NASCA

NATURAL SCIENCES
Curriculum Statement

higher education
& training

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NATURAL SCIENCES

Introduction

The field of Natural Sciences investigates physical, chemical and biological phenomena. This is done through scientific enquiry, and application of scientific models, theories, laws and principles in order to explain and predict events in the natural environment. The Natural Sciences field includes the subjects Physics, Chemistry and Biology. Physics focuses on the physical properties of matter and energy and the interactions and relationships between these, and attempts to develop mathematical and other models to explain physical phenomena. Chemistry focuses on the properties of matter and materials and the ways in which they change from one form to another and react with one another. Biology is the scientific study of living organisms from the molecular level to their interactions with one another and their environments.

This collection of subjects also deals with society's need to understand how the natural environment works in order to benefit from it and responsibly care for it. Scientific knowledge changes over time as scientists improve their knowledge and understanding. However, science is based on thorough investigation, debate and argument until a new idea is accepted by the scientific community.

NQF Level 4 Mathematics and English are recommended as co-requisites for Natural Sciences, given the mathematical and language demands of Natural Sciences. In Natural Sciences, we recommend that the Nature of Science be studied first, followed by Physics, Chemistry and Biology in parallel, to ensure progressive development within each of these sections.

Aims

1. Provide a worthwhile educational experience for all students to enable them to acquire sufficient understanding and knowledge to:
   - 1.1. Become confident citizens of South Africa, able to take or develop an informed interest in matters of scientific importance;
   - 1.2. Recognise the usefulness, and limitations, of the scientific method, and to appreciate its applicability in other disciplines and in everyday life;
   - 1.3. Be suitably prepared for further study in related scientific fields.

2. Develop thinking and process skills that:
   - 2.1. Are relevant to the study of science;
   - 2.2. Encourage curiosity about the natural world;
   - 2.3. Develop accurate and precise observation;
   - 2.4. Are useful in everyday life;
   - 2.5. Promote logical and critical thinking and self-reflection;
   - 2.6. Promote effective communication.

3. Develop attitudes relevant to science such as:
   - 3.1. Objectivity;
   - 3.2. Integrity;
   - 3.3. Creativity;
   - 3.4. Perseverance.

4. Stimulate interest in and care for the South African and global environment.
5. Promote an awareness that:
   - 5.1. The study and practice of science are co-operative activities, which are subject to socio-economic and political influences;
   - 5.2. The applications of science may benefit or harm the individual, the community and/or the

environment;
5.3. If used responsibly, science can enhance meaningful social, political and economic participation.

Exit-Level Outcomes

By the end of this course Students Should be Able to:

1. Understand and use subject-specific knowledge with regard to:
    - 1.1. Scientific phenomena, facts, concepts, definitions, principles, theories and laws;
    - 1.2. Scientific vocabulary, terminology and discourse (language of science);
    - 1.3. The process and application of scientific investigations and techniques;
    - 1.4. Scientific and technological applications with their social, economic and environmental implications.

2. Know and apply subject specific skills, namely:
    - 2.1. Find, organise, synthesise and communicate information from a variety of sources;
    - 2.2. Translate information from one form to another, e.g. table to graph, graph to text, text to diagram;
    - 2.3. Manipulate numerical and other data;
    - 2.4. Use data to identify patterns, trends and draw inferences;
    - 2.5. Draw conclusions based on reasoning;
    - 2.6. Hypothesise and predict;
    - 2.7. Solve problems in familiar and novel contexts;
    - 2.8. Evaluate information or investigative procedure.

3. Understand, adopt and apply the values related to the subject, namely:
    - 3.1. Use scientific knowledge effectively and critically, showing responsibility towards the environment and the health of others;
    - 3.2. Make responsible decisions using critical and creative thinking;
    - 3.3. Understand, adopt and display the values of ethical methodology and reporting of science.

These Exit-Level Outcomes cannot be precisely specified in the syllabus content because questions testing such skills may be based on novel contexts or information that is unfamiliar to the candidate. In answering such questions, candidates are required to use principles and concepts that are within the syllabus and apply them in a logical, reasoned or deductive manner to a novel situation.

Taxonomy and Weighting of Exit-Level Outcomes

These Exit-Level Outcomes are reflected in the following taxonomy.

Taxonomy of Cognitive Demands for Natural Sciences				
	Remembering	**Understanding**	**Applying and Analysing**	**Evaluating and Creating**
Approximate weighting	20%	30%	35%	15%
Descriptors	Name, label, list, define, state, describe, explain (descriptive)	Explain underlying scientific process, compare, give an example of, rearrange, infer, classify	Calculate, apply, demonstrate, solve, illustrate, construct, sequence, interpret, draw, analyse, distinguish, compare and contrast, debate	Evaluate, criticise, justify, generalise, validate, predict, invent, formulate, plan, design, evaluate and solve complex problems in novel contexts
Related exit-level outcomes	1. Understand and use subject-specific knowledge		2. Know and apply subject-specific skills	
	3. Understand, adopt and apply the values related to the subject			

Scheme of Assessment

The Natural Sciences course will be examined in three separate papers. This is done in order to avoid confusion between the disciplines of Physics, Chemistry and Biology, and to prevent a student from having to cover a vast breadth of content for any examination.

Paper	Type of Paper	Marks	Duration	Weighting
1	Physics	100	2 hours	33,3%
2	Chemistry	100	2 hours	33,3%
3	Biology	100	2 hours	33,3%

Structure of the Examination Papers

Paper 1 – Physics (2 hours, 100 marks)
Section A (Short Structured Questions) 30 marks
Section B (Long Questions) 70 marks

Paper 2 – Chemistry (2 hours, 100 marks)
Section A (Short Structured Questions) 30 marks
Section B (Long Questions) 70 marks

Paper 3 – Biology (2 hours, 100 marks)

Section A (Short Structured Questions)	30 marks
Section B (Short Free-Response Questions)	50 marks
Section C (Essay Question)	20 marks

Paper 1 and Paper 2 will contain data sheets with the necessary formulae, tables and other information.

Students are required to answer ALL questions in all papers. Questions on the Nature of Science can be asked in any or all of the three papers.

Section A of each paper will cover all categories of cognitive demand, and could include short structured questions such as:

- Multiple choice questions;
- Supply labels for diagrams;
- Supply scientific terms for definitions.

Section B of each paper could include questions requiring:

- Answers that vary from one word to a paragraph;
- Calculations;
- Drawing, analysis and interpretation of graphs, tables and other data representations.

Section C of Paper 3 consists of an essay question (requiring 2-3 pages of writing). This will be assessed on the presentation of correct information and the structure of the essay.

Guidelines for Lecturers and Materials Developers

The students envisaged in the NASCA curriculum are a varied group of adult and out-of-school students, and come from a wide range of backgrounds and socio-economic contexts. In addition, the modes of delivery are envisaged to be varied, ranging from face-to-face teaching in community colleges to distance learning in remote areas. The curriculum is therefore not prescriptive about learning activities or teaching methods, but allows for a range of teaching and learning styles. The sequence is not prescribed, although there is logic behind the order in which topics are presented in each section.

The teaching and learning that takes place in Natural Sciences should include a wide variety of learning experiences that promote the development of scientific skills and understanding, and that encourage values and attitudes that will enable students to be constructive citizens of South Africa. Lecturers and materials developers are encouraged to use a combination of strategies to allow for active participation and critical thinking. These strategies should include investigative and problem-solving skills, effective communication and reflection on the learning process.

In constructing learning activities, lecturers and materials developers should refer to the table of Exit-Level Outcomes, together with the taxonomy and weighting of these, to ensure that students achieve the necessary conceptual depth that will be assessed in the final examination.

Guidelines for Practicals

Because specialised laboratory equipment might not be readily available to many students, the activities should involve everyday found objects, but should illustrate the principles and processes of science. Many standard science practicals are available through You-Tube or other educational resources, and these resources should be used if physical equipment is unavailable. However, physically handling apparatus is an important component of science, so students are encouraged to engage in as much practical work as possible, or to observe videos of experiments on the Internet.

The table below gives some suggestions as guidance for how practical work can be incorporated for each discipline. Given the diverse nature of learning environments, it is not possible to prescribe practical work.

Topic	Suggested Practical	Possible Approaches
Scientific Enquiry (Nature of Science)	Practice observing "with a scientific eye" and making accurate recordings.	• Observe found objects such as leaves, flowers, seashells, or pebbles; • Record observations as accurate drawings, linear measurements, and/or verbal descriptions.
Scientific Enquiry (Nature of Science)	Conduct a simple controlled experiment, e.g., test the hypothesis that heat increases the rate of diffusion.	• Place a drop of food colouring into a glass container of cold water and a container of warm water. Measure the time it takes for the food colouring to spread throughout the container.
Motion in 1-Dimension (Physics)	Measure the gravitational acceleration of objects in free-fall using ball-bearings of different masses.	• Perform the experiment using ball-bearings and stop-watches; • Supply photographs or diagrams of objects of different masses in free-fall for students to analyse.
Force, Newton's Laws (Physics)	Determine the relationship between mass and weight by measuring the weights of various masses.	• Use a spring balance to measure the weights of objects with known masses; • Provided the weights (in Newtons) and masses (in *g* or *kg*) of various objects, and work out a mathematical formula that describes the relationship between these.
Momentum and Impulse (Physics)	Design and conduct a practical investigation to determine whether momentum is conserved in a 1-dimensional collision.	• Allow two trolleys to collide head-on (a 1-dimensional collision), and measure the initial and final momentum using the mass and velocity of the trolleys; • Allow two marbles or ball-bearings to collide head-on (a 1-dimensional collision), and measure the initial and final momentum using the mass and velocity of the marbles. (If no mass meter is available, students could assume the mass of a marble to be 4 g).

