

# Science

## Junior High

Grade 9

# Teacher Guide

Standards-Based



Papua New Guinea

Department of Education

**'FREE ISSUE  
NOT FOR SALE'**



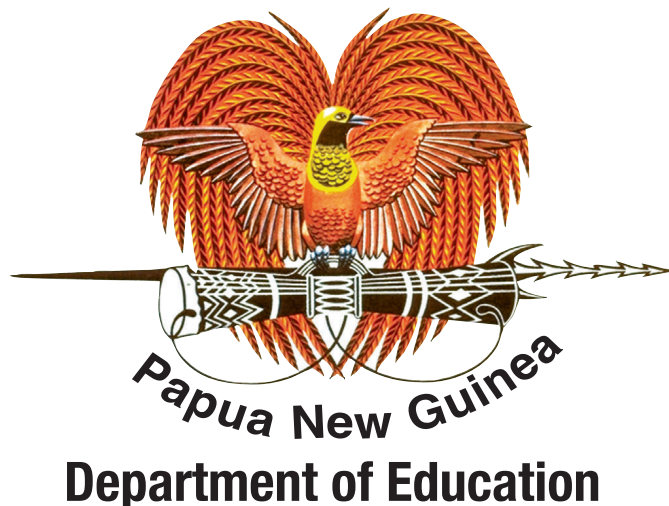
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**Issued free to schools by the Department of Education**

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*First Edition*

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Dr. Arnold Kukari, Technical Advisor - Curriculum, is acknowledged for his technical advice on the development of this teacher guide. Curriculum Panel (CP), Subject Advisory Committee (SAC), and Board of Studies (BoS) Committee members are also acknowledged for their consideration and endorsement of the Teacher Guide.

## Acronyms

AAL	Assessment AS Learning
AFL	Assessment FOR Learning
AOL	Assessment OF Learning
SSBoS	Secondary School Board of Studies
CDD	Curriculum Development Division
CP	Curriculum Panel
DA	Diagnostic Assessment
IHD	Integral Human Development
GoPNG	Government of PNG
OBC	Outcomes Based Curriculum
OBE	Outcomes Based Education
PNG	Papua New Guinea
SAC	Subject Advisory Committee
SBC	Standards Based Curriculum
SBE	Standards Based Education
SCG	Subject Curriculum Group
STEAM	Science, Technology, Engineering, Arts 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 21<sup>st</sup> Century knowledge, skills, values, and attitudes in their life after Grade 12.

Science education empowers students to be questioning, reflective and critical thinkers. It does this by giving students particular ways of looking at the world and by emphasising the importance of evidence in forming conclusions. Science education develops students' confidence to initiate and manage change to meet personal, vocational and societal needs. Science 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.

An appreciation of scientific knowledge, processes and values has the potential to help students build a more productive and ecologically-sustainable environment. It is important that students in secondary schools appreciate and understand how the study of science presents them with opportunities for responsible decision making in their local, national and global communities.

Learning about science enables students to explore the organisation and structure of the social, economic, political and technological world. They learn how science and technology are inter-related, and how their applications shape the way humans live.

They analyse the pressures and processes which determine the priorities for research and the direction and development of science and technology. They become aware that the promised benefits of research should improve the quality of life and be shared as widely as possible.

I encourage teachers to read each section of the guide carefully and become familiar with the content of the subject specified in the teaching and learning and other sections of the guide. I also encourage teachers to try out your own ideas and strategies that you believe will effectively work in your schools for your students.

I approve and commend this Grade 9 Science Teacher Guide to be used by teachers in all Junior High Schools throughout Papua New Guinea.



**UKE. W KOMBRA, (PhD)**  
Secretary for Education

## Introduction

This Grade 9 Science Teacher Guide is developed as a support document for the implementation of the Junior High Science Syllabus. It contains useful information that you should read and familiarize yourself with before you plan and teach the subject. The guidelines provided are translated from the content standards prescribed in the syllabus into teachable content.

The Teacher's Guide represents the present state of science expectations and is meant to be adjusted overtime. Its purpose is to support activities that advance standards based education practice and enhance classroom instruction. Such activities may include; formal study, dialogue and discussion, classroom observations, one-on-one professional development, coaching support, mentor-mentee collaborations, and other professional growth opportunities. Other suggested teaching and learning strategies provided in this guide will assist you to plan quality and interactive science lessons based on the knowledge, skills, attitudes and values from the benchmarks.

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 Science curriculum. Equal opportunities should be provided for all students to learn, apply and master STEAM principles and skills.

The teacher guide also contains samples of assessment tasks and rubrics that will help you to design quality assessments to measure students' performance against the intended content standards and evidence outcomes. The learning activities prepared must engage and motivate your students to think critically and communicate ideas freely with other students in their class.

Time allocation for Science is **240** minutes for grade 9.

## Structure of the Teacher Guide

There are four main parts 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, that is, morals and values education, cognitive and high level thinking, and 21<sup>st</sup> Century thinking skills, STEAM, and core curriculum 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. And 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 for 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 9 Science 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:

To this end, teachers are 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 Science syllabi and teacher guide to plan, teach and assess different Science units and topics, and the KSVAs described in the grade-level benchmarks;
- understand the Science national content standards, grade-level benchmarks, and evidence outcomes;
- effectively make sense of the content (KSVAs) described in the Science 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 Science skills, processes, concepts, ideas, principles, practices, values and attitudes;
- confidently interpret, translate and use Science 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 Science 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, 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 Physics 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;
- 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.

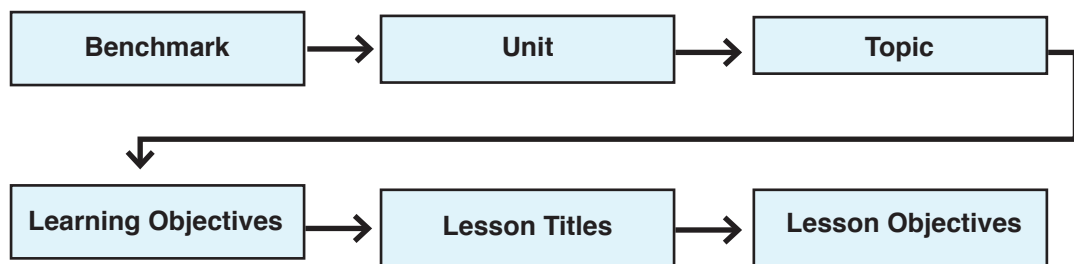
## How to use the Teacher Guide

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 9 and 10 Science Curriculum. Based on this understanding, teachers should be able to effectively use the teacher guide to do the following:

### Determine Learning Objectives and Lesson Topics

Topics and learning objectives have been identified and described in the Teacher Guide. Lesson objectives are derived from topics that are extracted from the grade-level benchmarks. Lesson topics 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 learning objectives and lesson topics. Teachers should use the examples provided in this teacher guide to formulate additional learning objectives and lesson topics to meet the educational or learning needs of their students.



### 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, 21<sup>st</sup> 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 21<sup>st</sup> Century Skills in Lesson Planning, Instruction and Assessment**

Teachers should integrate the cognitive, high level and 21<sup>st</sup> 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.**

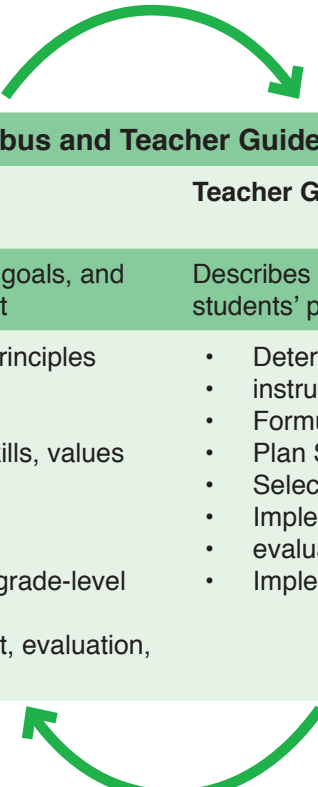
SBC does not mean that the content, lesson objectives, teaching and learning strategies, and assessment are standardised. This is a misconception and any attempt to standardise the components of curriculum without due consideration of the teaching and learning contexts, children's backgrounds and experiences, and different abilities and learning styles of children 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.

Grade 9 Science 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 Science knowledge, skills, values and attitudes.



Syllabus and Teacher Guide Alignment	
Syllabus	Teacher Guide
<p>Outlines the ultimate aim and goals, and what to teach and why teach it</p> <ul style="list-style-type: none"> <li>• Overarching and SBC principles</li> <li>• Content overview</li> <li>• Core curriculum</li> <li>• Essential knowledge, skills, values and attitudes</li> <li>• Strands and units</li> <li>• Evidence outcomes</li> <li>• Content standards and grade-level benchmarks</li> <li>• Overview of assessment, evaluation, and Reporting</li> </ul>	<p>Describes how to plan, teach, and assess students' performance</p> <ul style="list-style-type: none"> <li>• Determine topics for lesson planning, instruction and assessment</li> <li>• Formulate learning objectives</li> <li>• Plan SBC lesson plans</li> <li>• Select teaching and learning strategies</li> <li>• Implement SBC assessment and evaluation</li> <li>• Implement SBC reporting and monitoring</li> </ul>

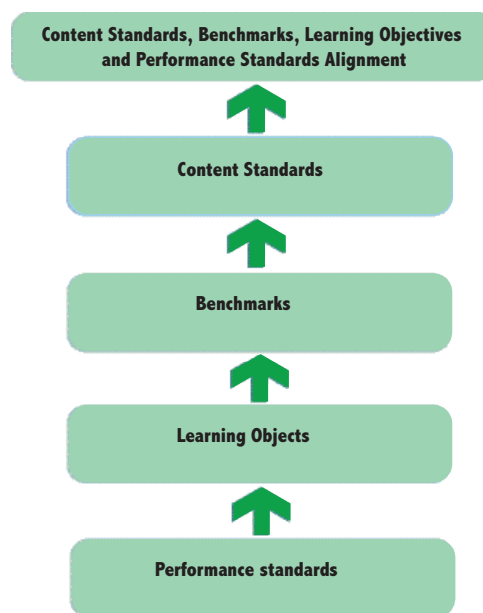
The syllabus outlines the ultimate aim and goals of SBE and SBC, what is to be taught and why it should be learned by students, the underlying principles and articulates the learning and proficiency standards that all students are expected to attain. On the other hand, the teacher guide expands on what 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 science 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 (see figure 3). 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 21<sup>st</sup> 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 SBE 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;
- 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.

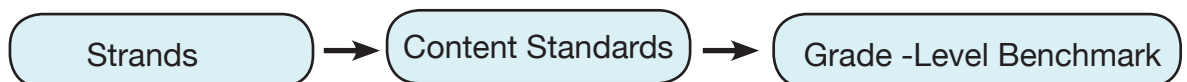
## Benchmarks

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 PNG students with students in other countries.

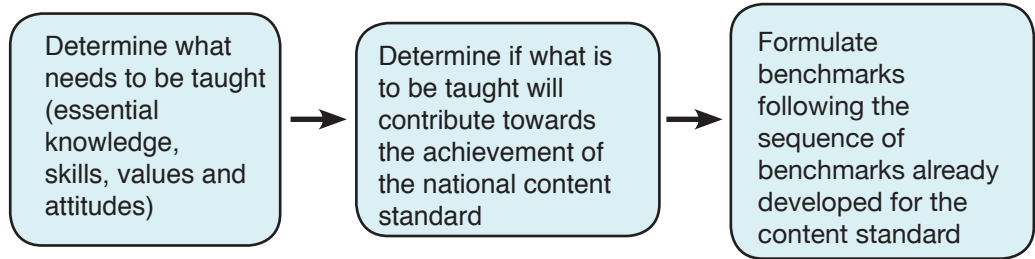
### Approach for Setting National Content Standards and Grade-Level Benchmarks



### *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 main towns of PNG using a map.

### 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
- 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);
- 21<sup>st</sup> Century skills (Refer to illustrative list in the Appendix);
- reading, writing and communication skills;
- STEAM principles and skills;
- essential values and attitudes (Core personal and social values, and sustaining values), and
- spiritual values and virtues

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

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

Core values and attitudes must not be taught in the classroom only; they must also be demonstrated by students in real life or related situations inside and outside of the classroom, at home, and in everyday life. Likewise, they must be promoted, fostered and modeled by the school community and its stakeholders, especially parents. A whole of school approach to values and attitudes teaching, promoting and modeling is critical to students and the whole school community internalising 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 extracurricular 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 21<sup>st</sup> Century skills and processes, and values and attitudes.

Science 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.  
build prototypes or models of solutions to problems.  
replicate a problem solution by building models and explaining how the problem was or could be solved.
- (v) test and reflect on the best solution chosen to solve a problem.  
collaborate with others on a problem and provide a report on the process of problem solving used to solve the problem.
- (vi) 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 21<sup>st</sup> 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 21<sup>st</sup> 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 21<sup>st</sup> 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 21<sup>st</sup> 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 21<sup>st</sup> 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.

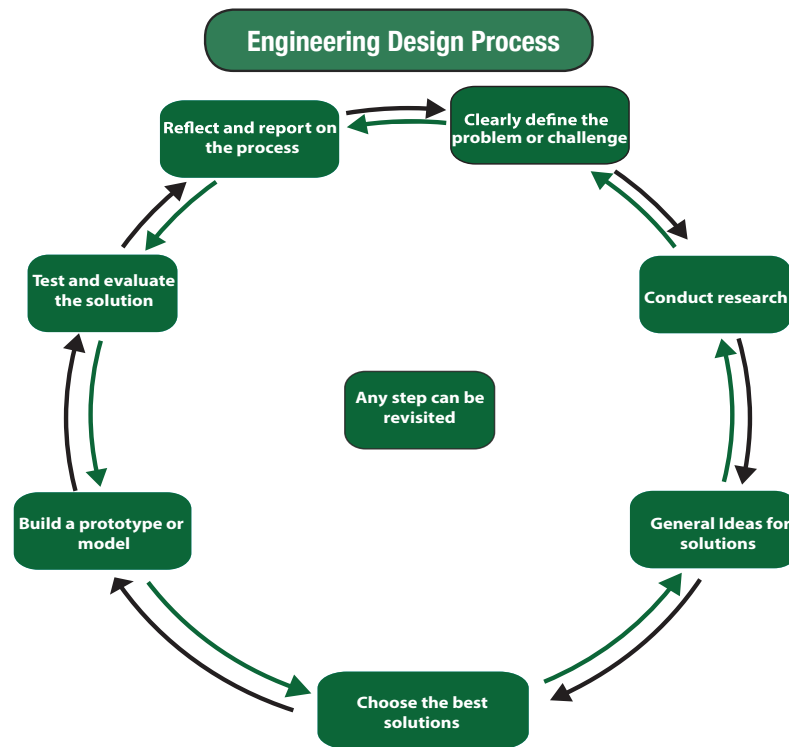
### ***Trial and Error***

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

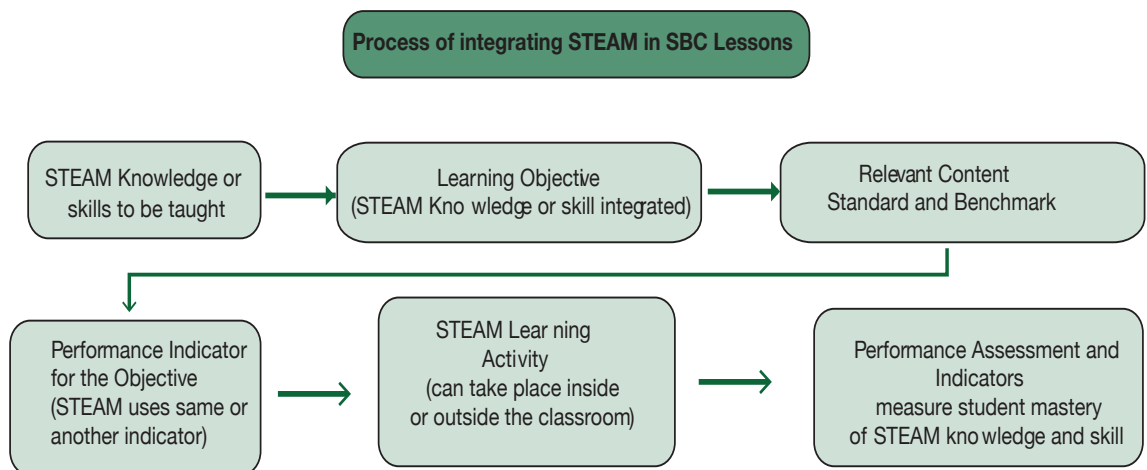
Effective STEAM lesson planning is key to the achievement of expected STEAM outcomes. STEAM skills can be planned and taught using separate STEAM-based lesson plans or integrated into the standards-based lesson plans. To effectively do this, teachers should know how to write effective standards and STEAM-based 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 Teachers are expected to integrate the essential STEAM principles, processes, skills, values and attitudes described in the grade 11 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.

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## 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 21<sup>st</sup> 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 21<sup>st</sup> 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.

# 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)

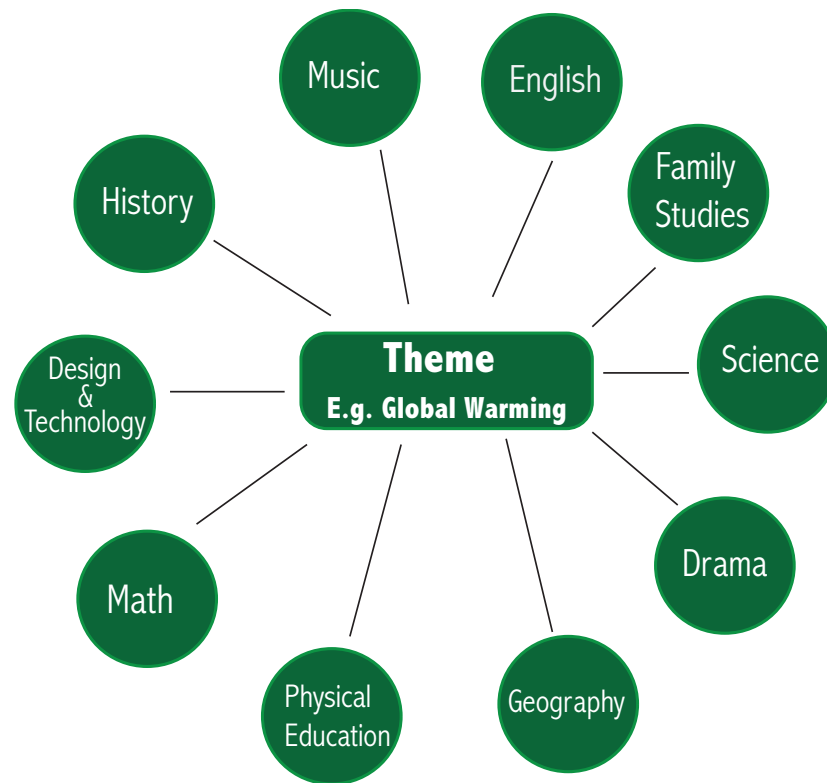
Teachers must develop intriguing curriculum by going beyond the traditional teaching of content based or fragmented teaching to one who is knowledge based and who should be perceived as a 21<sup>st</sup> Century innovative educator. Curriculum integration is a holistic approach to learning thus curriculum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

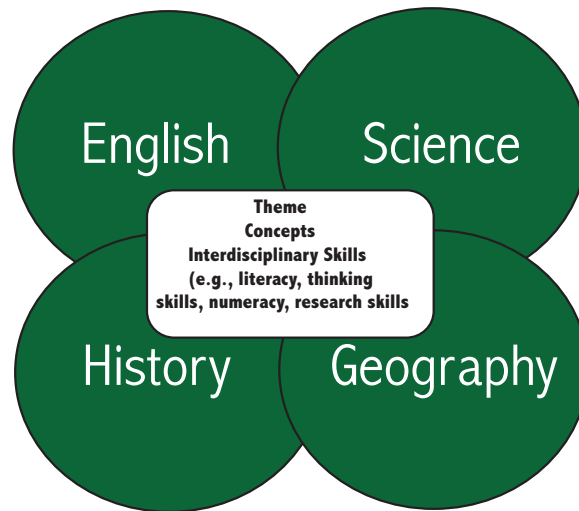
In this approach learning involves a theme or concept that will be taught right across all subject area of study by students. That is, content of a particular theme will be taught right across all subjects as shown in the diagram below. For instance, if the theme is global warming, subject areas create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



### (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. Interdisciplinary 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.

The three steps to planning project based curriculum (Chard 1998).

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 (Susan M. Drake and Rebecca C. Burns) 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 (Curtis, 2002)

### SUBJECT AREAS

Theme

Concepts

Life Skills

Real world Context -  
(Voluntary services/Part time  
job experience, exchange programs)

Students Questions

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;	
<ul style="list-style-type: none"> <li>• Public and private (privileged) knowledge</li> <li>• Specialised knowledge</li> <li>• Good and bad knowledge</li> <li>• Concepts, processes, ideas, skills, values, attitudes</li> <li>• Theory and practice</li> <li>• Fiction and non-fiction</li> <li>• Traditional, modern, and postmodern knowledge</li> </ul>	<ul style="list-style-type: none"> <li>• Subject and discipline-based knowledge</li> <li>• Lived experiences</li> <li>• Evidence and assumptions</li> <li>• Ethics and Morales</li> <li>• Belief systems</li> <li>• Facts and opinions</li> <li>• Wisdom</li> <li>• Research evidence and findings</li> <li>• Solutions to problems</li> </ul>

### Types of Processes

There are different types of processes. These include;	
<ul style="list-style-type: none"> <li>• Problem-solving</li> <li>• Logical reasoning</li> <li>• Decision-making</li> <li>• Reflection</li> </ul>	<ul style="list-style-type: none"> <li>• Cyclic processes</li> <li>• Mapping (e.g. concept mapping)</li> <li>• Modelling</li> <li>• Simulating</li> </ul>
<p><b>Science Inquiry processes include:</b></p> <ul style="list-style-type: none"> <li>• Gathering information</li> <li>• Analysing information</li> <li>• Evaluating information</li> <li>• Making judgements</li> <li>• Taking actions</li> </ul>	

## 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;**

- |   |   |
|---|---|
| <ul style="list-style-type: none"> <li>• Attributing</li> <li>• Comparing and contrasting</li> <li>• Grouping and classifying</li> <li>• Sequencing</li> <li>• Prioritising</li> <li>• Analysing</li> </ul> | <ul style="list-style-type: none"> <li>• Detecting bias</li> <li>• Evaluating</li> <li>• Metacognition (Thinking about thinking)</li> <li>• Making informed conclusions.</li> </ul> |
|---|---|

#### 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;**

- |   |  |
|---|--|
| <ul style="list-style-type: none"> <li>• Generating ideas</li> <li>• Deconstruction and reconstruction</li> <li>• Relating</li> <li>• Making inferences</li> <li>• Predicting</li> <li>• Making generalisations</li> <li>• Visualizing</li> </ul> | <ul style="list-style-type: none"> <li>• Synthesising</li> <li>• Making hypothesis</li> <li>• Making analogies</li> <li>• Invention</li> <li>• Transformation</li> <li>• Modeling</li> <li>• Simulating</li> </ul> |
|---|--|

**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

<ul style="list-style-type: none"> <li>• Listens, read, write, and speak with comprehension and clarity</li> <li>• Define and apply discipline-based conceptual vocabulary</li> <li>• Describe people, places, and events, and the connections between and among them</li> <li>• Arrange events in chronological sequence</li> <li>• Differentiate fact from opinion</li> <li>• Determine an author's purpose</li> <li>• Determine and analyse similarities and differences</li> <li>• Analyze cause and effect relationships</li> <li>• Explore complex patterns, interactions and relationships</li> <li>• Differentiate between and among various options</li> </ul>	<ul style="list-style-type: none"> <li>• Listens, read, write, and speak with comprehension and clarity</li> <li>• Define and apply discipline-based conceptual vocabulary</li> <li>• Describe people, places, and events, and the connections between and among them</li> <li>• Arrange events in chronological sequence</li> <li>• Differentiate fact from opinion</li> <li>• Determine an author's purpose</li> <li>• Determine and analyse similarities and differences</li> <li>• Analyze cause and effect relationships</li> <li>• Develop an ability to use and apply abstract principals</li> <li>• Explore and/or observe, identify, and analyse how individuals and/or societies relate to one another</li> </ul>
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**6. High Level Thinking Skills** - These skills include analysis, synthesis, and evaluation skills.

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

### Key Words

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

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

**iii. 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
<ul style="list-style-type: none"> <li>• Sanctity of life</li> <li>• Truth</li> <li>• Aesthetics</li> <li>• Honesty</li> <li>• Human</li> <li>• Dignity</li> <li>• Rationality</li> <li>• Creativity</li> <li>• Courage</li> <li>• Liberty</li> <li>• Affectivity</li> <li>• Individuality</li> </ul>	<ul style="list-style-type: none"> <li>• Self-esteem</li> <li>• Self-reflection</li> <li>• Self-discipline</li> <li>• Self-cultivation</li> <li>• Principal morality</li> <li>• Self-determination</li> <li>• Openness</li> <li>• Independence</li> <li>• Simplicity</li> <li>• Integrity</li> <li>• Enterprise</li> <li>• Sensitivity</li> <li>• Modesty</li> <li>• Perseverance</li> </ul>

### 2. Social Values

Core Values	Sustaining Values
<ul style="list-style-type: none"> <li>• Equality</li> <li>• Kindness</li> <li>• Benevolence</li> <li>• Love</li> <li>• Freedom</li> <li>• Common good</li> <li>• Mutuality</li> <li>• Justice</li> <li>• Trust</li> <li>• Interdependence</li> <li>• Sustainability</li> <li>• Betterment of human kind</li> <li>• Empowerment</li> </ul>	<ul style="list-style-type: none"> <li>• Plurality</li> <li>• Due process of law</li> <li>• Democracy</li> <li>• Freedom and liberty</li> <li>• Common will</li> <li>• Patriotism</li> <li>• Tolerance</li> <li>• Gender equity and social inclusion</li> <li>• Equal opportunities</li> <li>• Culture and civilisation</li> <li>• Heritage</li> <li>• Human rights and responsibilities</li> <li>• Rationality</li> <li>• Sense of belonging</li> <li>• Solidarity</li> <li>• Peace and harmony</li> <li>• Safe and peaceful communities</li> </ul>

## Types of Attitudes

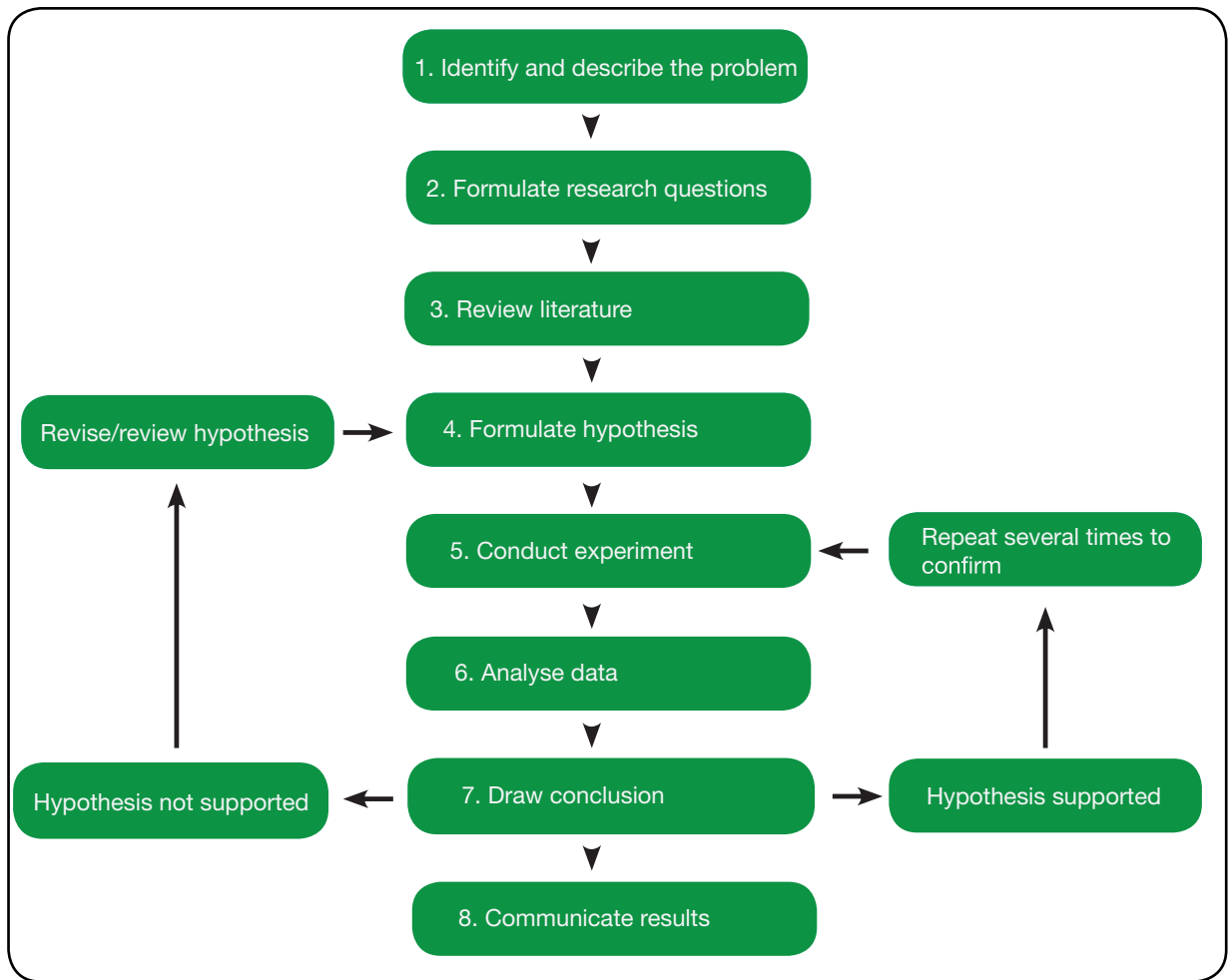
Attitudes - Ways of thinking and behaving, points of view	
<ul style="list-style-type: none"> <li>• Optimistic</li> <li>• Participatory</li> <li>• Critical</li> <li>• Creative</li> <li>• Appreciative</li> <li>• Empathetic</li> <li>• Caring and concern</li> <li>• Positive</li> <li>• Confident</li> <li>• Cooperative</li> </ul>	<ul style="list-style-type: none"> <li>• Responsible</li> <li>• Adaptable to change</li> <li>• Open-minded</li> <li>• Diligent</li> <li>• With a desire to learn</li> <li>• With respect for self, life, equality and excellence, evidence, fair play, rule of law, different ways of life, beliefs and opinions, and the environment.</li> </ul>

## 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 21<sup>st</sup> 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
<b>CASE STUDY</b> 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.
<b>DEBATE</b> 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.

## Strands, Units and Topics

The strand, units and topics are connected and aligned. The topics for each unit were derived from the grade level benchmarks. Unlike the units, the topics differ in grade levels. There are several topics for each unit depending on the content.

### Content overview

The teaching and learning of Science is organised under these four strands

- Science as Inquiry
- Life Science
- Physical Science
- Earth and Space Science.

Through achieving these strands, students' conceptual understandings of the biological, physical and earth and space world will be enhanced. The teaching and learning in these strands should be developed in conjunction with the Science as Inquiry strand. The emphasis placed on particular concepts may vary according to students' needs and location, including the physical, biological, technological and space nature of the environments in which they live.

### Grade 9

STRAND 1: SCIENCE AS INQUIRY		
Unit	Topic	Lesson Titles
Unit 9.1 Scientific Tools and Technology	Science Journal	What is a science journal?
		How to use a science journal
	Balances, Scales and Pulleys	Parts and functions of a balance
		Parts and functions of a scale
		Parts and functions of a pulley
	Microscope	Microscope components and functions
How to calculate magnifications of a microscope		
Scientific Research Skills	How to carry out a scientific research	
Unit 9.2 Measurement and Accuracy	International System of Units (SI)	What is SI Unit?
		Comparing SI Units and other conventional units
		Importance of SI unit in science
	Telling Locations	Why is time and location important in science?
		How to tell time and locations in relation to natural phenomena
		How to draw, read and interpret topographic maps
	Controls and Variables	Application of topographic maps
		What are controls and variables?
		Importance of Experimental Controls
		Methods of using controls and variables in science experiments
	Using Mathematical Functions in Science	Application of Quadratic Equations
		Application of Trigonometric Equations
	Importance of Hypothesis and or Misconceptions in Science Classes	Importance of Misconceptions in science classes
		What is a hypothesis?
		What is a misconception?
Comparing hypothesis and misconception and their applications		

**STRAND 2 : LIFE SCIENCE**

Unit 9.3 Classifying Organisms	Kingdoms of Living Things	How many kingdoms are there?	
		Knowing about dichotomous key	
		Classifying organisms	
		Investigating bacteria	
		Investigating protists	
		Investigating fungi	
	Classification of Plants	Vascular and non-vascular plants	
		Unicellular organisms	
		Multicellular organisms	
		Comparing unicellular and multicellular organisms	
		Plants nervous system	
	Classification of Animals	Classification of animals	
		Investigating animals	
	Unit 9.4 Cell Structure and Function	Plant Cell and Animal Cell Structures	Characteristics and functions of Plant cells
			Characteristics and functions of Animal cells
Comparing Plant and Animal Cells			
Cell Division in Plants and Animals		Phases of cell division	
		Cell division - meiosis	
		Cell division - mitosis	
		Dependency of multicellular organisms in internal systems	
Cell Transportation in Plants and Animals (Diffusion & Osmosis)		Diffusion	
		Osmosis	
		Similarities and differences between diffusion and osmosis	
		Concentration and movement of particles in diffusion and osmosis	
Photosynthesis and Respiration		Photosynthesis	
		Respiration	
		Chemical reactions in photosynthesis and respiration	
Tissues and Organs in Plants and Animals		What are Organs?	
		Types of organs in plants	
		Types of organs in animals	
		Care and safety of organs in animals	
Unit 9.5 Interactions and Relationships in the Environment		Food Chains and Food Webs	Biotic and abiotic factors
			How energy is recycled in plants and animals
			Comparing food chain and food web
	What are decomposers?		
	Effects of insecticides on food web-biomagnification		
	Plant and Animal Adaptations	Environmental factors that impact adaptation	
		Human causes that impact adaptation	
		What is equilibrium shift?	
		Genetic mutation	
	Species, Population and Habitats	Ecosystem – what is it?	
		Knowing the organisation of organisms in an ecosystem	
		Types of habitats	
		Types of populations	
		Types of species	
		Relationships between organisms in the environment	
		Factors that affect populations in an environment	

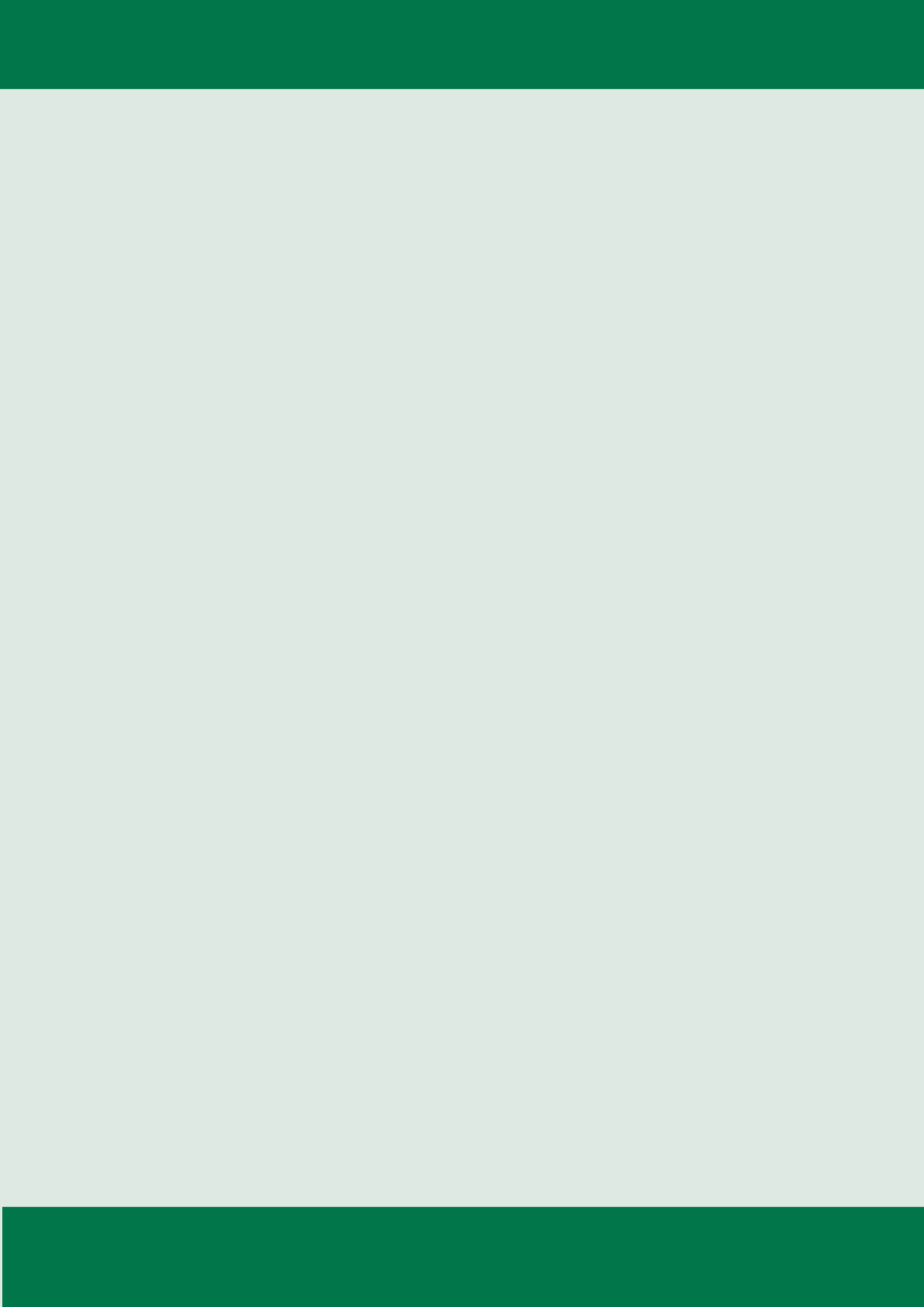
## STRAND 3: PHYSICAL SCIENCE

Unit 9.6 Matter and Energy	<b>Physical and Chemical Properties of Matter</b>	Physical properties of matter
		Heterogenous mixtures
		Homogenous mixtures
		Chemical properties of matter
		Binary compounds and properties
		Poly-elemental compounds and properties
		Physical reactions
		Chemical reactions
	<b>Acids, Bases, and their Applications</b>	Types of acids and bases
		Differences between acids and bases
		The pH scale
		Acidic solutions and substances
		Basic/alkaline solutions and substances
		Acid-base reactions and chemical formulas
		Applications of acids and bases in our life
	<b>Forms and Transformation of Energy</b>	Forms of energy
		Force and energy
		Transformation of energy – energy chain
		Conservation of energy
		Measuring energy -Efficiency
		Wasted energy
	<b>Energy and Work</b>	What is work?
		What is force?
		Work, force and distance
		Calculating work
	<b>Atoms, Elements and Compounds</b>	Discoveries of atoms, elements and compounds
		Relationships between atoms, elements and compounds
Existence of elements in nature		
What is an isotope?		
Knowing the masses of elements		
Make models of atoms, elements and compounds		
<b>The Periodic Table</b>	What is the periodic table?	
	How were elements' symbols created and represented?	
	The first 20 elements	
	Characteristics of the first 20 elements	
	Periods and groups of the periodic table	
Unit 9.7 Force and Motion	<b>Common Forces and their Characteristics</b>	Einstein and force
		Types of common forces
		Characteristics of common forces
		Force as vector
		Combining forces
	<b>Forces and Effects</b>	Friction
		Force, gravity and weight
		Projectile and orbital Motions
		Force and direction
		Net force
		Measuring force

	<b>Newton's First and Second Laws of Motion</b>	Isaac Newton and the laws of motion	
		Newton's first law of motion	
		Newton's second law of motion	
		Constant speed	
		Equilibrium	
		Balance and unbalanced forces	
		Overcoming inertia	
	<b>The Buoyant Force</b>	Nature of floating and sinking	
		What is buoyant force?	
		Causes and effects of buoyant force	
		investigating Archimede's principle	
	<b>Unit 9.8 Waves, Electricity and Magnetism</b>	<b>Nature and Properties of Waves</b>	What is wave?
			Properties of waves
			What are surface waves?
Electromagnetic wave			
Investigating mechanical waves			
Investigating transverse waves			
Investigating longitudinal waves			
Compressions and rarefactions			
<b>Interaction of Waves with Matter</b>		Wave interaction	
		Investigating reflection	
		Investigating Refraction	
		Investigating diffraction	
		Wave to wave interactions	
<b>Properties of Sound</b>		What is sound?	
		Types and characteristics of sound	
		Relationships between wave and sound	
		Investigating frequency, velocity and time	
<b>Light as Energy</b>		Nature of light	
		Light and life processes	
		Comparing light and sound-speed	
		The visible spectrum	
		Electromagnetic radiation	
		How are objects seen?- the eye	
		Universe and speed of light-light year	
<b>Electric Charges and Forces</b>		What is power?	
		Structure of an electron	
		Electric current	
		Electric charge	
		Electrical circuits	
		Resistance	
		Static electricity	
		Current and voltage	
	Measuring electricity		
	How to calculate house-hold use of electricity		

	<b>Magnets and Magnetic Field</b>	Exploring Earth's magnetic field Properties of an electromagnet How does an electromagnet work? Investigating electromagnetic fields Applications of magnets and electromagnets in life
<b>STRAND 4: EARTH AND SPACE</b>		
<b>Unit 9.9 Our Earth</b>	<b>The Earth's Structure</b>	Formation of the Earth
		Position of the Earth in Space
		Shape and size of the Earth
		Why is Earth not one solid mass?
		What materials make up the Earth?
		Making models of the Earth
	<b>The Earth's Atmosphere</b>	What is atmosphere?
		Layers of the atmosphere
		Chemical structure of the atmosphere
		What does atmosphere do?
		Human impact on the atmosphere
	<b>Waters, Seas/Oceans and Currents</b>	Oceans of the Earth
		Ground water and composition
		Sea water and composition
		Major currents of the Earth
		Movement of Currents of the Earth
		Difference between current and wave
		Causes and effects of ocean currents
	<b>Weathering and Erosion</b>	What is weathering?
		Mechanical/physical weathering
Chemical weathering		
What is erosion?		
Causes and effects of weathering		
Making models of weathering and erosion process		
<b>Evidence of Our Past</b>	What is a fossil?	
	Where fossils are found	
	Types of fossils	
	Fossilisation process	
	Types of fossilisation process	
	What do fossils tell us?	
<b>Unit 9.10 Weather and Climate</b>	<b>Local/PNG Weather Systems</b>	What is weather?
		What is climate?
		Difference between weather and climate
		Types of weather and places in PNG
		PNG weather system
		How to study and monitor weather
		Making equipment to study weather
		<b>Climates and Seasons</b>
	Difference between season and climate	
	Does climate affect weather?	

		Factors affecting climate
		Seasons on Earth
		Causes of seasons on Earth
		Effects of seasons on Earth
		Solstices and Equinoxes
		Why do we experience shortest day and longest night?
Unit 9.11 Space Science	<b>Earth, Moon and Sun</b>	Formation and composition of the moon
		Formation and composition of the sun
		Size, distance and gravity of sun, Earth and moon
		Orbit and rotation of Earth, moon and sun
		A journey to the moon
	<b>The Eclipses</b>	What is an eclipse?
		Types of eclipses
		Causes and effects of eclipses
		How do I see eclipses?
	<b>The Sun and the Planets</b>	What is the sun?
		The sun and the universe
		The sun and the planets
		Effects of the sun on Earth and other planets
		Making models of the solar system



# **Grade 9 Science**

## Teaching Content

# STRAND 1: SCIENCE AS INQUIRY

## Unit 9.1: Scientific Tools and Technology

Modern science and technology are interwoven into a complex that is sometimes called ‘techno-science’: the progress of science is dependent on the sophistication of instrumentation, whereas the progress of ‘high-tech’ instruments and apparatus is dependent on scientific research. Yet, how scientific research contributes to the development of instruments and apparatus for technological use, has not been systematically addressed in the philosophy of technology, nor in the philosophy of science. Philosophers of technology have taken an interest in the specific character of technological knowledge as distinct from scientific knowledge, thereby ignoring the contribution of scientific knowledge to technological developments. Philosophers of science such as the so-called New-Experimentalists, on the other hand, recently has become interested in the role of instrumentation, but merely focus on their role in testing scientific theories. By reviewing the two distinct developments and taking them a step further, an alternative explanation of the interwovenness of science and technology in scientific research is proposed. Additional to testing theories, instruments in scientific practice have an important role in producing reproducible phenomena, and these phenomena may have technological applications. Subsequently, technological development of these applications requires theoretical understanding of the phenomenon and of materials and physical conditions that produce it, is not for the sake of theories about the world, but for the sake of understanding a phenomenon and how it is technologically produced.

Every year, corporations and governments spend millions of dollars on research and design of new materials and technologies. Technology is the practical use of scientific knowledge, especially for industrial or commercial use. For example, scientists hypothesise and predict how new materials will make bicycles and cycling gear lighter, more durable, and more aerodynamic. Using wind tunnels, scientists test these new materials to see whether they improve the cyclist’s performance. If the cyclist’s performance improves, their hypothesis are supported. If their performance does not improve or it doesn’t improve enough, scientists will revise their hypothesis and conduct more tests.

## Topic 1: Science Journal

<b>Content standard 9.1.1</b>	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.
<b>Benchmark</b>	9.1.1.2 Formulate explanations by using logical thinking and evidence.
<b>Key question(s)</b>	How do you organise your findings and data observed when you carrying out your science investigations?
<b>Learning objectives</b>	By the end of the topic, students can: Organise their findings and data scientifically
<b>Vocabulary</b>	Learning logs, Journal,
<b>Knowledge</b>	How to organise findings and data
<b>Skills</b>	Apply the correct way of presenting data and findings
<b>Attitudes and values</b>	Appreciate the way data and findings are presented scientifically
<b>Teaching and Learning</b>	Sharing ideas about how to write a good science journal
<b>Assessment</b>	Students use the science journal process to write a journal for a selected science investigation.

### Content Background

#### What is the science journal?

A scientific journal is a periodical publication intended to further the progress of science, usually by recording and scientific investigations and reporting new research. There are thousands of scientific journals in publication, and many more have been published at various points in the past. Most journals are highly specialized, although some of the oldest journals such as Nature publish articles and scientific papers across a wide range of scientific fields.

Scientific journals contain articles that have been peer reviewed, in an attempt to ensure that articles meet the journal's standards of quality, and scientific validity. Although scientific journals are superficially similar to professional magazines, they are actually quite different. Issues of a scientific journal are rarely read casually, as one would read a magazine. The publication of the results of research is an essential part of the scientific method. If they are describing experiments or calculations, they must supply enough details that a teacher or an independent researcher could repeat the experiment or calculation to verify the results. Each such journal article becomes part of students' scientific record of all projects and investigations undertaken by every student.

#### Who writes scientific journals?

Content. Articles in scientific journals are mostly written by active scientists such as students, researchers and professors instead of professional journalists.

### How do I start writing a journal?

1. Find the right space to write. ...
2. Close your eyes and reflect on your day. ...
3. Ask yourself questions. ...
4. Dive in and start writing. ...
5. Time yourself. ...
6. Re-read your entry and add additional thoughts

Some examples of scientific journals are given in the table below.

<ul style="list-style-type: none"> <li>• Journal Science</li> <li>• Science</li> <li>• Nature</li> <li>• Science Advances</li> <li>• Science Translational Medicine</li> <li>• Engineering</li> <li>• Science Signaling</li> <li>• Energy and Environmental Science</li> <li>• Science</li> <li>• Cell</li> <li>• Biomaterials Science</li> <li>• Journal of Information Science</li> <li>• Clinical Science</li> </ul>	<ul style="list-style-type: none"> <li>• Science reports</li> <li>• Journal of Food Science and Technology</li> <li>• International Journal of Environmental Research and Public Health</li> <li>• Journal Biochemistry</li> <li>• Environmental Research</li> <li>• Science Education</li> <li>• Nature Immunology</li> <li>• Journal of Ecology</li> <li>• Journal of Biological Chemistry</li> <li>• Journal of Food Engineering</li> </ul>	<ul style="list-style-type: none"> <li>• Journal of Chemical Sciences</li> <li>• Journal of Nutrition</li> <li>• Scientific Data</li> <li>• Journal of Animal Science</li> <li>• Journal of High Energy Physics</li> <li>• Journal of Immunology</li> <li>• Journal of Public Health</li> <li>• New Scientist</li> <li>• Nature Medicine</li> <li>• Journal of Food Science</li> <li>• Nature Communications</li> <li>• Materials</li> <li>• Journal of Genetics and Genomics</li> </ul>
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### A sample of a science journal

	Name _____ Project Title. _____
<b>Dates</b>	
04/07/2020	

## Topic 2: Balances, Scales and Pulleys

<b>Content standard 9.1.1</b>	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.
<b>Benchmark</b>	<b>9.1.1.1</b> Select and use appropriate tools and technology to perform tests, collect data, analyse relationships, and display data.
<b>Key question</b>	Why is it important for me to know and understand the parts and functions and how to use the scientific tools and equipment before I use them?
<b>Learning objectives</b>	By the end of the topic, the students are able to: <ul style="list-style-type: none"> <li>• Know and understand the parts and functions of the tools and equipment used in scientific investigations</li> <li>• Use the tools and equipment correctly in scientific investigations</li> </ul>
<b>Vocabulary</b>	<ul style="list-style-type: none"> <li>• Balance, Scale, Pulley</li> </ul>
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• Parts and functions of balance</li> <li>• Parts and functions of scientific scale</li> <li>• Parts and functions of a pulley</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>• Identify the parts and functions of a balance, scale and pulley correctly</li> <li>• Use the balance, scale and pulley correctly in scientific investigations</li> </ul>
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>• Beware of the safety precautions when using scientific tools and equipment</li> </ul>
<b>Teaching and Learning</b>	<ul style="list-style-type: none"> <li>• Group demonstrations</li> </ul>
<b>Assessment</b>	1. Demonstrate how to use one of the tools and equipment correctly such as a balance

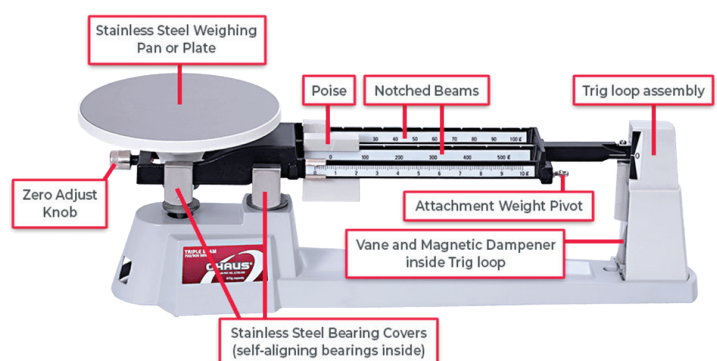
### Content Background

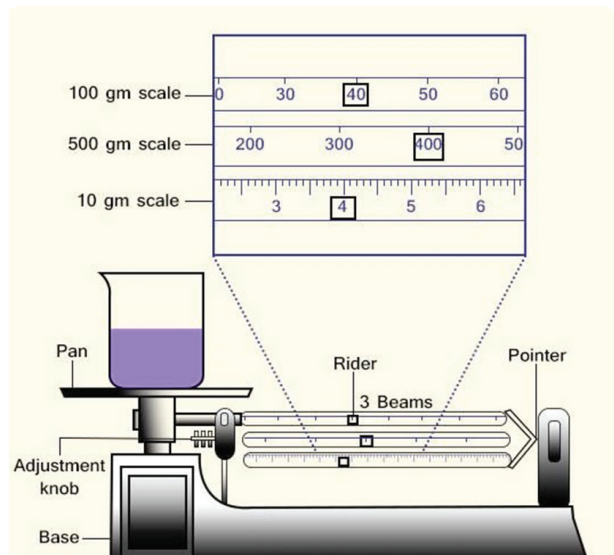
This study examines the understanding and effective use of technology, pedagogy, and content knowledge for high school science teachers focusing on technology integration into grades 9-10 classrooms to support science as inquiry teaching. To better prepare students for the science and technology of the 21<sup>st</sup> Century, the current science education reforms ask science teachers to integrate technology and inquiry-based teaching into their instruction.

Teachers are encouraged to apply “a variety of technologies, such as hand tools, measuring instruments, and calculators as an integral component of scientific investigation to support student inquiry. Utilizing technology tools in inquiry-based science classrooms allows students to work as scientists.

### Balance

A balance is used to measure the mass of an object. Units often used for mass are grams (g), kilograms (kg), and milligrams (mg). Two common types of balances used in science investigations are the electronic balance and the triple-beam balance. In order to get the most accurate measurements when using a balance, it is important to calibrate the balance often.



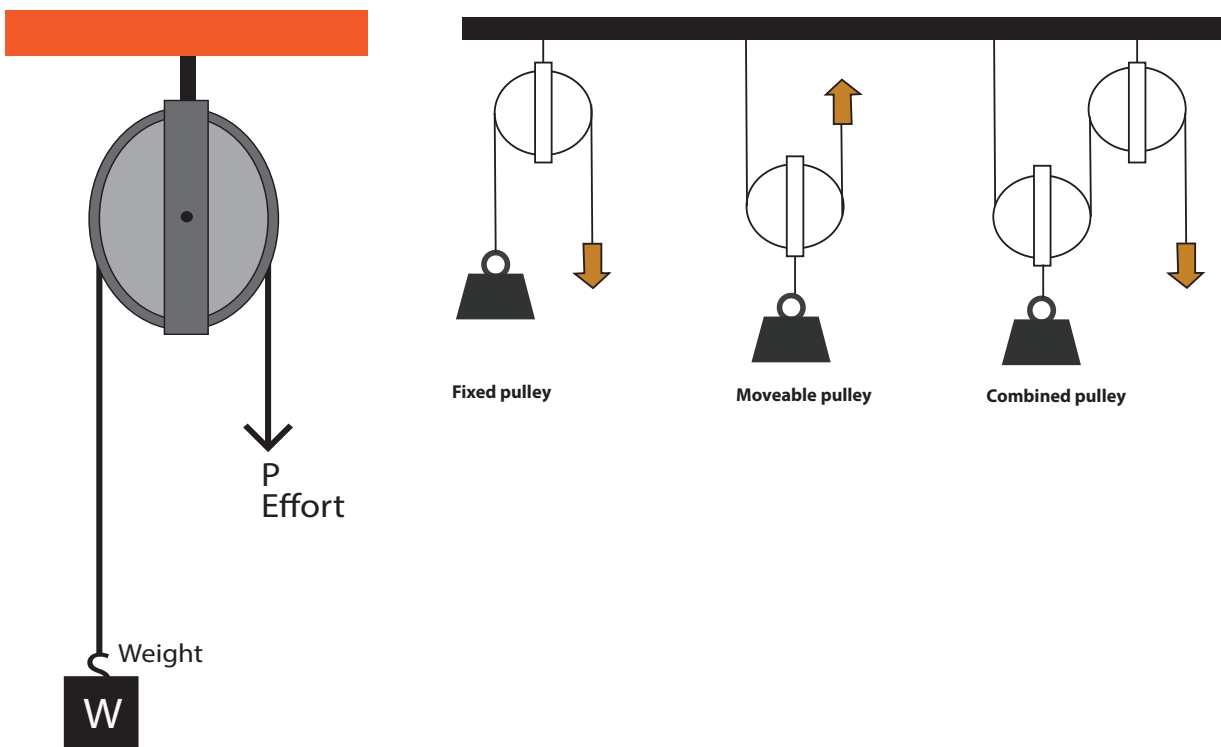


## Pulleys

Pulleys consist of a wheel that rotates on an axle—which is a rod through the center of the wheel—and a rope, cable, or chain. There are three main types of pulleys: fixed, movable, and compound. A fixed pulley’s wheel and axle stay in one place.

From ancient times man has always been keen in devising machines of different kinds for one basic reason: relieving humans from tasks that are tedious and involve massive efforts. Pulley mechanisms are one of these machines that have been serving mankind since the day they were invented.

A pulley mechanism consists of a wheel and string assembly and is designed for lifting heavier loads through a comparatively lower magnitude of effort. The mechanism can be better understood by studying the behavior of a “simple pulley.”



**Simple Pulley:**

A simple pulley basically consists of two components, the wheel and the string; the wheel may be made up of wood or metal and includes a groove cut along its circumferential periphery. The string is allowed to slide or pass through this groove with a load that is to be lifted fixed at one of its ends and an effort applied at the other end in order to lift the load. The pulley wheel is supported over a rigid frame about its central axis.

The applied effort through pulling of the string rotates the pulley and pulls the load upwards, helping the load to be lifted with ease.

A classic example of this mechanism can be witnessed over wells where the pulley and rope are used for lifting water-filled buckets.

Some important observations made by assessing this mechanism which may prove useful while calculating them are described below:

- The weight of the pulley block can be ignored as its too small compared to the load that's required to be lifted or rather moving heavier weights become more desirable for efficient response from these devices.
- The friction developed on either side of the pulley across the string contact can also be ignored, again due to its negligible occurrence.
- Calculations prove that the Mechanical Advantage (MA) and Velocity Ratio (VR) of this mechanism is unity under the discussed operational conditions.

In order to improve MA, VR, and efficiency, the above pulley mechanism is dimensioned through some intelligent combinations of extra pulleys and strings. These specialized pulley mechanisms are classified as follows, so let's study them one by one.

## How to Calculate First, Second and Third Pulley Systems

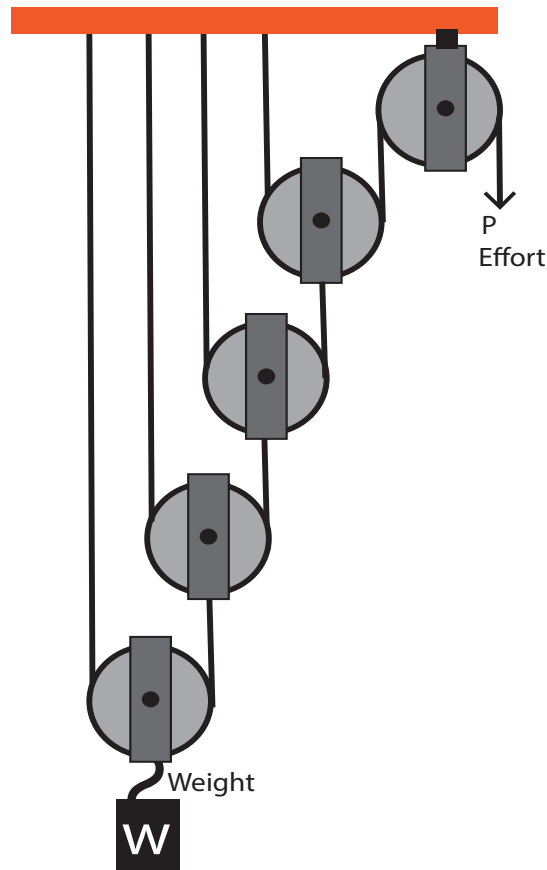
What are the 3 types of pulleys?

