Physics

Senior High

Grade 11

Teacher Guide

Standards-Based

Papua New Guinea
Department of Education

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Content

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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, Kinematics, Dynamics, Energy and Motion, Electricity and Electronics. 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 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.

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 commend and approve this Grade 11 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 21st Century.

Students should 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.

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. There 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 11 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 Chemistry 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 Physics 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.

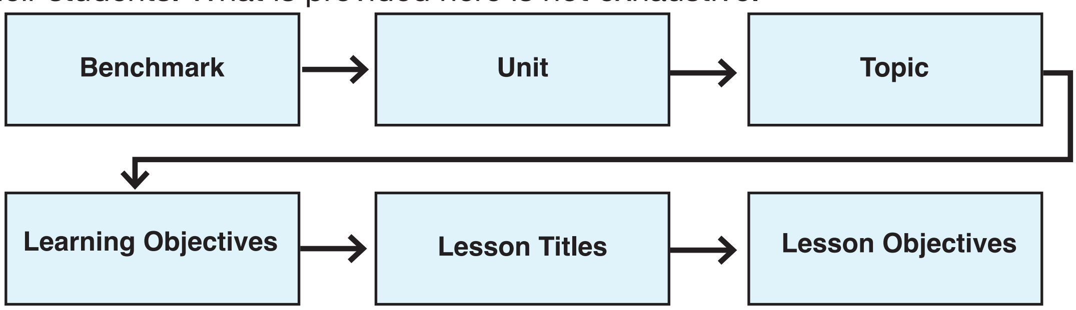
How to use the Teacher Guide

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.



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 science, 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 experience success 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

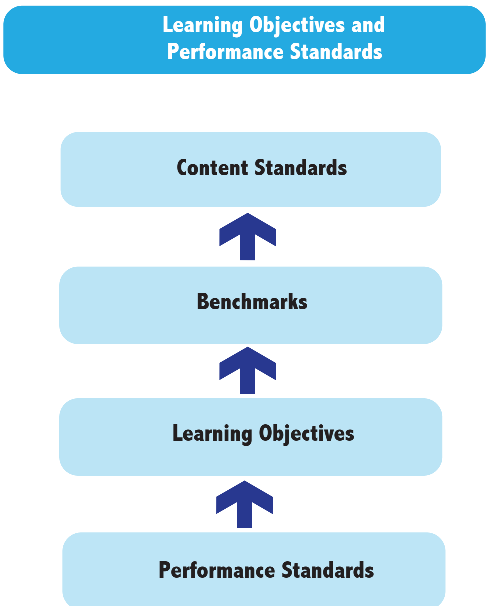
The syllabus outlines the ultimate aim and goals of SBE and SBC, what is to be taught and why it should be learned by students, the underlying principles and articulates the learning and proficiency standards that all students are expected to attain. On the other hand, the teacher guide expands on what 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.

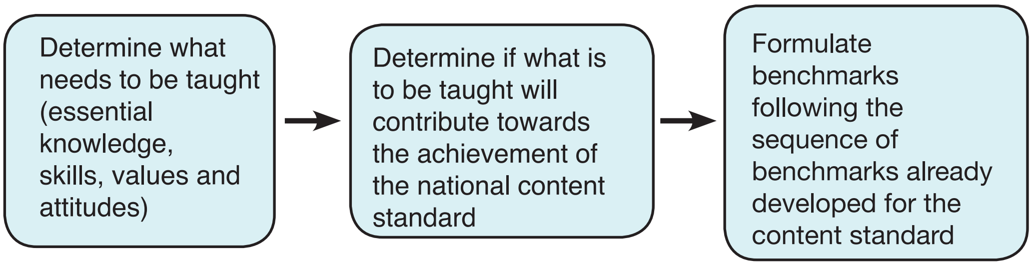
Approach for Setting National Content Standards and Grade-Level Benchmarks

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



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 all the layers of the earth.

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

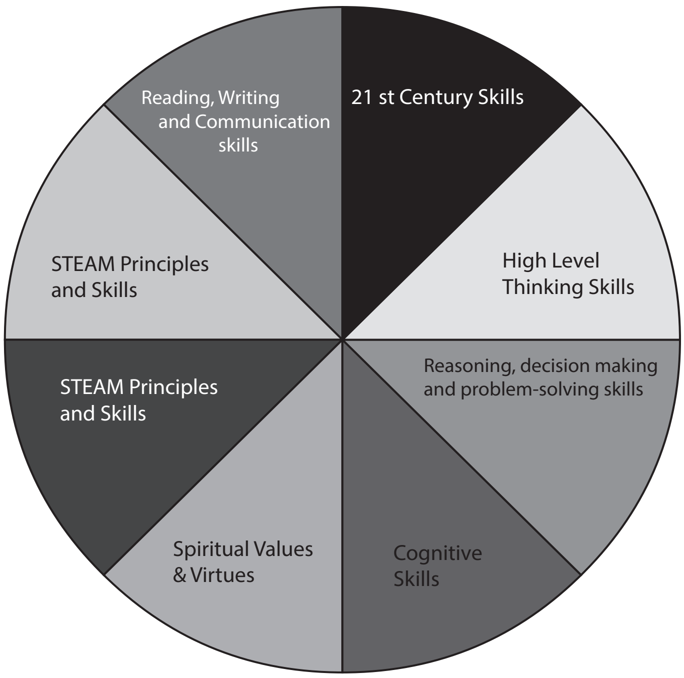
Proficiency standards describe what all students in a particular grade or school level can do at the end of a strand, or unit. These standards are sometimes called evidence outcomes because they indicate if students can actually apply or use what they have learnt in real life or similar situations. They 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,
- reading, writing and communication skills,
- STEAM principles and skills,
- essential values and attitudes (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 learnt 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.

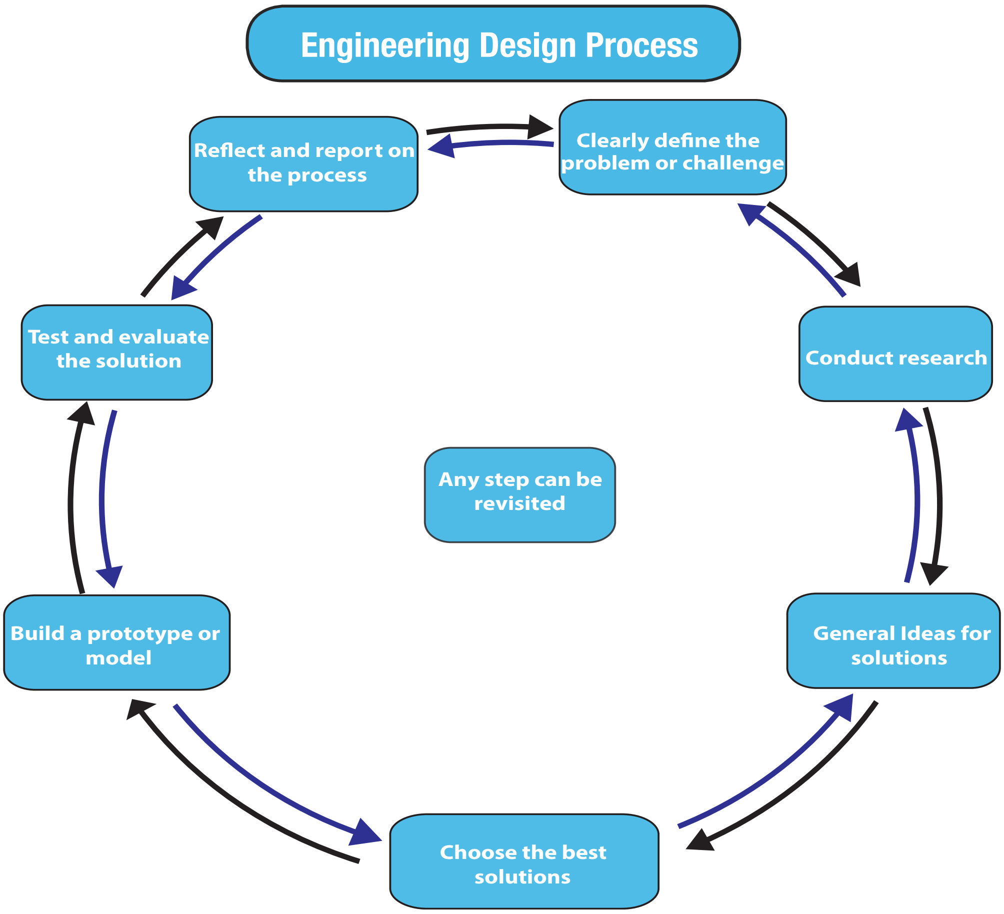
Trial and Error

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

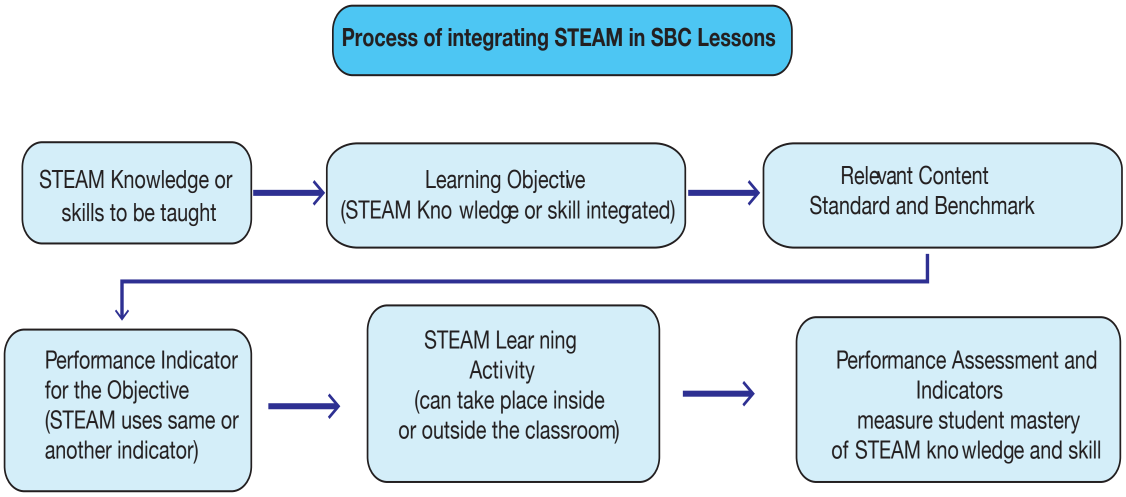
Effective STEAM lesson planning is key to the achievement of expected STEAM outcomes. STEAM skills can be planed and taught using separate STEAM-based lesson plans or integrated into the standards-based lesson plans. To effectively do this, teachers should know how to write effective standards and STEAM-based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

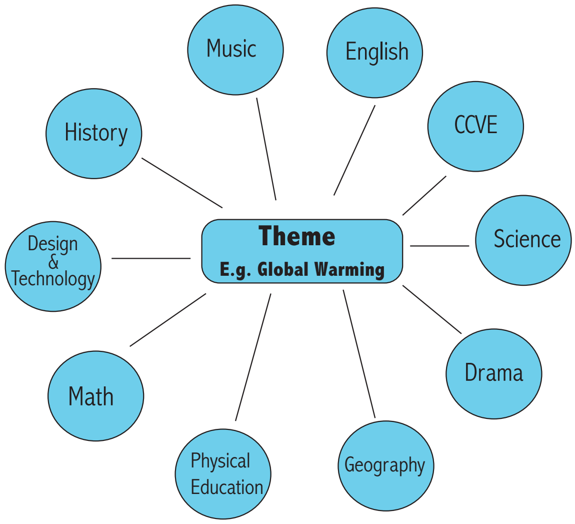
Teachers must develop intriguing curriculum by going beyond the traditional teaching of content based or fragmented teaching to one who is knowledge based and who should be perceived as a 21st Century innovative educator. Curriculum integration is a holistic approach to learning thus curriculum integration 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 good and services improving the general standard of living for PNG in the long run.

1. (i) Multidisciplinary Approach

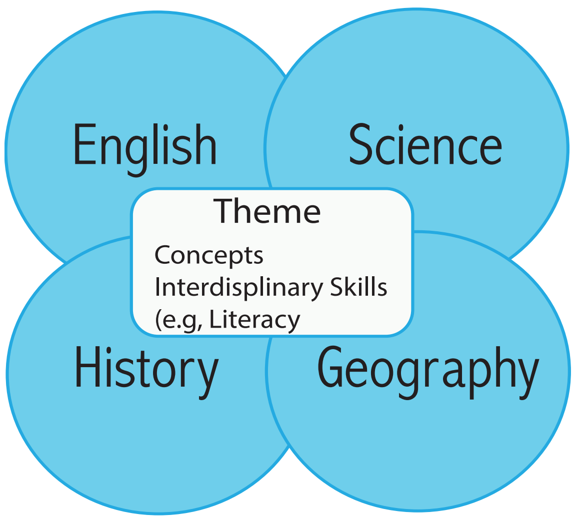
In this approach learning involves a theme or concept that will be taught right across all subject area of study by students. That is, content of a particular theme will be taught right across all subjects as shown in the diagram below. For instance, if the theme is global warming, subject areas create 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.

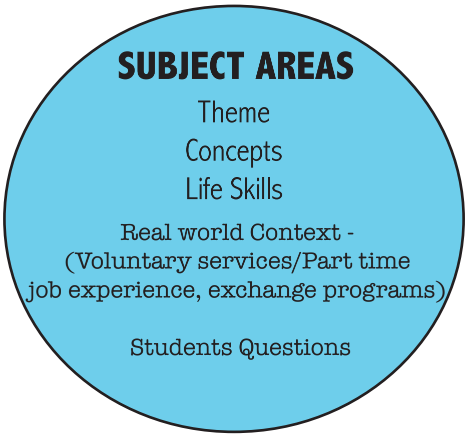
Below are the three steps to planning project based curriculum.

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	

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.

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

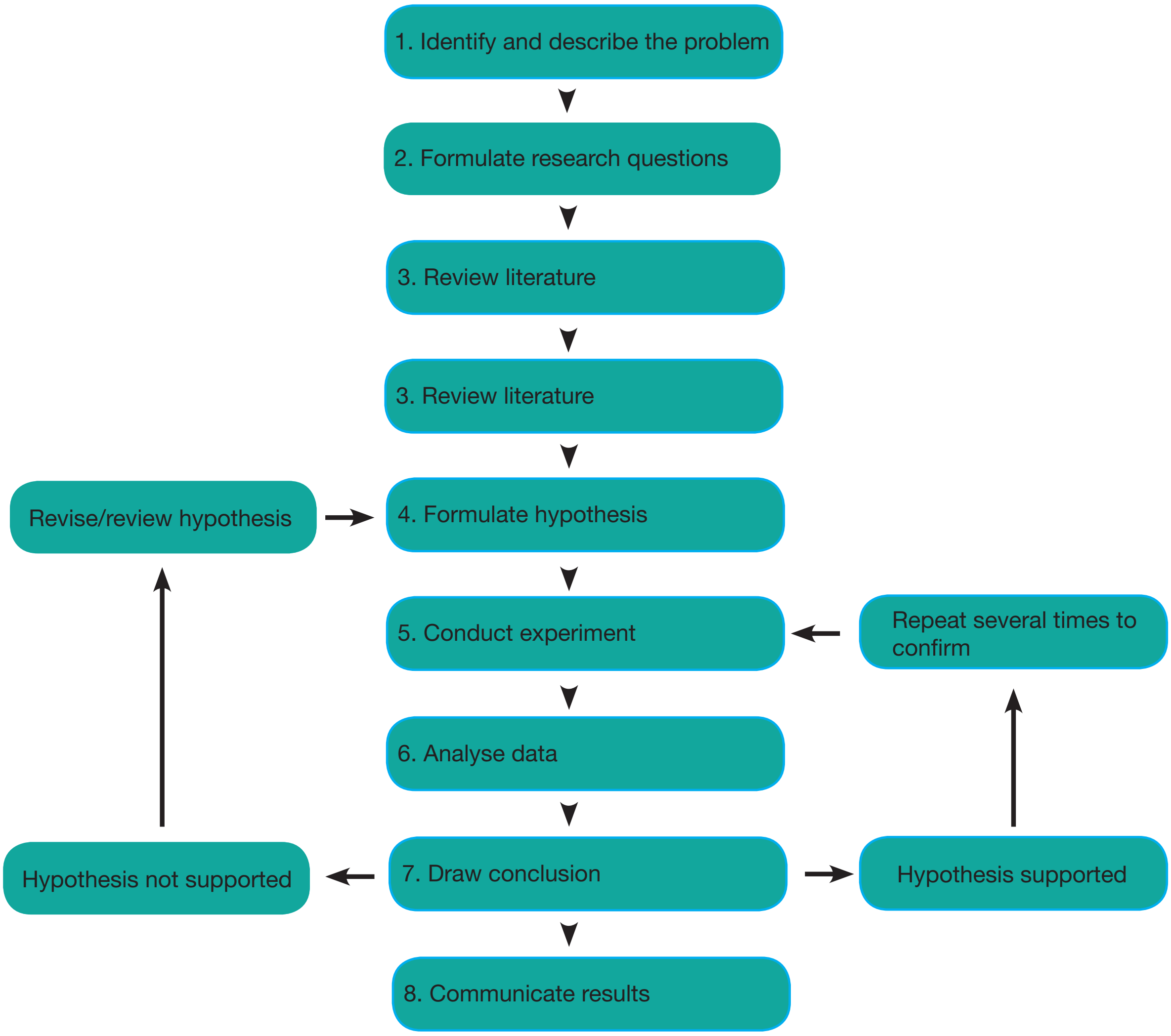
Attitudes - Ways of thinking and behaving, points of view	
• Optimistic • Participatory • Critical • Creative • Appreciative • Empathetic • Caring and concern • Positive • Confident • Cooperative	• Responsible • Adaptable to change • Open-minded • Diligent • With a desire to learn • With respect for 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 support the hypothesis, then the hypothesis is considered correct or valid.

If the data do not support the hypothesis, the hypothesis is considered incorrect or invalid. From here, if the hypothesis is invalid, the scientist can modify it and revert back to step 4.