		• Provide students with data of mass, positions and time for trolleys that collide, and use this to calculate the initial and final momentum of the trolleys.
Geometrical Optics (Physics)	Trace ray diagrams to show the path of a light ray passing between different media.	• Use a ray box and a Perspex block to trace ray diagrams for a light ray moving from air to Perspex and back into air again, for various angles of incidence; • Use a torch and cardboard with a slit in it to construct a ray box, and a clear container (glass or clear plastic) filled with water, to trace ray diagrams for a light ray moving from air to water and back into air again, for various angles of incidence; • Use given ray diagrams showing light rays passing from air into Perspex and back into air again, and describe the trend observed.
Electric Circuits (Physics)	Design and conduct a practical investigation to determine the relationship between current and voltage.	• Use an ammeter and voltmeter to measure current and voltage readings for a range of cell voltages, and use these to plot a graph in order to determine the relationship between current and voltage for a constant resistance. (Do not use a light bulb as the resistor); • Analyse photographs of various ammeter and voltmeter readings for a range of cell voltages, and use these to plot a graph in order to determine the relationship between current and voltage for a constant resistance; • Construct a virtual electrical circuit using circuit-builder software in order to determine the relationship between current and voltage for a constant resistance. (e.g. PhET free simulations from https://phet.colorado.edu).
Classification and Separation of Matter (Chemistry)	Separate mixtures using various techniques.	• Separate a mixture of sand and iron filings using a magnet; • Separate salt from water in a salt solution using evaporation; • Separate a sand-water mixture using filtration.
Intermolecular Forces (Chemistry)	Explore the effect of types of intermolecular force on rate of evaporation.	• Measure the rate of evaporation for equal quantities of paraffin or methylated spirits (induced dipole forces) and water (hydrogen bonding).
Reaction Rate (Chemistry)	Measure the effect of various factors on the reaction rate.	• Observe the effect of temperature and concentration on the rate of a chemical reaction e.g. between zinc and hydrochloric acid; • Observe the effect of temperature on the rate of a reaction using readily available substances e.g. caramelisation of sugar at different temperatures;

		• Observe the effect of temperature and concentration on the rate of a reaction using readily available substances e.g. steel wool that forms rust in salt water; • Watch videoclips showing experiments on reaction rates (www.youtube.com/ watch?v=r4IZDPpN-bk).
Acids, Bases and Neutralisation Reactions (Chemistry)	Conduct a neutralisation reaction.	• Use an indicator to observe a neutralisation reaction between an acid and a base e.g. between sodium hydroxide and hydrochloric acid; • Use an indicator to observe a neutralisation reaction between an acid and a base using readily available substances e.g. the reaction between vinegar and baking powder, using an indicator made from red cabbage, turmeric or tea.
Biodiversity and The Biomes of South Africa (Biology)	Study one biome.	• Collect climate data for the selected biome, either through direct measurement, or by referring to a climate website for South Africa (e.g. WeatherSA); • Identify adaptations of plants in the chosen biome.
Principles of Classification (Biology)	Hierarchical classification system.	• Classify found objects into a simple nested hierarchy; • Classify organisms (or photographs of organisms) from the selected biome into plants, animals or fungi based on visible evidence; • Classify the plants and animals into groups, e.g. plants into monocots and dicots, animals into insects, worms, molluscs or vertebrates based on shared features.
The History of Life (Biology)	Construct a timeline showing the history of life.	• Use a roll of single-ply toilet paper with perforations to illustrate the timeline. Each sheet represents 10 million years. Mark the events listed in the content in the correct places on the timeline.
Evolution (Biology)	Illustrate the theory of evolution by natural selection.	• Trace Darwin's Voyage of the Beagle on a globe, noting the continents and islands he visited, and the distance between them; • Demonstrate natural selection through games (search the Internet for suitable games).
Evidence Supporting Evolution (Biology)	Visit a museum or fossil park.	• Observe fossils on display; • Observe museum collections of vertebrates to see patterns in biodiversity.

Genetics and Heredity (Biology)	Simulate mitosis and meiosis.	• Use pieces of coloured wool to simulate the processes of mitosis and meiosis; • Watch videoclips showing simulations of mitosis and meiosis (www.youtube.com/watch?v=zGVBAHAsjJM).
Genetics and Heredity (Biology)	Continuous and discontinuous variation.	• Collect data on continuous variation, e.g. heights of members of the study group and show results as a histogram; • Collect data on discontinuous variation, e.g. blood type or tongue-rolling and plot results as a bar chart.
Genetics and Heredity (Biology)	Effect of natural selection on allele frequency.	• Simulate the effect of natural selection on frequency of a lethal recessive allele using beads to represent alleles. Draw line graphs to show the frequency of the normal allele and recessive allele in the population after each generation.
DNA Structure and Function (Biology)	Model of DNA.	• Construct a model of a DNA molecule using downloadable resources or instructions from the Internet (e.g. WikiHow); • Simulate DNA replication using your model of DNA or downloadable resources or instructions from the Internet; • Watch a YouTube simulation of DNA transcription and translation (e.g. https://youtu.be/NJxobgkPEAo).

This is not a complete list of experiments, and lecturers and materials developers are encouraged to incorporate experiments or simple demonstrations wherever possible to assist with the learning process.

Assumptions About Prior Knowledge and Skills

This course relies on students having a certain baseline of numerical and general knowledge and skills. Students who enrol for Natural Sciences should be able to:

- Apply rules of basic algebra in order to solve an equation with one unknown, and to change the subject of a formula;
- Plot data points on a Cartesian plane;
- Draw a straight-line graph;
- Find the gradient and intercepts of a straight-line graph;
- Manipulate fractions and ratios;
- Interpret the meaning of direct and inverse proportions;
- Know how to use a scientific calculator;
- Work with arithmetic powers (including reciprocals and square roots);
- Solve linear simultaneous equations;
- Comprehend and use the symbols $<$, $>$, $\approx$, $/$, [illegible], Σ, Δx, $\sqrt{}$;
- Calculate areas of right-angled and isosceles triangles;
- Use Pythagoras' theorem, similarity of triangles, the angle sum of a triangle;
- Apply basic trigonometric ratios to a right-angled triangle, (i.e. *sin*, *cos* and *tan*);
- List the characteristics of life;
- Have a basic understanding of cell structure and function;
- Understand terms such as autotrophic, heterotrophic, prokaryotic and eukaryotic;
- Draw line graphs, bar graphs, pie charts and histograms.

The Nature of Science

Introduction

Science is the study of the natural world and how it works. Scientists try to discover patterns in events in the natural world, and to understand those patterns through careful, systematic study. Through science, we have been able to develop an increasingly comprehensive and reliable understanding of many of the patterns in the universe, such as patterns of matter, energy, forces and motion, as well as patterns that relate to life.

Science provides a powerful way of investigating the world, and developing theories that explain our observations. It provides a framework for learning more about the universe, tackling new questions and revising theories in the light of new evidence. The means used to develop new knowledge are detailed observation, thinking, experimenting and validating findings.

Science provides the basis for technology, which has improved human life through medicines, electricity, materials to build houses, mobile phones and television. Science also enables us to consider the consequences of our actions, such as releasing raw sewage into rivers, or poaching endangered animals, or using electricity inefficiently.

Rationale for Content Selection

The intention of this section is to introduce students to scientific ways of thinking and scientific methods of inquiry. The disciplines of Physics, Chemistry and Biology are introduced. This section should be studied first, so that students obtain a holistic understanding of the commonalities in science, before embarking on a study of each of the disciplines Physics, Chemistry and Biology.

The Nature of Science Content Structure

Topic Heading	Topic (with Approximate Instructional Time)
1 The Nature of Science	1.1 What is Natural Science? (2 hours) 1.2 Scientific inquiry (3 hours) 1.3 Science in society (1 hour)

NATURAL SCIENCES

Section 1. The Nature of Science

Overview

Science is the systematic study of the natural world and how it works. Scientific inquiry begins with curiosity about a natural phenomenon, based on our observations of that phenomenon. The scientist then proposes a hypothesis that might explain the phenomenon. If the hypothesis is correct, he predicts what the outcome might be if he manipulates the situation through an experiment, or collects data in a different way.

The scientist sets up a research programme with other researchers to carry out further observations or experiments. He collects data in a careful and rigorous manner. Once he has sufficient data, he writes a scientific paper that is sent to a number of other scientists for review. Once they are satisfied, the paper is published in a journal or presented at a conference.

If the hypothesis is supported by many other scientists' research, it achieves the status of a theory. A scientific theory is supported by a great deal of evidence, and is consistent with all known facts. While the so-called "hard sciences" (Physics and Chemistry) arrive at Laws that explain physical phenomena, Biology has a few Laws, but many Principles, which are generally true, but which have exceptions.