### First System of Pulleys

As can be seen from the diagram, the lowermost pulley here carries the load (being lifted), which is fixed and hangs over the axle of the pulley.

An end of the string T1 attached firmly to an upper rigid frame, passes across the groove of this pulley and attaches its other to the axle of the second.

The same string configuration is repeated for all the pulleys until the first pulley where the preceding pulley's string end instead of attaching to the axle of the topmost pulley, slides down across its groove and ends towards the other side where the effort can be finally applied.



The applied effort lifts the weight and also the entire pulley system under the topmost pulley. Now, suppose if the applied effort raises the weight  $W$  and the pulley  $P_1$  by  $x$  meters, in order to maintain tightness of the string attached to its axle and balance the movement, pulley  $P_2$  has to move through a distance of  $2x$  meters.

The same theory applies to the pulley  $P_3$  which now must show a relative displacement of  $2 \times (2x) = 2^2x$ , also the pulley  $P_4$  must compensate the act with an upward lift of  $2 \times 2^2x = 2^3x$  and finally for the pulley  $P_4$  which is fixed with the upper frame, the string takes over the sequence to produce a displacement equal to  $2 \times 2^3x = 2^4x$ .

Therefore Velocity Ratio = Distance covered by effort/Distance covered by load =  $2^4x/x = 2^4$

Therefore if the above pulley system carries  $n$  number of pulleys then  $VR = 2^n$

And  $MA = W/P$  (standard equation)

Also efficiency  $\eta = MA/VR$

### Second System of Pulleys

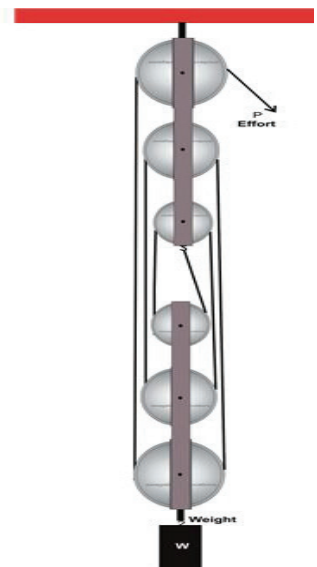
The diagram below shows the second system of pulleys consisting of two blocks. The upper block carries three wheels which freely rotate about their individual central axes and are supported over a single common axle which is firmly fixed to a rigid upper frame.

The lower block also contains similar pulley and axle mechanism; however the whole structure is supported by one end of an intertwined string configuration passing through the pulleys, as illustrated in the figure. The other end termination of the string which passes across the uppermost pulley is used for the application of the effort. The weight is supported by the axle of the lower block.

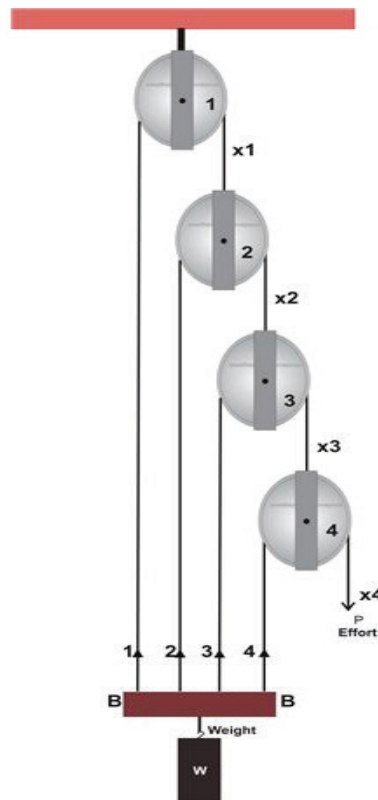
Through some observation it becomes obvious that for displacing the weight by some distance, say  $x$ , the applied effort has to move through a distance  $nx$ , where  $n$  is the total number of pulleys in the system.

Therefore, the velocity ratio can be expressed as  $nx/x = n$

And as usual  $MA$  and the efficiency may be written as given for the first system of pulleys.



## Third System of Pulleys



Source: Images Drawn by Swagatam, Courtesy – Applied Mechanics and Strength of Material

It is quite identical to the first system; however by looking at the figure it becomes clear that the operations involved are just in the reverse process.

The velocity ratio of the system can be tracked by following a unit movement of the weight.

Suppose, the attached weight is moved by a distance of  $x$  meters by the effort applied at  $P$ , this will cause an instantaneous slackening of the strings involved.

For supporting the action, the strings will go through a sequential tightening movement through the pulley rotations.

Therefore the slackening of string 1 (assuming to be equal to  $x$  meters) is compensated by pulley number two, which comes down and covers a distance of  $2x$  meters.

Also with slackening of string 2,  $x1$  gets pulled across a distance of  $2x - x = x$  meters.

Continuing further, with  $x1$  being pulled through  $x$  meters,  $x2$  gets pulled through a length of  $2x + x = 3x = (2^2 - 1)x$ .

The procedure is followed on to keep the relative position of pulley 3 constant and string 3 is pulled across a distance of  $(2 \times 3x + x) = 7x = (2^3 - 1)x$ , and finally string  $x4$ , which is actually the effort, crosses a distance of  $(2 \times 7x + x) = 15x = (2^4 - 1)x$  meters.

Therefore the VR of the system can be equated as = Distance Covered by Effort/Distance Covered by Weight =  $(2^4 - 1)x/x = 2^4 - 1$ , for the present example which consists of 4 pulleys.

In general for a particular third system of pulley having  $n$  number of pulleys,  $VR = 2^n - 1$ .

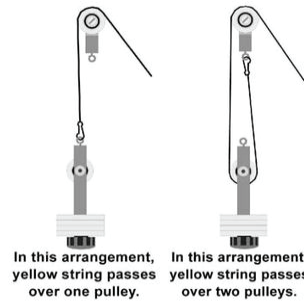
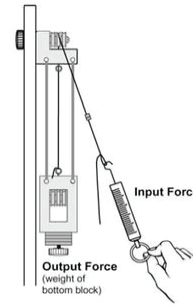
$MA$  and  $\eta$  may be taken as discussed for the previous systems.

An example of how pulley is used for science experiment is shown below

Doing the experiment



1. Record the output force (the weight of the bottom block) in the last column of the table below. This will be the same for each trial of the experiment.
2. Clip the end of the yellow string to the bottom block and pass the string over the middle pulley of the top block. In this arrangement, the yellow string passes over one pulley.
3. Use the spring scale to measure the force it takes to slowly lift the bottom block. This is the input force.
4. Record the input force in the table. Use the row corresponding to one pulley.
5. Take the yellow string off, and clip the end to the top block. Pass the string around the middle pulley on the bottom block and back over the middle pulley on the top block.
6. Measure the force it takes to slowly lift the bottom block (input force).
7. Record the input force in the row for two pulleys.
8. Rearrange the yellow string so that it passes over three pulleys. Then try arrangements that pass over four, five, and six pulleys.
9. Measure and record the input force it takes to lift the bottom block for each new setup.



Number of pulleys	Input force (newtons)	Output force (newtons)
1		
2		
3		
4		
5		
6		

Thinking about the data

- a. As the yellow string passes over more pulleys, what happens to the force used to lift the bottom block? Does this agree or disagree with your original idea about adding pulleys?
- b. Write a rule that describes how the input force changes as more pulleys are used to lift the block.

Scales



## Topic 3: Microscope

<b>Content standard 9.1.1</b>	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.
<b>Benchmark</b>	<b>9.1.1.1</b> Select and use appropriate tools and technology to perform tests, collect data, analyse relationships, and display data.
<b>Key question</b>	1. Why is it very important for students to know and understand parts, functions and the correct ways of using a microscope?
<b>Learning objectives</b>	By the end of this topic, the students can: <ul style="list-style-type: none"> <li>Identify the parts and functions of a microscope</li> <li>Correctly use the microscope in scientific investigations</li> </ul>
<b>Vocabulary</b>	<ul style="list-style-type: none"> <li>Microscope, Lenses, Slides, Specimen, magnification</li> </ul>
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>Parts and functions of a microscope</li> <li>Correct ways of using a microscope</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>Explain the parts and functions of a microscope</li> <li>Use the microscope correctly</li> </ul>
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>Appreciate the importance of a microscope in the study of life and microscopic world</li> </ul>
<b>Teaching and learning</b>	<ul style="list-style-type: none"> <li>Individual demonstration</li> </ul>
<b>Assessment</b>	1. Demonstrate correct use of a microscope and observe and record findings

### Content Background

A **microscope** (from the Ancient Greek: *mikrós*, “small” and *skopeîn*, “to look” or “see”) is an instrument used to see objects that are too small to be seen by the naked eye. Microscopy is the science of investigating small objects and structures using such an instrument. Microscopic means invisible to the naked eye unless aided by a microscope. In the late 16<sup>th</sup> century several Dutch lens makers designed devices that magnified objects, but in 1609 Galileo Galilei perfected the first device known as a microscope. Dutch spectacle makers Zaccharias Janssen and Hans Lipperhey are noted as the first men to develop the concept of the compound microscope.

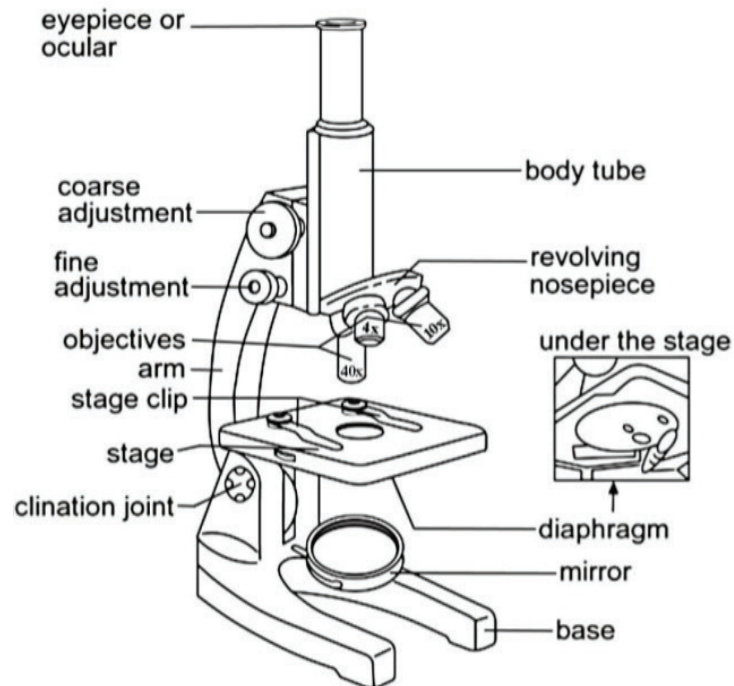
#### Rise of modern light microscope



Today, there are many types of microscopes, and they may be grouped in different ways. One way is to describe the way the instruments interact with a sample to create images, either by sending a beam of light or electrons to a sample in its optical path, or by scanning across, and a short distance from the surface of a sample using a probe. The most common microscope (and the first to be invented) is the optical microscope, which uses light to pass through a sample to produce an image. Other major types of microscopes are the fluorescence microscope, the electron microscope (both

the transmission electron microscope and the scanning electron microscope) and the various types of scanning probe microscopes

### **Microscope parts and functions**



### **Setting up and using the microscope**

A microscope is an optical instrument that uses a lens or a combination of lenses to produce magnified images of small objects, especially of objects too small to be seen by the unaided eye. The light microscope can be divided into six sub-categories. There are bright field, dark field, ultraviolet, fluorescence, phase contrast and differential interference contrast. The most common type of microscopy is the bright field microscopy.

### **Functions**

**Eyepiece Lens:** the lens at the top that you look through. They are usually 10X or 15X power.

**Tube:** Connects the eyepiece to the objective lenses

**Arm:** Supports the tube and connects it to the base

**Base:** The bottom of the microscope, used for support

**Illuminator:** A steady light source (110 volts) used in place of a mirror. If your microscope has a mirror, it is used to reflect light from an external light source up through the bottom of the stage.

**Stage:** The flat platform where you place your slides. Stage clips hold the slides in place. If your microscope has a mechanical stage, you will be able to move the slide around by turning two knobs. One moves it left and right, the other moves it up and down.

**Revolving Nosepiece or Turret:** This is the part that holds two or more objective lenses and can be rotated to easily change power.

**Objective Lenses:** Usually you will find 3 or 4 objective lenses on a microscope. They almost always consist of 4X, 10X, 40X and 100X powers. When coupled with a 10X (most common) eyepiece lens, we get total magnifications of 40X (4X times 10X), 100X, 400X and 1000X. To have good resolution at 1000X, you will need a relatively sophisticated microscope with an Abbe condenser. The shortest lens is the lowest power, the longest one is the lens with the greatest power. Lenses are color coded and if built to DIN standards are interchangeable between microscopes. The high power objective lenses are retractable (i.e. 40XR). This means that if they hit a slide, the end of the lens will push in (spring loaded) thereby protecting the lens and the slide. All quality microscopes have achromatic, parcentered, parfocal lenses.

**Rack Stop:** This is an adjustment that determines how close the objective lens can get to the slide. It is set at the factory and keeps students from cranking the high power objective lens down into the slide and breaking things. You would only need to adjust this if you were using very thin slides and you weren't able to focus on the specimen at high power. (Tip: If you are using thin slides and can't focus, rather than adjust the rack stop, place a clear glass slide under the original slide to raise it a bit higher)




**Condenser Lens:** The purpose of the condenser lens is to focus the light onto the specimen. Condenser lenses are most useful at the highest powers (400X and above). Microscopes with in stage condenser lenses render a sharper image than those with no lens (at 400X). If your microscope has a maximum power of 400X, you will get the maximum benefit by using a condenser lenses rated at 0.65 NA or greater. 0.65 NA condenser lenses may be mounted in the stage and work quite well. A big advantage to a stage mounted lens is that there is one less focusing item to deal with. If you go to 1000X then you should have a focusable condenser lens with an N.A. of 1.25 or greater. Most 1000X microscopes use 1.25 Abbe condenser lens systems. The Abbe condenser lens can be moved up and down. It is set very close to the slide at 1000X and moved further away at the lower powers.

**Diaphragm or Iris:** Many microscopes have a rotating disk under the stage. This diaphragm has different sized holes and is used to vary the intensity and size of the cone of light that is projected upward into the slide. There is no set rule regarding which setting to use for a particular power. Rather, the setting is a function of the transparency of the specimen, the degree of contrast you desire and the particular objective lens in use.

**Calculating total magnification**

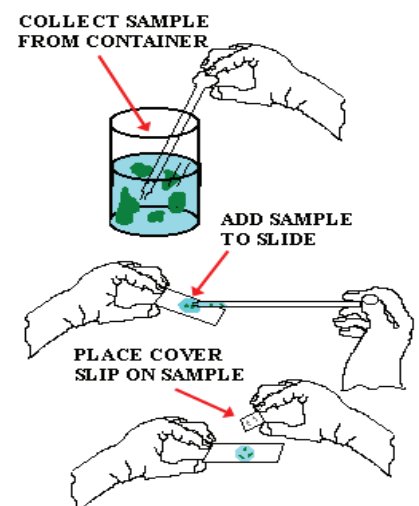
$$\text{Total Magnifications} = \text{Objective Lens Power} \times \text{Eyepiece Lens Power}$$

The table below shows how a bacteria (bacillus) looks like (size) using a simple bright-field microscope

Objective Lens Power	Eyepiece Lens Power	Total Magnifications	Sample (bacillus) magnifications
4x	10x	40x	 4 x Magnification
10x	10x	100x	 10 x Magnification
40x	10x	400x	 40 x Magnification
100x	10x	1000x	

The resolution of a microscope is taken as the ability to distinguish between two closely spaced objects and to reveal adjacent structural detail as distinct and separate. It is these impacts of diffraction that limit the ability to resolve fine details. Magnification is how much bigger a sample appears to be under the microscope than it is in real life. It is best to start out with the lowest magnification, get your specimen in focus, and then move up to the higher magnifications one at a time. This is the easiest way to ensure that you will be able to focus in on your object quickly. However, using a microscope with a more powerful magnification will not increase the resolution any further. It will increase the size of the image, but objects closer than 200nm will still only be seen as one point.

**Making a wet mount**



## Topic 4: Scientific Research Skills

Content standard 9.1.1	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	9.1.1.2 Formulate explanations by using logical thinking and evidence.
Key question	1. What are the steps involved in carrying out an effective scientific research?
Learning objectives	By the end of the topic, students can: <ul style="list-style-type: none"> <li>Apply the steps and processes involved in carrying out scientific research</li> </ul>
Vocabulary	<ul style="list-style-type: none"> <li>Research skills</li> </ul>
Knowledge	<ul style="list-style-type: none"> <li>Skills applied in a scientific research</li> <li>Steps used in a scientific research</li> </ul>
Skills	<ul style="list-style-type: none"> <li>Apply the skills involved in carrying out a scientific research</li> <li>Organise ideas and findings using logical thinking and evidence</li> </ul>
Attitudes and values	<ul style="list-style-type: none"> <li>Build confidence in ways of presenting findings scientifically.</li> </ul>
Teaching and learning	<ul style="list-style-type: none"> <li>Research discussions</li> </ul>
Assessment	1. Research and present findings on different types of research

### Content Background

Bill Trochim designed a method about the route of research. The method says that design, execution and evaluation are interlinked and not independent of each other. The foundation consist of the departure points, the topic, the objectives and the methods. Researchers have three important characteristics:

1. Attitude: a proper researchers should be objective, personal preferences should play no role in your research. You must also be open, by thin we mean that you will not ignore findings that might contradict your previous findings or hypothesis.
2. Knowledge
3. Skills

Doing research starts with a research plan where you define the problem and check if your research is done before and you consider a budget. Also you decide whether your research is fundamental of practical or qualitative and quantitative.

The difference between fundamental and applied research is the type of problem to be solved. Fundamental research is primarily not concerned with practical application whereas applied research focuses on solving problems that have a practical application. A theoretical problem questions scientific theory and the solution is sought using fundamental research. A practical problem is normally one that arises in daily life.

Applied research often has social relevance whereas fundamental research has a scientific relevance.

There are two distinct types of research

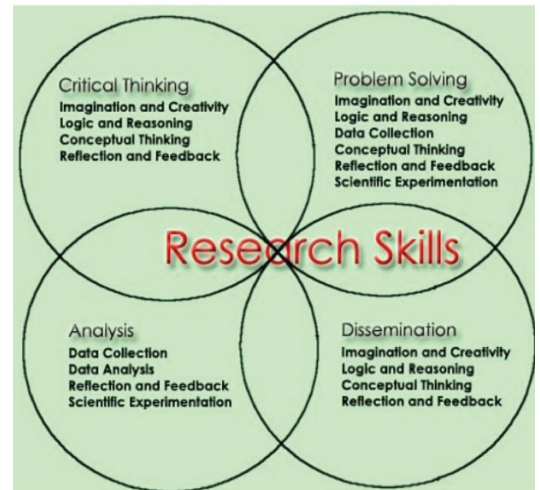
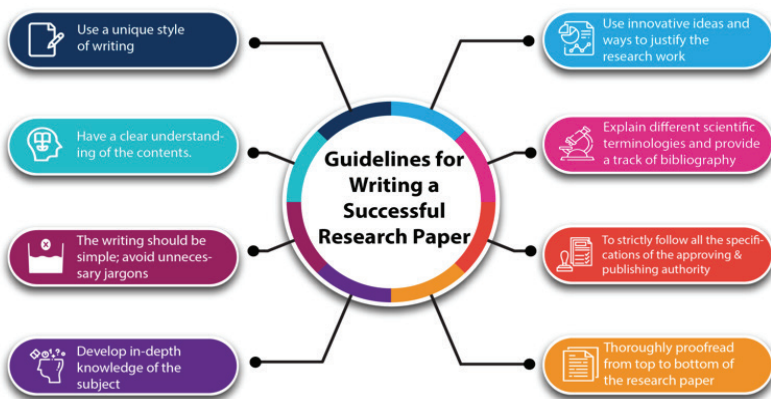
- Quantitative research is based on numerical information, figures that represent object, organizations and people. Tools used for quantitative research are statistics.
- Qualitative research is practiced in the field, it is mainly interested in the meaning that person attaches to a situation or experience. The research subjects are studied in their environment as a whole also known as **holism**. Methods used for this research are open and flexible where you can intervene unexpected happens. The most important aspect is the value and meaning that people attach to situations and issues.

**Fundamental approaches to research: paradigms.**

1. Empirical- analytical. Empirical refers to the research which is conduct using systems to assess what takes place in a certain setting. It means using experience as the source of knowledge. Analytical refers to the view of the results, which is critical and rational. Research findings demeant valid until they are refuted (fundamental).
2. Interpretative; means you are looking for an interpretation, the way people perceive situations and circumstances and how they behave There is a focus on people and the research is most often qualitative.
3. Critical- emancipatory. Critical describes this movement’s approach: concern with society. Emancipatory refers to the social processes that are being investigated and the equality between men and women.

To define the quality of a scientific research there are certain rules/objectives the research must follow.

- **Independence: unbiased and objectivity.** Inter-subjectivity is when researchers agree with one another as far as the results are concerned.



## Unit 9.2. Measurement and Accuracy

**Accuracy** of a **measured** value refers to how close a **measurement** is to the correct value. The uncertainty in a **measurement** is an estimate of the amount by which the **measurement** result may differ from this value. **Precision** of **measured** values refers to how close the agreement is between repeated **measurements**.

### Precision and Accuracy Errors in Scientific Measurements

- **Precision** – Refers to reproducibility or “How close the measurements are to each other.”
- **Accuracy** – Refers to how close a measurement is to the real or true value.
- **Systematic Error** – Produces values that are either all higher or all lower than the actual value
- **Random Error** – In the absence of Systematic Error, produces some values that are higher and some that are lower than the actual value.

### How do you measure the accuracy of an instrument?


The **accurate** measurements are near the center. To **determine** if a value is **accurate** compare it to the accepted value. As these values can be anything a concept called percent error has been developed. Find the difference (subtract) between the accepted value and the experimental value, then divide by the accepted value.

In **measurement** of a set, **accuracy** refers to closeness of the **measurements** to a specific value, while **precision** refers to the closeness of the **measurements**.

### How to Calculate the Accuracy of Measurements

### Precision and Accuracy

- **Precision** is a description of how close measurements are to each other ... The **SMALLER** the measure the **MORE** precise
  - EX: a second hand is more precise than a minute hand
- **Accuracy** is when you compare a measurement to a real, actual, or accepted value.
  - EX: a watch which is not set correctly is **NOT** accurate



accurate and precise
precise, but not accurate
not accurate not precise

To determine the **accuracy** of a **measurement**, calculate the standard deviation and compare the value to the true, known value whenever possible.

In laboratory experiments, we are concerned by how “correct” our measurements are, they must be accurate and precise

Accurate: How close a measured value is to the actual measurement.

Precise: How close a series of measurements are to each other.

For example:

The true value of a measurement is 23.255 mL. Below are 2 sets of data. Which one is precise and which is accurate?

1. 23.300, 23.275, 23.235 (Precise)
2. 22.986, 22.987, 22.987 (Accurate)

We want our measurements to be as precise and accurate as possible. For precision, we make sure we calibrate equipment and take careful measurements. For accuracy, we need a way to determine how close our instrument can get to the actual value

### Significant Figures

We need significant figures to tell us how accurate our measurements are. The more accurate the number is - the closer it is to the actual value.

Look at this data. Which is more accurate? Why? 25 cm, 25.2 cm, 25.22 cm

Answer: 25.22cm - The more numbers past the decimal (the more significant figures), the closer you get to the true value.

### How do we determine how many significant figures are in different pieces of lab equipment?

Significant Figure: Any digit in a measurement that is known for sure plus one final digit, which is an estimate. Example: 4.12 cm. This number has 3 significant figures. The 4 and 1 are known for certain. The 2 is an estimate. In general, the more significant figures you have, the more accurate the measurement will be. For determining significant figures with instrumentation, find the mark for the known measurements, and then estimate the last number between marks.

### Rules for significant figures

Rule 1: Nonzero digits are always significant

Rule 2: Zeros between nonzero digits are significant. For example: 40.7 (3 sig figs.), 87009 (5 sig figs.)

Rule 3: Zeros in front of nonzero digits are not significant. For example: 0.009587 (4 sig figs.). 0.0009 (1 sig figs.)

Rule 4: Zeros at the end of a number and to the right of the decimal point are significant. For example: 85.00 (4 sig figs.). 9.070000000 (10 sig figs.)

Rule 5: Zeros at the end of a number are not significant if there is no decimal. For example: 40,000,000 (1 sig fig)

Rule 6: When looking at numbers in scientific notation, only look at the number part (not the exponent part). For example:  $3.33 \times 10^{-5}$  (3 sig fig).  $4 \times 10^8$  (1 sig fig)

Rule 7: When converting from one unit to the next keep the same number of sig. figs. For example: 3.5 km (2 sig figs.) =  $3.5 \times 10^3$  m (2 sig figs.)

How many significant figures are there in the sample numbers below?

1. 35.02
2. 0.0900
3. 20.00
4.  $3.02 \times 10^4$
5. 4000

Answers: (1) 4 (2) 3 (3) 4 (4) 3 (5) 1

### Topic 1: International Systems of Units (SI)

<b>Content standard</b> 9.1.1	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.
<b>Benchmark</b>	9.1.1.5 Solve scientific problems by using quadratic equations and simple trigonometric, exponential, and logarithmic functions.
<b>Key question</b>	What is the main reason for learning and understanding (SI) Units?
<b>Learning objectives</b>	By the end of the topic, students can: <ul style="list-style-type: none"> <li>Understand the types of modern form of metric system, called the International System (SI).</li> <li>Apply the (SI) units correctly in classroom activities and in daily life.</li> </ul>
<b>Vocabulary</b>	<ul style="list-style-type: none"> <li>International System (SI)</li> </ul>
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>Modern form of metric system called the (SI) units</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>Solve scientific problems using quadratic equations</li> <li>Convert one (SI) unit to another</li> </ul>
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>Being diligent and appreciating the importance of (SI) units in school and daily life.</li> </ul>
<b>Teaching and learning</b>	<ul style="list-style-type: none"> <li>Pair and group work</li> </ul>
<b>Materials</b>	<ul style="list-style-type: none"> <li>Chart of (SI) Units and equivalents</li> </ul>
<b>Assessment</b>	1. Convert correctly using SI units

### Content Background

#### International System (SI)

The metric system of measurement was developed in 1795. A modern form of the metric system, called the International System (SI), was adopted in 1960 and provides the standard measurements that all scientists around the world can understand.

The SI system is convenient because unit sizes vary by powers of 10. Prefixes are used to name units. Look at **Table 2** for some common SI prefixes and their meanings. **Table 3** gives a list of equivalents that can be used to convert between English and SI units

TABLE 2: Common SI Prefixes

Prefixes	Symbol	Meaning	
kilo-	k	1, 000	thousandth
hector-	h	100	hundred
deka-	da	10	ten
dec-	d	0.1	tenth
centi-	c	0.01	hundredth
milli-	m	0.001	thousandth

TABLE 3: Unit System Equivalents

Type of Measurement	Equivalent
Length	1 in = 2.54 cm
	1 yd = 0.91 m
	1 ml = 1.61 km
Mass and Weight	1 oz = 28.35 g
	1 lb = 0.45 kg
	1 ton (short) = 0.91 tonnes (metric tons)
	1 lb = 4.45 N
Volume	1 in <sup>3</sup> = 16.39 cm <sup>3</sup>
	1 qt = 0.95 L
	1 gal = 3.78 L
Area	1 in <sup>2</sup> = 6.45 cm <sup>2</sup>
	1 yd <sup>2</sup> = 0.83 m <sup>2</sup>
	1 ml <sup>2</sup> = 2.59 km <sup>2</sup>
	1 acre = 0.40 hectares
Temperature	$OC = \frac{(OF - 32)}{1.8}$
	$K = OC + 273$

Weight is measured in standard Earth away

## Topic 2: Telling Locations

<b>Content standard 9.1.1</b>	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.
<b>Benchmark</b>	<b>9.1.1.1</b> Select and use appropriate tools and technology to perform tests, collect data, analyse relationships, and display data.
<b>Key question</b>	1. What are the main skills and knowledge required to be able to tell different locations on a map or real life locations?
<b>Learning objectives</b>	By the end of the topic, students can: <ul style="list-style-type: none"> <li>Identify locations on a map or real life locations using scientific equipment such as compass and directions of N/S/E/W.</li> <li>Use reference points to describe locations in both physical and natural environments.</li> </ul>
<b>Vocabulary</b>	<ul style="list-style-type: none"> <li>Compass, degrees, notebooks/journals, reference point, position (<i>in relation to an object</i>)</li> </ul>
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>Directions (N/S/E/W) on a map or in real life</li> <li>How to read a compass</li> <li>Physical and natural features of the environment</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>Demonstrate correct ways of reading and telling directions and locations on a map or in real life</li> </ul>
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>Take care when using a compass</li> <li>Value the importance of knowing about how to read maps and tell directions/locations</li> </ul>
<b>Teaching and learning</b>	<ul style="list-style-type: none"> <li>Discussions and research</li> </ul>
<b>Assessment</b>	1. Identify locations and use reference points, compass to give correct directions and distances using measurements, objects or geographical features such as buildings, rivers, sky and stars etc
<b>Materials</b>	<ul style="list-style-type: none"> <li>Maps, atlas, compass, physical features such as buildings, sky/stars,</li> </ul>

### Content Background

#### Describing Locations

How can students describe where they are in relation to other things or objects around them? Some might say they are sitting one meter away from the others. Some might say they are at home, while others might say they are on the left/right to each other. What if one of them gets up and say that she/he is on earth which is 150 million kilometres from the sun?

What do all these descriptions have in common? Each of these descriptions and their locations are relative to a certain point. A **reference point** is the starting point they chose to describe the location, or position, of an object. The reference points described above are from others, at home, and from the Sun. Some of these included the distances and directions from the reference points. Describing locations this way defines positions. A position/location is an object's distance and direction from a reference point.

Therefore, a complete description of position includes, distance, direction and reference point.

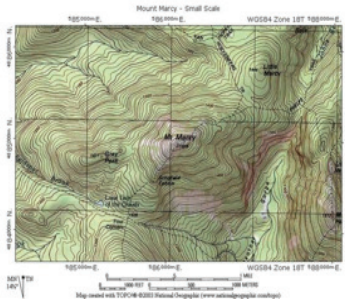
Topic 3: Topographic Maps

<b>Content standard 9.1.1</b>	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.
<b>Benchmark</b>	9.1.1.1 Select and use appropriate tools and technology to perform tests, collect data, analyse relationships, and display data.
<b>Key question</b>	What is a topographic map and why is it important in the study of science?
<b>Learning objectives</b>	By the end of the topic, students can: <ul style="list-style-type: none"> <li>• Explain the importance of the reasons for the usage of topographic maps in science.</li> <li>• Apply the skills used in using topographic maps in other related subjects.</li> </ul>
<b>Vocabulary</b>	Topographic map.
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• Skills of using topographic maps as tools and technology in learning science</li> <li>• Application of topographic maps in real life</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>• Use appropriate tools and techniques to make observations and gather data</li> <li>• Communicate findings on the use of topographic maps</li> <li>• Apply the skills learnt on how topographic maps are used to communicate findings about the life and nature</li> </ul>
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>• Confidently demonstrate the use and importance of understanding topographic maps.</li> <li>• Rationalise why topographic maps are a tool for use in real life</li> </ul>
<b>Teaching and Learning strategies</b>	<ul style="list-style-type: none"> <li>• Demonstration and understanding of what a topographic map is and how it is used in the study of science and other related subject fields.</li> </ul>
<b>Assessment</b>	1. Explain through research why it is important to know about topographic maps
<b>Materials</b>	<ul style="list-style-type: none"> <li>• Samples of topographic maps</li> </ul>

Content Background

General Information

- **Map Scale:** Maps come in a variety of scales, covering areas ranging from the entire earth to a city block (or less).

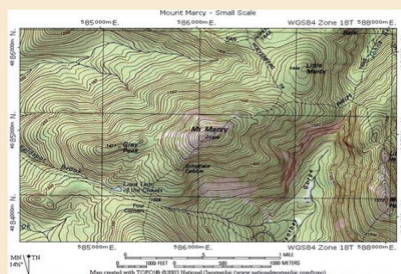


GENERAL PRINCIPLES OF GEOLOGICAL MAPPING.

- Preparing to go to the field.
- Things needed.
- Uses of G.P.S(geographical positioning system) and geological compass.
- Gridding of topographical map.
- Difference between traverse, outcrop, structural and geological maps.

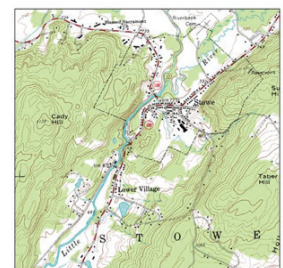
Map Projections

- A map projection is a flat map that represents the three-dimensional curved surface of Earth.
- Though no projection is entirely accurate, some types of projection maps are more useful to us than others.



Topographic Maps

- Detailed maps showing the elevations of hills and valleys of an area.
- Use lines, symbols, and colors to represent changes in elevation and features on Earth's surface.



**Topography = shape of the land**

**Lab Activity: Mapping the Earth's Surface**

- I. Purpose/Objective: Students will learn how to read latitude and longitude on a world map identify major landmarks and plot specific locations, given their coordinates.
- II. Standards Addressed: E.S. 1b and I & E 1f
- III. Hypothesis: None
- IV. Materials: World map, color pencils
- V. Procedure:
  1. Using the map from the instructor, label all the latitude and longitude lines onto your map.
  2. Label the equator and prime meridian onto your map.
  3. Write the names of each ocean and continent onto your map.
- VI. Data/Analysis
  1. Name one continent in each of the northern and southern hemisphere.
  2. List the continents and oceans that the equator passes through.
  3. List the continents and oceans that the prime meridian passes through.
  4. Write each of these map locations on your lab write-up, label them on your map, and identify the continent or ocean they are found on in your lab write-up: a) 15S, 65W b) 85N, 160E c) 40N, 88E d) 20S, 135E e) 40N, 140W f) 30N, 5E g) 45N, 105W h) 55N, 30W
  5. Locate the each of the following landmarks on your world map. Write the names in your lab write-up and give their coordinates:
 

i) Mount St. Helens, WA	j) Niagra Falls, NY
k) Mt. Everest, Nepal	l) The Congo
m) Rome, Italy	n) The Amazon River, Brazil
o) Hong Kong, China	p) The Nile River, Egypt
- VII. Conclusion
 

What was the purpose/objective for this lab activity? Where are most of the world's land masses (continents) located with respect to the equator? What is needed to find specific locations on a map? How are maps useful to us? Below your conclusion, sketch a map from memory that shows how you get from your home to school. Make sure to label all streets that you know, as well as any important landmarks.

## Topographic Map

1:24,000 Scale

<http://www.tnrcc.state.tx.us/gis/raster.html>

### Topic 4: Controls and Variables

<b>Content standard 9.1.1</b>	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.
<b>Benchmark</b>	9.1.1.7 Identify and examine possible reasons for inconsistent results, such as sources of error or uncontrolled conditions.
<b>Key question</b>	1. Why is it important that in science, controls and variables are essential when carrying out scientific investigations?
<b>Learning objectives</b>	By the end of the topic, students can: <ul style="list-style-type: none"> <li>• Explain possible reasons why it is important to utilise controls and variables in science investigations.</li> <li>• Analyse the importance of inconsistent results as a result of the use of controls and variables in scientific investigations.</li> </ul>
<b>Vocabulary</b>	<ul style="list-style-type: none"> <li>• Controls, variables, sources of error</li> </ul>
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• What are controls and variables</li> <li>• Reasons for using controls and variables in science investigations</li> <li>• How to use controls and variables in science experiments</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>• Identify and examine possible reasons why it is important to utilise controls and variables in science investigations.</li> <li>• Demonstrate how controls and variables are used in science experiments</li> <li>• Define with examples of the types of controls and variables used in a particular science experiment.</li> </ul>
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>• Be critical when selecting and using controls and variables in science experiments</li> <li>• Appreciate the importance of controls and variables in science investigations</li> </ul>
<b>Teaching and Learning strategies</b>	<ul style="list-style-type: none"> <li>• Carry out a demonstration on effective use of controls and variables during science investigations</li> </ul>
<b>Assessment</b>	1. Explain why controls are very important in scientific investigations
<b>Materials</b>	<ul style="list-style-type: none"> <li>• Examples of different types of controls and variables</li> </ul>

### Content Background

#### Controlled experiments, identifying variables and constants

A controlled experiment is a scientific investigation that tests how one factor affects another. Students at this grade need to do a lot of controlled experiments to help them to;

- discover answers to questions,
- test a hypothesis, and, or,
- collect data.

When conducting an experiment, students must identify factors that can affect the experiment's outcomes. A **variable** is any factor that can have more than one value. In controlled experiments, there are two kinds of variables – **independent** and **dependent** variables. The independent variable is the factor that you want to test. It is changed by the investigator to observe how it will affect a dependent variable. The dependent variable is the factor students observe or measure during the experiment. **Constants** are factors in the experiment that do not change.

#### Example of Controls & Variables

For example, suppose you want to figure out the fastest route to walk home from school. You will try several different routes and time how long it takes you to get home by each one. Since you are only interested in finding a route that is fastest for you, you will do the walking yourself.

**Topic 5: Importance of Hypothesis or Misconceptions in Science Classes**

<b>Content standard 9.1.1</b>	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.
<b>Benchmark</b>	<b>9.1.1.3</b> Distinguish between hypothesis and theory as scientific terms.
<b>Key questions</b>	<ol style="list-style-type: none"> <li>1. Why is it important to treat students' misconceptions as one of the most key tool to improve our ways of teaching and making students to change their ways of understanding nature through their personal experiences?</li> <li>2. Why is hypothesis an important aspect in science?</li> </ol>
<b>Learning objectives</b>	<p>By the end of this topic, the students can:</p> <ul style="list-style-type: none"> <li>• Analyse and explain that some of their personal experiences and prior knowledge about the world and nature cannot always be true through experimental proves and explanations,</li> <li>• Evaluate that many science phenomena are the ways scientists think, and these are called hypothesis which can only be proven through many science experiments, collecting data, analysing and communicating results.</li> </ul>
<b>Vocabulary</b>	<ul style="list-style-type: none"> <li>• Hypothesis, theory, misconception</li> </ul>
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• Importance of students' misconceptions</li> <li>• Importance of hypothesis in science</li> <li>• Similarities and differences between hypothesis, theory and misconceptions</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>• Distinguish the differences between hypothesis, theory and misconceptions.</li> <li>• Analyse why it is natural for students to establish personal experiences about natural phenomena.</li> <li>• Explain why students' prior knowledge about science should be used as the basis to learn new concepts and change their understandings to build new knowledge.</li> </ul>
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>• Accept that in science, it is natural for students to have misconceptions.</li> <li>• Respect each other's opinions about the world around them.</li> <li>• Cooperatively work with each other to communicate their findings about new ideas from their personal experiences.</li> </ul>
<b>Teaching and Learning strategies</b>	<ul style="list-style-type: none"> <li>• Group working to share ideas about old and new ideas in science.</li> <li>• Teacher develop challenges for students to prove their own misunderstandings and communicate new understandings.</li> </ul>
<b>Assessment</b>	<ul style="list-style-type: none"> <li>• Research prepare a report on a common scientific misconception and present findings.</li> </ul>
<b>Materials</b>	<ul style="list-style-type: none"> <li>• Prepare examples of misconceptions and hypothesis for students to distinguish and compare.</li> </ul>

**Content Background****Previous Research on Children's Misconceptions**

Pine, Messer and John (2001) carried out research into teachers' view of children's misconceptions in primary science. Their analysis revealed that children have a lot of misconceptions about science topics and these misconceptions are of considerable importance and cannot be ignored in the learning process, since they are bases upon which knowledge is built. Teachers described a range of methods used to find out what children know but it was not clear if finding out what children know "involves searching for their correct notions about topics or actively probing for misconceptions" (Pine, Messer, John, 2001, p92). The results also indicated that teachers may think misconceptions get in the way of the teaching process, and are best ignored or squashed as quickly as possible. However, teachers need to place as much emphasis on children's incorrect ideas as on their correct ones if they want to accomplish conceptual change in science.

Some studies managed to design lists with children's misconceptions. The table below provides some usual misconceptions that children have about "water cycle" as this is the target topic for this research.

Misconceptions in regard to:	
RAIN	CLOUDS
Rain comes from clouds sweating	Clouds come from somewhere above the sky
Rain comes from holes in clouds	Empty clouds are filled by the sea
Rain occurs because we need it	Clouds are formed by vapour from kettles
Rain fall from funnels in the clouds	Clouds are made of cotton wool or smoke
Rain occurs when clouds get scrambled and melt	Clouds collide and split open and the rain falls
Rain occurs when clouds are shaken by thunder	Clouds get cold and then rain falls

#### How can we as teachers help students in solving these misconceptions?

Eaton, Anderson and Smith (1984) aimed to find out if children's misconceptions interfere with science learning. The study was part of the Elementary Science Project, focused on the science teaching of 14 teachers and the data was collected through observations and audio-recorder lessons on the unit of light. It's worth mentioning that before the light and seeing unit was taught, children took a pre-test and after the unit they took the same test again, which was the basic source of information about children's conceptions. The results showed that students had difficulties in learning about light because neither their text nor their teachers adequately dealt with their misconceptions; "experiences and common sense can sometimes lead to inaccurate or incomplete conceptions that can prevent a student from learning" (Eaton, Anderson and Smith, 1984, p1).

Having read these two research findings, teachers should now respect and accept student's misconceptions. It is likely to be common in early age group. But if these are not addressed, these misconceptions will create teachers, students and the actual science concepts that may not be corrected and facts established in students for the rest of their life, especially if we don't address these in higher grades.

**Student's misconceptions should be used as the basis to change our way of what we think students know and don't know. They are entitled to their way of understanding the world. But we as science teachers should as much as possible make it our responsibility to change these ways of thinking by creating opportunities for them to revisit their ways of thinking, make corrections, and establish facts for the rest of their life. Let them create new hypothesis to revisit their misconceptions.**

Therefore, it is important for students to know that unsupported and supported hypotheses in the learning of science are accepted processes. For example, let's look at these question: "What happens if a hypothesis is not supported by an investigation? Was the scientific investigation a failure and a waste of time?" Absolutely not! Even when a hypothesis is not supported, students gain valuable information. They revise their hypothesis and test it again. Each time they test their hypothesis, they learn more about the topic they are studying.

## STRAND 2: LIFE SCIENCE

The life Science strand is about living things, their life processes, and their interrelationships and their environment. It deals with the structure and behaviour of organisms like plants, animals and human beings. It further explores the classification, cell structure and function, reproduction and heredity, characteristics of organisms, life cycles of organisms, and the interactions among all components, living and non-living parts of the natural environment and the inter-relationships with each other and the environment.

This strand is further broken down into three main units. These are (1) Classifying Organisms, (2) Cell Structure and Function, and (3) Interactions and Relationships in the Environment. These units are elaborated as per the key learning concepts for each of the units. All students are expected to achieve the required standards prescribed in this strand.

There are eleven (11) topics given for this strand and units and each topic is further expanded for teachers to use in their planning and teaching through the intended benchmarks.

### Unit 9.3. Classifying Organisms

The biological classification system show how living things are related to each other. For example, how can you tell if an organism is a bat or a cat? Does a cat has hair or fur? Which of these animals can fly, has fur, and has wings that are like skin that stretch over bone? It must be a bat and not a cat. In science, scientists use a tool called Dichotomous Key. The word **dichotomous** means “*divided into two parts*” so the key always use two characteristics to choose between. Each choice leads to another pair of characteristics and narrows down the possibility of what the organism could be.

#### Topic 1: Kingdoms of Living Things

<b>Content standard</b>	Students will be able to examine and make sense of the development, characteristics, processes, and interactions of living things and the natural environment.
<b>Benchmark</b>	<b>9.2.2.1</b> Explain the organization of life on Earth using the modern classification system.
<b>Key question</b>	How can you classify the six (6) kingdoms of living things?
<b>Learning objectives</b>	By the end of the topic, the students can: <ul style="list-style-type: none"><li>• Understand and effectively use the dichotomous key in classifying living things based on their characteristics.</li><li>• Create their own dichotomous keys according to their contexts in studying the 6 kingdoms.</li></ul>
<b>Vocabulary</b>	Dichotomous key, species, protists, plasma, bacteria, kingdom, fungi, protozoa,
<b>Knowledge</b>	<ul style="list-style-type: none"><li>• The biological classification system show how living things are related to each other.</li><li>• Dichotomous key is used in the process of classifying all living things.</li><li>• Study of internal and external structures of living things are observed to determine the characteristics of living things.</li></ul>
<b>Skills</b>	<ul style="list-style-type: none"><li>• Compare internal and external structures of living things</li><li>• Observe and record data of organisms</li><li>• Infer using the characteristics of organisms and explain these can be used to separate organisms into two.</li></ul>
<b>Inquiry</b>	<ul style="list-style-type: none"><li>• Classify – when you classify, you are using shared characteristics to group things together to see what items have in common and how they are similar or differ.</li></ul>
<b>Attitudes and values</b>	<ul style="list-style-type: none"><li>• Appreciate the importance of classifying living things in real world.</li></ul>

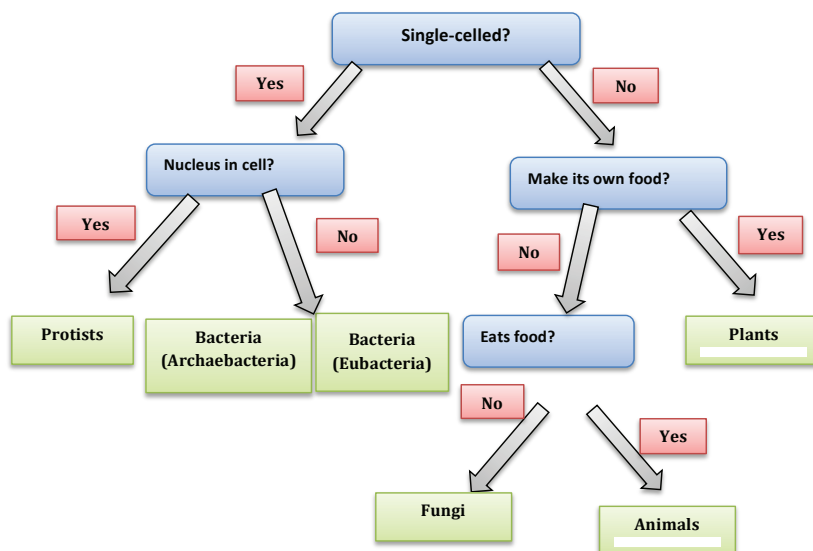
<b>Teaching and Learning strategies</b>	<ul style="list-style-type: none"> <li>Review the use of microscope, prepare samples of some microbes such as bacteria, algae and fungi. Other types of microbes.</li> <li>Organise students to work in groups</li> </ul>
<b>Assessment</b>	Compare and describe the characteristics of organisms using a microscope and classify these following the dichotomous key.
<b>Materials</b>	Microscope, microscope slides and covers, slime moulds, algae, other microorganisms, lab report sheet/science notebook.

## Content Background

### About Kingdoms

Earth is home of diverse species, which are specific types of living things. But how do scientists keep track of them all? They use a system of biological classification system called dichotomous key to group species into categories. The largest category of this system is called a Kingdom. Many scientists today use six (6) kingdoms: two for bacteria, and one each for protists, fungi, plants and animals.

#### Classifying most living things using dichotomous key



To define the kingdoms and subgroups further, scientists study both the internal and the external structures of living things. They also study their individual cells and the chemical processes inside the cells. These evidence suggests shared histories and common ancestors which then allow the scientists to group species according to how closely related they are.

### Bacteria (2 types)

These are small singled-celled organisms. Unlike organisms in other kingdoms, a bacterial cell does not contain a nucleus. The nucleus is like a command center of a cell. For this reason, bacteria are classified as prokaryotes – a word that means “before a nucleus”. Examples of bacteria are: cocci, bacilli, and spirochetes. They are the most common type of organism. Two kingdoms contain bacteria are; Archaeobacteria and Eubacteria.

Archaeobacteria (Archae) – these are “ancient bacteria that live on Earth before any other organism. Today, they live under deadly conditions where other organisms cannot such as, absence of oxygen, in swamps and mud, and extreme heat.

Eubacteria – these are quite different from their ancient relatives. They cannot survive in extreme conditions. Example: e.coli. Eubacteria has only one cell, but their cell functions are quite complex. They have a variety of ways of obtaining food. Some use sunlight to make food while others get their food from eating living things and non-living things.

### **Protists (3)**

This kingdom of organism has some of the characteristics of both plants and animals. Protists are organisms with nuclei in their cells that do not fit into fungi, plant, or animal kingdoms, but may have characteristics of each. Examples of protists are: amoeba, algae, protozoa, and slime mold. There are about 60, 000 known species.

### **Fungi (4)**

This kingdom of organism come in a variety of shapes and colours. Like all other kingdoms except bacteria, fungi cells have nuclei and cell walls. Their cell walls are made of the same substances as the hard cells of insects. Fungi range in size – from one single – celled organisms to huge masses as 30 cm. instead of making food or eating it, fungi absorb nutrients from their environment. They decompose, or break down the tissues of other organisms. They reproduce through spores. One example of fungi is a mushroom. There are more 70, 000 species.

### **Plants (5) and Animals (6)**

These two kingdoms will be studied in topics 2 and 3 in this unit.

### **Differences between living and nonliving things and what living things require to live**

- Recognize and describe the differences between living and non-living things (all living things reproduce, grow, develop, respond to stimuli, and die; and nonliving things do not).
- Identify what living things require in order to live (they require air, food, water, and an environment in which to live).

### **Physical and behavioral characteristics of major groups of living things**

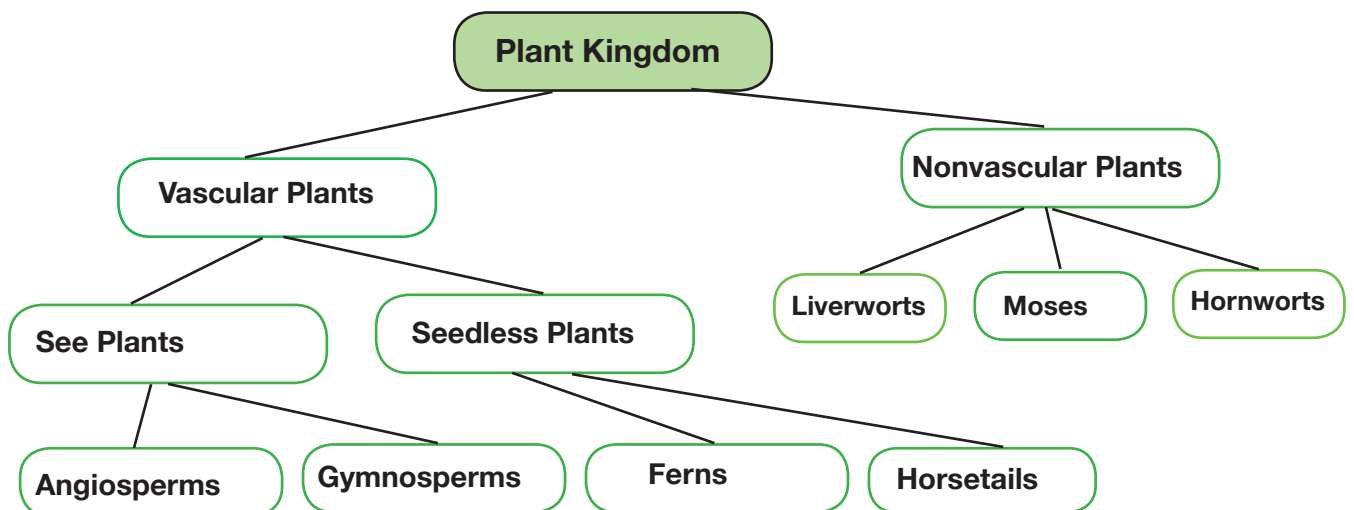
- Compare and contrast physical and behavioral characteristics that distinguish the following major groups of living things (insects, birds, mammals, fish, and flowering plants).
- Identify or provide examples of living things belonging to the following major groups of living things: insects, birds, mammals, fish, and flowering plants.

## Topic 2: Classification of Plants

<b>Content standard</b>	Students will be able to examine and make sense of the development, characteristics, processes, and interactions of living things and the natural environment.
<b>Benchmark</b>	<b>9.2.2.1</b> Explain the organization of life on Earth using the modern classification system.
<b>Key question</b>	How do vascular and nonvascular plants differ?
<b>Learning objectives</b>	By the end of the topic, students can: <ul style="list-style-type: none"> <li>• Explain through research that different species of plants can be classified using their characteristics.</li> </ul>
<b>Vocabulary</b>	<ul style="list-style-type: none"> <li>• Angiosperm, gymnosperm, nonvascular, vascular, multi-cellular,</li> </ul>
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• Classification of plants</li> <li>• Plants are multi-cellular organisms that have tissues and organs</li> <li>• All plants have cell walls</li> <li>• Green plants contain chloroplasts to make their own food using energy from the sun.</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>• Compare and contrast how seedless vascular plants reproduce</li> <li>• Evaluate and use dichotomous key to classify different species of plants.</li> <li>• Communicate research findings on different plant species.</li> </ul>
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>• Show care when using plants/leaves.</li> <li>• Appreciate the work of scientists who have worked so hard to design a system we use now to classify different plant species.</li> </ul>
<b>Teaching and Learning strategies</b>	<ul style="list-style-type: none"> <li>• Investigations in groups and individuals. This is a continuation of plant life study in lower grades, so as much as possible, students should be working independently through research and group discussions.</li> </ul>
<b>Assessment</b>	<ul style="list-style-type: none"> <li>• Determine the type of plant through research by drawing its classification system, scientific name, vascular or nonvascular, etc, and reasons for your answers.</li> </ul>
<b>Materials</b>	<ul style="list-style-type: none"> <li>• Reference books on classification of plants, lap report sheet, magnifying glass, samples of plants and plant leaves, sharp blades.</li> </ul>

### Content Background

Earth is home of a huge and impressive variety of plants which live and grow in different ways. Scientists have classified more than 300, 000 plant species, but all members of the plant kingdom share certain characteristics – plants are multicellular organisms that have tissues and organs. Their cells have cell walls that contain chloroplasts that use the sun’s energy to make their own food. The plant kingdom can be further classified into two main groups – vascular and nonvascular plants.



### Topic 3: Classification of Animals

<b>Content standard</b>	Students will be able to examine and make sense of the development, characteristics, processes and interactions of living things and the natural environment.
<b>Benchmark</b>	<b>9.2.2.1</b> Explain the organization of life on Earth using the modern classification system.
<b>Key question</b>	Can you further characterise a species using their physical, internal or external characteristics/features eg, fish?
<b>Learning objectives</b>	At the end of the topic, students are can: <ul style="list-style-type: none"> <li>• Describe the diversity of animal kingdom</li> <li>• Investigate the specimens and characteristics of different animal species and classify these organism into which of the 6 kingdoms.</li> <li>• Evaluate through research that different species of plants can be classified using their characteristics.</li> </ul>
<b>Vocabulary</b>	Amphibians, cnidarians, invertebrates, vertebrates, specialised cells, phylum, class, order, family, genus, species.
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• Animals require oxygen to breath</li> <li>• Animals consume other organism to get the nutrients and energy they need</li> <li>• Most animals reproduce sexually</li> <li>• Once and animal has been classified as an animal, it can be further classified into phylum, class, order, family, genus, and species.</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>• Synthesis – what would you do when you observe an animal that has feathers but cannot fly?</li> <li>• Compare characteristics of vertebrates and invertebrates</li> <li>• Analyse the main characteristics of each of the 6 animal kingdoms.</li> </ul>
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>• Respect the beauty of life and environment</li> <li>• Show willingness to change opinions and mindsets about characteristics of animals</li> </ul>
<b>Teaching and Learning strategies</b>	<ul style="list-style-type: none"> <li>• Groups and pair working teams</li> <li>• Students should be encouraged to be engaged seriously when observing specimens with hand lenses</li> <li>• Prepare specimens or real life samples in advance</li> </ul>
<b>Assessment</b>	1. Evaluate certain species of animals and identify which kingdom each animal belongs to.
<b>Materials</b>	Hand lens, preserved animals or parts, such as bones, shells, teeth, skull, or real-life species, science lab report, charts etc.

#### Content Background

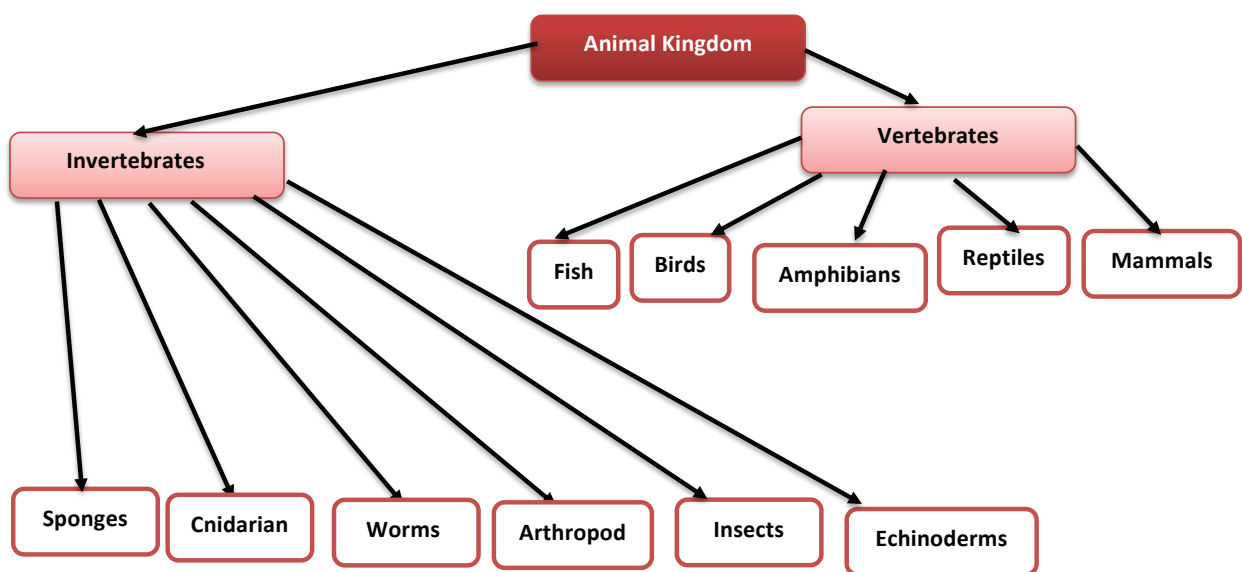
The kingdom Animalia have some of the same characteristics as organisms from other kingdoms. Like plants, animals have many cells. Animals do not make food from the sun but eat food from their environment. They break down and digest food for their energy and nutrients. The common characteristics of animals are:

- Multicellular with specialized cells that form tissues and organs
- Require oxygen to breath
- Consume other organisms to get their nutrients and energy they need
- Are able to move
- Most animals reproduce sexually

Once an animal has been identified as an animal, it can be further classified into six (6) categories which are; phylum, class, order, family, genus, and species. This is shown below in order as organized by scientists.

