NCCA
An Chomhairle Náisiúnta Curaclaim agus Measúnachta
National Council for Curriculum and Assessment

Draft Specification for Leaving Certificate Physical Science (formerly known as Physics and Chemistry)

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Contents

Senior cycle

Senior cycle aims to educate the whole person and contribute to human flourishing. Students' experiences throughout senior cycle enrich their intellectual, social and personal development and their overall health and wellbeing. Senior cycle has 8 guiding principles.

Senior Cycle Guiding Principles	
Wellbeing and relationships	Choice and flexibility
Inclusive education and diversity	Continuity and transitions
Challenge, engagement and creativity	Participation and citizenship
Learning to learn, learning for life	Learning environments and partnerships

These principles are a touchstone for schools and other educational settings, as they design their senior cycle. Senior cycle consists of an optional Transition Year, followed by a two-year course of subjects and modules. Building on junior cycle, learning happens in schools, communities, educational settings, and other sites, where students' increasing independence is recognised. Relationships with teachers are established on a more mature footing and students take more responsibility for their learning.

Senior cycle provides a curriculum which challenges students to aim for the highest level of educational achievement, commensurate with their individual aptitudes and abilities. During senior cycle, students have opportunities to grapple with social, environmental, economic, and technological challenges and to deepen their understanding of human rights, social justice, equity, diversity and sustainability. Students are supported to make informed choices as they choose different pathways through senior cycle and every student has opportunities to experience the joy and satisfaction of reaching significant milestones in their education. Senior cycle should establish firm foundations for students to transition to further, adult and higher education, apprenticeships, traineeships and employment, and participate meaningfully in society, the economy and adult life.

The educational experience in senior cycle should be inclusive of every student, respond to their learning strengths and needs, and celebrate, value, and respect diversity. Students vary in their family and cultural backgrounds, languages, age, ethnic status, beliefs, gender, and sexual identity as well as their strengths, needs, interests, aptitudes and prior knowledge, skills, values and dispositions. Every student's identity should be celebrated, respected, and responded to throughout their time in senior cycle.

At a practical level, senior cycle is supported by enhanced professional development; the involvement of teachers, students, parents, school leaders and other stakeholders; resources;

research; clear communication; policy coherence; and a shared vision of what senior cycle seeks to achieve for our young people as they prepare to embark on their adult lives. It is brought to life in schools and other educational settings through:

- effective curriculum planning, development, organisation, reflection and evaluation
- teaching and learning approaches that motivate students and enable them to improve
- a school culture that respects students and promotes a love of learning.

Rationale

Leaving Certificate science education provides a means by which students can investigate the natural world to foster an evidence-based understanding of how it works. Students learn that science, as a discipline, is a process that requires logic and creativity to construct scientific knowledge through the sharing of ideas and by developing, refining, and critically analysing these ideas. Students experience science as a personal and collaborative activity that is exciting, challenging and powerful in transforming the world in which we live

Leaving Certificate Physical Science provides an opportunity for students to engage with both physics and chemistry through interdisciplinary and applied learning. As students actively participate in experimental and research investigations, they will not only learn about how scientists work and how scientific ideas evolve, they will also enhance their scientific literacy. This hands-on, investigative approach helps students to appreciate the iterative and innovative nature of physical science and prepares them for careers in STEM, as well as pathways that require them to demonstrate a scientific habit of mind. These attributes are important when navigating a world, where sources of knowledge can often be subject to disinformation.

As students engage with core concepts and fundamental principles that underpin the physical sciences and through the application of this learning, they will develop a deeper awareness associated with real world issues and an ability to understand and respond to the many opportunities and challenges associated with our ever changing world.

Aims

The aim of Leaving Certificate Physical Science is to develop the student's curiosity, enthusiasm and enjoyment for studying physics and chemistry and to foster an appreciation of the interdisciplinary nature of the physical sciences.

More specifically, Leaving Certificate Physical Science aims to empower students to:

- build knowledge and understanding of specified core concepts and fundamental principles of physical science
- foster an appreciation for the interconnectedness and interdisciplinary nature of the study of physics and chemistry within physical science
- develop the skills, values and dispositions needed to apply this knowledge to explain concepts, analyse and solve problems, make predictions and justify events in a variety of systems and interactions within the physical science world
- develop an inquiring mind and demonstrate inquiry and practical skills consistent with the principles and practices of physics and chemistry
- understand how society and science are interwoven through everyday applications and the ethical implications of physical science.

Continuity and progression

Leaving Certificate Physical Science provides continuity and progression, building on the knowledge, skills, values, and dispositions from students' early childhood education through to the junior cycle curriculum, and extends to wider experiences within the school and progresses beyond senior cycle.

Junior Cycle

The learning at the core of junior cycle is described in the Statements of Learning, a number of which apply to scientific concepts, processes and practices, including problem-solving, design and communication skills, and to understanding and valuing the role and contribution of science and technology to society. Student learning in junior cycle science is unified through the Nature of Science strand, which emphasises the development of a scientific habit of mind.

There is an emphasis on inquiry through which learners develop an understanding and appreciation of structures, processes and fundamental concepts that are essential to all science, as well as the ability to apply scientific principles to their everyday lives. All of the key skills developed across the curriculum during junior cycle support student learning in senior cycle. Many junior cycle subjects and short courses have close links with and support the learning in junior cycle science, particularly mathematics, geography, CSPE, PE, SPHE, home economics and the technology subjects.

Junior Cycle Science has close links with Leaving Certificate Physical Science in helping students to continue to develop their evidence-based understanding of the natural world; to develop their capacity to gather and evaluate evidence; to consolidate and deepen their skills of working scientifically; to make them more self-aware as learners and to become more competent and confident in their ability to use and apply science in their everyday lives. Students build on these scientific concepts, processes and practices as they progress through the two years of Leaving Certificate Physical Science.

Beyond senior cycle

Leaving Certificate Physical Science builds a solid foundation for students to progress to diverse futures, including the worlds of work, Further Education and Training and Higher Education. The interdisciplinary study of physics and chemistry through physical science can lead to many exciting opportunities in both the specialised and wider areas of science, engineering, technology-related jobs, computer science, education, mathematics, medicine, business and finance. In addition, physical science incorporates creative design, testing and evaluation, synthesis, generalisation, visualisation and logical thinking.in areas such as problem-solving, communication, time management, organisation, and teamwork, which are relevant to all aspects of life beyond formal education.

Leaving Certificate Physical Science will contribute to the development of scientifically literate members of society. Many important challenges facing society such as energy demands, providing sufficient food and water, climate change and disease control, require major contributions from the scientific community. These challenges require not only innovative science solutions, but also social, political and economic ones that are informed by knowledge of the science that underpins the challenges. Society needs scientifically literate citizens who will address old and new challenges with rationality and scepticism, important principles embedded in Leaving Certificate Physical Science. Students learn the importance of reliable sources, peer review, ethics and evidence in logical decision-making and are well poised to apply this understanding to recognise and counter disinformation.

Student learning in senior cycle

Student learning in senior cycle consists of everything students learn **within** all of the subjects and modules they engage with **and** everything students learn which spans and overlaps **across** all of their senior cycle experiences. The overarching goal is for each student to emerge from senior cycle more enriched, more engaged and more competent as a human being than they were when they commenced senior cycle.

For clarity, the learning which spans **across** all of their senior cycle experiences is outlined under the heading 'key competencies'. The learning which occurs **within** a specific subject or module is outlined under the heading 'strands and learning outcomes'. However, it is vital to recognise that key competencies and subject or module learning are developed in an integrated way. By design, key competencies are integrated across the rationale, aims, learning outcomes and assessment sections of specifications. In practice, key competencies are developed by students in schools via the pedagogies teachers use and the environment they develop in their classrooms and within their school. Subjects can help students to develop their key competencies; and key competencies can enhance and enable deeper subject learning. When this integration occurs, students stand to benefit

- during and throughout their senior cycle
- as they transition to diverse futures in further, adult and higher education, apprenticeships, traineeships and employment, and
- in their adult lives as they establish and sustain relationships with a wide range of people in their lives and participate meaningfully in society.

When teachers and students make links between the teaching methods students are experiencing, the competencies they are developing and the ways in which these competencies can deepen their subject specific learning, students become more aware of the myriad ways in which their experiences across senior cycle are contributing towards their holistic development as human beings.

Key competencies

Key competencies is an umbrella term which refers to the knowledge, skills, values and dispositions students develop in an integrated way during senior cycle.

