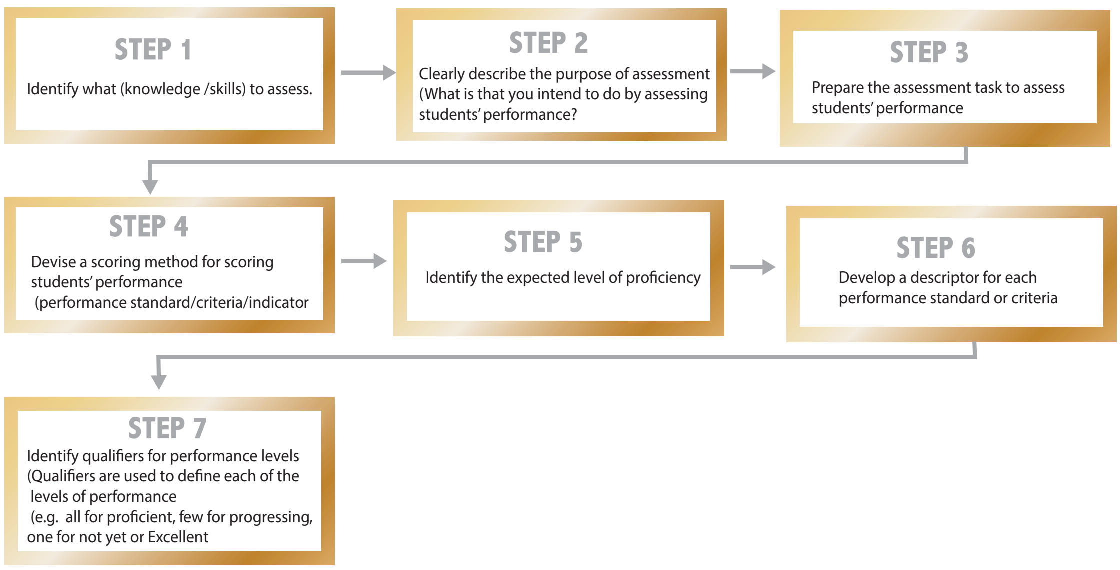
Assessment and reporting is an integral part of the delivery of any curriculum used in the schools. In Standard Based Curriculum (SBC) assessment encourages the use of benchmarks and commended types of assessment that promote standards for a range of purposes.

Standards-Based Assessment Cycle



Standards-Based Assessment Process

Teachers are required to use the steps outlined below when planning assessment. These steps will guide you to develop effective assessments to improve student's learning as well as evaluating their progress towards meeting national and grade –level expectations.



Purpose of Standards-Based Assessment

Standards-Based Assessment (SBA) serves different purposes. These include instruction and learning purposes. The primary purpose of SBA is to improve student learning so that all students can attain the expected level of proficiency or quality of learning.

Enabling purposes of SBA is to:

- Measure students' proficiency on well-defined content standards, benchmarks and learning objectives
- Ascertain students' attainment or progress towards the attainment of specific component of a content standard
- Ascertain what each student knows and can do and what each student needs to learn to reach the expected level of proficiency
- Enable teachers to make informed decisions and plans about how and what they would do to assist weak students to make adequate progress towards meeting the expected level of proficiency
- Enable students to know what they can do and help them to develop and implement strategies to improve their learning and proficiency level
- Communicate to parents, guardians, and relevant stakeholders the performance and progress towards the attainment of content standards or its components
- Compare students' performances and the performances of other students

Principles of Standards-Based Assessment

The principle of SBA is for assessment to be;

- emphasise on tasks that should encourage deeper learning,
- be an integral component of a course, unit or topic and not something to add on afterward,
- a good assessment requires clarity of purpose, goals, standards and criteria of practices that should use a range of measures allowing students to demonstrate what they know and can do,
- based on an understanding of how students learn
- improving performance that involves feedback and reflection,
- on-going rather than episodic,
- given the required attention to outcomes and processes, and
- be closely aligned and linked to learning objectives, benchmarks and content standards

Standards-Based Assessment Types

In standards-Based Assessment, there are three broad assessments types.

1. Formative Assessment

Formative assessment includes 'assessment *for* and *as Learning'* and is conducted during the teaching and learning of activities of a topic.

Purposes of assessment for Learning

- On-going assessment that allows teachers to monitor students on a day-to-day basis.
- Provide continuous feedback and evidence to the teachers that should enable them to identify gaps and issues with their teaching, and improve their classroom teaching practice.
- Helps students to continuously evaluate, reflect on, and improve their learning.

Purposes of assessment as Learning

- Occurs when students reflect on and monitor their progress to inform their future learning goals.
- Helps students to continuously evaluate, reflect, and improve their own learning.
- Helps students to understand the purpose of their learning and clarify learning goals.

2. Summative Assessment

Summative assessment focuses on 'assessment *of learning'* and is cconducted after or at the conclusion of teaching and learning of activities or a topic.

Purposes of assessment of Learning

- Help teachers to determine what each student has achieved and how much progress he/she has made towards meeting national and grade-level expectations.
- Help teachers to determine what each student has achieved at the end of a learning sequence or a unit.
- Enable teachers to ascertain each student's development against the unit or topic objectives and to set future directions for learning.
- Help students to evaluate, reflect on, and prepare for next stage of learning.