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' understanding 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 conceptual 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 affecting 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

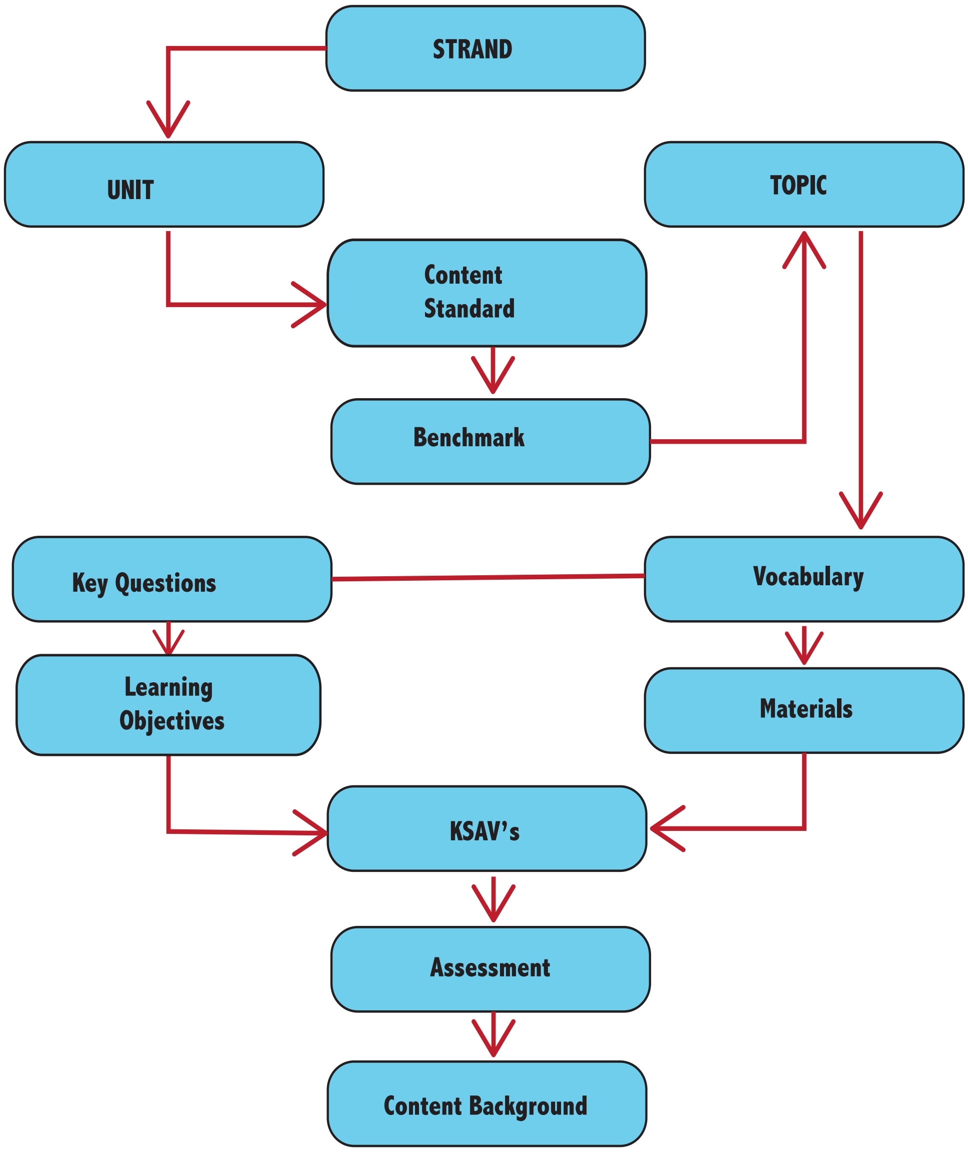
The table below outlines the contents of Grade 11 Physics in strands, units, topics and with the suggested lesson tittles to be taught in an academic year.
Teachers are provided with what will be taught under each of the four strands in a year. This overview will guide the teachers on how to plan their teaching programs for a school year in each term.

Strands	Units	Topics	Suggested Lesson Titles
Science as Inquiry	Quantities and Measurement	Quantities and Units	Traditional Measurement Systems & Physical Quantities
			Standard and Derived SI Units
			Unit Conversions
			Physical Quantities: Definition and Examples
		Dimensions, Significant Numbers and Scientific Notations	Dimensions
			Significant Figures
			Scientific Notations
			Order of Magnitude
		Error Analysis	Types of Errors and their definitions
			Uncertainties, Minimizing Errors
		Measuring Instruments	Measuring Instruments and their uses. Example: Timer, Thermometer, Measuring Cylinder, Balance, Vernier Caliper, Micrometer Screw Gauge
		Graphical Representations of Data and Information	Graphs (Dependent and Independent variable) and lines of best fit
			Linear and Direct Relationships
			Quadratic and Inverse Relationships
		Scalars and Vectors	Scalars and Vectors – Definition and Types
			Vector Addition, Subtraction, Multiplication (Geometric Approach)
			Vector Representation and Components
			Vector Resolution
			The Dot Product and Vectors: Definition, Formula and calculations
Physical Science	Kinematics (Motion)	Objects in Motion	What is Kinematics? - Studying the Motion of Objects
			What is Position in Physics? - Definition & Examples
		Characteristics of Motion	Distance and Displacement in Physics: Definition and Examples
			Speed and Velocity: Difference and Examples
			Acceleration: Definition, Equation and Examples
			Uniformly-Accelerated Motion and the Five Motion Equations
		Describing Motion	Representing Motion with Graphs
			Ticker Tape Diagrams: Analyzing Motion and Acceleration
			Using Position vs. Time Graphs to Describe Motion
			Determining Slope for Position vs. Time Graphs
			Using Velocity vs. Time Graphs to Describe Motion
			Determining Acceleration Using the Slope of a Velocity vs. Time Graph
			Velocity vs. Time: Determining Displacement of an Object
			Understanding Graphs of Motion: Giving Qualitative Descriptions
		Free Fall	Free Fall Physics Practice Problems
			Graphing Free Fall Motion: Showing Acceleration
		Projectile Motion	The Acceleration of Gravity: Definition & Formula
			Projectile Motion: Definition and Examples
			Projectile Motion Practice Problems
	Dynamics (Force and Motion)	Force	Force: Definition, unit and Types
			Forces: Balanced and Unbalanced (Net force)
			Force: Friction (definition)
			Static and kinetic friction
			Coefficient of friction

		Vector calculations of force	Addition and Subtraction of Forces (Vector)
			Free-Body Diagrams
			Net Force: Definition and Calculations
			The Normal Force: Definition and Examples
		Newton's Laws	Distinguishing Between Inertia and Mass
			Newton's Laws of Motion. First Law of Motion: Examples of the Effect of Force on Motion
			Mass and Weight: Differences and Calculations
			Newton's Second Law of Motion: The Relationship Between Force, mass and Acceleration
			Determining the Acceleration of an Object
			Determining the Individual Forces Acting Upon an Object
			Air Resistance and Free Fall
			Newton's Third Law of Motion: Examples of the Relationship Between Two Forces
			Newton's Laws and Weight, Mass & Gravity
		Applications of Newton's Laws	Identifying Action and Reaction Force Pairs
			Inclined Planes in Physics: Definition, Facts, and Examples
		Circular Motion	Uniform Circular Motion: Definition and Mathematics
			Speed and Velocity: Definition and Formula
			Centripetal Acceleration
			Centripetal Force and Centrifugal Force
			Angular Velocity
			Period of circular motion
			The Moons Motion
			Newton's Law of Gravitation
			Gravitational Field Strength
			Kepler's Law
		Rotational Motion	Differences Between Translational & Rotational Motion
			Rotational Kinematics: Definition & Equations
			Torque: Concept, Equation & Example
			Rotational Inertia & Change of Speed
			Rolling Motion & the Moment of Inertia
			Angular Momentum vs. Linear Momentum
			Conservation of Angular Momentum
		Simple Harmonic Motion	Simple Harmonic Motion (SHM): Definition, Formulas & Examples
			Hooke's Law & the Spring Constant: Definition & Equation
			Simple Harmonic Motion: Kinetic Energy & Potential Energy
			The Kinematics of Simple Harmonic Motion
			Spring-Block Oscillator: Vertical Motion, Frequency & Mass
			The Sinusoidal Description of Simple Harmonic Motion
			Pendulums in Physics: Definition & Equations
		Linear Momentum	Linear Momentum: Definition, Equation, and Examples
			Momentum and Impulse: Definition, Theorem and Examples
			Conservation of Linear Momentum: Formula and Examples
			Elastic and Inelastic Collisions: Difference and Principles
			Isolated Systems in Physics: Definition and Examples
			Understanding the Center of Mass & Center of Gravity
	Energy and Motionå	Work	Work: Definition, Characteristics, and Examples
			Work Done by a Variable Force
		Energy and Work	What is Energy? - Definition and Significance in Nature
			Kinetic Energy to Potential Energy: Relationship in Different Energy Types
			Work-Energy Theorem: Definition and Application
			KE and Collisions
			Energy changes and collision: (elastic and inelastic collisions)
		Simple Machines	Simple machines: (levers, pulleys, gears and wheel and axle)
			What is Mechanical Energy? - Definition & Examples
			Conservation of Mechanical Energy
			Calculating mechanical advantage (MA) of a machine
			Calculating velocity ratio (VR)of a machine
			Pulleys: Basic Mechanics

			Relationship between MA, VR and efficiency
		Mechanical Power	Power: Definition and Mathematics
			Power: Definition and rate of work done
			Power: Units
			Power: problems and calculations
	Electricity	Electrostatics	Insulators and Conductors: Examples, Definitions & Properties
			Electric Charge and Force: Definition, Repulsion & Attraction
			Charging by Induction
			Coulomb's Law: Variables Affecting the Force Between Two
			Charged Particles
			Electric Field & the Movement of Charge
			Electric Potential Energy: Definition & Formula
			Electric Potential: Charge Collections and Volt Unit
		Electricity	What is Electric Current? - Definition, Unit & Symbols
			Resistance and voltage: Definition and units and types
			Electric Circuit Fundamentals: Components & Types
			Series Circuits: Definition & Concepts
			Parallel Circuits: Definition & Concepts
			Applying Kirchhoff's Rules: Examples & Problems
			Resistor-Capacitor (RC) Circuits: Definition & Explanation
			Voltage Sources: Energy Conversion and Examples
		Ohm's Law	Resistors in series (Kirchhoff's Loop Rule)
			Resistors in Parallel (Kirchhoff's Junction Rule)
			Internal Resistance
			Resistivity
		Resistors	Types of resistors and their properties
			Variable resistors: Properties and functions
		Electrical Power	Electric Power: Definition and Equations
			Electrical Energy and Energy Rating
			Fuses and Circuit Breakers
			Electric Shock
			Electricity in the Home
		Electric Field Patterns	Gauss' Law: Definition & Examples
			The Potential of a Sphere
			The Potential of a Cylinder
	Electronics	Intrinsic and Extrinsic Semiconductors	Silicon Lattice
			Valance electrons and semiconductor materials
			Intrinsic Semiconductors
			Extrinsic Semiconductors (doping)
			Adding pentavalent and trivalent impurities
			P-type and n-type semiconductors
			p-n junction (forward and reverse biased)
		Diode and Transistor	Diode as a Rectifier
			Other Diodes (LED, LDR, PIN diode, Step-recovery diodes)
			Transistors (Junction transistor, Transistor structure)
			NPN Transistor as current amplifier
			PNP transistor as current amplifier
		Applications of diodes and resistors	Transistor as a switch
			Transistor as an amplifier
		Logic gates	Binary system
			Digital Signal Levels
			Electronic Symbols For Logic Gates
			Logic Gates (AND, OR, NOT)
			Logic Gates (NOR, NAND, XOR)
			The Truth Table
			Application of Gates in Simple Circuits

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 11 Physics

Teaching Content

Strand 1: Science as Inquiry

Unit: Quantities and Measurement	**Topic:** Quantities and Measurement (Introduction)
Content Standard 11.1.1	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 11.1.1.1	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:

vernier caliper, micrometre screw gauge

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

What is Physics? The word “Physics” comes from the Greek word ‘Physikos’ which means knowledge of nature. The aim of physics is to explain the fundamental nature of the universe by using the simplest explanation.

Physics refers to the basic principles that govern the behaviour of the physical reality (quantities). In other words physics is based on measurement of physical quantities.

Physical quantity is the property of an object that can be quantified or a quantity that is measurable. For instance, the physical quantities are the length of a rod or the mass of a body or timing of an event. Physical quantities are categories into **base quantities** and **derived quantities.**
Measurement is the act of obtaining or comparing a physical quantity’s size (magnitude) with respect to its unit (SI unit). For example, length of a meter ruler = 100 cm. Length = physical quantity, 100 = size/ quantity (numerical value) and cm = unit of measurement.

An overview of physical quantities and measurement

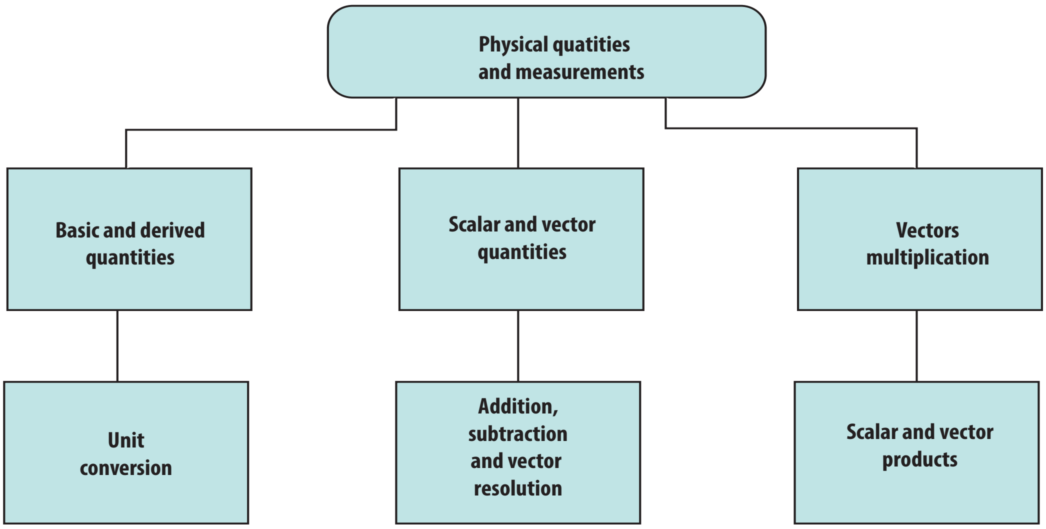


Table 1.1 shows all the basic (base) quantities

Basic Physical Quantities	SI units	Symbols	Dimension
Mass	kilogram(kg)	m	M
Length	metre (m)	l	L
Time	second (s)	t	T
Electric Current	ampere or amps (A)	I	
Thermodynamics/ Temperature	Degree Kelvin or Degree Celsius (^oK or ^oC)	K or T	
Amount of Substance	mole (mol)	N	
Luminous Intensity	Candela (Cd)		

Table 1.2 shows some examples of derived quantities

Derived Quantities	SI units	Symbols	Formulae	Special Name
Area	square metre (m^2)	A	A = l x w	
Volume	cubic metre (m^3)	V	V = l x w x h	
Speed or Velocity	metre per second (ms^{-1})	s or v	s = d/t	
Acceleration	meter per second square (ms^{-2})	a	a = v/t	
Density	mass per volume (kgm^{-3})	ρ	P = m/v	
Momentum	mass times velocity ($kgms^{-1}$)	p	p = mv	
Force	mass times acceleration ($kgms^{-2}$)	F	F = ma	Newton (N)
Pressure	mass per meter per square second ($kgm^{-1}s^{-2}$)	P	P = F/a	Pascal (Pa)
Work	mass times square meter per cubic second (kgm^2s^{-2})	W	W = F x s	Joules (J)
Power	mass times square meter per cubic second (kgm^2s^{-3})	P	P = W/t	Watt (W)
Frequency	per second	F	T =1/T	Hertz (Hz)

Unit Conversion and Prefixes

A prefix is a letter place in front of a word to modify its meaning. Unit conversion means changing of one unit into another. When changing a smaller unit into bigger unit simply divide it by an appropriate digit. Likewise and opposite, when changing a bigger unit into a smaller unit simply multiply it by an appropriate digit.

Table 1.3 shows the unit prefixes

Derived Quantities	SI units	Symbols
tera	$\times 10^{12}$	T
giga	$\times 10^{9}$	G
mega	$\times 10^{6}$	M
kilo	$\times 10^{3}$	K
deci	$\times 10^{-1}$	d
centi	$\times 10^{-2}$	c
milli	$\times 10^{-3}$	m
micro	$\times 10^{-6}$	μ
nano	$\times 10^{-9}$	n
pico	$\times 10^{-12}$	p

Example:

- 5740000 m = 5740 km = 5.74 Mm
- 0.00000233 s = 2.33×10^{-6} s = 2.33 μs

Unit: Quantities and Measurement

Topic: Dimensions, Significant Figures and Scientific Notations

Benchmark 11.1.1.1	Identify appropriate quantities, their units and measurement methods using the metric system.

Key question(s):

- What are dimensions of physical quantities and Significant figures, how can we calculate them? Dimension
- What are the importance of using significant figures and identification notices in science inquiry?

Vocabulary:

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

Learning Objective(s)

By the end of the topic, students can:

- Find dimensions of physical quantities and use significant figures and Scientific notation in calculations.

Materials

Prefix chart, conversion chart

Knowledge	Skills	Attitudes and Values
• Apply scientific inquiry and reasoning skills to find solutions to Dimensions, Significant figures and Scientific Notation problems	• Collecting, observing and analysing data • Measuring using measuring instruments • Estimating, predicting and interpreting data	• Being precise and accurate • Being sceptical and questioning

Assessment

- Students can be able to identify appropriate quantities, their units and measurement methods using the metric system.

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

Content Background

Dimensions of Physical Quantities

The power to which fundamental units are raised in order to obtain the unit of physical quantity is called the dimensions of that physical quantity.
If ‘A’ is any physical quantity then the dimensions of A are represented by [A] Mass, length and time are represented by M, L and T respectively.

Therefore, the dimensions of fundamental quantities are as follows:

[Mass] = [M]
[Length] = [L]
[Time] = [T]

Different Types of Variable Constants

Dimensional variables
The quantities like area, volume, velocity, force etc. possess dimensions and do not have a constant value. Such quantities are called **dimensional variables**.

Non-dimensional variables
The quantities like strain, angle and specific gravity are ratios which are mere numbers are dimensionless quantities and are called numeric. They have neither dimension nor constant value, they are called **non-dimensional variables.**

Dimensional Constants
The quantities like gravitational constant *g,* the velocity of light *c* and Plank's constant *h* have dimensions and constant values. They are called **dimensional constants**.

Non-dimensional Constants
The quantities which have no dimensions but have constant values are called **non-dimensional constants.** 1, 2,3, …, θ, π are non-dimensional constant.

Difference between Dimensional Formula and Dimensional Equation
The dimensional formula of a physical quantity may be defined as the expression that indicates which of the fundamental units of mass; length and time enter into the derived unit of that quantity and with what powers.

E.g. dimensional formula for velocity is $[M^0L^1T^{-1}] = [MLT^{-1}]$.

The equation obtained, when a physical quantity is equated with its dimensional formula is known as dimensional equation.

E.g. $[V] = [M^0L^1T^{-1}] = [V] = [MLT^{-1}]$ is a dimensional equation.

Uses of Dimensional Analysis

To check the correctness of a physical equation
By the principle of homogeneity of dimensions, the dimensions of all the terms on the two sides of an equation must be the same

To derive the form of a physical equation
To find the form of a physical equation, we first consider all the physical quantities on which a given physical quantity is likely to depend on. Then, by the application of the principle of homogeneity of dimensions, we eliminate those quantities on which the physical quantity does not depend.

To derive the relation between different units of different systems of a physical quantity:
The dimensional analysis is used to find the conversion factor when the system of units is changed from one type to another.

Steps:

- Let us consider a physical quantity 'Q' having dimensions $[M^x L^y T^z]$.
- Let the fundamental units of the first system be $M_1\ L_1\ T_1$ and the fundamental units of the second system be $M_2\ L_2\ T_2$. Let n_1 be the value of the quantity in the first system of units and n_2 be the value of the quantity in the second system of units.
- Now represent the same physical quantity, hence we can write

$$\boldsymbol{Q = n_1[M_1^x L_1^y T_1^z] = n_2[M_2^x L_2^y T_2^z]}$$

Hence, conversion factor for the physical quantity Q from the first system to the second

$$= \frac{\boldsymbol{n_2}}{\boldsymbol{n_1}} = \frac{[\boldsymbol{M_1^x L_1^y T_1^z}]}{[\boldsymbol{M_2^x L_2^y T_2^z}]}$$

$$= \frac{\boldsymbol{n_2}}{\boldsymbol{n_1}} = \left[\frac{\boldsymbol{M_1}}{\boldsymbol{M_2}}\right]^{\boldsymbol{x}} \left[\frac{\boldsymbol{L_1}}{\boldsymbol{L_2}}\right]^{\boldsymbol{y}} \left[\frac{\boldsymbol{T_1}}{\boldsymbol{T_2}}\right]^{\boldsymbol{z}}$$

The ratios $\left(\frac{M_1}{M_2}\right)$ and $\left(\frac{L_1}{L_2}\right)$ are called conversion factors for mass and length respectively.