Kingdom
1. Phylum
2. Class
3. Order
4. Family
5. Genus
6. Species

**Classifying Animal Kingdom.**



## Unit 9.4: Cell Structure and Function

All cells have structures that perform certain functions. Plant and animal cells look different, but they share many similar features. The common features they have are; cell membrane, nucleus, and cytoplasm. An organism cannot survive without cells performing their functions. All living things are made of cells, therefore, to stay alive and healthy, cells need food, water, and ways of removing wastes.

### Topic 1: Plant Cell and Animal Cell Structures

<b>Content standard</b>	Students will be able to examine and make sense of the development, characteristics, processes and interactions of living things and the natural environment.
<b>Benchmark</b>	<b>9.2.2.7</b> Analyse the growth, division, parts and functions of cells and the process in terms of cellular respiration.
<b>Key question</b>	Do all cells have the same structures and functions?
<b>Learning objectives</b>	At the end of the topic, students can: <ul style="list-style-type: none"> <li>• Explain the relationships between structures and functions of plant and animal cells</li> <li>• Analyse relationship between the shapes and structures of plant and animal cells.</li> <li>• Communicate findings to peers about structures and functions of plant and animal cells in a scientific way.</li> </ul>
<b>Vocabulary</b>	<ul style="list-style-type: none"> <li>• Chloroplast, cytoplasm, nucleus, organelle, cell wall, mitochondrion, cell membrane, vacuole, endoplasmic reticulum, golgi bodies</li> </ul>
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• Cell structures of plants of plant and animal cells</li> <li>• Functions of cell structures of plant and animal cells</li> <li>• Relationships between structures of plant and animal cells</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>• Make observations</li> <li>• Make/use models</li> <li>• Analyse relationships</li> <li>• Communicate findings</li> </ul>
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>• Appreciate the importance of plant and animal cells as the building blocks of all life forms.</li> </ul>
<b>Teaching and Learning strategies</b>	<ul style="list-style-type: none"> <li>• Group work</li> <li>• Teacher to organise students to work in small groups or pairs so they can observe and discuss the structures of plant and animal cells including their functions.</li> <li>• Report writing and presentation of findings to the class.</li> </ul>
<b>Assessment</b>	1. Make/use models, specimens etc, to make observations, analyse findings and present reports in a scientific way.
<b>Materials</b>	Hand lens or microscope, sample plant and animal cell specimens or close-up photos of these, report sheets,

### Content Background

#### Cell structures and their functions

Cell structure	Functions
Mitochondria	Provide energy for plants and animal cells
Vacuole	These structures store energy that are coming into the cells during photosynthesis or respiration
Nucleus	This is the control center of all cells. It carries information for reproduction and directs all cell activities.

<b>Cell membrane</b>	This is the outer covering of the plant and animal cells. Water, air and food enter through the cell membrane and waste products are removed through this.
<b>Golgi bodies</b>	Transport materials in the cells
<b>Cytoplasm</b>	Is a gel-like material that surrounds all parts of the cell within the membrane

Source: Houghton Mifflin Science,

**Sample Lesson 1. Plant Cells and Animal Cells**

**Objective.**

By the end of the lesson the students should be able to:  
Identify the structures and explain the functions of plant and animal cells.

**KQ:** How do cells carry out their functions of life?

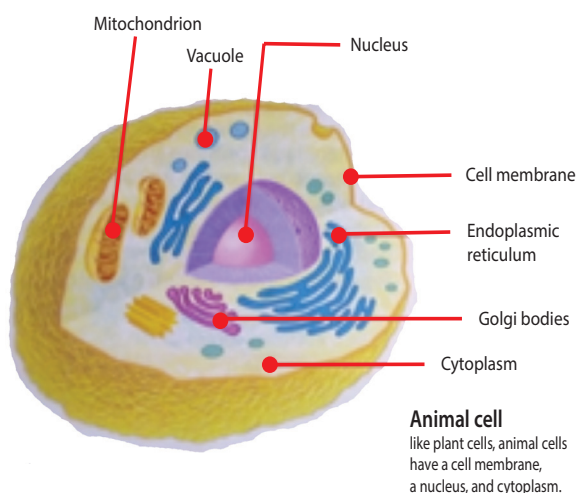
Knowledge	Inquiry Skills	Attitudes/Values
<ul style="list-style-type: none"> <li>All cells have structures that perform certain functions.</li> <li>Animal cells and plant cells look different, but they share many similar features.</li> </ul>	<ul style="list-style-type: none"> <li>Use models</li> <li>Observe how plant cells look like</li> <li>Compare different cells</li> <li>Infer why plants cells have thick cell wall</li> <li>Communicate findings</li> </ul>	<ul style="list-style-type: none"> <li>Cooperatively participate in designing cell models</li> </ul>

**Materials.**

Hand lens, close up photos of plant and animal cells, plastic bags, jar, clay, water, small battery, sand, paper, blade, and large leaf.

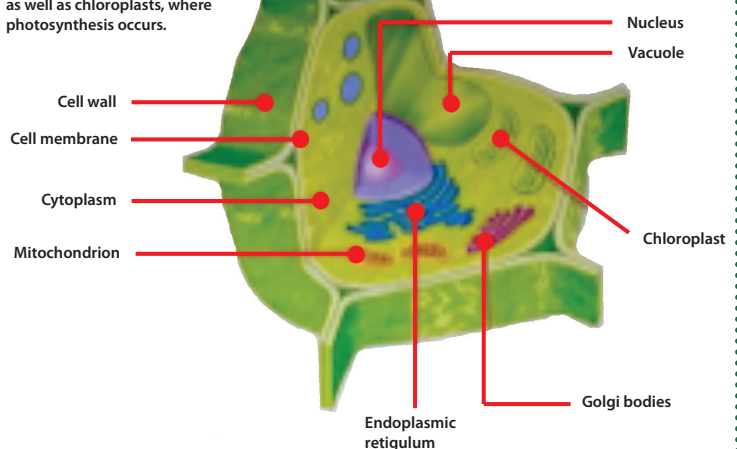
**Activity**

1. Use the hand lens to carefully examine the different structures of the plant and animal cells in the diagrams below.



**Plant Cell**

Unlike animal cells, plant cells have a cell wall, as well as chloroplasts, where photosynthesis occurs.



2. Cut the leaf across and observe the cross section of the leaf with the hand lens. Compare the microscopic view of the plant cell with the real plant leaf.
3. Write a short paragraph to explain your findings.
4. Study the two photos above and identify the similarities and differences in the plant and animal cells

Similarities	Differences

5. Fill in the functions of the cell structures listed in the table.

### Cell structures and their functions

Cell structure	Functions
Mitochondria	
Vacuole	
Nucleus	
Cell membrane	
Golgi bodies	
Cytoplasm	
Cell wall	
Chloroplast	

Source: Houghton Mifflin Science, pp 46

Use the materials in the materials list to make a model of a plant and animal cell. Name the structures of the cells using stick on or index cards. This task will be done by students themselves. They will plan how it will be done or the steps used to make these models. Colours can be used for each of the structure of the cells.

Discuss and find answers to the following questions;

- a. Why do you think plants have a thick wall surrounding each cell?
- b. How did making your cell model help you draw conclusions about the functions of certain parts of plant and animal cells?
- c. Explain why a cell has parts that work together as team

## Topic 2: Cell Division in Plants and Animals

<b>Content standard</b>	Students will be able to examine and make sense of the development, characteristics, processes and interactions of living things and the natural environment.
<b>Benchmark</b>	<b>9.2.2.8</b> Investigate the different cell parts, their functions, and how they are specialized into different tissue and organs.
<b>Key question</b>	How do cells divide in the processes of mitosis and meiosis?
<b>Learning objectives</b>	At the end of the topic, students can: <ul style="list-style-type: none"> <li>• Explain that cells of living things divide and reproduce genetically in a process called cell cycle.</li> <li>• Define and describe the four (4) major phases of cell division in the processes of mitosis and meiosis.</li> </ul>
<b>Vocabulary</b>	Mitosis, meiosis, chromosomes, cytokinin, hormone, anastral, amphiastral, spindle, phragmoplast, gamete, gametophyte
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• The processes of cell division</li> <li>• Differences between mitosis and meiosis</li> <li>• What are diploid and haploid offspring?</li> </ul>
<b>Skills</b>	Investigate the relationship between the mitotic and meiotic processes. Infer how to determine sources, production and combination of X and Y chromosomes.
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>• Show respect for life in terms of production, reproduction and replacement in the process of cell cycle.</li> <li>• Appreciate the fact that without cell mechanics and processes, there will be no life on earth.</li> </ul>
<b>Teaching and Learning strategies</b>	<ul style="list-style-type: none"> <li>• Group discussions.</li> <li>• Carry out research</li> <li>• Teacher to research and provide background information for students, including the study of Anton van Leeuwenhoek discoveries using a microscope.</li> </ul>
<b>Assessments</b>	<ol style="list-style-type: none"> <li>1. Research and present information on why cell division is important to an organism</li> <li>2. Research how human beings cells divide starting from a fertilised egg</li> </ol>
<b>Materials</b>	<ul style="list-style-type: none"> <li>• Cell life cycle charts</li> <li>• Models of cell division on mitosis and meiosis</li> <li>• Science report/journals</li> <li>• Teacher or students can visit <a href="http://www.eduplace.com/sp/">www.eduplace.com/sp/</a> to find more information on plant and animal cells.</li> </ul>

### Content Background

Cells of living organisms divide and reproduce genetically in a process called the cell cycle. This cell cycle is made up of four major phases: **G1**, **S**, **G2**, and **M phase**.

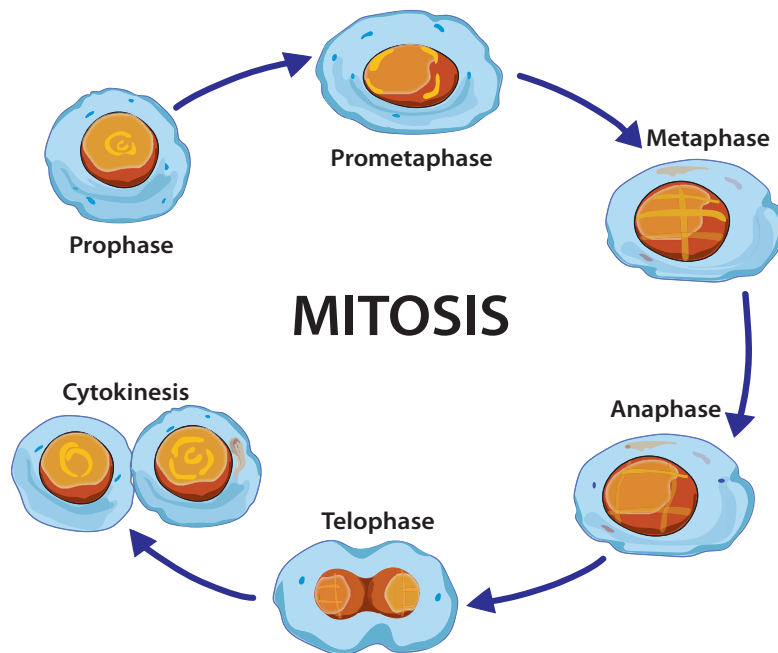
During **G1**, the cell evaluates the initiation of cell division. **S** phase is when the cell synthesizes the DNA and replicates its chromosomes. **G2** is the phase where the cell checks whether the replication was done correctly and if not, initiates necessary repairs. Lastly, **M** phase is the actual cell division.

In eukaryotes, two types of cell divisions exist: mitosis and meiosis. While these processes are similar in terms of principles, they also have distinct characteristics.

Organisms grow and reproduce through cell division. In eukaryotic cells, the production of new cells occurs as a result of mitosis and meiosis. These two nuclear division processes are similar but distinct. Both processes involve the division of a diploid cell, or a cell containing two sets of chromosomes (one chromosome donated from each parent).

## Mitosis

In mitosis, the genetic material (DNA) in a cell is duplicated and divided equally between two cells. The dividing cell goes through an ordered series of events called the cell cycle. The mitotic cell cycle is initiated by the presence of certain growth factors or other signals that indicate that the production of new cells is needed. Somatic cells of the body replicate by mitosis. Examples of somatic cells include fat cells, blood cells, skin cells, or any body cell that is not a sex cell. Mitosis is necessary to replace dead cells, damaged cells, or cells that have short life spans. Plant and animal cells both undergo mitotic cell divisions. Their main difference is how they form the daughter cells during cytokinesis. During that stage, animal cells form furrow or cleavage that gives way to formation of daughter cells. Due to the existence of rigid cell wall, plant cells don't form furrows.



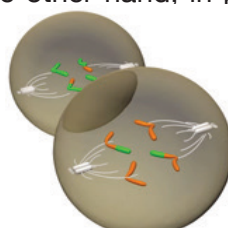
*The process of Mitosis*

Mitosis involves only one cell division that is composed of four major phases: prophase, metaphase, anaphase, and telophase. Meiosis is quite longer as it involves two successive divisions that results to the reduction in chromosome number. Basically, it is divided into two: meiosis I and meiosis II. Meiosis I and II have the same phases like mitosis, only different in some events.

**Meiosis** is the process by which gametes (sex cells) are generated in organisms that reproduce sexually. Gametes are produced in male and female gonads and contain one-half the number of chromosomes as the original cell. New gene combinations are introduced in a population through the genetic recombination that occurs during meiosis. Thus, unlike the two genetically identical cells produced in mitosis, the meiotic cell cycle produces four cells that are genetically different.

How does meiosis differ in plant and animal cells?

Meiosis is a type of cell division which reduces the chromosomes number. The processes are quite the same in plants and animals. However, in animals, it results into the formation of gametes which is a reproductive or sex cell. On the other hand, in plants, it forms spores which further grow into gametophyte.



sexual reproduction. During reproduction, when the sperm and egg unite to form a single cell, the number of chromosomes is restored in the offspring.

Meiosis begins with a parent cell that is diploid, meaning it has two copies of each chromosome. The parent cell undergoes one round of DNA replication followed by two separate cycles of nuclear division. The process results in four daughter cells that are haploid, which means they contain half the number of chromosomes of the diploid parent cell.

Meiosis has both similarities to and differences from mitosis, which is a cell division process in which a parent cell produces two identical daughter cells. Meiosis begins following one round of DNA replication in cells in the male or female sex organs. The process is split into meiosis I and meiosis II, and both meiotic divisions have multiple phases. Meiosis I is a type of cell division unique to germ cells, while meiosis II is similar to mitosis.

Meiosis I, the first meiotic division, begins with prophase I. During prophase I, the complex of DNA and protein known as chromatin condenses to form chromosomes. The pairs of replicated chromosomes are known as sister chromatids, and they remain joined at a central point called the centromere. A large structure called the meiotic spindle also forms from long proteins called microtubules on each side, or pole, of the cell. Between prophase I and metaphase I, the pairs of homologous chromosomes form tetrads. Within the tetrad, any pair of chromatid arms can overlap and fuse in a process called crossing-over or recombination. Recombination is a process that breaks, recombines and rejoins sections of DNA to produce new combinations of genes. In metaphase I, the homologous pairs of chromosomes align on either side of the equatorial plate. Then, in anaphase I, the spindle fibers contract and pull the homologous pairs, each with two chromatids, away from each other and toward each pole of the cell. During telophase I, the chromosomes are enclosed in nuclei.

The cell now undergoes a process called cytokinesis that divides the cytoplasm of the original cell into two daughter cells. Each daughter cell is haploid and has only one set of chromosomes, or half the total number of chromosomes of the original cell.

Meiosis II is a mitotic division of each of the haploid cells produced in meiosis I. During prophase II, the chromosomes condense, and a new set of spindle fibers forms. The chromosomes begin moving toward the equator of the cell. During metaphase II, the centromeres of the paired chromatids align along the equatorial plate in both cells. Then in anaphase II, the chromosomes separate at the centromeres. The spindle fibers pull the separated chromosomes toward each pole of the cell. Finally, during telophase II, the chromosomes are enclosed in nuclear membranes. Cytokinesis follows, dividing the cytoplasm of the two cells. At the conclusion of meiosis, there are four haploid daughter cells that go on to develop into either sperm or egg cells.

### **The four (4) major phases of Cell Division in the processes of mitosis and meiosis**

While the processes of mitosis and meiosis contain a number of differences, they are also similar in many ways. Both processes have a growth period called **interphase**, in which a cell replicates its genetic material and organelles in preparation for division.

Both mitosis and meiosis involve phases: **Prophase, Metaphase, Anaphase and Telophase**. Although in meiosis, a cell goes through these cell cycle phases twice. Both processes also involve the lining up of individual duplicated chromosomes, known as sister chromatids, along the metaphase plate. This happens in metaphase of mitosis and metaphase II of meiosis.

## The four (4) major phases of Cell Division in the processes of mitosis and meiosis

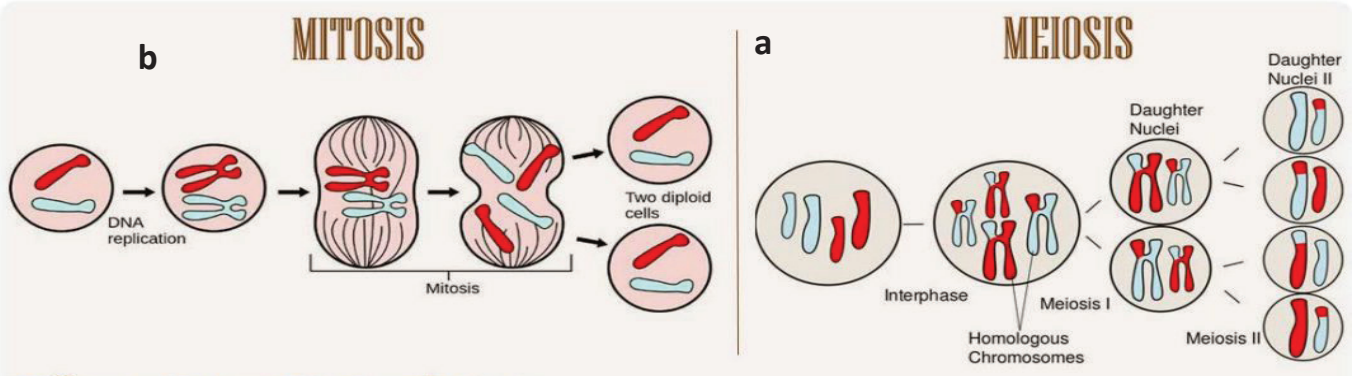
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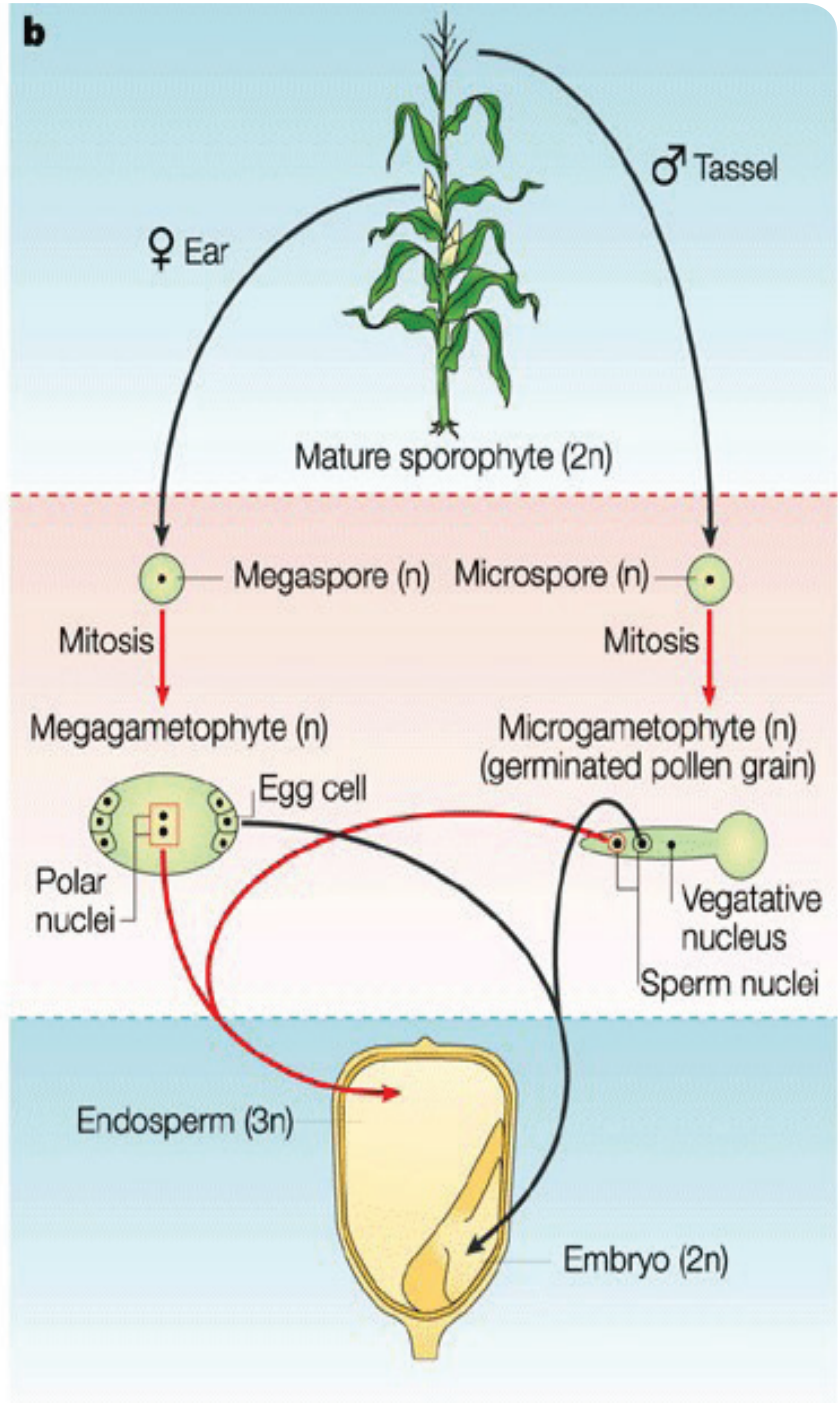
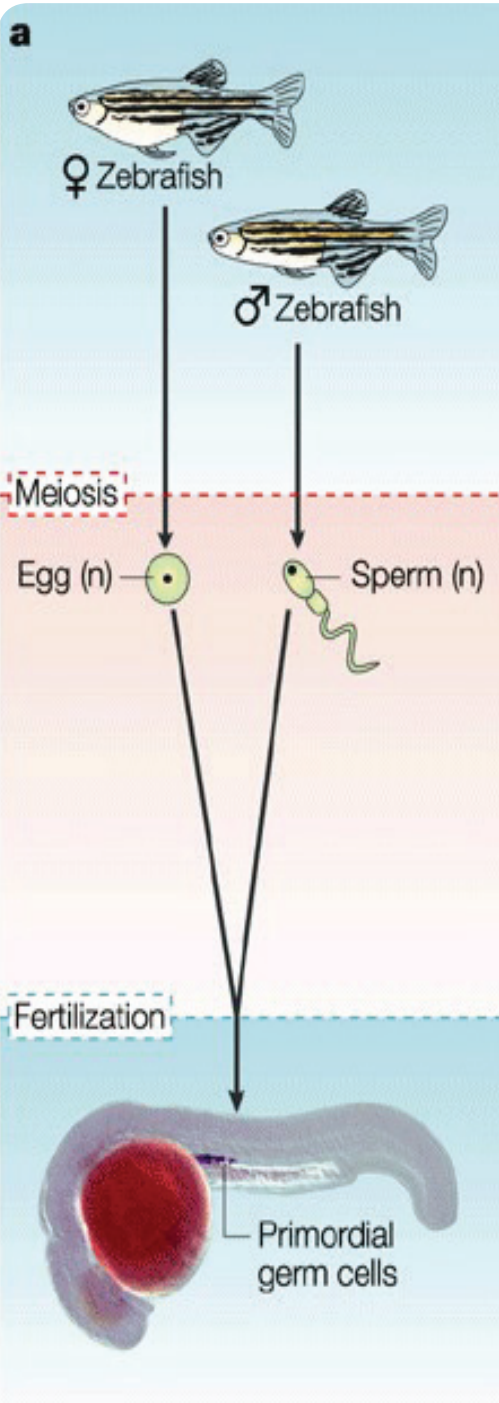
In addition, both mitosis and meiosis involve the separation of sister chromatids and the formation of daughter chromosomes. This event occurs in anaphase of mitosis and anaphase II of meiosis.

Finally, both processes end with the division of the cytoplasm that produces individual cells

<b>Interphase</b>	Before undergoing through the four phases, the cell first needs to grow and replicate its chromosomes in a preliminary stage called interphase. A sex cell will only undergo interphase once. No interphase will happen before meiosis II.
<b>Prophase</b>	<p>After interphase, the cell proceeds to prophase where the nuclear membrane disintegrates and the chromatin condenses to form the chromosomes.</p> <p>The mitotic cell undergoes prophase only once.</p> <p>Prophase in meiosis is relatively longer than that of mitosis. Prophase I in particular is composed of five stages: leptotene, zygotene, pachytene, diplotene, and diakinesis.</p> <p>During prophase I, homologous chromosomes form a tetrad that is composed of four chromatids. The homologous chromosomes that make up tetrads are not genetically identical because they came from two different parents.</p> <p>Prophase II will begin without having to undergo interphase. Again, the nuclear membrane disintegrates and the chromatin condenses.</p> <p>Bouquet Stage- None. Bouquet stage is the event wherein animal and plant chromosomes converge toward one side of the cell. This occurs during prophase I.</p> <p>Crossing over –None.</p> <p>Occurs during Pachytene of meiosis I. During crossing over, the chromosomes of each pair are exchange among each other.</p>
<b>Metaphase</b>	<p>During metaphase, the chromosomes align at the equatorial plate of the cell. This event is due to the presence of kinetochore microtubules that pull these chromosomes back and forth.</p> <p>Metaphase I and II of meiosis are quite similar to mitotic metaphase. During metaphase I, homologous chromosomes begin to align themselves at the equatorial plate as they bind to the mitotic spindle.</p> <p>During metaphase II, single chromosomes align at the equatorial plate after each cell is done forming the spindle fibers.</p>
<b>Anaphase</b>	<p>During this stage, each (single stranded) chromosome pair is segregated toward the opposite poles of the cell. This activity is initiated by the mitotic spindle.</p> <p>During anaphase I, (double stranded) chromosomes are separated toward each cellular pole.</p> <p>On the other hand, (single stranded) chromosomes are the ones being segregated during anaphase II.</p>



Differences Between Mitosis and Meiosis



### Asexual division

Mitosis occurs in somatic cells. Somatic cells (or vegetative cells) are cells that make up the bodies of living organisms, other than the sex cells. Somatic cells include muscle cells, bone cells, skin cells, nerve cells, etc. (collectively known as body cells)

### Sexual division

Meiosis occurs in sex cells or gametes. In animals like humans, meiosis takes place in male sperm cells and female egg cells in order to prepare them for sexual reproduction. In plants, sex cells are located in the pollen in the stamen and egg cells in the pistil.

### Duration

Mitosis involves only one cell division that is composed of four major phases: prophase, metaphase, anaphase, and telophase. Meiosis is quite longer as it involves two successive divisions that results to the reduction in chromosome number. Basically, it is divided into two: meiosis I and meiosis II. Meiosis I and II have the same phases like mitosis, only different in some events.

### Function

- Occurring in somatic cells, the main goal of mitosis is to facilitate growth, repair, and replacement. Since mitosis involves the division of somatic cells, it is really needed to produce more cells especially during the early stages of development.
- Aside from growth, it is also important to regenerate damaged and lost cells. For instance, damaged tissues can be repaired by mitosis through the production of new ones (i.e. scar tissues). Interestingly, some organisms utilize mitosis in order to replace entire body parts.
- Mitosis also occurs in prokaryotes as an essential form of asexual reproduction. Prokaryotes like bacteria reproduce through binary fission wherein they simply make duplicate copies of themselves. As a result, genetic variation is very rare.
- Meiosis occurs only in the sex cells of living organisms as a means to maintain the chromosome number of the offspring. Since fertilization involves the fusion of cells to produce a new cell, the number of alleles in their gametes should be regulated in order to avoid genetic defects.
- Another function of meiosis is the maintenance of genetic diversity on which the process of natural selection acts upon. Without it, the perpetuation of species would not be possible.

### Differences between Mitosis and Meiosis

#### 1. Cell Division

Mitosis: A somatic cell divides once. Cytokinesis (the division of the cytoplasm) occurs at the end of telophase.

Meiosis: A reproductive cell divides twice. Cytokinesis happens at the end of telophase I and telophase II.

#### 2. Daughter Cell Number

Mitosis: Two daughter cells are produced. Each cell is diploid containing the same number of chromosomes.

Meiosis: Four daughter cells are produced. Each cell is haploid containing one-half the number of chromosomes as the original cell.

#### 3. Genetic Composition

Mitosis: The resulting daughter cells in mitosis are genetic clones (they are genetically identical). No recombination or crossing over occur.

Meiosis: The resulting daughter cells contain different combinations of genes. Genetic recombination occurs as a result of the random segregation of homologous chromosomes into different cells and by the process of crossing over (transfer of genes between homologous chromosomes).

#### 4. Length of Prophase

**Mitosis:** During the first mitotic stage, known as prophase, chromatin condenses into discrete chromosomes, the nuclear envelope breaks down, and spindle fibers form at opposite poles of the cell. A cell spends less time in prophase of mitosis than a cell in prophase I of meiosis.

**Meiosis:** Prophase I consists of five stages and lasts longer than prophase of mitosis. The five stages of meiotic prophase I are leptotene, zygotene, pachytene, diplotene, and diakinesis. These five stages do not occur in mitosis. Genetic recombination and crossing over take place during prophase I.

#### 5. Tetrad Formation

**Mitosis:** Tetrad formation does not occur.

**Meiosis:** In prophase I, pairs of homologous chromosomes line up closely together forming what is called a tetrad. A tetrad consists of four chromatids (two sets of sister chromatids).

#### 6. Chromosome Alignment in Metaphase

**Mitosis:** Sister chromatids (duplicated chromosome comprised of two identical chromosomes connected at the centromere region) align at the metaphase plate (a plane that is equally distant from the two cell poles).

**Meiosis:** Tetrads (homologous chromosome pairs) align at the metaphase plate in metaphase I.

#### 7. Chromosome Separation

**Mitosis:** During anaphase, sister chromatids separate and begin migrating centromere first toward opposite poles of the cell. A separated sister chromatid becomes known as daughter chromosome and is considered a full chromosome.

**Meiosis:** Homologous chromosomes migrate toward opposite poles of the cell during anaphase

**Note:** Sister chromatids do not separate in anaphase I.

### Summary

- **Mitosis** and **meiosis** are nuclear division processes that occur during cell division.
- Mitosis involves the division of body cells, while meiosis involves the division of sex cells.
- The division of a cell occurs once in mitosis but twice in meiosis.
- **Two daughter cells** are produced after mitosis and cytoplasmic division, while **four daughter cells** are produced after meiosis.
- Daughter cells resulting from mitosis are **diploid** (2n offspring) while those resulting from meiosis are **haploid (n-offspring)**.
- Daughter cells that are the product of mitosis are genetically identical. Daughter cells produced after meiosis are genetically diverse.
- **Tetrad** formation occurs in meiosis but not mitosis.
- **There are two types of nuclear division:** Mitosis and Meiosis. Mitosis typically results in new somatic (body) cells. In animals, cell division occurs anywhere new cells are formed or as new cells replace old ones. However, some tissues in both plants and animals rarely divide once the organism is mature.

### Topic 3: Cell Transportation in Plants and Animals – Diffusion and Osmosis

<b>Content standard</b>	Students will be able to examine and make sense of the development, characteristics, processes and interactions of living things and the natural environment.
<b>Benchmark</b>	<b>9.2.2.8</b> Investigate the different cell parts, their functions, and how they are specialized into different tissue and organs.
<b>Key question</b>	How are substances transported in plants and animals?
<b>Learning objectives</b>	At the end of the topic, students can: <ul style="list-style-type: none"> <li>• Describe how substances are transported in plants and animals.</li> <li>• Investigate the similarities and differences in osmosis and diffusion.</li> </ul>
<b>Vocabulary</b>	Osmosis, diffusion, semipermeable membrane, equilibrium, solvent molecules, solute, solvent, concentration, phloem, xylem
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• The processes of osmosis and diffusion.</li> <li>• Patterns and movement of substances in osmosis and diffusion process in terms of energy and equilibrium.</li> <li>• Substances that take part in the processes of diffusion and osmosis.</li> <li>• Importance of passive transport process in both diffusion and osmosis processes.</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>• Make/use models to illustrate the processes of osmosis and diffusion.</li> <li>• Compare and contrast the two forms of transport (osmosis and diffusion) in plants and animals.</li> <li>• Evaluate how movements of particles in living cells occur in terms of energy.</li> </ul>
<b>Attitudes and values</b>	Show open-mindedness when studying diffusion in biology, physics and chemistry.
<b>Teaching and Learning strategies</b>	<ul style="list-style-type: none"> <li>• Group demonstrations</li> <li>• Teacher needs to prepare and try out the experiment prior to students doing the demonstration.</li> </ul>
<b>Assessment</b>	1. Design, experiment and explain using food colouring how diffusion occurs in terms of movement of substances and energy involved in a solution.
<b>Materials</b>	Food colouring or candy, water, plastic bags, background notes, science journal, reference books/library.

#### Content Background

Multicellular organisms require transport systems to supply their cells and remove waste products. Plants have two transport systems; plants xylem transports water and minerals, and phloem transports sugar and mineral acids dissolved in water to the plant cells. In most animals, the blood that circulates in the body distributes food and oxygen to different cells of the body. It also carries waste products to different parts of the body for excretion. Circulatory system consists of the heart and blood vessels.

A cell membrane is a special kind of barrier that holds important cell materials inside it, but allows water, gases and wastes to pass through. These substances travel across the membrane in different ways.

#### Osmosis and Diffusion

To compare and contrast these two forms of transport in plants and animals, students need to know the definitions, similarities of osmosis and diffusion and really understand what they mean.

**Osmosis:** Osmosis is the movement of solvent particles across a semipermeable membrane from a dilute solution into a concentrated solution. The solvent moves to dilute the concentrated solution and equalize the concentration on both sides of the membrane. Examples include red

blood cells swelling up when exposed to freshwater and plant root hairs taking up water. To see an easy demonstration of osmosis, soak gummy candies in water. The gel of the candies acts as a semipermeable membrane.

**Diffusion:** Diffusion is the movement of particles from an area of higher concentration to lower concentration. The overall effect is to equalize concentration throughout the medium. Examples include the scent of perfume filling a whole room and the movement of small molecules across a cell membrane. One of the simplest demonstrations of diffusion is adding a drop of food coloring to water. Although other transport processes do occur, diffusion is the key player.

### Similarities

Osmosis and diffusion are related processes that display similarities:

- Both osmosis and diffusion equalize the concentration of two solutions.
- Both diffusion and osmosis are passive transport processes, which mean they do not require any input of extra energy to occur. In both diffusion and osmosis, particles move from an area of higher concentration to one of lower concentration.

### Differences

Here's how they are different:

- Diffusion can occur in any mixture, including one that includes a semipermeable membrane, while osmosis always occurs across a semipermeable membrane.
- When people discuss osmosis in biology, it always refers to the movement of water. In chemistry, it's possible for other solvents to be involved. In biology, this is a difference between the two processes.

One big difference between osmosis and diffusion is that both solvent and solute particles are free to move in diffusion, but in osmosis, only the solvent molecules (water molecules) cross the membrane. This can be confusing because while the solvent particles are moving from higher to lower **solvent** concentration across the membrane, they are moving from lower to higher **solute** concentration, or from a more dilute solution to a region of more concentrated solution. This occurs naturally because the system seeks balance or equilibrium. If the solute particles can't cross a barrier, the only way to equalize concentration on both sides of the membrane is for the solvent particles to move in.

**You can consider osmosis to be a special case of diffusion in which diffusion occurs across a semipermeable membrane and only the water or other solvent moves.**

## Diffusion Versus Osmosis

Diffusion	Osmosis
Any type of substance moves from an area of highest energy or concentration to a region of lowest energy or concentration.	Only water or another solvent moves from a region of high energy or concentration to a region of lower energy or concentration.
Diffusion can occur in any medium, whether it is liquid, solid, or gas.	Osmosis occurs only in a liquid medium.
Diffusion does not require a semipermeable membrane.	Osmosis requires a semipermeable membrane.
The concentration of the diffusion substance equalizes to fill the available space.	The concentration of the solvent does not become equal on both sides of the membrane.
Hydrostatic pressure and turgor pressure do not normally apply to diffusion.	Hydrostatic pressure and turgor pressure oppose osmosis.
Diffusion does not depend on solute potential, pressure potential, or water potential.	Osmosis depends on solute potential.
Diffusion mainly depends on the presence of other particles.	Osmosis mainly depends on the number of solute particles dissolved in the solvent.
Diffusion is a passive process.	Osmosis is a passive process.
The movement in diffusion is to equalize concentration (energy) throughout the system.	The movement in osmosis seeks to equalize solvent concentration, although it does not achieve this.

### Facts to remember about diffusion and osmosis:

- Diffusion and osmosis are both passive transport processes that act to equalize the concentration of a solution.
- In diffusion, particles move from an area of higher concentration to one of lower concentration until equilibrium is reached. In osmosis, a semipermeable membrane is present, so only the solvent molecules are free to move to equalize concentration

### Topic 3: Photosynthesis and Respiration

<b>Content standard</b>	Students will be able to examine and make sense of the development, characteristics, processes and interactions of living things and the natural environment.
<b>Benchmark</b>	<b>9.2.2.11</b> Investigate and explain the chemical reactions that occur in photosynthesis and cellular respiration and that results in cycling of energy.
<b>Key question</b>	How do plants and animals carry out the processes of photosynthesis and respiration?
<b>Learning objectives</b>	By the end of the topic, all students can:
<b>Vocabulary</b>	Photosynthesis, chloroplast, chlorophyll, glucose, cell membrane, oxygen, carbon dioxide,
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• Functions of mitochondria</li> <li>• Functions of cell membrane</li> <li>• Functions of chloroplast</li> </ul>
<b>Skills</b>	
<b>Attitudes and values</b>	
<b>Teaching and Learning strategies</b>	
<b>Assessment</b>	
<b>Materials</b>	

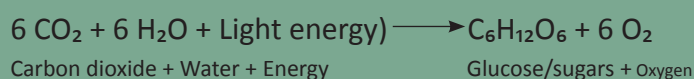
#### Content Background

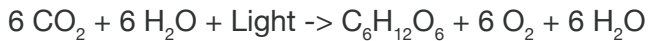
All living things need energy to survive. Plants use a process called **Photosynthesis** to make food by harnessing the energy of sunlight. This process takes place in **chloroplasts**, and depends on the green pigment called the **chlorophyll**. Chlorophyll captures energy from sunlight. During photosynthesis, a remarkable series of chemical reactions join water from the ground with carbon dioxide from the air. The by-products are oxygen, which the plant releases into the air, and a molecule called **glucose**. Glucose is one of the high energy compounds that are classified as sugars. Plants use sugars for food including animals which depend of plants for their food.

#### Photosynthesis

##### Photosynthesis Definition

Photosynthesis is the biochemical pathway which converts the energy of light into the bonds of glucose molecules. The process of photosynthesis occurs in two steps. In the first step, energy from light is stored in the bonds of *adenosine triphosphate* (ATP), and *nicotinamide adenine dinucleotide phosphate* (NADPH). These two energy-storing cofactors are then used in the second step of photosynthesis to produce organic molecules by combining carbon molecules derived from carbon dioxide (CO<sub>2</sub>). The second step of photosynthesis is known as the [Calvin Cycle](#). These organic molecules can then be used by [mitochondria](#) to produce ATP, or they can be combined to form glucose, [sucrose](#), and other carbohydrates. The chemical equation for the entire process can be seen



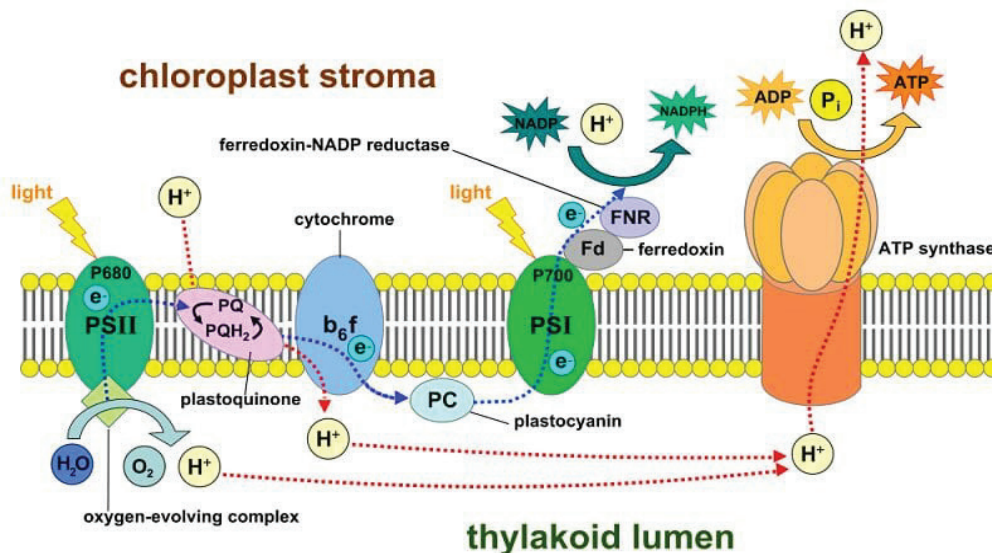


Above is the overall reaction for photosynthesis. Using the energy from light and the hydrogens and electrons from water, the [plant](#) combines the carbons found in carbon dioxide into more complex molecules. While a 3-carbon [molecule](#) is the direct result of photosynthesis, glucose is simply two of these molecules combined and is often represented as the direct result of photosynthesis due to glucose being a foundational molecule in many cellular systems. You will also notice that 6 gaseous oxygen molecules are produced, as a by-product. The plant can use this oxygen in its mitochondria during [oxidative phosphorylation](#). While some of the oxygen is used for this purpose, a large portion is expelled into the atmosphere and allows us to breathe and undergo our own oxidative phosphorylation, on sugar molecules derived from plants. You will also notice that this equation shows water on both sides. That is because 12 water molecules are split during the light reactions, while 6 new molecules are produced during and after the Calvin cycle. While this is the general equation for the entire process, there are many individual reactions which contribute to this pathway.

## Stages of Photosynthesis

### The Light Reactions

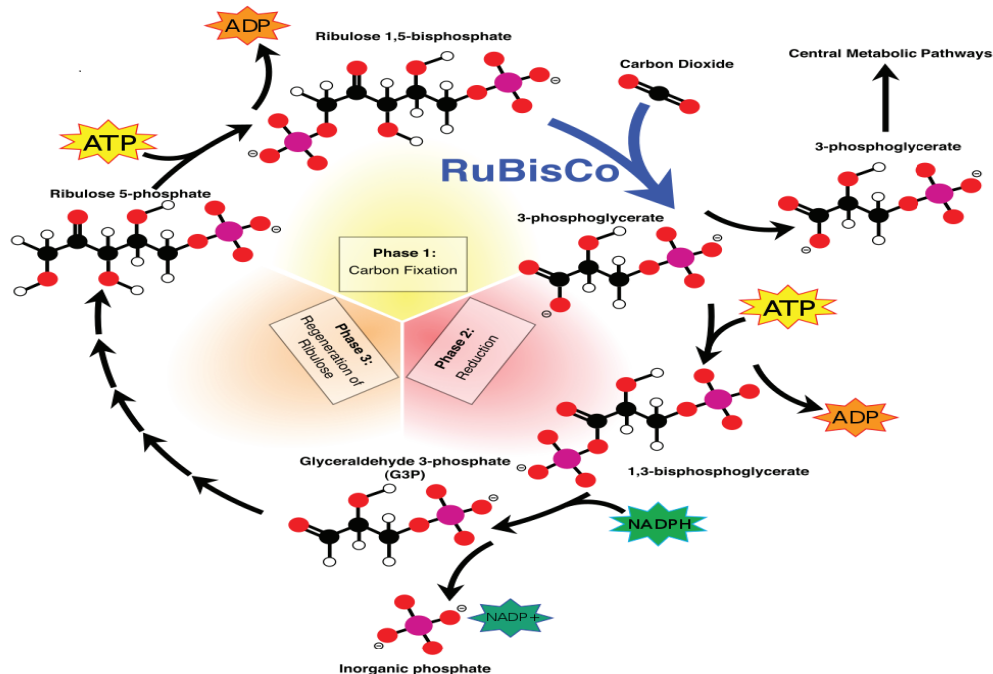
The light reactions happen in the *thylakoid membranes* of the chloroplasts of plant cells. The thylakoids have densely packed protein and enzyme clusters known as *photosystems*. There are two of these systems, which work in conjunction with each other to remove electrons and hydrogens from water and transfer them to the cofactors ADP and NADP<sup>+</sup>. These photosystems were named in the order of which they were discovered, which is opposite of how electrons flow through them. As seen in the image below, electrons excited by light energy flow first through *photosystem II* (PSII), and then through *photosystem I* (PSI) as they create NADPH. ATP is created by the protein [ATP synthase](#), which uses the build-up of hydrogen atoms to drive the addition of phosphate groups to ADP.



The entire system works as follows. A photosystem is comprised of various proteins that surround and connect a series of *pigment molecules*. Pigments are molecules that absorb various photons, allowing their electrons to become excited. [Chlorophyll a](#) is the main pigment used in these systems, and collects the final energy transfer before releasing an electron. Photosystem II starts this process of electrons by using the light energy to split a water molecule, which releases the hydrogen while siphoning off the electrons. The electrons are then passed through plastoquinone, an enzyme complex that releases more hydrogens into the *thylakoid space*. The electrons then flow through a cytochrome complex and plastocyanin to reach photosystem I. These three complexes form an [electron transport chain](#), much like the one seen in mitochondria. Photosystem I then uses these electrons to drive the reduction of NADP<sup>+</sup> to NADPH. The additional ATP made during the light reactions comes from ATP synthase, which uses the large gradient of hydrogen molecules to drive the formation of ATP.

## The Calvin Cycle

With its *electron carriers* NADPH and ATP all loaded up with electrons, the plant is now ready to create storable energy. This happens during the *Calvin Cycle*, which is very similar to the citric acid cycle seen in mitochondria. However, the citric acid cycle creates ATP other electron carriers from 3-carbon molecules, while the Calvin cycle produces these products with the use of NADPH and ATP. The cycle has 3 phases, as seen in the graphic below.

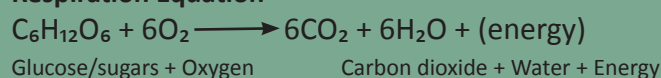


During the first phase, a carbon is added to a 5-carbon sugar, creating an unstable 6-carbon sugar. In phase two, this sugar is reduced into two stable 3-carbon sugar molecules. Some of these molecules can be used in other metabolic pathways, and are exported. The rest remain to continue cycling through the Calvin cycle. During the third phase, the five-carbon sugar is regenerated to start the process over again. The Calvin cycle occurs in the *stroma* of a *chloroplast*. While not considered part of the Calvin cycle, these products can be used to create a variety of sugars and structural molecules.

## Products of Photosynthesis

The direct products of the light reactions and the Calvin cycle are 3-phosphoglycerate and G3P, two different forms of a 3-carbon sugar molecule. Two of these molecules combined equals one glucose molecule, the product seen in the photosynthesis equation. While this is the main food source for plants and animals, these 3-carbon skeletons can be combined into many different forms. A structural form worth note is *cellulose*, and extremely strong fibrous material made essentially of strings of glucose. Besides sugars and sugar-based molecules, oxygen is the other main product of photosynthesis. Oxygen created from photosynthesis fuels every respiring *organism* on the planet.

### Respiration Equation



Photosynthesis involves the use of energy from sunlight, water and carbon dioxide to produce glucose and oxygen to produce carbon dioxide and water.

## Topic 4: Tissues and Organs in Plants and Animals

<b>Content standard</b>	Students will be able to examine and make sense of the development, characteristics, processes and interactions of living things and the natural environment.
<b>Benchmark</b>	<b>9.2.2.10</b> Explore the differences between the processes of mitosis and meiosis.
<b>Key question</b>	What are the tissues and organs in plants and animals, including their functions?
<b>Learning objectives</b>	At the end of the topic, students can: <ul style="list-style-type: none"> <li>Investigates different tissues and organs and their functions in plant and animal structures and systems.</li> </ul>
<b>Vocabulary</b>	Tissues, organs, villi, xylem, phloem, capillaries, veins
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>Different tissue and organ systems of plants</li> <li>Different tissue and organs of animals</li> <li>How tissue and organ systems work in plants</li> <li>How tissue and organ systems work in animals</li> <li>Health related problems involving human tissue and organ systems</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>Identify structures and functions of different systems in plants and animals.</li> <li>Compare and contrast the different tissue and organ systems of animals and plants.</li> <li>Evaluate health related problems/issues of the heart, liver and lungs.</li> </ul>
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>Respect and care for your body systems, including health related problems of the heart, liver, and lungs.</li> <li>Value and care for plants because their functions depend on the tissues and organs they have.</li> </ul>
<b>Teaching and Learning strategies</b>	<ul style="list-style-type: none"> <li>Groups and individual work</li> <li>Teacher to provide more background information on plants and animals tissues and organs</li> </ul>
<b>Assessment</b>	1. Compare and explain the relationship between two organ systems in a human body that work together through research and presentation.
<b>Materials</b>	Charts of tissue and organ systems of plants and animals, science journal, background information on the types of health related problems of human body systems.

### Content Background

Plants and animals have life systems that enable them to survive. Animal systems relate to major structures that support their functions (teeth break down food, the stomach digests food, bones support the body, lungs take in air, and the heart circulates blood). Animal systems relate to major structures that support their functions (roots absorb water and anchor the plant, leaves make food, the stem transports water and food, petals attract pollinators, flowers produce seeds, and seeds produce new plants).

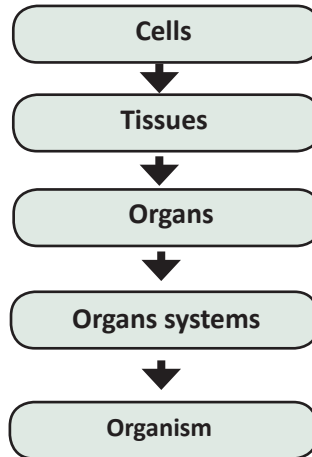
### Tissues

Complex organisms (multicellular organisms) have many type cells. Each cell has special structures that allow it to carry out specific tasks. A group of cells that has a common structure and function is called a tissue. Both plants and animals have tissues that perform specific jobs. For example, the tissue covering a plant's leaves protect the leaves, while underlying leaf tissues perform photosynthesis. Most multicellular organisms have a variety of tissues. Apart from these main tissues, there are also other important tissues in animals including, villi, muscles, and nerves. In plants, xylem and phloem vessels are special tissues that transport water, minerals and nutrients from the soil to and from all cells and parts of the plants. In plant leaves, the exchanges of gases are done through the stomata and are transported to all parts of the plant through phloem vessels.

**Organs**

Organs are made of several tissue types that work together to perform one or more functions. A plant's leaves are organs, as are its roots and flowers.

The brain, heart, and liver are three human organs. Some organs like kidneys perform more than one function. Kidneys remove wastes from the body and also help control blood pressure. Organ systems include; circulatory system, musculoskeletal system, respiratory system, and nervous system.

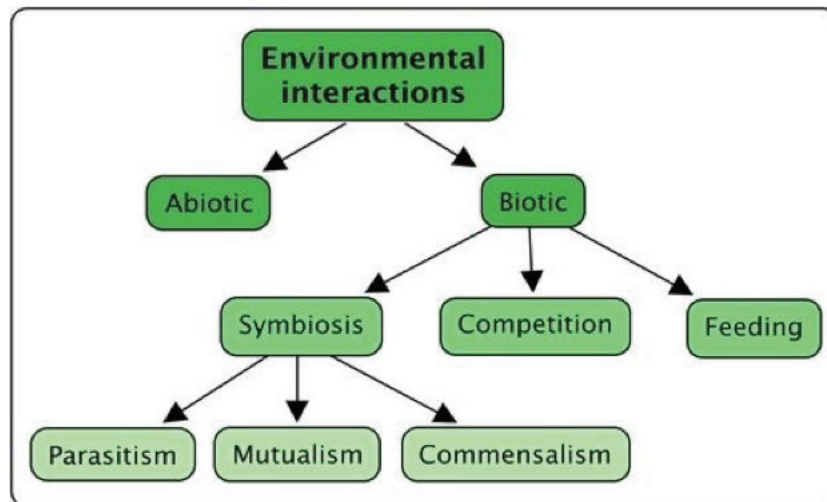
**Summary of tissues and organs in plants and animals**

## Unit 9.5: Interactions and Relationships in the Environment

In ecology, a biological interaction is the effect that a pair of organisms living together in a community have on each other. They can be either of the same species (intraspecific interactions), or of different species (interspecific interactions). These effects may be short-term, like pollination and predation, or long-term; both often strongly influence the evolution of the species involved. A long-term interaction is called a symbiosis. Symbioses range from mutualism, beneficial to both partners, to competition, harmful to both partners. Interactions can be indirect, through intermediaries such as shared resources or common enemies. This type of relationship can be shown by net effect based on individual effects on both organisms arising out of relationship.

Several recent studies have suggested non-trophic species interactions such as habitat modification and mutualisms can be important determinants of food web structures. However, it remains unclear whether these findings generalize across ecosystems, and whether non-trophic interactions affect food webs randomly, or affect specific trophic levels or functional groups.

Although biological interactions, more or less individually, were studied earlier, Edward Haskell (1949) gave an integrative approach to the thematic, proposing a classification of “co-actions”, later adopted by biologists as “interactions”. Close and long-term interactions are described as symbiosis, symbioses that are mutually beneficial are called mutualistic. The mind map below shows a typical illustration of this relationship in a biome.

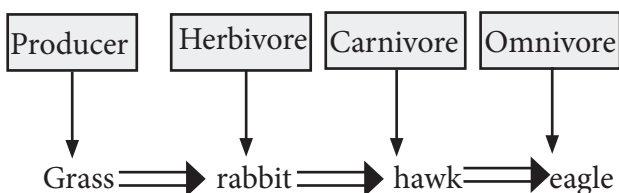


Topic 1: Food Chains and Food Webs	
<b>Content standard</b>	Students will be able to examine and make sense of the development, characteristics, processes and interactions of living things and the natural environment.
<b>Benchmark</b>	<b>9.2.2.11</b> Investigate and explain the chemical reactions that occur in photosynthesis and cellular respiration and that results in cycling of energy.
<b>Key question</b>	<ul style="list-style-type: none"> <li>What are the main parts of a food web?</li> </ul>
<b>Learning objectives</b>	At the end of the topic, students can: <ul style="list-style-type: none"> <li>Explain how each species in an ecosystem depends on each other.</li> <li>Investigate the roles each part of the food web plays in an ecosystem.</li> </ul>
<b>Vocabulary</b>	Food chain, food web, ecosystem, producers, herbivores, carnivores, omnivores, and decomposers, niche
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>Similarities between food chains and food webs</li> <li>Parts of a food web</li> <li>Role or niche of species in an ecosystem</li> <li>Effects of insecticides on food webs</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>Classify different species in an ecosystem.</li> <li>Evaluate which species or organism belongs to a food web.</li> </ul>
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>Appreciate the importance and the roles the decomposers and other parts of the food web in an ecosystem.</li> </ul>
<b>Teaching and Learning strategies</b>	<ul style="list-style-type: none"> <li>Group work on different types of food webs in different ecosystem.</li> <li>Teacher to research and find out more about the discovery of biomagnification from biologists such as Rachel Carson.</li> </ul>
<b>Assessment</b>	1. Research a daily life of a selected species and present findings on how it lives in that ecosystem.
<b>Materials</b>	Charts, science folio, also search online for <a href="http://www.eduplace.com/scp/">www.eduplace.com/scp/</a>

### Content Background

As you learned in topic 3 as well as in primary level, energy and nutrients are transferred from plants to animals. A food chain describes the transfer of energy from producers to consumers. A group of overlapping (energy transfer from and to more than one organism) within food chains form a food web.

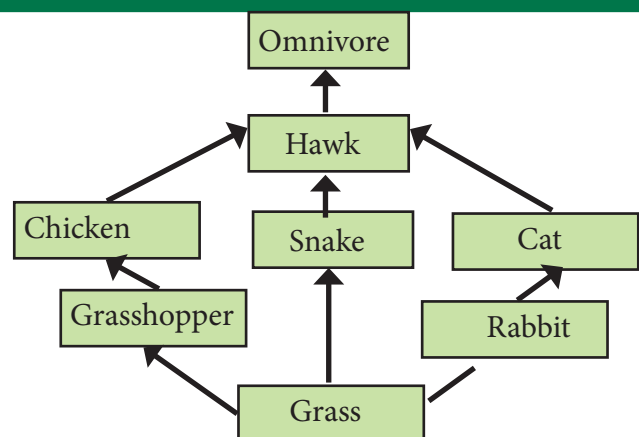
#### Example of a food chain and parts in the ecosystem



#### Decomposers

– Organisms such as worms and microbes that feed on dead plants and animals, breaking them down into nutrients that enrich the soil for plants to use again.