1.1 What is Natural Science?

Content:

- The nature of science and scientific knowledge;
- The purpose of science;
- The value of science;
- Scientific disciplines;
- The limitations of science.

Learning Outcomes:

Students Should be Able to:

1.1.1 Describe the nature of science as a comprehensive and reliable way of understanding patterns observed in the natural world;

1.1.2 Describe the purpose of science as developing generalizable theories that explain events in the natural world through careful, systematic study;

1.1.3 Explain the value of science in developing deeper understanding of natural phenomena and the ability to predict future events;

1.1.4 Demonstrate understanding that although much scientific knowledge is long- lasting, it is subject to modification as new information becomes available;

1.1.5 Distinguish between the terms *theory*, *hypothesis* and *prediction* as used in science;

1.1.6 Give examples of broad scientific disciplines, such as Physics, Chemistry, Biology, Geology, and Environmental Science;

1.1.7 Differentiate the fields of study of Physics, Chemistry and Biology, and indicate overlaps between the disciplines, such as biochemistry (intersection between

Chemistry and Biology) and properties of matter (intersection between Physics and Chemistry);

1.1.8 Identify the limitations of science in its inability to investigate phenomena that cannot be proved or disproved, such as beliefs, the purpose of life, issues of good and evil.

1.2 Scientific Enquiry

Content:

- The process of scientific enquiry;
- Presenting scientific reports;
- Scientific reasoning.

Learning Outcomes Students Should be Able to:

1.2.1 Explain that scientific knowledge is based on systematically-collected (rigorous) evidence, with no fixed sequence of steps followed by every scientist;

1.2.2 Describe observation as the essence of science, specifically observation using the senses, instruments that enhance the senses (e.g. microscopes, telescopes), and instruments that detect stimuli that humans cannot detect (e.g., magnetic fields, electrical fields, electromagnetic waves);

1.2.3 Explain the importance of recording accurate data in the form of measurements, verbal descriptions, photographs or diagrams;

1.2.4 Describe the use of controlled experiments as one way of collecting rigorous evidence in science, specifically experiment and control, dependent, independent and controlled variables, accurate data recording, replication of experiments;

1.2.5 Explain how analysis of data enables inferences to be made;

1.2.6 Identify the structure and style of a scientific report;

1.2.7 Explain the importance of avoiding bias by striving for objectivity in collecting and interpreting data, for example, by having many different investigators or groups of investigators working on a problem;

1.2.8 Explain how science uses logical reasoning, specifically inductive and deductive reasoning, in advancing our understanding of the natural world;

1.2.9 Distinguish between science and pseudoscience, applying the reasoning and methods of scientific inquiry to detect pseudoscience.

1.3 Science in Society

Content:

- The ethics of science;
- Social responsibilities of scientists;
- The benefits and disadvantages of scientific discoveries.

Learning Outcomes

Students Should be Able to:

1.3.1 Identify the ethical norms of science, such as accurate record-keeping, openness, replication, critical review of each other's work, honesty in reporting results;

1.3.2 Describe the importance of ethics in research, such as avoiding unnecessary pain and suffering, taking care of animals in captivity, and obtaining informed consent from human participants in research;

1.3.3 Explain how research should be evaluated in terms of possible harmful effects of applying the results of the research;

1.3.4 Discuss the social responsibilities of scientists in how their findings are applied in society, as well as advising government and the general public about the benefits and risks of applying scientific discoveries, for example, genetically modified food, or the risk of climate change;

1.3.5 Evaluate the benefits of applying scientific discoveries for humans, and the risks of their application to the natural environment, for example, the benefits and disadvantages of the Green Revolution.

Physics

Introduction

Physics focuses on the physical properties of matter and energy and the interactions and relationships between these, and attempts to develop mathematical models to explain physical phenomena. Physics concepts are usually organised under the themes Mechanics, Waves, Electricity and Magnetism, Heat and Modern Physics.

Rationale for Content Selection

The intention of this course is for students to engage with a narrow selection of content as deeply as possible. Therefore, to avoid the temptation to include too great a breadth of content for the time available for the Physics component, the content that has been included has been carefully selected to cover concepts and skills that are core to the Physics discipline. Mastery of this content will give students a solid foundation for further study in the discipline. The main topic headings selected for this curriculum are:

- Mechanics;
- Waves;
- Electricity and Magnetism.

Physics Content Structure

Topic Heading	Topic (With Approximate Instructional Time)
1 Basic scientific skills (5% weighting)	1.1 Physical quantities, units and measurement (1 hour); 1.2 Problem-solving techniques (1 hour); 1.3 Graph drawing, analysis and interpretation (2 hours).
2 Mechanics (55% weighting)	2.1 Vectors (4 hours); 2.2 Motion in 1-dimension (12 hours); 2.3 Force, Newton's Laws (10 hours); 2.4 Momentum and impulse (3 hours); 2.5 Work, power and energy (3 hours).
3 Waves (10% weighting)	3.1 Transverse and longitudinal waves (3 hours); 3.2 Geometrical optics (2 hours).
4 Electricity and Magnetism (30% weighting)	4.1 Electrostatics (5 hours); 4.2 Electric circuits (7 hours); 4.3 Magnetism (1 hour); 4.4 Electromagnetism (4 hours).

The guidelines for instructional time given in the table above do not include self-study time, which should be included in the learning programme.

Details of Content Coverage for Physics

Section 1. Basic Scientific Skills

Overview

The basic scientific skills described in this section will be applied in all the other sections of the Physics component of this curriculum. This section should be thoroughly covered at the start of the course, to make sure that all learners are confident in the basic skills required to be able to tackle the remainder of the course.

1.1 Physical Quantities, Units and Measurement

Content:

- Physical quantities;
- SI units and conversions;
- Scientific notation.

Learning Outcomes:

Students Should be Able to:

1.1.1 Write physical quantities as a numerical magnitude and a unit;

1.1.2 Recall the following base quantities and their SI units: mass (kg), length (m), time (s), current (A), temperature (K);

1.1.3 Convert between various scales of measurement: temperature (Celsius and Kelvin), length (km, m, cm, mm), mass (kg, g), pressure (kPa, atm);

1.1.4 Display numerical values in scientific notation;

1.1.5 Use the following prefixes and their symbols: nano (n), micro (μ), milli (m), centi (c), deci (d), kilo (k), mega (M), giga (G);

1.1.6 Relate the different orders of magnitude to the sizes and masses of common objects, ranging from an atom to the Earth.

1.2 Problem-Solving Techniques

Content:

- Problem solving strategies and procedures.

Learning Outcomes:

Students Should be Able to:

1.2.1 Use diagrams as problem solving tools;

1.2.2 Apply steps in problem solving procedures to solve single and multi-step problems;

1.2.3 Reflect on and interpret answers to calculations.

1.3 Graph Drawing, Analysis and Interpretation

Content:

- Constructing a graph from given data;
- Analysing and extracting information from a graph.

Learning Outcomes:

Students Should be Able to:

1.3.1 Select appropriate variables and scales for graph plotting;

1.3.2 Accurately construct a straight-line graph from given data;

1.3.3 Analyse a graph to extract meaningful information, namely:

- Value and physical meaning of the gradient of a straight-line graph;
- Value and physical meaning of the intercepts of a straight-line graph;
- Physical interpretation of the shape of a non-linear graph.

Section 2. Mechanics

Overview

Mechanics is the study of motion and its causes. The greatest contribution to the development of mechanics was by Isaac Newton, who developed the three laws of motion and his law of universal gravitation to predict and explain phenomena. He showed that the physical world can be explained by a few special laws that can be expressed using mathematical formulae.

2.1 Vectors

Content:

- Introduction to vectors and scalars;
- Vectors in 2-dimensions.

Learning Outcomes:

Students Should be Able to:

2.1.1 State what is meant by scalar and vector quantities, and give examples of each;

2.1.2 Add vectors that are co-linear (in 1-dimension) using a graphical method (head-to-tail) as well as by calculation;

2.1.3 Add two vectors that are at right angles to determine the resultant using a graphical method (head-to-tail or tail-to-tail) as well as by calculation;

2.1.4 Determine the x and y-components of a vector on the Cartesian plane.

2.2 Motion in 1-Dimension

Content:

- Position, displacement, distance;
- Speed, velocity, acceleration;
- Graphs of motion;
- Equations of motion;
- Projectile motion.

Learning Outcomes:

Students Should be Able to:

2.2.1 Define position, displacement and distance;

2.2.2 Define position relative to a frame of reference;

2.2.3 Determine displacement and distance for 1-dimensional motion;

2.2.4 Define speed, instantaneous velocity and average velocity;

2.2.5 Determine speed, instantaneous velocity and average velocity for 1-dimensional motion;

2.2.6 Define acceleration;

2.2.7 Determine acceleration for 1-dimensional motion with uniform acceleration;

2.2.8 Plot graphs of position vs time, velocity vs time and acceleration vs time;

2.2.9 Interpret and determine information from graphs of position vs time, velocity vs time and acceleration vs time for 1-dimensional motion with uniform acceleration;

2.2.10 Use the kinematics equations of motion to solve problems for 1-dimensional motion;

2.2.11 Verify that the gravitational acceleration of objects in free-fall is constant using experimental data of ball-bearings of different masses in free-fall;

2.2.12 Explain that objects in free-fall (projectiles) accelerate towards the earth with a constant acceleration of 9,8 $m \cdot s^{-2}$;

2.2.13 Apply graphs and kinematics equations of motion to objects in free-fall, in familiar and novel contexts.

2.3 Force, Newton's Laws

Content:

- Mass and weight;
- Types of forces;
- Free body diagrams;
- Balanced and unbalanced forces;
- Newton's laws of motion.