Significant figure: shorter way of writing very large or small numbers. There are mathematical rules in writing significant figures.

Scientific notation: short hand way of writing very large or small numbers using a number between 1 and 10.

A x 10^n

Where; A = a number between 1 and 10
n = integer

Order of magnitude: another way of writing very large or small numbers using only the power of 10. The base figure of 3.2 and above increases the integer by 1.
Example: 3.1 x 10^3 =10^3 and 3.2 x 10^3 = 10^4

Unit: Quantities and Measurement **Topic:** Error analysis

Content Standard 11.1.2	Design and conduct appropriate types of scientific investigations to answer different questions.

Key question(s):

- What types of errors and uncertainties are found in Scientific Investigations?

Vocabulary:

Random error, Systematic error, parallax error, zero error

Learning Objective(s)

By the end of the topic, students can:

- State and analyse errors and uncertainties in Scientific investigations

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
• Analyse errors in and interpret data and information	• Collecting, observing and analysing data • Estimating, predicting and interpreting data • Communicating scientific data	• Being sceptical and questioning • Being precise and accurate

Assessment

- Students can be able to design and conduct appropriate types of scientific investigations to analyse different questions involving error.

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

Content Background

Every measurement an experimenter makes has uncertainty to some degree. The uncertainties are of two kinds: (1) random errors, or (2) systematic errors. For example, in measuring the time required for a weight to fall to the floor, a random error will occur when an experimenter attempts to push a button that starts a timer simultaneously with the release of the weight. If this random error dominates the fall time measurement, then if we repeat the measurement many times (N times) and plot equal intervals (bins) of the fall time ti on the horizontal axis against the number of times a given fall time ti occurs on the vertical axis, our results (see histogram below) should approach an ideal bell-shaped curve (called a Gaussian distribution) as the number of measurements N becomes very large.

Uncertainty due to Instrumental Precision

Not all errors are statistical in nature. That means some measurements cannot be improved by repeating them many times. For example, assume you are supposed to measure the length of an object or the weight of an object. The accuracy will be given by the spacing of the tick marks on the measurement apparatus. You can read off whether the length of the object lines up with a tick mark or falls in between two tick marks, but you could not determine the value to a precision of 1/10 of a tick mark distance. Typically, the error of such a measurement is equal to one half of the smallest subdivision given on the measuring device. So, if you have a meter stick with tick marks every mm, you can measure a length with it to accuracy of about 0.5 mm. While in principle you could repeat the measurement numerous times, this would not improve the accuracy of your measurement!

Note: This assumes of course that you have not been sloppy in your measurement but made a careful attempt to line up one end of the object with the zero of the meter stick as accurately as you can, and that you read off the other end of the meter stick with the same care. If you want to judge how careful you have been, it would be useful to ask your lab partner to make the same measurements, using the same meter stick, and then compare the results.

Systematic Errors

Systematic errors occur when characteristics of the system we are examining, or the instruments we use are different from what we assume them to be. For example, if a voltmeter we are using was calibrated incorrectly and reads 5% higher than it should, then every voltage reading we record using this meter will have an error of 5%. Clearly, taking the average of many readings will not help us to reduce the size of this systematic error. If we knew the size and direction of the systematic error we could correct for it and thus eliminate its effects completely. Even when we are unsure about the effects of a systematic error we can sometimes estimate its size (though not its direction) from knowledge of the quality of the instrument. For example, the meter manufacturer may guarantee that the calibration is correct to within 1%. (Of course, one pays more for an instrument that is guaranteed to have a small error.) We could minimize this 5% error by calculating 5% from the final answer and subtracting it.

Propagation of Errors

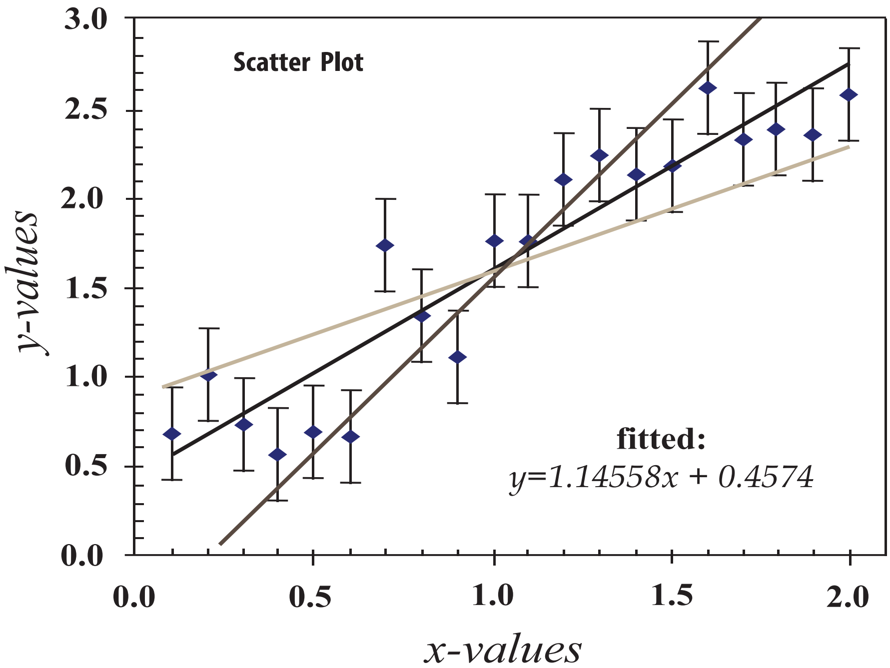
Even simple experiments usually call for the measurement of more than one quantity. The experimenter inserts these measured values into a formula to compute a desired result. He/she will want to know the uncertainty of the result. Here, we list several common situations in which error propagation is simple, and at the end we indicate the general procedure. If you are faced with a complex situation, ask your lab instructor for help.

Many types of measurements, whether statistical or systematic in nature, are not distributed according to a Gaussian. Examples are the age distribution in a population, and many others. However, it can be shown that if a result R depends on many variables, than evaluations of R will be distributed rather like a Gaussian - and more so when R depends on more variables - , even when the individual variables are not. The theorem in the following, we assume that our measurements are distributed as simple Gaussians.

Fitting a Straight Line through a Series of Points

Frequently in the laboratory you will have the situation that you perform a series of measurements of a quantity y at different values of x, and when you plot the measured values of y versus x you observe a linear relationship of the type $y = ax + b$. Your task is now to determine, from the errors in x and y, the uncertainty in the measured slope a and the intercept b. There is a mathematical procedure to do this, called "linear regression" or "least-squares fit". Such fits are typically implemented in spreadsheet programs and can be quite sophisticated, allowing for individually different uncertainties of the data points and for fits of polynomials, exponentials, Gaussian, and other types of functions to the data. If you have no access or experience with spreadsheet programs, you want to instead use a simple, graphical method, briefly described in the following.

Plot the measured points (x,y) and mark for each point the errors Dx and Dy as bars that extend from the plotted point in the x and y directions. Draw the line that best describes the measured points (i.e. the line that minimizes the sum of the squared distances from the line to the points to be fitted; the least-squares line). This line will give you the best value for slope a and intercept b. Next, draw the steepest and flattest straight lines; see the Figure below, still consistent with the measured error bars. From these two lines you can obtain the largest and smallest values of a and b still consistent with the data, amin and bmin, amax and bmax. From their deviation from the best values you then determine, as indicated in the beginning, the uncertainties a_{min} and b_{min}. a_{max} and b_{max}. From their deviation from the best values you then determine, as indicated in the beginning, the uncertainties D*a* and D*b*.



Other Errors

Apart from the two main errors of Random (Accidental) and Systematic we have; parallax error, index or zero error, raw or gross error, cosine error, personal reaction error, absolute error and percentage error.

Unit: Quantities and Measurement **Topic:** Measuring Instruments

Content Standard 11.1.1.3	Use appropriate tools and techniques to make observations and gather data.

Key question(s):

- What instruments are used in scientific inquiry?

Vocabulary:

Least count, uncertainty

Learning Objective(s)

By the end of the topic, students can:

- Demonstrate with confidence the use of basic measuring instruments and analyse the readings to a reasonable degree of accuracy.

Materials

Vernier Calliper, Micrometre Screw, gauge, ruler, tape measure, balance, ammeter, voltmeter, scale and other measuring devices available in schools

Knowledge	Skills	Attitudes and Values
• Analyse and evaluate developments in physics from the past and present and its impacts on people and the environment; and use the information and tools to support and make informed decisions	• Collecting, observing and analysing data by measuring using equipment • Estimating, predicting and interpreting data • Communicating scientific data	• Optimistic in and confident in taking measurement. • Being sceptical and questioning

Assessment

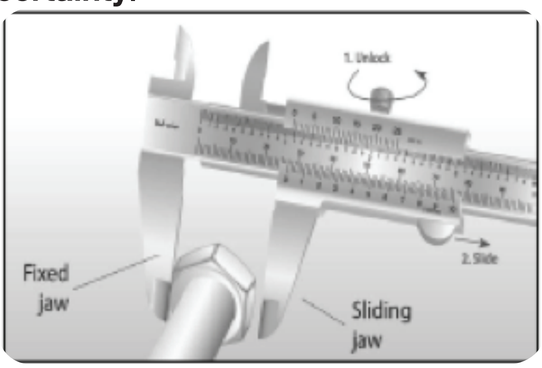
- Identify the reasons on how to use appropriate tools and techniques to measure objects.

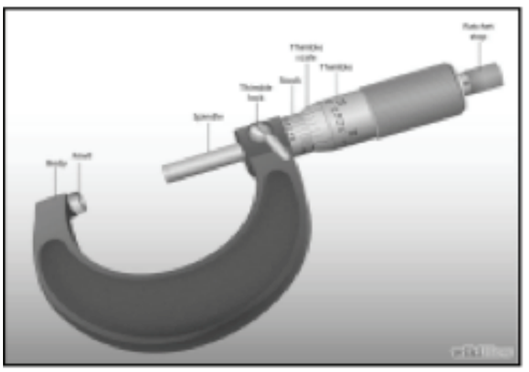
Teacher to develop assessment rubric on the assessment tasks mentioned above.

Content Background

Instrument Uncertainty and Least Count

Each **instrument** has an inherent amount of **uncertainty** in its measurement. Even the most precise **measuring device** cannot give the actual value because to do so would require an infinitely precise instrument. A measure of the accuracy of an instrument is given by its **uncertainty**.





Unit: Quantities and Measurement **Topic:** Graphical Representation of Data and Information

Benchmark 11.1.1.3	Use mathematical operations to analyse and interpret data, and present relationships between variables in appropriate forms.

Key question(s):

- How do we graph and interpret data

Vocabulary:

Scalar, vector

Learning Objective(s)

By the end of the topic, students can:

- Graph experimental data and interpret them.

Materials

Graph papers, variables

Knowledge	Skills	Attitudes and Values
• Communicate scientific data and information from investigations and laboratory work in different ways	• Collecting, observing and analysing data by using measuring equipment • Estimating, predicting and interpreting data • Communicating scientific data	• Appreciative and critical in processing information • Solidarity in interpreting data

Assessment

- Demonstrate with confidence the use of basic measuring instruments and analyse the readings to a reasonable degree of accuracy.

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

Content Background

Graphs of data serve the following purpose.

1. to show what has happened
2. to show the relationship between quantities
3. to show distribution

There are then the following general types of graphs

1. time series
2. scatter plot
3. histogram (a type of bar graph)

What about the axes?

- Independent Variable — usually plotted on the horizontal axis
- Dependent Variable — usually plotted on the vertical axis
- Explanatory Variable — usually plotted on the horizontal axis
- Response Variable — usually plotted on the vertical axis

- Categorical Variables — represented by different symbols on the same coordinate system
- Lurking Variables (Hidden Variables)

What's interesting?

- slope of tangent: rate of change of y with x
  - o in calculus the result is called the derivative and the process is known as differentiation
  - o interesting features
- maximum and minimum
- cusps
- inflection points
- asymptotes
- area under curve: cumulative product of x and y

Unit: Quantities and Measurement

Topic: Scalars and Vectors

Benchmark 11.1.1.4 Apply mathematical operations to solve scalar and vector operations.

Key question(s):

- What are scalars and vectors?

Vocabulary:

Scalar, vector

Learning Objective(s)

By the end of the topic, students can:

- Define scalar and vector quantities and give examples of each type together with their respective units and symbols.

Materials

Graph papers, variables

Knowledge	Skills	Attitudes and Values
• Relate relevant traditional knowledge, beliefs, and skills to principles and concepts of physics.	• collecting, observing and analysing data using measuring equipment • estimating, predicting and interpreting data • communicating scientific data	• Appreciate the use of vectors in daily life situations.

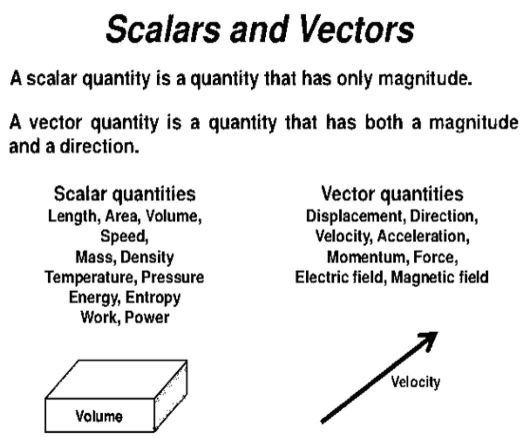
Assessment

- Define scalar and vector quantities and give examples of each type together with their respective units and symbols.

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

Content Background

The quantity is either a vector or a scalar. These two categories can be distinguished from one another by their distinct definitions: Scalars are quantities that are fully described by a magnitude (or numerical value) alone. Vectors are quantities that are fully described by both a magnitude and a direction.



Strand 2: Physical Science

Unit: Kinematics **Topic:** Characteristics of Motion

Content Standard 11.2.1	Students will be able to examine and explain the structure, properties and changes of motion with motion equation.
Benchmark 11.2.1.1	Derive and use equations of motion.

Key question(s):

- What is kinematic?
- How does the description of an object's position depend on a reference point?
- How can you describe the position of an object in two?

Vocabulary:

Motion, kinematics, position

Learning Objective(s)

By the end of the topic, students can:
- Define kinematics
- Describe how motion takes place
- Explain position in terms of reference point, distance & direction in one dimension & two dimensions

Materials

Diagrams of motion and position

Knowledge	Skills	Attitudes and Values
• Describing how the motion takes place using the terms distance, speed & acceleration • Vector quantities displacement, velocity & acceleration • The position of one object in relation to another object	• Explaining the meaning of the terms 'displacement', 'speed', 'velocity' and 'acceleration'. Use these terms to describe the motion of objects • Communicating in scientific terms	• Appreciate the significance of objects in motion.

Assessment

- Apply five motions of equation to solve problems.

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

Content Background

Kinematics

Kinematics is the branch of classical mechanics that describes the motion of points, objects and systems of groups of objects, without reference to the causes of motion (i.e., forces). The study of **kinematics** is often referred to as the "geometry of motion."

Motion

In physics, **motion** is the change in position of an object with respect to its surroundings in a given interval of time. Motion is mathematically described in terms of displacement, distance, velocity, acceleration, and speed. ... An object's motion cannot change unless it is acted upon by a force.

Position

Position is a place where someone or something is located or has been put. In **physics, position** is usually a number on an axis. ... A number where direction doesn't matter is called a scalar. Position is a vector, because direction matters. But distance is a scalar.

Unit: Kinematics **Topic:** Characteristics of Motion

Benchmark 11.2.1.1 Derive and use equations of motion.

Key question(s):

- What is the difference between distance, displacement, speed, velocity and acceleration?
- What does a velocity-time graph, acceleration time graph & distance-time graph indicate about an object's motion & it's slope

Vocabulary:

Displacement, velocity, acceleration, average velocity, instantaneous velocity

Learning Objective(s)

By the end of the topic, students can:

- Explain the characteristics of motion.
- Apply five motion equations to solve problems.
- Using Ticker tape

Materials

Ticker tape timer, ticker timer

Knowledge	Skills	Attitudes and Values
• Scalar is a quantity that has only size (or magnitude) • Vector is a quantity that involves both size and direction • Understanding of: • -Uniform linear motion	• Explaining the meaning of the terms 'displacement', 'speed', 'velocity' and 'acceleration'. Use these terms to describe the motion of objects • Communicating in scientific terms	• Being critical in analysing motion. • Appreciate the usefulness of characteristics of motion in physical world.

Assessment

- Apply five motions of equation to solve problems.

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

Content Background

Displacement

The motion in which all the particles of a body move through the same distance in the same time is called translatory motion. There are two types of translatory motions: rectilinear motion; curvilinear motion. Since linear motion is a motion in a single dimension, the distance travelled by an object in particular direction is the same as displacement. The SI unit of displacement is the.

The equivalent of displacement in rotational motion is the angular displacement measured in radian. The displacement of an object cannot be greater than the distance because it is also a distance but the shortest one. Consider a person travelling to work daily. Overall displacement when he returns home is zero, since the person ends up back where he started, but the distance travelled is clearly not zero.

Velocity

Velocity refers to a displacement in one direction with respect to an interval of time. It is defined as the rate of change of displacement over change in time. Velocity is a vectorial quantity, representing a direction and a magnitude of movement. The magnitude of a velocity is called speed. The SI unit of speed is that is metre per second.

Average velocity

The average velocity of a moving body is its total vectorial displacement scaled by the reciprocal of the length of the elapsed time interval.
The magnitude of the average velocity is called an average speed.

Instantaneous velocity
In contrast to an average velocity, referring to the overall motion in a finite time interval, the instantaneous velocity of an object describes the state of motion at a specific point in time. It is defined by letting the length of the time interval tend to zero, that is, the velocity is the time derivative of the displacement as function of time.
The magnitude of the instantaneous velocity is called the ***instantaneous speed.***

Acceleration

Acceleration is defined as the rate of change of velocity with respect to time. Acceleration is the second derivative of displacement i.e. acceleration can be found by differentiating position with respect to time twice or differentiating velocity with respect to time once. The SI unit of acceleration is or metre per second squared.

This is the easiest of the three equations to derive using algebra. Start from the definition of acceleration.

$$a = \frac{\triangle v}{\triangle t}$$

Expand Δv to $v - v_0$ and condense Δt to t.

$$a = \frac{v - v_0}{t}$$

Then solve for v as a function of t.
$v = v_0 + at$ [1]

This is the first equation of motion. It's written like a polynomial — a constant term (v0) followed by a first order term (at). Since the highest order is 1, it's more correct to call it a linear function.

The symbol v0 [vee nought] is called the initial velocity or the velocity a time t = 0. It is often thought of as the "first velocity" but this is a rather naive way to describe it. A better definition would be to say that an initial velocity is the velocity that a moving object has when it first becomes important in a problem. Say a meteor was spotted deep in space and the problem was to determine its trajectory, then the initial velocity would likely be the velocity it had when it was first observed. But if the problem was about this same meteor burning up on reentry, then the initial velocity likely be the velocity it had when it entered Earth's atmosphere. The answer to "What's the initial velocity?" is "It depends". This turns out to be the answer to a lot of questions.