3. Authentic Assessment

- Is performed in a real life context that approximates as much as possible, the use of a skill or concept in the real world.
- Is based on the development of a meaningful product, performance or process
- Students develop and demonstrate the application of their knowledge, skills, values and attitudes in real life situations which promote and support the development of deeper levels of understanding.
- Uses either summative or formative assessment methods in real life context.

Authentic assessment refers to assessment that:

- Looks at students actively engaged in completing a task that represents the achievement of a learning objective or standard.
- Takes place in real life situations.
- Asks students to apply their knowledge, skills, values and attitudes in real life situations.
- Students are given the criteria against which they are being assessed.

Performance Assessment

Performance assessment is a form of testing that requires students to perform a task rather than select an answer from a ready-made list. For example, a student may be asked to explain historical events, generate scientific hypotheses, solve math problems, converse in a foreign language, or conduct research on an assigned topic. Teachers, then judge the quality of the student's work based on an agreed-upon set of criteria. It is an assessment which requires students to demonstrate that they have mastered specific skills and competencies by performing or producing something.

Types of performance assessment

i. Products

This refers to concrete tangible items that students create through either the visual, written or auditory media such as:

- Creating a health/physical activity poster.
- Video a class game or performance and write a broadcast commentary.
- Write a speech to be given at a school council meeting advocating for increased time for health and physical education in the curriculum.
- Write the skill cues for a series of skill photo's.
- Create a brochure to be handed out to parents during education week.
- Develop an interview for a favourite sportsperson.
- Write a review of a dance performance.
- Essays.
- Projects.

ii. Process Focused Tasks

It shows the thinking processes and learning strategies students use as they work such as:

- Survival scenarios.
- Problem solving initiative/adventure/ activities.
- Decision making such as scenario's related to health issues.
- Event tasks such as creating a game, choreographing a dance/gymnastics routine, creating an obstacle course.
- Game play analysis.
- Peer assessment of skills or performances.
- Self-assessment activities.
- Goal setting, deciding a strategy and monitoring progress towards achievement.

iii. Portfolio

This refers to a collection of student work and additional information gathered over a period of time that demonstrates learning progress.

iv. Performances

It deals with observable affective or psycho-motor behaviours put into action such as:

- Skills check during game play.
- Role plays.
- Officiating a game.
- Debates.
- Performing dance/gymnastics routines.
- Teaching a skill/game/dance to peers.

Assessment Strategies

It is important for teachers to know that, assessment is administered in different ways. Assessment does not mean a test only. There are many different ways to find out about student's strengths and weaknesses. Relying on only one method of assessing will not reflect student's achievement.

Provided in the table below is a list of suggested strategies you can use to assess student's performances. These strategies are applicable in all the standards-based assessment types.

Assessment Strategies

STRATEGY	DESCRIPTION
ANALOGIES	Students create an analogy between something they are familiar with and the new information they have learned. When asking students to explain the analogy, it will show the depth of their understanding of a topic.
CLASSROOM PRESENTATIONS	A classroom presentation is an assessment strategy that requires students to verbalize their knowledge, select and present samples of finished work, and organize their thoughts about a topic in order to present a summary of their learning. It may provide the basis for assessment upon completion of a student's project or essay.
CONFERENCES	A conference is a formal or informal meeting between the teacher and a student for the purpose of exchanging information or sharing ideas. A conference might be held to explore the student's thinking and suggest next steps; assess the student's level of understanding of a particular concept or procedure; and review, clarify, and extend what the student has already completed
DISCUSSIONS	Having a class discussion on a unit of study provides teachers with valuable information about what the students know about the subject. Focus the discussions on higher level thinking skills and allow students to reflect their learning before the discussion commences.
ESSAYS	An essay is a writing sample in which a student constructs a response to a question, topic, or brief statement, and supplies supporting details or arguments. The essay allows the teacher to assess the student's understanding and/or ability to analyse and synthesize information.
EXHIBITIONS/ DEMONSTRATIONS	An exhibition/demonstration is a performance in a public setting, during which a student explains and applies a process, procedure, etc., in concrete ways to show individual achievement of specific skills and knowledge.
INTERVIEWS	An interview is a face-to-face conversation in which teacher and student use inquiry to share their knowledge and understanding of a topic or problem, and can be used by the teacher to explore the student's thinking; assess the student's level of understanding of a concept or procedure and gather information, obtain clarification, determine positions, and probe for motivations.
LEARNING LOGS	A learning log is an ongoing, visible record kept by a student and recording what he or she is doing or thinking while working on a particular task or assignment. It can be used to assess student progress and growth over time.
OBSERVATION	Observation is a process of systematically viewing and recording students while they work, for the purpose of making programming and instruction decisions. Observation can take place at any time and in any setting. It provides information on students' strengths and weaknesses, learning styles, interests, and attitudes.
PEER ASSESSMENT	Assessment by peers is a powerful way to gather information about students and their understanding. Students can use set criteria to assess the work of their classmates.
PERFORMANCE TASKS	During a performance task, students create, produce, perform, or present works on "real world" issues. The performance task may be used to assess a skill or proficiency, and provides useful information on the process as well as the product.