#### Example of a food web



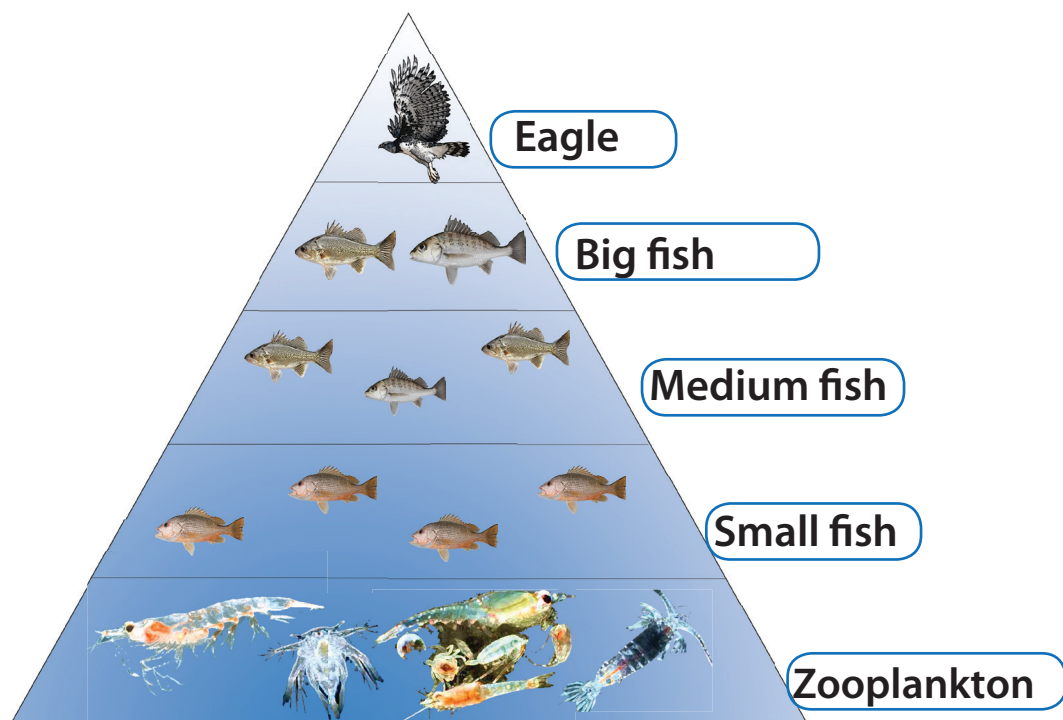
A food web shows the feeding relationships, or transfer of energy within an ecosystem. Although each ecosystem has a different food web, all food webs have the same parts: producers, herbivores, carnivores, omnivores, and decomposers. These parts are also organised in the same way.

Producers are always found at the bottom of the food web. Producers like plants and algae use the energy of the sun to make food. This energy passes to herbivores, which are plant-eating animals. Herbivores are primary consumers, the first order of animals in any food chain. Animals that eat herbivores are called carnivores because they get their energy from eating other animals. Omnivores get their energy from eating both animals and plants. Carnivores and omnivores are found at or near the top of the food web.

Decomposers are organisms that feed on dead plants and animals, breaking them down into nutrients that enrich the soil. This transfer of nutrients from plant to animals to decomposers and back to plants, occurs in every ecosystem. Thus, a food web shows all the feeding relationships in an ecosystem. Some examples of ecosystems are; grassland, pond, sea, forest, desert, seashore, mountain, and swamp. In healthy ecosystems, populations of each species are relatively stable. Each population is big enough to reproduce and small enough so that it does not use up all of its food resources. In most ecosystems, there are the top carnivores such as lions and eagles. These organisms play an important role in ensuring that an ecosystem is healthy because they cannot survive without healthy numbers of other plant and animal populations.

### Biomagnification

As each animal feeds, energy and nutrients pass up the food web. Along with energy and nutrients, toxins from chemicals such as DDT (insecticide) may pass up the food chain and remain in the body of the organisms that eat them. If these organisms are eaten, the toxins are passed up the food chain. Animals at the top of the food chain contain the highest concentration of the toxins because they receive these from all the animals at the lower levels. This effect is called biomagnification. And it is important to note that natural processes do not break down the insecticide DDT, so it concentrates in animals at the top of the food chain, as shown in the diagram below.



## Topic 2: Plant and Animal Adaptations

<b>Content standard</b>	Students will be able to examine and make sense of the development, characteristics, processes and interactions of living things and the natural environment.
<b>Benchmark</b>	<b>9.2.2. 19</b> Assess dynamic equilibrium in organisms, populations and ecosystems and explain the effect of equilibrium shifts. <b>9.2.2.20</b> Investigate and describe environmental factors and personal choices that may lead to a genetic mutation or changes in an organism's development.
<b>Key question</b>	What are some causes and effects of organisms' population and adaptation in an ecosystem?
<b>Learning objectives</b>	At the end of the topic, students can: <ul style="list-style-type: none"> <li>Identify the causes and effects of organisms' population and their adaptation in different ecosystems.</li> <li>Describe environmental factors and personal choices that may lead to a genetic mutation or changes in an organism's development.</li> <li>Investigate the effects of equilibrium shifts.</li> </ul>
<b>Vocabulary</b>	Adaptation, equilibrium shift, ecosystem, population, genetic mutation, environmental factors
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>Causes and effects of equilibrium shifts</li> <li>Plants and animals adaptation</li> <li>Population and ecosystems</li> <li>Environmental factors or personal choices that may lead to an organism's genetic mutation.</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>Analyse environmental factors that can result in equilibrium shifts.</li> <li>Evaluate different ways that a plant or animal can adapt</li> <li>Explore examples of genetic mutation</li> </ul>
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>Develop and sense of safe and peaceful communities for all organisms in an ecosystem.</li> <li>Show respect for all plant and animal ecosystems, including national parks and wild-life populations.</li> </ul>
<b>Teaching and Learning strategies</b>	<ul style="list-style-type: none"> <li>Group work</li> <li>Excursions into national parks</li> <li>Teacher to plan and organise class/grade excursion to reserve parks etc; with guided interview/questionnaires for students to complete.</li> </ul>
<b>Assessment</b>	1. Design a set of research questions to be used during an excursion to a reserved park for plants or animals and present findings others.
<b>Materials</b>	Science journal, questionnaires, record sheets for data compilation and presentation, camera.

### Content Background

#### Inheritance and reproduction strategies:

Recognize that plants and animals reproduce with their own kind to produce offspring with features that closely resemble those of the parents; recognize and explain that some features are the result of interactions with the environment, such as a plant's height being related to the amount of sunlight it receives, or a baby animal not gaining weight because it is not getting enough food.

Recognize and explain that some features that are inherited from parents help living things survive, such as the waxy coating on some plants' leaves helping the plants stay alive in dry climates or an animal's colouring helping it hide from predators.

Identify and describe different strategies that increase the numbers of offspring that survive, such as a plant producing many seeds or mammals caring for their young.

#### Responses of living things to environmental conditions:

A. Describe the effect of lack of water and lack of sunlight on plants.

B. Describe how different animals respond to high and low temperatures, and to danger.

C. Describe humans' bodily responses to exercise and to high and low temperatures.

### Topic 3: Species, Population and Habitats

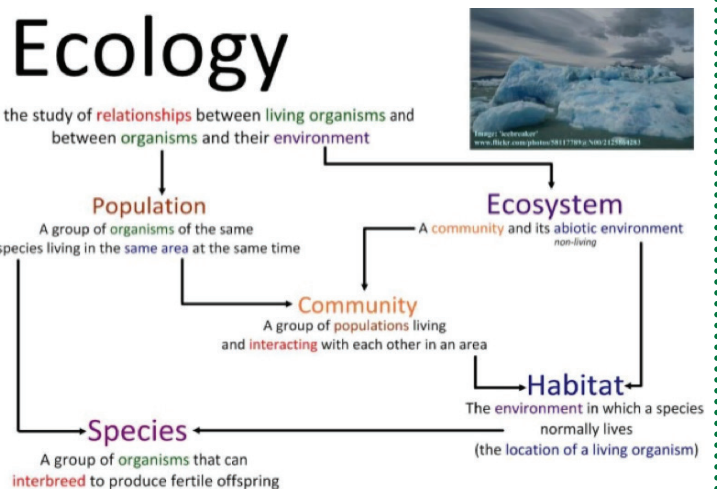
<b>Content standard</b>	Students will be able to examine and make sense of the development, characteristics, processes and interactions of living things and the natural environment.
<b>Benchmark</b>	<b>10.2.1.7</b> Examine the dynamic equilibrium in organisms, populations, and ecosystems and explain the effect of equilibrium shifts.
<b>Key question</b>	How is the dynamic equilibrium of organisms related to populations and ecosystems?
<b>Learning objectives</b>	<ul style="list-style-type: none"> <li>Investigate the equilibrium dynamics in organisms and its relationship to populations of organisms and their ecosystems and the effects of equilibrium shifts.</li> <li>Describe equilibrium in organisms, populations and ecosystems and the effects if there is a shift</li> </ul>
<b>Vocabulary</b>	Dynamic equilibrium, equilibrium shifts, habitat, population, ecosystem, species
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>Causes and effects of equilibrium shifts in different ecosystems</li> <li>Population, species, and habitats</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>Explain equilibrium in organisms, populations and ecosystems and how they are linked/ relate.</li> <li>Investigate the dynamic equilibrium in organisms, populations and ecosystems.</li> </ul>
<b>Attitudes and values</b>	Promote sustainability and inter-relationships amongst all life in the communities.
<b>Teaching and Learning strategies</b>	Inquiry based
<b>Assessment</b>	<ol style="list-style-type: none"> <li>Human populations are rapidly growing in some countries, including PNG. How are people finding the food, water, and land they need? Are these factors limiting population growth? Research how people meet their basic needs in your community or elsewhere.</li> </ol>
<b>Materials</b>	

### Content Background

Ecologists often work at five broad levels, sometimes discretely and sometimes with overlap: organism, population, community, ecosystem, and biosphere. Organisms make up a population. Multiple populations of different species make up a community. Communities in a particular area make up an ecosystem.

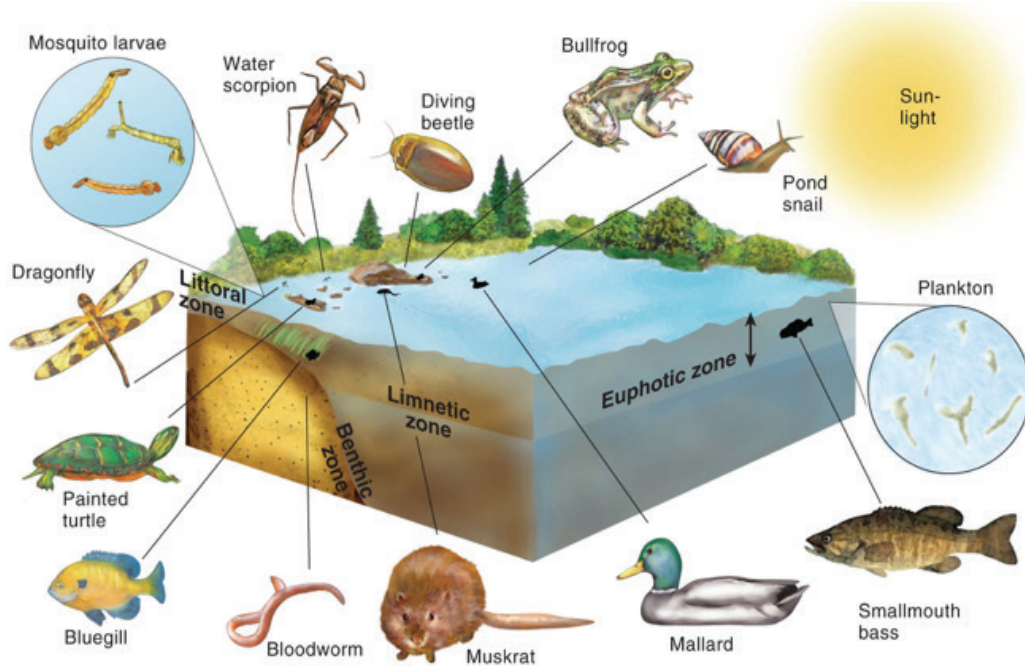
What is the relationship between species population community ecosystem and biome?

A community is all of the populations of different species that live in the same area and interact with one another. A community is composed of all of the biotic factors of an area. An ecosystem includes the living organisms (all the populations) in an area and the non-living aspects of the environment



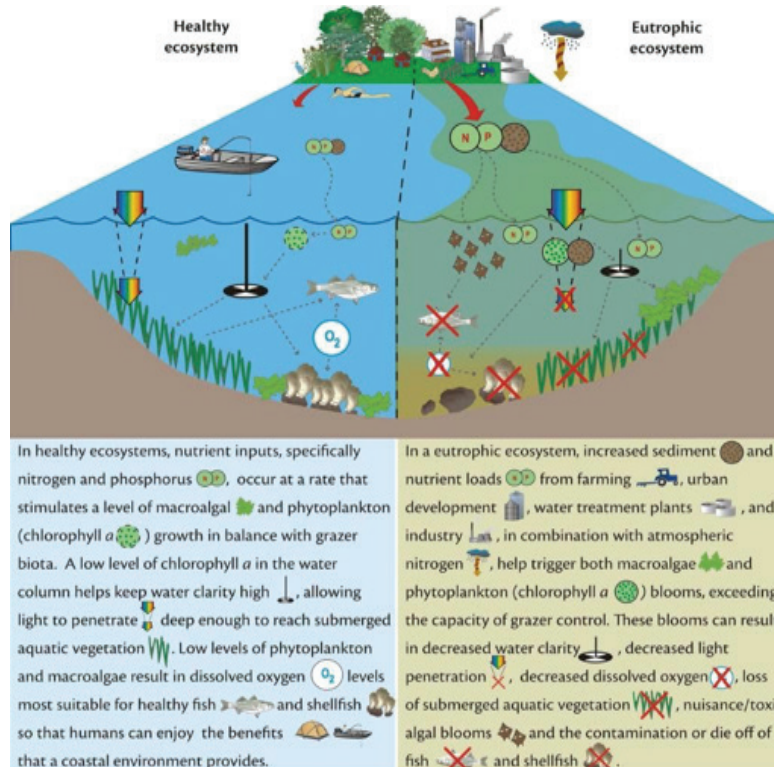
### What are all the populations in an ecosystem?

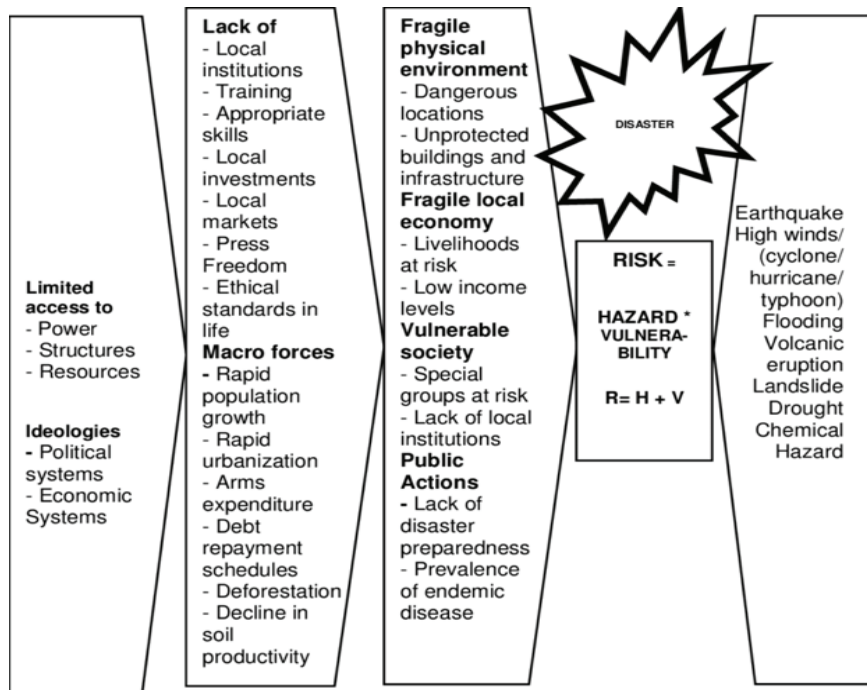
All the populations in an ecosystem are called a community. When you combine the living factors of a community together with the non-living factors of the area it lives in, you have an ecosystem. The non-living factors of an ecosystem would be water, soil, temperature, light, and climate. An example of an ecosystem is shown in the picture below.



Below are (diagram 1) an example of healthy and eutrophic (polluted) ecosystems, and (2) some causes or factors that contribute to the destruction of an ecosystem.

Diagram 1: An example of healthy and eutrophic (polluted) ecosystems





### Activities (case studies)

In groups, study the three natural and man-made hazards on the environment in PNG described below and identify sources, causes, effects and possible solutions to these. The third photo (Case 3) is only photo. Identify what it is and apply the same strategy as in Case 1 and 2 to identify possible solutions for the problem.

#### Case 1.

Flow characteristics in the Markham delta have been observed from preliminary geological (Liu et al., 1995) and hydrographic (Buleka et al., 1999) studies. Grab samples between the river mouth and 300 m water depth show that the channel floor contains sand and gravel suggesting very energetic sea floor currents capable of transporting coarse sediment. Turbidity currents are likely to be generated at the river mouth and were the suggested cause of damage to SEACOM submarine cables crossing the New Britain trench at water depths of 6000 m.

#### Case 2.

On a wider scale in the actively seismic zone of the northern coast of PNG, the 1998 tsunami occurred with 15 m waves battering the Sissano lagoon (McSaveney et al., 2000; Tappin et al., 2001). Slope failures are most likely to occur on high relief canyon walls, sometimes aided by the low-yield strength of unconsolidated muddy seafloor sediments.

#### Case 3.



# STRAND 3: PHYSICAL SCIENCE

## Unit 9.6: Matter and Energy

This unit provides students with the opportunity to examine the interactions among elements as they form compounds through chemical reactions. Students become familiar with the formulas and naming of binary compounds, and investigate the Law of Conservation of Mass. The recognition that mass is conserved in chemical reactions allows students to balance equations with both words and symbols, and classify them by type. The principles of acid-base chemistry are studied and extended to large-scale environmental interactions. Students investigate the use of chemistry in biological, industrial, and domestic settings, recognizing that chemical use is common in modern society.

This cluster builds on the particle theory of matter learned in previous grades. Students become familiar with the basic constituents of matter by learning about the historical development of the atomic model and the periodic table. Various investigations of the properties of elements and compounds will acquaint students with chemical symbols and families, as well as with natural phenomena and everyday technologies that demonstrate chemical change.

Topic 1: Physical and Chemical Properties of Matter	
<b>Content standard</b>	Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy.
<b>Benchmark</b>	9.3.3.1 Distinguish between physical and chemical properties.
<b>Key question</b>	What is the difference between physical change and chemical change?
<b>Learning objectives</b>	By the end of the topic, the students can: 1. Analyse and justify the difference between physical and chemical change. 2. Define and explain physical and chemical properties of pure and impure substances. 3. Distinguish between a mixture and a compound
<b>Vocabulary</b>	• Heterogeneous mixtures, Homogeneous mixtures, colloids, composite materials, binary compounds, poly-elemental compounds, precipitate, suspension, toxic, lustre,
<b>Knowledge</b>	• Physical properties can be measured without changing a substance's chemical identity. • Chemical properties can be measured only by changing a substance's chemical identity.
<b>Skills</b>	• Careful observation of physical and chemical reactions,
<b>Attitudes and values</b>	• Patient in observation, sceptical about physical and chemical reactions.
<b>Teaching and Learning strategies</b>	Teacher to provide handouts on matter and its properties, different types of mixtures and compounds with their chemical and physical properties.
<b>Assessment</b>	1. Explain why clear lime water turns milky when carbon dioxide reacts with it.
<b>Materials</b>	Lime, water, plastic bottle, straw

### Content Background

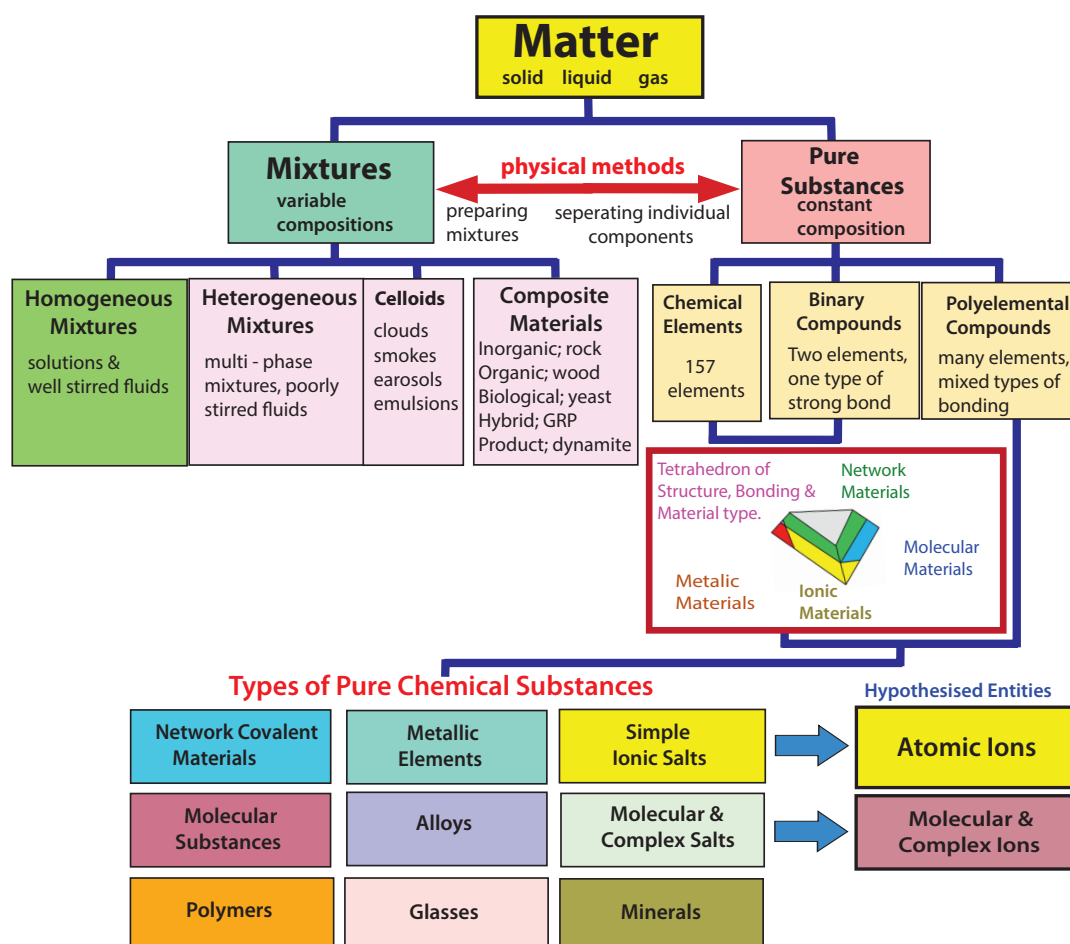
Matter can be classified according to physical and chemical properties. Matter is anything that occupies space and has mass. The three states of matter are solid, liquid, and gas. A physical change involves the conversion of a substance from one state of matter to another, without changing its chemical composition.

Students could take part in a brainstorming or KWL session to activate student's prior knowledge about chemical and physical properties. Teachers should remind students that they investigated the physical properties of various minerals in earlier grades, The Earth's Crust. These included colour, texture, streak, lustre, and hardness. Teachers could demonstrate the chemical properties of selected minerals by adding vinegar or dilute hydrochloric acid to limestone and quartz.

Students could be asked to compare the physical and chemical properties of a group of similar objects such as different types of gloves (e.g., oven mitts, latex gloves, ski-doo gloves). Students should recognize that the material which is used to construct the glove is chosen based on its physical and chemical properties so that they match the intended use of the glove. For example, the physical property of a ski-doo glove may include: bright, shiny colours to reflect light (to become more visible), exterior material must be water repellent, and a good insulating interior material. Chemical properties may include the use of a fire retardant material. In this particular example, manufacturers may not consider the chemical properties of the ski-doo glove to be the most important. As a point of interest, teachers could inform students that toxicity is a chemical property. Different substances have different levels of toxicity ranging from none to very poisonous.

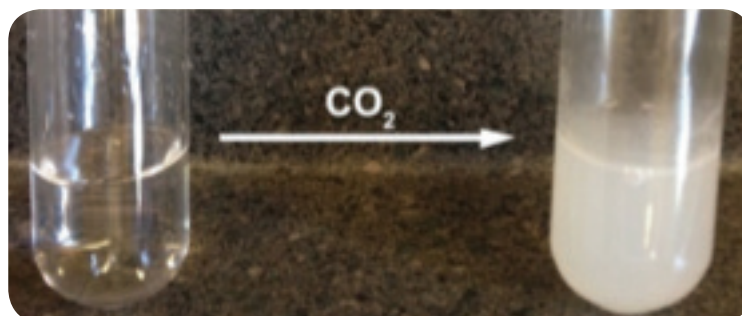
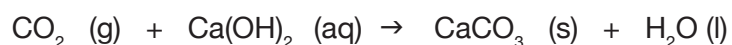
Students are expected to:

- Investigate materials and describe them in terms of their physical properties and chemical properties.
- Distinguish between physical and chemical properties - list examples of physical and chemical properties. Include: These include, Physical (i) colour (ii) malleability (iii) electrical conductivity (iv) magnetism (v) lustre (vi) density (vii) melting/boiling points (viii) texture Chemical (i) combustibility (ii) reactivity.



**How does Carbon Dioxide react with Lime Water?**

Carbon dioxide reacts with lime water to form calcium carbonate, which precipitates out of the solution. Calcium carbonate is chalk, and when it is produced, it precipitates and solid particles of chalk appear. The appearance of the solid makes the liquid appear milky. The white milky suspension/precipitate is caused by the formation of calcium carbonate. The characteristic test for CO<sub>2</sub> is checking that the lime water is milky. Bubbling carbon dioxide through the solution for an extended period of time makes the solution become clear and colourless. This happens as the carbon dioxide forms acidic carbonic acid when it dissolves in the water, the carbonic acid (H<sub>2</sub>CO<sub>3</sub>) reacts further with the calcium carbonate.

**Written as an equation**

## Topic 2: Acids, Bases and their Applications

<b>Content standard</b>	Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy.
<b>Benchmark</b>	<b>9.3.3.1</b> Distinguish between physical and chemical properties.
<b>Key questions</b>	1. What are some common examples of acids that can be found at home? 2. What are some common bases that can be found at home?
<b>Learning objectives</b>	By the end of this topic, students can: • Investigate and describe acids and bases using their chemical properties. • Describe the applications of acids and bases in industries and in their everyday lives.
<b>Vocabulary</b>	• Acidic, Basic, alkaline, Neutralisation, ion, cation, anion, valency, indicators, litmus paper
<b>Knowledge</b>	• Acid-base reaction is a neutralisation reaction. • pH scale indicates how acidic or basic a solution is.
<b>Skills</b>	• Identifying solutions and liquids as acids or bases.
<b>Attitudes and values</b>	• Sense of cautious and appreciate the processes of producing salts. Value the importance of acids and bases in nature and life.
<b>Teaching and Learning strategies</b>	Teacher to provide handouts for students, prepare lab lesson with procedures and materials as outlined in the content background.
<b>Assessment</b>	1. Use the pipette to add 20 mL of the sodium hydroxide solution to a volumetric flask. Fill up to the mark with water and shake well. Much hydrochloric acid is added to neutralise the solution. Conduct research and present findings on how acids and bases are useful or harmful to humans
<b>Materials</b>	Volumetric flask, conical flasks, sodium hydroxide solution, hydrochloric acid solution, pipette and indicator

### Content Background

#### Acid

An *acid* is a substance that gives away hydrogen ions ( $H^+$ ). For this reason, when an acid is dissolved in water, the balance between hydrogen ions and hydroxide ions ( $OH^-$ ) is shifted. There will be more hydrogen ions than hydroxide ions in the solution. This kind of solution is **acidic**.

When acid is added to water, it:

- taste sour,
- changes the colour of litmus paper to red
- reacts with some metals (eg. iron) to release hydrogen, and
- reacts with base to form salts.
- promotes certain chemical reactions (eg, acid catalysis)

#### Base

A *base* is a substance that takes in hydrogen ions ( $H^+$ ). When a base is dissolved in water, the balance between hydrogen ions and hydroxide ions ( $OH^-$ ) shifts the opposite way. Being the cause that the base “soaks up” hydrogen ions, the result are that a solution with more hydroxide ions than hydrogen ions. This kind of solution is alkaline or basic solution.

Bases are substances that taste bitter and change the colour of red litmus paper to blue. Bases react with acids to form salts and promote certain chemical reactions (base catalysis).

#### Acid-Base Reaction

A chemical reaction that occurs between an acid and a base is called an acid-base reaction or neutralisation reaction. Often when an acid and base react, a salt and water will be formed.

**Example 1**

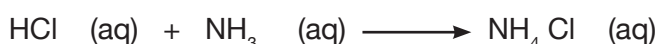
Hydrochloric acids react with sodium hydroxide to form sodium chloride (a salt) and water. Sodium chloride is made up of  $\text{Na}^+$  cations from the base (NaOH) and  $\text{Cl}^-$  anions from the acid (HCl).

**Example 2**

Hydrogen bromide reacts with potassium hydroxide to form bromide (a salt) and water. Potassium bromide is made up of  $\text{K}^+$  cations from the base (KOH) and  $\text{Br}^-$  anions from the acid (HBr).

**Example 3**

Hydrochloric acid reacts with ammonia to form ammonium chloride (a salt). Ammonium chloride is made up of  $\text{NH}_4^+$  cations from the base ( $\text{NH}_3$ ) and  $\text{Cl}^-$  anions from the acid (HCl).



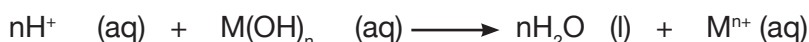
Note that in the first two examples, the base contained  $\text{OH}^-$  ions, and therefore the products were a salt and water. NaCl (table salt) and KBr are both salts. In the third example,  $\text{NH}_3$  also acts as a base, despite not having  $\text{OH}^-$  ions. A salt is still formed as the only product, but no water is produced.

**Acid and Metal Hydroxides**

When an acid reacts with a metal hydroxide a salt and water are formed. This is briefly explained in above examples. Some examples are:

- $\text{HCl (aq)} + \text{NaOH (aq)} \longrightarrow \text{H}_2\text{O (l)} + \text{NaCl (aq)}$
- $2\text{HBr (aq)} + \text{Mg(OH)}_2 \text{ (aq)} \longrightarrow 2\text{H}_2\text{O (l)} + \text{MgBr}_2 \text{ (aq)}$
- $3\text{HCl (aq)} + \text{Al(OH)}_3 \text{ (aq)} \longrightarrow 3\text{H}_2\text{O (l)} + \text{AlCl}_3 \text{ (aq)}$

We can write a general equation for this type of reaction:



Where n the group is number of the metal and M is the metal.

**Acid and Metal Oxide**

When an acid reacts with a metal oxide a *salt* and *water* are also formed. Some examples are:

- $2\text{HCl (aq)} + \text{Na}_2\text{O (aq)} \longrightarrow \text{H}_2\text{O (l)} + 2\text{NaCl (aq)}$
- $2\text{HBr (aq)} + \text{MgO (aq)} \longrightarrow \text{H}_2\text{O (l)} + \text{MgBr}_2 \text{ (aq)}$
- $6\text{HCl (aq)} + \text{Al}_2\text{O}_3 \text{ (aq)} \longrightarrow 3\text{H}_2\text{O (l)} + 2\text{AlCl}_3 \text{ (aq)}$

Now we can write a general equation for the reaction of a metal oxide with an acid.

eg: The general equation that must be understood for all metal oxides with acid reactions is:



Where n is the group number of the metal, the x and y represents the ratio in which the metal combines with the oxide and depends on the valency of the metal.

## Acid and a Metal Carbonate

When an acid reacts with a metal carbonate a salt, carbon dioxide and water are formed. Look at the following examples:

1. Nitric acid reacts with sodium carbonate to form sodium nitrate, carbon dioxide and water.



2. Sulphuric acid reacts with calcium carbonate to form calcium sulphate, carbon dioxide and water.



3. Hydrochloric acid reacts with calcium carbonate to form calcium chloride, carbon dioxide and water.



When balancing out, don't forget to use the general equation above.

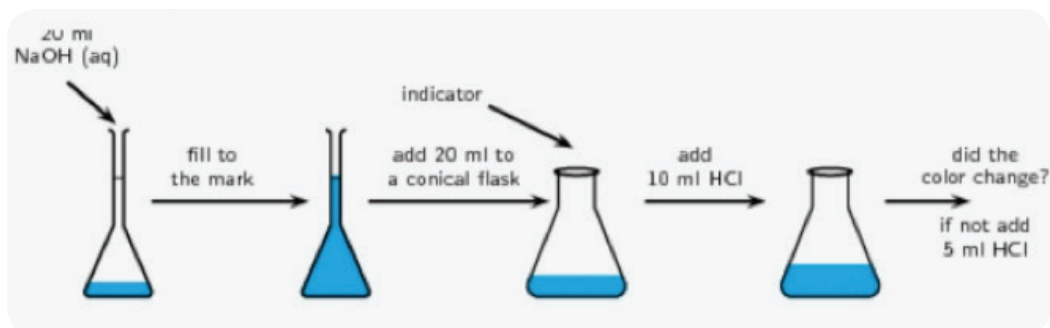
## Experiment

*Title:* Acid-base reaction

*Aim:* To investigate acid-base reaction

*Apparatus and Materials:* Volumetric flask, conical flasks, sodium hydroxide solution, hydrochloric acid solution, pipette and indicator.

### Method



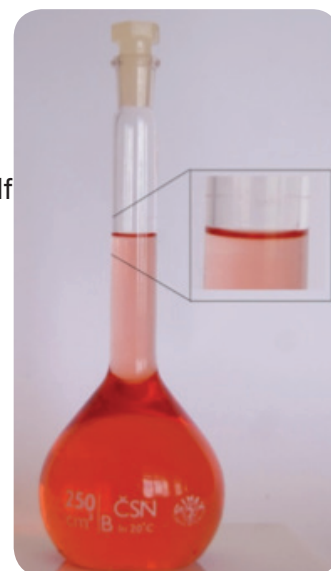
1. Use the pipette to add 20 ml of the sodium hydroxide solution to a volumetric flask. Fill up to the mark with water and shake well.
2. Measure 20 ml of sodium hydroxide solution into a conical flask. Add a few drops of indicator.
3. Slowly add 10 ml of hydrochloric acid. If there is a colour change stop. If not add another 5 ml. continue adding 5 ml increments until you notice a colour change.
4. Observe the changes taking place and record your findings

### Results:

The solution changes colour after a set amount of hydrochloric acid is added.

**Conclusion:** When a set amount of hydrochloric is added to the solutions of sodium hydroxide, the colour changes.

**Safety:** - Acids and Bases **BURNS!** So take extra care



## The pH Scale

What is pH and pH scale?

pH Value	H <sup>+</sup> Concentration (Relative to pure water)	Example
0	10 000 000	Battery acid
1	1 000 000	Gastric acid
2	100 000	Lemon juice, vinegar
3	10 000	Orange juice, soda
4	1 000	Tomato juice, acid rain
5	100	Black coffee, bananas
6	10	Urine, milk
7	1	Pure water
8	0.1	Sea water, eggs
9	0.01	Baking soda
10	0.001	Great salt lake, milk of magnesia
11	0.000 1	Ammonia solution
12	0.000 01	Soapy water
13	0.000 001	Bleach, oven cleaner
14	0.000 000 1	Liquid drain cleaner

The pH of a liquid or a solution is often an important piece of information in science. Measuring pH can be done simply and quickly using pH test paper, pH indicator stick, or a pH metre.

### pH Test Paper and Indicator Sticks

pH test paper and indicator sticks are pieces of paper or stiffer sticks that contain pH indicators. pH indicators are chemicals that change colour depending on how acidic or basic a solution is. To measure pH, a piece of pH test paper or an indicator stick is dipped into the liquid. The colour of the dipped paper or stick is then matched to a colour key that comes with the container of pH test paper or indicator stick. Each colour on the key represents a different pH. An example of a used pH indicator stick and the corresponding colour key is shown below.



### Topic 3: Forms and Transformation of Energy

<b>Content standard</b>	Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy.
<b>Benchmark</b>	<b>9.3.3.6</b> Investigate the properties of different states of matter in terms of the motion and regulation of atoms and molecules.
<b>Key questions</b>	<ol style="list-style-type: none"> <li>1. What are the causes and sources of the different forms of energy?</li> <li>2. What is the law of conservation of energy?</li> </ol>
<b>Learning objectives</b>	<p>By the end of the topic, the students can:</p> <ul style="list-style-type: none"> <li>• Investigate and explain different forms of energy.</li> <li>• Calculate efficiency of energy converters.</li> <li>• Explain the law of conservation of energy.</li> </ul>
<b>Vocabulary</b>	efficiency, joule
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• Energy is the ability to do work.</li> <li>• Efficiency is the percentage of the input energy which is turned into useful energy.</li> <li>• Heat is neither created nor destroyed but transformed from one form to another or transferred from one place to another.</li> <li>• all forms of energy have a source and cause</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>• Critical thinking, calculating, investigating</li> </ul>
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>• Value the fact that the energy in the universe is constant</li> <li>• Appreciate the use of energy in everyday life.</li> </ul>
<b>Teaching and Learning strategies</b>	<ul style="list-style-type: none"> <li>• Provide handouts; prepare some pictures or samples of energy and energy transformation.</li> <li>• Prepare experiments for students to understand the sources and of energy types.</li> </ul>
<b>Assessment</b>	<ol style="list-style-type: none"> <li>1. Investigate and make a model to describe the energy transformation that occurs in a hydroelectricity power plant.</li> </ol>
<b>Materials</b>	<ul style="list-style-type: none"> <li>- pictures of different types of energy source,</li> <li>- materials needed to build a prototype of hydroelectricity power plant.</li> </ul>

### Content Background

#### What is Energy?

Energy is very important to us, you might have thought of it as challenging to define what it means. It is easier to say that energy can do work. If you have a lot of energy, then you can do a lot of work. You do *work* when you use a force to move something. *Energy* is the ability to do work. The more energy something has, the more work it can do.

#### Measuring Energy

In talking about how much energy something has, it is important to have a unit for measuring energy. The unit for measuring energy is called the *joule* (*J*). This unit was named after a British scientist called James Joule. One joule of energy is used to lift a 100 gram mass one metre. Because a joule is only a small amount of energy, it is common to use kilojoules (kJ) and megajoules (MJ).

**1 kilojoule = 1000 joules**

**1 megajoule = 1 000 000 joules**

## Forms of Energy

There are many forms (types) of energy.

- **Kinetic Energy**

Any moving object has *kinetic energy*. When you run you have kinetic energy. A moving train has a large amount of kinetic energy. As a moving object slows down, it loses kinetic energy. When it stops it has no kinetic energy.

Therefore the amount of kinetic energy in an object depends on its speed. The faster the object moves, the more kinetic energy it has. Kinetic energy also depends on the mass of the moving object. The larger the mass, the greater its kinetic energy. For example, a cyclist and a bus may travel at the same speed but the bus has much more kinetic energy because it has greater mass.

- **Gravitational Potential Energy**

A lot of energy around us is stored energy. We notice it only when it changes to other forms. It has the potential to do work, so stored energy is called potential energy. For example, the stored energy that something has when it is high up is called *gravitational potential energy*. This energy is there ready to be used because of the pull of gravity.

- **Elastic potential energy**

Stretching the springs or an elastic rubber has stored energy called *elastic potential energy*. As the stretched springs or elastic rubber returns back to their original size and shape, they release their stored energy.

- **Chemical Potential Energy**

Energy is stored in chemicals as chemical potential energy. When fuels such as woods and petrol are burned, this stored energy is released as heat and light. Foods also contain chemical energy which can be used by our bodies.

- **Nuclear Energy**

Energy is also stored inside atoms as *nuclear energy*. It can be released from some atoms, in nuclear power stations. Nuclear energy stored in hydrogen atoms is the source of the sun's energy.

- **Sound Energy**

Sound is a form of kinetic energy caused by vibrating objects. It travels from place to place as sound waves. The louder the sound is, the more energy it has, and the more work it can do by vibrating things such as your eardrums.

- **Heat Energy**

Heat is a form of energy that hot objects have. If heat energy is taken away from an object it becomes cooler. This is what happens in refrigerators and in air conditioned room.

- **Light energy**

Burning chemicals, very hot objects and stars all release light energy. It travels through space in waves (as do radio and TV waves, microwaves and ultraviolet waves). Light energy from the sun, called *solar energy*, is used by plants to make their food.

- **Electrical Energy**

Electrical energy is widely used because it is easily transmitted by wires to the place where it is needed. It can be changed into other forms of energy by the many electrical devices which have been invented. It can also be stored in batteries as electrical potential energy.

## Energy Changes

Energy can be *transferred* from one object to another. In soccer, a ball at rest is made to move by a moving foot when kicking the soccer ball. Some of the kinetic energy from the foot is transferred to the soccer ball. Another everyday energy transfer occurs when you heat water on stove. Heat is transferred from the gas flame or firewood to the water, causing it to boil.

Energy can also be *converted or transformed* from one form to another. For example, if you rub your hands together they become warm. You have converted the kinetic energy of your moving hands into heat energy. Sometimes, more than one form of energy is produced when an energy change occurs. For instance, a candle is designed to convert stored chemical energy into light, but some of the stored energy becomes heat.



## Wasted Energy

When we use energy, it often changes from one form to another. Sometimes one energy change follows another. The series of steps is called an energy chain. For example, the energy change for a moving car has three steps.

1. The stored chemical energy of the petrol is converted into heat energy when the petrol is burnt in the car's engine.
2. Some of this heat energy is then converted into kinetic energy of the moving engine parts.
3. This kinetic energy is finally transferred through the gears to the wheel.

The energy chain is not 100% efficient because each step in the chain involves some loss of energy. Friction between the moving parts of the engine produces heat. The heat is transferred to the air around the car. Also, as the engine parts move, they produce sound energy. In fact, engineers have calculated that if you start with 100 joules of chemical energy, you end up with only 20 joules of kinetic energy.

The efficiency of an energy converter is the percentage of the input energy which is turned into useful energy.

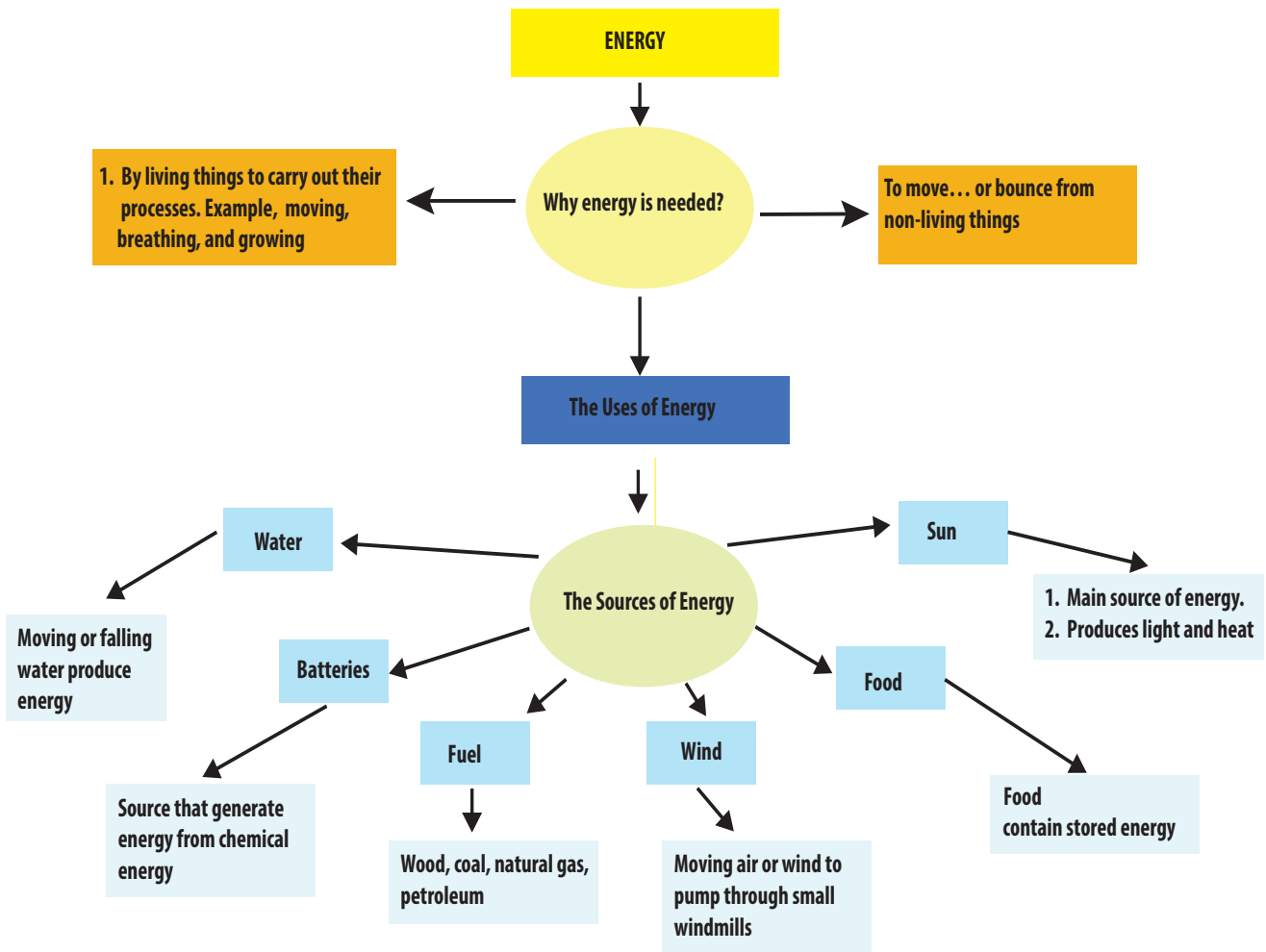
$$\text{Efficiency} = \frac{\text{useful energy}}{\text{input energy}} \times 100$$

For example, the efficiency of a car is about 20%. Because there is always some waste energy, the efficiency of an energy converter is always less than 100%.

## Conservation of Energy

The law of conservation of energy says that, energy cannot be made or destroyed – it can only be converted from one form to another. This means that the universe always has the same amount of energy, even though this energy is constantly being converted from one form to another and being transformed from one place to another.

Investigating Force and Energy



### Topic 4: Energy and Work

<b>Content standard</b>	Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy.
<b>Benchmark</b>	<b>9.3.3.6</b> Investigate the properties of different states of matter in terms of the motion and regulation of atoms and molecules.
<b>Key question</b>	<ol style="list-style-type: none"> <li>1. What is work?</li> <li>2. How can we calculate work?</li> <li>3. How does doing work on an object transfer its energy?</li> </ol>
<b>Learning objectives</b>	By the end of the topic, the students can: <ul style="list-style-type: none"> <li>• Explain the meaning of work</li> <li>• Investigate and explain how work and energy are related.</li> <li>• Calculate the amount of work done.</li> </ul>
<b>Vocabulary</b>	Work, energy, force, kilojoules, joules, megajoules, newton-meter.
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• Work is done when you use force to move something</li> <li>• 1 kilojoule = 1000 joules, 1 megajoule = 1 000 000 joules</li> <li>• Energy is the ability to do work and can be calculated.</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>• Critical thinking, measuring, investigate and calculating.</li> </ul>
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>• Value the fact that the amount of work done is determined by energy and can be calculated.</li> <li>• Appreciate the use of the formula <math>W=Fd</math> when calculating work done.</li> </ul>
<b>Teaching and Learning strategies</b>	Provide handouts; prepare problems that involve calculating work, prepare a table showing examples of different types of energy involved in every -day activities with the amount of energy in kilojoules for each.
<b>Assessment</b>	<ol style="list-style-type: none"> <li>1. Correctly calculate work done by applying the formula <math>W=Fd</math>.</li> </ol>
<b>Materials</b>	Diagrams to illustrate work being done. Prepared problems for calculating work.

### Content Background

#### What is work?

Energy is very important to us, you might have thought of it as challenging to define what it means. It is easier to say that energy can do work. If you have a lot of energy, then you can do a lot of work. You do work when you use a force to move something. *Energy* is the ability to do work. The more energy something has, the more work it can do.

The scientific meaning of **work** is the transfer of energy that occurs when a force is applied over a distance.

No work is done if an object is pushed and does not move. A force that does not make the object move does no work.

#### Calculating work

The amount of work done is easy to calculate. You must know two things to calculate work, force and distance as shown in the equation below;

$$\text{Work (in joules)} = \text{force (in newtons)} \times \text{distance (in meters)}$$

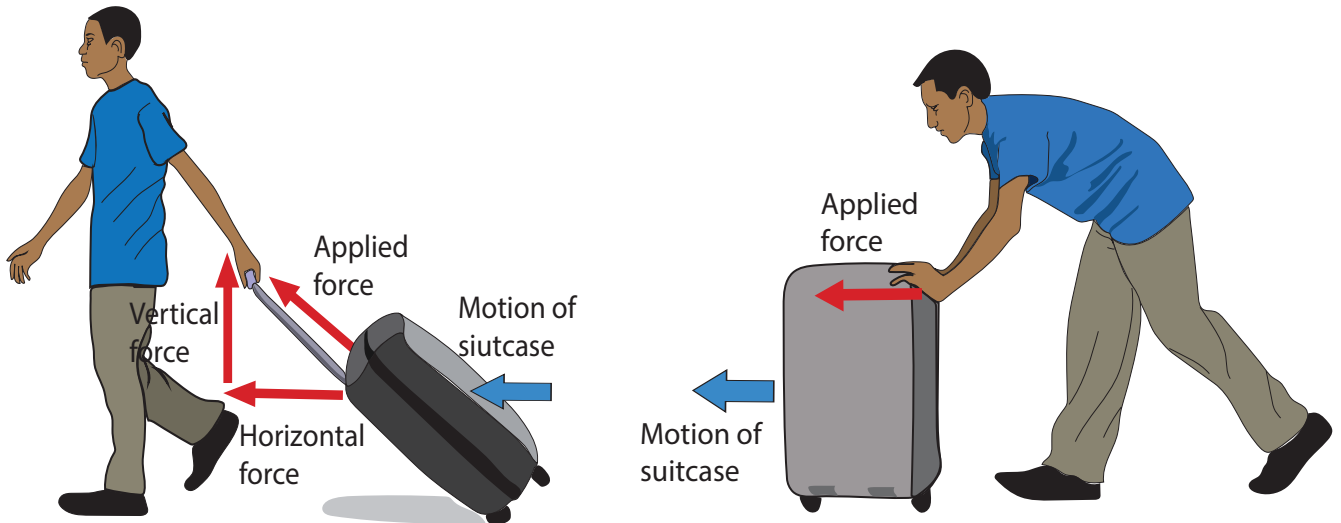
$$W = Fd$$

The force must be in newton (N) and distance must be in meter (m). When you multiply force and distance together, the result has units of newton-meter(N·m). The newton meter is also known as the joule(J). Like other types of energy, work is measured in joules. The joule is the standard unit of work and energy.

The distance in the work equation is the distance the object moves while the force is acting on it. Suppose you push on a book over a distance of 0.25 m and the book slides 3.0 m.

Which distance do you use? You calculate the work done using 0.25 m because the force was applied along that distance.

*A force that acts in the direction of motion does work.*



### Topic 5: Atoms, Elements and Compounds

<b>Content standard</b>	Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy.
<b>Benchmark</b>	9.3.3.3 Find the mass of an element in a given compound.
<b>Key question</b>	What are the relationships between atoms, elements and compounds?
<b>Learning objectives</b>	By the end of the topic, the students can: <ul style="list-style-type: none"> <li>Formulate research questions and communicate findings based on data and evidence on the relationships between atoms, elements and compounds.</li> <li>Apply skills of calculating average atomic mass of different elements and compounds.</li> </ul>
<b>Vocabulary</b>	<ul style="list-style-type: none"> <li>Isotopes, average mass, natural abundance</li> </ul>
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>Average atomic mass</li> <li>Relationship between Elements and compounds</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>Research and communicate findings based on data and evidence.</li> </ul>
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>Accept the fact that matter exist as elements, compounds or atoms.</li> </ul>
<b>Teaching and Learning strategies</b>	<ul style="list-style-type: none"> <li>Teacher provides groups with the words atoms, elements and compounds and students work in groups to research and provide a report from each group on their findings, including scientists, discoveries, and years discovered, debates, challenges, definitions and relationships between these three concepts.</li> </ul>
<b>Assessment</b>	<ol style="list-style-type: none"> <li>Calculate the average atomic mass of an element given its isotopes and their natural abundance.</li> <li>Make models of atoms, element and compound based on descriptions given.</li> </ol>
<b>Materials</b>	<ul style="list-style-type: none"> <li>Models of atoms, elements, compounds, elements and compounds can be provided as real samples, while atoms can have models to represent. Internet, library, chemistry textbooks. Science journal, periodic table.</li> </ul>

### Content Background

**Mass Number:** The total number of protons and neutrons in an atomic nucleus.

**Average Atomic Mass:** The Average Atomic Mass of an element is the sum of the masses of its isotopes, each multiplied by each natural abundance.

**Natural abundance:** The abundance of a particular isotope naturally found on the planet.

**Isotope:** The versions of an element that have different number of neutrons and different masses.

An element can have different number of neutrons in its nucleus, but it always has the same number of protons. The versions of an element with different neutrons have different masses and are called **isotopes**. The average atomic mass for an element is calculated by summing the masses of the element's isotopes, each multiplied by each natural abundance on earth. Therefore, when doing any mass calculations involving elements or compounds, always use atomic mass, which can be found on the periodic table.

The atomic number of an element defines the element's identity and signifies the number of protons in the nucleus of one atom. For example, the element Hydrogen (the lightest element) will always have one proton in its nucleus. The element Helium will always have two protons in its nucleus.

**Topic 6: The Periodic Table**

<b>Content standard</b>	Students will be able to explain and examine the structure, properties and changes of matter as well as sources, uses, conservation and changes of energy.
<b>Benchmark</b>	9.3.3.7 Analyse properties and components of different groups of elements in the periodic table.
<b>Key question</b>	What is the basic theme of organisation in the periodic table?
<b>Learning objectives</b>	By the end of this topic, the students can: <ul style="list-style-type: none"> <li>• Identify and write chemical symbols for common elements;</li> <li>• Recognize that elements are represented by an internationally agreed upon system of symbols.</li> <li>• Identify groups and periods in the periodic table.</li> <li>• Identify each element symbol as either an uppercase symbol or an uppercase letter followed by a lower case letter.</li> </ul>
<b>Vocabulary</b>	<ul style="list-style-type: none"> <li>• Groups of the periodic table, Periods of the periodic table</li> </ul>
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• Elements are classified in (1) periods and (2) groups in according to their properties in the periodic table.</li> <li>• This arrangement makes the study of elements and their compounds simple and systematic.</li> <li>• In the periodic table, elements with similar properties are placed in the same group.</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>• Identify groups and periods in the periodic table.</li> <li>• Analyse and explain why some elements have very different symbols from their English names.</li> <li>• Differentiate between groups and periods in the periodic table.</li> </ul>
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>• Appreciate the great research work Mendeleev put into classifying elements</li> </ul>
<b>Teaching and Learning strategies</b>	<ul style="list-style-type: none"> <li>• Teachers should emphasize the importance of all nations using the same set of symbols to represent elements. This creates a much easier means of communication, and it provides a common scientific language.</li> </ul>
<b>Assessment</b>	1. Research and organise elements according to groups and periods
<b>Materials</b>	The Periodic Table

**Content Background**

To help students develop the association between the element name and its symbol, teachers could subdivide the list of 20 elements into three parts:

- (i) Elements whose symbol is the first letter of its name,
- (ii) Elements whose symbol is made of two letters from its English name; and
- (iii) Elements whose symbol is based on its non-English name.

Teachers may want to elaborate on why some elements have very different symbols from what their “English” name suggests. For example, Iron has the symbol Fe, which is derived from its Latin name: Ferrum. Teachers could inform students that while chemical symbols of elements are generally either Greek or Latin in origin, some names are derived from other languages or sources. Interested students could be directed to conduct an internet search. Students should understand the importance of internationally recognized symbols (IUPAC). For example, Co represents the element cobalt, yet CO represents the chemical formula for the compound carbon monoxide.

Students should also be introduced to the diversity of elements that exist by directing them to the periodic table. It is not the intent of this course that students be able to recall specific characteristics of each of these elements. Students should be able to associate chemical symbols with their respective chemical name for the first 20 elements.

Teachers should emphasize the importance of all nations using the same set of symbols to represent elements. This creates a much easier means of communication, and it provides a common scientific language. Students should be able to:

- Identify and write chemical symbols for common elements;
- Recognize that elements are represented by an internationally agreed upon system of symbols; and,
- Identify each element symbol as either an uppercase symbol or an uppercase letter followed by a lower case letter.