The symbol v is the velocity some time t after the initial velocity. It is often called the final velocity but this does not make it an object's "last velocity". Take the case of the meteor. What velocity is represented by the symbol v? If you've been paying attention, then you should have anticipated the answer. It depends. It could be the velocity the meteor has as it passes by the moon, as it enters the Earth's atmosphere, or as it strikes the Earth's surface. It could also be the meteorite's velocity as it sits in the bottom of a crater. (In that case v = 0.) Are any of these the final velocity? Who knows? Someone could extract the meteorite from its hole in the ground and drive away with it. Is this relevant? Probably not, but it depends. There's no rule for this kind of thing. You have to parse the text of a problem for physical quantities and then assign meaning to mathematical symbols.

The last part of this equation at is the change in the velocity from the initial value. Recall that a is the rate of change of velocity and that t is the time after some initial event. Rate times time is change. Given an object accelerating at 10 m/s2, after 5 s it would be moving 50 m/s faster. If it started with a velocity of 15 m/s, then its velocity after 5 s would be…
15 m/s + 50 m/s = 65 m/s

Unit: Kinematics **Topic:** Describing Motion

Benchmark 11.2.1.2	Demonstrate the characteristics of motion by using graphs.

Key question(s):

- What is kinematic?
- How does the description of an object's position depend on a reference point?
- How can you describe the position of an object in two dimensions?

Vocabulary:

line of best fit,

Learning Objective(s)

By the end of the topic, students can:

- Define kinematics
- Describe how motion takes place
- Explain position in terms of reference point, distance & direction in one dimension & two dimensions.

Materials

Temperature measuring devices (or diagrams)

Knowledge	Skills	Attitudes and Values
• Describing how the motion takes place using the terms distance, speed & acceleration • Vector quantities displacement, velocity & acceleration • The position of one object in relation to another object	• Explaining the meaning of the terms 'displacement', 'speed', 'velocity' and 'acceleration'. Use these terms to describe the motion of objects • Communicating in scientific terms	• Confident and critical in describing motion • Being just in describing motion.

Assessment

- Investigate the different graphs of motion, describe the motion and solve the problem.

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

Content Background

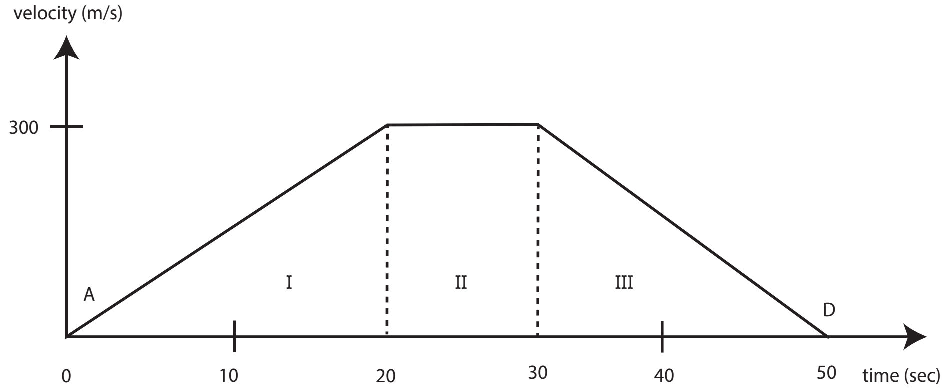
Graphs can be useful in studying motion. They show the changes in the motion of an object with time. There are three (3) main types of linear motion graphs;

(a) the displacement-time graph

(b) the velocity-time graph and

(c) the acceleration-time graph.

Let's study a velocity – time graph and try to understand some of its features.



What does each section represents? For velocity-time graph each section represents two (2) quantities;

(a) acceleration (gradient) and (b) displacement (area under the graph).

The graph shows constant acceleration, no acceleration and constant deceleration. Adding the total area under the graph will give us the total displacement the object cover in the forward direction.

Unit : Kinematics **Topic:** Free Fall

Benchmark 11.2.1.3 Analyse free fall and projectile motion.

Key question(s):

- What is free fall
- How can we determine the motion of a free fall?

Vocabulary:

Free fall, initial velocity, final velocity

Learning Objective(s)

By the end of the topic, students can:

- Determine the characteristics of a free falling body
- Construct graphs of motion of a free falling object.

Materials

Marbles or bearings,

Knowledge	Skills	Attitudes and Values
• Free falling objects experience downward acceleration of $9.8 m/s^2$ • Objects fall freely due to the effect of gravity on the object.	• Find the velocity of any free falling body. • Explain how and why objects fall freely to the ground.	• Appreciate the application of free fall in the physical world.

Assessment

- Study the motion of marbles or bearings falling freely and describe its motion.

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

Content Background

A free-falling object is an object that is falling under the sole influence of gravity. That is to say that any object that is moving and being acted upon only be the force of gravity is said to be "in a state of **free fall**." Such an object will experience a downward acceleration of 9.81 ms^{-2}. Whether the object is falling downward or rising upward towards its peak, if it is under the sole influence of gravity, then its gravitational acceleration value is 9.81 ms^{-2}.

Like any moving object, the motion of an object in free fall can be described by four kinematic equations. The kinematic equations that describe any object's motion are:

The Kinematic Equation

$$d = v_1 t + \frac{1}{2}at^2 \qquad v_f^2 = v_i^2 + 2ad$$

$$v_f = v_i + at \qquad d = \frac{v_1 + v_f}{2}t$$

The symbols in the above equation have a specific meaning: the symbol d stands for the **displacement**; the symbol **t** stands for the **time**; the symbol a stands for the **acceleration** of the object; the symbol vi stands for the **initial velocity** value; and the symbol vf v_f stands for the final **velocity**.

Unit: Kinematics **Topic:** Projectile Motion

Benchmark 11.2.1.3 Analyse free fall and projectile motion.

Key question(s):

- What is projectile motion?
- Why do some objects travel in a curved pathway?

Vocabulary:

Projectile Motion,

Learning Objective(s)

By the end of the topic, students can:

- Analyse the characteristics of objects travelling in a curved path.

Materials

Marbles or bearings, Table edge

Knowledge	Skills	Attitudes and Values
• A projectile is an object upon which the only force acting is gravity.	• Explain the applications of projectile motion in daily life. (e.g. kicking a soccer ball)	• Appreciate the applications of projectile motion in daily life situations.

Assessment

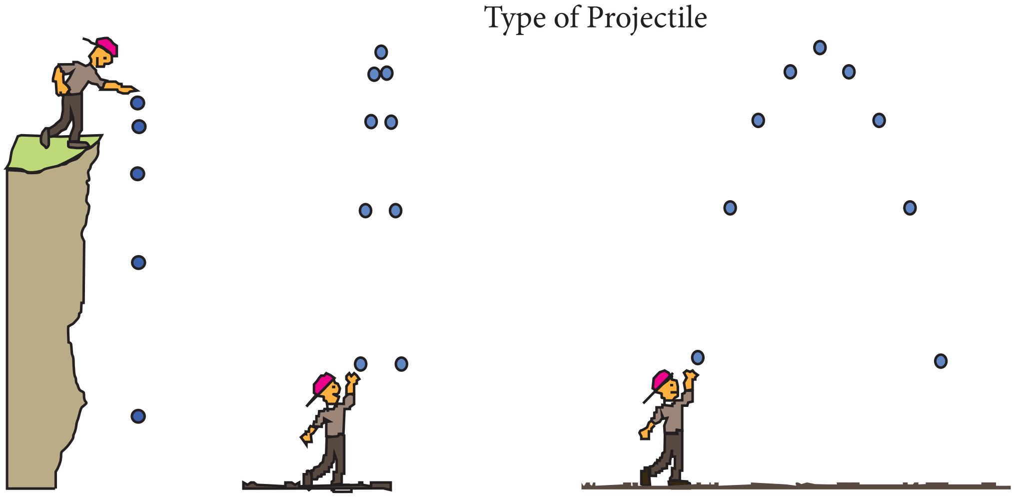
- Study the motion of marbles or bearings off the edge of a table or desk top and describe its motion.

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

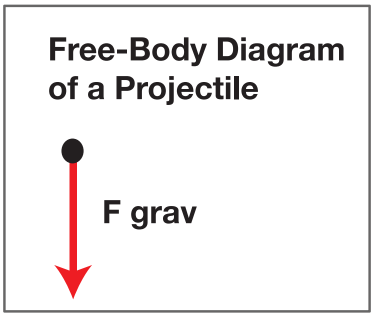
Content Background

A projectile is an object upon which the only force acting is gravity. There are a variety of examples of projectiles. An object dropped from rest is a projectile (provided that the influence of air resistance is negligible). An object that is thrown vertically upward is also a projectile (provided that the influence of air resistance is negligible). And an object which is thrown upward at an angle to the horizontal is also a projectile (provided that the influence of air resistance is negligible). A projectile is any object that once projected or dropped continues in motion by its own inertia and is influenced only by the downward force of gravity.

Type of Projectile



By definition, a projectile has a single force that acts upon it - the force of gravity. If there were any other force acting upon an object, then that object would not be a projectile. Thus, the free-body diagram of a projectile would show a single force acting downwards and labeled force of gravity (or simply F). Regardless of whether a projectile is moving downwards, upwards, upwards and rightwards, or downwards and leftwards, the free-body diagram of the projectile is still as depicted in the diagram below. By definition, a projectile is any object upon which the only force is gravity.



Unit : Force and Motion	**Topic:** Force
Content Standard 11.2.2	Students will be able to investigate and derive Newton's Laws of motion and apply it to the physical world.
Benchmark 11.2.2.1	Analyse the relationship between force, mass and motion of objects, and the major natural forces of gravitational, electric and magnetic.

Key question(s):

- What are some examples of forces?
- What are Newton's 1st, 2nd and 3rd laws of motion?

Vocabulary:

Force, Newton

Learning Objective(s)

By the end of the topic, students can:

- Analyse the relationship between force, mass, and motion of objects, and the major natural forces of gravitational, electric and magnetic.

Materials

Various objects with different masses.

Knowledge	Skills	Attitudes and Values
• F= ma (Newton's Second Law)	• Name the four different types of forces. • State the three Newton's laws of motion.	• Appreciate the application of Newton's laws in today's technology.

Assessment

- State and explain Newton's three laws of motion.

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

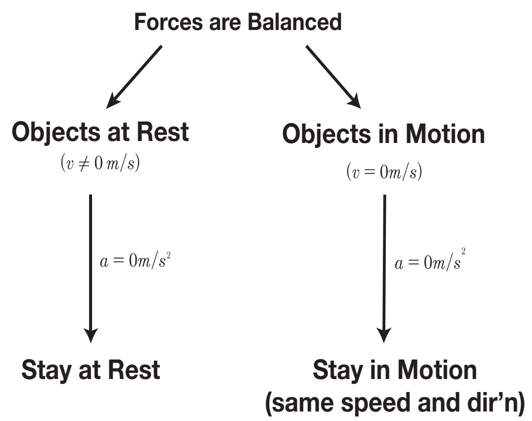
Content Background

Newton's First Law of Motion

Newton's first law of motion is often stated as

An object at rest stays at rest and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force.

There are two clauses or parts to this statement - one that predicts the behavior of stationary objects and the other that predicts the behavior of moving objects. The two parts are summarized in the following diagram.



The behavior of all objects can be described by saying that objects tend to “keep on doing what they’re doing” (unless acted upon by an unbalanced force). If at rest, they will continue in this same state of rest. If in motion with an eastward velocity of 5 m/s, they will continue in this same state of motion (5 m/s, East). If in motion with a leftward velocity of 2 m/s, they will continue in this same state of motion (2 m/s, left). The state of motion of an object is maintained as long as the object is not acted upon by an unbalanced force. All objects resist changes in their state of motion - they tend to “keep on doing what they’re doing.” Newton’s first law is also called the Law of Inertia.

Newton’s Second Law of Motion

Newton’s second law of motion can be formally stated as follows:

The acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object.

This verbal statement can be expressed in equation form as follows:

$$a = F_{net} / m$$

The above equation is often rearranged to a more familiar form as shown below. The net force is equated to the product of the mass times the acceleration.

$$F_{net} = m \times a$$

In this entire discussion, the emphasis has been on the net force. The acceleration is directly proportional to the net force; the net force equals mass times acceleration; the acceleration is in the same direction as the net force. It is important to remember this distinction

Consistent with the above equation, a unit of force is equal to a unit of mass times a unit of acceleration. By substituting standard metric units for force, mass and acceleration into the above equation, the following unit equivalency can be written.

$$1\ Newton = 1\ kg \times m/s^2$$

The definition of the standard metric unit of force is stated by the above equation. One Newton is defined as the amount of force required to give a 1-kg mass an acceleration of 1 ms-2.

Newton’s Third Law of Motion

Some forces result from contact interactions (normal, frictional, tensional, and applied forces are examples of contact forces) and other forces are the result of action-at-a-distance interactions (gravitational, electrical, and magnetic forces). According to Newton, whenever objects A and B interact with each other, they exert forces upon each other. When you sit in your chair, your body exerts a downward force on the chair and the chair exerts an upward force on your body. There are two forces resulting from this interaction - a force on the chair and a force on your body. These two forces are called action and reaction forces and are the subject of Newton’s third law of motion. Formally stated, Newton’s third law is:

For every action, there is an equal and opposite reaction.

The statement means that in every interaction, there is a pair of forces acting on the two interacting objects. The size of the forces on the first object equals the size of the force on the second object. The direction of the force on the first object is opposite to the direction of the force on the second object. Forces always come in pairs - equal and opposite action-reaction force pairs.

Unit: Force and Motion | **Topic:** Vector Calculation of Force

Benchmark 12.2.2.2	Use vectors to explain force and motion.

Key question(s):

- How can the resultant force acting in a system can be calculated?

Vocabulary:

Resultant Force,

Learning Objective(s)

By the end of the topic, students can:

- Analyse the process in calculating resultant forces

Materials

Ruler, Square grid papers

Knowledge	Skills	Attitudes and Values
• Sum of two or more vectors acting in a body determines the resultant force	• Determine the simplest way a force can be applied to move an object	• Appreciative of the application and function of resultant forces in the physical world.

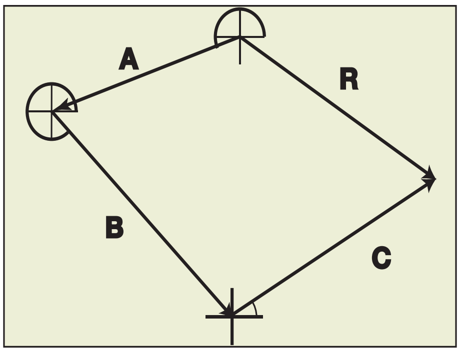
Assessment

- Calculate and represent resultant forces using vector diagrams.

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

Content Background

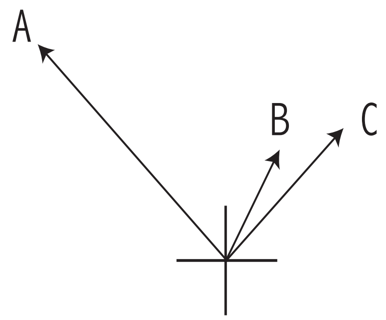
The resultant is the vector sum of two or more vectors. It is the result of adding two or more vectors together. If displacement vectors A, B, and C are added together, the result will be vector R. As shown in the diagram, vector R can be determined by the use of an accurately drawn, scaled, vector addition diagram.

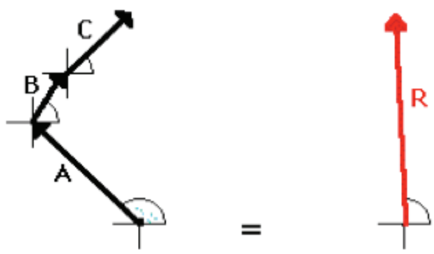


To say that vector R is the *resultant displacement* of displacement vectors A, B, and C is to say that a person who walked with displacements A, then B, and then C would be displaced by the same amount as a person who walked with displacement R. Displacement vector R gives the same *result* as displacement vectors A + B + C. That is why it can be said that: A + B + C = R

The above discussion pertains to the result of adding displacement vectors. When displacement vectors are added, the result is a *resultant displacement*. But any two vectors can be added as long as they are the same vector quantity. If two or more velocity vectors are added, then the result is a *resultant velocity*. If two or more force vectors are added, then the result is a *resultant* force. If two or more momentum vectors are added, then the result is resultant momentum.

In all such cases, the resultant vector (whether a displacement vector, force vector, velocity vector, etc.) is the result of adding the individual vectors. It is the same thing as adding A + B + C + ... "To do A + B + C is the same as to do R." As an example, consider a football player who gets hit simultaneously by three players on the opposing team (players A, B, and C). The football player experiences three different applied forces. Each applied force contributes to a total or resulting force. If the three forces are added together using methods of vector addition (discussed earlier), then the resultant vector R can be determined. In this case, to experience the three forces A, B and C is the same as experiencing force R. To be hit by players A, B, and C would result in the same force as being hit by one player applying force R. "To do A + B + C is the same as to do R." Vector R is the same result as vectors A + B + C!!





In summary, the resultant is the vector sum of all the individual vectors. The resultant is the result of combining the individual vectors together. The resultant can be determined by adding the individual forces together using vector addition methods.

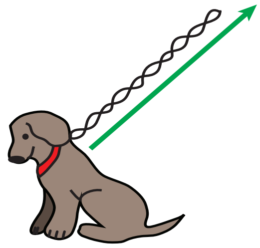
Trigonometric Method of Vector Resolution

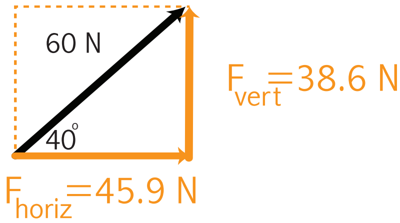
The trigonometric method of vector resolution involves using trigonometric functions to determine the components of the vector. Earlier the use of trigonometric functions to determine the direction of a vector was described. Now in this part of lesson, trigonometric functions will be used to determine the components of a single vector. Recall from the earlier discussion that trigonometric functions relate the ratio of the lengths of the sides of a right triangle to the measure of an acute angle within the right triangle. As such, trigonometric functions can be used to determine the length of the sides of a right angle triangle if an angle measure and the length of one side is known.

The method of employing trigonometric functions to determine the components of a vector are as follows:

1. Construct a rough sketch (no scale needed) of the vector in the indicated direction. Label its magnitude and the angle that it makes with the horizontal.
2. Draw a rectangle about the vector such that the vector is the diagonal of the rectangle. Beginning at the tail of the vector, sketch vertical and horizontal lines. Then sketch horizontal and vertical lines at the head of the vector. The sketched lines will meet to form a rectangle.
3. Draw the components of the vector. The components are the sides of the rectangle. The tail of each component begins at the tail of the vector and stretches along the axes to the nearest corner of the rectangle. Be sure to place arrowheads on these components to indicate their direction (up, down, left, right).
4. Meaningfully label the components of the vectors with symbols to indicate which component represents which side. A northward force component might be labeled Fnorth. A rightward force velocity component might be labeled vx; etc.
5. To determine the length of the side opposite the indicated angle, use the sine function. Substitute the magnitude of the vector for the length of the hypotenuse. Use some algebra to solve the equation for the length of the side opposite the indicated angle.
6. Repeat the above step using the cosine function to determine the length of the side adjacent to the indicated angle.

The method mentioned earlier is illustrated below for determining the components of the force acting upon Fido. As the 60 Newton tension force acts upward and rightward on Fido at an angle of 40 degrees to the horizontal, the components of this force can be determined using trigonometric functions.





$$\sin 40^0 = \frac{F_{vert}}{60\ N} \qquad \cos 40^0 = \frac{F_{horiz}}{60\ N}$$

$$F_{vert} = 60\ N \times \sin 40^0 \qquad F_{horiz} = 60\ N \times \cos 40^0$$

$$F_{vert} = 38.6\ N \qquad F_{horiz} = 45.9\ N$$

In conclusion, a vector directed in two dimensions has two components - that is, an influence in two separate directions. The amount of influence in a given direction can be determined using methods of vector resolution. Two methods of vector resolution have been described here - a graphical method (parallelogram method) and a trigonometric method.