PORTFOLIOS	A portfolio is a collection of samples of a student's work, and is focused, selective, reflective, and collaborative. It offers a visual demonstration of a student's achievement, capabilities, strengths, weaknesses, knowledge, and specific skills, over time and in a variety of contexts.
QUESTIONS AND ANSWERS (ORAL)	In the question–and-answer strategy, the teacher poses a question and the student answers verbally, rather than in writing. This strategy helps the teacher to determine whether students understand what is being, or has been, presented, and helps students to extend their thinking, generate ideas, or solve problems.
QUIZZES, TESTS, EXAMINATIONS	A quiz, test, or examination requires students to respond to prompts in order to demonstrate their knowledge (orally or in writing) or their skills (e.g., through performance). Quizzes are usually short; examinations are usually longer. Quizzes, tests, or examinations can be adapted for exceptional students and for re-teaching and retesting.
QUESTIONNAIRES	Questionnaires can be used for a variety of purposes. When used as a formative assessment strategy, they provide teachers with information on student learning that they can use to plan further instruction.
RESPONSE JOURNALS	A response journal is a student's personal record containing written, reflective responses to material he or she is reading, viewing, listening to, or discussing. The response journal can be used as an assessment tool in all subject areas.
SELECTED RESPONSES	Strictly speaking a part of quizzes, tests, and examinations, selected responses require students to identify the one correct answer. The strategy can take the form of multiple-choice or true/false formats. Selected response is a commonly used formal procedure for gathering objective evidence about student learning, specifically in memory, recall, and comprehension.
STUDENT SELF-ASSESSMENTS	Self-assessment is a process by which the student gathers information about, and reflects on, his or her own learning. It is the student's own assessment of personal progress in terms of knowledge, skills, processes, or attitudes. Self-assessment leads students to a greater awareness and understanding of themselves as learners.

Samples of Assessment Types

Sample 1: Formative Assessment

Strand 2: Physical Science

Content Standard: 11.2.1 Students will be able to examine and explain the structure, properties and changes of motion with motion equation.

Topic: Object in Motion

Benchmark: 11.2.1.1 Derive and use equations of motion.

Lesson Title What is Kinematics?

Lesson Objective: By the end of the lesson, students should be able to de-
scribe
kinematics.

Materials: Motion diagrams

What is to be assessed? (KSAVs)

Knowledge	Skills	Values and Attitudes
• Solviong problems using motion graphs	• Drawing up motion graphs and solve related problems	• Display confidence in drawing up motion graphs • Appreciate the usefulness of objects in motion

Scientific Thinking: Think about how information from a real problem can be displayed onto a motion graph.

Purpose of the assessment

To measure students' proficiency on the achievement of the benchmark and learning objectives.

Expected level of proficiency

Design Motion graphs and display information in order to find solutions to given problems.

Assessment Strategy

This assessment can be conducted in one lesson as an assessed lesson exercise.

Performance Task

Draw a Motion graphs to represent given information to solve problems.

Assessment Tool

An exercise will be used to measure their level of proficiency

Assessment Scoring

Rubrics must be developed to articulate the real proficiency of the child. This is an analytical rubrics used to assess the child's learning through the assessment tool a lesson exercise.

Performance standards/ Criteria	**A**	**B**	**C**	**D**	**Score**
	Advance 10	Proficient 9 - 5	Progressing 3 - 4	Not Yet 2	__/10 Marks
Draw a Motion graphs to represent given information to solve related problems. **10 marks**	Correct sketch of the Motion graphs and represented all information correctly and answered all the related questions with clear calculation steps	Correct sketch of the Motion graphs and represented all information correctly and answered all the related questions.	Satisfactory sketch of the Motion graphs and represented most information correctly and answered some of the related questions.	Poor sketch of the Motion graphs and represented few information and answered only one of the related questions.	

Recommended Resources:

- 'Grade 11 Physics Save Book'
- Worksheet
- Essential of Physics

Sample 2: Summative Assessment

Strand 2: Physical Science

Content Standard 11.2.1: Students will be able to examine and explain the structure, properties and changes of motion with motion equation.

Topics 1- 5: *(Refer to the topics in kinematics unit)*

Unit: Kinematics

Benchmark: 11.2.1.1 to 11.2.1.3 *(Refer to the benchmarks in kinematics unit)*

Lesson topics: *(Refer to the lesson topics in kinematics unit)*

Instructional Objective (s): *(Refer to kinematics unit)*

Knowledge	Skills	Values and Attitudes
• Motion, equations of motion, trigonometry and algebraic laws.	• Drawing up Motion graphsnand apply algebraic laws to solve related problems	• Appreciate the usefulness of Motion and problems display confidences in solving motion related problems.

Scientific Thinking: Think about how to solve motion related questions.

What is to be assessed? - (KSAVs)

The unit, Unit: "Kinematics" of Strand 2

Purpose of the assessment

To measure students' proficiency on the achievement of the benchmarks and learning objectives in this unit. (This assessment is to be conducted after teaching the unit)

Expected level of proficiency

All students are expected to;

- Describe the characteristics of motion by applying the equations of motion and graphs.
- Explain characteristics of motion by using graphs

Assessment Strategy

This assessment can be conducted in one lesson as a unit test, or as an as-signment.

Performance Task

Students will do an assignment out of 20 marks. You can use other assessment tools (assignment, projects, etc.) assess students proficiency on these benchmarks.

Task: Students will be given two week to complete this assignment. They are to;

1. Investigate who is the fastest runner in class.
2. Draw a motion graph to determine the speed of students.

Assessment Tool

An assignment will be used to measure students' proficiency.

Assessment Scoring

Rubrics must be developed to articulate the real proficiency of the child. This is an analytical rubrics used to assess the child's learning through the assessment tool an assignment.