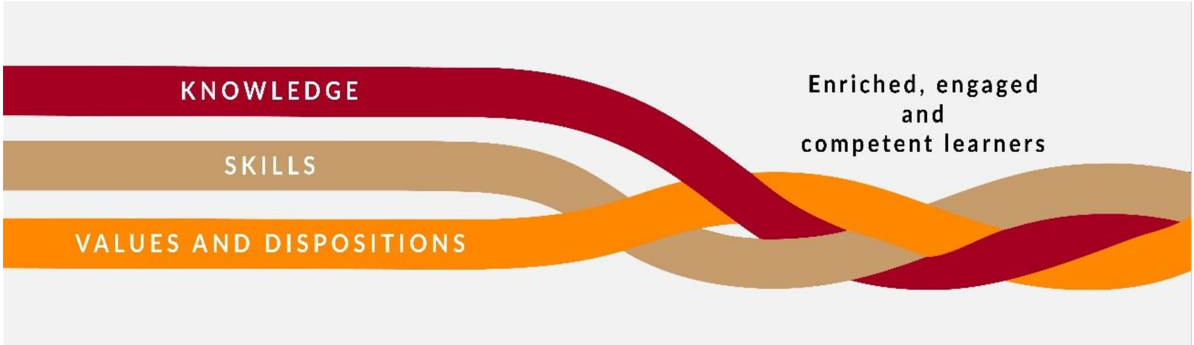

Figure 1 The components of key competencies and their desired impact

The knowledge which is specific to this subject is outlined below under 'strands of study and learning outcomes'. The epistemic knowledge which spans across subjects and modules is incorporated into the key competencies.

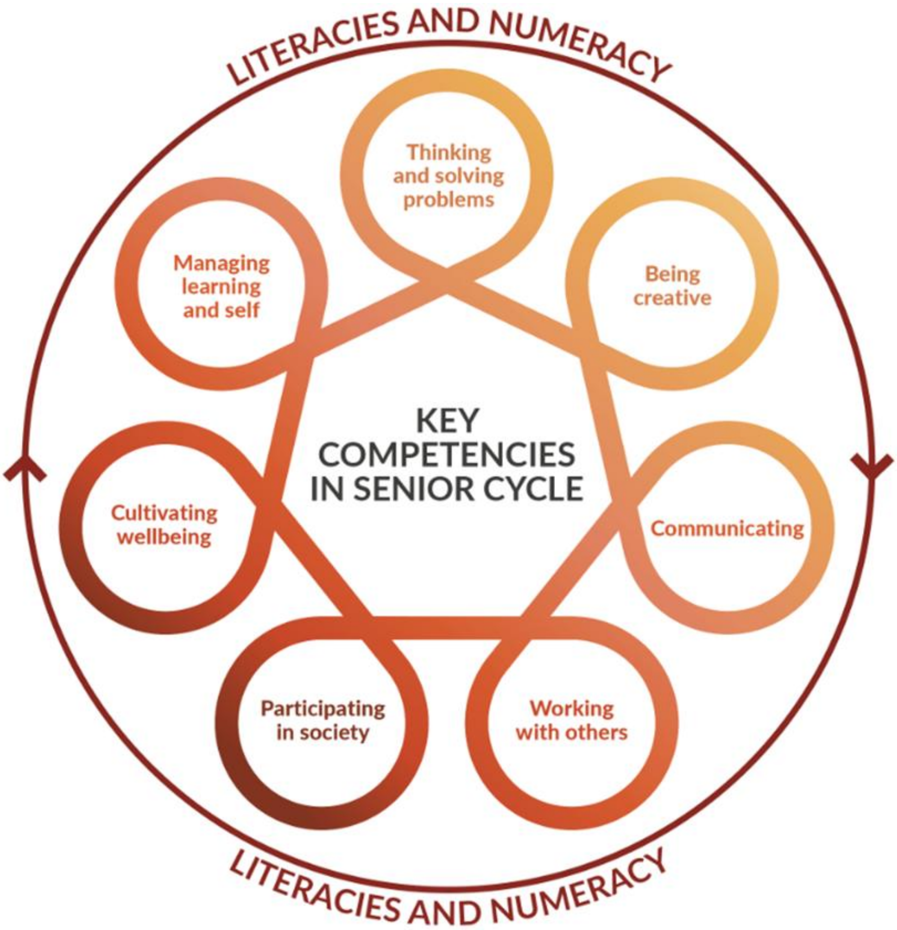

Figure 2 Key Competencies in Senior Cycle, supported by literacies and numeracy.

These competencies are linked and can be combined; can improve students' overall learning; can help students and teachers to make meaningful connections between and across different areas of learning; and are important across the curriculum.

The development of students' literacies and numeracy contributes to the development of competencies and vice-versa. Key competencies are supported when students' literacies and numeracy are well developed and they can make good use of various tools, including technologies, to support their learning.

The key competencies come to life through the learning experiences and pedagogies teachers choose and through students' responses to them. Students can and should be helped to develop their key competencies irrespective of their past or present background, circumstances or experiences and should have many opportunities to make their key competencies visible. Further detail in relation to key competencies is available at https://ncca.ie/en/senior-cycle/senior-cycle-redevelopment/student-key-competencies/

The key competencies can be developed in Leaving Certificate Physical Science in a range of ways. For example, students develop the key competency of **being creative** as they become curious about the world and learn to express these curiosities in the form of scientific questions. As they seek answers to these questions through investigation, they do so with an open mind, as they try out different approaches and investigative methods. Student creativity is developed initially as they engage in the design and planning stages of investigations and is further developed as they engage in all aspects of investigative work, turning their ideas into action.

Students in Leaving Certificate Physical Science develop a scientific habit of mind and draw upon a set of established scientific principles, developing the key competency of **thinking and solving problems**. Students access, gather and process information from a variety of sources in both familiar and unfamiliar situations. They ask questions, observe, gather and work with data as they investigate scientific phenomena and use evidence to construct and justify conclusions. As critical thinkers, students need to continually examine their lines of argument, the evidence for their claims, and the motivations behind their beliefs.

Communication and collaboration are inherent to the work of a scientist and students have rich opportunities to develop the key competencies of **communicating** and **working with others** in Leaving Certificate Physical Science. The key competency of **communicating** is developed as students prepare and communicate qualitative and quantitative information gained from investigations using primary and secondary sources. Students develop an awareness of the need to present ideas in ways that are true to the claims being made but also appropriate to the intended audience. They observe, listen, remain open to different perspectives and learn to figure things out for themselves. They frame scientific arguments by making claims and use logical reasoning informed by evidence, applying appropriate scientific notation and nomenclature and using relevant scientific language. Students work with each other in pairs, groups and teams and through these experiences gain an appreciation of group dynamics. They take on different roles, work together to achieve shared goals, give and respond to feedback from their teachers and peers, and interact safely and responsibly. This contributes to an understanding and appreciation that working collectively helps motivation and capitalises on all the talents in the group. Students learn to navigate difficult tasks, negotiate and resolve differences of opinion as they discuss different strategies and achieve consensus. Students also learn about the importance of being adaptable and being willing to learn from mistakes, appreciating the social concept of productive failure, all of which contributes to the development of resilience, supporting the development of **cultivating wellbeing.**

Literacies and numeracy support the development of key competencies in a Leaving Certificate Physical Science classroom, and vice versa. Literacy concerns students' ability to use and put words together to explain their understanding of concepts through a variety of means, including written, reading, spoken, and digital. Numeracy is particularly relevant where students gather primary data and interpret and critically evaluate primary and secondary data, using a variety of analogue and digital means. Students engage in scientific inquiry and develop data-driven representations to explain these phenomena, enhancing their scientific literacy.

Students have multiple opportunities throughout the specification to develop key competencies as they engage actively with the learning outcomes, particularly when they are supported by learning outcomes in the unifying strand.

Strands of study and learning outcomes

This Leaving Certificate Physical Science specification is designed for a minimum of 180 hours of class contact time. Physical science sits firmly within the discipline of science, with energy and matter identified as the fundamental concepts connecting physics and chemistry in this interdisciplinary subject. There are five interrelated strands: The Nature of Science, a unifying strand, and four contextual strands – Matter, Energy, The Interconnected Nature of Energy and Matter, and Our Physical Science Environment. The design of the strands reflects the interconnected nature of the subject of Leaving Certificate Physical Science.