Learning Outcomes:

Students Should be Able to:

2.3.1 Differentiate between mass and weight;

2.3.2 Calculate the weight of an object on earth;

2.3.3 Identify all of the forces acting on an object, including weight, normal force, applied force, frictional force and tension force;

2.3.4 Draw free body diagram(s) to represent the forces acting on an object;

2.3.5 State Newton's first, second and third laws of motion;

2.3.6 Apply Newton's laws of motion to various scenarios involving forces in equilibrium and non-equilibrium (include multiple coupled objects, but **exclude** object on an inclined plane), in familiar and novel contexts.

2.4 Momentum and Impulse

Content:

- Linear momentum;
- Impulse;
- Momentum in collisions.

Learning Outcomes:

Students Should be Able to:

2.4.1 Define linear momentum and impulse;

2.4.2 Calculate the momentum of a moving object;

2.4.3 Calculate the change in momentum of an accelerating object;

2.4.4 Define force as the rate of change of momentum;

2.4.5 State the principle of conservation of momentum;

2.4.6 Apply the principle of conservation of momentum to solve problems involving collisions between two bodies in 1-dimension, in familiar and novel contexts.

2.5 Work, Power and Energy

Content:

- Energy conversion and conservation;
- Work;
- Power.

Learning Outcomes:

Students Should be Able to:

2.5.1 List examples of different forms of energy, including kinetic energy, potential energy (gravitational, chemical, elastic), electrical energy, light energy, thermal energy and nuclear energy;

2.5.2 Define kinetic energy and gravitational potential energy in words and using mathematical expressions: $E_k = \frac{1}{2} mv^2$ and $E_p = mgh$;

2.5.3 Define mechanical energy;

2.5.4 State the principle of the conservation of mechanical energy;

2.5.5 Apply the principle of conservation of mechanical energy to various contexts, including objects that are dropped or thrown vertically upwards, and the motion of a swing or pendulum;

2.5.6 Define work done as the force multiplied by the distance moved in the direction of the force $W = F_x \Delta x$;

2.5.7 Apply the relationship for work done to various related problems, in familiar and novel contexts;

2.5.8 Define power as the work done divided by the time taken to do the work;

2.5.9 apply the relationship for power to various related problems, in familiar and novel contexts.

3 Waves

Overview

We experience waves all the time in the world around us, whenever we see or hear anything. We can represent waves using simple diagrams that show their structure and characteristics. By understanding waves we can predict their behaviour in different conditions, and we can put them to use in many helpful ways.

3.1 Transverse and Longitudinal Waves

Content:

- Properties of waves;
- Transverse and longitudinal waves.

Learning Outcomes:

Students Should be Able to:

3.1.1 Describe wave motion as a vibration in a medium, resulting in the transfer of energy without matter being transferred;

3.1.2 Differentiate between transverse and longitudinal waves, and give examples of each;

3.1.3 Define frequency, wavelength, period and amplitude;

3.1.4 Draw a diagram of a transverse wave and indicate the wavelength, amplitude, particle movement and direction of propagation of the wave;

3.1.5 Define the wave speed as the product of the frequency and wavelength of a wave $v = f\lambda$ (the wave equation);

3.1.6 Apply the wave equation to solve problems involving transverse and longitudinal waves, in familiar and novel contexts.

3.2 Geometrical Optics

Content:

- Reflection of light;
- Refraction of light;
- Total internal reflection.

Learning Outcomes:

Students Should be Able to:

3.2.1 Describe reflection of light;
3.2.2 Define normal, angle of incidence and angle of reflection;
3.2.3 State that, for reflection, the angle of incidence is equal to the angle of reflection;
3.2.4 Define refraction as a change of wave speed in different media, while the frequency remains constant;
3.2.5 Define angle of refraction, refractive index and optical density;
3.2.6 Draw ray diagrams to show the path of light as it travels between mediums with different optical densities;
3.2.7 Explain critical angle and total internal reflection;
3.2.8 Apply the concepts of reflection, refraction, critical angle and total internal reflection in various familiar and novel contexts.

4 Electricity and Magnetism

Overview

Electricity and magnetism are very important aspects of Physics, because they underlie many of the daily tools and instruments that we rely on. The ability to understand and harness electricity has resulted in the development of lighting and other electrical devices. An understanding of the relationship between electricity and magnetism has led to the development of motor cars and other machines.

4.1 Electrostatics

Content:

- Forces between charges;
- Coulomb's law;
- Electric field.

Learning Outcomes:

Students Should be Able to:

4.1.1 Describe charge as either positive or negative, and measured in coulombs;
4.1.2 State that unlike charges attract and like charges repel;
4.1.3 Explain the attraction between a charged object and a neutral object (polarisation);
4.1.4 State Coulomb's Law in words and mathematically: $F = \frac{kQ_1Q_2}{r^2}$;

4.1.5 Solve problems using Coulomb's Law to calculate the force exerted on a charge by one or more charges in 1-dimension;

4.1.6 Describe an electric field as a region in which an electric charge experiences a force;

4.1.7 Draw the electric field of an isolated point charge and recall that the direction of the field lines gives the direction of the force acting on a positive test charge;

4.1.8 Draw the electric field pattern between two isolated point charges;

4.1.9 Define the magnitude of the electric field at a point as the force per unit charge, $E = F/q$;

4.1.10 Calculate the electric field at a point due to a number of point charges in 1-dimension, using the equation $E = \frac{kQ}{r^2}$.

4.2 Electric Circuits

Content:

- Conventional current;
- Potential difference;
- Resistance;
- Energy transfer in electrical circuits.

Learning Outcomes:

Students Should be Able to:

4.2.1 State that current (I) is a rate of flow of charge, measured in amperes;

4.2.2 Apply the equation $I = Q/t$;

4.2.3 Explain conventional current;

4.2.4 Define electromotive force (*emf*) as the work done in moving a unit charge around a complete circuit, measured in volts;

4.2.5 Define the potential difference (V) across an element in a circuit as the work done to move a unit charge through the element, measured in volts;

4.2.6 Draw diagrams to show how to connect an ammeter to measure current through a circuit element, and a voltmeter to measure voltage across a circuit element;

4.2.7 Define resistance;

4.2.8 Apply the formulae for the equivalent resistance of a number of resistors in series and in parallel;

4.2.9 State that the current is constant through each element in a series circuit;

4.2.10 State that the total potential difference is equal to the sum of the potential differences across the individual elements in a series circuit;

4.2.11 Calculate the equivalent resistance of resistors connected in series: $R_s = R_1 + R_2 + \ldots$;

4.2.12 State that the potential difference is constant across circuit elements that are connected in parallel;

4.2.13 State that the current from the source is the sum of the currents in the separate branches of a parallel circuit;

4.2.14 Calculate the equivalent resistance of resistors connected in parallel: $1/R_p = 1/R_1 + 1/R_2 + \ldots$;

4.2.15 State that the potential difference across the separate branches of a parallel circuit is the same and apply the principle to new situations or to solve related problems;

4.2.16 State Ohm's Law in words and mathematically: $R = V/I$;

4.2.17 Solve problems for circuits involving resistors connected in series and parallel;

4.2.18 Define power as the rate at which electrical energy is converted in an electric circuit, measured in watts;

4.2.19 State that electrical power dissipated in a device is equal to the product of the potential difference across the device and current flowing through it: $P = IV$;

4.2.20 Apply the concepts of electrical energy and power to solve related problems, in familiar and novel contexts;

4.2.21 Apply knowledge of electrical circuits, energy and power to everyday electrical appliances, for example the torch, kettle etc.

4.3 Magnetism

Content:

- Magnets;
- Magnetic field.

Learning Outcomes:

Students Should be Able to:

4.3.1 Describe a permanent magnet as having a north pole and a south pole;

4.3.2 State that like poles repel and unlike poles attract;

4.3.3 Define the magnetic field;

4.3.4 Describe the magnetic field around a bar magnet and a pair of bar magnets placed close together;

4.3.5 Explain how a compass indicates the direction of a magnetic field;

4.3.6 Describe the Earth's magnetic field .

4.4 Electromagnetism

Content:

- Magnetic effect of a current;
- Force on a current-carrying conductor.