Performance standards/ Criteria	A Advance 20	B Proficient 13-19	C Progressing 6-12	D Not Yet 2-5	Score __/20 Marks
(10 marks) Criteria/ Constraints	Assignment was completed with all constraints and criteria met or exceeded. Reflects attention to detail and quality.	Assignment was completed with some of the constraints and criteria met. Reflects some attention to detail, but quality is minimal.	Assignment was completed with a few of the constraints and criteria met. Reflects minimal effort and lacks detail or quality.	Assignment was not completed and does not reflect the adherence to the constraints or criteria.	
(10 marks) Presentation of Motion Graph	Correct sketch of the Motion Graph and represented all information correctly and answered all the related questions with clear calcula-tion steps	Correct sketch of the Motion Graph and represented all information correctly and answered all the related questions.	Satisfactory sketch of the Motion Graph and represented most information correctly and answered some of the related questions.	Shows poor knowledge of the person or persons involved in these major events	

Analysis. (3 marks)	Student carefully analyzed the information collected and drew appropriate and inventive conclusions supported by the evidence.	Student shows good effort in analyzing the evidence collected.	Student conclusions could have been supported by stronger evidence. Level of analysis could have been deeper	Student conclusions simply involved restating information. Conclusions were not supported by evidence.	
Time Management	Assignment completed and turned in on time. Student worked diligently when assignment time was available. Student was on task most of the time.	Assignment was completed, but had notable errors. Student utilized assignment time somewhat efficiently, but spent time socializing. Student was on task 70% - 80% of the time.	Assignment was not turned in on time and/or complete. The student was on task less than 60% of the time.	Assignment was not turned in on time and was not completed. Student wasted Assignment time and at times was disruptive to others.	

Recommended Resources:

- Essential of Physics
- Grade 11 Physics Save Book

Sample 3: Authentic Assessment

Strand 2: Physical Science

Content Standard: 11.2.2 Students will be able to Investigate and derive Newton's Laws of motion and apply it to solve real life problems.

Unit : Force and Motion

Benchmark: 11.2.2.1 to 11.2.2.5 *(Refer to the benchmarks in unit: force and motion, strand 2)*

Topics: *(Refer to the topics in the unit force and motion)*

Instructional Objective: (Refer to the topics in unit: force and motion, strand 2*)*

What is to be assessed? - (KSAVs)
The essential knowledge, skills, attitudes and values in the unit "Force and Motion"

Purpose of the assessment

To measure students proficiency on the achievement of the benchmarks and learning objectives in this unit. This assessment is to be conducted after teaching this unit.

Expected level of proficiency

All students are expected to:

- Use vectors to explain force and motion
- Apply the laws of motion to determine the effects of forces on the linear motion of objects
- Explain the characteristics of motion by using graphs

Assessment Strategy

This assessment can be conducted as a project, practical test or assignment relating to a real life situation.

Performance Task

Students will do a Real World Application Project (Sinusoidal Modeling) out of 30 marks. You can use other assessment tools (assignment, projects, etc.) to assess student's proficiency on these benchmarks.

Task: Students will be given three weeks to complete this project. They are to:

- Investigate any real-world phenomenon that can be modelled by a sinusoid.
- Research and collect data, develop a predictive model, graph it, and present it to the class using a visual presentation platform like, iMovie, Powerpoint, etc.
- Choose any topic, and the freedom to be as creative and outside-the-box with this project as they wish.

Note: Students should now understand that any variable that is cyclical, harmonic, oscillating, or periodic in nature can be modeled graphically by a sine or cosine wave. There are countless applications of sinusoid modeling in real life.

Some of these applications include:

- Changes in Temperature over time.
- Hours of daylight over time.
- Population growth/decay over time.
- Ocean wave heights (high and low tides) over time .
- Sound waves.
- Electrical currents.
- Ferris wheels and roller coasters.
- Tsunamis and tidal waves.
- Earthquakes.
- Wheels and Swings.

Task Details: Students are to;

- Collect no less than 12 real-world data points that can be modeled sinusoidally. The more data, the better! Providing 24 or more data points will earn maximum points on the rubric.
- A predictive model of the format y = Asin (Bx + C)+ D or y = Acos (Bx + C) + D for the data must be developed using the techniques they learned in class. This model could be used to predict outcomes into the future.
- A neatly organized graph of the original data and a graph of their developed model must both be embedded in their presentation. To produce these graphs they may use their graphing calculators, the Desmos app, or they may draw the graphs themselves. Pictures or screenshots of their graphs may be used. The objective is to compare the two graphs side-by-side or on top of one another, so they could see how accurate and predictive their model is.
- A reflection must be submitted with your project (1-2 paragraphs). This reflection should be neatly and logically written/typed with no grammatical errors, and should summarize their experience in doing this project. What did they learn? What did they enjoy or dislike? What would they change? How well did they work with their partner? Etc.