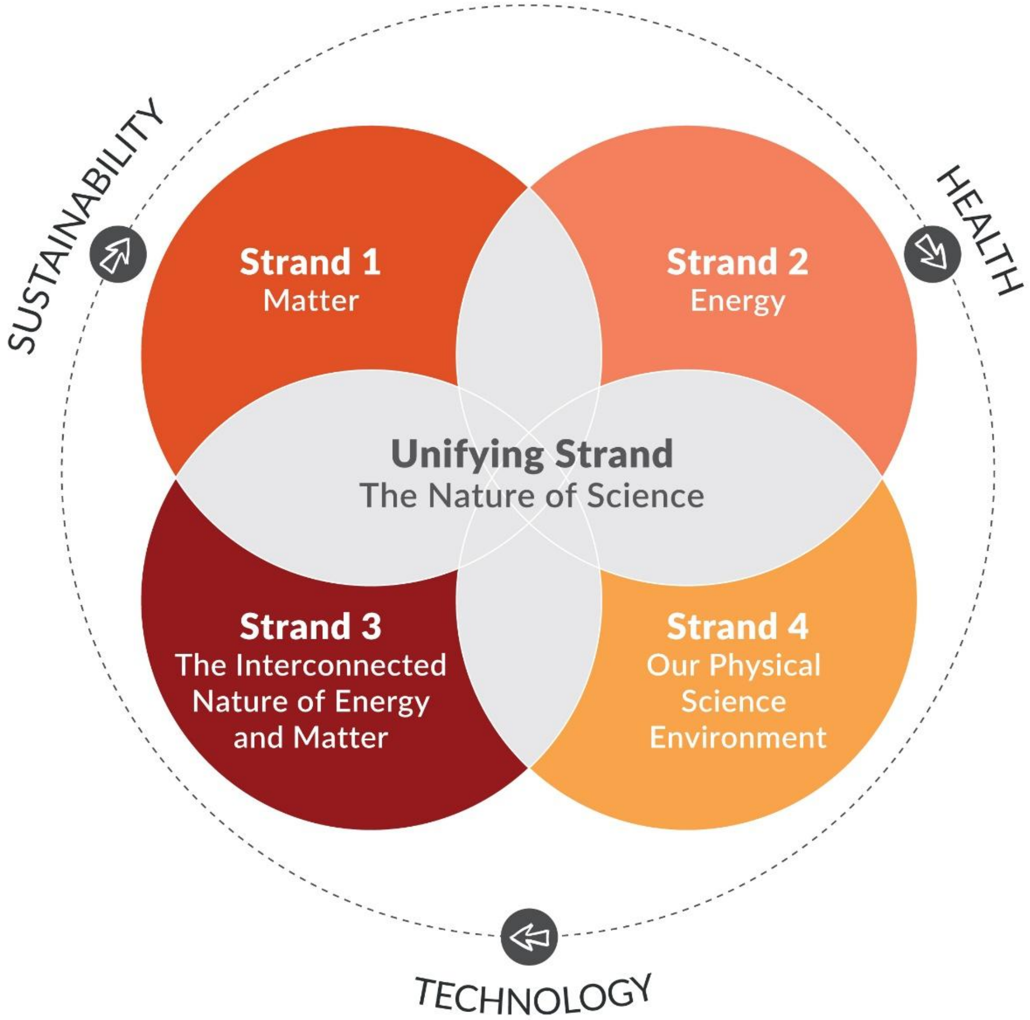

Figure 3 Overview of Leaving Certificate Physical Science

Nature of Science underpins Leaving Certificate Physical Science and so is considered a unifying strand; it permeates all the strands of the specification. The learning outcomes in this strand identify the knowledge, skills, values and dispositions related to scientific practices which are essential to students' learning about science throughout the course, underpinning the activities and content in the other strands.

The learning outcomes in the contextual strands; Matter, Energy, The Interconnected Nature of Energy and Matter, and Our Physical Science Environment, identify the knowledge of physical science; i.e. the core concepts, models and theories that describe, explain and predict physical and chemical phenomena. The sequence in which the strands and learning outcomes are presented does not imply any particular order of teaching and/or learning.

The specification identifies three cross-cutting themes, Technology, Health and Sustainability. They act as lenses through which students can explore the application of knowledge from physical science.

Learning outcomes should be achievable relative to students' individual aptitudes and abilities. Learning outcomes promote teaching and learning processes that develop students' knowledge, skills, values and dispositions incrementally, enabling them to apply their key competencies to different situations as they progress. Students studying at both Ordinary level and Higher level will critically engage with Physical Science, but the context, information and results arising from that engagement will be different, as outlined in Table 1.

Table 1: Design of learning outcomes for Ordinary and Higher level

Ordinary Level	Higher Level
• Students engage with a broad range of knowledge, mainly concrete in nature, but with some elements of abstraction or theory.	• Students engage with a broad range of knowledge, including theoretical concepts and abstract thinking with significant depth in some areas.
• Students demonstrate and use a moderate range of cognitive skills and tools to use information, plan and develop investigative strategies, select from a range of procedures and apply known solutions to a variety of problems. They identify and apply knowledge, skills, values and dispositions in a variety of familiar and unfamiliar contexts.	• Students demonstrate and use a broad range of cognitive skills and tools to evaluate, use information, plan and develop investigative strategies and determine solutions to varied problems. They identify and apply knowledge, skills, values and dispositions in a wide variety of familiar and unfamiliar contexts.
• Students develop scientific literacy skills when selecting evidence and data to communicate findings and draw conclusions to questions posed by themselves and others.	• Students develop, demonstrate and use scientific literacy skills and use appropriate evidence and data to effectively communicate findings and draw justified conclusions to questions posed by themselves and others.
• Students apply learning to familiar everyday applications and make connections between theory and practical applications.	• Students apply their learning to a broad set of everyday applications and make concrete connections between theory and practical applications.

An overview of each strand is provided below, followed by a table. The right-hand column contains learning outcomes which describe the knowledge, skills, values and dispositions students should be able to demonstrate after a period of learning. The left-hand column outlines specific areas that students learn about. Taken together, these provide clarity and coherence with the other sections of the specification. Appendix 1 provides a glossary of action verbs used in the learning outcomes.

Unifying Strand: The Nature of Science

This strand builds on the unifying strand from Junior Cycle Science and continues to bring to life the practices and norms underpinning the facts, concepts, laws and theories of science. Building on existing knowledge, students develop an appreciation of science as a process and a way of knowing, thinking and doing. They also develop an understanding that the discipline of science includes understanding the nature of scientific knowledge as well as how this knowledge is generated, established, developed, applied and communicated. In senior cycle it is expected that students will be able to meet these learning outcomes with a greater degree of independence.

As they learn to work like scientists, they develop a habit of mind that sees them rely on a set of established principles and practices associated with scientific inquiry to gather evidence, generate models and test their ideas on how the natural world works. It becomes apparent that the process of science, is often complex and iterative, following many different paths, but always underpinned by these established principles and practices. Students learn to obtain and evaluate primary data (data collected by themselves) and secondary data (data collected by somebody else).

Students develop an understanding that whilst science is powerful, generating knowledge that forms the basis for many advances and innovations in society, it has limitations. They will also discover that the application of scientific knowledge to real world issues and problem-solving can be influenced by considerations such as economic, social, sustainability and ethical factors.

Unifying Strand Learning outcomes

Students learn about	Students should be able to
U1. Scientific knowledge • the nature of scientific knowledge • science as a community that relies on clear communication, international conventions, peer review and reproducibility • recognising bias	1. appreciate how scientists work and how scientific ideas are modified over time 2. conduct research relevant to scientific issues, evaluating different sources of information including secondary data, understanding that a source may lack detail or show bias

Students learn about	Students should be able to
U2. Investigating in science	
• questioning, predicting • objectivity	1. recognise and pose questions that are appropriate for scientific investigation 2. pose testable hypotheses developed using scientific theories and explanations, evaluate and compare strategies for investigating hypotheses
• giving due consideration to the limits of the precision and accuracy of measurement and the role of calibration in this process • identifying potential sources of random and systematic error • evaluating data in terms of accuracy, precision, repeatability and reproducibility • safe and effective laboratory practice and appropriate risk assessment	3. design, plan and conduct investigations; explain how reliability, validity, accuracy, precision, error, fairness, safety, integrity, and the selection of suitable equipment have been considered
• distinguishing between fundamental and derived units, using SI units, prefixes and powers of ten for order of magnitude, converting units and using an appropriate number of significant figures in calculations • making justified conclusions	4. produce and select data (qualitatively/quantitatively), critically analyse data to identify patterns and relationships, identify anomalous observations, draw and justify conclusions
• communicating using investigative logs, posters, infographics, case studies, presentations and reports	5. review and reflect on the skills and thinking used in carrying out investigations, and apply their learning and skills to solving problems in unfamiliar contexts 6. organise and communicate their research and investigative findings in a variety of ways fit for purpose and audience, using relevant scientific terminology and representations
U3. Science in society	
• relating science to society by considering economic, social, sustainability and ethical factors	1. research and present information on the contribution that scientists make to scientific discovery and invention, and evaluate its impact on society