Learning Outcomes:

Students Should be Able to:

4.4.1 Draw the direction of the magnetic field near a current-carrying wire and a current-carrying loop;

4.4.2 State the effect on the magnetic field of changing the magnitude and / or direction of the current;

4.4.3 Explain how an electromagnet works;

4.4.4 Determine the direction of the force on a current-carrying conductor in a magnetic field.

General Information for Physics

Table of Constants

Name	Symbol	Value
Gravitational acceleration	g	9,8 $m \cdot s^{-2}$
Speed of light in a vacuum	c	3,0 $10^{8} m \cdot s^{-1}$
Coulomb's constant	k	9,0 $10^{9} N \cdot m^{2} \cdot C^{-2}$
Charge on electron	e	-1,6 10^{-19} C
Electron mass	m_e	9,11 10^{-31} kg

Table of Formulae

Mechanics	$v_f = v_i + a\Delta$ OR $v = u + a\Delta$	$v_f^2 = v_i^2 + 2a\Delta x$ OR $v^2 = u^2 + 2a\Delta x$
	$\Delta x = v_i\Delta + \frac{1}{2} a\Delta t^2$ OR $\Delta x = u\Delta + \frac{1}{2} a\Delta t^2$	$\Delta x = \frac{1}{2} (v_f+v_i)/\Delta$ OR $\Delta x = \frac{1}{2} (v+u)/\Delta$
	$F_g = mg$	$F_{net} = ma$
	$p = mv$	$F_{net} \Delta = \Delta$
	$W = F_x \Delta x$	$P = W/\Delta$
	$E_k = \frac{1}{2}mv^2$	$E_p = mgh$
Waves	$v = f$	$T = 1/f$

Electricity and Magnetism	$F = \frac{kQ_1Q_2}{r^2}$	$E = \frac{kQ}{r^2}$
	$E = F/q$	$I = Q/t$
	$V = W/Q$	$R = V/I$
	$R_s = R_1 + R_2 + \ldots$	$1/R_p = 1/R_1 + 1/R_2 + \ldots$
	$emf = IR_{external} + Ir_{internal}$	$P = IV$

Summary of Key Quantities, Symbols and Units

Quantity	Symbol	Unit Symbol
mass	m	kg
position	x	m
displacement	Δx	m
velocity	v	$m{\cdot}s^{-1}$
initial velocity	v_i or u	$m{\cdot}s^{-1}$
final velocity	v_f or v	$m{\cdot}s^{-1}$
acceleration	a	$m{\cdot}s^{-2}$
gravitational acceleration	g	$m{\cdot}s^{-2}$
time (instant)	t	s
time interval	Δt	s
energy	E	J
kinetic energy	E_k	J
potential energy	E_p	J
work	W	J
power	P	W
momentum	p	$kg{\cdot}m{\cdot}s^{-1}$
force	F	N
weight	F_g or w	N
normal force	F_N	N
tension	F_T	N
friction force	F_f	N
wavelength	λ	m
frequency	f	Hz or s^{-1}
period	T	s
speed of light	c	$m{\cdot}s^{-1}$
charge	Q, q	C

electric field	*E*	$N \cdot C^{-1}$ or $V \cdot m^{-1}$
potential difference	*V*	V
emf	*emf*	V
current	*I, i*	A
resistance	*R*	Ω
internal resistance	*r*	Ω

Glossary of Terms Used in Physics Papers

1. *Calculate* is used when a numerical answer is required. All working should be clearly shown, and the answer should be given with the correct units.
2. *Define* means to give the definition, e.g. define the term work.
3. *Describe* means to give a detailed account of a phenomenon or process, e.g. describe the movement of particles in a transverse wave.
4. *Explain* means to give a detailed account of the reasoning behind a phenomenon or process, e.g. explain why motion remains constant when all forces are balanced.
5. *Determine* means to arrive at an answer through either calculation or reasoning or a combination of both, e.g. use the given information to determine the resultant force.
6. *Discuss* means to give a critical account of the points involved in the topic.
7. *Find* is a general term that could include calculation, reasoning, interpretation etc.
8. *List* means to provide a number of points with no discussion.
9. *Predict* or *deduce* means to show a logical connection between pieces of information.
10. *Sketch* when applied to graph work, means to show just the shape and / or position of the curve. In diagrams, *sketch* means that a simple, freehand but neat drawing is acceptable, e.g. sketch a velocity-time graph to represent the motion.
11. *State* means to give a short, clear answer with little or no supporting argument, e.g. state the principle of conservation of linear momentum.

BIOLOGY

Introduction

Biology is the scientific study of living organisms from the molecular level to their interactions with one another and their environment. Biology at foundational level is selected from a range of topics, which include molecules and cells, genetics and heredity, evolution and diversity, structure and function of animals and plants, and ecology. This curriculum focuses on the topics Evolution and diversity, linking them with genetics and heredity.

Rationale for Content Selection

The intention of this course is to develop ways of thinking that are important in Biology. Because limited time is available for Biology, a decision was made to focus on content that gives opportunities to develop higher order thinking skills, and that provides the core foundation for further study in Biology. Evolution is the core principle in Biology that explains the patterns of similarities and differences in the biodiversity we see around us. A study of the biomes of South Africa serves to raise awareness of the wealth of biodiversity in our country, and the need to conserve the biodiversity. Studying the mechanisms of heredity help us to understand the mechanisms of evolution. Since these are the core principles in Biology, they will provide a strong foundation for further study in Biology.

Biology Content Structure

Topic Heading	Topic
1. Biodiversity (28%)	1.1 Biodiversity and the biomes of South Africa (8 hours); 1.2 Principles of classification (7 hours); 1.3 The history of life (1 hour).
2. Evolution (24%)	2.1 The theory of evolution by natural selection (7 hours); 2.2 Evidence supporting evolution (7 hours).
3. Genetics and Heredity (48%)	3.1 Patterns of inheritance (13 hours); 3.2 DNA structure and function (15 hours).

The guidelines for instructional time given in the table above do not include self-study time, which should be included in the learning programme.

Details of Content Coverage for Biology

Section 1. Biodiversity

Overview

Biodiversity can be described at three levels: the amount of genetic diversity within each species, the variety of species inhabiting an area, and the variety of ecosystems within an area. South Africa has enormously rich biodiversity at each level of biodiversity. This section raises awareness of South Africa's biodiversity by exploring the biomes (major ecosystems) of South Africa, and the variety of species in the country. Threats to biodiversity and conservation efforts are addressed.

Species can be classified according to a hierarchical classification scheme, based on similarities and differences between species and groups of species. The Linnaean classification system is introduced in this section. The highest level of organisation in the classification scheme is the Kingdom. This section introduces the distinguishing characteristics of the five kingdoms: Bacteria, Protista, Fungi, Plantae and Animalia. The history of the major groups of living organisms is illustrated.

1.1 Biodiversity and the Biomes of South Africa

Content

- Definitions of the biosphere and biomes;
- Factors defining biomes;
- Exploring the biomes of South Africa.

Learning Outcomes:

Students Should be Able to:

1.1.1 Define the biosphere as all parts of the Earth on which life can exist;

1.1.2 Define a biome as an area with a characteristic climate and main types of vegetation;

1.1.3 Identify the nine major terrestrial biomes of South Africa on a map of South Africa (SANBI - South African National Biodiversity Institute www.sanbi.org);

1.1.4 Identify the major differences between the nine major terrestrial biomes with reference to climate, soils and main vegetation;

1.1.5 Explain the concept of adaptation, with reference to at least one example of a plant from each biome;

1.1.6 Select one South African biome for detailed study (preferably the biome in which the candidate lives), collect climatic data, type of soils, altitude, main vegetation and animal life in the biome from Internet sources such as PlantZAfrica (www.pza.sanbi.org) or books;

1.1.7 Describe threats to and conservation of the biome;

1.1.8 Write a comprehensive report on the biome, including drawings, photographs, and graphs showing precipitation and temperature records available from WeatherSA (www.weathersa.co.za/);

1.1.9 Explain the classifications of plant species used in the Red List, and illustrate the classifications with reference to the chosen biome (search for Red List on the SANBI website);

1.1.10 Explain the concept of sustainability, and investigate one plant in South Africa that is used by humans, and how it should be used sustainably (search for sustainable use of plants on the SANBI website).

1.2 Principles of Classification

Content:

- Extent of biodiversity;
- Taxonomic levels ;
- Characteristics of the five kingdoms.

Learning outcomes:

Students Should be Able to:

1.2.1 Demonstrate awareness of the extent of biodiversity in South Africa;

1.2.2 Represent biodiversity of the most abundant groups of plants and animals in the form of graphs and charts;

1.2.3 Define a species using the biological species concept;

1.2.4 Correctly use the binomial system of naming species;

1.2.5 Apply the nested hierarchical classification system to classify species according to genus, family, order, class, *phylum* (animals) or division (plants), kingdom;

1.2.6 Distinguish among the five kingdoms according to shared characteristics of organisms within each kingdom:

- Bacteria: prokaryotic, uni-cellular, autotrophic, heterotrophic or saprotrophic;
- Protista: eukaryotic, uni-cellular or simple multi-cellular, autotrophic or heterotrophic;
- Fungi: eukaryotic, having chitin in the cell walls, uni-cellular or simple multi-cellular, saprotrophic;
- Plantae: eukaryotic, having cellulose in the cell walls, multi-cellular, most having differentiated tissues, autotrophic;
- Animalia: eukaryotic, with no cell walls, multi-cellular, most having differentiated tissues, heterotrophic.

1.3 The History of Life

Content:

- Life has an extremely long history.

Learning Outcomes:

Students Should be Able to:

1.3.1 Construct a timeline showing key events in the history of life on earth, including the earliest bacteria, the first eukaryotes, first land plants, first fish, first amphibians, first reptiles, first flowering plants, first mammals, first birds, first pre-humans.

Section 2. Evolution

Overview

This section studies evolution by natural selection. Life evolves from previously-existing life-forms by the process of natural selection. Supporting evidence for evolution comes from study of artificial selection, the fossil record, comparative anatomy, and biogeography. Artificial selection illustrates natural selection.