Criteria	Model/Exemplar	Proficient	Developing	Beginning	
	(4 points	**(3 points)**	**(2 points)**	**(1 point)**	
Data Collection	Data is authentic, appropriately labeled and clearly presented in an X-Y table. Contains 24 or more measurements.	Data is authentic, appropriately labeled and clearly presented in an X-Y table. Contains 13-23 measurements.	Data is authentic, appropriately labeled and clearly presented in an X-Y table. Contains 12 measurements.	Data is incorrectly labeled, not presented in an X-Y table, and contains less than 12 measurements.	
Mathematical Calculations/ Model Development	All calculations are very clear, organized, and neatly completed with no inaccuracies.	All calculations are clear, organized, and neatly completed with 1-2 inaccuracies.	Most calculations are clear, organized, and neatly completed with 3-4 inaccuracies.	Calculations are unclear and disorganized and 5 or more inaccuracies may be present.	
Graphs	All graphs are neatly produced, axes are appropriately scaled and labeled, data points are accurately plotted, colorful, and smooth curves are drawn.	All graphs are neatly produced, axes are appropriately scaled and labeled, data points are accurately plotted, colorful, and smooth curves are drawn.	All graphs are not neatly produced, axes are not appropriately scaled and labeled, data points are not accurately plotted, and smooth curves are not drawn.	All graphs are not neatly produced, axes are not appropriately scaled and labeled, data points are not accurately plotted, and smooth curves are not drawn	

Visual Presentation	The presentation is clear, colorful, creative and entertaining, shows a great deal of editing and audio/visual effects, keeps the audience fully engaged, fully utilizes available technology, and lasts 5-10 minutes.	The presentation is clear and colorful, shows some editing and audio/visual effects, keeps the audience mostly engaged, and fully utilizes technology, and lasts 3-5 minutes	The presentation is bland and basic, does not show editing or effects, keeps the audience moderately engaged, and does not fully utilize technology, and lasts 1-2 minutes	The presentation is erratic and poorly produced, lacks effort, does not show any editing or effects, the audience is not engaged, and does not utilize technology, and lasts under 1 minute.	
Effort and Collaboration	An exceeding amount of time and effort are present and the task responsibilities were shared equitably among group partners.	A substantial amount of effort is present and the task responsibilities were shared equitably among group partners.	An average amount of effort is present, and the task responsibilities were not shared equitably among group partners.	A poor amount of effort is present, and the task responsibilities were not shared equitably among group partners.	
Reflection	Writing is clear, concise, and well organised. Thoughts are expressed in a coherent and logical manner. Contains 2 or more paragraphs with very few grammatical errors present.	Writing is mostly clear, concise, and well organized. Thoughts are expressed in a coherent and logical manner. Contains 1-2 paragraphs with several grammatical errors present.	Writing is unclear and disorganized. Thoughts are not expressed in a logical manner. Contains 1-2 paragraphs with several grammatical errors present.	Writing is unclear and disorganized. Thoughts ramble and make little sense. Contains 1 paragraph with many grammatical errors present.	

Sample 4: STEAM Assessment

(Integrated Strands in relation to the project from integrated subjects)

Unit: (Integrated Units from all Subjects in this project)

Content Standard: (Integrated Content Standard from all Subjects in project)

Benchmark: (Integrated Benchmarks from all Subjects in this project)

Topic: (Integrated Topics from all Subjects in this project)

Lesson topic: (Integrated Topics from all Subjects in concern)

Instructional Objective (s): Students will be able to;

- Create a STEAM project "building a prototype model of a catapult launching system" to enhance their understand of this concept

VASK-MT	
Values/Attitudes	Appreciate the beauty of the application of mathematics during the designing process of the project.
Skills	Calculating size and space Time management and efficiency, Linear measurement and scaling techniques, Calculating mechanical advantage
Knowledge	Size and space Time management and efficiency, Linear measurement and scaling techniques
Mathematical Thinking	Think about how to integrate and apply the mathematical knowledge in the project

What is to be assessed? - (KSAVs)

Integrated subjects concepts used designing the projects.

Purpose of the assessment

To measure students proficiency on the achievement of the benchmarks and learning objectives for integrated subjects in the project. (STEAM Project)

Expected level of proficiency

All students are expected to:

- Build a prototype model of a catapult launching system through integrating concepts learned in other subjects.

Performance Task

Student will carry out a project worth 30 marks that should contribute to the School Learning Improvement Program (SLIP). This project will assess students proficiency on the mentioned benchmarks. In order for this assessment type to attain its intended purpose the following must be done carefully;

Task: Students will be given a month to complete this project.

1. All grade 12 Science teachers discuss the STEAM project with their HOD
2. The Science HOD brings this project to the attention of the Head Teacher hence it will involve the learning of all grade 12 classes in the school.
3. Once approved by the Head Teacher, the Science HOD now convenes a meeting with all other subject HOD to integrate this project into their learning. HOD for Science will have developed criteria already and will discuss around that.
4. The HOD for other subjects meet with their respective subject teachers to gauge their views and write up criteria's with reference to the theme of the project, "STEM Design and Engineering Challenge" bringing out the essence of their subjects in this project.
5. The Head Teacher then convenes a meeting with all teachers as they are now aware of the project. HOD for respective subjects give feedback from their meetings. Issues concerning this project must be ironed out and all subjects now carry out this assessment, starting with Science.