## Periodic table of the Elements

Group	1 1A	2 2A											13 3A	14 4A	15 5A	16 6A	17 7A	18 8A	
1	<b>H</b> Hydrogen 1.0078																		<b>He</b> Helium 4.0026
2	<b>Li</b> Lithium 6.938	<b>Be</b> Beryllium 9.0122																	<b>Ne</b> Neon 20.180
3	<b>Na</b> Sodium 22.990	<b>Mg</b> Magnesium 24.305																	<b>Ar</b> Argon 39.948
4	<b>K</b> Potassium 39.098	<b>Ca</b> Calcium 40.078	<b>Sc</b> Scandium 44.956	<b>Ti</b> Titanium 47.867	<b>V</b> Vanadium 50.942	<b>Cr</b> Chromium 51.996	<b>Mn</b> Manganese 54.938	<b>Fe</b> Iron 55.845	<b>Co</b> Cobalt 58.933	<b>Ni</b> Nickel 58.693	<b>Cu</b> Copper 63.546	<b>Zn</b> Zinc 65.38	<b>Ga</b> Gallium 69.723	<b>Ge</b> Germanium 72.63	<b>As</b> Arsenic 74.922	<b>Se</b> Selenium 78.96	<b>Br</b> Bromine 79.904	<b>Kr</b> Krypton 83.798	
5	<b>Rb</b> Rubidium 85.468	<b>Sr</b> Strontium 87.62	<b>Y</b> Yttrium 88.906	<b>Zr</b> Zirconium 91.224	<b>Nb</b> Niobium 92.906	<b>Mo</b> Molybdenum 95.96	<b>Tc</b> Technetium 98.9062	<b>Ru</b> Ruthenium 101.07	<b>Rh</b> Rhodium 102.91	<b>Pd</b> Palladium 106.42	<b>Ag</b> Silver 107.87	<b>Cd</b> Cadmium 112.41	<b>In</b> Indium 114.82	<b>Sn</b> Tin 118.71	<b>Sb</b> Antimony 121.76	<b>Te</b> Tellurium 127.60	<b>I</b> Iodine 126.90	<b>Xe</b> Xenon 131.29	
6	<b>Cs</b> Cesium 132.91	<b>Ba</b> Barium 137.33		<b>Hf</b> Hafnium 178.49	<b>Ta</b> Tantalum 180.95	<b>W</b> Tungsten 183.84	<b>Re</b> Rhenium 186.21	<b>Os</b> Osmium 190.23	<b>Ir</b> Iridium 192.22	<b>Pt</b> Platinum 195.08	<b>Au</b> Gold 196.97	<b>Hg</b> Mercury 200.59	<b>Tl</b> Thallium 204.38	<b>Pb</b> Lead 207.2	<b>Bi</b> Bismuth 208.98	<b>Po</b> Polonium (209)	<b>At</b> Astatine (210)	<b>Rn</b> Radon (222)	
7	<b>Fr</b> Francium (223)	<b>Ra</b> Radium (226)		<b>Rf</b> Rutherfordium (261)	<b>Db</b> Dubnium (262)	<b>Sg</b> Seaborgium (266)	<b>Bh</b> Bohrium (264)	<b>Hs</b> Hassium (269)	<b>Mt</b> Meitnerium (268)	<b>Ds</b> Darmstadtium (268)	<b>Rg</b> Roentgenium (268)	<b>Cn</b> Copernicium (268)	<b>Uut</b> Ununtrium (268)	<b>Fl</b> Flerovium (268)	<b>Uup</b> Ununpentium (268)	<b>Lv</b> Livermorium (268)	<b>Uus</b> Ununseptium (268)	<b>Uuo</b> Ununoctium (268)	
			<b>La</b> Lanthanum 138.91	<b>Ce</b> Cerium 140.12	<b>Pr</b> Praseodymium 140.91	<b>Nd</b> Neodymium 144.24	<b>Pm</b> Promethium (145)	<b>Sm</b> Samarium 150.36	<b>Eu</b> Europium 151.96	<b>Gd</b> Gadolinium 157.25	<b>Tb</b> Terbium 158.93	<b>Dy</b> Dysprosium 162.50	<b>Ho</b> Holmium 164.93	<b>Er</b> Erbium 167.26	<b>Tm</b> Thulium 168.93	<b>Yb</b> Ytterbium 173.04	<b>Lu</b> Lutetium 174.97		
			<b>Ac</b> Actinium (227)	<b>Th</b> Thorium 232.04	<b>Pa</b> Protactinium 231.04	<b>U</b> Uranium 238.03	<b>Np</b> Neptunium (237)	<b>Pu</b> Plutonium (244)	<b>Am</b> Americium (243)	<b>Cm</b> Curium (247)	<b>Bk</b> Berkelium (247)	<b>Cf</b> Californium (251)	<b>Es</b> Einsteinium (252)	<b>Fm</b> Fermium (257)	<b>Md</b> Mendelevium (258)	<b>No</b> Nobelium (259)	<b>Lr</b> Lawrencium (262)		

## Unit 9.7: Force and Motion

The unit is organized based on two ideas: forces and motion and types of interactions. Students build an understanding of forces and interactions and Newton's first Law. Students demonstrate proficiency in planning and conducting investigations, analyzing data and using mathematical calculations to support claims, and applying scientific ideas to solve problems, and to use these practices to demonstrate understanding of the core ideas. The crosscutting concepts of cause and effect and structure and function are called out as organizing concepts for these core ideas.

Topic 1: Common Forces and their Characteristics	
<b>Content standard</b>	Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy.
<b>Benchmark</b>	<b>9.3.3.9</b> Demonstrate and explain why applying a force to an object perpendicular to the direction of its motion causes the object to change direction but not speed (e.g., Earth's gravitational force causes a satellite in a circular orbit to change direction but not speed).
<b>Key question</b>	What is the difference between force and motion?
<b>Learning objectives</b>	By the end of the topic, the students can: <ul style="list-style-type: none"> <li>• Define force, and give examples of forces.</li> <li>• Describe how forces combine and affect motion.</li> </ul>
<b>Vocabulary</b>	Force, net force, newton
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• Force is a push or a pull acting on an object.</li> <li>• The SI unit of force is the newton (N).</li> <li>• The net force on an object is the combination of all of the forces acting on the object.</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>• Distinguish between force and motions</li> <li>• Identify common forces</li> </ul>
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>• Appreciate how forces affect daily lives.</li> </ul>
<b>Teaching and Learning strategies</b>	<ul style="list-style-type: none"> <li>• Teacher provides examples on how to go about with the calculations and also provides groups with the objects and problems to solve to find the net force of given objects.</li> </ul>
<b>Assessment</b>	<ol style="list-style-type: none"> <li>1. Calculate the net force of two objects moving in the same direction, and one in the opposite direction.</li> <li>2. Determine and explain the direction of the net force of an object.</li> </ol>
<b>Materials</b>	Any object can be used

### Content Background

#### What is Force?

Any time the motion of an object changes, a force has been applied. Force can cause a stationary object to start moving or a moving object to accelerate. The moving object may change its speed, its direction, or both. How much an object's motion changes when a force is applied depends on the strength of the force and the object's mass.

**Force** is defined as a push or a pull acting on an object. Examples of forces include friction and gravity.

Another example of force is applied force. It occurs when a person or thing applies force to an object, like the girl pushing the swing in Figure 4.1. The force of the push causes the swing to move.

#### Force as a Vector

Force as a Vector Force is a vector because it has both size and direction. For example, the girl in the Figure is pushing the swing away from herself. That's the direction of the force. She can give the swing a strong push or a weak push. That's the size, or strength, of the force. Like other vectors, forces can be represented with arrows. The length of each arrow represents the strength of the force, and the way the arrow points represents the direction of the force.



Example 1: Two forces applied in the same direction, with force B stronger than force A



Example 2: Two forces applied in opposite directions, with force B equal to force A



A force is a physical agent that can deform an object or change its state of rest or of motion.

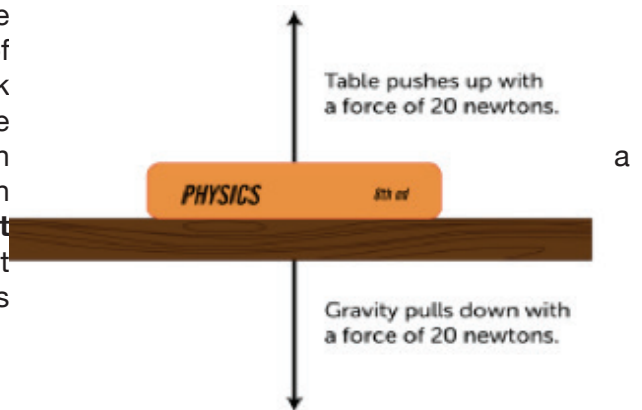
### SI Unit of Force

The SI unit of force is the newton (N). One newton is the amount of force that causes a mass of 1 kilogram to accelerate at  $1 \text{ m/s}^2$ . Thus, the newton can also be expressed as  $\text{kg}\cdot\text{m/s}^2$ . The newton was named for the scientist Sir Isaac Newton, who is famous for his law of gravity.

### Combining Forces

More than one force may act on an object at the same time. In fact, just about all objects on Earth have at least two forces acting on them at all times.

One force is gravity, which pulls objects down toward the center of Earth. The other force is an upward force that may be provided by the ground or other surface. Consider the example of a book resting on a table. Gravity pulls the book downward with a force of 20 newtons. At the same time, the table pushes the book upward with a force of 20 newtons. The combined forces acting on the book — or any other object — are called the **net force**. This is the overall force acting on an object that takes into account all of the individual forces acting on the object.



### Forces Acting in Opposite Directions

When two forces act on an object in opposite directions, like the book on the table, the net force is equal to the difference between the two forces. In other words, one force is subtracted from the other to calculate the net force. If the opposing forces are equal in strength, the net force is zero. That's what happens with the book on the table. The upward force minus the downward force equals zero ( $20 \text{ N up} - 20 \text{ N down} = 0 \text{ N}$ ). Because the forces on the book are balanced, the book remains on the table and doesn't move. In addition to these downward and upward forces, which generally cancel each other out, forces may push or pull an object in other directions.

When opposing forces are unbalanced, the net force is greater than zero.

### Forces Acting in the Same Direction

Two forces may act on an object in the same direction. You can see an example below.

After the man on the left lifts up the couch, he will push the couch to the right with a force of 25 newtons. At the same time, the man to the right is pulling the couch to the right with a force of 20 newtons. When two forces act in the same direction, the net force is equal to the sum of the forces. This always results in a stronger force than either of the individual forces alone. In this case, the net force on the couch is 45 newtons to the right, so the couch will move to the right.



## Topic 2: Forces and Effects

<b>Content standard</b>	Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy.
<b>Benchmark</b>	<b>9.3.3.11</b> Examine the relationship between the universal law of gravitation and the effect of gravity on an object at the surface of Earth.
<b>Key question</b>	How does gravity affect the motion of objects? How is weight related to gravity?
<b>Learning objectives</b>	By the end of the topic, the students can: <ul style="list-style-type: none"> <li>• Define gravity.</li> <li>• State Newton's law of universal gravitation.</li> <li>• Explain how gravity affects the motion of objects.</li> </ul>
<b>Vocabulary</b>	Gravity, law of universal gravitation, orbit, projectile motion
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• Gravity is an attractive force between all objects that have mass.</li> <li>• The law of universal gravitation states that the gravitational force increases as the mass of either object increases or as the objects move closer.</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>• Critical thinking, problem solving, investigate and calculate</li> </ul>
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>• Value the importance of Newton's law of universal gravitation.</li> </ul>
<b>Teaching and Learning strategies</b>	Teacher should provide handouts and prepare worksheets for students to solve problems.
<b>Assessment</b>	1. Investigate and explain how gravity affects the motion of objects.
<b>Materials</b>	Handouts, diagram showing Newton's Law of universal gravitation.

### Content Background

#### What is gravity?

Gravity has traditionally been defined as a force of attraction between two masses. According to this conception of gravity, anything that has mass, no matter how small, exerts gravity on other matter. The effect of gravity is that objects exert a pull on other objects. Unlike friction, which acts only between objects that are touching, gravity also acts between objects that are not touching. In fact, gravity can act over very long distances.

#### Earth's Gravity

You are already very familiar with Earth's gravity. It constantly pulls you toward the centre of the planet. It prevents you and everything else on Earth from being flung out into space as the planet spins on its axis. It also pulls objects above the surface, from meteors to skydivers, down to the ground. Gravity between Earth and the moon and between Earth and artificial satellites keeps all these objects circling around Earth. Gravity also keeps Earth moving around the sun.

#### Gravity and Weight

Weight measures the force of gravity pulling on an object. Because weight measures force, the SI unit for weight is the newton (N). On Earth, a mass of 1 kilogram has a weight of about 10 newtons because of the pull of Earth's gravity on the moon, which has less gravity, the same mass would weigh less. Weight is measured with a scale, like the spring scale below. The scale measures the force with which gravity pulls an object downward.



Money hangs below this hand-held scale. It is pulled downwards by gravity. The scale measures the strength of that pull.

#### Law of Gravity

People have known about gravity for thousands of years. After all, they constantly experienced gravity in their daily lives. They knew that things always fall toward the ground. However, it wasn't until Sir Isaac Newton developed his law of gravity in the late 1600s that people really began to understand gravity.

### Newton's Law of Universal Gravitation

Newton was the first one to suggest that gravity is universal and affects all objects in the universe. That's why his law of gravity is called the law of universal gravitation. Universal gravitation means that the force that causes an apple to fall from a tree to the ground is the same force that causes the moon to keep moving around Earth.

Universal gravitation also means that while Earth exerts a pull on you, you exert a pull on the Earth. In fact, there is gravity between you and every mass around us. Even tiny molecules of gas are attracted to one another by the force of gravity. Newton's law had a huge impact on how people thought about the universe. It explains the motion of objects not only on Earth but in outer space as well.

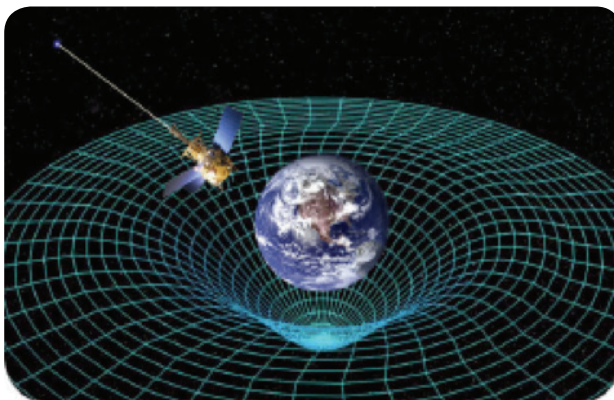
### Factors That Influence the Strength of Gravity

Newton's law also states that the strength of gravity between any two objects depends on two factors: the masses of the objects and the distance between them.

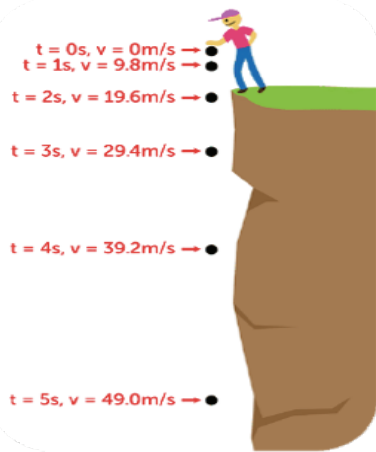
- Objects with greater mass have a stronger force of gravity. For example, because Earth is so massive, it attracts you and your chair more strongly than you and your desk attract each other. That's why you and the desk remain in place on the floor rather than moving toward one another.
- Objects that are closer together have a stronger force of gravity. For example, the moon is closer to Earth than it is to the more massive sun, so the force of gravity is greater between the moon and Earth than between the moon and the sun. That's why the moon circles around Earth rather than the sun.

### Einstein's Theory of Gravity

Newton's idea of gravity can predict the motion of most but not all objects. In the early 1900s, Albert Einstein came up with a theory of gravity that is better at predicting how all objects move. Einstein showed mathematically that gravity is not really a force in the sense that Newton thought. Instead, gravity is a result of the warping, or curving, of space and time. Imagine a bowling ball pressing down on a trampoline. The surface of the trampoline would curve downward instead of being flat. Einstein theorized that Earth and other very massive bodies affect space and time around them in a similar way. This idea is represented in the figure below. According to Einstein, objects curve toward one another because of the curves in space and time, not because they are pulling on each other with a force



Gravity and Motion Regardless of what gravity is — a force between masses or the result of curves in space and time — the effects of gravity on motion are well known. You already know that gravity causes objects to fall down to the ground. Gravity affects the motion of objects in other ways as well. Acceleration Due to Gravity When gravity pulls objects toward the ground, it causes them to accelerate. Acceleration due to gravity equals  $9.8 \text{ m/s}^2$ . In other words, the velocity at which an object falls toward Earth increases each second by  $9.8 \text{ m/s}$ . Therefore, after 1 second, an object is falling at a velocity of  $9.8 \text{ m/s}$ . After 2 seconds, it is falling at a velocity of  $19.6 \text{ m/s}$  ( $9.8 \text{ m/s} \times 2$ ), and so on. You can compare the acceleration due to gravity on Earth, the moon, and Mars with “Freefall”



A boy drops an object at time  $t = 0$  s.

At time  $t = 1$  s, the object is falling at a velocity of 9.8 m/s.

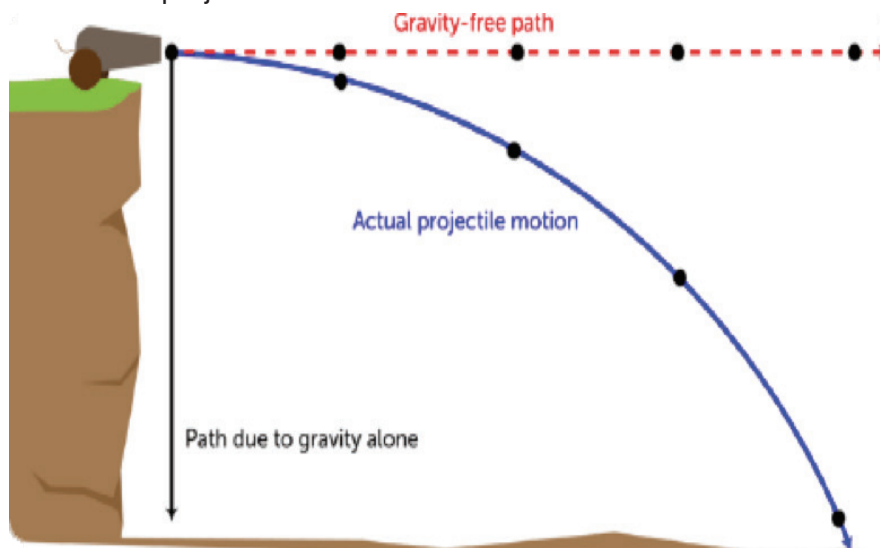
What is its velocity by time  $t = 5$ ?

We might think that an object with greater mass would accelerate faster than an object with less mass. After all, its greater mass means that it is pulled by a stronger force of gravity. However, a more massive object accelerates at the same rate as a less massive object. The reason? The more massive object is harder to move because of its greater mass. As a result, it ends up moving at the same acceleration as the less massive object. Consider a bowling ball and a basketball. The bowling ball has greater mass than the basketball. However, if you were to drop both balls at the same time from the same distance above the ground, they would reach the ground together. This is true of all falling objects, unless air resistance affects one object more than another. For example, a falling leaf is slowed down by air resistance more than a falling acorn because of the leaf's greater surface area. However, if the leaf and acorn were to fall in the absence of air (that is, in a vacuum), they would reach the ground at the same time.

### Projectile Motion

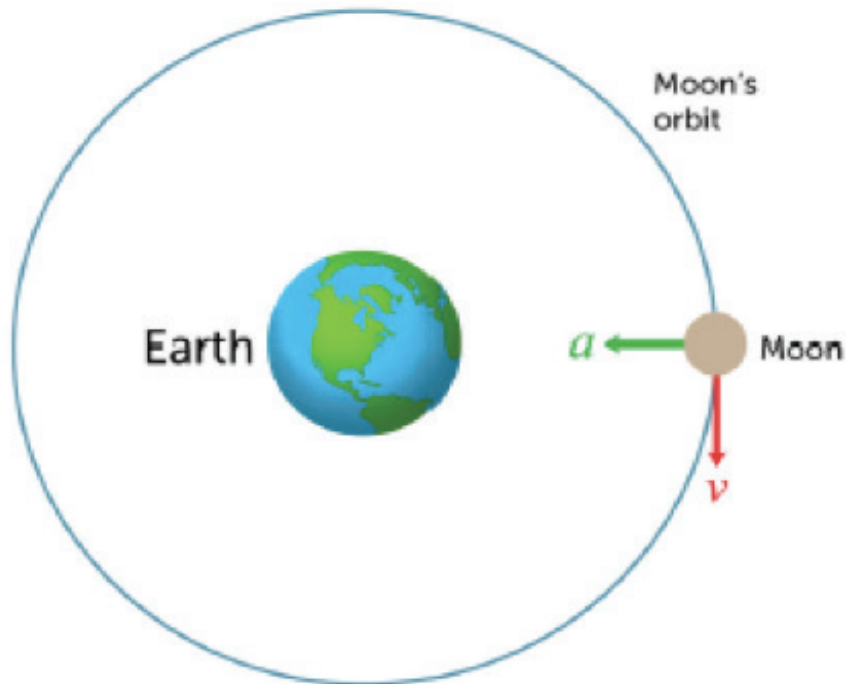
Earth's gravity also affects the acceleration of objects that start out moving horizontally, or parallel to the ground.

A cannon shoots a cannon ball straight ahead, giving the ball horizontal motion. At the same time, gravity pulls the ball down toward the ground. Both forces acting together cause the ball to move in a curved path. This is called projectile motion.



Projectile motion also applies to other moving objects, such as arrows shot from a bow. To hit the bull's eye of a target with an arrow, you actually have to aim for a spot above the bull's eye. That's because by the time the arrow reaches the target, it has started to curve downward toward the ground.

**Orbital Motion** The moon moves around Earth in a circular path called an orbit. Why doesn't Earth's gravity pull the moon down to the ground instead? The moon has enough forward velocity to partly counter the force of Earth's gravity. It constantly falls toward Earth, but it stays far enough away from Earth so that it actually falls around the planet. As a result, the moon keeps orbiting Earth and never crashes into it. The diagram below shows how this happens.



In this diagram, "v" represents the forward velocity of the moon, and "a" represents the acceleration due to gravity. The line encircling Earth shows the moon's actual orbit, which results from the combination of "v" and "a."

### Topic 3: Newton's First Law of Motion

<b>Content standard</b>	Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy.
<b>Benchmark</b>	<b>9.3.3.12</b> Establish that when forces are balanced, no acceleration occurs; thus an object continues to move at a constant speed or stays at rest (Newton's first law).
<b>Key question</b>	<ol style="list-style-type: none"> <li>1. How does the mass of an object affect its acceleration when an unbalanced force is applied to it?</li> <li>2. How does an objects mass affect its Inertia?</li> </ol>
<b>Learning objectives</b>	By the end of the topic, the students can: <ul style="list-style-type: none"> <li>• Explain Newton's first law of motion.</li> <li>• Define inertia, and explain its relationship to mass</li> </ul>
<b>Vocabulary</b>	Inertia, Newton's First Law of Motion
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• Newton's first law of motion states that an object moves at a constant velocity unless an unbalanced force acts on it.</li> <li>• Inertia is the tendency of an object to resist a change in its motion.</li> </ul>
<b>Skills</b>	Critical thinking, problem solving, investigate
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>• Value the importance of Newton's first law of motion.</li> </ul>
<b>Teaching and Learning strategies</b>	Teacher should provide handouts and prepare worksheets for students to solve problems. Prepare demonstrations of Newton's first law of motion.
<b>Assessment</b>	1. Explain what is inertia and how is it related to Newton's first law of motion?
<b>Materials</b>	

### Content Background

#### Forces

A soccer ball sits on the ground, motionless, until you kick it. Your science book sits on the table until you pick it up. If you hold your book above the ground, then let it go, gravity pulls it to the floor. In every one of these cases, the motion of the ball or book was changed by something pushing or pulling on it. An object will speed up, slow down, or turn only if something is pushing or pulling on it.

A force is a push or a pull. Think about throwing a ball. Your hand exerts a force on the ball, and the ball accelerates forward until it leaves your hand. After the ball leaves your hand, the force of gravity causes its path to curve downward. When the ball hits the ground, the ground exerts a force, stopping the ball.

A force can be exerted in different ways. For instance, a paper clip can be moved by the force a magnet exerts, the pull of Earth's gravity, or the force you exert when you pick it up. These are all examples of forces acting on the paper clip.

This golf club exerts a force by pushing on the golf ball.



## Combining Forces

More than one force can act on an object at the same time. If you hold a paper clip near a magnet, you, the magnet, and gravity all exert forces on the paper clip. The combination of all the forces acting on an object is the net force.

When more than one force is acting on an object, the net force determines the motion of the object. In this example, the paper clip is not moving, so the net force is zero.

How do forces combine to form the net force? If the forces are in the same direction, they add together to form the net force. If two forces are in opposite directions, then the net force is the difference between the two forces, and it is in the direction of the larger force.

## Balanced and Unbalanced Forces

A force can act on an object without causing it to accelerate if other forces cancel the push or pull of the force. Look at Figure 2. If you and your friend push on a door with the same force in opposite directions, the door does not move. Because you both exert forces of the same size in opposite directions on the door, the two forces cancel each other.

Two or more forces exerted on an object are balanced forces if their effects cancel each other and they do not cause a change in the object's motion. If the forces on an object are balanced, the net force is zero. If the forces are unbalanced forces, their effects don't cancel each other. Any time the forces acting on an object are unbalanced, the net force is not zero and the motion of the object changes.

When the forces on an object are balanced, no change in motion occurs. A change in motion occurs only when the forces acting on an object are unbalanced.



This door is not moving because the forces exerted on it are equal and in opposite directions.



The door is closing because the force pushing the door closed is greater than the force pushing it open.

## Newton's First Law of Motion

Newton's first law of motion states that an object's motion will not change unless an unbalanced force acts on the object. If the object is at rest, it will stay at rest. If the object is in motion, it will stay in motion and its velocity will remain the same. In other words, neither the direction nor the speed of the object will change as long as the net force acting on it is zero.

When a pool player pushes the pool stick against the white ball, the white ball is set into motion. Once the white ball is rolling, it rolls all the way across the table and stops moving only after it crashes into the cluster of colored balls. Then, the force of the collision starts the colored balls moving. Some may roll until they bounce off the raised sides of the table. Some may fall down into the holes at the edges of the table.

None of these motions will occur, however, unless that initial push of the pool stick is applied. As long as the net force on the balls is zero, they will remain at rest.



Force from the moving pool stick starts the white ball rolling. Force from the moving white ball sets the other balls into motion.



Pool balls remain at rest until an unbalanced force is applied to them. After they are in motion, they stay in motion until another force opposes their motion.

### Inertia

Newton's first law of motion is also called the law of inertia. Inertia is the tendency of an object to resist a change in its motion. If an object is already at rest, inertia will keep it at rest. If the object is already moving, inertia will keep it moving. Think about what happens when you are riding in a car that stops suddenly. Your body moves forward on the seat. Why? The brakes stop the car but not your body, so your body keeps moving forward because of inertia. That's why it's important to always wear a seat belt.

The car keeps changing direction, but the riders keep moving in the same direction as before. They slide to the opposite side of the car as a result.

### Inertia and Mass

The inertia of an object depends on its mass. Objects with greater mass also have greater inertia. Think how hard it would be to push a big box full of books, like the one in Figure Below. Then think how easy it would be to push the box if it was empty. The full box is harder to move because it has greater mass and therefore greater inertia.



### Overcoming Inertia

To change the motion of an object, inertia must be overcome by an unbalanced force acting on the object. Until the soccer player kicks the ball in a penalty, the ball remains motionless on the ground. However, when the ball is kicked, the force on it is suddenly unbalanced. The ball starts moving across the field because its inertia has been overcome.

### Topic 4: The Buoyant Force

<b>Content standard</b>	Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy.
<b>Benchmark</b>	<b>9.3.3.13</b> Explore the nature of Floating and Sinking.
<b>Key question</b>	1. How does the buoyant force determine whether an object floats or sinks?
<b>Learning objectives</b>	By the end of the topic, the students can: <ul style="list-style-type: none"> <li>• Explain how the buoyant force determines why an object floats or sinks in fluid.</li> <li>• Explain Archimede's principal</li> </ul>
<b>Vocabulary</b>	Buoyant force, Archimede's principal, sinking and floating
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• The buoyant force is caused by the pressure that is exerted by a fluid on an object in the fluid.</li> <li>• According to Archimedes' principle, the buoyant force on an object is equal to the weight of the fluid it displaces.</li> </ul>
<b>Skills</b>	Careful observation, critical thinking, investigation
<b>Attitudes and values</b>	Patient in observation, sceptical about Buoyant Force
<b>Teaching and Learning strategies</b>	Teacher should provide handouts, prepare materials and do a demonstration on what causes the buoyant force.
<b>Assessment</b>	1. Investigate and justify why does an object sink or float in water.
<b>Materials</b>	Any object can be used, glass cup of water

#### Content Background

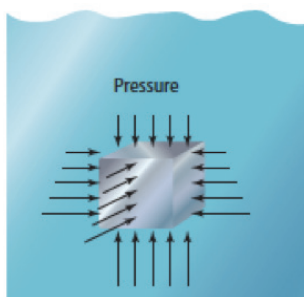
##### The Buoyant Force

Think about the forces that are acting on a person as he/she floats motionless on the surface of a pool or lake. According to Newton's second law of motion, the forces on you must be balanced. Earth's gravity is pulling the person downward, so an upward force must be balancing the weight. This force is called the buoyant force.

The buoyant force is an upward force that is exerted by a fluid on any object in the fluid.

##### What causes the buoyant force?

The buoyant force is caused by the pressure that is exerted by a fluid on an object in the fluid. The figure below shows a cube-shaped object submerged in a glass of water. The water exerts pressure everywhere over the surface of the object. Recall that the pressure exerted by a fluid has two properties. One is that the direction of the pressure on a surface is always perpendicular to the surface. The other is that the pressure exerted by a fluid increases as you go deeper into the fluid.



The pressure exerted on the bottom of the cube is greater than the pressure on the top. The fluid exerts a net upward force on the cube.

##### Sinking and Floating

If you drop a stone into a pool of water, it sinks. But if you toss a twig on the water, it floats. An upward buoyant force acts on the twig and the stone, so why does one float and one sink? The buoyant force pushes an object in a fluid upward, but gravity pulls the object downward. If the weight of the object is greater than the buoyant force, the net force on the object is downward and it sinks. If the buoyant force is equal to the object's weight, the forces are balanced and the object floats. As shown below, the fish floats because the buoyant force on it balances its weight. The rocks sink because the buoyant force acting on them is not large enough to balance their weight.



The weight of a rock is more than the buoyant force exerted by the water, so it sinks to the bottom.

**Changing the Buoyant Force** Whether an object sinks or floats depends on whether the buoyant force is smaller than its weight. The weight of an object depends only on the object's mass, which is the amount of matter the object contains. The weight does not change if the shape of the object changes. A piece of modeling clay contains the same amount of matter whether it's squeezed into a ball or pressed flat. Buoyant Force and Shape Buoyant force does depend on the shape of the object. The fluid exerts upward pressure on the entire lower surface of the object that is in contact with the fluid. If this surface is made larger, then more upward pressure is exerted on the object and the buoyant force is greater.

**The Buoyant Force Doesn't Change with Depth** Suppose you drop a steel cube into the ocean. You might think that the cube would sink only to a depth where the buoyant force on the cube balances its weight. However, the steel sinks to the bottom, no matter how deep the ocean is. The buoyant force on the cube is the difference between the downward force due to the water pressure on the top of the cube and the upward force due to water pressure on the bottom of the cube. The following figure shows that when the cube is deeper, the pressure on the top surface increases, but the pressure on the bottom surface also increases by the same amount. As a result, the difference between the forces on the top and bottom surfaces is the same, no matter how deep the cube is submerged. The buoyant force on the submerged cube is the same at any depth.



Because the cube on the right is deeper, the pressure on its upper surface is increased due to the weight of the water inside the dashed lines. The pressure on the bottom surface also increases by this amount.

### Archimedes' Principle

A way of determining the buoyant force was given by the ancient Greek mathematician Archimedes more than 2,200 years ago. According to Archimedes' principle, the buoyant force on an object is equal to the weight of the fluid it displaces. To understand Archimedes' principle, think about what happens if you drop an ice cube in a glass of water that's filled to the top. The ice cube takes the place of some of the water and causes this water to overflow. Another way to say this is that the ice cube displaced water that was in the glass. Suppose you caught all the overflow water and weighed it. According to Archimedes' principle, the weight of the overflow, or displaced water, would be equal to the buoyant force on the ice cube. Because the ice cube is floating, the buoyant force is balanced by the weight of the ice cube. So, the weight of the water that is displaced, or the buoyant force, is equal to the weight of the ice cube.

## Unit 9.8: Waves, Electricity and Magnetism

In this unit, students apply understanding of how wave properties and the interactions of electromagnetic radiation with matter can transfer information across long distances, store information, and investigate nature on many scales. Students understand that combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information. Students also demonstrate their understanding of engineering ideas by presenting information about how technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. Students demonstrate proficiency in asking questions and using mathematical thinking to demonstrate understanding of the core ideas. The crosscutting concepts of cause and effect and stability and change are highlighted as organizing concepts for these disciplinary core ideas.

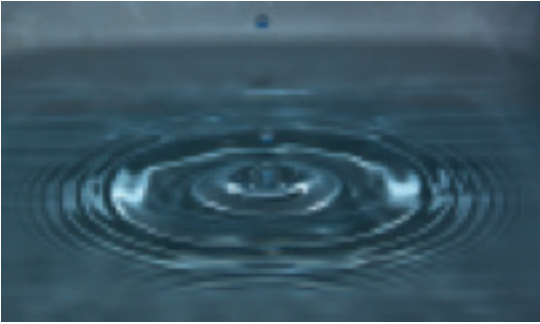
Topic 1: Nature and Properties of Waves	
<b>Content standard</b>	Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy.
<b>Benchmark</b>	<b>9.3.3.13</b> Examine transverse and longitudinal waves in mechanical media, such as springs and ropes, and on the earth (seismic waves).
<b>Key question</b>	1. What are mechanical, transverse, longitudinal and surface waves?
<b>Learning objectives</b>	By the end of the topic, the students can: <ul style="list-style-type: none"> <li>• Define mechanical wave.</li> <li>• Describe transverse waves.</li> <li>• Identify longitudinal waves.</li> <li>• Describe surface waves.</li> </ul>
<b>Vocabulary</b>	longitudinal wave, mechanical wave, surface wave, transverse wave
<b>Knowledge</b>	<ol style="list-style-type: none"> <li>1. A mechanical wave is a disturbance in matter that transfers energy from place to place.</li> <li>2. A longitudinal wave is a wave in which the medium vibrates in the same direction that the wave travels.</li> <li>3. A transverse wave is a wave in which the medium vibrates at right angles to the direction that the wave travels.</li> <li>4. A surface wave is a wave that travels along the surface of a medium. eg water</li> </ol>
<b>Skills</b>	1. Investigate and analyse the transfer of energy through matter as waves.
<b>Attitudes and values</b>	Optimistic and Creative
<b>Teaching and Learning strategies</b>	Teacher can demonstrate the transfer of energy in different waves using the materials listed or view videos and illustrations
<b>Assessment</b>	1. Draw or illustrate the transfer of energy in a transverse wave. Label the crests and troughs, and add an arrow to show the direction the wave is traveling.
<b>Materials</b>	Rope, coils of spring, bowl of water, videos of waves, handouts, illustrations & diagrams

### Content Background

Ocean waves are among the most impressive waves in the world. They clearly show that waves transfer energy. In the case of ocean waves, energy is transferred through matter. But some waves, called electromagnetic waves, can transfer energy without traveling through matter. These waves can travel through space. You can read more about electromagnetic waves in the chapter “Electromagnetic Radiation.” Waves that transfer energy through matter are the focus of the present chapter. These waves are called mechanical waves.

**Mechanical Waves** A mechanical wave is a disturbance in matter that transfers energy from place to place. A mechanical wave starts when matter is disturbed. An example of a mechanical wave is pictured below. A drop of water falls into a pond. This disturbs the water in the pond. What

happens next? The disturbance travels outward from the drop in all directions. This is the wave. A source of energy is needed to start a mechanical wave. In this case, the energy comes from the falling drop of water.



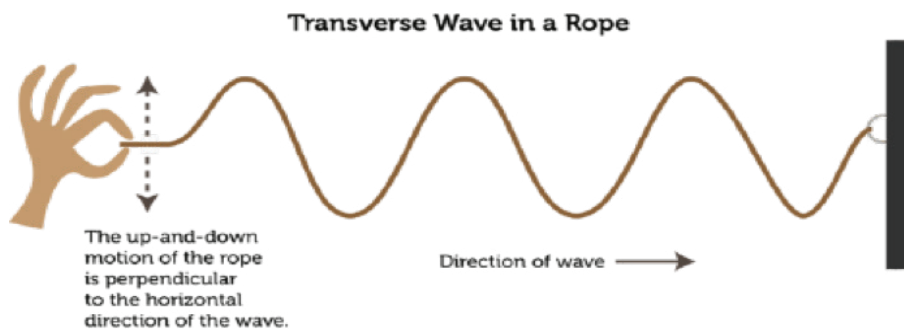
A drop of water causes a disturbance that travels through the pond as a wave

### The Medium

The energy of a mechanical wave can travel only through matter. This matter is called the medium (plural, media). The medium in the figure is a liquid — the water in the pond. But the medium of a mechanical wave can be any state of matter, including a solid or a gas. It's important to note that particles of matter in the medium don't actually travel along with the wave. Only the energy travels. The particles of the medium just vibrate, or move back-and-forth or up-and-down in one spot, always returning to their original positions. As the particles vibrate, they pass the energy of the disturbance to the particles next to them, which pass the energy to the particles next to them, and so on. Types of Mechanical Waves There are three types of mechanical waves. They differ in how they travel through a medium. The three types are transverse, longitudinal, and surface waves. All three types are described in detail below.

### Transverse Waves

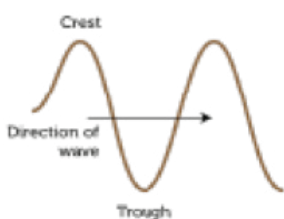
A transverse wave is a wave in which the medium vibrates at right angles to the direction that the wave travels. An example of a transverse wave is a wave in a rope, like the one pictured below. In this wave, energy is provided by a person's hand moving one end of the rope up and down. The direction of the wave is down the length of the rope away from the person's hand. The rope itself moves up and down as the wave passes through it.



*In a transverse wave, the medium moves at right angles to the direction of the wave.*

### Crests and Troughs

#### Parts of a Transverse Wave



A transverse wave can be characterized by the high and low points reached by particles of the medium as the wave passes through. This is illustrated in the figure below. The high points are called crests, and the low points are called troughs.

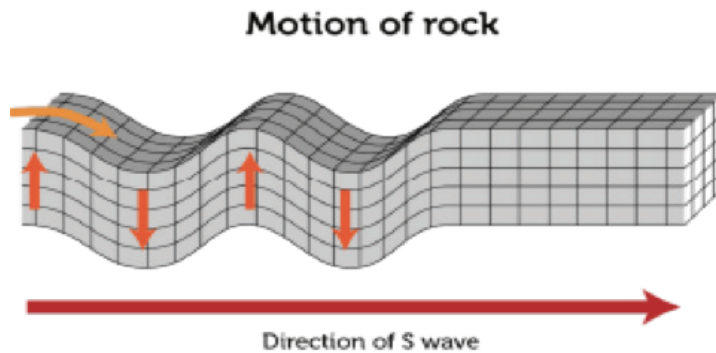
*Crests and troughs are the high and low points of a transverse wave.*

### Types of Mechanical Waves

There are three types of mechanical waves. They differ in how they travel through a medium. The three types are transverse, longitudinal, and surface waves.

### Types of Mechanical Waves

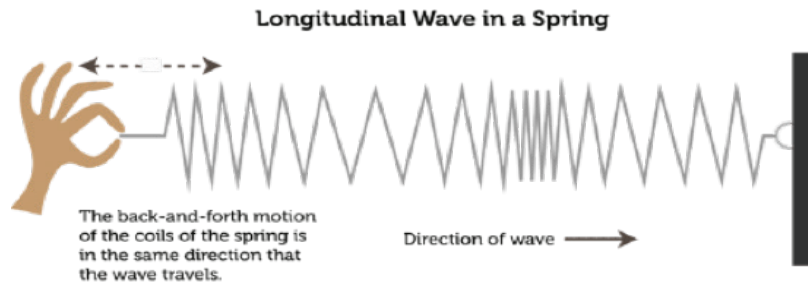
There are three types of mechanical waves. They differ in how they travel through a medium. The three types are transverse, longitudinal, and surface waves.



*An S wave is a transverse wave that travels through rocks under Earth's surface.*

### Longitudinal Waves

A longitudinal wave is a wave in which the medium vibrates in the same direction that the wave travels. An example of a longitudinal wave is a wave in a spring, like the one in the figure below. In this wave, the energy is provided by a person's hand pushing and pulling the spring. The coils of the spring first crowd closer together and then spread farther apart as the disturbance passes through them. The direction of the wave is down the length of the spring, or the same direction in which the coils move.



*In a longitudinal wave, the medium moves back and forth in the same direction as the wave.*

### Compressions and Rarefactions

A longitudinal wave can be characterized by the compressions and rarefactions of the medium. This is illustrated in Figure 15.6. Compressions are the places where the coils are crowded together, and rarefactions are the places where the coils are spread apart. P Waves Earthquakes cause longitudinal waves as well as transverse waves. The disturbance that causes an earthquake sends longitudinal waves through underground rocks in all directions from the disturbance. Earthquake waves that travel this way are called primary, or P, waves. They are illustrated in Figure 15.7.

### Surface Waves

A surface wave is a wave that travels along the surface of a medium. It combines a transverse wave and a longitudinal wave. Ocean waves are surface waves. They travel on the surface of the water between the ocean and the air. In a surface wave, particles of the medium move up and down as well as back and forth. This gives them an overall circular motion.

**Parts of a Longitudinal Wave**

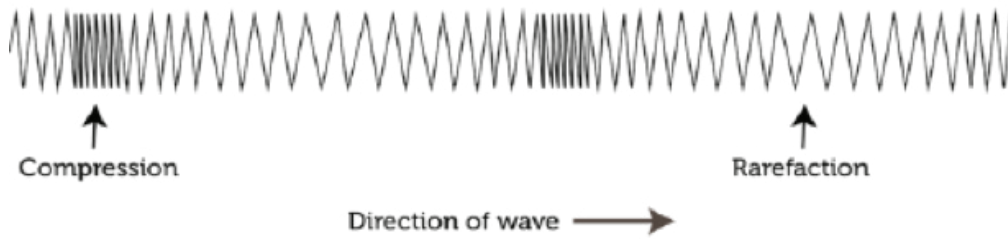


Figure 15.6 The compressions and rarefactions of a longitudinal wave are like the crests and troughs of a transverse wave.

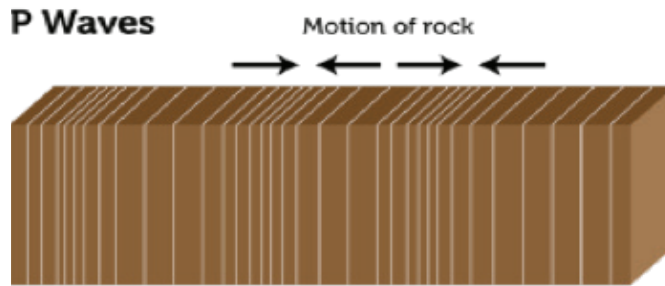


Figure 15.7 P waves are longitudinal waves that travel through rocks under Earth's surface

**How Particles Move in a Surface Wave**

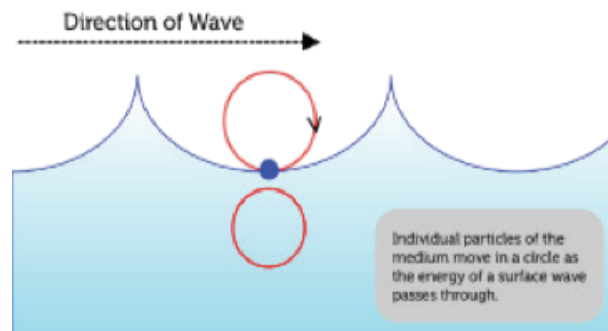


Figure 15.8 Surface waves are both transverse and longitudinal waves.

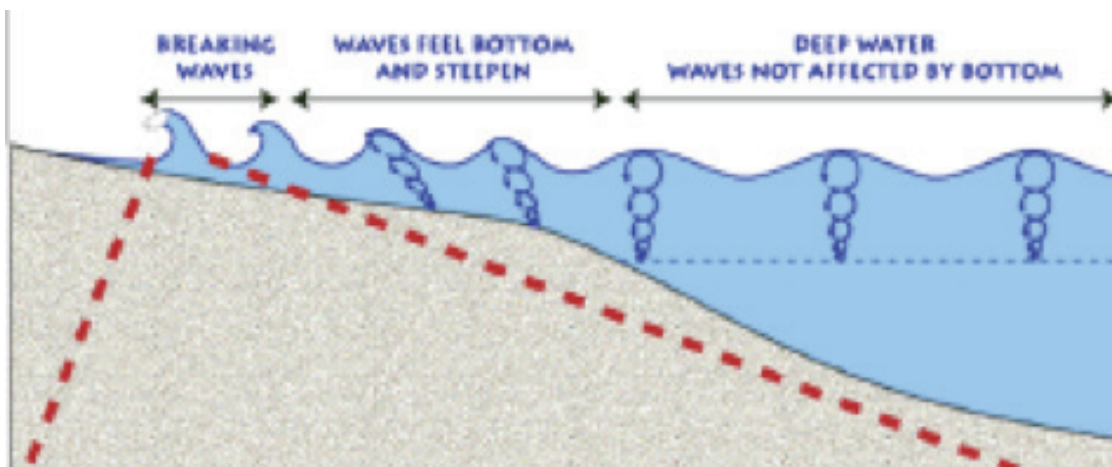


Figure 15.9 Waves topple over and break on the shore because of friction with the bottom in shallow water.

## Topic 2: Interaction of Waves with Matter

<b>Content standard</b>	Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy.
<b>Benchmarks</b>	<p><b>9.3.3.12</b> Compare transverse and longitudinal waves and their properties.</p> <p><b>9.3.3.13</b> Examine transverse and longitudinal waves in mechanical media, such as springs and ropes, and on the earth (seismic waves).</p>
<b>Key question</b>	<ol style="list-style-type: none"> <li>How can we differentiate between wave reflection, refraction and diffraction?</li> <li>What properties of sound waves might determine how loud a sound is?</li> </ol>
<b>Learning objectives</b>	<p>By the end of the topic, the students can:</p> <ul style="list-style-type: none"> <li>Describe wave reflection, refraction, and diffraction.</li> <li>Explain how wave interference affects the amplitude of waves.</li> </ul>
<b>Vocabulary</b>	diffraction, reflection, refraction, standing wave, wave interference
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>Wave reflection occurs when waves bounce back from a barrier they cannot pass through.</li> <li>Wave refraction occurs when waves bend as they enter a new medium at an angle.</li> <li>Wave diffraction occurs when waves pass through an opening in an obstacle.</li> </ul>
<b>Skills</b>	Analyse and predict through illustration how waves interact with matter.
<b>Attitudes and values</b>	Optimistic and Creativity
<b>Teaching and Learning strategies</b>	Teachers should allow students to experiment the examples given to reinforce the definitions of wave interactions with matter.
<b>Assessment</b>	<ol style="list-style-type: none"> <li>Create a sketch of sound waves to show why you can hear a sound on the other side of brick wall.</li> </ol>
<b>Materials</b>	Handouts, diagrams and illustrations. Videos.

### Content Background

#### Wave Interactions

Waves interact with matter in several ways. The interactions occur when waves pass from one medium to another. Besides bouncing back like an echo, waves may bend or spread out when they strike a new medium. These three ways that waves may interact with matter are called reflection, refraction, and diffraction. Each type of interaction is described in detail below.

#### Reflection

An echo is an example of wave reflection. Reflection occurs when waves bounce back from a barrier they cannot pass through. Reflection can happen with any type of waves, not just sound waves. For example, Figure 17.2 shows the reflection of ocean waves off a rocky coast. Light waves can also be reflected. In fact, that's how we see most objects. Light from a light source, such as the sun or a light bulb, shines on the object and some of the light is reflected. When the reflected light enters our eyes, we can see the object.



Figure 17.2 Ocean waves are reflected by rocks on shore.

Reflected waves have the same speed and frequency as the original waves before they were reflected. However, the direction of the reflected waves is different. When waves strike an obstacle head on, the reflected waves bounce straight back in the direction they came from. When waves strike an obstacle at any other angle, they bounce back at the same angle but in a different direction. This is illustrated in Figure 17.3.

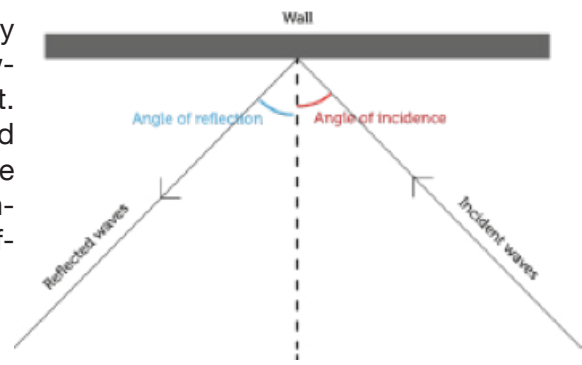


Figure 17.3 Waves strike a wall at an angle, called the angle of incidence. The waves are re-flected at the same angle, called the angle of reflection, but in a different direction. Both angles are measured relative to a line that is perpendicular to the wall.

**Refraction**

Refraction is another way that waves interact with matter. Refraction occurs when waves bend as they enter a new medium at an angle. You can see an example of refraction in Figure 17.4. Light bends when it passes from air to water. The bending of the light causes the pencil to appear broken. Why do waves bend as they enter a new medium? Waves usually travel at different speeds in different media. For example, light travels more slowly in water than air. This causes it to refract when it passes from air to water.



Figure 17.4 This pencil looks broken where it enters the water because of refraction of light waves.

**Diffraction** Did you ever notice that when you're walking down a street, you can hear sounds around the corners of buildings? Figure 17.5 shows why this happens. As you can see from the figure, sound waves spread out and travel around obstacles. This is called diffraction. It also occurs when waves pass through an opening in an obstacle. All waves may be diffracted, but it is more pronounced in some types of waves than others. For example, sound waves bend around corners much more than light does. That's why you can hear but not see around corners. For a given type of waves, such as sound waves, how much the waves diffract depends on two factors: the size of the obstacle or opening in the obstacle and the wavelength. This is illustrated in Figure 17.6.

- Diffraction is minor if the length of the obstacle or opening is greater than the wavelength.
- Diffraction is major if the length of the obstacle or opening is less than the wavelength.

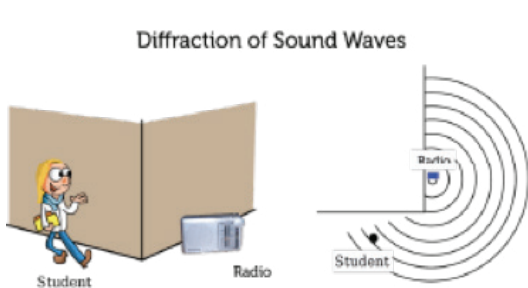


Figure 17.5 The person can hear the radio around the corner of the building because of the diffraction of sound waves.

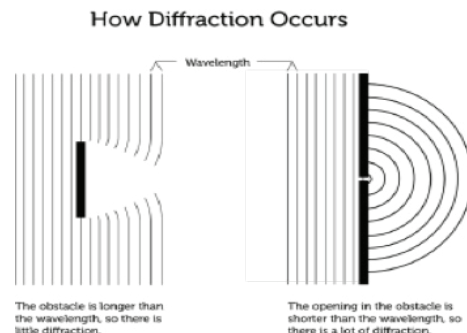


Figure 17.5 The person can hear the radio around the corner of the building because of the diffraction of sound waves.

## Wave Interference

Waves interact not only with matter in the ways described above. Waves also interact with other waves. This is called wave interference. Wave interference may occur when two waves that are traveling in opposite directions meet. The two waves pass through each other, and this affects their amplitude. How amplitude is affected depends on the type of interference. Interference can be constructive or destructive.

### Constructive Interference

Constructive interference occurs when the crests of one wave overlap the crests of the other wave. This is illustrated in Figure 17.7. As the waves pass through each other, the crests combine to produce a wave with greater amplitude.

#### Constructive Interference

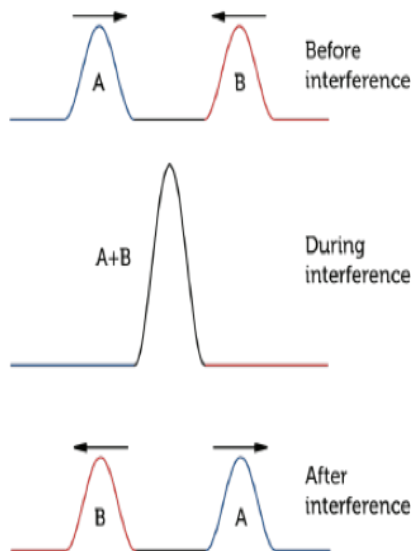


Figure 17.7 Constructive interference increases wave amplitude.

### Destructive Interference

Destructive interference occurs when the crests of one wave overlap the troughs of another wave. This is illustrated in Figure 17.8. As the waves pass through each other, the crests and troughs cancel each other out to produce a wave with less amplitude.

#### Destructive Interference

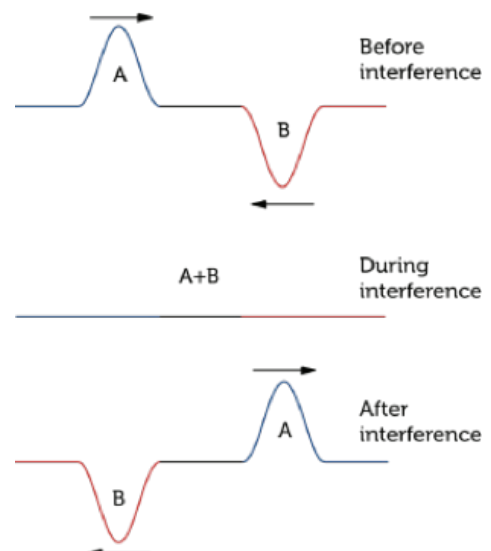


Figure 17.8 Destructive interference decreases wave amplitude.

**Standing Waves** When a wave is reflected straight back from an obstacle, the reflected wave interferes with the original wave and creates a standing wave. This is a wave that appears to be standing still. A standing wave occurs because of a combination of constructive and destructive interference between a wave and its reflected wave. It's easy to generate a standing wave in a rope by tying one end to a fixed object and moving the other end up and down. When waves reach the fixed object, they are reflected back. The original wave and the reflected wave interfere to produce a standing wave. Try it yourself and see if the wave appears to stand still.

### Topic 3: Properties of Sound

<b>Content standard</b>	Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy.
<b>Benchmark</b>	<b>9.3.3.15</b> Verify sound as a longitudinal wave whose speed depends on the properties of the medium in which it propagates.
<b>Key question</b>	1. What is the relationship between sound and wave? 2. What is the relationship between Velocity, Frequency and Wavelength of a Wave?
<b>Learning objectives</b>	By the end of the topic, the students can: <ul style="list-style-type: none"> <li>• Explain the relationship between sound and wave.</li> <li>• Calculate velocity and frequency</li> </ul>
<b>Vocabulary</b>	Wavelength, amplitude, time-period, velocity, frequency
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• The minimum distance in which a sound wave repeats itself is called its wavelength.</li> <li>• The maximum displacement of the particles of the medium from their original undisturbed positions, when a wave passes through the medium is called amplitude of the wave.</li> <li>• The time required to produce one complete wave or cycle or cycle is called time-period of the wave.</li> <li>• The distance travelled by a wave in one second is called velocity of the wave or speed of the wave.</li> </ul>
<b>Skills</b>	Confidently calculate velocity using the wave equation.
<b>Attitudes and values</b>	Confident, critical and responsible.
<b>Teaching and Learning strategies</b>	Investigate the wave equation and allow students to calculate velocity and frequency using the formula $F = 1/\text{Time-period and } v = f \times \lambda$
<b>Assessment</b>	1. Calculate problems about velocity and frequency using the appropriate equation.
<b>Materials</b>	Handouts, worksheets & videos

### Content Background

#### What are the characteristics of Sound Waves?

Sound is a form of energy which makes us hear. It travels in the form of wave. Sound wave can be described by five characteristics. Let us study through this article about it.

The sensation felt by our ears is called sound. It is a form of energy which makes us hear. We hear several sounds around us in our everyday life. We know that sound travels in the form of wave.

A wave is a vibratory disturbance in a medium which carries energy from one point to another without there being a direct contact between the two points. We can say that a wave is produced by the vibrations of the particles of the medium through which it passes.

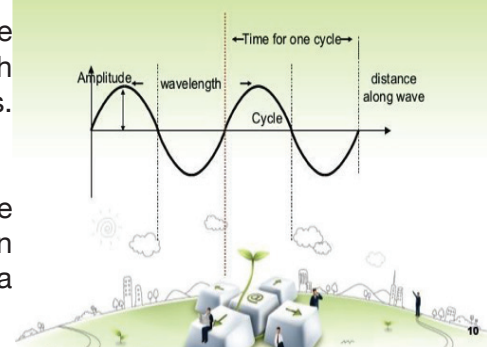
#### There are two types of waves: Longitudinal waves and Transverse waves.

**Longitudinal Waves:** A wave in which the particles of the medium vibrate back and forth in the 'same direction' in which the wave is moving. Medium can be solid, liquid or gases. Therefore, sound waves are longitudinal waves.

**Transverse Waves:** A wave in which the particles of the medium vibrate up and down 'at right angles' to the direction in which the wave is moving. These waves are produced only in a solids and liquids but not in gases.

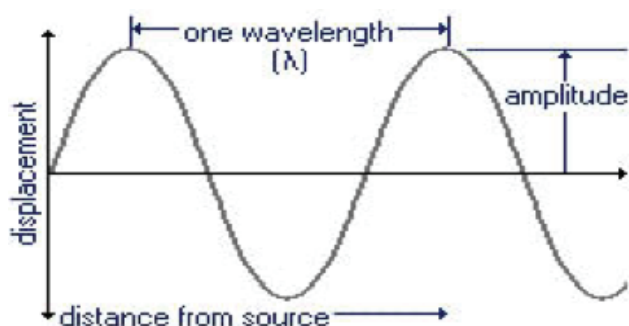
*Sound is a longitudinal wave which consists of compressions and rarefactions travelling through a medium.*

#### Characteristic of Sound Waves



**Sound wave can be described by five characteristics: Wavelength, Amplitude, Time-Period, Frequency and Velocity or Speed.**

### 1. Wavelength



Source: [www.sites.google.com](http://www.sites.google.com)

The minimum distance in which a sound wave repeats itself is called its wavelength. That is it is the length of one complete wave. It is denoted by a Greek letter  $\lambda$  (lambda). We know that in a sound wave, the combined length of a compression and an adjacent rarefaction is called its wavelength. Also, the distance between the centres of two consecutive compressions or two consecutive rarefactions is equal to its wavelength.

**Note:** The distance between the centres of a compression and an adjacent rarefaction is equal to half of its wavelength i.e.  $\lambda/2$ . The S.I unit for measuring wavelength is metre (m).

### 2. Amplitude

When a wave passes through a medium, the particles of the medium get displaced temporarily from their original undisturbed positions. The maximum displacement of the particles of the medium from their original undisturbed positions, when a wave passes through the medium is called amplitude of the wave. In fact the amplitude is used to describe the size of the wave. The S.I unit of measurement of amplitude is metre (m) though sometimes it is also measured in centimetres. Do you know that the amplitude of a wave is the same as the amplitude of the vibrating body producing the wave?