2.1 The Theory of Evolution by Natural Selection

Content

- Development of the theory of evolution by natural selection;
- The theory of evolution by natural selection;
- Natural selection in action, e.g. antibiotic resistance;
- Mechanisms of speciation and reproductive isolation.

Learning Outcomes

Students Should be Able to:

2.1.1 Describe the contributions of Charles Darwin and Alfred Wallace to the development of the theory of evolution by natural selection, specifically:

- Darwin's observations during the voyage of the Beagle, particularly different species found on different landmasses and islands, similarity of fossils to living species, different fossils found in different layers of sedimentary rock;
- Darwin's reluctance to publish;
- Wallace's paper on evolution by natural selection;
- The joint presentation of the theory of evolution by natural selection;

2.1.2 Describe the theory of evolution by natural selection in terms of over-production of offspring in every generation, resulting in a struggle to survive, heritable variation between individuals, differential reproductive success between individuals, resulting in gradual shift of the population in the direction of favourable adaptations;

2.1.3 Exemplify natural selection using the example of antibiotic resistance;

2.1.4 Illustrate how geographical isolation gives rise to speciation, with reference to Galapagos finches;

2.1.5 Explain mechanisms of reproductive isolation including temporal isolation, ecological isolation, behavioural isolation, gamete incompatibility, hybrid sterility.

2.2 Evidence Supporting Evolution

Content:

- Artificial selection;
- Fossil record;
- Comparative anatomy;
- Bio-geography.

Learning Outcomes
Students Should be Able to:

2.2.1 Explain how artificial selection mimics natural selection, with reference to:

- *Brassica* giving rise to cabbages, broccoli, cauliflower and brussel sprouts;
- Origin of cattle breeds for different purposes;

2.2.2 Explain how the fossil record supports evolution, including:

- How fossils form in sedimentary rock;
- Relative and radiometric dating of fossils;
- Patterns of succession seen in the fossil record, such as mammal-like reptiles to mammals in southern Africa;
- similarities and differences between fossils and modern species, e.g. the skull and pelvic girdle of *Australopithecus* and modern humans.

2.2.3 Explain how comparative anatomy supports evolution with reference to modification of the vertebrate forelimb for flying (bat), swimming (dolphin), fast running (horse) and digging (mole);

2.2.4 Explain how biogeography supports evolution, e.g. the distribution of large flightless birds on different landmasses.

Section 3. Genetics and Heredity

Overview

Evolution by natural selection depends on heritable variation in organisms, that is, variation that is passed on from one generation to another. The science of genetics provides strong evidence that characteristics do pass from one generation to another, and it provides some Principles that explain the patterns of inheritance. Gregor Mendel founded the science of genetics, and his work had an enormous impact on understanding of the mechanisms of evolution by natural selection.

The chemical nature of hereditary material was discovered in the mid-20th century. Deoxyribonucleic acid (DNA) encodes the information that controls the structure and functioning of every organism, and is passed on from one generation to the next. It controls the synthesis of proteins at particular stages in an organism's development.

Studying and manipulating the structure and functioning of DNA is cutting-edge research in Biology at present.

3.1 Patterns of Inheritance

Content

- Mendel and the science of genetics;
- Cell division;
- The nature of genes and alleles and their role in determining the phenotype;
- Solving genetics problems;
- Variation.

Learning Outcomes:
Students Should be Able to:

3.1.1 Define inheritance and describe the importance of Mendel's work to understanding inheritance;

3.1.2 Identify the following structures in a cell: nucleus, nuclear membrane, chromosomes, centromere, chromatin, homologous pairs;

3.1.3 Describe the role of chromosomes in passing information accurately from one generation to the next;

3.1.4 Identify, with the aid of diagrams, prophase, metaphase, anaphase and telophase of mitosis;

3.1.5 Identify, with the aid of diagrams, prophase, metaphase, anaphase and telophase of meiosis I and meiosis II;

3.1.6 Define the terms haploid and diploid, and explain the need for a reduction Division prior to fertilisation;

3.1.7 Define a gene as a unit of inheritance and distinguish clearly between the terms gene and allele;

3.1.8 Explain the terms dominant, recessive, homozygous, heterozygous, genotype, phenotype, F_1 generation and F_2 generation;

3.1.9 Solve genetics problems involving monohybrid crosses;

3.1.10 Describe the determination of sex in humans – XX and XY chromosomes;

3.1.11 Describe mutation as a change in the structure of a gene and nondisjunction as failure of homologous pairs to separate properly during meiosis;

3.1.12 Illustrate the effects of gene mutations, such as in sickle cell anaemia, and chromosomal nondisjunction, such as in Downs' syndrome;

3.1.13 Describe the role of random segregation of homologous pairs during meiosis, random fertilisation of sperm and egg, and mutations in producing genotypic and phenotypic variation;

3.1.14 Differentiate between continuous and discontinuous variation, such as height of people of the same age (continuous variation) and human blood type (discontinuous variation);

3.1.15 Explain that natural selection acts on variation in phenotypes, which are determined by genotypes;

3.1.16 Explain how natural selection influences the survival of alleles in a population by differential survival of phenotypes that have a heritable, genetic basis;

3.1.17 Define the terms gene pool, allele frequency and microevolution.

3.2 DNA Structure and Function

Content:

- The Structure of DNA;
- Replication of DNA;
- The role of DNA in protein synthesis;
- The effect of mutations on DNA structure and function.

Learning Outcomes

Students Should be Able to:

3.2.1 Explain the relationship between chromosomes, genes and DNA;

3.2.2 Illustrate the structure of a DNA molecule as a double helical-structure, consisting of two parallel strands of nucleotides;

3.2.3 Describe the components of a nucleotide (ribose or deoxyribose sugar, phosphate and nitrogenous base, being adenine, guanine, cytosine and thymine or uracil);

3.2.4 Describe the process of DNA replication, and relate it to mitosis and meiosis;

3.2.5 Explain that DNA carries the genetic code, which is transcribed into sequences of amino acids to form proteins that are responsible for phenotypic characteristics;

3.2.6 Explain the importance of exact replication of DNA for transmission of genetic material to other cells and the next generation;

3.2.7 Describe the structure, types and location of messenger-RNA, transfer-RNA and ribosomal-RNA;

3.2.8 Differentiate between the structure of DNA and RNA;

3.2.9 Explain the transcription of a gene into m-RNA, including the role of the promoter, RNA polymerase, complementary base pairing, nucleotide joining and the stop signal;

3.2.10 Explain the translation of m-RNA into a polypeptide chain, including initiation of protein synthesis on the ribosomes, the role of t-RNA, the start codon, elongation of the polypeptide chain, the role of the stop codon, and disassembly of the ribosome-polypeptide complex;

3.2.11 Explain the concept of the triplet code, and use the genetic code to translate a sequence of mRNA codons into t-RNA anticodons and an amino-acid sequence;

3.2.12 Explain the effects of mutations on the triplet code, including base-pair substitutions, deletions and insertions;

3.2.13 Apply the processes of mutations in DNA to genetic mutations and phenotypic variation, and thereby to natural selection.

General Information for Biology

Summary of Key Quantities, Symbols and Units

Quantity	Symbol	Unit Symbol
Length	l	m, cm, mm, µm
Geological time		mya
Temperature	T	°C

Glossary of Terms Used in Biology Papers

1. *State* means to give the facts about a topic, e.g. state the function of mRNA in protein synthesis.
2. *List* means to construct a list relevant to a topic, but without giving details, e.g. list four sources of evidence supporting evolution.
3. *Define* means to give the definition, e.g. define the term genotype.
4. *Describe* means to give a detailed account of a structure or process, e.g. describe the process of natural selection.
5. *Explain* means to give a detailed account, but also to give reasons for certain steps, e.g. explain how meiosis contributes to genetic variation.
6. *Compare* means to set two structures or processes in contrast to each other and to identify the similarities and differences, e.g. compare continuous and discontinuous variation.
7. *Differentiate* means to focus on the differences between two similar structures or concepts, e.g. differentiate between natural selection and artificial selection.
8. *Discuss* means to consider an issue from several different angles; consider the pros and cons of a solution to a problem, e.g. discuss the effects of the use of antibiotics for relatively minor illnesses.
9. *What is meant by* …. usually means that a definition should be given.
10. *Tabulate* means to give your answer in the form of a table, e.g. tabulate three differences between mitosis and meiosis.
11. *Find* is a general term that often requires you to calculate, measure or solve a problem, e.g. find the ratio of red flowers to white flowers in a genetic cross.
12. *Exemplify* means to give an example of a concept or process.

Chemistry

Introduction

Chemistry spans the divide between the macroscopic and microscopic. It is one branch of Natural Sciences but itself consists of many branches, such as inorganic chemistry, organic chemistry, physical chemistry and biochemistry. Chemistry focuses on the properties of matter and materials and the ways in which they change from one form to another and react with one another.

Rationale for Content Selection

This chemistry curriculum aims to help students develop their understanding of several concepts that are commonly viewed as foundational to chemistry, and then to extend their understanding to some selected and more advanced topics. The curriculum thus begins with an introduction to matter before shifting focus to the chemical changes that matter undergoes. It is envisaged that this approach will scaffold students for more advanced chemistry studies and/or their study of other science subjects. The teaching and study of chemistry theory can be greatly enhanced through the use of practical activities that traditionally employ specialist resources but these are often difficult to access. Since chemistry occurs within us and all around us, suitable practical activities employing resources available in everyday life can successfully be incorporated into the learning experience of this curriculum to either introduce, illustrate or re-inforce chemistry theory.