The grade 12 Science teachers will now do the following;

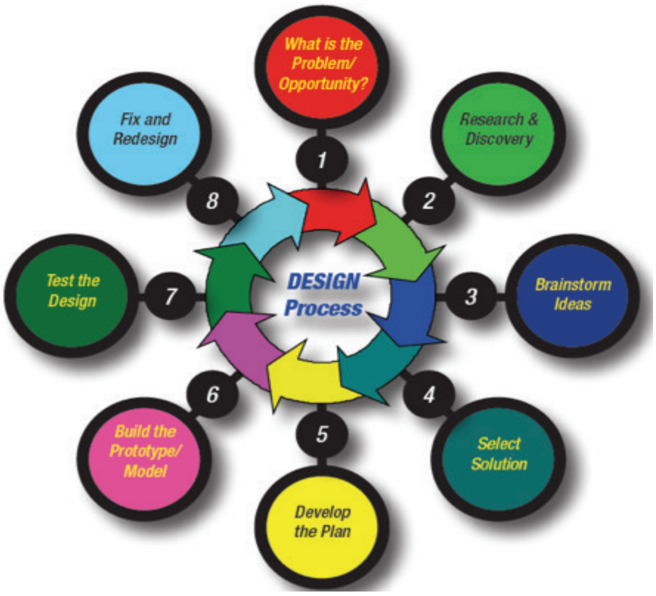
(i) Group the students into groups of 6 to design (drawing and manual) a tangible technology that will enhance the notion of "building a prototype model of a catapult launching system"

(ii) The teacher then assesses their designs and the best designs now compete with the other best designs from other grade 12 classes.

(iii) All the best designers now create models of their designs with assistance from their class members. At this stage the other subjects now carry forward this assessed projects theme, 'building a prototype model of a catapult launching system" however in the context of their subjects. STEAM is an integrated approach of teaching. All subjects must incorporate the theme put forward by Science. They develop criteria that should address this theme. For instance; Technology and Industrial Arts (TIA) will develop criteria that will engage the students to construct the models. Mathematics teachers will develop criteria to test students' knowledge of the Mathematical thinking process of Engineering Design thinking when they create the models around the theme of "prototype model of a catapult launching system". The English subject teachers will set criteria and guidelines for students on how to write reports so they write to tell others what they have learned and experienced. They must also be given guidelines to writing report. Students get to write report of how they designed this technology. The Science teacher will provide criteria for the students in terms of the physical, chemical, biological and geological properties of the materials used to work out the size and shape of the technology.

Task: Students will be given 6 weeks to complete this project. They are to;

- Design and build a prototype model of a catapult launching system that is easy to use and easy to transport.
- Follow the Design Process to prepare their prototype model in time.
- Write and prepare a short presentation to explain the catapult that was built and the process of building it.



Design Specification:

The catapult should be designed to launch a golf ball at least fifteen feet, to a 18cm x 18cm target.

- The catapult should include a system for determining range, reliability, and accuracy.
- The catapult should be mobile, yet stable. Outriggers or other support systems need to be included to maintain stability when the launcher is used.
- The catapult should be no larger than 30cm long x 30 cm deep x 90cm tall.
- The catapult should feature a locking pin or trigger that activates the catapult to launch.
- Your team should prepare to deliver a presentation about the merits of your catapult model and design.

Assessment Strategy

Design Project will be used to measure student's proficiency.

The students will be reinforced in the following STEAM concepts.

Science

- Applications of simple machines, including wheels and axles, levers, and pulleys
- Balance and equilibrium
- Energy transformations, such as rotary motion to linear motion
- Mechanical advantage

Technology and Engineering

- Prototyping and modelling
- Invention and innovation
- Structural integrity/strength
- Brainstorming and problem solving
- Trial and error engineering concepts

Arts

- Sketching and painting

Mathematics

- Calculating size and space
- Time management and efficiency
- Linear measurement and scaling techniques
- Calculating mechanical advantage

Project Rubric

Category	Advanced	Satisfactory	Partial Credit	Unacceptable
	9 -10 points	7- 8 points	1 - 6 points	0 points
Quality/ Workmanship	Maximum effort was put forth to complete the project in a professional manner. Project demonstrates a high degree of quality and attention to detail. Workmanship is excellent.	Some effort was made to complete the project to a level that was sufficient for grading, but does not meet a professional level of quality or appearance. Workmanship is of acceptable quality.	Minimal effort was made to complete the project and the quality and workmanship is sub-par, but still meets the minimal standard.	Little or no effort was made to produce a quality project. Project obviously does not meet minimal standards.
Creativity/ Design	Project reflects many fundamental elements of design and creativity. Project demonstrates an advanced understanding of creative thinking and attention to aesthetics and presentation.	Project reflects some of the elements of design and creativity, but lacks attention to aesthetics and presentation.	Project was completed, but does not reflect the acceptable levels of design and creativity. Effort was minimal and project is mediocre at best.	Project was not completed on time or reflects little or no effort to complete assignment at an acceptable level.
Functionality	Project meets or exceeds the design requirements of purpose and functionality. All elements of the design have been met and the project does what it was designed to do.	Project meets some of the design requirements of purpose and functionality. Not all elements of the design have been met, but the project does what it was designed to do.	Project is somewhat functional, but reflects minimal effort. It is intermittent and doesn't always do what it was designed to do.	Project does not work and demonstrates a lack of effort or understanding of the basic elements of functionality and purpose.
Design Process	Project reflects a clear understanding and application of design process including evidence of research, brainstorming, design and problem solving, prototyping and testing.	Project reflects some understanding and application of accepted design loop principles and sequence including evidence of research, brainstorming, design and problem solving, prototyping and testing.	Project reflects minimal understanding and application of design process.	Project does not show evidence that design process was used. Project does not meet accepted levels of design criteria.
Criteria/ Constraints	Project was completed with all constraints and criteria met or exceeded. Reflects attention to detail and quality.	Project was completed with some of the constraints and criteria met. Reflects some attention to detail, but quality is minimal.	Project was completed with a few of the constraints and criteria met. Reflects minimal effort and lacks detail or quality.	Project was not completed and does not reflect the adherence to the constraints or criteria.