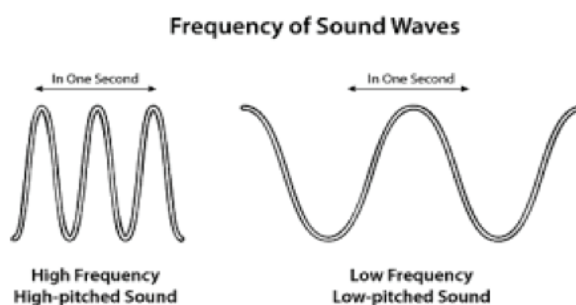
### 3. Time-Period

The time required to produce one complete wave or cycle or cycle is called time-period of the wave. Now, one complete wave is produced by one full vibration of the vibrating body. So, we can say that the time taken to complete one vibration is known as time-period. It is denoted by letter T. The unit of measurement of time-period is second (s).

**Why Speed and Velocity are not always equal in magnitude?**

### 4. Frequency

The number of complete waves or cycles produced in one second is called frequency of the wave. Since one complete wave is produced by one full vibration of the vibrating body, so we can say that the number of vibrations per second is called frequency. For example: if 10 complete waves or vibrations are produced in one second then the frequency of the waves will be 10 hertz or 10 cycles per second. Do you know that the frequency of a wave is fixed and does not change even when it passes through different substances?



The S.I unit of frequency is hertz or Hz. A vibrating body emitting 1 wave per second is said to have a frequency of 1 hertz. That is 1 Hz is equal to 1 vibration per second.

Do you know that the frequency of a wave is fixed and does not change even when it passes through different substances?

The S.I unit of frequency is hertz or Hz. A vibrating body emitting 1 wave per second is said to have a frequency of 1 hertz. That is 1 Hz is equal to 1 vibration per second.

Sometimes a bigger unit of frequency is known as kilohertz (kHz) that is 1 kHz = 1000 Hz. The frequency of a wave is denoted by the letter f.

The frequency of a wave is the same as the frequency of the vibrating body which produces the wave.

### What is the relation between time-period and frequency of a wave?

The time required to produce one complete wave is called time-period of the wave. Suppose the time-period of a wave is T seconds.

In T seconds number of waves produced = 1

So, in 1 second, number of waves produced will be =  $1/T$

But the number of waves produced in 1 second is called its frequency.

Therefore,  $F = 1/\text{Time-period}$

$f = 1/T$

where f = frequency of the wave

T = time-period of the wave

### 5. Velocity of Wave (Speed of Wave)

The distance travelled by a wave in one second is called velocity of the wave or speed of the wave. It is represented by the letter v. The S.I unit for measuring the velocity is metres per second (m/s or ms<sup>-1</sup>).

### What is the relationship between Velocity, Frequency and Wavelength of a Wave?

Velocity = Distance travelled/ Time taken

Let  $v = \lambda / T$

Where T = time taken by one wave.

**$v = f \times \lambda$**

This formula is known as wave equation.

Where v = velocity of the wave

f = frequency

$\lambda$  = wavelength

Velocity of a wave = Frequency X Wavelength

This applies to all the waves like transverse waves like water waves, longitudinal waves like sound waves and the electromagnetic waves like light waves and radio waves

Therefore we have learnt various characteristics of sound waves.

**Sound** can only travel through a medium (substance) while light can travel through empty space.

Sound is a form of mechanical energy caused by vibrations of matter. Light is electromagnetic energy caused by interacting electric and magnetic fields. ... Light travels much faster than sound.

How is light energy different from sound energy?

Is sound affected by light?

Light does not really affect sound. Sound is made of vibrations (aka rapid pressure fluctuations) in air, water, or solid material. ... Now, the timescale (for example, the oscillation speed or the wave speed) for light is much faster than that for sound, so sound doesn't even notice when light is around

What is light heat and sound?

Heat, light, and sound are all forms of energy. Heat can be transferred by radiation, conduction and convection. Visible light can be produced, reflected, refracted, and separated into light of various colors. Sound is created by vibration and cannot travel through a vacuum.

**Topic 4: Light as Energy**

<b>Content standard</b>	Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy.
<b>Benchmark</b>	<b>9.3.3.16</b> Demonstrate the properties of light through different mediums.
<b>Key question</b>	1. What are the properties of light waves? 2. How do light waves react with different matter?
<b>Learning objectives</b>	By the end of the topic, the students can: <ul style="list-style-type: none"> <li>• Explain the properties of the relationship of light waves with matter through absorption, transmission, reflection, refraction, scattering, and diffraction.</li> <li>• Develop models to demonstrate that light waves are reflected, absorbed and transmitted through different materials.</li> </ul>
<b>Vocabulary</b>	Absorption, Diffraction, Transmittance, Reflection, Refraction, Scattering
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• Light is absorbed by a material if the frequency of the wave is near some resonant frequency characteristic of the material.</li> <li>• One of the most important wavelike behaviours of light is reflection.</li> <li>• Any light that is not absorbed or reflected at an interface is transmitted.</li> <li>• Scattering describes the interaction of light with small particles.</li> <li>• The sudden change in direction of light waves is called refraction.</li> <li>• When light interacts with some sort of obstacle or slit, it forms distinct diffraction patterns that reveal the wavelike nature of light.</li> </ul>
<b>Skills</b>	Experiment and demonstrate the properties of light with different materials.
<b>Attitudes and values</b>	Optimistic and Creativity
<b>Teaching and Learning strategies</b>	Learn about absorption, transmission, reflection, refraction, scattering, and diffraction through experiments.
<b>Assessment</b>	1. Demonstrate the properties of light when it interacts with different materials.
<b>Materials</b>	Plastic, box, Laser, Sticks, Aluminum foil, Tissue paper, Wax paper, Cardboard, Acrylic paint, Blocks, Poster, Pins

**Content Background**

Light is all around us. It not only lets us see in the dark, but the properties of light are important to many aspects of our lives. Reflections in rear-view mirrors of cars help to keep us safe. Refraction through lenses of eyeglasses or contact lens' helps some people see better. More generally, electromagnetic waves (of which visible light is one example) are transmitted as a signal that our radios pick up so we can listen to music. Pulses of infrared light are transmitted as signals so we can communicate with our TVs. This backgrounder is all about visible light and how we interact with it.

“Light” (more precisely, visible light) is the type of electromagnetic radiation that is detectable by the human eye. Light, as with all matter, can be described either as a wave or as a particle (a “photon”).

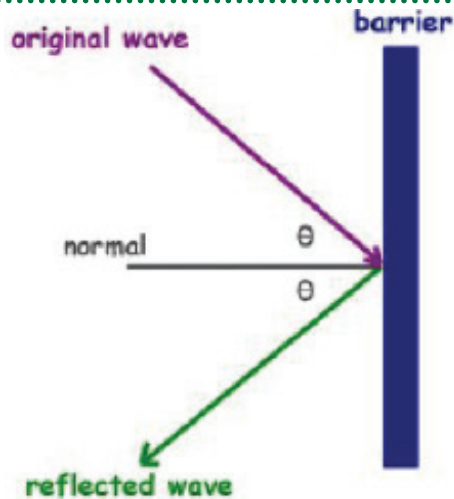
**Absorption**

Light is absorbed by a material if the frequency of the wave is near some resonant frequency characteristic of the material. This frequency can describe the difference between atomic energy levels, the vibration of molecular bonds, or the vibration of atoms in a crystal lattice. We can think of the vibrational energy, this jiggling of atoms, as heat. For example, when we “soak up the sun,” the sunlight we absorb excites a resonance in our skin and heats us up.

**Reflection**

One of the most important wavelike behaviors of light is reflection.

We see things by detecting the light that is reflected off of objects, and the color of objects we see is determined by light reflected back to us or transmitted through a transparent material. When light reaches an interface between two different mediums, some of the wave will bounce off the surface. The properties of the two mediums determine the intensity and frequency of reflected light. The law of reflection states that the angle of incidence and angle of reflection are equal, as sketched to the side.



### Transmission

Any light that is not absorbed or reflected at an interface is transmitted. For example, if the frequency of light does not excite a resonance of the material, it is not absorbed, but rather transmitted. The amount of light transmitted depends on the speed of light in the medium.

### Refraction

Light travels at different speeds in different materials. Because of this, the path of the light will change directions as it passes from one material to another. We call this sudden change in direction refraction, and it is a characteristic of all waves (e.g. sound). A classic example of refraction is a straw sticking out of a glass of water (see figure).

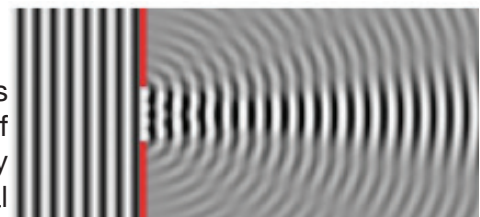


### Scattering

Scattering is similar to reflection, but it is a common special case that doesn't strictly follow the law of reflection. Scattering describes the interaction of light with small particles. Because these particles are so small, light essentially gets reflected in all directions. This effect allows us to see dust particles floating in air when they are illuminated.

### Diffraction

When light interacts with some sort of obstacle or slit, it forms distinct diffraction patterns that reveal the wavelike nature of light. Diffraction is not something usually seen in everyday life, but its properties have both a physical and technological importance.



**Light** is electromagnetic radiation within a certain portion of the electromagnetic spectrum. The word usually refers to visible light, which is the visible spectrum that is visible to the human eye and is responsible for the sense of sight.[1] Visible light is usually defined as having wavelengths in the range of 400–700 nanometres (nm), or  $4.00 \times 10^{-7}$  to  $7.00 \times 10^{-7}$  m, between the infrared (with longer wavelengths) and the ultraviolet (with shorter wavelengths).[2][3] This wavelength means a frequency range of roughly 430–750 terahertz (THz).

The main source of light on Earth is the Sun. Sunlight provides the energy that green plants use to create sugars mostly in the form of starches, which release energy into the living things that

digest them. This process of photosynthesis provides virtually all the energy used by living things. Historically, another important source of light for humans has been fire, from ancient campfires to modern kerosene lamps. With the development of electric lights and power systems, electric lighting has effectively replaced firelight. Some species of animals generate their own light, a process called bioluminescence. For example, fireflies use light to locate mates, and vampire squids use it to hide themselves from prey.

The primary properties of visible light are intensity, propagation direction, frequency or wavelength spectrum, and polarization, while its speed in a vacuum, 299,792,458 metres per second, is one of the fundamental constants of nature. Visible light, as with all types of electromagnetic radiation (EMR), is experimentally found to always move at this speed in a vacuum.[4]

In physics, the term light sometimes refers to electromagnetic radiation of any wavelength, whether visible or not.[5][6] In this sense, gamma rays, X-rays, microwaves and radio waves are also light. Like all types of EM radiation, visible light propagates as waves. However, the energy imparted by the waves is absorbed at single locations the way particles are absorbed. The absorbed energy of the EM waves is called a photon, and represents the quanta of light. When a wave of light is transformed and absorbed as a photon, the energy of the wave instantly collapses to a single location, and this location is where the photon “arrives.” This is what is called the wave function collapse. This dual wave-like and particle-like nature of light is known as the wave–particle duality. The study of light, known as optics, is an important research area in modern physics.

### **Speed of light**

The speed of light in a vacuum is defined to be exactly 299,792,458 m/s (approx. 186,282 miles per second). The fixed value of the speed of light in SI units results from the fact that the metre is now defined in terms of the speed of light. All forms of electromagnetic radiation move at exactly this same speed in vacuum.

Different physicists have attempted to measure the speed of light throughout history. Galileo attempted to measure the speed of light in the seventeenth century. An early experiment to measure the speed of light was conducted by Ole Rømer, a Danish physicist, in 1676. Using a telescope, Rømer observed the motions of Jupiter and one of its moons, Io. Noting discrepancies in the apparent period of Io’s orbit, he calculated that light takes about 22 minutes to traverse the diameter of Earth’s orbit.[15] However, its size was not known at that time. If Rømer had known the diameter of the Earth’s orbit, he would have calculated a speed of 227,000,000 m/s.

How many years is a light year?

As defined by the International Astronomical Union (IAU), a light-year is the distance that light travels in vacuum in one Julian year (365.25 days).

Topic 5: Electrical Charges and Forces	
<b>Content standard</b>	Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy.
<b>Benchmarks</b>	<b>9.3.3.19</b> Analyse the electrical energy consumption of a household appliance. <b>9.3.3.20</b> Compare and contrast voltage (electric potential difference) and current in series and parallel circuits.
<b>Key question</b>	1. What household appliances consume the most electricity? 2. How much power does a household appliance use? 3. What is the electrical potential difference between voltage in a series and parallel circuit?
<b>Learning objectives</b>	By the end of the topic, the students can: <ul style="list-style-type: none"> <li>• Explain the electrical potential difference between voltage in series and complex circuits.</li> <li>• Calculate the amount of power usage by household appliances.</li> </ul>
<b>Vocabulary</b>	Static electricity, electric charge, coulombs, circuits, current, ampere, conductors, insulators, voltage, resistance, ohms
<b>Knowledge</b>	Static Electricity Electric charge Electric circuits Resistance
<b>Skills</b>	Calculate voltage, current and resistance
<b>Attitudes and values</b>	Appreciate the importance of electricity in their lives and mathematically calculate power usage to save energy.
<b>Teaching and Learning strategies</b>	Allow students to use formulae to calculate voltage, current and resistance of home appliances and makes recommendations of how to save energy.
<b>Assessment</b>	1. Students will calculate voltage, current and resistance using given situations
<b>Materials</b>	

### Content Background

#### What is electricity explain?

Electricity is the presence and flow of electric charge. ... It is a form of energy which we use to power machines and electrical devices. When electrical charges are not moving, electricity is called static electricity.

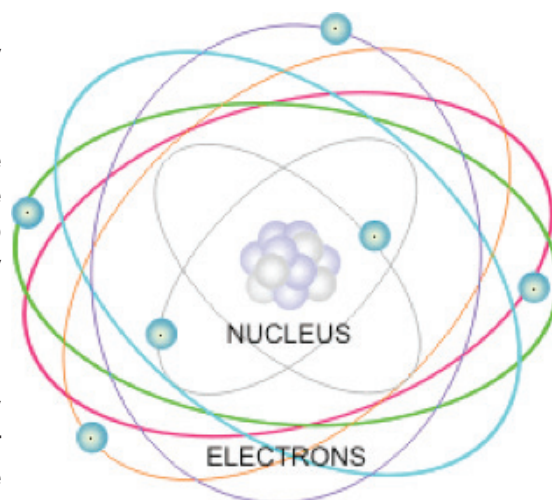
#### Electricity

Our modern technological society is largely defined by our widespread use of electrical energy. Electricity provides us with light, heat, refrigeration, communication, elevators, and entertainment. We are so dependent on electricity that when it is unavailable for even a few minutes, the word “crisis” comes to mind. Electrical energy is popular because it is so easily transmitted from one place to another, and converted into other forms of energy.

If you could see an atom, it would look a little like a tiny center of balls surrounded by giant invisible bubbles (or shells). The electrons would be on the surface of the bubbles, constantly spinning and moving to stay as far away from each other as possible.

Electrons are held in their shells by an electrical force.

The protons and electrons of an atom are attracted to each other. They both carry an electrical charge. An electrical charge is a force within the particle.



In order to understand how electric charge moves from one atom to another, we need to know something about atoms. Everything in the universe is made of atoms—every star, every tree, every animal. The human body is made of atoms. Air and water are, too. Atoms are the building blocks of the universe. Atoms are so small that millions of them would fit on the head of a pin.

Atoms are made of even smaller particles. The center of an atom is called the nucleus. It is made of particles called protons and neutrons. The protons and neutrons are very small, but electrons are much, much smaller. Electrons spin around the nucleus in shells a great distance from the nucleus. If the nucleus were the size of a tennis ball, the atom would be the size of the Empire State Building. Atoms are mostly empty space.

Protons have a positive charge (+) and electrons have a negative charge (-). The positive charge of the protons is equal to the negative charge of the electrons. Opposite charges attract each other. When an atom is in balance, it has an equal number of protons and electrons. The neutrons carry no charge and their number can vary.

### STATIC ELECTRICITY

Electricity has been moving in the world forever. Lightning is a form of electricity. It is electrons moving from one cloud to another or jumping from a cloud to the ground. Have you ever felt a shock when you touched an object after walking across a carpet? A stream of electrons jumped to you from that object. This is called static electricity.

Have you ever made your hair stand straight up by rubbing a balloon on it?

If so, you rubbed some electrons off the balloon. The electrons moved into your hair from the balloon. They tried to get far away from each other by moving to the ends of your hair.

They pushed against each other and made your hair move—they repelled each other. Just as opposite charges attract each other, like charges repel each other.

### Electric Charge

The simplest electrical phenomenon is static electricity, the temporary “charging” of certain objects when they are rubbed against each other.

Run a comb through your hair when it’s dry, and the hair and comb begin to attract each other, indicating that they are charged. Other familiar examples include clothes sticking together in the dryer, and the sudden shock that you sometimes get when shaking someone’s hand after walking across a carpet with rubber-soled shoes.

What you may not have noticed is that static electricity can result in both attractive and repulsive forces. The comb attracts the hair and vice-versa, but the hairs repel each other, and two combs similarly charged will likewise repel each other. To explain this we say that there are two types of electric charge, called positive and negative. When objects become charged by rubbing against each other, one always becomes positive and the other becomes negative. Positively charged objects (the hair, for instance) attract negatively charged objects (the comb) and vice-versa, but two positives repel each other, as do two negatives. In summary, like charges repel, while unlike charges attract.

What’s happening at the atomic level is this: All atoms contain particles called protons and electrons, which carry intrinsic positive and negative charges, respectively.

Ordinarily, the number of protons in a chunk of matter is almost exactly equal to the number of electrons, so their static-electricity effects cancel out on large scales. However, rubbing certain objects together transfers some of the electrons from one to the other, leaving the first object positively charged (because it now has an excess of protons) and the other object negatively charged (because it now has an excess of electrons).

In the official scientific system of units, the amount of electric charge on an object is measured in units called **coulombs** (abbreviated **C**).

The total charge on all the protons in a gram of matter is typically about 50,000 C, while the electrons in the same gram of matter would carry a total charge of -50,000 C. These numbers may seem

inconveniently large, but they're not very relevant to everyday life because all we normally measure is the excess of one type of charge over the other. The amount of excess charge that readily builds up on a person's hair is less than a **microcoulomb**, that is, 0.000001 C. ("Micro" is the metric prefix for a millionth, 0.000001.)

The charge of a single proton turns out to be  $1.6 \times 10^{-19}$  C, while the charge of a single electron is minus the same amount. Thus, the number of excess electrons on a charged comb is quite enormous, but only a tiny, tiny fraction of all the electrons in the comb.

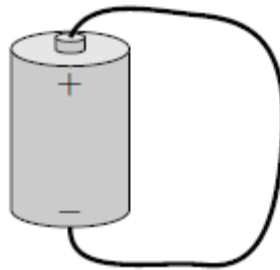
How long an object remains electrically charged depends on how easily the excess electrons can find their way back to the excess protons. Some materials, such as metals, allow electrons to move through them quite readily, while other materials, such as paper, plastic, and dry air, offer quite a bit of resistance to the motion of electrons. Materials in the first class are called **conductors**, while materials in the second class are called **insulators**.

The distinction between conductors and insulators is merely a matter of degree, however; all materials conduct to some extent.

Furthermore, any insulating material will become a good conductor if it is subjected to electrostatic forces that are strong enough to rip electrons out of the atoms. The most dramatic example is lightning: the sudden discharge of thunderclouds through a column of air, which is momentarily made into a conductor by the enormous static charges. The shock that you get when you shake someone's hand is the same phenomenon, on a much smaller scale.

### Electric Circuits

Although static electricity has its useful applications, more useful by far is a system that can continuously separate negative from positive charges, then extract energy from them as they move around to recombine. This is the principle of the electric circuit. Figure 5.1 shows a very simple electric circuit, consisting of a battery with its two ends connected by a single wire.



*Figure 5.1. A very simple electric circuit, consisting of a battery with its two ends connected by a metal wire. (Don't try this at home unless you don't mind running down the battery very quickly.)*

The battery uses chemical energy to separate negative from positive charges, always maintaining a slight excess positive charge on its "+" end and a slight excess negative charge on its "-" end. When the battery isn't connected to any conductors, these excess charges just sit there and do nothing of interest. Connect the two ends together with a metal wire, however, and the electrons will move along the wire in order to recombine with the protons. Along the way, they will collide with the atoms in the wire, creating a kind of "friction" that makes the wire get hot.

The battery, meanwhile, keeps replenishing the supply of electrons at its negative end, until its internal chemical reaction has gone to completion. In summary, this circuit converts chemical energy in the battery into electrical energy, which is then converted into thermal energy in the wire.

Figure 5.2 shows a slightly more complicated circuit, consisting of a battery, a pair of wires, and an ordinary incandescent light bulb. This circuit is essentially a flashlight. Because the filament of the bulb offers significantly more resistance to the flow of electrons than do the wires leading to it, the electrons will flow much more slowly in this circuit than in the previous one. Instead of creating thermal energy uniformly along the wires, this circuit concentrates the thermal energy at the point of greatest resistance, the filament. The filament becomes so hot that it glows.

The bulb around the filament keeps oxygen out, preventing chemical reactions of the hot metal filament with oxygen.

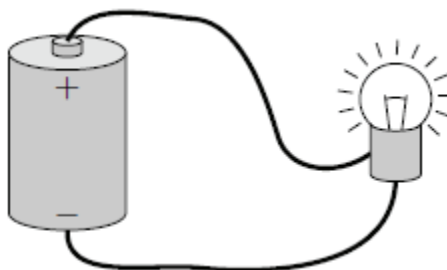


Figure 5.2. A “flashlight” circuit, consisting of a battery connected to a light bulb by a pair of wires. (The connections inside the bulb simply route the electric current through the filament.)

To understand electric circuits quantitatively, we need to know a little more about the battery. It turns out that a fresh battery, under most uses, provides a fixed amount of electrical energy to each electron that it pushes around the circuit.

This means that it provides a fixed amount of energy to each coulomb of electric charge that moves around the circuit, and that two coulombs of charge receive twice as much energy as one coulomb of charge. The amount of energy provided, per coulomb of charge moved, is called the battery’s voltage:

$$\text{Battery voltage} = \frac{\text{Energy provided}}{\text{Amount of charge}} \quad (5.1)$$

The standard unit of **voltage** is therefore the joule per coulomb, a unit that has its own name, the volt (V):

$$1 \text{ volt} = 1 \frac{\text{joule}}{\text{coulomb}} \quad (5.2)$$

According to equation 5.1, if you know the voltage of a battery and want to know how much energy it has released, you need to multiply by the amount of charge that it has moved:

$$\text{energy provided} = (\text{battery voltage}) \times (\text{amount of charge}). \quad (5.3)$$

For example, if a 12-volt car battery pushes 100 coulombs of charge out its terminal, it has provided 1200 joules of energy.

Very often, instead of talking about the total amount of charge pushed through a circuit element, we talk about the amount of charge that passes a given point per unit time. This quantity is called the **electric current**:

$$\text{current} = \frac{\text{Amount of charge passing}}{\text{Time elapsed}} \quad (5.4)$$

The standard unit of current is the **coulomb** per second, which is also called the **ampere** (or simply amp, abbreviated A):

$$1 \text{ ampere} = 1 \frac{\text{Coulomb}}{\text{second}} \quad (5.5)$$

For example, if 20 coulombs of charge pass by a point during a time of 5 seconds, the current would be 20/5 coulombs per second, or 4 amperes.

Currents of a few coulombs per second are quite common in electric circuits, even though a coulomb would be considered a huge amount of charge, were it unbalanced by an equal amount of opposite charge. In electrical wires, the negative charge of the moving electrons is almost exactly balanced, at every point, by the positive charge of the stationary protons.

In a single-loop circuit such as those shown in Figures 5.1 and 5.2, the value of the current will be the same at every point around the loop. Otherwise, unbalanced charges would be building up somewhere in the circuit, and this could never continue for more than a split-second, because those charges would repel each other with huge electrostatic forces.

### ***How can you predict how much current will flow in a given circuit?***

This is determined by two things: the voltage of the battery (or equivalent energy source) and the amount of resistance offered by the wires, filaments, and whatever else the electrons must pass through during their journey. The technical definition of **resistance** is simply the number of volts required, per ampere of current desired:

$$\text{resistance} = \frac{\text{Volts required}}{\text{Current desired}} \quad \text{Definition of resistance (5.6)}$$

A typical copper wire has relatively low resistance (not many volts required to push lots of current through it), while the filament of a light bulb has a moderately high resistance (quite a few volts required per ampere of current desired). Turning equation 5.6 around gives

$$\text{resistance} = \frac{\text{Voltage}}{\text{Resistance}} \quad (5.7)$$

This simply says that the greater the voltage, the greater the current, while the greater the resistance, the smaller the current.

The unit of resistance would be the volt per ampere, which also has its own name, the **Ohm** (abbreviated by  $\Omega$ , the capital Greek letter omega). A typical flashlight bulb has a resistance of about 10 ohms, so when you connect it to a 3-volt power source (a pair of 1.5 V batteries), you get a current of

$$\text{current} = \frac{3 \text{ V}}{10 \Omega} = 0.3 \text{ A.} \quad (5.8)$$

### **Energy and Power**

As already mentioned, voltage is energy per unit charge, so if you want to know how much energy has been provided by a battery, you simply multiply the voltage by the amount of charge that it has moved so far (see equation 5.3).

The same formula gives the amount of electrical energy used by a light bulb or any other device that consumes electrical energy, provided that you replace the battery voltage by the voltage difference between one end of the device and the other:

$$\text{energy used} = (\text{difference in voltage}) \times (\text{charge passing through}). \quad (5.9)$$

(In a complicated circuit, there may be other devices between your device and the battery, so the difference in voltage “seen” by your device may not be the full battery voltage.) If instead of multiplying by the amount of charge, we multiply by the current passing through the device, we get;

$$\begin{aligned}
 (\text{voltage difference}) \times (\text{current}) &= (\text{voltage difference}) \times \frac{\text{charge}}{\text{time}} \\
 &= \frac{\text{energy}}{\text{time}} = \text{power} \qquad (5.10)
 \end{aligned}$$

That is, the product of the voltage times the current gives the rate at which your device absorbs electrical energy. For instance, if 0.3 amperes of current are flowing through a flashlight bulb due to a 3-volt voltage difference across it, the rate at which it uses electrical energy is

$$(3 \text{ V})(0.3 \text{ A}) = 0.9 \text{ V}\cdot\text{A} = 0.9 \frac{\text{J}}{\text{C}} \cdot \frac{\text{C}}{\text{s}} = 0.9 \frac{\text{J}}{\text{s}} = 0.9 \text{ W} \qquad (5.11)$$

or just under one **watt**. If you leave this flashlight on for one hour, the total energy used is then

$$\text{energy} = (\text{power}) \times (\text{time}) = (0.9 \text{ W})(3600 \text{ s}) = 3240 \text{ J} \approx 3000 \text{ J}. \qquad (5.12)$$

The total chemical energy that can be extracted from a pair of flashlight batteries must be only a few times greater than this, because we all know that the batteries will power the flashlight for only a few hours before going dead.

### MEASURING ELECTRICITY

Electricity is measured in units of power called watts. It was named to honor James Watt, the inventor of the steam engine. One watt is a very small amount of power. It would require nearly 750 watts to equal one horsepower. A kilowatt represents 1,000 watts. A kilowatthour (kWh) is equal to the energy of 1,000 watts working for one hour. The amount of electricity a power plant generates or a customer uses over a period of time is measured in kilowatthours (kWh).

Kilowatthours are determined by multiplying the number of kW's required by the number of hours of use.

For example, if you use a 40-watt light bulb 5 hours a day, you have used 200 watthours, or 0.2 kilowatthours, of electrical energy.

**Topic 6: Magnets and Magnetic Field**

<b>Content standard</b>	Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy.
<b>Benchmark</b>	<b>9.3.3.21</b> Explore properties of magnets including Earth's magnetic field
<b>Key questions</b>	<ol style="list-style-type: none"> <li>1. What are the properties of a magnet?</li> <li>2. How does Earth's magnetic field work?</li> </ol>
<b>Learning objectives</b>	By the end of the topic, the students can: <ul style="list-style-type: none"> <li>• Identify and explain the properties of magnets.</li> <li>• Investigate and justify how the Earth's magnetic field work.</li> </ul>
<b>Vocabulary</b>	Magnet, magnetic field, magnetic pole, magnetism, ferromagnetic material, magnetic force
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• A magnet is a material or object that produces a magnetic field.</li> <li>• All magnets have two poles: the North Pole and the South Pole.</li> <li>• Earth is a giant magnet with north and south magnetic poles and a magnetic field called the magnetosphere.</li> </ul>
<b>Skills</b>	<ul style="list-style-type: none"> <li>• Careful observation of the magnets, Critical thinking, investigation</li> </ul>
<b>Attitudes and values</b>	<ul style="list-style-type: none"> <li>• Patient in observation,</li> <li>• Value the importance of a magnet</li> <li>• Appreciate the use of magnet in everyday life</li> </ul>
<b>Teaching and Learning strategies</b>	Teacher should provide handouts, prepare some pictures or illustrations of the magnetic field and do an experiment of the magnetic field using compass and bar magnet.
<b>Assessment</b>	1. Explain how and why a ferromagnetic material can be magnetized.
<b>Materials</b>	Bar magnets, ferromagnetic materials

**Content Background**

**Properties of Magnets**

A magnet is a material or object that produces a magnetic field. This magnetic field is invisible but is responsible for the most notable property of a magnet: a force that pulls on other ferromagnetic materials, such as iron, and attracts or repels other magnets.

**Magnetic Poles**

All magnets have two magnetic poles. The poles are regions where the magnet is strongest. The poles are called north and south because they always line up with Earth's north-south axis if the magnet is allowed to move freely. (Earth's axis is the imaginary line around which the planet rotates.) If a bar magnet is cut in half along the line between the north and south poles both halves would also have north and south poles. If you cut each of the halves in half, all those pieces would have north and south poles as well. Pieces of a magnet always have both north and south poles no matter how many times you cut the magnet.



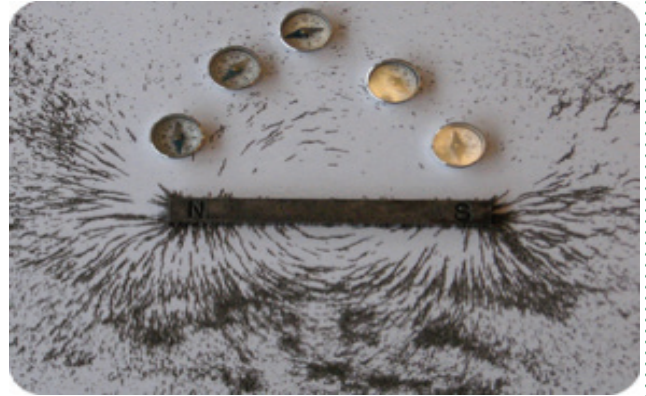
**Magnetic Force**

The force that a magnet exerts on certain materials is called magnetic force. Like electric force, magnetic force is exerted over a distance and includes forces of attraction and repulsion. North and south poles of two magnets attract each other, while two north poles or two south poles repel each other.

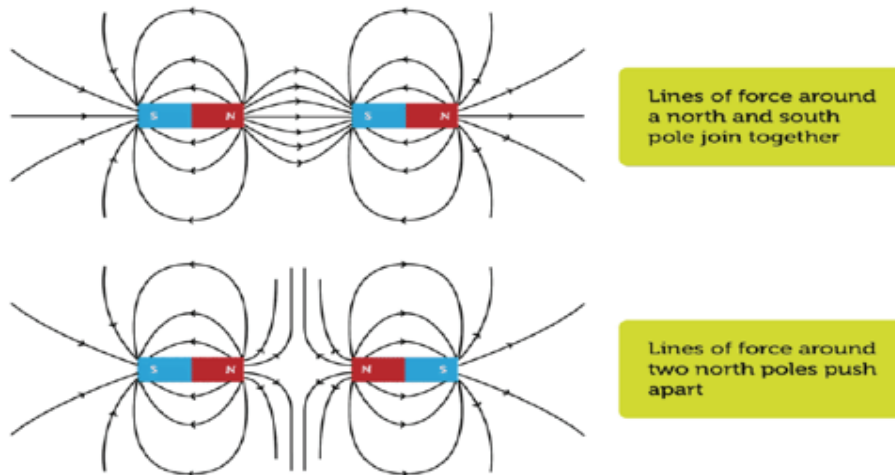
## Magnetic Field

Like the electric field that surrounds a charged particle, a magnetic field surrounds a magnet. This is the area around the magnet where it exerts magnetic force.

Magnets and Magnetism bits of iron, called iron filings, were placed under a sheet of glass. The picture on the right shows when the magnet was placed on the glass, it attracted the iron filings. The pattern of the iron filings shows the lines of force that make up the magnetic field of the magnet. The concentration of iron filings near the poles indicates that these areas exert the strongest force.

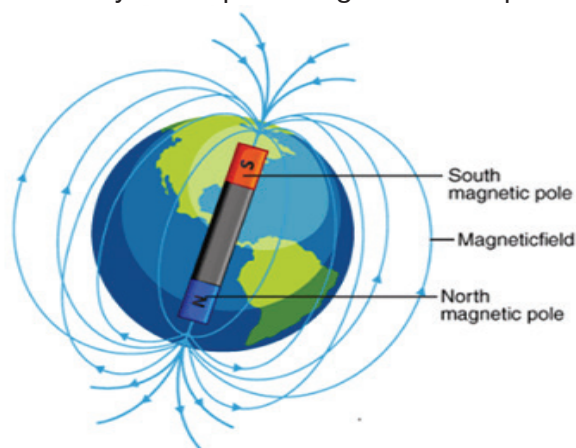


When two magnets are brought close together, their magnetic fields interact. The drawings below show how lines of force of north and south poles attract each other whereas those of two north poles repel each other. The animations at the URL below show how magnetic field lines change as two or more magnets move in relation to each other.



If you have ever used a compass then you know it always points north. If you suspend a refrigerator magnet, it will also point north. This suggests that there is a magnetic field all around us generated by the earth under your feet!

The earth's magnetic field extends millions of kilometres into outer space and looks very much like a bar magnet. The earth's south magnetic pole is actually near the North Pole and the magnetic north pole is in Antarctica! This is why a compass magnet's north pole actually points north (north and south poles attract).



# Strand 4: Earth and Spaces Science

## Unit 9.9: Our Earth

The geology of Papua New Guinea is very unique in that most of the natural processes that are responsible for shaping the planet Earth are found here. From the study of the continental and oceanic crusts, the processes of oogenesis and seafloor spreading underneath the oceans, students will be able to recognise and identify the structures such as mid-ocean ridges, trenches and transforms, and the magnetic anomalies which are all indicators of the past, present, and future evolution of the planet.

Students identify some common minerals, describe the origin of rocks and give examples of common rock types and how they are used. They use a map showing the location of earthquakes and volcanoes to identify the position of tectonic plate margins and describe the processes happening. Students understand how the geological occurrence and properties of an ore are related to how it is mined. They recognise the impact of mining on the physical environment and suggest ways in which the area can be rehabilitated: for example, students explain why topsoil is removed and stored during bauxite mining and replaced to begin rehabilitation.

Students recognise that humans have made use of the earth's materials according to properties of these materials: for example, they might describe how wet sand makes better sandcastles than does dry sand; explain why adding humus to a sandy soil makes plants grow better; suggest why chert is preferred to sandstone for the manufacture of stone tools; or discuss how the nature and variety of archaeological artefacts can be used to deduce how past civilisations lived and worked in their environment.

Students understand that the earth's resources are finite and argue the importance of conserving and replacing them: for example, they identify and take steps to remedy water wastage in their home or school by detecting leaky taps, monitoring the placement of sprinklers, describing water consumption in their community (taking into account seasonal variation and the nature of the water supply) or creating an effective plan to monitor community water use.

Students understand that the earth is composed of materials that are altered by forces within it and on its surface. They describe the processes of weathering, erosion and tides and how such physical processes affect the landscape. They give examples of erosion in their local area, such as in river beds, sand dunes or salt lakes, and evaluate the success of steps taken to remedy its effects.

### Topic 1: The Earth's Structure

<b>Content standard</b>	Students will be able to recognize and explain the processes that are responsible for shaping the planet Earth and describe the place of the planet in the solar system and beyond into the inter-intergalactic space.
<b>Benchmark</b>	<b>9.4.4.1</b> Examine the structure, size and the shape of the Earth.
<b>Key question</b>	<ol style="list-style-type: none"> <li>1. How is the Earth structured?</li> <li>2. How big is the Earth?</li> <li>3. Does the Earth have shape?</li> </ol>
<b>Learning objectives</b>	By the end of the topic, the students will be able to; <ul style="list-style-type: none"> <li>• Analyse the structure of the Earth</li> <li>• Evaluate the size and the shape of the Earth</li> </ul>
<b>Vocabulary</b>	Mantle, crust, outer core, inner core
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• Structure of the Earth</li> <li>• Size and shape of the Earth</li> </ul>
<b>Skills</b>	Comparing, analyse, visualising, modelling
<b>Attitudes and values</b>	Appreciative, optimistic, responsible, with desire to learn
<b>Teaching and Learning strategies</b>	Teachers prepare information (including pictures) and ask questions on the Earth's structure. Teachers can show videos related to the Earth's structure while the students use the information provided to answer the questions about the topic.
<b>Assessment</b>	1. Model the structure of the earth with labels
<b>Materials</b>	Information with pictures of the Earth, Model of the structure of the Earth, Globe

### Content Background

#### Objectives:

This virtual journey to the center of the Earth introduces the traveler to the structure, material properties and conditions within the Earth's interior. The size and scale of the Earth and of the Earth's internal structure are also emphasized because the journey utilizes a scale model of the depths within the Earth. Opportunities for creative writing and connections to literature are also provided through Jules Verne's 1864 science fiction novel, *A Journey to the Center of the Earth*, and the 20th Century Fox 1959 movie adaptation (titled *Journey to the Center of the Earth*) starring James Mason, Pat Boone, Arlene Dahl, and Diane Baker.

#### Background:

In the 1800's there was considerable scientific and popular interest in what was in the interior of the Earth. The details of the internal structure (crust, mantle, outer core, and inner core; and their composition and thicknesses; Figure 1) had not yet been discovered. And, although volcanic eruptions demonstrated that at least part of the interior of the Earth was hot enough to melt rocks, temperatures within the Earth and the existence of radioactivity were unknown. Jules Verne's book, *A Journey to the Center of the Earth* (1864, 272 pages; originally published in France as *Voyage au Centre de la Terre*), capitalized on this interest in the Earth and in adventure with an exciting science fiction story that is still popular today. Verne introduces us to a dedicated, and somewhat eccentric professor, and his nephew through whom the story is told (see selected quotations below), who eventually travel into the Earth's deep interior by entering into an opening in the crater of a volcano in Iceland.

Earth's inside structure is quite different to its hard, crusty shell. We sometimes get a glimpse of Earth's interior through the action of active volcanoes. Earth's rocky crust is by no means stationary and we regularly see evidence of crust movement in the form of earthquakes. Earthquakes in ocean regions produce destructive ocean waves called 'tsunamis'. The universal acceptance of plate tectonic theory is recognised as a major milestone in the earth sciences. It is comparable to the revolution caused by Darwin's theory of evolution or Einstein's theories about motion and gravity. Plate tectonics provide a framework for interpreting the composition, structure and internal crust. Each layer has its own chemical composition and properties

## Core

The core has two layers: an inner core that is solid and an outer core that is liquid. The core is mostly iron, with some nickel and takes up 16% of Earth's total volume. The metallic core accounts for Earth's magnetic field. Earth behaves as though it has a simple straight bar magnet at its centre, with the 'south' pole just below Canada and the 'north' pole opposite, not quite coincident with the geographical poles (see Figure 2). A compass needle's 'north' pole points northwards; because 'unlike' poles attract, Earth's magnetic pole in the Arctic must be the opposite type, 'south'. It is thought that streams of liquid metal within the outer core, combined with Earth's rotation, cause the magnetism. The strength of the magnetism may change from decade to decade and, over the period of 500 000 years, the magnetism reverses completely. This means that over the next 500 000 years, compasses will point south! Evidence of Earth's change in magnetic polarity (direction of north-south line of magnetism) is found in the rocks. Scientists have found that rocks within Earth's crust formed at different times. Within some rocks there are small particles of magnetite that are magnetic and, when the rocks were formed, these magnetite particles aligned themselves with Earth's magnetic field. As the rocks cooled, the direction of the particles' magnetic polarity was fixed. Therefore, by knowing the age of a rock and the magnetic polarity of the magnetite particles within it, we can determine the magnetic polarity and Earth's strength in times past.

## Mantle

The mantle is the thickest of Earth's layers and takes up 83% of Earth's volume. It extends down to about 2900 km from the crust to Earth's core and is largely composed of a dark, dense, igneous rock called 'peridotite', containing iron and magnesium. The mantle has three distinct layers: a lower, solid layer; the asthenosphere, which behaves plastically and flows slowly; and a solid upper layer. Partial melting within the asthenosphere generates magma (molten material), some of which rises to the surface because it is less dense than the surrounding material. The upper mantle and the crust make up the lithosphere, which is broken up into pieces called 'plates', which move over the asthenosphere. The interaction of these plates is responsible for earthquakes, volcanic eruptions and the formation of mountain ranges and ocean basins. The section on plate tectonic theory later in this topic explains the occurrence of these events further.

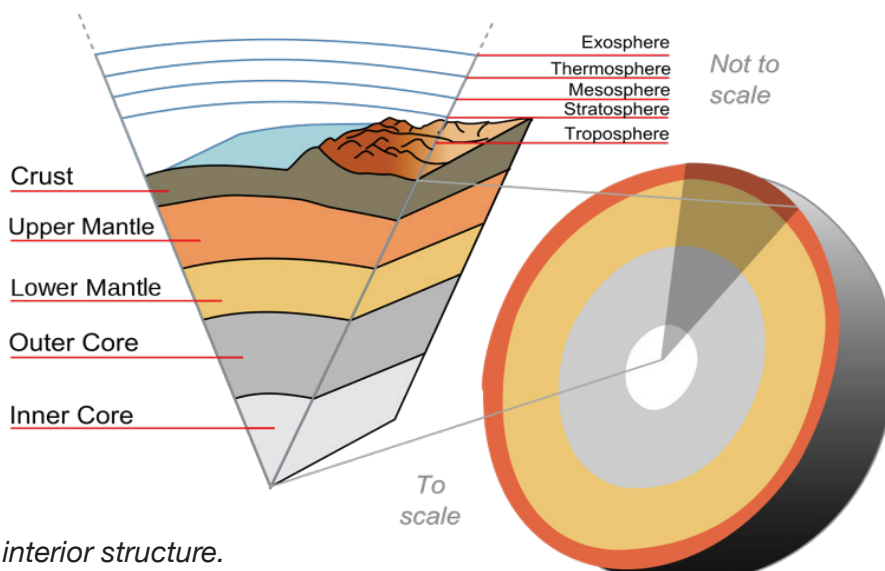


Figure 1. Earth's interior structure.

The Earth's crust is made up primarily of silicic (high percentage of Silicon and Oxygen) crystalline (distinct crystals of individual minerals are visible) rocks. The mantle makes up about 82% of the Earth by volume and consists of Iron- and magnesium rich silicate rocks. The core is mostly iron, with a small percentage of nickel. The outer core is molten and the inner core is solid.

## Topic 2: The Earth's Atmosphere

<b>Content standard</b>	Students will be able to recognize and explain the processes that are responsible for shaping the planet Earth and describe the place of the planet in the solar system and beyond into the inter-intergalactic space.
<b>Benchmarks</b>	<b>9.4.4.12</b> Determine that water cycles to and from the oceans, atmosphere and Earth through processes of evaporation, condensation, precipitation, surface run-off and percolation (filter) into the soil.
<b>Key questions</b>	<ol style="list-style-type: none"> <li>1. How is the Earth's atmosphere structured?</li> <li>2. What is the function of the different layers Earth's atmosphere?</li> </ol>
<b>Learning objectives</b>	By the end of the topic, the students will be able to; <ul style="list-style-type: none"> <li>• Examine the structure of the Earth's atmosphere</li> <li>• Explain the function of the different layers of the Earth's atmosphere</li> </ul>
<b>Vocabulary</b>	Ozone layer, greenhouse gas, Exosphere, Thermosphere, Mesosphere, Stratosphere, Troposphere
<b>Knowledge</b>	Earth's atmosphere
<b>Skills</b>	Comparing and contrasting, making inferences, visualising, modelling
<b>Attitudes and values</b>	Respect other's opinions, appreciative, creative
<b>Teaching and Learning strategies</b>	<ul style="list-style-type: none"> <li>• Teachers prepare information (including pictures) and ask questions on the Earth's atmosphere. Teachers can show videos related to the Earth's structure while the students use the information provided to answer the questions about the topic.</li> </ul>
<b>Assessment</b>	1. Model the different layers of the Earth's atmosphere
<b>Materials</b>	Charts with diagrams of the different layers of the Earth's atmosphere

### Content Background

#### The Earth's Atmosphere

The atmosphere surrounds Earth and protects us by blocking out dangerous rays from the sun. The atmosphere is a mixture of gases that becomes thinner until it gradually reaches space. It is composed of Nitrogen (78%), Oxygen (21%), and other gases (1%).

Oxygen is essential to life because it allows us to breathe. In addition, some of the oxygen has changed over time forming ozone. The ozone layer filters out the sun's harmful ultraviolet radiation. Recently, there have been many studies on how humans caused a hole to develop in the ozone layer.

Humans are also affecting Earth's atmosphere through the greenhouse effect. Due to increases in gases, such as carbon dioxide, that trap heat being radiated from the Earth, scientists believe that the atmosphere may have problems balancing the incoming solar radiation and the reradiated heat from Earth's surface creating the greenhouse effect.

The atmosphere is divided into five layers depending on how temperature changes with height. Most of the weather occurs in the first layer.

#### Layers of the Earth's Atmosphere

The atmosphere is divided into five layers. It is thickest near the surface and thins out with height until it eventually merges with space.

- The troposphere is the first layer above the surface and contains half of the Earth's atmosphere. Weather occurs in this layer.
- Many jet aircraft fly in the stratosphere because it is very stable. Also, the ozone layer absorbs harmful rays from the Sun.

- Meteors burn up in the mesosphere.
- The thermosphere is a layer with auroras. It is also where the space shuttle orbits.
- The atmosphere merges into space in the extremely thin exosphere. This is the upper limit of our atmosphere.

### The Troposphere

The troposphere is the lowest region of the Earth's atmosphere, where masses of air are very well mixed together and the temperature decreases with altitude.

The air is heated from the ground up because the surface of the Earth absorbs energy and heats up faster than the air. The heat is mixed through the troposphere because on average the atmosphere in this layer is slightly unstable.

Weather occurs in the Earth's troposphere. In fact, most clouds form in this layer.

### The Stratosphere

In the Earth's stratosphere, the temperature increases with altitude (as opposed to the troposphere, where it gets colder with altitude).

The increasing temperature in the stratosphere is caused by the presence of a layer of ozone near an altitude of 25 kilometers. The ozone molecules absorb high-energy UV rays from the sun, which warm the atmosphere at that level.

The terrestrial stratosphere is the region between the tropopause, or the end of the troposphere, and the level at which the maximum warming due to the presence of ozone takes place, which is at an altitude of about 50 kilometers.

This text is derivative from content on Windows to the Universe® (<http://windows2universe.org>)

### Ozone

The Ozone Hole.

The topic of ozone makes headlines on a regular basis, but why does a single molecule merit such media coverage? How important is the ozone in our atmosphere and why are scientists so concerned about its increase near the surface of the Earth and its disappearance higher up in the atmosphere?

First things first - what is ozone? Ozone is made of three oxygen atoms (O<sub>3</sub>). The oxygen in our atmosphere that we breathe is made up of two oxygen atoms (O<sub>2</sub>). Because of its chemical formulation, a single atom of oxygen (O) is unstable. That is, it wants to combine with something else. That is why oxygen is almost always found in pairs, in its (diatomic) form, where it is more stable. (O<sub>3</sub>) is less stable than (O<sub>2</sub>), because it wants to return to the diatomic state by giving up an oxygen atom.

When enough ozone molecules are present, it forms a pale blue gas. Ozone has the same chemical structure whether it is found in the stratosphere or the troposphere. Where we find ozone in the atmosphere determines whether we consider it to be Dr. Jekyll or Mr. Hyde.

In the troposphere, the ground-level or "bad" ozone is an air pollutant that damages human health, vegetation, and many common materials. It is a key ingredient of urban smog. In the stratosphere, we find the "good" ozone that protects life on Earth from the harmful effects of the Sun's ultraviolet rays. We have good reason to be concerned about the thinning of the ozone layer in the stratosphere. We also have good reason to be concerned about the buildup of ozone in the troposphere. Although simplistic, the saying "Good up high and bad nearby," sums up ozone in the atmosphere.

About 90% of the ozone in the Earth's atmosphere lies in the region called the stratosphere which is found between 16 and 48 kilometers (10 and 30 miles) above the Earth's surface. Ozone forms a kind of layer in the stratosphere, where it is more concentrated than anywhere else, but even there it is relatively scarce. Its concentrations in the ozone layer are typically only 1 to 10 parts of ozone per 1 million parts of air.

Ozone and oxygen molecules in the stratosphere absorb ultraviolet light from the Sun, providing a shield that prevents this radiation from passing to the Earth's surface. While both oxygen and ozone together absorb 95 to 99.9% of the Sun's ultraviolet radiation, only ozone effectively absorbs the most energetic ultraviolet light, known as UV-C and UV-B, which causes biological damage. The protective role of the ozone layer in the upper atmosphere is so vital that scientists believe life on land probably would not have evolved - and could not exist today - without it.

The term "shield" as a description of ozone in the stratosphere is a bit misleading because the molecules do not form an impermeable sphere around the Earth. Ozone continuously breaks apart into its oxygen atoms and reforms as ozone molecules, so a particular ozone molecule doesn't last very long. The "shield" changes constantly, but the atmospheric chemical processes maintain a dynamic equilibrium that keeps the overall amount of ozone constant - that is, it would if humans did not contribute to the chemical processes. There is compelling scientific evidence that ozone is destroyed in the stratosphere and that some human-released chemicals such as CFC's are speeding up the breakdown of ozone in the atmosphere.

While the stratospheric ozone issue is a serious one, in many ways it can be thought of as an environmental success story. Scientists detected the developing problem, and collected the evidence that convinced governments around the world to take regulatory action. Although the global elimination of ozone-depleting chemicals from the atmosphere will take decades yet, we have made a strong and positive beginning. For the first time in our species' history, we have tackled a global environmental issue on a global scale.

### **The Mesosphere**

In the Earth's mesosphere, the air masses are relatively mixed together and the temperature decreases with altitude. Atmospheric temperatures reach the lowest average value of around  $-90^{\circ}\text{C}$  in the mesosphere. This is also the layer in which a lot of meteors burn up while entering the Earth's atmosphere.

The mesosphere extends from the top of the stratosphere (the stratopause, located at about 50 kilometers) to an altitude of about 90 kilometers. Upper reaches of the atmosphere, such as the mesosphere, can sometimes be detected by looking at the limb of a planet.

### **The Thermosphere**

The Earth's thermosphere is the layer of the atmosphere which is first exposed to the Sun's radiation and so is first heated by the Sun. The air is so thin that a small increase in energy can cause a large increase in temperature.

The temperature in the thermosphere is very dependent on solar activity. When the Sun is active, temperatures can reach up to  $1,500^{\circ}\text{C}$  or higher!

Because of the thin air in the thermosphere, scientists can't measure the temperature directly. They measure the density of the air by how much drag it puts on satellites and then use the density to find the temperature.

The thermosphere also includes the region of the Earth's atmosphere called the ionosphere. The ionosphere is the region of the atmosphere that is filled with charged particles. Elevated temperatures can sometimes cause a molecule to become ionized, therefore, the ionosphere and thermosphere can overlap.

### **The Exosphere**

At very high altitudes, the atmosphere becomes very thin. The region where atoms and molecules escape into space is referred to as the exosphere. This is the true upper limit of the Earth's atmosphere. The exosphere extends from the thermosphere out to space.

## The Ionosphere

Scientists call the ionosphere an extension or a part of the thermosphere. So technically, the ionosphere is not another atmospheric layer, but a region of the atmosphere. The ionosphere represents less than 0.1% of the total mass of the Earth's atmosphere. Even so, it is extremely important!

The upper atmosphere is ionized by solar radiation. Under normal conditions free electrons and ions tend to recombine and a balance is established between electron and ion production and loss.

Ionization processes release energy which heat up the upper atmosphere. So temperature increases with height in the ionosphere region to the extent that by 150-200km, the Earth's atmosphere is extremely hot compared to surface temperatures.

Different regions of the ionosphere make long distance radio communication possible by reflecting the radio waves back to Earth. It is also home to auroras and the mega-ampere currents that heat the atmosphere at high latitudes during geomagnetically active times. During storms, depletions and enhancements of ionization occur depending on the local time and geographical location.

Aeronomy is a term of recent origin which is applied to the processes, both physical and chemical, of the ionosphere.

## Regions of the Ionosphere

The ionosphere can be further broken down into the D, E and F regions. The breakdown is based on what wavelength of solar radiation is absorbed in that region most frequently or on what level of radiation is needed to photo dissociate the molecules found in these individual regions.

The D region is the lowest in altitude, though it absorbs the most energetic radiation, hard x-rays.

The D region doesn't have a definite starting and stopping point, but includes the ionization that occurs below about 90km (or ionization that occurs below the E region).

The E region peaks at about 105km. It absorbs soft x-rays.

The F region starts around 105km and has a maximum around 600km. It is the highest of all of the regions. Extreme ultra-violet radiation (EUV) is absorbed there.

On a more practical note, the D and E regions (the lower parts of the ionosphere), reflect standard AM radio waves back to Earth. Radio waves with shorter lengths are reflected by the higher F region. Visible light, radar, television and FM wavelengths are all too short to be reflected by the ionosphere. So these types of global communication are made possible by satellite transmissions.

## The Sun's Effect on the Ionosphere

Invisible layers of ions and electrons are suspended in the Earth's atmosphere above about 60 kilometers in altitude. The main source of these layers is the Sun's ultraviolet light which ionizes atoms and molecules in the Earth's upper atmosphere. During this process, called photoionization, an electron is knocked free from a neutral atmospheric particle, which then becomes an ion.

Because the Sun's light is responsible for most of the ionization, the ionosphere reaches maximum densities just after local noon. In this region, at altitudes where the highest densities occur, about one in every 1000 air particles is ionized. Resulting ionospheric densities are about a million ions and electrons per cubic centimeter.

Flares and other energetic events on the Sun produce increased ultraviolet, x-ray and gamma-ray photons that arrive at the Earth just 8 minutes later and dramatically increase the density of the ionosphere on the dayside. These solar events also can produce high velocity protons and electrons (arriving at Earth hours to days later) that precipitate into the ionosphere in the Polar Regions producing large increases in the density of the ionosphere at low altitudes.

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### Topic 3: Waters, Seas/Oceans and Currents

<b>Content standard</b>	Students will be able to recognize and explain the processes that are responsible for shaping the planet Earth and describe the place of the planet in the solar system and beyond into the inter-intergalactic space.
<b>Benchmarks</b>	<p><b>9.4.4.2</b> Recognise that on continents surface water is found in lakes, streams and rivers and in the form of ice.</p> <p><b>9.4.4.3</b> Examine the relative distribution of oceans and continents.</p> <p><b>9.4.4.4</b> Distinguish between fresh water and ocean water.</p> <p><b>9.4.4.5</b> Determine the properties of lakes, rivers, and ground water.</p>
<b>Key questions</b>	<ol style="list-style-type: none"> <li>1. Where can you find surface water on the continents?</li> <li>2. What separate the five oceans from each other?</li> <li>3. Why is the fresh water different from ocean water?</li> <li>4. How can we define the properties lakes, rivers and groundwater?</li> </ol>
<b>Learning objectives</b>	<p>By the end of the topic, the students will be able to;</p> <ul style="list-style-type: none"> <li>• Investigate the surface water on the continents</li> <li>• Analyse the separation of the oceans by the continents</li> <li>• Distinguish between fresh water and ocean water</li> <li>• Explain the properties of lakes, rivers and groundwater</li> </ul>
<b>Vocabulary</b>	Surface water, groundwater, continents,
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• Surface water</li> <li>• Relative distribution of oceans and continents</li> <li>• Difference between fresh water and ocean water</li> <li>• Properties of lakes, rivers and groundwater</li> </ul>
<b>Skills</b>	Comparing and contrasting, distinguishing, analysing, relating, visualising
<b>Attitudes and values</b>	Open-minded, appreciative, responsible, respect other's opinion
<b>Teaching and Learning strategies</b>	Teachers prepare information (including pictures) and ask questions on the water, seas, oceans and currents while the students use the information provided to answer the questions about the topic.
<b>Assessment</b>	<ol style="list-style-type: none"> <li>1. Research on the major subdivisions of the oceans including the surface area, volume and the average depth of each of the five oceans.</li> </ol>
<b>Materials</b>	Charts with diagrams and information of the five oceans and the ground water and surface water

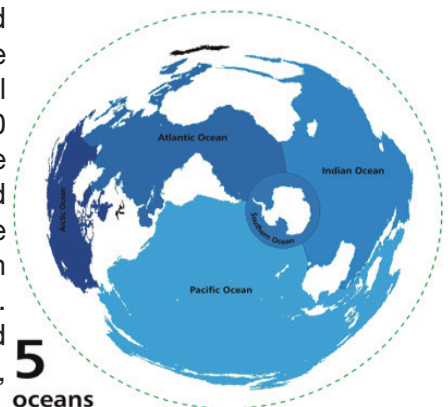
### Content Background

#### Seas

The sea is the interconnected system of all the Earth's oceanic waters, including the Atlantic, Pacific, Indian, Southern and Arctic Oceans. However, the word "sea" can also be used for many specific, much smaller bodies of seawater, such as the North Sea or the Red Sea.

Seas have always been essential for human development and trade, as at Singapore with its harbour (the world's busiest transshipment port) and the important shipping lanes through the Singapore Strait and the Strait of Malacca.

The sea, the world ocean or simply the ocean is the connected body of salty water that covers over 70% of Earth's surface (361,132,000 square kilometres (139,434,000 sq mi), with a total volume of roughly 1,332,000,000 cubic kilometres (320,000,000 cu mi)). It moderates Earth's climate and has important roles in the water cycle, carbon cycle, and nitrogen cycle. It has been travelled and explored since ancient times, while the scientific study of the sea—oceanography—dates broadly from the voyages of Captain James Cook to explore the Pacific Ocean between 1768 and 1779. The word sea is also used to denote smaller, partly landlocked sections of the ocean and certain large, entirely landlocked, saltwater lakes, such as the Caspian Sea and the Dead Sea.