Unit : Force and Motion **Topic:** Effect of Forces

Benchmark 12.2.2.3	Apply the laws of motion to determine the effects of forces on the linear motion of objects.

Key question(s):

- What are some effects of forces we experience in everyday life?

Vocabulary:

Inclined plane, Pulley system.

Learning Objective(s)

By the end of the topic, students can:

- Determine the effects of forces on objects by applying the laws of motion.

Materials

Inclined plane, pulley system, different objects to be in motion.

Knowledge	Skills	Attitudes and Values
• Collision of forces • Objects moving in an elevator	• Name the types and effects of forces. • Identify useful and harmful forces.	• Value the safe speed of a vehicle rounding a curve. • Appreciate the significance of force in daily life situations.

Assessment

- Determine the effects of forces using the laws of motion

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

Content Background

Some examples of identifying the effects of forces on motion are;

(a) collision of bodies (b) object movement in an elevator
(c) pulley system (d) Incline plane

All the above examples make use of any of Newton’s laws when in motion. Identifying the correct application and apply a suitable mathematical calculation to do the working out is important.

Unit: Force and Motion	**Topic:** Circular Motion
Benchmark 11.2.2.4	Analyse circular motion.

Key question(s):

- What causes an object to travel in a circular path?

Vocabulary:

Centripetal force, centrifugal force, safe speed.

Learning Objective(s)

By the end of the topic, students can:

- Determine the direction of motion for an object travelling in a circle.
- Explain why force causing the circular motion is directed toward the centre.

Materials

String, ball (or round objects),

Knowledge	Skills	Attitudes and Values
• Centripetal force keeps an object to travel a circular path.	• Name the factors that affect an object that travels in a circular path. • Calculate the amount of force required to keep an object to travel in a circular path.	• Value the safe speed of a vehicle rounding a curve.

Assessment

- Determine centripetal and centrifugal acceleration of an object.

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

Content Background

Calculation of the Average Speed

Uniform circular motion and circular motion at a constant speed is one of many forms of circular motion. An object moving in uniform circular motion would cover the same linear distance in each second of time. When moving in a circle, an object traverses a distance around the perimeter of the circle. So if your car were to move in a circle with a constant speed of 5 ms^{-1}, then the car would travel 5 meters along the perimeter of the circle in each second of time. The distance of one complete cycle around the perimeter of a circle is known as the **circumference**. With a uniform speed of 5 ms^{-1}, a car could make a complete cycle around a circle that had a circumference of 5 meters. At this uniform speed of 5 ms^{-1}, each cycle around the 5m circumference circle would require 1 second. At 5 ms^{-1}, a circle with a circumference of 20 meters could be made in 4 seconds; and at this uniform speed, every cycle around the 20 m circumference of the circle would take the same time period of 4 seconds. This relationship between the circumference of a circle, the time to complete one cycle around the circle, and the speed of the object is merely an extension of the average speed equation.

$$\text{Average Speed} = \frac{\text{distance}}{\text{time}} = \frac{\text{circumference}}{\text{time}}$$

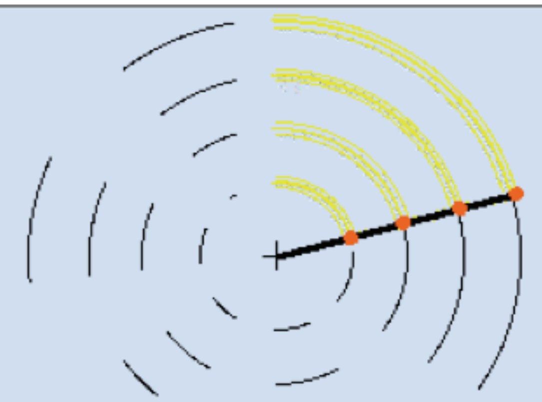
The circumference of any circle can be computed using from the radius according to the equation

Circumference = $2\pi r$

Combining these two equations above will lead to a new equation relating the speed of an object moving in uniform circular motion to the radius of the circle and the time to make one cycle around the circle (period).

Average Speed=$2\pi r/T$

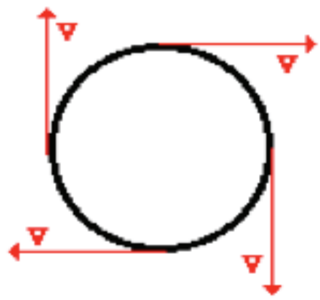
Where r represents the radius of the circle and T represents the period. This equation, like all equations, can be used as an algebraic recipe for problem solving. It also can be used to guide our thinking about the variables in the equation relate to each other. For instance, the equation suggests that for objects moving around circles of different radius in the same period, the object traversing the circle of larger radius must be traveling with the greatest speed. In fact, the average speed and the radius of the circle are directly proportional. A twofold increase in radius corresponds to a twofold increase in speed; a threefold increase in radius corresponds to a threefold increase in speed; and so on. To illustrate, consider a strand of four LED lights positioned at various locations along the strand. The strand is held at one end and spun rapidly in a circle. Each LED light traverses a circle of different radius. Yet since they are connected to the same wire, their period of rotation is the same. Subsequently, the LEDs that are further from the center of the circle are traveling faster in order to sweep out the circumference of the larger circle in the same amount of time. If the room lights are turned off, the LEDs created an arc that could be perceived to be longer for those LEDs that were traveling faster - the LEDs with the greatest radius.



Each bulb on the wire moves around the perimeter of the circle in the same amount of time; but the larger the radius of the circle, the greater the speed.

The Direction of the Velocity Vector

Objects moving in uniform circular motion will have a constant speed. But does this mean that they will have a constant velocity? Speed and velocity refer to two distinctly different quantities. Speed is a scalar quantity and velocity is a vector quantity. Velocity, being a vector, has both a magnitude and a direction. The magnitude of the velocity vector is the instantaneous speed of the object. The direction of the velocity vector is directed in the same direction that the object moves. Since an object is moving in a circle, its direction is continuously changing. At one moment, the object is moving northward such that the velocity vector is directed northward. One quarter of a cycle later, the object would be moving eastward such that the velocity vector is directed eastward. As the object rounds the circle, the direction of the velocity vector is different than it was the instant before. So while the magnitude of the velocity vector may be constant, the direction of the velocity vector is changing. The best word that can be used to describe the direction of the velocity vector is the word tangential. The direction of the velocity vector at any instant is in the direction of a tangent line drawn to the circle at the object's location. (A tangent line is a line that touches a circle at one point but does not intersect it.) The diagram at the right shows the direction of the velocity vector at four different points for an object moving in a clockwise direction around a circle. While the actual direction of the object (and thus, of the velocity vector) is changing, its direction is always tangent to the circle.



The direction of the velocity vector at every instant is in a direction tangent to the circle.

Unit: Force and Motion **Topic:** Rotational Motion

Benchmark 12.2.2.4	Analyse circular motion.

Key question(s):

- What is the difference between circular motion and rotational motion?

Vocabulary:

linear (tangential) velocity, angular velocity, and centripetal acceleration

Learning Objective(s)

By the end of the topic, students can:
- Differentiate between circular and rotational motion.
- Explain the characteristics of rotational motion

Materials

Materials:
String, objects

Knowledge	Skills	Attitudes and Values
• Rotational motion is the spinning of an object where the centre of mass and the axis of rotation changes.	• Explain the difference between circular and rotational motion	• Appreciate the importance of rotational motion in our planetary orbits.

Assessment

- Determine centripetal and centrifugal acceleration of an object.

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

Content Background

The main difference between these types of motion is that circular motion is a special case of rotational motion, where the distance between the body's centre of mass and the axis of rotation remains fixed.

Rotational motion is based around the idea of rotation of a body about its center of mass. In rotational motion, the axis of rotation and centre of mass could change whereas in circular motion, the axis of rotation and centre of mass does not change.

Circular motion is a movement of an object along the circumference of a circle or rotation along a circular path and can either have a constant angular rotation rate and constant speed, or it can exist with a changing rate of rotation.

Think of one of those fairground rides where people sit on dummy horses. Now imagine the horses spin around the post that holds them to the base of the ride. Then you have both rotational motion of the horse and circular motion as the horses move around the ride.

In a circular motion, the axis of rotation is inside the body, whiles the axis of rotation in the other case, and may be outside. Why the axis is outside in case of rotational motion.

The axis of rotation could pass through the body itself or lie outside the body. If the axis passes through the body, the word spin may be used to describe the rotation. Revolution or orbit would refer to where the axis of rotation lies outside the rigid body.

Translational and rotational quantities compared						
concept	**translation**		**connection**		**rotation**	
base quantities	s, r		s =			
coordinate systems	r =	$x\,\hat{\imath} + y\,\hat{\jmath}$	x = y = r^2 = θ =	r cos θ r sin θ $x^2 + y^2$ tan−1 (y/x)	r =	$r\,r^2 + \theta\,\theta^2$
velocity	v =	dr/dt	v =	ω × r	ω =	dθ/dt
acceleration	a =	$dv/dt = d^2r/dt^2$	a =	$\alpha \times r - \omega^2 r$	α =	$d\omega/dt = d^2\theta/dt^2$
equations of motion	v = x = v^2 =	$v_0 + at$ $x_0 + v_0 t + ½at^2$ $v_0^2 + 2a\,(x - x_o)$			ω = θ = ω2 =	$\omega_0 + \alpha t$ $\theta_0 + \omega^0 t$ + ½αt2 $\omega_0^2 + 2\alpha(\theta - \theta_0)$

Unit: Force and Motion **Topic:** Linear Momentum

Benchmark 11.2.2.5	Define and apply the laws of conservation of momentum

Key question(s):

- How is momentum conserved?
- What is the difference between elastic and inelastic collision?

Vocabulary:

Elastic collision, Inelastic collision, conservation of momentum

Learning Objective(s)

By the end of the topic, students can:
- Explain conservation of linear momentum
- Differentiate between elastic and inelastic collision

Materials

Carts (wheeled objects) bearings or marbles.

Knowledge	Skills	Attitudes and Values
• Momentum is mass in motion and is calculated as $p = m$ x v • For a collision occurring between two objects in an isolated system, the total momentum before the collision is equal to the total momentum after the collision.	• Define momentum of objects with mass in motion. • Use the principle of conservation of momentum to explain collision between two objects in isolated systems.	• Appreciate the importance of conservation of momentum in objects in motion.

Assessment

- Release two masses from opposite ends and make them collide. Use the speed (before and after collision) and mass to calculate the momentum of the system.

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

Content Background

Momentum

Momentum can be defined as "mass in motion." All objects have mass; so if an object is moving, then it has momentum - it has its mass in motion. The amount of momentum that an object has is dependent upon two variables: how much *stuff* is moving and how fast the *stuff* is moving. Momentum depends upon the variables mass and velocity. In terms of an equation, the momentum of an object is equal to the mass of the object times the velocity of the object.

$$Momentum = mass \times velocity$$

In physics, the symbol for the quantity momentum is the lower case p. Thus, the above equation can be rewritten as $\boldsymbol{p} = \boldsymbol{m}$ x $\boldsymbol{v}$
where $\boldsymbol{m}$ is the mass and $\boldsymbol{v}$ is the velocity. The equation illustrates that momentum is directly proportional to an object's mass and directly proportional to the object's velocity.

The units for momentum would be mass units times velocity units. The standard metric unit of momentum is the kg•m/s. While the kg•m/s is the standard metric unit of momentum, there are a variety of other units that are acceptable (though not conventional) units of momentum. Examples include kg•mi/hr, kg•km/hr, and g•cm/s. In each of these examples, a mass unit is multiplied by a velocity unit to provide a momentum unit. This is consistent with the equation for momentum

Momentum Conservation

One of the most powerful laws in physics is the law of momentum conservation. The law of momentum conservation can be stated as follows.

For a collision occurring between object 1 and object 2 in an isolated system, the total momentum of the two objects before the collision is equal to the total momentum of the two objects after the collision. That is, the momentum lost by object 1 is equal to the momentum gained by object 2.
For example, expressed in mathematical equation form as; let 1 and 2 be objects 1 and 2 respectively.

Momentum before collision = momentum after collision

- (mass 1 x initial velocity 1 moving right) + (mass 2 x velocity 2 moving left) = (mass 1 x final velocity 1) + (mass 2 x final velocity 2). Two different velocities since both objects travel different direction after the collision.
- (mass 1 x initial velocity 1 moving right) + (mass 2 x velocity 2 moving left) = (mass 1 + mass 2 times (final velocity). Same final velocity since both object stuck together after the collision.

Consider a collision between two objects - object 1 and object 2. For such a collision, the forces acting between the two objects are equal in magnitude and opposite in direction (Newton's third law). This statement can be expressed in equation form as follows.

$$F_1 = - F_2$$

The forces are equal in magnitude and opposite in direction.

The forces act between the two objects for a given amount of time. In some cases, the time is long; in other cases the time is short. Regardless of how long the time is, it can be said that the time that the force acts upon object 1 is equal to the time that the force acts upon object 2. This is merely logical. Forces result from interactions (or contact) between two objects. If object 1 contacts object 2 for 0.050 seconds, then object 2 must be contacting object 1 for the same amount of time (0.050 seconds). As an equation, this can be stated as

$$t_1 = t_2$$

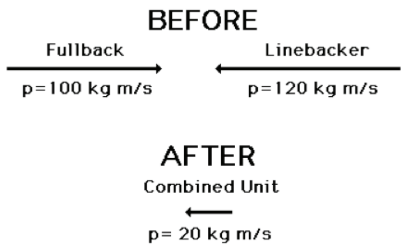
Since the forces between the two objects are equal in magnitude and opposite in direction, and since the times for which these forces act are equal in magnitude, it follows that the impulses experienced by the two objects are also equal in magnitude and opposite in direction. As an equation, this can be stated as

$$F_1 * t_1 = - F_2 * t_2$$

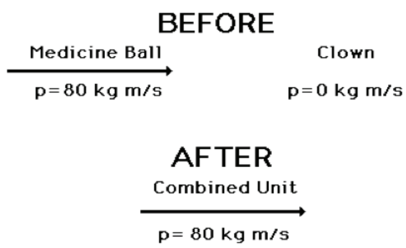
The impulses are equal in magnitude and opposite in direction.

Collisions

Collisions commonly occur in contact sports (such as football) and racket and bat sports (such as baseball, golf, tennis, etc.). Consider a collision in football between a fullback and a linebacker during a goal-line stand. The fullback plunges across the goal line and collides in midair with the linebacker. The linebacker and fullback hold each other and travel together after the collision. The fullback possesses a momentum of 100 kg*m/s, East before the collision and the linebacker possesses a momentum of 120 kg*m/s, West before the collision. The total momentum of the system before the collision is 20 kg*m/s, West (review the section on adding vectors if necessary). Therefore, the total momentum of the system after the collision must also be 20 kg*m/s, West. The fullback and the linebacker move together as a single unit after the collision with a combined momentum of 20 kg*m/s. Momentum is conserved in the collision. A vector diagram can be used to represent this principle of momentum conservation; such a diagram uses an arrow to represent the magnitude and direction of the momentum vector for the individual objects before the collision and the combined momentum after the collision.



Now suppose that a medicine ball is thrown to a clown who is at rest upon the ice; the clown catches the medicine ball and glides together with the ball across the ice. The momentum of the medicine ball is 80 kg*m/s before the collision. The momentum of the clown is 0 kg* m/s before the collision. The total momentum of the system before the collision is 80 kg*m/s. Therefore, the total momentum of the system after the collision must also be 80 kg*m/s. The clown and the medicine ball move together as a single unit after the collision with a combined momentum of 80 kg*m/s. Momentum is conserved in the collision.



Momentum is conserved for any interaction between two objects occurring in an isolated system. This conservation of momentum can be observed by a total system momentum analysis or by a momentum change analysis. Useful means of representing such analyses include a momentum table and a vector diagram.

Unit: Work, Energy and Power **Topic:** Work

Content Standard 11.2.3	Students will be able to identify and explain work, power and energy within physical and natural phenomenon
Benchmark 11.2.3.1	Define and explain work within physical systems.

Key question(s):

- What is work, its units and formula to calculate work?

Vocabulary:

Work, power, energy, joules

Learning Objective(s)

By the end of the topic, students can:
- Define work and its units
  Calculate work done

Materials

Wheel chair, ruler

Knowledge	Skills	Attitudes and Values
• Work is a measure of energy transfer.	• State examples of work done under physical systems.	• Appreciate work done by various variable forces.

Assessment

- Identify work, energy and mechanical power.

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

Content Background

Work is done when a force moves an object over a certain distance. Work (W) is proportional to the force F multiplied by the distance (s) of an object moved in the direction of the force, i.e.

$$W = F \times s$$

Work is measured in **joules** (J). 1 joule of work is done when a force of 1 newton moves an object through a distance of 1 metre, in the direction of the applied force.

$$1J = 1N \times 1m$$

No work is done in the scientific sense by someone standing still holding a heavy pile of block

Unit: Work, Energy and Power **Topic:** Work and Energy

Benchmark 11.2.3.2	Calculate the efficiency of energy transfer within physical systems.

Key question(s):

- How is energy transferred from one form to another
- How is energy transformed when two objects collide?

Vocabulary:

Potential Energy (PE), Kinetic energy (KE),

Learning Objective(s)

By the end of the topic, students can:
- Use the definition of work to calculate energy transfer.
- State the principle of conservation of energy

Materials

Various objects that can be collided,

Knowledge	Skills	Attitudes and Values
• Energy is measured in joules and $1J = 1Nm$ • Energy is neither created nor destroyed but converted from one form to another	• State examples of energy transformation • Calculate energy transfer within a physical system	• Develop an attitude to do work efficiently with less energy required

Assessment

- Calculate the energy within the system.

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

Content Background

Energy in physics is the capacity to do work. Work done $= F \times s$

$= mgh$

Work done is equal to the increase in potential energy
PE=mgh

The kinetic energy of a moving object is given by the formula:
KE=1/2 mv²
m is the mass of the object in kg,and v is the velocity in m/s

KE and work.

Consider a mass ***m*** which is acted on by a steady force ***F*** so that its velocity changes from ***u*** to ***v*** over a distance ***s***. We know that:

$$a = \frac{v^2 - u^2}{2s} \text{ and } F = ma$$

so $$F = \frac{m(v^2 - u^2)}{2s}$$

i.e $$Fs = \frac{1}{2}m(v^2 - u^2) = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

Note: *if* $u = 0$, then $Fs = \frac{1}{2}mv^2$

Unit: Work, Energy and Power **Topic:** Simple Machines

Benchmark 11.2.3.2	Calculate the efficiency of energy transfer within physical systems.

Key question(s):

- What are the advantages of using simple machines?
- How can we relate mechanical advantage with velocity ratio in a simple

Vocabulary:

Efficiency, Mechanical Advantage, Velocity ratio

Learning Objective(s)

By the end of the topic, students can:
- Determine the efficiency of a simple machine
- Explain the relationship between MA and VR

Materials

Lever, pulley system, wheel and axle.

Knowledge	Skills	Attitudes and Values
• Machines are clever devices that multiply force for us • $efficiency = \frac{power\ out}{power\ in}$ • s $M.A = \frac{load}{effort}$ • s $V.R = \frac{distance\ move\ by\ effort}{distance\ move\ by\ load}$	• Identify methods that require less force to do work efficiently	• Develop an attitude to do work efficiently with less energy required.

Assessment

- Identify efficiency, mechanical advantage, velocity ratio and calculate them.