Time Management	Project completed and turned in on time. Student worked diligently when project time was available. Student was on task most of the time.	Project was completed, but had notable errors. Student utilized project time somewhat efficiently, but spent time socializing. Student was on task 70% - 80% of the time.	Project was not turned in on time and/or complete. The student was on task less than 60% of the time.	Project was not turned in on time and was not completed. Student wasted project time and at times was disruptive to others.
Resource Management	Always takes responsibility for use and care of all building components and resources. Always returns building components and materials to proper storage compartments.	Consistently takes responsibility for use and care of building components and resources. Somewhat consistent in returning building components to proper storage compartments.	Sometimes takes responsibility for use and care of building components and resources. Inconsistent in returning building components to proper storage compartments.	Does not take responsibility for the proper use and care of building components and resources. Is careless and does not practice proper storage and safety practices.
Teamwork	Notable teamwork shown with a determination to participate/contribute to team success. Completed required individual tasks that contributed to the success of the team.	Teamwork was noted, but was sometimes off task or working on non-related tasks. Contributed to the success of the team, but could have been more engaged to complete tasks sooner.	Notable time off-task with minimal effort given for team success, or did the project alone without relying on others to do their share of the project.	Was not a team player. Either took over project completely, or did not engage in team direction or plans.
Writing/ Reflection	Writing/reflection is very well organized and explained. Student includes all details in design process. Document has almost no grammatical errors.	Writing/reflection is somewhat organized and explained. Student includes most details in design process. Document has very few grammatical errors.	Writing/reflection is not organized and explained. Student includes only a few details in design process. Document has many grammatical errors.	Writing/reflection is incomplete or not turned in. Student includes no details in design process. Document has many grammatical errors.
Presentation	Presentation was well organized and presented in a logical sequence. Presentation reflects a full knowledge of the topic with clear answers and explanations to questions asked.	Presentation was fairly organized and most information presented in a logical sequence. Answers to questions were vague or lacked clarity or accuracy.	Presentation was unorganized and lacked a logical sequence. Presentation reflected little attention to detail. Answers to questions were inaccurate and confusing.	Presentation was not acceptable and reflects a lack of organization or knowledge of the topic. Presentation shows little effort to meet expectations.

Glossary

Words	Definition
Atom	The smallest portion into which an element can be divided and still retain its properties, made up of a dense, positively charged nucleus surrounded by a system of electrons.
Capacitors	Devices used in electronic circuits to store charge and energy.
Commutator	Reverses the current flow in the coil every half-cycle to ensure the coil continues to rotate in the one direction.
Convection	The transfer of heat by the flow of particles in the heated material.
Electronics	Electronics is concerned with the development of tiny electrical circuits and the devices that are used to make these circuits.
Element	A substance that cannot be broken down into a simpler one by a chemical reaction.
Energy	A supply or source of electrical, mechanical or other forms of power that can generate work.
Experiment	A test, especially a scientific one, carried out in order to discover whether a theory is correct or what the results of a particular course of action would be.
Fluids	A subject whose molecules flow freely. These are substances that offer no permanent resistance to deforming forces.
Frequency	The number of complete vibrations per second
Hypothesis	A statement that predicts the outcome of a problem to be tested or experimented.
Matter	Refers to any materials which occupy space and can be examined by measuring, weighing or by experimental testing.
Mirage	An optical illusion that results from the total internal reflection of light in air.
Motion	The process in change of position of an object or particle at a particular time elapsed.
Period	The time required for one complete vibration or revolution.
Radiation	The flow of heat from one place to another via infrared rays without involving particles of matter.
Radioactivity	The phenomenon of emitting radioactive rays.
Scientific Inquiry Process	The scientific solving problems approach.
Solenoid	A long coil made up of many turns of wire that produces its own magnetic field.
Thermal Physics	The study of heat transfer and heating and cooling of matter.
Torque	The turning effect of a force.
Transistor	Small, three-terminal, semiconductor devices which have revolutionized electronics.
Vector	A physical quantity that can be measured with direction of the motion.
Wave	A disturbance caused in the process to transfer energy.

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Appendices

Appendix 1: Bloom's Taxonomy

LEVEL OF UNDERSTANDING	KEY VERBS
CREATING Can the student create a new product or point of view?	Construct, design, and develop, generate, hypothesize, invent, plan, produce, compose, create, make, perform, plan, produce, assemble, formulate,
EVALUATING Can the student justify a stand or decision?	Appraise, argue, assess, choose, conclude, critique, decide, defend, evaluate, judge, justify, predict, prioritize, provoke, rank, rate, select, support, monitor,
ANALYZING Can the student distinguish between the different parts?	Analyzing, characterize, classify, compare, contrast, debate, criticise, deconstruct, deduce, differentiate, discriminate, distinguish, examine, organize, outline, relate, research, separate, experiment, question, test,
APPLYING Can the student use the information in a new way	Apply, change, choose, compute, dramatize, implement, interview, prepare, produce, role play, select, show, transfer, use, demonstrate, illustrate, interpret, operate, sketch, solve, write,
UNDERSTANDING Can the student comprehend ideas or concepts?	Classify, compare, exemplify, conclude, demonstrate, discuss, explain, identify, illustrate, interpret, paraphrase, predict, report, translate, describe, classify,
REMEMBERING Can the student recall or remember the information?	Define, describe, draw, find, identify, label, list, match, name, quote, recall, recite, tell, write, duplicate, memorise, recall, repeat, reproduce, state,