Students learn about	Students should be able to
• individual and collective responsibility in addressing the impact of science on society	2. appreciate the role of science in society, and its personal, social and global importance, and how society influences scientific research
• evaluating evidence for relevance, accuracy, bias	3. evaluate media-based arguments concerning science and technology
U4. Modelling in science	
• models as powerful tools for understanding complex phenomena • evaluating and recognising the limitations of models	1. appreciate that models • are simplified representations of complex systems or phenomena with underlying assumptions • can be modified as more data becomes available from the system/phenomenon • can predict the behaviour of a system/phenomenon
• visualisation as a key aspect of understanding core concepts and fundamental principles • representation of an idea, structure, process or system, though a variety of means such as words, diagrams, numbers, graphs, equations, physical models or simulations	2. create and use models to represent their ideas about chemical and physical phenomena that cannot be observed directly
• verifying models using primary and secondary data	3. make connections between mathematical representations of a system and data obtained from that system
U5. Applications of physical science	
• the integrated nature of both chemical and physical core concepts and fundamental principles	1. appreciate the interdisciplinary nature of physical science
• everyday applications of physical science	2. illustrate how physical science is applied to address real-world problems and their related ethical considerations

Strand 1: Matter

In this strand, students are introduced to the four fundamental forces of nature; strong nuclear, weak nuclear, gravitational and electromagnetic, as they develop their understanding of the nature and behaviour of matter. They use the kinetic particle model as a tool to explain the behaviour of matter in various states, deepening their understanding by exploring how changes in kinetic energy relate to changes in state and examining the relationships between temperature, pressure and volume. They model and investigate the motion of a particle using verbal, mathematical and graphical representations to explain the kinematics and dynamics of motion in one dimension. Students investigate the concept of conservation as they experimentally explore the laws of conservation of mass and momentum, building connections between theoretical concepts and everyday phenomena.

Students develop their understanding of the atom and appreciate the evolution of the Bohr atomic model. It is here where students begin to appreciate and develop a practical understanding of the strong and weak nuclear fundamental force, as they explore the structure of the atom. Students recognise the Periodic Table as one of the most important and fundamental secondary sources for organising elements and predicting their properties. Students connect learning associated with atomic structure and the key trends associated with chemical behaviour, including electronegativity, ionisation energy and atomic size. The mole concept is introduced to support quantification of matter, along with concepts such as electrical conductivity and spontaneous radioactive decay.

Finally, students apply their knowledge to explore the physical and chemical properties of matter and investigate how the structure and properties of matter relate to the design and use of materials in the real world.

Strand 1 Learning outcomes

Students learn about	Students should be able to
1. The kinetic particle theory of matter • pure substances (elements, compounds) and mixtures (homogenous and heterogenous) in various states of matter	1. classify matter according to its physical state and composition

Students learn about	Students should be able to
• the particulate nature of matter, including assumptions and limitations of the model • the concept of intermolecular and intramolecular forces • the process of changing state as a physical change • phase changes and state symbols • solutions and the concept of concentration, solubility, and viscosity	2. use secondary sources and observations to model: • the nature and behaviour of matter at the particulate level • motion of a particle in solids, liquids and gases • how matter changes state • conservation laws in relation to particle motion 3. investigate the separation of homogeneous and heterogenous mixtures using primary and secondary data
• the relationship between temperature and kinetic energy of particles in motion	4. relate the concept of temperature to the kinetic energy of a system
• the concept of pressure and temperature and their influence on phase changes and the volume of solids, liquids and gases • the ideal gas law: *PV = nRT* • the concept of latent heat, melting point and boiling point	5. investigate the relationship between pressure, temperature and phase changes in matter, using primary and secondary data 6. apply the observed relationships between pressure, temperature and volume to everyday scenarios
• the concept of conserving mass • limitations when generating primary data	7. verify the law of conservation of mass, using primary and secondary data
2. Forces and motion of a particle	
• basic concepts for describing the motion of a particle; displacement, velocity, acceleration and time • mathematical models: ○ $v = \frac{\Delta s}{\Delta t}$ $a = \frac{\Delta v}{\Delta t}$ ○ $v = u + at$ ○ $v^2 = u^2 + 2as$ ○ $s = ut + \frac{1}{2}at^2$ • graphical models: ○ graphical representation and interpretation: displacement-time graphs, velocity-time graphs	1. model motion of a particle in a straight line 2. investigate constant and varying linear motion using primary and secondary data

Students learn about	Students should be able to
• types of forces – Normal, Frictional, Resistant, Tension, Gravitational, Electrical charge • resultant force as the sum of all forces	3. model the motion of a particle under a constant resultant force
• the concepts of mass and force ○ $F = ma$	4. investigate Newton's second law of motion using primary and secondary data
• the concept of density and pressure ○ $p = \frac{F}{A}$	5. investigative density and pressure using primary and secondary data
• the concept of momentum ○ $\rho = \frac{m}{v}$	6. investigate the principle of conservation of momentum using primary and secondary data
3. The atom	
• strong nuclear force and the structure of the atom • the octet rule and the concept of valency • the mass, charge and location of subatomic particles	1. appreciate Bohr's role in evolving the model of the atom 2. model the Bohr atom
• organisation and prediction to support understanding of chemical behaviour	3. appreciate the role of the Periodic Table as a fundamental secondary source in physical science
• mass number, atomic number and electronic structure of metals and non-metals • ionisation and conductivity	4. model the formation of ions, using secondary data
• chemical reactivity trends and relationships associated with atomic size, ionisation and electronegativity	5. analyse trends and relationships associated with chemical reactivity of elements using secondary data
• elements with the same mass number but different atomic number • stable and unstable isotopes • weak nuclear force and radioisotopes • radio decay through alpha and beta particles and gamma rays • observations and evidence that supports an understanding of different properties associated with isotopes of the same element	6. describe the structure of isotopes, using secondary data 7. model spontaneous radioactive decay, using secondary data 8. analyse evidence that supports the existence of isotopes, using secondary sources

Students learn about	Students should be able to
• the mole concept and how the number of particles, mass, relative atomic mass, molecular mass, volume and moles are interrelated • atomic mass unit, u • Avogadro constant	9. appreciate the significance and scale of the mole as a means of quantifying matter 10. relate the mole to Avogadro's constant
4. Chemical bonding • the nature of chemical bonds that lies on a continuum from ionic to pure covalent bonds • how electronegativity values support prediction of bonding type • shape: AB2, AB3, AB4 • properties of compounds including electrical conductivity, melting and boiling points and state of matter at room temperature	1. model different types of chemical bonding 2. predict the nature of chemical bonds between atoms, using secondary sources 3. relate the shape and properties of simple compounds to the nature of bonding present, using secondary data
5. Properties of matter and materials • physical properties: thermal and electrical conductivity, resistivity, density, solubility, melting and boiling point • chemical properties: reactivity • materials and their appropriate use	1. verify the properties of matter using primary and secondary data 2. evaluate the suitability of materials and their properties for use within health, technology and sustainability using secondary sources[CO]

Strand 2: Energy

In this strand students explore the creation and structure of the Universe, developing their understanding of the interconnected nature of matter and energy and the evolving nature of science. They develop their understanding of gravitational and electromagnetic forces as they learn about solar radiation as the primary source of energy for our planet and solar system. Students investigate nuclear fusion and the electromagnetic spectrum, focusing on the solar spectrum, where they have practical opportunities to engage with the ultraviolet (UV), visible and infrared (IR) regions. They deepen their understanding of energy, as a fundamental concept in science and are introduced to work as a means of energy transfer and power as a rate of transfer. Through this, they examine how the work energy principle can simplify the analysis of mechanical systems compared to using Newton's laws directly.

Building on their knowledge of the kinetic particle model and atomic theory students explore heat transfer through conduction convection and radiation, investigate the behaviour of light and examine the role of emission spectra as evidence in supporting modern atomic models. They apply this understanding to real world problems and applications, involving energy transfer, storage and efficiency.

The strand concludes with an introduction to electric current and the role of electron flow in energy conversion. Students use models to explain non-contact forces between charged objects and begin to theoretically connect energy and matter.