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

Content Background

A simple machine is a mechanical device that changes the direction or magnitude of a force.

$$\text{efficiency} = \frac{\text{power out}}{\text{power in}} \qquad \text{M.A.} = \frac{\text{load}}{\text{effort}} \qquad \text{V.R} = \frac{\text{distance moved by effort}}{\text{distance moved by load}}$$

Examples of simple machine are; pulley system, seesaw, gears, inclined plane and etc. In any simple machine, load and effort must be clearly identified and also the distance from the pivot or fulcrum to each of them (load and effort). According to the law of conservation of torque (law of conservation of energy), the left hand torque is always equals to the right hand torque. So the principles can be used to calculate efficiency, mechanical advantage and velocity ratio and etc.

Unit: Work, Energy and Power **Topic:** Mechanical Power

Benchmark 11.2.3.3	Apply the concepts of power to solve problems.

Key question(s):

- How can we relate mechanical advantage with velocity ratio in a simple machine?

Vocabulary:

Mechanical Power,

Learning Objective(s)

By the end of the topic, students can:

- Explain the relationship between MA and VR

Materials

Diagrams of mechanical power examples

Knowledge	Skills	Attitudes and Values
• Machines are clever devices that multiply force for us • $efficiency = \frac{power\ out}{power\ in}$ • s $M.A = \frac{load}{effort}$ • s $V.R = \frac{distance\ move\ by\ effort}{distance\ move\ by\ load}$	• Identify methods that require less force to do work efficiently • Power is the rate at which energy is transferred.	Develop an attitude to do work efficiently with less energy required.

Assessment

- Calculate mechanical power and energy transferred.

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

Content Background

Mechanical power refers to the rate at which work can be done or energy transferred. It is defined as the rate at which energy is transferred by a force. Furthermore, power output, as opposed to a power input. Power is equals to work or energy/time. SI unit for mechanical power is Watts.

$$Power = \frac{energy\ \ transfer}{time\ taken} = \frac{workdone}{time}$$

Unit: Electricity and Magnetism **Topic:** Electrostatics

Content Standard 11.2.4	Students will be able to investigate and explain the electricity principles and processes in the physical world
Benchmark 11.2.3.3	Explain charged particles as sources of electric fields and are subject to the forces of the electric fields from other charges.

Key question(s):

- What is electric charge?
- What is electric force?
- What have Coulomb's Law and Gauss' Law got to do with electrostatics.

Vocabulary:

Coulombs Law

Learning Objective(s)

By the end of the topic, students can:

- Explain the relationship between MA and VR

Materials

Diagrams of mechanical power examples

Knowledge	Skills	Attitudes and Values
• Gain understanding of matter around us. • Know what Gauss' Law. • $K_c = \frac{q_1 q_2}{r^2}$	• Solve problems associated with electrostatics	• Appreciate electrostatics and apply in real life situation.

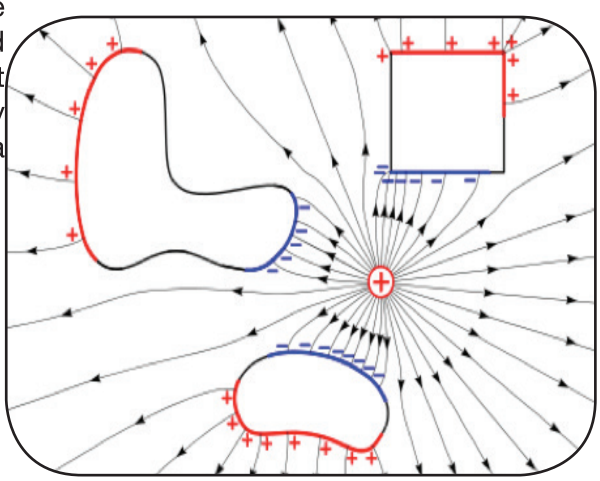
Assessment

- Calculate mechanical power and energy transferred.

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

Content Background

Electrostatics is a branch of physics that studies electric charges at rest. Whenever there is a charge, there is electric field due to force exerted by the charge on a neighbouring charge or collection of charges. Electric field is defined as the electric force per unit charge. The direction of the field is taken to be the direction of the force it would exert on a positive test charge. The electric field is radially outward from a positive charge and radially in toward a negative point charge. See figure below.



Coulomb's law is a function developed in the 1780s by physicist Charles Augustin de Coulomb. It explains how strong the force will be between two electrostatic charges. Electrostatic means electric charges without any motion. Coulomb's law explains the interaction between two electric charges. The magnitude of electrostatic force follows the function below.

$$F = K_c \frac{q_1 q_2}{r}$$

Where;

$W = p.d. \text{ x } q = EMF \text{ x } q$

$EMF = \frac{W}{q} = \frac{qBLv\sin\theta}{q}$

Unit: Electricity and Magnetism **Topic:** Electricity

Benchmark 11.2.4.2	Predict the voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors, capacitors and inductors.

Key question(s):

- What is Electric Current?(Define their units and types)

Vocabulary:

Ampere, voltage, direct current, alternating current.

Learning Objective(s)

By the end of the topic, students can:

- Explain the relationship between MA and VR

Materials

Diagrams of mechanical power examples

Knowledge	Skills	Attitudes and Values
• Current is the rate of flow of electron at a given time. • I=Q/t	• Explain the direction and behaviour of current in simple DC circuits	• Cautious and appreciate electric current principles in the environment.

Assessment

- Identify the flow of current and voltage using ammeter and voltmeter respectively.

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

Content Background

Electric current refers to the flow of charges (electrons). In order for electric current to flow there must be:

- A source of the current, such as a battery
- A conducting path for the current to flow from one terminal of the battery to the other.

The amount of electric charge moving around a circuit can be measured by an ammeter. An ammeter must be connected in series within the circuit. The electric current is measured in a unit called the ampere (A).

One ampere is equal to the rate of flow of one coulomb per second, through a particular point in a circuit One coulomb is the charge carried by 6.25×10^{18} electron: $I=Q/t$

Current that flows in a single direction is called direct current (DC) and current that alternates back and forth through the circuit is known as alternating current (AC). DC and AC current flow through a circuit when a voltage source is connected to it.

Voltage is the measure of the potential energy drop in a circuit. Simply, voltage is also the measure of the amount of energy flowing between two points in an electric circuit or across the terminals of a battery.

One volt means that each Coulomb of charge has given out one Joule of energy. Voltmeter is the instrument used to measure voltage across a cell or battery. It must be connected in parallel across a resistor/ component.

$$V = W/q \text{ or } V = E/q$$

where; V = voltage (V)

W or E = work or energy (J)

q = charge (C)

Unit: Electricity and Magnetism **Topic:** Ohm's Law

Benchmark 11.2.4.3	Solve problems involving Ohm's law.

Key question(s):

- What is Kirchhoff's Rules and how do we apply this to our electric circuit?
- What is Ohm's Law?

Vocabulary:

Ohm, Kirchhoff's rules

Learning Objective(s)

By the end of the topic, students can:
- Apply Kirchhoff's Rules in simple DC Circuits
- Apply Ohm's law in simple DC circuits

Materials

Diagrams of mechanical power examples

Knowledge	Skills	Attitudes and Values
• The current flowing into a point in a series circuit must be the same as current flowing out of that point • Ina parallel circuit, the total current flowing into the junction equals the total current leaving the current.	• Construct simple series and parallel circuits • Use Kirchhoff's rules in series and parallel circuits	• Appreciate the application of Kirchhoff's Rules in electrical appliances

Assessment

- Define and explain Kirchhoff's law using the electric circuit.

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

Content Background

Kirchhoff's rules are useful in finding unknown currents, voltages and resistances in a complicated circuit. It uses two very important laws as stated below.

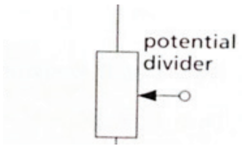
First Law: The Current Law

Current flow in circuits is produced when charge carriers travel though conductors. Current is defined as the rate at which this charge is carried through the circuit. A fundamental concept in physics is that charge will always be conserved. In the context of circuits this means that, since current is the rate of flow of charge, the current flowing into a point must be the same as current flowing out of that point. This is mathematically represented by the equation $I1+I2=I3$.

Second Law: The Voltage Law

As charge carriers flowing through a circuit pass through a component, they either gain or lose electrical energy, depending upon the component (cell or resistor for example). Microscopically, this is due to the fact that work is done on them by the electric forces inside the circuit components. The negative of the work done by these electric forces on a unit of charge which passes through a component is called the potential difference (voltage) across the component. In most circuits which you'll meet, it turns out that the work done by the electric forces around any closed loop in the circuit must be zero.

Kirchhoff's voltage law can be generalized to any loop containing any number of components. A more formal way of writing it is:



Georg Ohm, in full Georg Simon Ohm, (born March 16, 1789, Erlangen, Bavaria [Germany]—died July 6, 1854, Munich), German physicist who discovered the law, named after him, which states that the current flow through a conductor is directly proportional to the potential difference (voltage) and inversely proportional to the resistance. These discoveries were very crucial to mankind's understanding to electric circuits. This topic covers the subject well.
Ohm's Law deals with the relationship between voltage and current in an ideal conductor. This relationship states that:

The potential difference (voltage) across an ideal conductor is proportional to the current through it. The constant of proportionality is called the "resistance", R.

Ohm's Law is given by:

$V = I R$, where V is the potential difference between two points which include a resistance R. I is the current flowing through the resistance.

Unit: Electricity and Magnetism **Topic:** Resistors

Benchmark 11.2.4.4	Establish that any resistive element in a DC circuit dissipates energy, which heats the resistor.

Key question(s):

- What are resistors and their function?

Vocabulary:

Resistor, potentiometer, potential divider

Learning Objective(s)

By the end of the topic, students can:

- Describe any resistive elements in a DC circuit.

Materials

Various types of resistors, rheostat

Knowledge	Skills	Attitudes and Values
• Any resistive element in a DC circuit dissipates energy which heats the resistor.	• Explain how resistors function in electrical appliances	• Appreciate the application of resistors in daily used electrical appliances.

Assessment

- Calculate resistance and energy dissipates from any electric circuit.

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

Content Background

Resistors

Conductors intended to have resistance are called **resistors** (symbol)  and are made either from wires of special alloy or from carbon. Those in radio and television set have values from a few ohms up to millions of ohm, Figure 1
Variable resistors are used in electronics (and are then called potentiometers) as volume and other controls, Figure 2. Larger current versions are useful in laboratory experiments and consist of a coil or constantan wore (any alloy of 60% copper, 40% nickel) wound on a tube.

Figure 1

Figure 2

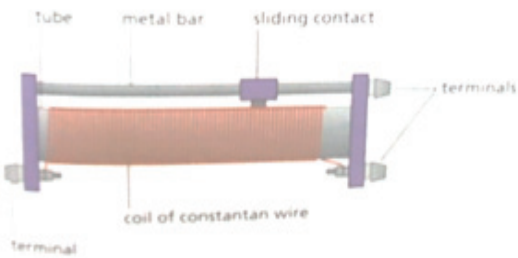


Figure 3

There are two ways of using such a variable resistor. It may be used as a **rheostat** (Figure 3) for changing the current in a circuit; only one end connection and the sliding contact are then required. In figure 4 a, moving the sliding contact to the left reduces the resistance and increase the current. It can also act as a **potential divider** for changing the p.d. applied to a device, all three connections being used. In figure 4 b, any fraction from the total p.d. of the battery to zero can be 'tapped off' by moving the sliding contact down.

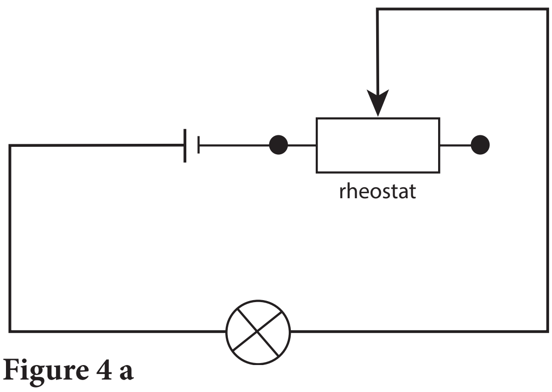


Figure 4 a

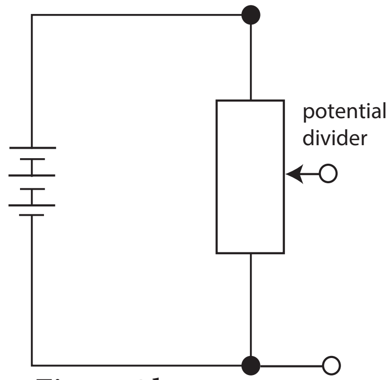


Figure 4 b

Resistors have colour coded bands as shown in Figure 5. In the orientation shown the first two bands on the left give digits 2 and 7; the third band gives the number of noughts (3) and the fourth band gives the resistor's 'tolerance' (or accuracy, here ± 10%). So the resistor has a value of 27 000 Ω (± 10%).

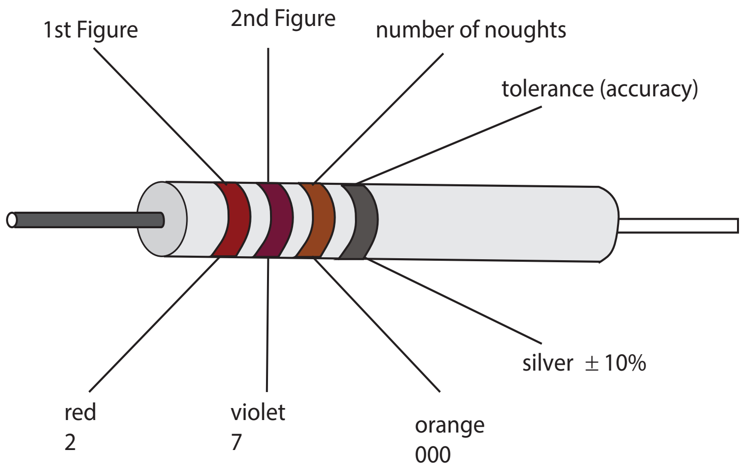


Figure	Colour
0	black
1	brown
2	red
3	orange
4	yellow
5	green
6	blue
7	violet
8	grey

resistor value $= 27000\,\Omega\ (\pm 10\%)$

$= 27\ \Omega\ (\pm 10\%)$

Unit: Electricity and Magnetism **Topic:** Electric Power

Benchmark 11.2.4.5	Calculate the power (rate of energy dissipation) in any resistive circuit element by using the formula $P=I^2 R$

Key question(s):

- What is electrical power?
- How does power consumed in homes?

Vocabulary:

Resistor, potentiometer, potential divider

Learning Objective(s)

By the end of the topic, students can:

- Describe any resistive elements in a DC circuit.

Materials

Various types of resistors, rheostat

Knowledge	Skills	Attitudes and Values
• The rate of energy transfer or the rate of doing work is called power. • Fuses are safety devices consisting of a strip of wire that melts and breaks an electric circuit if the current exceeds a safe level.	• Find the rate of work done in basic household electrical appliances. • Explain the functions of fuses and circuit breakers	• Cautious of power consumption when using electrical appliances • Appreciate the use of fuses and circuit breakers.

Assessment

- Calculate the power loss from given electric circuits.

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

Content Background

POWER

If Q coulomb of charge passes through a potential difference of V volts, the work done by theelectrical force is given by $W=QV$.

The rate of energy transfer or the rate of doing work is called power. In a circuit component like a bulb, the power can be calculated in term of potential difference and current.

$$P = \frac{W}{t} = \frac{QV}{t} = IV$$

The unit for power is watt (W). One watt is equal to one joule per second, *i.e.* $1\ W=1\ J/s$.
In terms of the volt and ampere, $1\ W=1\ V\ A$.
A larger unit for power is the kilowatt (kW), where 1 kW=1000 W.
Since $P=IV$ and $V=IR$, we can write:

$$P = IV = I^2R = \frac{V^2}{R}$$

The energy supplied in t seconds is given by:

$$W = I^2Rt = \frac{V^2t}{R} = VIt = Pt$$

Many electrical appliances state their power ratting. An electrical bulb marked '60 W,240 V'has a power consumption of 60 W when operated at 240 V.

Unit for Electrical Energy

The unit for electrical energy is the joule. In industry and household consumption of electricity, the unit kilowatt hour kWh is used. One kWh is the energy delivered in one hour at the rate of 1000 watts.

$$1kWh = 100 \text{ x } 360s = 3.6 \text{ x } 10^6 J$$

Unit: Electricity and Magnetism **Topic:** Electric Field Patterns

Benchmark 11.2.4.6	Determine the static electric field patterns produced by arrangement of electric charge(s)

Key question(s):

- How do the electric field patterns produced by the arrangement of electric charges?

Vocabulary:

Resistor, potentiometer, potential divider

Learning Objective(s)

By the end of the topic, students can:

- Define and apply electric power and electrical Determine the electric field patterns produced by the arrangement of electric charges.

Materials

Models of positive and negative charges,

Knowledge	Skills	Attitudes and Values
• Electric field lines always leave positive charges and end on negative charges. • No two electric filed lines ever cross. • Electric field strength is defined as the force per unit positive charge placed in the field.	• Draw the electric field between parallel plates and surrounding point charges. • Apply mathematics to calculate the force experienced by a charge in an electric field.	• Appreciate the behaviour and impact of electric fields in the physical world.

Assessment

- Construct electrical field lines.

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

Content Background

Whenever there is a charge, there is electric field due to force exerted by the charge on a neighbouring charge or collection of charges. Electric field is defined as the electric force per unit charge. The direction of the field is taken to be the direction of the force it would exert on a positive test charge. The electric field is radially outward from a positive charge and radially in toward a negative point charge. See figure on the rigth.

The mathematical equation is;

$$E = F/q$$

$$E = kq/r^2,$$

where,

E = electric field

k = proportional constant ($9 \times 10^9\ Nm^2C^{-2}$)

q = charge (C)

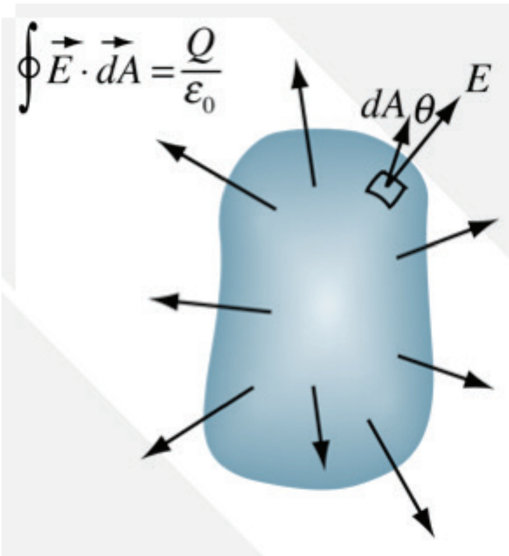
r^2 = distance where the charge is located (m)

Coulomb's law is a function developed in the 1780s by physicist Charles Augustin de Coulomb. It explains how strong the force will be between two electrostatic charges. Electrostatic means electric charges without any motion. Coulomb's law explains the interaction between two electric charges. The magnitude of electrostatic force follows the function below.

$$F = K_c \frac{q_1 q_2}{r^2}$$

The figure shows how Coulomb's Force act; similar charges pushing against each other and opposite charges attract each other

Gauss's law states that the net flux of an electric field through a closed surface is proportional to the enclosed electric charge. ... The electric flux is defined as the electric field passing through a given area multiplied by the area of the surface in a plane perpendicular to the field.



The total of the electric flux out of a closed surface is equal to the charge Q enclosed divided by the permittivity εo.

These two laws for a start are fundamental to the study of Electrostatics. Every scholar who intends to study Physics will always encounter them.