Chemistry Content Structure

Topic Heading	Topic
1. Matter (50% Weighting)	1.1 Particle theory of matter and the three states of matter (2 hours); 1.2 Classification and separation of matter (2 hours); 1.3 Atomic structure (3 hours); 1.4 Periodic table and periodicity (4 hours); 1.5 Particles substances are made of (4 hours); 1.6 Types of chemical bonding (3 hours); 1.7 Chemical formulae and naming of compounds (3 hours); 1.8 Intermolecular forces (4 hours); 1.9 Types of organic molecules (3 hours); 1.10 Carboxylic acids and esters (2 hours).
2. Chemical Change (50% Weighting)	2.1 Representing chemical change (4 hours); 2.2 Stoichiometry (8 hours); 2.3 Energy changes during chemical reactions (4 hours); 2.4 Reaction rate (4 hours); 2.5 Chemical equilibrium (4 hours); 2.6 Acids, bases and neutralisation reactions (4 hours);

The guidelines for instructional time given in the table above do not include self-study time, which should be included in the learning programme.

Details of Content Coverage for Chemistry

Section 1. Matter

Overview

Various experiments/demonstrations provide evidence that the solid, liquid and gaseous states of all types of matter consists of particles. Kinetic molecular theory describes the movement of particles making up the solid, liquid and gaseous state of a substance.

Matter consisting of a physical combination of more than one type of atom or chemical combination of atoms/ions are referred to as mixtures. The separation technique employed for a specific mixture depends on the properties of the substances it contains.

The smallest particle of matter is the atom and over time different scientists have described various models of the atom. One model of the atom describes it as containing three subatomic particles (neutrons, protons and electrons) with the neutral neutrons and positive protons bound in a nucleus at the center of the atom and negative electrons spinning in orbitals surrounding the nucleus. There are different types of atoms, each with its own number of protons. The different types of atoms are known as elements and are listed on the periodic table, arranged in such a way that illustrates the patterns in their chemical and physical properties, known as periodicity.

While some types of matter consists of individual atoms, other forms of matter consists of charged atoms called ions or of two or more atoms bonded together to form molecules. The shape of a molecule can be predicted using the valence shell electron pair repulsion theory. The intermolecular forces between molecules depends on the polarity of the bonds they contain and their molecular geometry.

Molecules containing the element carbon are usually described as organic, and there are several different types of organic molecules. Each type is names according to the IUPAC (International Union of Pure and Applied Chemistry) system depending on the functional groups of atoms contained by the molecule.

1.1 Particle Theory of Matter and the Three States of Matter

Content:

- Particle nature of matter;
- States of matter;
- State changes;
- Kinetic molecular theory.

Learning Outcomes:

Students Should be Able to:

1.1.1 State the Kinetic molecular theory;

1.1.2 Describe the states of matter (solid, liquid and gas) in terms of the arrangement and movement of the particles of matter;

1.1.3 Explain the state changes in terms of Kinetic molecular theory.

1.2 Classification and Separation of Matter

Content:

- Mixtures and pure substances;
- Heterogeneous and homogeneous mixtures;
- Separation of mixtures.

Learning Outcomes:

Students Should be Able to:

1.2.1 Define and differentiate between elements and compounds, mixtures and pure substances, heterogeneous and homogenous mixtures;

1.2.2 Classify different examples of matter according to a classification scheme for matter involving homogenous mixtures (solid, liquid and gaseous solutions), heterogeneous mixtures, compounds (ionic and covalent) and elements (metals, metalloids and non-metals);

1.2.3 Identify examples from everyday life of elements, compounds, pure substances, homogenous mixtures, heterogeneous mixtures;

1.2.4 Describe the separation of different types of mixtures (solid-solid, solid-liquid when soluble and insoluble, liquid-liquid when miscible and immiscible).

1.3 Atomic Structure

Content:

- Subatomic particles;
- Atomic structure.

Learning Outcomes:

Students Should be Able to:

1.3.1 Differentiate between atoms and molecules;

1.3.2 List the subatomic particles (electrons, protons and neutrons), their charges and location within an atom;

1.3.3 Draw simple atomic models (Bohr models) to represent atoms in terms of their subatomic particles.

1.4 Periodic Table and Periodicity

Content:

- Periodic table and periodicity;
- Aufbau diagrams;
- Spectroscopic electron configurations;
- Lewis dot diagrams;
- Mass number and Atomic number.

Learning Outcomes:

Students Should be Able to:

1.4.1 State the chemical symbol when given the name, or the name when given the symbol, for the first 20 elements of the periodic table as well as iron, cobalt, nickel, copper, zinc, palladium, silver, platinum, gold and mercury;

1.4.2 Explain the arrangement of elements on the periodic table in terms of metals, metalloids and non-metals; increasing atomic number and number of valence electrons from left to right across a period; increasing number of shells from top to bottom down a group;

1.4.3 State the names given to group 1 and 2 metals and groups 17 and 18 non-metals in the periodic table;

1.4.4 Draw Aufbau diagrams (using Hund's rule and Pauli's exclusion principle) and Lewis dot diagrams for the first 20 elements of the periodic table;

1.4.5 Identify the specific element(s) represented by a particular Aufbau diagram or Lewis dot diagram;

1.4.6 Represent the first 20 elements of the periodic table using spectroscopic electron configurations;

1.4.7 Identify the specific element(s) represented by a particular spectroscopic electron configuration;

1.4.8 Define mass number and atomic number;

1.4.9 Calculate the number of neutrons in atoms of different elements, using the mass and atomic numbers of each element.

1.5 Composition of Particle Substances

Content:

- Atoms, ions and molecules;
- Octet rule;
- Anion and cation formation;
- Compound ions.

Learning Outcomes:

Students Should be Able to:

1.5.1 Differentiate between individual atoms, ions and molecules;

1.5.2 State the octet rule;

1.5.3 Apply the octet rule to describe the formation of cations by metal atoms, and anions by non-metal atoms;

1.5.4 State the name of compound ions such as hydroxide, ammonium, nitrate, nitrite, sulfate, sulfite and carbonate.

1.6 Types of Chemical Bonding

Content:

- Elements and compounds;
- Ionic, covalent and metallic bonding;
- Electronegativity;
- Bond polarity.

Learning Outcomes:

Students Should be Able to:

1.6.1 Differentiate between an element and a compound;

1.6.2 Describe ionic bonding in words and using Lewis dot diagrams;

1.6.3 Describe the formation of molecules of elements (the 7 diatomic gases) and molecules of compounds (covalent bonding) in words and using Lewis dot diagrams;

1.6.4 Define electronegativity and explain the trend in electronegativity on the periodic table;

1.6.5 Define polar and non-polar molecules;

1.6.6 Identify whether simple diatomic molecules will be polar or non-polar based on the relative electronegativities of the atoms involved;

1.6.7 Describe metallic bonding and explain the hardness/softness of metals, electrical and thermal conductivity in terms of metallic bonding;

1.6.8 Identify the types of bonding in various everyday materials.

1.7 Chemical Formula and Naming of Compounds

Content:

- Scientific and common names of compounds;
- Chemical formulae of compounds;
- Mole concept;
- Molar mass.

Learning Outcomes:

Students Should be Able to:

1.7.1 State the scientific name of compounds (such as salts) as well as the common names of compounds (such as common acids and bases);

1.7.2 Determine chemical formulae for compounds using the concept of valency or cation and anion tables;

1.7.3 Describe one mole of a substance as containing Avogadro's number of particles;

1.7.4 Define molar mass;

1.7.5 Calculate the molar mass from the chemical formulae of chemical compounds, using the periodic table.

1.8 Intermolecular Forces

Content:

- Intramolecular vs. Intermolecular forces;
- Types of intermolecular forces.

Learning Outcomes:

Students Should be Able to:

1.8.1 Define and differentiate between intramolecular and intermolecular forces;

1.8.2 Explain the following types of intermolecular forces: ion-dipole forces, ion-induced dipole forces, Van der Waals forces (dipole-dipole, dipole-induced dipole and induced dipole-induced dipole/London/dispersion forces);

1.8.3 Identify the type of intermolecular force between specific types of particles (atoms, ions or molecules);

1.8.4 Explain the effect of intermolecular forces on boiling point, melting point and rate of evaporation.

1.9 Types of Organic Molecules

Content:

- Hydrocarbons;
- Functional groups and homologous series;
- IUPAC (International Union of Pure and Applied Chemistry).

Learning Outcomes:

Students Should be Able to:

1.9.1 Define the term 'organic' as used in chemistry;

1.9.2 Define functional group, hydrocarbon and homologous series;

1.9.3 Name and draw the structural formulae and condensed structural formulae of organic molecules containing the following functional groups: alkanes, alkenes, alkyne, alkyl halides, alcohols, ketones, aldehydes, with up to 8 carbon atoms on the parent chain;

1.9.4 Identify everyday examples and uses of these various types of organic molecules.

1.10 Carboxylic Acids and Esters

Content:

- Structure of carboxylic acids;
- Reactions with carboxylic acids to form esters.