Strand 2 Learning outcomes

Students learn about	Students should be able to
1. The origins of the Universe	
• energy and matter originating from an extremely hot, dense state • cooling and expansion and the origins of space and time • limitations of the Big Bang theory • formation of the fundamental forces, particles and first atoms • formation of the structure of the Universe	1. outline the Big Bang theory as an explanation of the early development of the universe using secondary sources 2. model expansion and cooling of the universe
• mass/energy conversion, $E=mc^2$	3. appreciate the interconnected nature of energy and matter during the early development of the Universe

Students learn about	Students should be able to
• nuclear fusion of hydrogen nuclei into helium in the sun resulting in large amounts of energy being radiated across the Solar System • weak nuclear and gravitational forces	4. analyse observations evidence that supports the Big Bang theory, using secondary sources 5. model the process of nuclear fusion in the sun
• solar radiation and the electromagnetic spectrum • photons, wavelength and frequency • infra red and visible energy (heat and light) as the most useful forms of solar radiation on Earth	6. recognise the role the sun plays as the primary energy source for the Earth 7. relate regions of the electromagnetic spectrum to their wave properties, applications and uses
2. A work-energy model	
• the interconnected nature of work, force and energy ○ $W = Fs$	1. relate the concepts of work, force and energy
• different forms of mechanical energy and conversions • motion and energy redistribution and storage in a system • $E_P = mgh$, $E_k = \frac{1}{2}mv^2$	2. explore everyday energy conversions and apply the law of the conservation of energy, where work is being done
• the law of the conservation of energy	3. investigate the principle of conservation of energy using primary and secondary data
• power as the rate at which energy is transferred or converted per unit time ○ $P = \frac{W}{t}$	4. relate the concepts of energy, time and power
• Sankey diagrams as a means of modelling energy flow in a system • forces, limitations of design and energy dissipation • the concept of efficiency ○ $\frac{P_o\ x\ 100}{P_i}$	5. evaluate energy efficiency in relation to useful and non-useful outputs in everyday energy conversions, using primary and secondary data
• energy recovery systems in electric and hybrid cars	6. investigate the purpose of regenerative braking in electric and hybrid cars using secondary sources[CO]

Students learn about	Students should be able to
3. Electromagnetic energy (heat)	
• energy exchanged between materials as a result of temperature difference	1. demonstrate the transfer of infra-red radiation into more useful forms of energy
• particle models of heating: conduction, convection • wave model: radiation	2. model the concept of heat transfer
• U-value as the rate of transfer of heat through a material	3. investigate the impact of thermal insultation on energy consumption and sustainability using secondary sources[CO]
• insulation as a material that acts as a barrier to slow the transfer of energy • properties of thermal insulators	4. investigate the impact of materials to act as thermal insulators using primary and secondary data
4. Electromagnetic energy (light)	
• ray diagrams • reflection ○ $i = r$	1. model wave behaviour; reflection and refraction

• refraction
  ○ refractive index
  ○ $n = \frac{\sin i}{\sin r}$ $n = \frac{c1}{c2}$ $n = \frac{1}{\sin C}$
• the critical angle and total and internal reflection
• $c = f\lambda$
	2. verify models for reflection, refraction and diffraction using primary and secondary data

• diffraction ○ $n\lambda = dsin\theta$ • wave-particle duality • evidence that supports the particle and wave model of light	3. analyse evidence that supports light as a particle and wave, using secondary data
• useful applications of the behaviour of light within health and industry including fibre optics for communication, diagnostic imaging and biomedical sensors	4. investigate applications of optics that solve an everyday problem using secondary sources[CO] 5. evaluate the suitability of materials for use in fibre optics, using secondary sources[CO]
• applications of light that support the monitoring of health indicators including heart rate and blood oxygen levels	6. model how a smart device uses light to monitor health indicators

Students learn about	Students should be able to

5. Electron energy
 	
• electronic structure; s, p, d
• emission spectra as photons of specific wavelengths, and colour unique to each element
• energy levels and quantum states
  ○ $E_2 - E_1 = hf$
 	
• flame tests and spectroscopy
 	
• electrons being ejected or released from the surface of materials (generally a metal), when light of a suitable frequency falls on them
• $E = hf$
• $\varphi = hfo$
  ○ threshold frequency fo
  ○ work function φ
• the principle of conservation of energy underpins the effect
  ○ $E = \varphi + \frac{1}{2}mv_{max^2}$
• the particle model of light
 	
• applications of the photoelectric effect
	1. model excitation energy transfer using secondary data
	
	2. appreciate how the analysis of emission spectra data has contributed to our understanding of objects in the universe
	
	3. identify elements using primary and secondary data
	
	4. use secondary data to verify the photoelectric effect and the effect of varying
	  • the intensity of incident radiation
	  • the frequency of incident radiation
	
	5. investigate everyday applications of the photoelectric effect using secondary sources[CO]

6. Electrical energy
 	
• electrically neutral objects and how they become charged
• the conservation of charge and energy in interactions
• electric current as the flow of electrons through a conductor in a complete circuit
• free electrons and bound electrons
• doping; n type, p type and p-n junction, depletion layer
	1. demonstrate forces
	  • between charged objects
	  • between charged and neutral objects
	
	2. classify materials as conductors, semi-conductors or insulators
	
	3. model electric current in insulators, conductors and semi-conductors

Strand 3: The Interconnected Nature of Energy and Matter

In this strand, the focus of student learning is on understanding how matter and energy interact in both physical and chemical contexts. Their knowledge of the kinetic particle model changes of state forms the foundation for exploring the nature of chemical reactions and the thermodynamic principles that govern them. Key concepts such as temperature, heat transfer, latent heat and specific heat capacity are investigated further, with students conducting practical experiments to understand energy flow in physical process. This strand introduces the concept of enthalpy, allowing students to examine how energy is stored, transferred and conserved in chemical systems.

Students apply their knowledge to real-world scenarios, including fuels and combustion, gaining insight into energy efficiency, storage and release. Through the study of endothermic and exothermic reactions, they relate energy changes to chemical bonding and use collision theory to model and analyse rates of reaction. Students explore the fundamentals of circuitry and return to the concept of rates as they explore power through the verification of models. Students are introduced to the concept of mass-energy equivalence and explore the energy potential of nuclear processes, giving them an appreciation for the broader applications of energy transformations in science and technology.

Engaging with the learning in this strand supports the development of strong practical and theoretical learning, supporting students to be able to explain, model and investigate the interactions between matter and energy in a variety of systems and applications they will meet in Strand 4.

Strand 3 Learning outcomes

Students learn about	Students should be able to
1. Chemical change	
• evidence that indicates a chemical reaction has taken place including change in colour, temperature, formation of a gas, precipitate, formation of light	1. distinguish between physical and chemical change 2. recognise evidence that confirms a chemical reaction has taken place using primary and secondary data
• different types of chemical reactions including combustion, acid-base and redox	3. classify chemical reactions

Students learn about	Students should be able to
• chemical formulae that describe the relative amounts of elements present in a molecule or compound • empirical formula	4. describe the relationship between chemical formulae and chemical composition
• balancing chemical equations	5. relate the law of conservation of mass to the rationale for balancing chemical equations
2. Enthalpy change	
• thermometric properties of materials and thermometers • the Kelvin and Celsius temperature scales	1. investigate the suitability of materials for measuring temperature using primary and secondary data
• relationships between heat energy and temperature change • heat capacity; $C = \frac{Q}{\Delta\theta}$ • specific heat capacity; $c = \frac{Q}{m\Delta\theta}$	2. determine specific heat capacity using primary data (solid or liquid) and secondary data (solid and liquid)
• heat storage systems • the impact of energy efficiency policy on society	3. relate the concept of vapor compression to the operation of heat storage systems using secondary sources
• the concept of energy poverty • modern energy efficient heat systems	4. investigate energy poverty using secondary sources[CO]
• latent heat; $L = Q$ • specific latent heat; $l = \frac{Q}{m}$ • vaporisation of steam and fusion of ice	5. determine the specific latent heat using primary data and secondary data
• the principle of the law of conservation of energy underpinning all thermochemical processes • a change in enthalpy (ΔH) as a measure of the heat change in a process, at a constant pressure	6. explain enthalpy changes in a reaction in terms of making and breaking bonds
• Hess's law as a series of reactions and energy cycles	7. model Hess's law
• temperature and change in enthalpy (ΔH)	8. identify chemical reactions as endothermic and exothermic, using primary and secondary data