The most abundant solid dissolved in seawater is sodium chloride. The water also contains salts of magnesium, calcium, and potassium, amongst many other elements, some in minute concentrations. Salinity varies widely, being lower near the surface and the mouths of large rivers and higher in the depths of the ocean; however, the relative proportions of dissolved salts varies little across the oceans. Winds blowing over the surface of the sea produce waves, which break when they enter shallow water.

Winds also create surface currents through friction, setting up slow but stable circulations of water throughout the oceans. The directions of the circulation are governed by factors including the shapes of the continents and Earth's rotation (the Coriolis effect). Deep-sea currents, known as the global conveyor belt, carry cold water from near the poles to every ocean. Tides, the generally twice-daily rise and fall of sea levels, are caused by Earth's rotation and the gravitational effects of the orbiting Moon and, to a lesser extent, of the Sun. Tides may have a very high range in bays or estuaries. Submarine earthquakes arising from tectonic plate movements under the oceans can lead to destructive tsunamis, as can volcanoes, huge landslides or the impact of large meteorites.

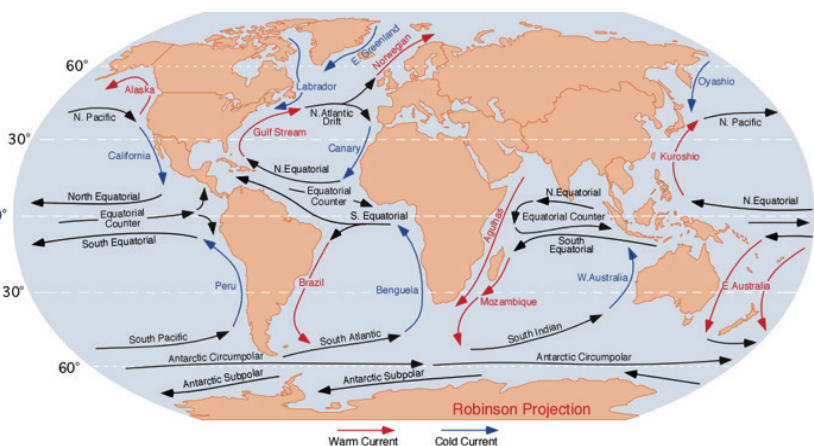
A wide variety of organisms, including bacteria, protists, algae, plants, fungi, and animals, live in the sea, which offers a wide range of marine habitats and ecosystems, ranging vertically from the sunlit surface and shoreline to the great depths and pressures of the cold, dark abyssal zone, and in latitude from the cold waters under polar ice caps to the colourful diversity of coral reefs in tropical regions. Many of the major groups of organisms evolved in the sea and life may have started there.

The sea provides substantial supplies of food for humans, mainly fish, but also shellfish, mammals and seaweed, whether caught by fishermen or farmed underwater. Other human uses of the sea include trade, travel, mineral extraction, power generation, warfare, and leisure activities such as swimming, sailing, and scuba diving. Many of these activities create marine pollution. The sea is important in human culture, with major appearances in literature at least since Homer's *Odyssey*, in marine art, in cinema, in theatre and in classical music. Symbolically, the sea appears as monsters such as Scylla in mythology and represents the unconscious mind in dream interpretation.

### Currents

Wind blowing over the surface of the sea causes friction at the interface between air and sea. Not only does this cause waves to form but it also makes the surface seawater move in the same direction as the wind. Although winds are variable, in any one place they predominantly blow from a single direction and thus a surface current can be formed. Westerly winds are most frequent in the mid-latitudes while easterlies dominate the tropics. When water moves in this way, other water flows in to fill the gap and a circular movement of surface currents known as a gyre is formed. There are five main gyres in the world's oceans: two in the Pacific, two in the Atlantic and one in the Indian Ocean. Other smaller gyres are found in lesser seas and a single gyre flows around Antarctica. These gyres have followed the same routes for millennia, guided by the topography of the land, the wind direction and the Coriolis effect.

The surface currents flow in a clockwise direction in the Northern Hemisphere and anticlockwise in the Southern Hemisphere. The water moving away from the equator is warm, and that flowing in the reverse direction has lost most of its heat. These currents tend to moderate the Earth's climate, cooling the equatorial region and warming regions at higher latitudes. Global climate and weather forecasts are powerfully affected by the world ocean, so global climate modeling makes use of ocean circulation models as well as models of other major components such as the atmosphere, land



Surface currents: red—warm, blue—cold

### Topic 4: Weathering and Erosion

<b>Content standard</b>	Students will be able to recognize and explain the processes that are responsible for shaping the planet Earth and describe the place of the planet in the solar system and beyond into the inter-intergalactic space.
<b>Benchmarks</b>	<b>9.4.4.6</b> Investigate different kinds of soil and determine their locations in rock layers. <b>9.4.4.12</b> Determine that water cycles to and from the oceans, atmosphere and Earth through processes of evaporation, condensation, precipitation, surface run-off and percolation (filter) into the soil.
<b>Key questions</b>	1. How does weathering affect the surface of the Earth? 2. What is weathering/ 3. What is erosion?
<b>Learning objectives</b>	By the end of the topic, the students will be able to; • Analyse how weathering affect the surface of the Earth • Identify defferent types of weathering?
<b>Vocabulary</b>	mechanical weathering, chemical weathering
<b>Knowledge</b>	Weathering process
<b>Skills</b>	Investigate, analyse, sequencing, modelling
<b>Attitudes and values</b>	Appreciative, open-minded, respect the environment
<b>Teaching and Learning strategies</b>	Teachers prepare information (including pictures) and ask questions on weathering and erosion while the students will use the information provided to answer the questions about the topic.
<b>Assessment</b>	1. Construct a model of weathering and erosion process
<b>Materials</b>	Charts with diagrams and information of weathering and erosion

### Content Background

#### What Is Weathering?

The footprints that astronauts left on the Moon will be there forever. Why? This is because the Moon has no atmosphere and, as a result, has no weathering. Weathering is one of the forces on Earth that destroy rocks and landforms. Without weathering, geologic features would build up but would be less likely to break down.

Weathering is the process that changes solid rock into sediments. Sediments were described in the Rocks chapter. With weathering, rock is disintegrated. It breaks into pieces.

Once these sediments are separated from the rocks, erosion is the process that moves the sediments. Erosion is the next chapter's topic. The four forces of erosion are water, wind, glaciers, and gravity.

- Water is responsible for most erosion. Water can move most sizes of sediments, depending on the strength of the force.
- Wind moves sand-sized and smaller pieces of rock through the air.
- Glaciers move all sizes of sediments, from extremely large boulders to the tiniest fragments.
- Gravity moves broken pieces of rock, large or small, downslope.

While plate tectonics forces work to build huge mountains and other landscapes, the forces of weathering gradually wear those rocks and landscapes away. Together with erosion, tall mountains turn into hills and even plains. The Appalachian Mountains along the east coast of North America were once as tall as the Himalayas.

No human being can watch for millions of years as mountains are built, nor can anyone watch as those same mountains gradually are worn away. But imagine a new sidewalk or road. The new road is smooth and even. Over hundreds of years, it will completely disappear, but what happens over one year? What changes would you see (figure 1)? What forces of weathering wear down that road, or rocks or mountains over time?



Figure 1. A once smooth road surface has cracks and fractures, plus a large pothole.

### Mechanical Weathering

Mechanical weathering (also called physical weathering) breaks rock into smaller pieces. These smaller pieces are just like the bigger rock, just smaller. That means the rock has changed physically without changing its composition. The smaller pieces have the same minerals, in just the same proportions as the original rock.

There are many ways that rocks can be broken apart into smaller pieces. Ice wedging is the main form of mechanical weathering in any climate that regularly cycles above and below the freezing point (figure 2). Ice wedging works quickly, breaking apart rocks in areas with temperatures that cycle above and below freezing in the day and night, and also that cycle above and below freezing with the seasons.

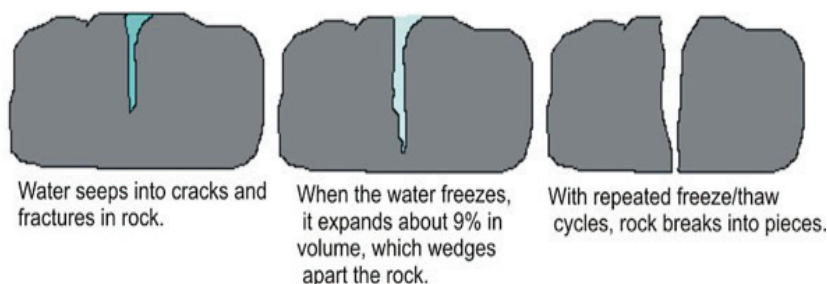


Figure 2. Ice wedging

Ice wedging breaks apart so much rock that large piles of broken rock are seen at the base of a hillside, as rock fragments separate and tumble down. Ice wedging is common in Earth's Polar Regions and mid-latitudes, and also at higher elevations, such as in the mountains. Abrasion is another form of mechanical weathering. In abrasion, one rock bumps against another rock.

- Gravity causes abrasion as a rock tumbles down a mountainside or cliff.
- Moving water causes abrasion as particles in the water collide and bump against one another.
- Strong winds carrying pieces of sand can sandblast surfaces.
- Ice in glaciers carries many bits and pieces of rock. Rocks embedded at the bottom of the glacier scrape against the rocks below.

Abrasion makes rocks with sharp or jagged edges smooth and round. If you have ever collected beach glass or cobbles from a stream, you have witnessed the work of abrasion (figure 3).

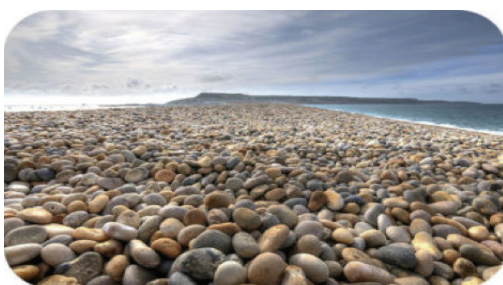


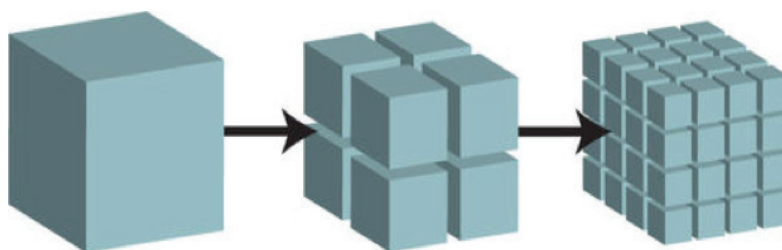
Figure 3. Rocks on a beach are worn down by abrasions as passing waves cause them to strike each other

Plants and animals can do the work of mechanical weathering (figure 4). This could happen slowly as a plant's roots grow into a crack or fracture in rock and gradually grow larger, wedging open the crack. Burrowing animals can also break apart rock as they dig for food or to make living spaces for themselves.



Figure 4. (a) Human activities are responsible for enormous amounts of mechanical weathering, by digging or blasting into rock to build homes, roads, subways, or to quarry stone. (b) Salt weathering of building stone on the island of Gozo, Malta

Mechanical weathering increases the rate of chemical weathering. As rock breaks into smaller pieces, the surface area of the pieces increases figure 5. With more surfaces exposed, there are more surfaces on which chemical weathering can occur.



As rock breaks into smaller pieces, overall surface area increases.

Figure 5. Mechanical weathering may increase the rate of chemical weathering.

### Chemical Weathering

Chemical weathering is the other important type of weathering. Chemical weathering is different from mechanical weathering because the rock changes, not just in size of pieces, but in composition. That is, one type of mineral changes into a different mineral. Chemical weathering works through chemical reactions that cause changes in the minerals.

Most minerals form at high pressure or high temperatures deep in the crust, or sometimes in the mantle. When these rocks reach the Earth's surface, they are now at very low temperatures and

pressures. This is a very different environment from the one in which they formed and the minerals are no longer stable. In chemical weathering, minerals that were stable inside the crust must change to minerals that are stable at Earth's surface.

Remember that the most common minerals in Earth's crust are the silicate minerals. Many silicate minerals form in igneous or metamorphic rocks. The minerals that form at the highest temperatures and pressures are the least stable at the surface. Clay is stable at the surface and chemical weathering converts many minerals to clay (figure 6).



Figure 6. Deforestation in Brazil reveals the underlying clay-rich soil.

There are many types of chemical weathering because there are many agents of chemical weathering. Water is the most important agent of chemical weathering. Two other important agents of chemical weathering are carbon dioxide and oxygen.

### Chemical Weathering by Water

A water molecule has a very simple chemical formula,  $H_2O$ , two hydrogen atoms bonded to one oxygen atom. But water is pretty remarkable in terms of all the things it can do. Remember from the Earth's Minerals chapter that water is a polar molecule. The positive side of the molecule attracts negative ions and the negative side attracts positive ions. So water molecules separate the ions from their compounds and surround them. Water can completely dissolve some minerals, such as salt.

Hydrolysis is the name of the chemical reaction between a chemical compound and water. When this reaction takes place, water dissolves ions from the mineral and carries them away. These elements have undergone leaching. Through hydrolysis, a mineral such as potassium feldspar is leached of potassium and changed into a clay mineral. Clay minerals are more stable at the Earth's surface.

### Chemical Weathering by Oxygen

Oxidation is a chemical reaction that takes place when oxygen reacts with another element. Oxygen is very strongly chemically reactive. The most familiar type of oxidation is when iron reacts with oxygen to create rust (figure 8). Minerals that are rich in iron break down as the iron oxidizes and forms new compounds. Iron oxide produces the red color in soils.

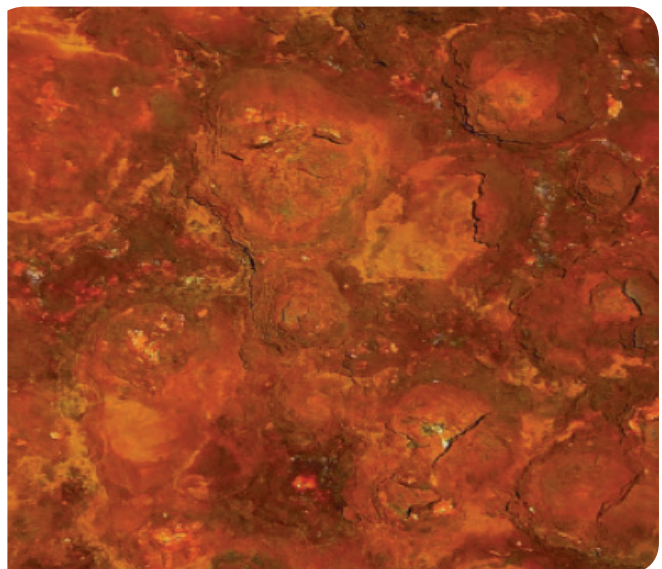


Figure 8. When iron rich minerals oxidize, they produce the familiar red color found in rust

### Topic 5: Evidence of Our Past

<b>Content standard</b>	Students will be able to recognize and explain the processes that are responsible for shaping the planet Earth and describe the place of the planet in the solar system and beyond into the inter-intergalactic space.
<b>Benchmark</b>	<b>9.4.4.13</b> Investigate and describe the origin and evolution of the atmosphere and interrelationship of geologic processes, biologic processes, and human activities on its composition and dynamics.
<b>Key questions</b>	<ol style="list-style-type: none"> <li>1. What are some other examples of mythical creatures that may be based on fossils?</li> <li>2. Why is it so rare for an animal to be preserved as a fossil?</li> <li>3. Why are examples of amazing fossil preservation so valuable for scientists?</li> <li>4. Many fossils of marine organisms have been found in the middle of continents, far from any ocean.</li> </ol>
<b>Learning objectives</b>	<p>By the end of the topic, the students will be able to;</p> <ul style="list-style-type: none"> <li>• Explain why it is rare for an organism to be preserved as a fossil.</li> <li>• Distinguish between body fossils and trace fossils.</li> <li>• Describe five types of fossilization.</li> <li>• Explain the importance of index fossils, and give several examples.</li> <li>• Describe what a living fossil is.</li> </ul>
<b>Vocabulary</b>	Fossil, body fossil, cast, fossil fuel, fossilisation, index fossil, living fossil, mold, trace fossil
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• Fossils</li> <li>• How fossils are formed</li> <li>• Types of fossils</li> </ul>
<b>Skills</b>	Investigate, analyse, compare and contrast, making generalisation, making inference, modelling
<b>Attitudes and values</b>	Appreciative, respect beliefs and opinions, critical, creative, willing to learn
<b>Teaching and Learning strategies</b>	Teachers prepare information (including pictures and videos) and ask questions on formation of fossils and types of fossils while the students will use the information provided to answer the questions about the topic.
<b>Assessment</b>	1. Construct a model of any type of fossil
<b>Materials</b>	Charts with pictures of the five types of fossils

### Content Background

#### Fossils

Throughout human history, people have discovered fossils and wondered about the creatures that lived long ago. In ancient times, fossils inspired legends of monsters and other strange creatures. The Chinese writer Chang Qu reports the discovery of “dragon bones”, which were probably dinosaur fossils in China 2,000 years ago. The griffin, a mythical creature with a lion’s body and an eagle’s head and wings, was probably based on skeletons of Protoceratops that were discovered by nomads in Central Asia (Figure 1).



Another fossil reminded the Greeks of the coiled horns of a ram. The Greeks named them ammonites after the ram god Ammon. Similarly, legends of the Cyclops may be based on fossilized elephant skulls found in Crete and other Mediterranean islands. Can you see why (Figure 2)?



Many of the real creatures whose bones became fossilized were no less marvelous than the mythical creatures they inspired (Figure 3). The giant pterosaur Quetzalcoatlus had a wingspan of up to 12 meters (39 feet). The dinosaur Argentinosaurus had an estimated weight of 80,000 kg, equal to the weight of seven elephants! Other fossils, such as the trilobite and ammonite, impress us with their bizarre forms and delicate beauty.



Figure 3. *Kolihapeltis* sp (left) and Ammonite (right)

### How Fossils Form

A fossil is any remains or trace of an ancient organism. Fossils include body fossils, left behind when the soft parts have decayed away, as well as trace fossils, such as burrows, tracks, or fossilized waste (feces) (Figure 4).



Figure 4. Coprolite (fossilized waste or feces) from a meat-eating dinosaur.

The process of a once living organism becoming a fossil is called fossilization. Fossilization is a very rare process: of all the organisms that have lived on Earth, only a tiny percentage of them ever become fossils. To see why, imagine an antelope that dies on the African plain. Most of its body is quickly eaten by scavengers, and the remaining flesh is soon eaten by insects and bacteria, leaving behind only scattered bones. As the years go by, the bones are scattered and fragmented into small pieces, eventually turning into dust and returning their nutrients to the soil. It would be rare for any of the antelope's remains to actually be preserved as a fossil.

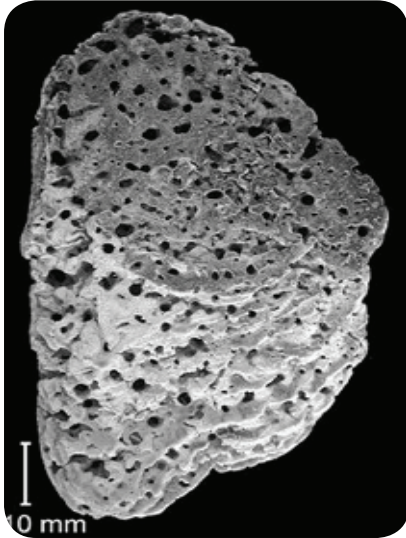


Figure 5. Fossil shell that has been attacked by a boring sponge.

Source: [https://s3-us-west-2.amazonaws.com/candimngs/wfk3VY/250px-Cliona\\_in\\_Ostrea\\_edulis\\_-\\_Eemian.JPG](https://s3-us-west-2.amazonaws.com/candimngs/wfk3VY/250px-Cliona_in_Ostrea_edulis_-_Eemian.JPG)

On the ocean floor, a similar process occurs when clams, oysters, and other shellfish die. The soft parts quickly decay, and the shells are scattered over the sea floor. If the shells are in shallow water, wave action soon grinds them into sand-sized pieces. Even if they are not in shallow water, the shells are attacked by worms, sponges, and other animals (Figure 11.5).

For animals that lack hard shells or bones, fossilization is even more rare. As a result, the fossil record contains many animals with shells, bones, or other hard parts, and few soft-bodied organisms. There is virtually no fossil record of jellyfish, worms, or slugs. Insects, which are by far the most common land animals, are only rarely found as fossils. Because mammal teeth are much more resistant than other bones, a large portion of the mammal fossil record consists of teeth. This means the fossil record will show many organisms that had shells, bones or other hard parts and will almost always miss the many soft-bodied organisms that lived at the same time.

Because most decay and fragmentation occurs at the surface, the main factor that contributes to fossilization is quick burial. Marine animals that die near a river delta may be buried by sediment carried by the river. A storm at sea may shift sediment on the ocean floor, covering and helping to preserve skeletal remains.

On land, burial is rare, so consequently fossils of land animals and plants are less common than marine fossils. Land organisms can be buried by mudslides or ash from a volcanic eruption, or covered by sand in a sandstorm. Skeletons can be covered by mud in lakes, swamps, or bogs as well. Some of the best-preserved skeletons of land animals are found in the La Brea Tar Pits of Los Angeles, California. Although the animals trapped in the pits probably suffered a slow, miserable death, their bones were preserved perfectly by the sticky tar.

In spite of the difficulties of preservation, billions of fossils have been discovered, examined, and identified by thousands of scientists. The fossil record is our best clue to the history of life on Earth, and an important indicator of past climates and geological conditions as well. The fossil record also plays a key role in our lives. Fossil fuels such as coal, gas, and oil formed from the decayed remains of plants and animals that lived millions of years ago.

## Types of Fossils

Fossilization can occur in many ways. Most fossils are preserved in one of five processes (Figure 6): preserved remains, permineralization, molds and casts, replacement, and compression.

### Preserved Remains

The rarest form of fossilization is the preservation of original skeletal material and even soft tissue. For example, insects have been preserved perfectly in amber, which is ancient tree sap. Several mammoths and even a Neanderthal hunter have been discovered frozen in glaciers. These preserved remains allow scientists the rare opportunity to examine the skin, hair, and organs of ancient creatures. Scientists have collected DNA from these remains and compared the DNA sequences to those of modern creatures.

### Permineralization

The most common method of fossilization is permineralization. After a bone, wood fragment, or shell is buried in sediment, it may be exposed to mineral-rich water that moves through the sediment. This water will deposit minerals into empty spaces, producing a fossil. Fossil dinosaur bones, petrified wood, and many marine fossils were formed by permineralization.

### Molds and Casts

In some cases, the original bone or shell dissolves away, leaving behind an empty space in the shape of the shell or bone. This depression is called a mold. Later the space may be filled with other sediments to form a matching cast in the shape of the original organism. Many mollusks (clams, snails, octopi and squid) are commonly found as molds and casts because their shells dissolve easily.

### Replacement

In some cases, the original shell or bone dissolves away and is replaced by a different mineral. For example, shells that were originally calcite may be replaced by dolomite, quartz, or pyrite. If quartz fossils are surrounded by a calcite matrix, the calcite can be dissolved away by acid, leaving behind an exquisitely preserved quartz fossil.

### Compression

Some fossils form when their remains are compressed by high pressure. This can leave behind a dark imprint of the fossil. Compression is most common for fossils of leaves and ferns, but can occur with other organisms, as well.



Figure 6. Five types of fossils: insect preserved in amber, petrified wood, cast and mold of a clam shell, compression fossil of a fern and pyritized ammonite.

**Clues from Fossils**

Fossils are our best form of evidence about the history of life on Earth. In addition, fossils can give us clues about past climates, the motions of plates, and other major geological events.

The first clue that fossils can give is whether an environment was marine (underwater) or terrestrial (on land). Along with the rock characteristics, fossils can indicate whether the water was shallow or deep, and whether the rate of sedimentation was slow or rapid. The amount of wear and fragmentation of a fossil can allow scientists to estimate the amount of wave action or the frequency of storms.

Often fossils of marine organisms are found on or near tall mountains. For example, the Himalayas, the tallest mountains in the world, contain trilobites, brachiopods, and other marine fossils. This indicates that rocks on the seabed have been uplifted to form huge mountains. In the case of the Himalayas, this happened when the Indian Subcontinent began to ram into Asia about 40 million years ago.

Fossils can also reveal clues about past climate. For example, fossils of plants and coal beds have been found in Antarctica. Although Antarctica is frozen today, in the past it must have been much warmer. This happened both because Earth's climate has changed and because Antarctica has not always been located at the South Pole.

One of the most fascinating patterns revealed by the fossil record is a number of mass extinctions, times when many species died off. Although the mass extinction that killed the dinosaurs is most famous, the largest mass extinction in Earth history occurred at the end of the Permian period, about 250 million years ago. In this catastrophe, it is estimated that over 95% of species on Earth went extinct! The cause of these mass extinctions is not definitely known, but most scientists believe that collisions with comets or asteroids were the cause of at least a few of these disasters.

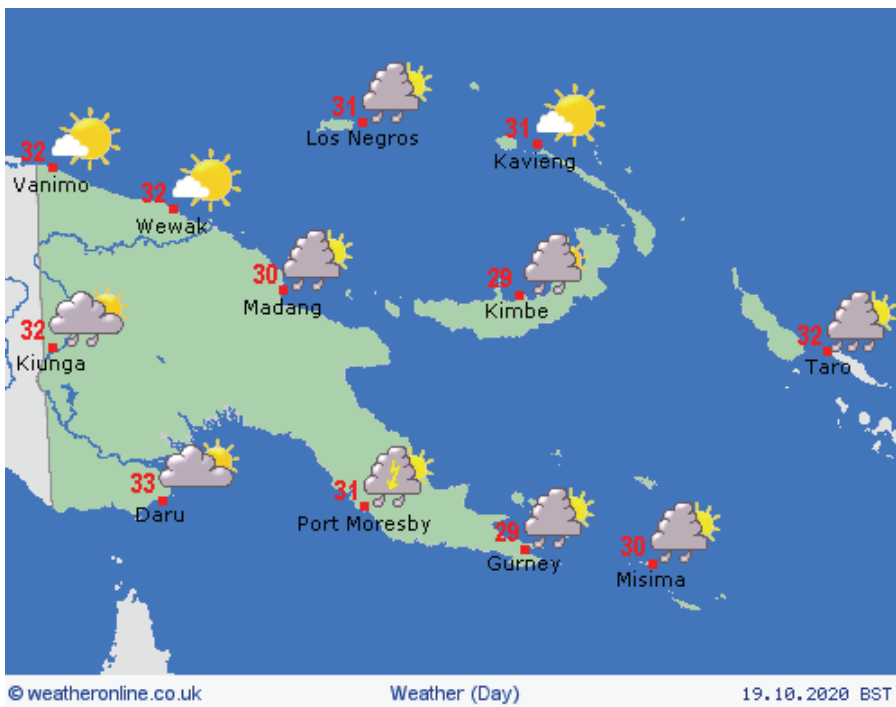
## Unit 9.10: Weather and Climate

Topic 1: PNG Weather Systems	
<b>Content standard</b>	Students will be able to recognize and explain the processes that are responsible for shaping the planet Earth and describe the place of the planet in the solar system and beyond into the inter-intergalactic space.
<b>Benchmark</b>	<p><b>9.4.4.14</b> Analyse that scientific evidence for atmospheric composition changes over geologic time.</p> <p><b>9.4.4.17</b> Investigate potential changes to the atmosphere and climate due to human, biologic, and geologic activity.</p>
<b>Key questions</b>	<ol style="list-style-type: none"> <li>1. Why is Papua New Guinean climate described as tropical climate?</li> <li>2. What factors determine the two seasons of Papua New Guinea?</li> <li>3. How can we compare the rainfall and temperatures along the coast and highlands?</li> </ol>
<b>Learning objectives</b>	<p>By the end of the topic, the students will be able to;</p> <ul style="list-style-type: none"> <li>• Analyse Papua New Guinea's climate</li> <li>• Examine factors that determine the two seasons of Papua New Guinea</li> <li>• Compare and contrast the rainfall and temperatures on the coast and up in the highlands using data.</li> </ul>
<b>Vocabulary</b>	Climate, weather, season, monsoons, weather systems
<b>Knowledge</b>	PNG weather systems
<b>Skills</b>	Compare and contrast, analyse, relating, visualising
<b>Attitudes and values</b>	Optimistic, appreciative, respect for evidence, desire to learn
<b>Teaching and Learning strategies</b>	Teachers prepare information (including PNG weather data) and ask questions on PNG weather systems while the students will use the information provided to answer the questions about the topic.
<b>Assessment</b>	1. Use data to construct a bar graph to compare and contrast the climate on the coast and in the highlands of Papua New Guinea
<b>Materials</b>	Charts with data (including table & graphs) of PNG weather

### Content Background

The main variable of Papua New Guinea's climate is not temperature or air pressure, but rainfall. Papua New Guinea's climate can be described as tropical climate, with the coastal plains averaging a Temperature of 28°C, the inland and mountain areas averaging 26°C, and the higher mountain regions, 23°C. The area's relative humidity is quite high, and ranges between 70 and 90 percent.

The extreme variations in rainfall are linked with the monsoons. Generally speaking, there is a dry season (June to September), and a rainy season (December to March). Western and northern parts of Papua New Guinea experience the most precipitation, since the north- and westward-moving monsoon clouds are heavy with moisture by the time they reach these more distant regions.



Source: <https://www.weatheronline.co.uk/PapuaNewGuinea.htm>

The climate in Papua New Guinea is hot and humid throughout the year along the coasts and in the plains, while it is progressively cooler, and then colder, as you go up in altitude. In much of the country, covered with dense rainforests, there is no dry season, so we can speak of **equatorial climate**, while in some inland valleys and along the south coast, there is a relatively dry season from July to September, and therefore the climate is **tropical**.

The climate is influenced by the **monsoon circulation**: the northwest monsoon prevails from December to April, and the southeast monsoon from May to October. Usually, each monsoon brings rainfall on the exposed slope, but in many areas, it rains during both the monsoons, so it rains all year round.

**Rainfall** typically ranges from 2,000 to 4,000 millimeters (80 to 160 inches) per year, with some higher peaks on the most exposed slopes, where it reaches as high as 7/8 meters (23/26 feet) per year, while it drops to 1,000/1,500 mm (40/60 in) on the southern coast, overlooking the Gulf of Papua and the Coral Sea.

On the coasts, the **temperatures** are high and stable throughout the year in the north, around 30 °C (86 °F) during the day, while in the south, located farther from the Equator, they decrease a bit in the period that can be called winter, from June to September.

Papua New Guinea is an island state, formed by the eastern part of New Guinea (the western part belonging to Indonesia) plus some smaller islands (including New Britain, New Ireland, Manus and Bougainville).

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## EQUATORIAL CLIMATE

### Madang

In **Madang**, on the north-eastern coast of New Guinea, 3,500 mm (138 in) of rain fall per year, with a maximum of 430 mm (17 in) in April and a minimum of 120 mm (4.7 in) in August, so we are in the area that has an equatorial climate. Here is the average precipitation.

### Madang – Average precipitation

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Prec. (mm)	305	300	380	430	385	275	195	120	145	255	340	370	3500
Prec. (in)	2	11.8	15	16.9	15.2	10.8	7.7	4.7	5.7	10	13.4	14.6	137.8
Days	17	16	19	18	17	11	11	9	10	11	13	18	170

As mentioned, temperatures along the coasts are high throughout the year, and in particular, they are very stable in the areas with an equatorial climate. Here are the average temperatures of Madang.

### Madang – Average temperatures

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min (°C)	23	23	23	23	23	22	22	22	22	22	23	23
Max (°C)	30	30	30	30	30	30	29	29	30	30	30	30
Min (°F)	73	73	73	73	73	72	72	72	72	72	73	73
Max (°F)	86	86	86	86	86	86	84	84	86	86	86	86

The amount of sunshine on the coasts is generally decent, but not exceptional; however, it is a little higher from May to October. Here are the sunshine hours in Madang.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hours	5	5	5	5	7	7	7	7	7	7	6	5

To the east of the eastern part of New Guinea, which constitutes the largest portion of the country, the islands (including New Ireland, New Britain and Bougainville) are very rainy throughout the year as well. In general, the rains are most abundant from December to April, but not everywhere: in **Lae**, facing south-east in the Huon Gulf, the rains are most abundant in July and August, when more than 500 mm (20 in) fall per month.

## TROPICAL CLIMATE

### Port Moresby

The capital, Port Moresby, is located in the southern area, which, as mentioned, is less rainy and more sheltered, so much so that it receives only 1,000 mm (40 in) of rain per year, with a relatively dry period from May to November, when rainfall drops below 70 mm (2.8 in) per month; in particular, the rains are scarce from June to October. Here is the average precipitation.

Port Moresby - Average precipitation

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Prec. (mm)	180	195	170	105	65	35	30	18	25	35	50	110	1018
Prec. (in)	7.1	7.7	6.7	4.1	2.6	1.4	1.2	0.7	1	1.4	2	4.3	40.1
Days	9	8	10	6	3	4	3	2	2	3	4	7	61

In the capital, the best period is the one that runs from June to September, in fact, it is also the least hot, with maximum temperatures around 29/30 °C (84/86 °F), instead of the 31/32 °C (88/90 °F) that are recorded in the rest of the year. Here are the average temperatures.

## Port Moresby - Average temperatures

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min (°C)	23	22	22	22	22	22	21	21	22	22	22	23
Max (°C)	31	31	31	31	30	30	29	30	30	31	32	32
Min (°F)	73	72	72	72	72	72	70	70	72	72	72	73
Max (°F)	88	88	88	88	86	86	84	86	86	88	90	90

Being that the rains are less frequent, the amount of sunshine in Port Moresby is higher than in other areas of the country.

## Port Moresby – Sunshine

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hours	7	7	8	8	8	9	10	10	10	9	9	8

The sea is always warm enough for swimming throughout the country, although in the southernmost part, where the capital is located, it becomes a bit less warm from July to October, as we can see in the following table.

## Port Moresby – Sea temperature

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp (°C)	29	29	29	29	28	27	26	25	26	26	28	29
Temp (°F)	84	84	84	84	82	81	79	77	79	79	82	84

## MOUNTAINS

The interior of the mainland (eastern New Guinea) is crossed by mountains: in the north, we find the Victor Emanuel Range and the Bismarck Mountains, the latter culminating in Mount Wilhelm, 4,509 meters (14,793 feet) high, while in the south, we find the Owen Stanley Mountains, whose highest peak is Mount Victoria, 4,038 meters (13,248 feet) high.

At 1,500 meters (5,000 feet) of altitude, the temperature is pleasant: cool at night and warm during the day.

Goroka

Here are the average temperatures of Goroka, located at 1,600 meters (5,2520 feet) above sea level, in the Eastern Highlands province.

Goroka - Average temperatures

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min (°C)	16	16	16	16	15	15	15	15	16	15	16	16
Max (°C)	27	26	26	27	26	26	26	26	26	27	27	28
Min (°F)	61	61	61	61	59	59	59	59	61	59	61	61
Max (°F)	81	79	79	81	79	79	79	79	79	81	81	82

In Goroka, 1,700 mm (68 in) of rain fall per year; there is a relatively dry season from June to August, when, however, some showers can still occur.

Goroka - Average precipitation

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Prec. (mm)	155	214	270	175	150	45	70	50	150	130	145	165	1720
Prec. (in)	6.1	8.4	10.6	6.9	5.9	1.8	2.8	2	5.9	5.1	5.7	6.5	67.7
Days	13	13	12	12	12	12	12	12	12	13	13	13	150

The sun in the mountainous areas shines less often than on the coasts, and the sky is often cloudy.

Goroka – Sunshine

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hours	5	5	4	5	4	5	4	5	5	5	5	5

Above 3,500 meters (11,500 ft), the forest is replaced by a sparse mountain vegetation: here, the cold is constant and sometimes it can even snow.

From the mountains, numerous rivers flow, such as the Sepik and the Fly, which in lowland areas, often at great distance from the mouth, give rise to marshes and swamps, where mangroves and gallery forests grow.

### TROPICAL CYCLONES

Papua New Guinea can be affected by tropical cyclones of the South Pacific. Typically, cyclones are formed from November to mid-May, although they are more likely from late November to mid-April. The part of the country that is directly affected is the center-south. The map below is an indication of the areas that have been affected in the past. The northern areas, however, may be partly affected, with an increase in wind, clouds, and waves.

The climate of Papua New Guinea is also influenced by the so-called ENSO cycle. In El Niño years, the rainy season is warmer and drier than normal, and the monsoon arrives often late, while the dry season is cooler than normal in the south. On the other hand, in La Niña years, the rainy season from December to April is more intense than normal and can lead to flooding, while the dry season is warmer than normal in the south. During neutral phases (neither El Niño nor La Niña), however, it's more likely for cyclones to form.

## Topic 2: Climates and Seasons

<b>Content standard</b>	Students will be able to recognize and explain the processes that are responsible for shaping the planet Earth and describe the place of the planet in the solar system and beyond into the inter-intergalactic space.
<b>Benchmarks</b>	<b>9.4.4.11</b> Examine the basic hydrological properties and processes, and see how features of the <b>planet interact</b> . <b>9.4.4.14</b> Analyse that scientific evidence for atmospheric composition changes over geologic time.
<b>Key questions</b>	1. What is the difference between weather, climate, season, and environment?
<b>Learning objectives</b>	By the end of the topic, the students will be able to; <ul style="list-style-type: none"> <li>• Distinguish between weather and climate; and weather and seasons</li> <li>• Describe climatic zones and seasons on Earth.</li> </ul>
<b>Vocabulary</b>	Weather, climate, seasons
<b>Knowledge</b>	Differences between weather, climate and season
<b>Skills</b>	Compare and contrast, making generalisation, visualising
<b>Attitudes and values</b>	Open-minded, appreciative, desire to learn
<b>Teaching and Learning strategies</b>	Teachers prepare information (including pictures of seasons) and ask questions on the difference between climates and seasons while the students will use the information provided to answer the questions about the topic.
<b>Assessment</b>	1. Research on why the northern hemisphere has 4 seasons
<b>Materials</b>	Charts with pictures of the different seasons

### Content Background



The four seasons vary significantly in characteristics, and can prompt changes in the world around them. (Image: © Shelli Jensen | Shutterstock)

A **season** is a period of the year that is distinguished by special climate conditions. The four seasons—spring, summer, fall, and winter—follow one another regularly. Each has its own light, temperature, and weather patterns that repeat yearly. In the Northern Hemisphere, winter generally begins on December 21 or 22.

The passing of a year can bring a marked change in the weather and the surrounding environment.

The passing of a year can bring a marked change in the weather and the surrounding environment. The four seasons — winter, spring, summer, autumn — can vary significantly in characteristics, and can prompt changes in the world around them. Let's take an overview of these four separate periods.

### **The annual cycle**

Attributes of the seasons may vary by location, but there are still broad definitions that cross most of the boundaries.

In the spring, seeds take root and vegetation begins to grow. The weather is warmer, and often wetter. Animals wake or return from warmer climates, often with newborns. Melting snow from the previous season, along with increased rainfall, can cause flooding along waterways, according to the Federal Emergency Management Agency (FEMA).

In the summer, temperatures may increase to their hottest of the year. If they spike too high, heat waves or droughts may cause trouble for people, animals, and plants. For example, in the summer of 2003, the high temperatures claimed more than 30,000 lives, according to Encyclopedia Britannica. Rainfall may increase in some areas, as well. Others may receive less water, and forest fires may become more frequent.

In the autumn, or fall, temperatures cool again. Plants may begin to grow dormant. Animals might prepare themselves for the upcoming cold weather, storing food or traveling to warmer regions. Various cultures have celebrated bountiful harvests with annual festivals. Thanksgiving is a good example. "Thanksgiving in the United States is a historical commemoration but it has a spiritual dimension strongly associated with homecoming and giving praise for what has been bestowed upon us," Cristina De Rossi, an anthropologist at Barnet and Southgate College in London, told Live Science.

Winter often brings a chill. Some areas may experience snow or ice, while others see only cold rain. Animals find ways to warm themselves, and may have changed their appearance to adapt. "In a similar way to the Autumnal theme, Winter festivals celebrate the return of the light during a time of deepest physical darkness," said De Rossi. The Indian festival of Diwali, for example, which takes place between October and November, celebrates the triumph of righteousness, and of light over darkness.

### **Location**

The timing and characteristics of the seasons depends upon the location on Earth. Regions near the equator experience fairly constant temperatures throughout the year, with mild winters barely apparent from warm summers. This is because it gets fairly constant light from the sun, due to its position on the outer curve of the Earth, according to the Atmospheric Radiation Measurement (ARM) program.

For areas to the north and south, the seasons can change more significantly. People closer to the poles might experience icier, more frigid winters, while those closer to the equator might suffer hotter summers. Other factors can also affect the weather and temperature over the seasons; some areas experience dry summers as temperatures spike, while others might call summer their "wet season." A wet season is when the average precipitation of an area is 2.4 inches (60 millimetres) or more, according to the British Broadcasting Company (BBC). Mountainous regions might experience more snowfall than plains within the same latitude, while oceanfront property could see an increase in violent tropical storms as the weather shifts.

The time of year a region experiences a season depends on whether it is in the northern or southern hemisphere. The Southern Hemisphere experiences winter while its northern neighbours chart summer; the north sees the slow blossom of spring while the south brings in the autumn harvest.

### Earth and the sun

The cycle of seasons is caused by Earth's tilt toward the sun. The planet rotates around an (invisible) axis. At different times during the year, the northern or southern axis is closer to the sun. During these times, the hemisphere tipped toward the star experiences summer, while the hemisphere tilted away from the sun experiences winter, according to the National Oceanic and Atmospheric Administration (NOAA).

At other locations in Earth's annual journey, the axis is not tilted toward or away from the sun. During these times of the year, the hemispheres experience spring and autumn.

The astronomical definition of the seasons relates to specific points in Earth's trip around the sun. The summer and winter solstice, the longest and shortest day of the year, occur when Earth's axis is either closest or farthest from the sun. The summer solstice in the Northern Hemisphere occurs around June 21, the same day as the winter solstice in the Southern Hemisphere, according to NOAA. The south's summer solstice occurs around December 21, the winter solstice for the north. In both hemispheres, the summer solstice marks the first day of astronomical summer, while the winter solstice is considered the first day of astronomical winter.

Equinoxes are another significant day during Earth's journey around the Sun. On these days, the planet's axis is pointed parallel to the Sun, rather than toward or away from it. Day and night during the equinoxes are supposed to be close to equal. The spring, or vernal, equinox for the northern hemisphere takes place around March 20, the same day as the south's autumnal equinox. The vernal equinox in the southern hemisphere occurs around September 20, when people in the north celebrate the autumnal equinox. The vernal equinox marks the first day of astronomical spring for a hemisphere, while the autumnal equinox ushers in the first day of fall. [Infographic: Earth's Solstices & Equinoxes Explained]

But changes in the weather often precede these significant points. The meteorological seasons focus on these changes, fitting the seasons to the three months that best usher them in. December to February marks meteorological winter in the Northern Hemisphere and meteorological summer in the southern. March, April, and May are lauded as spring or autumn, depending on the location, while June through August are the months of summer for the north and winter for the south. September, October, and November conclude the cycle, ushering in fall in northern regions and spring in southern, according to NOAA.

The seasons can bring a wide variety to the year for those locations that experience them in full. The weather in each one may allow people to engage in activities that they cannot perform in others — skiing in the winter, swimming in the summer. Each season brings with it its own potential dangers, but also its own particular brand of beauty.

### Climate seasons

What are the four climate seasons?

The passing of a year can bring a marked change in the weather and the surrounding environment. The four seasons — winter, spring, summer, autumn — can vary significantly in characteristics, and can prompt changes in the world around them.

Are seasons weather or climate?

“Seasons” are patterns in weather during a specific part of the year. Most parts of the world follow a pattern of a hot, cool, cold, and warm season each year — summer, fall, winter, and spring. ...

“Climate” is the same pattern from one year to the next.

What are the six seasons?

The seasons are traditionally classified into six categories. They are named as Spring, **Autumn**, Winter, Summer, Monsoon and prevernal season. Explanation: In a year, the six seasons divided the twelve months equally.

How the seasons are formed?

The **seasons are caused** by the tilt of the Earth's rotational axis away or toward the sun as it travels through its year-long path around the sun. The Earth has a tilt of 23.5 degrees relative to the "ecliptic plane" (the imaginary surface **formed** by its almost-circular path around the sun).

How do you define climate?

noun. the composite or generally prevailing weather conditions of a region, as temperature, air pressure, humidity, precipitation, sunshine, cloudiness, and winds, throughout the year, averaged over a series of years. a region or area characterized by a given climate: to move to a warm **climate**.

What factors affect climate?

The climate of any particular place is influenced by a host of interacting factors. These include latitude, elevation, nearby water, **ocean currents**, topography, vegetation, and prevailing wind

What are examples of climate?

Regions that include rainforests or have monsoon seasons are examples of tropical climates. Polar climates are the coldest of all of Earth's climate types. Ice caps and tundras are both found where we have polar climates. Mild climates are one of two temperate climate types o

Does climate affect weather?

Global analyses show that the amount of water vapour in the atmosphere has in fact increased due to human-caused warming. This extra moisture is available to storm systems, resulting in heavier rainfalls. Climate change also alters characteristics of the atmosphere that affect weather patterns and

What is Prevernal season?

1 : early flowering or leafing —used of plants that unfold their leaves or flowers before the rest of the plants in their locality. 2 : of or relating to the end of winter and the beginning of spring : occurring early in the growing season prevernal activity of a ground spider prevernal group of migratory birds.

What are the names of seasons?

A season is a part of a year. Most areas of the Earth have four seasons in a year: spring, summer, autumn (British English) or fall (US English), and winter. In some areas there are a different number of seasons.

What season does it rain the most?

Spring is the rainiest season of the year as measured by the number of days with precipitation. During spring, the best precipitation dynamics of winter and summer converge.

What is called a season?

A season is a division of the year marked by changes in weather, ecology, and amount of daylight. ... In temperate and subpolar regions, four seasons based on the Gregorian calendar are generally recognized: spring, summer, autumn or fall, and winter. The definition of seasons is also cultural.

How is summer season formed?

It is summer in June in the Northern Hemisphere because the sun's rays hit that part of Earth more directly than at any other time of the year. It is winter in December in the Northern Hemisphere, because that is when it is the South Pole's turn to be tilted toward the sun.

What does the shortest day of the year mean?

For that hemisphere, the winter solstice is the day with the shortest period of daylight and longest night of the year, when the Sun is at its lowest daily maximum elevation in the sky. ... Although the winter solstice itself lasts only a moment, the term sometimes refers to the day on which it occurs.

## Unit 9.11: Space Science

Topic 1: Earth, Moon and Sun	
<b>Content standard</b>	Students will be able to recognize and explain the processes that are responsible for shaping the planet Earth and describe the place of the planet in the solar system and beyond into the inter-intergalactic space.
<b>Benchmark</b>	<b>9.4.4.18.</b> Explain using models or illustrations on the types of eclipses and how they occur. <b>9.4.4.19</b> Investigate and explain the effects of Moon on the Earth.
<b>Key question</b>	<ol style="list-style-type: none"> <li>1. Why is the Earth important?</li> <li>2. How do you know the Earth is round?</li> <li>3. Why is the moon important?</li> <li>4. How is the moon structured?</li> <li>5. Why is the Sun important?</li> <li>6. What is the sun made of?</li> </ol>
<b>Learning objectives</b>	By the end of the topic, the students will be able to; <ul style="list-style-type: none"> <li>• Investigate why the Earth is round</li> <li>• Analyse the importance and the structure of the Moon</li> <li>• Analyse the importance and the structure of the Sun</li> </ul>
<b>Vocabulary</b>	Earth, planet, solar system, terrestrial bodies, craters, magnetosphere, orbit, rotation
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• Importance and composition of the Earth</li> <li>• Importance and composition of the Moon</li> <li>• Importance and composition of the Sun</li> </ul>
<b>Skills</b>	Analyse, compare and contrast, investigate, making generalisation, making inference
<b>Attitudes and values</b>	Appreciative, critical, respect opinions, open-minded, willing to learn
<b>Teaching and Learning strategies</b>	Teachers prepare information (including pictures and videos) and ask questions on the importance and composition of the Earth, Moon and Sun while the students will use the information provided to answer the questions about the topic.
<b>Assessment</b>	1. Research more on the formation of the Earth, Moon and Sun
<b>Materials</b>	Charts with pictures of the Earth, Moon and Sun

### Content Background

Earth is our home planet. Scientists believe Earth and its moon formed around the same time as the rest of the solar system. They think that was about 4.5 billion years ago. Earth is the fifth-largest planet in the solar system. Its diameter is about 8,000 miles. And Earth is the third-closest planet to the sun. Its average distance from the sun is about 93 million miles. Only Mercury and Venus are closer.

Earth has been called the “Goldilocks planet.” In the story of “Goldilocks and the Three Bears,” a little girl named Goldilocks liked everything just right. Her porridge couldn’t be too hot or too cold. And her bed couldn’t be too hard or too soft. On Earth, everything is just right for life to exist. It’s warm, but not too warm. And it has water, but not too much water.

Earth is the only planet known to have large amounts of liquid water. Liquid water is essential for life. Earth is the only planet where life is known to exist.

### What Does Earth Look Like?

From space, Earth looks like a blue marble with white swirls and areas of brown, yellow, green and white. The blue is water, which covers about 71 percent of Earth’s surface. The white swirls are clouds. The areas of brown, yellow and green are land. And the areas of white are ice and snow.

The equator is an imaginary circle that divides Earth into two halves. The northern half is called the Northern Hemisphere. The southern half is called the Southern Hemisphere. The northernmost point on Earth is called the North Pole. The southernmost point on Earth is called the South Pole.

### How Do We Know Earth Is Round?

Humans have known that Earth is round for more than 2,000 years! The ancient Greeks measured shadows during summer solstice and also calculated Earth's circumference. They used positions of stars and constellations to estimate distances on Earth. They could even see the planet's round shadow on the moon during a lunar eclipse. (We still can see this during lunar eclipses.)

Today, scientists use geodesy, which is the science of measuring Earth's shape, gravity and rotation. Geodesy provides accurate measurements that show Earth is round. With GPS and other satellites, scientists can measure Earth's size and shape to within a centimeter. Pictures from space also show Earth is round like the moon.

Even though our planet is a sphere, it is not a perfect sphere. Because of the force caused when Earth rotates, the North and South Poles are slightly flat. Earth's rotation, wobbly motion and other forces are making the planet change shape very slowly, but it is still round.

### What Are Earth's Different Parts?

Earth consists of land, air, water and life. The land contains mountains, valleys and flat areas. The air is made up of different gases, mainly nitrogen and oxygen. The water includes oceans, lakes, rivers, streams, rain, snow and ice. Life consists of people, animals and plants. There are millions of species, or kinds of life, on Earth. Their sizes range from very tiny to very large.

Below Earth's surface are layers of rock and metal. Temperatures increase with depth, all the way to about 12,000 degrees Fahrenheit at Earth's inner core.

Earth's parts once were seen as largely separate from each other. But now they are viewed together as the "Earth system." Each part connects to and affects each of the other parts. For example:

Clouds in the air drop rain and snow on land.

Water gives life to plants and animals.

Volcanoes on land send gas and dust into the air.

People breathe air and drink water.

Earth system science is the study of interactions between and among Earth's different parts.



Figure 1. The Earth ([https://www.nasa.gov/sites/default/files/thumbnails/image/edu\\_what\\_is\\_earth\\_0.jpg](https://www.nasa.gov/sites/default/files/thumbnails/image/edu_what_is_earth_0.jpg))

Source: <https://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/what-is-earth-58.html>

## MOON

### Facts about the Moon

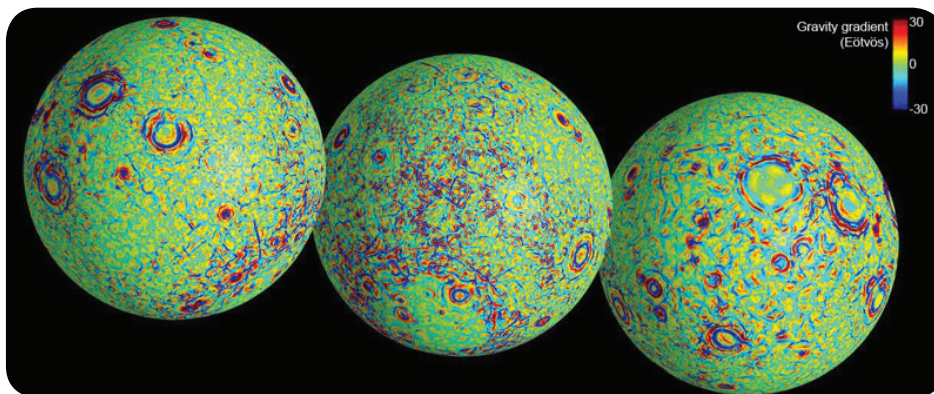
- The Moon is Earth's only natural satellite and the fifth largest moon in the solar system.
- The Moon's presence helps stabilize our planet's wobble, which helps stabilize our climate.
- The Moon's distance from Earth is about 240,000 miles (385,000km).
- The Moon has a very thin atmosphere called an exosphere.
- The Moon's entire surface is cratered and pitted from impacts.

Earth's Moon is the only place beyond Earth where humans have set foot.

The brightest and largest object in our night sky, the Moon makes Earth a more livable planet by moderating our home planet's wobble on its axis, leading to a relatively stable climate. It also causes tides, creating a rhythm that has guided humans for thousands of years. The Moon was likely formed after a Mars-sized body collided with Earth.

Our moon is the fifth largest of the 190+ moons orbiting planets in our solar system.

Earth's only natural satellite is simply called "the Moon" because people didn't know other moons existed until Galileo Galilei discovered four moons orbiting Jupiter in 1610.



*These maps of the near and far side of the moon show gravity gradients as measured by NASA's GRAIL mission. Red and blue areas indicate stronger gradients due to underlying mass anomalies.*

*Image Credit: NASA/JPL-Caltech/CSM*

### Size and Distance

With a radius of 1,079.6 miles (1,737.5 kilometers), the Moon is less than a third the width of Earth. If Earth were the size of a nickel, the Moon would be about as big as a coffee bean.

The Moon is farther away from Earth than most people realize. The Moon is an average of 238,855 miles (384,400 kilometers) away. That means 30 Earth-sized planets could fit in between Earth and the Moon.

The Moon is slowly moving away from Earth, getting about an inch farther away each year.

### Orbit and Rotation

The Moon is rotating at the same rate that it revolves around Earth (called synchronous rotation), so the same hemisphere faces Earth all the time. Some people call the far side &mdash; the hemisphere we never see from Earth &mdash; the "dark side," but that's misleading. As the Moon orbits Earth, different parts are in sunlight or darkness at different times. The changing illumination is why, from our

perspective, the Moon goes through phases. During a “full moon,” the hemisphere of the Moon we can see from Earth is fully illuminated by the sun. And a “new moon” occurs when the far side of the Moon has full sunlight, and the side facing us is having its night.

The Moon makes a complete orbit around Earth in 27 Earth days and rotates or spins at that same rate, or in that same amount of time. Because Earth is moving as well — rotating on its axis as it orbits the sun — from our perspective, the Moon appears to orbit us every 29 days.

### **Structure**

Earth’s Moon has a core, mantle and crust.

The Moon’s core is proportionally smaller than other terrestrial bodies’ cores. The solid, iron-rich inner core is 149 miles (240 kilometers) in radius. It is surrounded by a liquid iron shell 56 miles (90 kilometers) thick. A partially molten layer with a thickness of 93 miles (150 kilometers) surrounds the iron core.

The mantle extends from the top of the partially molten layer to the bottom of the Moon’s crust. It is most likely made of minerals like olivine and pyroxene, which are made up of magnesium, iron, silicon and oxygen atoms.

The crust has a thickness of about 43 miles (70 kilometers) on the Moon’s near-side hemisphere and 93 miles (150 kilometers) on the far-side. It is made of oxygen, silicon, magnesium, iron, calcium and aluminum, with small amounts of titanium, uranium, thorium, potassium and hydrogen.

Long ago the Moon had active volcanoes, but today they are all dormant and have not erupted for millions of years.

### **Formation**

The leading theory of the Moon’s origin is that a Mars-sized body collided with Earth about 4.5 billion years ago. The resulting debris from both Earth and the impactor accumulated to form our natural satellite 239,000 miles (384,000 kilometers) away. The newly formed Moon was in a molten state, but within about 100 million years, most of the global “magma ocean” had crystallized, with less-dense rocks floating upward and eventually forming the lunar crust.

### **Surface**

With too sparse an atmosphere to impede impacts, a steady rain of asteroids, meteoroids and comets strikes the surface of the Moon, leaving numerous craters behind. Tycho Crater is more than 52 miles (85 kilometers) wide.

Over billions of years, these impacts have ground up the surface of the Moon into fragments ranging from huge boulders to powder. Nearly the entire Moon is covered by a rubble pile of charcoal-gray, powdery dust and rocky debris called the lunar regolith. Beneath is a region of fractured bedrock referred to as the megaregolith.

The light areas of the Moon are known as the highlands. The dark features, called maria (Latin for seas), are impact basins that were filled with lava between 4.2 and 1.2 billion years ago. These light and dark areas represent rocks of different composition and ages, which provide evidence for how the early crust may have crystallized from a lunar magma ocean. The craters themselves, which have been preserved for billions of years, provide an impact history for the moon and other bodies in the inner solar system.

If you looked in the right places on the Moon, you would find pieces of equipment, American flags, and even a camera left behind by astronauts. While you were there, you’d notice that the gravity on the surface of the Moon is one-sixth of Earth’s, which is why in footage of moonwalks, astronauts appear to almost bounce across the surface.

The temperature reaches about 260 degrees Fahrenheit (127 degrees Celsius) when in full sun, but in darkness, the temperatures plummet to about -280 degrees Fahrenheit (-173 degrees Celsius).

### **Water on the Moon**

During the initial exploration of the moon, and the analysis of all the returned samples from the Apollo and the Luna missions, we thought that the surface of the moon was dry.

The first definitive discovery of water was made in 2008 by the Indian mission Chandrayaan-1, which detected hydroxyl molecules spread across the lunar surface and concentrated at the poles. Missions such as Lunar Prospector, LCROSS, and Lunar Reconnaissance Orbiter, have not only shown that the surface of the Moon has a global hydration, but there are actually high concentrations of ice water in the permanently shadowed regions of the lunar poles.