Appendix 2: 21st Century Skills

WAYS OF THINKING	Creativity and innovation Think creatively Work creatively with others Implement innovations Critical thinking, problem solving and decision making Reason effectively and evaluate evidence Solve problems Articulate findings Learning to learn and meta-cognition Self-motivation Positive appreciation of learning Adaptability and flexibility
WAYS OF WORKING	Communication Competency in written and oral language Open minded and preparedness to listen Sensitivity to cultural differences Collaboration and teamwork Interact effectively with others Work effectively in diverse teams Prioritise, plan and manage projects
TOOLS FOR WORKING	Information literacy Access and evaluate information Use and manage information Apply technology effectively ICT literacy Open to new ideas, information, tools and ways of thinking Use ICT accurately, creatively, ethically and legally Be aware of cultural and social differences Apply technology appropriately and effectively
LIVING IN THE WORLD	Citizenship – global and local Awareness and understanding of rights and responsibilities as a global citizen Preparedness to participate in community activities Respect the values and privacy of others Personal and social responsibility Communicate constructively in different social situations Understand different viewpoints and perspectives Life and career Adapt to change Manage goals and time Be a self-directed learner Interact effectively with others

Appendix 3: Standards-Based Lesson Plan Template

Standards-Based Lesson Plan (Integrating STEAM)

Topic:

Lesson Topic:

Grade:

Length of Lesson:

National Content Standard

Grade Level Benchmark

Essential Knowledge, Skills, Values, and Attitudes

Knowledge:

Skills:

Values:

Attitudes:

Materials:

- **Lesson Objective:**

Essential Questions:

Lesson Procedure

Teacher Activities	Student Activities
Introduction	
Body	
Guided Practice	
Independent Practice	
Conclusion	

Performance Assessment and Standards

<table>
<tr><td colspan="5">National Content Standard :</td></tr>
<tr><th>Lesson Topic</th><th>Topic</th><th>Benchmark</th><th colspan="2">Performance Assessment</th></tr>
<tr><td rowspan="4"></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td colspan="4">PROFICIENCY RUBRIC</td></tr>
<tr><th>Advanced</th><th>Proficient</th><th>Partially Proficient</th><th>Novice</th></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>

Appendix 4: Standards-Based Lesson Plan Template-Integrating STEAM

Standards-Based Lesson Plan (Integrating STEAM)

Topic:
Lesson Topic:
Grade:
Length of Lesson:

National Content Standard

Grade Level Benchmark

Essential Knowledge, Skills, Values, and Attitudes

Knowledge:

Skills:

Values:

Attitudes:

STEAM Knowledge and Skill

Knowledge:

Skill:

Performance Indicator:

STEAM Performance Indicator:

Materials:

- **Lesson Objective:**

Essential Questions:

Lesson Procedure

Teacher Activities	Student Activities
Introduction	
Body	
Modelling	
Guided Practice	
Independent Practice	
Conclusion	

Performance Assessment and Standards

National Content Standard :				
Lesson Topic	**Topic**	**Benchmark**	**Performance Assessment**	
	PROFICIENCY RUBRIC			
	Advanced	**Proficient**	**Satisfactory**	**Poor**

STEAM Activity

Appendix 5: Time Allocation

SBC Senior High School Time Allocation						
No.	Subject		Periods/Week	Sample Period and Time Break ups		Total min/week
				Single Period	Block Period	
1	English		8	2 x 40 min	3 x 80 min	320
2	General Mathematics		8	2 x 40 min	3 x 80 min	320
3	Advanced Mathematics		10	5 x 80 min (2 periods/day)		400
4	Citizenship and Christian Values Education		2	2 x 40 min		80
5	Character and Social Development		2	2 x 40 min		80
6	Physical Education		3	1 x 40 min	1 x 80 min	120
7	Geology		6	4 x 40 min	1 x 80 min	240
8	Physics		6	4 x 40 min	1 x 80 min	240
9	Biology		6	4 x 40 min	1 x 80 min	240
10	Chemistry		6	4 x 40 min	1 x 80 min	240
11	Agriculture		6	3 x 40 min	1 x 120 min	240
12	Social Science	Geography	6	4 x 40 min	1 x 80 min	240
		History	6	4 x 40 min	1 x 80 min	240
		Political Science	6	4 x 40 min	1 x 80 min	240
		Ecomonics	6	4 x 40 min	1 x 80 min	240
		Environment	6	4 x 40 min	1 x 80 min	240
13	Arts	Music	6	4 x 40 min	1 x 80 min	240
		Theatre Arts	6	4 x 40 min	1 x 80 min	240
		Visula Arts	6	4 x 40 min	1 x 80 min	240
14	Business Studies		6	4 x 40 min	1 x 80 min	240
15	Technology and Industrial Arts	Textile Technolgy	6	3 x 40 min	1 x 120 min	240
		Food Technolgy	6	3 x 40 min	1 x 120 min	240
		Construction Technology	6	3 x 40 min	1 x 120 min	240
		Communication Technolgy	6	3 x 40 min	1 x 120 min	240
		Computer Technolgy	6	3 x 40 min	1 x 120 min	240
16	Information Communication, Computer Technology		3		1 x 120 min	120
17	Guidance					40
18	Library Skills					40
19	Religious Education					40

‘FREE ISSUE - NOT FOR SALE’