Students learn about	Students should be able to
• how bond-making releases energy and bond-breaking requires energy • simple energy profile diagrams as a means of describing energy transfer in a chemical reaction • the role of catalysts in improving efficiency	9. model energy transfer in exothermic and endothermic reactions
3. Combustion	
• compounds that include carbon-hydrogen bonds and those that do not	1. distinguish between organic and inorganic compounds using secondary sources
• categories of fuels with stored chemical energy	2. classify fuels as renewable and non-renewable
• combustion as a chemical reaction that involves a fuel reacting with an oxidant to form new substances, releasing energy • complete and incomplete combustion	3. model combustion of a fuel 4. predict the products of combustion using primary and secondary data
• everyday applications to solve a problem	5. explore how smoke and carbon monoxide detectors work to respond to the products of incomplete combustion of a fuel using secondary sources[CO]
• experimental values versus standard values	6. investigate the energy change of combustion reactions using primary and secondary data
4. Chemical kinetics	
• chemical reactions occur between particles when they collide • motion of a particle • effective collisions and rate of reaction	1. model collision theory 2. relate the concept of collision theory to rate of reaction
• factors that affect the rate of chemical reactions including temperature, concentration, surface area and the action of a catalyst • graphical models: ○ graphical representation and interpretation of reaction rate graphs	3. investigate factors that affect rates of a reaction using primary and secondary data

Students learn about	Students should be able to
• mathematical models: ○ initial, average and instantaneous rate • how environmental conditions may influence a rate of reaction	4. recognise the role that environmental conditions play in maximising rate of reaction using secondary sources
5. Electric power • electric potential and current, work, power, potential difference, voltage and emf • $I = \frac{q}{t}$ • $V = \frac{W}{q}$ • $W = I^2Rt$ • $P = I^2R$ • $P = VI$ • circuit components: voltage source, switch, light bulb, resistor, thermistor ammeter, voltmeter, diode, LDR, LED	1. verify models that describe: • the relationship between current and charge • the relationship between work, charge and potential difference • the relationship between electric current, conventional current, power and resistance • the rate of conversion of electrical energy in components of electric circuits
• circuitry • safety in mains electricity: earthing, MCBs and RCDs	2. model: • series and parallel circuits • fuses and circuit breakers
• Ohm's Law ○ $V = IR$	3. investigate the relationship between current and voltage using primary and secondary data
• integrated circuits and semiconductor chips	4. discuss the use of integrated circuits in modern devices using secondary sources
6. Harnessing energy from nuclear processes • light energy converted to electrical energy	1. model a photovoltaic cell
• $E = mc^2$	2. explore the concept of mass energy equivalence
• controlled and uncontrolled chain reaction	3. model nuclear fission using secondary sources and data
• design and material choice in relation to the immense energy released	4. evaluate a nuclear reactor in terms of design and material choice using secondary sources[CO]

Students learn about	Students should be able to
• power generation, safety and waste processing	5. explore nuclear fission and fusion in relation to electrical generation using secondary sources[CO]

Strand 4: Our Physical Science Environment

In this strand students bring their learning together as they explore real-world applications of physical and chemical concepts related to space, pharmaceuticals and health, the environment and electrochemical cell technology. This strand presents rich opportunities for students to develop their critical awareness of scientific issues and extend and develop their ability to investigate and communicate in science, as they relate and apply their learning to broader applications and technologies that address a variety of issues in our modern world. It also provides concrete opportunities for students to explore the cross-cutting themes of health, sustainability and the technology and apply their learning and understanding of the physical and chemical concepts engaged with across strands of study, leaving them with an increased level of readiness to embrace the world as scientifically literate citizens.

Strand 4 Learning outcomes

Students learn about	Students should be able to
1. Space	
• the fundamental gravitational force that holds the universe together • how objects with mass are attracted towards on another; $F = \frac{Gm_1m_2}{r^2}$	1. relate the concept of gravity to the position and motion of planets and satellites using secondary data
• centripetal force and it's relationship to geostationary orbits; $F = \frac{mv^2}{r}$	2. compare natural and artificial satellites
• the transmission of radio signals to and from satellites	3. explore, using secondary sources, the role of artificial satellites in[CO]: • communication • GPS navigation • weather forecasting • scientific research
• solar panels and the photovoltaic effect	4. describe how energy is stored and converted in an artificial satellite

Students learn about	Students should be able to
• how materials used may protect satellites from extreme environmental conditions in space	5. relate materials used in satellites in space to their properties
• ethical issues such as those associated with the environment and sustainability; governance and policy; privacy, security and social concerns	6. discuss an ethical issue associated with artificial satellites[CO]
2. Pharmaceuticals and health	
• acid-base reactions and proton transfer; Brønsted-Lowry theory • strong and weak acids and bases • acid—base neutralisation	1. model acid-base reactions 2. investigate everyday acid-base neutralisation reactions using primary and secondary data
• common everyday substances with medicinal properties and medicinal products that either block or neutralise acid secretion in the body	3. explore medicinal products that treat excess acid production using secondary sources [CO]
• redox reactions and electron transfer • oxidation and reduction • oxidising and reducing agents • conservation of charge	4. model redox reactions 5. apply oxidations numbers to balance redox reactions using secondary sources
• quantifying matter in a context • quality control to verify the concentration of active pharmaceutical ingredients, detect impurities and monitor drug stability	7. explore the role of volumetric analysis in relation to quality control in the pharmaceutical industry using secondary sources[CO]
• primary standards • volumetric analysis as a chemical process for determining concentrations	6. verify the concentration of iron in an iron tablet using volumetric analysis
• imaging methods and their appropriateness for use	7. explore diagnostic and therapeutic applications of the electromagnetic spectrum using secondary sources[CO]
3. The environment	
• the interaction of short and long wavelength infrared radiation • $c = f\lambda$	1. model the greenhouse effect 2. relate the ideal gas law to the greenhouse effect

Students learn about	Students should be able to
• greenhouse gases that influence temperatures on Earth by absorption and re-radiation of infrared radiation • trapping of heat • principal sources and sinks of greenhouse gasses	3. compare the natural and anthropogenic greenhouse effect
• key indicators of global climate change that include temperature, atmospheric composition, ocean conditions and cryosphere changes	4. identify key indicators of global climate change, using secondary data
• the air quality index • Particulate Matter (PM) as inhalable particles, composed of sulphate, nitrates, ammonia, sodium chloride, black carbon, mineral dust or water • PM size; $PM_{2.5}$ and PM_{10}	5. compare trends in air quality, using data from secondary sources[CO] 6. explore the impacts of poor air quality on human health, using secondary data[CO]
• direct and indirect human activities that contribute to a carbon footprint over the life cycle of a product or service • carbon capture	7. analyse factors that contribute to the carbon footprint of a product or service using secondary data[CO] 8. create a plan to reduce the carbon footprint of a product or service[CO] 9. recognise the importance of real - world evidence in discussions relating to climate change 10. research strategies that support industrial decarbonisation using secondary sources[CO]
• technological innovations that address the environmental crisis	11. explore the role of technology in addressing the environmental crisis using secondary sources[CO]
4. Electrochemical cell technology	
• rechargeable and non-rechargeable cells • cathode, anode and electrolyte functions in cells	1. compare a primary and secondary cell
• redox reactions that produce a flow of electrons, including the copper-zinc system	2. create a simple galvanic and electrolytic cell

Students learn about	Students should be able to
• use electrochemical series as a guide to the relative tendency of metals to be oxidised	
• lithium-ion	3. recognise the significance of secondary cells in a modern world
• lithium ion and zinc based batteries	4. evaluate the suitability of materials for use as electrochemical cells, using secondary sources
• critical raw materials • extraction and processing of valuable metallic materials from the Earth • ethical issues and alternatives	5. research metal ore mining using secondary sources[CO]
• chemical cells that convert and transfer chemical energy to electrical energy • fuel cells that generate energy using a constant supply of external reactants	6. compare chemical cells with fuels cells 7. describe the operation of a hydrogen fuel cell
• hydrogen fuel cells as versatile alternatives to fossil fuels • environmental benefits, performance and efficiency and practical applications	8. explore hydrogen fuel cell projects and initiatives as fuel sources using secondary sources[CO]

Teaching for student learning

Leaving Certificate Physical Science supports the use of a range of teaching and learning approaches that respond to the strengths, needs and interests of all students. The course is student-centred in its design and emphasises a practical and applied experience of physical science for each learner. Through tasks that connect physical and chemical concepts with practical and applied learning, students engage with Leaving Certificate Physical Science as a relatable science that holds meaning for their lives. They gradually and progressively develop learning that can be brought from one activity to the next, building their capacity to work like a scientist. Students learn through practical experiences such as investigating, modelling and exploring real-life applications. In planning for teaching and learning, teachers are encouraged to provide ample opportunity for students to engage with the learning outcomes of the specification through the lens of the unifying strand. This is best achieved when teachers support, as appropriate, students' independent engagement with the learning outcomes.