Scientists also found the lunar surface releases its water when the Moon is bombarded by micrometeoroids. The surface is protected by a layer, a few centimeters of dry soil that can only be breached by large micrometeoroids. When micrometeoroids impact the surface of the moon, most of the material in the crater is vaporized. The shock wave carries enough energy to release the water that's coating the grains of the soil. Most of that water is released into space.

### **Atmosphere**

The Moon has a very thin and weak atmosphere, called an exosphere. It does not provide any protection from the sun's radiation or impacts from meteoroids.

### **Magnetosphere**

The early Moon may have developed an internal dynamo, the mechanism for generating global magnetic fields for terrestrial planets, but today, the Moon has a very weak magnetic field. The magnetic field here on Earth is many thousands of times stronger than the Moon's magnetic field.

### **Rings**

The Moon has no rings.

### **Moons**

Earth's Moon has no moons of its own.

### **Potential for Life**

The many missions that have explored the Moon have found no evidence to suggest it has its own living things. However, the Moon could be the site of future colonization by humans. The discovery the Moon harbors water ice, and that the highest concentrations occur within darkened craters at the poles, makes the Moon a little more hospitable for future human colonists.



Figure 2. Full Moon

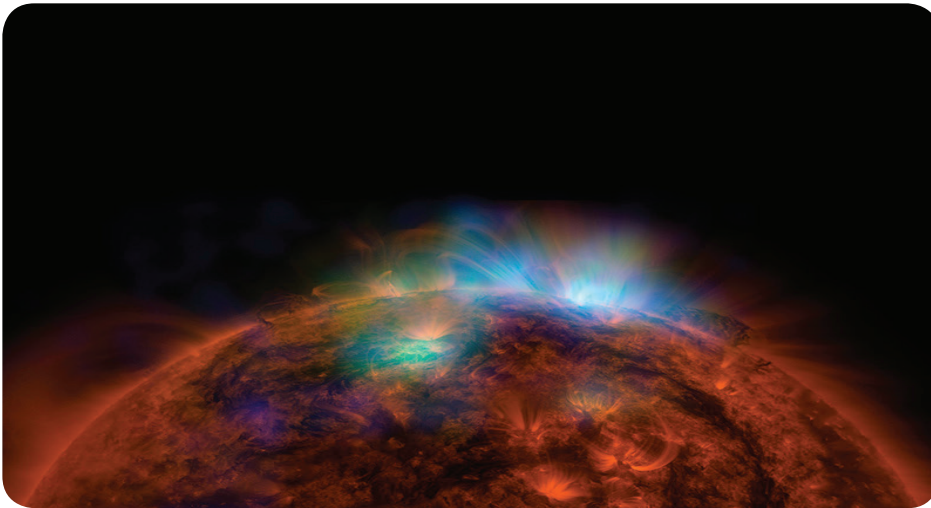
Source: <https://solarsystem.nasa.gov/moons/earths-moon/overview/>

## Sun Facts

The Sun is the largest object within our solar system, comprising 99.8% of the system's mass. The Sun is located at the center of our solar system, and Earth orbits 93 million miles away from it. Though massive, the Sun still isn't as large as other types of stars. It's classified as a yellow dwarf star. The Sun's magnetic field spreads throughout the solar system via the solar wind.

The Sun—the heart of our solar system—is a yellow dwarf star, a hot ball of glowing gases. Its gravity holds the solar system together, keeping everything from the biggest planets to the smallest particles of debris in its orbit. Electric currents in the Sun generate a magnetic field that is carried out through the solar system by the solar wind—a stream of electrically charged gas blowing outward from the Sun in all directions.

The connection and interactions between the Sun and Earth drive the seasons, ocean currents, weather, climate, radiation belts and aurorae. Though it is special to us, there are billions of stars like our Sun scattered across the Milky Way galaxy.



*Figure 3. X-rays stream off the sun in this image showing observations from by NASA's Nuclear Spectroscopic Telescope Array, or NuSTAR, overlaid on a picture taken by NASA's Solar Dynamics Observatory (SDO). Image credit: NASA/JPL-Caltech/GSFC*

The Sun is a yellow dwarf star, a hot ball of glowing gases at the heart of our solar system. Its gravity holds the solar system together, keeping everything – from the biggest planets to the smallest particles of debris – in its orbit. The connection and interactions between the Sun and Earth drive the seasons, ocean currents, weather, climate, radiation belts and auroras. Though it is special to us, there are billions of stars like our Sun scattered across the Milky Way galaxy.

The Sun has many names in many cultures. The Latin word for Sun is “sol,” which is the main adjective for all things Sun-related: solar.

### Size and Distance

With a radius of 432,168.6 miles (695,508 kilometers), our Sun is not an especially large star—many are several times bigger—but it is still far more massive than our home planet: 332,946 Earths match the mass of the Sun. The Sun's volume would need 1.3 million Earths to fill it.

### Earth and the Sun

The Sun is 93 million miles (150 million kilometers) from Earth. Its nearest stellar neighbor is the Alpha Centauri triple star system: Proxima Centauri is 4.24 light years away, and Alpha Centauri A and B—two stars orbiting each other—are 4.37 light years away. A light year is the distance light travels in one year, which is equal to 5,878,499,810,000 miles or 9,460,528,400,000 kilometers.

**Orbit and Rotation**

The Sun, and everything that orbits it, is located in the Milky Way galaxy. More specifically, our Sun is in a spiral arm called the Orion Spur that extends outward from the Sagittarius arm. From there, the Sun orbits the center of the Milky Way Galaxy, bringing the planets, asteroids, comets and other objects along with it. Our solar system is moving with an average velocity of 450,000 miles per hour (720,000 kilometers per hour). But even at this speed, it takes us about 230 million years to make one complete orbit around the Milky Way.

The Sun rotates as it orbits the center of the Milky Way. Its spin has an axial tilt of 7.25 degrees with respect to the plane of the planets' orbits. Since the Sun is not a solid body, different parts of the Sun rotate at different rates. At the equator, the Sun spins around once about every 25 days, but at its poles the Sun rotates once on its axis every 36 Earth days.

**Formation**

The Sun and the rest of the solar system formed from a giant, rotating cloud of gas and dust called a solar nebula about 4.5 billion years ago. As the nebula collapsed because of its overwhelming gravity, it spun faster and flattened into a disk. Most of the material was pulled toward the center to form our Sun, which accounts for 99.8% of the mass of the entire solar system.

Like all stars, the Sun will someday run out of energy. When the Sun starts to die, it will swell so big that it will engulf Mercury and Venus and maybe even Earth. Scientists predict the Sun is a little less than halfway through its lifetime and will last another 6.5 billion years before it shrinks down to be a white dwarf.

**Structure**

The Sun, like other stars, is a ball of gas. In terms of the number of atoms, it is made of 91.0% hydrogen and 8.9% helium. By mass, the Sun is about 70.6% hydrogen and 27.4% helium.

The Sun's enormous mass is held together by gravitational attraction, producing immense pressure and temperature at its core. The Sun has six regions: the core, the radiative zone, and the convective zone in the interior; the visible surface, called the photosphere; the chromosphere; and the outermost region, the corona.

At the core, the temperature is about 27 million degrees Fahrenheit (15 million degrees Celsius), which is sufficient to sustain thermonuclear fusion. This is a process in which atoms combine to form larger atoms and in the process release staggering amounts of energy. Specifically, in the Sun's core, hydrogen atoms fuse to make helium.

The energy produced in the core powers the Sun and produces all the heat and light the Sun emits. Energy from the core is carried outward by radiation, which bounces around the radiative zone, taking about 170,000 years to get from the core to the top of the convective zone. The temperature drops below 3.5 million degrees Fahrenheit (2 million degrees Celsius) in the convective zone, where large bubbles of hot plasma (a soup of ionized atoms) move upwards. The surface of the Sun—the part we can see—is about 10,000 degrees Fahrenheit (5,500 degrees Celsius). That's much cooler than the blazing core, but it's still hot enough to make carbon, like diamonds and graphite, not just melt, but boil.

**Surface**

The surface of the Sun, the photosphere, is a 300-mile-thick (500-kilometer-thick) region, from which most of the Sun's radiation escapes outward. This is not a solid surface like the surfaces of planets. Instead, this is the outer layer of the gassy star.

We see radiation from the photosphere as sunlight when it reaches Earth about eight minutes after it leaves the Sun. The temperature of the photosphere is about 10,000 degrees Fahrenheit (5,500 degrees Celsius).

**Atmosphere**

Above the photosphere lie the tenuous chromosphere and the corona (crown), which make up the thin solar atmosphere. This is where we see features such as sunspots and solar flares.

Visible light from these top regions is usually too weak to be seen against the brighter photosphere, but during total solar eclipses, when the moon covers the photosphere, the chromosphere looks like a red rim around the Sun, while the corona forms a beautiful white crown with plasma streamers narrowing outward, forming shapes that look like flower petals.

Strangely, the temperature in the Sun's atmosphere increases with altitude, reaching as high as 3.5 million degrees Fahrenheit (2 million degrees Celsius). The source of coronal heating has been a scientific mystery for more than 50 years.

**Potential for Life**

The Sun itself is not a good place for living things, with its hot, energetic mix of gases and plasma. But the Sun has made life on Earth possible, providing warmth as well as energy that organisms like plants use to form the basis of many food chains.

**Moons**

The Sun and other stars don't have moons; instead, they have planets and their moons, along with asteroids, comets, and other objects.

**Rings**

The Sun does not have rings.

**Magnetosphere**

The electric currents in the Sun generate a complex magnetic field that extends out into space to form the interplanetary magnetic field. The volume of space controlled by the Sun's magnetic field is called the heliosphere.

The Sun's magnetic field is carried out through the solar system by the solar wind—a stream of electrically charged gas blowing outward from the Sun in all directions. Since the Sun rotates, the magnetic field spins out into a large rotating spiral, known as the Parker spiral.

The Sun doesn't behave the same way all the time. It goes through phases of its own solar cycle. Approximately every 11 years, the Sun's geographic poles change their magnetic polarity. When this happens, the Sun's photosphere, chromosphere and corona undergo changes from quiet and calm to violently active. The height of the Sun's activity, known as solar maximum, is a time of solar storms: sunspots, solar flares and coronal mass ejections. These are caused by irregularities in the Sun's magnetic field and can release huge amounts of energy and particles, some of which reach us here on Earth. This space weather can damage satellites, corrode pipelines and affect power grids.

Source: <https://solarsystem.nasa.gov/solar-system/sun/in-depth/>

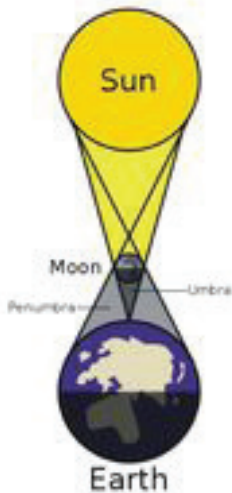
## Topic 2: The Eclipses

<b>Content standard</b>	Students will be able to recognize and explain the processes that are responsible for shaping the planet Earth and describe the place of the planet in the solar system and beyond into the inter-intergalactic space.
<b>Benchmark</b>	<b>9.4.4.18.</b> Explain using models or illustrations on the types of eclipses and how they occur. <b>9.4.4.19</b> Investigate and explain the effects of Moon on the Earth.
<b>Key questions</b>	1. How does solar eclipse occur? 2. How does lunar eclipse occur?
<b>Learning objectives</b>	By the end of the lesson, the students will be able to; <ul style="list-style-type: none"> <li>• Investigate the cause and effects of solar eclipse</li> <li>• Investigate the cause and effects of solar eclipse</li> </ul>
<b>Vocabulary</b>	Solar eclipse, lunar eclipse
<b>Knowledge</b>	<ul style="list-style-type: none"> <li>• Causes and effects of solar eclipse</li> <li>• Causes and effects of lunar eclipse</li> </ul>
<b>Skills</b>	Making inferences, comparing and contrasting, modelling, visualising, analysing
<b>Attitudes and values</b>	Optimistic, appreciative, respect for beliefs and opinions, creative, critical
<b>Teaching and Learning strategies</b>	Teachers prepare information (including pictures of solar eclipse and lunar eclipse) and ask questions on the solar eclipse and lunar eclipse while the students will use the information provided to answer the questions about the topic.
<b>Assessment</b>	1. Demonstrate how solar and lunar eclipse by using the models of the Earth, Moon and the Sun
<b>Materials</b>	Charts with pictures (including diagrams, videos) of how solar eclipse and lunar eclipse occur

### Content Background

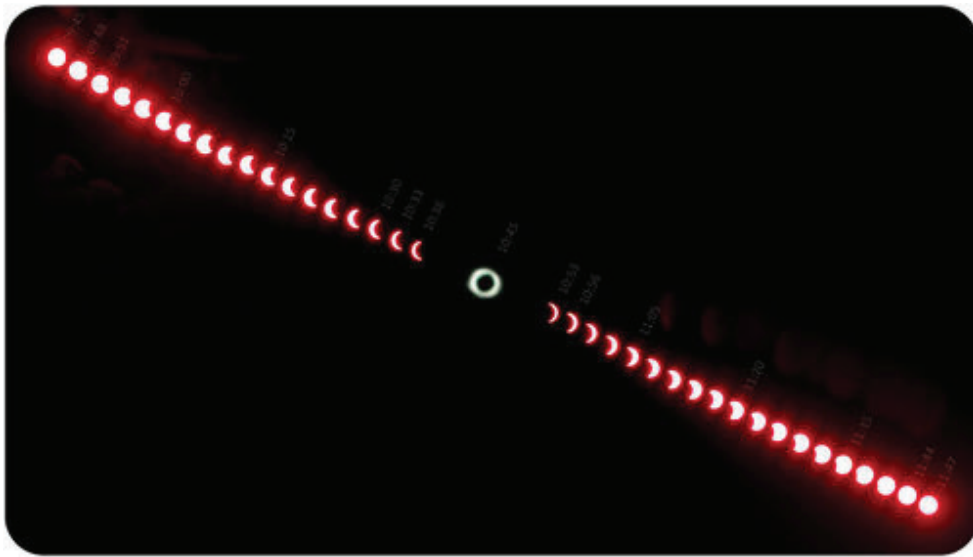
#### Solar Eclipses

A solar eclipse occurs when the new moon passes directly between the Earth and the Sun (Figure below). This casts a shadow on the Earth and blocks Earth's view of the Sun.



A solar eclipse, not to scale.

A total solar eclipse occurs when the Moon's shadow completely blocks the Sun (Figure below). When only a portion of the Sun is out of view, it is called a partial solar eclipse.



A solar eclipse shown as a series of photos.

Solar eclipses are rare and usually only last a few minutes because the Moon casts only a small shadow (Figure below).

A BBC video of a solar eclipse is seen here: <http://www.youtube.com/watch?v=eOvWioz4PoQ>.



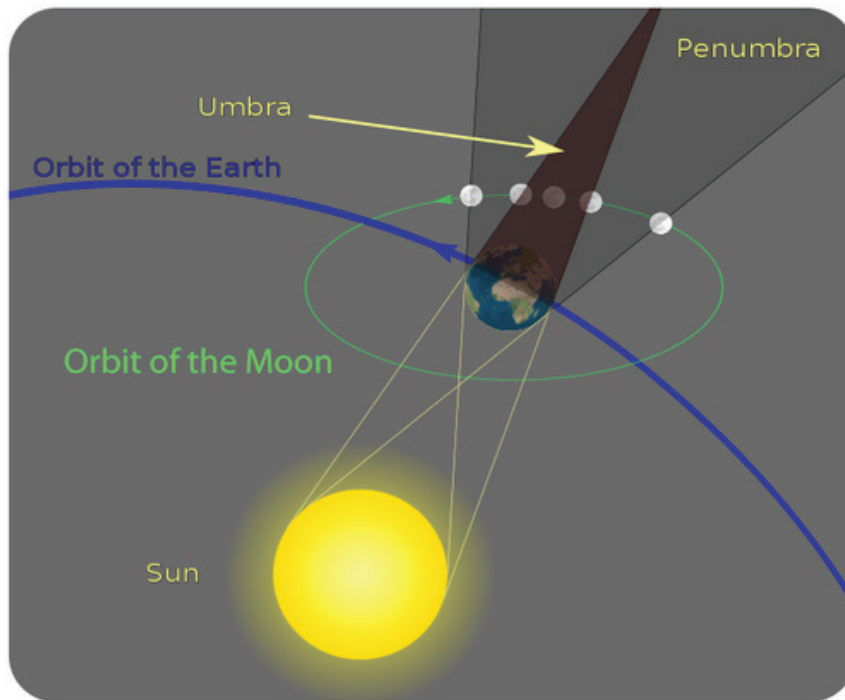
The Moon's shadow in a solar eclipse covers a very small area.

As the Sun is covered by the moon's shadow, it will actually get cooler outside. Birds may begin to sing, and stars will become visible in the sky. During a solar eclipse, the corona and solar prominences can be seen.

A solar eclipse occurs when the Moon passes between Earth and the Sun in such a way that the Sun is either partially or totally hidden from view. Some people, including some scientists, chase eclipses all over the world to learn or just observe this amazing phenomenon. Learn more at: <http://www.kqed.org/quest/television/eclipse-chasers>.

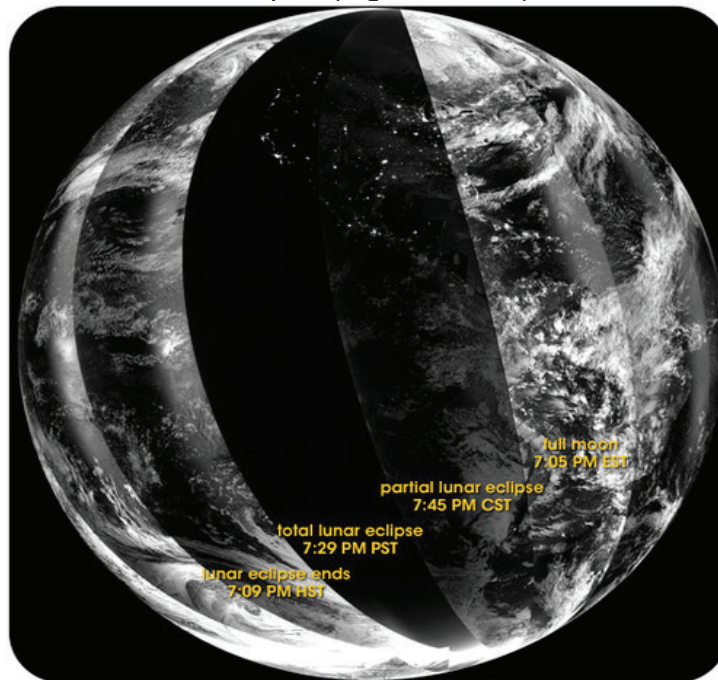
### A Lunar Eclipse

A lunar eclipse occurs when the full moon moves through Earth's shadow, which only happens when Earth is between the Moon and the Sun and all three are lined up in the same plane, called the ecliptic (Figure below). In an eclipse, Earth's shadow has two distinct parts: the umbra and the penumbra. The umbra is the inner, cone-shaped part of the shadow, in which all of the light has been blocked. The penumbra is the outer part of Earth's shadow where only part of the light is blocked. In the penumbra, the light is dimmed but not totally absent.



A lunar eclipse.

A total lunar eclipse occurs when the Moon travels completely in Earth's umbra. During a partial lunar eclipse, only a portion of the Moon enters Earth's umbra. Earth's shadow is large enough that a lunar eclipse lasts for hours and can be seen by any part of Earth with a view of the Moon at the time of the eclipse (Figure below).



Partial lunar eclipses occur at least twice a year, but total lunar eclipses are less common.

The moon glows with a dull red coloring during a total lunar eclipse, which you can see in this video of a lunar eclipse over Hawaii: <http://www.youtube.com/watch?v=2dk-IPAi04>.

Source: <https://courses.lumenlearning.com/sanjac-earthscience/chapter/the-sun-and-the-earth-moon-system/>

Topic 3: The Sun and the Planets	
<b>Content standard</b>	Students will be able to recognize and explain the processes that are responsible for shaping the planet Earth and describe the place of the planet in the solar system and beyond into the inter-intergalactic space.
<b>Benchmark</b>	<b>9.4.4.11</b> Examine the basic hydrological properties and processes, and see how features of the planet interact. <b>10.4.4.21</b> Investigate and understand scientific concepts related to the origin and evolution of the universe.
<b>Key questions</b>	<ol style="list-style-type: none"> <li>1. How many planets are in the solar system?</li> <li>2. Why is the Sun important in the solar system?</li> <li>3. Which of the planet is the largest in the solar system?</li> </ol>
<b>Learning objectives</b>	By the end of the topic, the students will be able to; <ul style="list-style-type: none"> <li>• Study and compare the eight planets in the solar system</li> <li>• Investigate why the Sun is important in the solar system</li> <li>• Analyse and compare the composition of the planets in the solar system</li> </ul>
<b>Vocabulary</b>	Planets, solar system, moons, meteors meteorites
<b>Knowledge</b>	The sun and the planets in the solar system
<b>Skills</b>	Compare and contrast, making inferences, relating, visualising, modelling
<b>Attitudes and values</b>	Optimistic, critical, appreciative, open-minded, respect beliefs and opinions
<b>Teaching and Learning strategies</b>	Teachers prepare information (including pictures showing the order of planets from the Sun) and ask questions on the Sun and the eight planets while the students will use the information provided to answer the questions about the topic.
<b>Assessment</b>	<ol style="list-style-type: none"> <li>1. Demonstrate the order of the eight planets from the Sun by using the constructed models</li> <li>2. Research why pluto is no longer a planet.</li> </ol>
<b>Materials</b>	Charts with pictures (including pictures showing the order of planets from the Sun)

### Content Background

There are eight planets that orbit the central star in the solar system known as the Sun. These planets all revolve around the Sun in somewhat circular orbits and each orbit the Sun in the same plane, which is known as the ecliptic. The planets vary in size, distance from the Sun, and how long they need to complete one orbit of the Sun.



**Figure 1.** Order of planets from the Sun

**Sun**

The dominant object in the solar system is the Sun, which is a typical star. It is thought to be as much as 4.6 billion years old, and its mass makes up over 98 percent of the entire solar system. The magnetic field of the Sun holds the planets in orbit around it. Composed of 74 percent hydrogen and 25 percent helium, along with other different elements, the Sun converts hydrogen into helium through thermonuclear reactions that occur within its core, creating incredible temperatures that can reach 25 million degrees.

**Mercury and Venus**

Mercury and Venus are the two planets that have orbits inside that of the Earth's. Mercury is now the smallest of the planets since Pluto was downgraded to a "dwarf planet" by the scientific community in 2006. Mercury is 3,030 miles in diameter and lies at an average of 36 million miles from the Sun, making it the closest planet to the star. It takes a little under 88 days to orbit the Sun and rotates once on its axis every 58.6 days. Venus is the second planet from the Sun and has an orbital period of 224.7 days. Venus has an average temperature of 850 degrees Fahrenheit due to the constant cloud cover that envelopes the planet and keeps the intense heat in. Venus has a diameter of 7,523 miles and is 67 million miles from the Sun.

**Earth and Mars**

Earth is one of the four "terrestrial planets" along with Mercury, Venus and Mars; all four have a rocky core. Earth's distance from the Sun is 93 million miles, allowing life to flourish. The Earth is 7,926 miles in diameter and takes 365.3 days to make it around the Sun once, which is called a solar year. Mars is the fourth planet from the Sun and is the most like Earth. However, it is 142 million miles from the star and takes almost 687 days to make one revolution around it. Mars is 4,222 miles in diameter and needs 24 hours and 37 minutes to spin once on its axis.

**Jupiter**

The largest of all the planets, Jupiter is 317 times more massive than Earth with a diameter of 88,846 miles. It is the fifth planet in the solar system and is 483 million miles away from the Sun, needing 4,332.5 days to finish an orbit. It spins on its axis rapidly, with a day on Jupiter completed in 9 hours and 55 minutes. Jupiter has no solid surface, as it is composed of hydrogen and ice beneath a deadly atmosphere of helium, methane, and hydrogen. Jupiter has 28 moons, with more being discovered on a regular basis.

**Saturn**

The sixth planet from the Sun, Saturn is the second largest with a diameter of 74,898 miles. It requires 10,759 days to get around the Sun just once and has an average temperature of minus 300 degrees Fahrenheit. Saturn has rings that encircle it that are comprised of rock, ice, and other debris; these rings are visible from Earth and make the planet one of the most viewed objects in the heavens. Saturn has 30 moons and is much like Jupiter in its composition.

**Uranus**

Uranus is unlike the other planets in that it rotates "on its side", possibly the result of some ancient collision with another celestial object. It is the third planet in terms of size, with a diameter of 31,763 miles and Uranus takes 30,684 days to orbit the Sun. It is 1.784 billion miles from the Sun, has 21 moons, and is believed to have a rocky core. However, the warmest it gets on Uranus is minus 300 degrees.

**Neptune**

Even with a diameter of 30,775 miles Neptune is too far from Earth to be seen with the naked eye. It was discovered by using mathematical calculations in 1846 when Uranus's orbit seemed to be affected by another large body. Neptune is 2.794 billion miles distant from the Sun, takes 60,190 days to orbit it just a single time, and has eight known moons, with many more potentially there but unseen by human eyes.

Source: <https://sciencing.com/sun-planets-5078839.html>

# 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 planning 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, analyze 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

## A sample guidelines on how to develop a simple STEAM lesson – An Inquiry based

To understand better about STEAM lesson planning, let's study this scenario of a teacher who also wanted to know this.

An Inquiry Based Question

What? We're not going to start with science? In order to make a good STEAM lesson, we need good bones. An inquiry based question will give us those bones. What do I mean by "inquiry based"?

An inquiry based question causes the student to stop and think. It is impossible to answer with a one syllable answer. It also has:

- Multiple solutions
- Multiple ways of getting to the solution
- Interest

Is the question "What is  $9 + 5$ " inquiry based? No, this question is fact based. The student can answer in one syllable. In this case 14.

A better question would be "How many ways can you make 14?"

The **example problem** we are going to use is "How many rectangles can you make that have an area of 24?"

While the interest isn't super high on this problem, it's a lot higher than a worksheet with the instructions "find the area".

I almost always use math as my starting point because I'm a math teacher. It's what I know. But you could easily start with any of the other subjects.

**For example:**

**S** – "How do plants grow?" or a more specific example, "What is the best fertilizer to grow tomatoes?"

**T** – "Let's make a computer game!"

**E** – "What is the best shape to make a tower out of?"

**M** – "Let's budget and plan a vacation."

Bonus subject **A** (Arst) – "Do different colours elicit different emotions?"

Once you have the basic question hammered out, it becomes easy to add the different subjects in.

### How Does Science Fit in the STEAM Lesson?

Scientists observe the natural world. Thinking about your starter problem, what can you add to that lesson that would help your students observe the world around them? Or how can you relate your problem to the world around them?

With my example problem, I might think about why someone would care about different size rectangles.

Maybe we are building flower beds and want to know the best shape for a flower bed. As a bonus for me (because I homeschool) we could actually build the flower bed. Now our project ties into the real world, and it's something someone might actually need to do.

And if I actually build the flower bed, we add even more science by observing our plants and noticing what makes them thrive, or not.

Some key words to think about when thinking about science, what can my students:

- observe
- explore
- wonder
- predict
- hypothesize

### **How Does Technology Fit in the STEAM Lesson?**

Technology can sometimes be a hard one to fit into a lesson. Especially if you are not tech friendly.

Start with the technology that you use that enhances your life. My idea of using technology for this lesson would be to have them take a picture of their finished plans and share it on Facebook. That's technology, right?

Well, it's better than nothing.

As lesson designers, we also need to keep our students' experience in mind. For my students (who are younger than 10), posting something to Facebook is a new experience and might be a valuable add to the lesson.

It might help to make a list of what we could do with technology.

I would encourage you to add technology to lessons that require doing on the students' part.

While watching a movie is technically technology, they aren't really gaining any technological understanding by watching it.

Here are some examples of some programs that might be helpful for a student to learn to use:

- Publisher
- Excel
- PowerPoint
- Video editing software
- Picture editing software
- Graphing calculator

I find it easiest to add technology in two places: gathering and organizing data and sharing results.

Perhaps with our problem, we will have students make an advertisement on publisher for the size of flower bed they want to create with a goal of mom picking their size. For more ideas on incorporating technology, see this introduction to exploring with graphing calculators.

### **How Does Engineering Fit in the STEAM Lesson?**

Engineers design. They have an emphasis on testing limits: the highest, strongest, longest lasting, etc...

The engineering in STEM also refers to following the Engineering Design Process. It looks a lot like the Scientific Method that I grew up with. Basically, you define the problem, then try a bunch of stuff until you find the solution.

If you want details (in a handy flow chart no less) visit Science Buddies.

Engineers:

- Design
- Build
- Create
- Test

In my problem, I might add a secondary problem. Which size is going to be the strongest? Or perhaps, the most efficient?

Then my students could build models and test their theories.

### **How Does Mathematics Fit in the STEAM Lesson?**

Mathematics is the study of patterns.

Does that definition surprise you? Our current education model has math as a skill set for solving problems. And it certainly has that too. But the reason for that skill set is in finding patterns.

Ask yourself, is there a pattern we can discover with the lesson I am creating?

In my lesson, I would want my students to figure out a quick way to find the area of a rectangle.

So, a question I would have as part of their lesson is, “How did you find the area of this rectangle, now, how can you apply that information to all rectangles?”

### **Bonus Subject: Art – How does Arts fit in?**

Artists are also designers.

But unlike their engineering counterpart, their focus is on communicating ideas and beauty.

Like technology, the easiest place to add art is in the end when it’s time to communicate findings.

Under the technology section, I decided I would have my students create a poster to convince me of which size garden to create.

Perhaps though, I would do the poster in stages.

Stage 1: Get your ideas on the poster.

Stage 2: Make it beautiful.

### **Putting a STEAM Lesson Together:**

Now that you have all of the pieces on your STEAM lesson key ideas, it’s time to put them in a sentence or two and see how they fit into a lesson plan.

My focus for this lesson is: Students will test, design, and create a flower bed that has an area of 10 m by 30 cm. They will create a persuasive poster to sell their idea to the class and myself.

## 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: The Solar System and beyond**

**Lesson Topic:** Properties of planets, and other components of the solar system

**Grade: 10**

**Length of Lesson:** 80 minutes

**National Content Standard:**

**10.4.4** Students will be able to recognise and explain the processes that are responsible for shaping the planet Earth and describe the place of the planet in the solar system and beyond into the inter-intergalactic space

**Grade Level Benchmark: 10.4.4.21** Investigate and understand scientific concepts related to the origin and evolution of the universe.

#### Essential Knowledge, Skills, Values, and Attitudes

**Knowledge:** Subject and discipline-based knowledge

**Skills:** Evaluating – Reasoning-Calculating, approximating

**Values:** Common Good and interdependence

**Attitudes:** Cooperatively collaborate, betterment of human kind

#### STEAM Knowledge and Skill

**Knowledge:** Calculation process, relative sizes of the 8 planets

**Skill:** Evaluating, reasoning, comparing, measuring, make model

#### Performance Indicator:

Identify correct formula to calculate the relative/approximate sizes of the 8 planets using ratio and scale.

**Materials:** Clay, plasticines, paint, scientific calculators, paint, watercolours, paint brushes, scrap/crepe papers, weighing machines, clear papers, strings, 1 meter sticks, markers, card boards, table of universal relative sizes of the 8 planets from textbook

- **Lesson Objective:** Students will be able to compare and construct the relative/approximate sizes of the 8 planets in our solar system.

#### Essential Questions:

What is the largest planet in the solar system?

What is the smallest planet in the solar system?

How do I correctly calculate the relative/approximate size of the 8 planets? (they are so huge)

What STEAM principles and practices can be used to construct the relative/approximate size of the 8 planets in our solar system?

Teachers can adjust this lesson for other grades. It is the concepts, content and skill that are important for that grades. The process is the same and is applicable for all grades.

- Analyse the context and background, and clearly define the problem.
- Conduct research to determine design criteria, financial or other constraints, and availability of materials.
- Generate ideas for potential solutions, using processes such as brainstorming, mathematical calculations, design, and sketching.
- Choose the best solution.
- Build a prototype or model.
- Test and evaluate the solution.
- Repeat steps if necessary to modify the design or correct faults, especially scaling and ratio.
- Reflect and report on the process.

## Lesson Procedure

Teacher Activities	Student Activities
<b>Introduction</b>	
<ul style="list-style-type: none"> <li>• Explain what students will learn and how it will be useful.</li> <li>• Connect what they will learn to prior learning or experience.</li> </ul>	<ul style="list-style-type: none"> <li>• Listen to the teacher.</li> </ul>
<b>Body</b>	
<b>Modeling</b>	
<ul style="list-style-type: none"> <li>• Analyse the context and background of the 8 planets, and clearly define the problem. (how to scale and calculate ratio)</li> <li>• Conduct research to determine design criteria, other constraints, and availability of materials of the 8 planets.</li> <li>• Generate ideas for potential solutions, using processes such as brainstorming, calculating using scales and ratio, and sketching.</li> <li>• Choose the best solution.</li> <li>• Build a prototype or model of the 8 planets.</li> <li>• Test and evaluate the relative sizes of the 8 planets.</li> <li>• Repeat steps as necessary to modify the design or correct faults.</li> <li>• Reflect and report on the process.</li> </ul>	<ul style="list-style-type: none"> <li>• Listen and respond when prompted by the teacher.</li> <li>• Discuss and defend your hypothesis within the group-brainstorming</li> <li>• Discuss and identify correct formulas for ratio and scaling</li> <li>• Distribute tasks of sketching of the prototype within the group</li> <li>• Construct the prototype cooperatively and collaboratively</li> <li>• Test and evaluate the relative sizes of the 8 planets.</li> <li>• Repeat steps as necessary to modify the design or correct faults, especially your measurements.</li> <li>• Reflect and report on the process.</li> </ul>
<b>Guided Practice</b>	
<ul style="list-style-type: none"> <li>• Give students the set project/task</li> <li>• Ask students to go about carrying out the task.</li> <li>• Ascertain if students understand what they are supposed to do.</li> </ul>	<p>Refer to above</p> <p>Refer to above</p>
<b>Independent Practice</b>	
<ul style="list-style-type: none"> <li>• Supervise and facilitate</li> </ul>	<ul style="list-style-type: none"> <li>• Work in their groups on the project/task</li> </ul>
<b>Conclusion</b>	
<ul style="list-style-type: none"> <li>• Ascertain if students understand what they are supposed to do.</li> </ul>	<ul style="list-style-type: none"> <li>• Listen to the teacher.</li> <li>• Present or display models to the class</li> </ul>

## Performance Assessment and Standards

**National Content Standard: 10.4.4.** Students will be able to recognise and explain the processes that are responsible for shaping the planet Earth and describe the place of the planet in the solar system and beyond into the inter-intergalactic space

Lesson Topic	Topic	Benchmark	Performance Assessment	
Properties of planets, and other components of the solar system	The Solar System and beyond	<b>10.4.4.21.</b> Investigate and understand scientific concepts related to the origin and evolution of the universe.	Student correctly designs and makes a model of the solar system based on their relative/approximate sizes.	
	PROFICIENCY RUBRIC			
	<b>Advanced</b>	<b>Proficient</b>	<b>Partially Proficient</b>	<b>Novice</b>
	Identify all the 8 planets with the correct relative/ approximate size and justified at least one reason	Identify all the 8 planets with the correct relative/ approximate size	Identify more than 50% of all the 8 planets with the correct relative/ approximate size	Identify less than 50% of all the 8 planets with the correct relative/ approximate size

## STEAM Activity

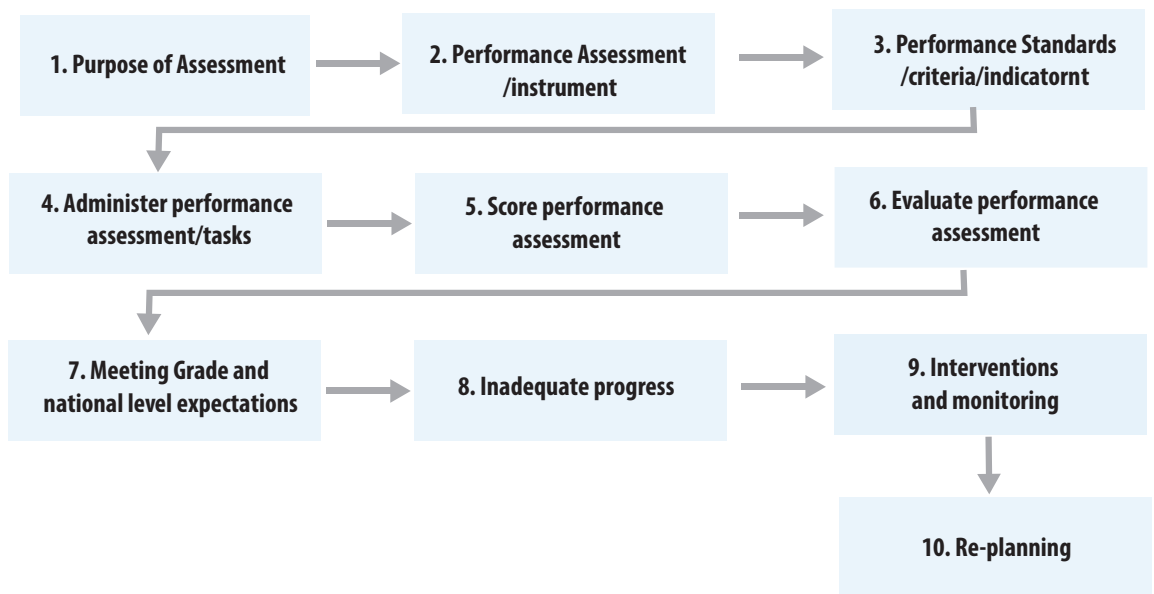
Students create a model of the 8 planets with the correct relative/approximate sizes. Use the information provided in the lesson plan and the guidelines on how STEAM subjects are addressed above for this challenge.

# 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 conducted 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.

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## Assessment Strategies

STRATEGY	DESCRIPTION
<b>ANALOGIES</b>	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.
<b>CLASSROOM PRESENTATIONS</b>	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.
<b>CONFERENCES</b>	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
<b>DISCUSSIONS</b>	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.
<b>ESSAYS</b>	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.
<b>EXHIBITIONS/ DEMONSTRATIONS</b>	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.
<b>INTERVIEWS</b>	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.
<b>LEARNING LOGS</b>	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.
<b>OBSERVATION</b>	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.
<b>PEER ASSESSMENT</b>	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.
<b>PERFORMANCE TASKS</b>	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.

<b>PORTFOLIOS</b>	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.
<b>QUESTIONS AND ANSWERS (ORAL)</b>	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.
<b>QUIZZES, TESTS, EXAMINATIONS</b>	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.
<b>QUESTIONNAIRES</b>	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.
<b>RESPONSE JOURNALS</b>	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.
<b>SELECTED RESPONSES</b>	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.
<b>STUDENT SELF-ASSESSMENTS</b>	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 3: Physical Science

**Content Standard:** Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy.

**Topic:** Electric Current and Circuits

**Benchmark: 10.3.3.2:** Investigate and describe qualitatively the relationship among current, voltage (electric potential difference), and resistance in a simple electric circuit.

**Lesson Title:** Types of Electricity-Circuits-Series Circuit

**Lesson Objective:** By the end of this lesson, students can:

- Construct and explain the relationship between current, voltage and resistance in a series circuit.

**Materials:** Connecting wires, dry cells, bulbs, switch

#### What is to be assessed? (KSAVs)

Knowledge	Skills	Values and Attitudes
<ul style="list-style-type: none"> <li>• Same current flow through each bulb (resistor) in a series circuit.</li> <li>• When the resistors are in series, we add them to work out the total resistance.</li> <li>• The sum of the voltages across the bulb (resistor) is always equal to the dry cell (battery) voltage.</li> </ul>	<ul style="list-style-type: none"> <li>• Constructing and deconstructing.</li> <li>• Discussing and analyzing</li> </ul>	<ul style="list-style-type: none"> <li>• Critical and Appreciative in constructing series circuits.</li> <li>• Creativity and sustainability</li> </ul>

*Scientific Thinking:* Think about the relationship between current, voltage and resistance in a series circuit.

#### Purpose of the assessment

To measure students' proficiency on the achievement of the lesson objective.

#### Expected level of proficiency

Correctly construct a series circuit with 3V power supply, a resistor (light bulb) and measure its current.

**Assessment Strategy**

This lesson is suitable for a double period lab session to complete it. Teacher must group students in advance before the actual lesson.

**Performance Task**

Construct a series circuit to represent given information to solve problems.

**Assessment Tool**

A laboratory practical lesson will be used to measure students' 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 7-9	Progressing 5-6	Not Yet 1-4	___/10 Marks
<b>Construct a series circuit consisting of 6V dry cell and a bulb.</b>	Correctly constructed of series circuit with correct dry cell voltage and a bulb	Constructed a series circuit consisting of 6V dry cell and a bulb.	Constructed a series circuit with incorrect voltage dry cell and a bulb.	Incorrectly constructed a series circuit consisting of 6V dry cell and a bulb.	

**Recommended Resources:**

- Outcomes Edition SCIENCE Grade 10
- Fundamental Science for Melanesia Book 3

### Sample 2: Summative Assessment

#### Strand 3 : Physical Science

**Content Standard:** Students will be able to explain and examine the structure, properties, and changes of matter as well as sources, uses, conservation, and changes of energy.

**Topics :** *Chemical Reactions and Equations*

**Benchmark: 10.3.3.5:** Name and write chemical formulas and balance chemical equations.

**Lesson Title:** All the lessons covered in this topic.

**Lesson Objective:** By the end of this lesson, students can:

- Correctly write balanced chemical formulae.

**Materials:** Activity sheet

#### What is to be assessed? (KSAVs)

Knowledge	Skills	Values and Attitudes
<ul style="list-style-type: none"> <li>• Chemical reactions are represented by writing a chemical sentence, which is called a chemical equation. It is a way of representing what happens during a reaction using chemical formulae in place of words.</li> </ul>	<ul style="list-style-type: none"> <li>• Constructing and deconstructing.</li> <li>• Discussing and analyzing</li> </ul>	<ul style="list-style-type: none"> <li>• Critical and Appreciative in constructing series circuits.</li> <li>• Creativity and sustainability</li> </ul>

**Scientific Thinking:** Think about how to write balanced chemical equations.

**Purpose of the Assessment:** To measure students' proficiency on the achievement of the benchmark and learning objectives.

**Expected Level of Proficiency:** Correctly write balanced chemical equations.

**Assessment Strategy:** This lesson can be conducted in one lesson as a unit test, or as an assignment.

**Performance Task:** Write balanced chemical equations.

**Assessment Tool:** An assignment or test will be used to measure students' proficiency.

### Assessment Scoring

Rubrics must be developed to articulate the real proficiency of the child. This is a sample of an analytical rubric used to assess the child's learning through the assessment tool, an assignment or a test.

Performance standards/ Criteria	A	B	C	D	Score
	Advance 10	Proficient 7-9	Progressing 5-6	Not Yet 1-4	___/20 Marks
(10 marks) Write correct formulae of compounds or elements.	Write all correct formulae of compounds or elements	Write correct formulae of compounds or elements	Write about half of all correct formulae of compounds or elements	Write at least 1 or 2 correct formulae of compounds or elements	
(10 marks) Write correct formulae of compounds or elements.	All chemical formulae written are balanced with states included	Chemical formulae written are balanced with states included	Half the chemical formulae written are balanced with states included	At least 1 or 2 chemical formulae written are balanced with states included	

#### Recommended Resources:

- Outcomes Edition SCIENCE Grade 10
- Fundamental Science for Melanesia Book 3

**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

<b>VASK-MT</b>	
<b>Values/Attitudes</b>	Appreciate the beauty of the application of mathematics during the designing process of the project.
<b>Skills</b>	Calculating size and space Time management and efficiency, Linear measurement and scaling techniques, Calculating mechanical advantage
<b>Knowledge</b>	Size and space Time management and efficiency, Linear measurement and scaling techniques
<b>Mathematical Thinking</b>	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 9 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 9 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.

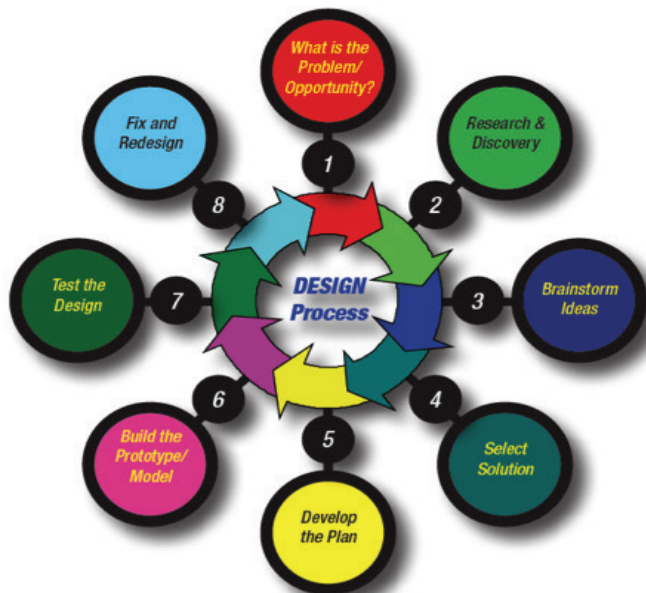
The grade 9 Science teachers will now do the following;

- (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 9 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
<b>Quality/ Workmanship</b>	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.
<b>Creativity/ Design</b>	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.
<b>Functionality</b>	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.
<b>Design Process</b>	Project reflects a clear understanding and application of design process including evidence of research, brainstorming, design and problem solving, prototyping and testing.	Project reflects some understanding and application of accepted design loop principles and sequence including evidence of research, brainstorming, design and problem solving, prototyping and testing.	Project reflects minimal understanding and application of design process.	Project does not show evidence that design process was used. Project does not meet accepted levels of design criteria.
<b>Criteria/ Constraints</b>	Project was completed with all constraints and criteria met or exceeded. Reflects attention to detail and quality.	Project was completed with some of the constraints and criteria met. Reflects some attention to detail, but quality is minimal.	Project was completed with a few of the constraints and criteria met. Reflects minimal effort and lacks detail or quality.	Project was not completed and does not reflect the adherence to the constraints or criteria.

<b>Time Management</b>	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.
<b>Resource Management</b>	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.
<b>Teamwork</b>	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.
<b>Writing/ Reflection</b>	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.
<b>Presentation</b>	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
<b>Abiotic factor</b>	The nonliving part of an ecosystem
<b>Allele</b>	One of different forms of a gene for a trait
<b>Ampere (A)</b>	The units used to measure the amount of electric current flowing in a conductor
<b>Amplitude</b>	The maximum distance a wave varies from its rest position
<b>Angiosperm</b>	A vascular plant that produces seeds from flowers
<b>Assessment</b>	Activities given to students to measure the progress of their learning
<b>Assessment Strategies</b>	Different styles and ways of assessing students work
<b>Assessment Tasks</b>	Test of knowledge and skills gain throughout the particular unit or topic
<b>Benchmark</b>	Assessment of content standards at the end of each level of schooling
<b>Biochemistry</b>	The study of chemistry of living things such as plants, animals or people
<b>Biomass</b>	Once- living matter that can be used as an energy source
<b>Biotechnology</b>	The use of cells and bacteria in chemical processes, especially in food and chemical industries
<b>Buoyant force</b>	An upward force applied by a fluid on an object in the fluid
<b>Chromosomes</b>	Thread-like structures found in the nucleus of cells. They contain the instructions to run the cell. The number of chromosomes in the nucleus is constant for each species, eg, humans have 46.
<b>Concentration</b>	The amount of a particular solute in a given amount of solution
<b>Conferencing</b>	A conversation between the teacher and student or in small groups
<b>Constants</b>	The factors in an experiment that remain the same
<b>Content Standards</b>	Statements that describe what students should know and do in each subject area
<b>Control test</b>	A test or experiment where controls and variables are used
<b>Convection current</b>	A loop of moving gas or liquid caused by rising warm gas or liquid and sinking cool gas or liquid
<b>Cytoplasm</b>	Materials that surround the internal parts of the cell
<b>Decibel (dB)</b>	The units used to measure the loudness of sound
<b>Diagnostic Assessment</b>	An assessment given to identify child's strengths and learning needs for improvement.
<b>Dichotomous key</b>	A tool used to identify organisms based on contrasting pairs of characteristics
<b>Diffusion</b>	Process that spreads substances through a gas or liquid from higher to lower concentration
<b>Displacement</b>	The difference between the initial, or starting position and the final position of an object that has moved

<b>DNA</b>	Deoxyribonucleic acid- the genetic material of all living things
<b>Doppler effect</b>	The change of pitch when a sound source is moving in relation to an observer
<b>Efficiency</b>	The ratio of output work to input work
<b>Electromagnetic spectrum</b>	The band of radiation that includes radio waves, microwaves, infrared radiation, visible light, x-rays, ultraviolet light, and gamma rays
<b>Electron</b>	A negatively charged particle in an atom
<b>Endothermic reaction</b>	A reaction in which energy is absorbed
<b>Enzyme</b>	A chemical found in living things that helps control which chemical reactions are to take place
<b>Enzym</b>	A catalyst that speeds up chemical reactions in living things
<b>Epicenter</b>	A point on the Earth's surface directly above the location of initial plate boundary movement during an earthquake
<b>Fission</b>	A nuclear reaction in which atomic nuclei split and release energy
<b>Frequency</b>	The number of wavelengths that pass by a point each second
<b>Fusion</b>	The forcing of two small atomic nuclei to join together thus releasing energy
<b>Gene</b>	A part of a cell that is passed on from parent to child and that controls particular characteristics
<b>Genetic code</b>	The sequence of three (3) bases (called a triplet or codon) along the DNA or RNA that specifies the next amino acids in the protein
<b>Global Positioning System (GPS)</b>	A worldwide navigation system that uses satellite signals to determine receiver's location
<b>Gymnosperm</b>	A vascular plant that produces seeds, but not flowers or fruits
<b>Hazards</b>	A situation that poses a level of threat to life, health, property or environment
<b>Heterogeneous</b>	Mixed unevenly
<b>Homogeneous</b>	Mixed evenly
<b>Homologous structures</b>	Structures that are similar in different species
<b>Hormone</b>	The chemical message that travels through the blood and carries special information for certain cells
<b>Hydrocarbon</b>	A compound that contains only carbon and hydrogen atoms
<b>Hydroelectric energy</b>	Electric energy generated from moving water
<b>Hypothesis</b>	A theory or suggested explanation for something that has not yet been proven.
<b>Immune system</b>	An organ system that fights disease and foreign agents
<b>Inertia</b>	The tendency of an object to resist a change in its motion
<b>Ion</b>	An atom that has a different number of electrons than protons
<b>Isotopes</b>	Atoms with the same number of protons but different number of neutrons
<b>Longitudinal wave</b>	A wave in which particles move back and forth in the same direction as the wave travels

<b>Meiosis</b>	Cell division that reduces the number of chromosomes by half. The special type of cell division which produces the sex cells (sperm and ova). Each sex cell contains half the number of chromosomes normally found in a body cell.
<b>Menstruate</b>	To have a monthly flow of blood from the uterus
<b>Metalloid</b>	An element that has physical and chemical properties of both metals and nonmetals
<b>Mitosis</b>	Cell division that reduces the number of chromosomes by half. The special type of cell division which produces the sex cells (sperm and ova). Each sex cell contains half the number of chromosomes normally found in a body cell.
<b>Molecules</b>	The smallest unit of a substance, consisting of one or more atoms.
<b>Momentum</b>	When something continues to move, speed or gain speed.
<b>Mutation</b>	Any change in a genome or a chromosome
<b>Mutation</b>	A permanent change in the genes of an organism, or an organism with such a change
<b>Natural phenomena</b>	Things that happen naturally such as movement of stars, tides, and
<b>Natural selection</b>	The process by which the organisms that are best adapted to their environment survive and reproduce
<b>Natural selection</b>	The way the plants and animals die when they are weak or not suitable for the place where they live, while the stronger ones continue to exist.
<b>Nitrogen fixation</b>	The process of Nitrogen gas changing into usable nitrogen compounds
<b>Nonvascular</b>	Lacking a water-transport system
<b>Nuclear energy</b>	Is the energy stored in the nucleus of an atom. It is the energy that holds the nucleus together. The nucleus of Uranium atom is an example of nuclear energy.
<b>Nucleus</b>	A part of a cell that directs all activities and carries information for cell reproduction
<b>Observations</b>	A careful watch over and experiment using Science as Inquiry skills
<b>Opaque</b>	Not letting light pass through
<b>Optical telescope</b>	An instrument that gathers light to form an enlarged image of a distant object
<b>Organ</b>	Two or more type of tissue that work together to perform a function
<b>Organelle</b>	A structure that has a specific task within the cell
<b>Osmosis</b>	A type of diffusion that allows water to pass but not the solutes in the water
<b>Parasitism</b>	The relationship in which one organism lives in or on another organism and harms it in some way.
<b>Performance Standards</b>	What students must do to demonstrate proficiency
<b>Periodic table</b>	The table that arranges the elements according to atomic number
<b>pH scale</b>	System of measuring the strength of different acids and bases
<b>Phagocyte</b>	A cell that consumes harmful invading organisms in your body
<b>Photon</b>	A particle of electromagnetic radiation
<b>Plate boundary</b>	The edge of a tectonic plate

<b>Polymer</b>	A substance made of giant molecules formed by the joining of many simple molecules (monomers). For example, the addition polymer polyethylene, or the condensation polymer nylon
<b>Portfolio</b>	Collections of student work that exhibit the students' efforts, progress and achievements in one or more areas
<b>Practical Tasks</b>	Activities involving students to display or do both indoor and outdoor
<b>Precipitation</b>	Any form of water that falls to earth's surface from clouds
<b>Predation</b>	Interaction in which one organism catches and feeds on an organism of another species
<b>Pressure</b>	The amount of force exerted per unit area
<b>Protist</b>	A single-celled or multicellular organism that may share characteristics with plants, fungi and animals
<b>Proton</b>	A positively charged particle in the nucleus of an atom
<b>Radiation</b>	When a substance emits electromagnetic waves that carry energy
<b>Rarefaction</b>	The region of a longitudinal wave where the particles of the medium are farthest apart
<b>Recording</b>	An act of collecting and entering of raw scores from students through assessable tasks
<b>Reflection</b>	Light bouncing off a surface
<b>Refraction</b>	The bending of light rays when they bounce from one material to another
<b>Relationships</b>	The connection between two or more organisms and their involvement with one another including their abiotic environment
	The process of making identical copies of DNA
<b>Replication</b>	to present parents and guardians correct information about students' academic performance
<b>Reporting</b>	Complete orbit around an object
<b>Revolution</b>	A cell structure where proteins are manufactured
<b>Ribosome</b>	A complete turn about an axis
<b>Rotation</b>	Skills scientists apply to investigate the nature of sciences in the world.
<b>Science process skills</b>	The pulling apart of plate boundaries under the ocean floor
<b>Sea-floor spreading</b>	Development of new communities after an ecosystem has been disturbed
<b>Secondary succession</b>	When something continues to move, increase or develop to gain momentum
<b>seismic</b>	A wave that carries the energy released when rock move at plate boundaries
<b>Seismic wave</b>	A judgment sometimes for official purposes which you make about your abilities, principles or decisions
<b>Self – Assessment</b>	A system that uses the reflection of sound waves to find underwater objects
<b>Sonar</b>	Sound is a form of energy, just like electricity and light. Sound is made when air molecules vibrate and move in a pattern called waves, or sound waves.
<b>Sound</b>	A body of information or statistics gathered over a period of time from students' performance

<b>Students Records</b>	A body of information or statistics gathered over a period of time from students' performance
<b>Sustainability</b>	Able to continuously maintain over a period of time
<b>Symbiosis</b>	Relationship in which two species live close to each other
<b>Tectonic plate</b>	An irregular section of the lithosphere that floats on earth's mantle
<b>Tests</b>	Way of discovering by questions or practical activities to measure someone's knowledge, ability or experience
<b>Thermal equilibrium</b>	When objects in contact are the same temperature
<b>Thermal expansion</b>	An increase in size of a sample of matter when it is heated
<b>Transverse wave</b>	A wave in which particles move up and down or side-to-side at right angles to the direction the wave travels
<b>Transverse wave</b>	A wave in which the disturbance is perpendicular to the direction the wave travels
<b>Trophic level</b>	Each step in the movement of energy through a food web
<b>Use variable</b>	To keep all conditions in an experiment the same except for the variable, or the condition that is being tested in the experiment
<b>Vaporization</b>	The change in state from liquid to gas
<b>Variable</b>	Any factor that can have more than one value
<b>Wavelength</b>	The distance between a point on one wave and the same point on the next wave
<b>X-ray</b>	A high energy electromagnetic wave that has a slightly shorter wavelength and higher frequency than an ultraviolet wave

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# Appendices

## Appendix 1: Bloom's Taxonomy

LEVEL OF UNDERSTANDING	KEY VERBS
<b>CREATING</b> 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,
<b>EVALUATING</b> 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,
<b>ANALYZING</b> 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,
<b>APPLYING</b> 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,
<b>UNDERSTANDING</b> Can the student comprehend ideas or concepts?	Classify, compare, exemplify, conclude, demonstrate, discuss, explain, identify, illustrate, interpret, paraphrase, predict, report, translate, describe, classify,
<b>REMEMBERING</b> 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: 21<sup>st</sup> Century Skills

<b>WAYS OF THINKING</b>	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
<b>WAYS OF WORKING</b>	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
<b>TOOLS FOR WORKING</b>	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
<b>LIVING IN THE WORLD</b>	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)**

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**Topic:****Lesson Topic:****Grade:****Length of Lesson:**

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**National Content Standard****Grade Level Benchmark****Essential Knowledge, Skills, Values, and Attitudes****Knowledge:****Skills:****Values:****Attitudes:**

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**Materials:**

---

- **Lesson Objective:**

**Essential Questions:**

**Lesson Procedure**

Teacher Activities	Student Activities
<b>Introduction</b>	
<b>Body</b>	
<b>Guided Practice</b>	
<b>Independent Practice</b>	
<b>Conclusion</b>	

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

### Standards-Based Lesson Plan (Integrating STEAM)

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**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:**

## Performance Assessment and Standards

National Content Standard:

Lesson Topic	Topic	Benchmark	Performance Assessment	
	<b>PROFICIENCY RUBRIC</b>			
	<b>Advanced</b>	<b>Proficient</b>	<b>Partially Proficient</b>	<b>Novice</b>



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