Unit: Electronics **Topic:** Intrinsic and Extrinsic Semiconductors

Content Standard 11.2.5	Students will be able to examine and explain semiconducting devices and electronic systems.
Benchmark 11.2.5.1	Explain how atoms interact by transferring or sharing electrons.

Key question(s):

- What are semi-conductors and how do they function?

Vocabulary:

Intrinsic Semiconductor, Extrinsic semiconductor,

Learning Objective(s)

By the end of the topic, students can:

- Explain the functions of semiconductors.

Materials

Diagram or sample model of Crystal lattice of silicon and germanium

Knowledge	Skills	Attitudes and Values
• Semi-conductors are solid substances or devices that have conductivity between that of an insulator and that of most metals, either due to the addition or an impurity or because of temperature effects.	• Critical thinking skills are enhanced.	• Appreciate the use of semiconductors in electrical appliances.

Assessment

- Explain the difference between intrinsic and extrinsic semiconductors.

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

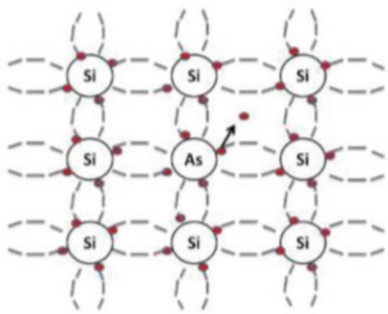
Content Background

Intrinsic Semiconductor

An intrinsic semiconductor also called an undoped semiconductor or i-type semiconductor is a pure semiconductor without any significant dopant species present.

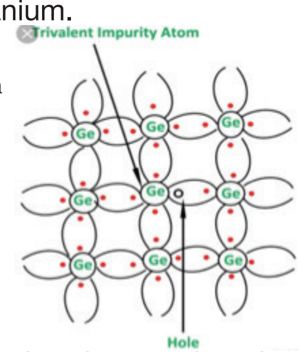
Extrinsic Semiconductor

Extrinsic semiconductors are components of many common electrical devices. A semiconductor diode consists of p-type and n-type semiconductors placed in junction with another. Currently, most semiconductor diodes use doped silicon or germanium.



Crystal lattice of silicon

This produces n-type semiconductor



Crystal lattice of germanium

This produces n-type semiconductor

When n-type and p-type semiconductor come together they produced a PN Junction (PN type semiconductor). A device made from PN junction is called a *diode*.

Unit: Electronics **Topic:** Diodes and Transistors

Benchmark 11.2.5.2	Investigate the uses of semiconductor materials from which solid state devices, such as the diode and transistors are made.

Key question(s):

- What are diodes, their uses and how they function in electrical appliances?
- What are diodes, their uses and how they function in electrical appliances?

Vocabulary:

Diodes, transistors

Learning Objective(s)

By the end of the topic, students can:

- Distinguish between diodes and transistor

Materials

Samples of diodes and transistors

Knowledge	Skills	Attitudes and Values
• Diodes are electronic devices made mostly from semiconducting materials of silicon and germanium. • Transistors are semiconductor devices used to amplify or switch electronic signals and electrical power.	• Explain the functions of diodes and transistors.	• Appreciate the use of diodes and transistors in electrical appliances

Assessment

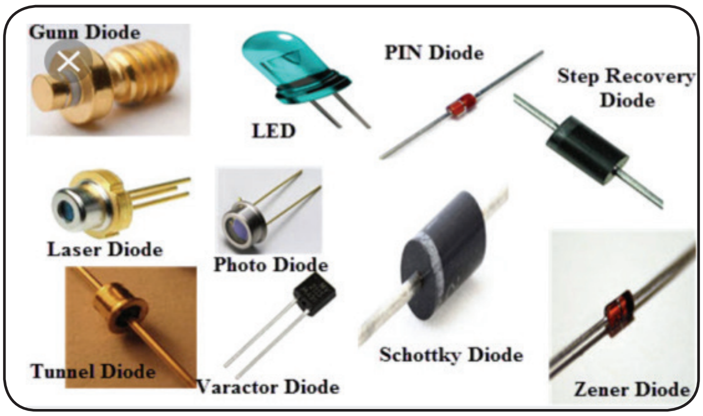
- Differentiate between a NPN transistor and PNP transistor.

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

Content Background

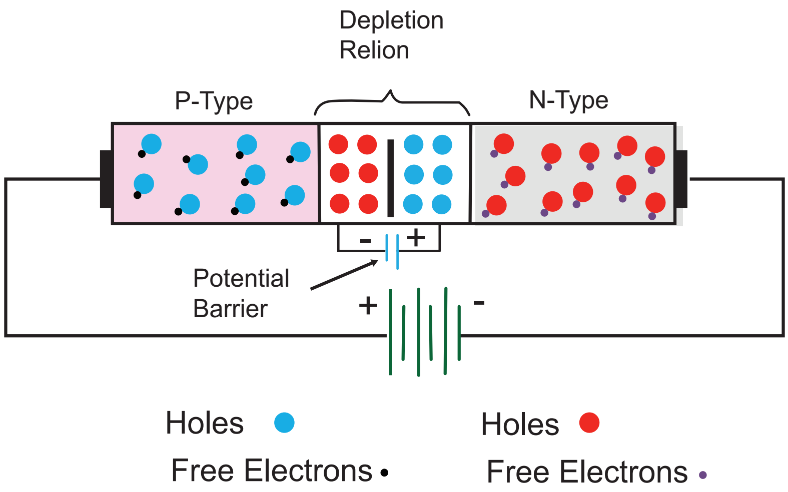
Diodes

Diodes are electronic devices made mostly from semiconducting materials of silicon and germanium.



Transistors

Transistors are semiconductor devices used to amplify or switch electronic signals and electrical power.



Basically transistors are produced when two diodes are combined together. There are two types of transistors:

(a) PNP transistor (b) NPN transistor

Unit: Electronics **Topic:** Application of Diodes

Benchmark 11.2.5.3	Describe the behaviour and applications of the diode and the transistor.

Key question(s):

- What are the functions and applications of diodes and resistors in electronic circuits?

Vocabulary:

Diodes, transistors

Learning Objective(s)

By the end of the topic, students can:

- Distinguish between diodes and transistor

Materials

Samples of diodes and transistors

Knowledge	Skills	Attitudes and Values
• When current flows through a diode, it is said to be forward biased. • When a diode is reverse biased, no current flows through it. • Transistor amplifies or switches electronic signals and electrical power.	• Explain the functions of diodes and transistors in electronic circuits.	• Appreciate the use of diodes and transistors in electrical appliances.

Assessment

- Define the function of diode and explain the transistors work.

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

Content Background

Some Common Applications of Diodes

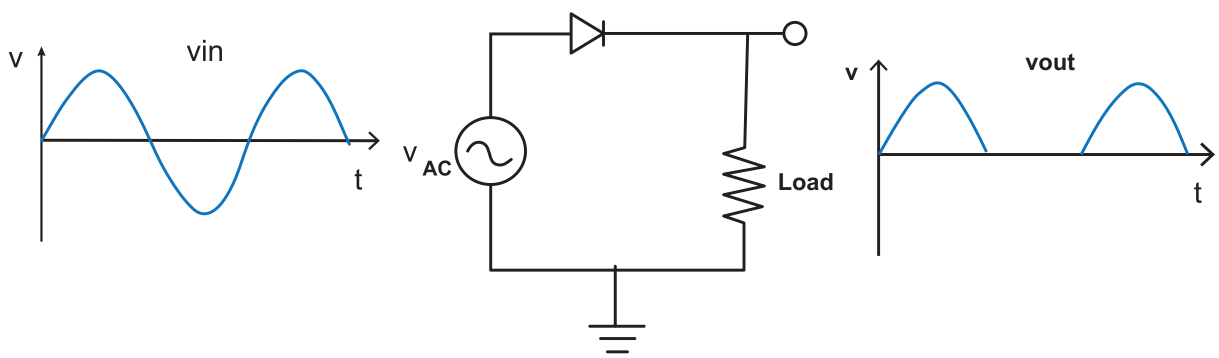
Before taking a look at various applications of diodes, let us quickly take a peak at a small list of common applications of diodes.

- Rectifiers
- Clipper Circuits
- Clamping Circuits
- Reverse Current Protection Circuits
- In Logic Gates
- Voltage Multipliers

Diode as a Rectifier

The most common and important application of a diode is the rectification of AC power to DC power. Using the diodes, we can construct different types of rectifier circuits.

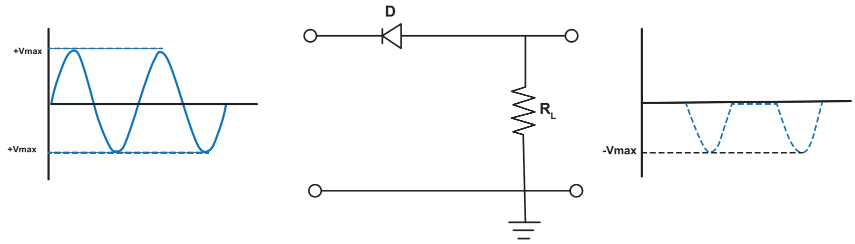
The basic types of these rectifier circuits are half wave, full wave center tapped and full bridge rectifiers. A single or combination of four diodes is used in most of the power conversion applications. Below figure shows diode operation in a rectifier.



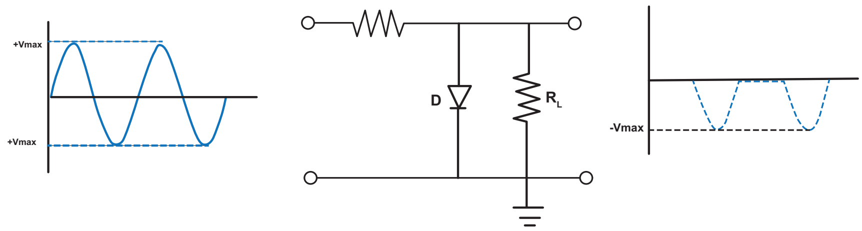
- During the positive half cycle of the input supply, anode is made positive with respect to cathode so the diode gets forward biased. These results to flow a current to the load. Since the load is resistive the voltage across the load resistor will be same as the supply voltage that means the input sinusoidal voltage will appear at the load. And the load current flow is proportional to the voltage applied.
- During the negative half-cycle of the input sinusoidal wave, anode is made negative with respect to cathode so the diode gets reverse-biased. Hence, no current flows to the load. The circuit becomes open circuit and no voltage appears across the load.
- Both voltage and current at the load side are of one polarity means the output voltage is pulsating DC. Very often this rectification circuit has a capacitor that is connected across the load to produce steady and continuous DC currents without any ripples.

Diodes in Clipping Circuits

Clipping circuits are used in FM transmitters where noise peaks are limited to a particular value so that excessive peaks are removed from them. The clipper circuit is used to put off the voltage beyond the preset value without disturbing the remaining part of the input waveform. Based on the diode configuration in the circuit, these clippers are divided into two types; series and shunt clipper and again these are classified into different types.



Positive series clipper



Positive shunt clipper

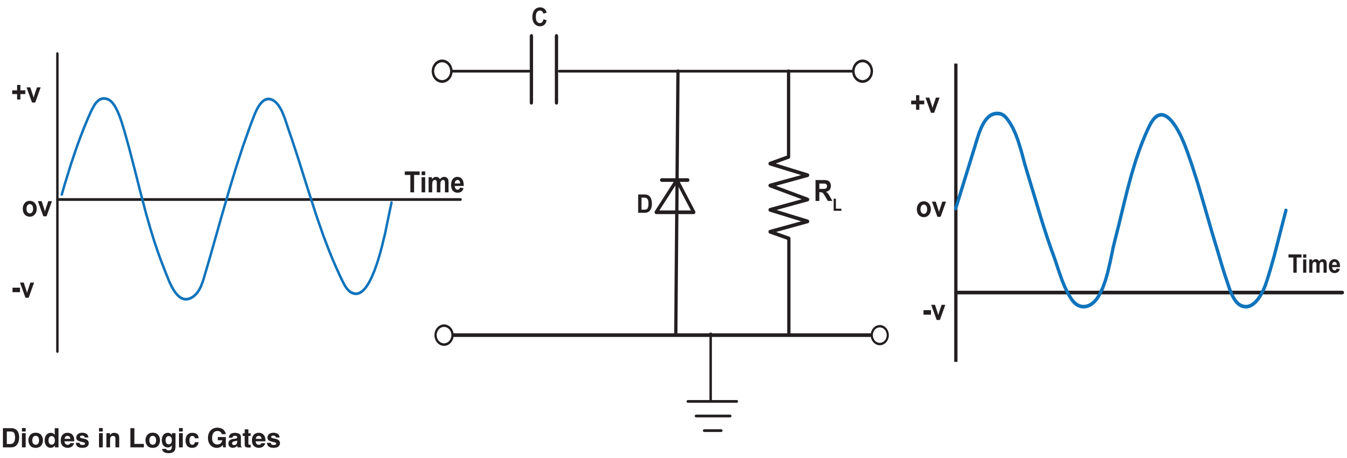
The above figure shows the positive series and shunt clippers. Using these clipper circuits, positive half cycles of the input voltage waveform will be removed. In positive series clipper, during the positive cycle of the input, the diode is reverse-biased so the voltage at the output is zero. Hence the positive half-cycle is clipped off at the output. During the negative half cycle of the input, the diode is forward-biased and the negative half cycle appears across the output.

In positive shunt clipper, the diode is forward-biased during the positive half cycle so the output voltage is zero as diode acts as a closed switch. And during negative half cycle diode is reverse-biased and acts as open switch so the full input voltage appear across the output. With the above two diode clippers positive half-cycle of the input is clipped at the output.

Diodes in Clamping Circuits

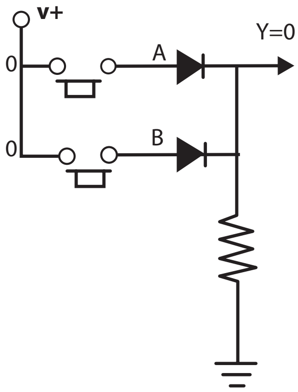
A clamper circuit is used to shift or alter either positive or negative peak of an input signal to a desired level. This circuit is also called as level shifter or DC restorer. These clamping circuits can be positive or negative depends on the diode configuration. In positive clamping circuit, negative peaks are raised upwards so the negative peaks fall on the zero level. In case of the negative clamping circuit, positive peaks are clamped so that it pushes downwards such that the positive peaks fall on the zero level.

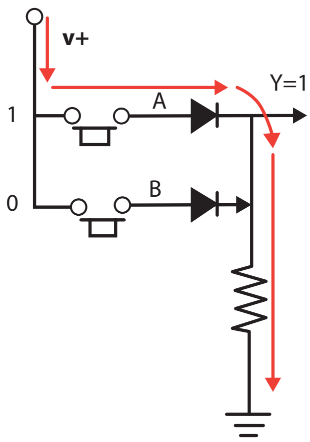
Look at the below diagram for understanding the diode application in clamping circuits. During the positive half-cycle of the input, diode is reverse-biased so the output voltage is equal to the sum of input voltage and capacitor voltage (considering the capacitor is initially charged). During the negative half-cycle of the input, diode is forward-biased and behaves as a closed switch so the capacitor charges to a peak value of the input signal.



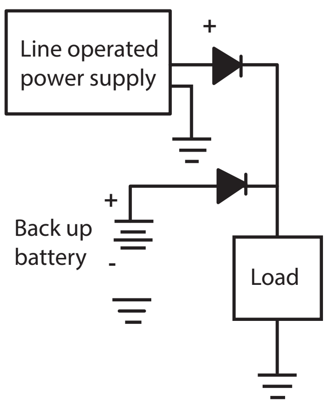
Diodes in Logic Gates

Diodes can also perform digital logic operations. Low and high impedance states of logic switch are analogous to the forward and reverse-biased conditions of the diode respectively. Thus, the diode can perform logic operations such as AND, OR, etc. Although diode logic is an earlier method with some limitations, these are used in some applications. The below figure shows the OR gate logic implemented using a pair of diodes and a resistor.





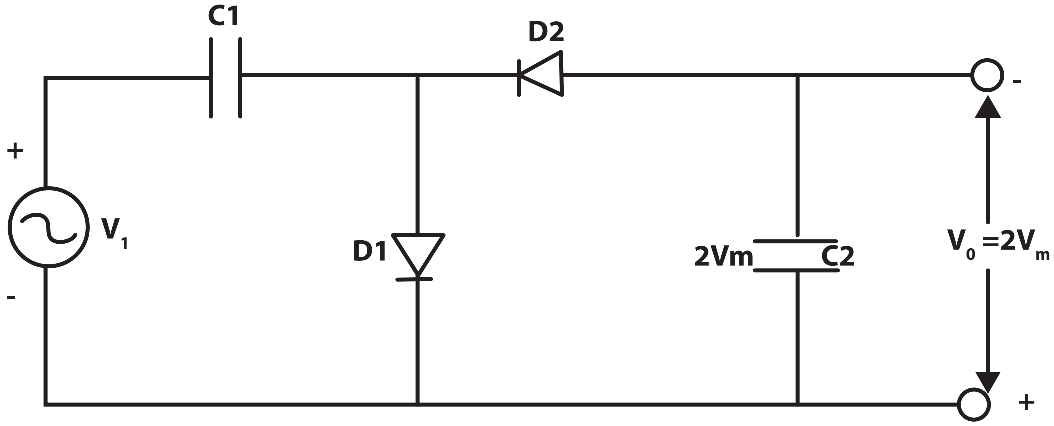
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1



In the above circuit input voltage is applied at V and by controlling the switches we get the OR logic at the output. Here logic 1 means high voltage and logic 0 means zero voltage. When both switches are in open state, both the diodes are in reverse-biased condition and hence the voltage at the output Y is zero. When any one of the switch is closed, the diode becomes forward-bias and as a result the output is high.

Diodes in Voltage Multiplier Circuits

Voltage multiplier consist of two or more diode rectifier circuits which are cascaded to produce a DC output voltage equal to the multiplier of the applied input voltage. These multiplier circuits are of different types like voltage doubler, tripler, quadrupler, etc. By the usage of diodes combination with capacitors, we get the odd or even multiple of the input peak voltage at the output

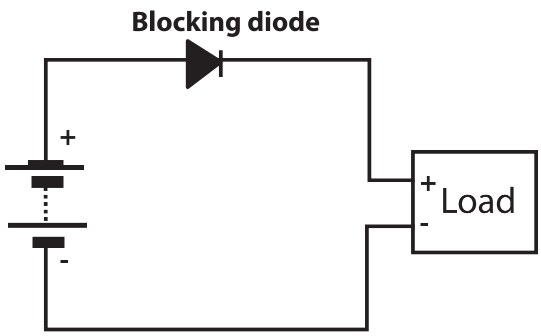


Above figure shows a half-wave voltage doubler circuit whose DC output voltage is twice that of peak input AC voltage. During the positive half-cycle of the AC input, diode D1 is forward-biased and D2 is reverse-biased. So the capacitor C1 charges up to peak voltage Vm of the input through the diode D1. During the negative half-cycle of the AC input, D1 is reverse-biased and D2 is forward-biased. So, capacitor C2 starts charging thorough D2 and C1. Thus, the total voltage across the C2 is equal to the 2Vm.

During next positive half-cycle, the diode D2 is reverse-biased so the capacitor C2 will discharge through the load. Likewise by cascading the rectifier circuits we will get the multiple values of input voltage at the output.