Providing opportunities for students to develop a range of inquiry skills will be necessary to progress along the continuum of inquiry[1]. Teachers are best positioned to make professional judgements on how to develop these skills with their students through an appropriate balance of teacher guidance and student self-direction. This is enabled through rich tasks that are structured, appropriately scaffolded, and inclusive. Through such tasks, students design, conduct and report on their investigations. They confidently pose hypotheses, predict outcomes and record their results and conclusions. They select and manipulate apparatus safely to test their hypotheses. They learn to interrogate and interpret data; primary data, that they collect themselves as well as secondary data collected by others. As they research scientific issues and explore real-life applications, students engage with secondary sources, sources of information published by others, learning which has a value far beyond Leaving Certificate Physical Science. Students are encouraged to use the most appropriate and meaningful methods and media to organise and analyse data and information sources, including digital technologies.

Collaboration and communication are inherent to working like a scientist. The learning outcomes provide opportunities for teachers to design learning experiences that support collaboration, such as group work and peer discussions. By engaging in well-structured discussions, students have opportunities to engage in reasoned argument, listen to each other and reflect on their own work and that of others. Teachers can guide students to choose between visual presentations such as case studies, infographics and poster presentations[2], which allows students to select the most appropriate communication format to both engage with research and communicate their investigative findings in an efficient and effective manner. Learning outcomes with the superscript^{CO} signpost for teachers rich opportunities in the strands of study that support the development of this type of learning.

Students vary in the amount and type of support they need to be successful. Levels of demand in any learning activity will differ, as students bring different ideas and levels of understanding to it. The use of inclusive and accessible pedagogies, such as differentiated activities, with strategies such as adjusting the degree of proficiency required, varying the

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[1] See Junior Cycle Science Specification (pp. 13-14) for further information on the continuum of inquiry
[2] Case studies, infographics and poster presentations use a combination of graphics and text to communicate both concisely and effectively to peers. Case studies explore and analyse an issue in depth using a variety of sources. Infographics present complex information in a more engaging and user friendly manner. Poster presentations distil key investigative findings and are supported through oral communication.

amount and the nature of teacher intervention, and varying the pace and sequence of learning promotes inclusivity. As well as varied teaching and learning strategies, varied assessment strategies will support learning and provide information that can be used as feedback so that teaching and learning activities can be modified in ways that best suit individual students. By setting appropriate and engaging tasks, asking questions of varying cognitive domain and giving feedback that promotes learner autonomy, assessment will support learning as well as summarising achievement.

Digital Technology

Digital technology can play a role to further enhance learning, teaching and assessment. It can help to create opportunities for students to develop scientific knowledge, skills, values and dispositions in ways that are more engaging, and also in ways that could not have been achieved without the use of technology. For example, as students engage with Leaving Certificate Physical Science, they will have opportunities to use digital technology to:

- collect, record, analyse, organise and display data and information
- visualise the core concepts, models and theories that describe, explain and predict physical and chemical phenomena
- develop a deeper understanding of data through choosing the right tools for data collation, visualisation, analysis, and representation of results
- develop and improve investigative research, communication, and report writing skills
- become more independent learners through, for example, appropriate digital/online supports
- enhance their experience in the classroom and laboratory such as the use of virtual labs and simulations
- communicate effectively with others
- create and develop good quality documents that use both graphics and text to communicate accurately and concisely
- engage in virtual and/or blended learning experiences
- understand the strengths, limitations and ethical considerations of AI tools
- develop their understanding of how scientists use digital technology in their work.

Assessment

Assessment in senior cycle involves gathering, interpreting, using and reporting information about the processes and outcomes of learning. It takes different forms and is used for a variety of purposes. It is used to determine the appropriate route for students through a differentiated curriculum, to identify specific areas of strength or difficulty for a given student and to test and certify achievement. Assessment supports and improves learning by helping students and teachers to identify next steps in the teaching and learning process.

As well as varied teaching strategies, varied assessment strategies will support student learning and provide information to teachers and students that can be used as feedback so that teaching and learning activities can be modified in ways that best suit individual learners. By setting appropriate and engaging tasks, asking questions and giving feedback that promotes learner autonomy, assessment will support learning and promote progression, support the development of student key competencies and summarise achievement.

Assessment for certification

Assessment for certification is based on the rationale, aims and learning outcomes of this specification. There are two assessment components: a written examination and an additional assessment component comprising of a Physical Science in Practice Investigation. The written examination will be at higher and ordinary level. The Physical Science in Practice Investigation will be based on a common brief. Each component will be set and examined by the State Examinations Commission (SEC).

In the written examination, Leaving Certificate Physical Science will be assessed at two levels, Higher and Ordinary (Table 1). Examination questions will require students to demonstrate learning appropriate to each level. Differentiation at the point of assessment will also be achieved through the stimulus material used, and the extent of the structured support provided for examination students at different levels.

Table 2 Overview of assessment for certification

Assessment component	Weighting	Level
Physical Science in Practice Investigation	40%	Comon brief
Written examination	60%	Higher and Ordinary level

Additional assessment component: Physical Science in Practice Investigation

The Physical Science in Practice Investigation provides an opportunity for students to display evidence of their learning throughout the course, in particular, the learning set out as outcomes in the unifying strand. It involves students completing a piece of work during the course and, in Year 2, submitting for marking to the State Examinations Commission (SEC), evidence of their ability to conduct scientific research on a particular issue and to conduct an experiment on an aspect of that issue by generating appropriate primary data. The assessment has been designed to be naturally integrated into the flow of teaching and learning and to exploit its potential to be motivating and relevant for students, to draw together the learning outcomes and cross-cutting themes of the course and to highlight the relevance of learning in Physical Science to their lives[3].

The senior cycle key competencies, developed by the students through all their learning in this course, will be applied through engagement with the Physical Science in Practice Investigation. The Physical Science in Practice Investigation provides opportunities for students to pursue their interests in Physical Science, to demonstrate their skills in scientific inquiry and scientific communication, to make their own investigative decisions, acquire a depth of conceptual understanding as they apply their learning in a real-life context and self-manage their own learning.

Investigation Brief

An *Investigation Brief* will be published annually by the SEC in Term 2 of Year 1 of the course. As well as setting out the specific requirements of the Physical Science in Practice Investigation, the brief will:

- allow students to develop their thinking and ideas on aspect(s) they would like to investigate, related to the brief
- facilitate teachers and students in their planning
- include stimulus material to set a context for the investigation
- allow students to develop an investigative log that they can draw upon as they complete their investigation.

[3] It is envisaged that the AAC will take up to 20 hours to complete. Further details will be provided in the Guidelines to support the Physical Science in Practice Investigation.

Building on their learning to date, students will learn more about the nature of investigation through research and experimentation. Students should be empowered in realising that research and experimentation is more about engaging with and learning from the process, rather than focusing on the final product. Students should give an authentic account of how their investigative work unfolds, discuss and explain the outcomes of their investigation and how they might revise aspects of the process. In addition, they should make connections and link their learning to appropriate real-life applications of their learning.

To complete the Physical Science in Practice Investigation, students carry out the following:

- Scientific research on an issue related to the brief. They gather, process and evaluate information from secondary sources. The knowledge gained from this phase of the investigation may help to inform their experimental work.
- An experiment related to an issue within the brief. They generate a hypothesis, plan, and design their experiment. They carry out their experiment and gather appropriate primary data. Once they have gathered their primary data, they analyse the data and form conclusions.
- Make a concrete connection between their investigative findings within a real-life application.

Students communicate their investigative findings using relevant scientific terminology and representations and develop an evidence-based argument in response to the brief. Upon completion, students submit a report of their investigation in Year 2 in a format prescribed by the SEC.

Schools have a high degree of autonomy in planning and organising the completion of the investigation. A separate document, *Guidelines for the Physical Science in Practice Investigation*, gives guidance on a range of matters related to the organisation, implementation, and oversight of the investigation.

Descriptors of quality for the Physical Science in Practice Investigation

The descriptors below relate to the learning achieved in the Physical Science in Practice Investigation. In particular, the investigation requires students to:

- consider issues related to real-world applications of physics and chemistry
- demonstrate research and experimental investigative skills
- relate their investigative work to real-life physical science contexts
- communicate their investigative findings appropriately and effectively.