Learning Outcomes:

Students Should be Able to:

1.10.1 Name and draw the structural formulae and condensed structural formulae of unbranched carboxylic acids (from methanoic acid to butanoic acid);

1.10.2 Describe the carboxylic acids as weak acids;

1.10.3 Use IUPAC names and structural formulae to describe the reaction of a carboxylic acid with an alcohol to form an ester, e.g. methanol + ethanoic acid methyl ethanoate + water;

1.10.4 Identify commercial applications of esters.

Section 2. Chemical Changes

Overview

Chemical changes happen within living organisms and in non-living systems. The chemical change from reactants to products can be described using chemical equations involving words, models or chemical symbols. Due to the laws of constant composition and conservation of mass, chemical equations must be balanced. The coefficients of reactants and products in balanced chemical equations play a key role in chemical calculations of quantities such as molar concentrations, limiting reagents and percentage yield.

Chemical changes involve energy being absorbed (to break existing chemical bonds) and energy being released (when new chemical bonds are formed). Depending on the relative amounts of energy absorbed or energy released, a chemical reaction can be described as exothermic or endothermic. The changes in potential energy over the course of chemical reactions can be represented using potential energy profiles. It is important to develop an understanding of these energy changes that take place during chemical reactions.

Some chemical reactions (such as those in a fireworks display) happen very quickly while others may take place very slowly (such as the rusting or iron). The rate of a chemical reaction is the change in reactant/product concentration per unit time and this can be measured in various ways depending on the characteristics of a particular reaction. In this section, the factors that influence the rate of a chemical reaction will be explored.

In a closed system, chemical reactions are reversible. Initially only the forward reaction takes places but as the product concentration increases the reverse reaction begins. Left undisturbed, a dynamic equilibrium will be reached in which the rate of forward and reverse reactions are equal. This section explores the effects of various stresses on this state of dynamic equilibrium.

Different types of chemical reactions are explored, such as neutralisation reactions, redox reactions and electrochemical reactions.

2.1 Representing Chemical Change

Content:

- Chemical change;
- Chemical equations.

Learning Outcomes:

Students Should be Able to:

2.1.1 Represent chemical reactions using words, models and chemical symbols (including state symbols);

2.1.2 State the laws of constant composition and conservation of matter;

2.1.3 Balance chemical equations correctly.

2.2 Stoichiometry

Content:

- Limiting reagent;
- Theoretical, actual and percentage yield;
- Empirical and molecular formula.

Learning Outcomes:

Students Should be Able to:

2.2.1 Define limiting reagent, theoretical yield, actual yield and percentage yield;

2.2.2 Calculate number of moles, volume, concentration, limiting reagent and percentage yield for chemical reactions;

2.2.3 Determine the empirical and molecular formulae when given the percentage composition of a particular compound.

2.3 Energy Changes During Chemical Reactions

Content:

- Potential energy profiles;
- Exothermic and endothermic reactions;
- Catalysis.

Learning Outcomes:

Students Should be Able to:

2.3.1 Define exothermic and endothermic;

2.3.2 Label and interpret potential energy profiles for exothermic and endothermic reactions;

2.3.3 Draw labelled potential energy profiles for exothermic and endothermic chemical reactions;

2.3.4 Explain the effect of catalysis using potential energy profiles.

2.4 Reaction Rate

Content:

- Measuring reaction rate;
- Factors affecting reaction rate.

Learning Outcomes:

Students Should be Able to:

2.4.1 Describe experimental methods for measuring reaction rate depending on the particular chemical reaction;

2.4.2 List the factors affecting the rate of a chemical reaction;

2.4.3 Apply collision theory to explain how variations in these factors affect the reaction rate;

2.4.4 Apply the concept of reaction rates to everyday life scenarios.

2.5 Chemical Equilibrium

Content:

- Reversible reactions;
- Dynamic equilibrium;
- Factors affecting equilibrium and Le Chatelier's principle.

Learning Outcomes:

Students Should be Able to:

2.5.1 Describe what is meant by a reversible reaction;

2.5.2 Draw simple graphs of concentration against time and reaction rate against time to illustrate chemical equilibrium (only include graphs that illustrate the process of the initial equilibrium, exclude the impact of various factors that alter the position of the equilibrium);

2.5.3 State Le Chatelier's principle;

2.5.4 List the factors that affect equilibrium, namely temperature, concentration and pressure (for gases);

2.5.5 Apply Le Chatelier's principle to explain the effect of changes in the factors that affect equilibrium.

2.6 Acids, Bases and Neutralisation Reactions

Content:

- Arrhenius and Bronsted-Lowry models of acids and bases;
- Neutralisation reactions;
- Chemical indicators.

Learning Outcomes:

Students Should be Able to:

2.6.1 Define acids and bases according to the Arrhenius model and Bronsted-Lowry model;

2.6.2 Predict the products of reactions between:

2.6.2.1 Acids and metal hydroxides;

2.6.2.2 Acids and metal oxides;

2.6.2.3 Acids and metal carbonates; and

2.6.2.4 Acids and metals.

2.6.3 Explain the difference between strong and concentrated acids/bases and between weak and dilute acids/bases;

2.6.4 Apply the concept of neutralisation reactions to everyday life scenarios.

General Information for Chemistry

Table of Constants

Name	Symbol	Value
Avogadro's constant	N_A	$6{,}02\ \ 10^{23}$ mol^{-1}
Molar Volume of gas at STP	V_M	$22{,}4$ dm^{3} mol^{-1}
Standard temperature	T^{θ}	273 K
Standard pressure	P^{θ}	$1{,}013\ \ 10^{5}$ Pa

Table of Formulae

Stoichiometry	$n = m / M$	$n = N / N_A$
	$n = v / V_m$	$c = n / v$ OR $c = m / Mv$
	percentage yield = actual yield / theoretical yield 100%	
Rate of reaction	*rate of reaction* $= \Delta\,[reactant]/\Delta t$ OR *rate of reaction* $= \Delta\,[product]/\Delta t$	

Summary of Key Quantities, Symbols and Units

Quantity	Symbol	Unit Symbol
Concentration	c	mol dm^{-3}
Mass	m	g
Molar mass	M_m	g mol^{-1}
Molar volume	V_m	dm^{3} mol^{-1}
Number of moles	n	mol
Number of particles	N	-
Pressure	P	Pa
Temperature	T	K
Time (instantaneous)	t	s
Volume	v	dm^{3}

Glossary of Terms Used in Chemistry Papers

1. *Calculate* is used when a numerical answer is required. All working should be clearly shown, and the answer should be given with the correct units.
2. *Classify* means to state the category to which something belongs, e.g. classify the following elements as metals, metalloids or non-metals.
3. *Define* means to give the definition, e.g. define the term 'mass number'.
4. *Describe* means to give a detailed account of a phenomenon or process, e.g. describe experimental methods for measuring reaction rate.
5. *Determine* means to arrive at an answer through either calculation or reasoning or a combination of both, e.g. determine the empirical and molecular formula for a compound with a particular composition.
6. *Differentiate* means to focus on the differences between two similar structures or concepts, e.g. differentiate between homogenous mixtures and heterogenous mixtures.
7. *Draw* means to illustrate (not necessarily to scale) using scientific conventions, e.g. draw an afbau diagram for the element chlorine.
8. *Explain* means to give a detailed account of the reasoning behind a phenomenon or process, e.g. explain catalysis.
9. *Discuss* means to give a critical account of the points involved in the topic.
10. *Identify* means to recognise instances, examples, types of something, e.g. identify the polar molecules in the list provided.
11. *Interpret* means to make meaning from information provided in some form, e.g. interpret the K_c value for a particular chemical equilibrium.
12. *Label* means to provide the names for parts or sections of something, e.g. label the following potential energy profile.
13. *List* means to provide a number of points with no discussion.
14. *Predict* or *deduce* means to show a logical connection between pieces of information.
15. *Represent* means to show/illustrate an object or phenomenon, e.g. represent the following chemical reaction using words, models and chemical symbols.
16. *Sketch*, when applied to graph work, means to show just the shape and / or position of the curve. In diagrams, sketch means that a simple, freehand but neat drawing is acceptable, e.g. sketch a graph of reactant concentration vs. time for the chemical reaction.
17. *State* means to give a short, clear answer with little or no supporting argument, e.g. state the law of constant composition.
18. *Write* means to use written words and/or symbols to represent something, e.g. write spectroscopic electron configurations for the first 20 elements of the periodic table.

Suggested Study Hours

Natural Sciences is a 30 credit course, which relates to 300 notional study hours.

It is envisaged that a typical one-year offering of the course will cover 30 weeks, excluding revision and examination time. Students should therefore spend 10 hours per week on Natural Sciences. This should consist of 6 hours of face-to-face instruction and 4 hours of self-study.

We recommend that the Nature of Science be studied first, followed by Physics, Chemistry and Biology in parallel, to ensure progressive development within each of these sections.

A suggested time allocation for the course is shown in the table below:

Component	Face-to-Face Teaching Time	Self-Study Time
The Nature of Science	6 hours per week x 1 week	4 hours per week x 1 week
Physics	2 hours per week x 29 weeks	4 hours per week x 29 weeks
Chemistry	2 hours per week x 29 weeks	
Biology	2 hours per week x 29 weeks	
Total Course Hours	**300 hours**	

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