Diodes in Reverse Current Protection

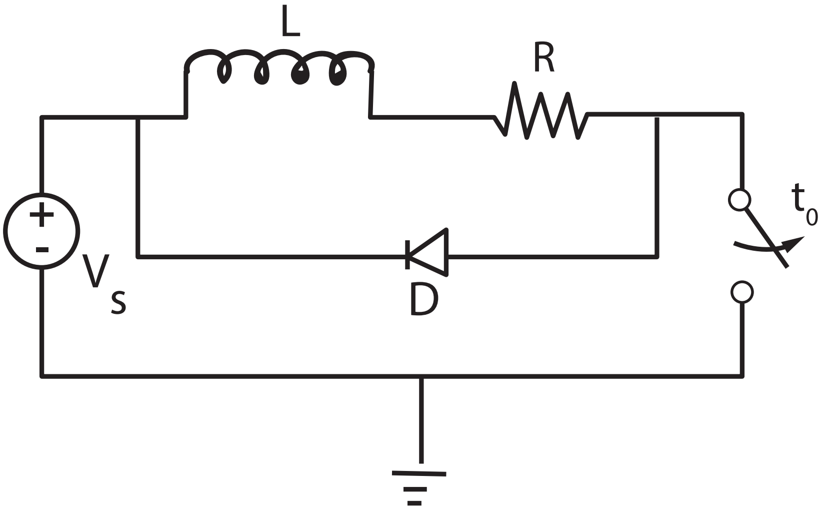
The reverse polarity or current protection is necessary to avoid the damage that occurs due to connecting the battery in a wrong way or reversing the polarities of the DC supply. This accidental connection of supply causes to flow a large amount current, thorough the circuit components results to explode them. Therefore, a protective or blocking diode is connected in series with the positive side of the input to avoid the reverse connection problem.



Above figure shows the reverse current protection circuit where diode is connected in series with the load at the positive side of the battery supply. In case of the correct polarity connection, diode gets forward-biased and load current flows through it. But, in case of wrong connection, the diode is reverse-biased and that doesn't allow any current to flow to the load. Hence, the load is protected against the reverse current.

Diodes in Voltage Spike Suppression

In case of an inductor or inductive loads, sudden removal of supply source produces a higher voltage due to its stored magnetic field energy. These unexpected spikes in the voltage can cause the considerable damage to the circuit components. Hence, a diode is connected across the inductor or inductive loads to limit the large voltage spikes. These diodes are also called by different names in different circuits such as snubber diode, flyback diode, suppression diode, and freewheeling diode and so on.



In the above figure the freewheeling diode is connected across the inductive load for suppressing of voltage spikes in an inductor. When the switch is suddenly opened, the voltage spike is created in the inductor. Therefore, the freewheeling diode makes the safe path to flow the current to discharge the voltage offered by the spike.

Diodes in Solar Panels

The diodes which are used for protection of solar panels are called as bypass diodes. If the solar panel is faulty or damaged or shaded by fallen leaves, snow and other obstructions, the overall output power decreases and arise hot spot damage because the current of the rest of the cells must flow through this faulty or shaded cell causes a overheating. The main function of the bypass diode is to protect the solar cells against this hot spot heating problem.

Unit: Electronics **Topic:** Logic Gates

Benchmark 11.2.5.4	Establish that the physical and electrical properties of transistors and the role of transistors in electric circuits.

Key question(s):

- What are logic gates?
- How do logic gates function?

Vocabulary:

Truth table, Logic gate

Learning Objective(s)

By the end of the topic, students can:

- Describe logic gates and explain how they function in electric circuits.

Materials

Diagrams of various logic gates

Knowledge	Skills	Attitudes and Values
• Logic gates are switching circuits used in digital electronic systems, like computers • High output and input are indicated by logic level 1 in the truth table • Low output and input are indicated by logic level 0 in the truth table	• Explain the use of logic gates in the physical world (e.g. car door warning system).	• Appreciate the functions of logic gates in electronic circuits.

Assessment

- Identify each logic gate and construct their truth table.

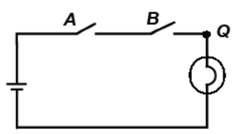
Teacher to develop assessment rubric on the assessment tasks mentioned above.

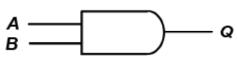
Content Background

The AND Gate

To determine the decisions made by AND gate, we look at the potential of point Q in figure 6. When point Q is at zero potential, the bulb will be off (logic 0). When it is at higher potential, the bulb will be on (logic 1). Notice that when A and B or both switches are off, Q will also be off. Q is only on when A and B are both on. This information is shown in the truth table.

Figure 6





Truth table an AND circut

A	B	Q
0	0	0
0	1	0
1	0	0
1	1	1

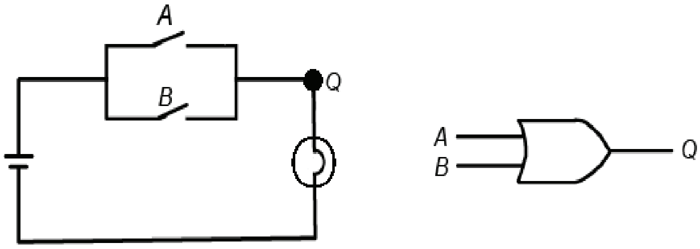
Use of an AND Gate

An AND gate can be used in a bank security system. The bank opens when a switch at the vault and a switch on the bank manager's desk are pressed. AND gate could also be used in a motor vehicle. The car can only be started when door 1 and 2 are closed.

The OR Gate

Figure 7 below shows a circuit that helps us understands how an OR gate work. The OR truth table is given below.

Figure 7



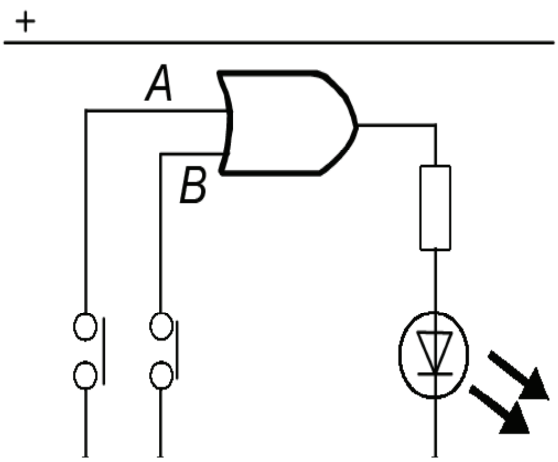
*Truth table for an **OR** gate*

A	B	Q
0	0	0
0	1	1
1	0	1

Thus for the OR gate, the output is 1 if the input A or input B are both 1.

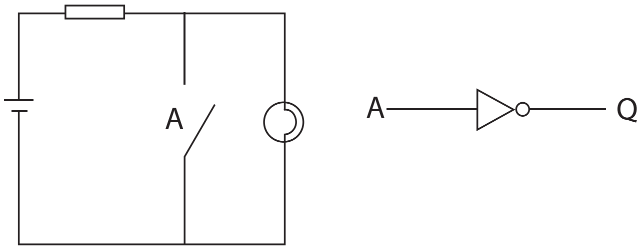
Use of an OR gate

Figure 8 shows an OR gate being used in a car door warning signal. Each switch is installed on a car door. When either is open, the input is unconnected and so behaves as if it is high. The output is high and the LED warning light glows.



The NOT gate

A NOT gate, or INVERTER, has only one input. The function of this gate is simply to always produce an output the opposite of it input. Thus a 1 at the input results in a 0 at the output, and vice versa.



Truth table for a NOT gate

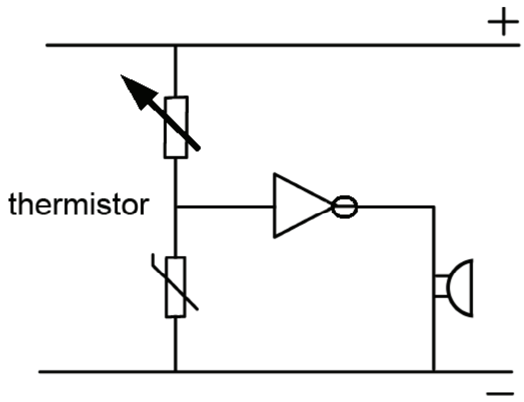
A	Q
0	1
1	0

Figure 9

Thus the NOT gate gives an output that is not the same as the input. In figure 9, the lamp glows (1) when the switch is off. When the switch is closed, (on), the lamp is off (0).

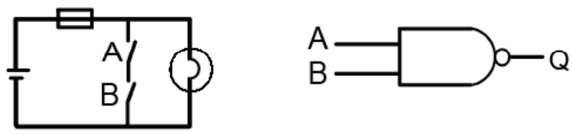
Use of a NOT gate

A NOT gate can be used in a fire alarm circuit (figure 10). The buzzer in the circuit will sound an alarm when the temperature of the thermistor reaches a certain value. The sensitivity of the circuit can be changed by adjusting the variable resistor.



The NAND gate

All logic circuits are simply combinations of the three basic gates AND, OR and NOT. A NAND gate can be made by connecting an AND gate to an INVERTER (NOT) gate. The output of a NAND gate is opposite to that of an AND gate. (NAND stand for Not AND).
Thus for NAND gate, the output is 1 if input A and B are not both 1.



Truth table for the ***NAND*** gate

A	B	Q
0	0	1
0	1	1
1	0	1
1	1	0

Figure 11: *An AND gate combined with a NOT gate to give a NAND gate.*

Use of a NAND gate

Figure 12 below shows a circuit for a simple burglar alarm using a NAND gate. The buzzer will sound either when the LDR is illuminated (by the burglar's torch) or the switch is closed (by the burglar's foot acting on a pressure mat.

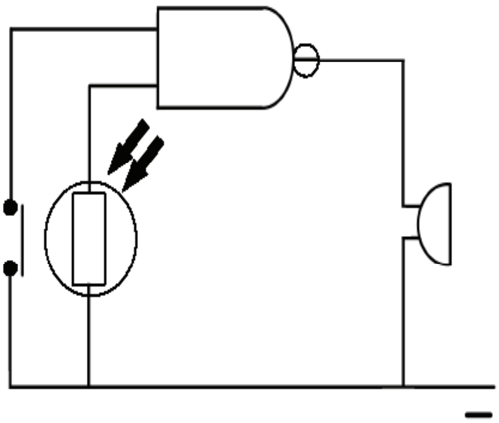


Figure 12: Using a NAND gate in a burglar alarm system

The NOR gate

A NOR gate is made by connecting an OR gate to an INVERTER (NOT) gate. The output of a NOR gate is 1 if neither input A nor input B is 1. (NOR stand for Not OR)

Figure 13: Circuit symbol for a NOR gate, an OR gate combined with a NOT gate to give a NOR gate and the truth gate for a NOR gate.

Use of a NOR gate

Figure 14 below shows an automatic lighting system. When neither the switch is pressed nor the LDR is under bright light, the bulb is turned on automatically. The light comes automatically at dark.

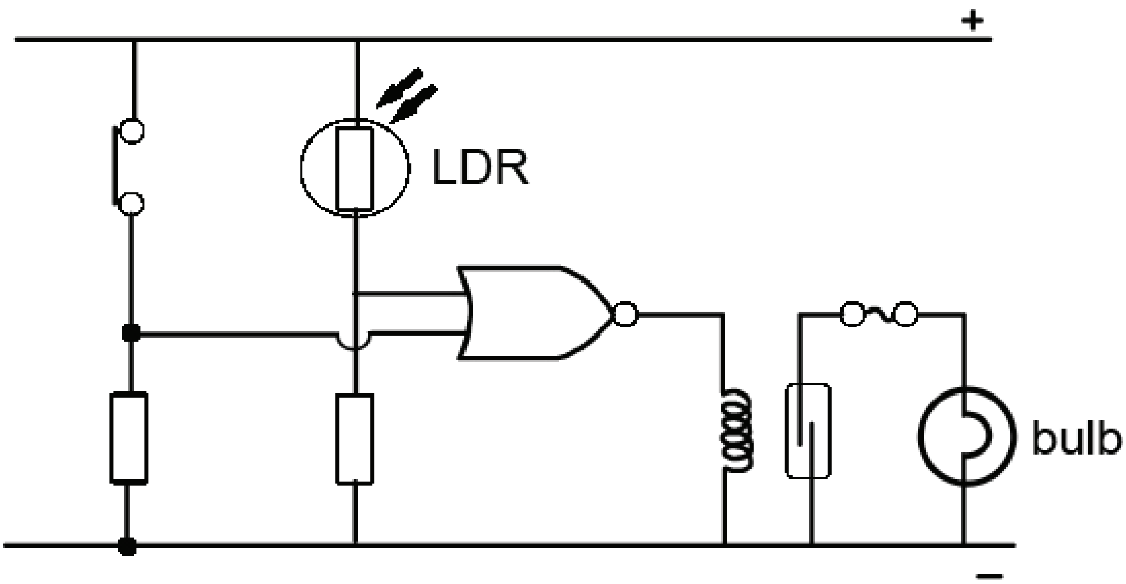


Figure 14: Using a NOR gate in an automatic lighting system

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	
Modelling	
• 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.	
	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

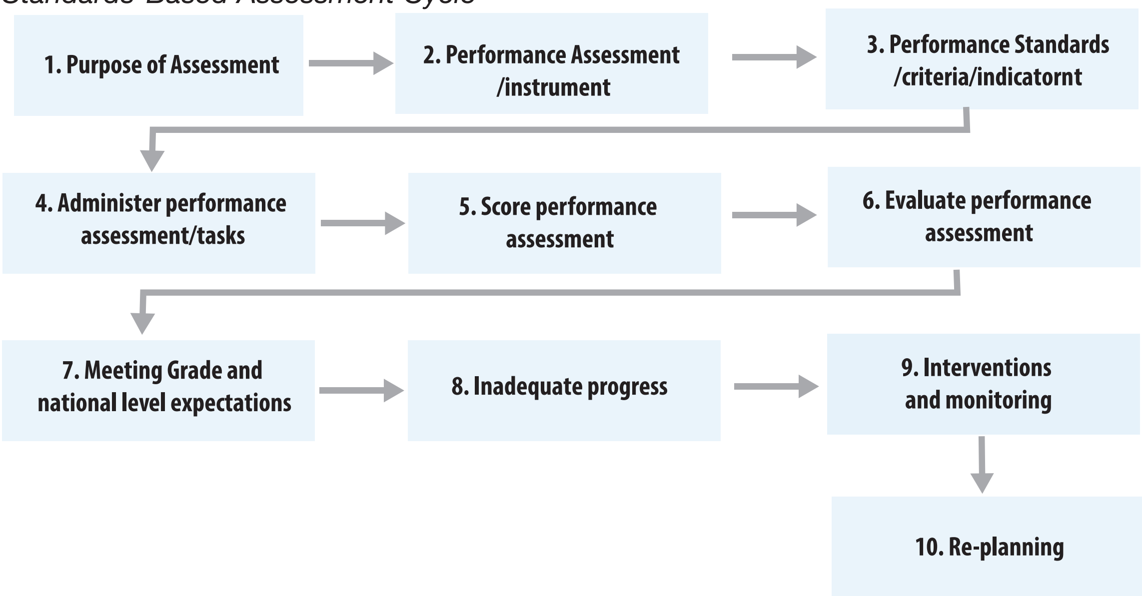
Students create a model of a measuring device that is essential in measuring and can be used in the derivation processes of units.

Assessment, Monitoring and Reporting

What is Standards-Based Assessment (SBA)?

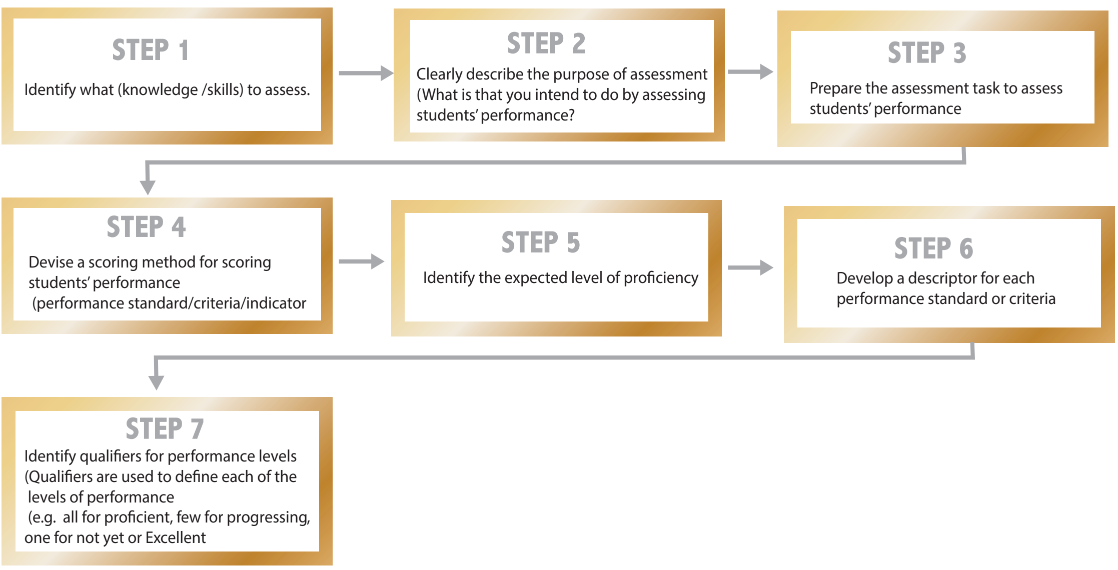
Assessment and reporting is an integral part of the delivery of any curriculum used in the schools. In Standard Based Curriculum (SBC) assessment encourages the use of benchmarks and commended types of assessment that promote standards for a range of purposes.

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 of practices that promote deeper understanding of learning processes by developing their capacity for self-assessment,
- for 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 relat-ed 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 assignment.

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	B	C	D	Score
	Advance 20	**Proficient 13-19**	**Progressing 6-12**	**Not Yet 2-5**	**__/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 $y = A\sin(Bx + C) + D$ or $y = A\cos(Bx + C) + D$ 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	Score
	(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

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;

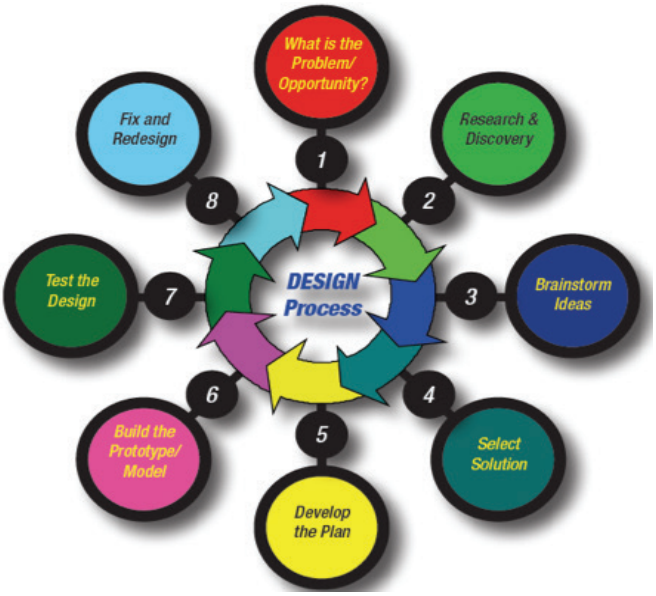
(i) Group the students into groups of 6 to design (drawing and manual) a tangible technology that will enhance the notion of "building a prototype model of a catapult launching system"

(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 under-standing and ap-plication 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 com-pleted 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

National Content Standard :				
Lesson Topic	**Topic**	**Benchmark**	**Performance Assessment**	
	Advanced	**Proficient**	**Partially Proficient**	**Novice**

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**	
	Advanced	**Proficient**	**Satisfactory**	**Poor**

STEAM Activity