Table 3: Descriptors of quality: Physical Science in Practice Investigation

	Students demonstrating a high level of achievement	Students demonstrating a moderate level of achievement	Students demonstrating a low level of achievement
Research Investigation	use relevant research to identify and explore the issue(s) in the brief and evaluate a wide range of appropriate sources; use a large number of varied, balanced and referenced sources; engage thoroughly with the physical and chemical concepts being investigated; summarise research findings through a critical lens; develop a clear and concise research question that can be tested experimentally.	use research to identify and explore the issue(s) in the brief and evaluate a range of appropriate sources; use a number of balanced and referenced sources; engage with the physical and chemical concepts being investigated; summarise research findings; develop a research question that can be tested experimentally.	use research that may be somewhat relevant to the issue(s) in the brief to be explored; use some referenced sources; engage in a limited way with the physical and chemical concepts being investigated; make some reference to research findings; demonstrate a tentative connection between a research question developed and experimental investigation.
Experimental Investigation	develop and pose a testable hypothesis underpinned by physical science concepts; generate high quality primary data through	pose a testable hypothesis underpinned by physical science concepts; generate primary data through appropriate	pose a testable hypothesis; generate some primary data through

	appropriate investigative design and methods; analyse primary data and draw valid and justified conclusions, related to the research question and hypothesis; evaluate the investigation with an acknowledgement of the limitations of the investigation.	investigative design and methods; analyse primary data and draw valid and justified conclusions, with some link to the related to the research question and hypothesis; evaluate the investigation with some acknowledgement of limitations of the investigation.	investigative design and methods; analyse primary data and draw conclusions, with a tentative link to the related to the research question and hypothesis; evaluate the investigation somewhat.
Applications of learning in real-life context	relate their research and experimental investigative findings to appropriate real-life physical science contexts; locate real-life application(s) within broader societal and scientific issues relating to the brief.	relate their research and experimental investigative findings to real-life physical science contexts; locate real-life application(s) within the issues relating to the brief.	relate their investigative findings to a real-life context; may not locate real-life application(s) within the issues relating to the brief.
Communication	present the findings of their investigation in a clear and coherent manner; use appropriate scientific terminology and a variety of engaging formats to communicate their evidence based findings; communicate clearly the links between the investigative findings and real-life applications.	present the findings of their investigation in a clear manner; use appropriate scientific terminology and engaging formats to communicate their evidence based findings; communicate the links between the investigative findings and real-life applications.	present the findings of their investigation, unclear at times; use some scientific terminology and communicate their findings; communicate the investigative findings and real-life applications.

Written examination

The written examination will consist of a range of question types. The senior cycle key competencies (figure 2) are embedded in the learning outcomes and will be assessed in the context of the learning outcomes. The written examination paper will include a selection of questions that will assess, appropriate to each level:

- the learning described in the four contextual strands of the specification and the unifying strand
- application of physical science to issues relating to the cross-cutting themes — sustainability, health, and technology.

Reasonable accommodations

This Leaving Certificate Physical Science specification requires that students engage with the nature of the subject on an ongoing basis throughout the course. The assessment for certification in Leaving Certificate Physical Science involves a written examination worth 60% of the available marks and an additional component worth 40%. In this context, the scheme of Reasonable Accommodations, operated by the State Examinations Commission (SEC), is designed to assist students who would have difficulty in accessing the examination or communicating what they know to an examiner because of a physical, visual, sensory, hearing, or learning difficulty. The scheme assists such students to demonstrate what they know and can do, without compromising the integrity of the assessment. The focus of the scheme is on removing barriers to access, while retaining the need to assess the same underlying knowledge, skills, values, and dispositions as are assessed for all other students and to apply the same standards of achievement as apply to all other students. The Commission makes every effort when implementing this scheme to accommodate individual assessment needs through these accommodations.

There are circumstances in which the requirement to demonstrate certain areas of learning when students are being assessed for certification can be waived or exempted, provided that this does not compromise the overall integrity of the assessment.

More detailed information about the scheme of Reasonable Accommodations in the Certificate Examinations, including the accommodations available and the circumstances in which they may apply, is available from the State Examinations Commission's Reasonable Accommodations Section.

Before deciding to study Leaving Certificate Physical Science, students, in consultation with their school and parents/guardians should review the learning outcomes of this specification and the details of the assessment arrangements. They should carefully consider whether or not they can achieve the learning outcomes, or whether they may have a special educational need that may prevent them from demonstrating their achievement of the outcomes, even after reasonable accommodations have been applied. It is essential that if a school believes that a student may not be in a position to engage fully with the assessment for certification arrangements, they contact the State Examinations Commission.

Leaving Certificate Grading

Leaving Certificate Physical Science will be graded using an 8-point grading scale. The highest grade is a Grade 1; the lowest grade is a Grade 8. The highest seven grades (1-7) divide the marks range 100% to 30% into seven equal grade bands 10% wide, with a grade 8 being awarded for percentage marks of less than 30%. The grades at Higher level and Ordinary level are distinguished by prefixing the grade with H or O respectively, giving H1-H8 at Higher level, and O1-O8 at Ordinary level.

Table 4: Leaving Certificate Grading

Grade	% marks
H1/O1	90 - 100
H2/O2	80 < 90
H3/O3	70 < 80
H4/O4	60 < 70
H5/O5	50 < 60
H6/O6	40 < 50
H7/O7	30 < 40
H8/O8	< 30

Appendix 1 Glossary of action verbs

This glossary is designed to clarify the learning outcomes. Each action verb is described in terms of what the learner should be able to do once they have achieved the learning outcome. This glossary will be aligned with the command words used in the assessment.

Action verb	Students should be able to
Analyse	study or examine something in detail, break down in order to bring out the essential elements or structure; identify parts and relationships, and to interpret information to reach conclusions
Apply	select and use information and/or knowledge and understanding to explain a given situation or real circumstances
Appreciate	recognise the meaning of, have a practical understanding of
Classify	group things based on common characteristics
Conduct	to perform an activity
Communicate	present using appropriate language in a suitable format
Compare	give an account of the similarities and (or) differences between two (or more) items or situations, referring to both (all) of them throughout
Create	to bring something into existence; to cause something to happen as a result of one's actions
Demonstrate	prove or make clear by reasoning or evidence, illustrating with examples or practical application
Describe	develop a detailed picture or image of, for example a structure or a process, using words or diagrams where appropriate; produce a plan, simulation or model
Design	to conceive, create and execute according to a plan
Determine	obtain the only possible answer by calculation, substituting measured or known values of other quantities into a standard formula
Devise	plan, develop or create something by careful thought
Discuss	offer a considered, balanced review that includes a range of arguments, perspectives, factors or hypotheses, grounded in appropriate evidence
Distinguish	make the differences between two or more concepts or items clear
Evaluate (data)	collect and examine data to make judgments and appraisals; describe how evidence supports or does not support a conclusion in an inquiry or investigation; identify the limitations of data in conclusions; make judgments about the ideas, solutions or methods
Evaluate (ethical judgement)	collect and examine evidence to make judgments and appraisals; describe how evidence supports or does not support a judgement; identify the limitations of evidence in conclusions; make judgments about the ideas, solutions or methods
Explain	give a detailed account including reasons or causes
Explore	observe or study in order to establish facts
Identify	recognise patterns, facts, or details; provide an answer from a number of possibilities; recognise and state briefly a distinguishing fact or feature
Investigate	observe, study or examine in detail in order to establish facts, and reach new insights and/or conclusions
Model	represent an idea, structure, process or system through a variety of means such as words, diagrams, equations, physical models or

Action verb	Students should be able to
	simulations; use models to describe, explain, make predictions and solve problems, recognising that all models have limitations.
Organise	to arrange; to systematise or methodise
Outline	give the main points, restricting to essential pieces of information
Plan	to devise or project a method or a course of action
Pose	put forward for consideration
Predict	give an expected result of an event; explain a new event based on observations or information using logical connections between pieces of information
Present	show something for others to consider
Produce	bring into existence by intellectual or creative ability
Recognise	identify facts, characteristics or concepts that are critical (relevant/appropriate) to the understanding of a situation, event, process or phenomenon
Reflect	to consider in order to correct or improve
Relate	associate, giving reasons
Research	to inquire specifically, using involved and critical investigation
Review	to re-examine deliberately or critically, usually with a view to approval or dissent; to analyse results for the purpose of giving an opinion
Use	apply knowledge or rules to put theory into practice
Verify	give evidence to support the truth of a statement